Tishk International University
Science Faculty
IT Department

Wireless Networking

Lecture 5: GSM Networks

4th Grade - Fall Semester

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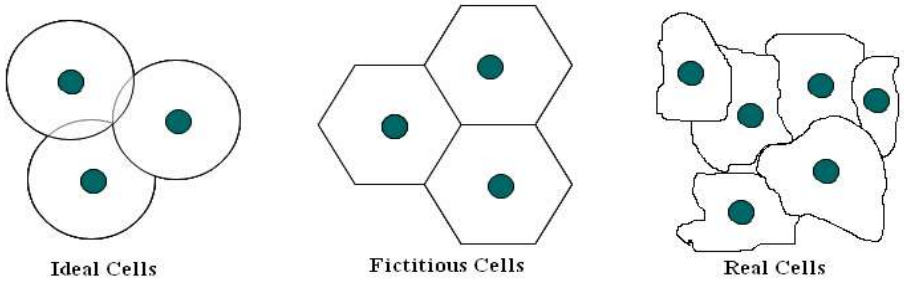
Agenda

- GSM (Cellular) Network Basics
- Cellular Network Generations
- GSM Frequencies
- GSM Architecture
- Handover
- Frequency Reuse with Examples

Cellular (GSM) Network Basics

- GSM is an abbreviation for **Global System for Mobile Communications**
- **Cellular network**: is a radio **network** distributed over land through cells where each **cell** includes a fixed location transceiver known as base station.
- **Cell** is the Basic unit in the GSM System and it is the area where radio coverage is given by one base station.
- These cells together provide radio coverage over larger geographical areas.

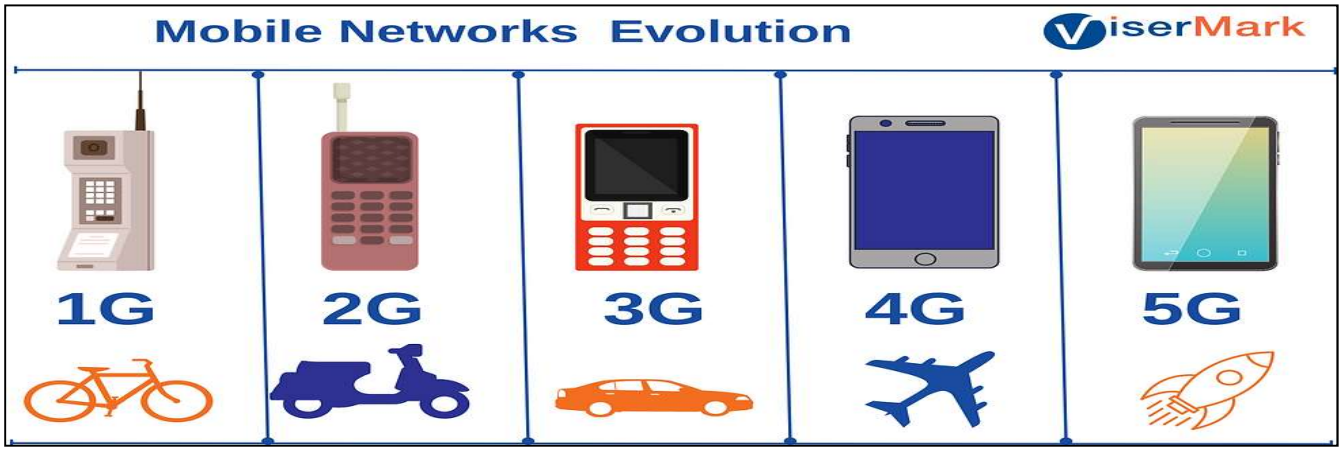


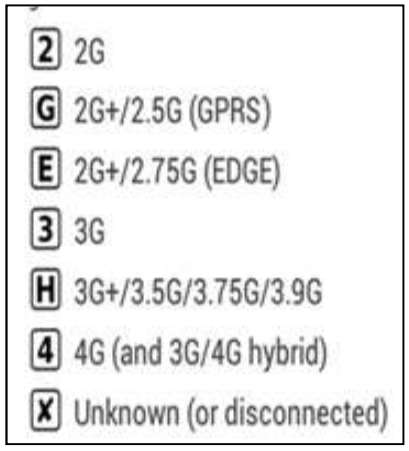
Cellular Network Generations

- **1G Networks**: are an analog technology where the phones generally had poor voice quality and security while battery was heavy and has less capacity.
- **2G Networks**: are based on a digital technology with GSM standard and it was designed to provide secure and reliable communication channel. 2G capabilities are achieved by allowing multiple users on a single channel via multiplexing. Its fundamental services were SMS, roaming, conference calls, call hold, and billing based on services. The data communication was based on GPRS (General Packet Radio Service) and EDGE (Enhanced Data Rates for GSM Evolution).
- **3G Networks:** facilitate greater voice and data capacity, support a wider range of applications, and increase data transmission at a lower cost. With this generation, web browsing, email, video downloading, picture sharing and other Smartphone technology. It was based on UMTS (Universal Mobile Telecommunications System), and later HSPA (High speed packet access).

