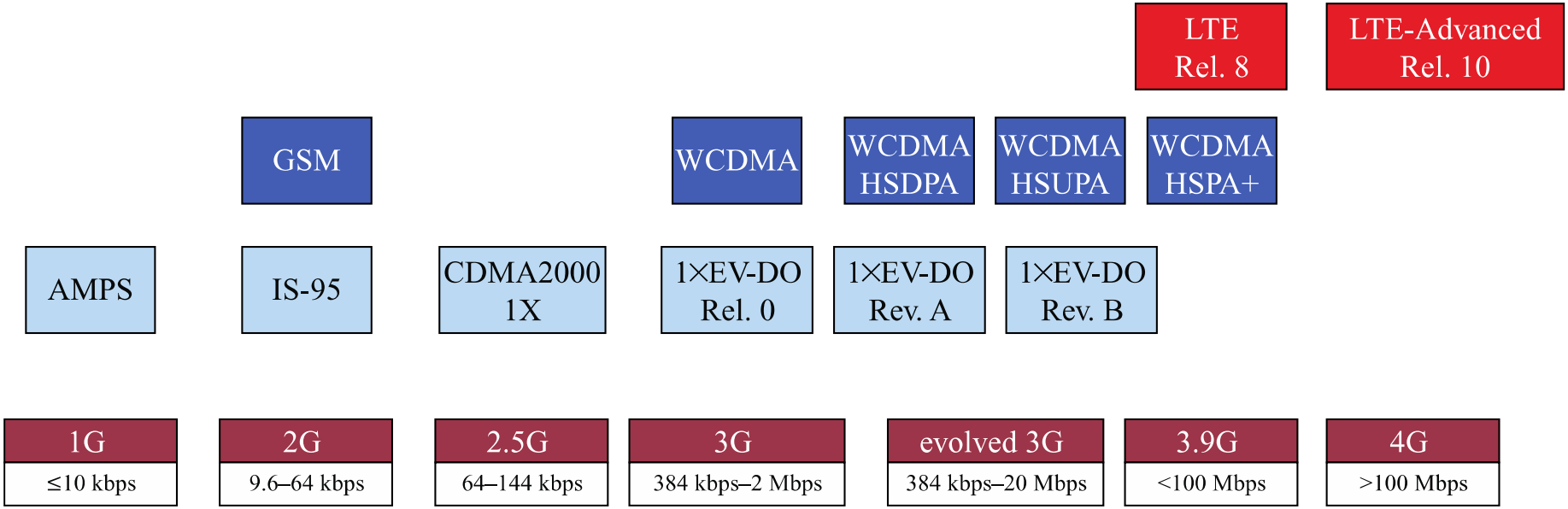
Cellular Networks

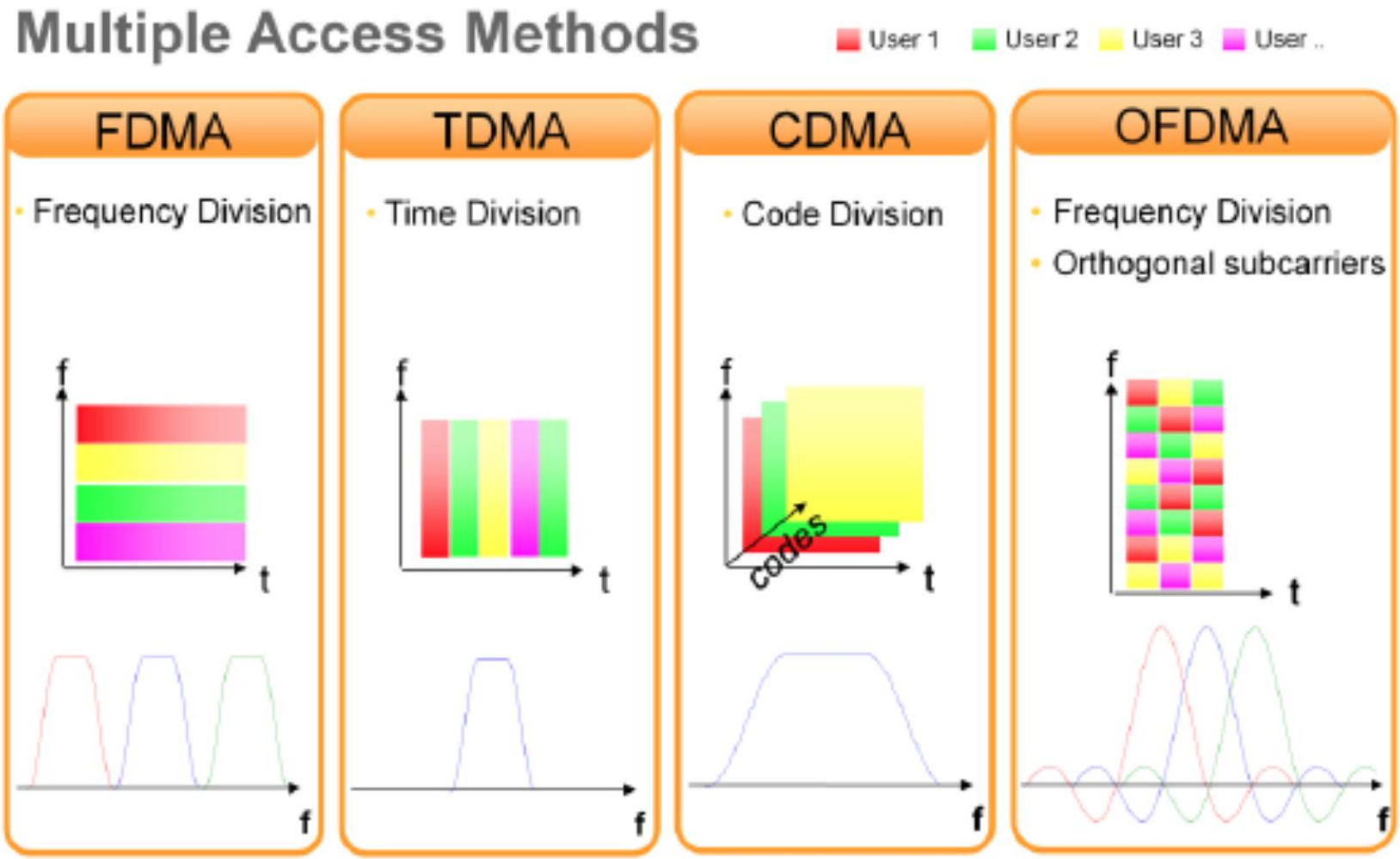
Cellular Networks

- Revolutionary development in data communications and telecommunications
- Foundation of mobile wireless
  - Telephones, smartphones, tablets, wireless Internet, wireless applications
- Supports locations not easily served by wireless networks or WLANs
- Four generations of standards
  - 1G: Analog
  - 2G: Still used to carry voice
  - 3G: First with sufficient speeds for data networking, packets only
  - 4G: Truly broadband mobile data up to 1 Gbps



EVOLUTION OF CELLULAR WIRELESS SYSTEMS

Multiple Access Methods

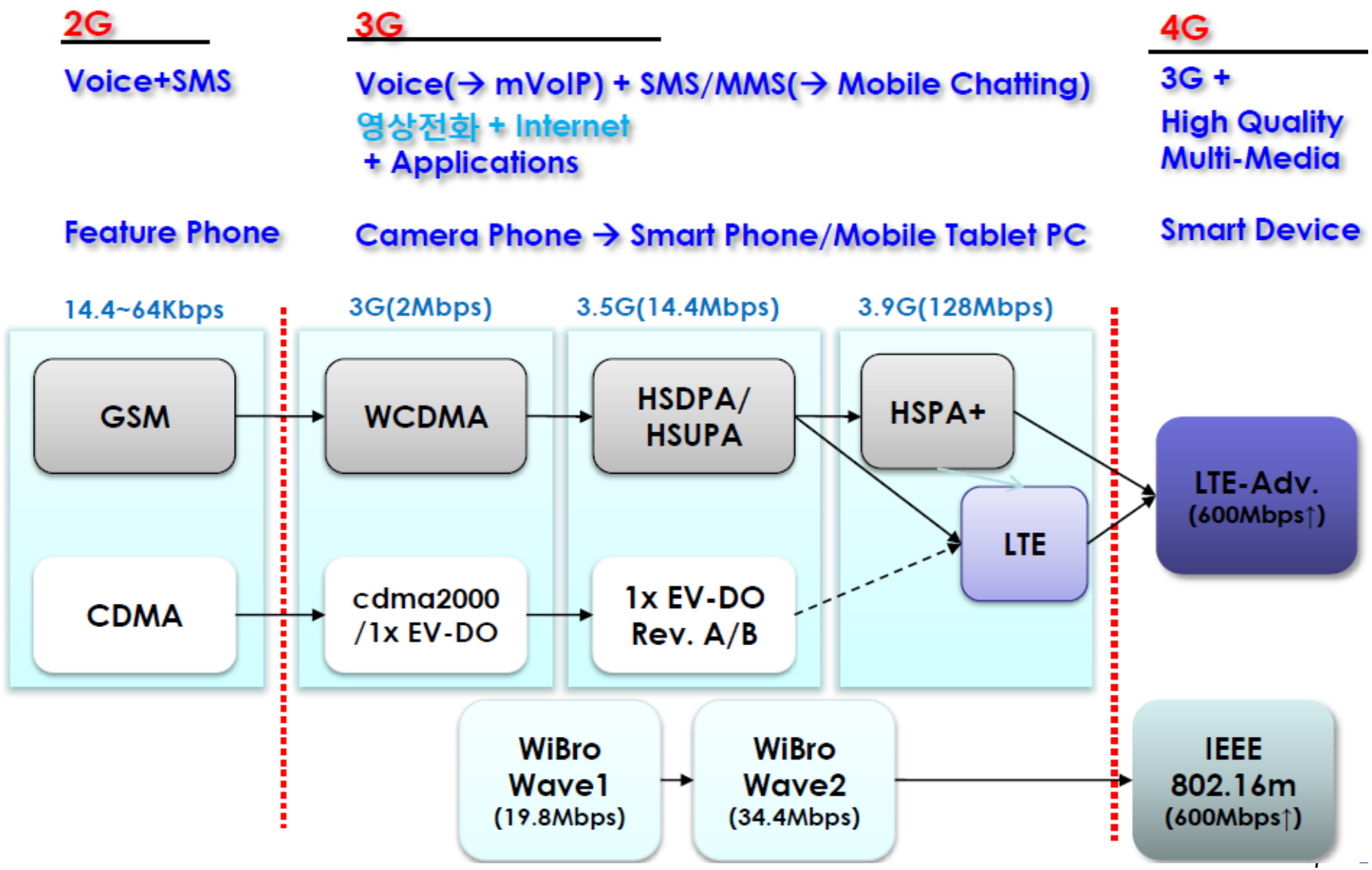


- **Frequency Division Multiple Access (FDMA):** In order to accommodate various devices on the same wireless network, FDMA divides the
available spectrum into sub-bands or channels. Using this technique, a dedicated channel can
be allocated to a user, while other users occupy other channels or frequencies.
- **Time Division Multiple Access (TDMA):** The channel bandwidth is shared in the time domain. It assigns a relatively narrow spectrum allocation to each user, but in this case the bandwidth is shared between a set of users.
- **Code Division Multiple Access (CDMA):** Instead of sharing resources in the time or frequency domain, the devices are able to use the system at the same time and using the same frequency. This is possible because each transmission is separated using a unique channelization code.
- **Orthogonal Frequency Division Multiple Access (OFDMA):** OFDMA uses a large number of closely spaced narrowband carriers. In a conventional FDM system, the frequency spacing between carriers is chosen with a sufficient guard band to ensure that interference is minimized and can be cost effectively filtered.

