

# UNIVERSAL MOBILE TELECOMMUNICATIONS SYSTEM (UMTS)

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AP/CSE

# Evolution : From 2G to 3G

- Services must be independent from radio access technology and is not limited by the network infrastructure.
- Support of multimedia and all of its components.
- Increased data rate.
- Convergence of existing networks.
- Video Telephony.
- MP3 downloads.
- Potential good applications like TV on a mobile phone.
- However, to convert to UMTS, the network needs to be reengineered from the ground up.
  - Actually uses the lower 3 layers of the OSI model.

# Evolution : From 2G to 3G

- GPRS – General Packet Radio Services
  - 2.5G protocol
  - Involved only software changes to the GSM network.
  - Used under utilized TDMA channels more effectively.
  - Increased data rates to a max of 170 Kbps.
- EDGE – Enhanced Data rates for GSM Evolution.
  - 2.75G protocol.
  - Required minimal hardware changes
  - Added a new encoding scheme that allowed for more bits to be added into each time slice.
  - Data can now be passed optimally at 384 Kbps.
- Both of these use TDMA over GSM

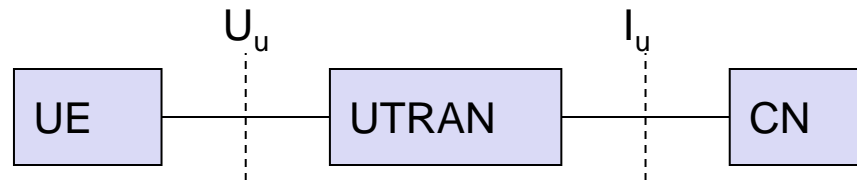
- 3G Standard for Cellular Communication
- Uses W-CDMA (Wideband CDMA)
  - 5 MHz of bandwidth for each channel.
  - Several thousand users can be supported on each cell site.
- Offers 11 Mbps download speeds in theory.
  - Uplink speeds are much slower
  - Most users are finding download throughput of about 384 Kbps.
    - However, this is still much faster than the 14.4 Kbps optimally that GSM offered.

# UMTS - Standards

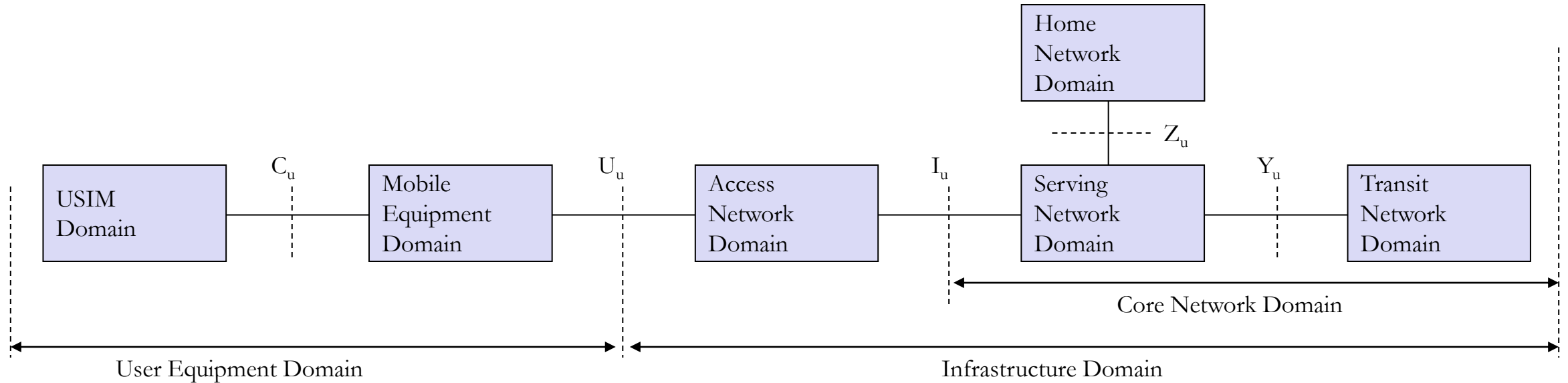
- The 3G standard was written by the International Telecommunication Union (ITU)
  - The standard is referred as IMT-2000 (International Mobile Telecommunications for the year 2000)
- The key to the standards is the available data over the air interface
  - 2 Mbps in fixed or in-building environments
  - 384 kbps in pedestrian or urban environments
  - 144 kbps in wide area mobile environments
  - Variable data rates in large geographic area systems (satellite)

# UMTS Architecture

- UE (User Equipment)
- UTRAN (UMTS Terrestrial Radio Access Network)
  - Cell level mobility
  - Radio Network Subsystem (RNS)
  - Encapsulation of all radio specific tasks
- CN (Core Network)
  - Inter system handover
  - Location management if there is no dedicated connection between UE and UTRAN



# UMTS Domains and Interfaces



- **User Equipment Domain**
  - Assigned to a single user in order to access UMTS services
- **Infrastructure Domain**
  - Shared among all users
  - Offers UMTS services to all accepted users

# UMTS Domains and Interfaces

- Universal Subscriber Identity Module (USIM)
  - Functions for encryption and authentication of users
  - Located on a SIM inserted into a mobile device
- Mobile Equipment Domain
  - Functions for radio transmission
  - User interface for establishing/maintaining end-to-end connections
- Access Network Domain
  - Access network dependent functions
- Core Network Domain
  - Access network independent functions
  - Serving Network Domain
    - Network currently responsible for communication
  - Home Network Domain
    - Location and access network independent functions

