11 Data Communication

Week 11 Multiple Access

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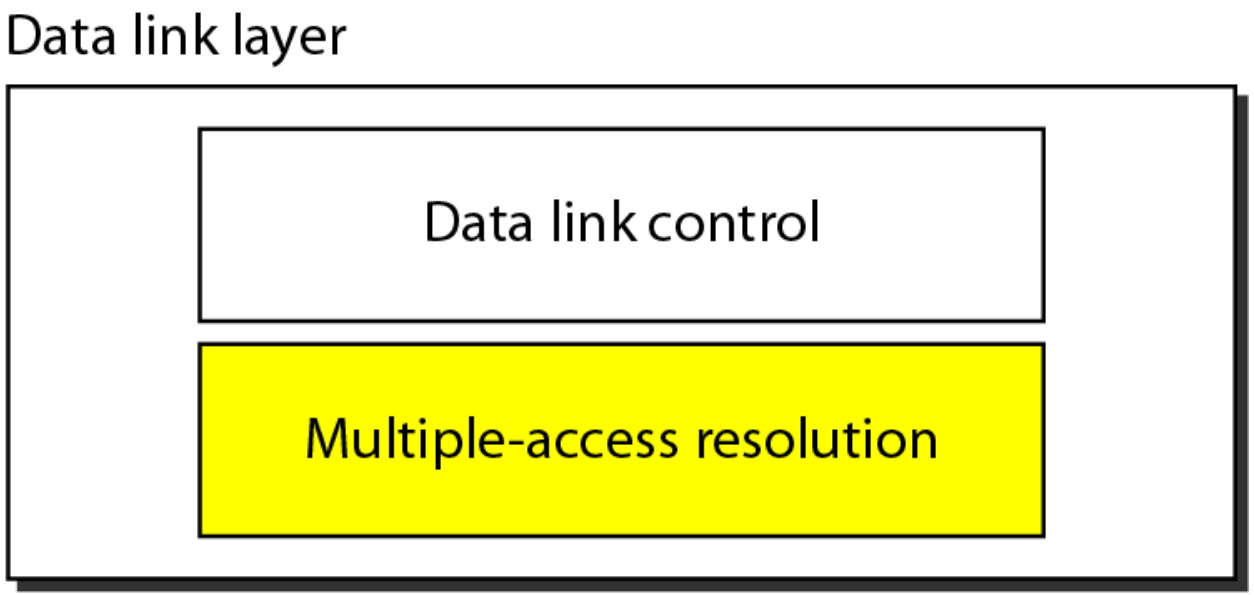
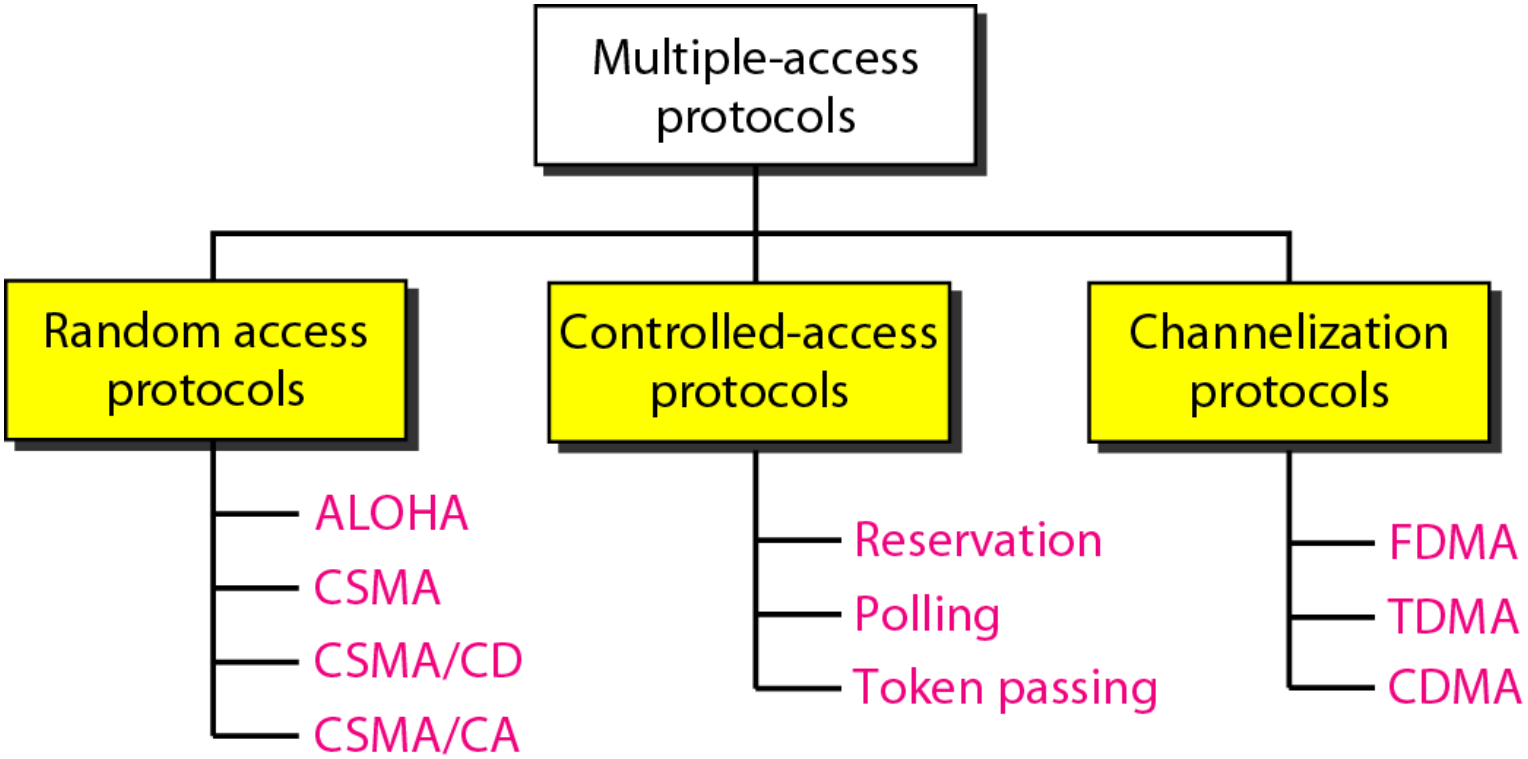
Multiple Access

- Data Link Layer divided into two sublayers
  - The upper sublayer is responsible for data link control
  - The lower sublayer is responsible for resolving access to the shared media



Multiple Access Protocols



Random Access Protocols

- In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits, or does not permit, another station to send.
- At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.
- What we discuss:

ALOHA

Slotted ALOHA

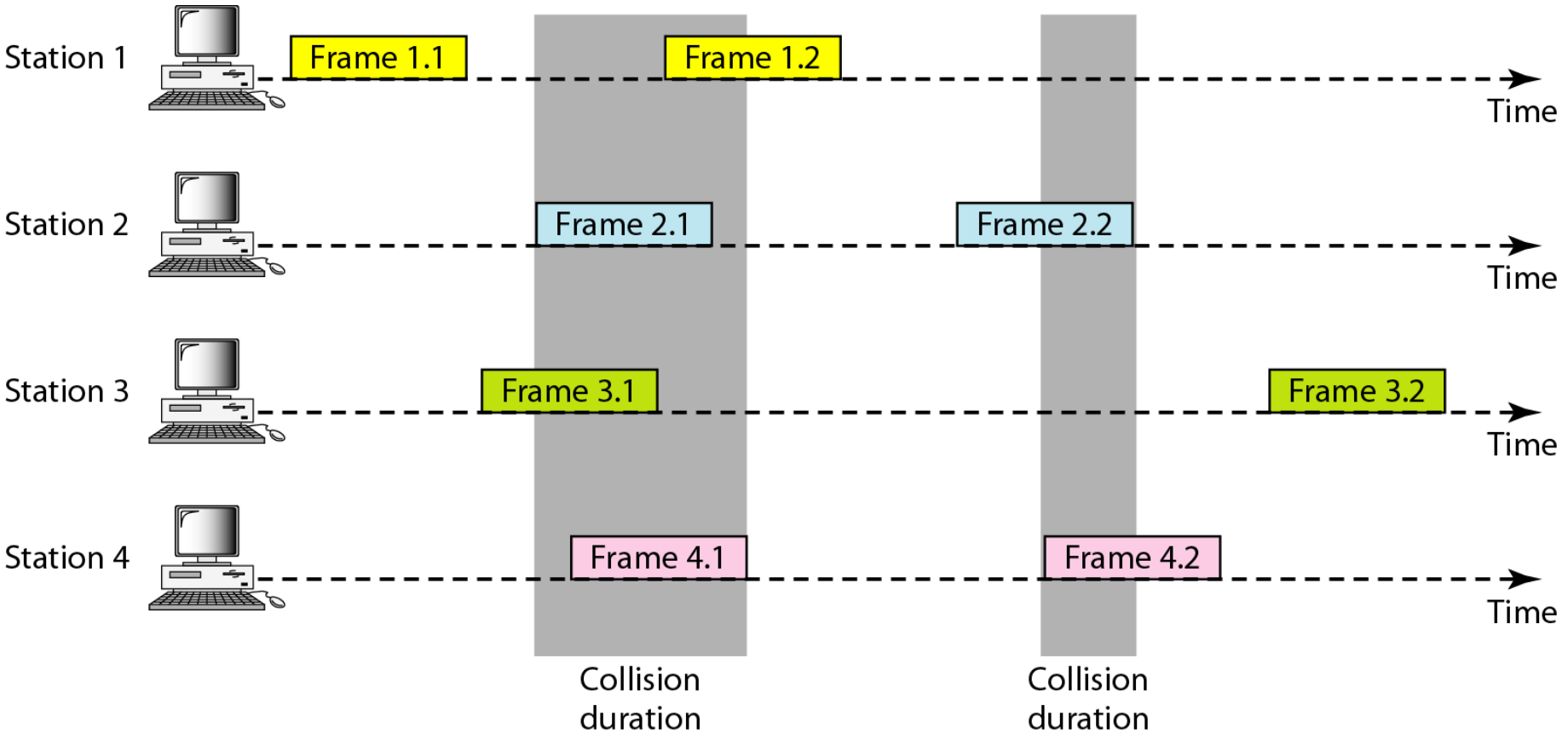
CSMA/CD

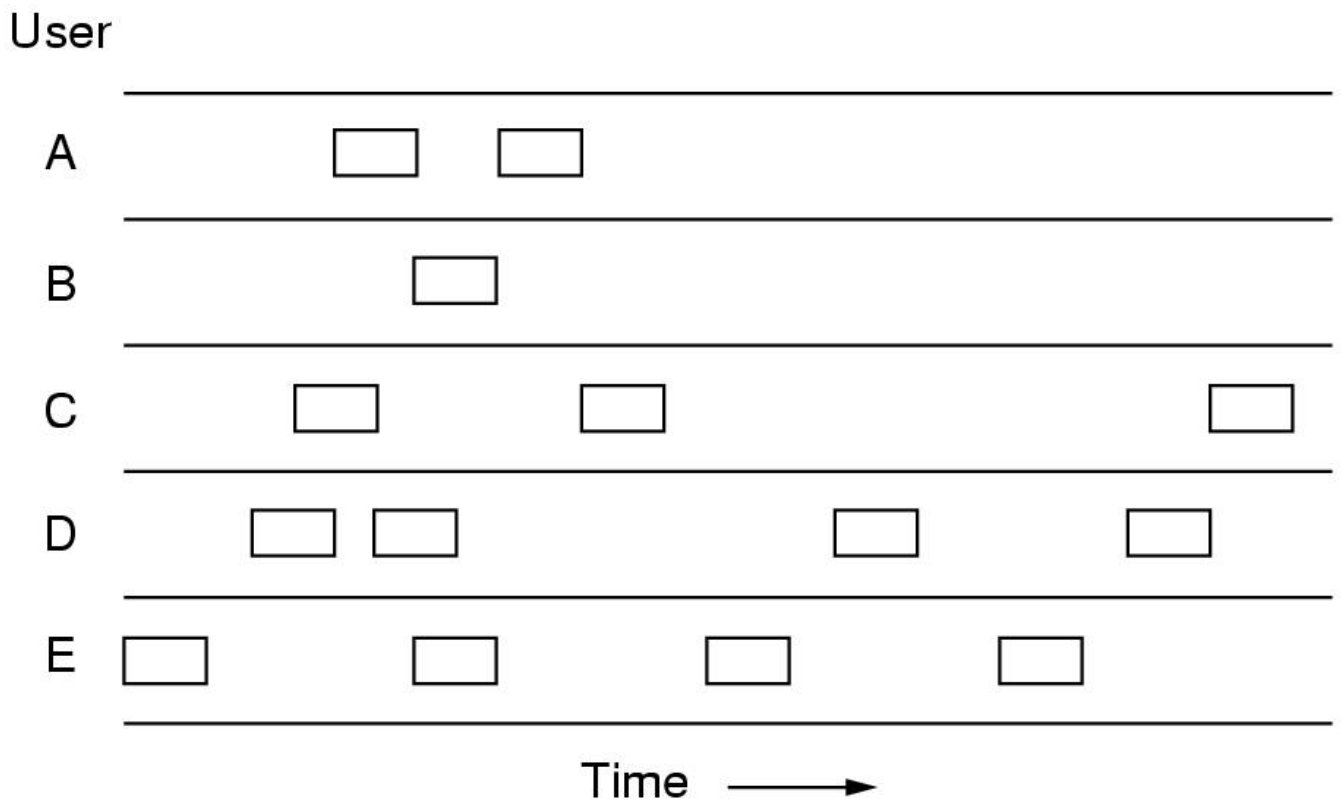
CSMA/CA

ALOHA Protocol

- ALOHA is developed in the 1970s at the University of Hawaii.
- The basic idea is simple:
  - Let users transmit whenever they have data to be sent.
- If two or more users send their packets at the same time, a collision occurs and the packets are destroyed.
- If there is a collision,
  - the sender waits a random amount of time and sends it again.
- The waiting time must be random. Otherwise, the same packets will collide again.

Frames in a pure ALOHA Networks



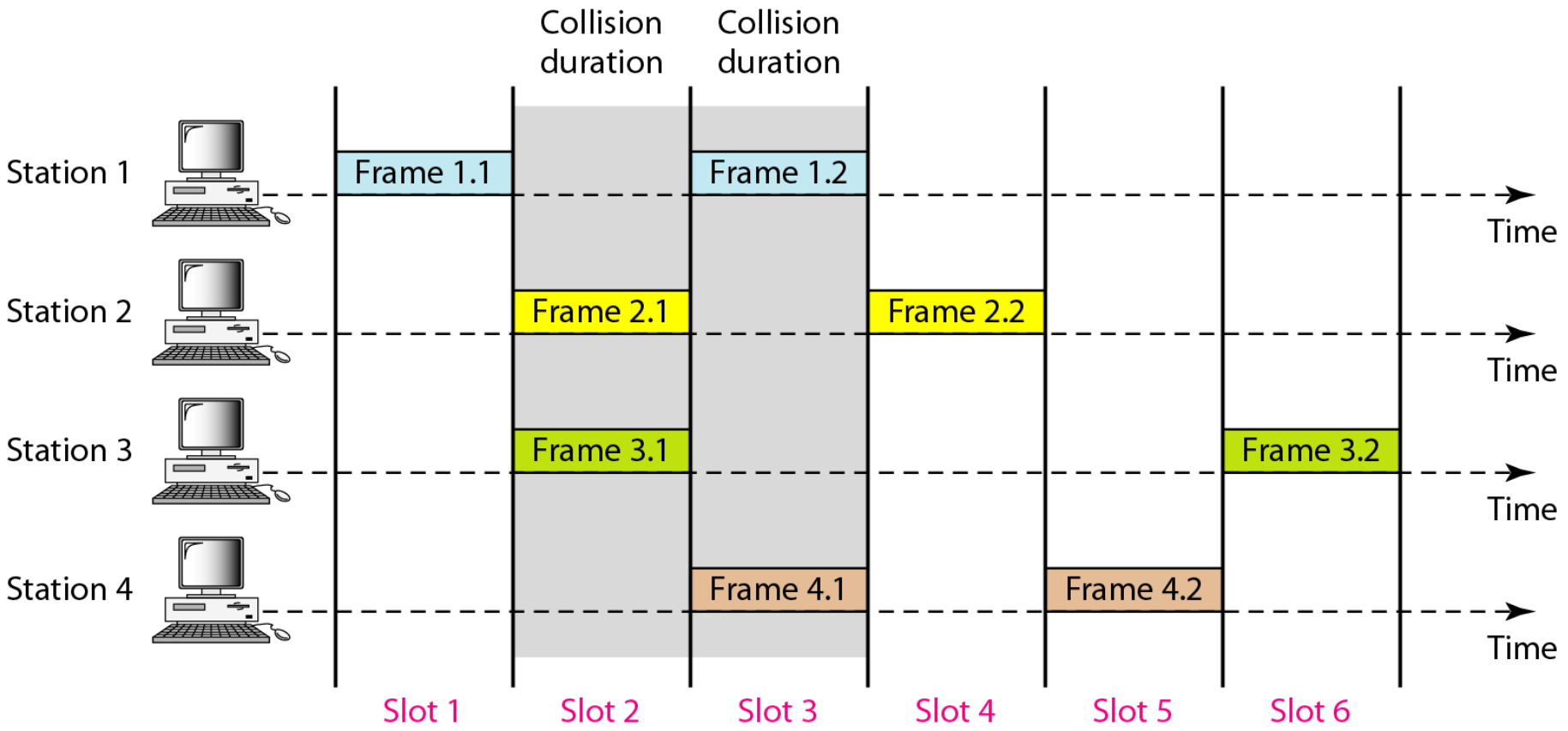


- Note that all packets have the same length because the throughput of ALOHA systems is maximized by having a uniform packet size.

Example

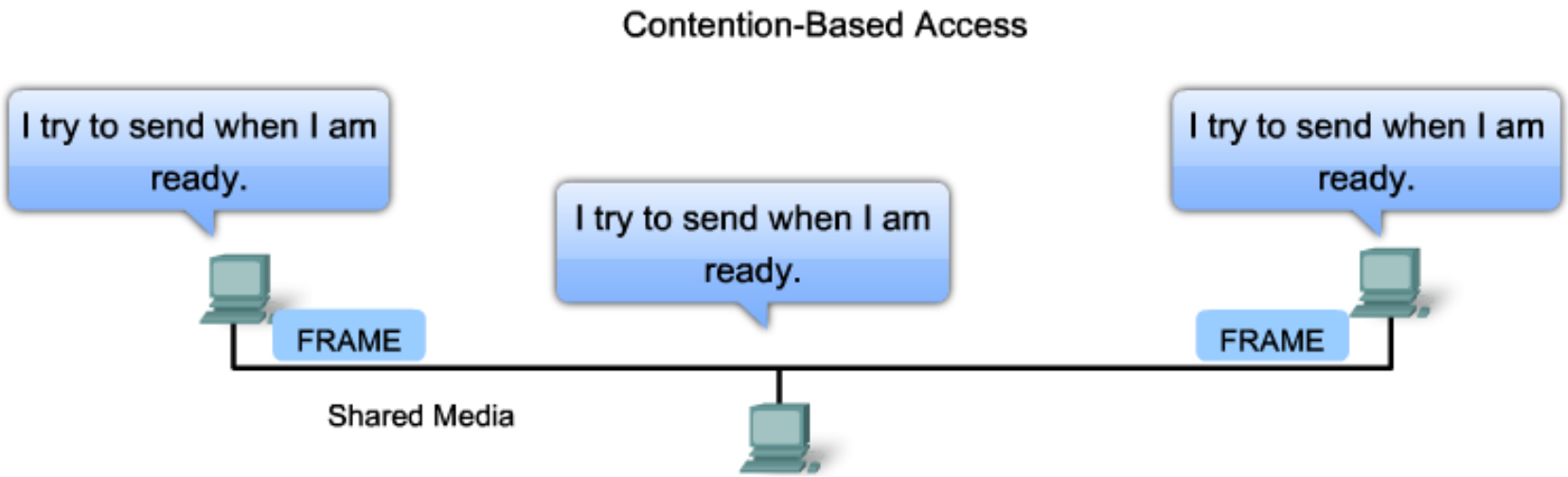
- A pure ALOHA network transmits 200-bit frames on a shared channel of 200 kbps. What is the requirement to make this frame collision-free?
- **Solution**
- Average frame transmission time Tfr is 200 bits/200 kbps or 1 ms. The vulnerable time is 2 × 1 ms = 2 ms. This means no station should send later than 1 ms before this station starts transmission and no station should start sending during the one 1-ms period that this station is sending.

