Wireless Technology Applications
Wireless Wide Area Network
Part I

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Introduction

- A wireless wide area network (WWAN) spans a geographical area as large as an entire country or even the entire world
- uses mobile telecommunication cellular network technologies
- GSM, GPRS, EDGE, UMTS, CDMA2000, HSDPA, HSUPA or 3G, 3.5G, 3.9G,…4G
- voice or data network

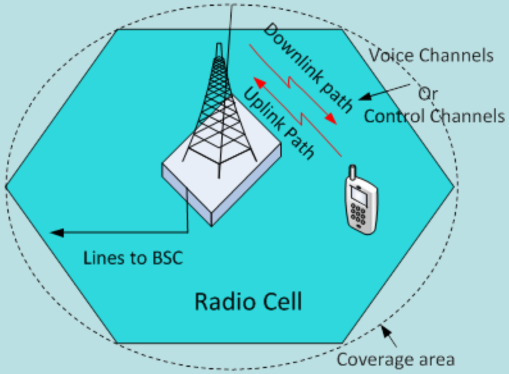
Introduction

- Smartphones, PDAs and PCMCIA/USB cellular adaptor cards plugged into notebook computers

Basic of Cellular Network

Radio cell

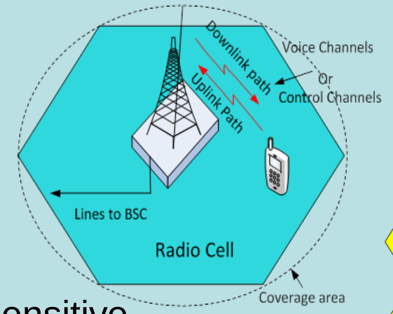
- a smaller area of a cellular mobile network
- Hexagonal cell pattern is idealized
- Signal attenuation restricts distance between sender and receiver

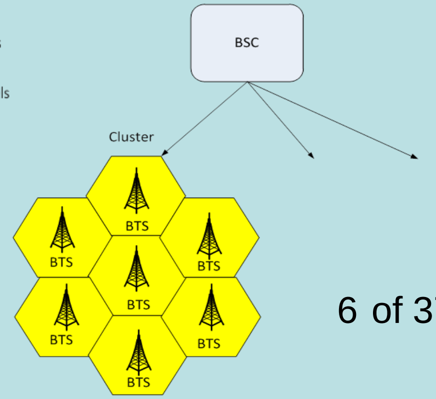


Basic of Cellular Network

Radio cell and Cluster

- contains a base transceiver station having a number of RF channels to provide a smaller coverage area about typical cell radius approximately 30 kilometer
- sizes vary from some 100 m up to 35 km depending on user density, geography, transceiver power
- A few cells are adjacent to each other to extend the coverage area of wireless wide area network to form **a cluster**

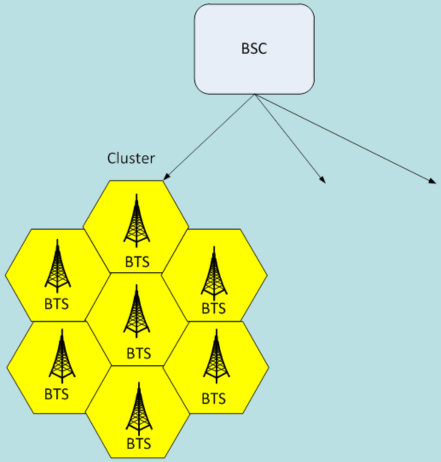




Basic of Cellular Network

Base Station Controller (BSC)

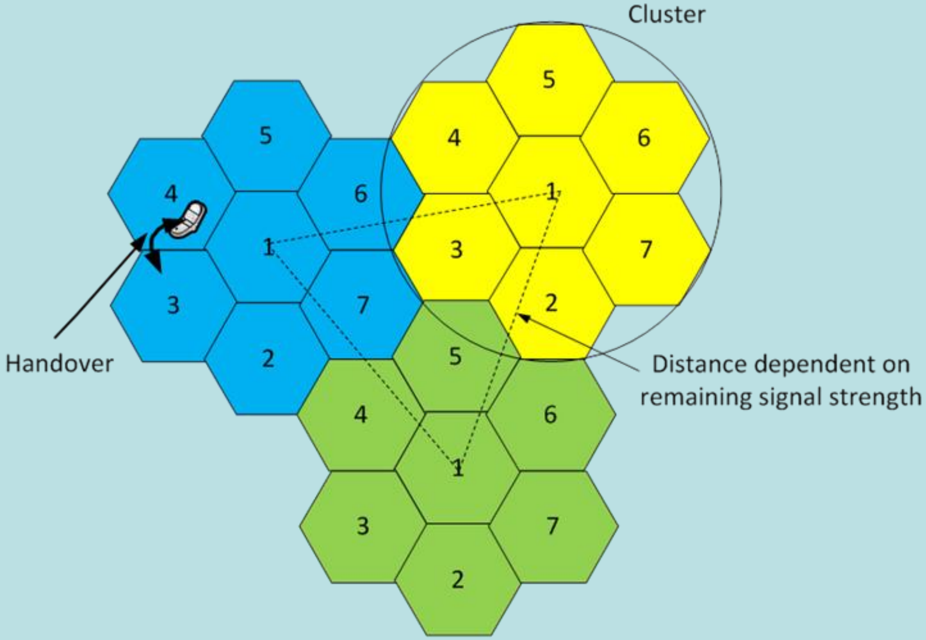
- One or more than one BTSs are connected to a which will provide the link between cellular network and wired telephone world
- controls all the base transceiver stations in the cellular networks