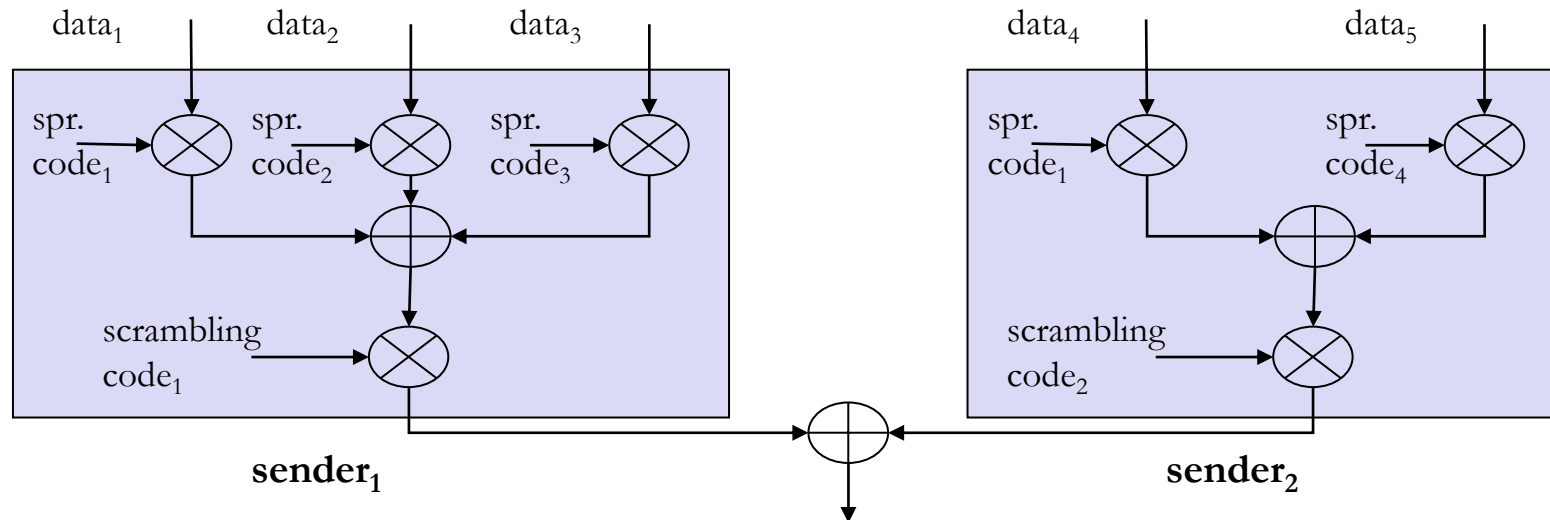


# UMTS Radio Interface

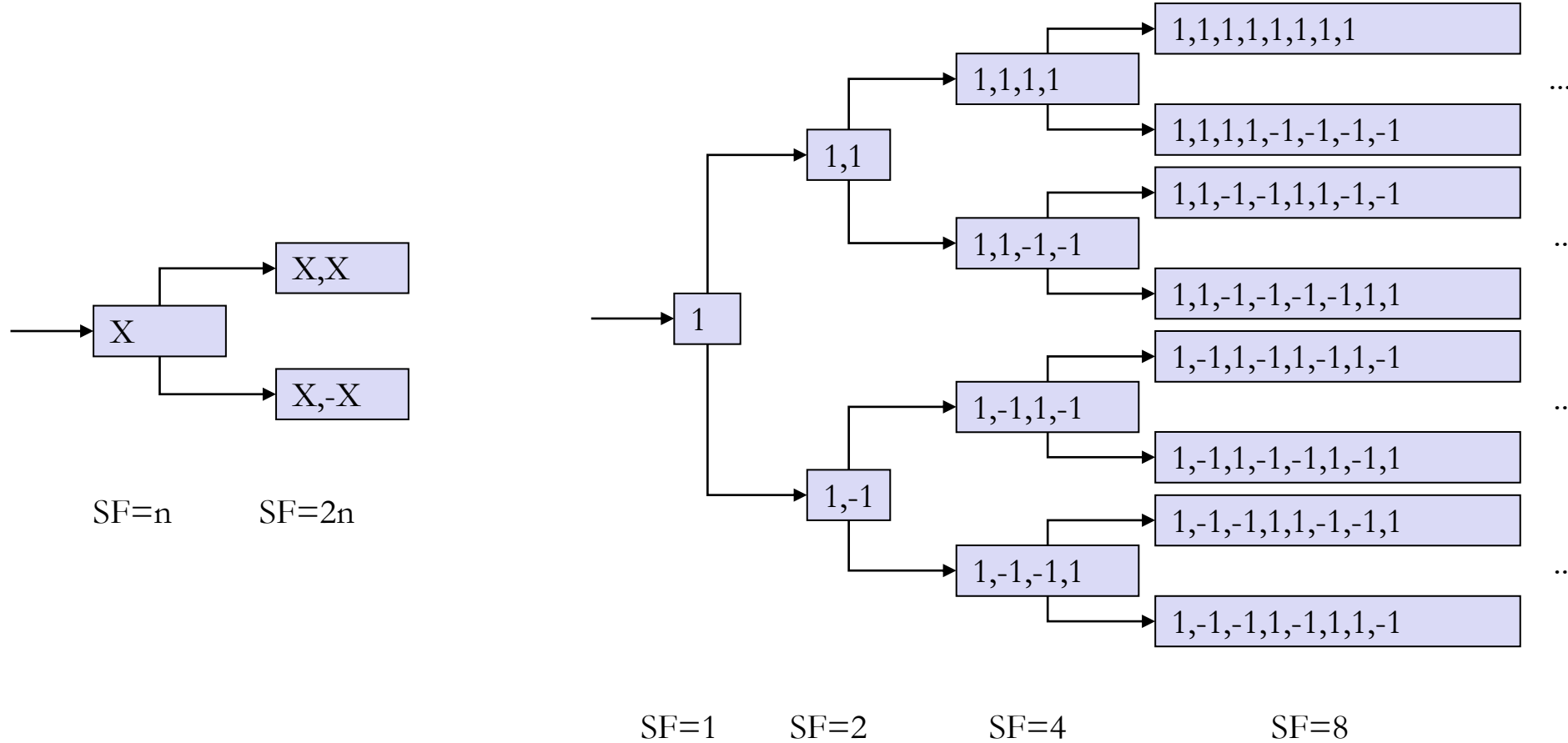
- Spreading and scrambling of user data
- OVSF coding (orthogonal variable spreading factor)
- UMTS FDD frame structure (WCDMA)
- UMTS TDD Frame Structure