Mobile Evolution

1G	2G	3G	4G	5G
1981	1992	2001	2010	2019
2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Basic voice service using analog protocols	Designed primarily for voice using the digital standards (GSM/CDMA)	First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)	True mobile broadband on a unified standard (LTE)	'Tactile Internet' with service-aware devices and fiber-like speeds
				?
Analogue	Digital	Mobile broadband	Mobile internet (PS only)	
			Mobile internet explosion fueled by Ux revolution	

Evolution of Mobile Communication



Evolution of Mobile Communication

- 채널 대역폭: 협대역 → 광대역
- 다중 액세스: 회선기반의 CDMA (협대역 → 광대역) → 패킷기반의 OFDMA
- 변조방식: BPSK/QPSK → 8PSK/16QAM → 64QAM
- 다중안테나; 단일 셀 기반 기술(다이버시티 → MIMO 다중화 → Single Cell MU-MIMO) → 다중 셀 기반 기술(Multi-cell MU-MIMO, CoMP, ICIC etc.)

	CDMA		WCDMA		LTE			WiBo		
	EvDo Rev.A	EvDo Rev.B	HSDPA	HSPA+ (Rel.7)	Rel.8	Rel.9	Rel.10	Rel. 1.0 Wave 1	Rel. 1.0 Wave 2	Rel. 2.0
다중접속	CDMA (협대역 → 광대역)				OFDMA/SC-FDMA			OFDMA		
Duplexing	FDD		FDD/TDD					TDD		FDD/TDD
대역폭	1.25	1.25x3	5		1.4/3/5/**10**/20/40			10	10	5/10/**20**
변조방식	QPSK/8PSK /16QAM		16QAM	~16QAM	~64QAM					
MIMO	Diversity			2x2 MIMO	2x2 MIMO		4x4 MIMO	Diversity	2x2 MIMO	4x4 MIMO
최대전송 속도(Mbps)	3.1 1.8	9.3 5.4	14.4 5.76	28 11.5	73.4 36.6		293.7 146.7	19.97 5.04	37.44 10.08	350 200
음성 전송	회선기반 음성				패킷기반 mVoIP					

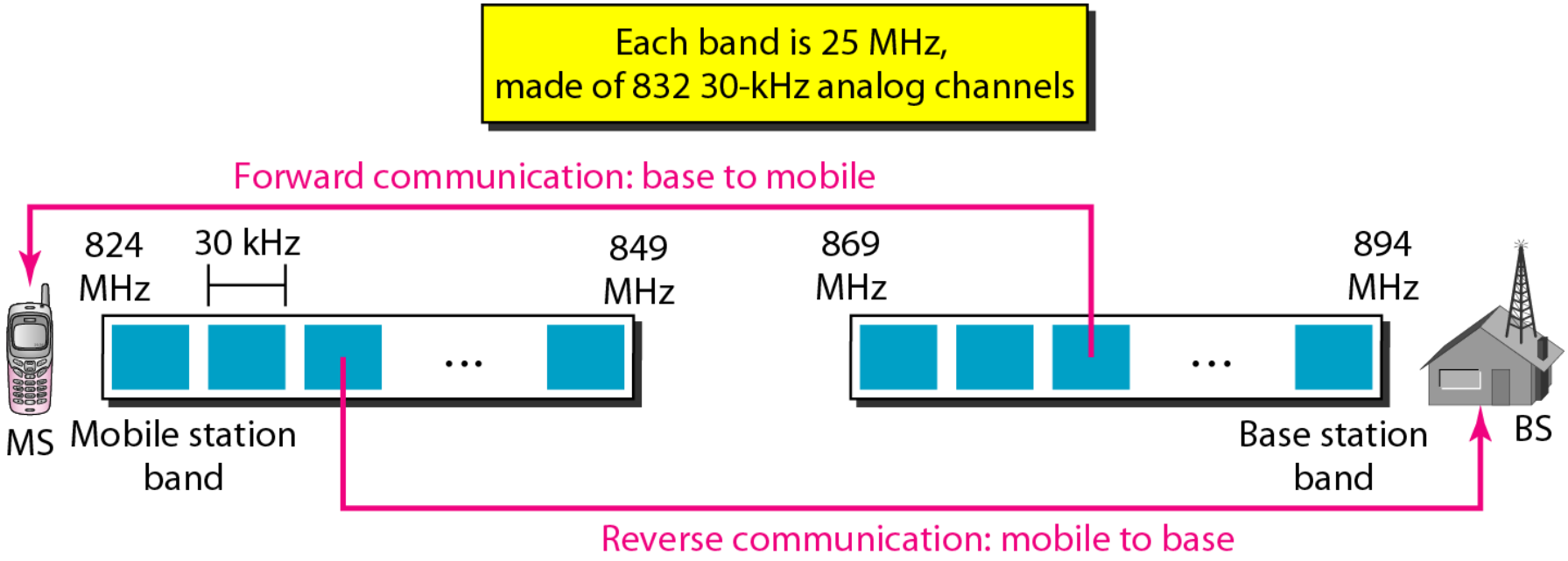
First-Generation Analog

- Advanced Mobile Phone System (AMPS)
  - One 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
- Frequency reuse exploited

Table 10.4 AMPS Parameters

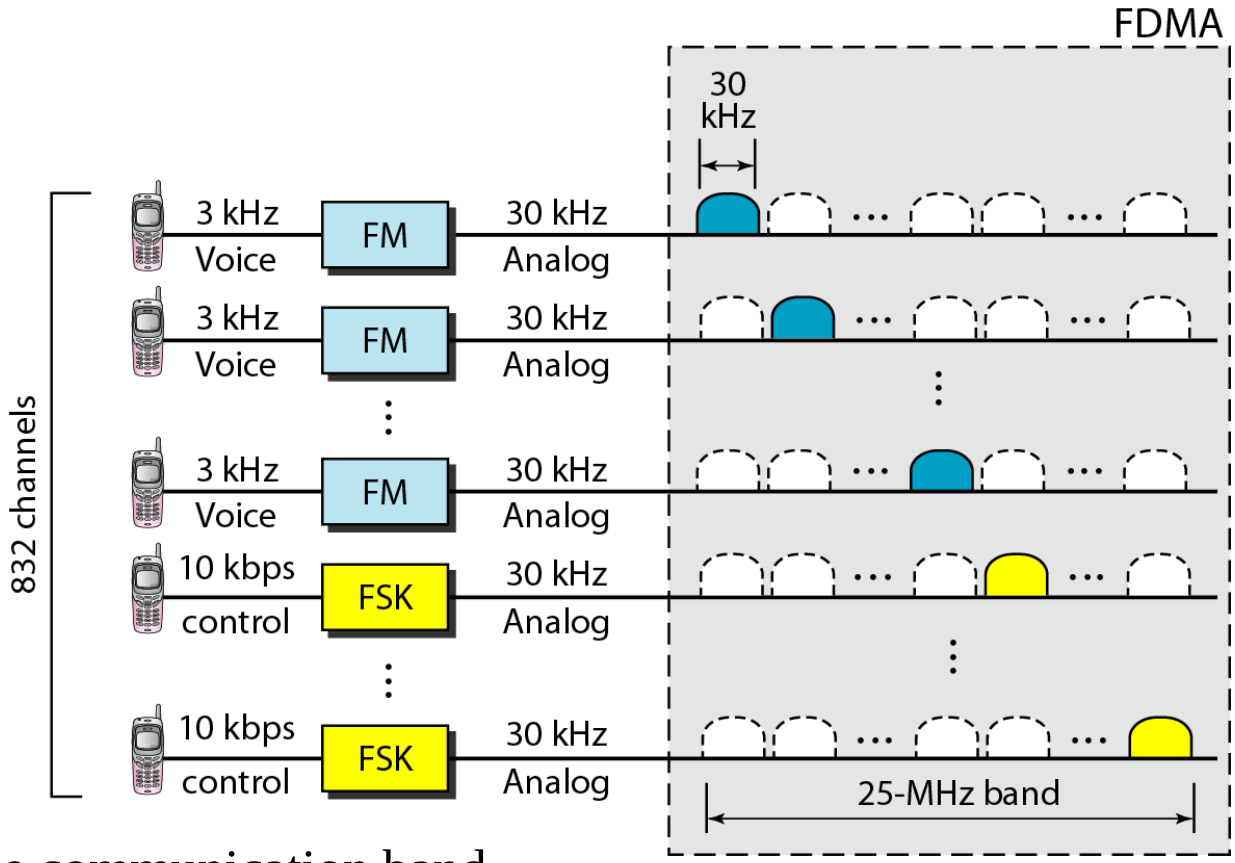
Base station transmission band	869 to 894 MHz
Mobile unit transmission band	824 to 849 MHz
Spacing between forward and reverse channels	45 MHz
Channel bandwidth	30 kHz
Number of full-duplex voice channels	790
Number of full-duplex control channels	42
Mobile unit maximum power	3 watts
Cell size, radius	2 to 20 km
Modulation, voice channel	FM, 12-kHz peak deviation
Modulation, control channel	FSK, 8-kHz peak deviation
Data transmission rate	10 kbps
Error control coding	BCH (48, 36,5) and (40, 28,5)

AMPS Bands


Each band is 25 MHz,
made of 832 30-kHz analog channels
Forward communication: base to mobile
824 MHz
30 kHz
849 MHz
869 MHz
894 MHz
MS
Mobile station band
Base station band
BS
Reverse communication: mobile to base

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.



AMPS reverse communication band

AMPS Operation

When a call is placed, the following sequence of events occurs:

1. The subscriber initiates a call by keying in the telephone number of the called party and presses the send key.
2. The MTSO verifies that the telephone number is valid and that the user is authorized to place the call; some service providers require the user to enter a personal identification number (PIN) as well as the called number to counter theft.
3. The MTSO issues a message to the user's cell phone indicating which traffic channels to use for sending and receiving.
4. The MTSO sends out a ringing signal to the called party. All of these operations (steps 2 through 4) occur within 10 s of initiating the call.
5. When the called party answers, the MTSO establishes a circuit between the two parties and initiates billing information.
6. When one party hangs up, the MTSO releases the circuit, frees the radio channels, and completes the billing information.

