Cellular Networks (1/2)

- 1G to B3G -

Sogang University

Jaewoo So

서강대학교 SOGANG UNIVERSITY

학습에 앞서

■학습개요

– 이동통신 망 구조 및 무선 접속 프로토콜을 이해한다.

■학습목표

– 이동통신 망 구조를 이해한다.
– AMS, GSM, IS-95 표준의 무선 접속 프로토콜 동작을 학습한다.
– 위성 통신 구조를 이해한다.

1. Cellular Telephony

Cellular telephony *is designed to provide communications between two moving units, called mobile stations (MSs), or between one mobile unit and one stationary unit, often called a land unit.*

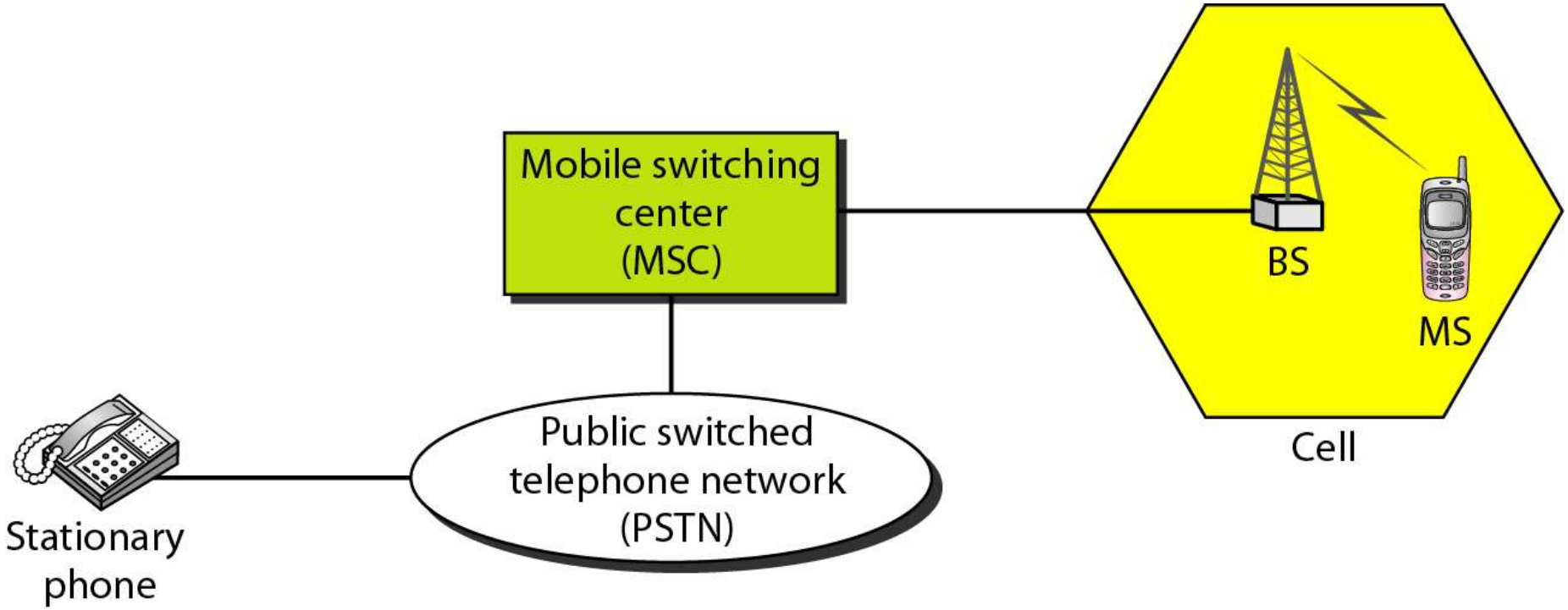
Topics discussed in this section:

Frequency-Reuse Principle
Transmitting
Receiving
Roaming
First Generation
Second Generation
Third Generation

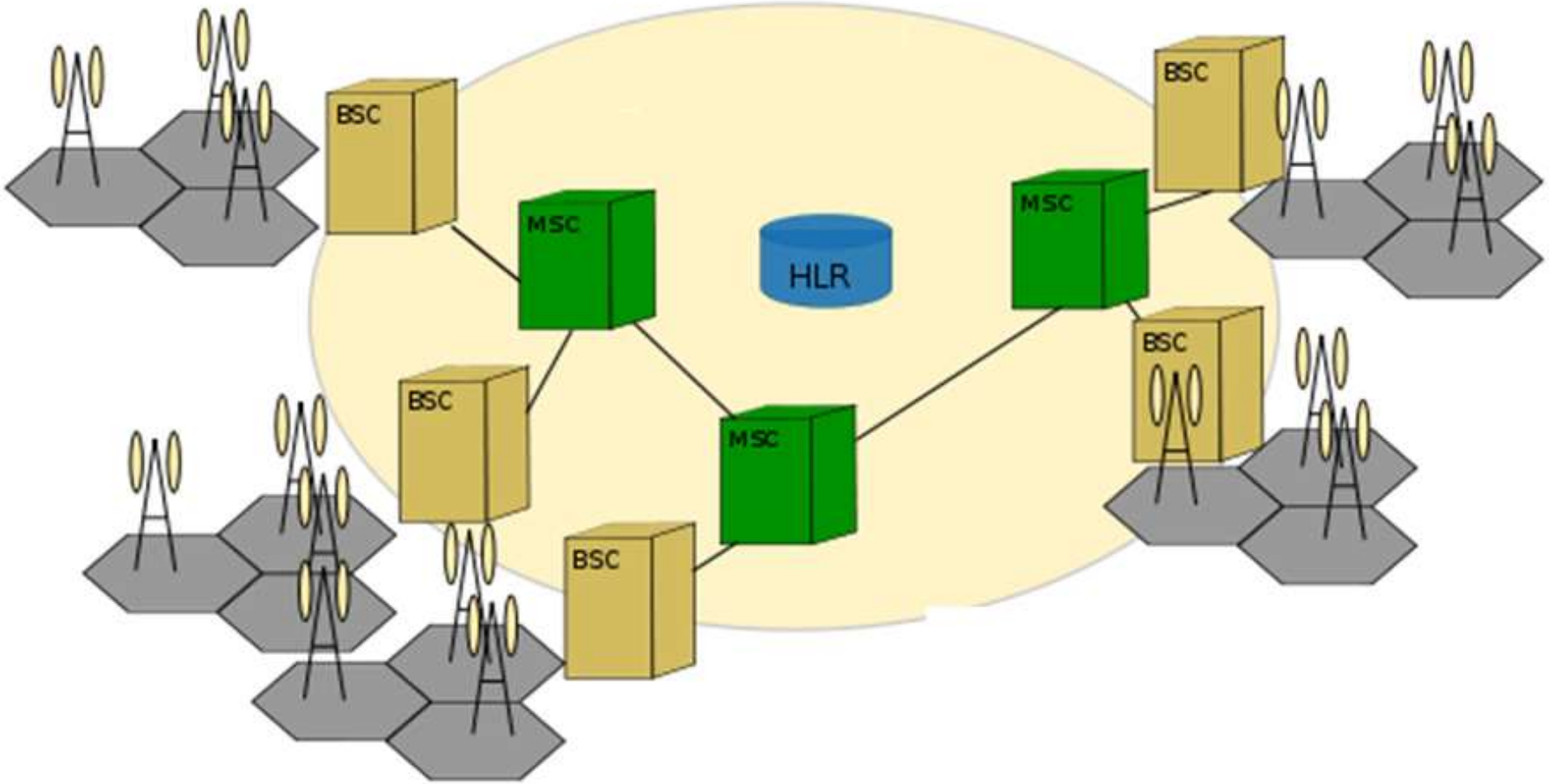
1. Cellular Telephony

- Base station (BS)
  - A solar or AC powered network station and controls each cell
- Mobile switching center (MCS)
  - Controls the BSs
  - Coordinates communication between all the BSs and the telephone central office.
- Mobile station (MS)
  - Moving units
- Home location register (HLR)
  - The HLR is a database used for storage and management of subscriptions.
  - It stores permanent data about subscribers, including a subscriber's service profile, location information, and activity status.
- Visitor location register (VLR)
  - The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.
- Wireless Links
  - Downlink (forward link): from the BS to MSs
  - Uplink (reverse link): from MSs to the BS

