Mobile Communications

3GPP Public Land Mobile Networks:
GSM (2G), GPRS (2.5G), UMTS (3G)

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- *What is the architecture of the GSM (2G) network:*
  network elements, interfaces, addresses, logical channels, protocol stack?
- *How are the calls processed:*
  Mobile Terminated Call, Mobile Initiated Call?
- *How was GSM modified to support data in GPRS (2.5G)?*
- *What is the Attach procedure? What is a PDP context?*
- *What is the GPRS protocol stack?*
- *What are their key differences between 3G and 2G:*
  radio access and architecture points of view?
- *Why is power control so important in WCDMA?*
  How is it controlled?
- *How is data transferred in a WCMDA dedicated channel?*

GSM (2G)

GSM - Overview

- Formerly: Groupe Spéciale Mobile (founded 1982)
- Now: Global System for Mobile Communication

- Pan-European telecom standard

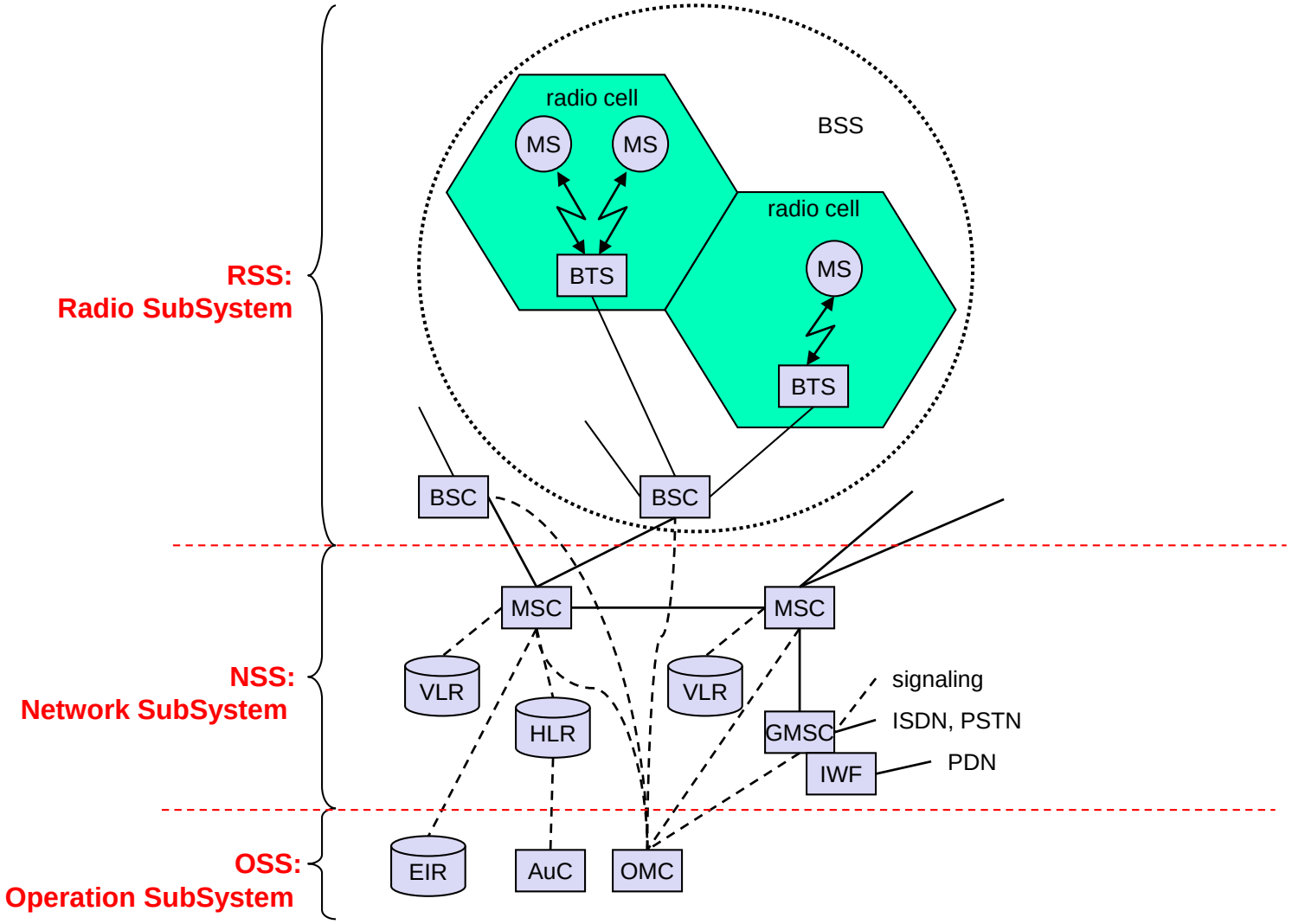
  ETSI: European Telecommunications Standardisation Institute

- Seamless roaming

- Basic services provided

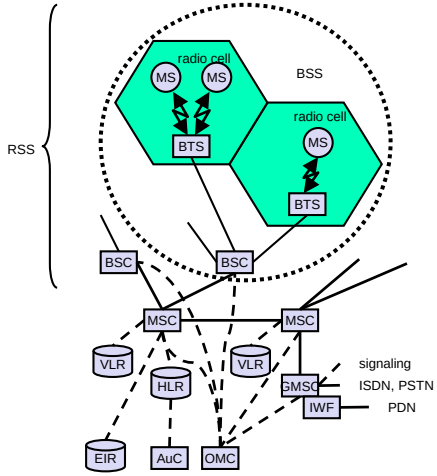
  voice services, short message service, data services

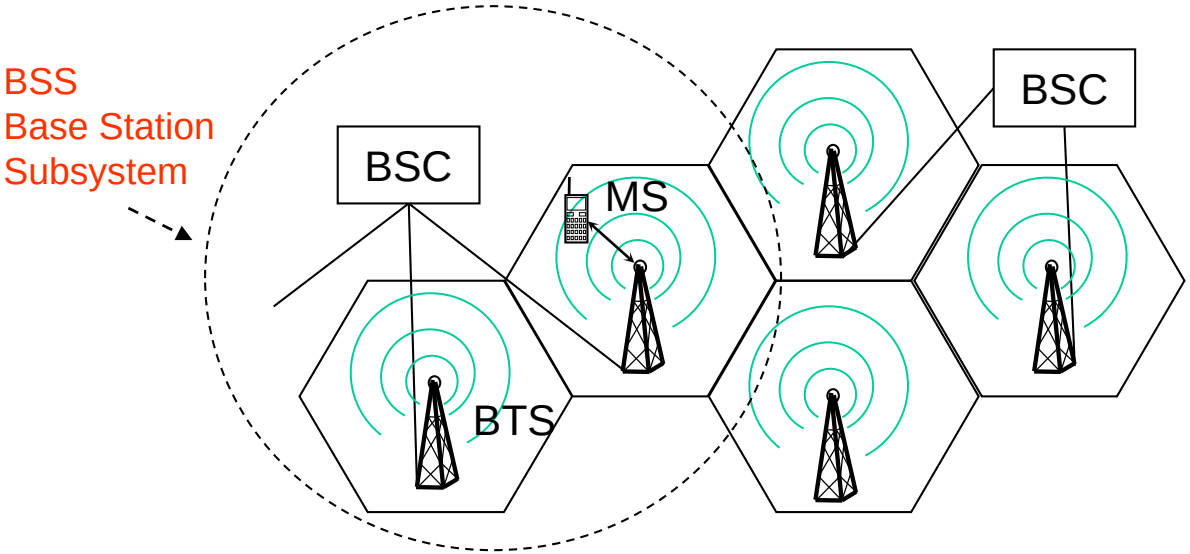
GSM Architecture – Public Land Mobile Network (PLMN)



GSM Architecture – Radio Subsystem (RSS)

- MS - Mobile Station
  Mobile terminal equipment
- BTS - Base Transceiver Station
  Transmitter, receiver and antennas
- BSC - Base Station Controller
  control of several BTS and MS

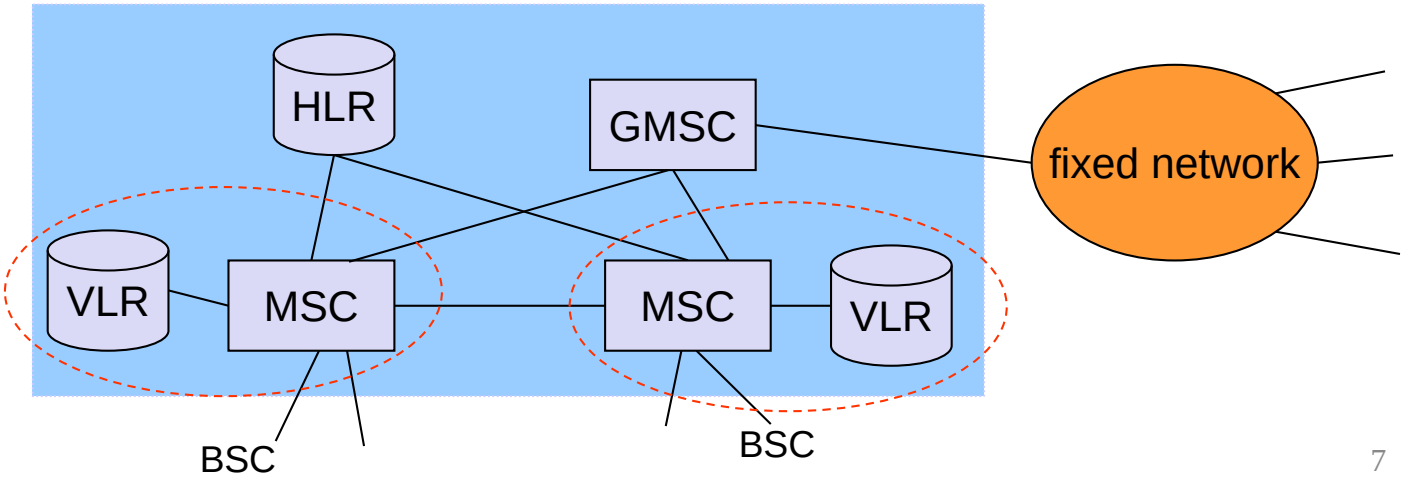




GSM Architecture – Network Subsystem (NSS)

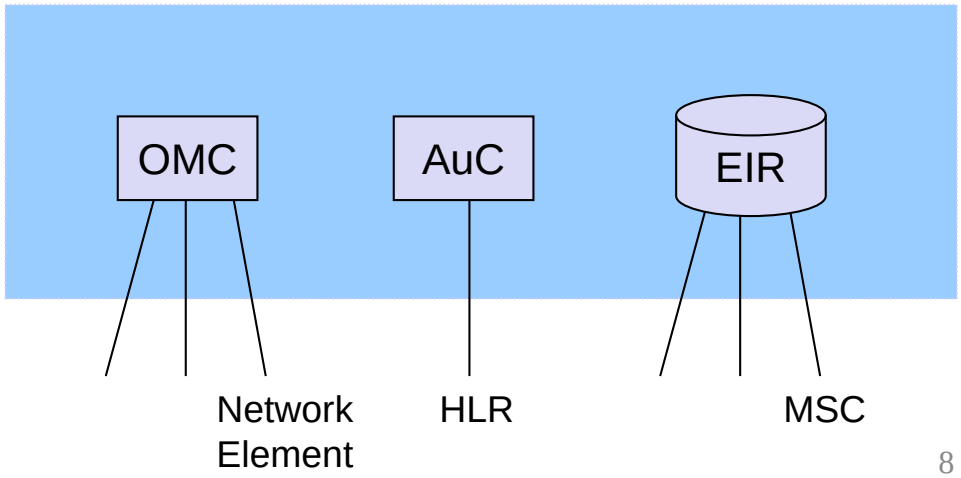
- Circuit switching, mobility management
- Interconnection to other networks, system control

- MSC - Mobile Switching Centre: circuit switching
- HLR - Home Location Register: associated to PLMN (telecom operator)
- VLR - Visitor Location Register: associated to MSC
- GMSC - Gateway MSC: interconnection to other networks



GSM Architecture – Operation Subsystem (OSS)

- Centralized operation, management and maintenance of GSM system
- OMC - Operation and Management
  Control of the radio and network subsystems
- AuC - Authentication Centre
  Executes security functions and contains security data
- EIR - Equipment Identity Register
  Registration and information on Mobile Stations



Mobile Addresses

- **IMSI** - International Mobile Subscriber Identity
  - » uniquely identifies the user; stored in the SIM card
  - » composed by

    Mobile Country Code (MCC) + Mobile Network Code (MNC) + Mobile Subscriber Identification Number (MSIN)

- **MSISDN** - Mobile Subscriber Integrated Services Digital Network Number
  - » the telephone number
  - » associated to the service
  - » stored in the SIM card

- **MSRN** - Mobile Station Roaming Number
  - » a temporary location dependent ISDN number; generated by local VLR for each mobile station in its area
  - » calls are routed to the MS by using the MSRN
  - » The MSRN has same structure as the MSISDN

    Country Code of visited network (CC) + National Destination Code (NDC) of visited network + Subscriber Number (SN) in current mobile network

- **TMSI** - Temporary Mobile Subscriber Identity
  - » 32 bits
  - » local number allocated by VLR; may be changed periodically
  - » hides the IMSI over the air interface; transmitted instead of IMSI

Mobile Switching Center

- Switching of 64 kbit/s channels
- Paging and call forwarding
- Location registration and forwarding of location information

Home Location Register (HLR)

- Central master database
  - » data from every user that has subscribed the operator
  - » one database per operator
  - » may be replicated

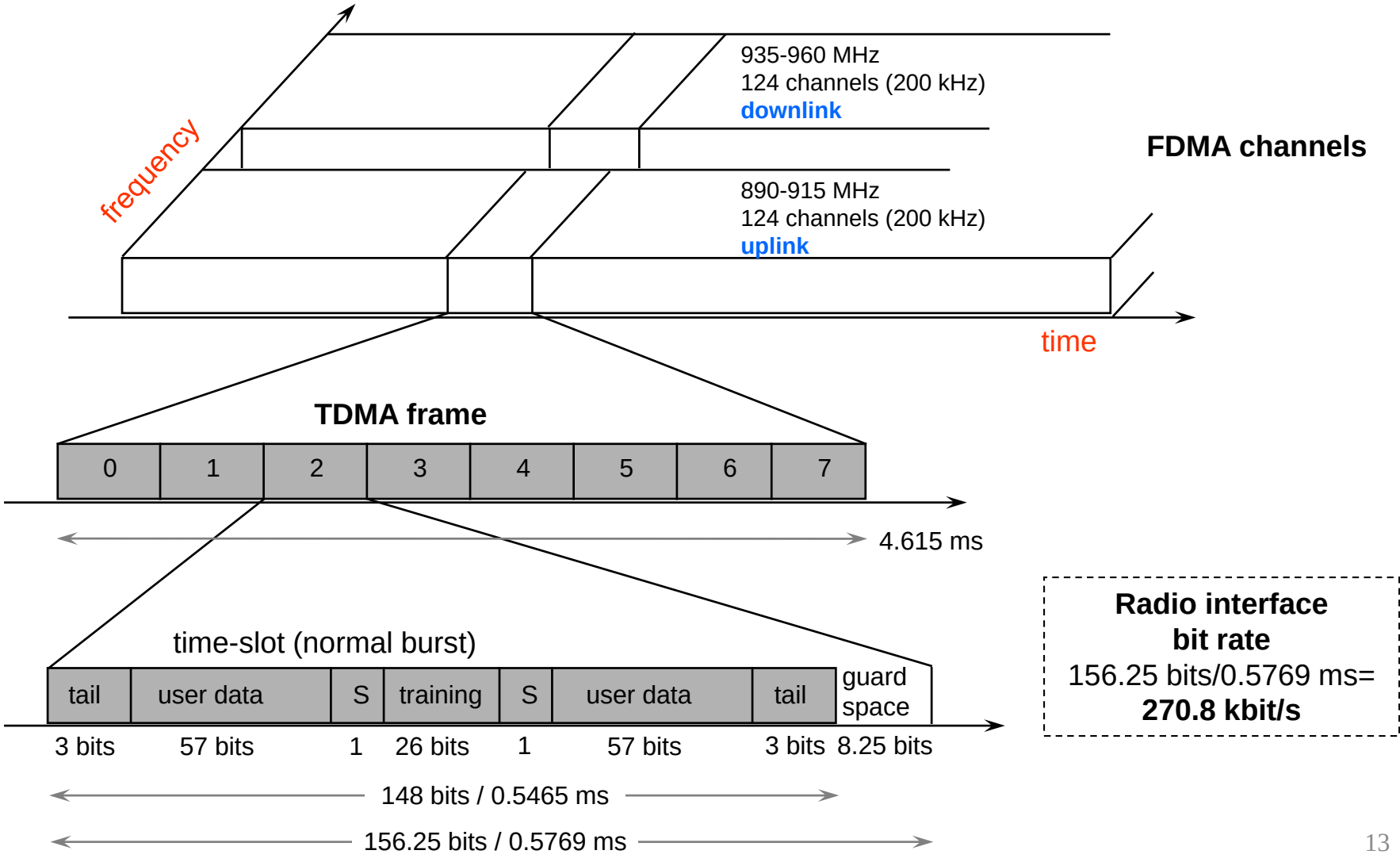
- HLR contains
  - » Subscriber data
    - – IMSI - International Mobile Subscriber Identity
    - – List of subscribed services with parameters and restrictions
  - » Location data
    - – current MSC/VLR address