Slotted ALOHA



Contention-based Access

- Contention-based access - All nodes operating in half-duplex compete for the use of the medium, but only one device can send at a time. However, there is a process if more than one device transmits at the same time. Ethernet LANs using hubs and WLANs are examples of this type of access control. Figure below shows contention-based access.



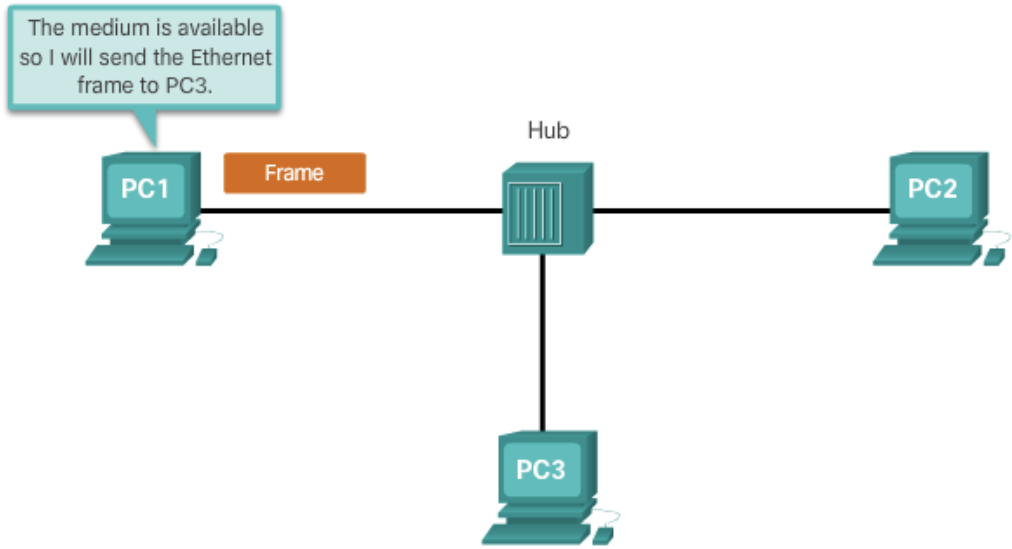
Characteristics	Contention-Based Technologies
• Stations can transmit at any time • Collision exist • There are mechanisms to resolve contention for the media	• CSMA/CD for 802.3 Ethernet networks • CSMA/CA for 802.11 wireless networks

Carrier Sense Multiple Access / Collision Detection (CSMA/CD)

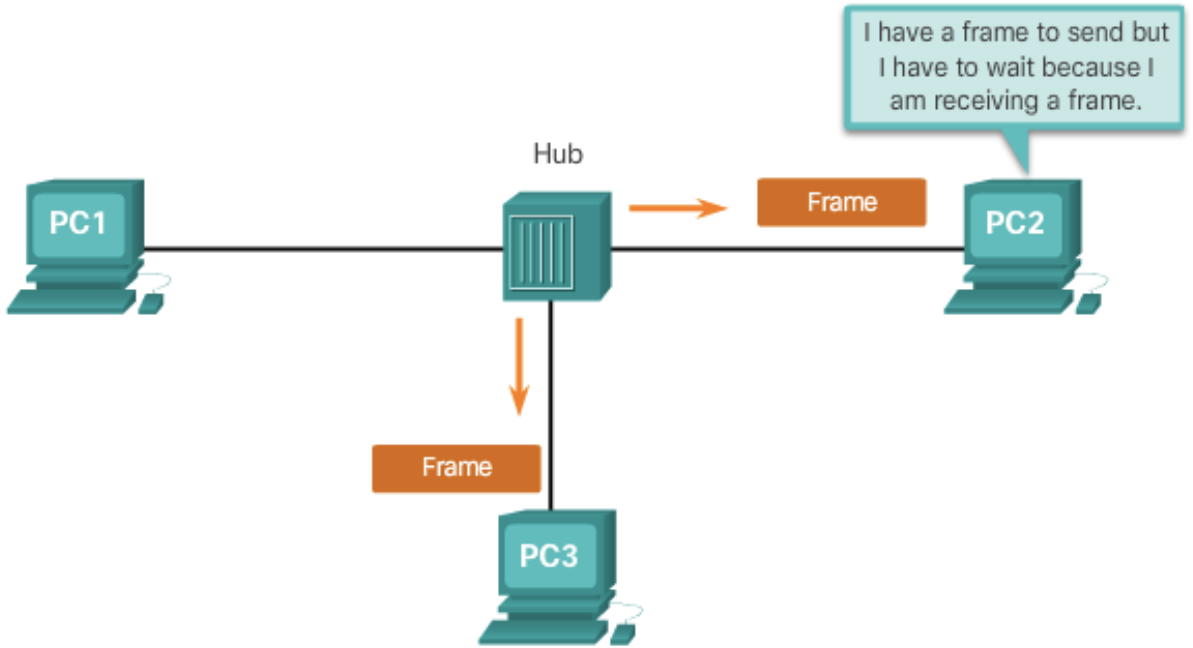
- WLANs, Ethernet LANs with hubs, and legacy Ethernet bus networks are all examples of contention-based access networks. All of these networks operate in half-duplex mode. This requires a process to govern when a device can send and what happens when multiple devices send at the same time.

- The Carrier Sense Multiple Access/Collision Detection (CSMA/CD) process is used in half-duplex Ethernet LANs. Figure 1 shows an Ethernet LAN using a hub. The CSMA process is as follows:

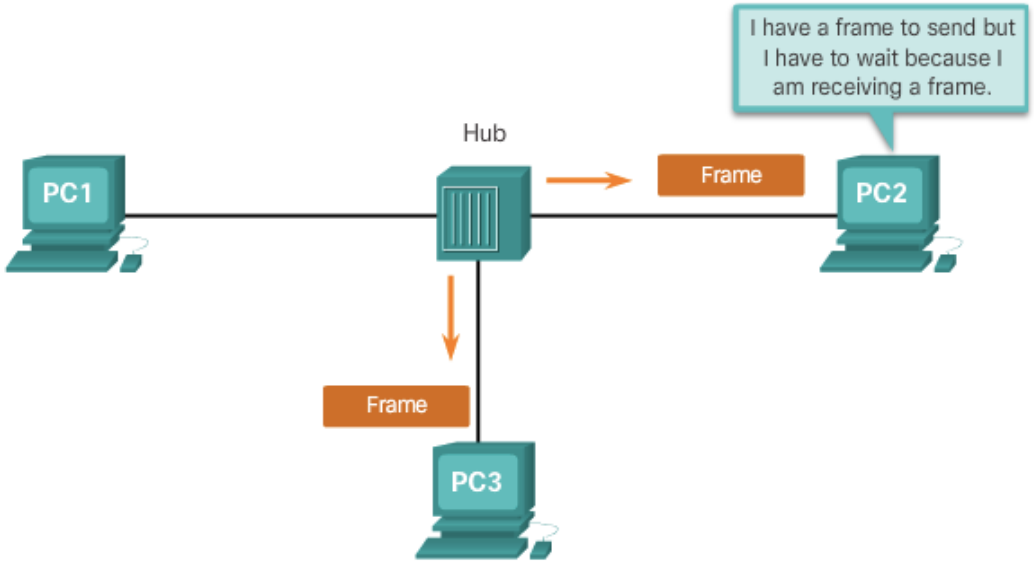
  1. PC1 has an Ethernet frame to send to PC3.
  2. PC1's NIC needs to determine if anyone is transmitting on the medium. If it does not detect a carrier signal, in other words, it is not receiving transmissions from another device, it will assume the network is available to send.
  3. PC1's NIC sends the Ethernet Frame, as shown in Figure 1.