Basic of Cellular Network

Handover

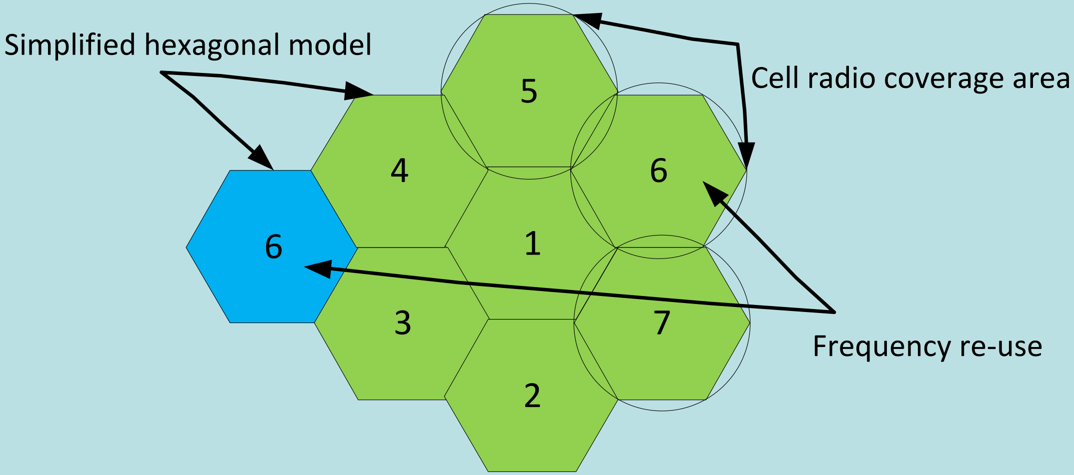
- changed from a cell to other during a phone call, the connection will be passed to the neighbour cell



Basic of Cellular Network

Frequency Re-use

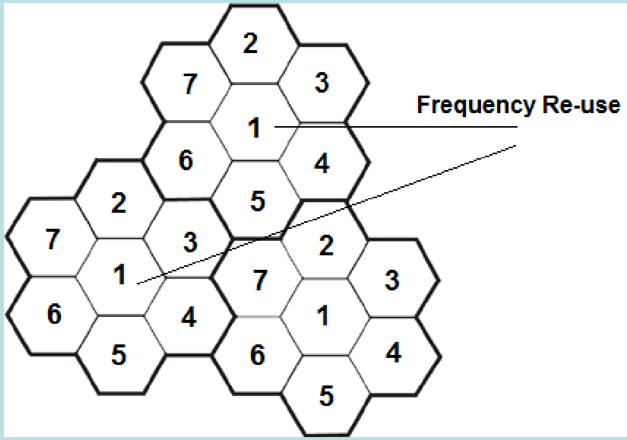
- Employed by using Space Division Multiple Access (SDMA)
- the re-use of frequency channel at the distant cells for high number of subscribers
- lower the transmit power of the BTS at a cell to minimise the interference with a smaller cell in size



Basic of Cellular Network

Cell Planning

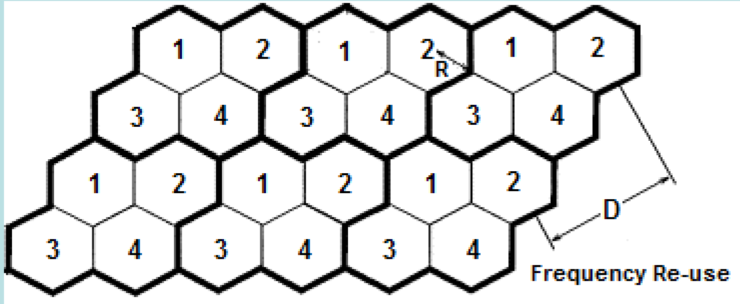
- to maximize capacity and minimize interferences
- **more cells per cluster:**
  - Less channels per cell
  - Lower system capacity
  - Less co-channel interference (co-channel cells have larger distance in between)



Basic of Cellular Network

Cell Planning

- to maximize capacity and minimize interferences
- **fewer cells per cluster:**
  - More channels per cell
  - Higher system capacity
  - More co-channel interference (co-channel cells are nearby)



