UNIK

UNIVERSITY OF OSLO

UNIK4230: Mobile Communications

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Network Architecture and Functionality

Agenda

- Network Architecture
- Protocol stacks
- Air Interface
- System Capacity

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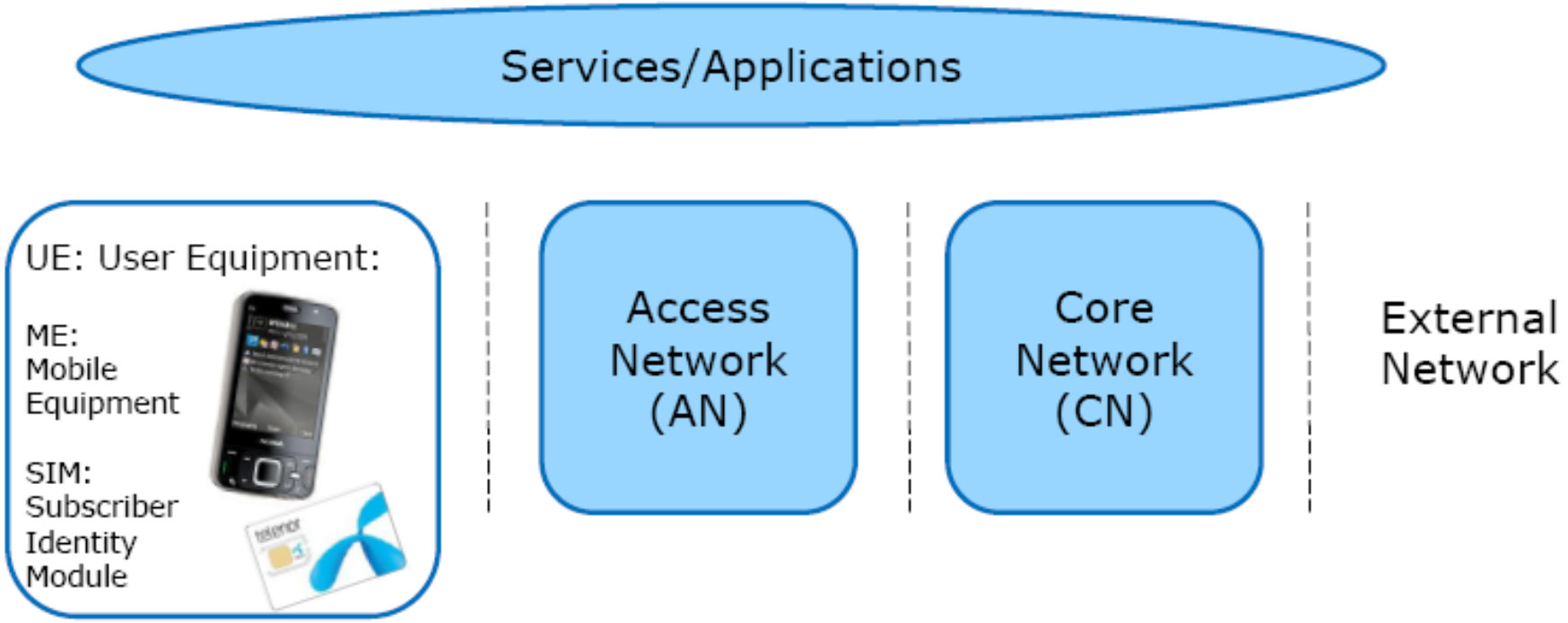
- System Capacity

Overview of Network Architecture



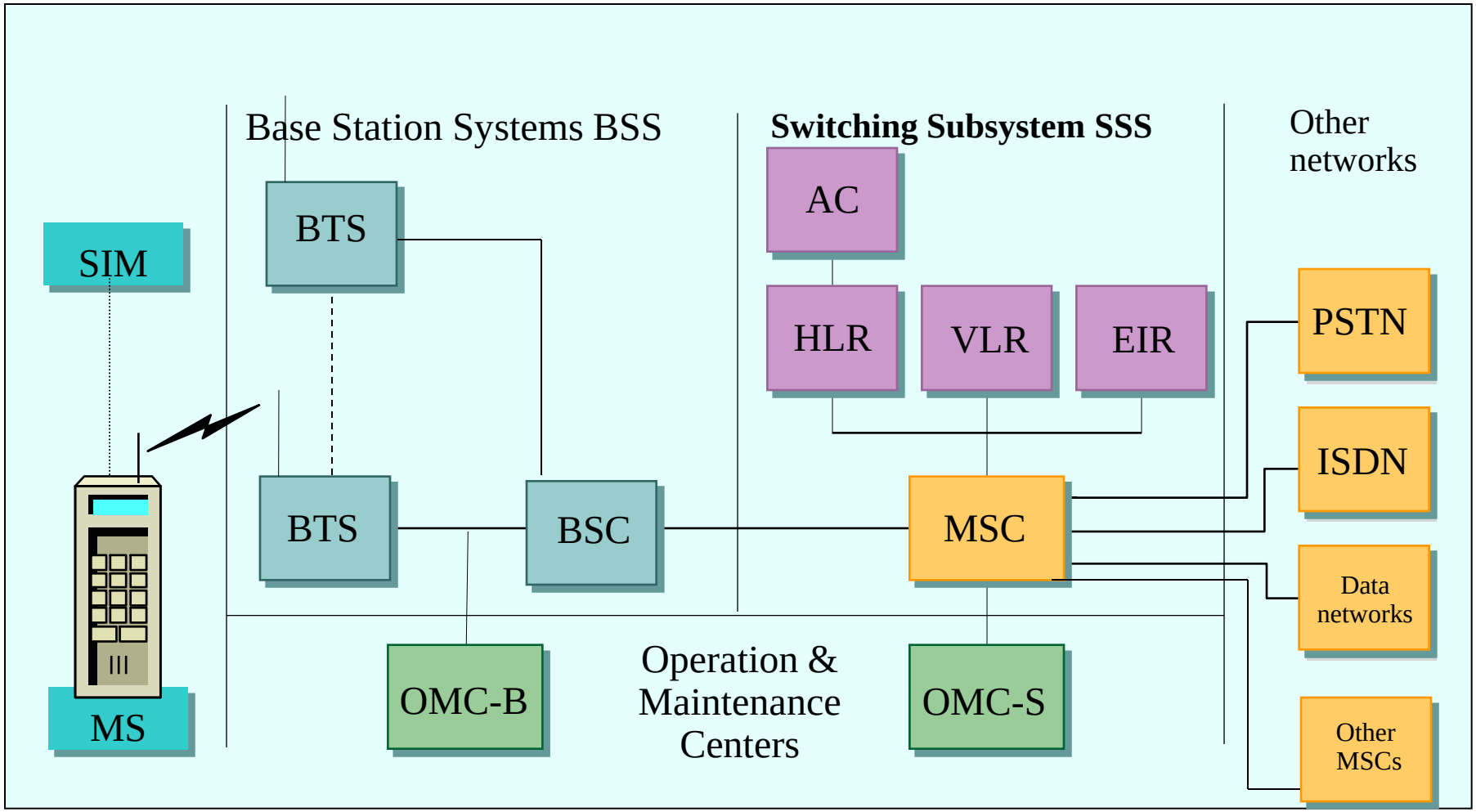
Overview of network architecture

A typical mobile network consists of user equeption (UE)/mobile equepment (ME), access network (AN) and the core network (CN)

- UE/ME: Interface with user, handle radio functionality
- AN: Communication to and from user equipment handles all radio related functionality in the network
- CN: Communication between AN and external networks, handles all switching and routing services.

Service and application lie over the network; network operator may provide them or they come from external (mostly from external)

Architecture of GSM Network



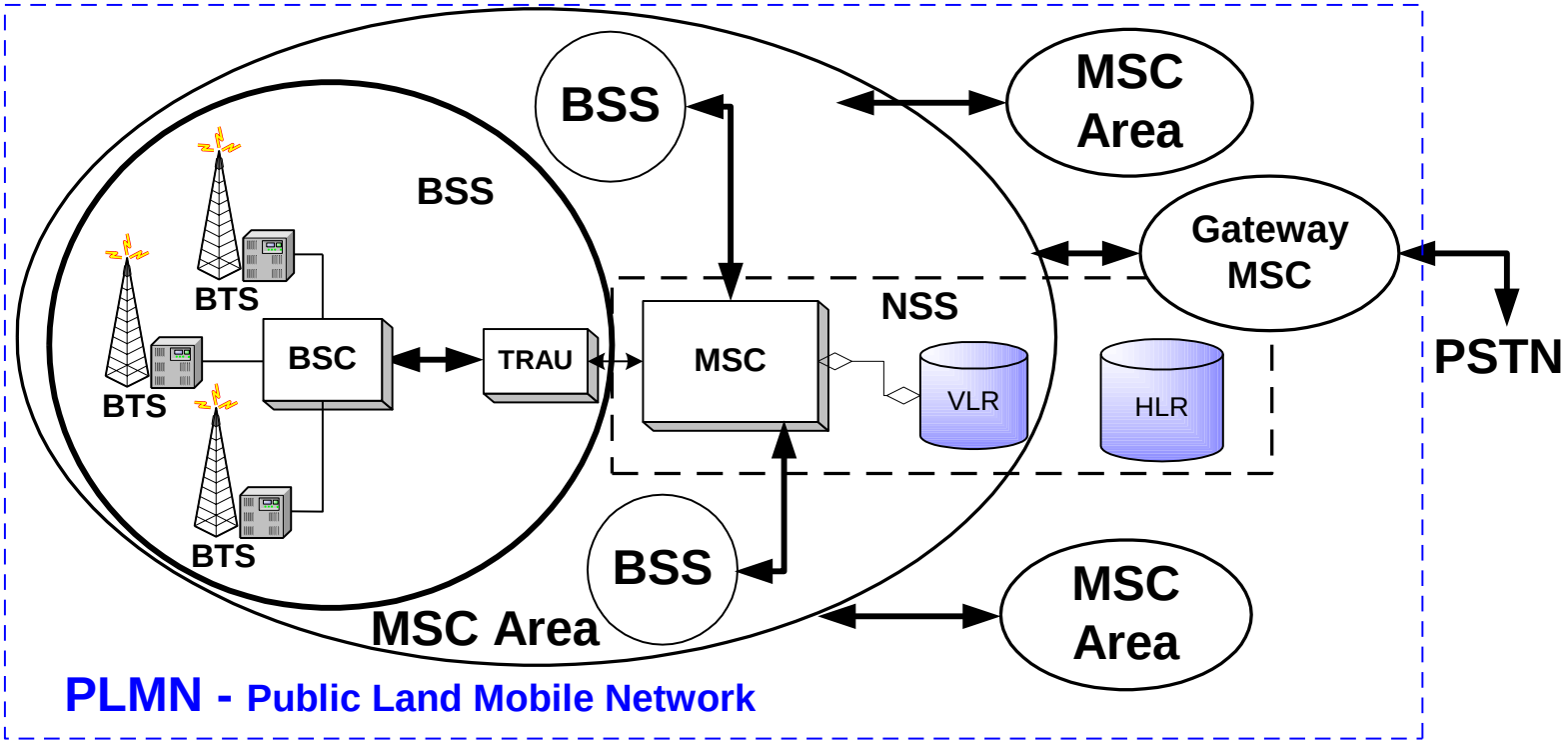
GSM Standards

GSM Standard

Series	Specifications area
01	General
02	Service aspects
03	Network aspects
04	MS-BS interface and protocol
05	Physical layer and radio path
06	Speech coding specification
07	Terminal adapter for MS
08	BS-MSC interface
09	Network internetworking
10	Service internetworking
11	Equipment and type approval specification
12	Operation and maintenance

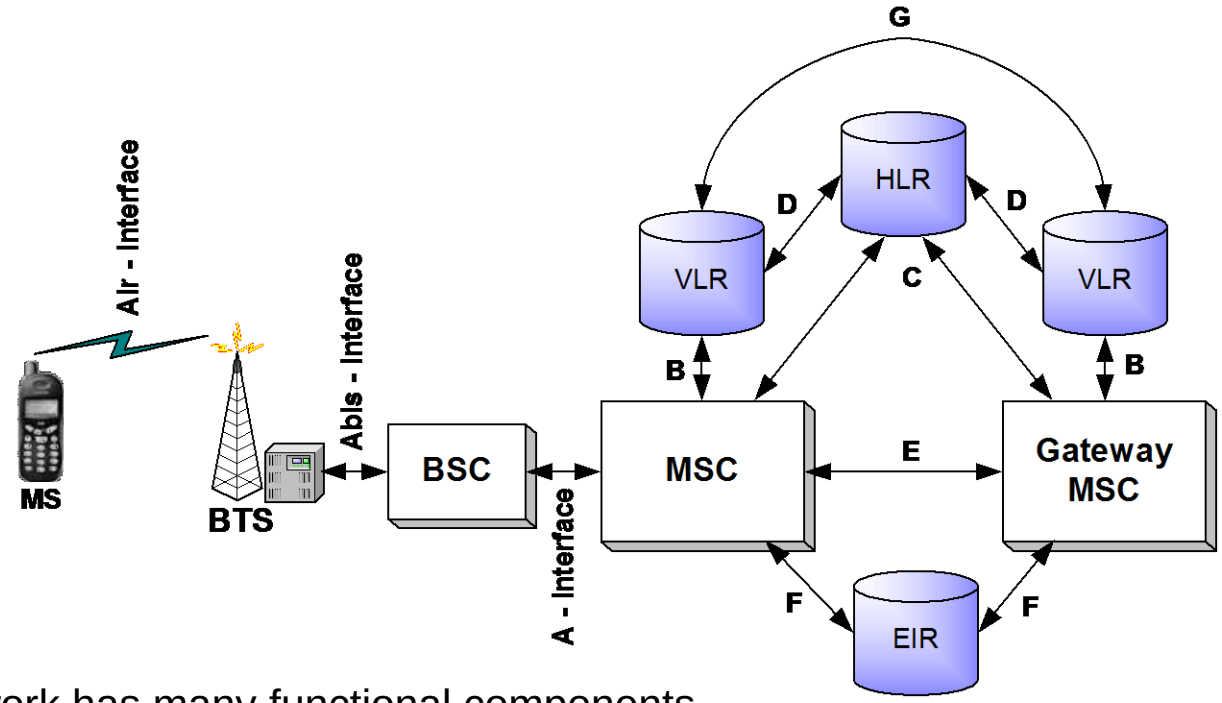
- Divided into 12 series
- Standardization efforts coordinated by ETSI
- www.etsi.org
- Specifications available online – free of charge
- Standardization and public availability of specification - one of fundamental factors of GSM success