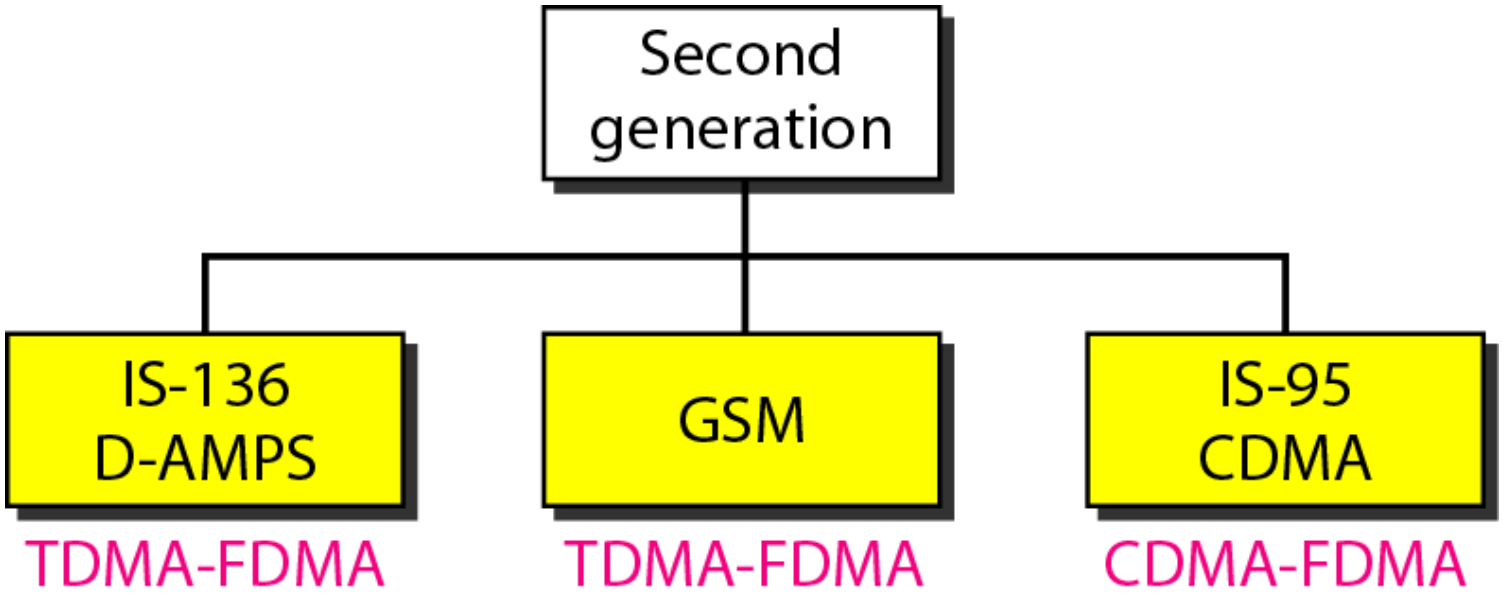
AMPS Control Channels

- Each AMPS service includes 21 full-duplex 30-kHz control channels, consisting of
  - 21 reverse control channels (RCCs) from subscriber to base station, and
  - 21 **forward channels** from the base station to subscriber.
  - These channels transmit digital data using FSK.

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
  - Using FDMA/TDMA or CDMA
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users, by using TDMA or CDMA

Second Generation Cellular Telephone Systems



Digital-AMPS Global System for Mobile communications

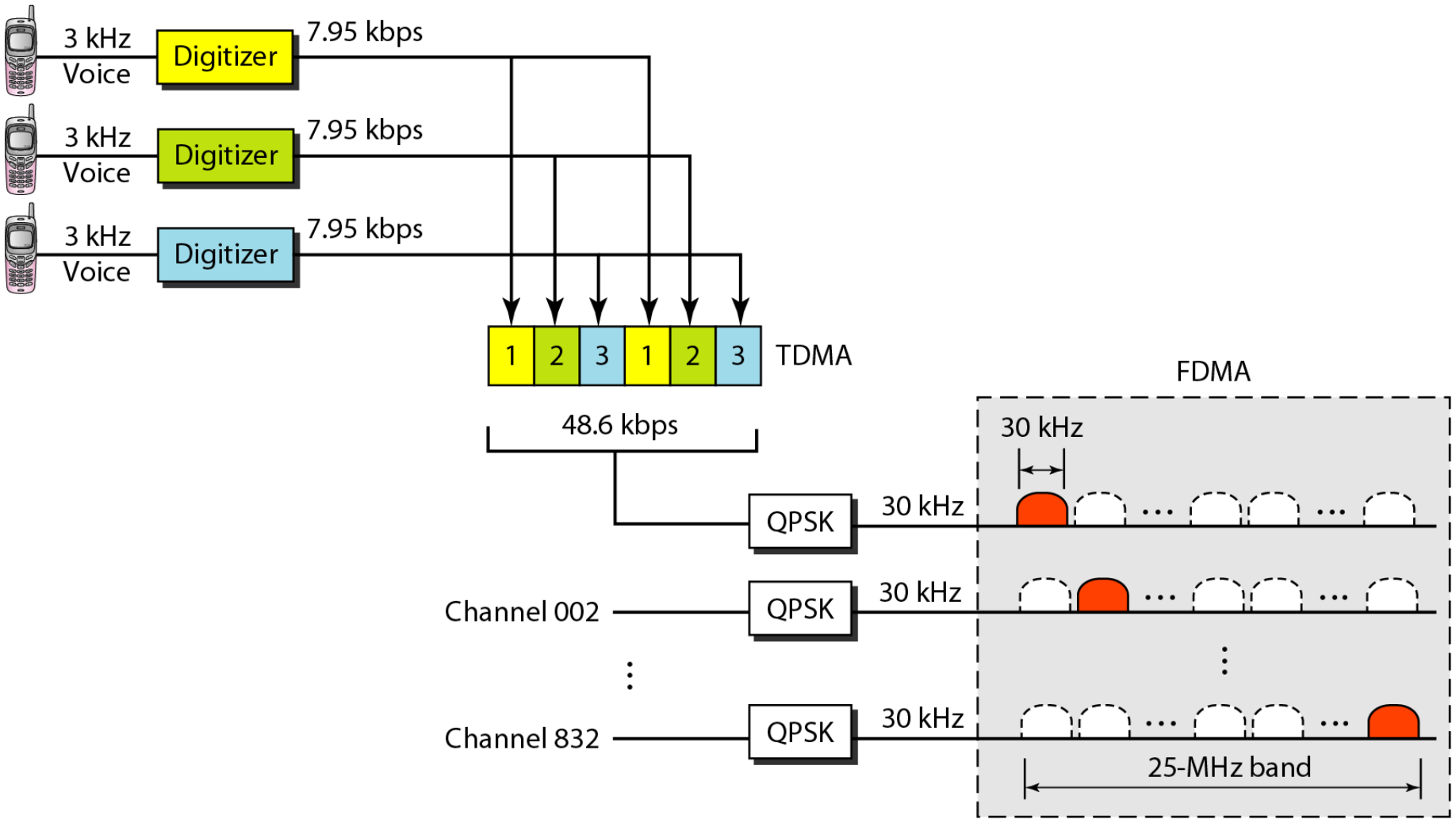
Second Generation Parameters

	GSM	IS-136	IS-95
Year introduced	1990	1991	1993
Access method	TDMA	TDMA	CDMA
Base station transmission band	935 to 960 MHz	869 to 894 MHz	869 to 894 MHz
Mobile station transmission band	890 to 915 MHz	824 to 849 MHz	824 to 849 MHz
Spacing between forward and reverse channels	45 MHz	45 MHz	45 MHz
Channel bandwidth	200 kHz	30 kHz	1250 kHz
Number of duplex channels	125	832	20
Mobile unit maximum power	20 W	3 W	0.2 W
Users per channel	8	3	35
Modulation	GMSK	$\pi/4$ DQPSK	QPSK
Carrier bit rate	270.8 kbps	48.6 kbps	9.6 kbps
Speech coder	RPE-LTP	VSELP	QCELP
Speech-coding bit rate	13 kbps	8 kbps	8, 4, 2, 1 kbps
Frame size	4.6 ms	40 ms	20 ms
Error control coding	Convolutional 1/2 rate	Convolutional 1/2 rate	Convolutional 1/2 rate forward; 1/3 rate reverse

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.

D-AMPS Transmission



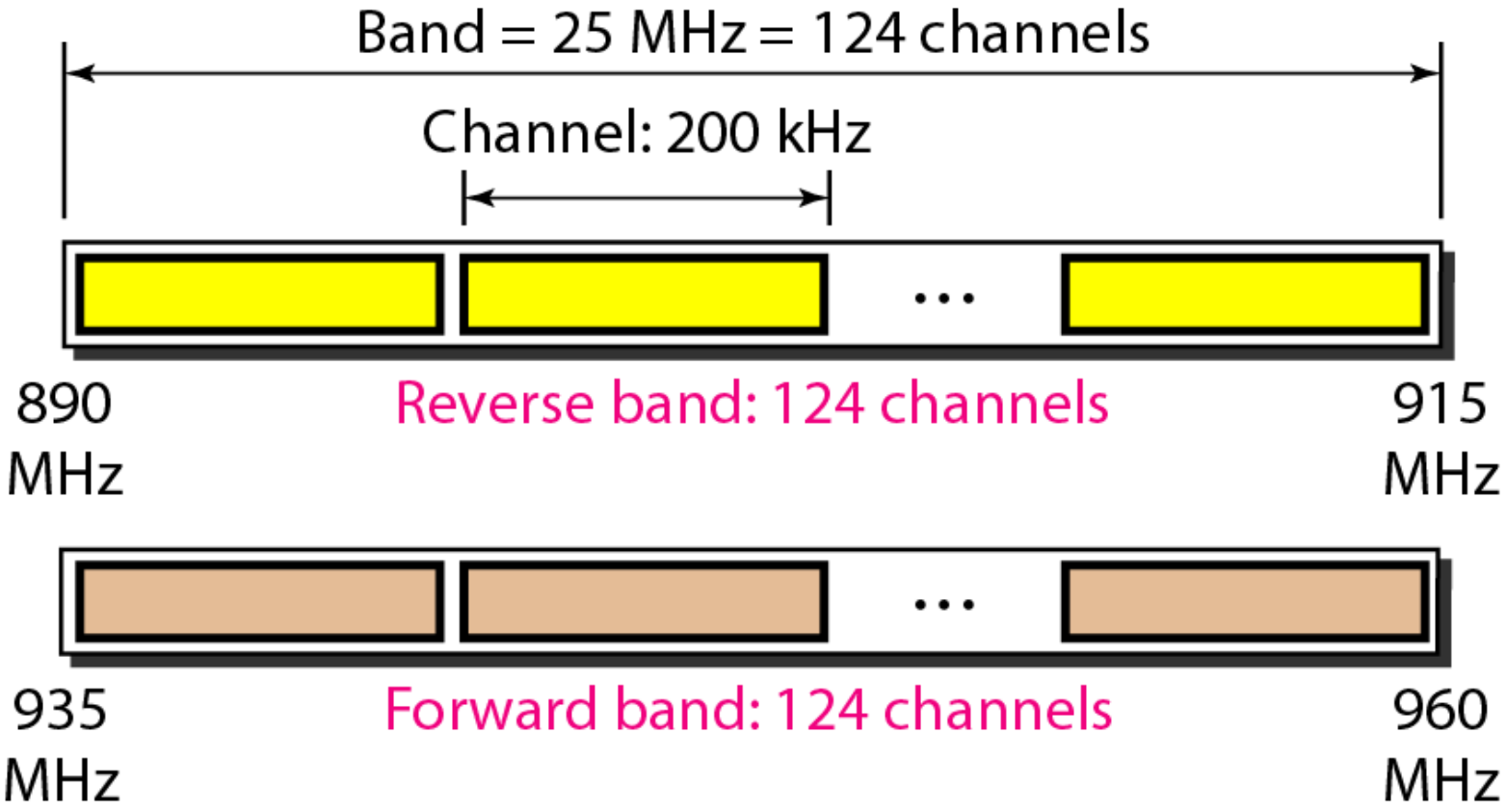
Global System for Mobile Communications (GSM)

- A European standard that was developed to provide a common second-generation technology for all Europe.
  - Over 6.9 billion subscriber units by the end of 2013
- GSM is a digital cellular phone system using TDMA and FDMA.
- Bands
  - Two bands for duplex communication
- Reuse factor
  - Because of the complex error correction mechanism, GSM allows a reuse factor as low as 3.

