UNIK4230: Mobile Communications
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Mobile: 99 27 10 19

Network Architecture and Functionality

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Agenda

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

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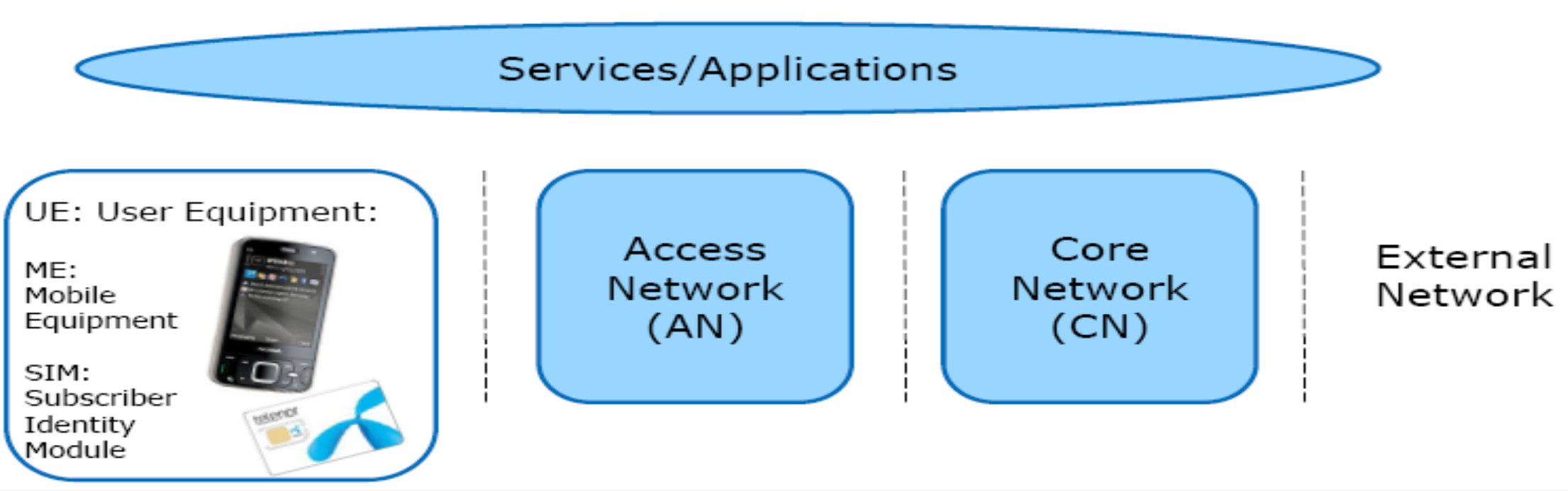
- System Capacity

Overview of Network Architecture



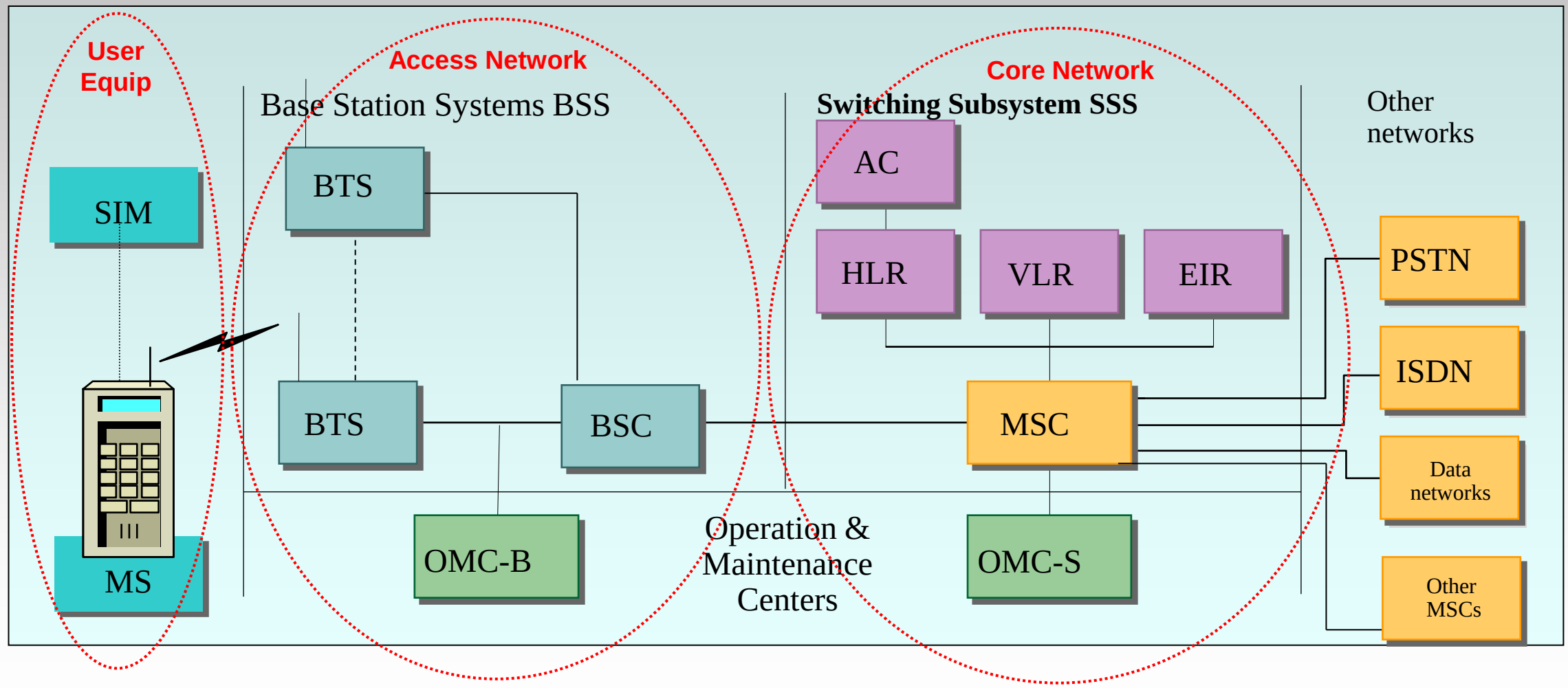
Overview of network architecture

A typical mobile network consists of user equipment (UE)/mobile equipment (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



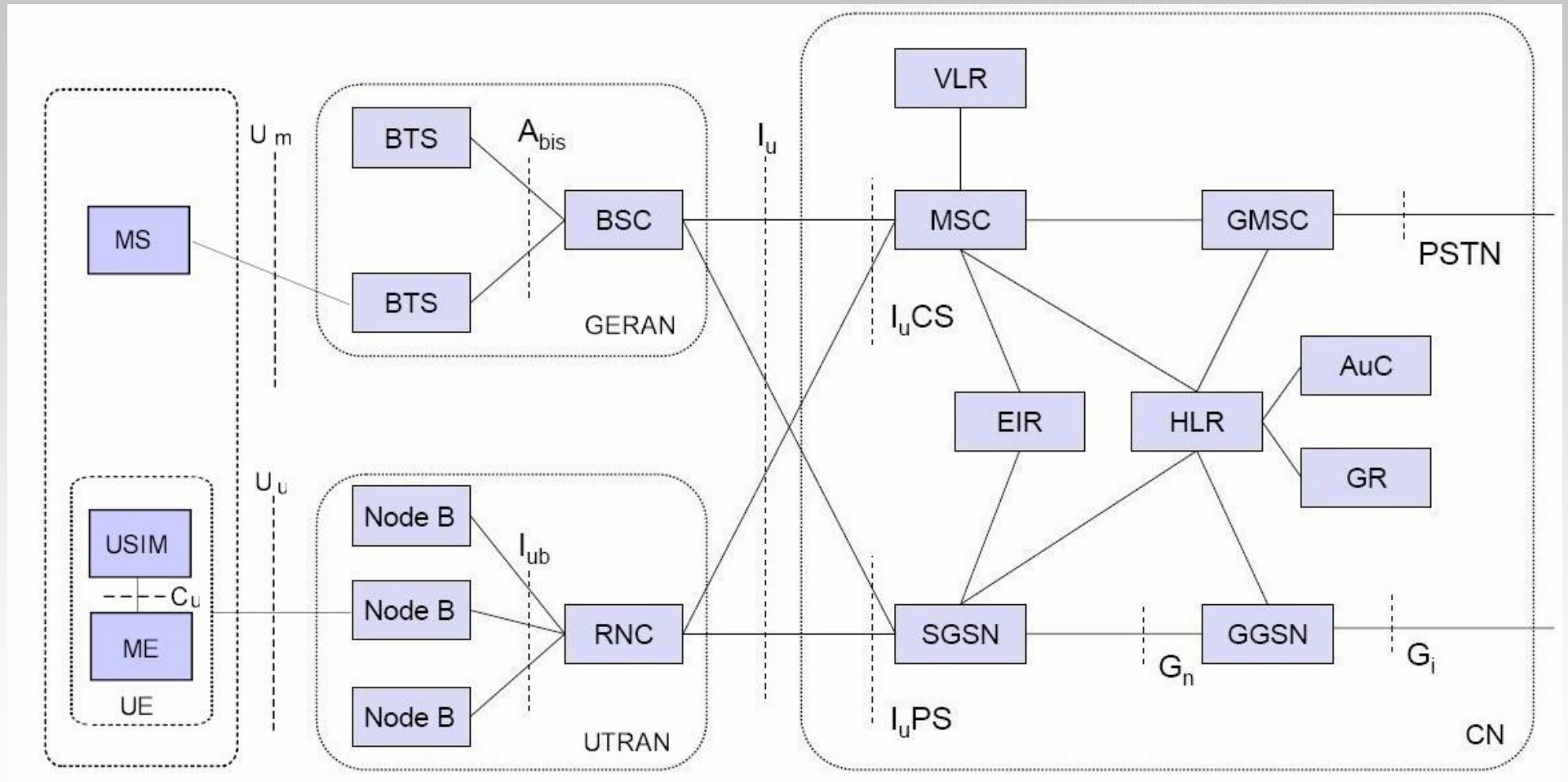
GSM Standards

GSM Standard

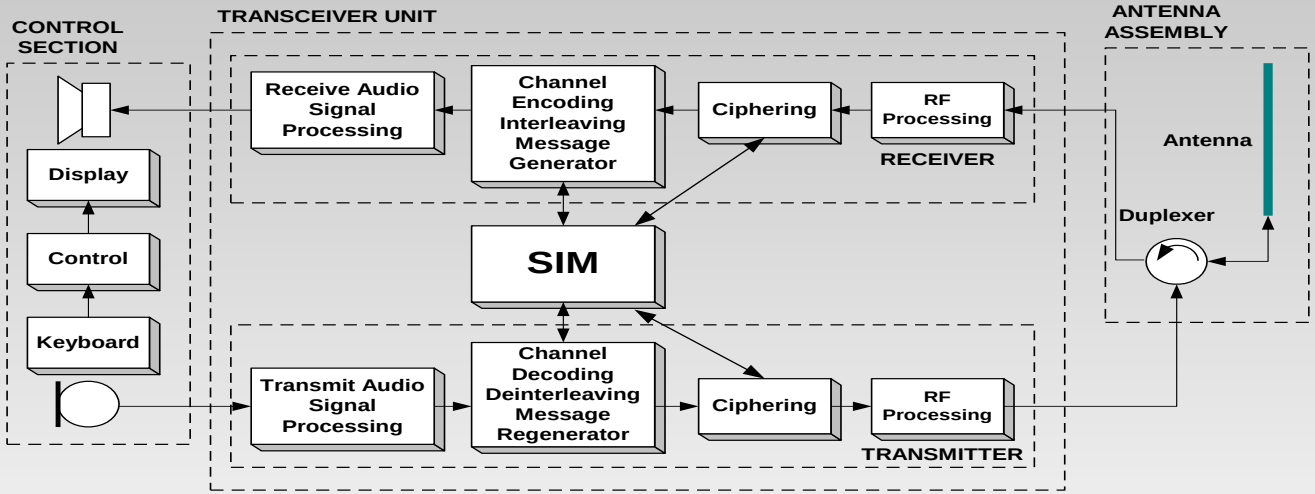
Series	Specifications area
01	General
02	Service aspects
03	Network aspects
04	MS-BS interface and protocol
05	Physical layer and radio path
06	Speech coding specification
07	Terminal adapter for MS
08	BS-MSC interface
09	Network internetworking
10	Service internetworking
11	Equipment and type approval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



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.
- If it resides on the MSC side, it provides substantial changes in the backhaul – 4 users over a single T-1/E-1 TDMA channel.
- 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 can be implemented as an integral part of MSC (old). Now a days, HLR is mostly a standalone entity.