# Spreading and scrambling of user data

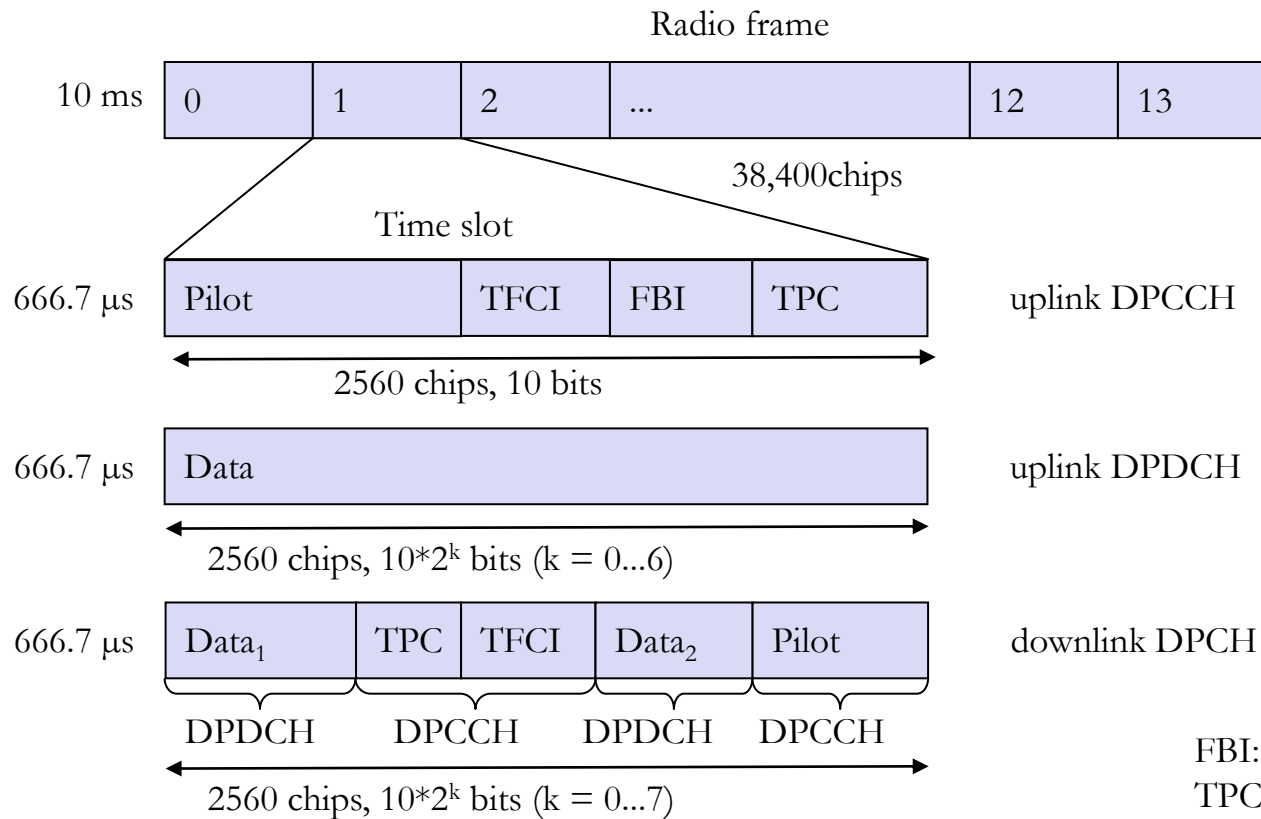
- Constant chipping rate of 3.84 Mchip/s
- Different user data rates supported via different spreading factors
  - higher data rate: less chips per bit and vice versa
- User separation via unique, quasi orthogonal scrambling codes
  - users are not separated via orthogonal spreading codes
  - much simpler management of codes: each station can use the same orthogonal spreading codes
  - precise synchronization not necessary as the scrambling codes stay quasi-orthogonal



# OVSF coding



# UMTS FDD Frame Structure (W-CDMA)



## W-CDMA

- 1920-1980 MHz uplink
- 2110-2170 MHz downlink
- chipping rate:  
3.840 Mchip/s
- soft handover
- QPSK
- spreading factor: UL: 4-256;  
DL: 4-512

FBI: Feedback Information

TPC: Transmit Power Control

TFCI: Transport Format Combination Indicator

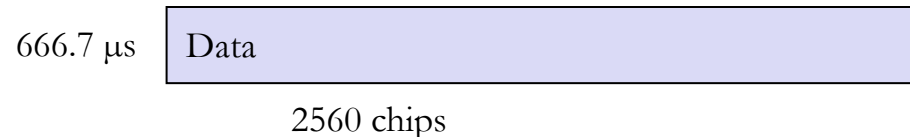
DPCCH: Dedicated Physical Control Channel

DPDCH: Dedicated Physical Data Channel

DPCH: Dedicated Physical Channel

# Dedicated Physical Data Channel

- Offered Data Rates
  - 960 kbps, 480, 240, 120, 60, 30, and 15 kbps (spreading factor 256).
- 960 kbps
  - spreading factor 4,
  - 640 bits per slot,
  - 15 slots per frame,
  - 100 frames