GSM Radio Link

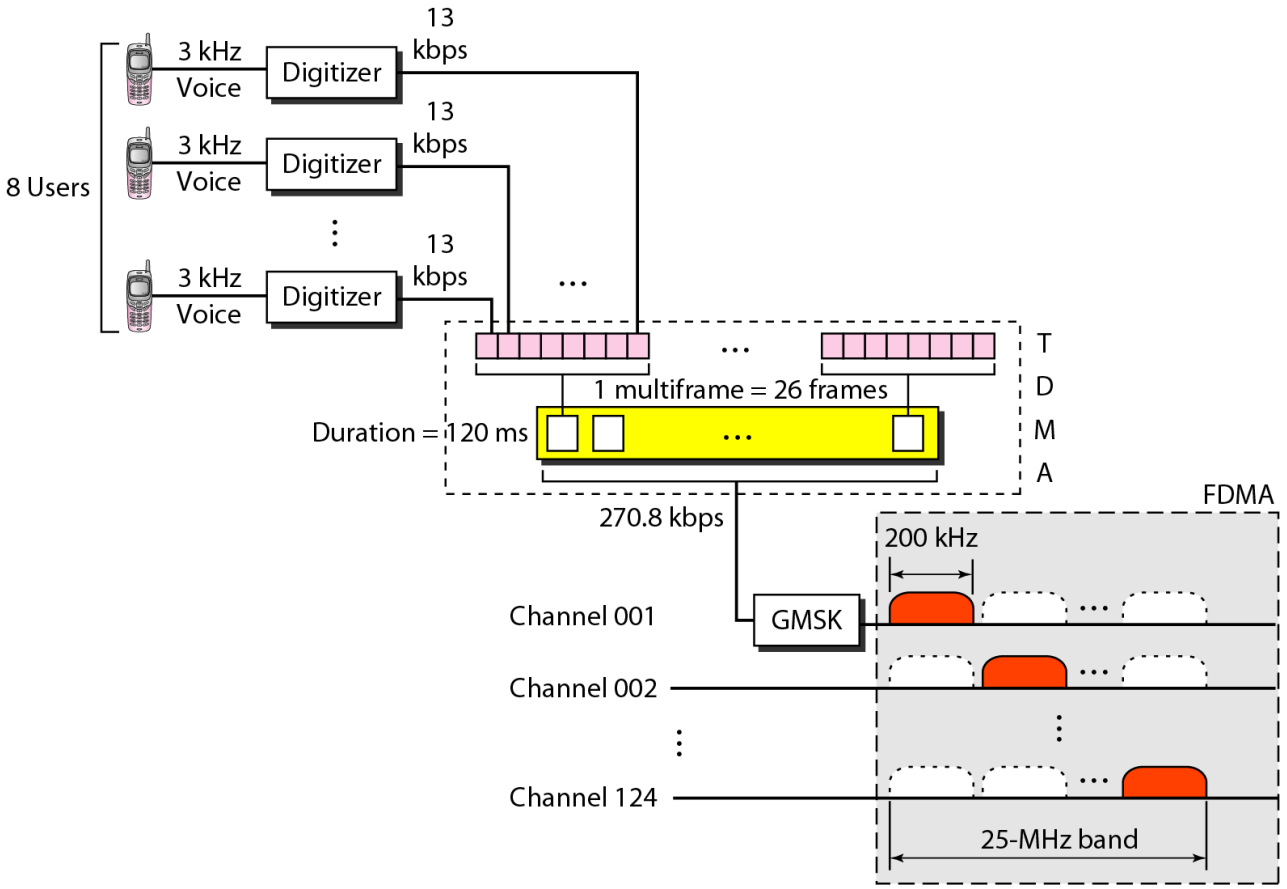
- Combination of FDMA and TDMA
- 200 kHz carriers
- Each with a data rate of 270.833 kbps
- 8 users share each carrier

GSM Bands

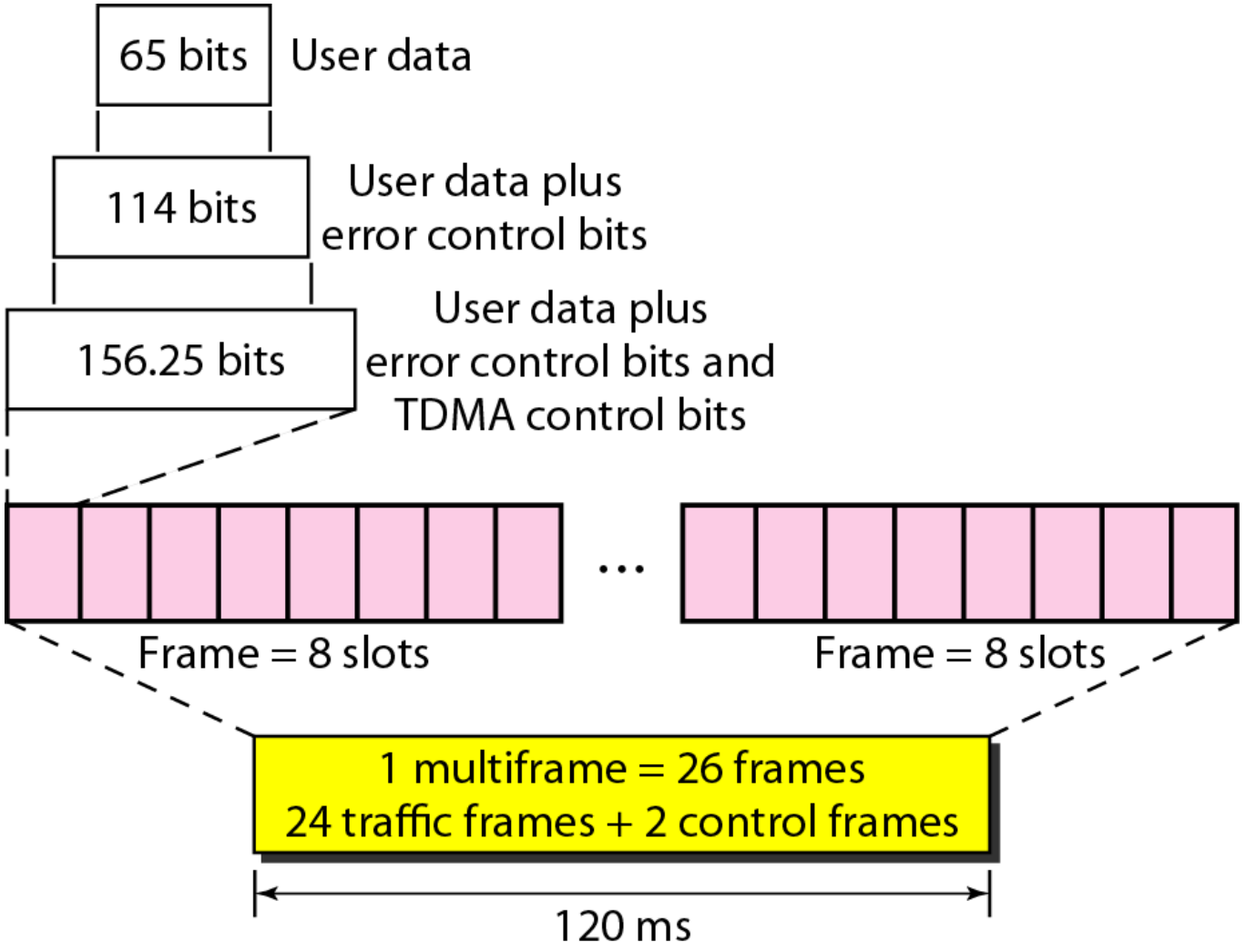

Band = 25 MHz = 124 channels
Channel: 200 kHz
890 MHz
Reverse band: 124 channels
915 MHz
935 MHz
Forward band: 124 channels
960 MHz

GSM 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



GSM Multiframe Components

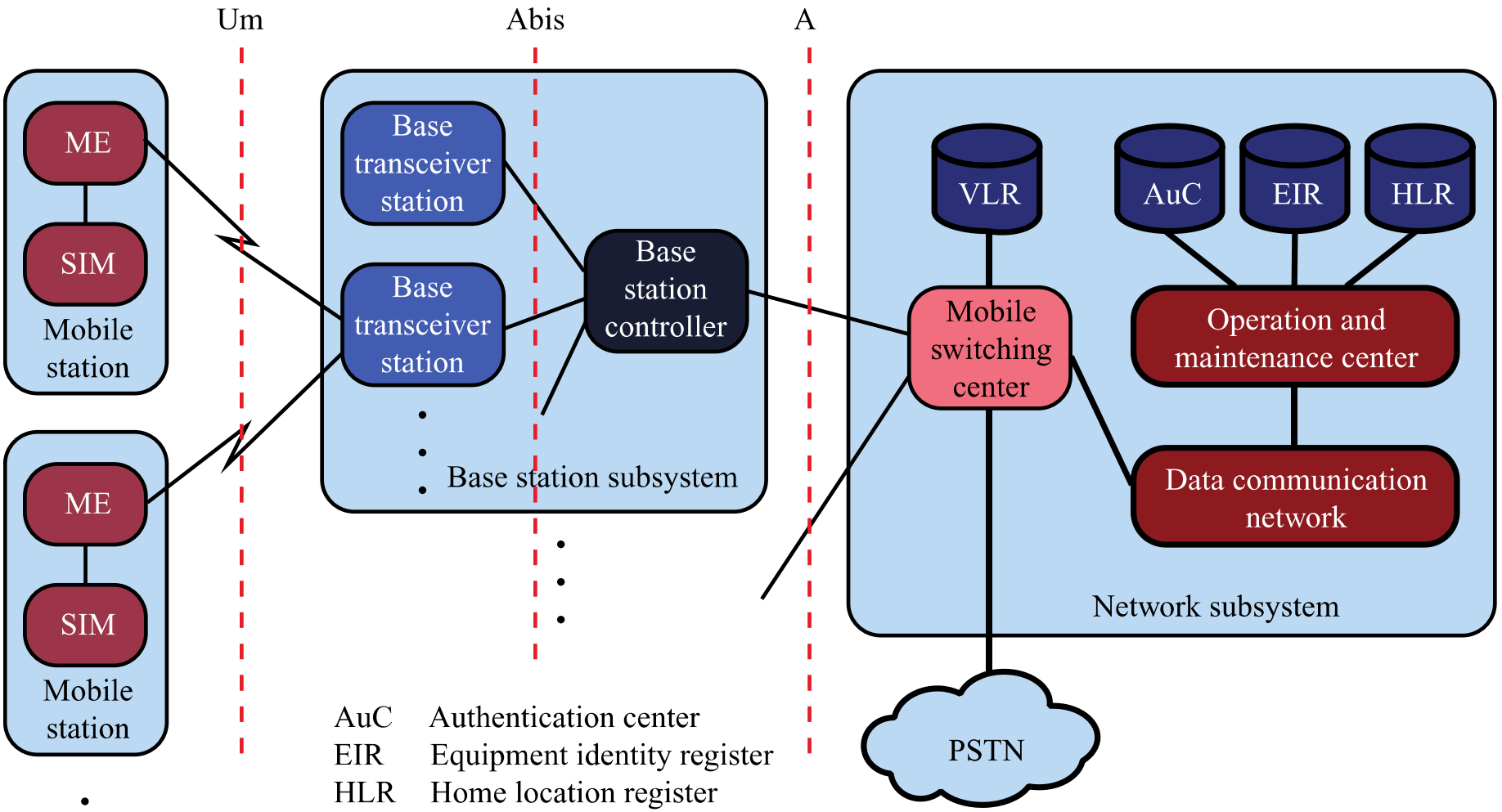


GSM Architecture

- Mobile station communicates across the Um interface (air interface) with base station transceiver in the same cell as mobile unit