Cellular Network Generations

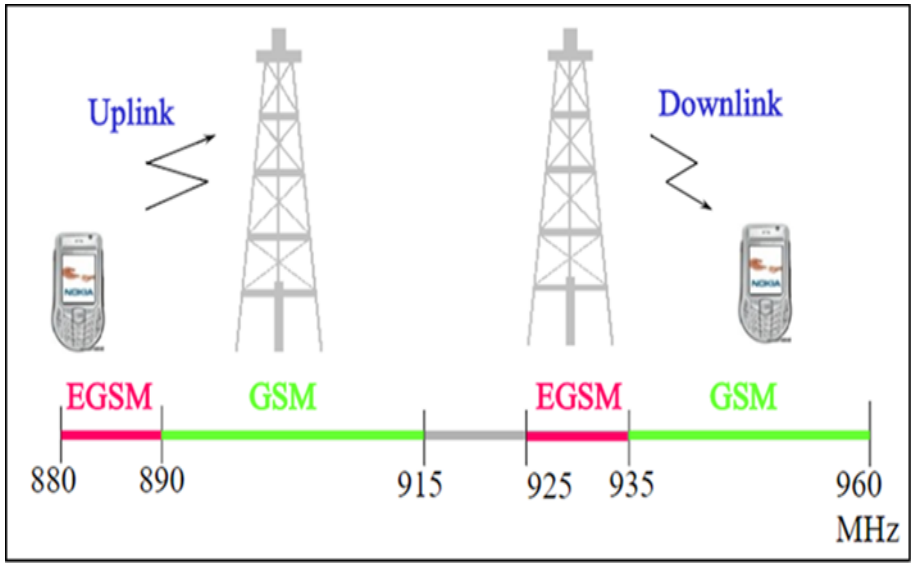
- **4G Networks**: are IP-based “anytime, anywhere” voice, data, and multimedia telephony at faster data rates than 3G. It was based on LTE (Long Time Evolution) that integrates all communications (data, voice and video) using the IP protocol.
- **5G Networks**: are the latest cellular generation began in 2018 and will take several years for worldwide adoption. 5G increases speed but at a cost of deploying many more cell towers and higher frequencies.





GSM Frequencies

- Originally designed on 900MHz range, now also available on 800MHz, 1800MHz and 1900 MHz ranges.
- Separate Uplink and Downlink frequencies



System	Frequency		Bandwidth	Channel Number	ARFCN
	UpLink	DownLink			
EGSM	880 - 890	925 - 935	10 MHz	50	974 - 1023
GSM	890 - 915	935 - 960	25 MHz	125	0 - 124
GSM 1800	1710 - 1785	1805 - 1880	75 MHz	375	512 - 886
GSM 1900	1850 - 1910	1930 - 1990	60 MHz	300	512 - 811

Frequency Allocation in Iraq

	Operator	Frequency		Bandwidth	Channel Number	ARFCN
		UpLink	DownLink			
GSM900	Zain	880.1 - 891.7	925.1 - 936.7	11.6 MHz	58	975 - 1023 and 0 - 8
	Korek	891.7 - 903.3	936.7 - 948.3	11.6 MHz	58	9 - 66
	Asiacell	903.3 - 914.9	948.3 - 949.9	11.6 MHz	58	67 - 124

	Operator	Frequency		Bandwidth	Channel Number	ARFCN
		UpLink	DownLink			
GSM1800	Zain	1725.1 - 1732.6	1820.1 - 1827.6	7.5 MHz	38	588 - 625
	Korek	1740.1 - 1747.6	1835.1 - 1842.6	7.5 MHz	38	663 - 700
	Asiacell	1755.1 - 1762.6	1850.1 - 1857.6	7.5 MHz	38	738 - 775

Sample of Mobile Specifications

Samsung I9500 Galaxy S4

Released 2013, April
130g, 7.9mm thickness
Android 4.2.2, up to 5.0.1
16/32/64GB storage, microSD card slot

5.0"
1080x1920 pixels

13MP
1080p

2GB
Exynos 5

REVIEW | OPINIONS | COMPARE

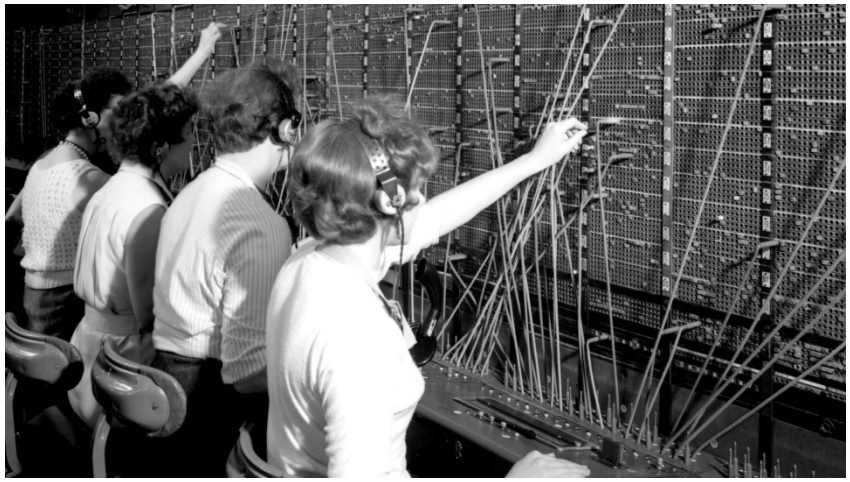
NETWORK	Technology	GSM / HSPA
	2G bands	GSM 850 / 900 / 1800 / 1900
	3G bands	HSDPA 850 / 900 / 1900 / 2100
	Speed	HSPA 42.2/5.76 Mbps, LTE Cat3 100/50 Mbps
	GPRS	Yes
	EDGE	Yes