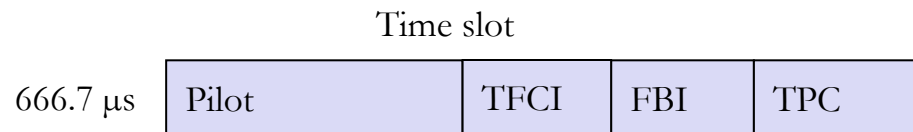


# Typical UTRA-FDD uplink data rates

User data rate [kbit/s]	12.2 (voice)	64	144	384
DPDCH [kbit/s]	60	240	480	960
DPCCH [kbit/s]	15	15	15	15
Spreading	64	16	8	4

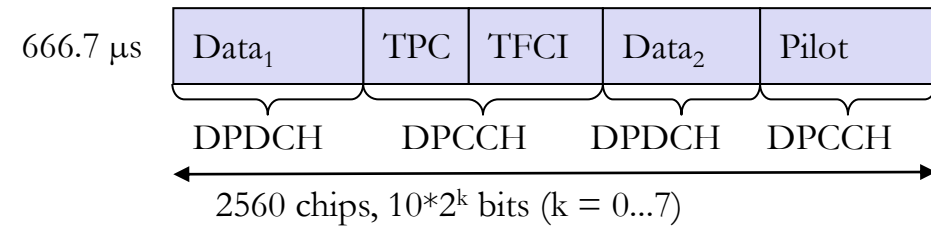
# Dedicated Physical Control Channel

- Constant spreading factor 256
- Pilot is used for channel estimation.
- Transport Format Combination Identifier (TFCI) specifies the channels transported within the DPDCHs.
- Feedback Information Field (FBI) supports soft handover.
- Transmit Power Control (TPC) is used for controlling the transmission power of a sender



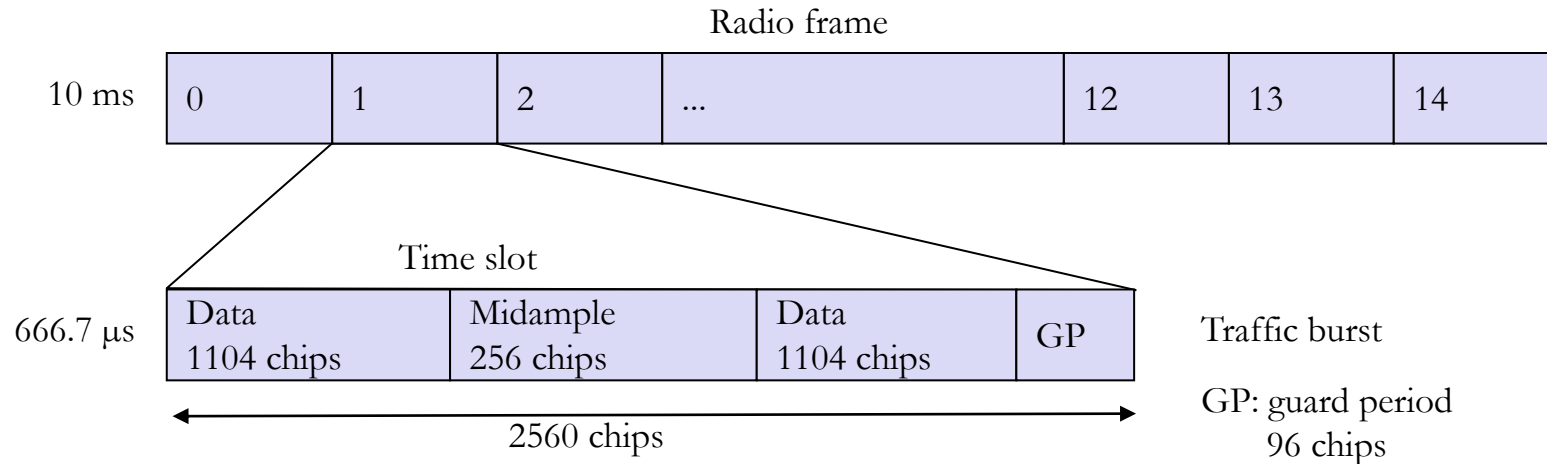
# Dedicated Physical Channel

- Spreading factors between 4 and 512 are available
- data rates for data channels (DPDCH) within a DPCH are
  - 6 kbit/s (SF=512),
  - 24 kbit/s
  - 51 kbit/s
  - 90 kbit/s
  - 210,
  - 432,
  - 912,
  - 1,872 kbit/s (SF=4)





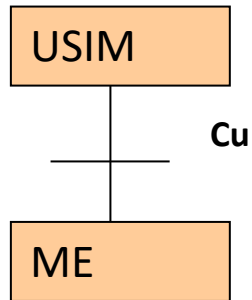
# UMTS TDD Frame Structure



## TD-CDMA

- 2560 chips per slot
- spreading factor: 1-16
- symmetric or asymmetric slot assignment to UL/DL (min. 1 per direction)

# User Equipment Architecture



- User Equipment → any UMTS enabled mobile device
- User Equipment Domain handles the access of the user onto the UMTS services
- USIM – User Services Identity Module
  - Extended SIM functionality
  - Functions for user identification, authentication and encryption
  - Integrated into SIM card (of the established format)
  - Most recent Mobile Equipment can handle both SIM and USIM
- Mobile Equipment Domain responsible for air interface
  - User interface for end-to-end connections