Figure 16.1 *Cellular system*



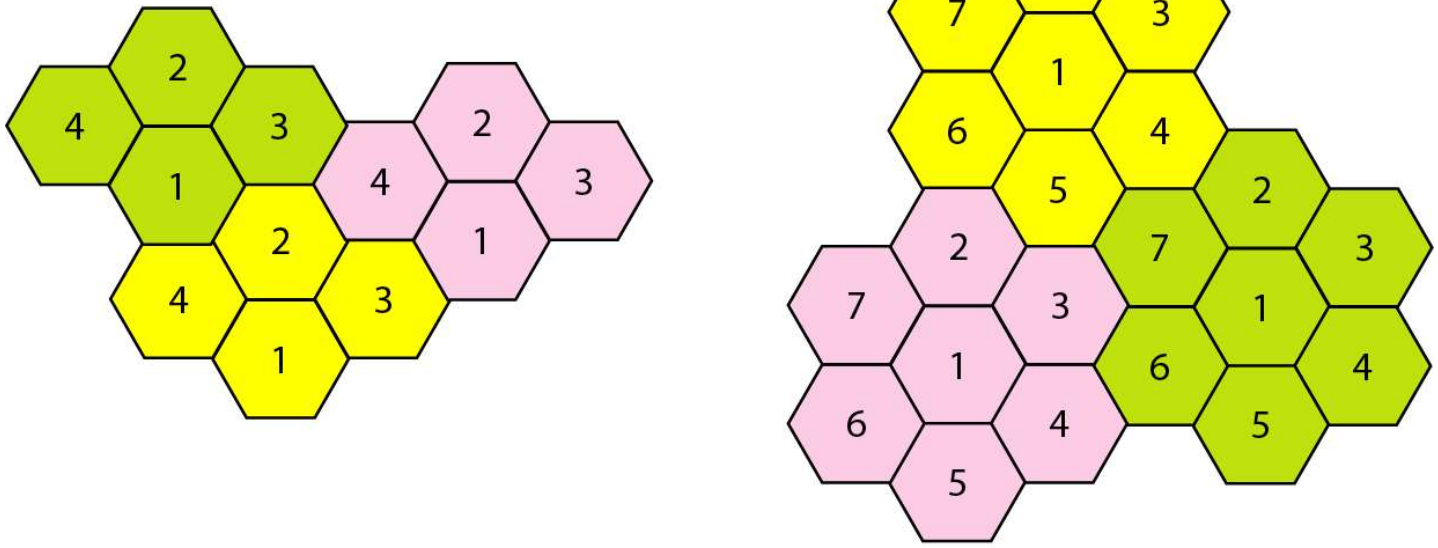
1. Cellular Telephony



Frequency-Reuse Principle

- In general, **neighboring cells cannot use the same set of frequencies** for communication because it may create interference for the users located near the cell boundaries.
- However, the set of frequencies available is limited, and frequencies need to be reused.
- A frequency reuse pattern is a configuration of *N* cells, *N* being the reuse factor, in which each cell uses a unique set of frequencies.

Figure 16.2 *Frequency reuse patterns*



a. Reuse factor of 4

b. Reuse factor of 7

1. Cellular Telephony

Transmitting, to place a call from a mobile station

- The caller enters a code of 7 or 10 digits (a phone number) and presses the send button.
- The MS then scans the band, seeking a setup channel with a strong signal.
- The MS sends the data (phone number) to the closet BS using that channel.
- The BS relays the data to the MSC.
- The MSC sends the data to the telephone central office.

- If the called party is available, a connection is made.
- The MSC assigns an unused voice channel to the call, and a connection is established.

Receiving when a mobile phone is called

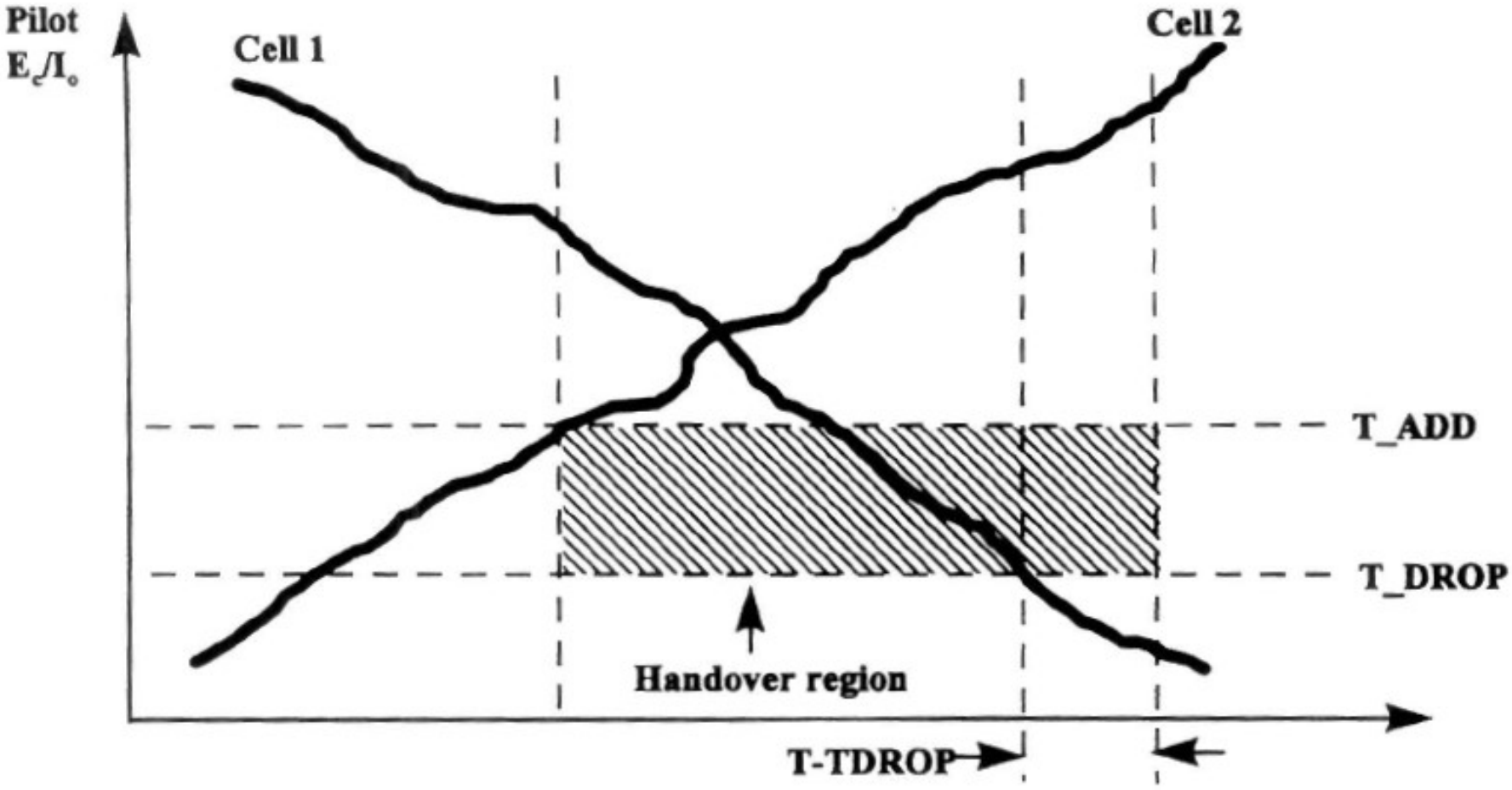
- The telephone central office sends the number to the MSC.
- The MSC searches for the location of the MS by broadcasting a query signal in a process called paging.
- Once the MS is found, the MSC transmits a ringing signal.
- When the MS answers, the BS assigns a voice channel to the call.