Visitor Location Register (VLR)

- Local database
  - » data of all users currently in the domain of the VLR
  - » VLR is associated to a MSC
- For each user, VLR has information on
  - » Subscriber identity
    - – IMSI - International Mobile Subscriber Identity
  - » Temporary addresses
    - – MSRN - Mobile Station Roaming Number
    - – TMSI - Temporary Mobile Subscriber Identity
  - » Temporary location
    - – LAI - Location Area Identification

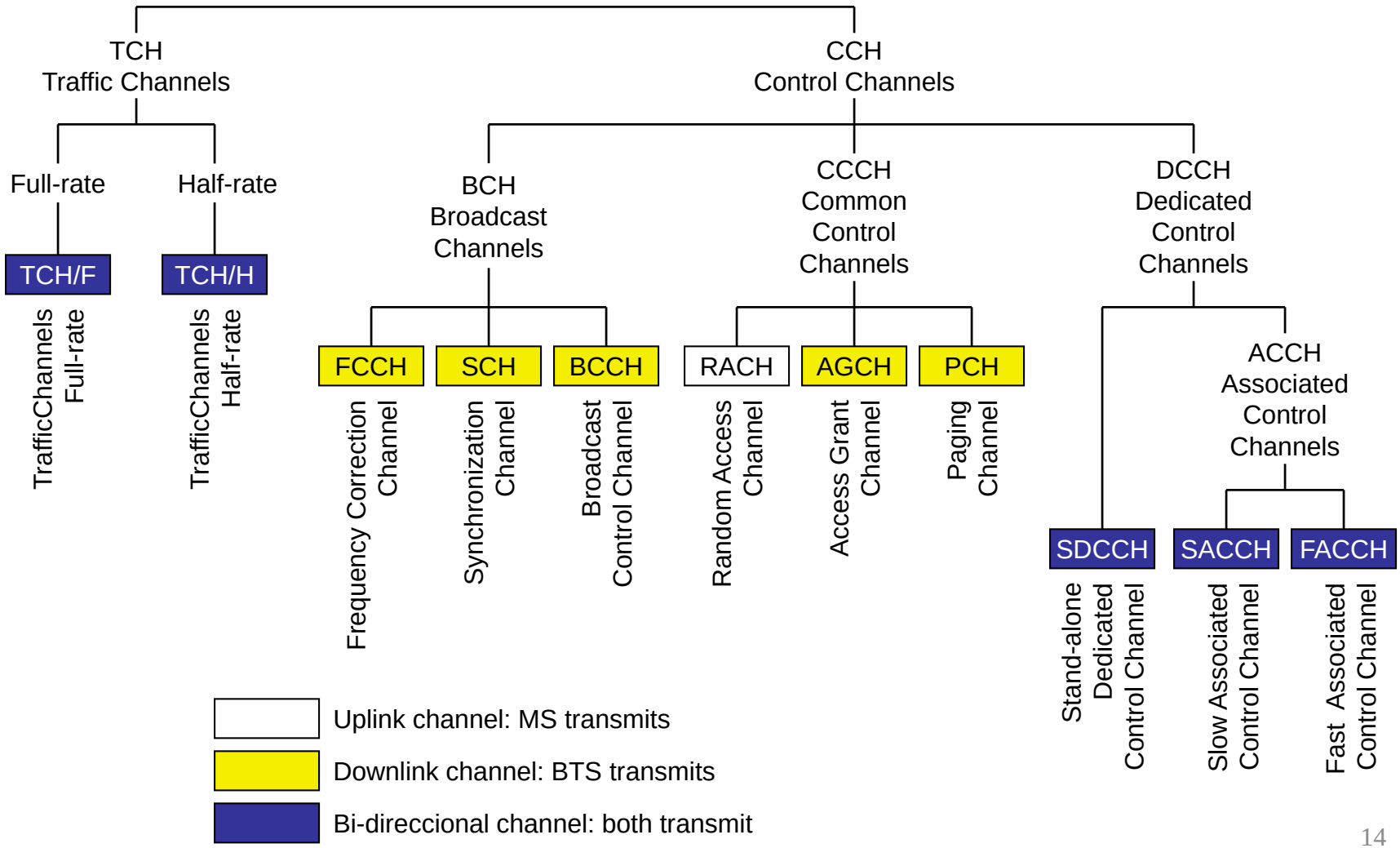
GSM – FDD, TDMA/FDMA

Duplex: FDD
Multiple Access: TDMA+FDMA



Radio interface bit rate
156.25 bits/0.5769 ms=
270.8 kbit/s

Logical Channels



Logical Channels

Channel		Direction	Application	Allocation
TCH Traffic Channels	TCH/H TCH/F	BTS ↔ MS	User data	Allocated by network on demand by MS
BCH Broadcast Channels	FCCH	BTS → MS	Carrier synchronization	Permanent
	SCH		Frame synchronisation	
	BCCH		General network information Cell information (present and adjacent)	
CCCH Common Control Channels	RACH	BTS ← MS	Request SDCCH for signalling Request TCH for handover	Multiple access with slotted Alhoa contention between MS
	AGCH	BTS → MS	Confirmation of SDCCH or TCH request	Permanent
	PCH		Allert MS to a call originated in the network	
DCCH Dedicated Control Channels	SDCCH	BTS ↔ MS	Registration / location updating Call control procedures	Allocated by network on demand
	SACCH		Control information between MS and BTS during the progress of a call or call set up	Associated to a specific TCH or SDCCH
	FACCH		Exchange of time critical control information during the progress of a call	Allocated by network or MS (*)

(*) Fast allocation by setting S bit; bits are stolen from TCH

Transmission Power

- Mobile station power classes

GSM 900			GSM 1800		
8 W	39 dBm	vehicular	4 W	36 dBm	vehicular
5 W	37 dBm	portable	1 W	30 dBm	portable
2 W	33 dBm	portable	0.25 W	24 dBm	portable
0.8 W	29 dBm	portable			

usual classes

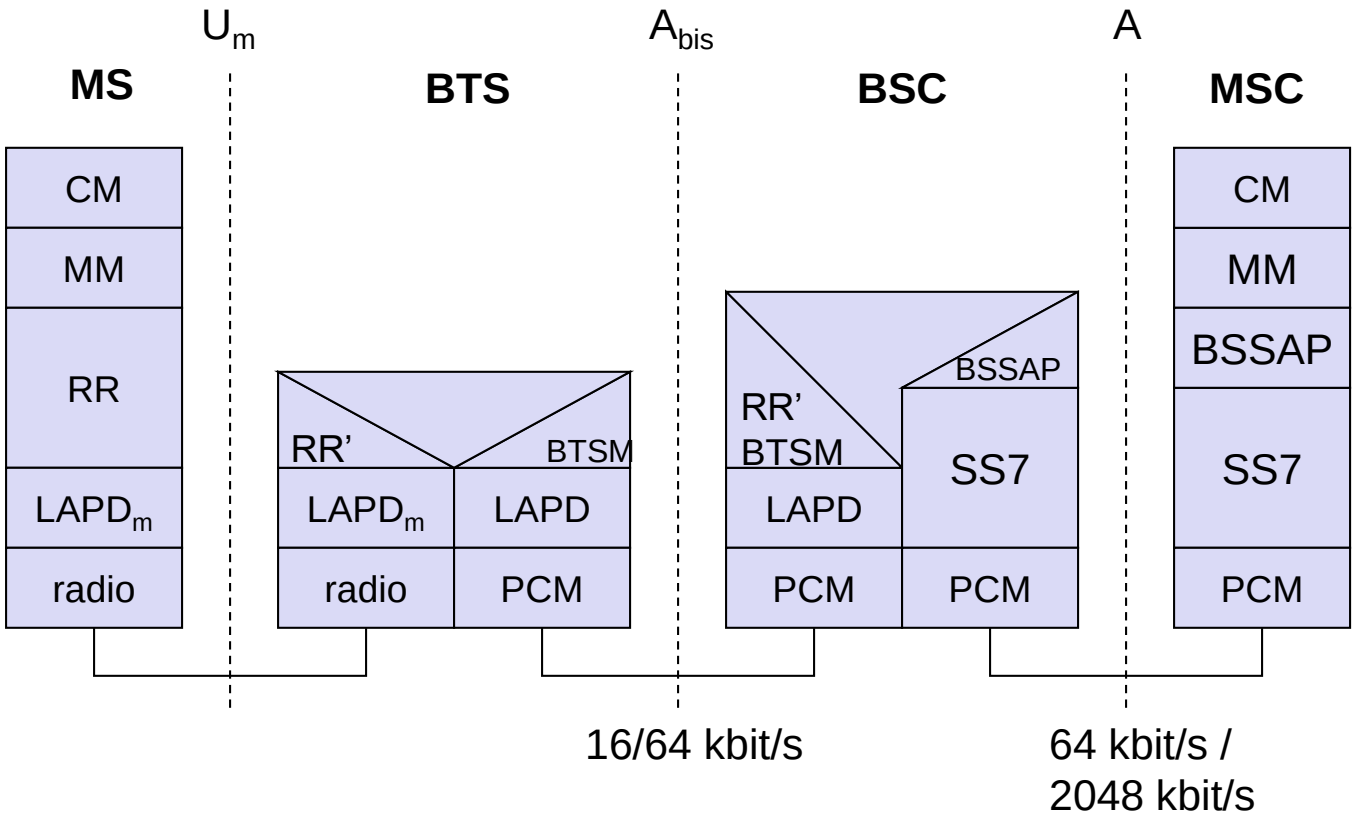
Power Control

- Implemented in uplink and downlink
- Objective: lowest power level which provides desired quality (BER)
- Procedure
  - » MS measures power received and BER and sends result on SACCH
  - » BTS sends new power level on SACCH, if and when necessary
- Control range

GSM 900	GSM 1800	Comments
5 - 39 dBm	0 - 36 dBm	effective maxima depend on cell size and MS capability control steps of 2 dB

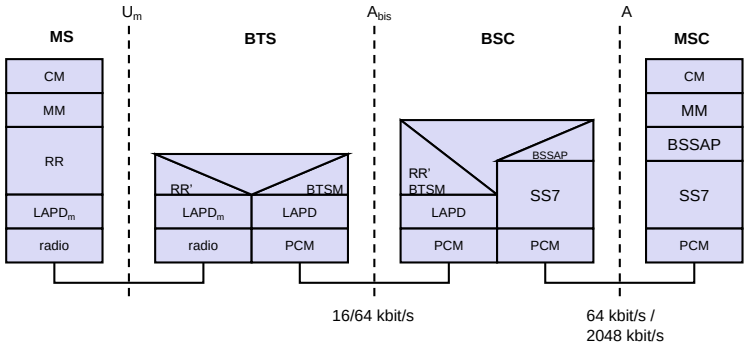
- Channels with no power control - use maximum power for the cell
  - » downlink BCH and CCCH: power set by BTS
  - » uplink RACH
    - – BCCH broadcasts maximum power level for the cell
    - – MS uses this value to set RACH transmission power

GSM Protocol Layers for Signaling



GSM Protocol Layers for Signaling

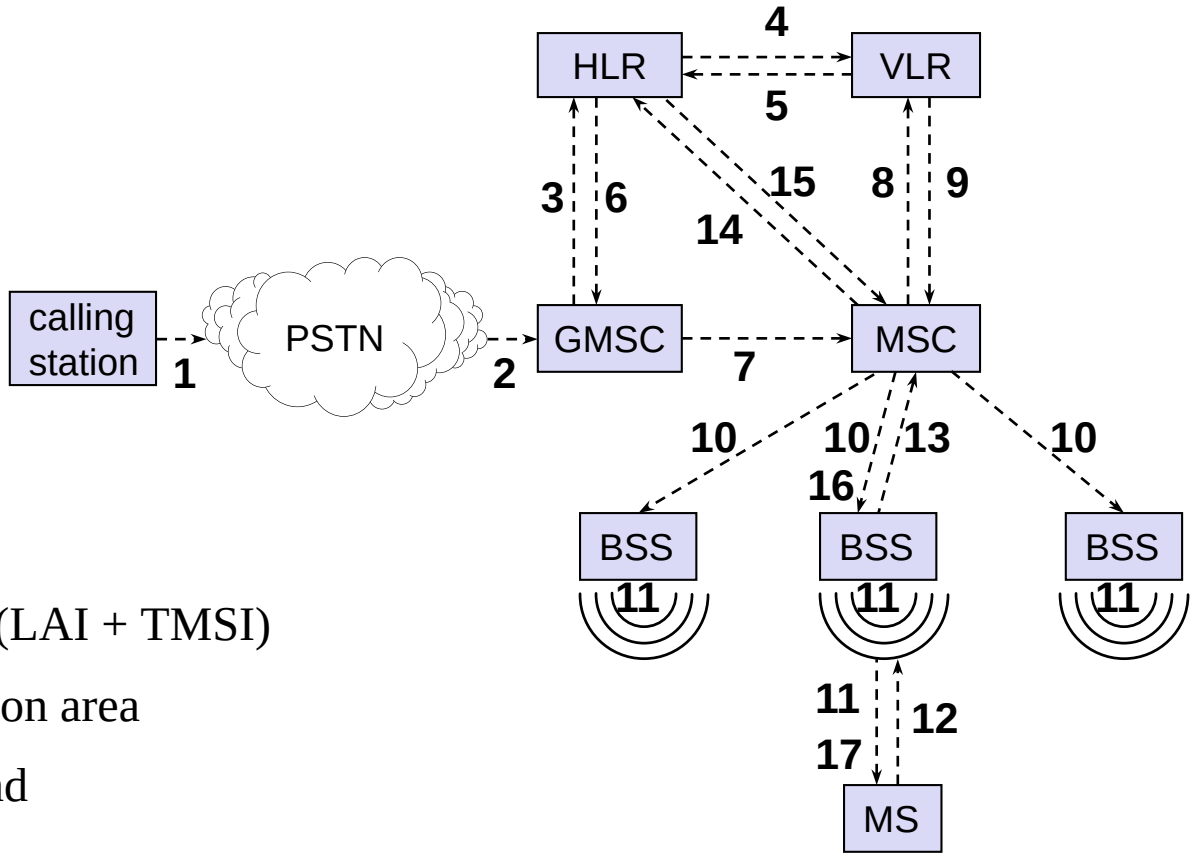
- CM (Connection Management)
  - » call control, short messages
- MM (Mobility Management)
  - » registration, authentication, location and handover management
- RR (Radio Resource Management)
  - » setup, maintenance and release of radio channels
  - » control of radio transmission quality



- LAPDm ("Link Access Protocol D-channel" modified)
  - » modified version of ISDN LAPD protocol