GSM Channels

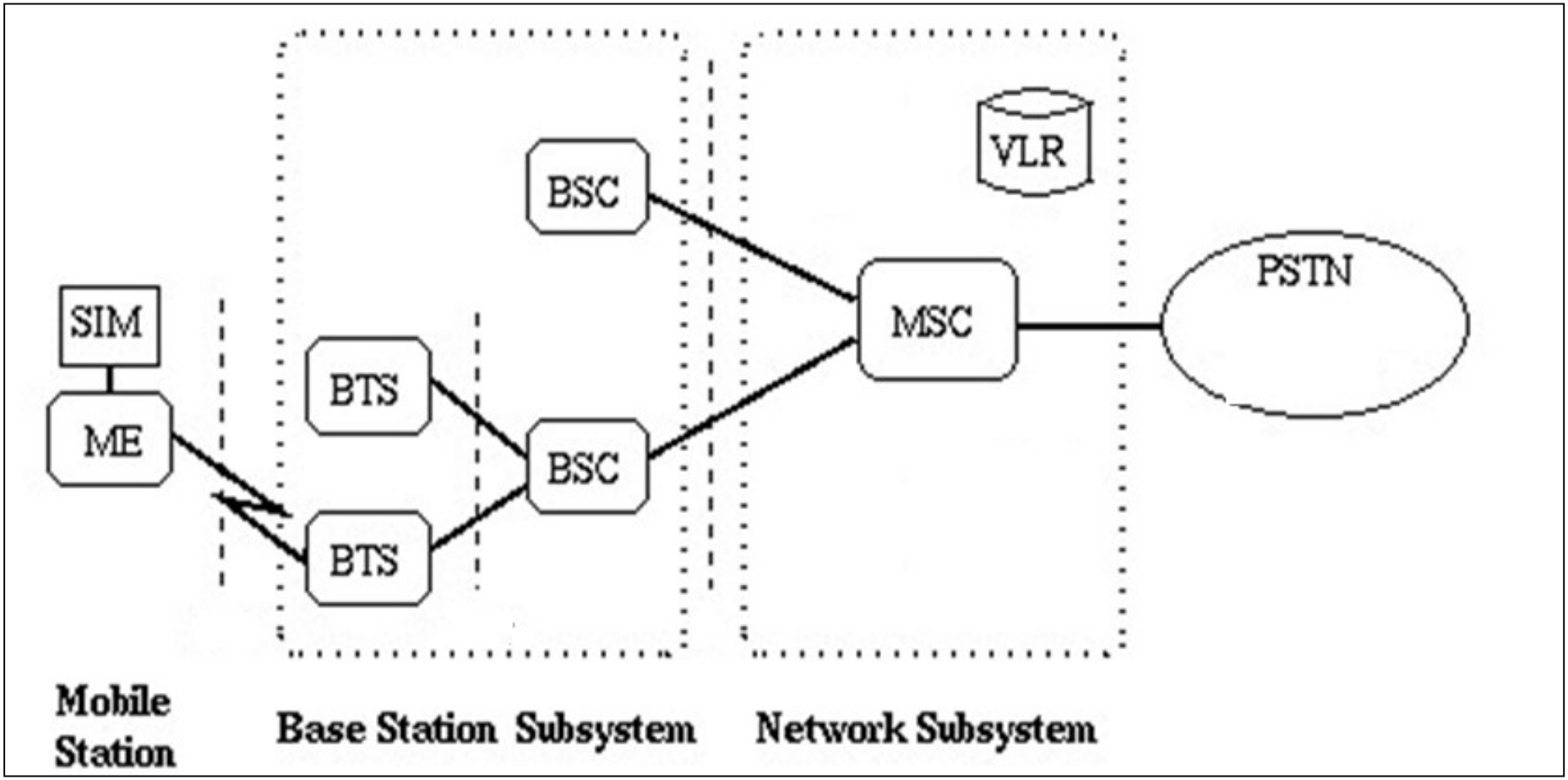
- The base stations need to serve many mobile terminals at the same time (both downlink and uplink), so we need multiple access scheme for GSM system
- GSM system adopt FDMA and TDMA together
- Each channel has frequency bandwidth of 200 KHz and time slot of 0.577 ms.
- A single GSM frequency channel is *divided* into *eight* timeslots.
- In GSM, there are two major categories of GSM Logical Channels:
  - Traffic channels: for speech and data.
  - Control Channels: to manage the access to the network.

Telephone Exchange

- A **telephone exchange** is a telecommunications system used in the public switched telephone network or in large enterprises.
- An exchange consists of electronic components and in older systems also human operators that interconnect (*switch*) telephone subscriber lines or virtual circuits of digital systems to establish telephone calls between subscribers.



GSM Architecture



Mobile Station (MS)

Mobile Station: is the user's handset and has two parts

1. **The International Mobile Equipment Identity (IMEI) number** is a unique identification or serial **number** that all mobile phones and smartphones have. It is normally 15 digits long.