- Mobile equipment (ME) – physical terminal, such as a telephone or PCS
  - ME includes radio transceiver, digital signal processors and subscriber identity module (SIM)

- GSM subscriber units are generic until SIM is inserted
  - SIMs roam, not necessarily the subscriber devices



AuC Authentication center
EIR Equipment identity register
HLR Home location register
ME Mobile equipment
PSTN Public switched telephone network
SIM Subscriber identity module
VLR Visitor location register

13.9 OVERALL GSM ARCHITECTURE

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users

- Central element of NS is the mobile switching center (MSC)

Mobile Switching Center (MSC) Databases

- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

Generalized Packet Radio Service (GPRS)

- Phase 2 of GSM

- Provides a datagram switching capability to GSM
  - Instead of sending data traffic over a voice connection which requires setup, sending data, and teardown
  - GPRS allows users to open a persistent data connection
  - Also has a new system architecture for data traffic
  - 21.4 kbps from a 22.8 kbps gross data rate
  - Can combine up to 8 GSM connections
    - Overall throughputs up to 171.2 kbps

Enhanced Data Rates for GSM Evolution (EDGE)

- The next generation of GSM
  - Not yet 3G, so called "2.G" by some
- Three-fold increase in data rate
  - Up to 3 bits/symbol for 8-PSK from 1 bit/symbol for GMSK for GSM.
  - Max data rates per channel up to 22.8 × 3 = 68.4 kbps per channel
  - Using all eight channels in a 200 kHz carrier, gross data transmission rates up to 547.2 kbps became possible
    - Actual throughput up to 513.6 kbps.
- A later release of EDGE (3GPP Release 7) increased downlink data rates over 750 kbps and uplink data rates over 600 kbps

Advantages of CDMA over TDMA

- **Frequency diversity:** Because the transmission is spread out over a larger bandwidth, frequency-dependent transmission impairments, such as noise bursts and selective fading, have less effect on the signal.
- **Multipath resistance:** In addition to the ability of DSSS to overcome multipath fading by frequency diversity, the chipping codes used for CDMA not only exhibit low cross correlation but also low autocorrelation. Therefore, a version of the signal that is delayed by more than one chip interval does not interfere with the dominant signal as much as in other multipath environments.
- **Privacy:** Because spread spectrum is obtained by the use of noise-like signals, where each user has a unique code, privacy is inherent.
- **Graceful degradation:** With FDMA or TDMA, a fixed number of users can access the system simultaneously. However, with CDMA, as more users access the system simultaneously, the noise level and hence the error rate increases; only gradually does the system degrade to the point of an unacceptable error rate.

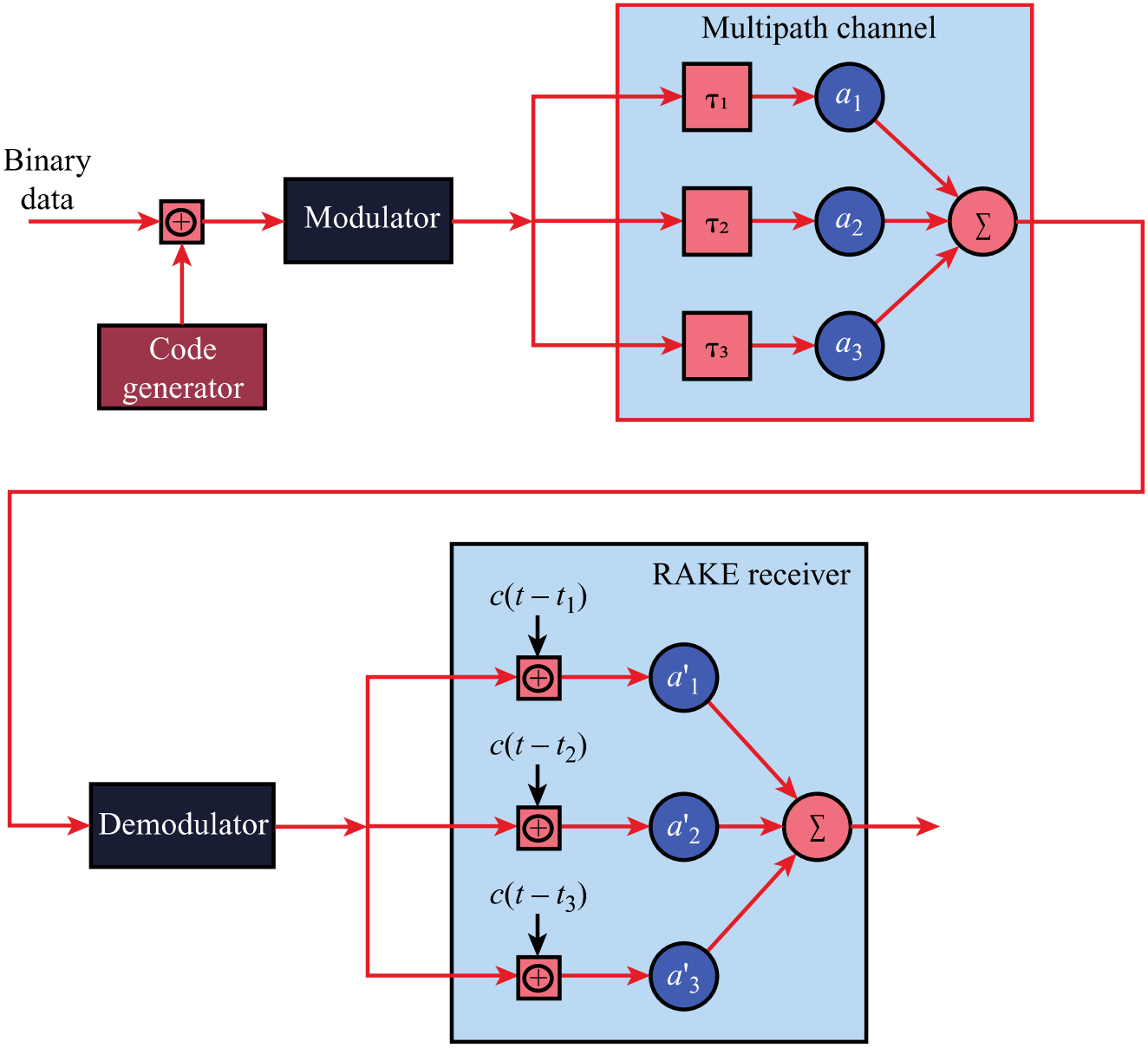
Drawbacks of CDMA

- **Near-far problem:** Signals closer to the receiver are received with less attenuation than signals farther away. Given the lack of complete orthogonality, the transmissions from the more remote mobile units may be more difficult to recover. Thus, power control techniques are very important in a CDMA system.
- **Soft handoff:** As is discussed subsequently, a smooth handoff from one cell to the next requires that the mobile unit acquires the new cell before it relinquishes the old. This is referred to as a soft handoff and is more complex than the hard handoff used in FDMA and TDMA schemes.

Mobile Wireless CDMA Design Considerations

- **RAKE receiver** – when multiple versions of a signal arrive more than one chip interval apart, RAKE receiver attempts to recover signals from multiple paths and combine them
  - See Chapter 9

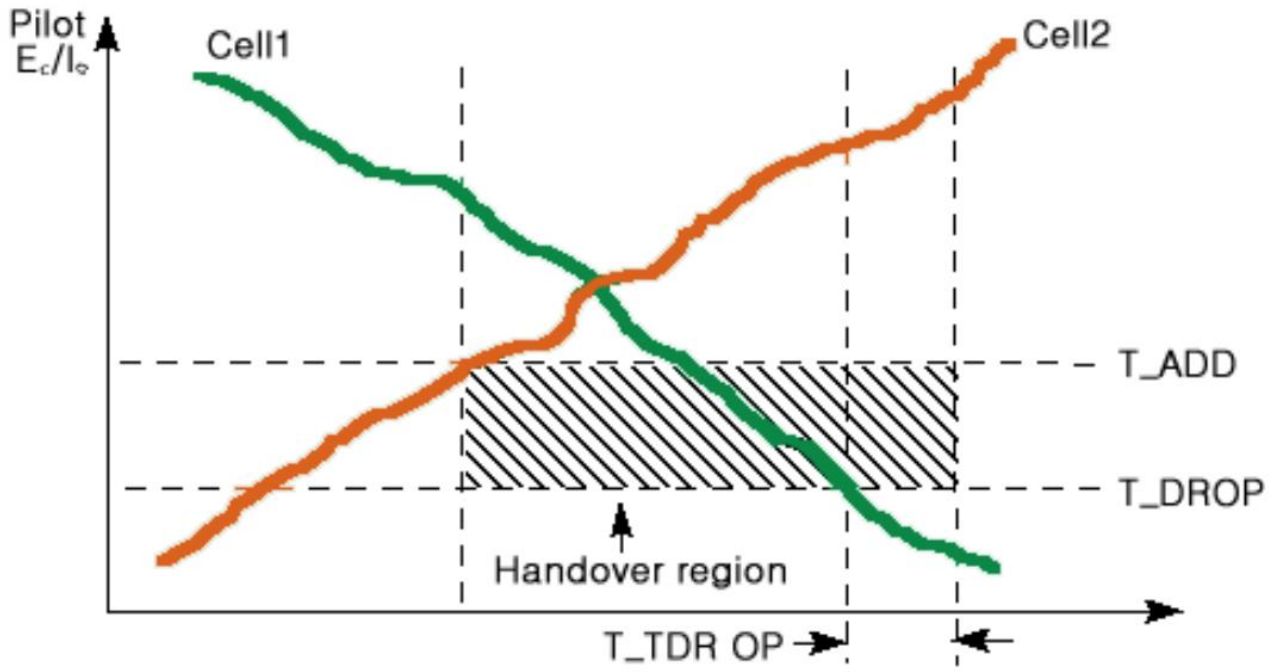
- **Soft Handoff** – mobile station temporarily connected to more than one base station simultaneously
  - Requires that the mobile acquire a new cell before it relinquishes the old
  - More complex than hard handoff used in FDMA and TDMA schemes