Handoff, Roaming

- Handoff
  - When, during a conversation, the MS moves from one cell to another, the MSC changes the channel carrying the call (hands the signal off from the old channel to a new one).
  - Hard Handoff
    - An MS only communicates with one BS.
    - Communication must first be broken with the previous BS before communication can be established with the new one.
  - Soft Handoff
    - An MS can communicate with two BSs at the same time.
    - During handoff, an MS may continue with the new BS before breaking off from the old one.
- Roaming
  - Roaming means, in principle, that a user can have access to communication or can be reached where there is coverage.
  - A service provider usually has limited coverage.
  - Neighboring service providers can provide extended coverage through a roaming contract.

1. Cellular Telephony

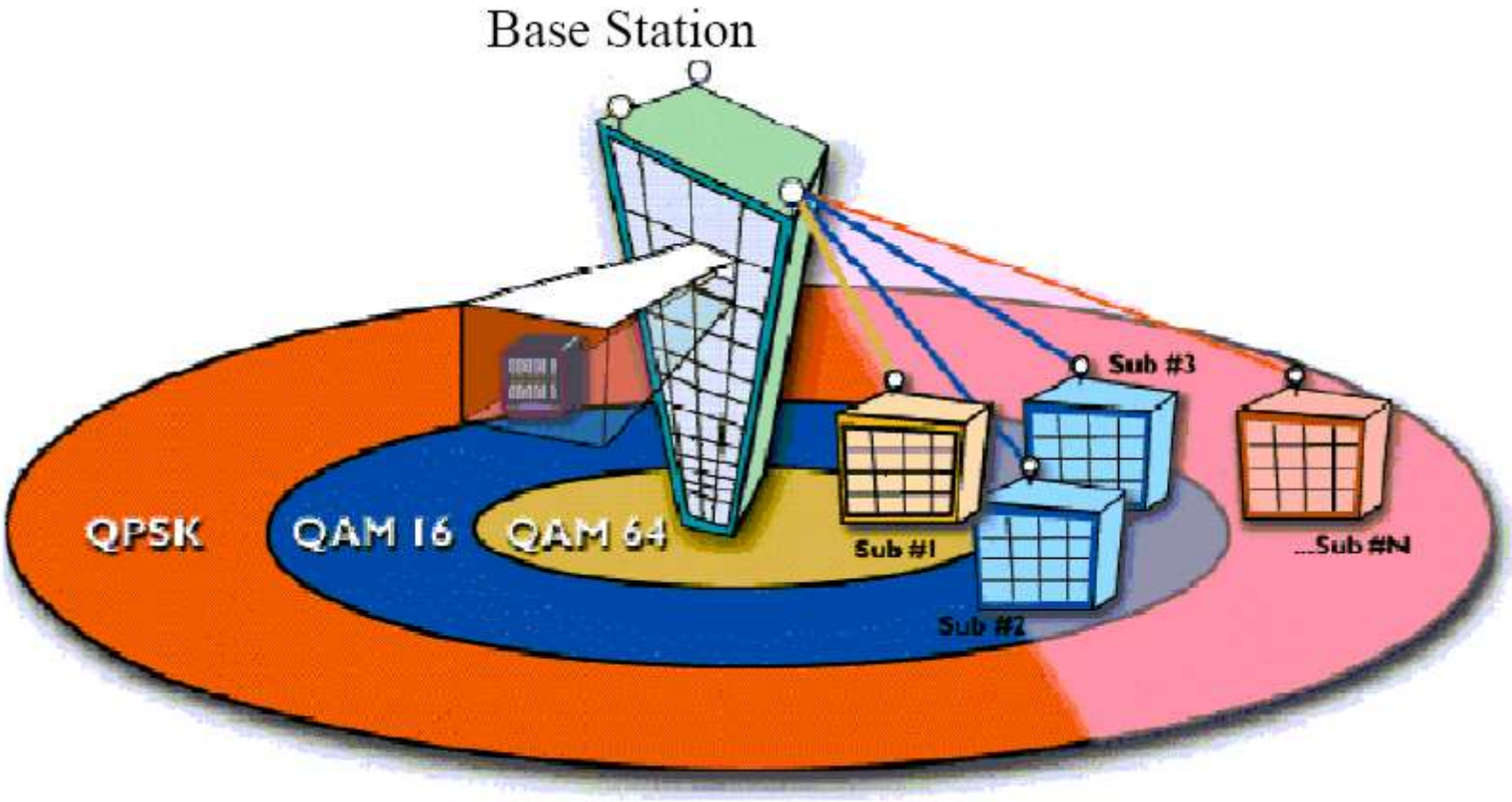
- Soft handoff in a CDMA system



Adaptive Modulation and Coding

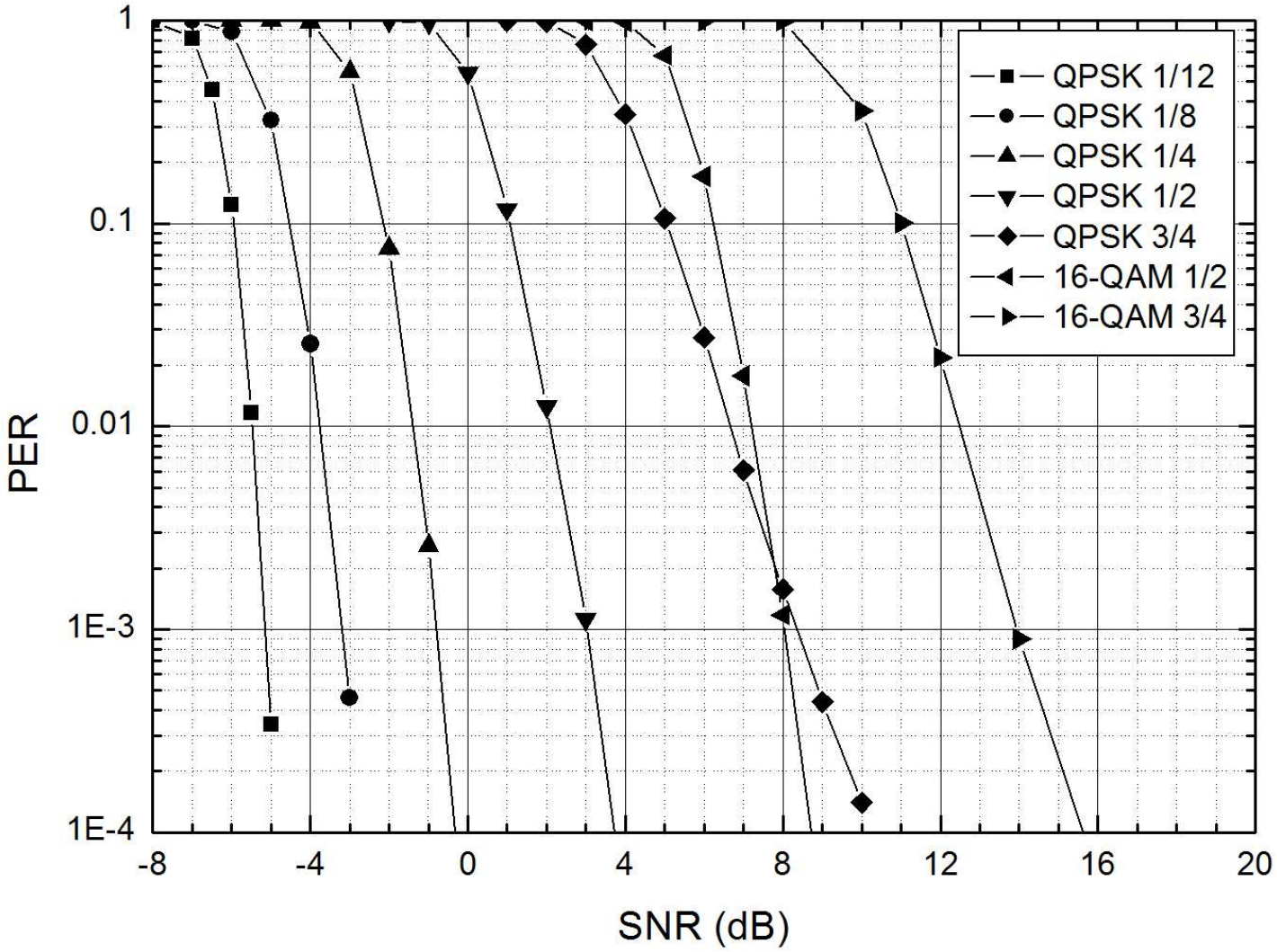
- The BER performance depends on the SNR.
- Adaptive Modulation and Coding (AMC)
  - The mobile worldwide interoperability for microwave access (WiMAX) system enables optimization of each user's data rate by allowing the base station (BS) to set the modulation and coding scheme (MCS) on a link-by-link basis.
  - A user close to the BS could use a high-rate modulation scheme, thereby giving the system more throughput. In contrast, a weak signal from a more remote user might only permit the use of a lower-rate modulation scheme to maintain the connection quality and link stability.
  - The adaptive modulation and coding scheme maximizes instantaneous usage of a wireless channel by adjusting the MCS level