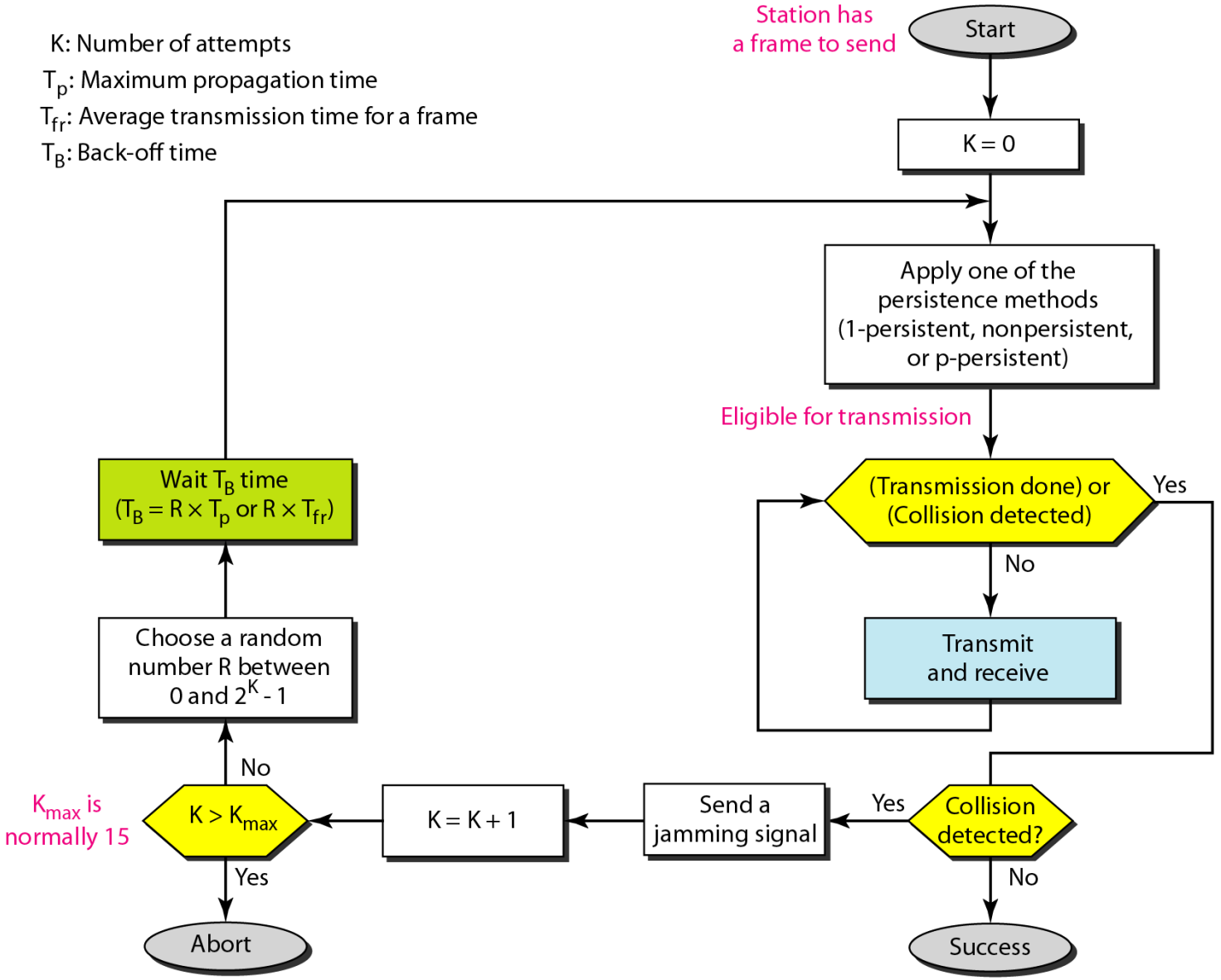
4. The Ethernet hub receives the frame. An Ethernet hub is also known as a multiport repeater. Any bits received on an incoming port are regenerated and sent out all othe
shown in Figure.



5. If another device, such as PC2, wants to transmit, but is currently receiving a frame, it must wait until the channel is clear.
6. All devices attached to the hub will receive the frame. Because the frame has a destination data link address for PC3, only that device will accept and copy in the entire frame. All other devices' NICs will ignore the frame, as shown in Figure.



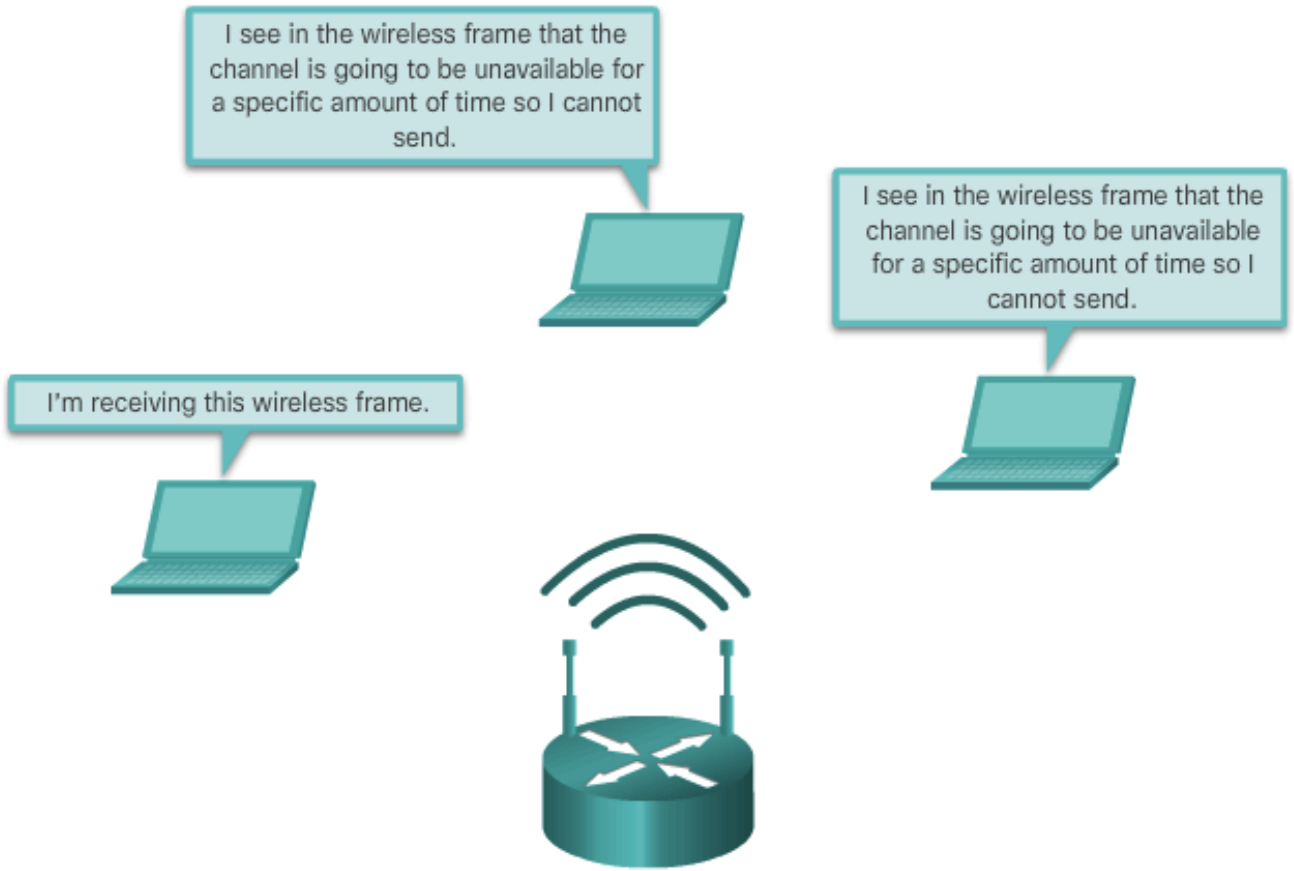
- If two devices transmit at the same time, a collision will occur. Both devices will detect the collision on the network. This is done by the NIC comparing data transmitted with data received, or by recognizing the signal amplitude is higher than normal on the media. The data sent by both devices will be corrupted and will need to be resent.

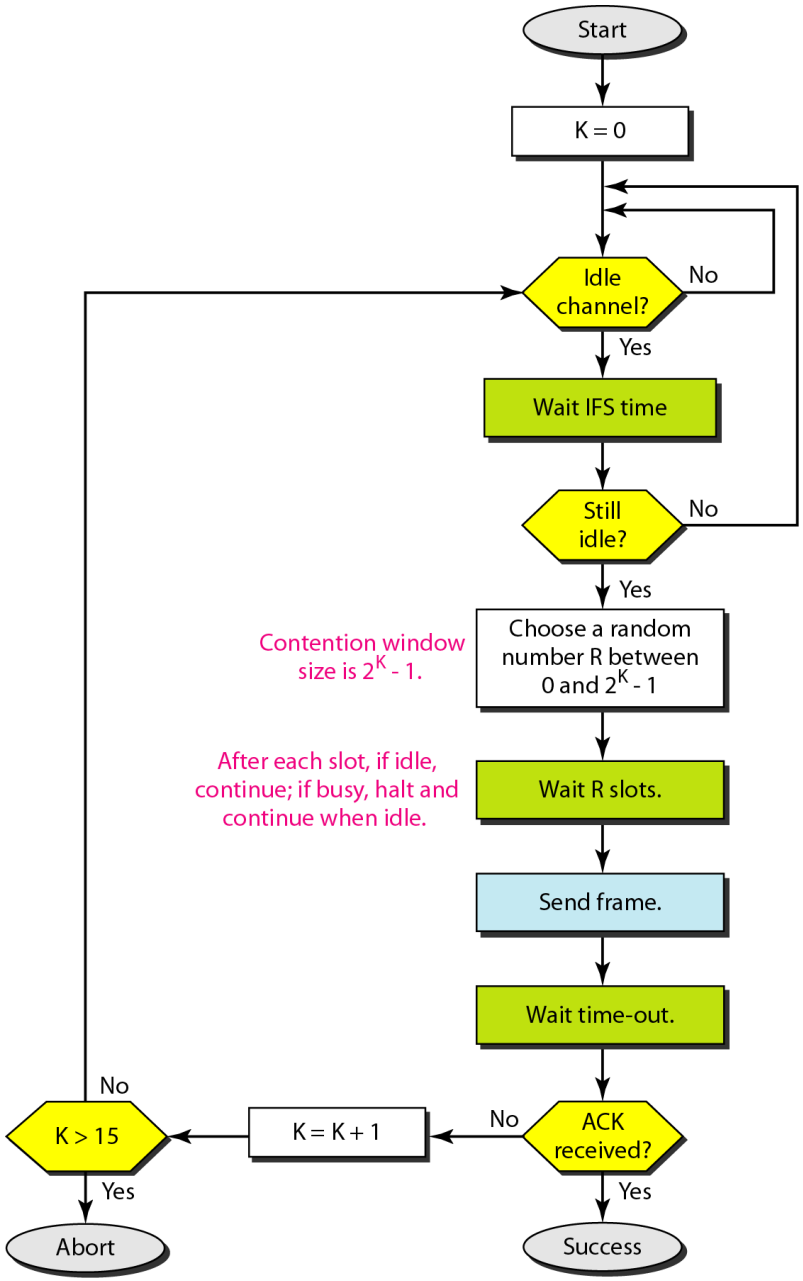

K: Number of attempts
T_p: Maximum propagation time
T_{fr}: Average transmission time for a frame
T_B: Back-off time
Station has a frame to send
Start
K = 0
Apply one of the persistence methods (1-persistent, nonpersistent, or p-persistent)
Eligible for transmission
(Transmission done) or (Collision detected)
Yes
No
Transmit and receive
Collision detected?
Yes
No
Success
Send a jamming signal
K = K + 1
$K > K_{max}$
No
Yes
Abort
K_{max} is normally 15
Choose a random number R between 0 and $2^K - 1$
Wait T_B time ($T_B = R \times T_p$ or $R \times T_{fr}$)

Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

- Another form of CSMA that is used by IEEE 802.11 WLANs is Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). CMSA/CA uses a method similar to CSMA/CD to detect if the media is clear. CSMA/CA also uses additional techniques.
- CSMA/CA does not detect collisions but attempts to avoid them by waiting before transmitting. Each device that transmits includes the time duration that it needs for the transmission. All other wireless devices receive this information and know how long the medium will be unavailable, as shown in the figure. After a wireless device sends an 802.11 frame, the receiver returns an acknowledgment so that the sender knows the frame arrived.
- Whether it is an Ethernet LAN using hubs, or a WLAN, contention-based systems do not scale well under heavy media use. It is important to note that Ethernet LANs using switches do not use a contention-based system because the switch and the host NIC operate in full-duplex mode.