Singapore Polytechnic

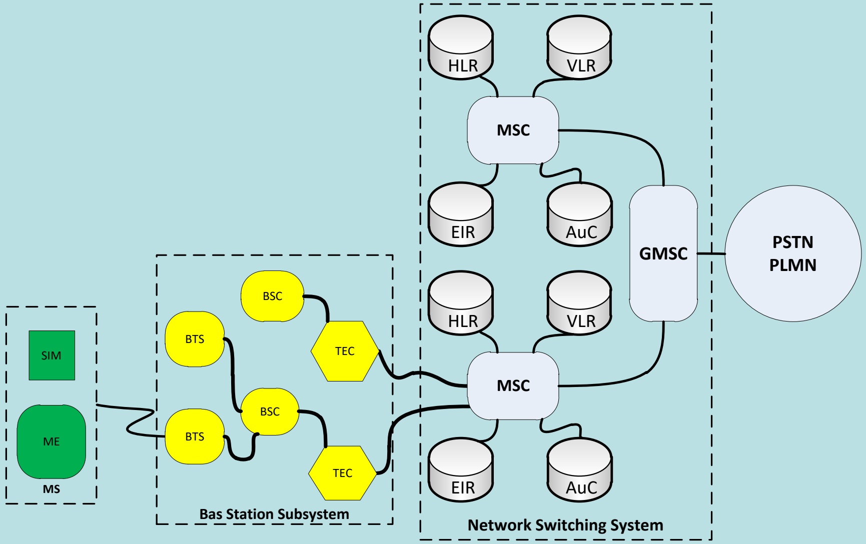
GSM architecture

- GSM is the most successful technology
- The first GSM call was made in Finland on 1st July 1991.
- 3.4 billion subscribers worldwide
- New connections are added at the rate of 15 per second, or 1.3 million per day

GSM architecture

Three main sections

- Mobile Station (MS)
- Base Station Subsystem (BSS)
- Network Switching Subsystem (NSS)



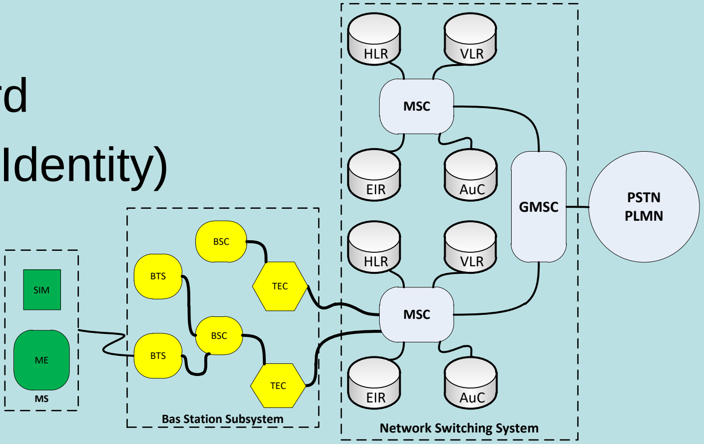
GSM architecture

Mobile Station (MS)

- which consists of Mobile Equipment (ME)
  - IMEI (International Mobile Equipment Identity)
  - main functions: modulation/demodulation, ciphering/deciphering, channel encoding/decoding and voice encoding/decoding

and

- Subscriber Identity Module (SIM)
  - consists of a microchip and a memory card
  - the IMSI (International Mobile Subscriber Identity)
  - a secret key for authentication
  - unique to each subscriber



GSM architecture

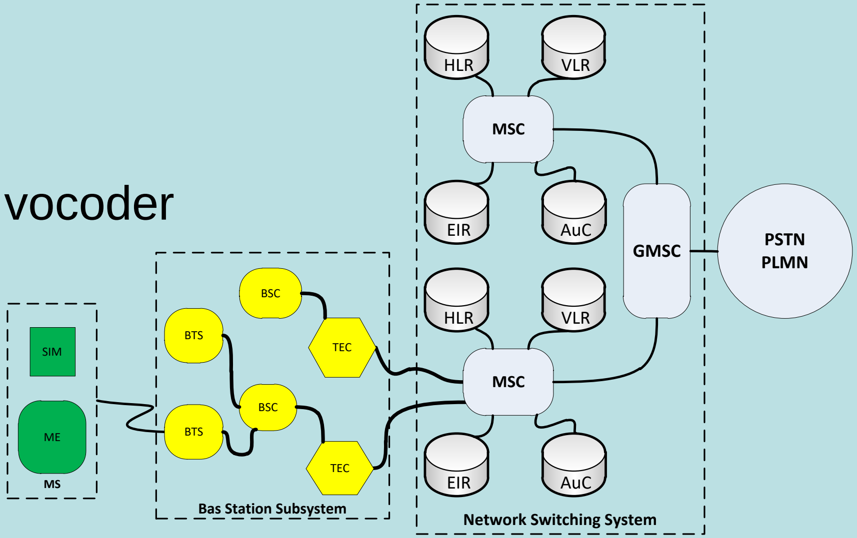
Base Station Subsystem (BSS)