1. Cellular Telephony



- Tradeoff between link robustness and capacity
- Adaptation on a burst by burst basis
- Modulation format QPSK/16QAM/64QAM

Packet Error Rate (PER) Performance in the Uplink



How to select the MCS level?

- Method

1) Maximizing the instantaneous data rate while maintaining a given PER constraint.

$$MCS(\gamma) = \arg\max \{R_i | PER(\gamma) < 1\%\}$$

2) Maximizing the user throughput

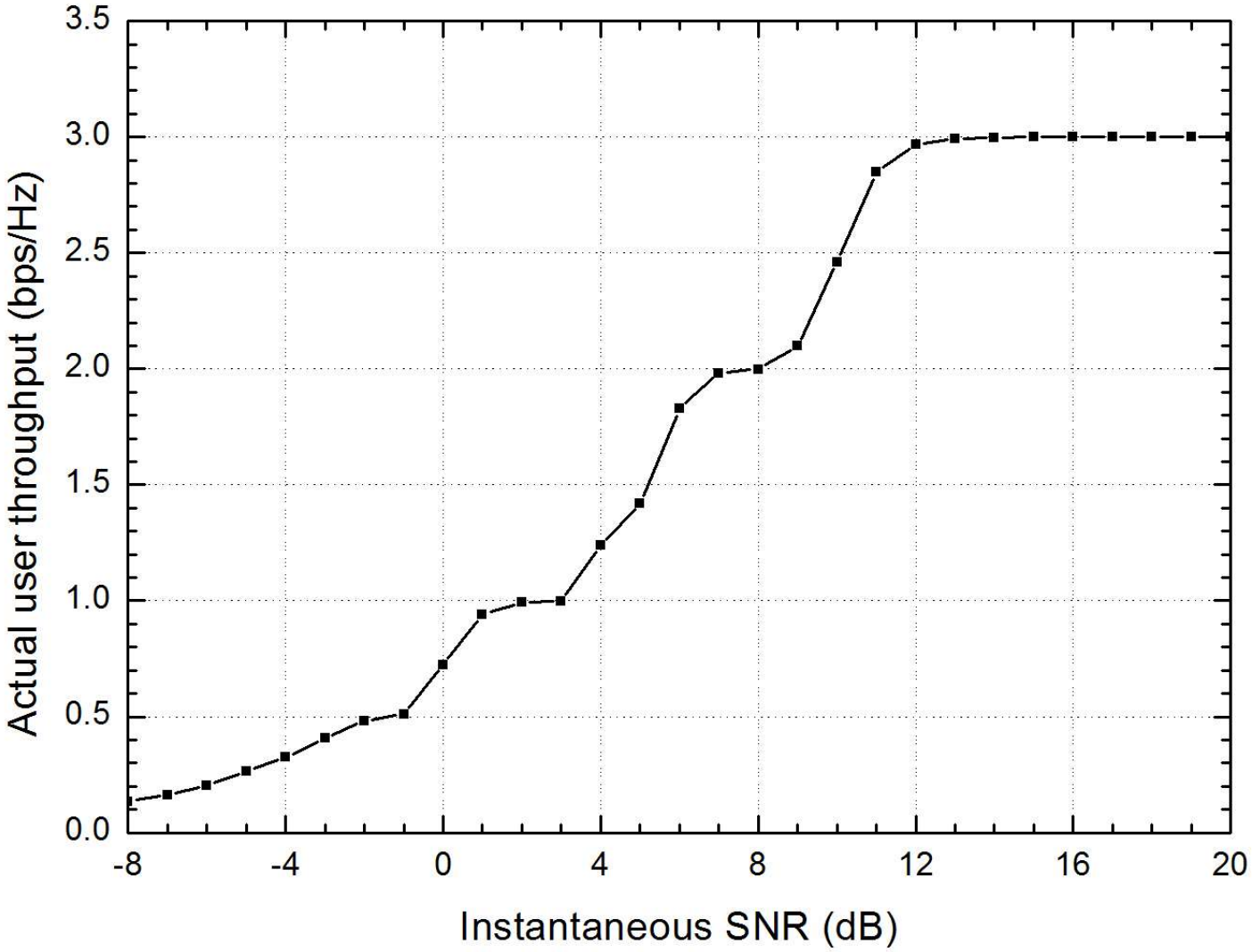
$$MCS(\gamma) = \arg\max \{R_i(1-PER(\gamma))\}$$

Threshold for downlink

MCS level	Modulation & Coding	Rate, R_i (bps/Hz)	Threshold (dB)
1	QPSK 1/12	0.16	-5.6
2	QPSK 1/8	0.25	-3.8
3	QPSK 1/4	0.5	-1.4
4	QPSK 1/2	1.0	2.1
5	QPSK 3/4	1.5	6.6
6	16QAM 1/2	2.0	7.2
7	16QAM 3/4	3.0	12.2
8	64QAM 1/2	3.0	12.5
9	64QAM 2/3	4.0	16.3
10	64QAM 3/4	4.5	18.6
11	64QAM 5/6	5.0	22.8