- **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 MSC

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:

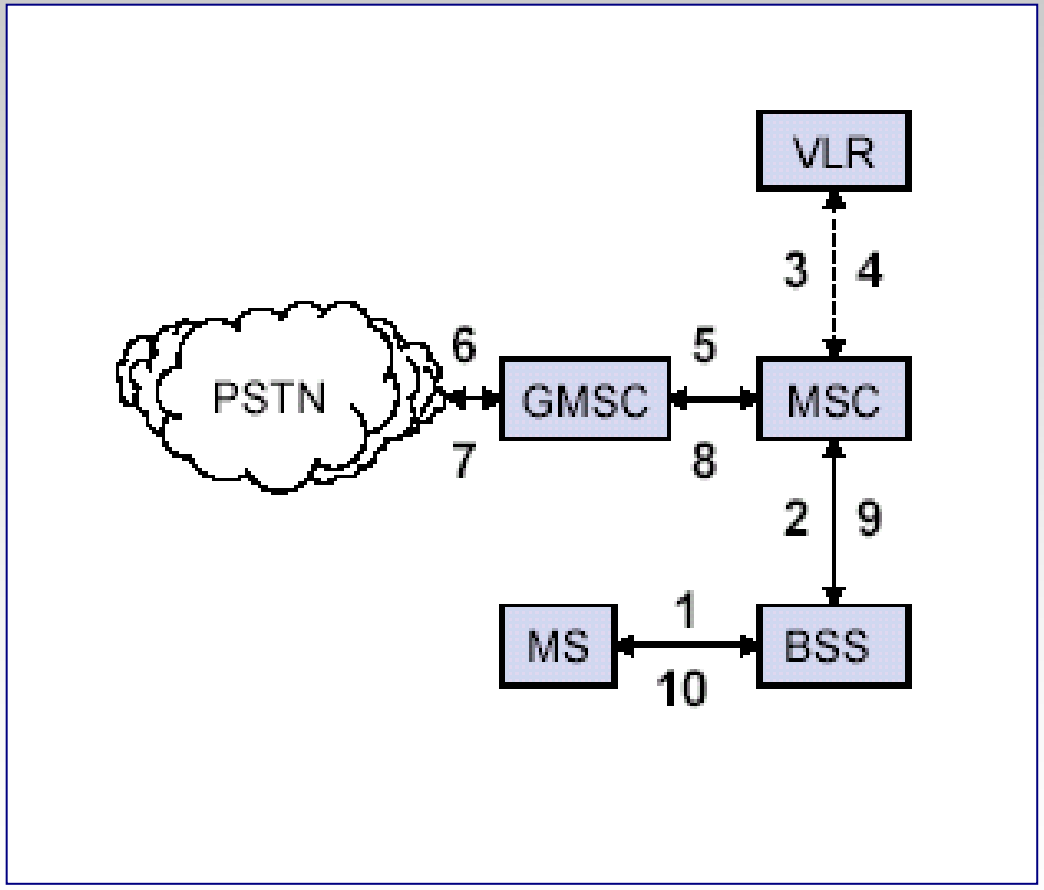
-A3 algorithm for authentication
- A5 algorithm for encryption
- A8 algorithm for key generation

- 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.

