Mobile Computing
(Part-1)

Introduction

GENERATIONS

Cellular Concepts

FDMA, TDMA and CDMA

GSM

CDMA

GPRS

What Is Mobile Computing?

- What is computing?

  Operation of computers

  (according to oxfords advance learner's dictionary)

- What is the mobile?

  That someone /something can move or be moved easily and quickly from place to place

- What is mobile computing?

  Users with portable computers still have network connections while they move

What Is Mobile Computing?

- **A simple definition could be:**
  Mobile Computing is using a computer (of one kind or another) while on the move

- **Another definition could be:**
  Mobile Computing is when a (work) process is moved from a normal fixed position to a more dynamic position.

- **A third definition could be:**
  Mobile Computing is when a work process is carried out somewhere where it was not previously possible.

What Is Mobile Computing? (Cont.)

- **Mobile Computing** is an umbrella term used to describe technologies that enable people to access network services anyplace, anytime, and anywhere.

- Mobile computing can be defined as a computing environment over physical mobility.

Comparison to Wired Net

- **Wired Networks**
  - high bandwidth
  - low bandwidth variability
  - can listen on wire
  - high power machines
  - high resource machines
  - need physical access(security)
  - low delay
  - connected operation

- **Mobile Networks**
  - low bandwidth
  - high bandwidth variability
  - hidden terminal problem
  - low power machines
  - low resource machines
  - need proximity
  - higher delay
  - disconnected operation

Why Go for Mobile?

- **Enable anywhere/anytime connectivity**
- Bring computer communications to areas without pre-existing infrastructure
- Enable mobility
- Enable new applications
- An exciting new research area

Types of Wireless Devices

- Laptops
- Palmtops
- PDAs
- Cell phones
- Pagers
- Sensors
- …

Challenges

- Disconnection
- Low bandwidth
- High bandwidth variability
- Low power and resources
- Security risks
- Wide variety terminals and devices with different capabilities (Device attributes)
- Fit more functionality into single, smaller device

MOBILE COMPUTING

- The user of a mobile computing environment will be able to access data, information or other logical objects from any device in any network while on the move.

- Mobility
  - User Mobility
  - Device Mobility

MOBILE COMPUTING Cont.

- **Anywhere, Anytime Information:** This is the generic definition of ubiquity, where the information is available anywhere, all the time.
- **Virtual Home Environment:** (VHE) is defined as an environment in a foreign network such that the mobile users can experience the same computing experience as they have in their home or corporate computing environment.
  - For example, one would like to put ones room heater on when one is about 15 minutes away from home.

MOBILE COMPUTING Cont.

- **Nomadic Computing:** The computing environment is nomadic and moves along with the mobile user.
  - This is true for both local and remote services.

- **Pervasive Computing:** A computing environment, which is pervasive in nature and can be made available in any environment.

- **Ubiquitous Computing:** A disappearing (nobody will notice its presence) everyplace computing environment. User will be able to use both local and remote services.

MOBILE COMPUTING Cont.

- **Global Service Portability:** Making a service portable and available in every environment. Any service of any environment will be available globally.

- **Wearable Computers:** Wearable computers are those computers that may be adorned by humans like a hat, watch, shoe or clothes (these are wearable accessories).

Mobile Computing Functions

- We can define a computing environment as mobile if it supports one or more of the following characteristics:
- **User Mobility**
- **Network Mobility**
- **Device Mobility**
- **Service Mobility**
- **Bearer Mobility**
- **Session Mobility**
- **Host Mobility (client –server, ip)**

Issues in categories

- Software Issues - Apps
- Technical Issues - Battery, h/w
- Network Issues - connection
- User Interface Issues - understanding
- Security Issues - attacks

Future of Mobile Computing

- Use of Artificial Intelligence
- Integrated Circuitry -> Compact Size
- Increases in Computer Processor speeds
- etc….

Still, Open Areas…

- Interference
- Regulations and Spectrum
- Low Bandwidth
- High delays, large delay variations
- Lower security, simpler to attack
- Shared medium
- Adhoc networking

1G, 2G, 3G & 4G

Mobile Generations….

Wireless Standards: History

- A new generation of cellular standards has appeared approximately **every tenth year**
  - 1G systems were introduced in **1981.**
- Each generation is characterized by
  - new frequency bands,
  - higher data rates and
  - non-backwards compatible transmission technology.
- 3G is considered successor to 1G and 2G.

1G

- 1G: The original **analog** cellular systems are considered the first generation of mobile telephony (1G).
- In the early 1980s, 1G systems were deployed.
- AMPS

2G

- After 1G, second generation of mobile telephony (2G) came into being.
- The difference between 1G and 2G is in the signaling techniques used:
  - 1G used analog signaling,
  - 2G used **digital signaling.**
  - 2G-based mobile telephony were intended primarily for **voice transmission** and **Data** (low rate)
  - 3G for high speed data rate

2.5G

- 2.5G used some of the advanced technique like **packet-switching**
- This can use some of the existing 2G infrastructure in GSM and CDMA networks.
- GPRS is a 2.5G technology used by GSM operators.
- Some protocols, such as EDGE(Enhanced Data rates for GSM Evolution) for GSM and CDMA2000 1x-RTT for CDMA have data rate of above 144 kbps are considered close to 3G.

2.5G Cell Phone Systems

- between original 2G digital phones and the newer 3G phones.

- bring data transmission capability to 2G phones in addition to normal voice service.

- permits subscribers to exchange e-mails and access the Internet by cell phone.

1. General Packet Radio Service, GPRS

–uses one or more of the eight TDMA time slots in a GSM phone system to transmit data rather than digitized voice.

- data rate is from 20 kbps up to 160 kbps
- typical rate is about 40 kbps, which is more than enough for e-mail and short message service but poor for Internet access.
- involves an automatic rate adjustment algorithm that adjusts the class and data rate to the robustness of the wireless channel.

2. Enhanced Data Rate for GSM Evolution, EDGE

- based upon GPRS system but uses 8-PSK modulation to achieve even higher data rates up to 384 kbps, thereby tripling the rate.

- theoretical max. data rate is 473.6 kbps with all eight slots used

- if implemented, EDGE needs linear power amplifiers at the base station and in the handset.

CDMA2000 –

- uses 1.25 MHz wide channels
- packet-based; permits a data rate of 144 kbps
- uses three 1.25 MHZ channels = 3.75 MHz
- Evolution-Data Optimized,

  a recent version has higher rate approaching 3.1 Mbps downlink and an uplink rate up to 1.8 Mbps. These speeds qualify for 3G.

Evolving of 3G Standards: IMT 2000

- 3G has been specified as **International Mobile Telecommunications-2000** (IMT — 2000) as per definition of International Telecommunication Unit(ITU).
- IMT-2000 specifications embodies standards for mobile phones and mobile telecommunications services as per ITU

3G goals

- Unifying pre-3G technologies
  - 3G uses CDMA while 1G used FDMA and 2G used TDMA, CDMA
- Making Global roaming feasible
- Higher security level
- Advanced Video:
  - Streaming
  - IPTV
  - Mobile TV

What is 3G?

3G refers to the third generation of cellular wireless standards. Its aim is to

- provide a **wide range of data rates** for internet access to mobile as well as stationary users and
- is able to efficiently support both **Voice & Data application.**

3G Data rate

- 3G data rate
  - a minimum data rate of 2 Mbit/s for stationary or walking users, and
  - 384 kbit/s in a moving vehicle
    - Note: 2G was limited to 128 and 144 kbps respectively
- ITU *does not clearly specify* minimum or average rates
  - so various rates are sold as 3G intended to meet customers expectations of broadband data.

How to use 3G?

- 3G Compatible device
- 3G service provider

First 3G International launch

- The first pre-commercial 3G network was best launched by NTT DoCoMo in Japan branded FOMA, in May 2001 on a pre-release of W-CDMA technology.

- The first commercial launch of 3G was also by NTT DoCoMo in Japan on 1 October 2001, although it was initially somewhat limited in scope

3G in India

- 20 May 2010: Concluded spectrum Auction
  - Raised 50,968.37 Crore INR
  - Operators: Bharti Airtel, Aircel, Idea Cellular, Reliance Communications, S Tel, Tata Teleservices, Vodafone Essar

- Tata Docomo was first one to launch ☺
- Others to launch soon

Beyond 3G

- Beyond 3G is fourth generation of wireless standards (4G) which is not yet well-defined.
- 4G will be a super-enhanced version of 3G, when all networks are expected to embrace Internet protocol (IP) technology
- IMT-Advanced (under ITU) is currently under study to define the fourth generation (4G) of mobile communications.

INTRODUCTION: 4G

A brief d*iscussion on these terminologies follows …..*

- *Wireless Standard*
- Next generation futuristic wireless system

4G BASICS

- 4G infrastructure shall be all IP-based (including IPV6 and MIPV6)
- This shall develop into an optimized packet-switched networks supporting high data speed.
- Expected data rates for 4G are:
  - 100 MBPS for high mobility devices and
  - 1 GBPS for slow moving objects or stationary objects

4G EXPECTED FEATURES (*INFERRED FROM VARIOUS RESEARCH PAPERS)*

- 4G shall co-exist and interwork with 2G and 3G systems as well as satellite, WLAN, IEEE 802.16e (WMAN – WiMAX)
- Achieve local/global roaming capabilities
- 4G shall have clear advantages in terms of bandwidth, coverage, power consumption and spectrum usage

4G EXPECTED FEATURES

(*INFERRED FROM PAPERS) CONTD…*

- 4G shall be “Always Best Connected” i.e. the user shall be connected through best network.
- A 4G terminal shall support multi-mode, multi-access and reconfiguration capabilities.
- 4G shall combine existing and emerging services such as voice, data, streamed multimedia, sensory, e-health, and social networking on mobile devices at best.
- 4G envisages that mobile services shall be available on Mobile Cloud.
  - With mobile cloud the various developers and service providers shall be able to make their services available to the end mobile user.

Cellular Concept

Cellular Telephone Service

1940s MTSs (Mobile Telephone Systems or Manual Telephone systems):

– all calls were handled by an operator, use FM

- use a single carrier frequency in the 35 MHz to 45 MHz range for both the mobile unit and base station

- half duplex operation,

-120 kHz bandwidth per channel

- only one conversation could take place at a time

- could not be accessed directly through the PSTN with five digit long numbers.

1964 IMTS (Improved Mobile Telephone Systems):

– use several carrier frequencies and could, therefore, handle several simultaneous mobile conversations at the same time

-high output power between 13 W and 30 W and a range of 25 mile radius

-transmit power a channel bandwidth of 30 kHZ increasing the number of channels, .

Cellular Telephone Service

Disadvantages of early mobile telephone systems: High cost, limited availability, and narrow frequency allocation.

1983 AMPS (Advanced Mobile Phone System)
– the first U.S. cellular telephone system by AT&T with 666 30 kHz half-duplex mobile telephone channels, was based on analog radio technologies and has been phased out.

AMPS Specifications

Parameter	AMPS
Frequency Band:	
Forward Link	869 – 894 MHz
Reverse Link	824 – 849 MHz
Channel Spacing	30 kHz
Spacing between Transmission and Reception	45 MHz
Number of Channels	832 (previously 666)
Coverage Radius	2 – 20 km
Audio Signal	
Type of Modulation	FM
Frequency Deviation	+/- 12 khz
Control Signal	
Type of Modulation	FSK
Frequency Deviation	+/- 8 khz
Data Transmission Rate	10 kbps

Fundamental Concepts of Cellular Phone

- Coverage zone – a large geographic area.
- Cells – the small sections of the large geographic area. It is defined by its physical size, and the size of its population.

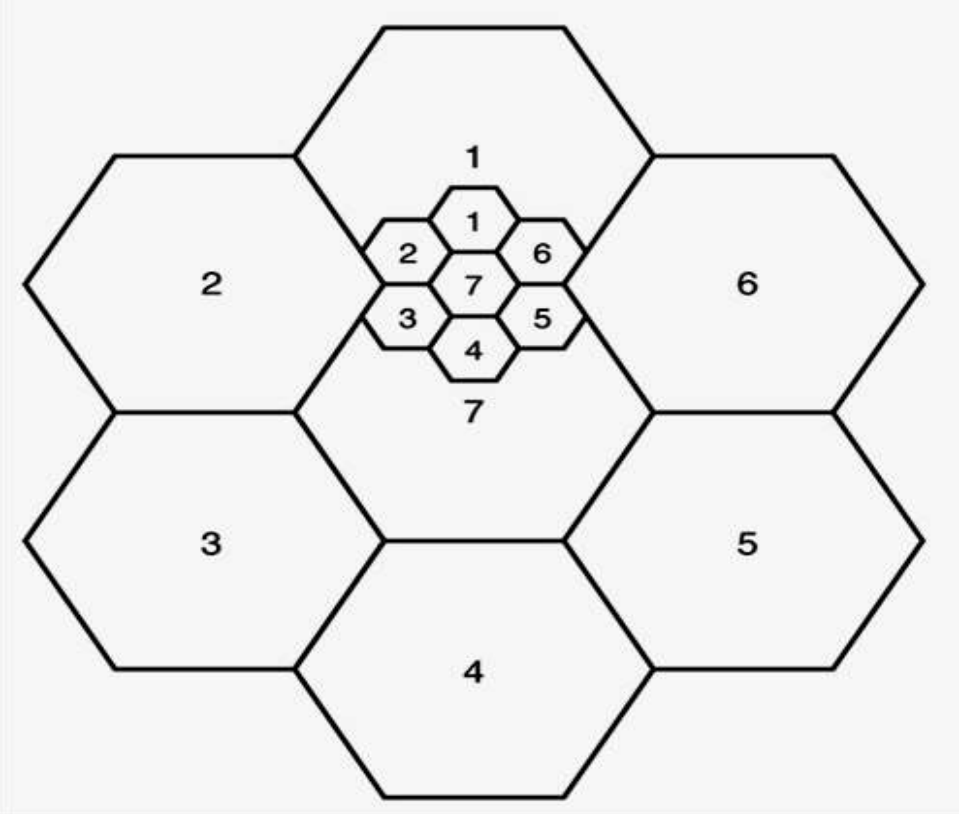
  a. Macrocells – large cells typically have a radius 1 mile and 15 miles with base station transmit power between 1 W and 6 W.

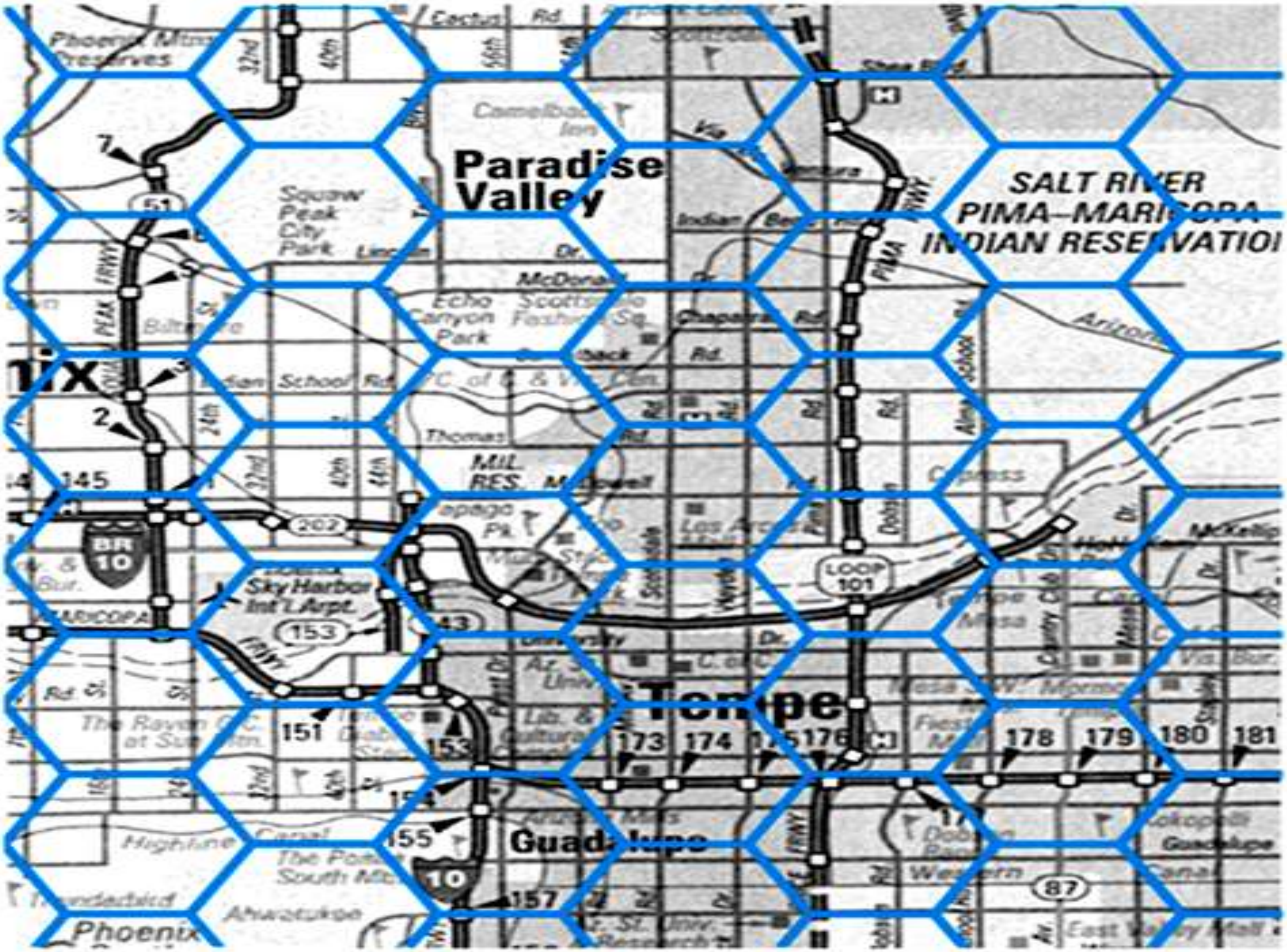
  b. Microcells – the smallest cells typically have a radius of 1500 feet or less with base station transmit power between 0.1 W & 1 W

Cellular Telephone Systems

Honeycomb – the pattern formed by the hexagonal- shaped cells.

Picocells – very small cells used indoor.