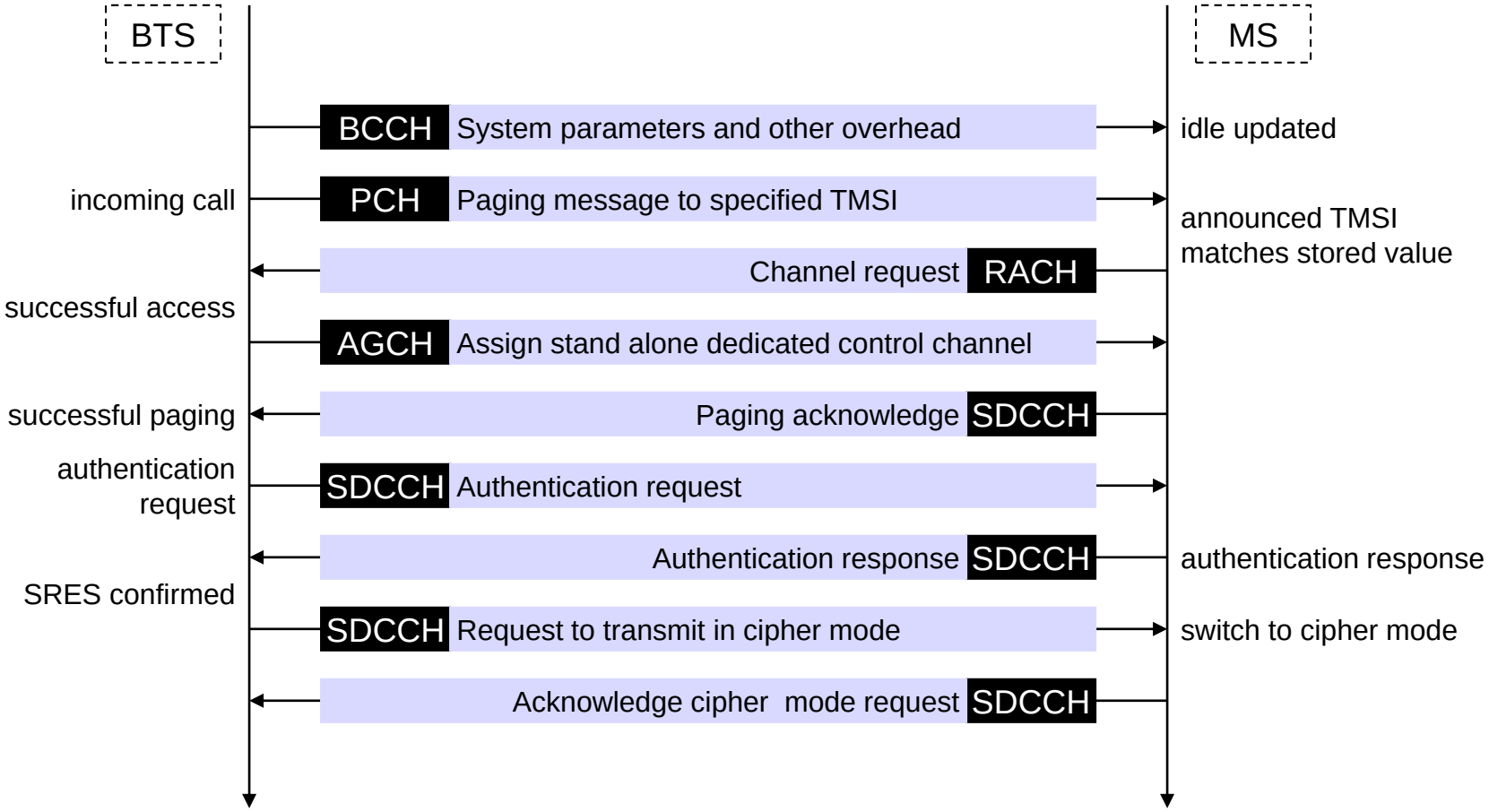
Mobile Terminated Call

- 1: calling a GSM subscriber
- 2: forwarding call to GMSC
- 3: signal call setup to HLR
- 4, 5: get routing info (MSRN) from VLR
- 6: forward routing info to GMSC
- 7: route call to current MSC
- 8, 9: get current status of MS (LAI + TMSI)
- 10, 11: paging of MS in location area
- 12, 13: MS answers paging and authentication request
- 14, 15: security checks
- 16, 17: set up connection



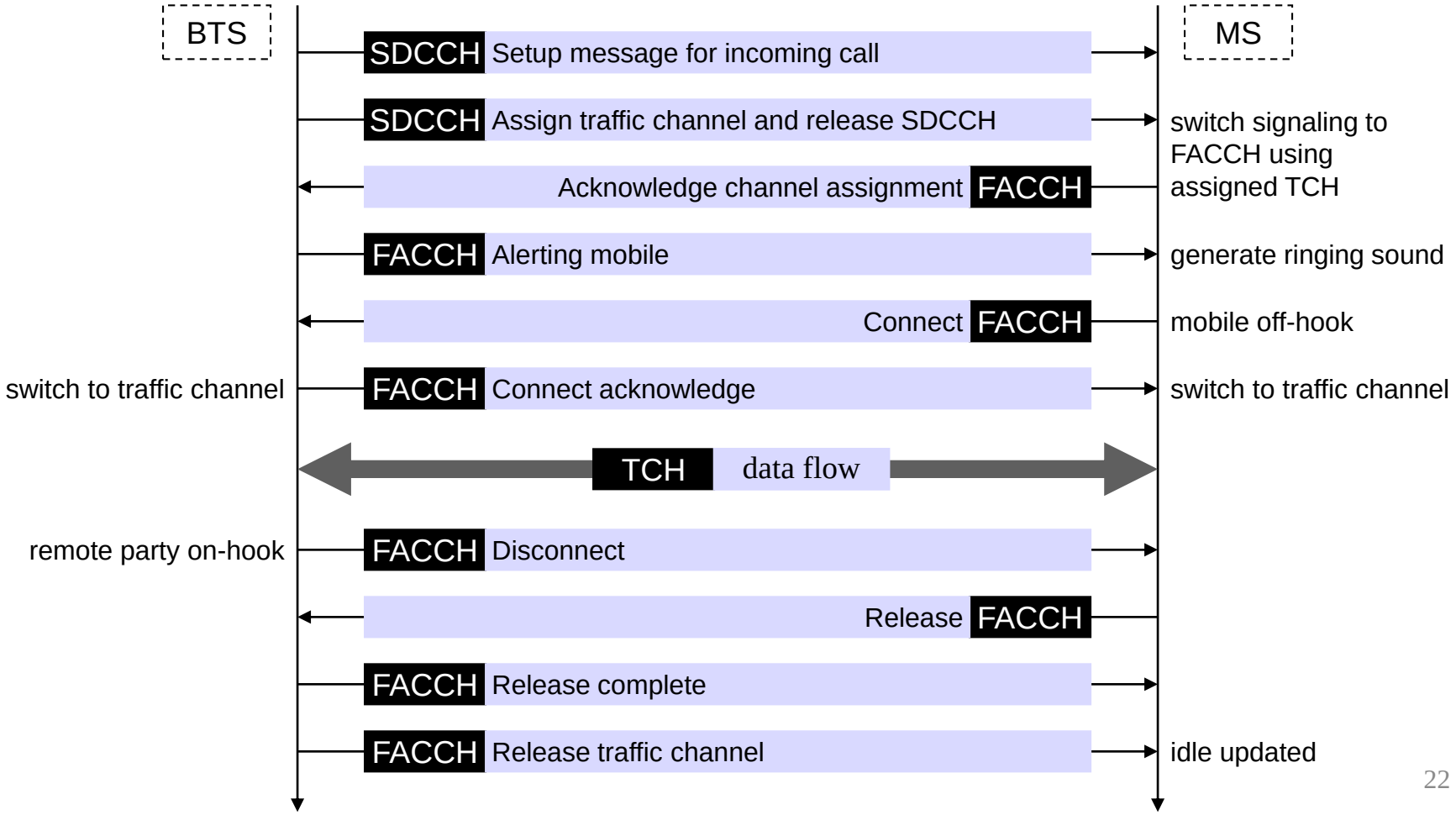
Mobile Terminated Call

Channel activity at radio interface



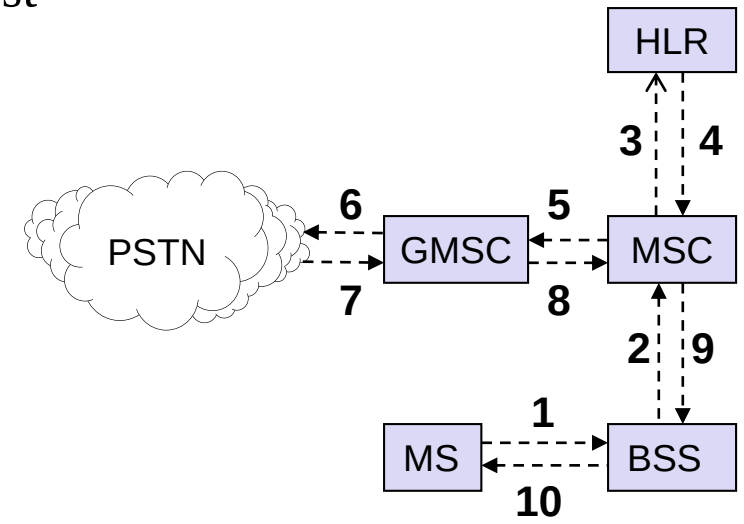
Mobile Terminated Call

Channel activity at radio interface (cont.)



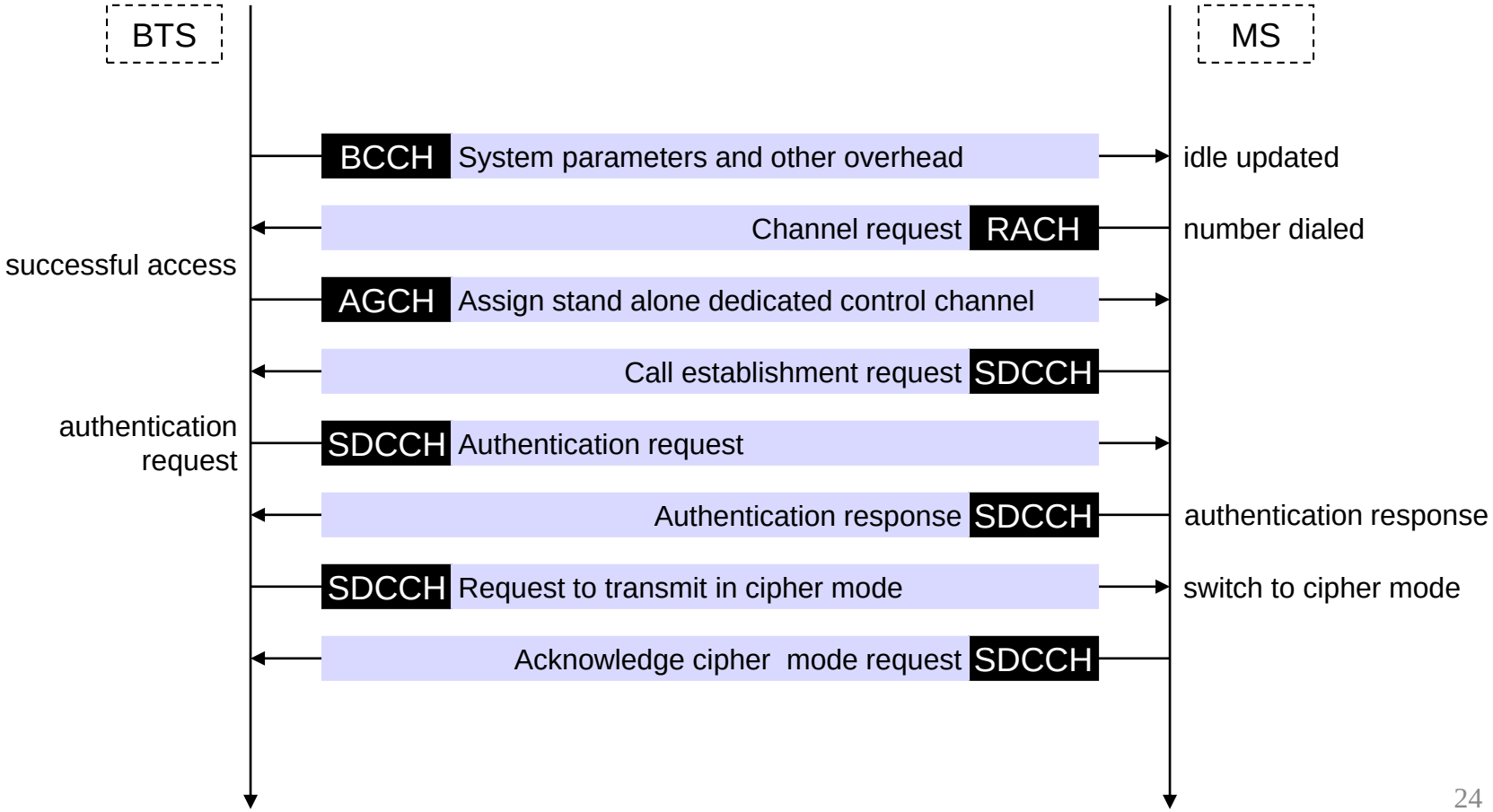
Mobile Originated Call

- 1, 2: connection and authentication request
- 3, 4: security check
- 5-8: check resources (obatain circuit)
- 9-10: set up call