GSM Network Layout



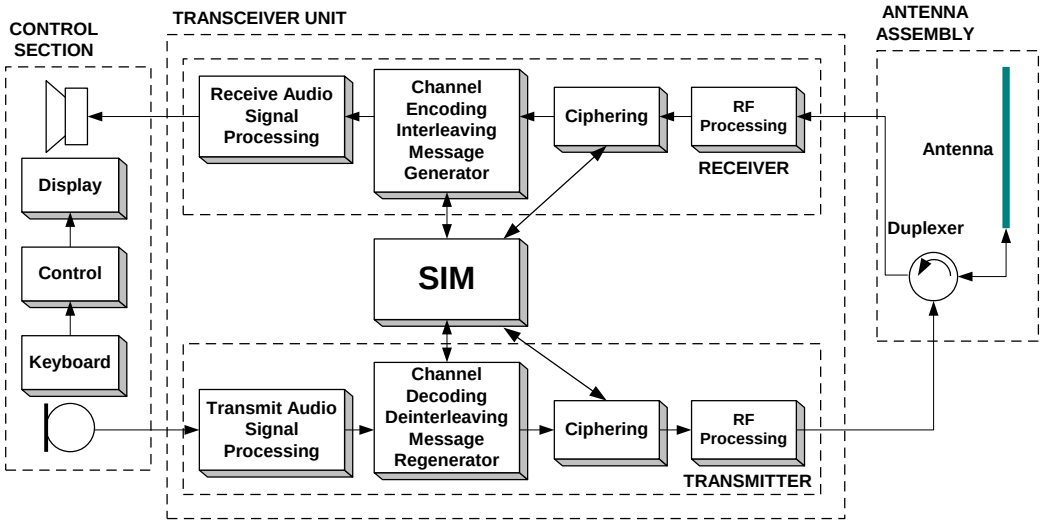
- GSM system layout is standardized
  - Standardization involves:
    - Elements of the network
    - Communication Interfaces
  - Standard layout allows for the use of equipment from different suppliers

GSM Components and Interfaces



- Network has many functional components
- Components are integrated through a network protocol – MAP
- Standardized interfaces
  - Um (air interface)
  - A – GERAN interface
  - A-Bis (somewhat standardized)

Mobile Station (MS)



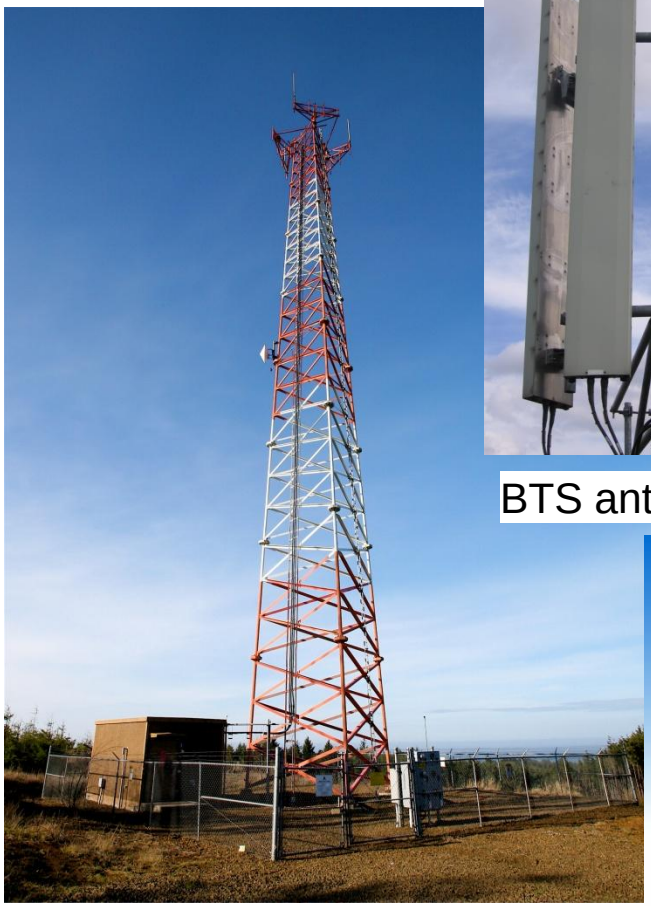
Functional diagram of GSM mobile

- Two functional parts
  - HW and SW specific for GSM radio interface
  - Subscriber Identity Module (SIM)
- SIM – detaches user identity from the mobile
  - Stores user information
  - Without SIM – only emergency calls

Most popular GSM phone
Nokia 1100 – 200M+ sold

SIM card

Base Transceiver Station (BTS)



Typical BTS installation

BTS antenna system

Macrocell BTS radio cabinet hosts TX/RX

- BTS is a set of transceivers (TX/RX).
- GSM BTS can host up to 16 TX/RX.
- In GSM one TX/RX is shared by 8 users.
- The main role of TX/RX is to provide conversion between traffic data on the network side and RF communication on the MS side.
- Depending on the application, it can be configured as macrocell, microcell, omni, sectored, etc.

Femto-cell

Base Station Controller (BSC) and TRAU

Typical BSC

- BSC plays a role of a small digital exchange.
- It can be connected to many BTSs and it offloads a great deal of processing from MSC
- One BSC connects to several tens to couple of hundred BTS
- Some of BSC responsibilities:
  - Handoff management
  - MAHO management
  - Power control
  - Clock distribution
  - Operation and maintenance
- TRAU is responsible for transcoding the user data from 16Kb/sec to standard ISDN rates of 64Kb/sec.
- It can physically reside on either BSC side or MSC side.
- TRAU, BSC and BTSs form Base Station Subsystem (BSS)

TRAU = Transcoding and Rate Adaptation Unit

Mobile Switching Center (MSC)

- Responsible for connecting the mobile to the landline side
- GSM MSC is commonly designed as a regular ISDN switch with some added functionality for mobility support
- GSM Network can have more than one MSC
- One of the MSC has an added functionality for communication with public network – Gateway MSC (GMSC)
- All calls from the “outside networks” are routed through GMSC

Register- HLR/VLR

- **HLR** – Home Location Register
- Database for permanent or semi-permanent data associated with the user
- Logically, there is only one HLR per network
- Typical information stored in HLR: International Mobile Service Identification Number (IMSI), service subscription information, supplementary services, current location of the subscriber, etc.
- HLR is usually implemented as an integral part of MSC

- **VLR** – Visitor Location register
- Temporary database that keeps the information about the users within the service area of the MSC
- Usually there is one VLR per MSC
- The main task of the VLR is to reduce the number of queries to HLR. When the mobile, registers on the system its information is copied from HLR to VLR
- VLR is usually integrated with the switch

AuC/EIR

- AUC – Authentication center
- Integral part of HLR
- Can be only SW function or special build HW with enhanced security (within HLR)

- For security 3 algorithms are specified in GSM:

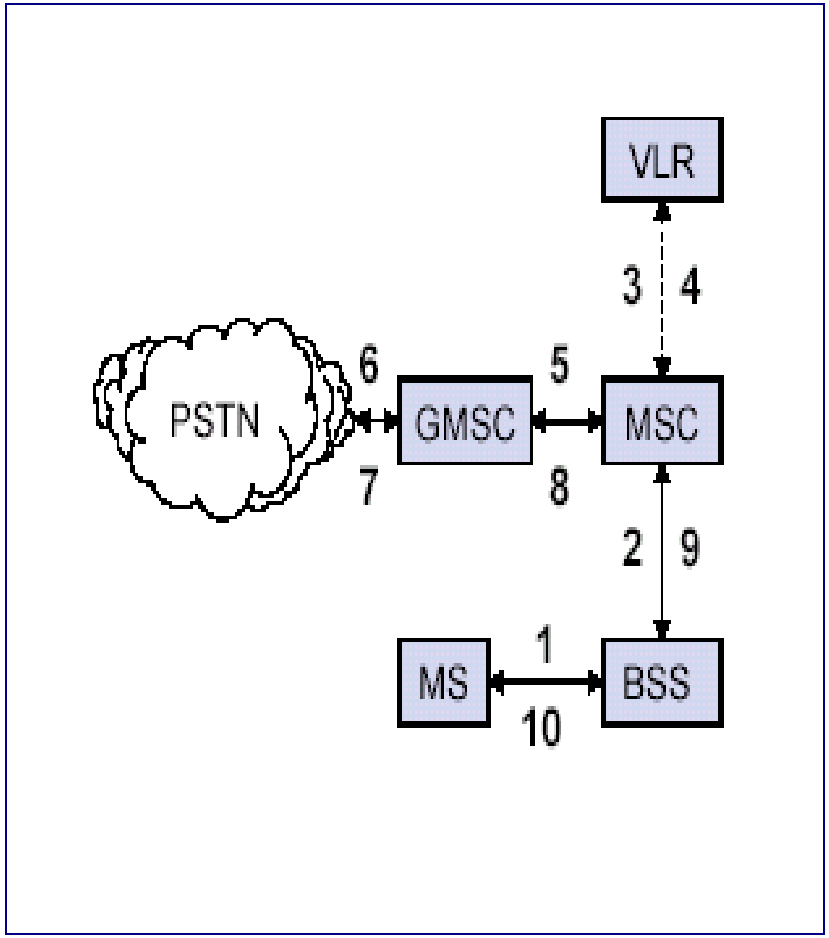
-A3 algorithm for authentication
- A5 algorithm for encryption
- A8 algorithm for key generation

- EIR – Equipment Identity Registry
- Responsible for tracking equipment and eligibility for service
- Maintains three lists
  - White list – approved mobile types
  - Black list – barred mobile types
  - Gray list – tracked mobile types

Operation and Maintenance Center (OMC)

- The Operation and Maintenance Center is the functional entity through which the Network Operator can monitor and control the system.
- Functions related to administrative or commercial management of the PLMN:
  - subscribers
  - terminals
  - billing
  - accounting
  - statistics
- Network Monitoring and repair
  - Alarms from all the cell sites, BSCs & MSCs are extended to the OMC
- Network Upgrades
  - Like software upgrades to the switches.
- Maintenance

Call Routing- Outgoing Call



1. MS sends dialled number to BSS
2. BSS sends dialled number to MSC

3,4 MSC checks VLR if MS is allowed the requested service.If so,MSC asks BSS to allocate resources for call.

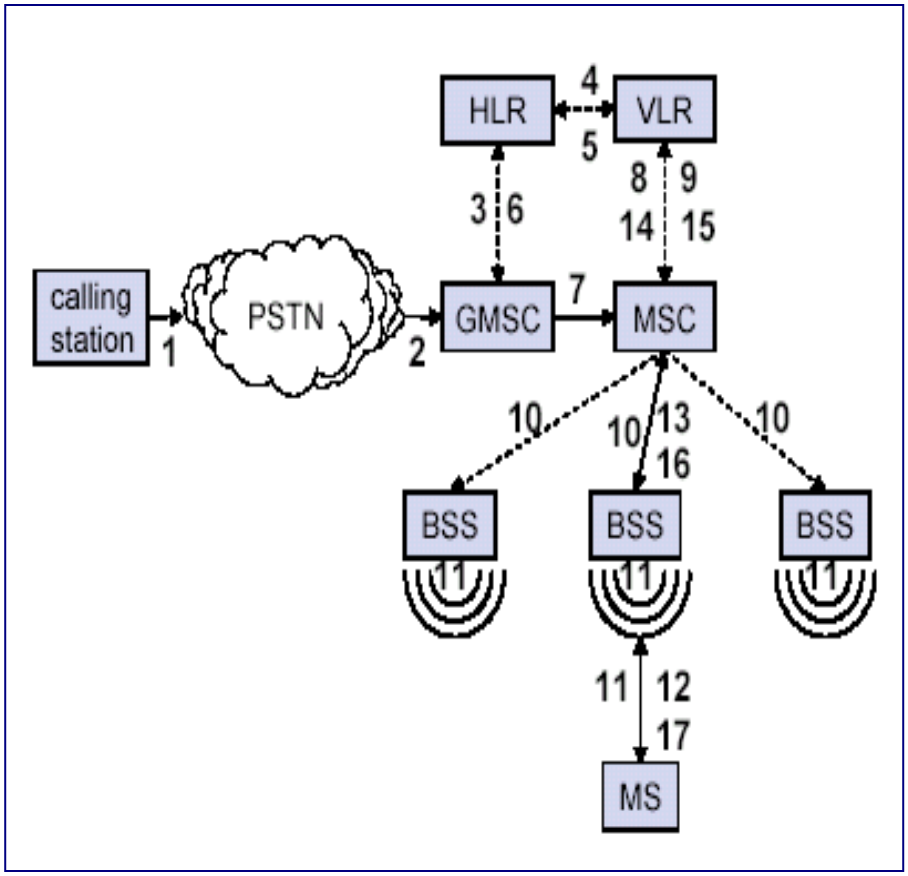
5 MSC routes the call to GMSC

6 GMSC routes the call to local exchange of called user

7, 8,

9,10 Answer back(ring back) tone is routed from called user to MS via GMSC,MSC,BSS