2. A **subscriber identity module (SIM)** is an integrated circuit that is intended to securely store the international mobile subscriber identity (IMSI) number and its related key, which are used to identify and authenticate subscribers on mobile telephony devices.

Base Station Subsystem

- **Base Station Controller (BSC)**
  - Controls the channel (time slot) allocation implemented by the BTSes
  - Manages the handovers within BSS area
  - Knows which mobile stations are within the cell and informs the MSC/VLR about this
- **Base Transceiver System (BTS)**
  - Controls several transmitters
  - Each transmitter has 8 time slots, some used for signaling, on a specific frequency
  - The communication channel between the BTS and BSC is referred to as the ABIS interface.

Network and Switching Subsystem

- The backbone of a GSM network is a telephone network with additional cellular network capabilities
- **Mobile Switching Center (MSC)**: A typical telephony exchange which supports mobile communications
- **Visitor Location Register (VLR):** is a database, part of the MSC that contains the location of the active Mobile Stations
- **Gateway Mobile Switching Center (GMSC)**: is the link between the GSM system and PSTN and other GSM operators.

Location Update Procedures

- The cells overlap and usually a mobile can ‘see’ several towers (cells).
- The Mobile monitors the identifier for the BSC controlling the cells
- When the mobile reaches a new BSC’s area, it requests an location update
- The update is forwarded to the MSC, entered into the VLR, the old BSC is notified and an acknowledgement is passed back

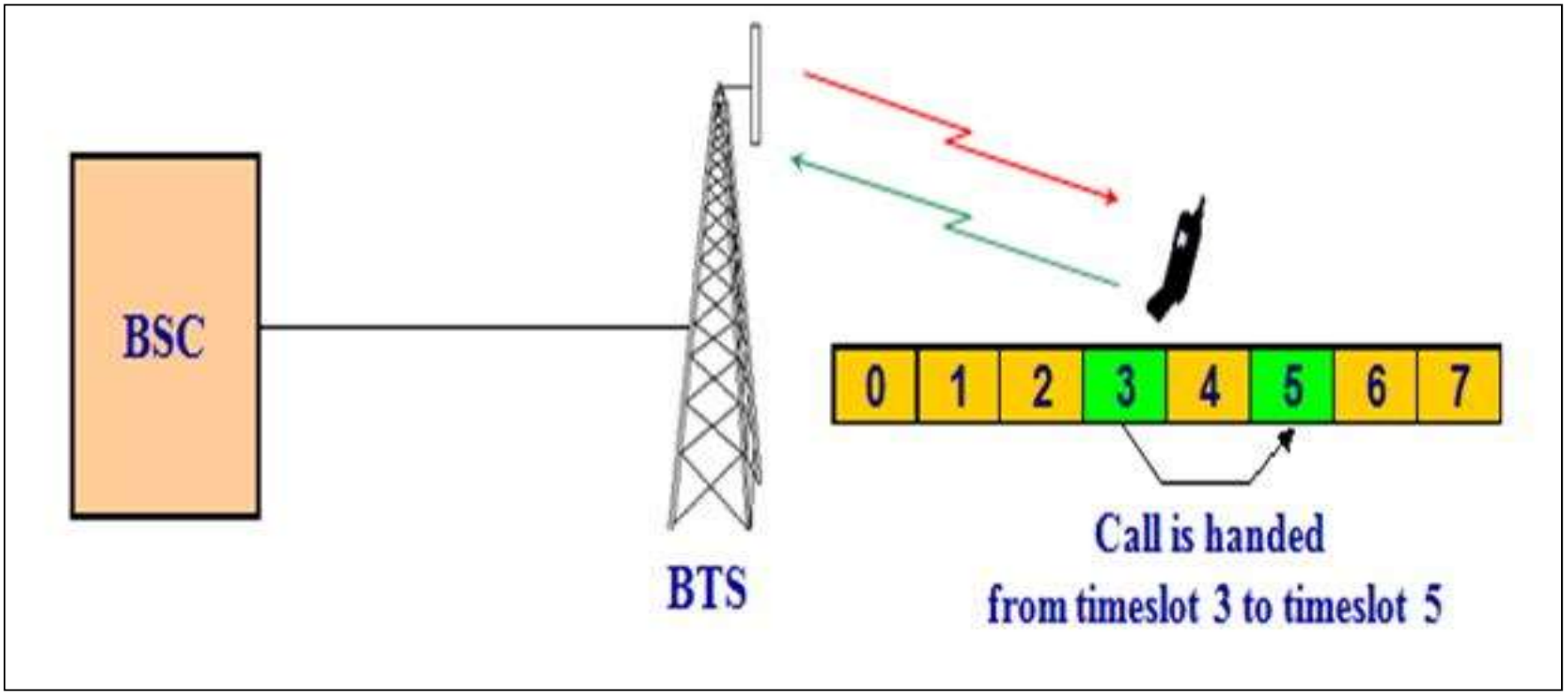
Handover

- Handover is special processing for a call in progress, when there is a change in the location.
- There tow types:
  - Hard handoff: is when the mobile is told to switch over to the new BTS.
  - Soft handoff: is when the mobile is connected to two BTSes simultaneously