Phoenix Mtn Preserves
Cactus Rd.
32nd
40th
56th
Shea Blvd.
Camelback Inn
7
51
Paradise Valley
Squaw Peak City Park
Lincoln Dr.
McDonald Dr.
SALT RIVER
PIMA–MARICOPA
INDIAN RESERVATIO
PEAK FRWY
PIMA FRWY
Echo Canyon Park
Scottsdale Fashion Sq.
Chaparral Rd.
Arizona
ix
3
2
School Rd.
24th
Thomas Rd.
MIL. RES.
McDowell
145
202
BR 10
Sky Harbor Int'l Arpt.
153
MARICOPA
LOOP 101
Mesa
University Dr.
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Highline Canal
Guadalupe
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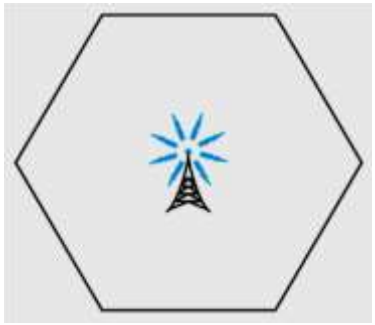
Western Canal
87
East Valley Mall
Phoenix

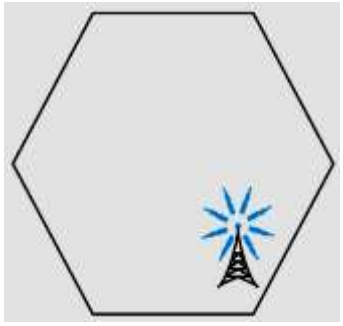
Fundamental Concepts of Cellular Phone

Different locations of base station transmitters:

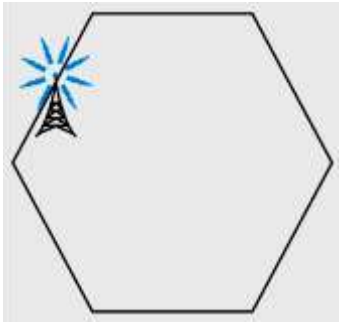
1. Center-excited cell



2. Corner-excited cell



3. Edge-excited cell



Frequency Allocation: Bands

1. 800 – 900 MHz – original frequency assignment; previously occupied by UHF TV channels 68 through 83
2. 824 and 849 MHz – reserved for uplink
3. 869 and 849 MHz – are for downlink

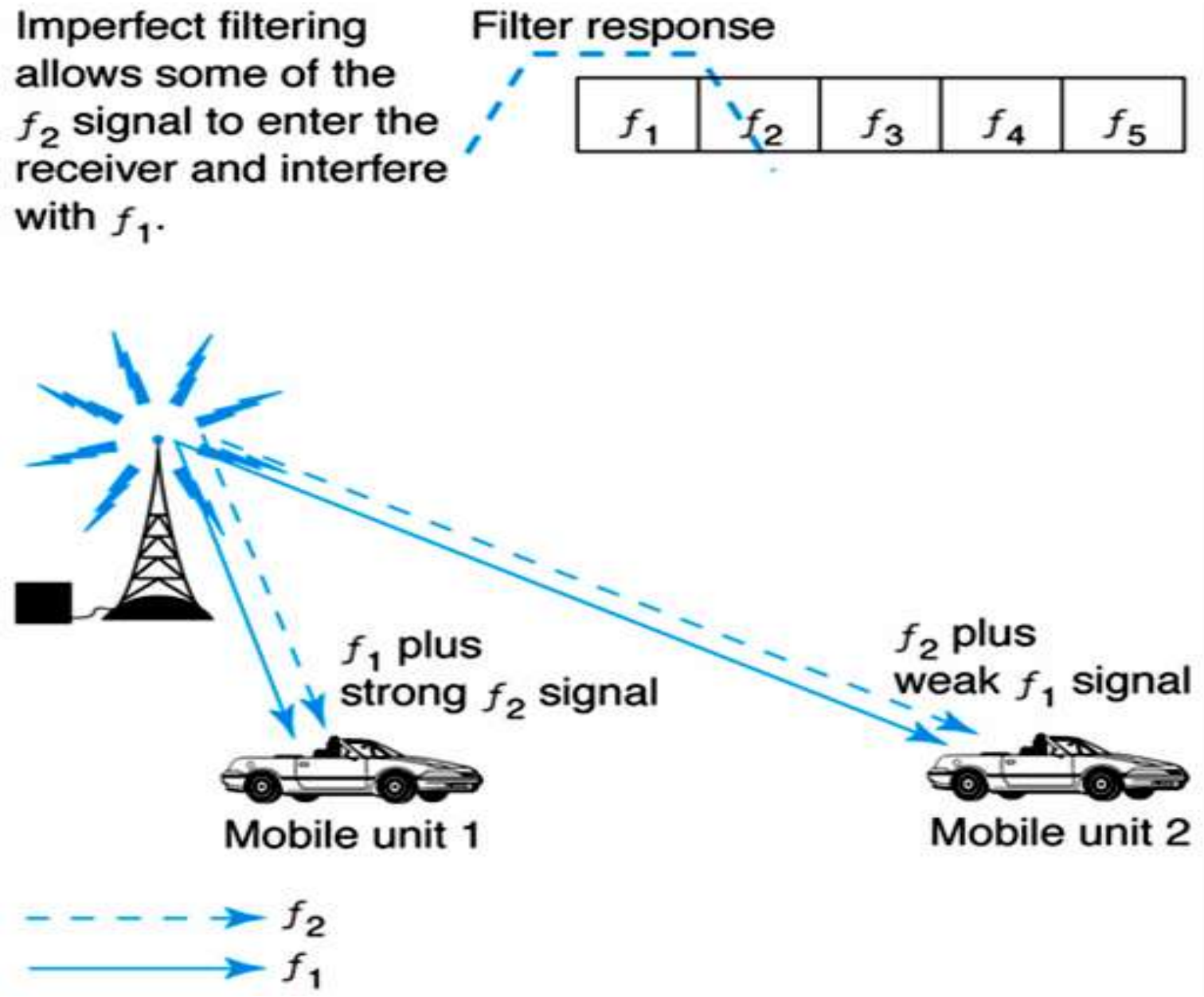
Both 2) and 3) are divided into 832 channels with 30 kHz bandwidth.

4. 30 kHz, 200 kHz, 1.25 MHz – the different bandwidths used in different ways by different companies in different locations.
5. 700 to 800 Mhz – abandoned UHF TV channels for digital high-definition TV in 2009.
6. 1700 to 1750 Mhz – from military
7. 1900 to 2300 Mhz – available for 3G.

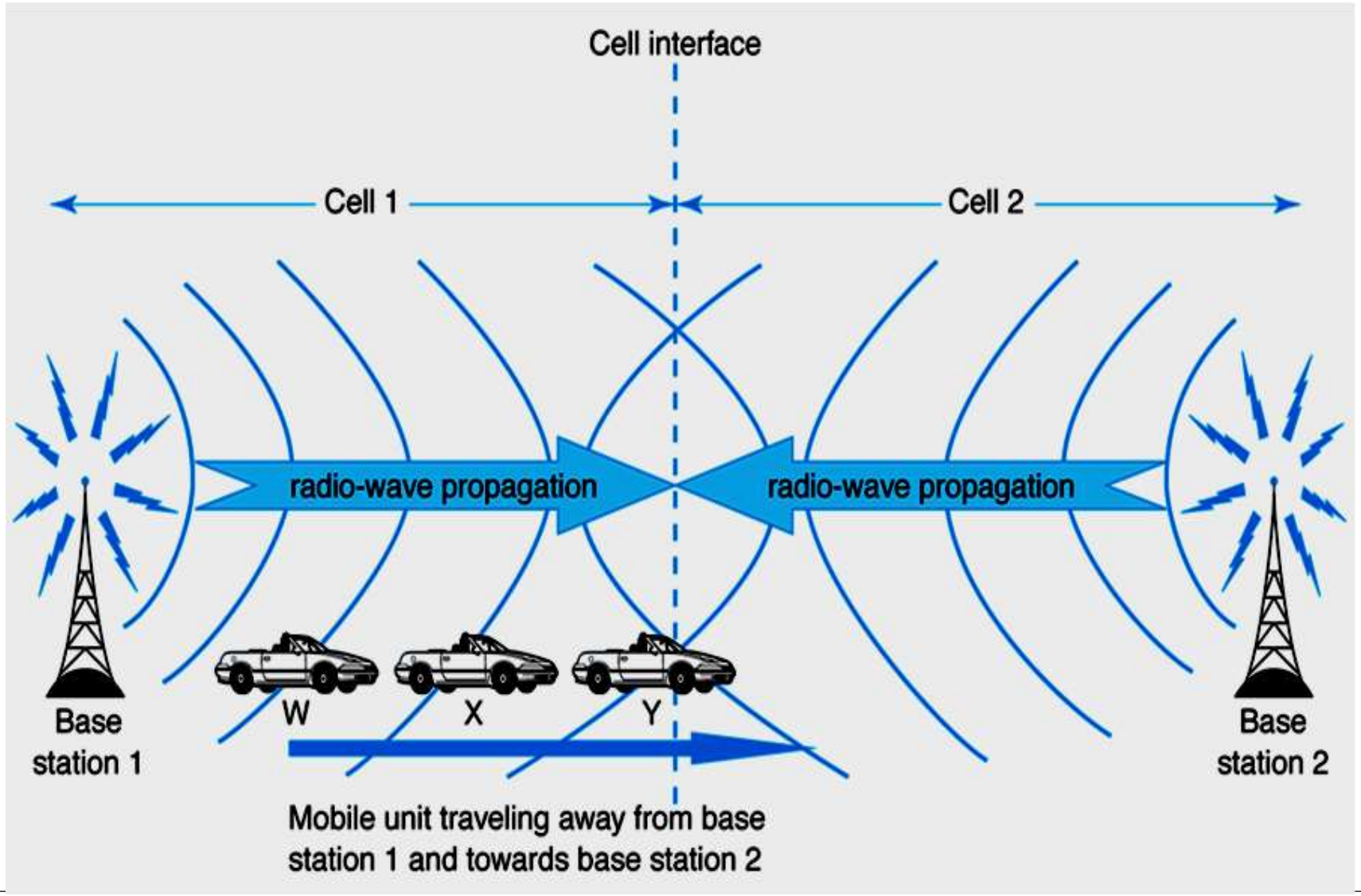
Multiple Access – refers how the subscribers are allocated to the assigned frequency spectrum.

Types:

1. Frequency reuse
2. FDMA - the spectrum is divided into many smaller channels.
3. TDMA – multiple users use different time slots
4. CDMA – with unique coding, up to 64 subscribers can share a 1.25 Mhz channel.
5. SDMA – it uses highly directional antennas to pinpoint users and reject others on the same frequency.


Imperfect filtering allows some of the f_2 signal to enter the receiver and interfere with f_1.
Filter response
f_1
f_2
f_3
f_4
f_5
f_1 plus strong f_2 signal
f_2 plus weak f_1 signal
Mobile unit 1
Mobile unit 2
f_2
f_1

Handoff


Cell interface
Cell 1
Cell 2
radio-wave propagation
radio-wave propagation
W
X
Y
Base station 1
Base station 2
Mobile unit traveling away from base station 1 and towards base station 2

Cellular Telephone Systems

Types of Handoff:

1. Hard Handoff – a connection that is momentarily broken during the cell-to-cell transfer. **It is a break-before-make process**.

2. Soft Handoff – a flawless handoff, normally takes approximately 200ms, which is imperceptible to voice telephone users, although the delay may be disruptive when transmitting data.

Multiple Access – refers how the subscribers are allocated to the assigned frequency spectrum.

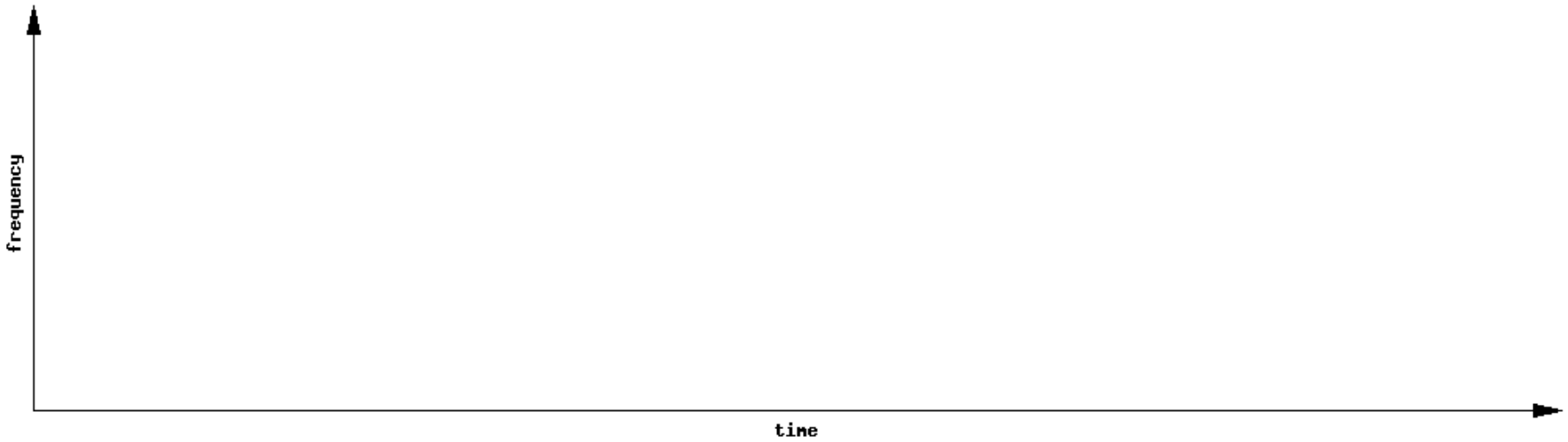
Types:

1. FDMA - the spectrum is divided into many smaller channels.
2. TDMA – multiple users use different time slots
3. CDMA – with unique coding, up to 64 subscribers can share a 1.25 Mhz channel.
4. SDMA – it uses highly directional antennas to pinpoint users and reject others on the same frequency.

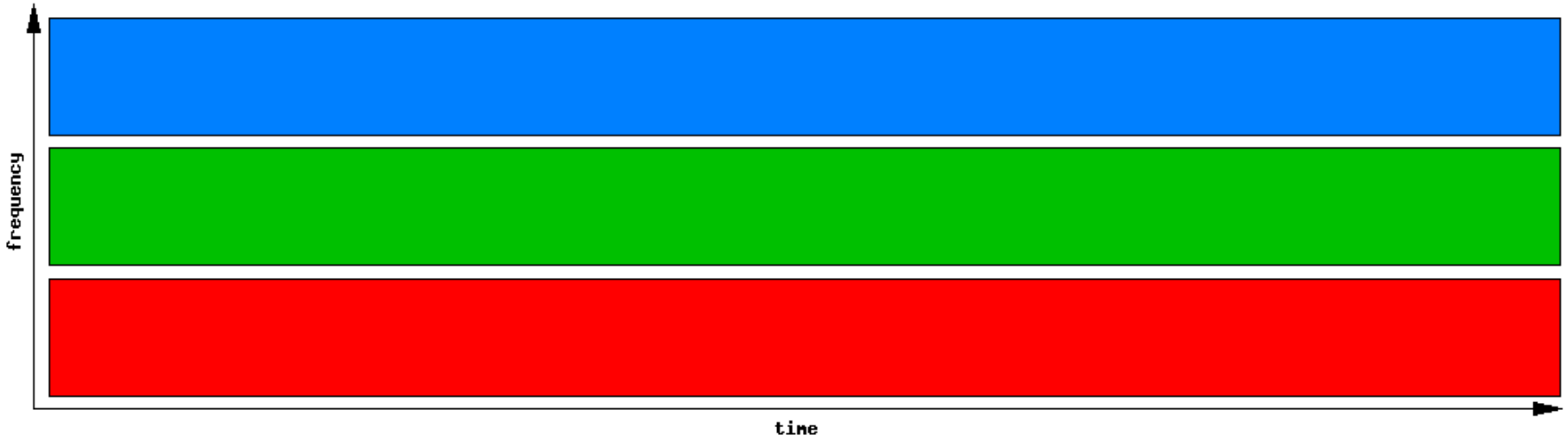
FDMA

- Frequency
- Division
- Multiple
- Access

FDMA



FDMA

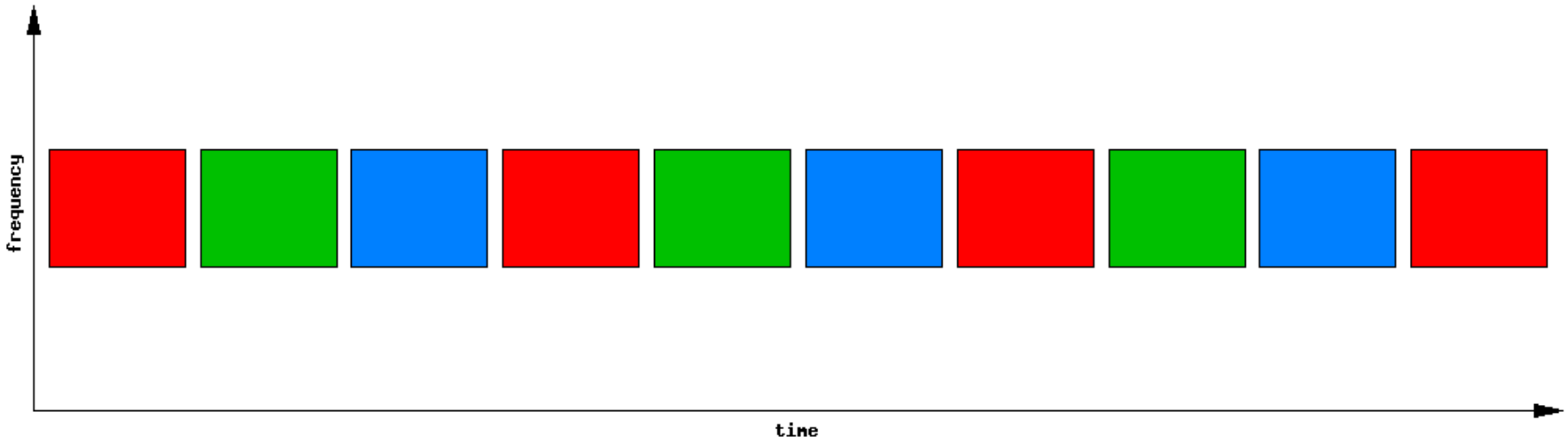


(1G Cellular Networks)

TDMA

- Time
- Division
- Multiple
- Access

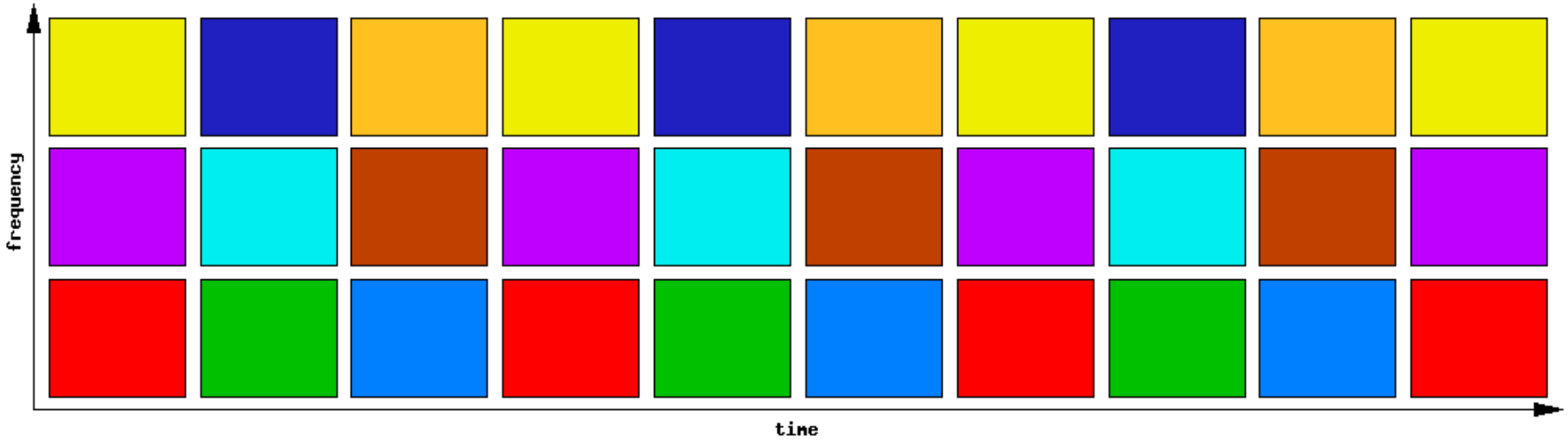
TDMA



F/TDMA

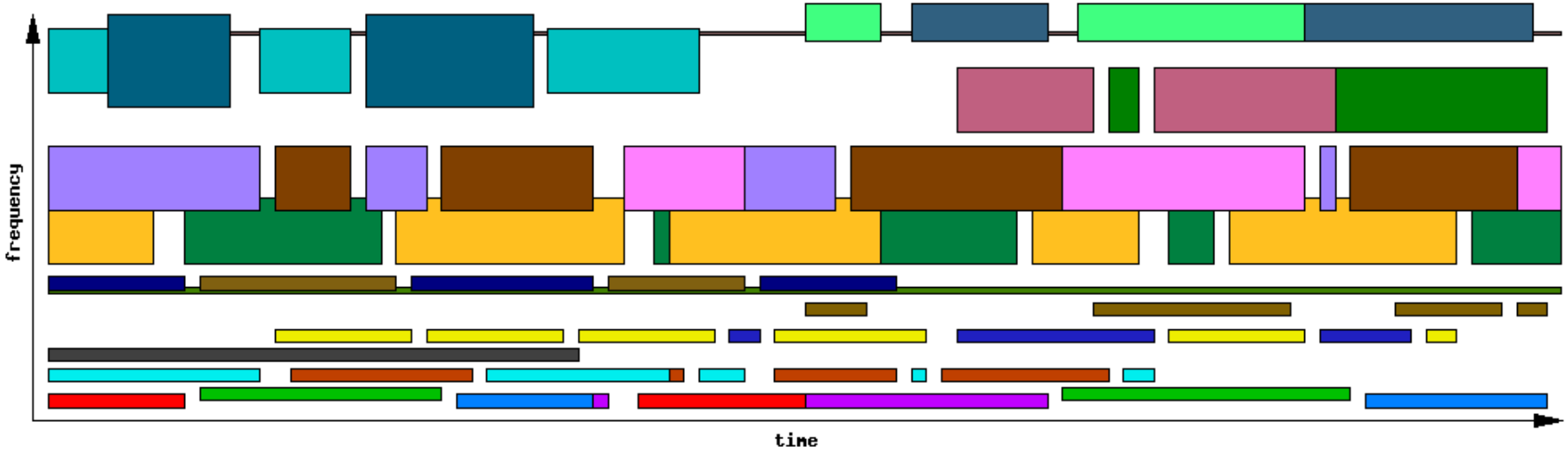
- Frequency and Time
- Division
- Multiple
- Access

F/TDMA



- (2G Cellular Networks)