# UE – User Equipment

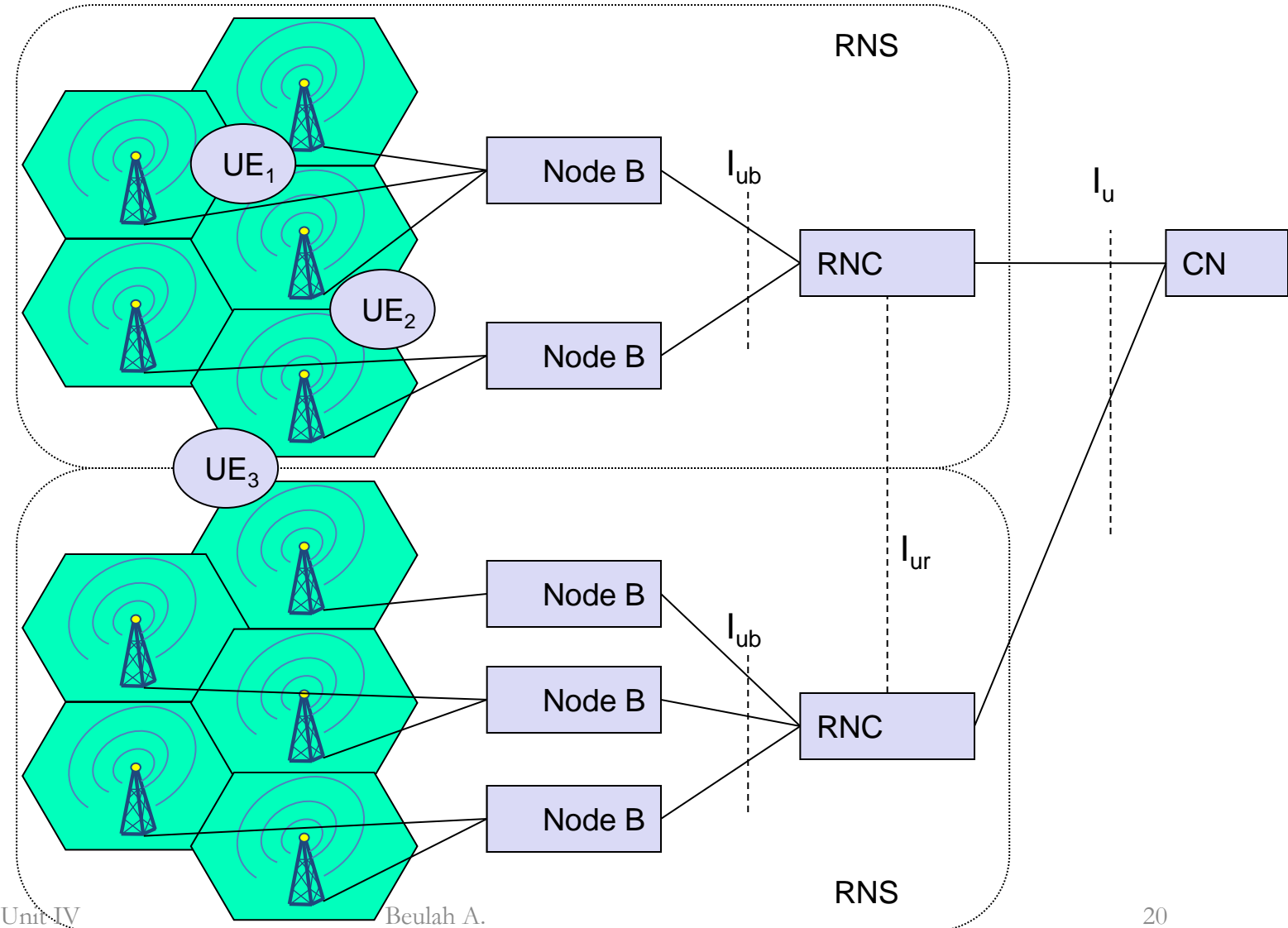
- The UE is the counterpart of several nodes of the architecture.
- As the counterpart of a node B, the UE performs
  - Signal quality measurements, inner loop power control, spreading and modulation, and rate matching.
- As a counterpart of the RNC, the UE
  - Has to cooperate during handover and cell selection, performs encryption and decryption, and participates in the radio resource allocation process.
- As a counterpart of the CN, the UE
  - Has to implement mobility management functions, performs bearer negotiation, or requests certain services from the network.

# UTRAN Architecture

RNC: Radio Network Controller

RNS: Radio Network Subsystem

- UTRAN comprises several RNSs
- Node B can support FDD or TDD or both
- RNC is responsible for handover decisions requiring signaling to the UE
- Cell offers FDD or TDD



# Radio Network Controller

- Call admission control
  - The RNC calculates the traffic within each cell and decides, if additional transmissions are acceptable or not
- Congestion control
  - The RNC allocates bandwidth to each station in a cyclic fashion and must consider the QoS requirements
- Encryption/Decryption
  - The RNC encrypts all data arriving from the fixed network before transmission over the wireless link (and vice versa)
- ATM switching and multiplexing, protocol conversion
  - The connections between RNCs, node Bs, and the CN are based on ATM. An RNC has to switch the connections to multiplex different data streams.
- Radio bearer setup and release
  - An RNC has to set-up, maintain, and release a logical data connection to a UE