9.12 Principle of RAKE Receiver

Soft Handover

- A cell phone is simultaneously connected to two or more cells (or cell sectors) during a call.
- Active Set, Candidate Set, Neighbor Set, Remaining Set



IS-95 CDMA

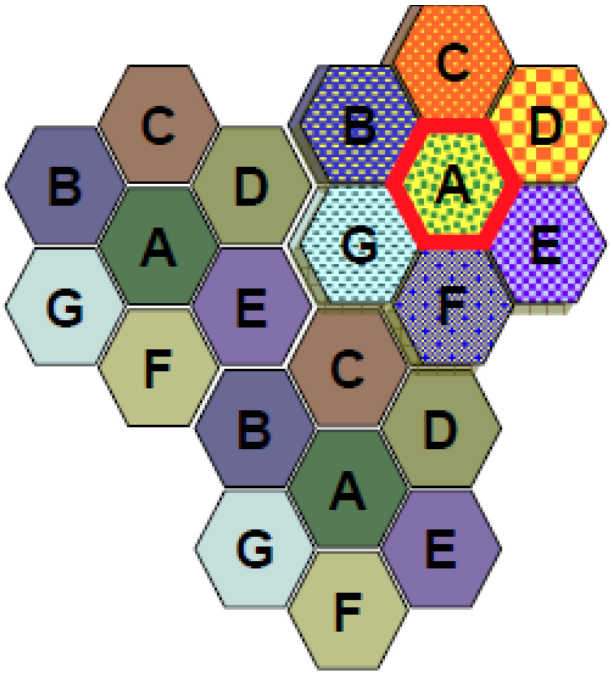
- IS-95 2G digital cellular standard, used mainly in North America
- Motivation
  - Intended as a new system (greenfield) or replacement for AMPS (not an upgrade)
  - Increase system capacity
  - Add new features/services
- History:
  - 1990 Qualcomm proposed a code division multiple access (CDMA) digital cellular system claimed to increase capacity by factor 20 or more
  - Started debate about how CDMA should be implemented and the advantages vs. TDMA (religious tones to debate)
  - 1992 TIA started study of spread spectrum cellular
  - 1993 TIA IS-95 code division multiple access (CDMA) standards completed

IS-95 System Features

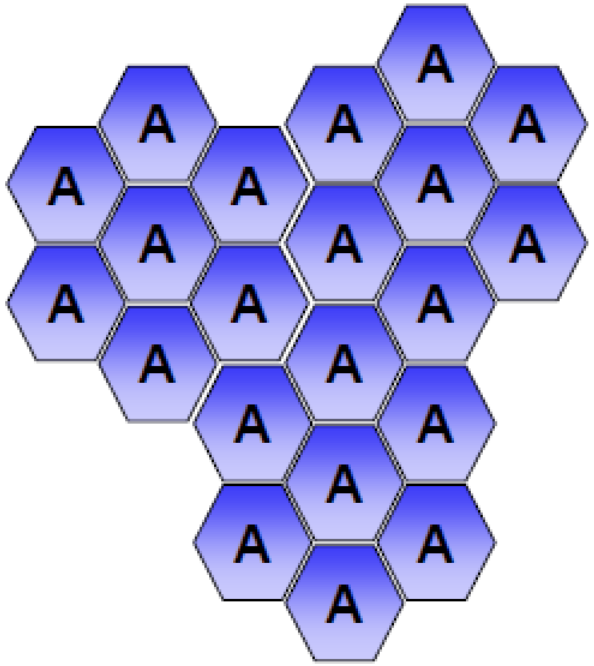
- Digital Voice
  - QCELP fixed rate 14.4Kbps coder
  - variable rate QCELP coder: 9.6, 4.8, 2.4, 1.2 Kbps
    - Use of voice activation to reduce interference
    - As data rate reduces, the transmitter can reduce the power to achieve the same error rates
- Low power handsets (sleep mode supported)
- Soft Handoff possible
- Advanced Telephony Features (call waiting, voice mail, etc.)
- Traffic Channel
  - Pair of **1.25 MHz** radio channels (up/downlink)
  - Several users share a radio channel separated by a code not a timeslot or frequency!
- Universal frequency reuse (frequency reuse cluster size K =1)
  - Simple planning and large capacity increase

Universal Frequency Reuse

Frequency Reuse Factor = 7
for AMPS



CDMA Universal
Frequency Reuse



Frequency Reuse Factor = 4 or 3
for GSM Systems

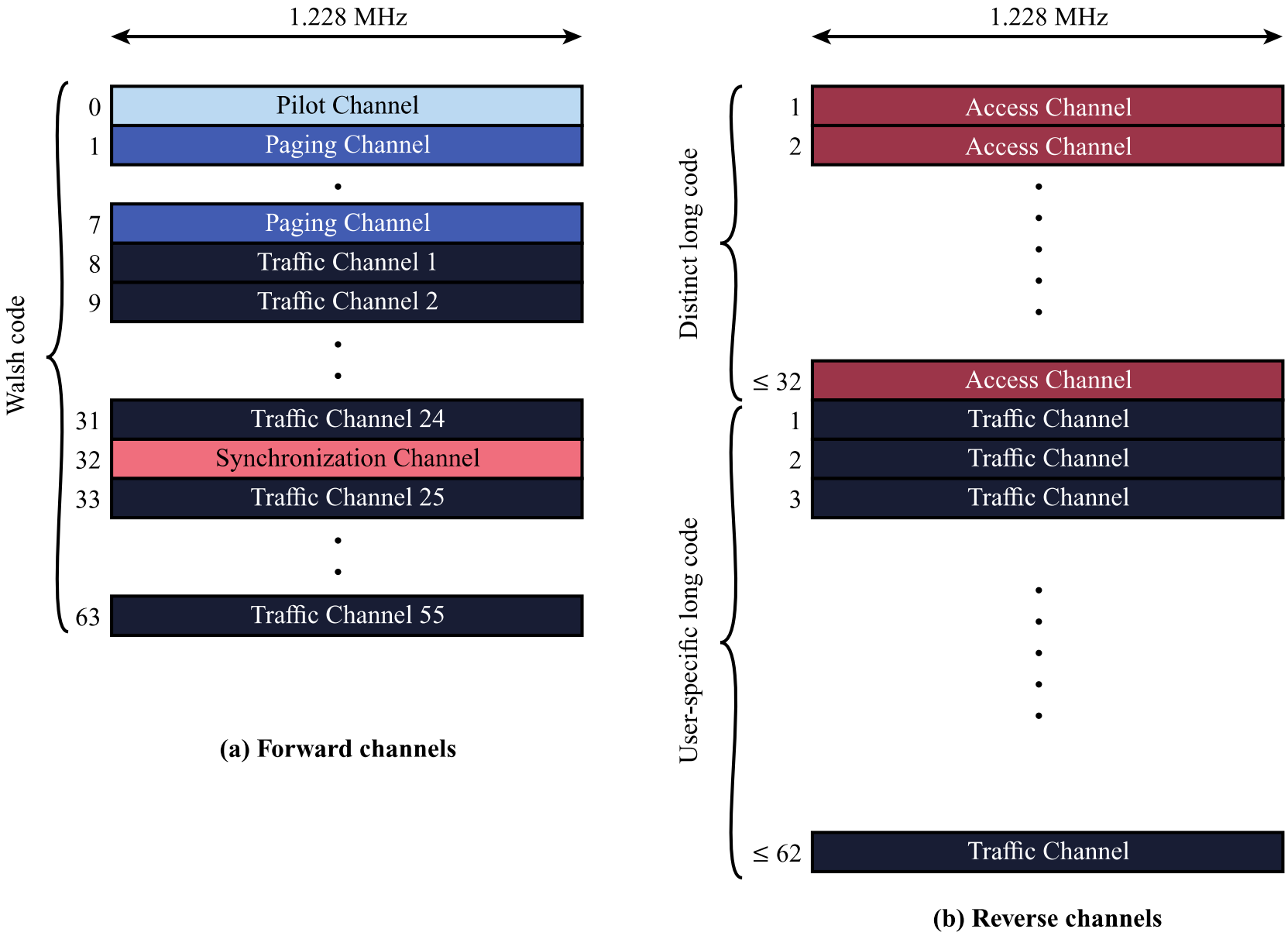
IS-95 Logical Channels

- CDMA systems define multiple channels per frequency channel
  - **Pilot channel**: Provides a reference to all signals (beacon)
  - **Sync channel**: Used for obtaining timing information
  - **Paging channel**: Used to "page" the mobile terminal when there is an incoming call
  - **Traffic channel**: Carries actual voice or data traffic : fundamental code channel

IS-95 Forward Link

- 19.2 ksps (kilosignals per second) x 64 cps (chips per second) = 1.228 Mcps (megachips per second)

- Forward link channels
  - **Pilot** (channel 0) - allows the mobile unit to acquire timing information, provides phase reference and provides means for signal strength comparison
  - **Synchronization** (channel 32) - used by mobile station to obtain identification information about cellular system
  - **Paging** (channels 1 to 7) - contain messages for one or more mobile stations
  - **Traffic** (channels 8 to 31 and 33 to 63) – the forward channel supports 55 traffic channels
    - 9600 or 14,400 bps