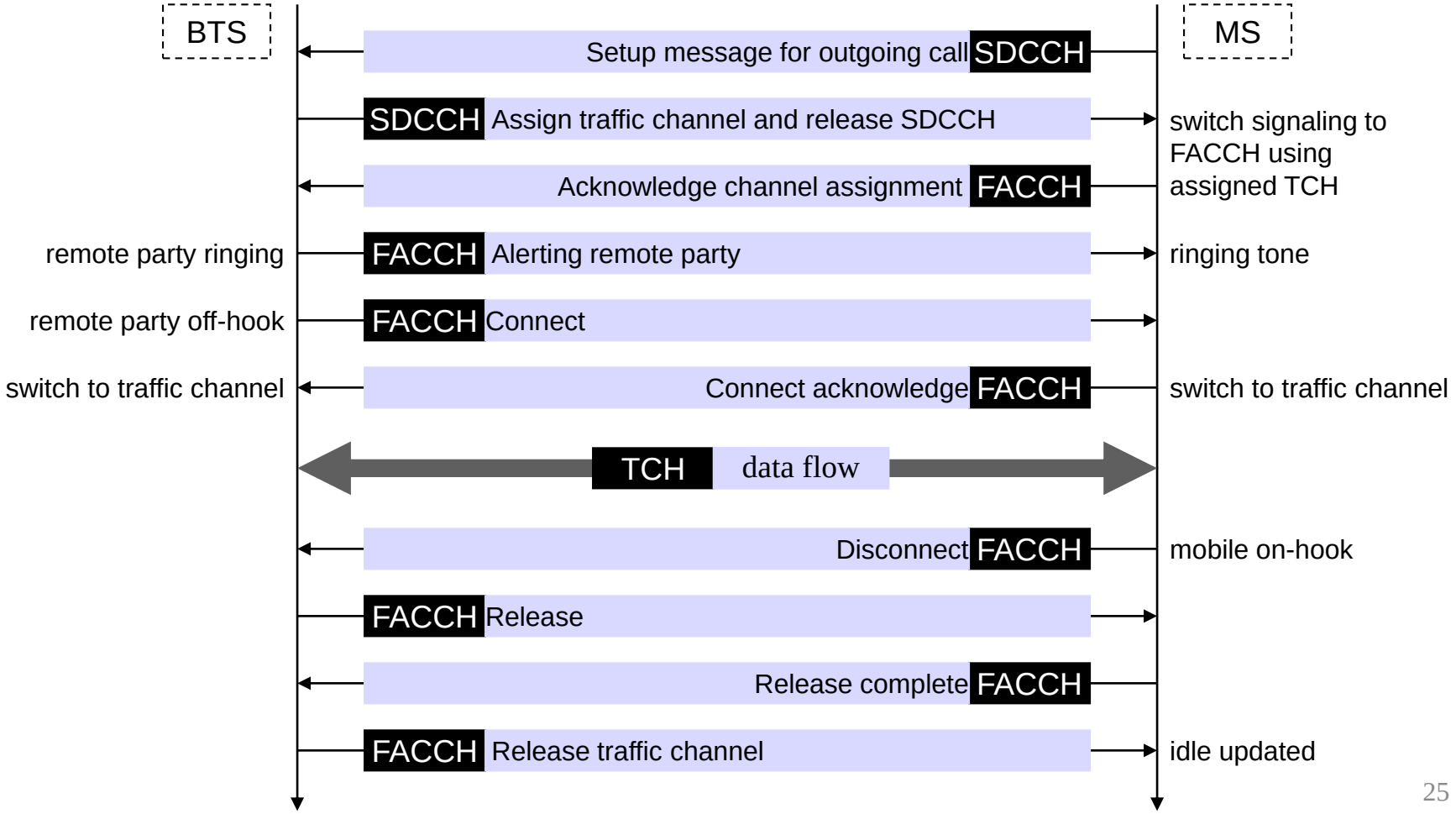
Mobile Originated Call

Channel activity at radio interface



Mobile Originated Call

Channel activity at radio interface



GPRS – General Packet Radio Service

GPRS - General Packet Radio Service

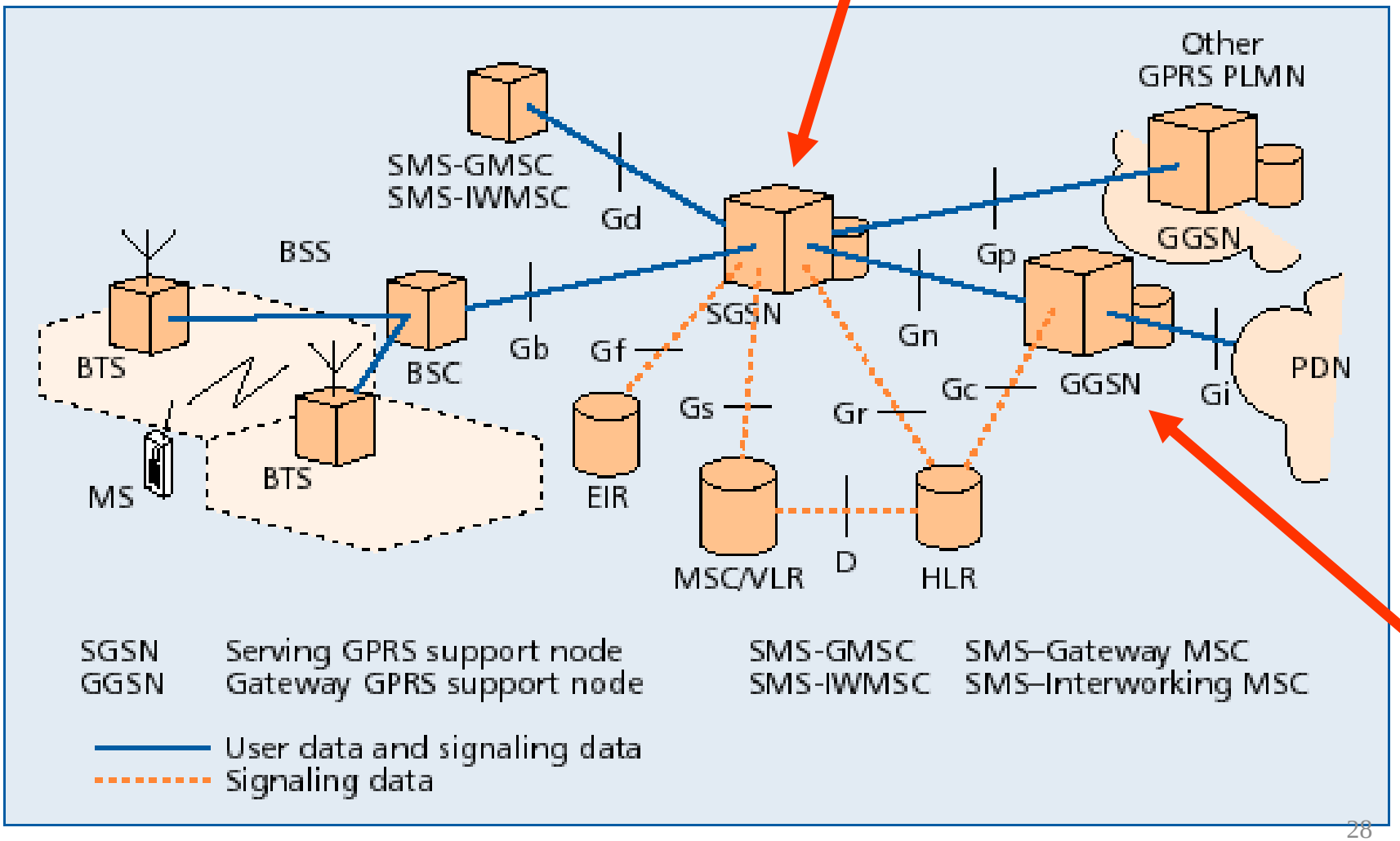
- Adds packet switching to GSM

  data transferred as packets

- Simplifies access to Internet

- Improves network efficiency

GPRS Architecture

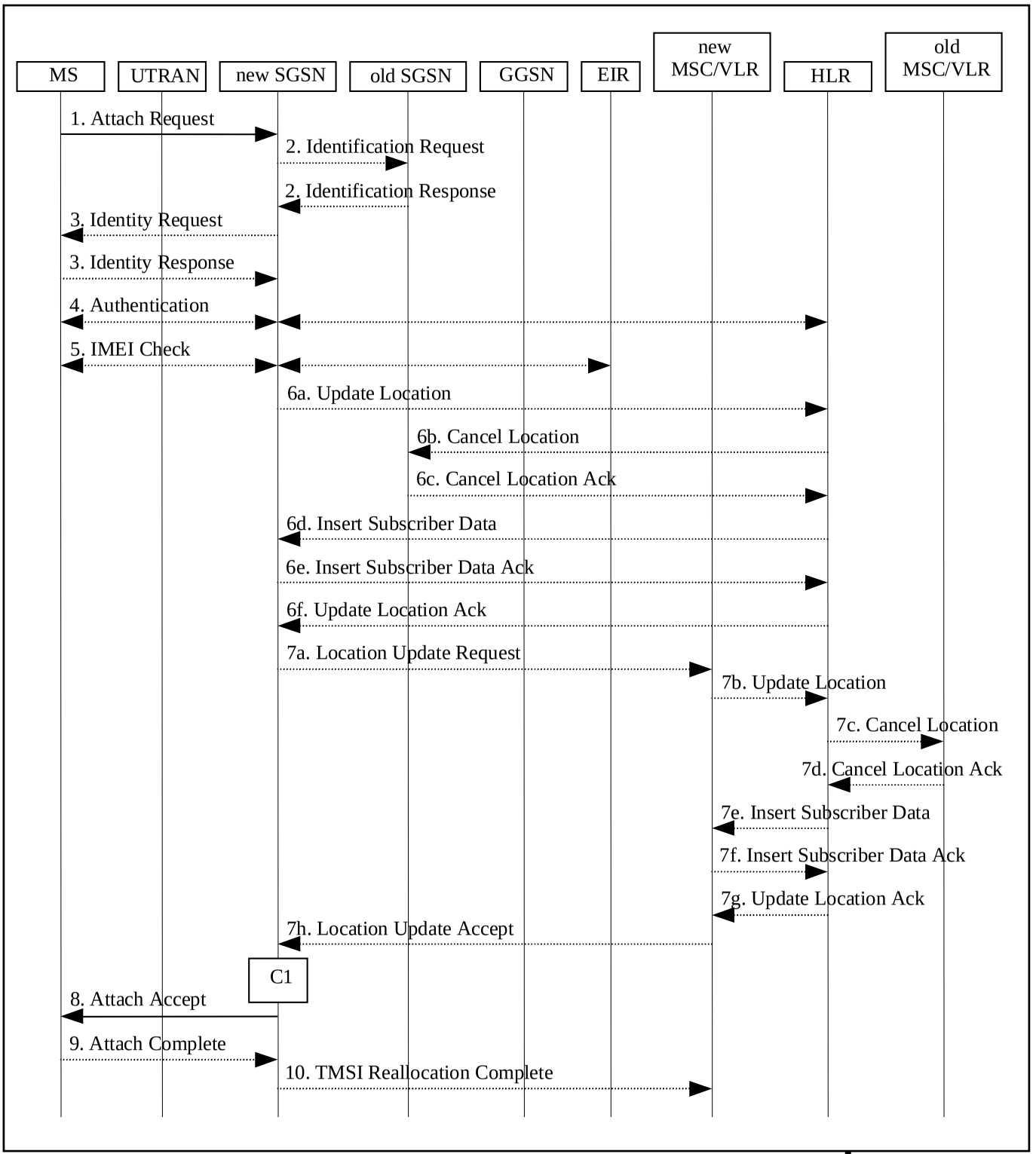


GPRS Architecture

- Addition of 2 new network elements: SGSN, GGSN
- **SGSN:** *Serving GPRS Support Node*
  - » Authentication
  - » Packet switch
  - » Control of the logical link
  - » Mobility management
  - » Traffic accounting
- **GGSN:** *Gateway GPRS Support Node*
  - » Router for the IPv4/IPv6 Internet
- xGSNs network elements
  - » Interconnected by common packet network (eg. IP over Ethernet)
  - » Tunnels established between SGSN and GGSN:
    GTP (GPRS Tunneling Protocol)

Terminal Attachment to GPRS

- Before using GPRS
  - » terminal must perform **Attach** procedure
- During Attach
  - » Network verifies if user is subscribed
  - » Subscriber profile transferred from HLR to SGSN
  - » Temporary packet identifier assigned to subscriber: P-TMSI
- GPRS Attach may be combined with GSM attach

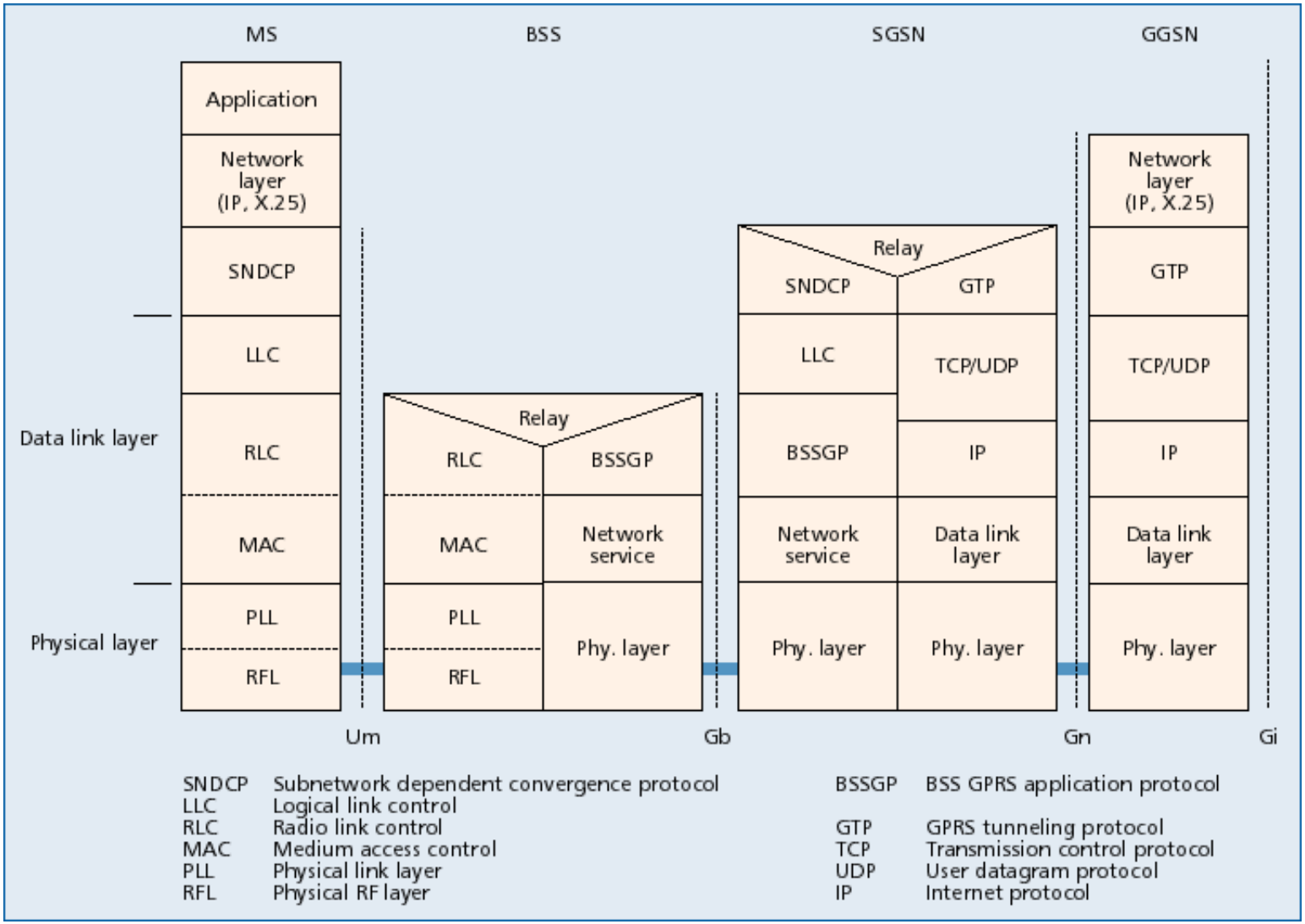


Combined GSM/GPRS Attach

PDP Context

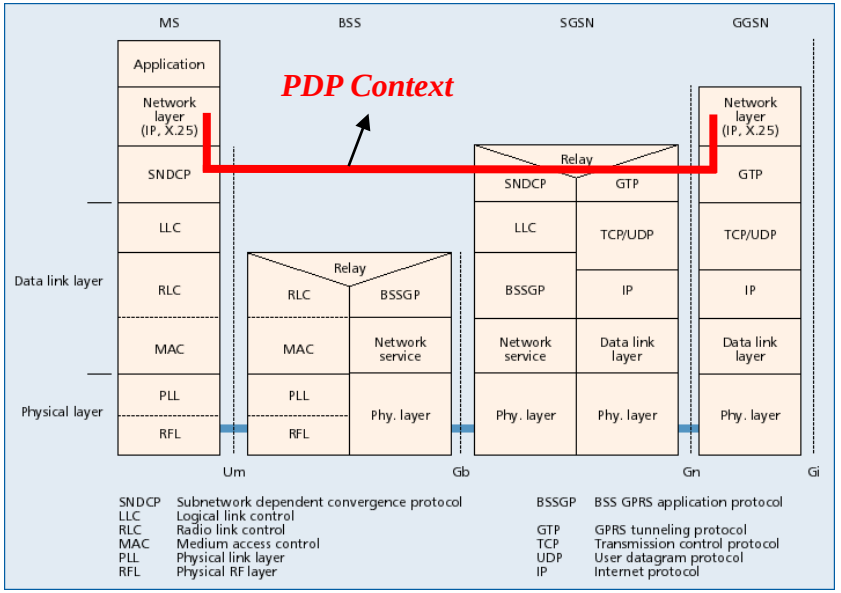
- Establishment of a packet session (after successful Attach procedure)
  - » Terminal obtains IP address
  - » PDP context is defined and stored and MS, SGSN and GGSN
- PDP context contains
  - » Type of external packet network (e.g. IPv4 or IPv6)
  - » Address assigned to the MS (e.g. IPv4 address)
  - » GGSN address (default gateway)
- GGSN makes the association between IMSI and IP addresses
- Context created ➔ terminal reachable ➔ data can be transferred