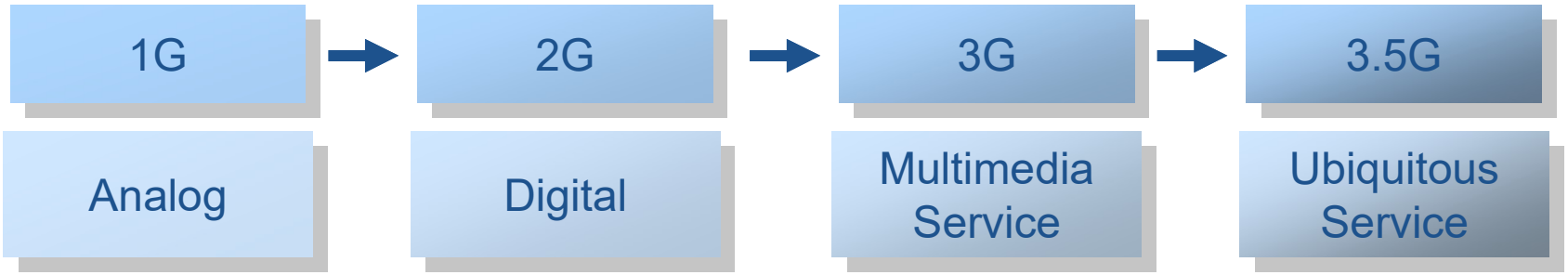
1. Cellular Telephony

- Average User Throughput



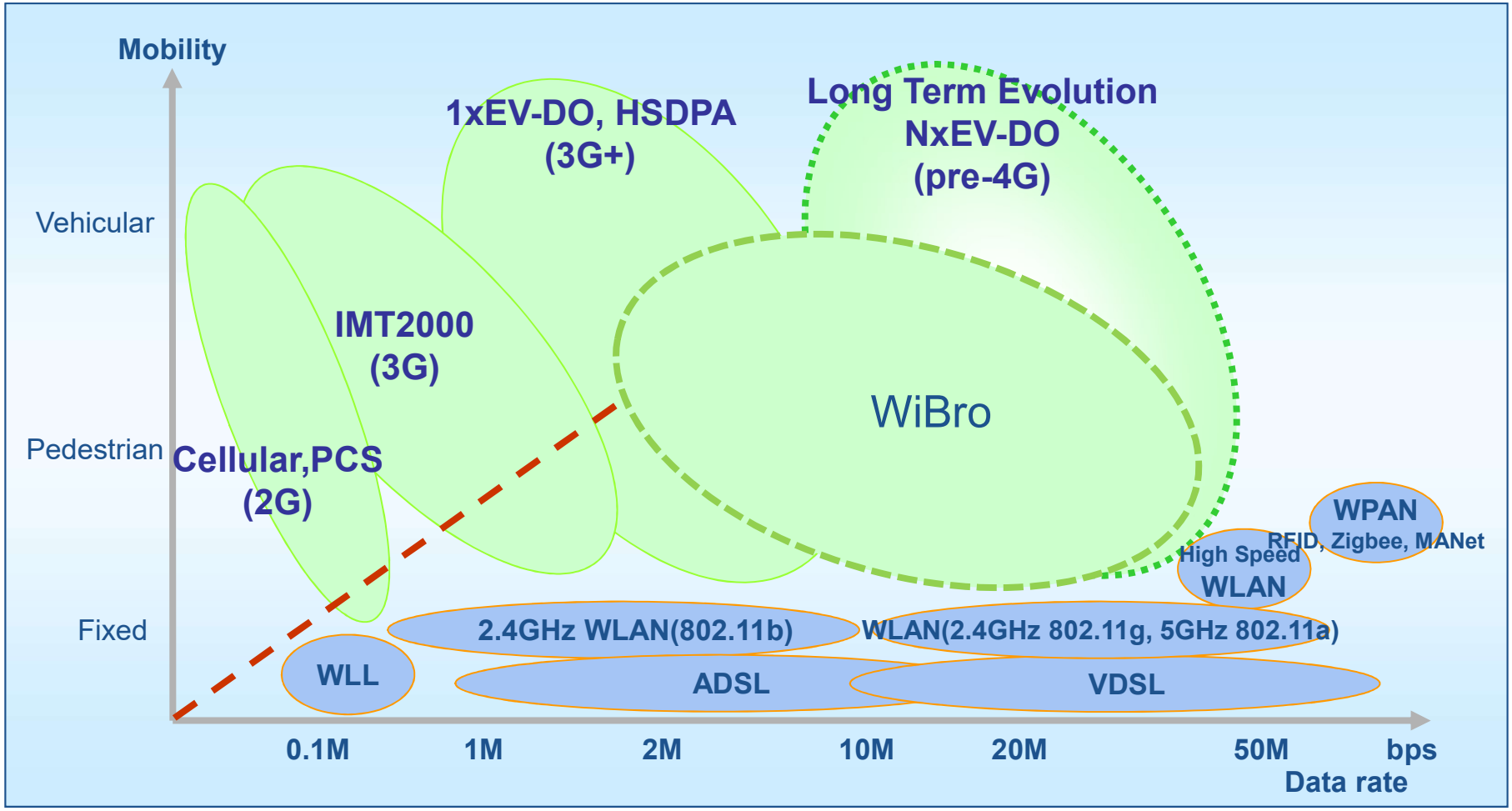
1. Cellular Telephony

Evolution Path



• FM Modulation • Cellular concept • Hard Handoff • SMS • Cell Planning	• Digital modulation • Data Compression • Error Control • Soft Handoff • SMS • High Quality Voice	• Multimedia • >>100 kbps Data • Dynamic RRM • Packet Data	• Complete Freedom of Wireless Access • Seamless Service • Integrated Service • Multimode Terminal • >>10 Mbps data • Full IP based packet da • High Quality Multimedia
AMPS	IS-95A/IS-95B GSM/GPRS	CDMA2000 1xEV-DO WCDMA	CDMA2000 1xEV-DV HSDPA, HSUPA, LTE IEEE 802.16e(WiBro), 802.16
7~28.8 kbps	7~115 kbps	0.144~2 Mbps	~10 Mbps ~100 Mbps/Gbps