13.10 IS-95 CHANNEL STRUCTURE

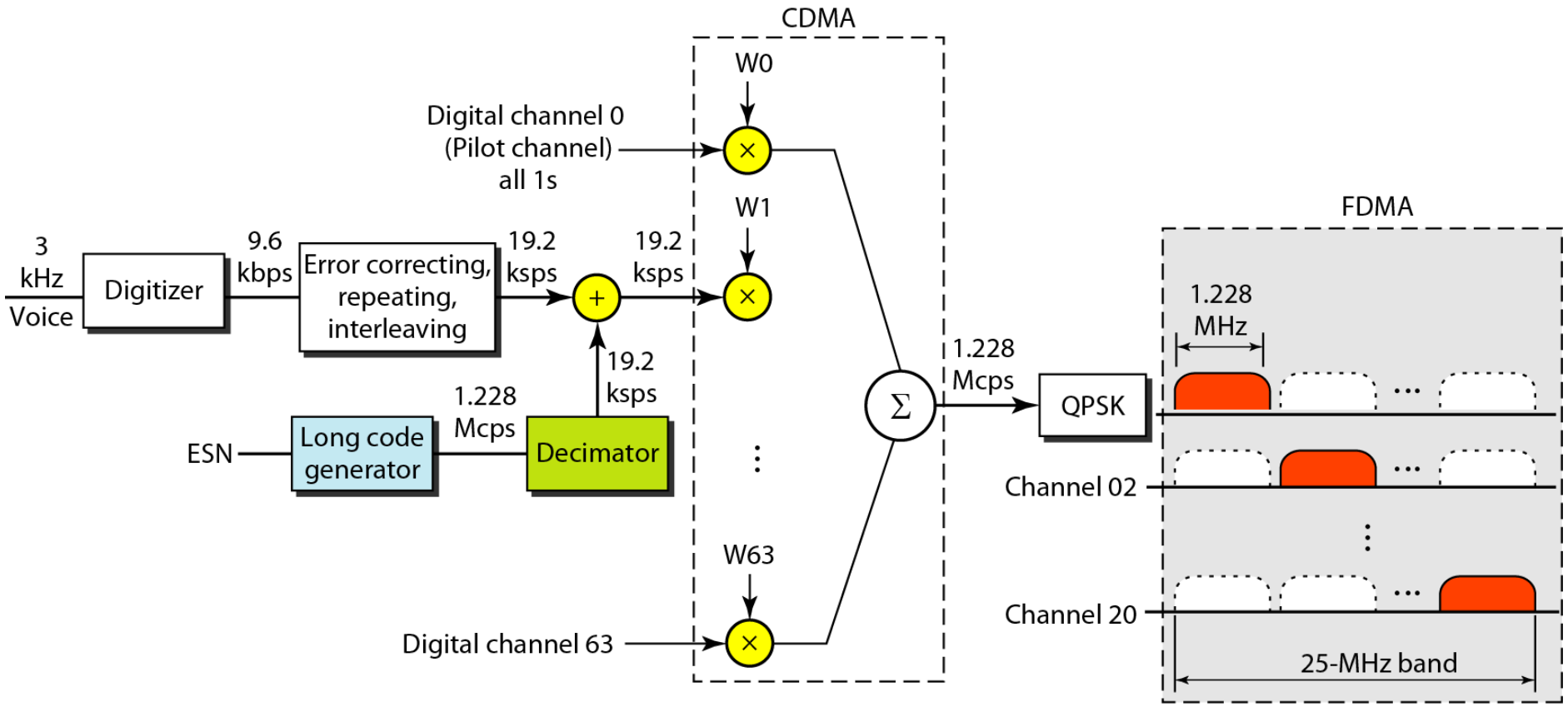
IS-95 Forward Link Channel Parameters

Channel	Sync	Paging		Traffic Rate Set 1				Traffic Rate Set 2			
Data rate (bps)	1200	4800	9600	1200	2400	4800	9600	1800	3600	7200	14400
Code repetition	2	2	1	8	4	2	1	8	4	2	1
Modulation symbol rate (sps)	4800	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
PN chips/ modulation symbol	256	64	64	64	64	64	64	64	64	64	64
PN chips/bit	1024	256	128	1024	512	256	128	682.67	341.33	170.67	85.33

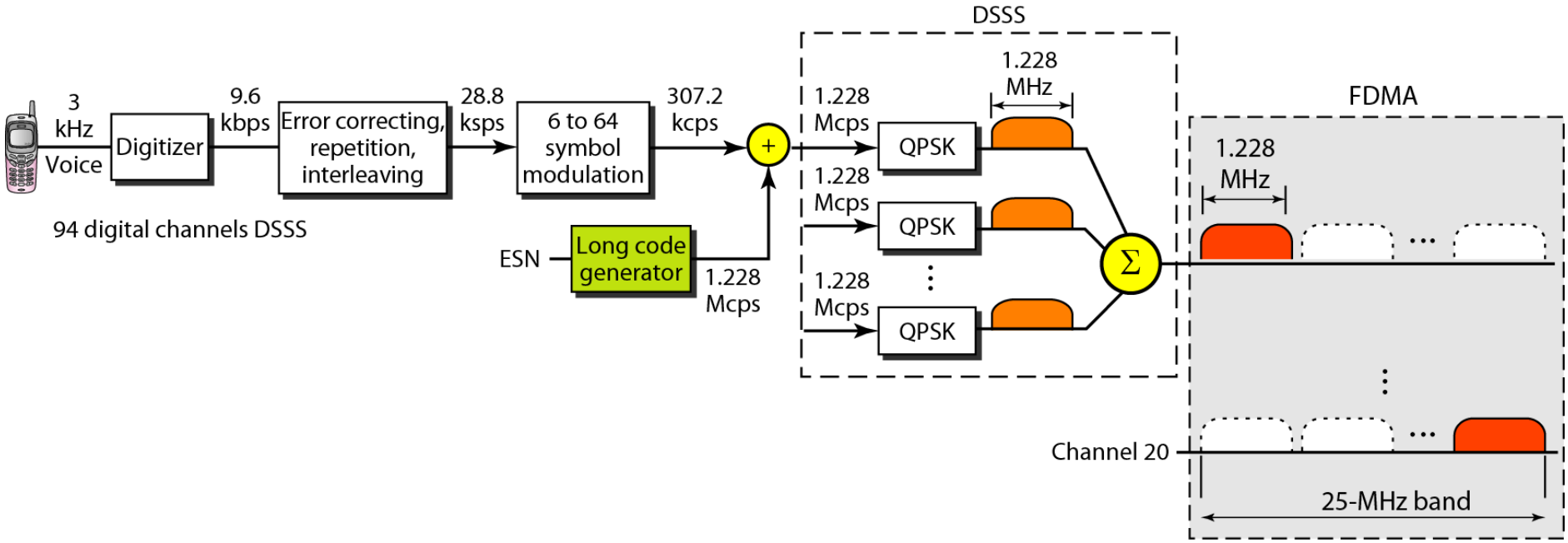
IS-95 Reverse Link Channel Parameters

Channel	Access	Traffic Rate Set 1				Traffic Rate Set 2			
Data rate (bps)	4800	1200	2400	4800	9600	1800	3600	7200	14400
Code rate	1/3	1/3	1/3	1/3	1/3	1/2	1/2	1/2	1/2
Symbol rate before repetition (sps)	14,400	3600	7200	14,400	28,800	3600	7200	14,400	28,800
Symbol repetition	2	8	4	2	1	8	4	2	1
Symbol rate after repetition (sps)	28,800	28,800	28,800	28,800	28,800	28,800	28,800	28,800	28,800
Transmit duty cycle	1	1/8	1/4	1/2	1	1/8	1/4	1/2	1
Code symbols/ modulation symbol	6	6	6	6	6	6	6	6	6
PN chips/ modulation symbol	256	256	256	256	256	256	256	256	256
PN chips/bit	256	128	128	128	128	256/3	256/3	256/3	256/3

IS-95 Forward Transmission



IS-95 Reverse Transmission



IS-95

- Two Data Rate Sets
  - 9600, 4800, 2400, 1200 bps
  - 14400, 7200, 3600, 1800 bps
- Frequency-Reuse Factor
  - Normally 1
- Soft Handoff
  - IS-95 enables an MS to do a soft handoff.

CDMA Capacity

- Capacity: The number of users supported
- Calculate the capacity of a CDMA system with W = 1.25 MHz, R = 10 Kbps, and E_b/N_0 = 7 dB.

$$\frac{E_b}{N_0} = \frac{S}{N}\frac{B}{R}$$

Transmission Power

- The transmission power assignment to *N* users is feasible

$$\sum_{j=1}^{N} \frac{1}{\frac{W}{r_j \gamma_j} + 1} < 1$$

where r_j and g_j is the data rate and the target signal-to-interference ratio (SIR) of the *j*th user, respectively.

Personal communications system (PCS)

- Does not refer to a single technology such as GSM, IS-136, or IS-95.

- Use any second-generation technology (GSM, IS-136, or IS-95).
- Use the 1900-MHz band
- Offer communication services such as short message service (SMS).

ITUs initial View of Third-Generation Capabilities

- The ITU's International Mobile Telecommunications for the year 2000 (IMT-2000) initiative
- Voice quality comparable to the public switched telephone network
- 144 kbps data rate available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
  - Much higher rates were developed

Third-Generation

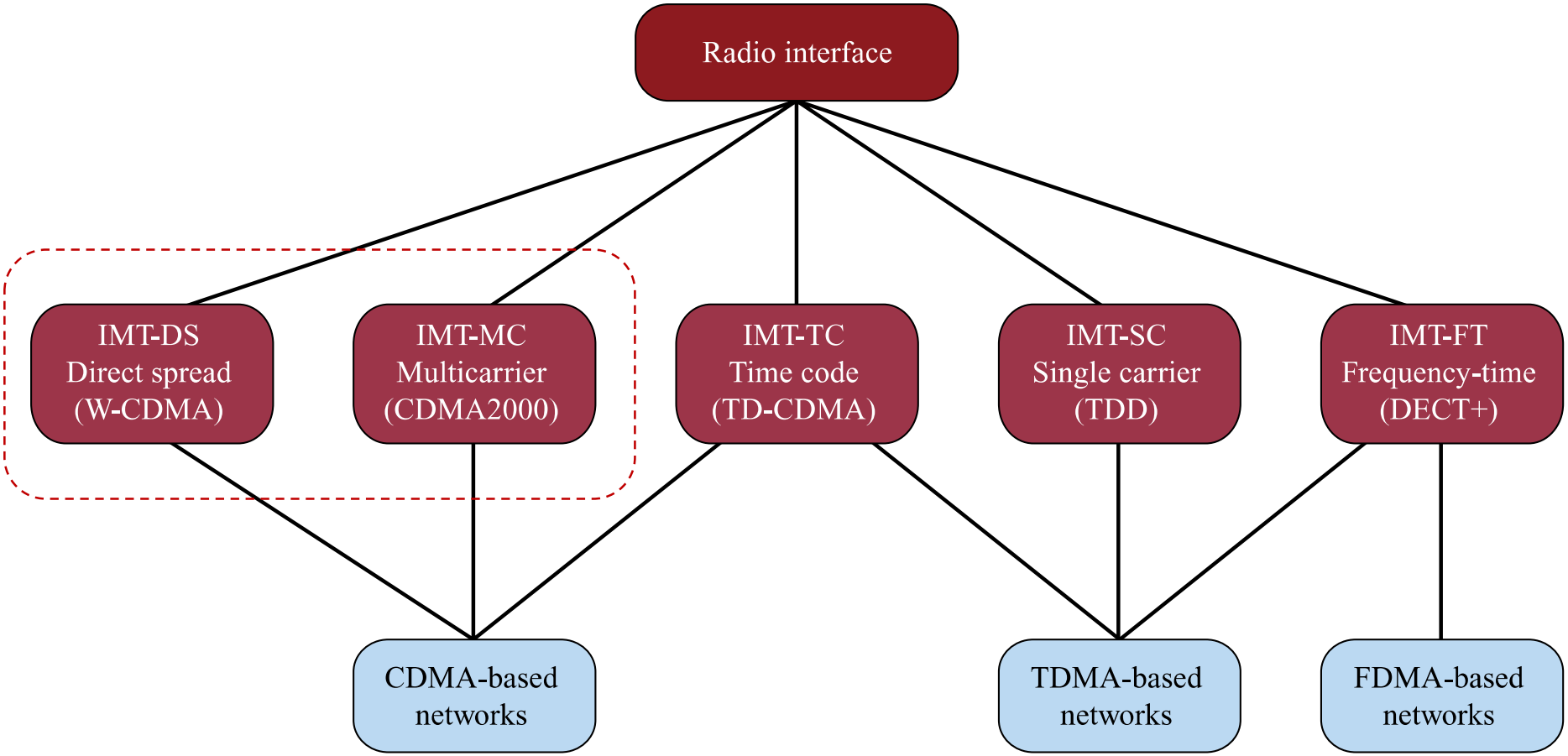
- The third generation provides both digital data and voice communication.