- consists of Base Transceiver Station (BTS)
  - performs most of the functions of Mobile Equipment of the Mobile Station and to collect measurements to support the simultaneous operations of a few Mobile Stations inside a particular cell
- Base Station Controller (BSC)
  - management of the radio resources and
  - handover

and

- Transcoding Equipment (TCE)
  - to convert the bit rate used in GSM vocoder

  to 64 kbits/s used in ISDN



GSM architecture

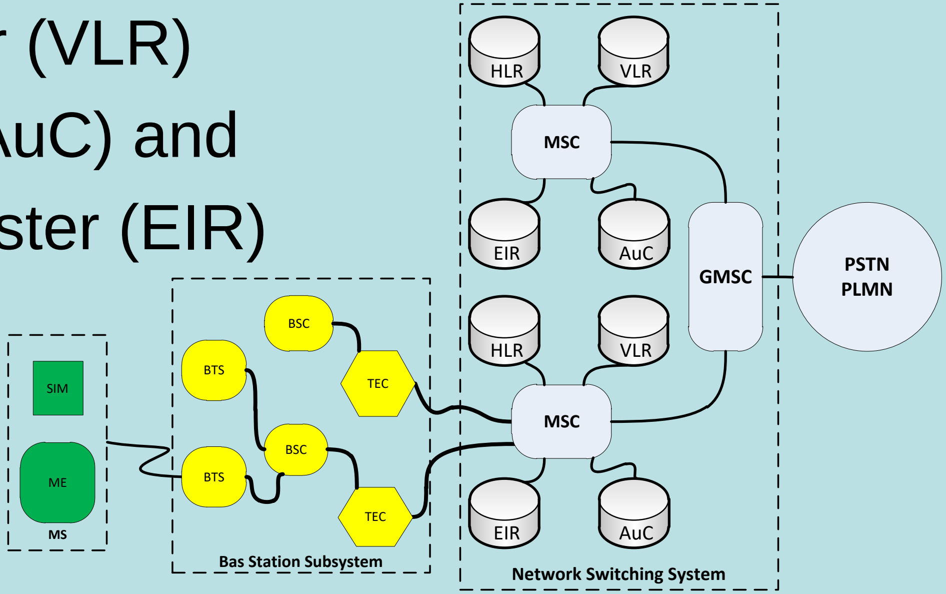
GSM supports three types of voice coding:

- Full rate at 13 kbits/s
- Enhanced full rate at 12.2 kbits/s
- Half rate at 6.5 kbits/s

GSM architecture

Network Switching Subsystem (NSS)

- consists of Gateway Mobile Switching Centre (GMSC)
- Mobile Switching Centre (MSC)
- Home Location Register (HLR)
- Visitor Location Register (VLR)
- Authentication Centre (AuC) and
- Equipment Identity Register (EIR)



GSM architecture

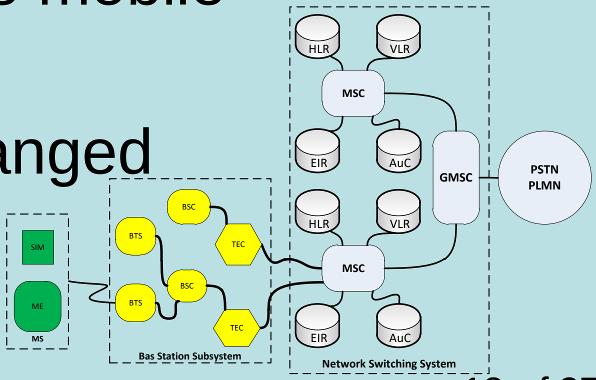
Mobile Switching Centre (MSC)

- interconnecting mobile users to other mobile and fixed network users

Home Location Register (HLR)

- the information related to each mobile subscriber
- the type of subscription, services that the user can use, the subscriber's current location and the mobile equipment status
- The database remains intact and unchanged

Until the termination of the subscription



Official (Open), Non-sensitive

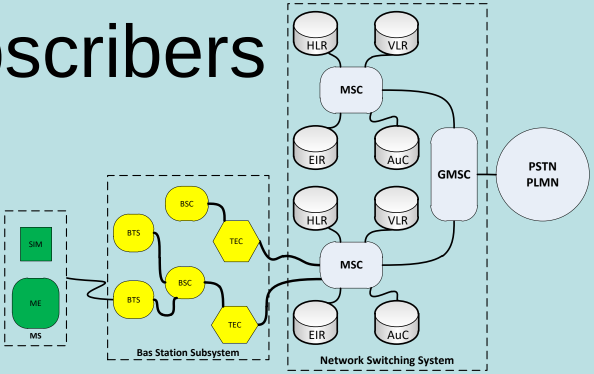
GSM architecture

Visitor Location Register VLR)

- the information of subscribers inside a coverage region
- the database is dynamic

Authentication Centre (AuC)

- the data required to protect the network against false subscribers and
- to protect the calls of regular subscribers



GSM architecture

Authentication process

- A random number is sent from the GSM network to the Mobile Station.
- This random number is then encrypted using the authentication key stored both in the SIM and the authentication centre.
- The encrypted random number is sent back from the Mobile Station to the Authentication Centre and
- It will be compared with its locally encrypted random number at the Authentication Centre.