F/TDMA



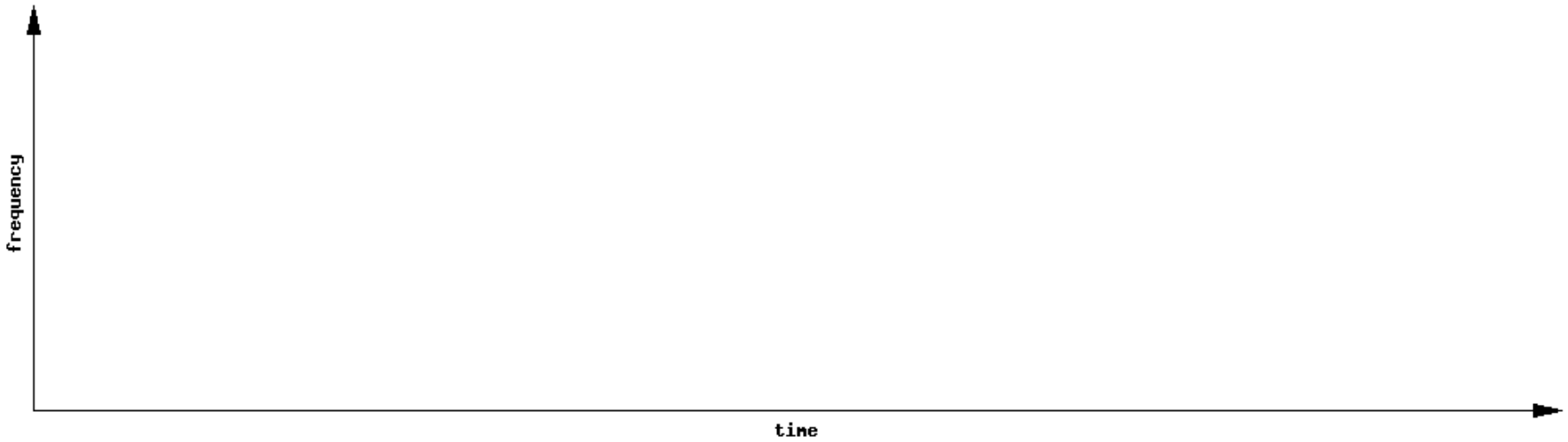
- Ham Bands

CDMA

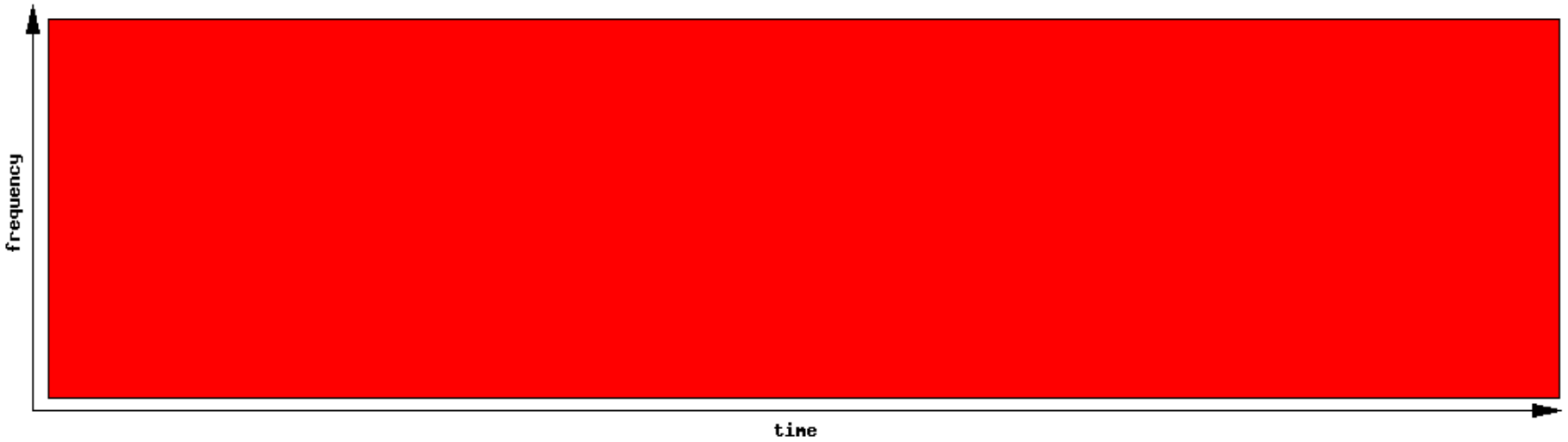
- CODE
- Division
- Multiple
- Access

?

CDMA

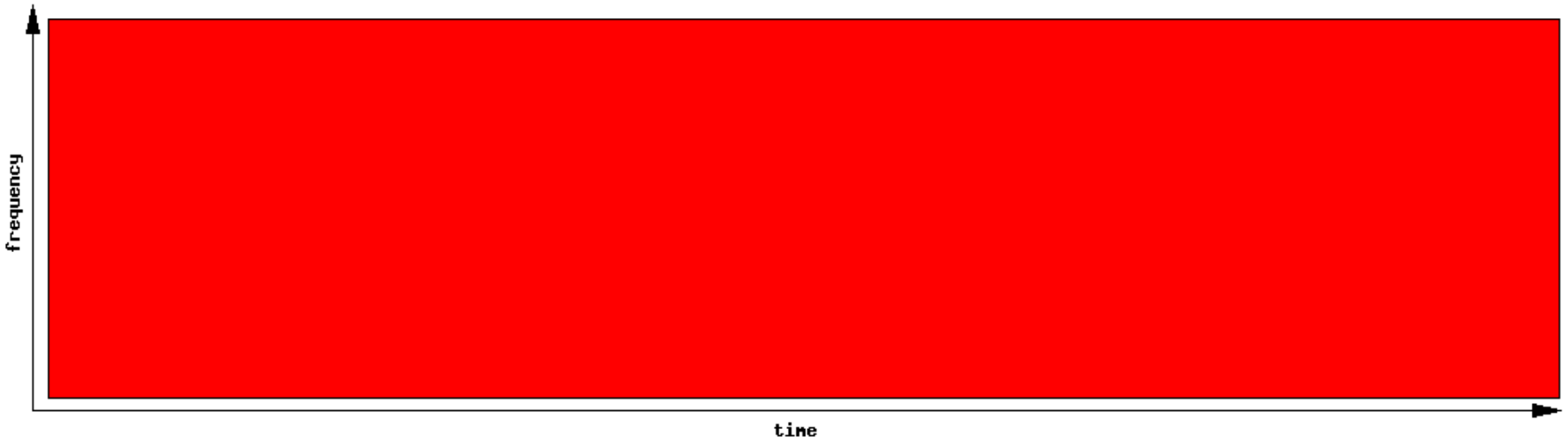


CDMA



Uses the whole band, for the whole time

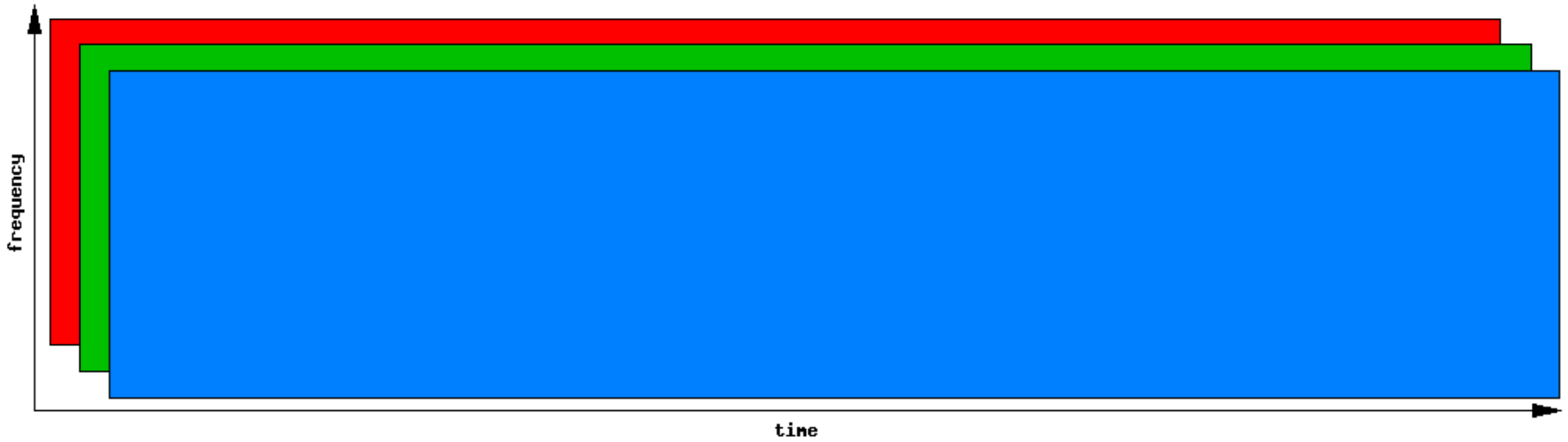
CDMA



Everyone transmits on top of everyone else.
How do we show this?

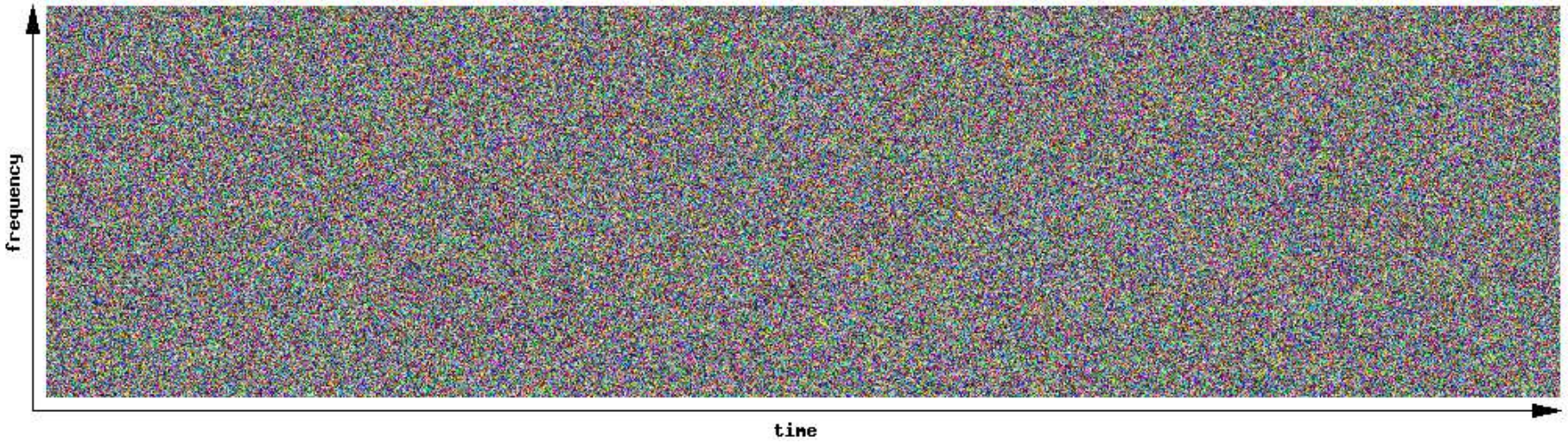
CDMA

Some people show it like this...



… but preferred one is..

CDMA



(3G Cellular Networks)

YES.
With different codes,
and if you know the right code, you can receive just the person transmitting with that code.

FDMA/TDMA/CDMA

Which telecommunication service is better for you?

Say…

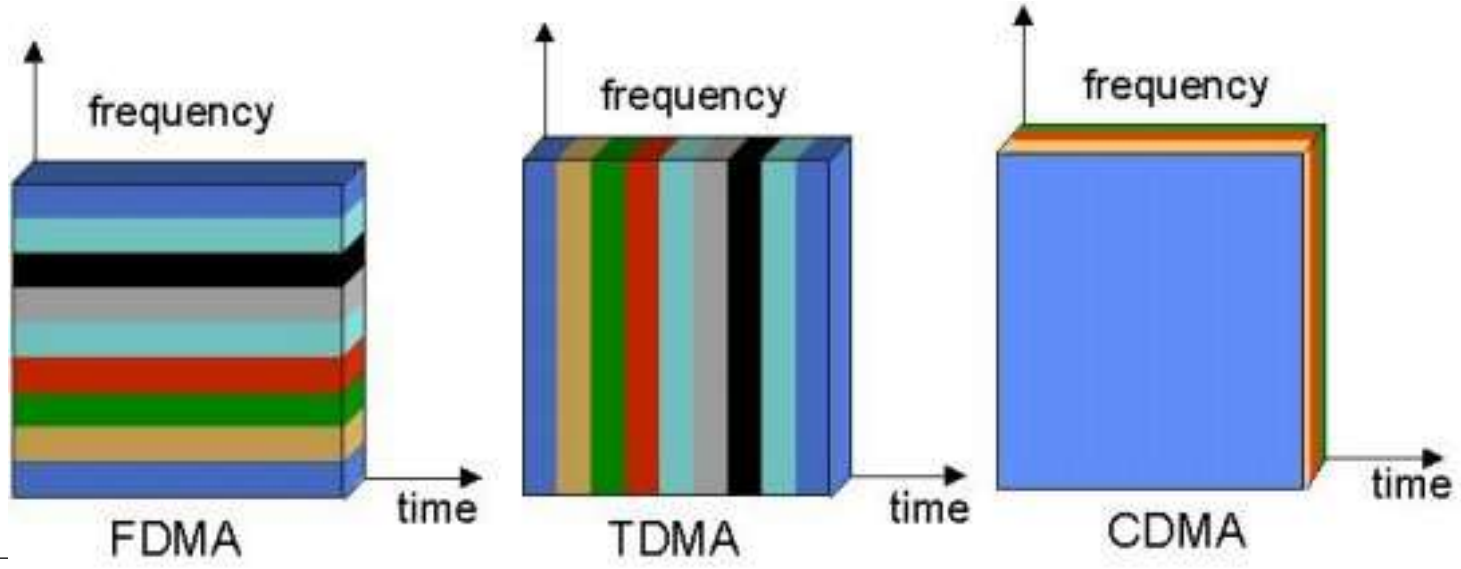
- FDMA – Large room divided up into small rooms. Each pair of people takes turns speaking.

- TDMA – Large room divided up into small rooms. Three pairs of people per room, however, each pair gets 20 seconds to speak.

- CDMA – No small rooms. Everyone is speaking in different languages. If voice volume is minimized, the number of people is maximized.

Definitions

- TDMA – Time Division Multiple Access
- FDMA – Frequency Division Multiple Access
- CDMA – Code Division Multiple Access



General Specification of TDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 832 Channels spaced 30kHz apart (3 users/channel)
- DQPSK modulation scheme
- 48.6kbps bit rate
- Interim Standard (IS) – 54
- Digital AMPS (Advanced Mobile Phone System)
- Uses Time Division Duplexing (TDD) usually

Advantages of TDMA

- Flexible bit rate
- No frequency guard band required
- No need for precise narrowband filters
- Easy for mobile or base stations to initiate and execute hands off
- Extended battery life
- TDMA installations offer savings in base station equipment, space and maintenance
- The most cost-effective technology for upgrading a current analog system to digital

Disadvantages to using TDMA

- Requires network-wide timing synchronization
- Requires signal processing fro matched filtering and correlation detection
- Demands high peak power on uplink in transient mode
- Multipath distortion

General Specification of FDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 832 Channels spaced 30kHz apart (3 users/channel)
- DQPSK modulation scheme
- 48.6kbps bit rate
- Used in analog cellular phone systems (i.e. AMPS)
- Uses Frequency Division Duplexing (FDD)
- ISI (Intersymbol Interference) is low

Advantages of FDMA

- If channel is not in use, it sits idle
- Channel bandwidth is relatively narrow (30kHz)
- Simple algorithmically, and from a hardware standpoint
- Fairly efficient when the number of stations is small and the traffic is uniformly constant
- Capacity increase can be obtained by reducing the information bit rate and using efficient digital code
- No need for network timing
- No restriction regarding the type of baseband or type of modulation

Disadvantages to using FDMA

- The presence of guard bands
- Requires right RF filtering to minimize adjacent channel interference
- Maximum bit rate per channel is fixed
- Small inhibiting flexibility in bit rate capability
- Does not differ significantly from analog system

General Specification of CDMA

- Rx: 869-894MHz Tx: 824-849MHz
- 20 Channels spaced 1250kHz apart (798 users/channel)
- QPSK/(Offset) OQPSK modulation scheme
- 1.2288Mbps bit rate
- IS-95 standard
- Operates at both 800 and 1900 MHz frequency bands

CDMA Operation

- Spread Spectrum Multiple Access Technologies

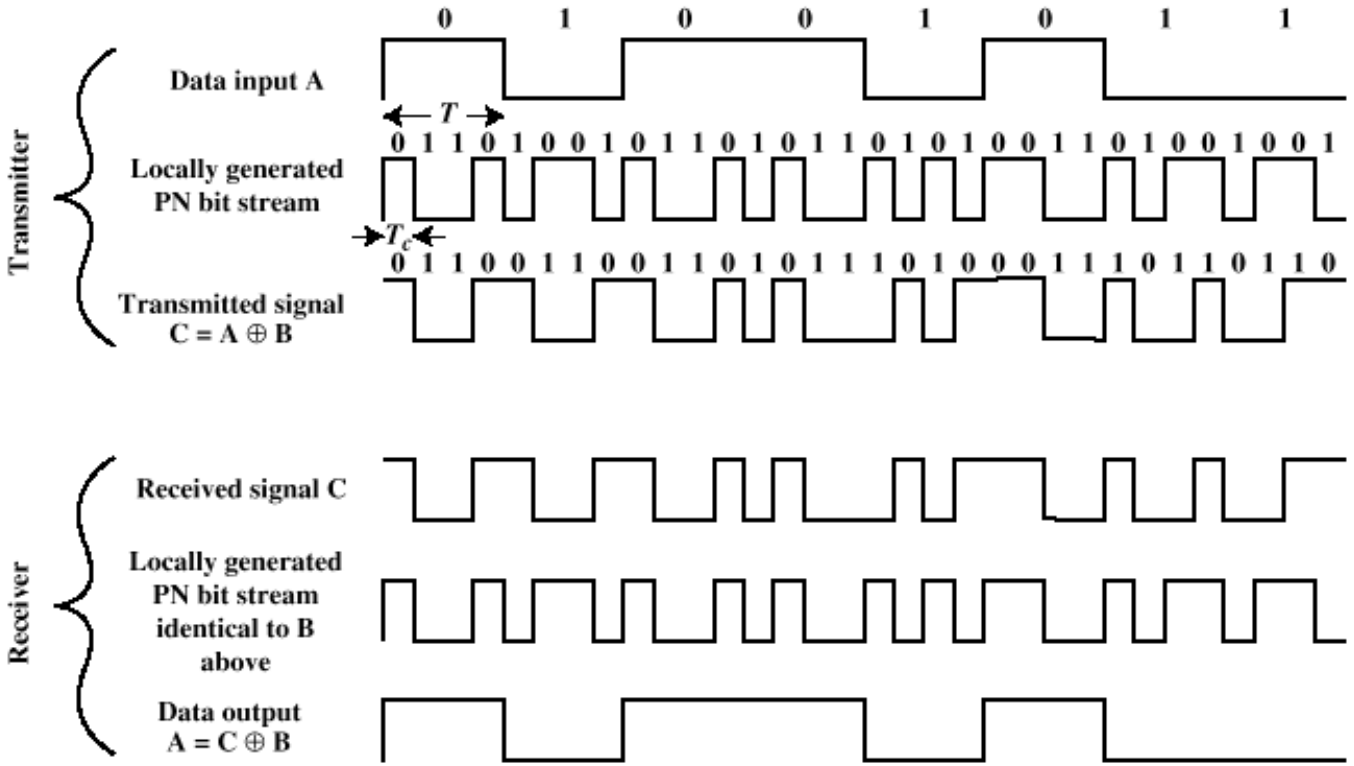


Figure 7.6 Example of Direct Sequence Spread Spectrum

Advantages of CDMA

- Many users of CDMA use the same frequency, TDD or FDD may be used
- Multipath fading may be substantially reduced because of large signal bandwidth
- No absolute limit on the number of users
- Easy addition of more users
- Impossible for hackers to decipher the code sent
- Better signal quality
- No sense of handoff when changing cells

Disadvantages to using CDMA

- As the number of users increases, the overall quality of service decreases
- Self-jamming
- Near- Far- problem arises

Cell Structure

Advantages of cell structures:

- higher capacity, higher number of users
- less transmission power needed
- more robust, decentralized
- base station deals with interference, transmission area etc. locally

Problems:

- fixed network needed for the base stations
- handover (changing from one cell to another) necessary
- interference with other cells

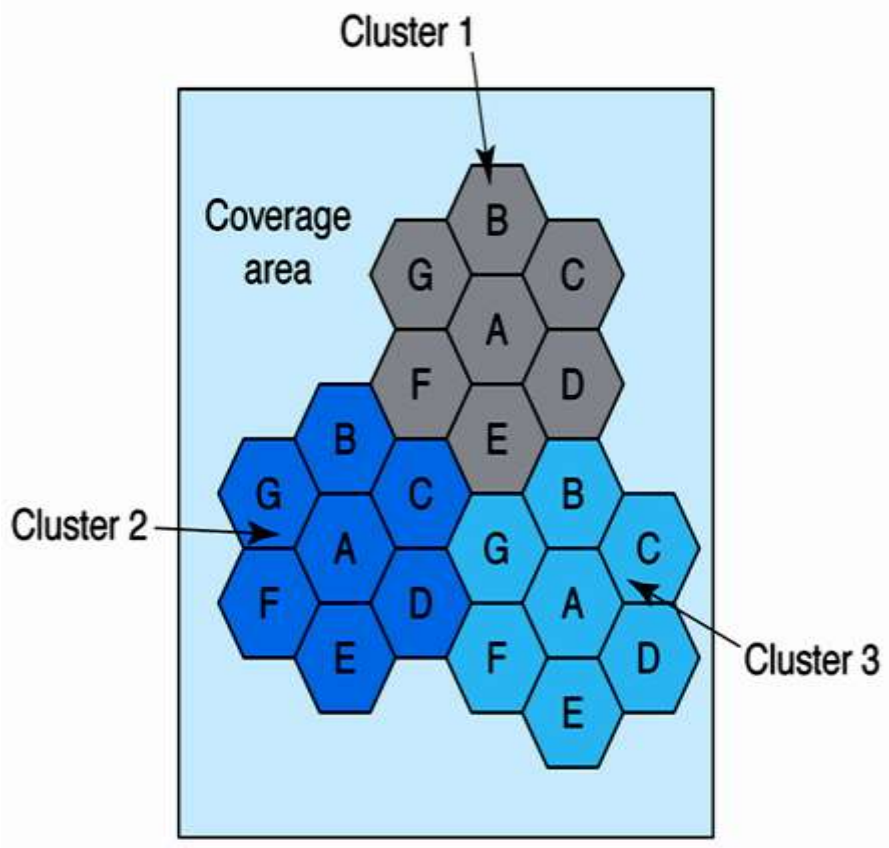
Frequency Reuse

Frequency reuse

– the process in which the same set of frequencies (channels) can be allocated to more than one cell, provided the cells are separated by sufficient distance.