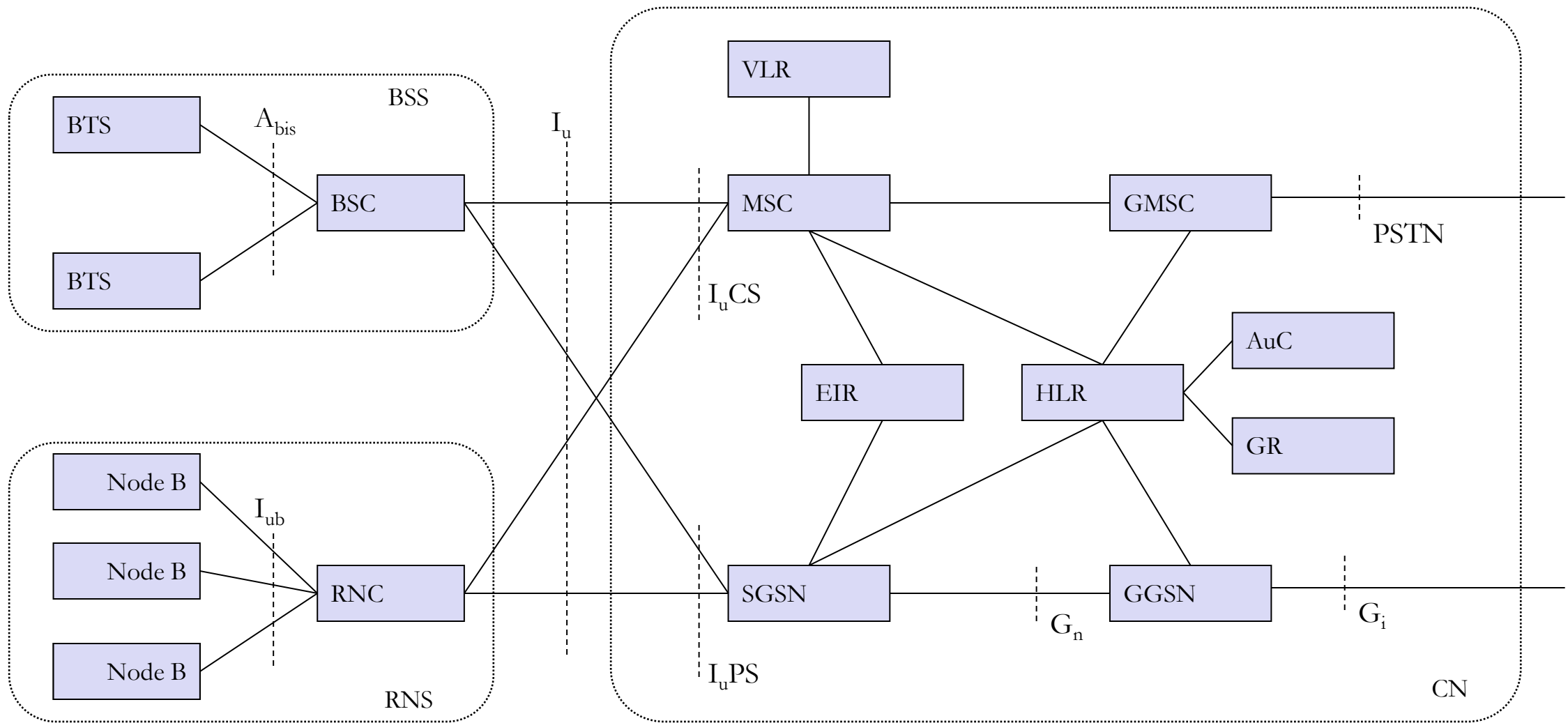
# Radio Network Controller

- Code allocation
  - The CDMA codes used by a UE are selected by the RNC
- Power control
  - The RNC only performs a relatively loose power control (the outer loop).
  - This outer loop of power control helps to minimize interference between neighbouring cells or controls the size of a cell
- Handover control and RNS relocation
  - Depending on the signal strengths received by UEs and node Bs, an RNC can decide if another cell would be better suited for a certain connection
- Management
  - The network operator needs a lot of information regarding the current load, current traffic, error states etc. to manage its network

# Node B

- Node B connects to one or more antennas creating one or more cells.
- The cells can either use FDD or TDD or both
- An important task of a node B is the inner loop power control to mitigate near-far effects.
- Node B also measures connection qualities and signal strengths
- Node B can even support a special case of handover, a so-called softer handover which takes place between different antennas of the same node B

# Core Network Architecture





# Core Network Architecture

- The Core Network (CN) and thus the Interface  $I_u$ , too, are separated into two logical domains:
- Circuit Switched Domain (CSD)
  - Circuit switched service incl. signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
  - $I_u$ CS
  - Mobile Switching Centre (MSC)
    - Switching CS transactions
  - Visitor Location Register (VLR)
    - Holds a copy of the visiting user's service profile, and the precise info of the UE's location
  - Gateway MSC (GMSC)
    - The switch that connects to external networks
  - Home Location Register (HLR)
    - Stores master copies of users service profiles
    - Stores UE location on the level of MSC/VLR/SGSN
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)
  - $I_u$ PS
  - Serving GPRS Support Node (SGSN) (Similar function as MSC/VLR)
  - Gateway GPRS Support Node (GGSN) (Similar function as GMSC)