GSM architecture

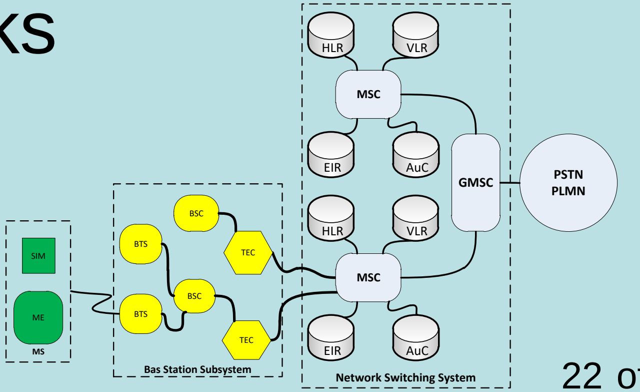
Encryption

- communications between mobile users
- a new ciphering key is generated for each new connection using the random number used in the authentication process and
- the authentication key stored in both in the SIM and the Authentication Center

GSM architecture

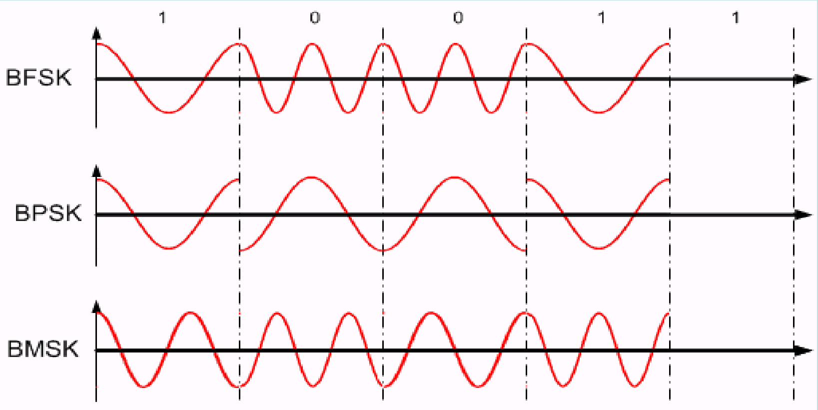
Gateway Mobile Switching Centre

- an edge function within a PLMN (Public Land Mobile Network)
- terminates the PSTN (Public Switched Telephone Network) signalling
- traffic formats and converts this to protocols employed in mobile networks



GSM Air Interface

- Gaussian Minimum Shift keying (GMSK) Gaussian filter prior to modulation
- high spectral efficiency
- no abrupt change in the phase of the sine function at the symbol period
- **Spectral efficiency** : the number of bits per second that can be transmitted per Hz of bandwidth
- Five frequency band
  - GSM-400
  - GSM-850
  - GSM-900
  - GSM-1800
  - GSM-1900



GSM Air Interface

Frequency Division Duplex (FDD)

- allocated frequency spectrum has to be divided into two groups for uplink and downlink

Variant	Uplink (MHz)	Downlink (MHz)	Total Bandwidth	Duplex-frequency	Channels
GSM-400	451-458 and 479-486	461-468 and 489-496	Twice 14 MHz	10 MHz	Twice 72
GSM-850	824-849	869-894	Twice 25 MHz	45 MHz	Twice 124
GSM-900 (primary band)	890-915	935-960	Twice 25 MHz	45 MHz	Twice 124
DCS-1800	1,710-1,785	1,805-1,880	Twice 75 MHz	95 MHz	Twice 373
PCS-1900	1,850-1,910	1,930-1,990	Twice 60 MHz	80 MHz	Twice 300

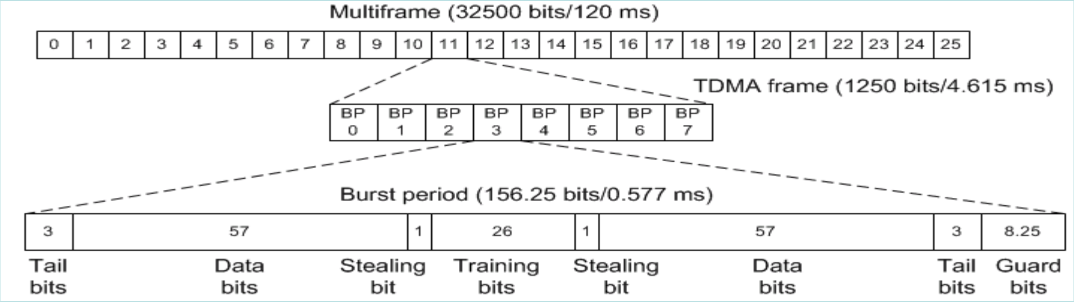
GSM Air Interface

Frequency Division Multiple Access (FDMA)