IEEE 802.11 WLAN

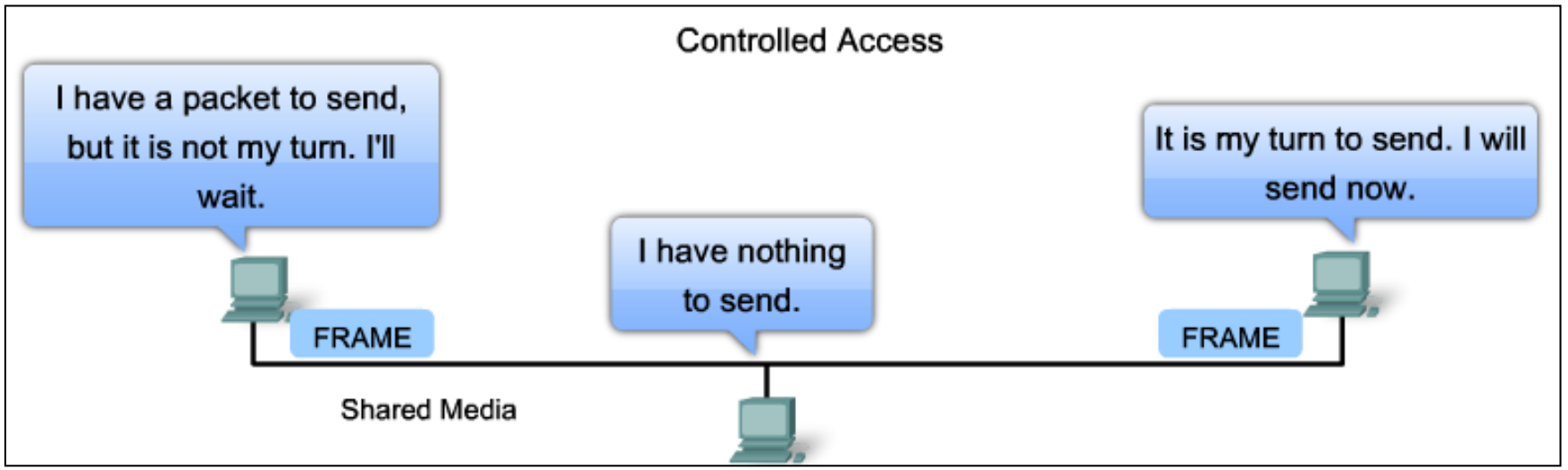


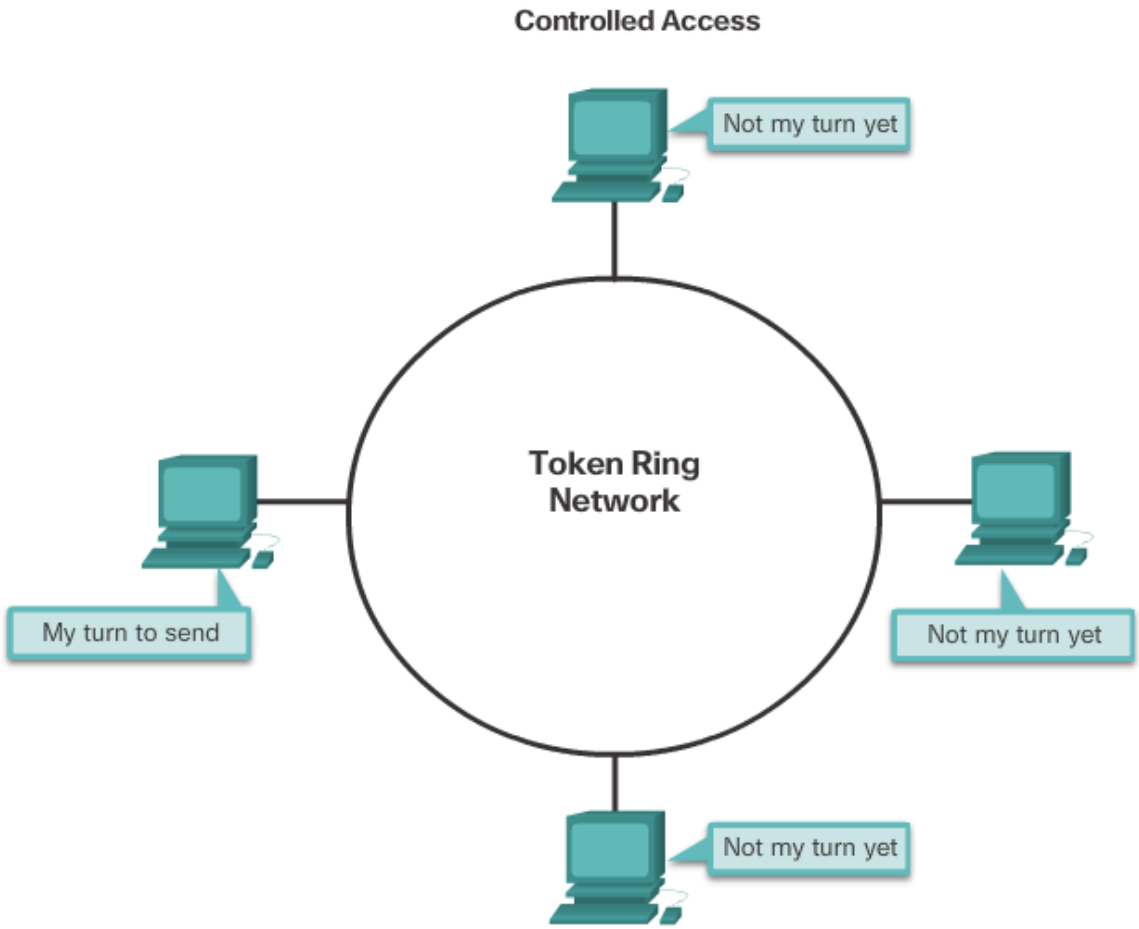

Start
K = 0
Idle channel?
No
Yes
Wait IFS time
Still idle?
No
Yes
Contention window size is $2^K - 1$.
Choose a random number R between 0 and $2^K - 1$
After each slot, if idle, continue; if busy, halt and continue when idle.
Wait R slots.
Send frame.
Wait time-out.
No
ACK received?
No
K = K + 1
K > 15
Yes
Yes
Abort
Success

Controlled Access

- In controlled access, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations.
- What we discuss:

Token Pasing





Characteristics	Controlled Access Technologies
• Only one station can transmit at a time • Devices wishing to transmit must wait their turn • No collisions • May use a token passing method	• Token Ring (IEEE 802.5) • Fiber Distributed Data Interface (FDDI)

Channelization

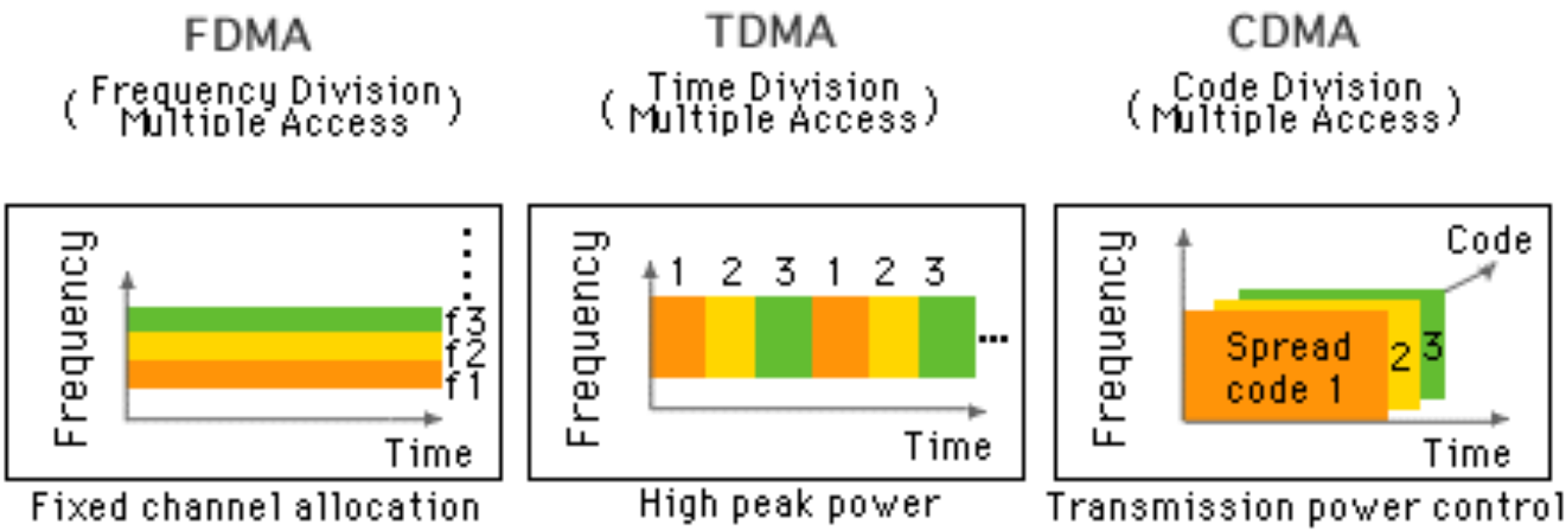
- Channelization is a multiple-access method in which the available bandwidth of a link is shared in time, frequency, or through code, between different stations. In this section, we discuss three channelization protocols.