Cluster

– groups of cells



Frequency Reuse

The number of channels available in a cluster, F:

$$F = GN$$

The total channel capacity in a given area, C:

$$C = mF$$

Where:

G = # of channels in a cell

N = # of cells in a cluster = 3, 7, or 12

m = # of clusters in a given area

Cellular Telephone Systems

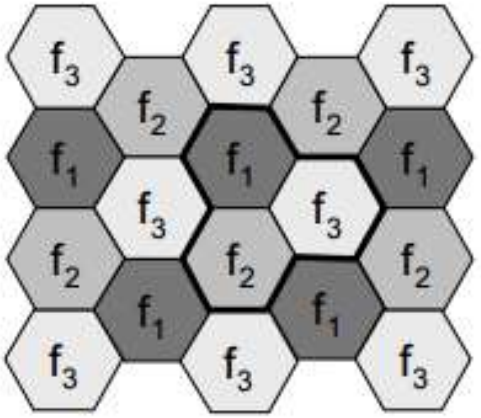
Example:

Determine the number of channels per cluster and the total channel capacity for a cellular telephone area comprised or 10 clusters with seven cells in each cluster and 10 channels in each cell.

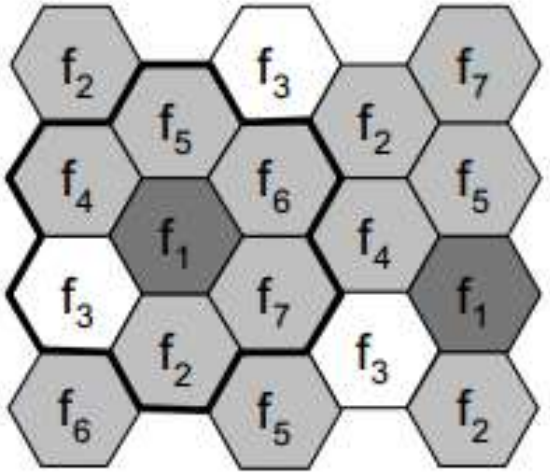
F = 10(7) **channels per cluster**

C = 10(7)(10) **total channels**

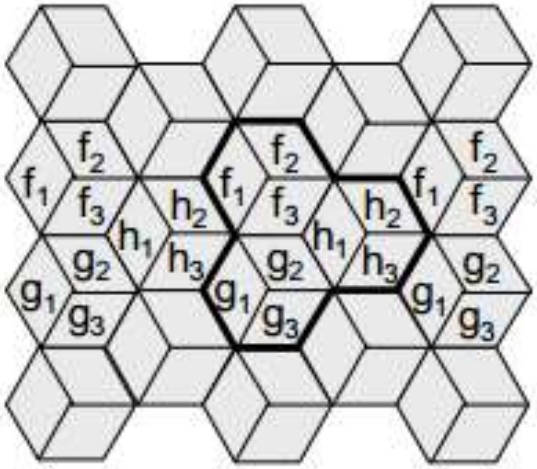
Frequency Planning



3 cell cluster



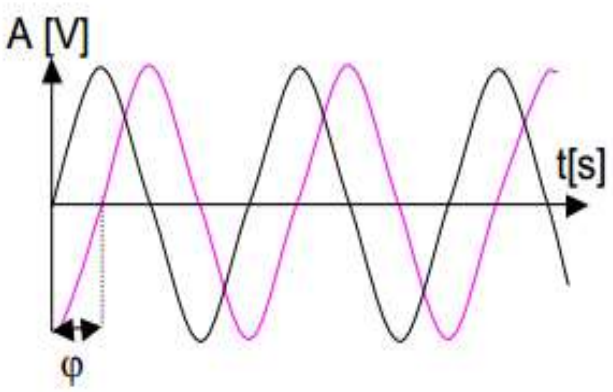
7 cell cluster

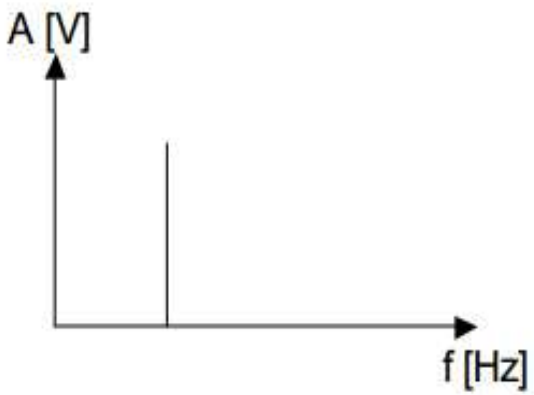


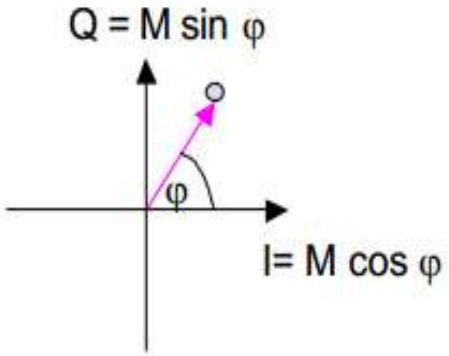
3 cell clusters with
3 sectors antennas

Basics on signals

- Different representations of signals
  - amplitude (amplitude domain)
  - frequency spectrum (frequency domain)
  - phase state diagram (amplitude M and phase φ in polar coordinates)







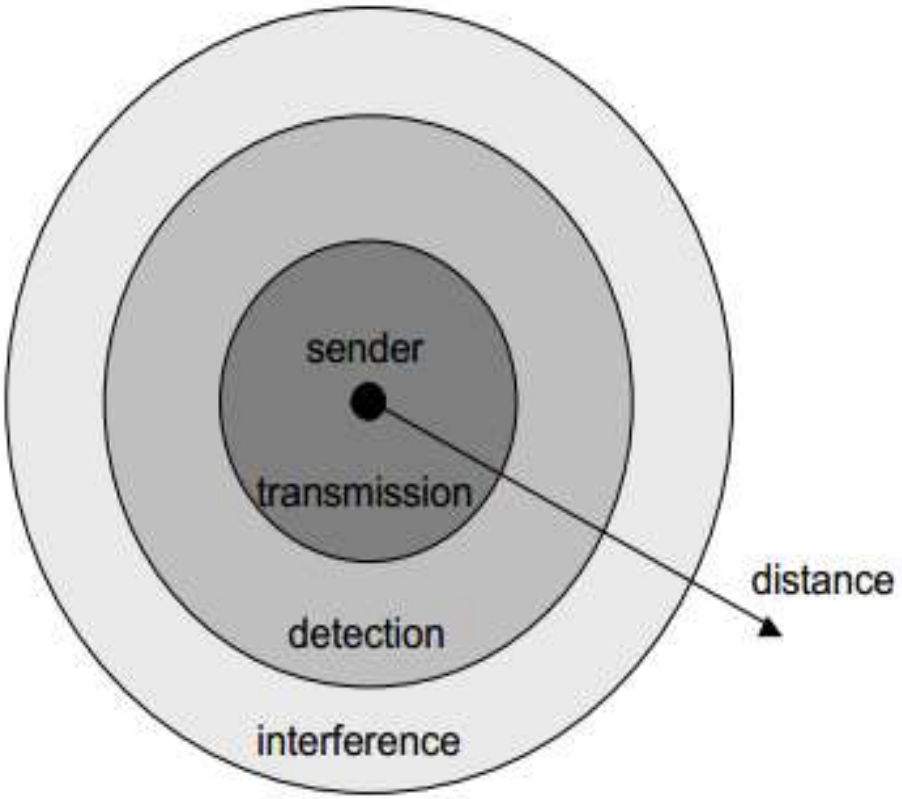
- Composed signals transferred into frequency domain using Fourier transformation
- Digital signals need
  - infinite frequencies for perfect transmission
  - modulation with a carrier frequency for transmission (analog signal!)

Signal Propagation ranges

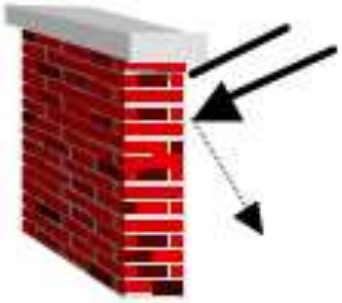
Transmission range
- communication possible
- low error rate

Detection range
- detection of the signal possible
- no communication possible

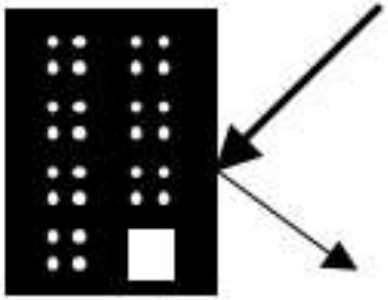
Interference range
- signal may not be detected
- signal adds to the background noise



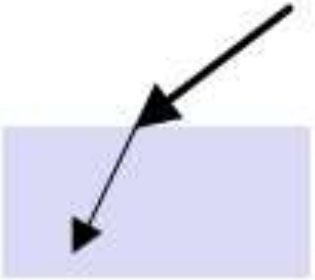
Signal Propagation



shadowing



reflection



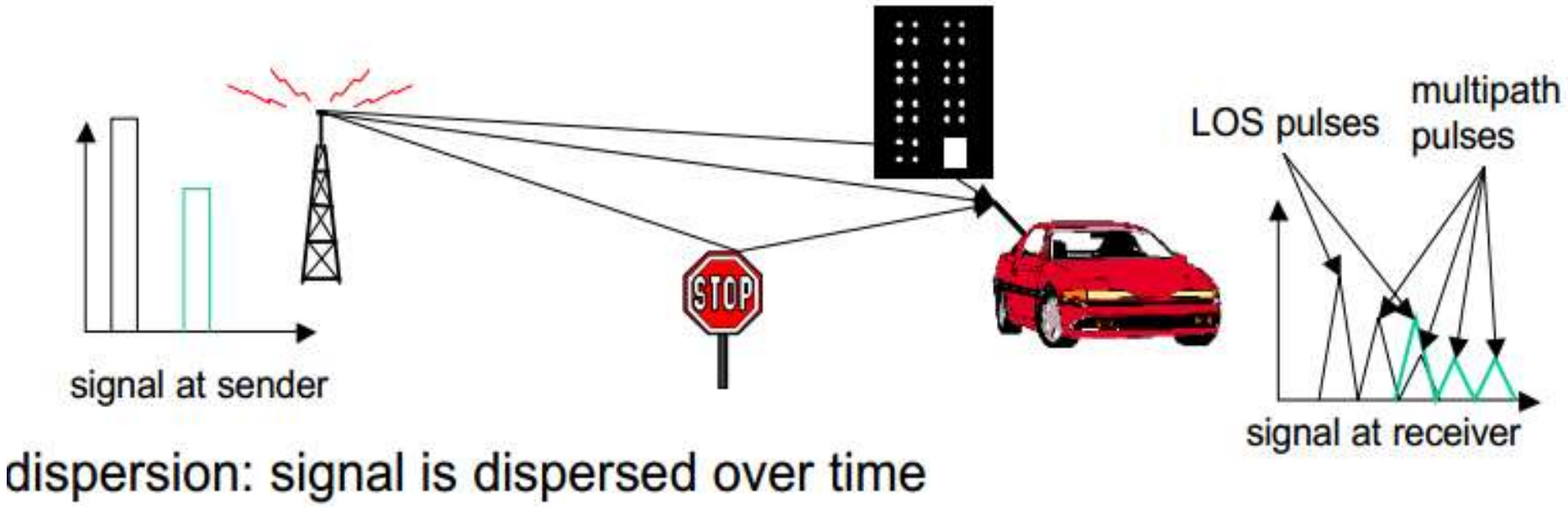
refraction

scattering

diffraction

Multipath Propagation

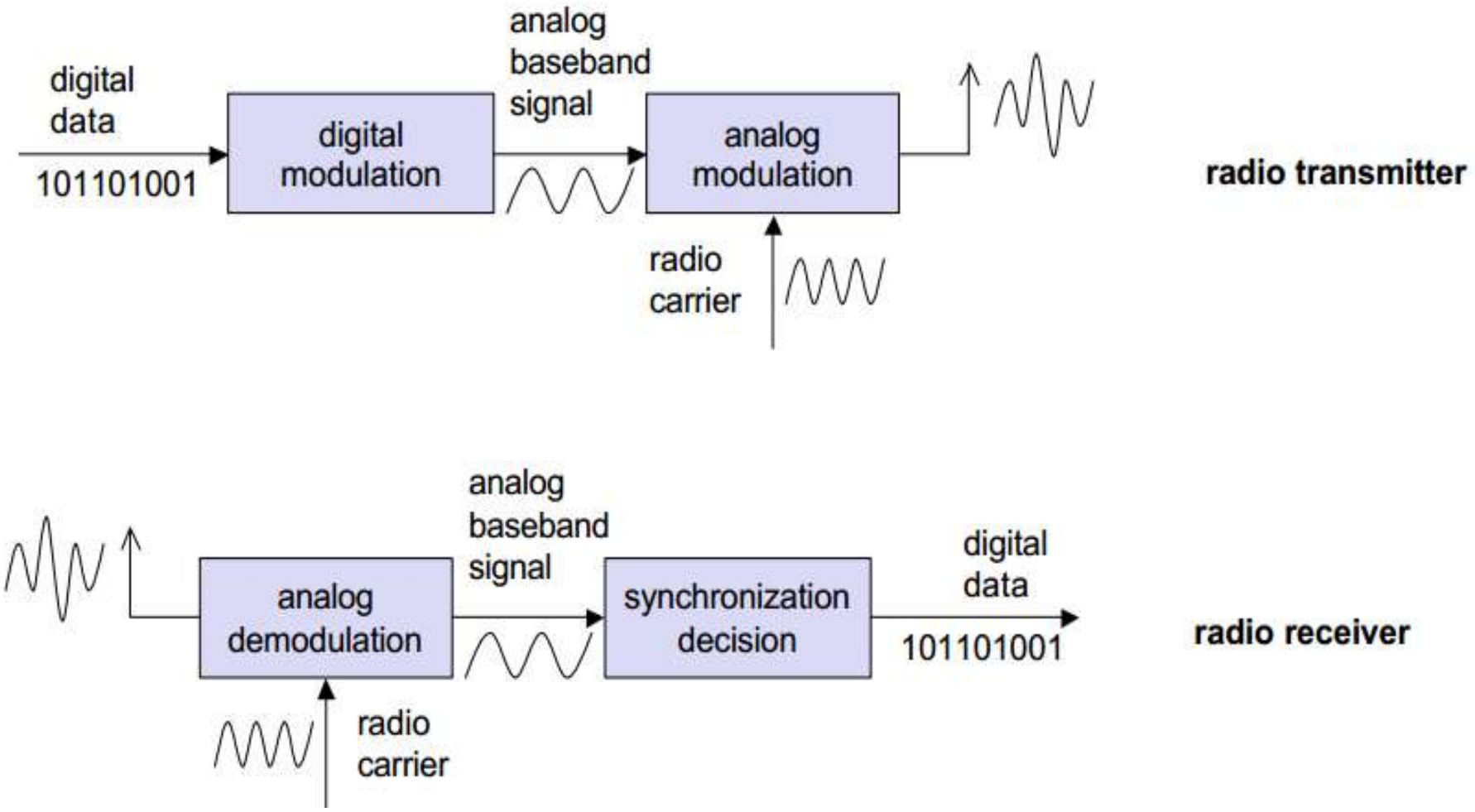
- Signal can take many different paths between sender and receiver due to **reflection, scattering, diffraction**



Modulation

- Basic schemes
  - Amplitude Modulation
  - Frequency Modulation
  - Phase Modulation

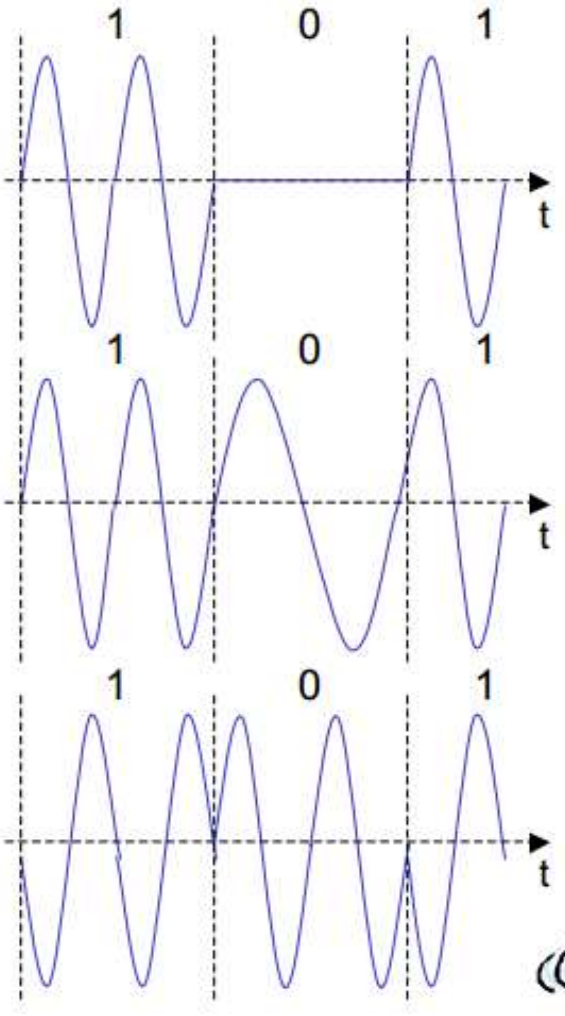
Modulation & Demodulation



Digital Modulation

Modulation of digital signals known as Shift Keying

- Amplitude Shift Keying (ASK):
  - very simple
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - more complex
  - robust against interference



Spread Spectrum Technology

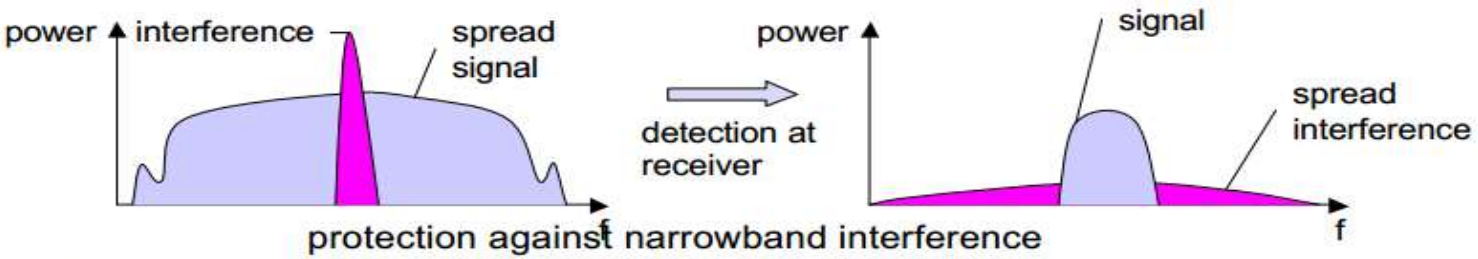
veritas iustitia libertas
Freie Universität Berlin

Spread spectrum technology

Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference

Solution: spread the narrow band signal into a broad band signal using a special code

protection against narrow band interference



Side effects:

- coexistence of several signals without dynamic coordination
- tap-proof

Alternatives: Direct Sequence, Frequency Hopping

DSSS : Direct Sequence

XOR of the signal with pseudo-random number (chipping sequence)

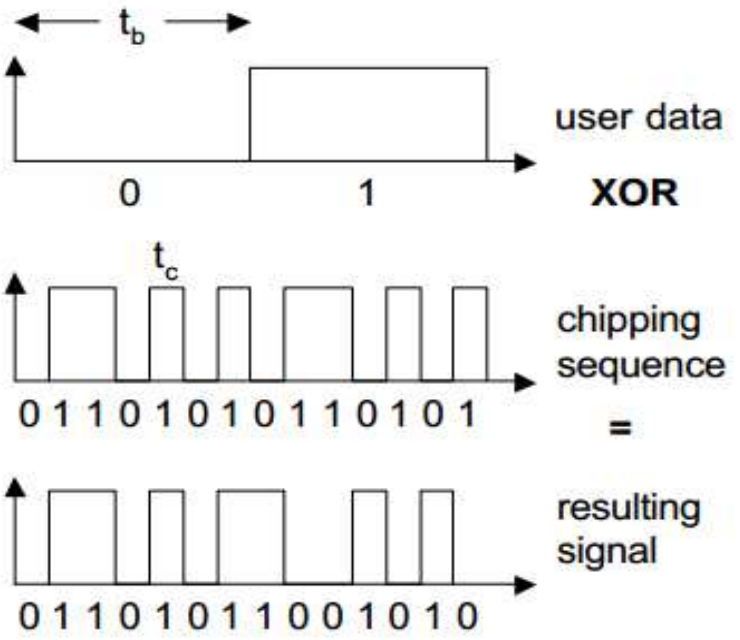
- many chips per bit (e.g., 128) result in higher bandwidth of the signal