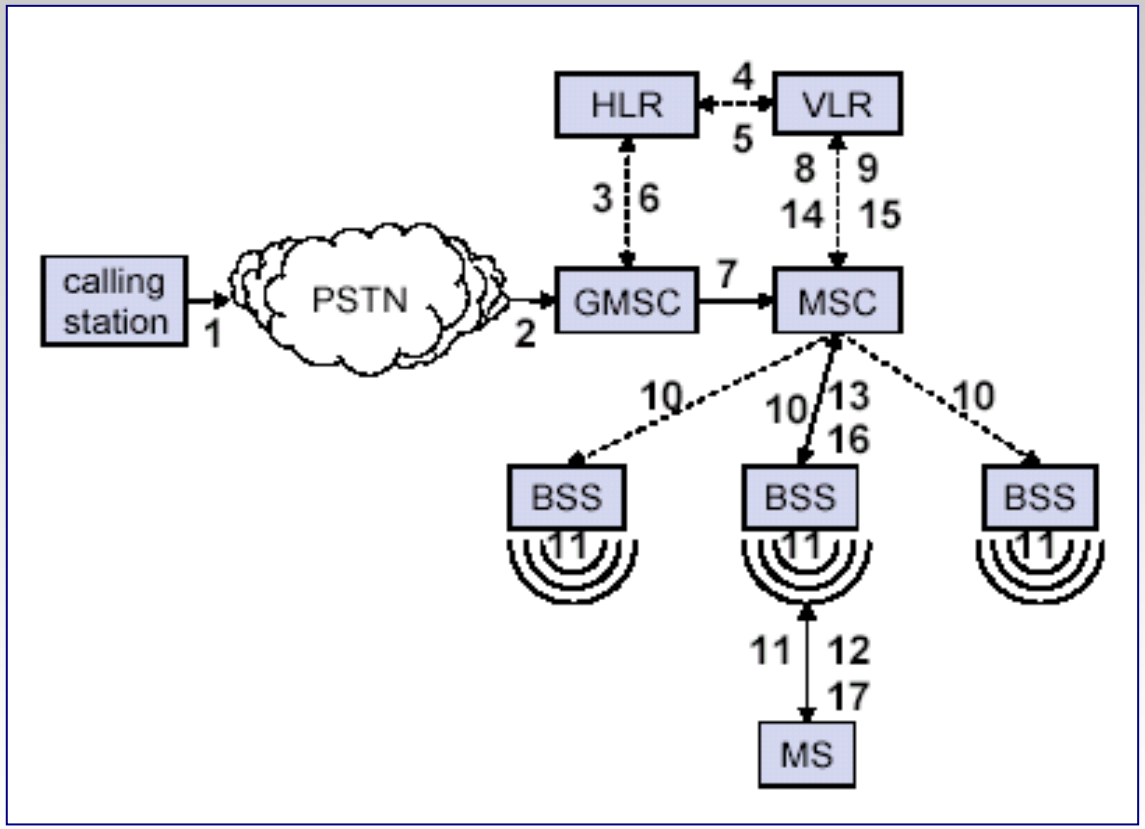
5 MSC routes the call to GMSC

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

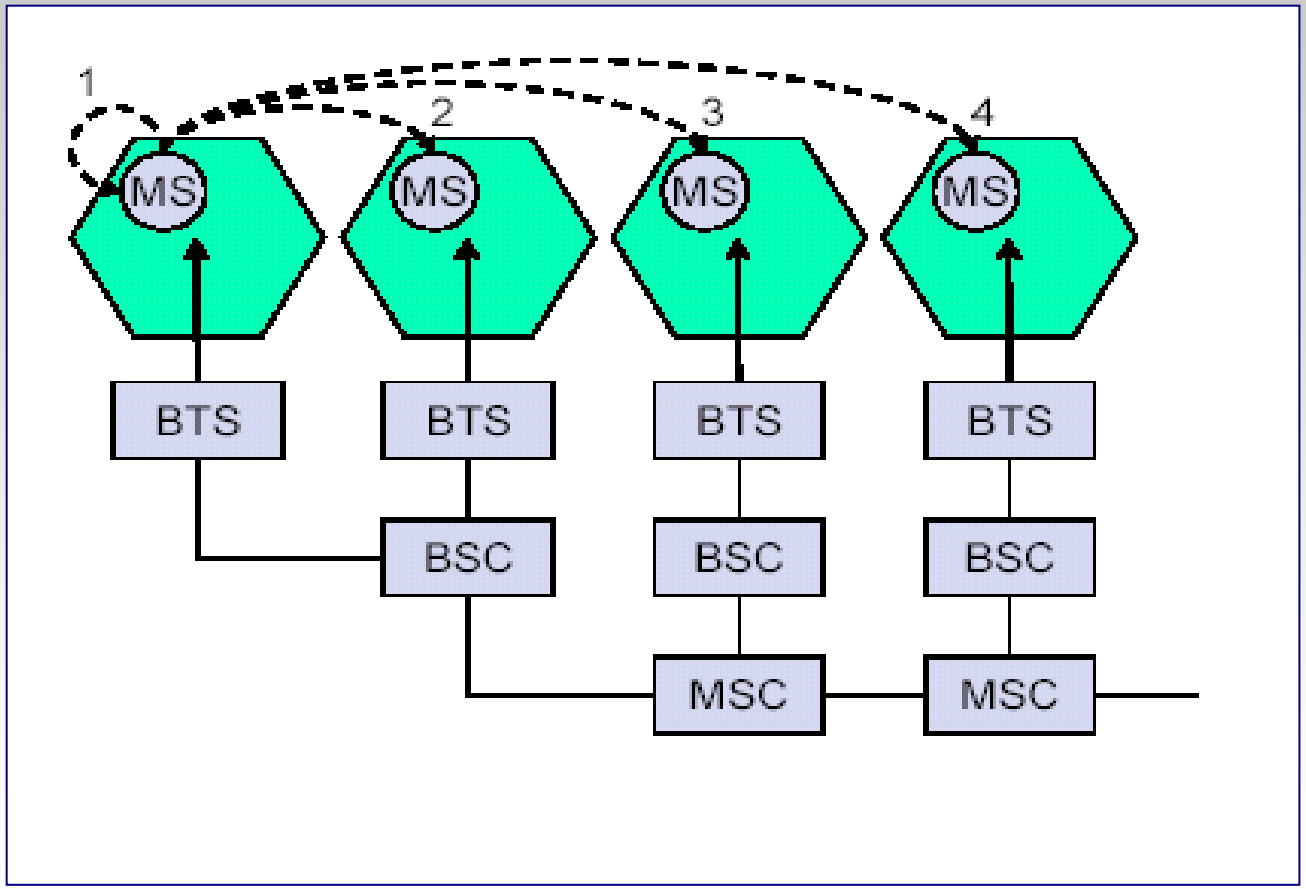
10.11. Paging of MS

12.13. MS answers

14.15. Security checks

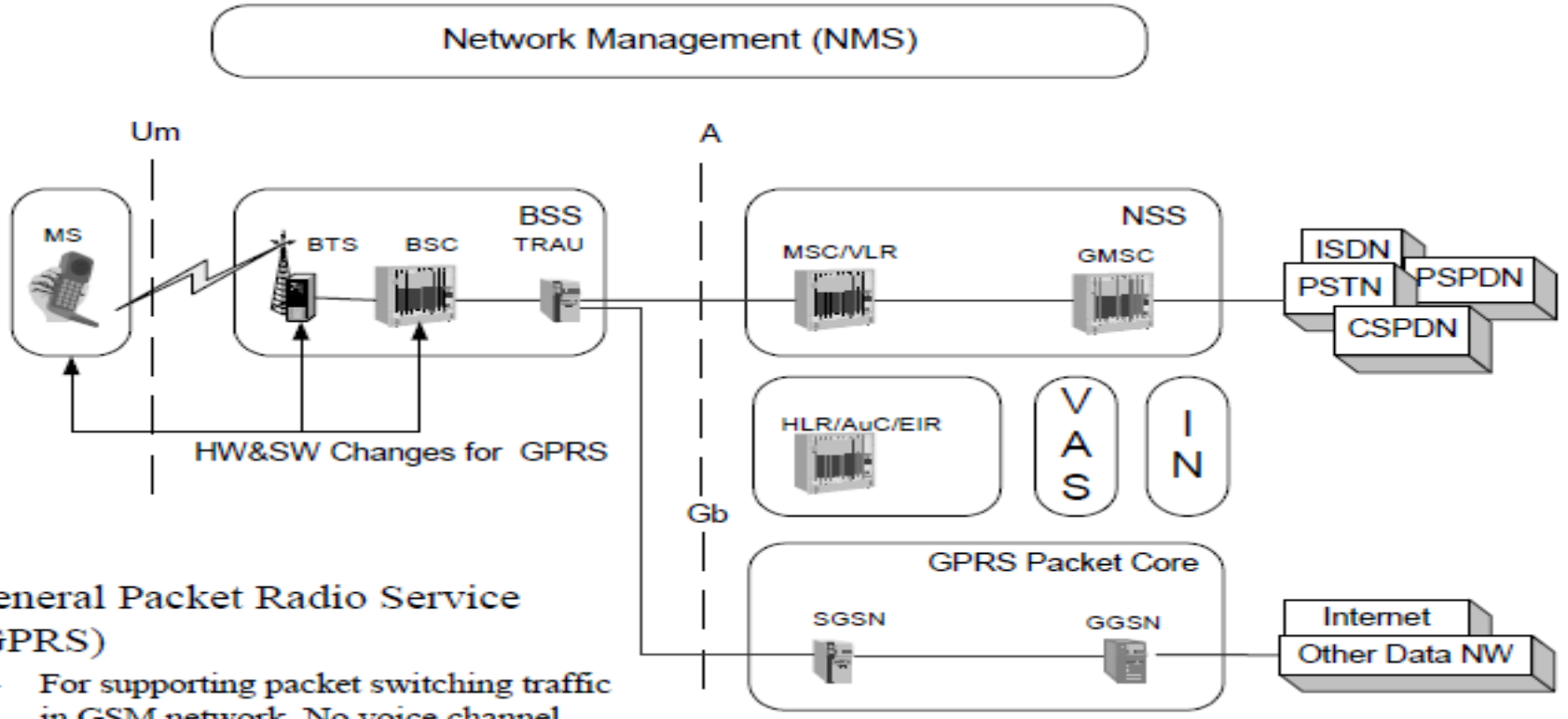
16.17. Set up connection

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



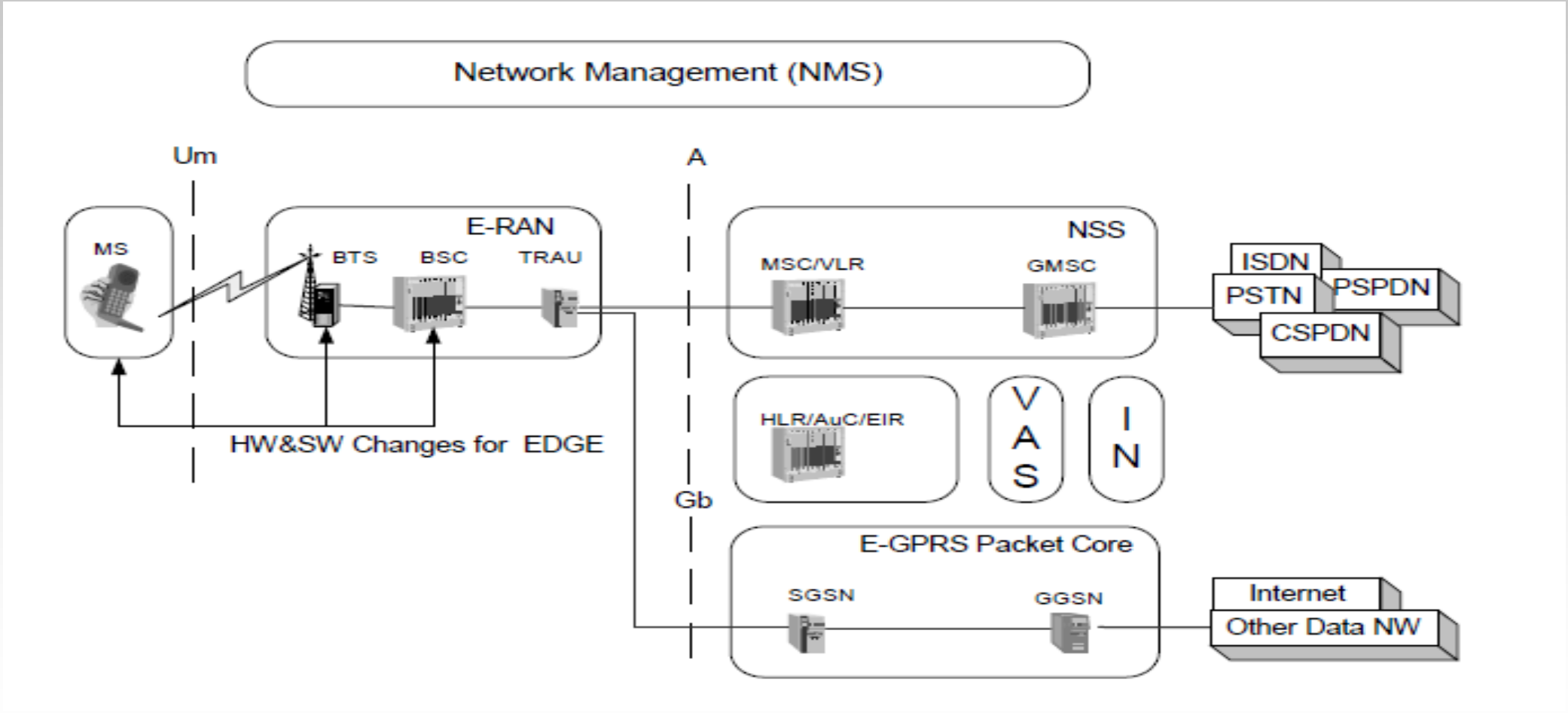
- General Packet Radio Service (GPRS)
  - For supporting packet switching traffic in GSM network. No voice channel reservation.
  - Support for asymmetric traffic.

- 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 functions 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)



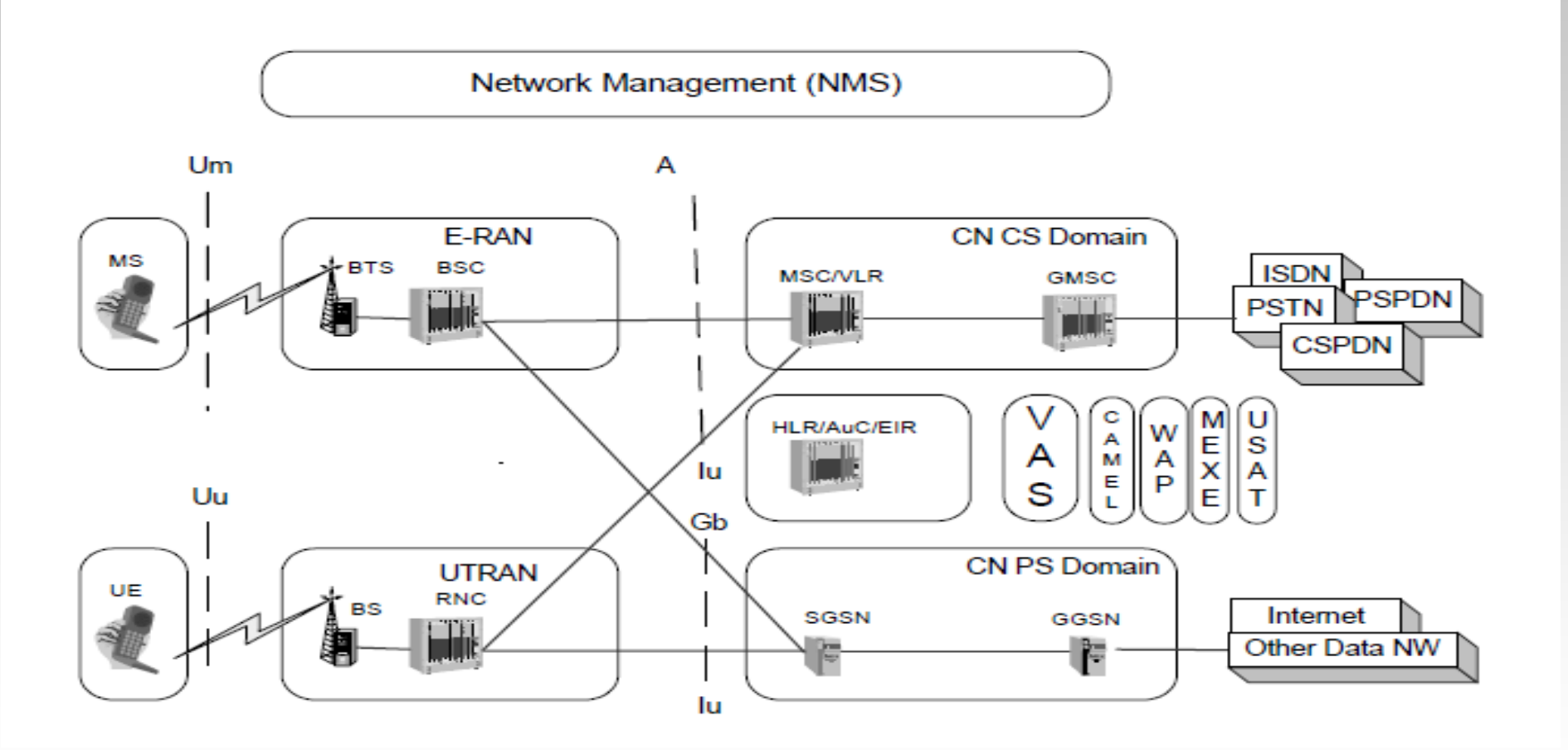
Enhanced Data Rate for GSM Evolution (EDGE)

- 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: Introduction of 3G Network

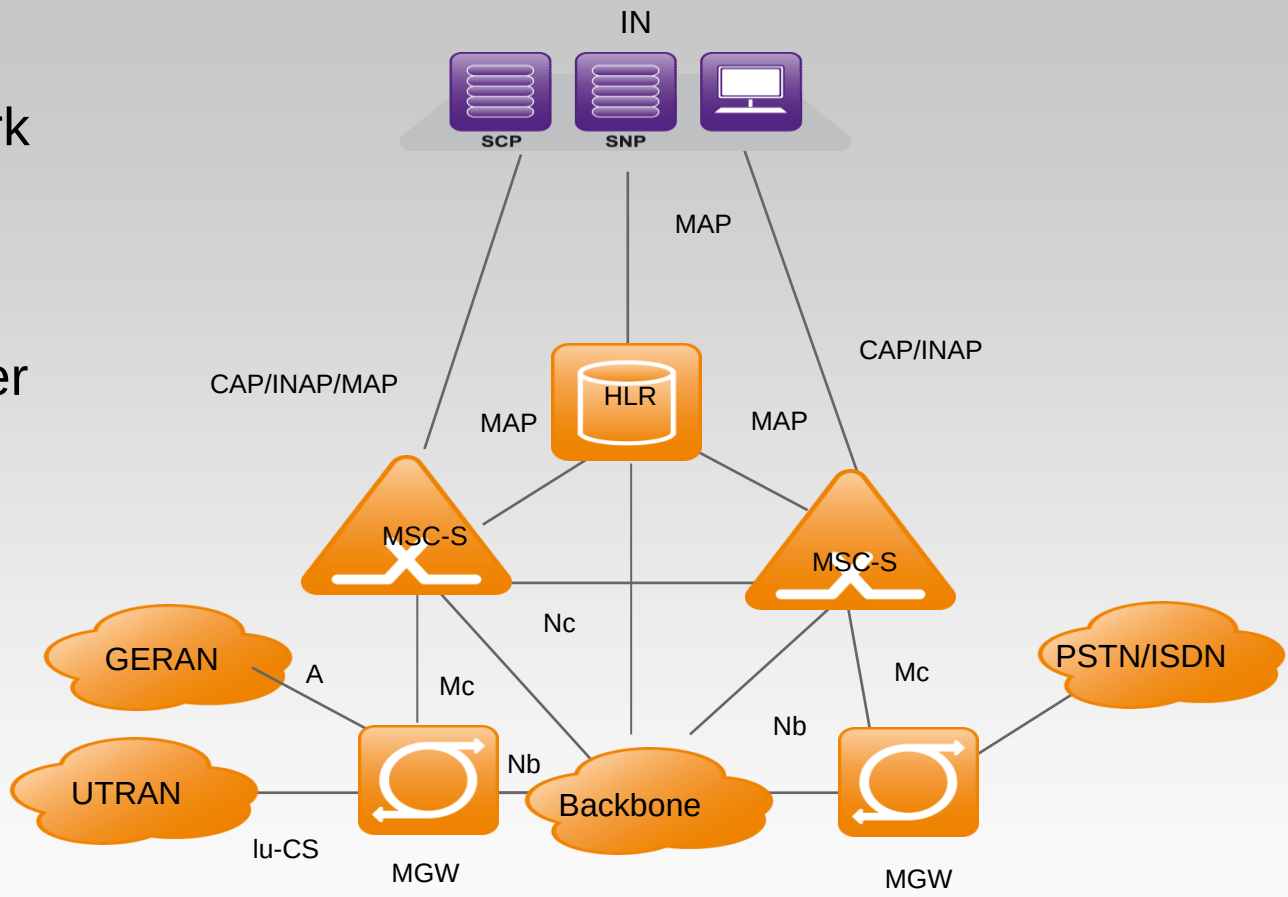


Release 99: 3G Network

- 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. In practice, most operators uses common CS Core (MSC/VLR, HLR) for 2G & 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.