1. Cellular Telephony



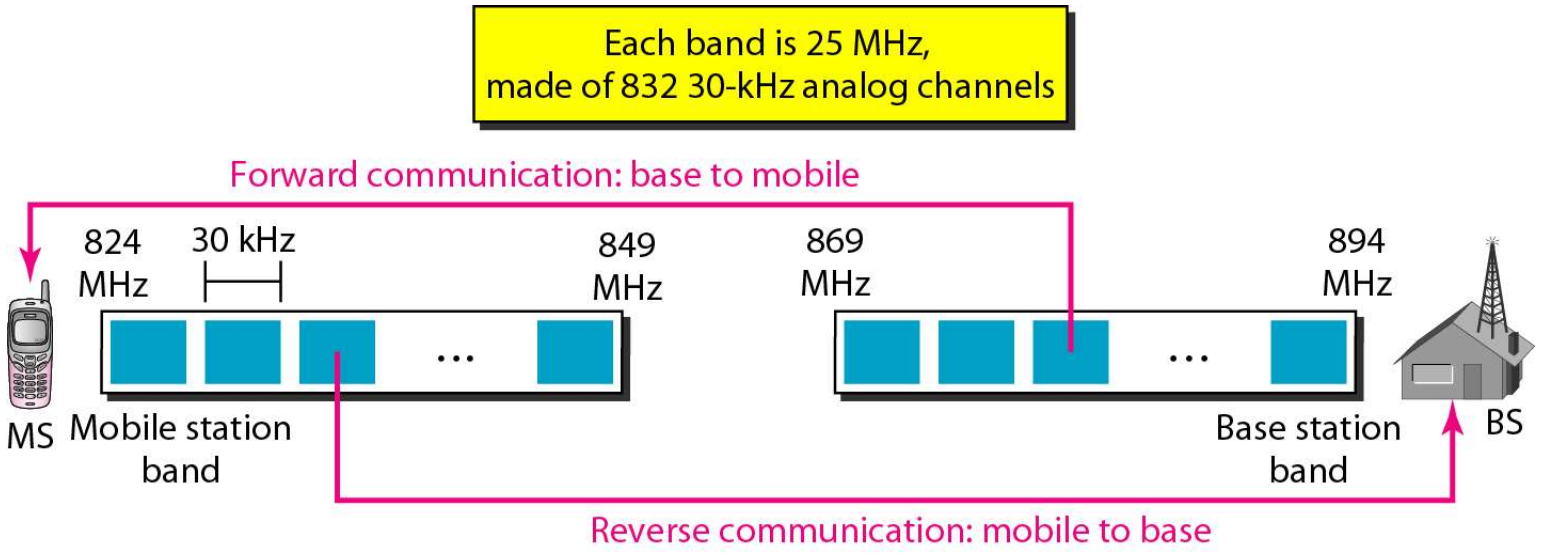
1. Cellular Telephony

Mobile Data Service Evolution

(1) First Generation

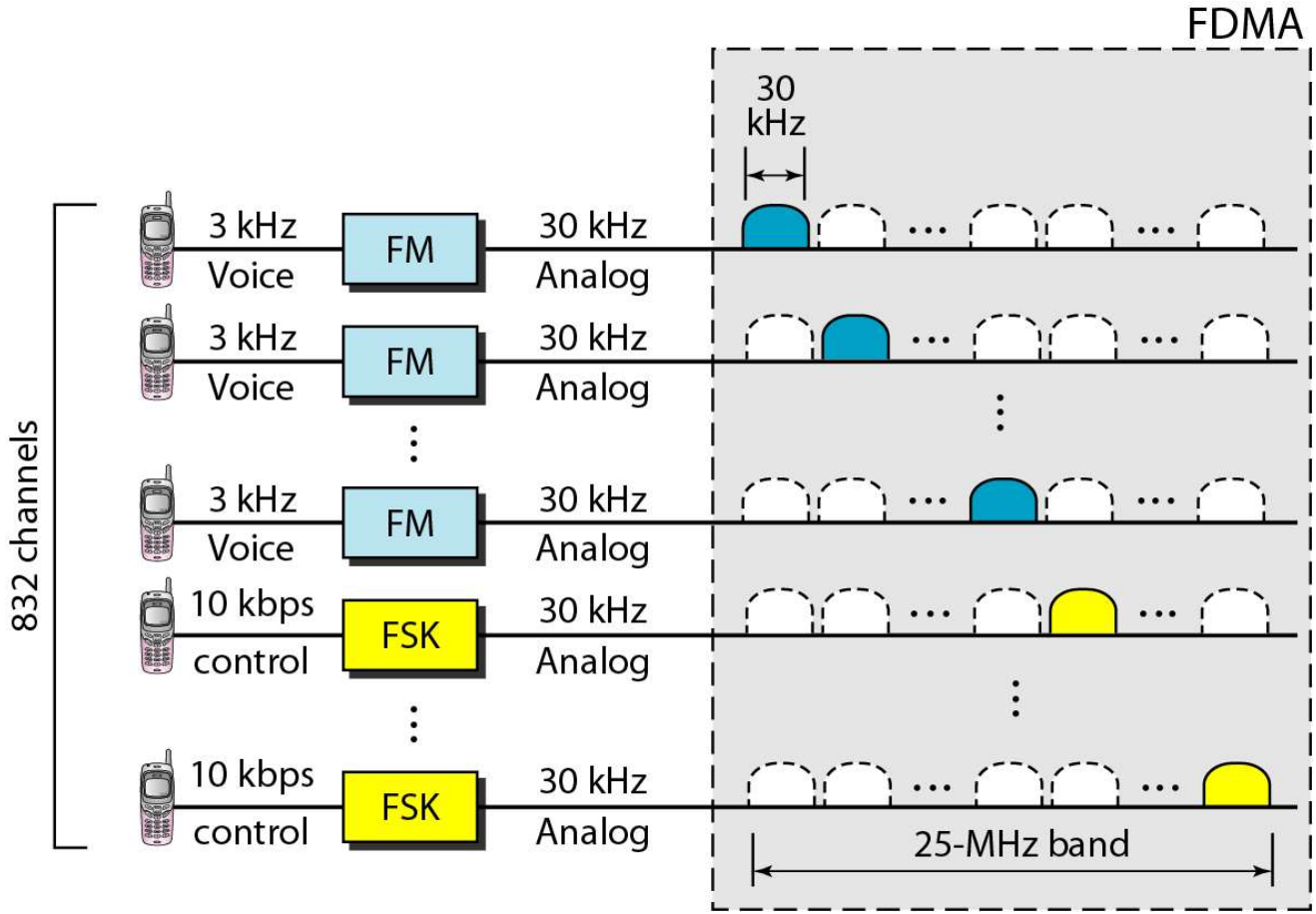
- Advanced Mobile Phone System (AMPS)
  - On e of the leading analog cellular systems in North America.
  - AMPS is an analog cellular phone system using FDMA.
- Bands
  - AMPS operates in the ISM 800-MHz band.
  - Two separate analog channels,
    - forward communication: 869 ~ 894 MHz
    - reverse communication: 824 ~ 849 MHz

Figure 16.3 *Cellular bands for AMPS*



- Transmission
  - AMPS uses FM and FSK for modulation.
  - Voice channels are modulated using FM
  - Control channels use FSK to create 30-kHz analog signals.

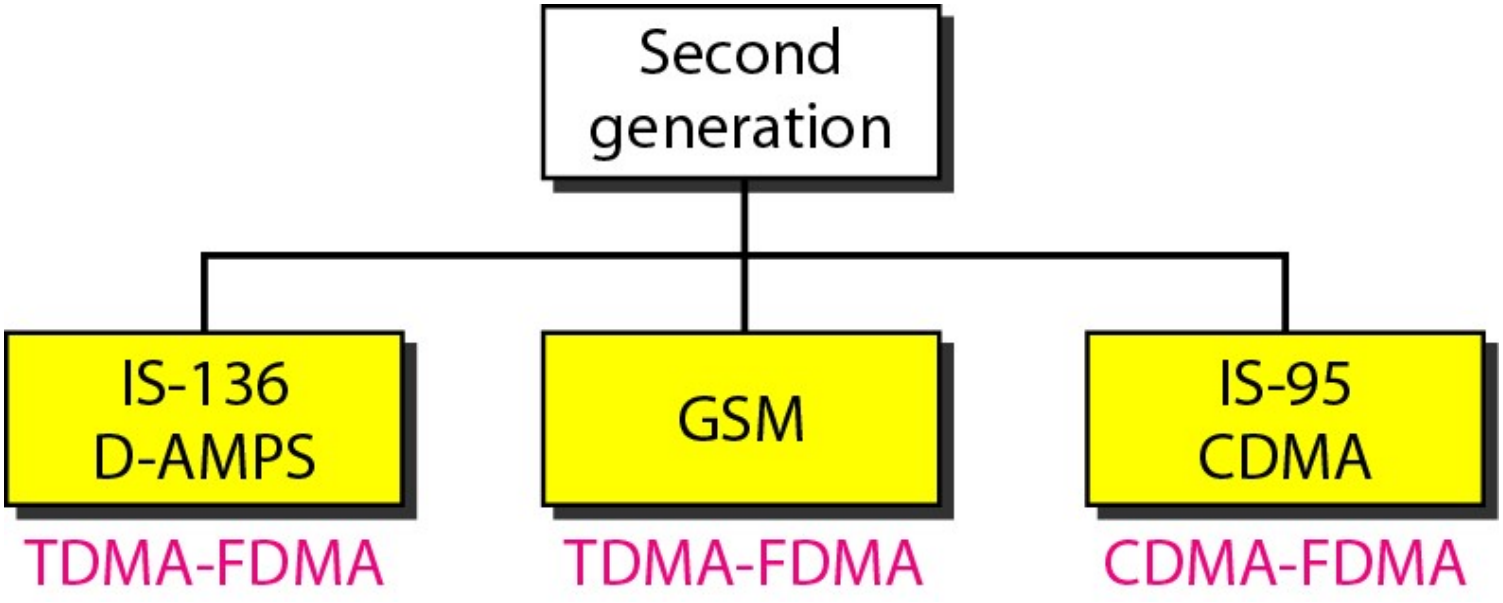
Figure 16.4 *AMPS reverse communication band*



(2) Second Generation

- To provide higher-quality (less noise-prone) mobile voice communications, the second generation of the cellular phone network was developed.
- While the first generation was designed for analog voice communication, the second generation was mainly designed for digitized voice.