Frequency Division Multiple Access (FDMA)

Time Division Multiple Access (TDMA)

Code Division Multiple Access (CDMA)

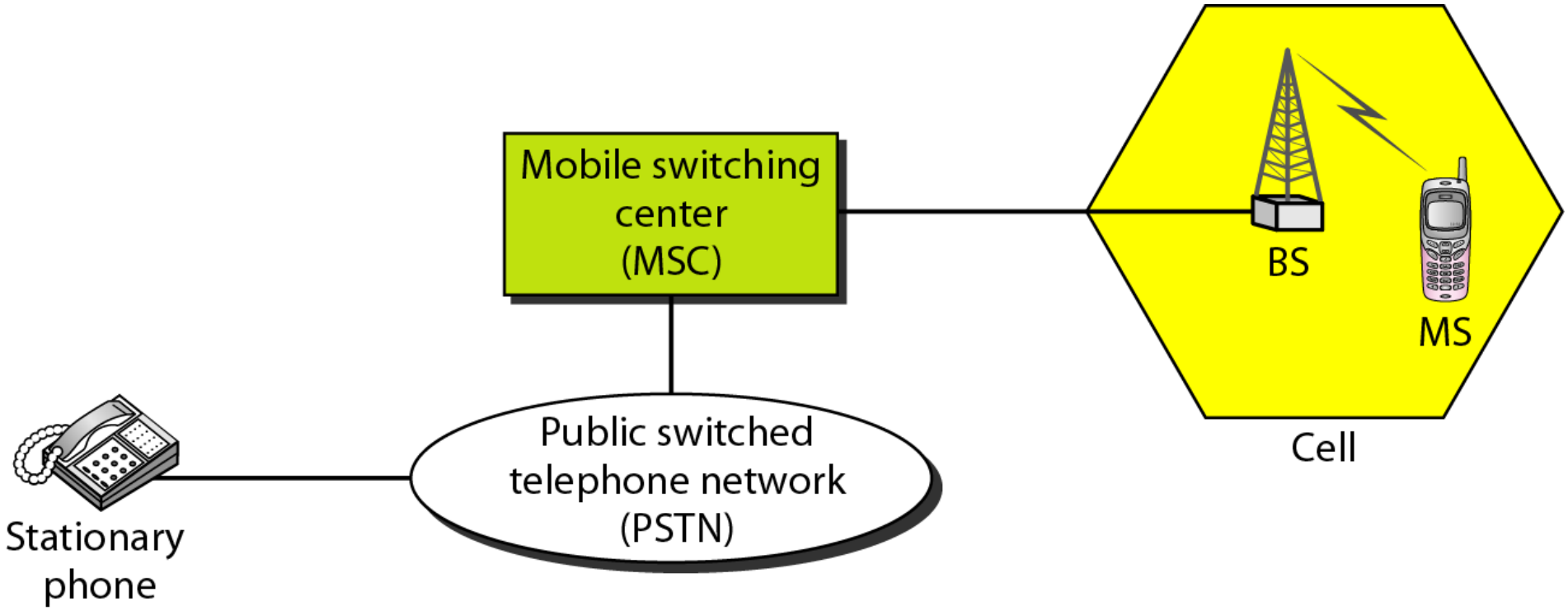
FDMA, TDMA, CDMA



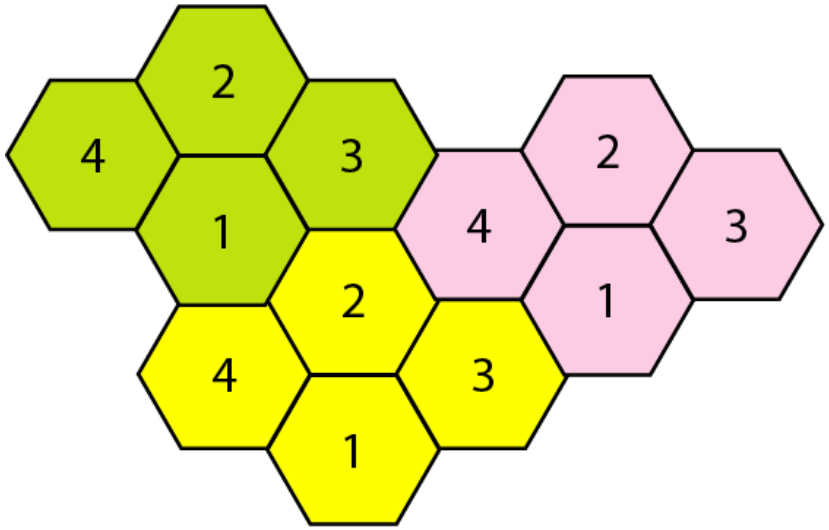
Item	FDMA	TDMA	CDMA
Frequency use	Frequency reuse according to interference	Repeated use of same frequency based on interference	Same frequency use.
Transmit mode	Continuous transmission	Burst transmission (mobile station) Continuous transmission or burst transmission(base station)	Continuous transmission
Handling of different transmission rates	Difficult (use of multiple carries) Equalizer, interference suppressor necessary for higher transmission rates	Easy (Use of multiple slots, variable slot length)	Easy(use of multiple codes)
System characteristics	Equalizer, interference suppressor necessary for higher transmission rates. Control channels (downlinks)	Equalization and interference suppression needed as the degree of multiplexing increases.	With DS-CDMA, control of transmission power is essential, RAKE reception for enhanced quality and interference
Inter-BS nchronization needed	Control channels (downlinks)	Synchronization needed	Synchronization needed for soft handover.
Example applications	Analog vehicle phones, handheld phones	TDMA-TDD:PHS, TDMA-FDD:PDC,GSM	CDMA-FDD:IS-95