Agenda

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

Protocol: GSM

- In any telecommunication system, signaling is required to coordinate the necessarily distributed functional entities of the network.
- The transfer of signaling information in GSM follows the layered OSI model

Layer 1: Physical Layer

- Radio Transmission

Layer 2: Data Link Layer (DLL)

- provides error-free transmission between adjacent entities, based on the ISDN's LAPD protocol for the U_m and A_{bis} interfaces, and on SS7's Message Transfer Protocol (MTP) for the other Layer interfaces

Layer 3: Networking or Messaging Layer

- Responsible for the communication of network resources, mobility, code format and call-related management messages between various network entities

Protocol Stack structure of GSM

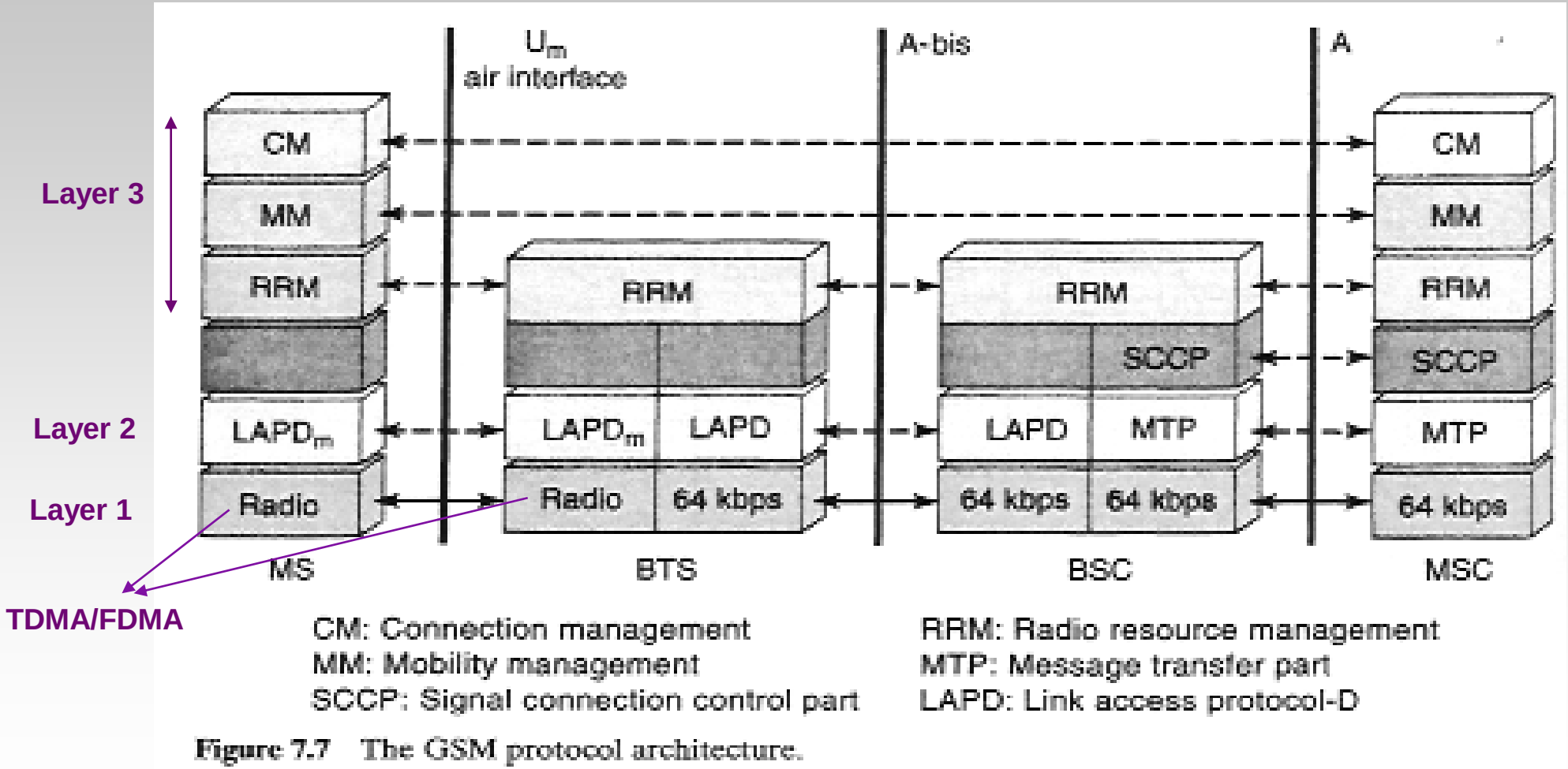


Figure 7.7 The GSM protocol architecture.

Protocol Stack structure of GSM

U_m

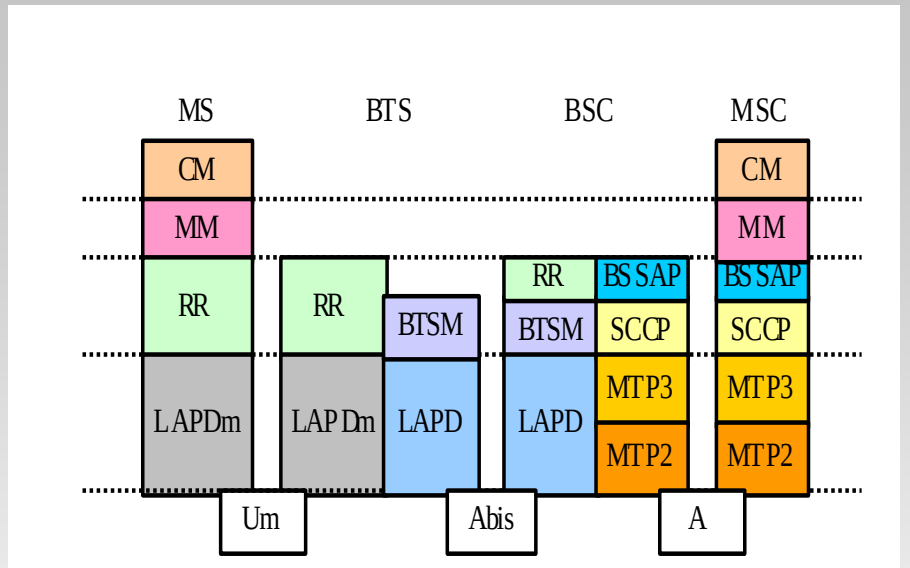
- Radio interface between MS and BTS
- each physical channel supports a number of logical channels

A_{bis}

- between BTS and BSC
- primary functions: traffic channel transmission, terrestrial channel management, and radio channel management

A

- between BSC and MSC
- primary functions: message transfer between different BSCs to the MSC



- The data link layer (layer 2) over the radio link is based on a modified LAPD (Link Access Protocol for the D channel) referred to as LAPDm (m like mobile).
- The Message Transfer Protocol (MTP) level 2 of the SS7 protocol is used at the A interface.

Agenda

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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

Propagation Characteristic

For Operator

General Priority

900MHz

1800MHz

1900MHz

High

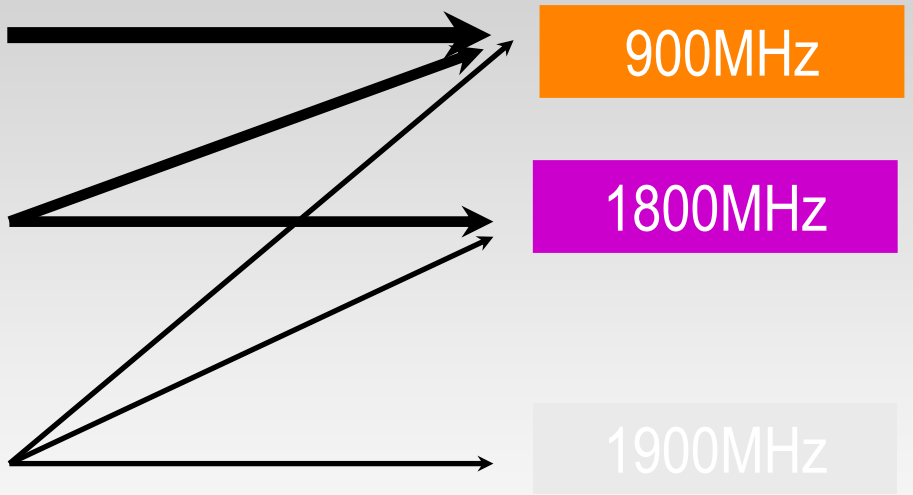
Low

Reason

For Subscriber

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

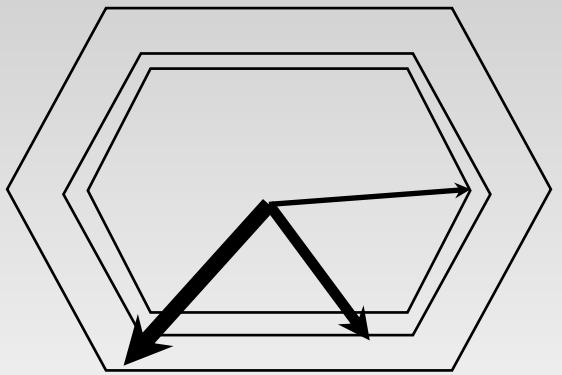
Propagation characteristic

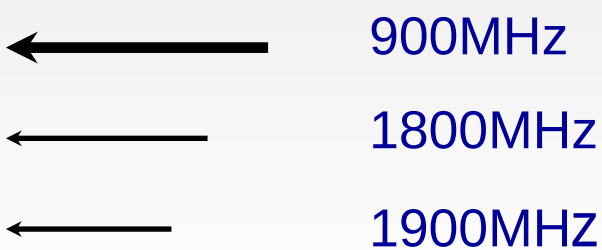
The higher the propagation frequency

The higher the propagation loss

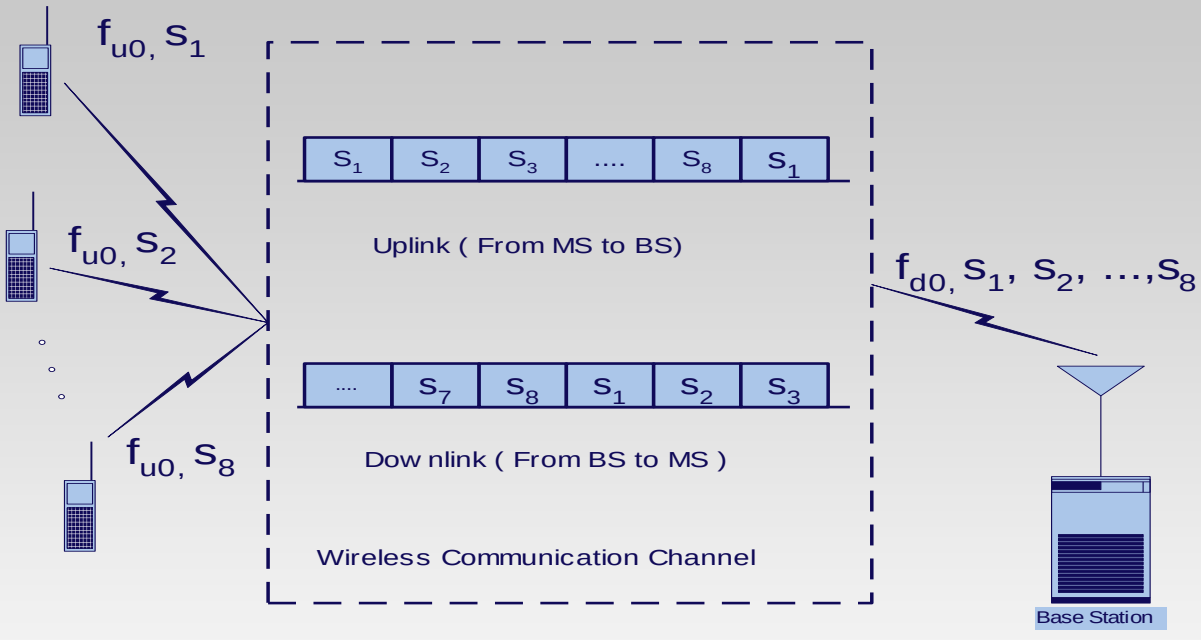
The smaller the cell coverage radius.