Advantages

- reduces frequency selective fading
- in cellular networks
  - base stations can use the same frequency range
  - several base stations can detect and recover the signal
  - soft handover

Disadvantages

- precise power control necessary



t_b: bit period
t_c: chip period

FSSS : Frequency Spread

Discrete changes of carrier frequency

- sequence of frequency changes determined via pseudo random number sequence

Two versions

- Fast Hopping:
  several frequencies per user bit
- Slow Hopping:
  several user bits per frequency

Advantages

- frequency selective fading and interference limited to short period
- simple implementation
- uses only small portion of spectrum at any time

Disadvantages

- not as robust as DSSS
- simpler to detect

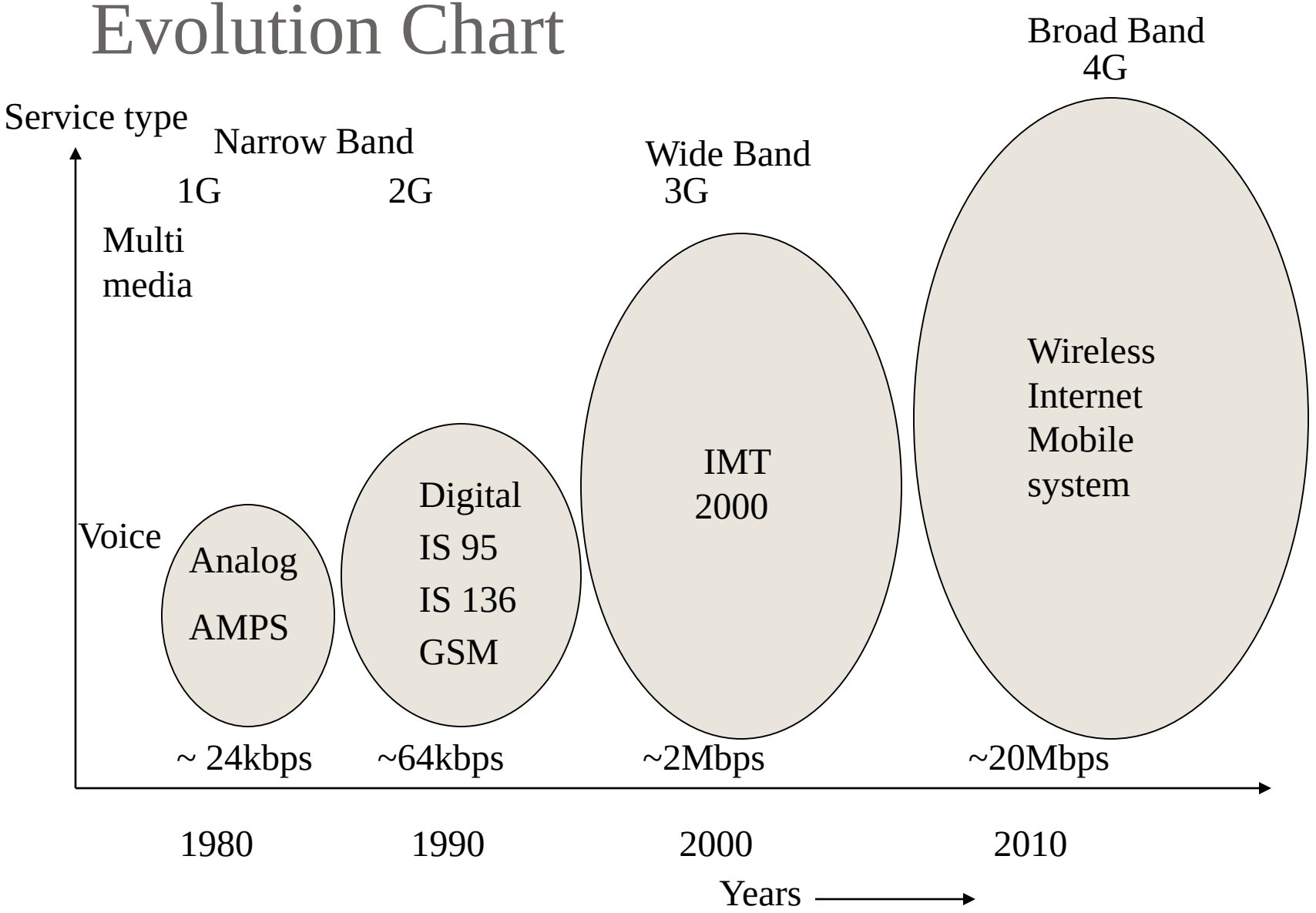
GSM

GSM thru Generations

- 2nd Generation
  - GSM -9.6 Kbps (data rate)

- 2.5 Generation (Future of GSM)
  - HSCSD (High Speed ckt Switched data)
    - Data rate : 76.8 Kbps (9.6 x 8 kbps)
  - GPRS (General Packet Radio service)
    - Data rate: 14.4 - 115.2 Kbps
  - EDGE (Enhanced data rate for GSM Evolution)
    - Data rate: 547.2 Kbps (max)
- 3 Generation
  - WCDMA(Wide band CDMA)
    - Data rate : 0.348 – 2.0 Mbps

Evolution Chart



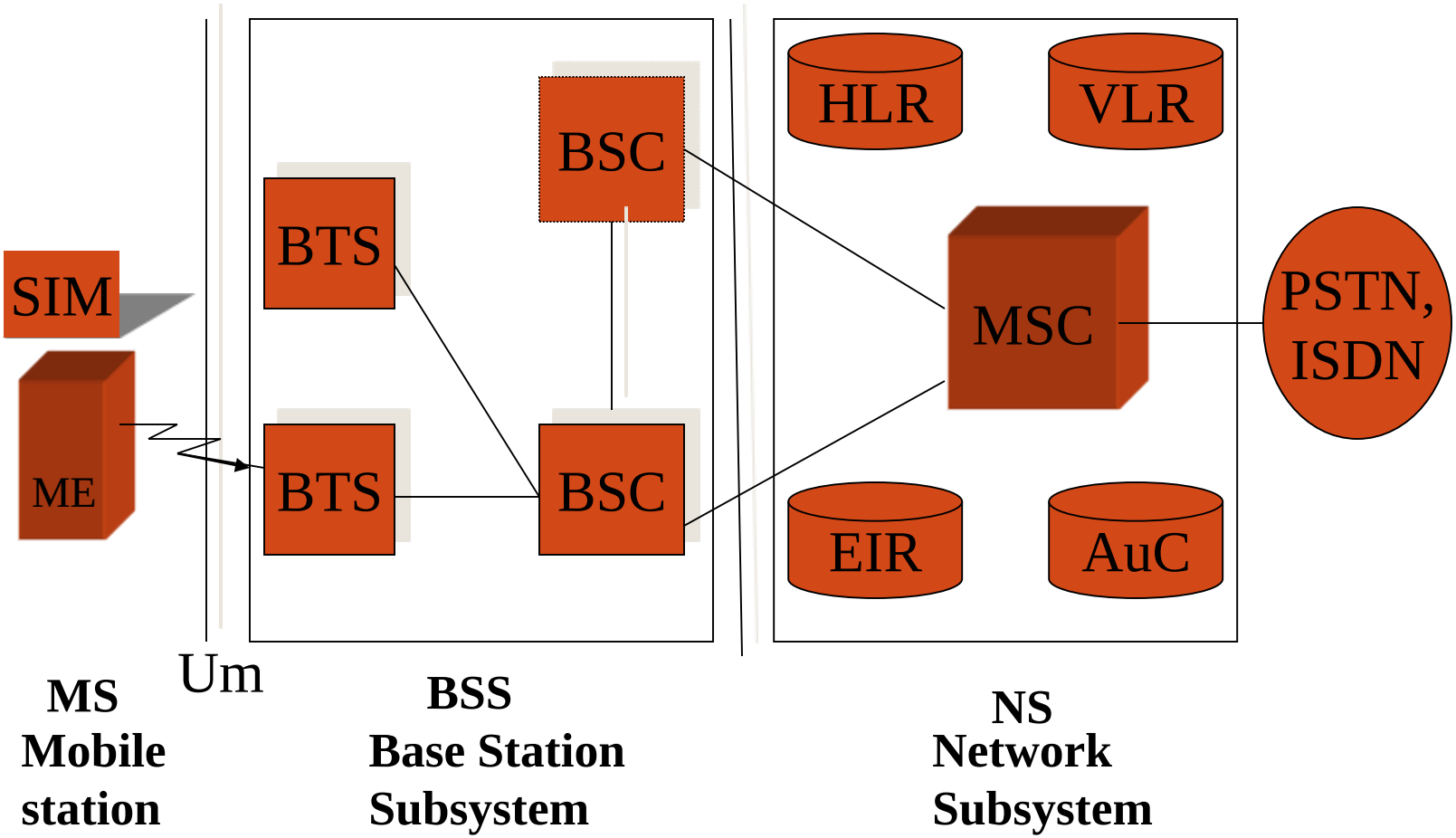
GSM - Overview

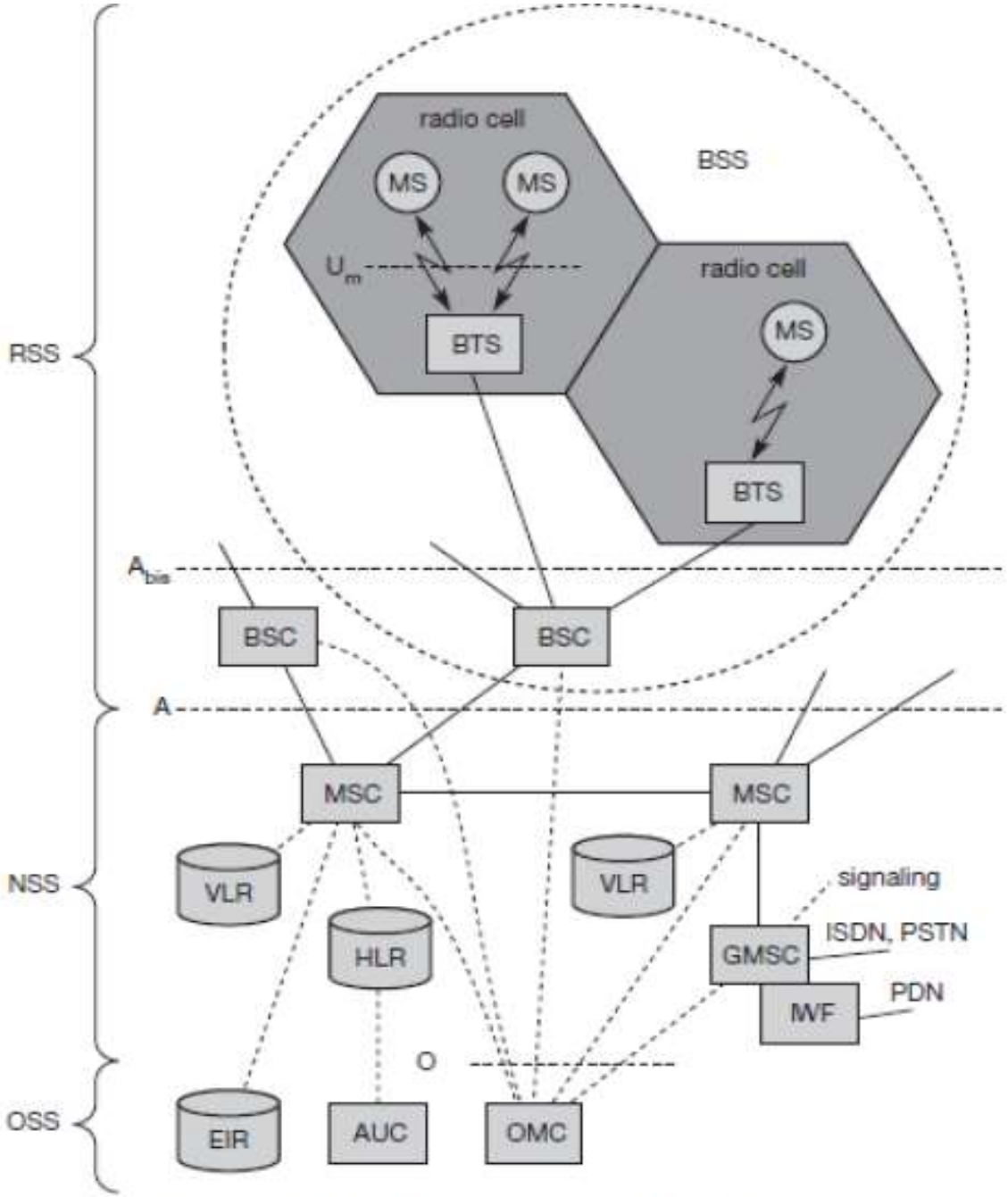
- Global System for Mobile Communication
- Architecture
- Components & Sub Systems
- Types of services
- Call originating and receiving

GSM

The European TDMA Digital **Cellular Standard**

- General Architecture Of GSM





Functional Architecture of a GSM System

GSM

The European TDMA Digital Cellular Standard

- Mobile Station (MS): Two Blocks
  - Mobile Equipment (ME)
  - Subscribers Identity Module (SIM)

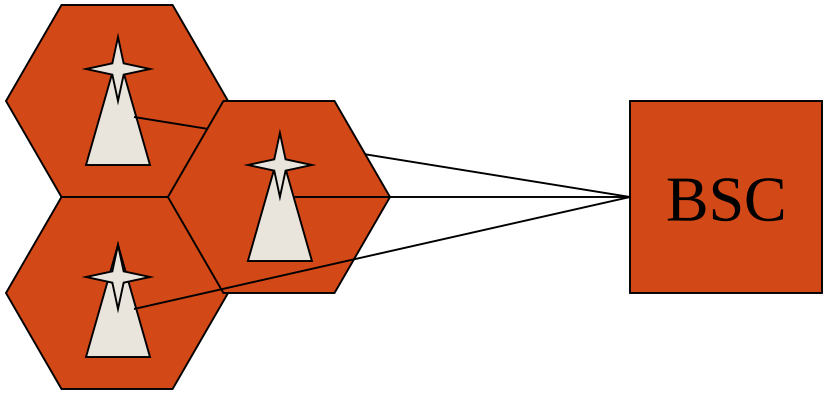
Function of Mobile Station:

1. Personal Mobility
2. IMEI (International Mobile Equipment Identity)
3. IMSI (International Mobile Subscriber Identity)

GSM

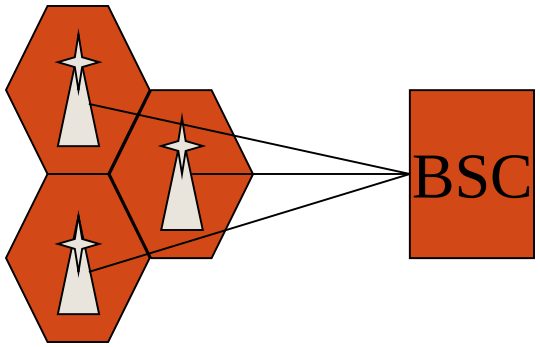
The European TDMA Digital Cellular Standard

- Base Station Subsystem (BSS)
  - Base Transceiver Station (BTS)
  - Base Station Controller (BSC)



GSM

The European TDMA Digital Cellular Standard



BSC: Base station Controller

1. It manages radio resources for one or more BTS.
2. Allocation and Deallocation of channels.
3. Transmitter power control.
4. Handoff control

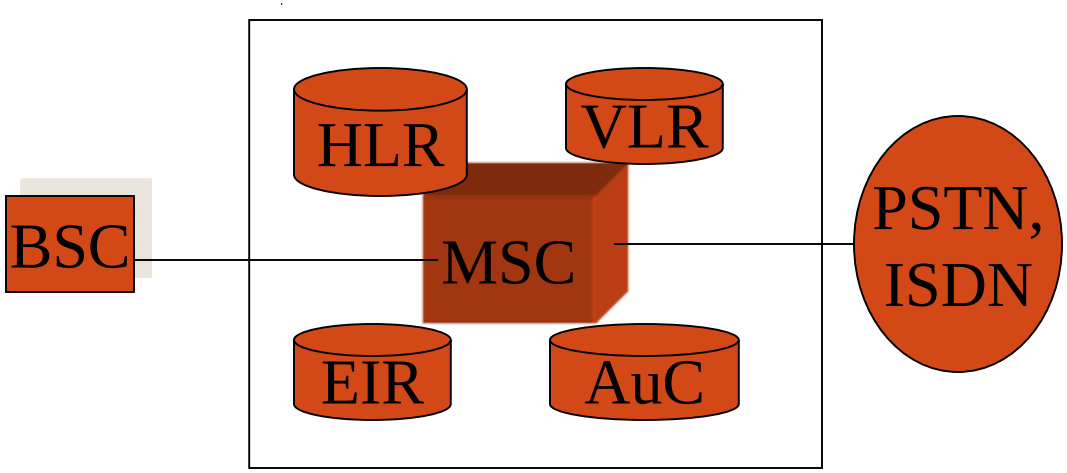
BTS : Base Tranceiver station

1. It defines the cell .

2. It handles the radio link protocol with the mobile station

GSM

The European TDMA Digital Cellular Standard



- **Network Subsystem**
  - **MSC: Mobile Switching Center**
  - **HLR: Home Location Register**
  - **VLR: Visitor Location register**
  - **AuC: Authentication Center**
  - **EIR: Equipment Identity Register**

GSM

The European TDMA Digital Cellular Standard

- Mobile Switching center:(MSC)
  - call set up/supervision/release
  - call routing
  - billing information colllection
  - mobility management
  - paging, alerting, echo cancellation
  - connection to BSC, other MSC and other local exchange networks
  - Access to HLR and VLR

GSM

The European TDMA Digital Cellular Standard

- Home Location Register (HLR)
  - One HLR per GSM operator
  - Contains permanent database of all the subscribers in the network
  - contains MSRN(mobile station routing no.)
  - It is reffered for every incomming call

GSM

The European TDMA Digital Cellular Standard

- Visitor Location Register(VLR)
  - Temporary visitors database
  - One VLR per MSC
- Authentication Center(AuC)
  - Provides security
  - Authentication and encryption
- Equipment Identity Register:
  - Contains IMEI

GSM

The European TDMA Digital Cellular Standard

- **Services Provided By GSM**

1. Tele services

- Basic Teleservice
- Calling – Voice Communication
- Voice mailbox
- SMS
- Emergency calling
- Voice Messaging

GSM

The European TDMA Digital Cellular Standard

Services Provided By GSM (Cont..)