Cellular Generation

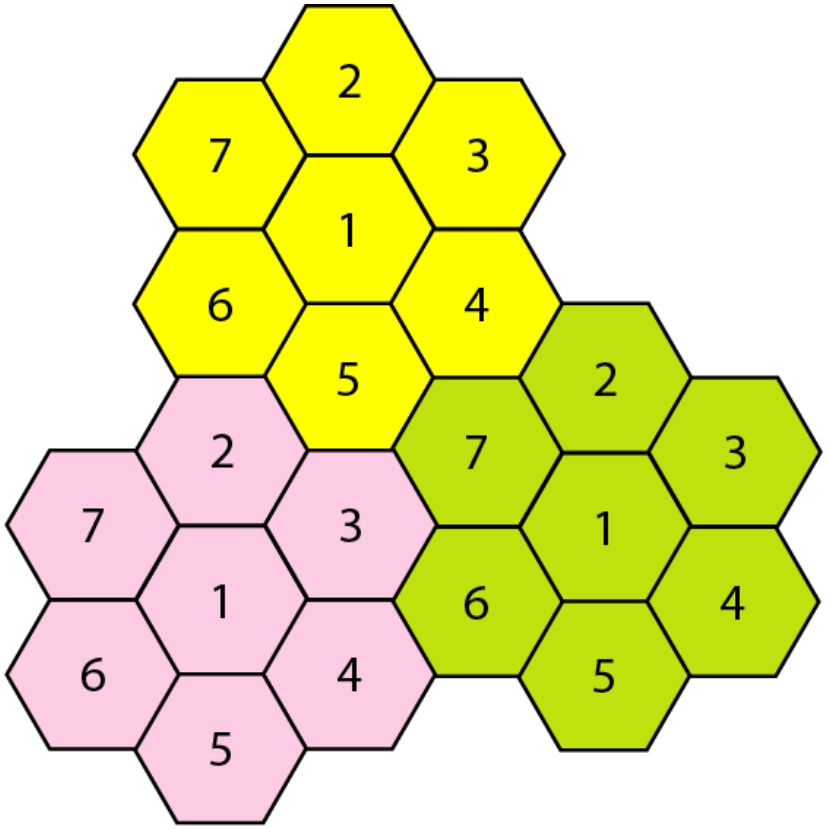
Celullar System



Frequency Reuse



a. Reuse factor of 4

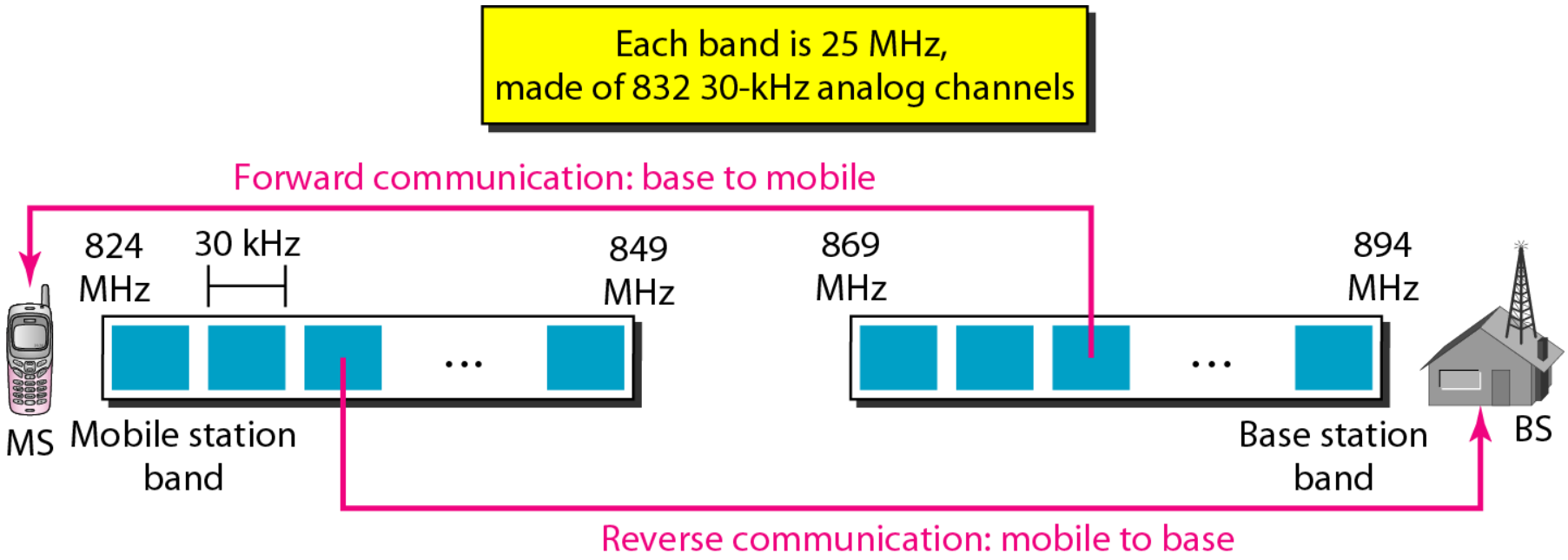


b. Reuse factor of 7

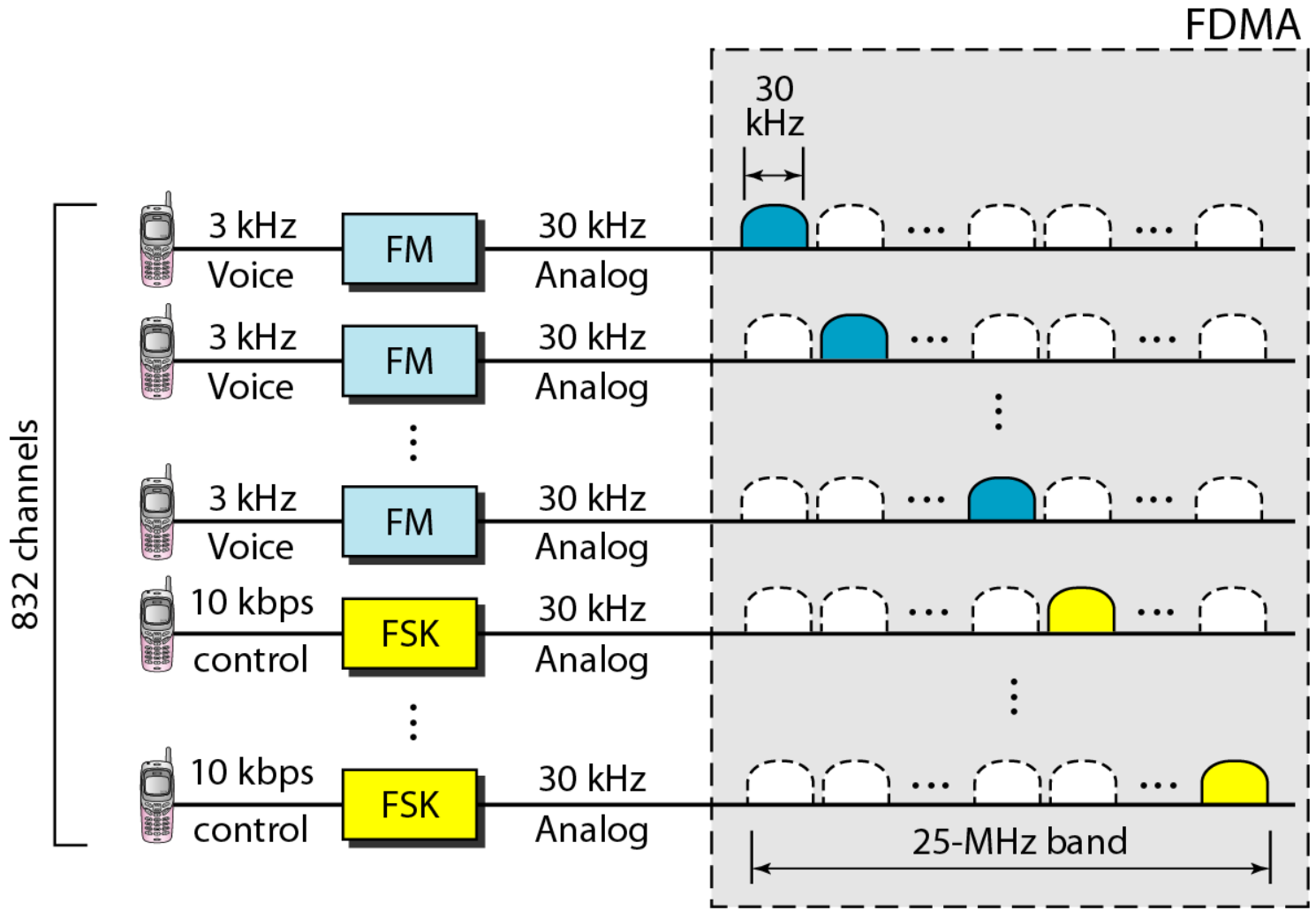
FDMA

AMPS is an analog cellular phone system using FDMA.