Cell coverage radius :





TDMA Access Scheme



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

TDMA = Time Division Multiple Access

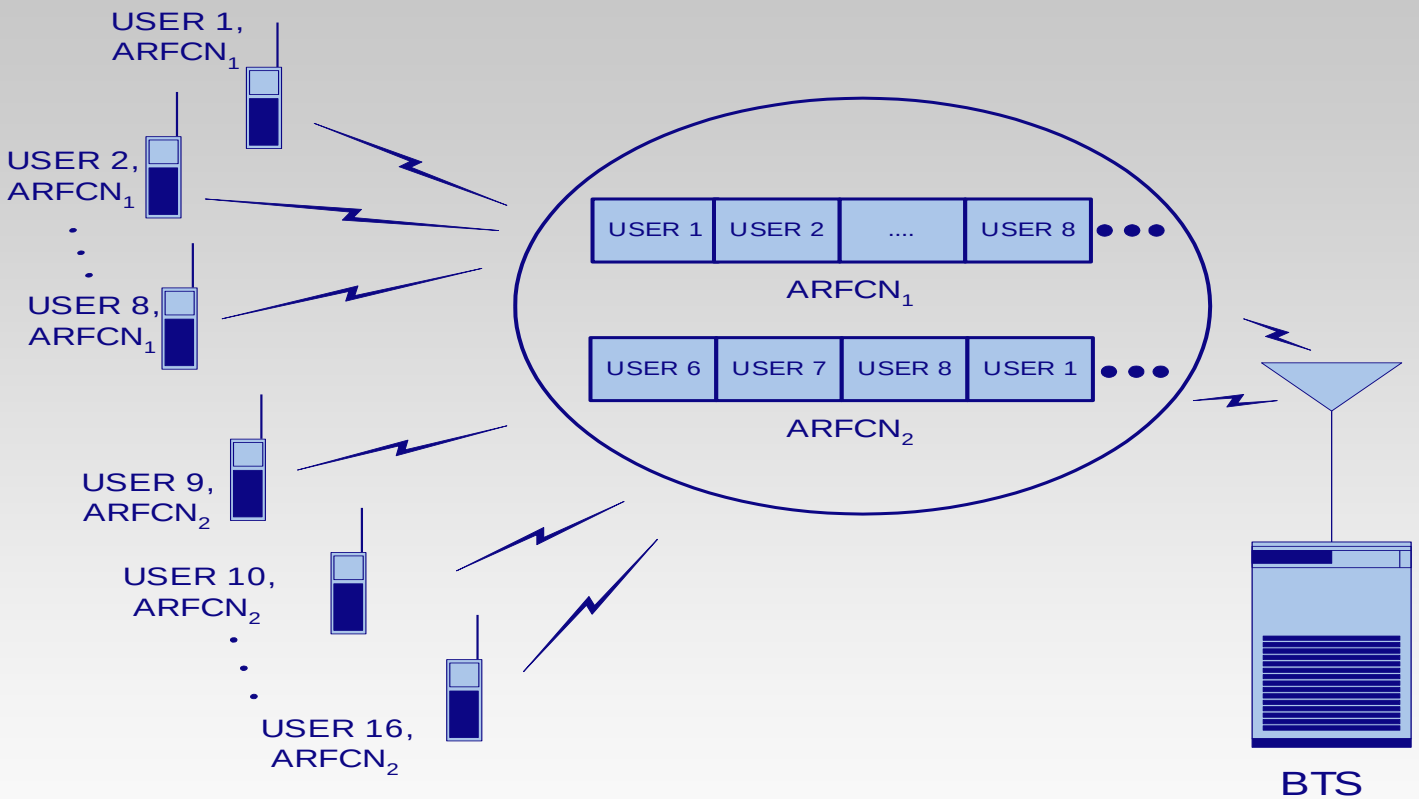
GSM as a TDMA system

GSM is a combination of FDMA and TDMA

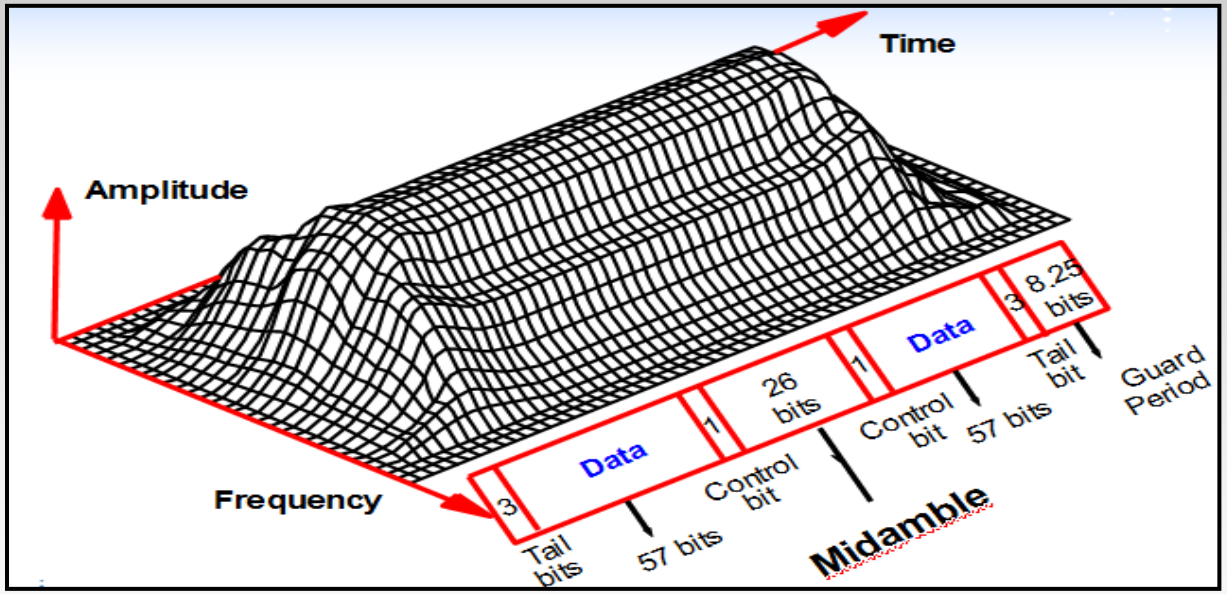
TDMA supports:

- Up to 8 full rate users
- Up to 16 half rate users

GSM uses Frequency Division Duplexing



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

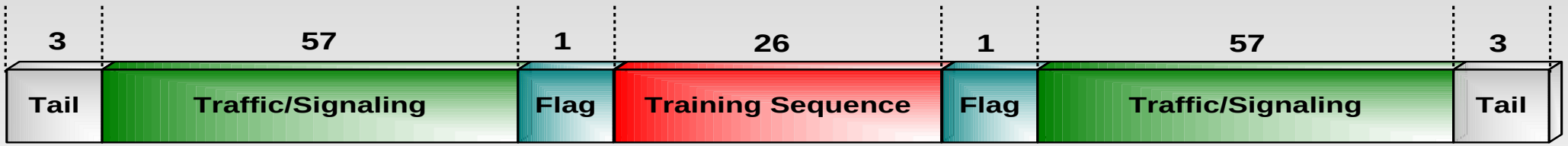
Format of a burst defied by its function

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

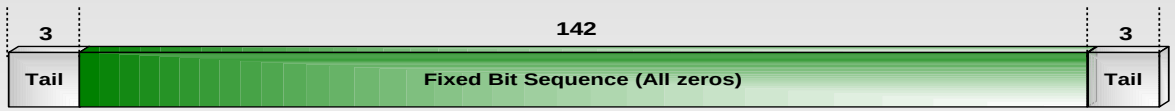
Frequency Correction Burst

Sometimes referred to as the F-burst

Provides mobile with precise reference to the frequency of the broadcast control channel

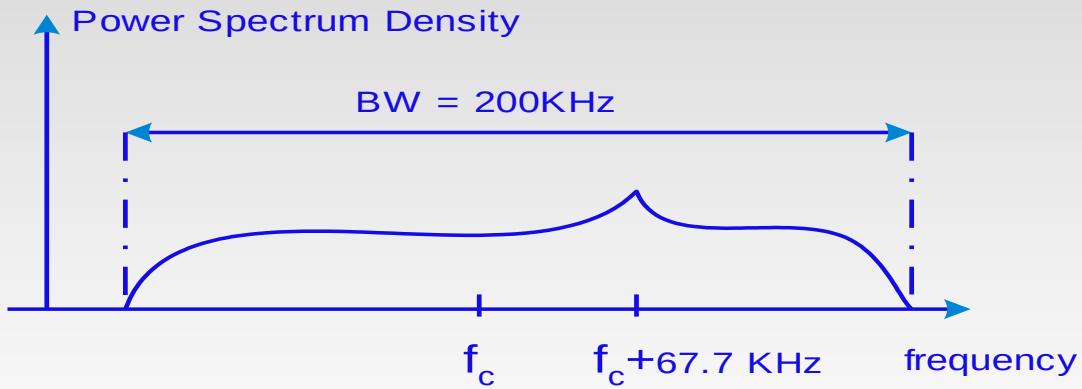
Inserting the F-bursts on the control channel produces spectral peak 67.7 KHz above the central frequency of the carrier

Only on the forward link



Frequency correction burst

- Format of the F-burst
- Fixed sequence consists of all zeros



- Spectral characteristics of the control channel.
- The peak in the spectrum allows for easier MS network acquisition