Figure 16.5 *Second-generation cellular phone systems*

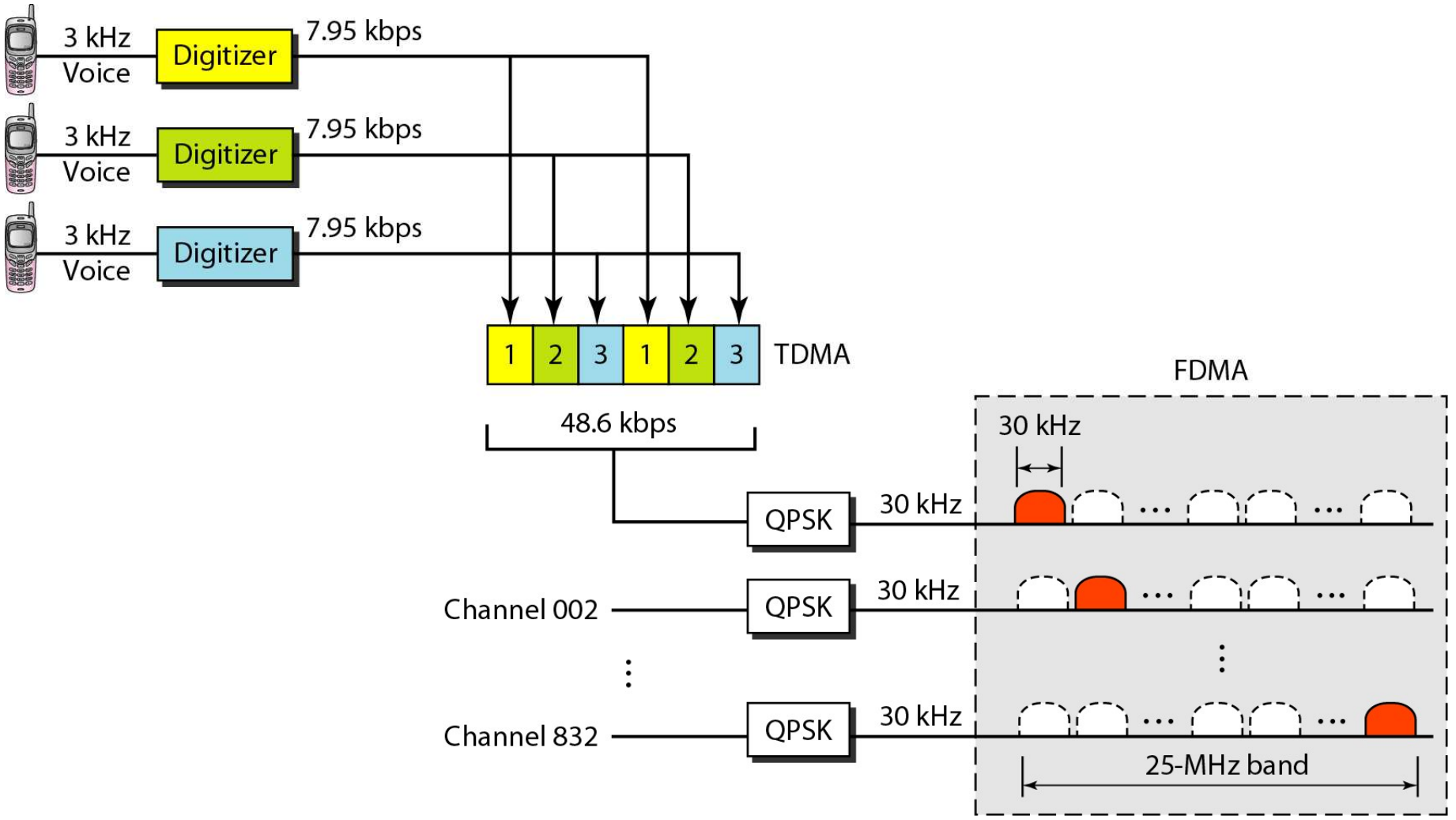


Digital-AMPS Global System for Mobile communications

D-AMPS (Digital AMPS)

- Digital AMPS (D-AMPS)
  - The evolution of the analog AMPS.
  - D-AMPS was first defined by IS-54 (Interim Standard 54) and later revised by IS-136.
  - D-AMPS, or IS-136, is a digital cellular phone system using TDMA and FDMA.
- Band
  - D-AMPS uses the same bands and channels as AMPS.
- Transmission
  - The system sends 25 frames per send, with 1944 bits per frame.
  - Each frame lasts 40 ms and is divided into six slots shared by three digital channels.
  - Each channel is allotted two slots.