Handover Categories

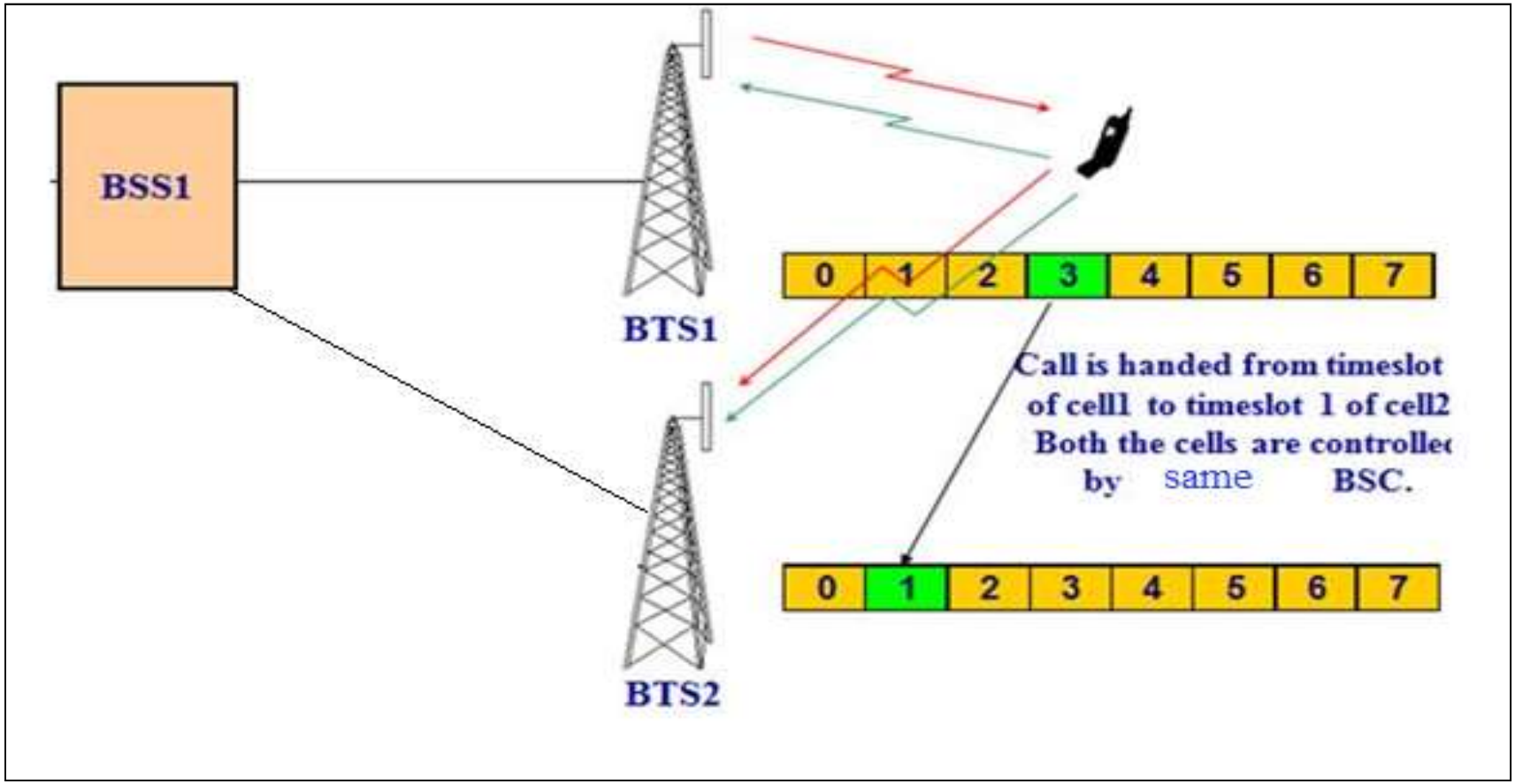
1. Intra-BTS handover

This occurs within the same BTS when there are some interference takes place. In this case mobile will be locked to the same BTS but the channel allocated to that mobile will change.