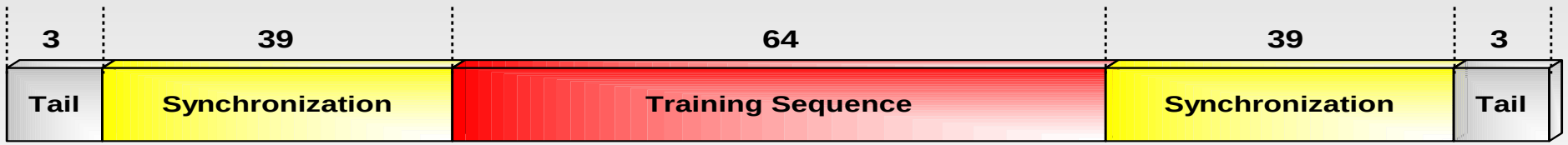
Synchronization Burst

Facilitates the synchronization of the MS to the network at the base band

Commonly referred to as S-burst

Only on the forward link

The same sync sequence is used in all GSM networks



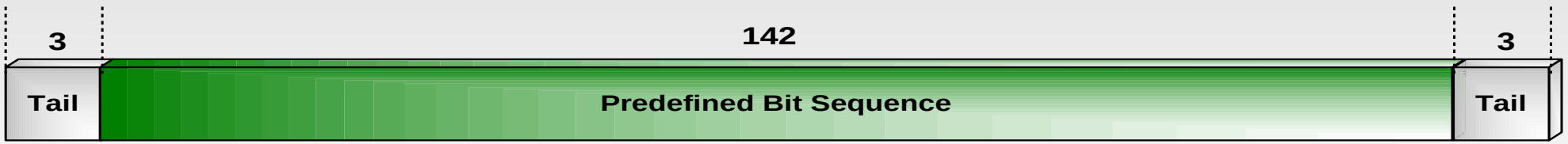
Synchronization burst

Dummy Burst

Supports MAHO

Used to ensure constant power level of the broadcast control channel

Only on the forward link



Dummy burst

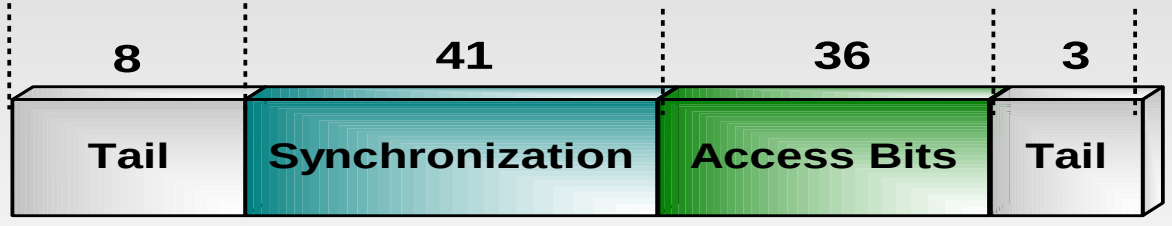
Access Burst

Used when the MS is accessing the system

Shorter in length – burst collision avoidance

Extended synchronization sequence

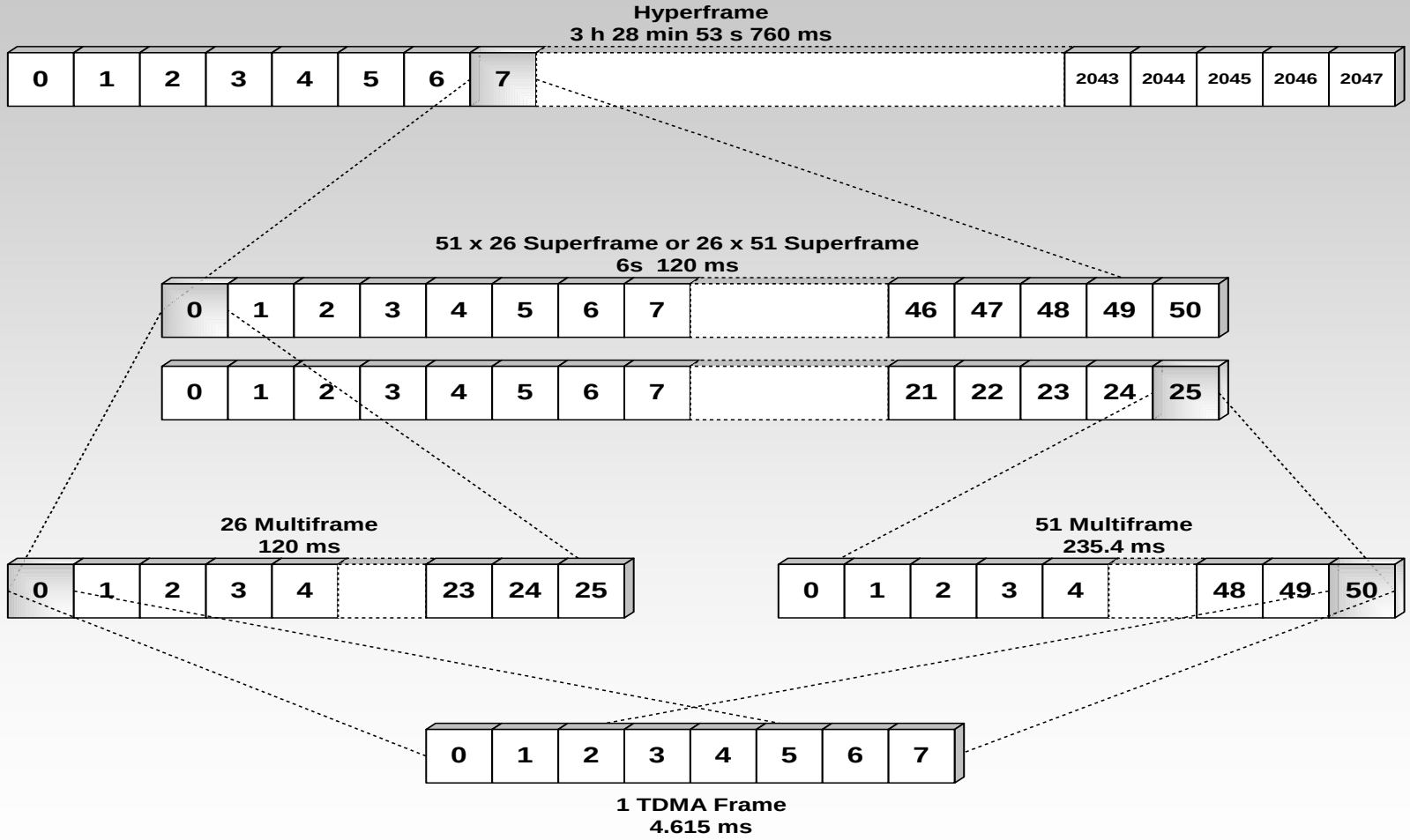
Used only on the reverse link



Access burst

- GSM mobiles use slotted ALOHA to access the system
- In the case of collision – a hashing algorithm is provided

GSM TDMA Hierarchical Organization



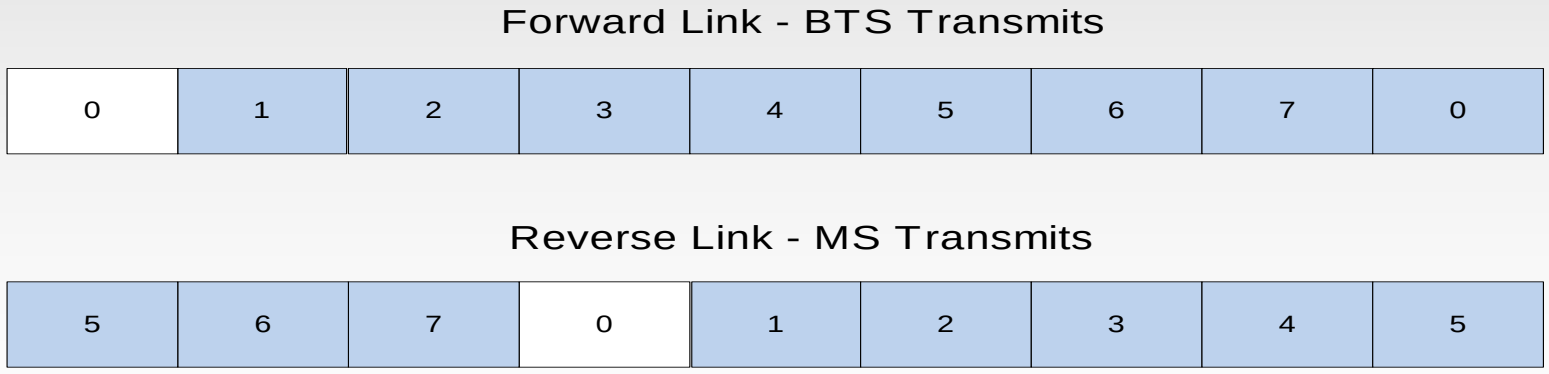
GSM Time Division Duplex

Communication on the forward and reverse link does not happen simultaneously

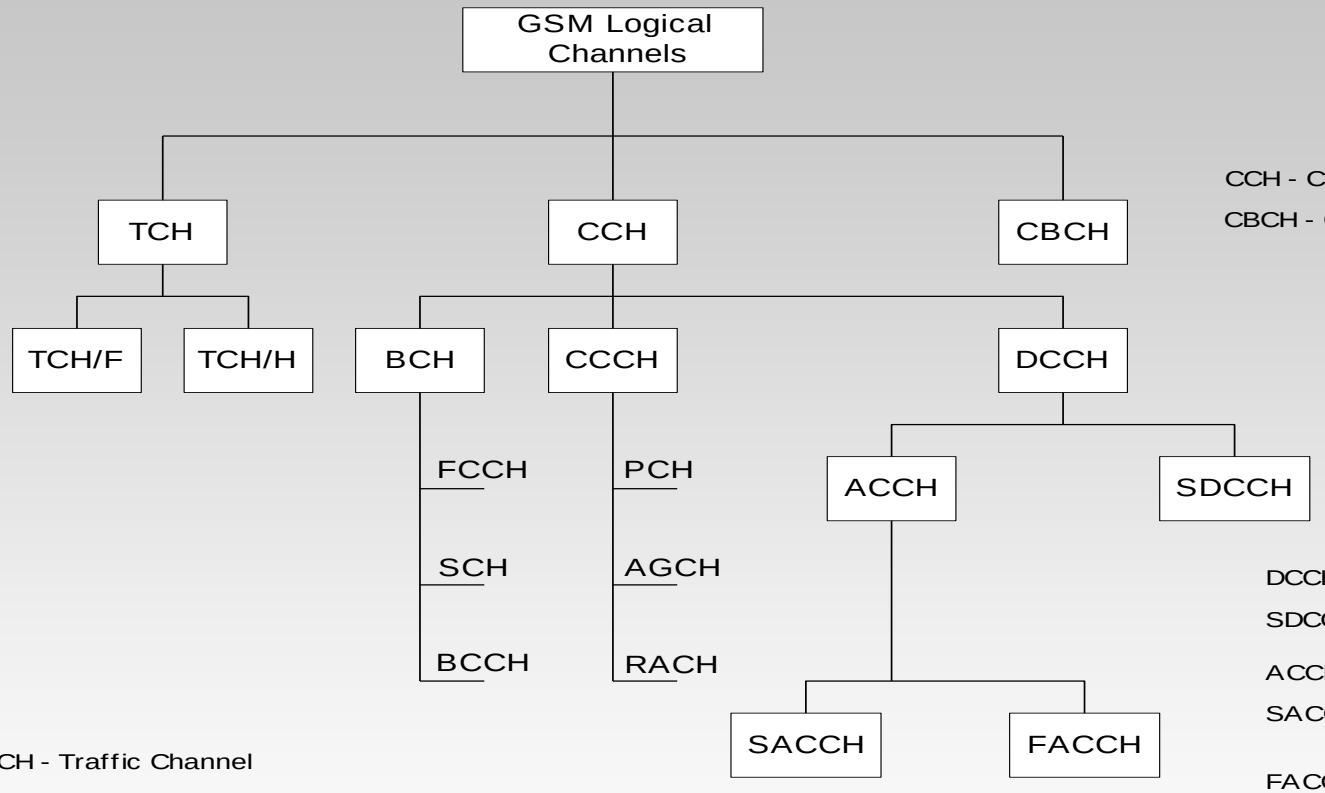
Delay of three slots between TX and RX

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:

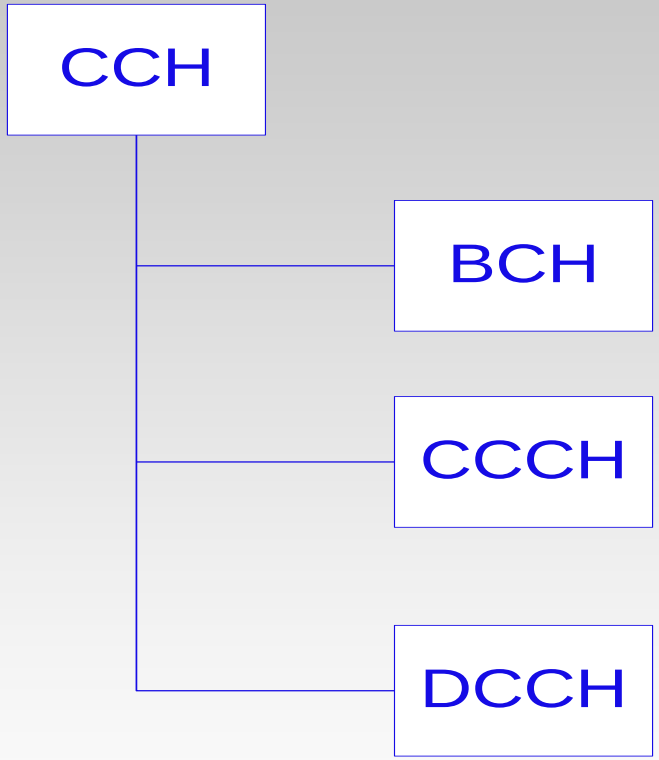
- **Voice (6.5 Kb/sec)**
- **Date at rates:**
  - **4.8 Kb/sec**
  - **2.4 Kb/sec**