- the division by frequency into bandwidth of 200 kHz

Time Division Multiple Access (TDMA)

- Each of these frequency channels is then divided in time
- **burst period** : fundamental unit of time in this TDMA scheme
- the basic unit for the definition of logical channels: eight burst periods are grouped into a **TDMA frame**

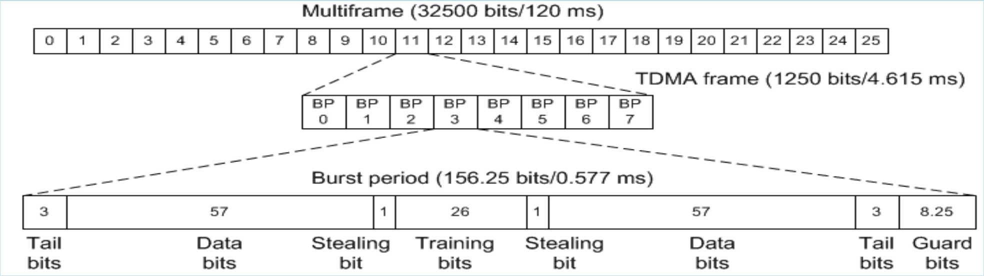


GSM Air Interface

Example 5.1

Find the number of burst period in GSM-900?

- The bandwidth allocated for uplink/downlink = (915-890/960-935) 25 MHz
- Channel bandwidth = 200 kHz
- Therefore, no. of channels = (25MHz)/(200kHz) = 125 channels
- Since, 8 burst periods in one channel,
- Hence, 8 X 125 = 1000 burst periods.

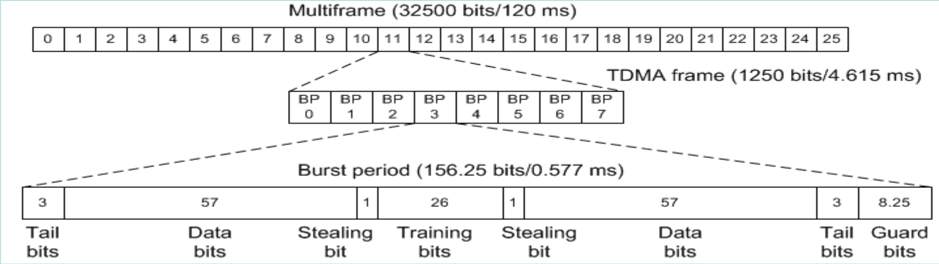


GSM Air Interface

Example 5.1 (continued)

- In Figure, it is shown that a **multiframe** consisting of 26 TDMA frames requires 120 ms for transmission of 32500 bits.
- Hence, the bitrate for GSM = 32500bits/ 120ms = 270.833 kbits/s

- Each TDMA frame = 32500/26 = 1250 bits and
- Time taken for each frame = 1250bits/270.833 kbps = 4.615 ms
- No. of bits / burst period = 1250 bits/8 = 156.25 bits and requires 0.577 ms for transmission.



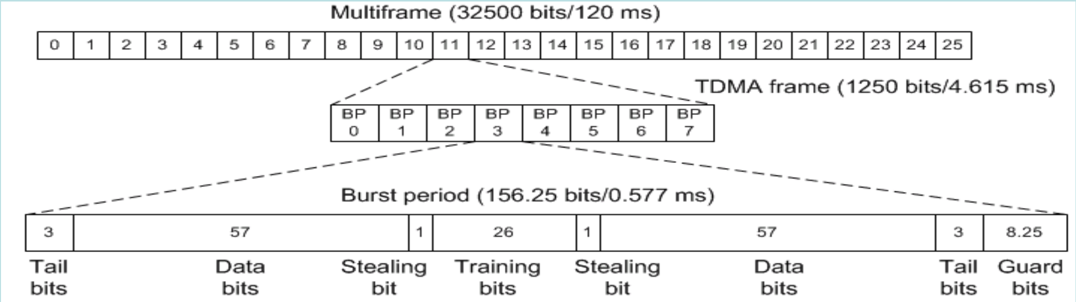
GSM Air Interface

Channels are defined by the number and position of their corresponding burst periods

- dedicated channels
  - mainly **traffic channels** which are allocated to mobile stations

and

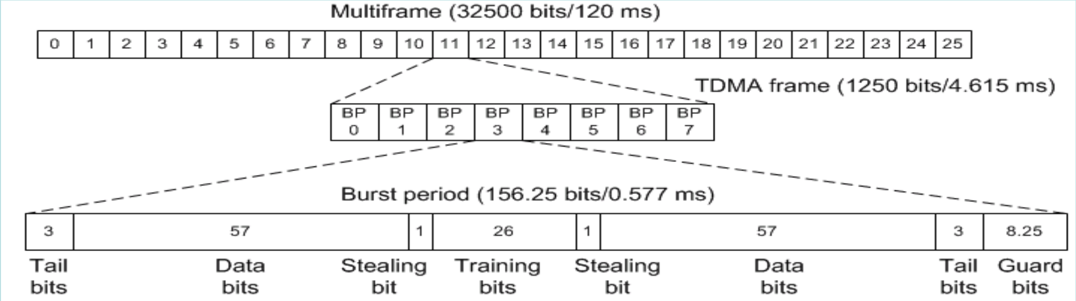
- common channels
  - mainly **control channels** which are used by mobile stations in idle mode