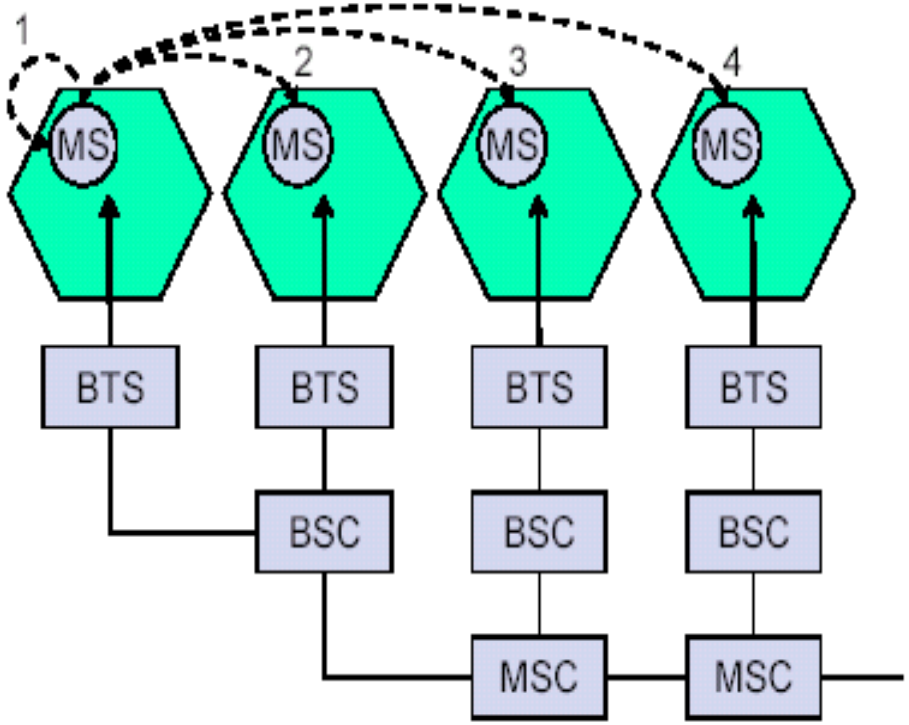
Call Routing- Incomoing Call



1. Calling a GSM subscribers
2. Forwarding call to GSMC
3. Signal Setup to HLR
4. 5. Request MSRN from VLR
6. Forward responsible MSC to GMSC
7. Forward Call to current MSC
8. 9. Get current status of MS

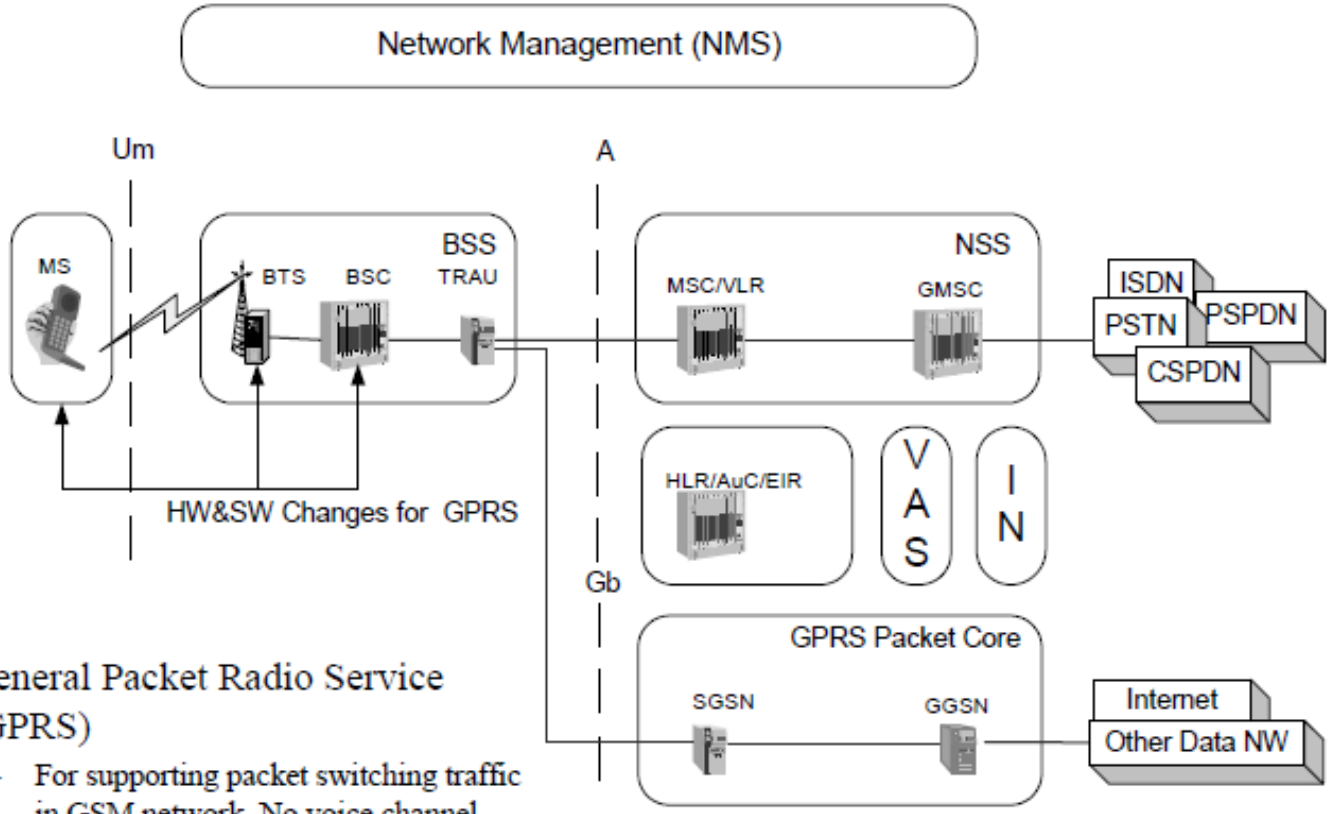
10.11. Paging of MS
12.13. MS answers
14.15. Security checks
16.17. Set up connection

Handover



- Between 1 and 2 – Inter BTS / Intra BSC
- Between 1 and 3 – Inter BSC/ Intra MSC
- Between 1 and 4 – Inter MSC

GPRS Network architecture



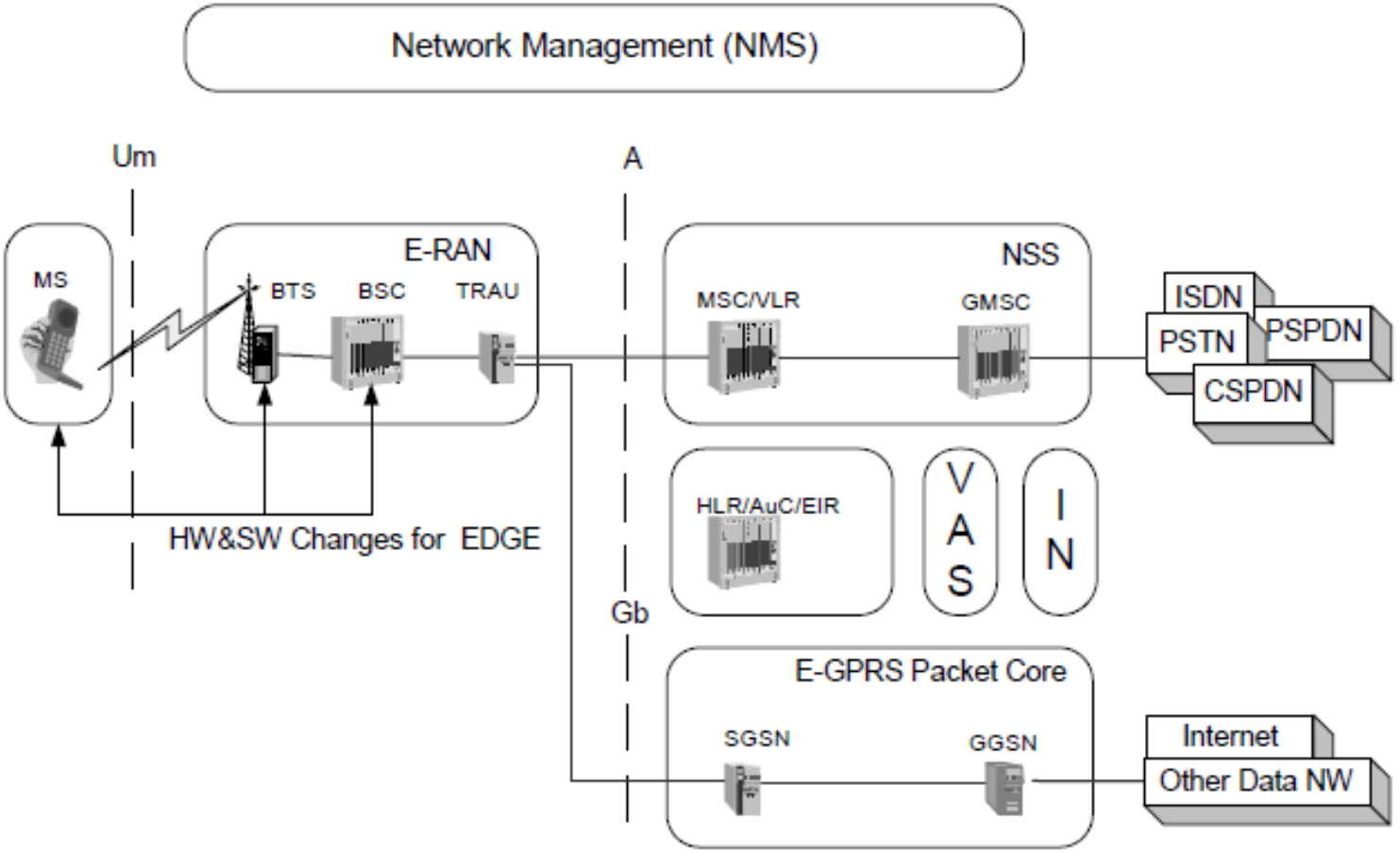
- General Packet Radio Service (GPRS)
  - For supporting packet switching traffic in GSM network. No voice channel reservation.
  - Support for asymmetric traffic.

- Requires new service nodes:
  - Serving GPRS Support Node (SGSN).
  - Gateway GPRS Support Node (GGSN).
- Can not guarantee the QOS.

General Packed Radio Data (GPRS)

- GPRS is another new transmission capability for GSM that will be especially developed to accommodate for high-bandwidth data traffic
- GPRS handle rates from 14.4Kbps using just one TDMA slot, and up to 115Kbps using all eight time slots
- It introduces packet switching - can accommodate the data traffic characteristics
- **PCU** (Packet Control Unit): It decides whether the data is to be routed to the packet switched or circuit switched network
- **SGSN** (Serving GPRS Support Node): It is functionaing same as MSC but in the packet switched domain. It is gateway to the services within the network
- **GGSN** (Gateway GPRS Support Node): Gateway between GPRS/EDGE network and external packet switched network. It is a combination of gateway, router and firewall.

Enhanced Data Rate for GSM Evolution (EDGE)



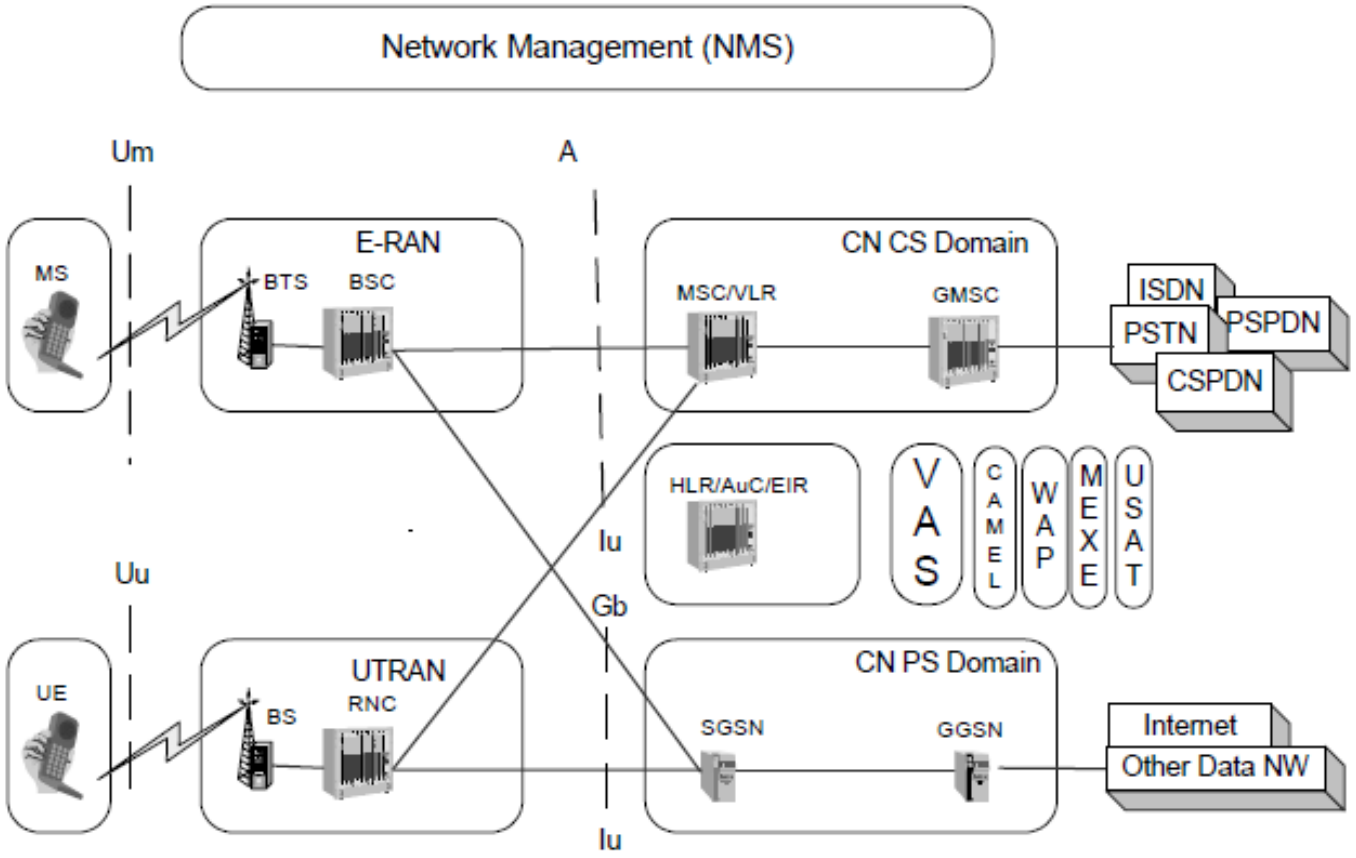
Enhanced Data Rate for GSM Evolution (EDGE)

- Packet switched
- Upgrades the modulation scheme
  - From GMSK to 8-PSK
  - Phase-1: speed ~48 Kb/sec per time slot, ~384 Kb/sec for all 8 time slots
  - Maximum speed ~59 Kb/sec per time slot, ~473.6 Kb/sec for all 8 time slots
  - Variable data rate – depending on the channel conditions
- Defines several different classes of service and mobile terminals
- Data rates not available everywhere in the cell.