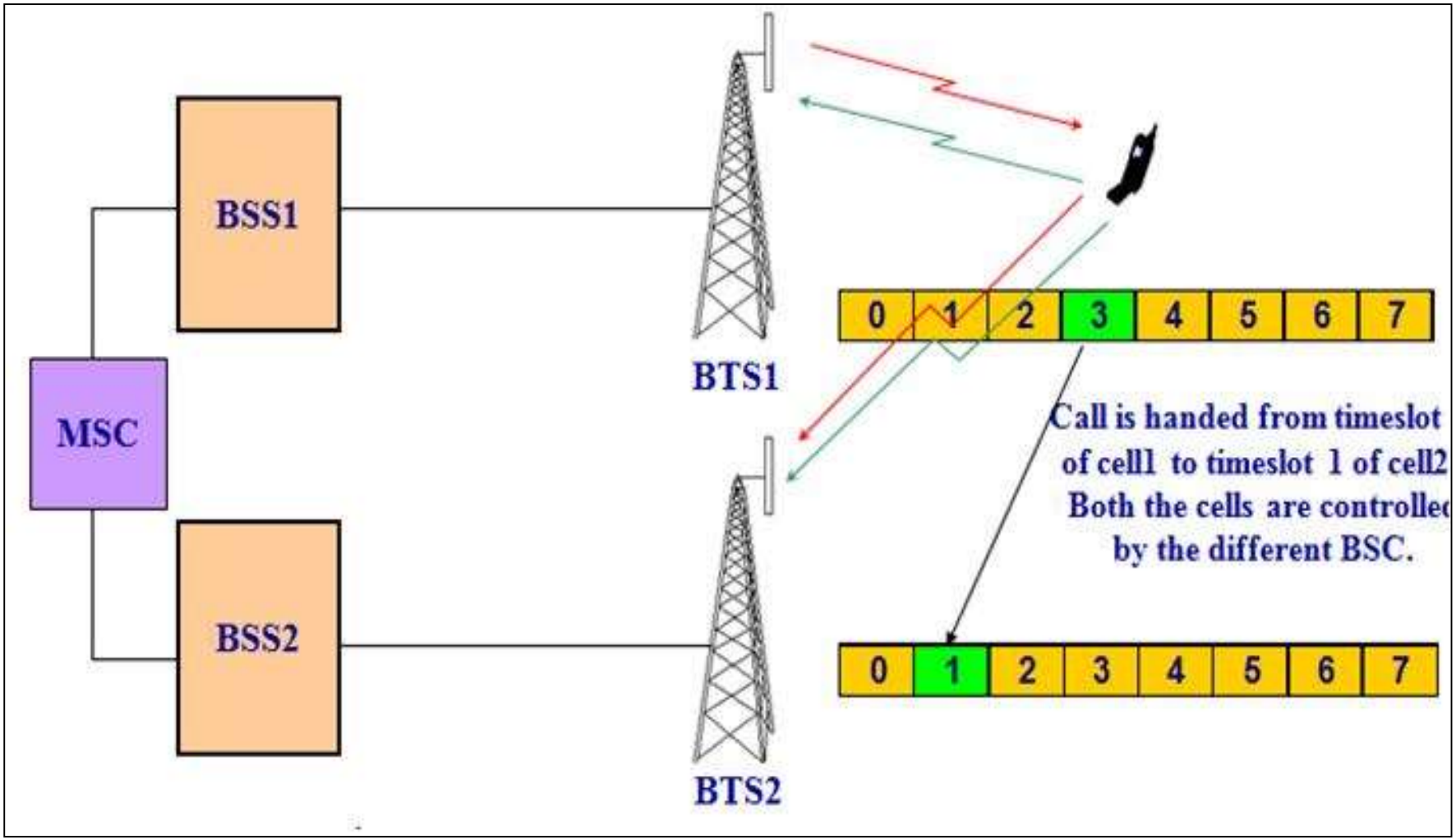
2. Inter-BTS Intra BSC handover

This type of handover occurs when the mobile moves out of the coverage of one BTS into another BTS and both BTSs are controlled by the same BSC. BSC will take care of the handover by allocating a channel for the user in the second BTS.