# UMTS Handover

- Hard Handover
- Soft Handover
- Softer Handover

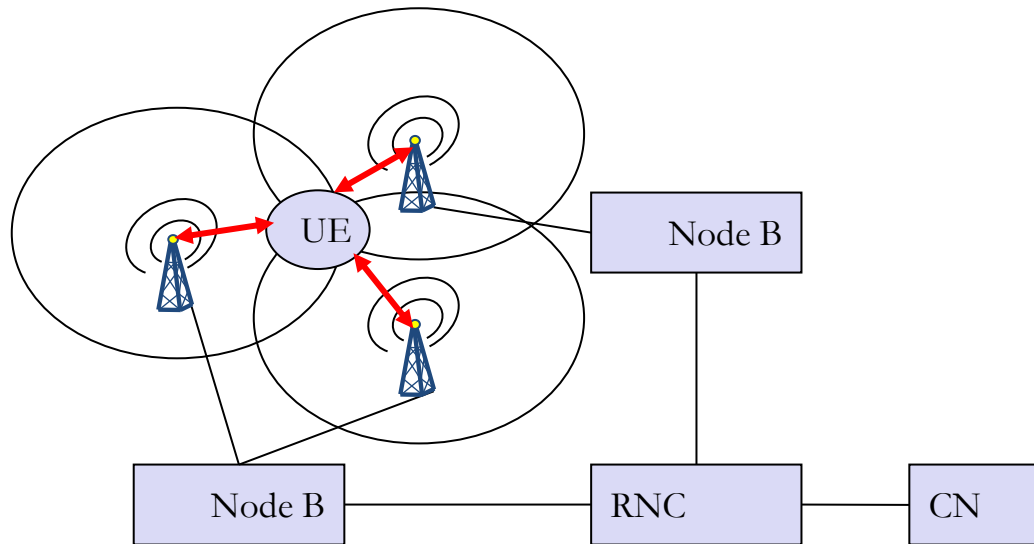
# Hard Handover

- All the old radio links in the UE are removed before the new radio links are established.
- Inter Frequency Handover
  - Changing the carrier frequency, is a hard handover
  - Receiving data at different frequencies at the same time requires a more complex receiver
- Inter System Handovers
  - Handovers to and from GSM or other IMT-2000 systems

# Soft Handover

- Soft handover means that the radio links are added and removed in a way that the UE always keeps at least one radio link to the UTRAN
- Soft handovers are well known from traditional CDMA networks as they use macro diversity, a basic property of
- CDMA

# Support of Mobility: Macro Diversity

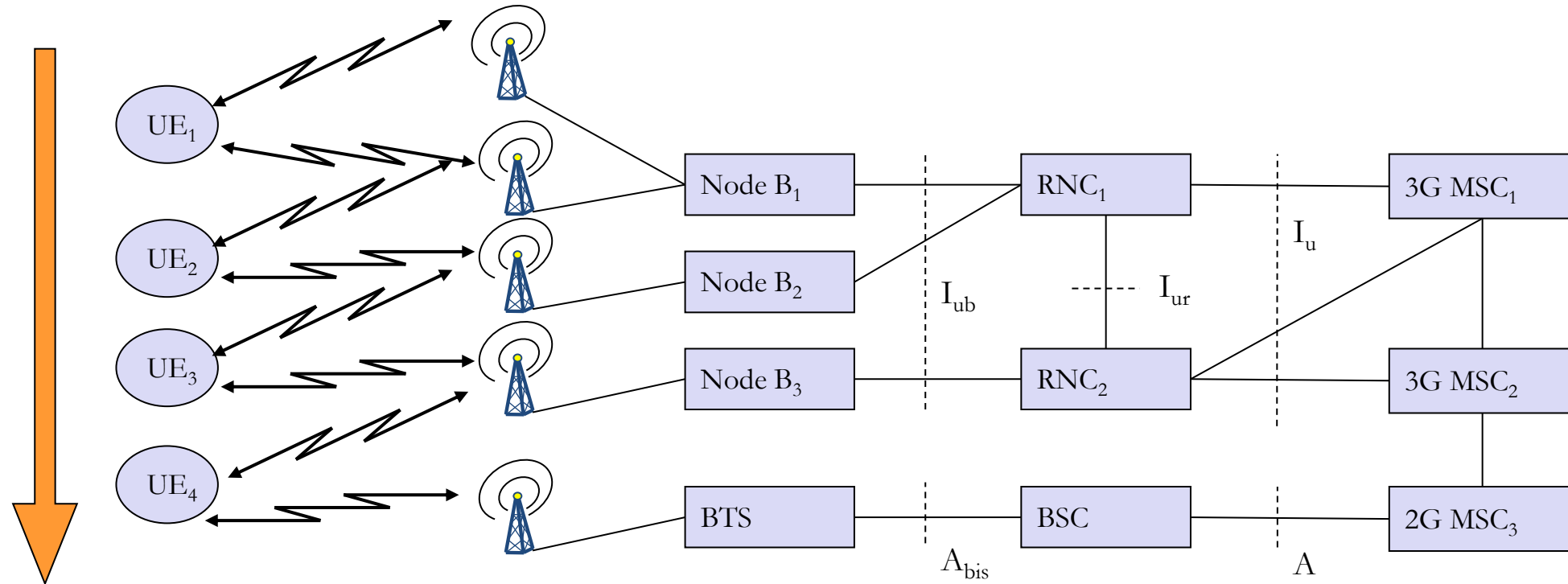


- UE can receive signals from up to three different antennas, which may belong to different node Bs.
- Downlink
  - The RNC splits the data stream and forwards it to the node Bs.
  - The UE combines the received data again.
- Uplink
  - UE simply sends its data which is then received by all node Bs involved.
  - The RNC combines the data streams received from the node Bs.
- The fact that a UE receives data from different antennas at the same time makes a handover soft.
- Moving from one cell to another is a smooth

# Softer Handover

- Softer handover is a special case of soft handover where the radio links that are added and removed belong to the same Node B

# Handover Types in UMTS



# Handover Types in UMTS

- Intra-node B, intra-RNC
  - UE1 moves from one antenna of node B1 to another antenna. This type of handover is called softer handover.
  - In this case node B1 performs combining and splitting of the data streams.
- Inter-node B, intra-RNC:
  - UE2 moves from node B1 to node B2.
  - In this case RNC1 supports the soft handover by combining and splitting data.
- Inter-RNC
  - When UE3 moves from node B2 to node B3 two different types of handover can take place.
  - internal inter-RNC handover and external inter-RNC handover.
- Inter-MSC
  - MSC2 takes over and performs a hard handover of the connection.
- Inter-system
  - UE4 moves from a 3G UMTS network into a 2G GSM network.
  - This is hard handover.