Protocol Architecture – Data Plane



Protocol Architecture – Data Plane

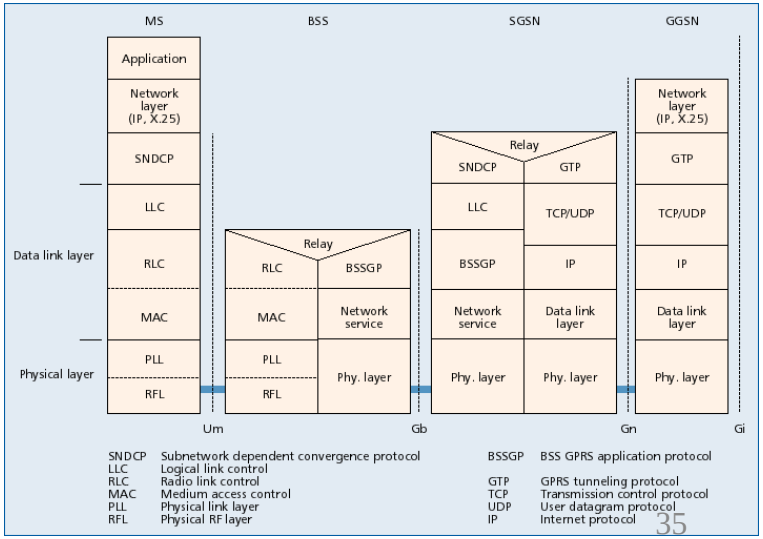
- GTP - GPRS Tunneling Protocol
  - » Tunnel; transports IP packets
  - » Used at the networks backbone
  - » GTP packets transported over UDP/IP



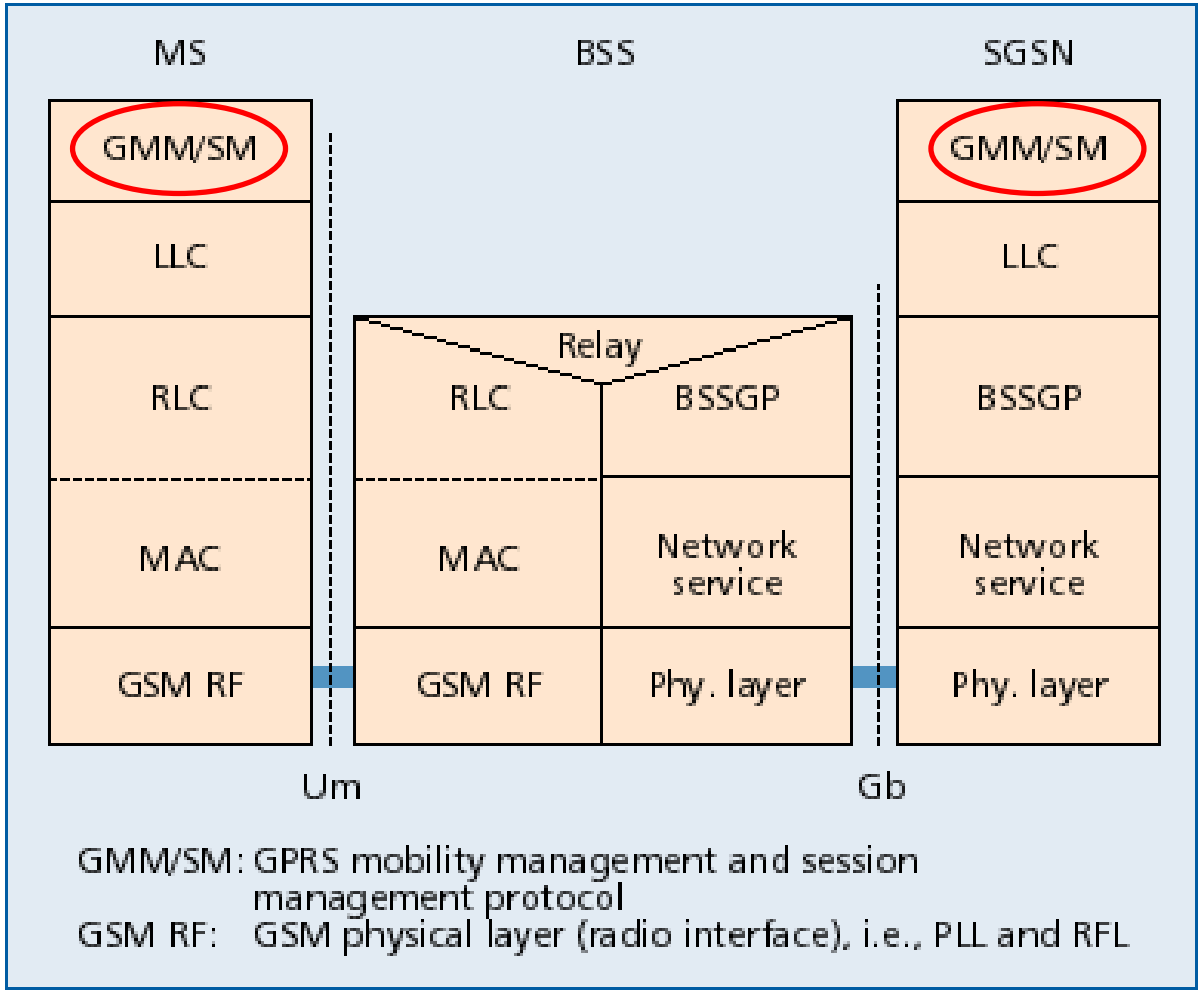
- SNDCP - Subnetwork Dependent Convergence Protocol
  - » Packet transference between MS e SSGN
  - » Header compression, data protection

Protocol Architecture – Data Plane

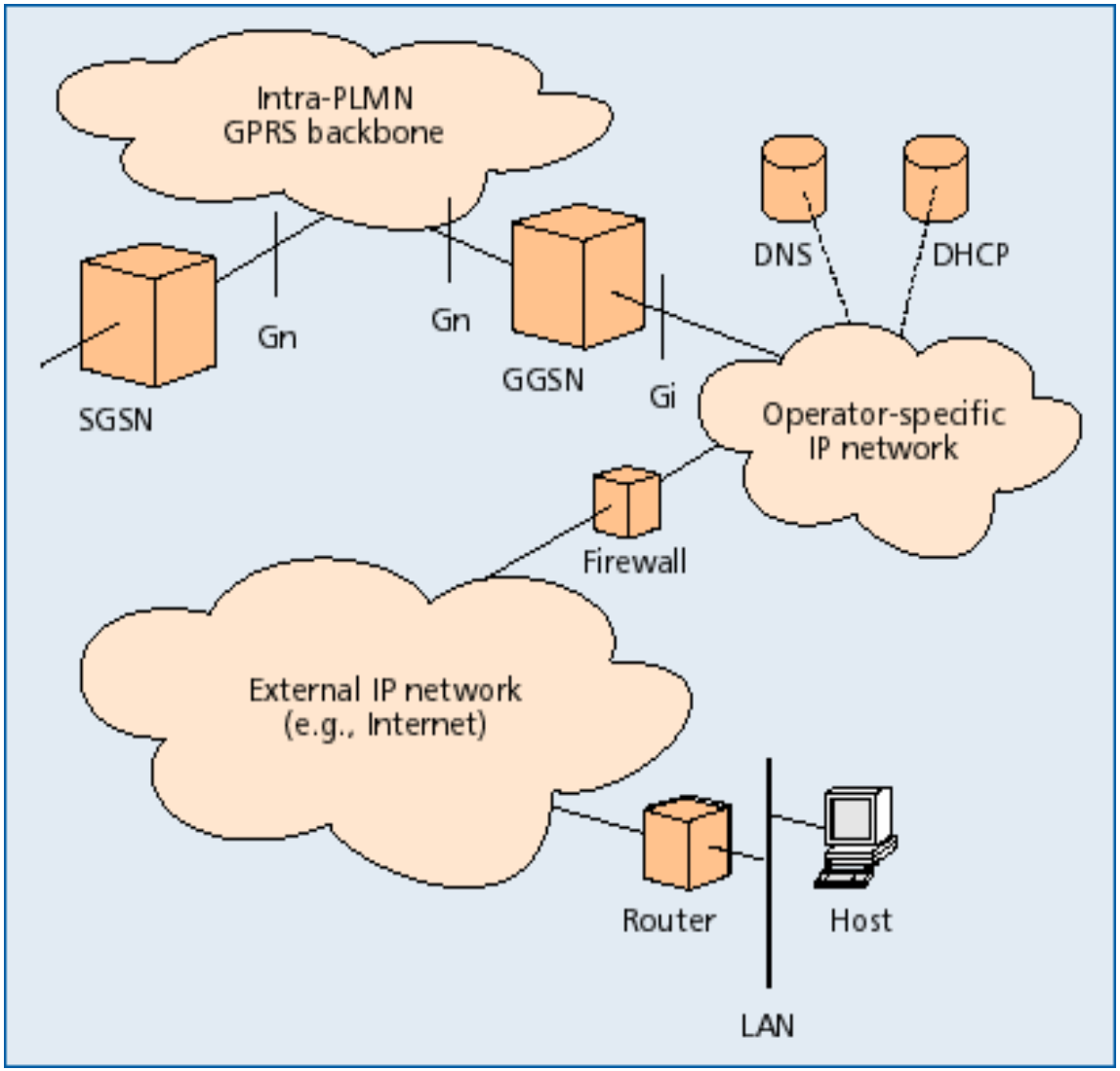
- LLC (MS-SSGN)
  - Logical link connection between MS and SSGN; based on LAPDm (GSM)
  - In order delivery, flow control
  - Acknowledge and not-acknowledge services
- RLC
  - Reliable link between MS and BSS
  - Segments and reassembles LLC frames into RLC blocks
  - ARQ of blocks
- MAC
  - Based on slotted Aloha
  - Logical channels
- PLL+RLF (Physical Link Layer)
  - Provide physical channel for data
  - Error detection, FEC
  - Modulation; same used in GSM