GSM Air Interface

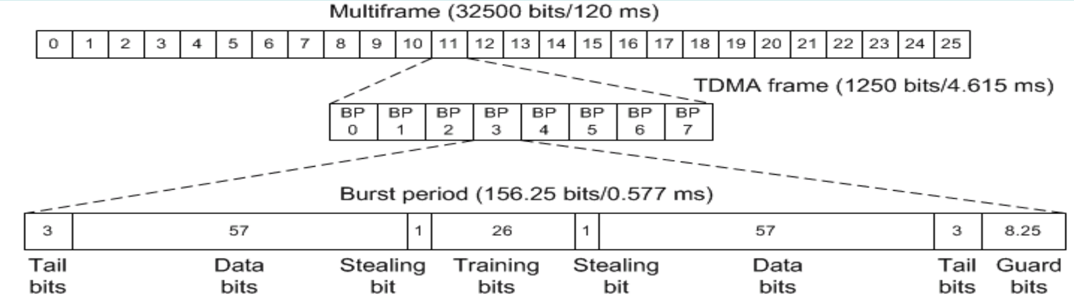
In Figure,

- frames 0-11 and 13-24 in multiframe: traffic channels
- frame 12 : SACCH (Stand-alone Dedicated Control Channel) and
- frame 25: currently unused.
- The SACCH for most short transactions, including initial call setup step, registration and SMS (Short Message Service) transfer
- It has a payload data rate of 0.8 kbit/s.
- Up to eight SDCCHs can be time-multiplexed onto a single physical channel



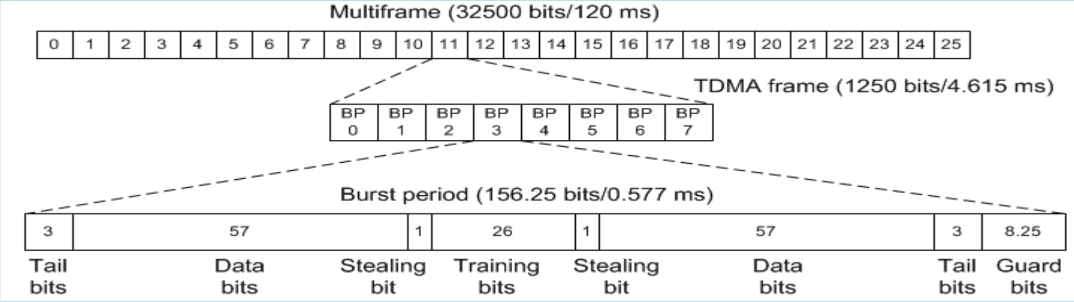
GSM Air Interface

- Four different types of bursts used for transmission in GSM
- Normal burst shown in Figure and it is used to carry data and signalling.
- Out of 156.25 bits,
  - 114 bits are used to data
  - 26 bits are training sequence used for equalization
  - 1 stealing bit for each information block (used for FACCH (Fast Associated Control Channel))
  - 3 tail bits at each end for synchronization and
  - 8.25 guard bits to separate the burst periods



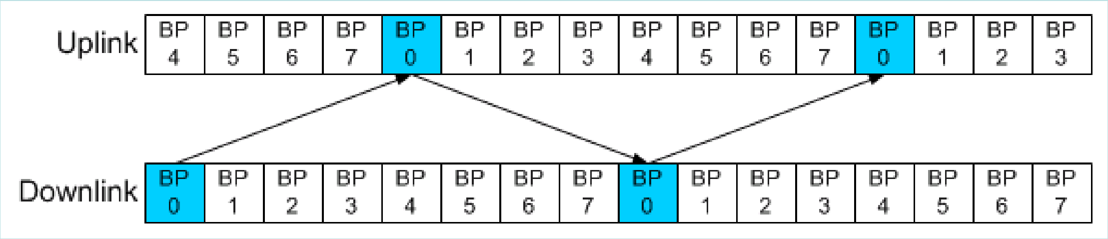
GSM Air Interface

- The other three burst structures are F, S and access bursts.
- The F burst, used on the FCCH (Frequency Correction Channel)
- the S burst, used on the SCH (Synchronization Channel), have the same length as a normal burst, but a different internal structure
- the access burst is shorter than the normal burst, and is used only on the RACH (Random Access Channel).