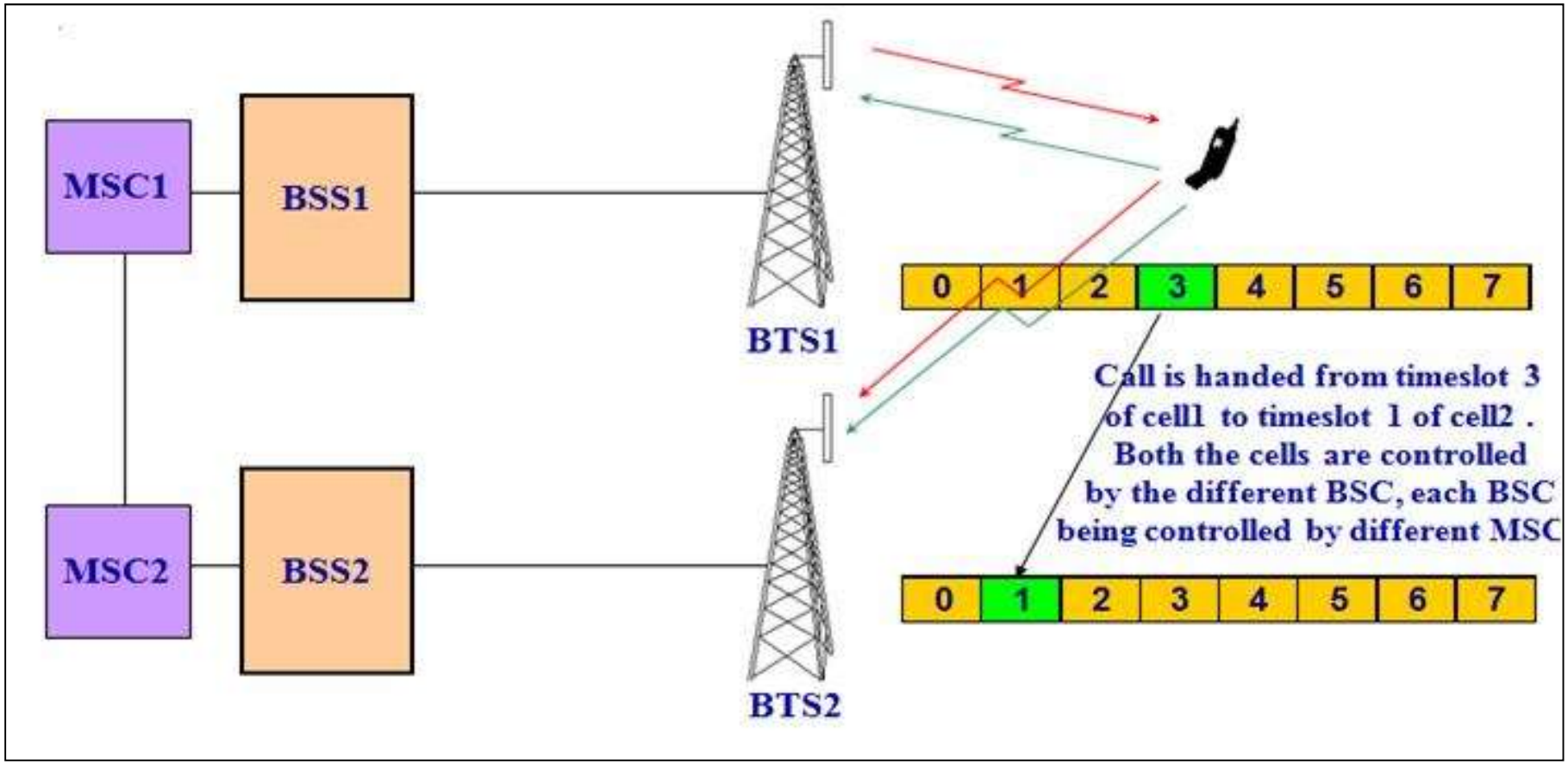
3. *Inter-BSC handover*

This handover occurs between two BSCs. Therefore it has to be controlled by MSC



4. *Inter-MSC handover*

In this occasion handover occurs between two MSCs.



Roaming

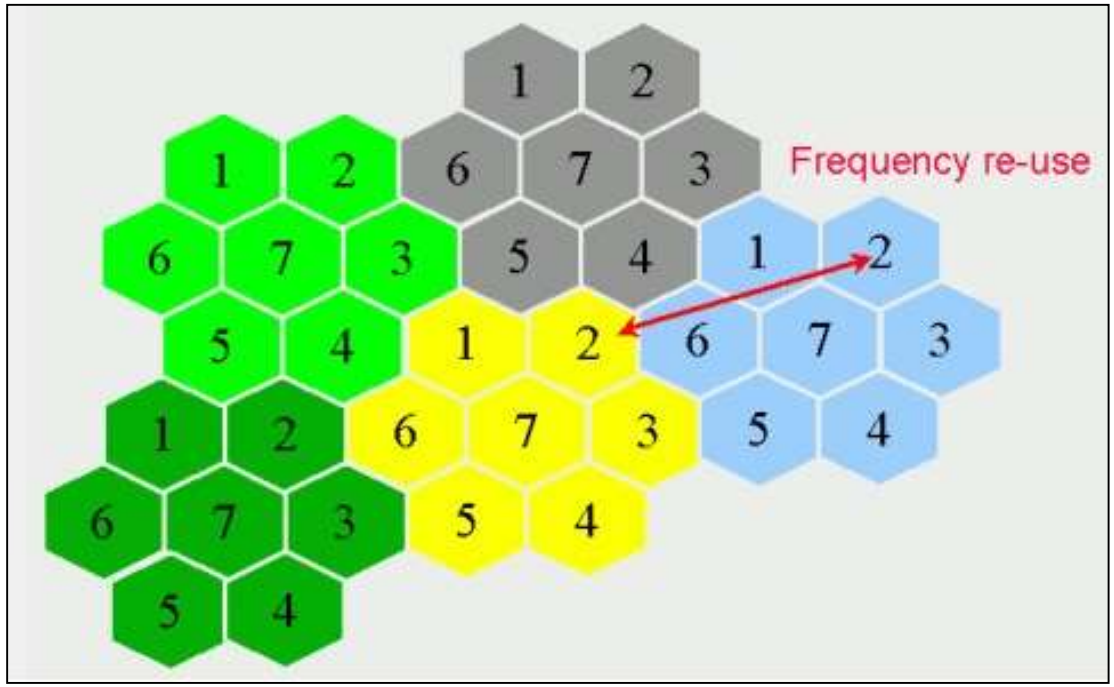
- When a the mobile enters another operators network, it can be allowed to use the services of this operator
- Roaming provides higher flexibility and mobility for GSM users.
- Roaming Limitations:
  - Operator to operator agreements and contracts
  - Higher billing rates

Frequency Reuse

- In GSM transmission power is carefully controlled to allow communication within the cell using a given frequency band while limiting the power at that frequency that escapes the cell into adjacent cells.
- The same frequency is not used in the adjacent cells
- The objective is to use the same frequency band in multiple cells at some distance from one another.
- At the same cell multiple frequency bands are assigned, the number of bands depending on the traffic expected.

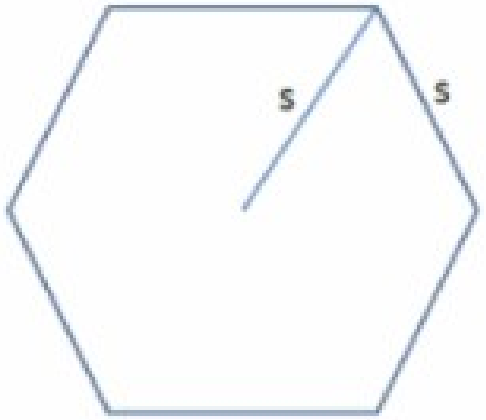
Frequency Reuse

- A key design
  - The most used GSM cell model is Hexagon
  - The it is required to determine the minimum separation between two cells using the same frequency band so that the two cells do not interfere with each other.