Protocol Architecture – Control Plane

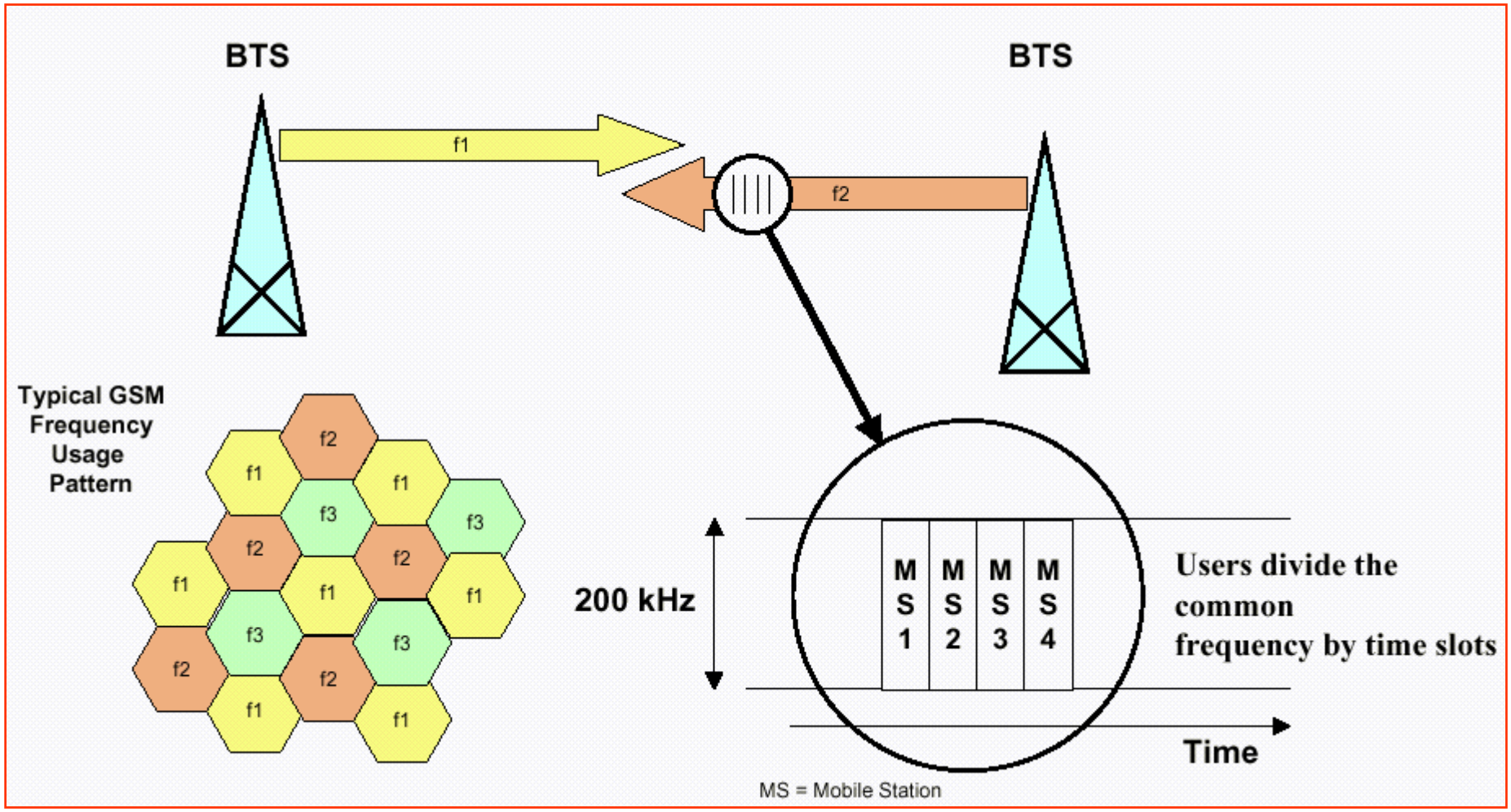


Interconnection to an IP Network

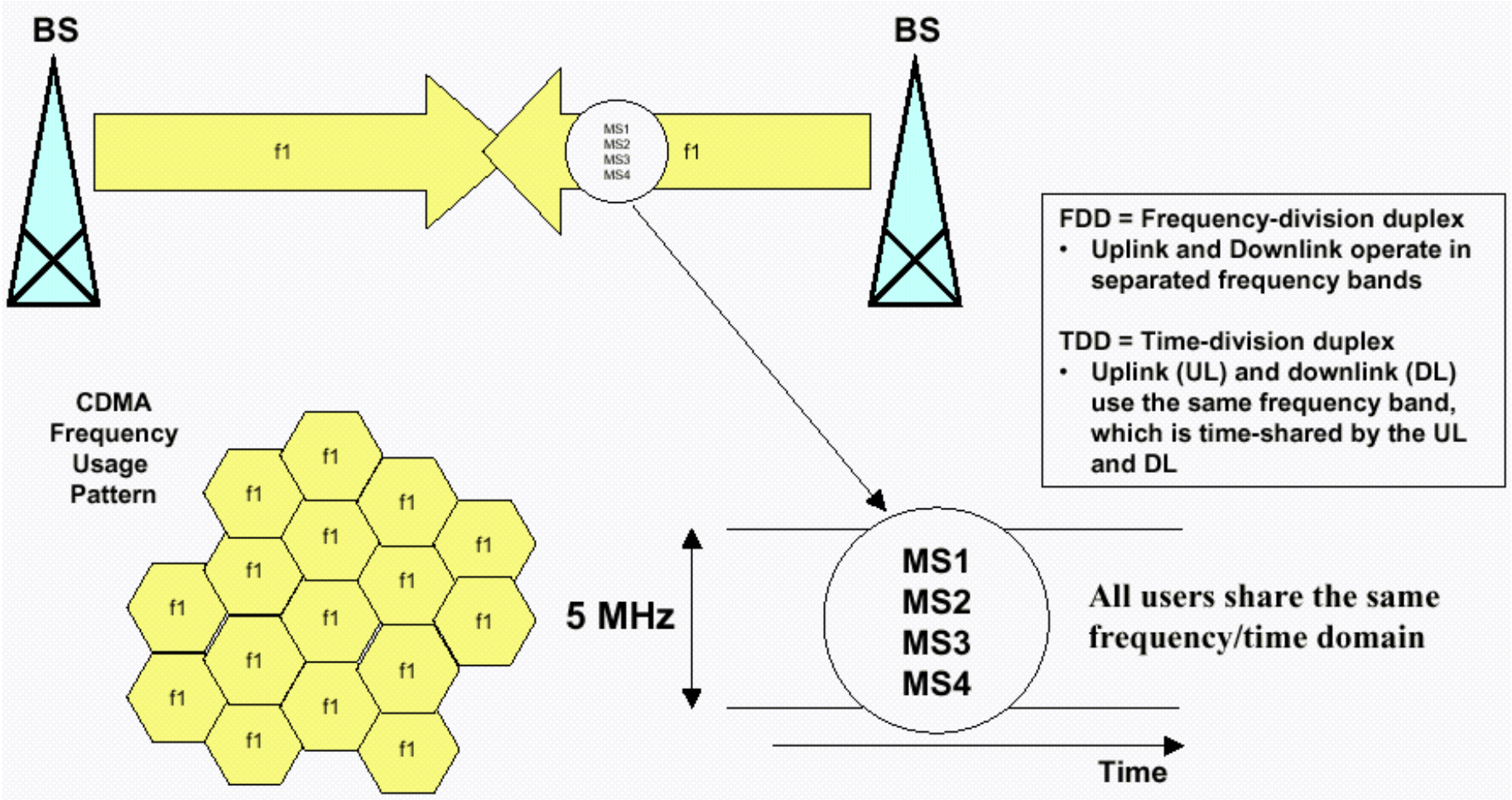


UMTS (3G) - WCDMA

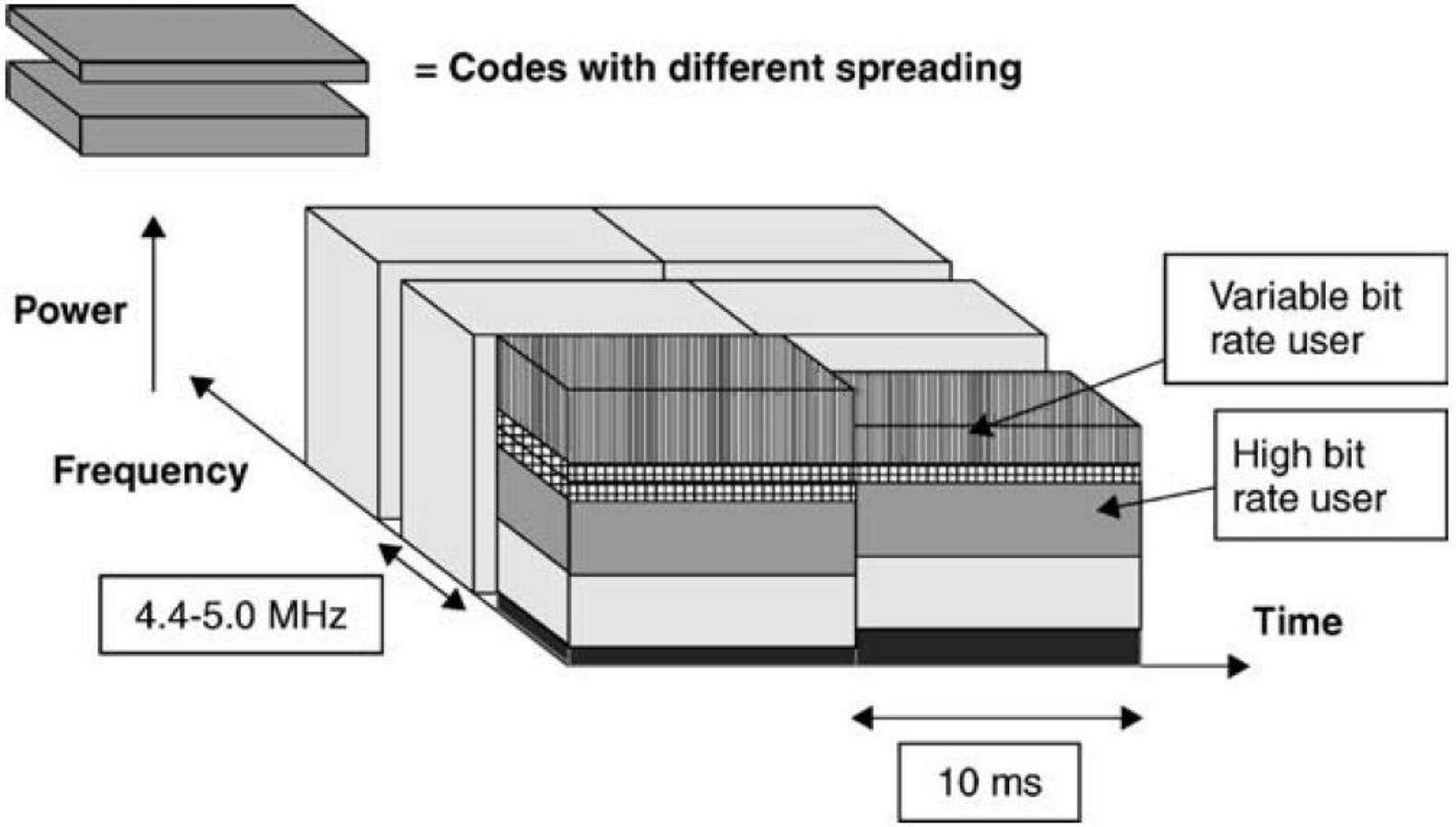
GSM → TDMA


BTS
BTS
f1
f2
Typical GSM Frequency Usage Pattern
f1
f2
f3
200 kHz
MS 1
MS 2
MS 3
MS 4
Users divide the common frequency by time slots
Time
MS = Mobile Station

WCDMA


BS
BS
f1
MS1
MS2
MS3
MS4
f1
FDD = Frequency-division duplex
• Uplink and Downlink operate in separated frequency bands
TDD = Time-division duplex
• Uplink (UL) and downlink (DL) use the same frequency band, which is time-shared by the UL and DL
CDMA Frequency Usage Pattern
5 MHz
MS1
MS2
MS3
MS4
All users share the same frequency/time domain
Time

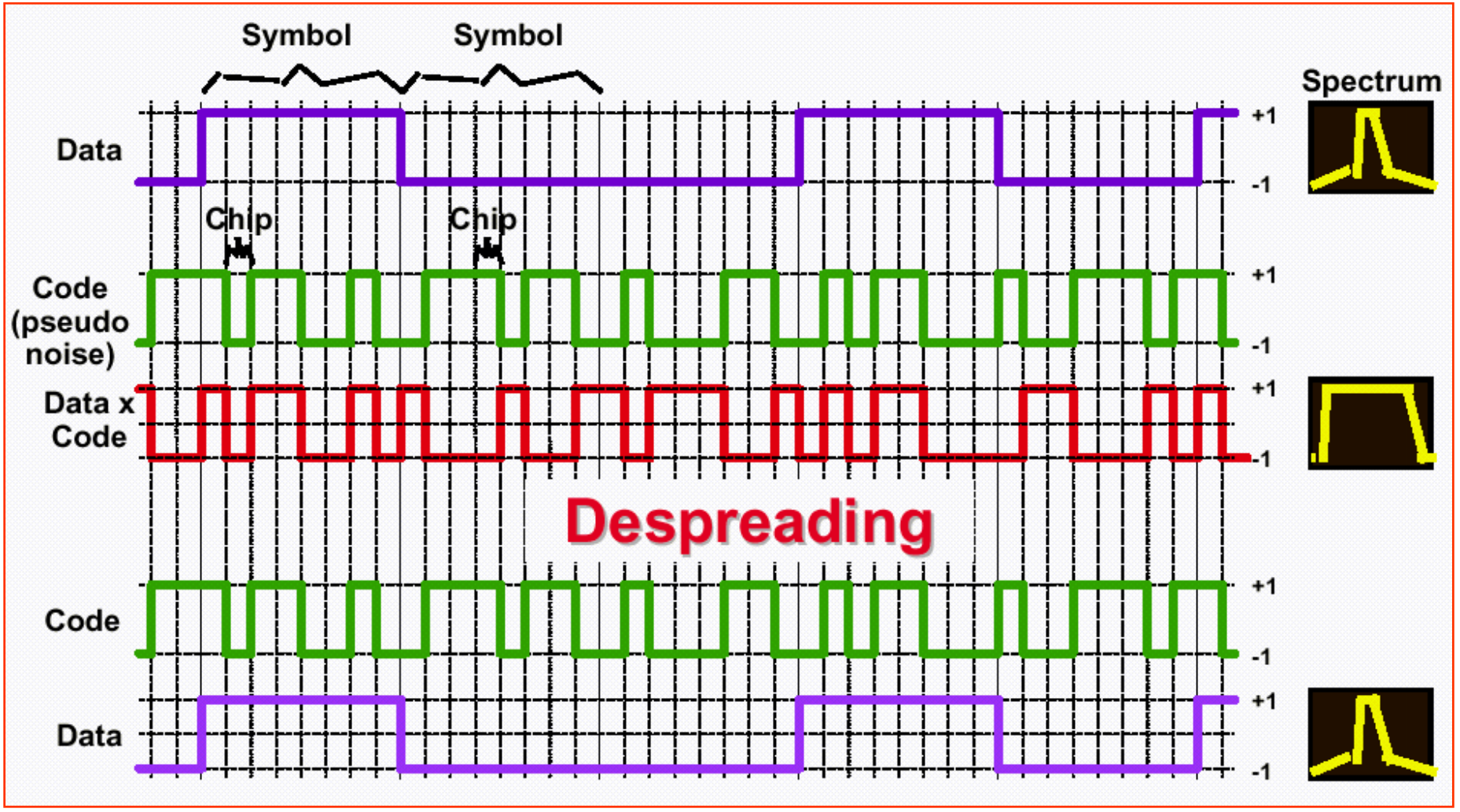
Allocation of Bandwidth in WCDMA - Time/Frequency/Code Space



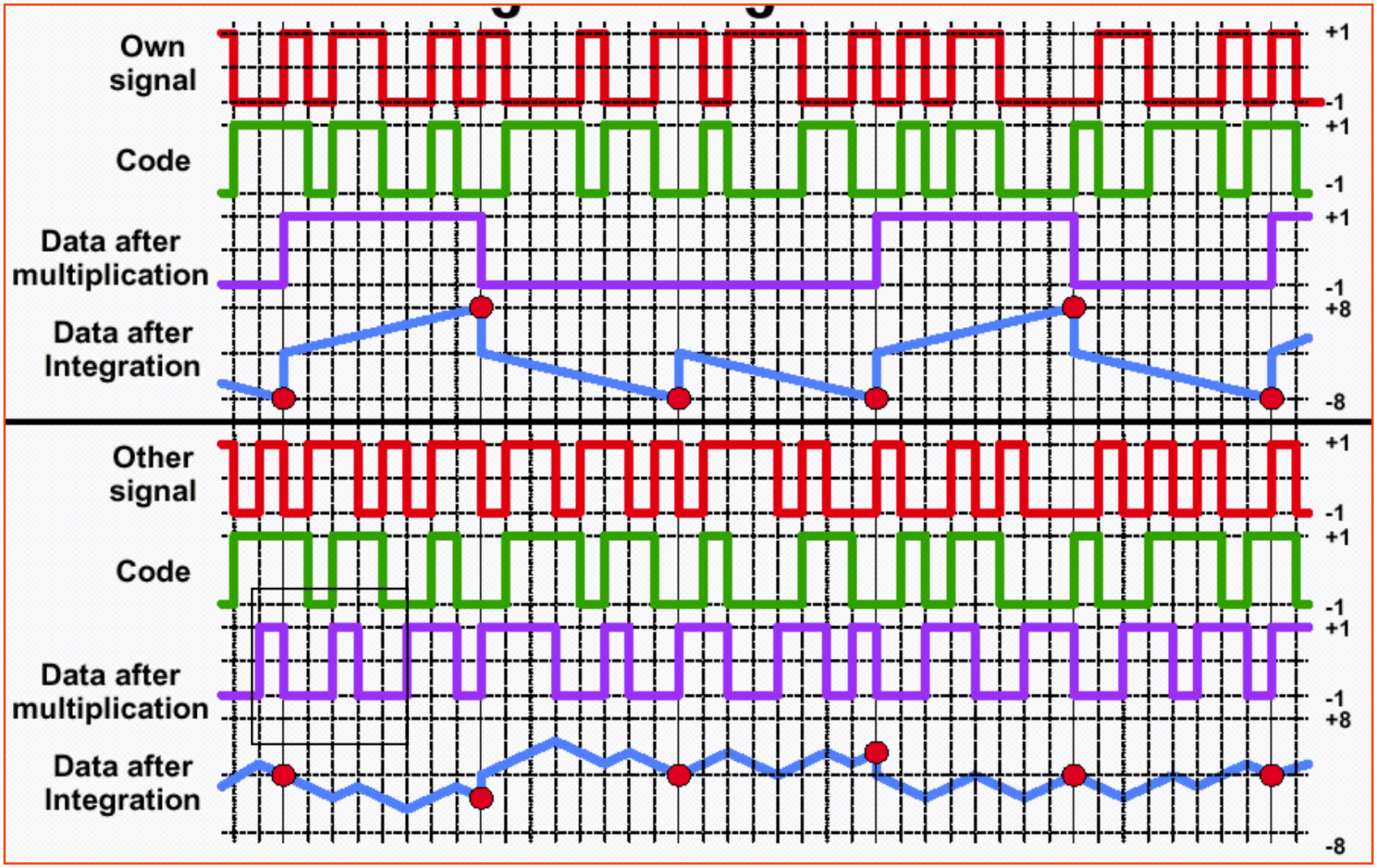
Comparison GSM/WCDMA

	WCDMA	GSM
Carrier spacing	5 MHz	200 kHz
Frequency reuse factor	1	1–18
Power control frequency	1500 Hz	2 Hz or lower
Quality control	Radio resource management algorithms	Network planning (frequency planning)