2. Bearer Services

- Transmission of data
- Low Speed data transfer (upto 9.6 Kbps)
- Synchronous /asynchronous

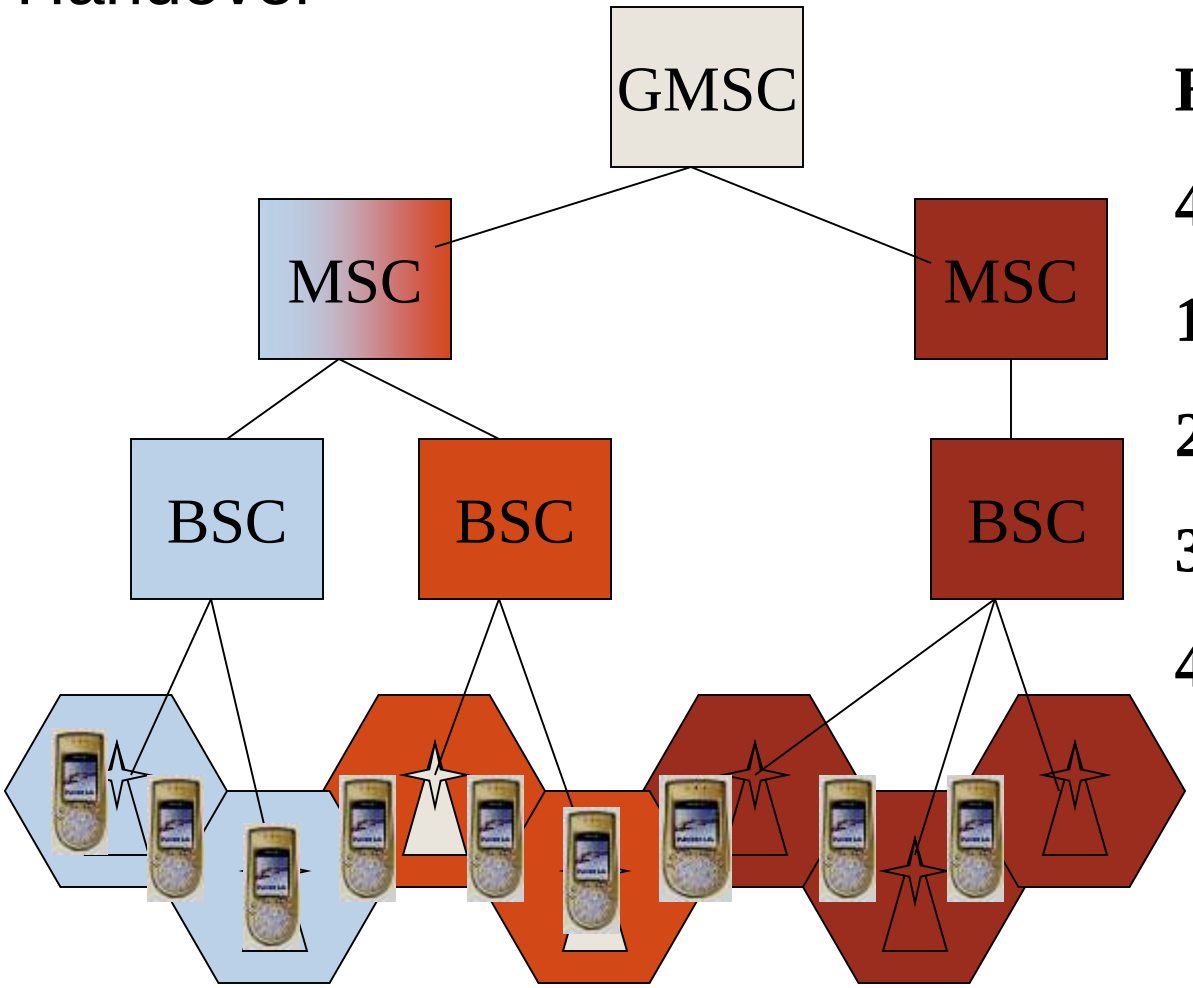
3. Supplementary Services

- call offering , call forwarding, call restriction, call waiting, call hold
- Multiparty teleconferencing, special schemes

GSM

The European TDMA Digital Cellular Standard

- Handover



Handover is of

4 types

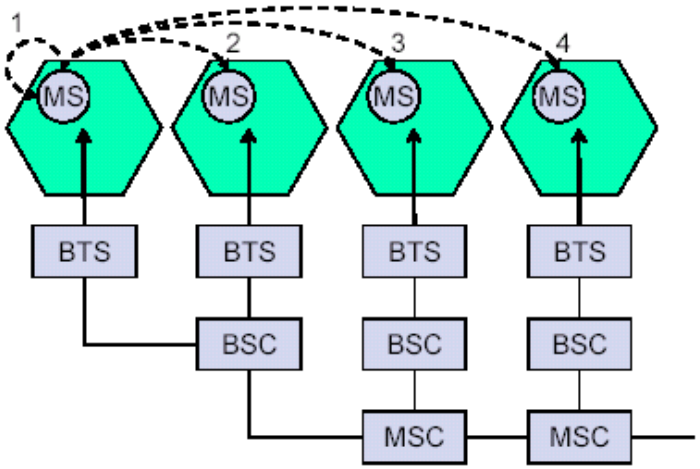
1. Intra BTS

2. Intra BSC

3. Inter BSC

4. Inter MSC

Handovers



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

GSM

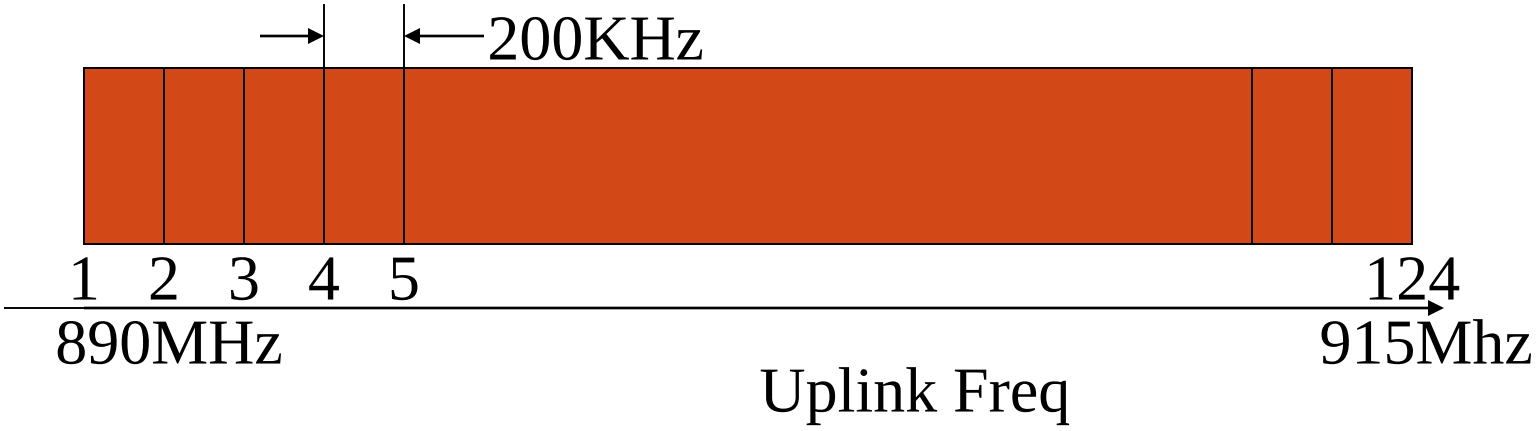
The European TDMA Digital Cellular Standard

- GSM Radio Aspects :
  - Uplink(Mobile to base)
    - 890-915 MHz (Total 25 MHz)
  - Downlink (Base to Mobile)
    - 935-960 MHz (Total 25 MHz)
  - Total 45 MHz spacing for duplex operation
  - GSM uses TDMA and FDMA

GSM

The European TDMA Digital Cellular Standard

- GSM Using FDMA



Total Frequency range(Uplink)=25Mhz

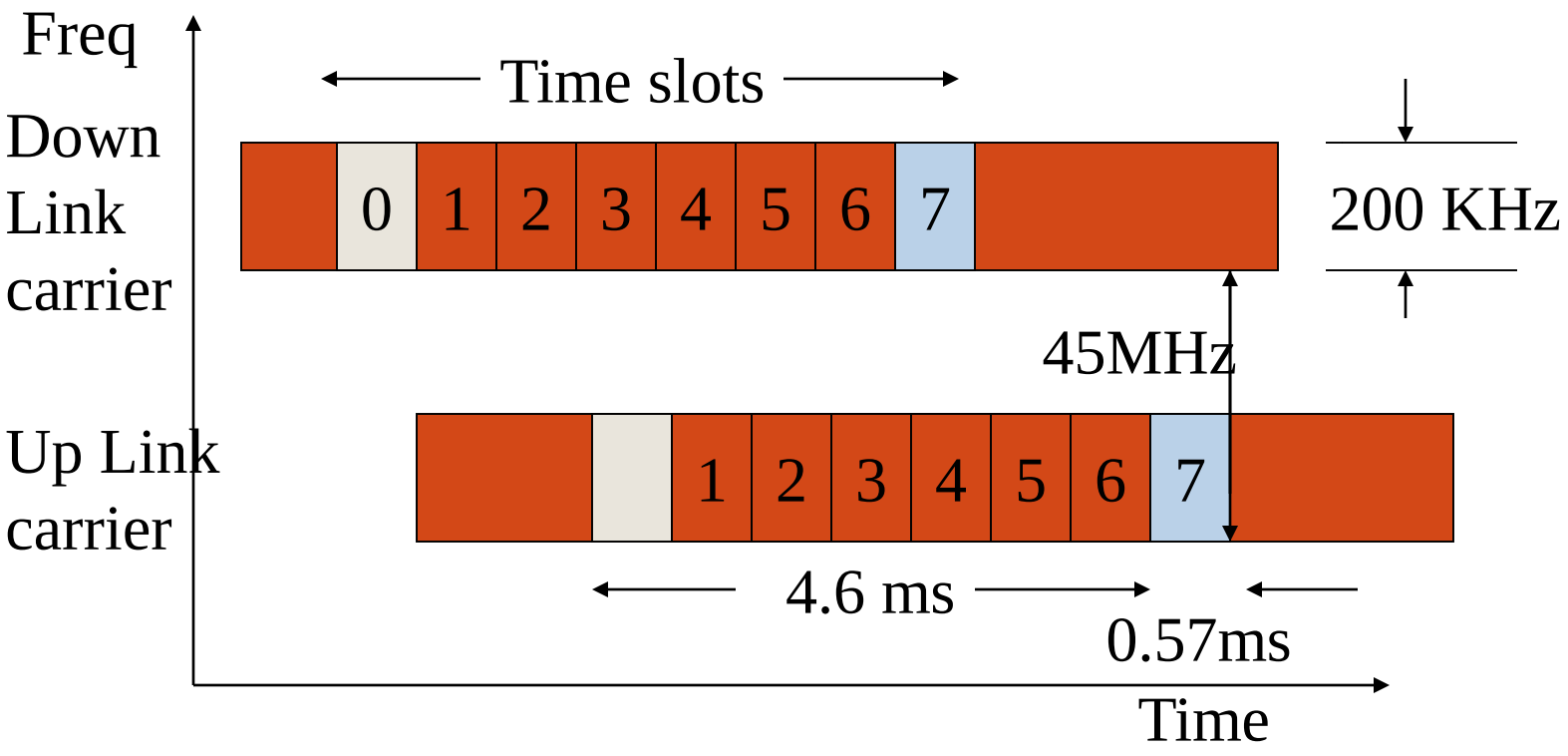
Spacing between two carriers= 200kHz

No. of Carriers=25MHz/200KHz = 124

GSM

The European TDMA Digital Cellular Standard

- GSM Using TDMA
  - TDMA Frame is divided into 8 time slots.



GSM

The European TDMA Digital Cellular Standard

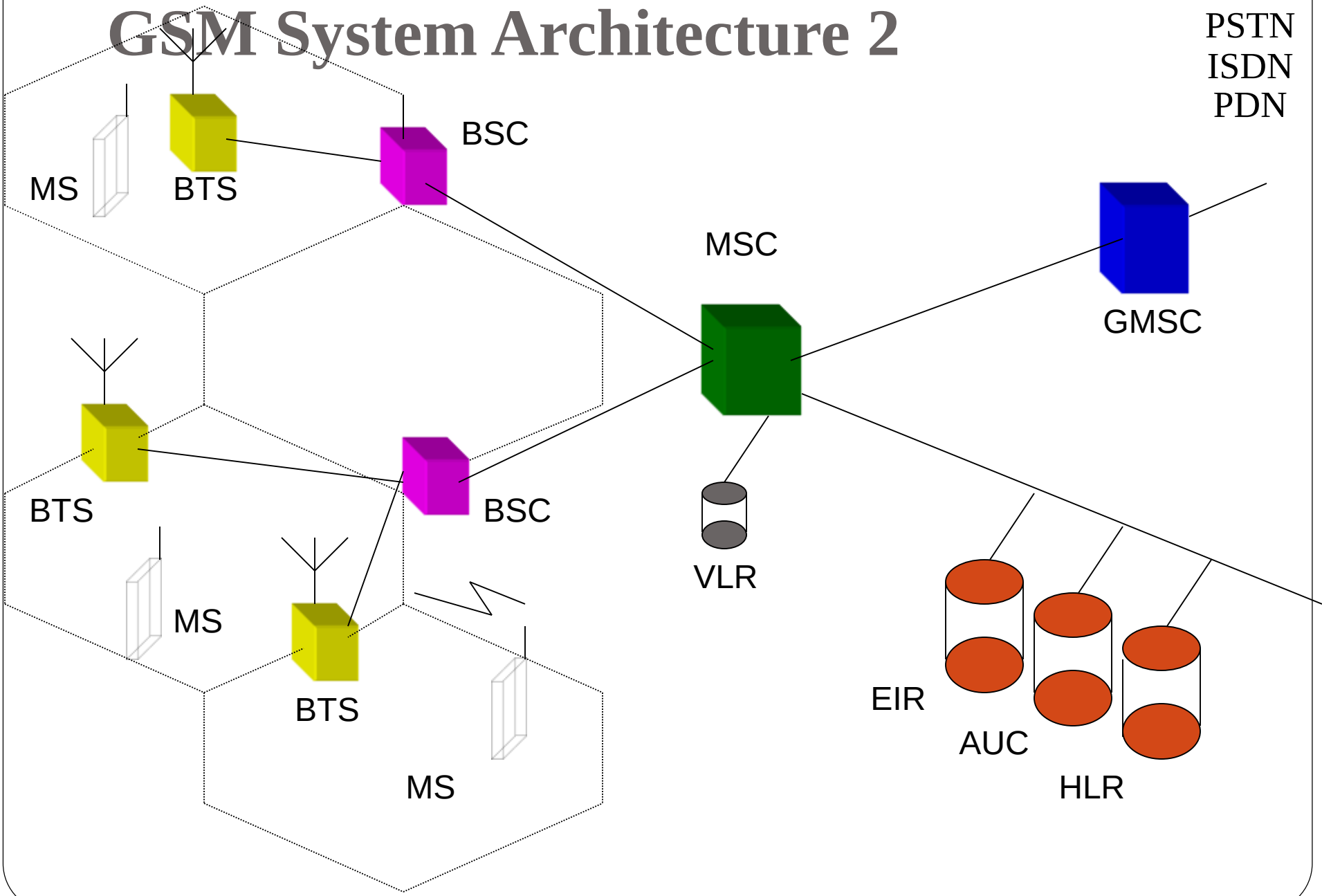
- Classification of Channels
- 1 Traffic (TCH)
  - Speech
    - Full rate 22.8 kb/s
    - Half rate 11.4 kb/s
  - Data
    - 9.6kb/s
    - 4.8kb/s
    - 2.4kb/s

GSM

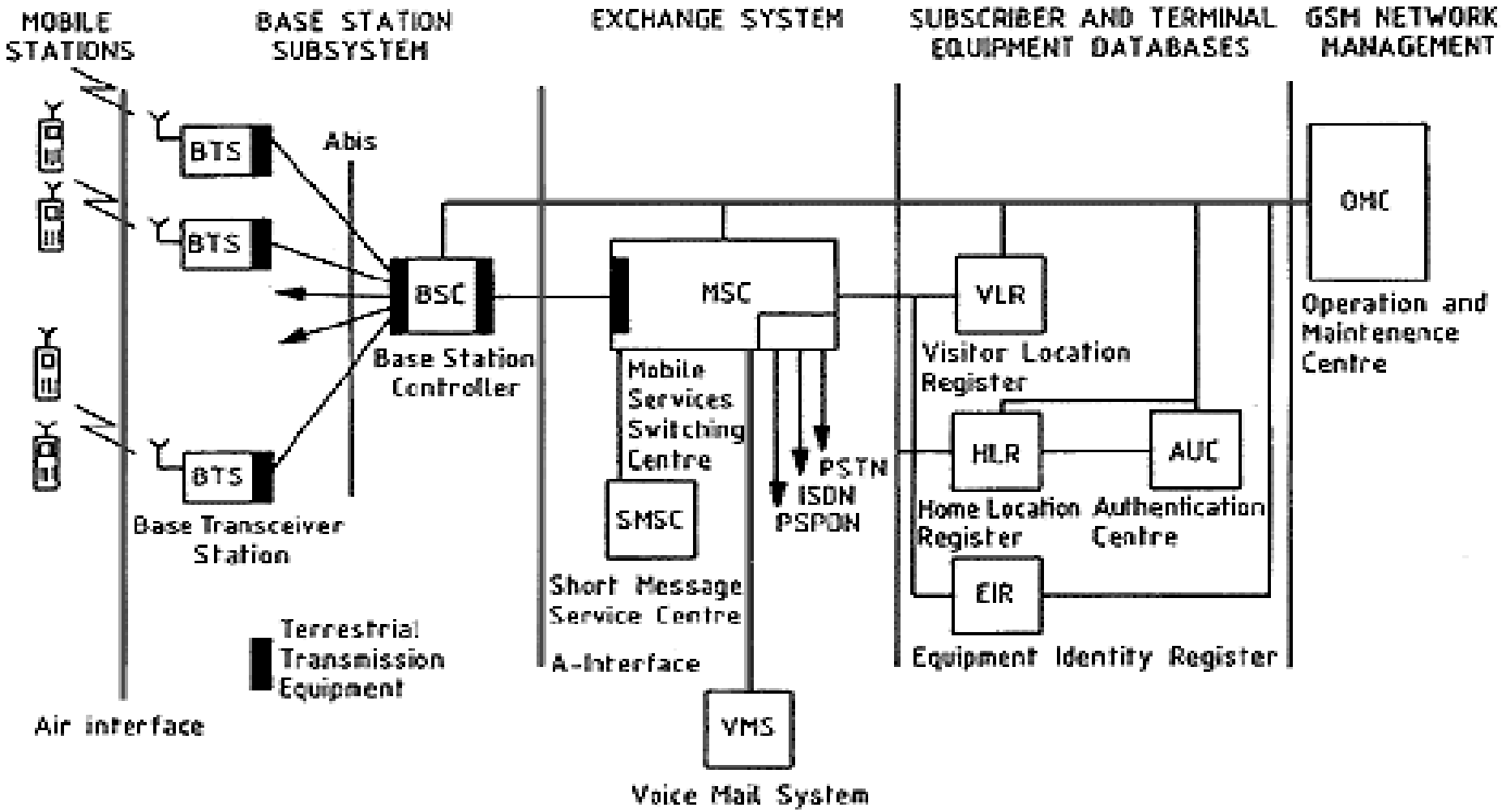
The European TDMA Digital Cellular Standard

- 2 Control (CCH)
  - Broadcast (BCCH)
    - Freq correction (FCCH)
    - Synchronization (SCH)
  - Common (CCH)
    - Paging (PCH)
    - Access grant (AGCH)
    - Random Access (RACH)
  - Dedicated (DCCH)
    - Fast Associative (FACCH)
    - Slow Associative (SACCH)
    - Stand alone (SDCCH)

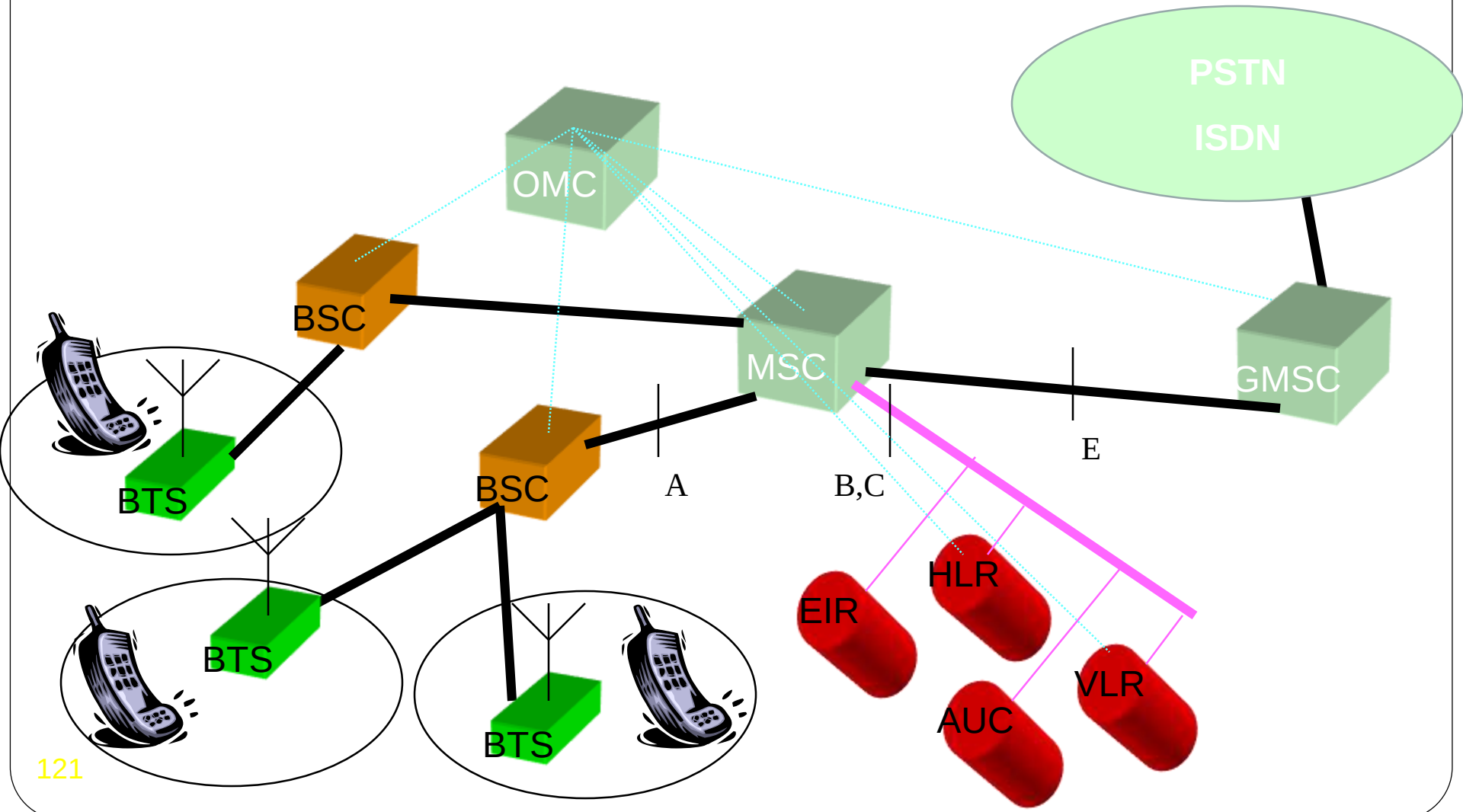
GSM System Architecture 2



GSM


MOBILE STATIONS
BASE STATION SUBSYSTEM
EXCHANGE SYSTEM
SUBSCRIBER AND TERMINAL EQUIPMENT DATABASES
GSM NETWORK MANAGEMENT
BTS
BTS
BTS
Abis
BSC
Base Station Controller
Base Transceiver Station
MSC
Mobile Services Switching Centre
SMSC
Short Message Service Centre
PSTN
ISDN
PSPDN
A-Interface
VLR
Visitor Location Register
HLR
Home Location Register
AUC
Authentication Centre
EIR
Equipment Identity Register
OMC
Operation and Maintenence Centre
VMS
Voice Mail System
Terrestrial Transmission Equipment
Air interface