GSM Air Interface

- For each MS,
- transmit only on one of the eight burst periods and
- also receive on one of the eight burst periods.
- Therefore, it is not necessary for MS to transmit and receive at the same time.
- In Figure, the uplink and downlink are separated in time by 3 burst periods.



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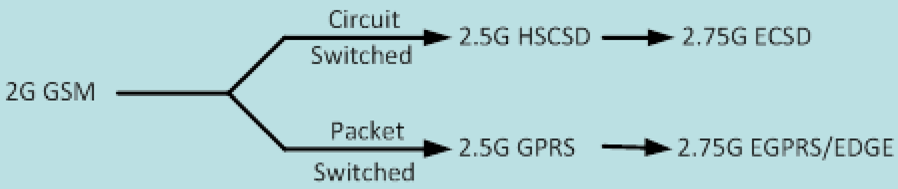
Evolution path

- Today, transmission of data information is equally, if not more important, than transmission of voice information.
- Therefore, GSM network has to evolve from circuit switched network to packet switched network.
- One very important consideration in this evolution path is the additional cost that telcos has to invest to upgrade their existing GSM infrastructure.
- If the additional investment is higher than the potential revenue that telcos will eventually earn from their subscribers, there will be no incentive for them to upgrade their infrastructure

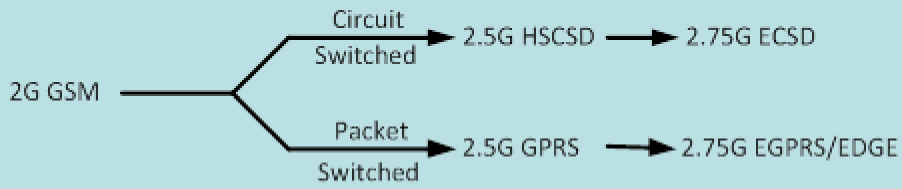


Evolution path

Two paths of evolution to enable data transmission

First Path

- circuit switching network
- 2.5G HSCSD (High-Speed Circuit Switch Data)
- the bit rate per burst period/time slot is increased from 9.6 kbps (2G GSM) to 14.4 kbps and
- with the ability to use up to four burst periods/time slots per TDMA frame, the bit rate can increase to 14.4kbps×4=57.6kbps.
- To further increase the bit rate, ECSD (Enhanced Circuit Switch Data) allows 48 kbps per time slot and with up to eight time slots per TDMA frame, the maximum bit rate is 48kbps×8=384kbps.

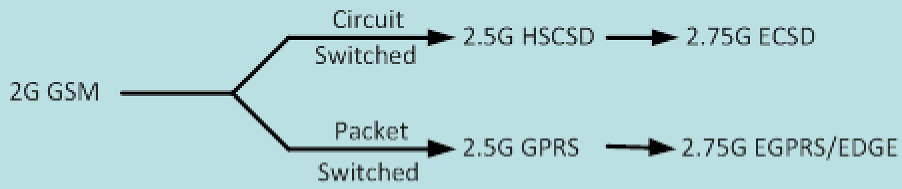


Evolution path

Two paths of evolution to enable data transmission

Second Path

- packet switching network
- four different coding schemes
- The difference between different coding schemes lies in the bits allocation between data information and error correction codes

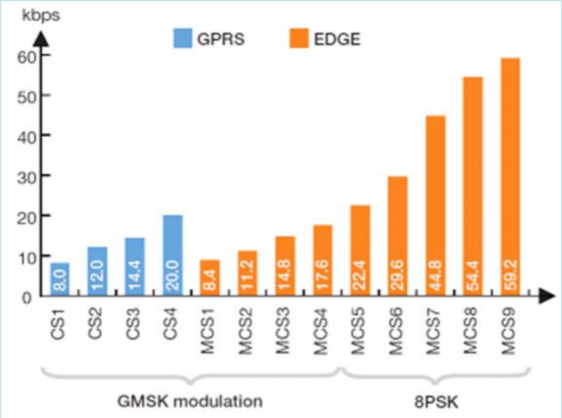


Evolution path

Two paths of evolution to enable data transmission

Second Path

- Using CS4 (Coding Scheme) which is least robust but fastest with up to eight time slots, the maximum bit rate is 20kbps×8=160kbps.
- To further increase the bit rate, EDGE allows nine different coding schemes.
- Using MCS9 (Modulation and Coding Scheme) and up to eight time slots, the maximum bit rate is 59.2kbps×8=473.6kbps.
- The three-fold increase in the bit rate is due to the use of 8PSK modulation with 3 bits/symbol in EDGE compared to the use of BMSK modulation with one bit/symbol in GPRS.



Evolution path

The main difference between ECSD and EDGE

- the mode of payment for the data service.
- For ECSD, consumers are charged for their connection time since it is circuit-switched
- For EDGE, they are charged for the amount of data transferred since it is packet-switched
- Therefore, GPRS allows always-on-line connectivity for data transmission.
- Hence, our focus will be on packet-switching network: the preferred method to transfer data information,