EGPRS modulation and coding scheme (MCS)

Coding and modulation scheme (MCS)	Speed (kbit/s/slot)	Modulation
MCS-1	8.80	GMSK
MCS-2	11.2	GMSK
MCS-3	14.8	GMSK
MCS-4	17.6	GMSK
MCS-5	22.4	8-PSK
MCS-6	29.6	8-PSK
MCS-7	44.8	8-PSK
MCS-8	54.4	8-PSK
MCS-9	59.2	8-PSK

Release 99: 3G Network

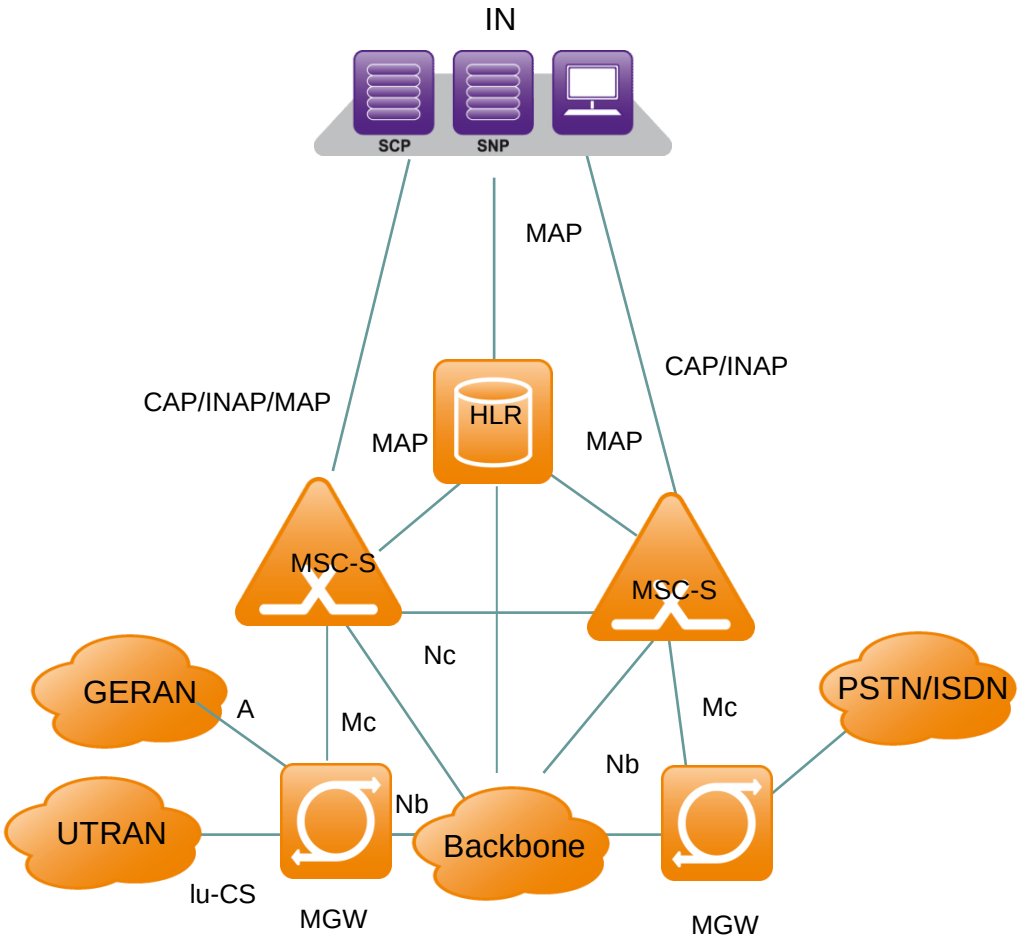


Release 99: 3G Network

- Release 99 standardization introduced new Radio Interface for 3G
- NodeB for 3G Access Network-similar to BTS in 2G
- RNC (Radio Network Controller) as similar to BSC in 2G
- Interoperability with GSM
  - Possibility to re-use 2G MSC/VLR and HLR also for 3G

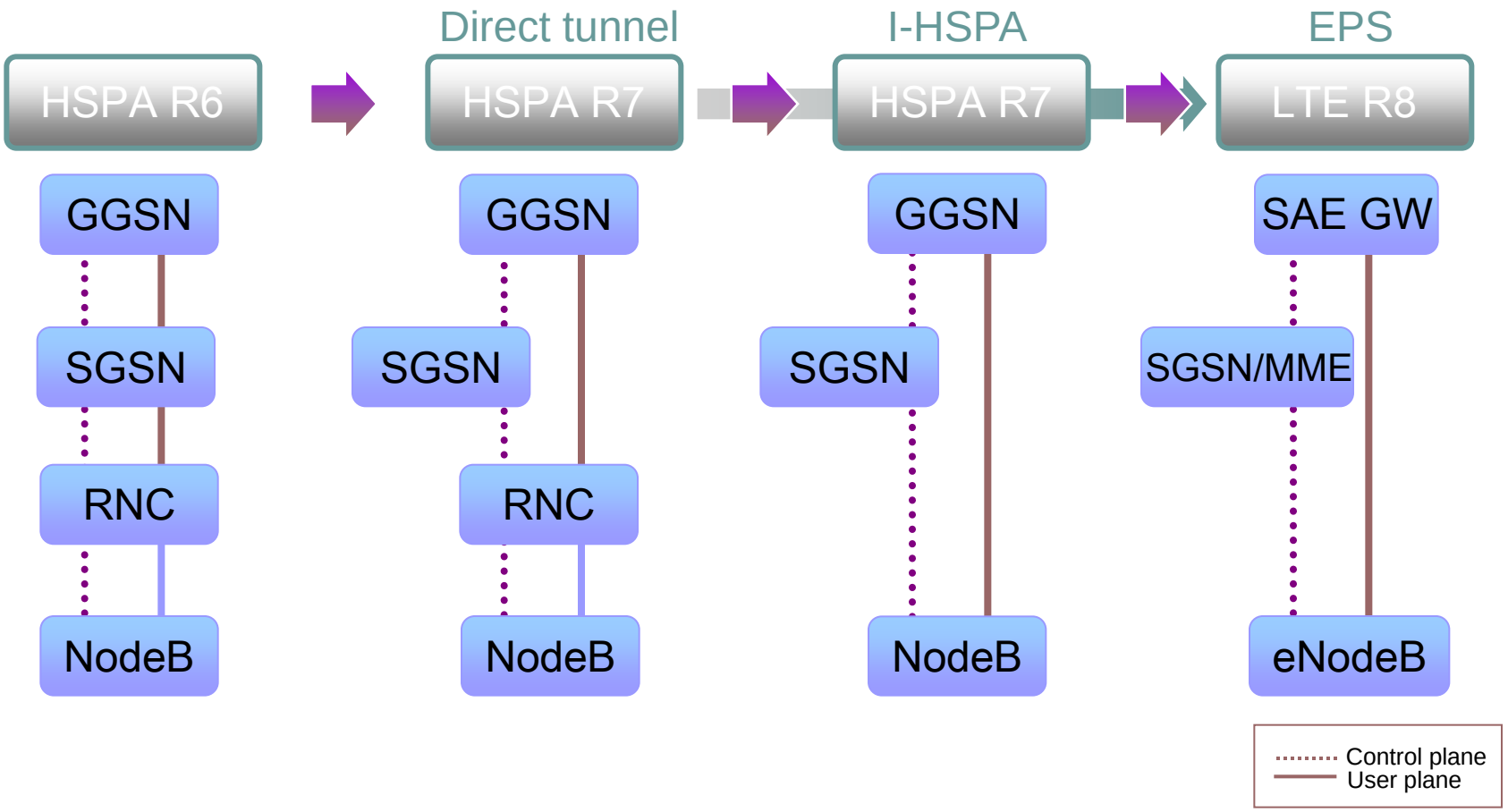
3GPP Rel-4

- 3GPP Rel-4 introduces separation of Call Control and User Data in CS Core Network
  - MSC Server (MSC-S) or Mobile Softswitch (MSS) for Call Control purpose
  - MGW (Media Gateway) for Payload or User Data handling
- MSC-S is controlling MGW and can have one or more MGW
- This separation provides transmission bandwidth saving and IP as backhaul between MGWs.



Packet Core Evolution

User plane evolution

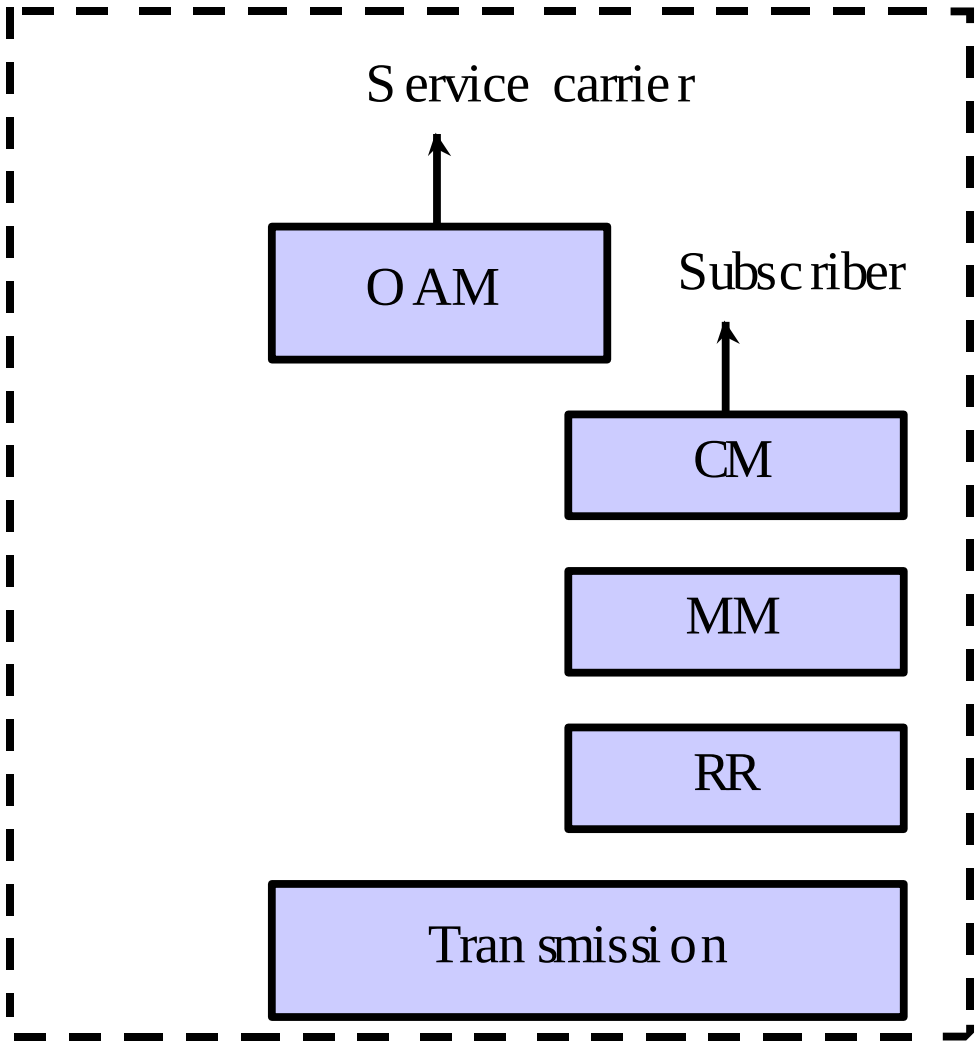


User plane connectivity model rapidly evolving towards flatter and streamlined model where GW connected directly to radio access nodes