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

Control Channels

GSM Defines 3 types of Control Channels:

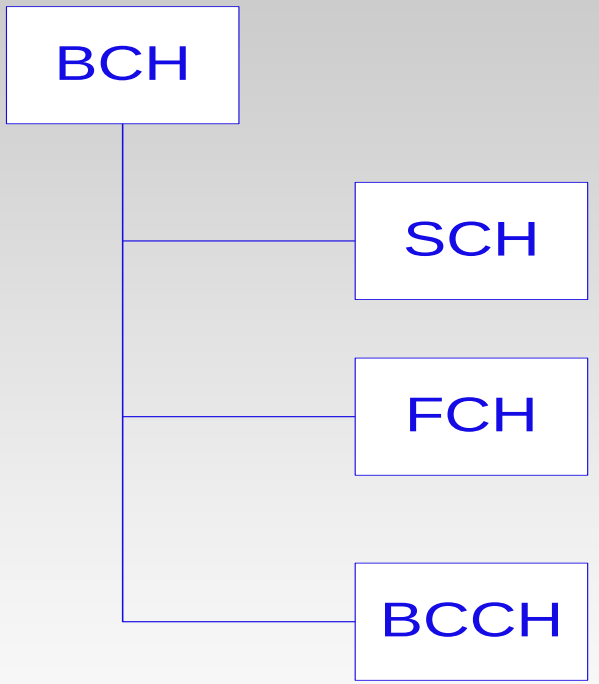
1. **Broadcast Channels (BCH)**
   - Broadcast information that helps mobile system acquisition, frame synchronization, etc. They advertise properties and services of the GSM network.
   - Forward link only
2. **Common Control Channels (CCCH)**
   - Facilitate establishment of the link between MS and 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:

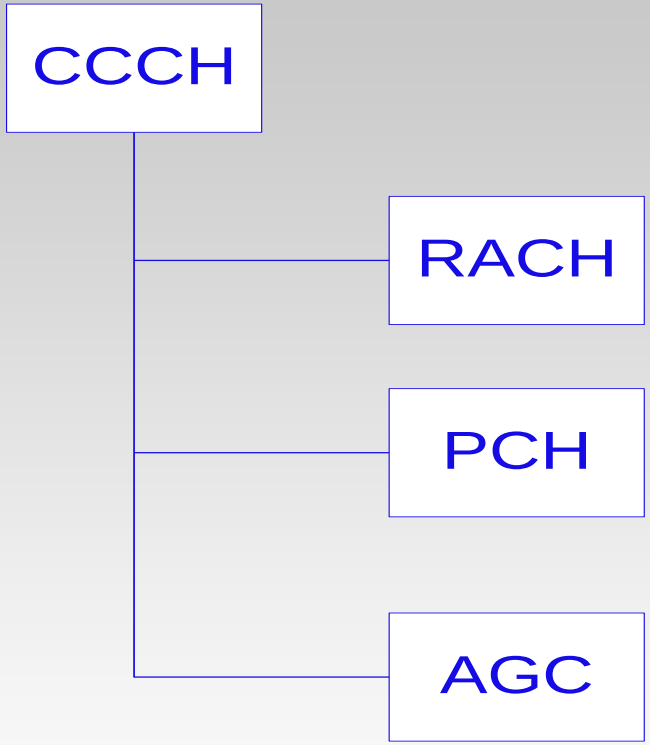
1. **Synchronization channel (SCH)**
   - Provides a known sequence that helps mobile synchronization at the baseband
   - Communicates with S-burst
   - Broadcasts Base Station Identity Code (BSIC)
2. **Frequency Correction channel (FCH)**
   - Helps mobile tune its RF oscillator
   - Communicates with 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:

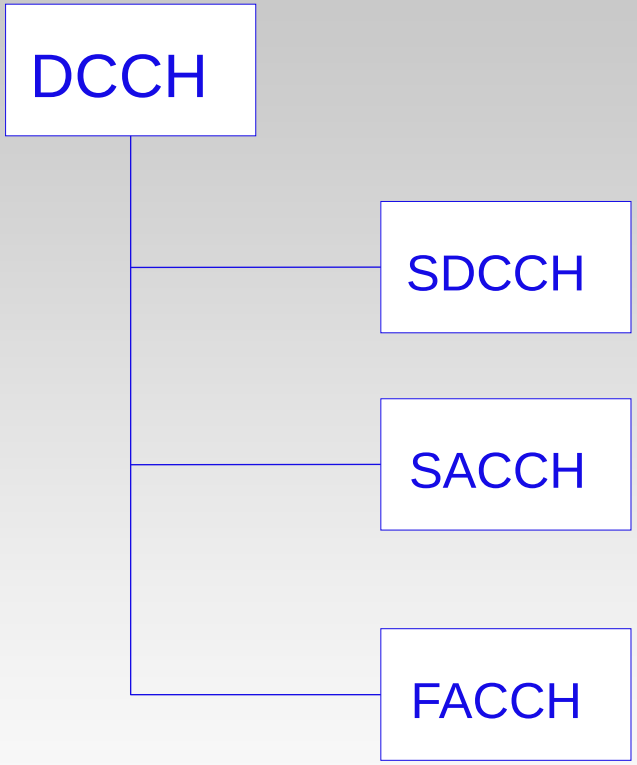
1. Random Access Channel (RACH)
   - Used by mobile to initialize communication
   - Mobiles use slotted ALOHA
   - Reverse link only
2. Paging Channel (PCH)
   - Used by the system to inform the mobile about an incoming call
   - Forward link only
   - GSM Supports DRX
3. Access Grant Channel (AGC)
   - 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



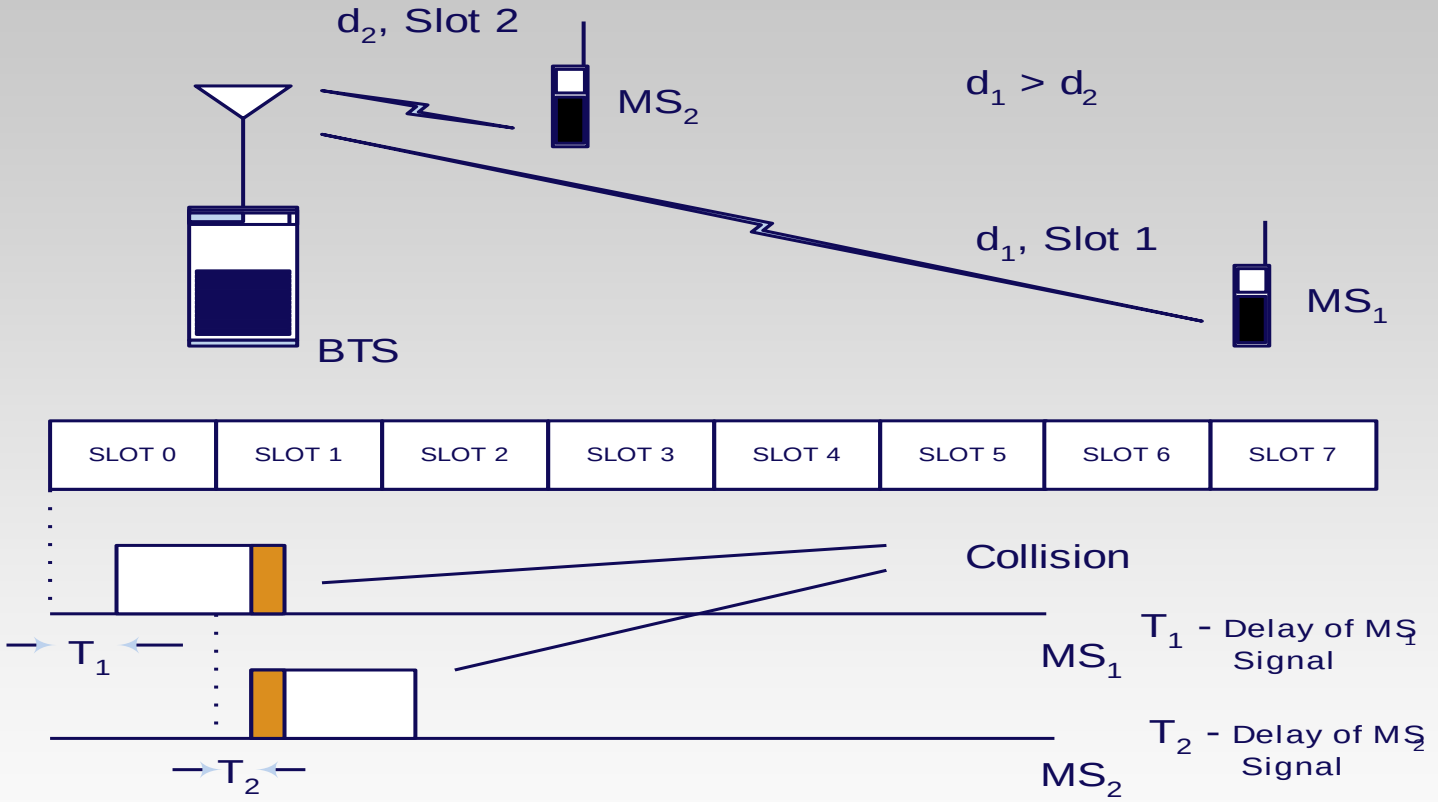
Logical Channels- Summary

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

Timing Advance

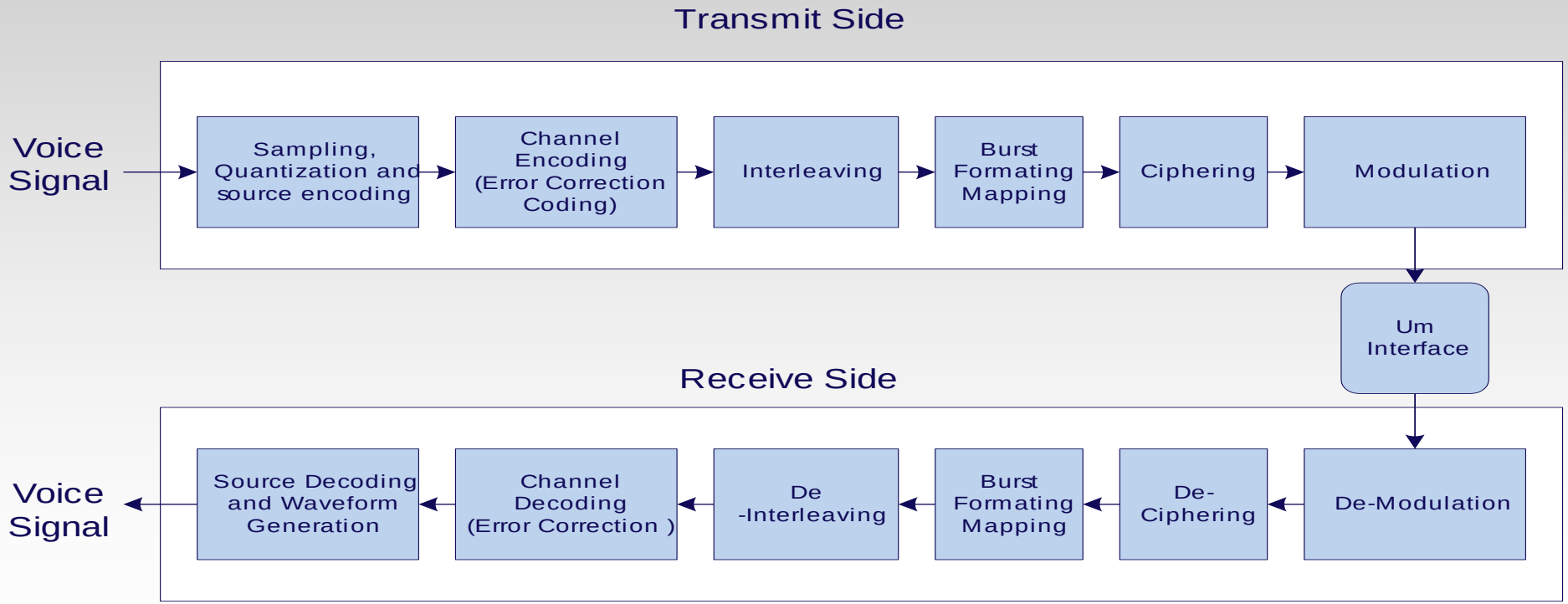
- Mobiles randomly distributed in space
- Timing advance prevents burst collision on the reverse link
- Maximum advancement is 63 bits