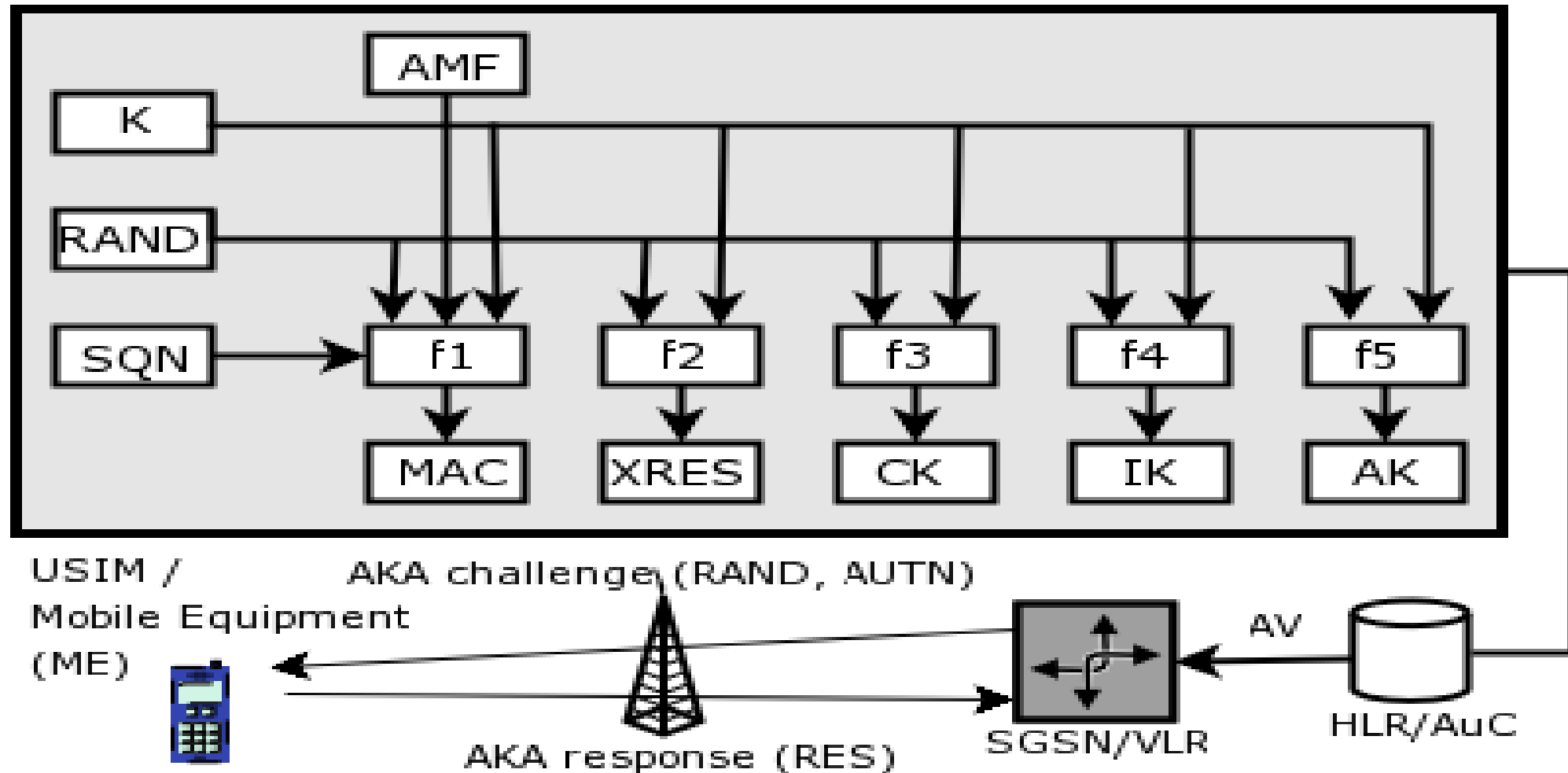
# QoS Classes

Traffic class	Conversational class	Streaming class	Interactive class	Background
<b>Fundamental characteristics</b>	Preserve time relation between information entities of the stream  Conversational pattern (stringent and low delay)	Preserve time relation between information entities of the stream	Request response pattern  Preserve data integrity	Destination is not expecting the data within a certain time  Preserve data integrity
<b>Example of the application</b>	Voice, videotelephony, video games	Streaming multimedia	Web browsing, network games	Background download of emails

# Security and Authentication

- Security in GSM is weak by our today's standards, mostly broken and only one way (client-to-network auth)
- Authentication in UMTS
  - Basis is a common secret key  $K$ , which is only known by the USIM (User Services Identity Module) in the UE and by the HLR/AuC of the provider
  - The VLR or SGSN which should authenticate the user requests from the HLR/AuC 1..n AV(Auth Vectors)
  - Each AV is a 5-tuple consisting of
    - RAND (random challenge) and XRES (expected response) for the user authentication
    - CK (cipher key) for protection of confidentiality, IK (integrity key) for protection of integrity, AUTN (auth token) for network authentication

# Security and Authentication



# Security and Authentication

- RAND and AUTN are sent to the UE/USIM, which checks AUTN and computes the response RES to the challenge RAND
- RES is sent to the VLR/SGSN which compares it to XRES
- Integrity and confidentiality
  - By request of MSC/VLR or SGSN the communication can be encrypted with CK or IK between UE and RNC
  - Encryption takes place on the RLC layer and prevents forgery of data and encryption

# Summary

- From 2G to 3G
- Architecture of UMTS
  - UE
  - UTRAN
  - CN
- UMTS Handover
- UMTS Security

# Test your understanding

- Any idea about Virtual Home Environment (VHE)??
- What type of handover will happen when a mobile handset switch between 2G and 3G?

# References

Jochen H. Schller, “Mobile Communications”, Second Edition, Pearson Education, New Delhi, 2007.

Prasant Kumar Pattnaik, Rajib Mall, “Fundamentals of Mobile Computing”, PHI Learning Pvt. Ltd, New Delhi – 2012.