GSM network layout



Abbreviations

- ISC: International switching center
- OMC: Operations and maintenance center
- GMSC: Gateway switching center
- MSC: Mobile switching center
- VLR: Visitor location register
- HLR: Home Location register
- EIR: Equipment Identification register
- AUC: Authentication center
- BSC: Base station controller
- BTS: Base transceiver station
- MS: Mobile subscriber
- TMSI: Temporary Mobile Subscriber Identity
- IMSI: International Mobile Subscriber Identity
- MSRN: Mobile Station Roaming Number

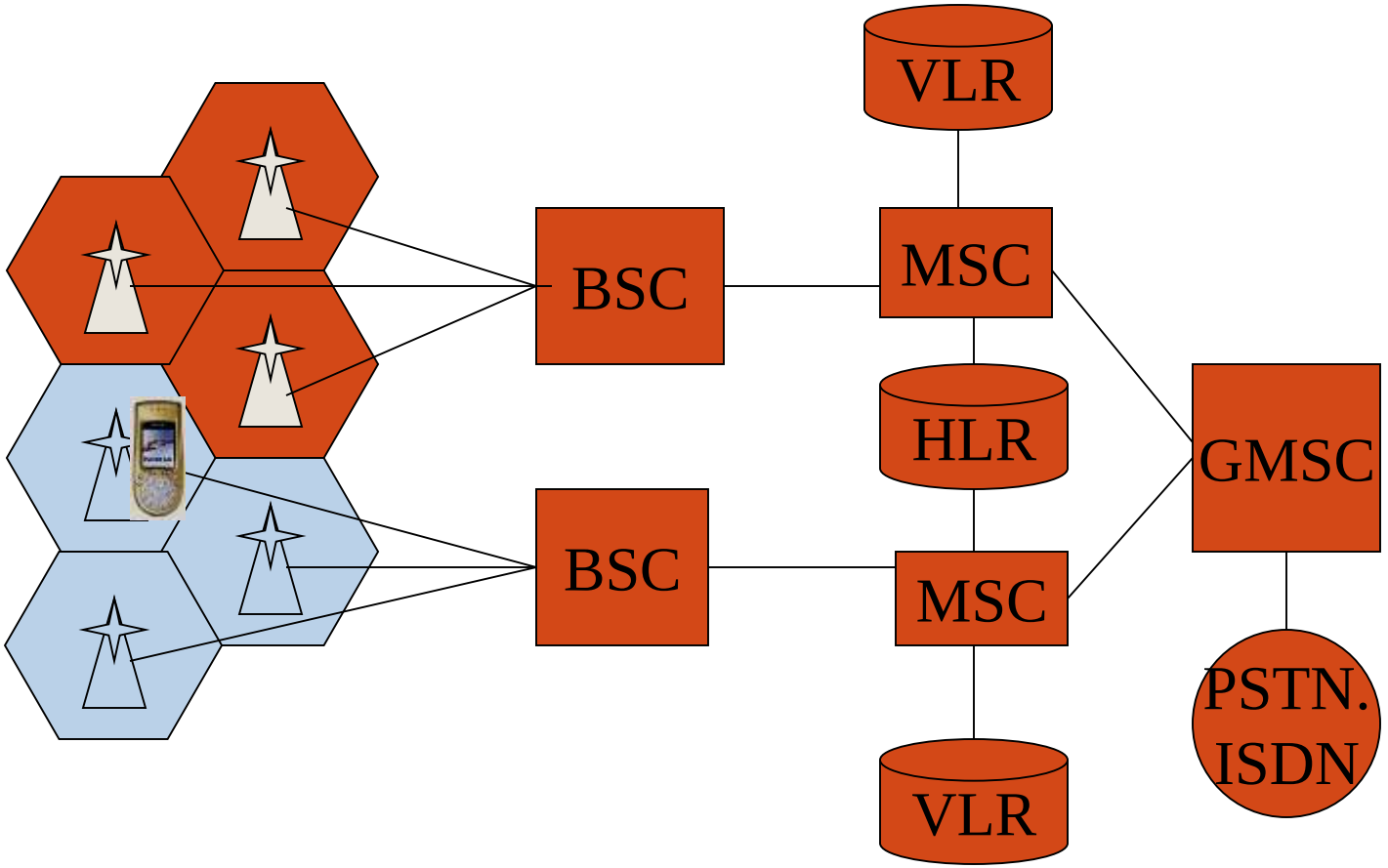
Call Routing

- Call Originating from MS
- Call termination to MS

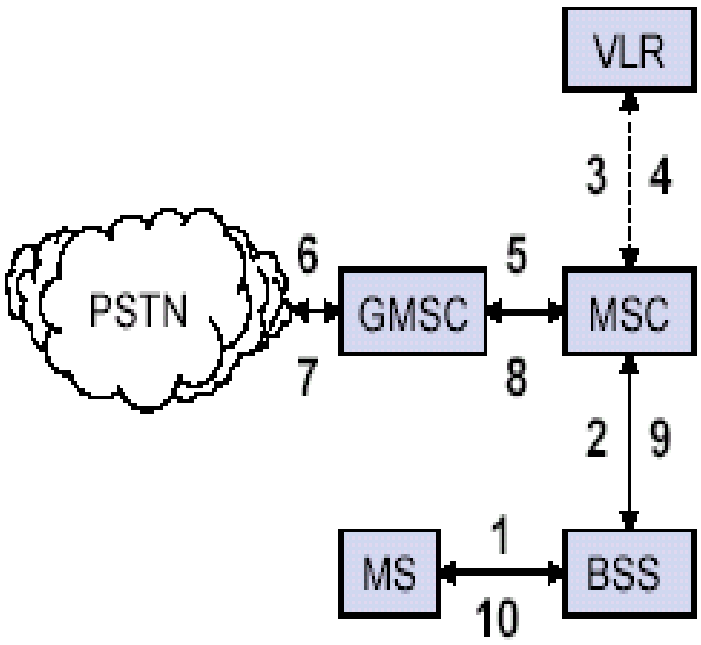
GSM

The European TDMA Digital Cellular Standard

- Mobile call originating



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.

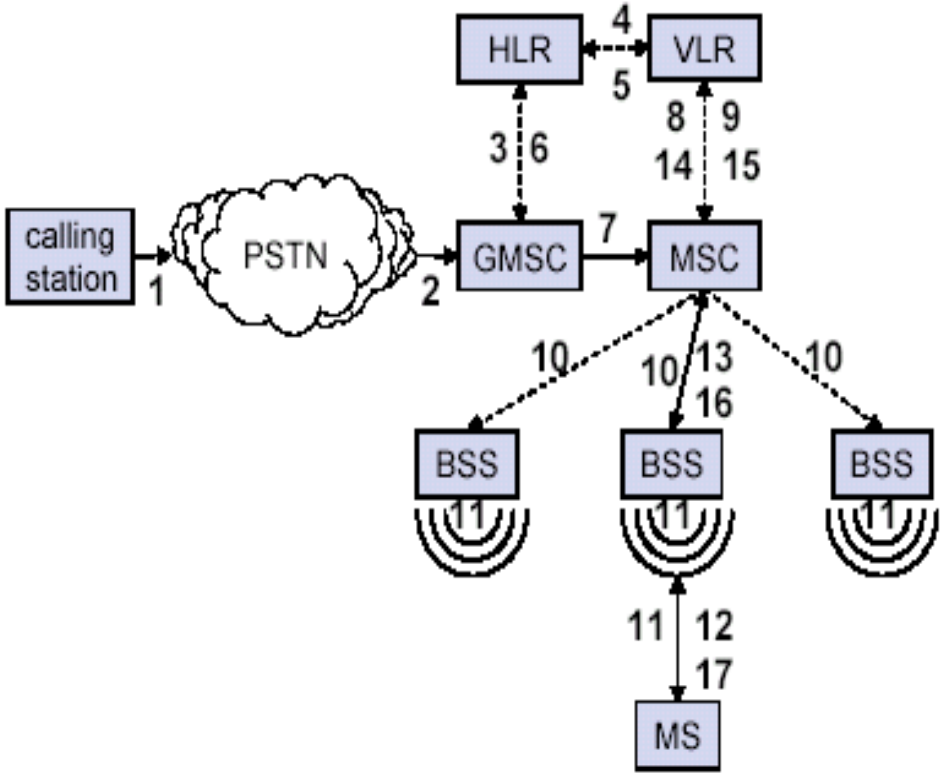
5 MSC routes the call to GMSC

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

Incoming 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

Types of handover (same as “handoff”)

- There are four different types of handover in the GSM system.
- Handover involves transferring a call between:
  - Channels (time slots) in the same cell
  - Cells (Base Transceiver Stations) under the control of the same Base Station Controller (BSC),
  - Cells under the control of different BSCs, but belonging to the same Mobile services Switching Center (MSC), and
  - Cells under the control of different MSCs.

Location management

- Set of procedures to:
  - track a mobile user
  - find the mobile user to deliver it calls
- Current location of MS maintained by 2-level hierarchical strategy with
  - **HLRs and**
  - **VLRs.**

GSM & CDMA

A comparison

GSM

- Time Division Multiple Access Based Technology
- 200 kHz bandwidth per carrier
- Deployed in reuse pattern 3/9, 4/12, 7/21
- Available operating frequency 900, 1800, 1900 MHz
- Using SIM Card

CDMA

- Code Division Multiple Access Based Technology
- 1.25 MHz bandwidth per carrier
- Reuse factor 1
- Available operating frequency 450, 800, 1900 MHz
- Using RUIM Card

CDMA

- Inherently superior receive sensitivity (approx. -121 dB)
- Tradeoff between Capacity, Coverage and Quality
- Soft/Softer hand-off (make before break):
  - Precise power control algoriths minimize interference
- Multiple diversities:
  - Receive Spatial Diversity trough two receive antennas
  - Path diversity trough rake receivers
  - Frequency diversity trough spread spectrum
  - Time diversity trough interleaving

GSM

- Fixed coverage
- Receive sensitivity improvement (approx. -108dB), relies on external solutions (masthead pre-amplifier, high power amplifier)
- Hard hand-off (break before make)

Summary

- CDMA, compared with GSM (TDMA) technology, provide :
  - better spectrum efficiency (more capacity)
  - better coverage (less sites required)
  - better voice quality
  - better data capability
  - better forward compatibility (same spectrum can be reused)

Working of CDMA

How CDMA works

- The words "code" and "division" are important parts of how CDMA works.
- CDMA uses codes to convert between analog voice signals and digital signals. CDMA also uses codes to separate (or divide) voice and control data into data streams called "channels."
- These digital data stream channels should not be confused with frequency channels.

Generating a CDMA signal

- There are five steps in generating a CDMA signal.
  1. analog to digital conversion
  2. vocoding
  3. encoding and interleaving
  4. channelizing the signals
  5. conversion of the digital signal to a Radio Frequency (RF) signal

Analog to digital conversion

- The first step of CDMA signal generation is analog to digital conversion, sometimes called A/D conversion.
- CDMA uses a technique called Pulse Code Modulation (PCM) to accomplish A/D conversion.

Voice Compression

- The second step of CDMA signal generation is voice compression.
- CDMA uses a device called a vocoder to accomplish voice compression.
- The term "vocoder" is a contraction of the words "voice" and "code."
- Vocoders are located at the BSC and in the phone.

Variable Rate Vocoder

- A CDMA vocoder varies compression of the voice signal into one of four data rates based on the rate of the user's speech activity.
- The four rates are: Full, 1/2, 1/4 and 1/8.
- The vocoder uses its full rate when a person is talking very fast.
- It uses the 1/8 rate when the person is silent or nearly so.

Vocoder types

- CDMA systems can use either an 8 kbps (kilobytes per second) or a 13 kbps vocoder.
- Recently the CDMA community adopted a new 8 kbps vocoder.
- This new vocoder is usually referred to as the EVRC (Extended Variable Rate Coding).
- It combines the quality of 13 kbps vocoding with the capacity of the 8kbps data rate.

Encoding and interleaving

- Encoders and interleavers are built into the BTS and the phones.
- The purpose of the encoding and interleaving is to build redundancy into the signal so that information lost in transmission can be recovered.

How encoding works

- The type of encoding done at this stage is called "convolutional encoding."
- A simplified encoding scheme is the repitition code: Each bit is repeated three times.
- These encoded bits are called symbols.
- The decoder at the receiver uses a majority logic rule.
- Thus, if an error occurs, the redundancy can help recover the lost information.

How interleaving works

- Interleaving is a simple but powerful method of reducing the effects of burst errors and recovering lost bits.
- In the example shown here the symbols from each group are interleaved (or scrambled) in a pattern that the receiver knows.
- De-interleaving at the receiver unscrambles the bits, spreading any burst errors that occur during transmission.

Channelizing

- The encoded voice data is further encoded to separate it from other encoded voice data.
- The encoded symbols are then spread over the entire bandwidth of the CDMA channel.
- This process is called channelization.
- The receiver knows the code and uses it to recover the voice data.

Two kinds of codes

- CDMA uses two important types of codes to channelize users.
  - Walsh codes channelize users on the forward link (BTS to mobile).
  - Pseudorandom Noise (PN) codes channelize users on the reverse link (mobile to BTS).

Walsh codes

- Walsh codes provide a means to uniquely identify each user on the **forward link**.
- Walsh codes have a unique mathematical property--they are "**orthogonal**."
- In other words, **Walsh codes** are unique enough that the voice data can only be recovered by a receiver applying the same Walsh code.

PN codes

- **Pseudorandom Noise** (PN) codes uniquely identify users on the reverse link.
- A PN code is one that appears to be random, but isn't.
- The PN codes used in CDMA yield about 4.4 trillion combinations of code.
- This is a key reason why CDMA is so secure.

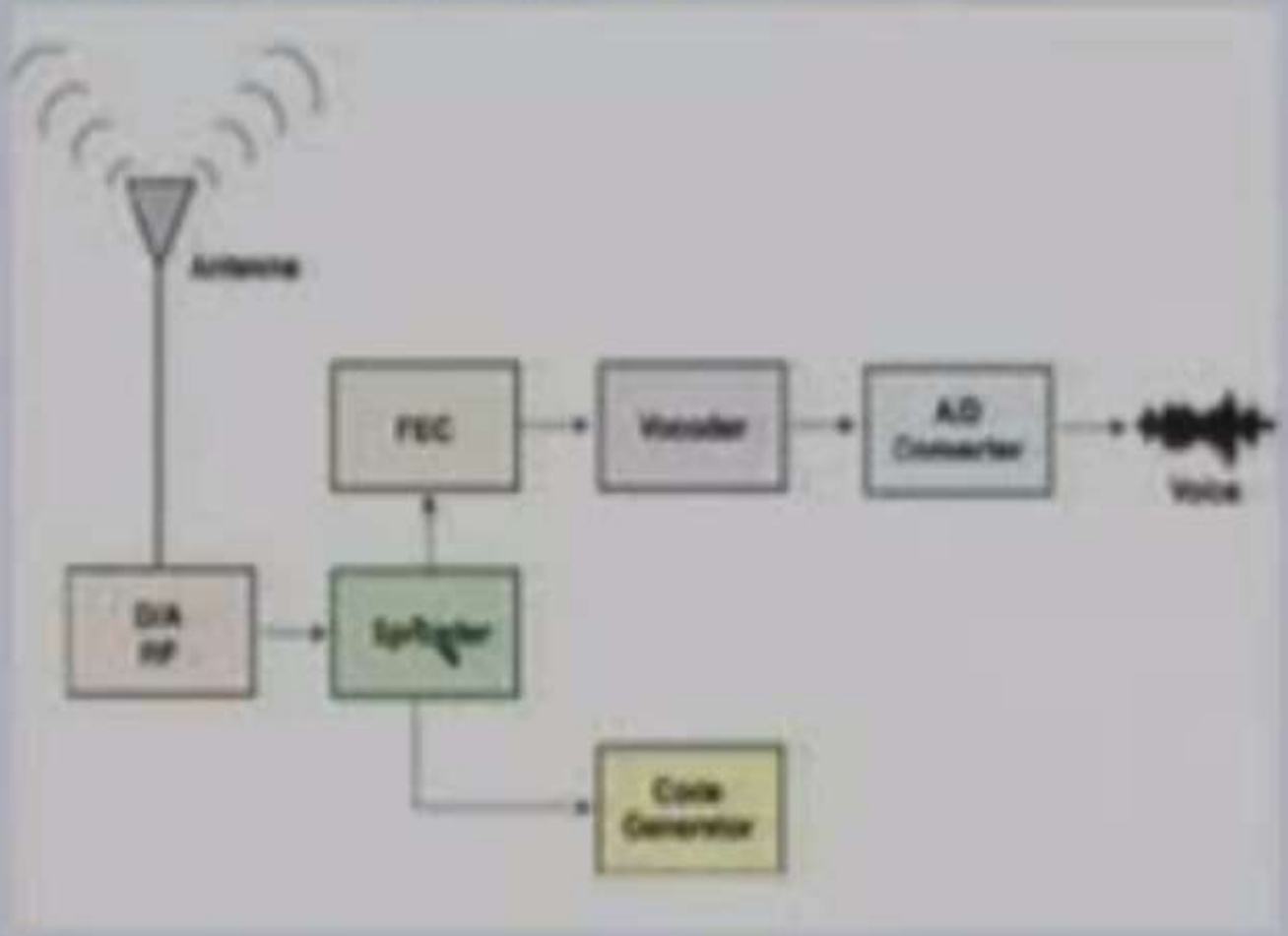
Digital to Radio Frequency (RF) conversion

- The BTS combines channelized data from all calls into one signal.
- It then converts the digital signal to a Radio Frequency (RF) signal for transmission.

The receiving end ...

- After the CDMA signal is transmitted, the receiver must reverse the signal generation process to recover the voice, as follows:
  1. Conversion of RF signal to digital signal
  2. Despreading the signal
  3. Deinterleaving and decoding
  4. Voice decompression
  5. Digital to analog voice recovery

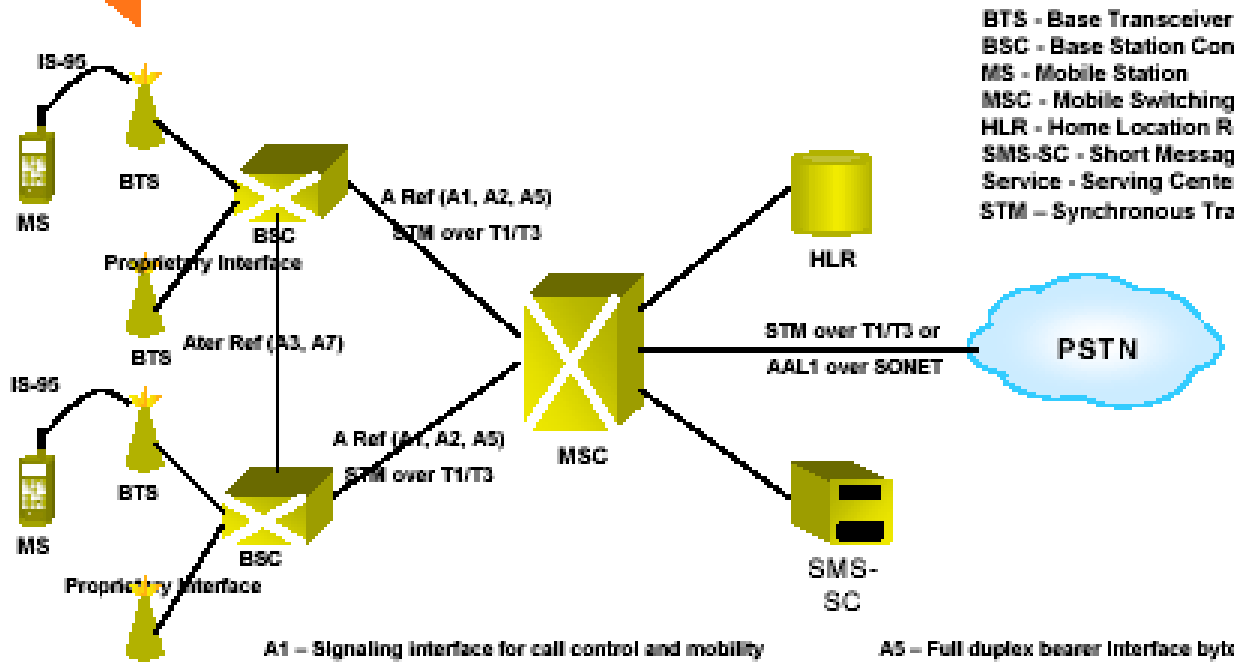
The Receiver



Code channels used in CDMA

- A code channel is a stream of data designated for a specific use or person.
- This channel may be voice data or overhead control data.
- Channels are separated by codes.
- The forward and reverse links use different types of channels.