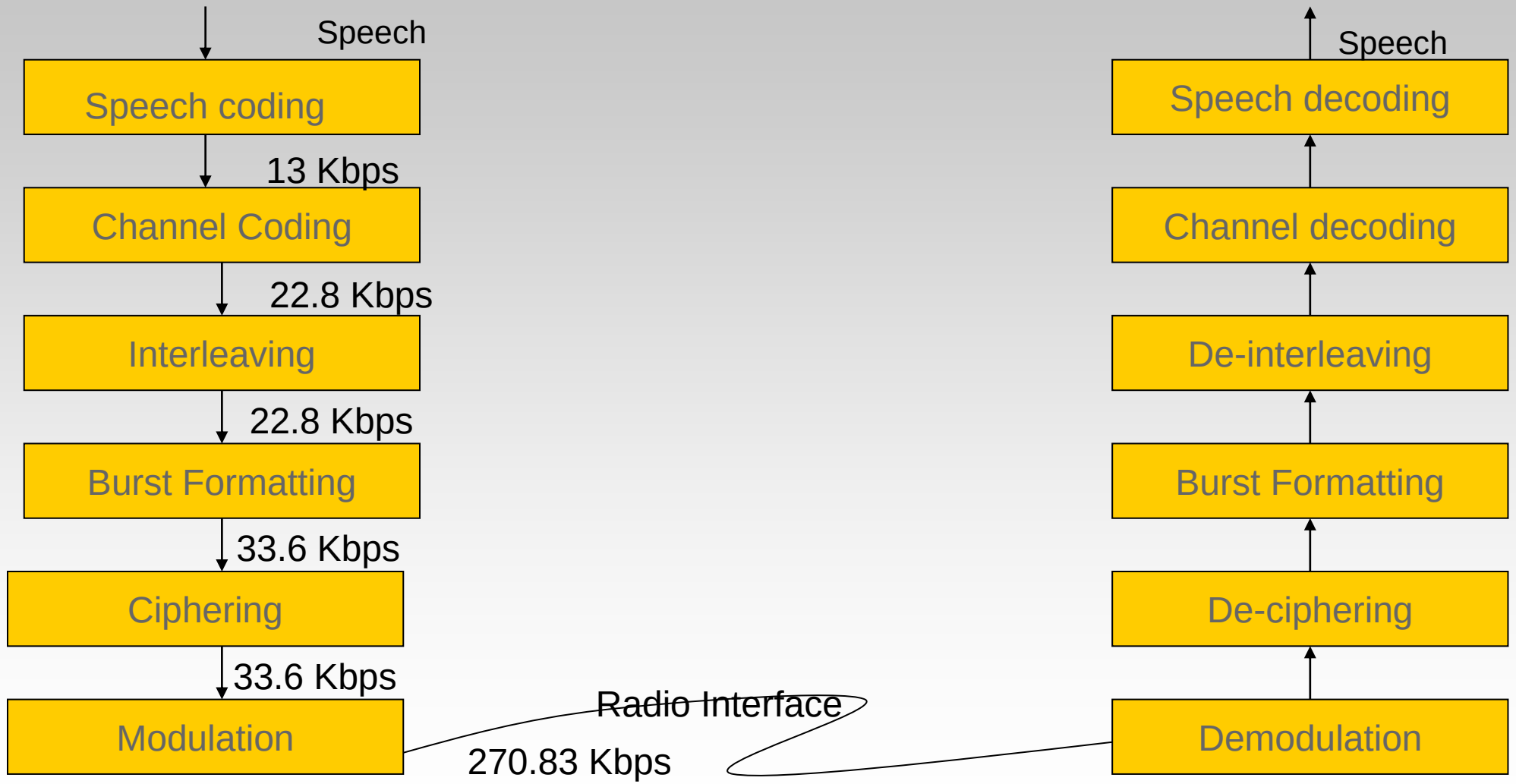
$$D\max = \frac{1}{2}\left(3\times10^{8}\ \frac{\mathrm{m}}{\mathrm{s}}\cdot 63\mathrm{bit}\cdot 3.693\times10^{-6}\ \frac{\mathrm{s}}{\mathrm{bit}}\right)\approx 35\mathrm{km}$$

Signal Processing- From voice to Radio waves

As a digital TDMA technology GSM implements extensive signal processing



Signal Processing- From voice to Radio waves



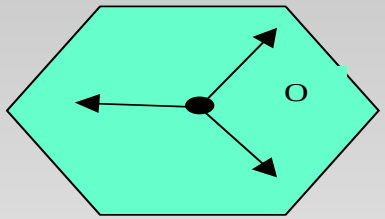
Agenda

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

Cell Mode Layout

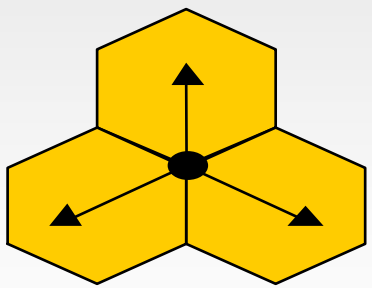
Omni-directional cell

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

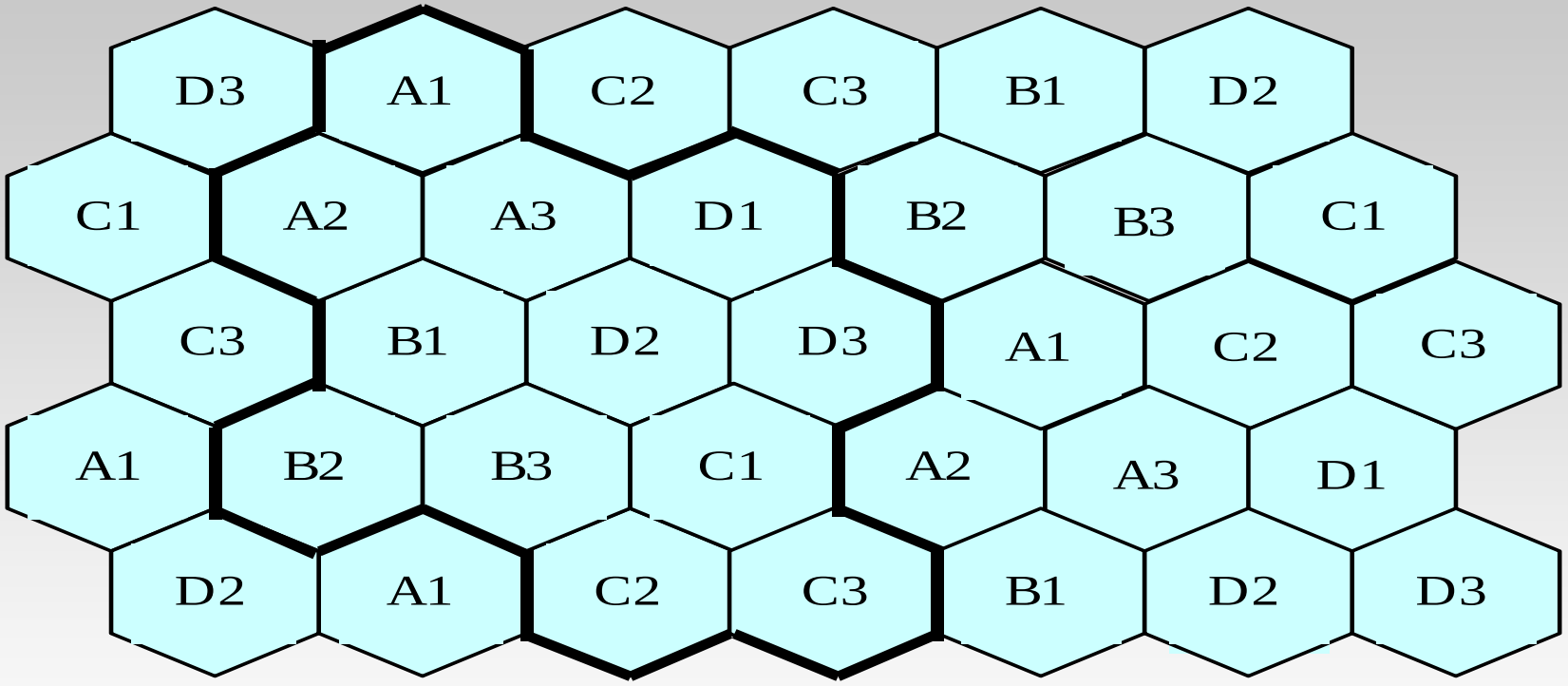
Erlang :

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.

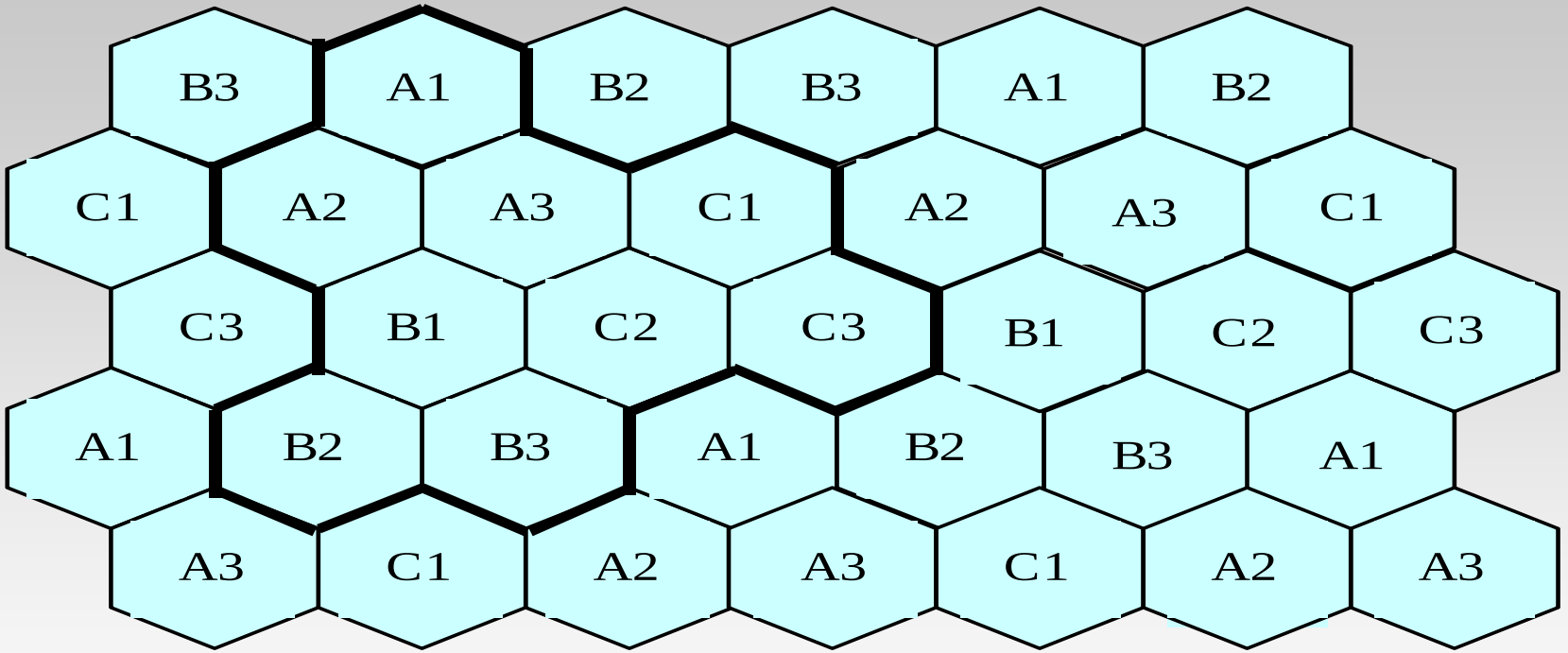
Frequency Reuse



“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.