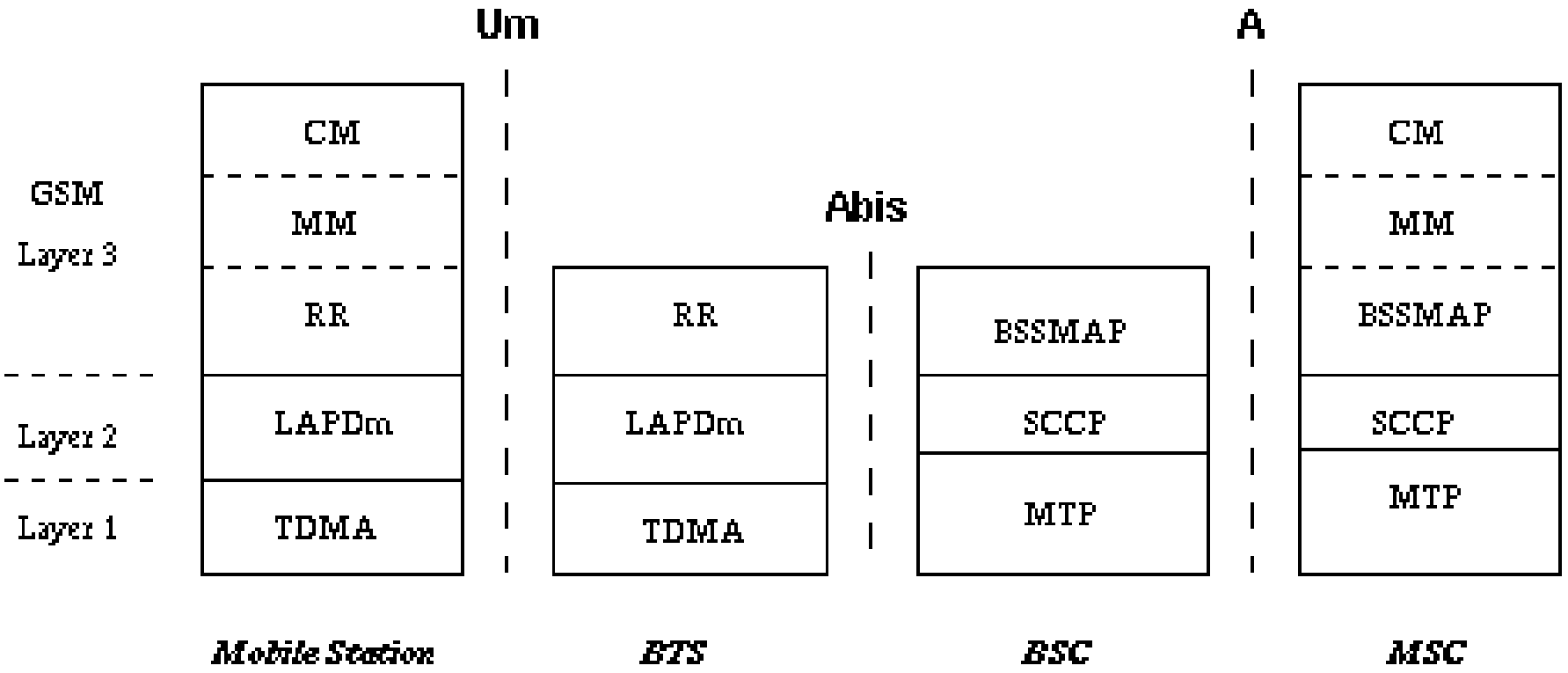
Agenda

- Network Architecture
- Protocol stacks
- Air Interface
- System Capacity

Overview: Functional Layer of GSM-I



Protocol Stack structure of GSM



Protocol structure of GSM

- Layer 1(physical layer) uses the channel structures over the air interface.
- Layer 2(data link layer): Across the Um interface, the data link layer is a modified version of the LAPD protocol used in ISDN, called LAPDm. Across the A interface, the Message Transfer Part layer 2 of Signalling System Number 7 is used.
- Layer 3 is divided into 3 parts
- Radio Resources (RR) Management
  - Controls the setup, maintenance, and termination of radio and fixed channels, including handovers.
- Mobility Management (MM)
  - Manages the location updating and registration procedures, as well as security and authentication.
- Connection Management (CM)
  - Handles general call control, similar to CCITT Recommendation Q.931, and manages Supplementary Services and the Short Message Service.

Agenda

- Network architecture
- Protocol stacks
- Air Interface
- System Capacity

GSM Air Interface - Um

- Interface between the MS and the GSM network
- Subject to rigorous standardization process
- We examine:
  - Channelization
  - Multiple access scheme
  - Interface organization:
    - On the physical level
    - On the logical level

Frequency allocation

System	Band	Uplink (MHz)	Downlink (MHz)	Channel Number
T-GSM-380	380	380.2–389.8	390.2–399.8	Dynamic
T-GSM-410	410	410.2–419.8	420.2–429.8	Dynamic
GSM-450	450	450.4–457.6	460.4–467.6	259–293
GSM-480	480	478.8–486.0	488.8–496.0	306–340
GSM-710	710	728.0–746.0	698.0–716.0	Dynamic
GSM-750	750	777.0–792.0	747.0–762.0	438–511
T-GSM-810	810	806.0–821.0	851.0–866.0	Dynamic
GSM-850	850	824.0–849.0	869.0–894.0	128–251
P-GSM-900	900	890.0–915.0	935.0–960.0	1–124
E-GSM-900	900	880.0–915.0	925.0–960.0	975–1023, 0-124
R-GSM-900	900	876.0–915.0	921.0–960.0	955–1023, 0-124
T-GSM-900	900	870.4–876.0	915.4–921.0	Dynamic
DCS-1800	1800	1710.0–1785.0	1805.0–1880.0	512–885
PCS-1900	1900	1850.0–1910.0	1930.0–1990.0	512–810

US bands

GSM is FDD technology

Mapping formulas

Frequency Resource

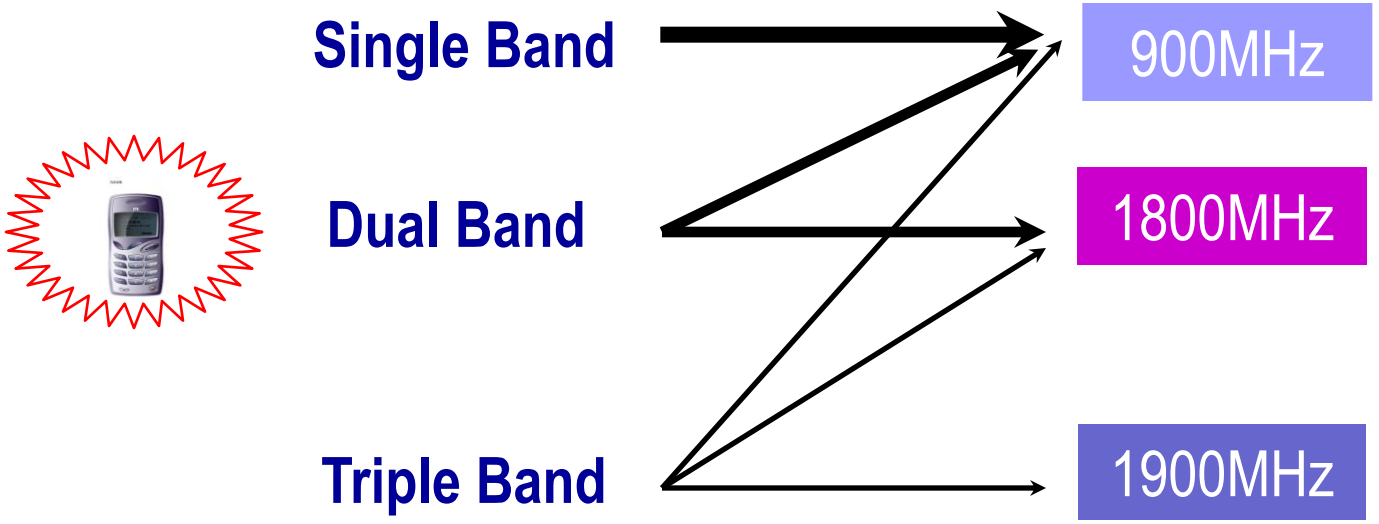
GSM900 :
up: 890~915MHz
down: 935~960MHz
duplex interval: 45MHz
bandwidth: 25MHz，
frequency interval: 200KHz

GSM1800 :
up: 1710-1785MHz
down: 1805-1880MHz
duplex interval: 95MHz，
working bandwidth: 75MHz，
frequency interval: 200KHz

GSM1900MHz:
up:1850~1910MHz
down:1930~1990MHz
duplex interval: 80MHz，
working bandwidth: 60MHz，
frequency interval: 200KHz

Frequency Resource

Single Band Network

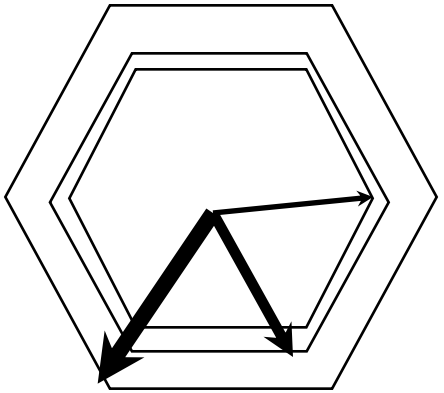


In a sense, the network determines the handsets can be selected.
But nowadays, most handsets support **dual band.**

Frequency Resource

Single Band Network

Cell coverage radius :



Propagation characteristic

The higher the propagation frequency

The higher the propagation loss

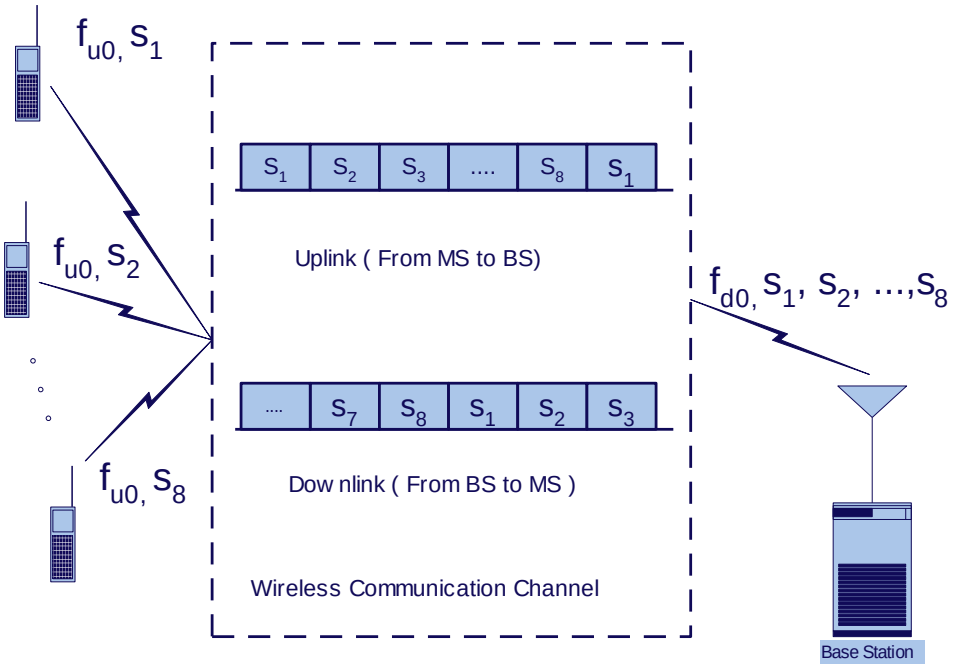
The smaller the cell coverage radius.

900MHz

1800MHz

1900MHz

TDMA Access Scheme

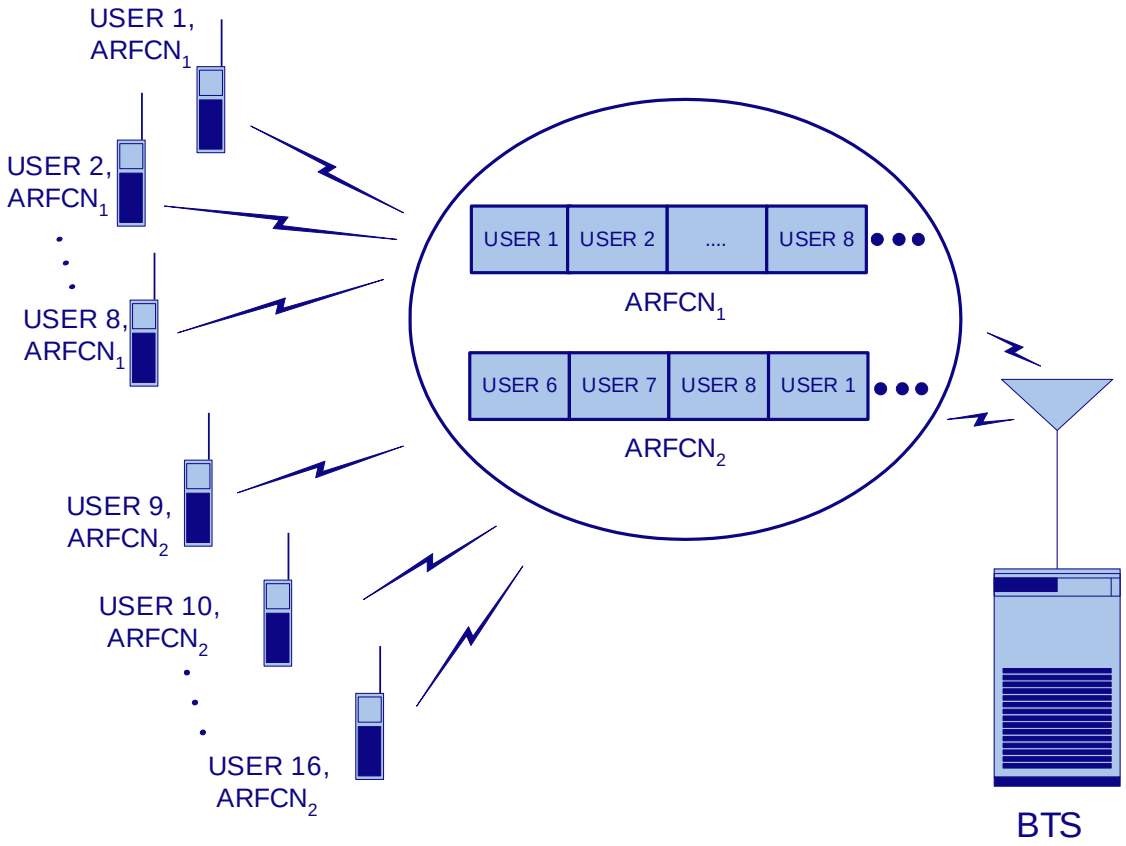


TDMA = Time Division Multiple Access

- Multiple users operate on the same frequency, but not at the same time.
- Advantages of TDMA:
  - Relatively low complexity
  - MAHO
  - Different user rates can be accommodated
  - Easier integration with the landline
- Disadvantages:
  - High sync overhead
  - Guard times
  - Heavily affected by the multipath propagation