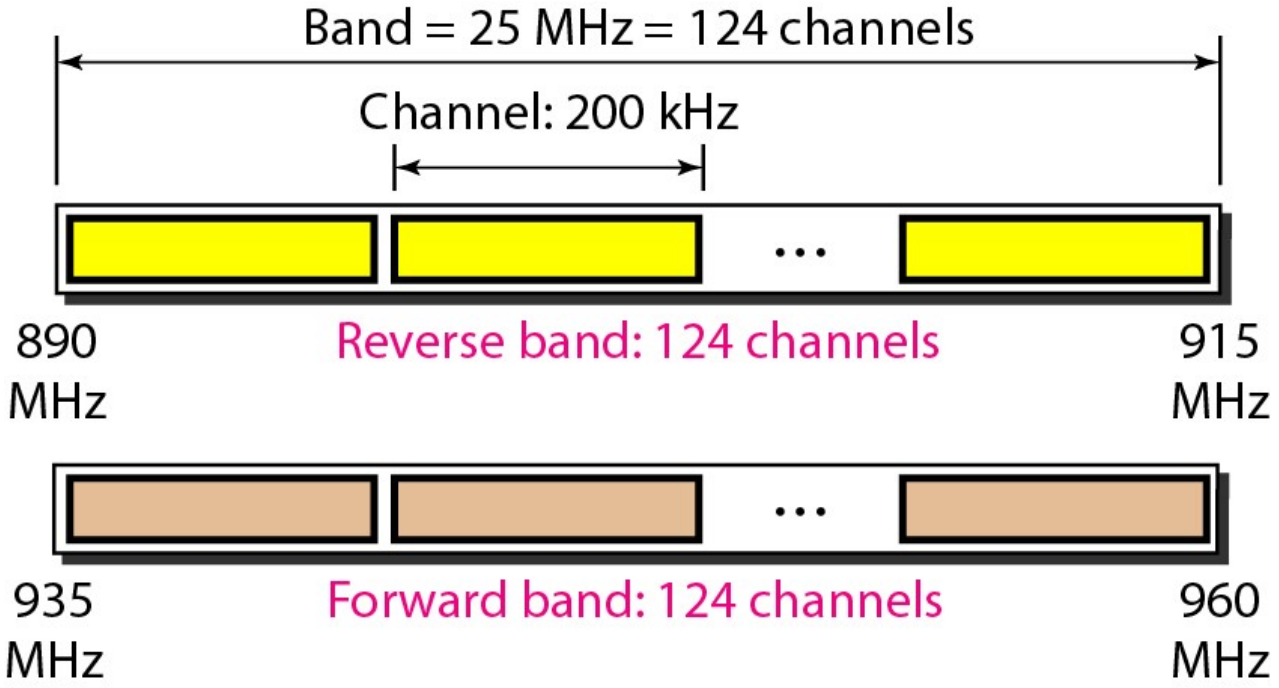
Figure 16.6 *D-AMPS*



GSM

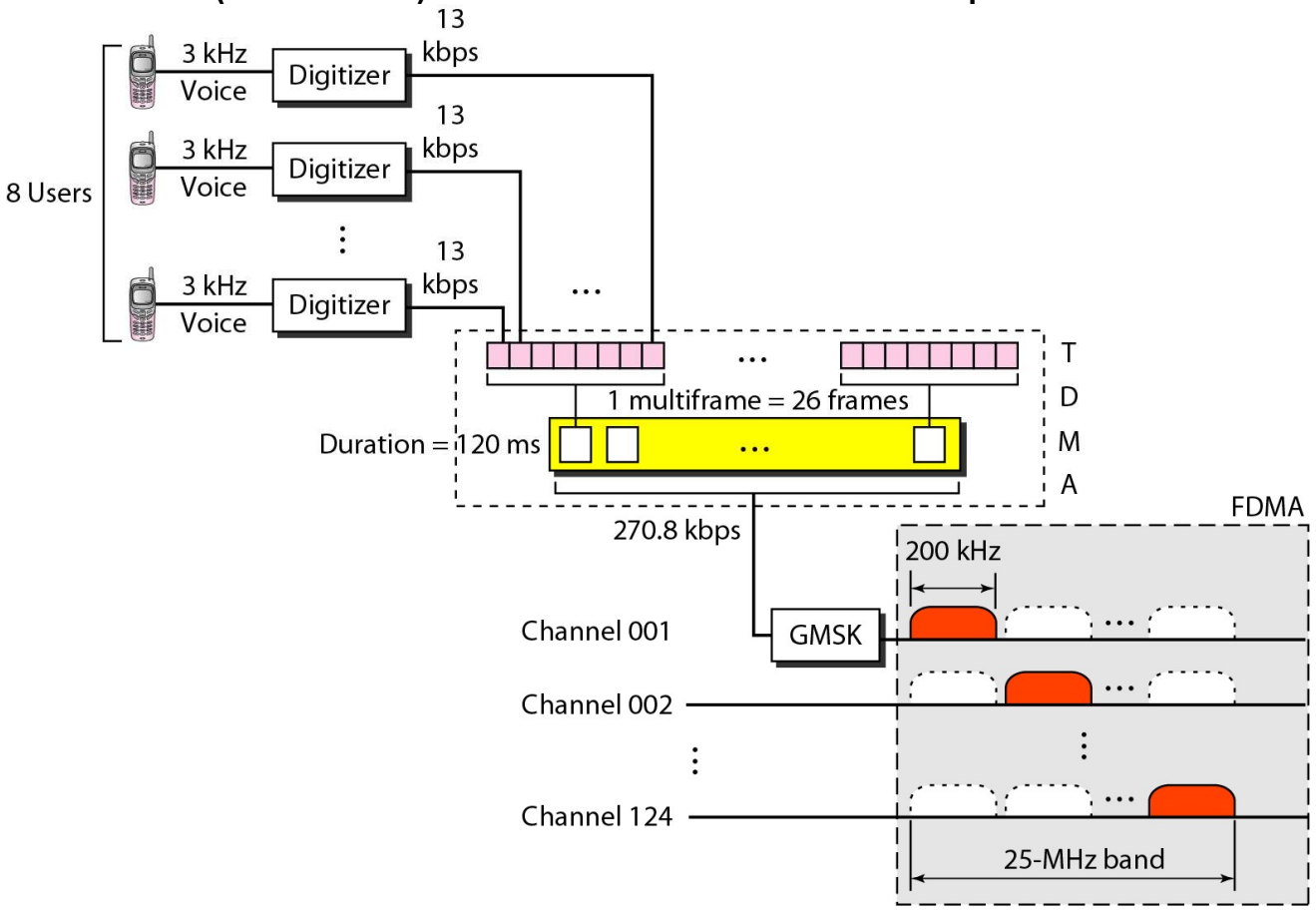
- GSM (Global System for Mobile Communication)
  - A European standard that was developed to provide a common second-generation technology for all Europe.
  - GSM is a digital cellular phone system using TDMA and FDMA.
- Bands
  - Two bands for duplex communication.

Figure 16.7 *GSM bands*



1. Cellular Telephony

- Transmission
  - Each slot carries 156.25 bits
  - 8 slots share a frame (TDMA).
  - 26 frames also share a multiframe (TDMA).
  - Channel data rate = (1/120ms) x 26 x 156.25 = 270.8 kbps



- Reuse factor
  - Because of the complex error correction mechanism, GSM allows a reuse factor as low as 3.

Figure 16.9 *Multiframe components*

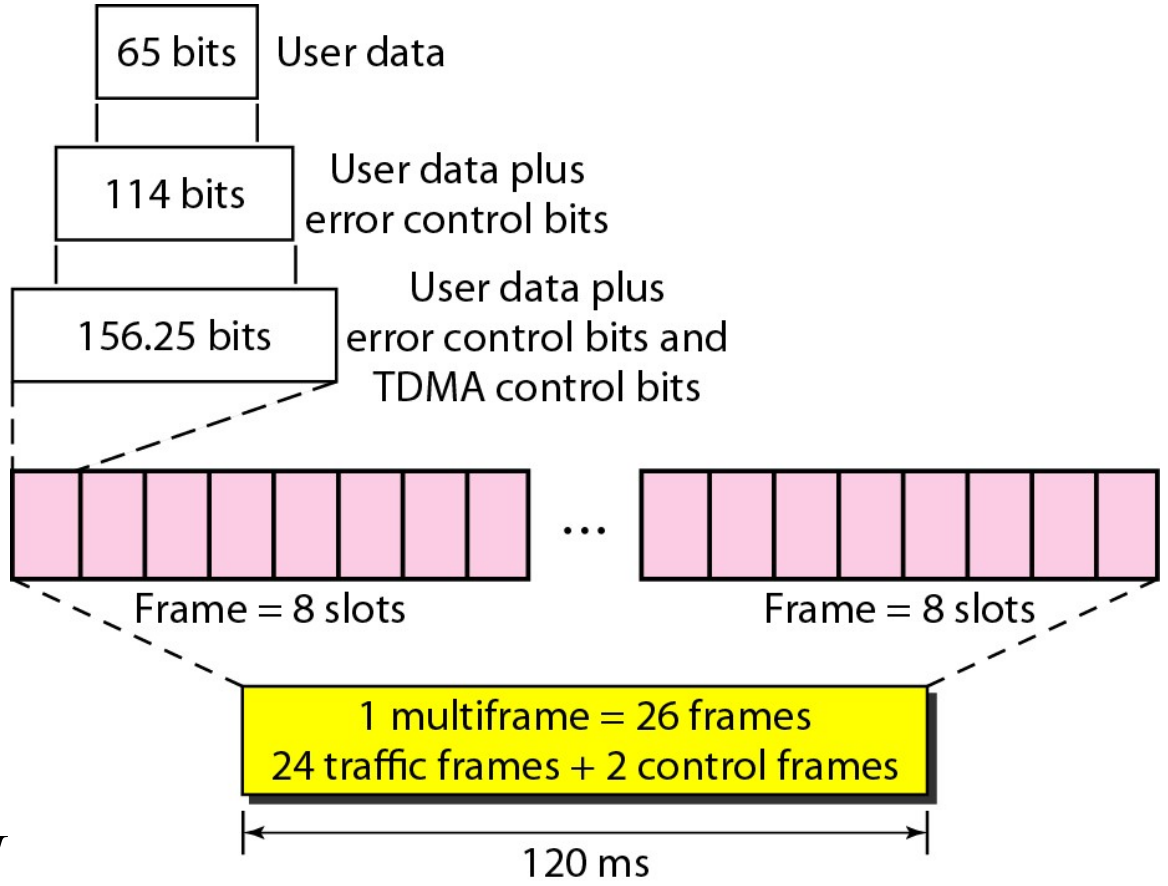


Figure 16.8 *GSM*