2G cdmaOne (IS-95 + IS-41)



BTS - Base Transceiver Station
BSC - Base Station Controller
MS - Mobile Station
MSC - Mobile Switching Center
HLR - Home Location Registry
SMS-SC - Short Message
Service - Serving Center
STM – Synchronous Transfer Mode

A1 – Signaling interface for call control and mobility Management between MSC and BSC

A2 – 64 kbps bearer interface for PCM voice

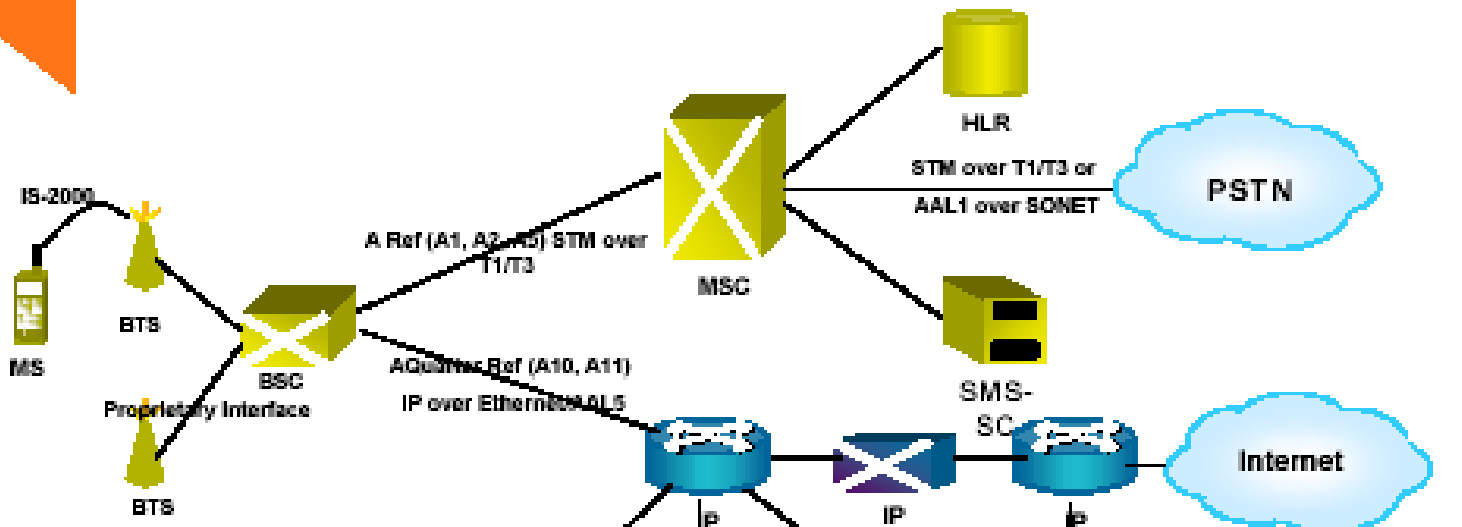
A3 – Signaling interface for inter-BSC mobile handoff

A5 – Full duplex bearer interface byte stream (SMS ?)

A7 – Bearer interface for inter-BSC mobile handoff

COMMUNICATIONS

CDMA2000 1x Network



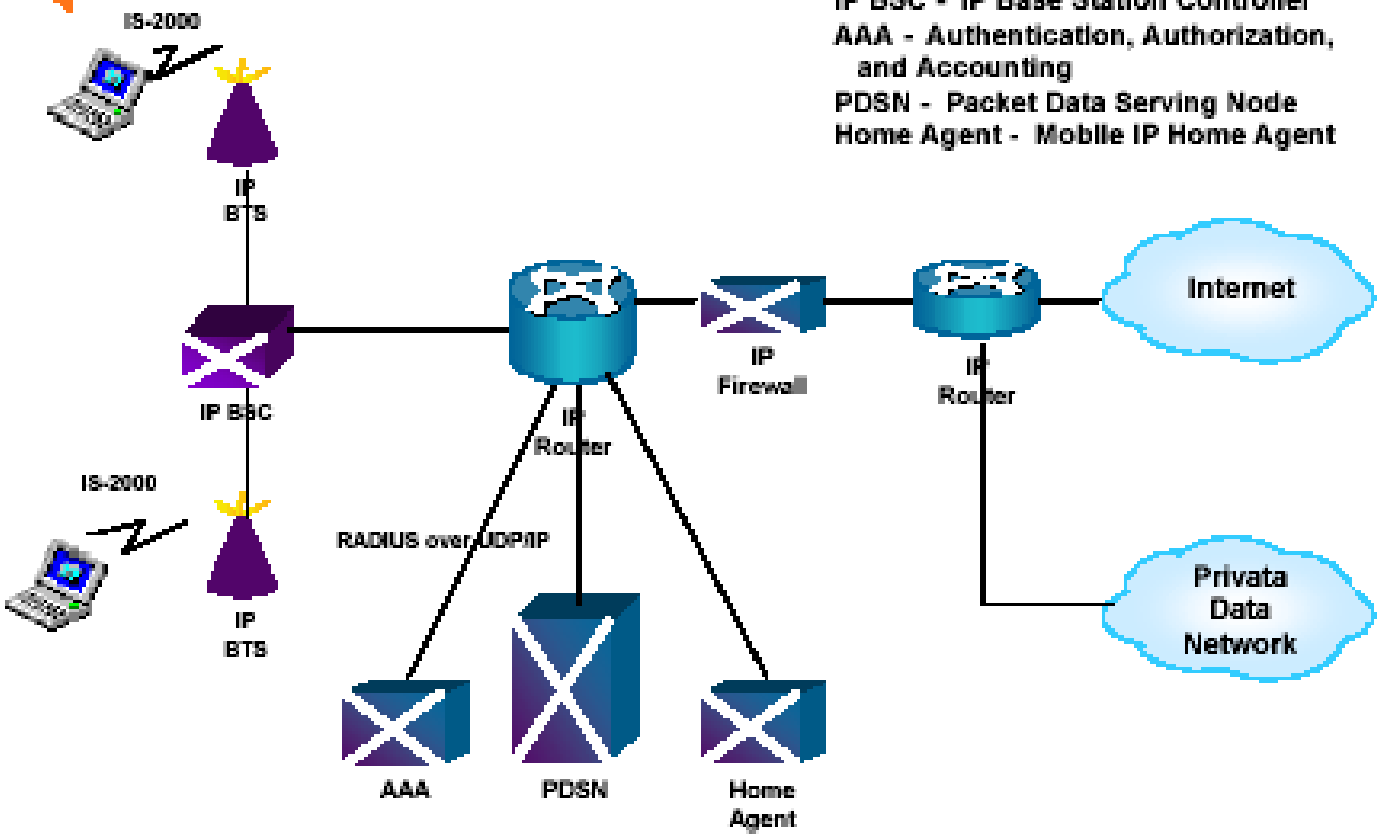
BTS - Base Transceiver Station
BSC - Base Station Controller
MS - Mobile Station
MSC - Mobile Switching Center
HLR - Home Location Registry
SMS-SC - Short Message Service - Serving Center
STM – Synchronous Transfer Mode
PDSN – Packet Data Serving Node
AAA – Authentication, Authorization, and Accounting
Home Agent – Mobile IP Home Agent

A10 – Bearer interface between BSC (PCF) and PDSN for packet data
A11 – Signaling interface between BSC (PCF) and PDSN for packet data

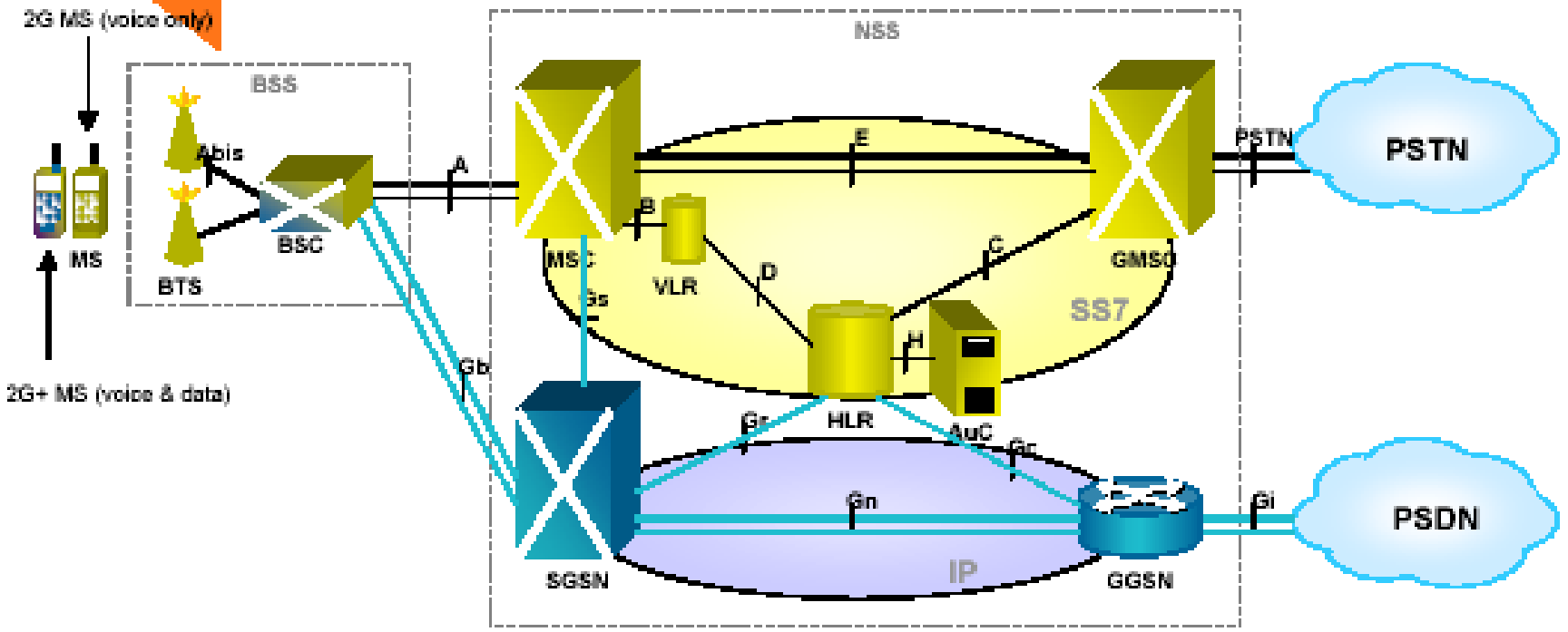
NEXTEL COMMUNICATIONS

1xEVDO -- IP Data Only

IP BTS - IP Base Transceiver Station
IP BSC - IP Base Station Controller
AAA - Authentication, Authorization, and Accounting
PDSN - Packet Data Serving Node
Home Agent - Mobile IP Home Agent



2.5G Architectural Detail



BSS Base Station System

BTS Base Transceiver Station

BSC Base Station Controller

NSS Network Sub-System

MSC Mobile-service Switching Controller

VLR Visitor Location Register

HLR Home Location Register

AuC Authentication Server

GMSC Gateway MSC

SGSN Serving GPRS Support Node

GGSN Gateway GPRS Support Node

GPRS General Packet Radio Service

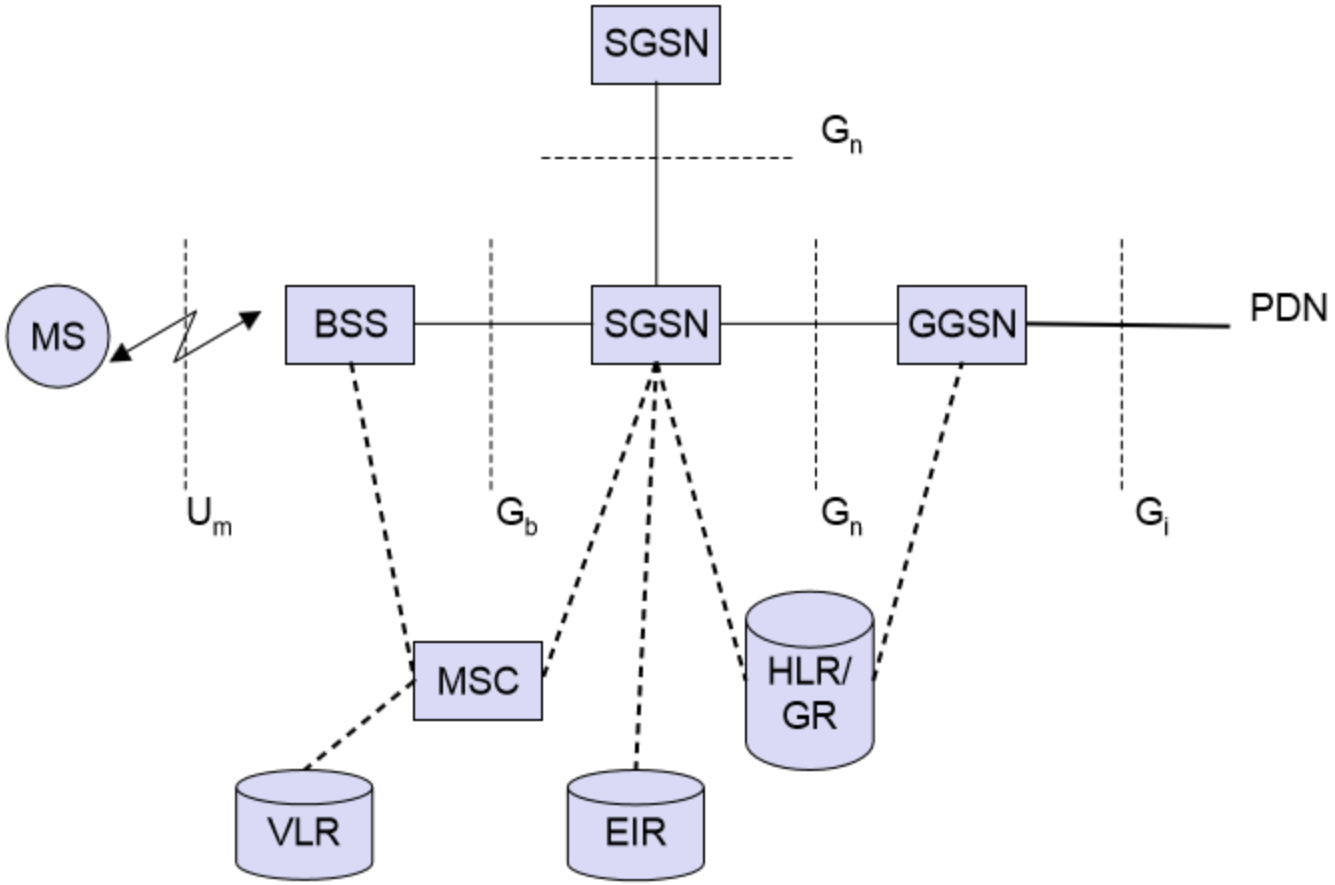
GSM GPRS

Data services in GSM: GPRS

- GPRS (General Packet Radio Service)
  - packet switching
  - using free slots only if data packets ready to send (e.g., 115 kbit/s using 8 slots temporarily)
  - standardization 1998, introduced 2000

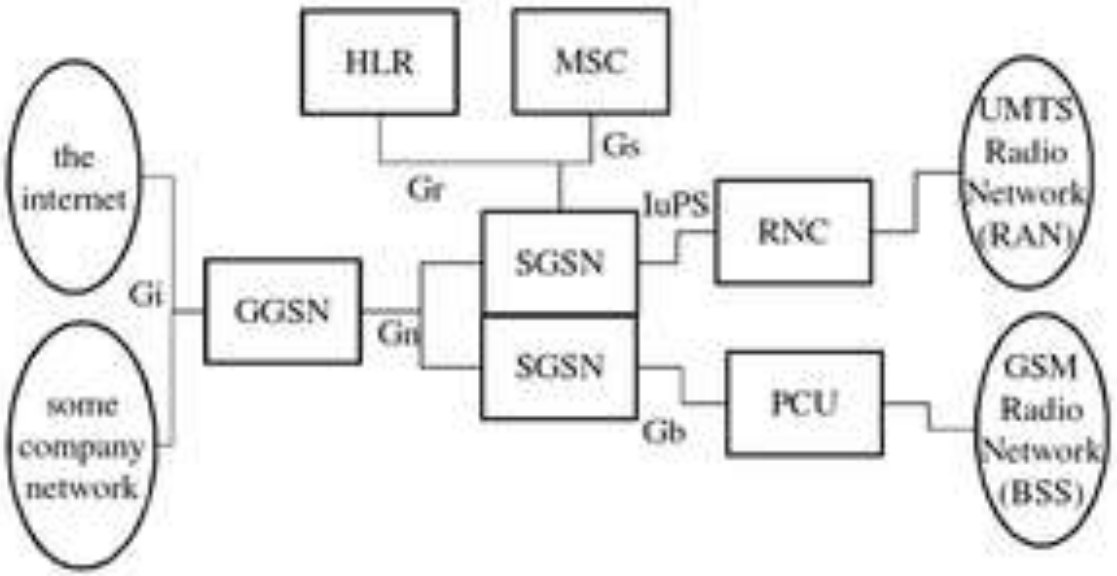
- GPRS network elements GSN (GPRS Support Nodes)
  - GGSN (Gateway GSN)
    - interworking unit between GPRS and PDN (Packet Data Network)
  - SGSN (Serving GSN)
    - supports the MS (location, billing, security)
  - GR (GPRS Register)
    - user addresses

GPRS architecture and interfaces



GPRS support nodes (GSN)

- A GSN is a network node which supports the use of GPRS in the GSM core network.
- All GSNs should have a *Gn* interface and support the GPRS tunnelling protocol.
- There are two key variants of the GSN, namely
  - Gateway GPRS Support Node, and
  - Serving GPRS Support Node.


HLR
MSC
the internet
Gs
Gr
IuPS
RNC
UMTS Radio Network (RAN)
SGSN
Gi
GGSN
Gn
SGSN
some company network
PCU
GSM Radio Network (BSS)
Gb

Advantages

- Speed
- Always on connectivity
- New and better applications
- GSM operator costs – As an upgraded network, no major infrastructure changes

Theory Part

GPRS

What is GPRS?

- The General Packet Radio Service (GPRS) network is an "always on", private network for **data**.
- It **uses the existing GSM network** to transmit and receive TCP/IP based data to and from GPRS mobile devices.
- Private IP addresses are typically dynamically assigned **within the network to mobile devices**.
- Firewalls typically reside at the APN to isolate the public and private networks. IP addresses allocated to mobile GPRS devices are therefore not addressable from outside the GPRS network (e.g. from the Internet) without specialized services or infrastructure.

GPRS

- GPRS (General Packet Radio Service) is a very widely deployed wireless data service, available now with most GSM networks.

- GPRS customers enjoy advanced, feature-rich data services such as e-mail on the move, multimedia messages and location-based services.

- **General packet radio service (GPRS)** is a **packet oriented mobile data service** available to users of the 2G cellular communication systems global system for mobile communications (GSM), as well as in the 3G systems.

GPRS conti…

- In 2G systems, GPRS provides data rates of 56-114 kbit/s
- 2G cellular systems combined with GPRS are often described as *2.5G*
- GPRS data transfer is typically **charged per megabyte** of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time.

GPRS Charging & QoS as compared to CSD

- GPRS data transfer is typically **charged per megabyte of traffic transferred**, while data communication via traditional circuit switching is billed per minute of connection time, independent of whether the user actually is using the capacity or is in an idle state.

- GPRS is a best-effort packet switched service.
  - In circuit switching, a certain quality of service (QoS) is guaranteed during the connection for non-mobile users.

Serving GPRS Support Node (SGSN)

- A Serving GPRS Support Node (SGSN) is responsible for the delivery of data packets from and to the mobile stations within its geographical service area.
- Its tasks include packet routing and transfer, mobility management (attach/detach and location management), and authentication and charging functions.
- The location register of the SGSN stores location information (e.g., current cell, current VLR) and user profiles (e.g., IMSI, address(es) used in the packet data network) of all GPRS users registered with this SGSN.

Common SGSN Functions

- Detunnel GTP packets from the GGSN (downlink)
- Tunnel IP packets toward the GGSN (uplink)
- Carry out mobility management as Standby mode mobile moves from one Routing Area to another Routing Area
- Billing user data

Gateway GPRS Support Node (GGSN)

- The Gateway GPRS Support Node (GGSN) is a main component of the GPRS network. The GGSN is responsible for the interworking between the GPRS network and external packet switched networks, like the Internet and X.25 networks.

- From an external network's point of view, the GGSN is a router to a sub-network, because the GGSN ‘hides’ the GPRS infrastructure from the external network.

Gateway GPRS Support Node (GGSN)

- When the GGSN receives data addressed to a specific user, it checks if the user is active. If it is, the GGSN forwards the data to the SGSN serving the mobile user, but if the mobile user is inactive, the data is discarded. On the other hand, mobile-originated packets are routed to the right network by the GGSN.

- In short, the GGSN is the anchor point that enables the mobility of the user terminal in the GPRS/UMTS networks.

THANK YOU