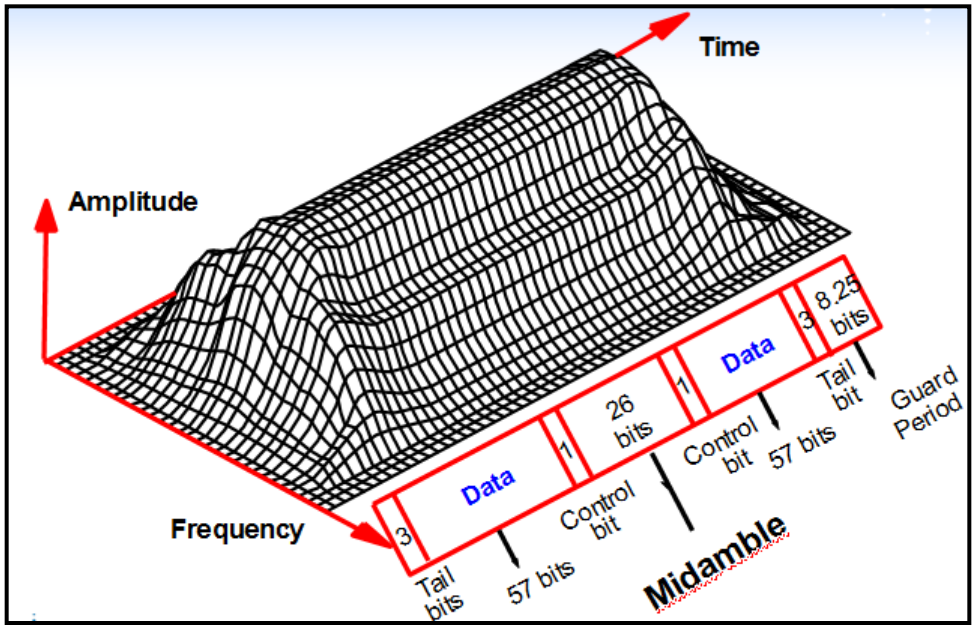
GSM as a TDMA system

- **GSM is a combination of FDMA and TDMA**
- **TDMA supports:**
  - Up to 8 full rate users
  - Up to 16 half rate users
- **GSM uses Frequency Division Duplexing**



ARFCN = Absolute Radio Frequency Channel Number

GSM bursts

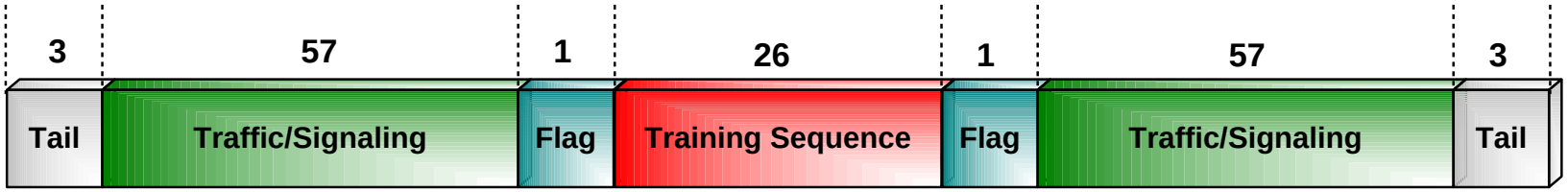


Time/Frequency/Amplitude diagram for GSM normal burst

- Data sent over one time slot = burst
- Five types: normal, frequency correction, synchronization, dummy, access
- Format of a burst defied by its function
- DL: normal, frequency correction, synchronization, dummy
- UL: normal, access

Normal bursts

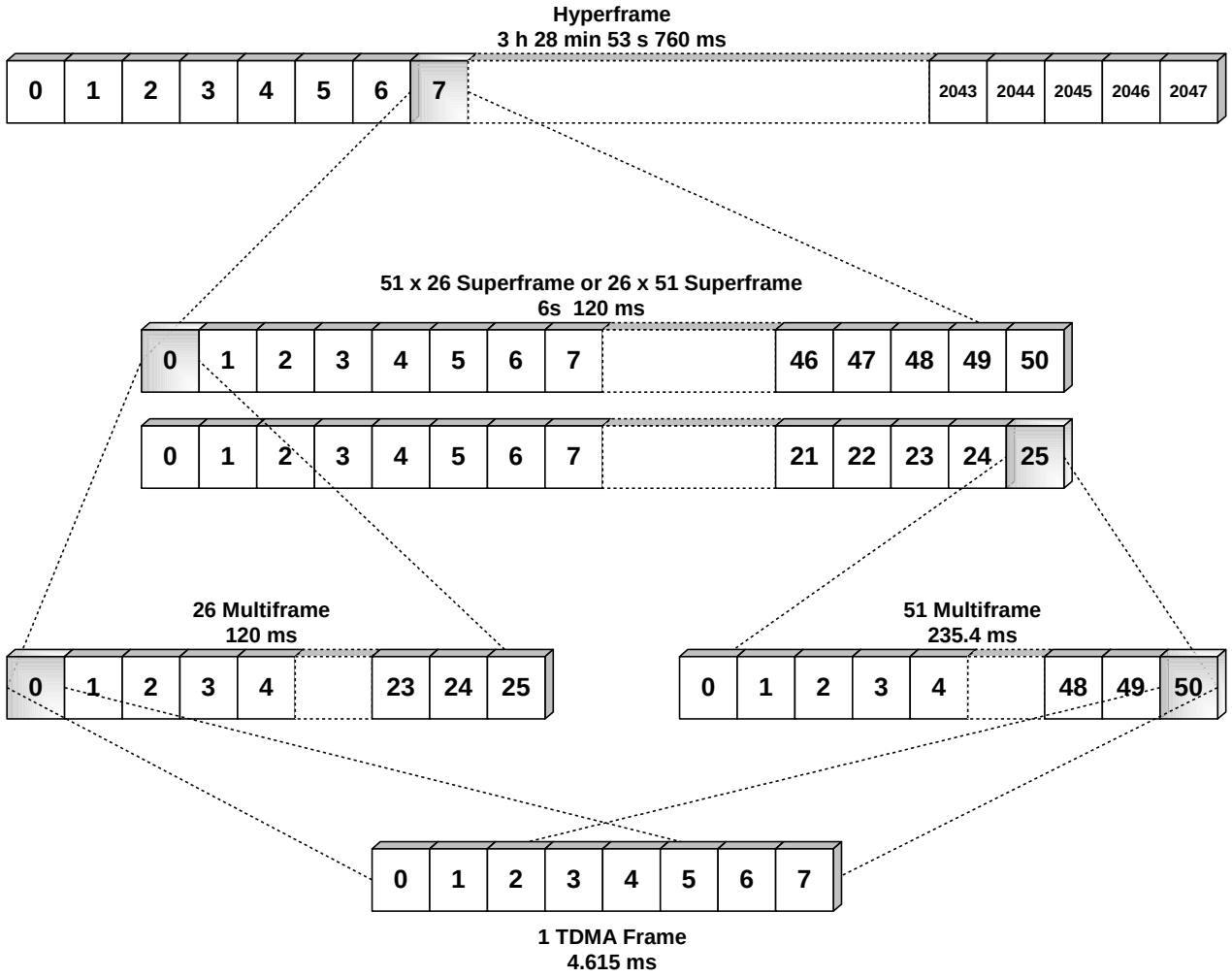
- **Used to carry information on both control and traffic channels**
- **Mixture of data and overhead**
- **GSM defines 8 training sequences assigned in color code mode**
- **Both on the forward and reverse link**



Normal burst

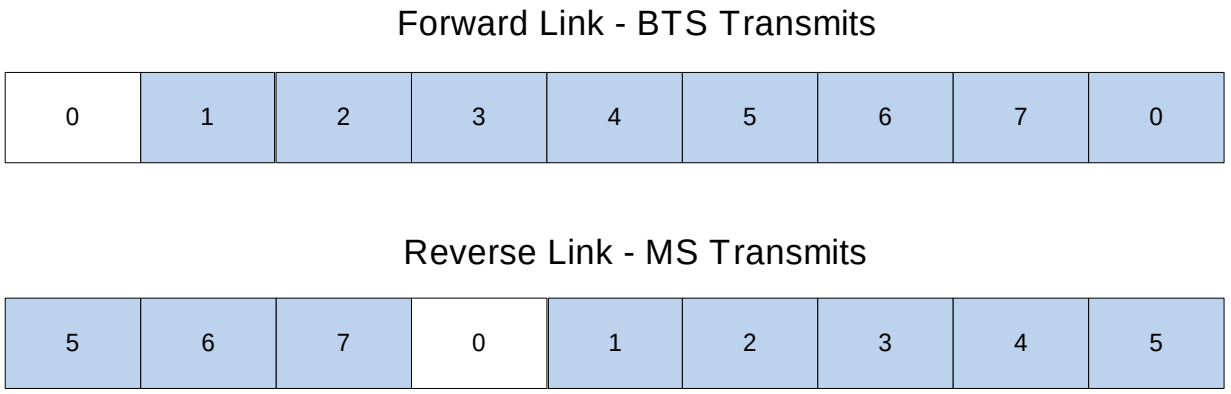
- Total of 114 encoded user information bits
- Total of 34 overhead bits

GSM TDMA Hierarchical Organization

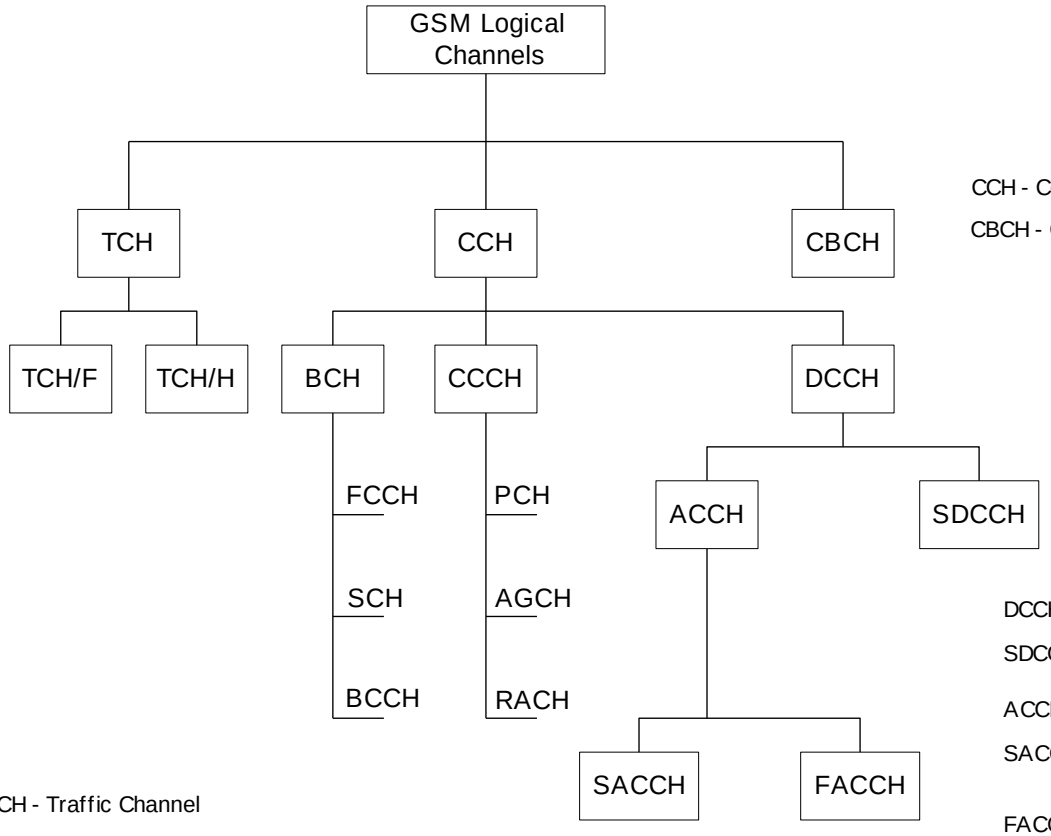


GSM Time Division Duplex

- **Communication on the forward and reverse link does not happen simultaneously**
- **Delay of three slots between TX and RX**
- **Time division duplexing avoids RF duplexer at the RF stage**
  - Reduces the cost of mobile
  - Saves battery



GSM Logical Channels



CCH - Control Channel

CBCH - Cell Broadcast Channel

DCCH - Dedicated Control Channels

SDCCH - Stand-alone Dedicated Control Channel

ACCH - Associated Control Channels

SACCH - Slow Associated Control Channel

FACCH - Fast Associated Control Channel

TCH - Traffic Channel

TCH/F - Traffic Channel (Full Rate)

TCH/H - Traffic Channel (Half Rate)

BCH - Broadcast Channels

FCCH - Frequency Correction Channel

SCH - Synchronization Channel

BCCH - Broadcast Control Channel

CCCH - Common Control Channels

PCH - Paging Channel

AGCH - Access Grant Channel

RACH - Random Access Channel

Traffic Channels (TCH)

- **Traffic channel carries speech and user data in both directions**
  - Full rate ~ 33.85 Kb/sec
  - Half rate ~ 16.93 Kb/sec
  - Full rate uses 1 slot in every frame
  - Half rate uses 1 slot in every other frame

Full Rate TCH can carry:

- **Voice (13 Kb/sec)**
- **Date at rates:**
  - **9.6 Kb/sec**
  - **4.8 Kb/sec**
  - **2.4 Kb/sec**