- The third-generation concept started in 1992, when ITU issued a blueprint called the Internet Mobile Communication 2000 (IMT-2000).
  - Support for packet-switched and circuit-switched data services
  - A band of 2 GHz, Bandwidths of 2 MHz
  - Interface to the Internet

Alternative interfaces

- Five alternatives for smooth evolution from 1G and 2G systems

- Two most prevalent based on CDMA
  - Wideband CDMA (WCDMA)
  - CDMA2000



13.11 IMT-2000 TERRESTRIAL RADIO INTERFACES

CDMA Design Considerations

- Bandwidth – limit channel usage to 5 MHz
- Chip rate – depends on desired data rate, need for error control, and bandwidth limitations; 3 Mcps or more is reasonable
- Multirate – advantage is that the system can flexibly support multiple simultaneous applications from a given user and can efficiently use available capacity by only providing the capacity required for each service

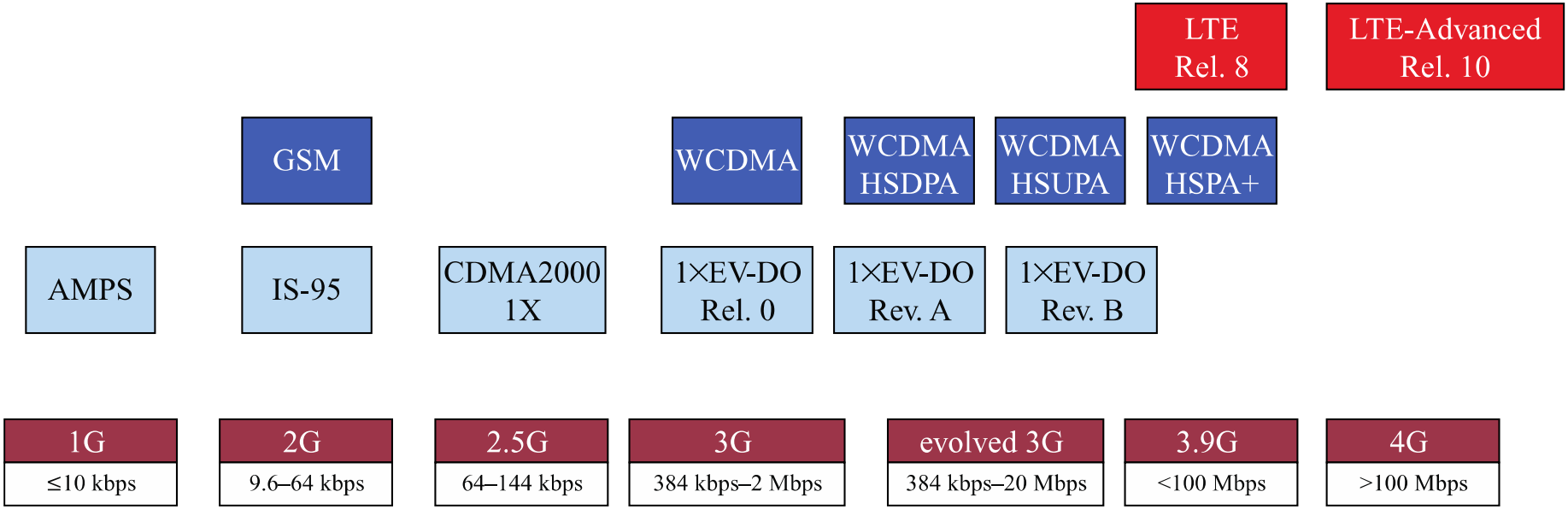
WCDMA and UMTS

- WCDMA is part of a group of standards from
  - IMT-2000
  - Universal Mobile Telephone System (UMTS)
  - Third-Generation Partnership Project (3GPP) industry organization

- 3GPP originally released GSM
  - Issued Release 99 in 1999 for WCDMA and UMTS
  - Subsequent releases were "Release 4" and onwards
  - Many higher layer network functions of GSM were carried over to WCDMA

WCDMA and UMTS

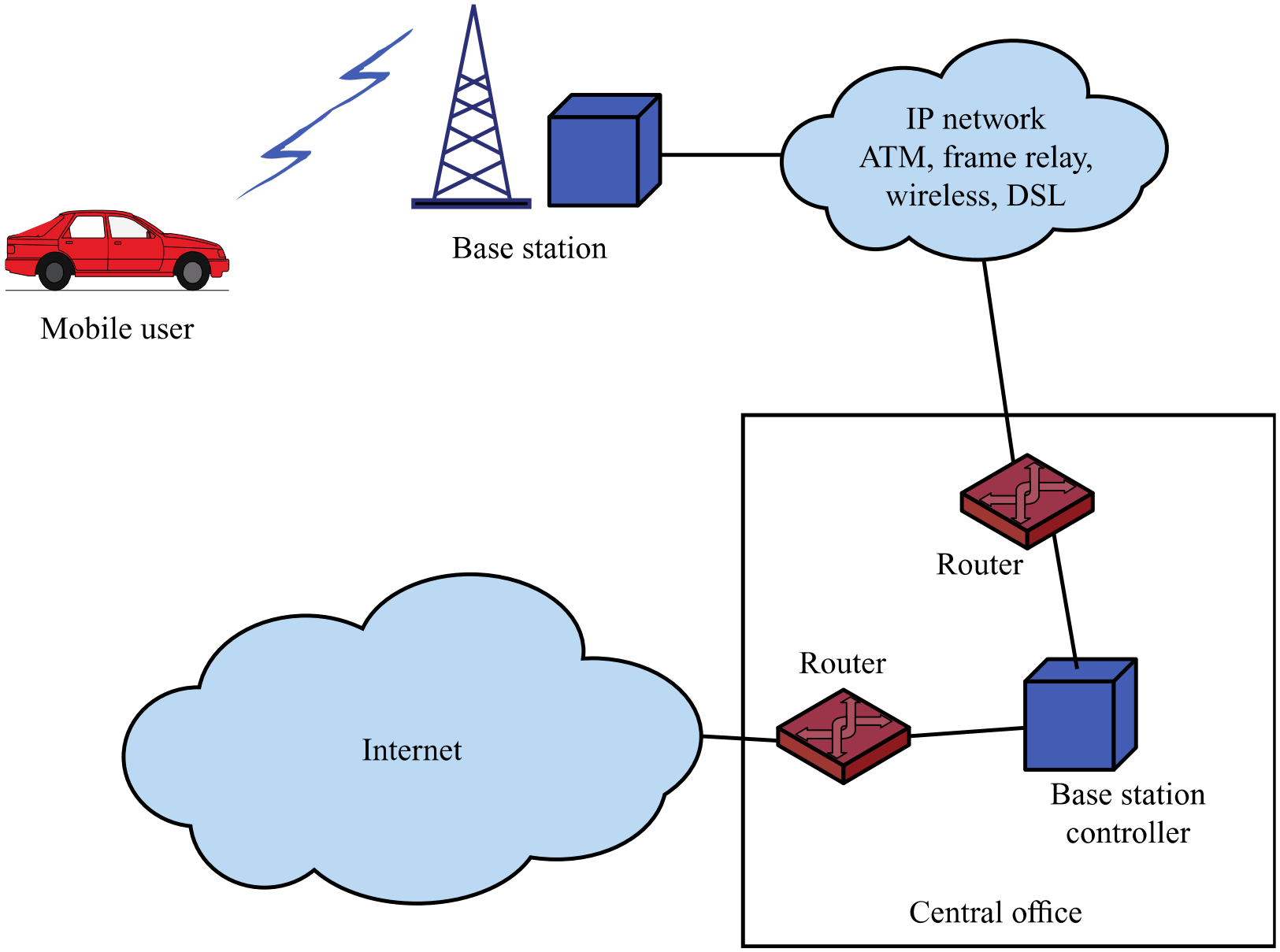
- 144 kbps to 2 Mbps, depending on mobility
- High Speed Downlink Packet Access (HSDPA)
  - Release 5
  - 1.8 to 14.4 Mbps downlink
  - Adaptive modulation and coding, hybrid ARQ, and fast scheduling
- High Speed Uplink Packet Access (HSUPA)
  - Release 6
  - Uplink rates up to 5.76 Mbps
- High Speed Packet Access Plus (HSPA+)
  - Release 7 and successively improved in releases through Release 11
  - Maximum data rates increased from 21 Mbps up to 336 Mbps
  - 64 QAM, 2×2 and 4×4 MIMO, and dual or multi-carrier combinations
- 3GPP Release 8 onwards introduced Long Term Evolution (LTE)
  - Pathway to 4G, Chapter 14



13.13 EVOLUTION OF CELLULAR WIRELESS SYSTEMS

CDMA2000 and EV-DO

- CDMA2000 first introduced 1xRTT (Radio Transmission Technology)
  - 1 times the 1.2288 Mcps spreading rate of a 1.25 MHz IS-95 CDMA channel
  - Not 3G, so considered by some as "2.5G"
- Evolution-Data Only (1×EV-DO)
  - Also 1×EV-DV (data/voice) which never succeeded
  - 1×EV-DO Release 0
    - 2.4 Mbps uplink, 153 kbps downlink
    - Only using 1.25 MHz of 5 MHz required of CDMA
  - 1×EV-DO Release A
    - 3.1 Mbps downlink, 1.8 Mbps uplink, QoS
  - 1×EV-DO Release B
    - 5 MHz bandwidth, 14.7 Mpbs uplink, 5.4 Mbps downlink
- EV-DO uses only IP, but VoIP can be used for voice



13.14 CDMA2000 1XEV-DO CONFIGURATION ELEMENTS

CDMA2000 1XEV-DO Revision B
Per-carrier Link Parameters: Forward Link

Data rate (kbps)	Number of slots	Packet size (bytes)	Packet duration (ms)	Code rate	Modulation
38.4	16	128	26.67	1/5	QPSK
76.8	8	128	13.33	1/5	QPSK
153.6	4	128	6.67	1/5	QPSK
307.2	2	128	3.33	1/5	QPSK
614.4	2	256	3.33	1/3	QPSK
921.6	2	384	3.33	1/3	8PSK
1228.8	2	512	3.33	1/3	16QAM
1843.2	1	384	1.67	1/3	8 PSK
2457.6	1	512	1.67	1/3	16QAM
3686.4[2]	1	768	1.67	1/3	64QAM
4300.8[2]	1	896	1.67	1/3	64QAM
4915.2[2]	1	1024	1.67	1/3	64QAM

[1]Not a comprehensive list of all standardized options
[2]Optional

CDMA2000 1XEV-DO Revision B
Per-carrier Link Parameters: Reverse Link

Data rate (kbps)	Number of slots	Packet size (bytes)	Packet dura-tion (ms)	Effective Code rate	Modulation
4.8	16	16	26.67	1/5	BPSK
9.6	16	32	26.67	1/5	BPSK
19.2	16	64	26.67	1/5	BPSK
28.8	16	96	26.67	1/5	BPSK
38.4	16	128	26.67	1/5	BPSK
57.6	16	192	26.67	1/5	QPSK
76.8	16	256	26.67	1/5	QPSK
115.2	16	384	26.67	1/5	QPSK
153.6	16	512	26.67	1/5	QPSK
230.4	16	768	26.67	1/5	QPSK
307.2	16	1024	26.67	1/5	QPSK
460.8	16	1536	26.67	1/3	8 PSK