Spreading, Despreading



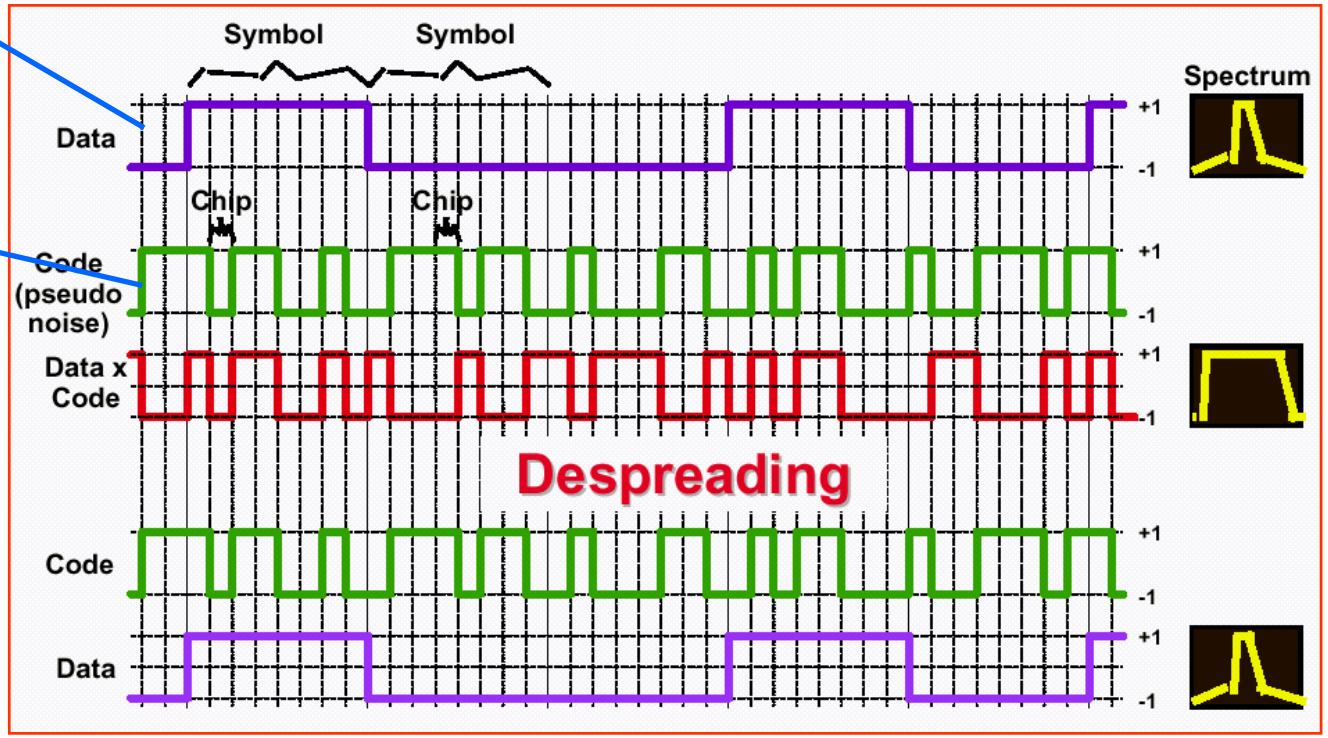
Despreading - Own vs Other Signals



Spreading Factor, Bitrate

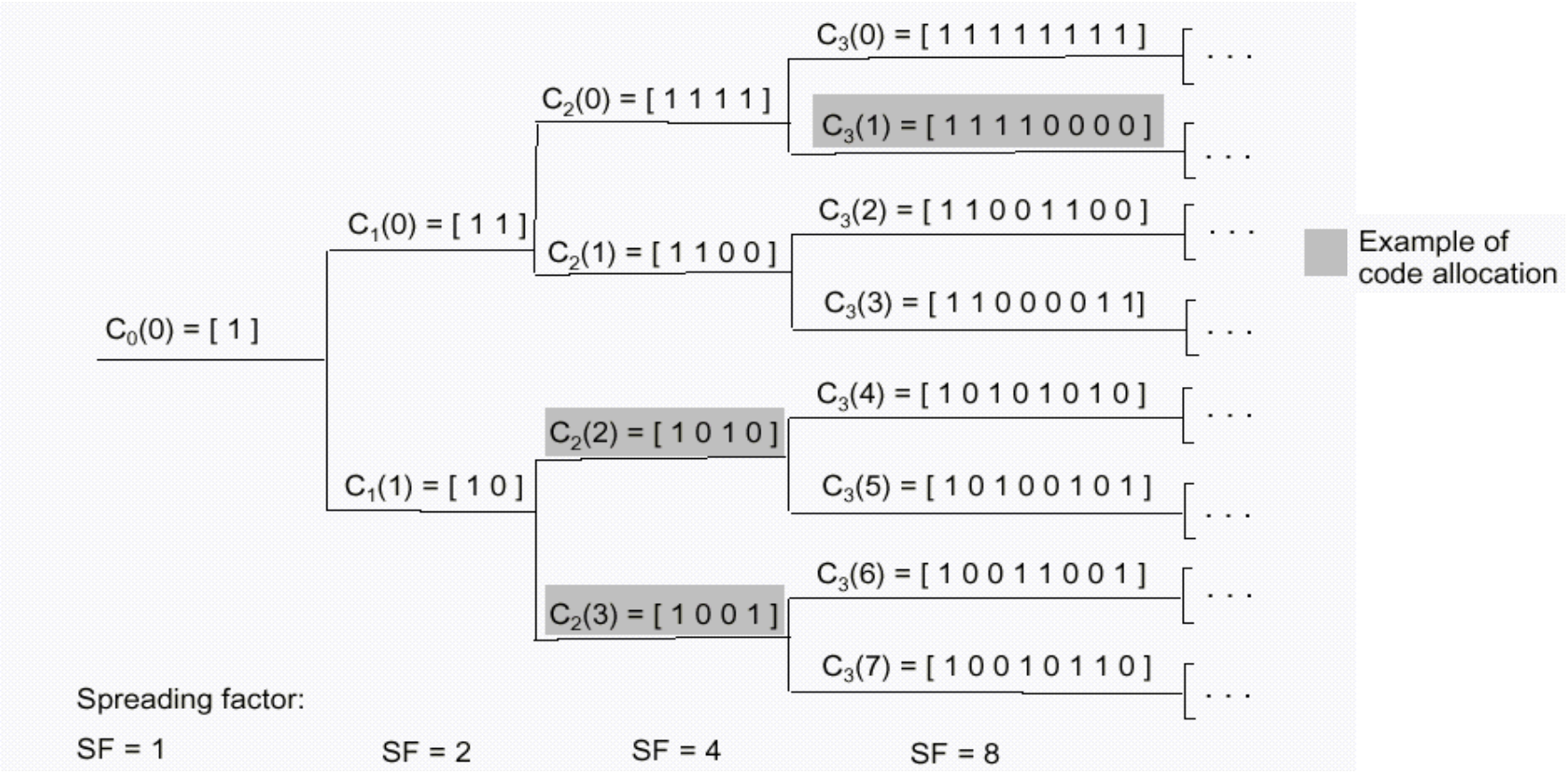
- **Chiprate = 3.84 Mchip/s**
- **SF=8 (chip/bit)**
- **Bitrate = $3.84*10^6 / 8 = 480$ kbit/s : SF ↗ ➔ Bitrate ↘**

3.84 Mchip/s



Spreading Codes

- Hierarchical selection of codes → orthogonality



Uplink Capacity – Maximum Number (N) of users

- Ideal power control (every sinal received with same power)
- N users transmitting at bitrate R bit/s

$$\frac{S}{I} = \frac{S}{S(N-1)} = \frac{1}{N-1} \approx \frac{1}{N}$$

$$\frac{E_b}{I_0} = \frac{S/R}{I/W} = \frac{W}{R}\frac{S}{I} = \frac{W}{R}\frac{1}{N-1} \approx \frac{W}{RN}$$

N – number of users

S – power received form each user (W)

I – interference from other users (W)

E_b – energy received per information bit (J/bit)

I_0 – Interference spectral density (J/Hz)

W –chip rate (chip/s)

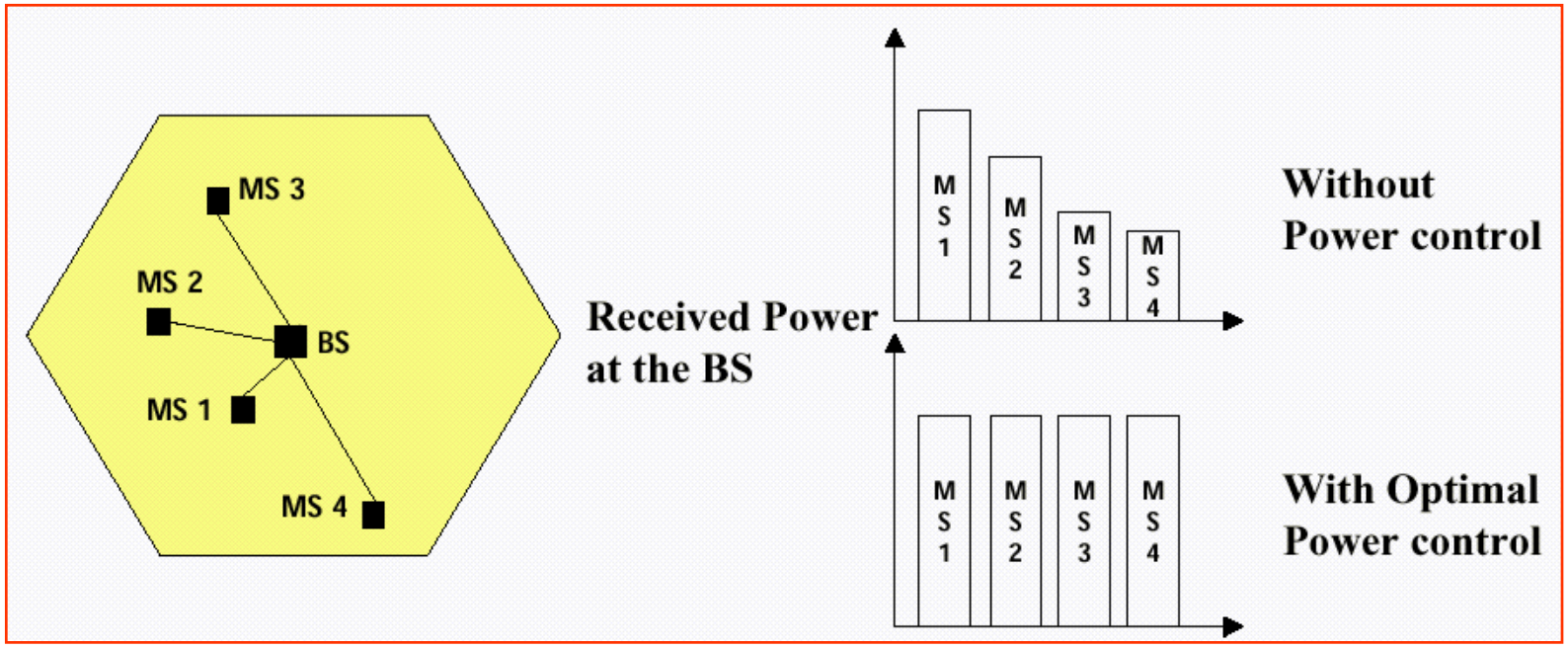
R – information bitrate (bit/s)

$$N \cong \frac{W}{R}\frac{1}{\frac{E_b}{I_0}}$$

- E_b/I_o decreases ➔ BER increases, or alternatively, for a given E_b/I_o , (BER),
  - RN ~ $\sum_{i=1}^{N} R_i$ ➔ must be managed ➔ **admission control**

Power Control

- Enable equal powers to be received at the Base Station
- Enable terminals to transmit at lowest possible power
  - » Low power ➔ low interference on other terminals ➔ more calls admitted



Power Control – Adaptation Mechanisms

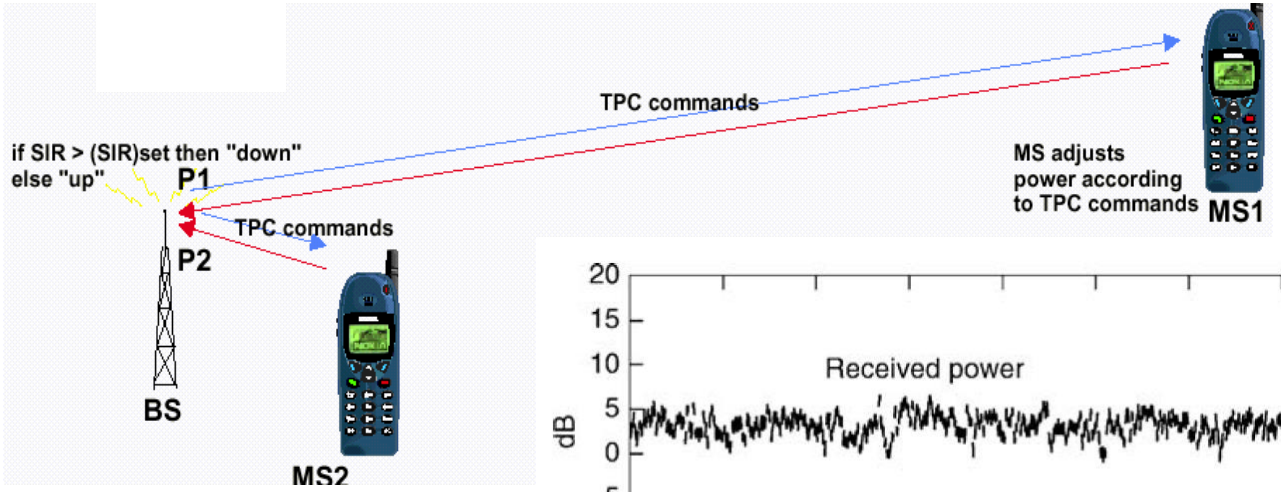
- Open loop control
  - » Used in the uplink during call establishment
  - » Power Tx determined based on the power Rx in common channel
    - – terminal assumes same attenuation in downlink and uplink
    - – Problem ➔ duplex in frequency ➔ different attenuations for both directions

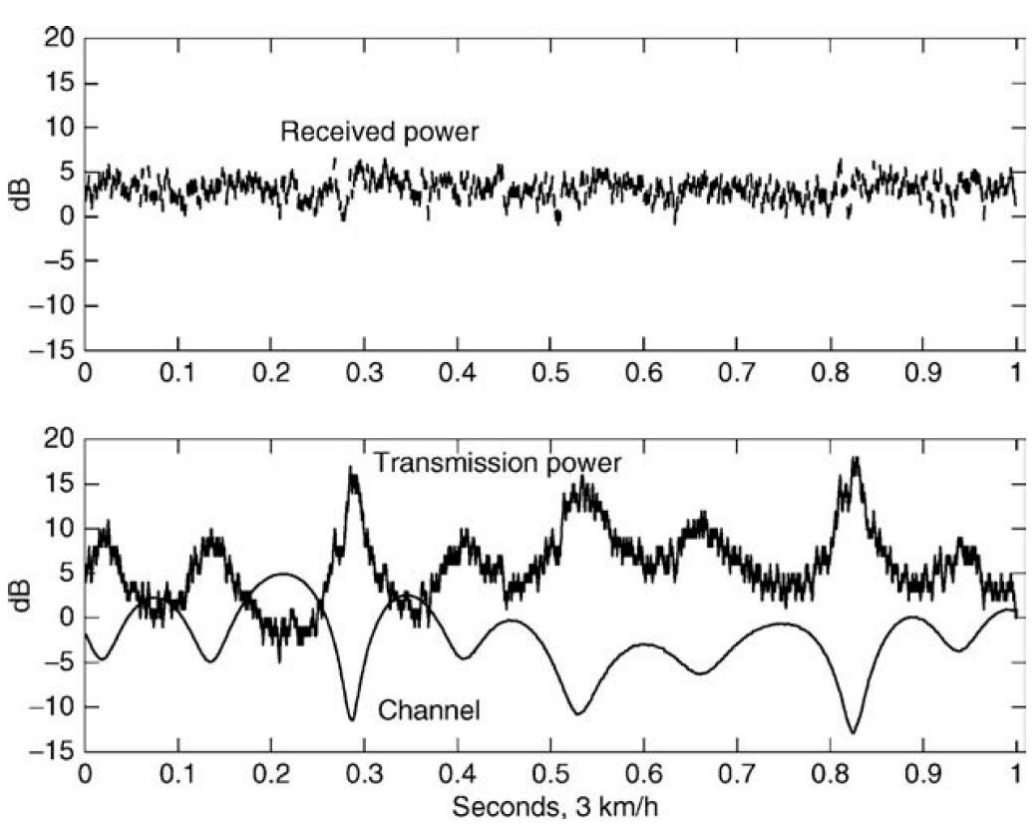
- Closed loop control
  - » Frequent commands sent by Terminal/BS to order increase/decrease Tx power
    - – one command per timeslot (1500 command/s)
  - » SIR measurement ➔ comparison with SIR objective