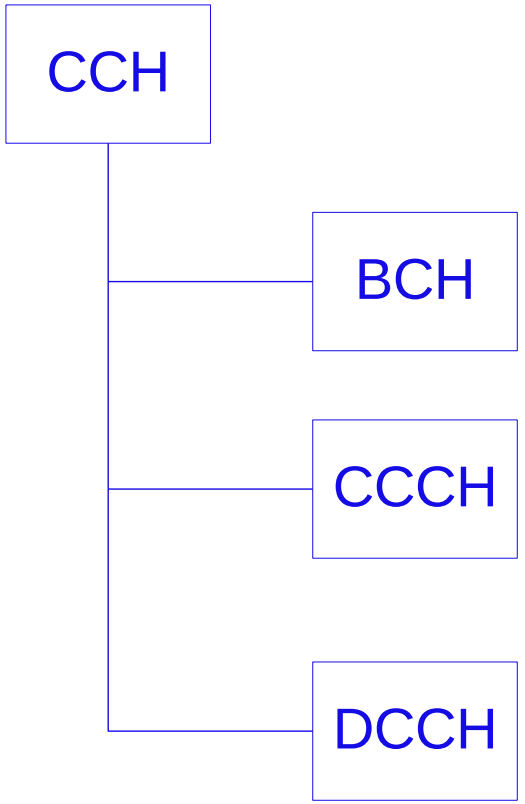
Half Rate TCH can carry:

- **Voice (6.5 Kb/sec)**
- **Date at rates:**
  - **4.8 Kb/sec**
  - **2.4 Kb/sec**

- **Data rates differ due to differences in Error Control Coding**

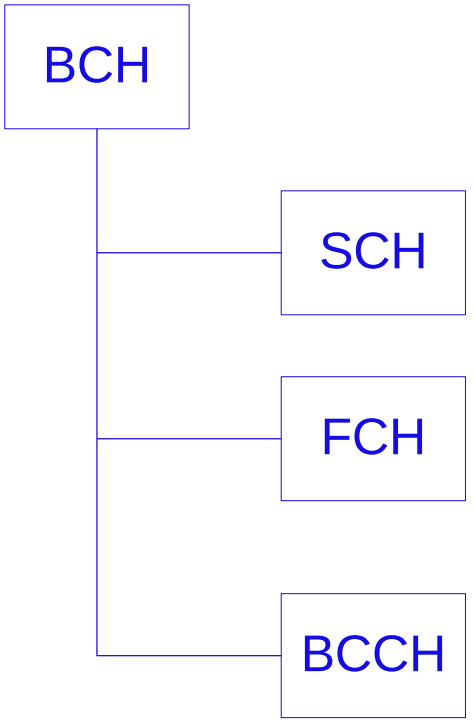
Control Channels

- **GSM Defines 3 types of Control Channels:**
  1. **Broadcast Channels (BCH)**
     - Broadcast information that helps mobile system acquisition, frame synchronization, etc. They advertise properties and services of the GSM network.
     - Forward link only
  2. **Common Control Channels (CCCH)**
     - Facilitate establishment of the link between MS and system
     - Both forward and reverse link
  3. **Dedicated Control Channels (DCCH)**
     - Provide for exchange the control information when the call is in progress
     - Both forward and reverse – in band signaling



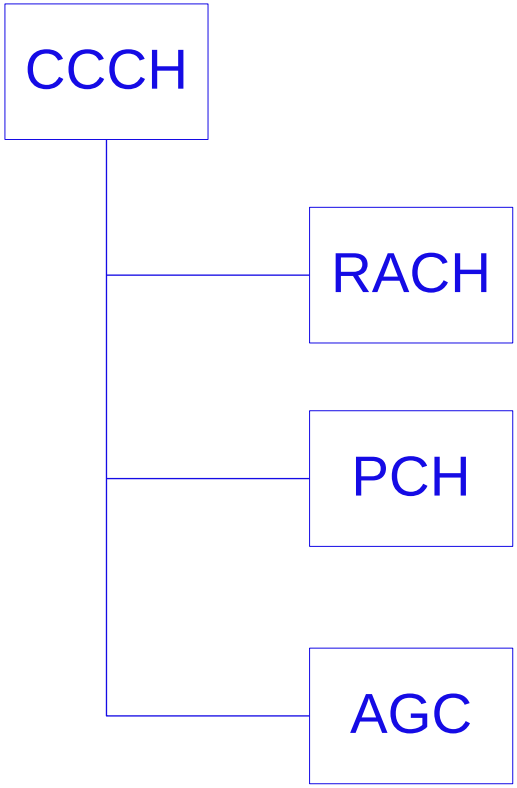
Broadcast Channels (BCH)

- **Three types of BCH:**
  1. **Synchronization channel (SCH)**
     - Provides a known sequence that helps mobile synchronization at the baseband
     - Communicates with S-burst
     - Broadcasts Base Station Identity Code (BSIC)
  2. **Frequency Correction channel (FCCH)**
     - Helps mobile tune its RF oscillator
     - Communicates with F-burst
  3. **Broadcast Control Channel (BCCH)**
     - Provides mobile with various information about network, its services, access parameters, neighbor list, etc.



Common Control Channel (CCCH)

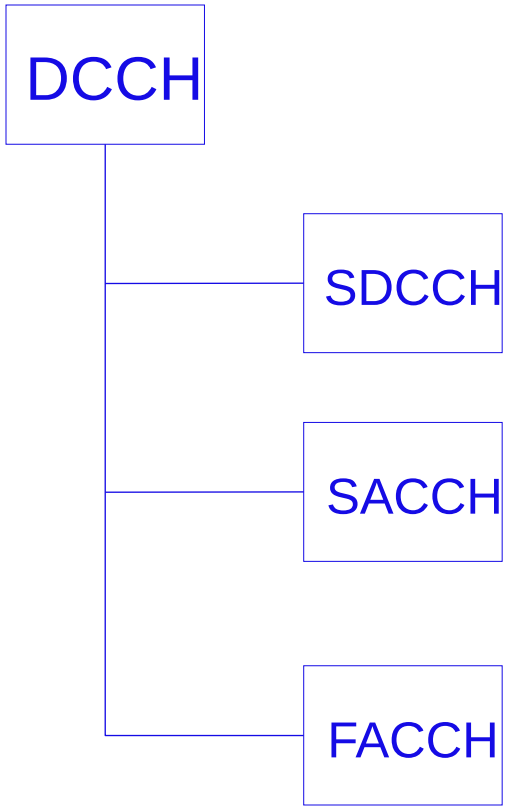
- Three types of CCCH:
  1. Random Access Channel (RACH)
     - Used by mobile to initialize communication
     - Mobiles use slotted ALOHA
     - Reverse link only
  2. Paging Channel (PCH)
     - Used by the system to inform the mobile about an incoming call
     - Forward link only
     - GSM Supports DRX
  3. Access Grant Channel (AGC)
     - Used to send the response to the mobiles request for DCCH
     - Forward link only



Dedicated Control Channels (DCCH)

- Three types of DCCH:
  1. Stand Alone Dedicated Control Channel (SDCCH)
     - Used to exchange overhead information when

       the call is not in progress
  2. Slow Associated Control Channel (SACCH)
     - Used to exchange time delay tolerant overhead information when the call is in progress
  3. Fast Associated Control Channel (FACCH)
     - Used to exchange time critical information when the call is in progress



Logical Channels- Summary

Channel	UL only	DL only	UL/DL	Point to point	Broadcast	Dedicated	Shared
BCCH		X			X		X
FCCH		X			X		X
SCH		X			X		X
RACH	X			X			X
PCH		X		X			X
AGCH		X		X			X
SDDCH			X	X		X	
SACCH			X	X		X	
FACCH			X	X		X	
TCH			X	X		X	

UL - Uplink DL - Downlink

GSM Operations: MS switch ON

- MS Switch on
  - Searches for Broadcast channel (BCH)
  - Synchronizes frequency and timing
  - Decodes BCCH (for cell and network information)
  - Checks if the network is allowed
  - Initiates location update
- Periodic update is done depending on the periodic update counter broadcast on the BCCH

GSM Operations: MOC

- Mobile Originated Call
  - Channel Request - RACH
  - Immediate Assign - AGCH
  - Service Request - SDCCH(intermediate channel allocated before allocation of TCH) - exchange of signaling and authentication information
  - Authentication (optional)
  - Ciphering (optional)
  - Set Up
  - Call Proceeding
  - Alerting
  - Connection

A traffic channel may be allocated at any time before the network informs the MS that the remote user has answered (Assignment)- GSM 02.01 8.1.0 D2

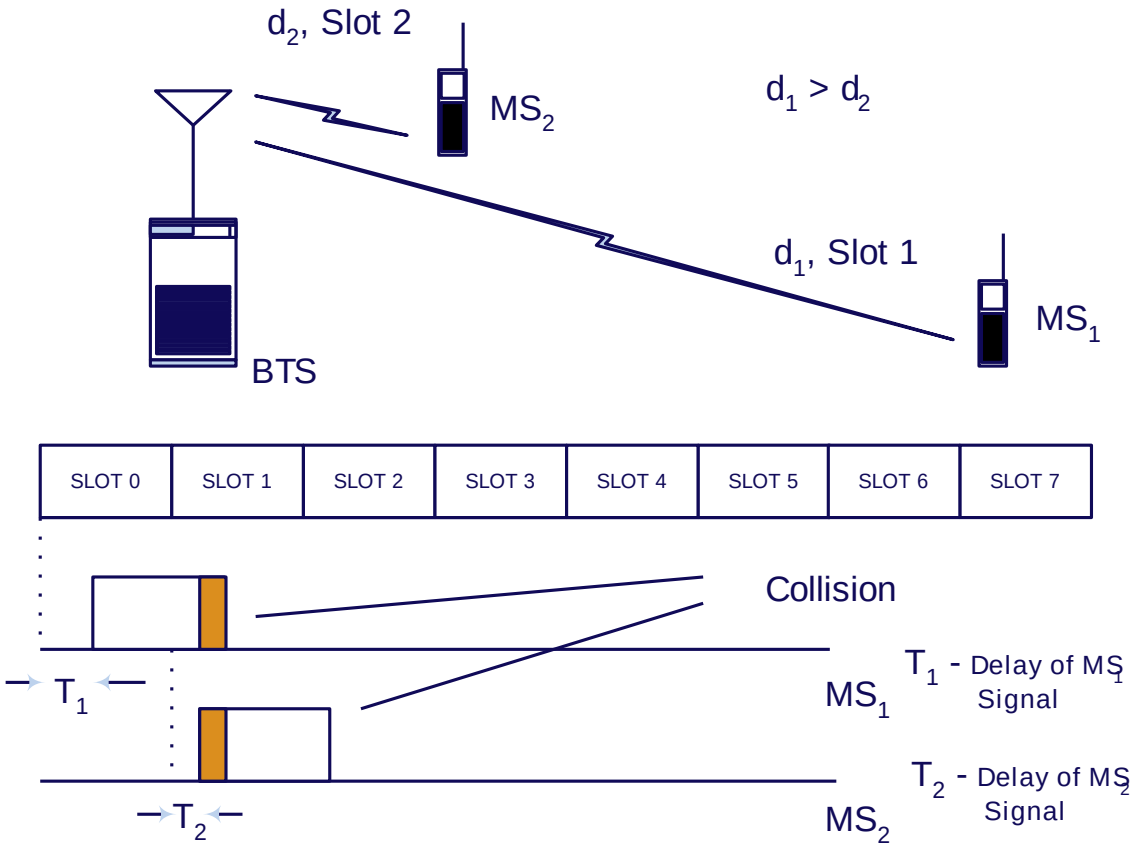
GSM Operations: MTC

- Mobile Terminated Call
  - Paging-PCH
  - Channel Request
  - Immediate Assign
  - Paging Response
  - Authentication (O)
  - Ciphering (O)
  - Set Up
  - Call Confirmed
  - Alerting
  - Connection

Can be a MTM (mobile to mobile) or FTM (Fixed Phone to Mobile)

Timing Advance

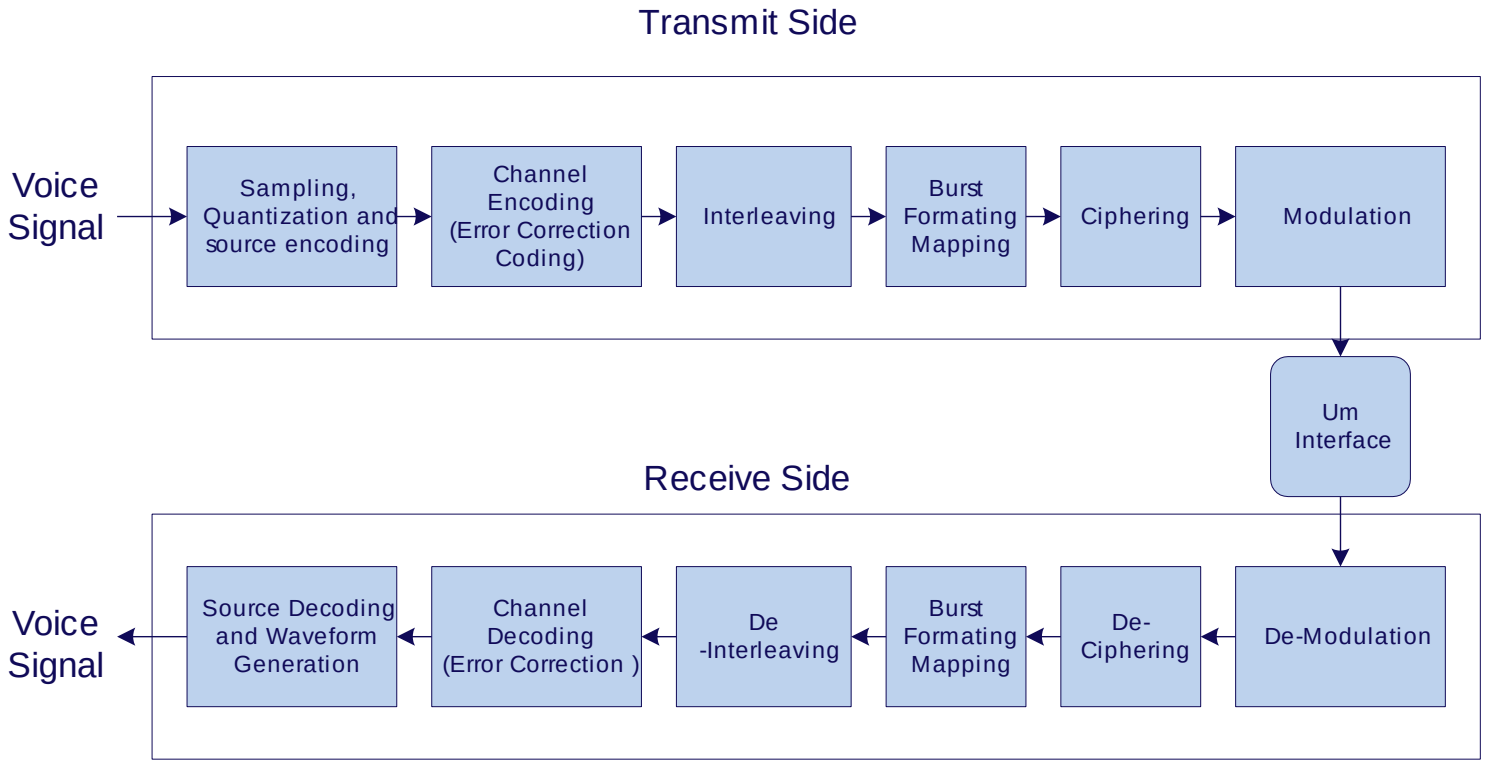
- Mobiles randomly distributed in space
- Timing advance prevents burst collision on the reverse link
- Maximum advancement is 63 bits