Hexagon Geometrical Formulas

- In a regular hexagon, the radius equals the side length. That is, a line from the center to any vertex will have the same length as any side.



$$\text{Area } A = \frac{3\sqrt{3}\, s^2}{2}$$

$$area\ of\ hexagonal = 1.5 * R^2\sqrt{3}$$

Area of Hexagonal = 2.6 * R^2

Frequency Reuse Parameters

- A key design
  - D=minimum distance between centers of cells that use the same frequency band
  - R=radius of cell
  - d= distance between centers of adjacent cells

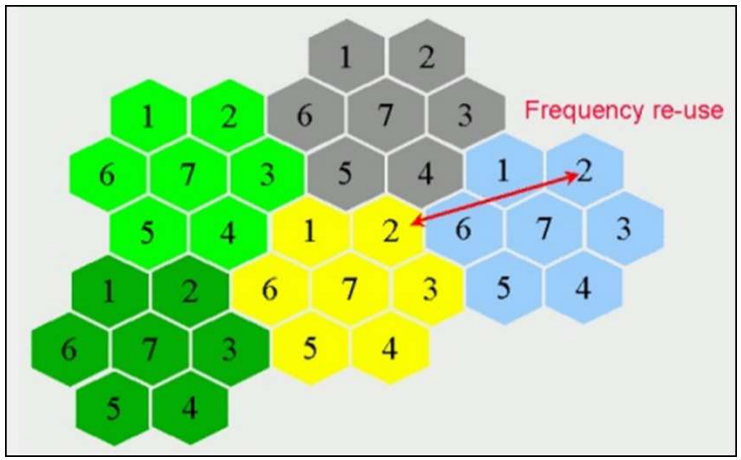
$$d = \sqrt{3}R$$

  - N= Reuse Factor: number of cells in repetitious pattern
  - K= total number of traffic channels allotted for the system.
  - Traffic channels for each cell = K / N
- In hexagonal cell pattern the following values of N are possible:
- N=1,3,4,7,9,12,13,16,19,21…..

Example 1: GSM Analysis

Assume a GSM system of 32 total cells, with a cell radius of 1.6 km, a total of 336 traffic channels, and a reuse factor of N=7.

- What is the geographic area covered?
- How many traffic channels are per cell?
- What is the total number of concurrent calls that can be handled by all cells?



Solution 1

- What is the geographic area covered?

– **Find the area for each cell**

Area of Hexagonal = $2.6 * R^2$

so for R =1.6 Km the area of cell = 6.65 km^2

Total Area = area of one cell * number of cells

= 6.656 * 32=213 km^2

– **How many traffic channels are per cell?**

the number of traffic channels per cell = total number of traffic channels / Reuse Factor

= 336 / 7 = 48 traffic channels per cell.

– **What is the total number of concurrent calls that can be handled by the full system?**

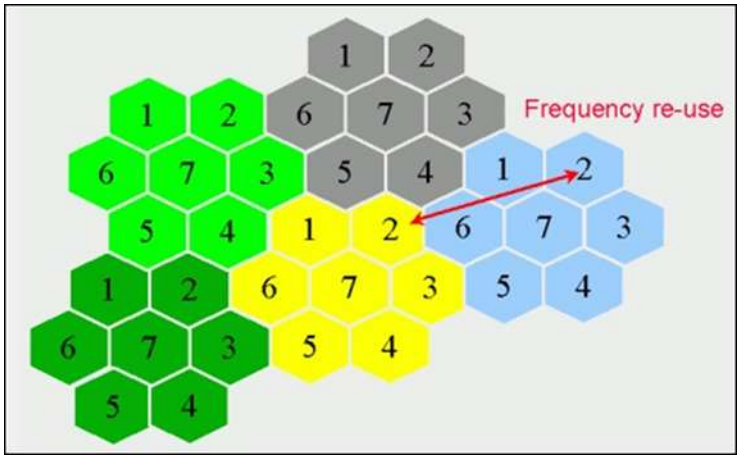
Total concurrent calls = traffic channels per cell* number of cells

= 48 * 32 =1536 total concurrent calls

Example 2: GSM Design

Design a GSM system with 2744 total concurrent calls, if you know that it has a total frequency bandwidth that supports 98 traffic channels, and a reuse factor of N=7 with the geographic area of 234 km^2

- How many channels are per cell?
- What is the total number of cells?
- What is the cell radius?



Solution 2

- How many channels are per cell?

  the number of traffic channels per cell = total number of traffic channels / Reuse Factor

  = 98 / 7 = 14 traffic channels per cell.

- What is the total number of cells?

  total number of cells = total number of concurrent calls / traffic channels per cell

  = 2744 / 14 = 196 cells

- Find the area of the cell

  area of the cell = total area / number of cells

  = 234/196 = 1.194 km^2

- What is the cell radius?

  Area of Hexagonal = 2.6 * R^2

  1.194 = 2.6 R^2

  R = 0.678 km