    ➔ request to increase/decrease Tx power

    Delta of 1 dB; range 70 dB

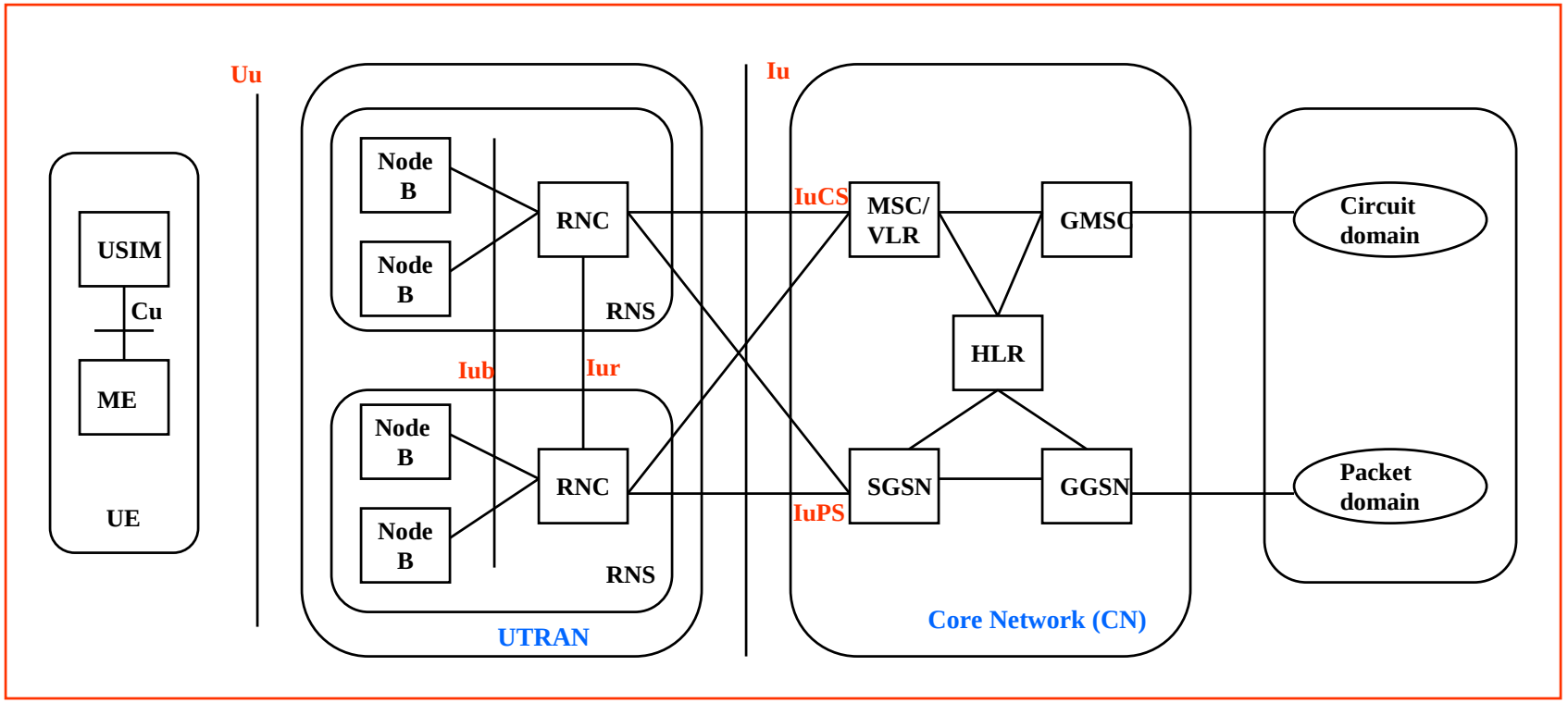
Power Control – Closed Loop





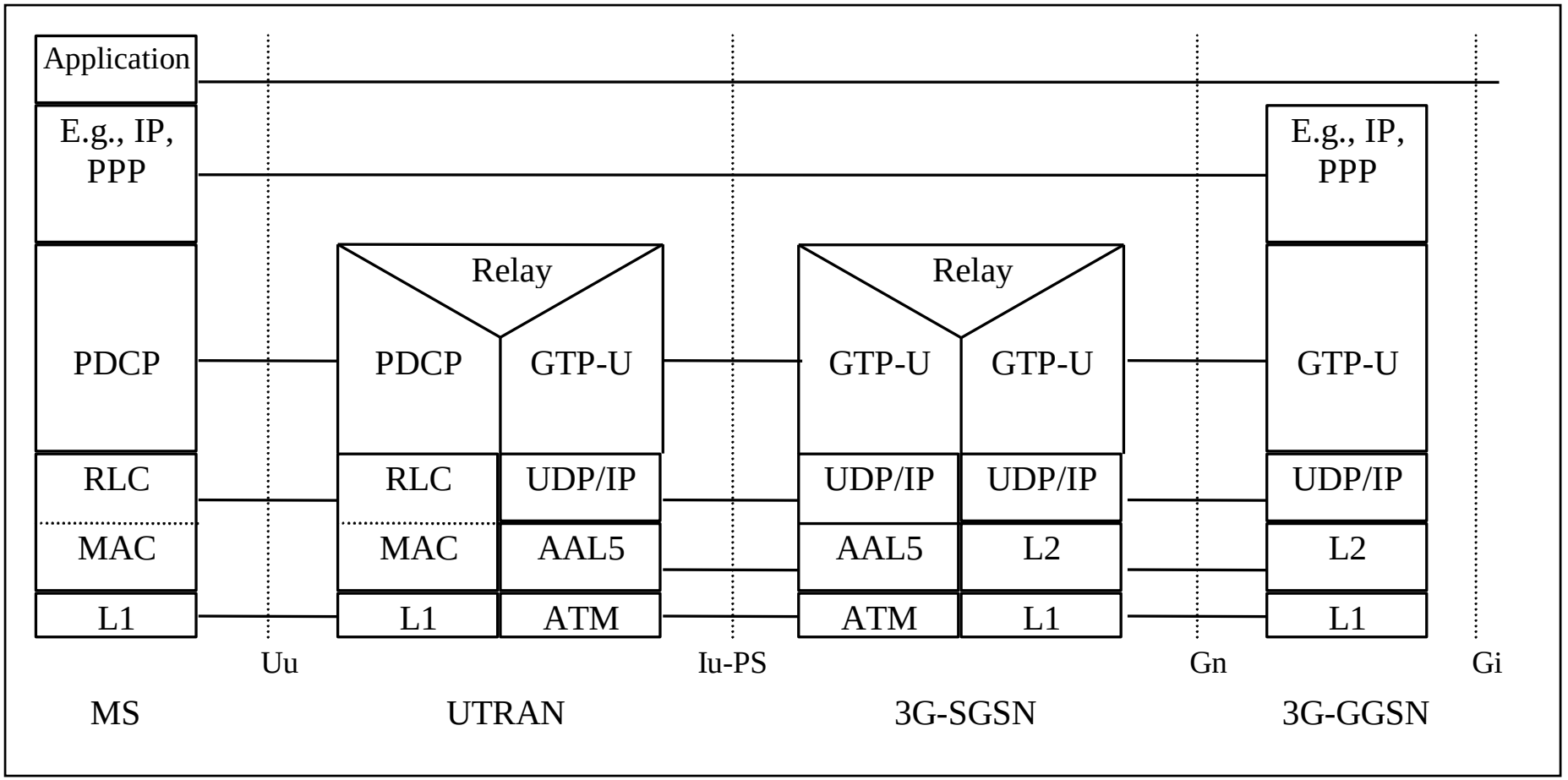
Network Architecture

UMTS Network Architecture



- Architecture UMTS: UTRAN + core network
- UTRAN: UMTS Terrestrial Radio Access network
- Core network
  - » Circuit domain (CS) → MSCs, GSM, voice, video
  - » Packet domain (PS) → xGSNs, GPRS, IP, data

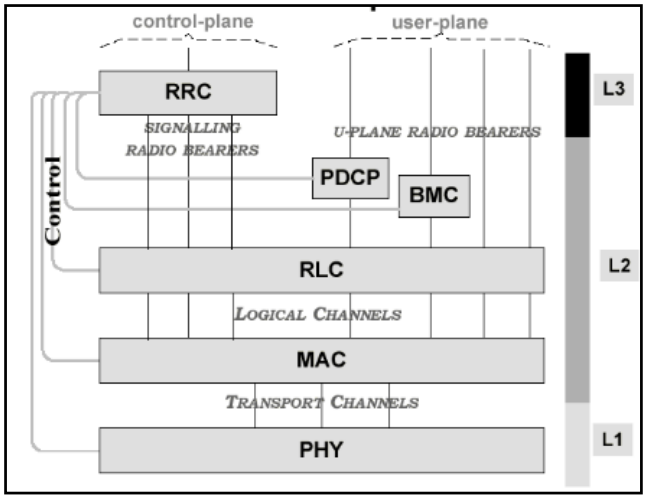
Packet Domain – User Plane Protocols



Radio Interface

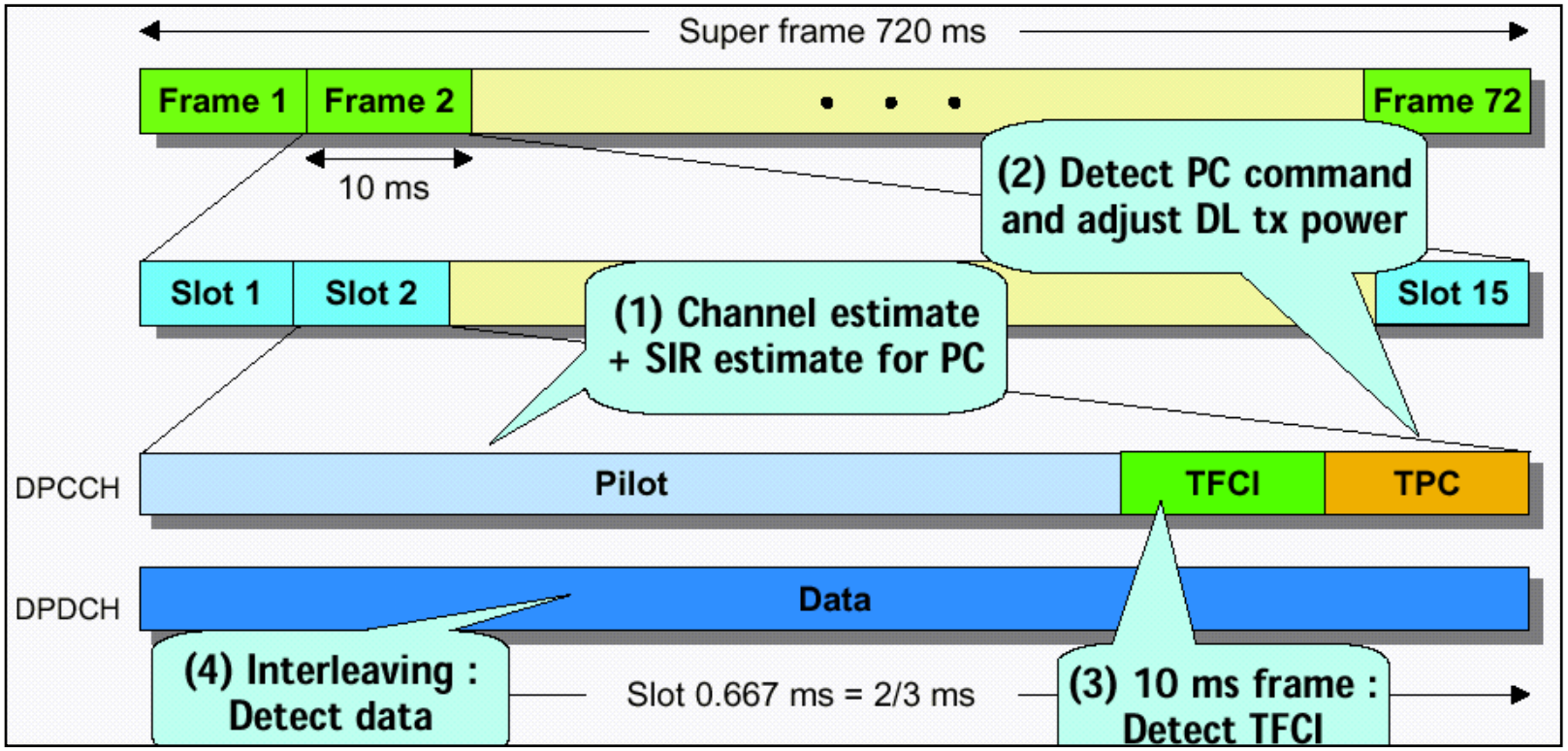
Protocols in the Radio Interface

- Physical (PHY)
  - » WCDMA, frame formats, modulations
- Medium Access Control (MAC)
  - » Multiple access to shared channels
- Radio Link Control (RLC)
  - » Segmentation | Flow control |Encryption
- Packet Data Convergence Protocol (PDCP)
  - » Compression of IP headers (TCP/IP, RTP/UDP/IP)
  - » Re-localization with no losses
- Broadcast/Multicast Protocol (BMC)
  - » Broadcast of common information in non-confirmed mode
- Radio Resource Control (RRC)
  - » Broadcast of system information. Paging. Cell selection
  - » Establishment of the RRC connection
  - » Mobility of the RRC connection
  - » Power control in downlink
  - » Open loop power control



Protocols between terminals and UTRAN (RNC or Node B)

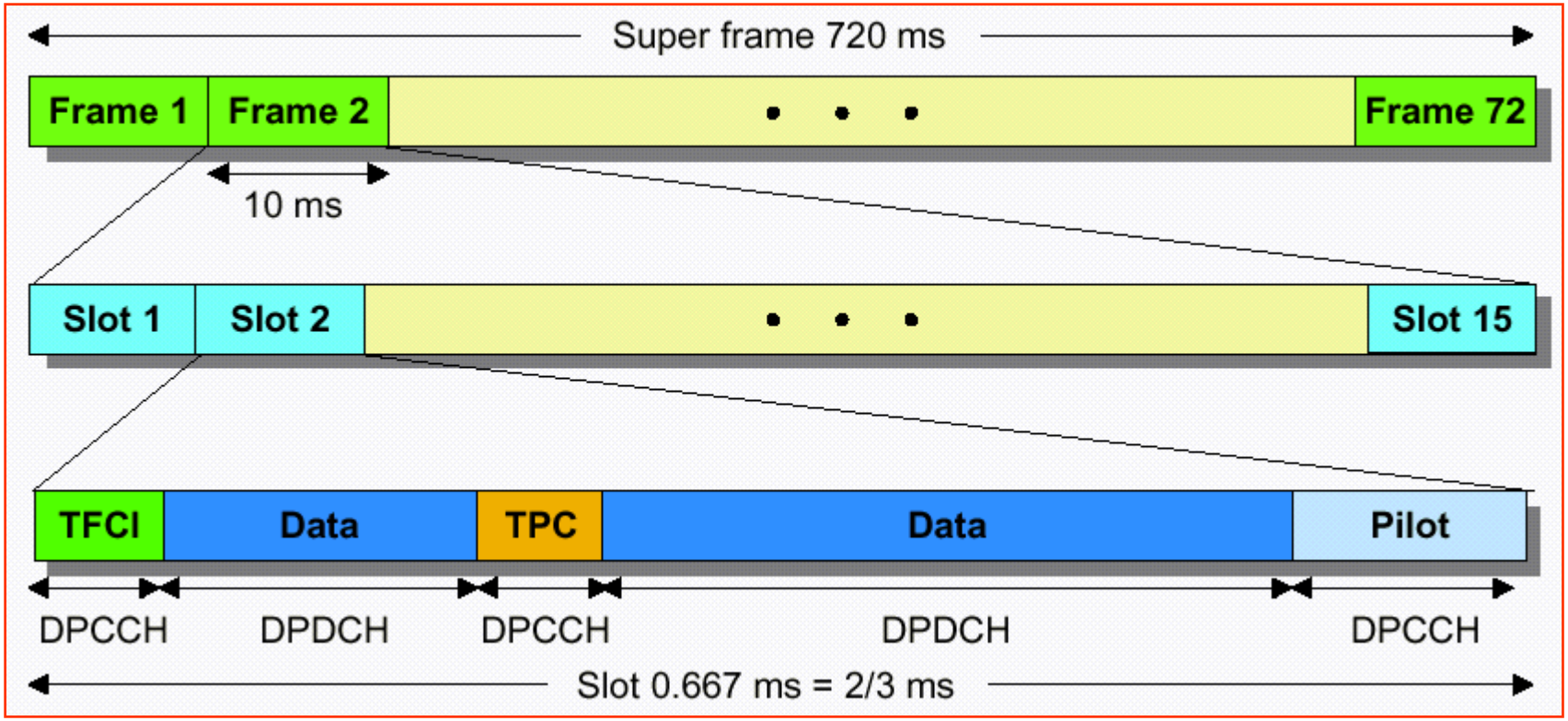
Dedicated Channel - Uplink



- **DPC**CH: dedicated control channel | **DPD**CH: dedicated data channel
- DPCCH and DPDCH sent respectively as In-phase and Quadrature components of modulation
  - » Pilot symbols → used to estimate channel response and interference (SIR)
  - » TFCI, Transport Format Combination Indicator → code, frame bitrate
  - » TPC, Transmit Power Control → controls the power to be transmitted in downlink
- Different codes for DPCCH and DPDCH

Dedicated Channel - Downlink

- » QPSK Modulation
- » DPCCH and DPDCH multiplexed in time



Homework

- Review slides
- GSM: read from Schiller, Chap. 4.1
- GPRS: read from Agilent Technologies, “Understanding General Packet Service (GPRS)”, Application Note 1377
- WCDMA: use book: “Harri Holma, Antti Toskala, WCDMA for UMTS - HSPA evolution and LTE, 5th edition, John Wiley & Sons
- Answer questions at moodle