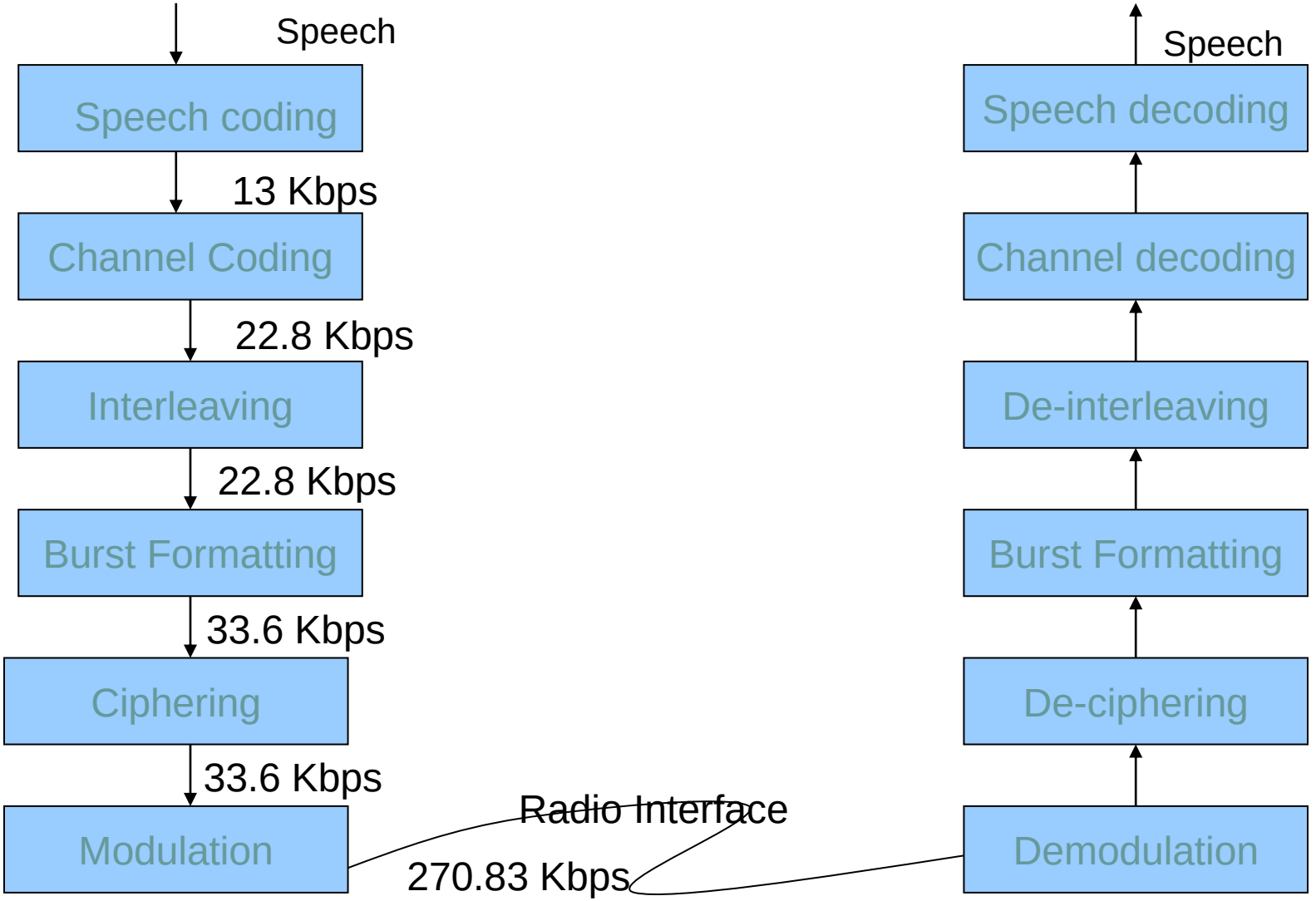
$$D\max = \frac{1}{2}\left(3\times10^{8}\,\frac{\mathrm{m}}{\mathrm{s}}\cdot 63\mathrm{bit}\cdot 3.693\times10^{-6}\,\frac{\mathrm{s}}{\mathrm{bit}}\right)\approx 35\mathrm{km}$$

Signal Processing- From voice to Radio waves

- **As a digital TDMA technology GSM implements extensive signal processing**



Signal Processing- From voice to Radio waves



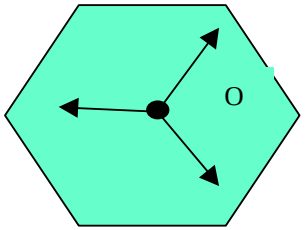
Agenda

- Network architecture
- Protocol stacks
- Air Interface
- System Capacity

Cell Mode Layout

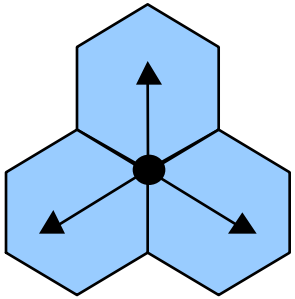
Omni-directional cell

Adopt omni-directional antenna，
the overall directional propagation characteristic is the same.



Directional cell

In general, cell with multi-sector is in common use. Every directional cell adopts directional antenna.



BTS Mode

❖ **Capacity**

When the traffic is very low, and no possibility for quick increment, Omni-directional cell is used in common. Otherwise, we suggest to adopt the sector cell.

Note: TRX-transceiver,each TRX handles 1 frequency.

❖ **Coverage Area**

Sector cell is often used to enlarge the cell coverage radius because of the higher antenna gain.

For special coverage ,such as road coverage, two-sector cell is adopted firstly.

System Capacity

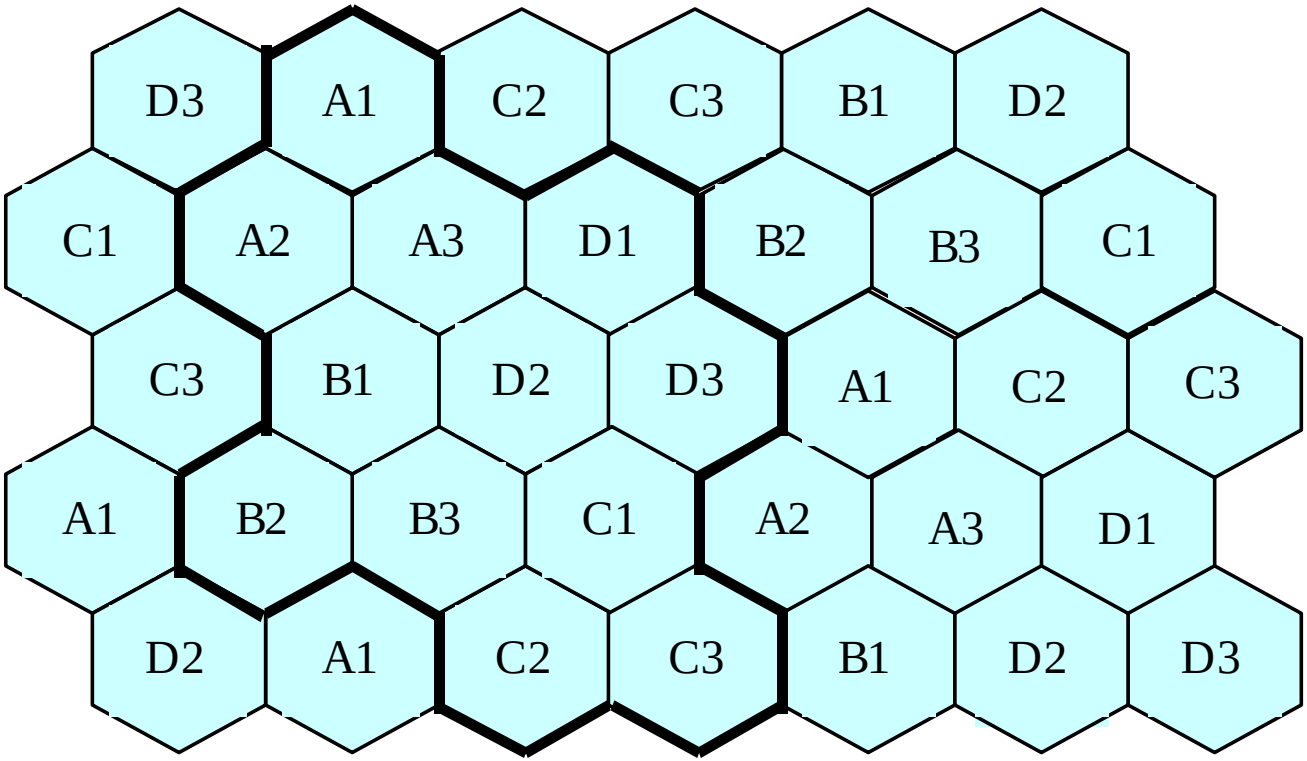
Erlang :

the traffic intensity of a totally occupied channel (i.e. the call hour of a unit hour or the call minute of a unit minute). For example, the traffic of a channel occupied for 30 minutes in an hour is 0.5 Erlang)

GOS:

defined as the probability of call blocking or the probability when the call delay time is longer than a given queuing time.

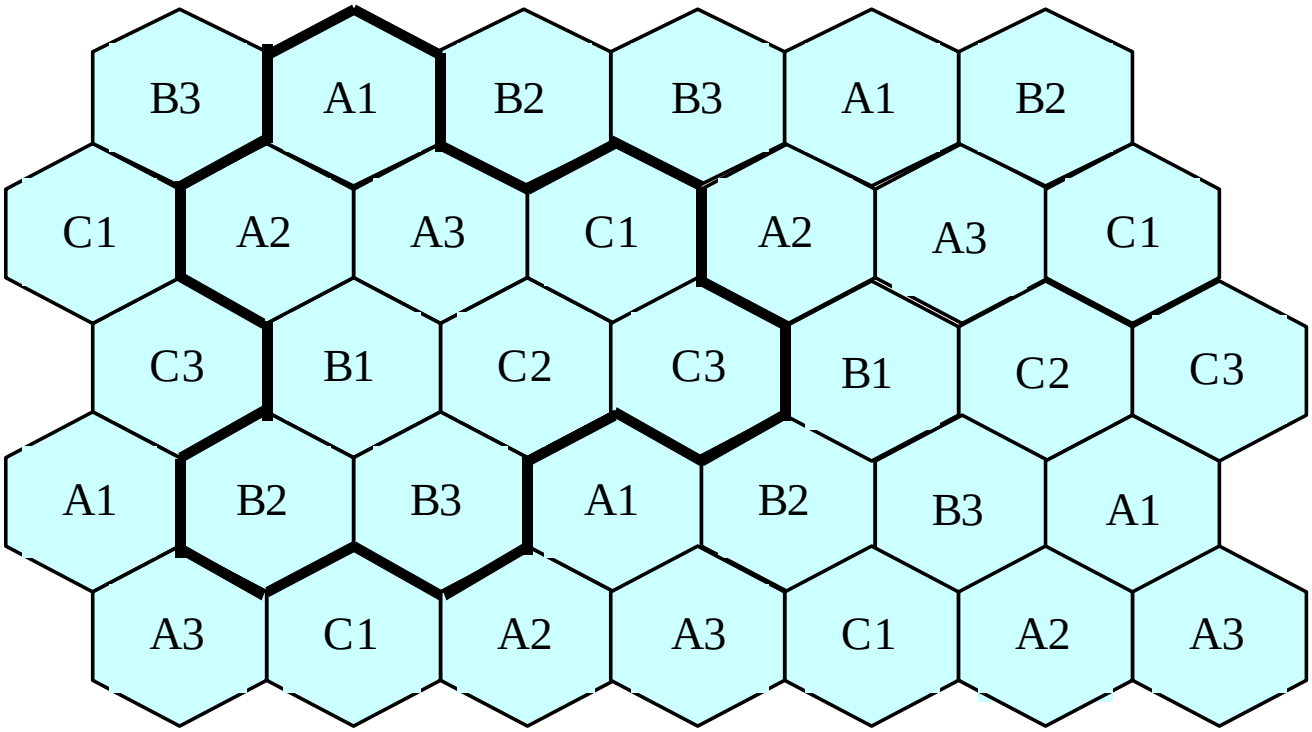
Frequency Reuse



“4 ´ 3” reuse mode:

one group includes 3 sectors /site ,12 frequency which are distributed to 4 sites. Every site owns 3 frequency.

Frequency Reuse



“3 ´ 3” reuse mode:

one group includes 3 sectors /site ,9 frequency which are distributed to 3 sites. Every site owns 3 frequency.