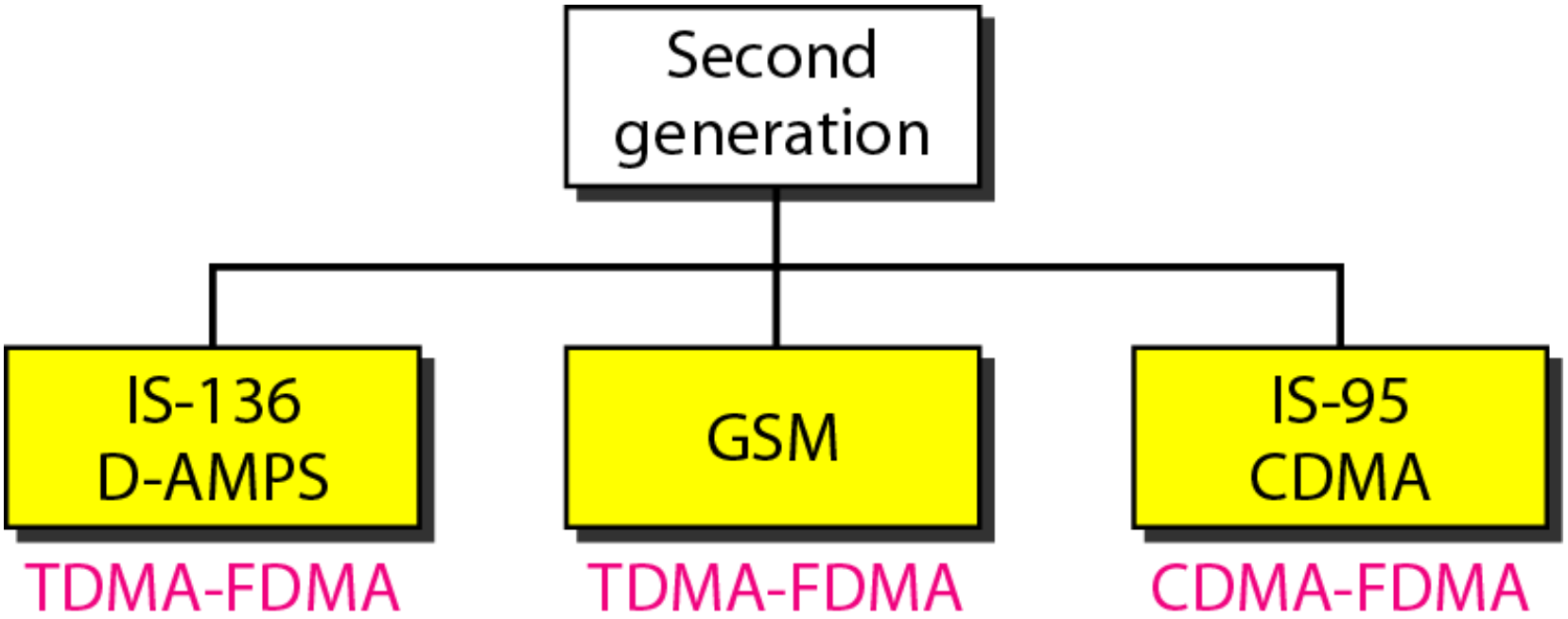
- Cellular Band for AMPS



AMPS reverse communication band

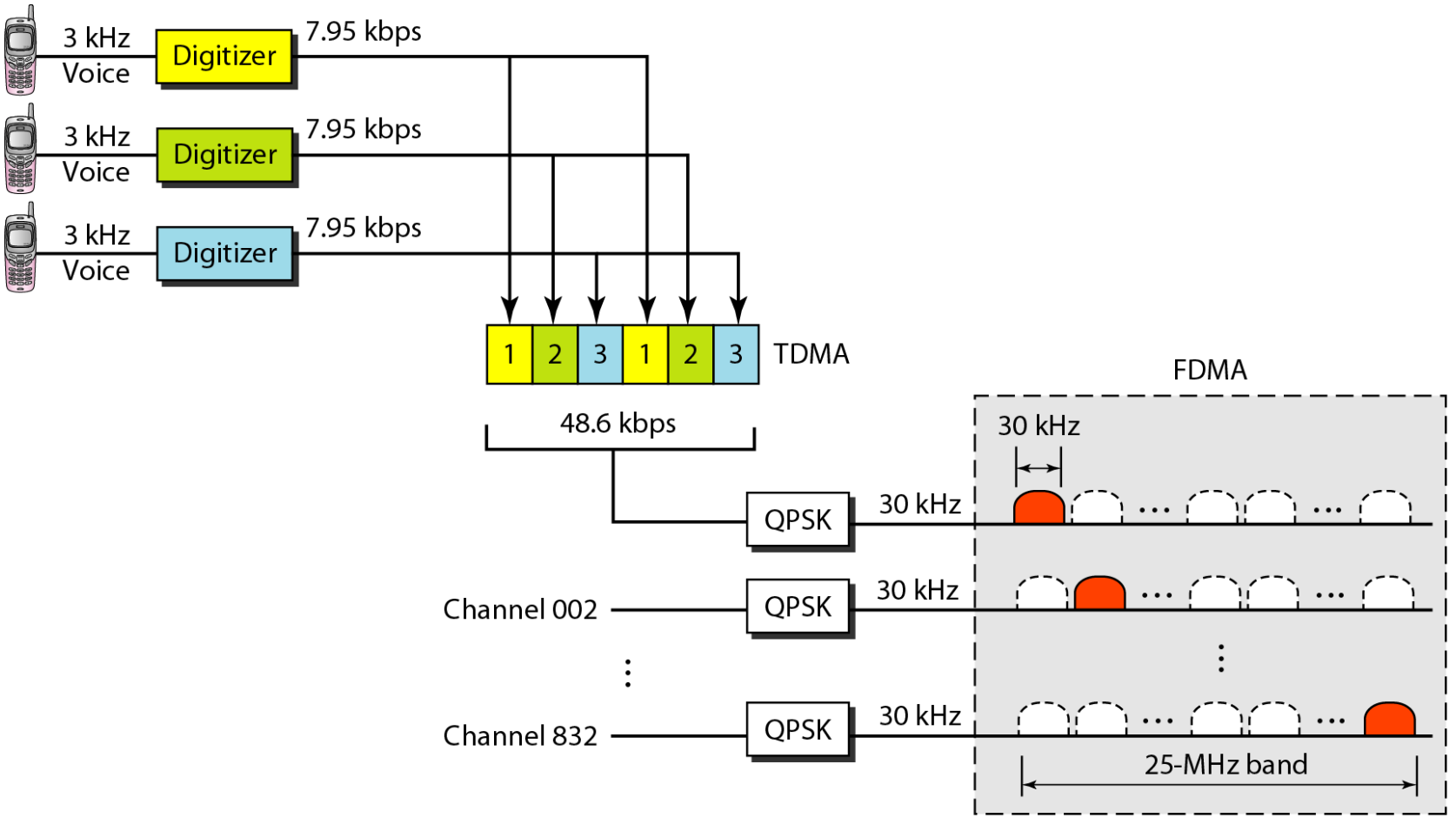


Second Generation Celullar System



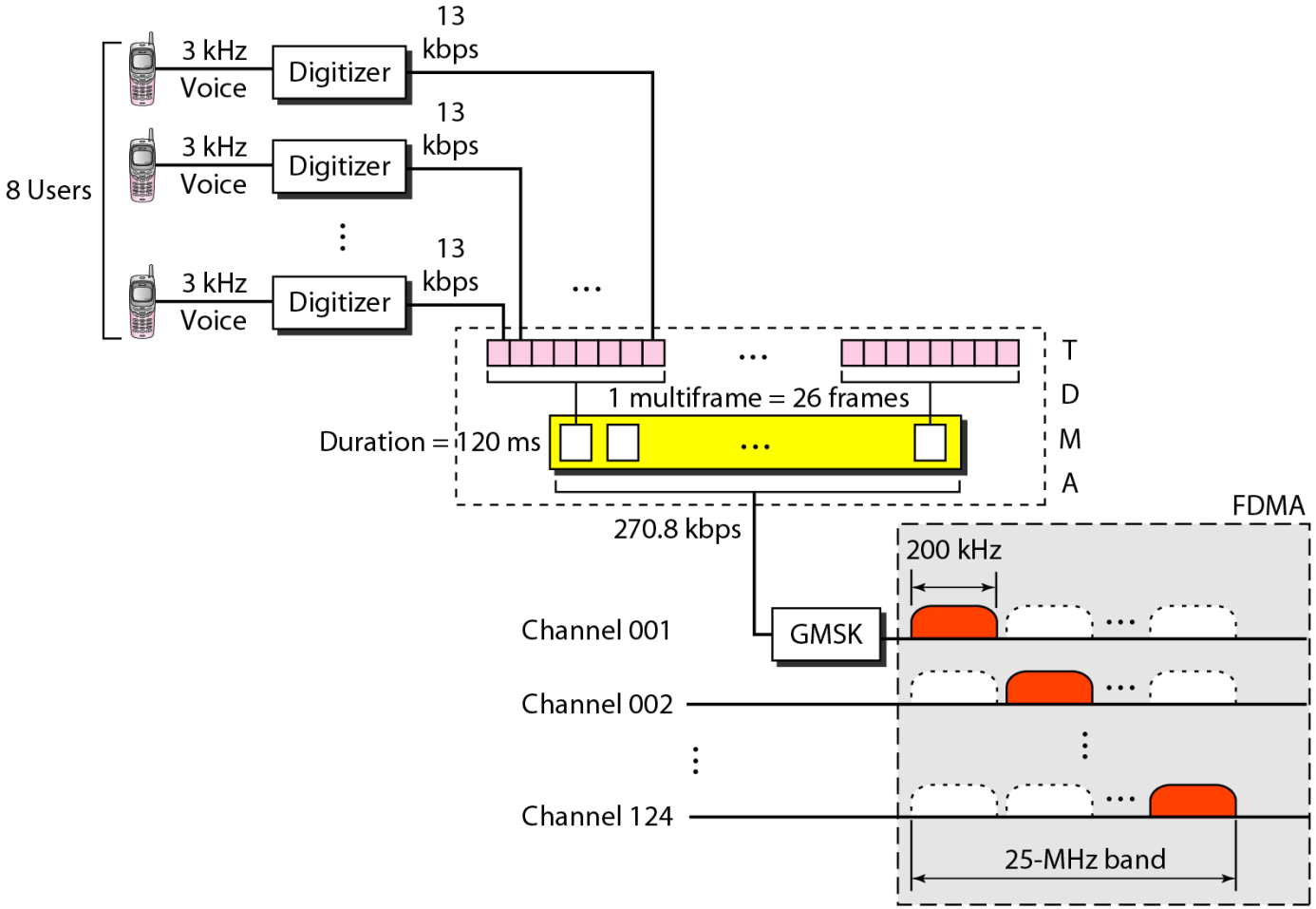
D-AMPS

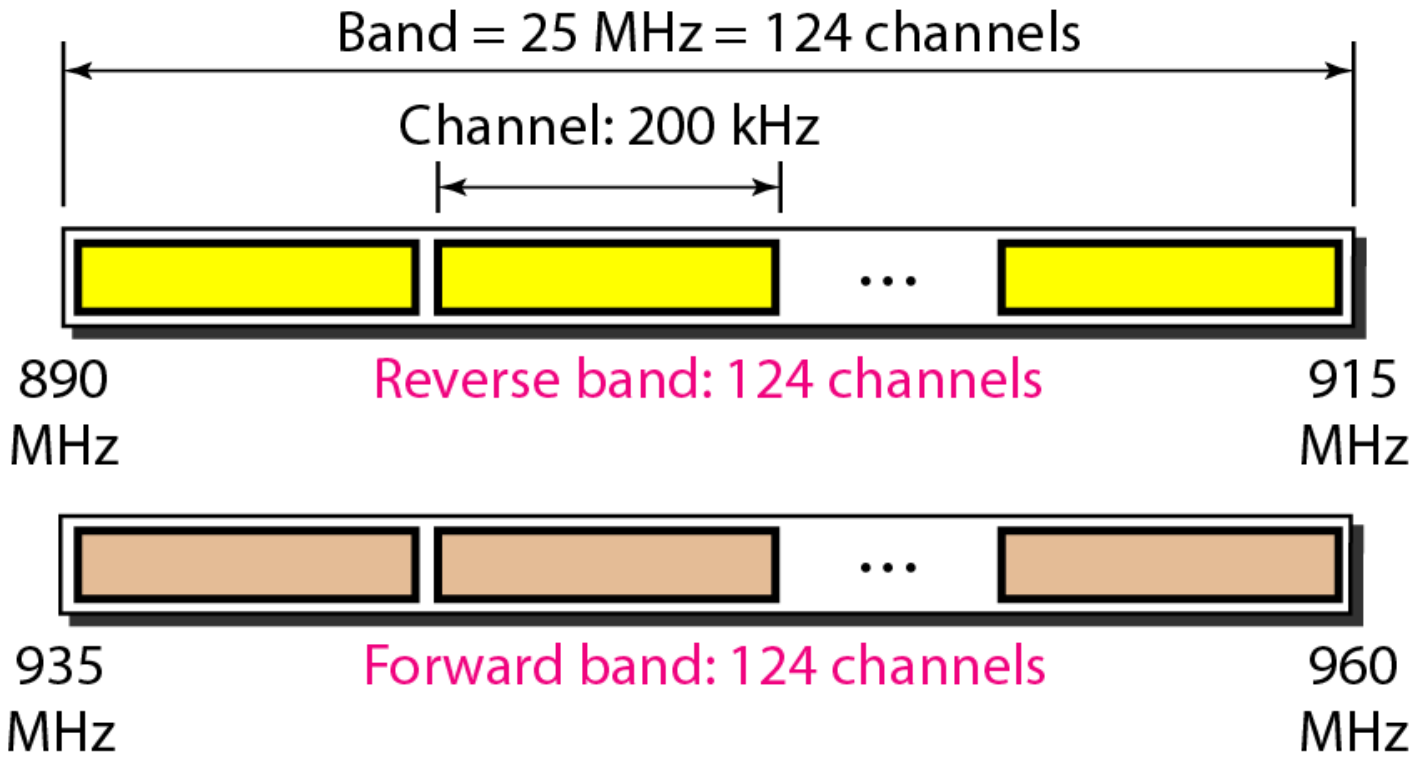
D-AMPS, or IS-136, is a digital cellular phone system using TDMA and FDMA.



Global System for Mobile (GSM)

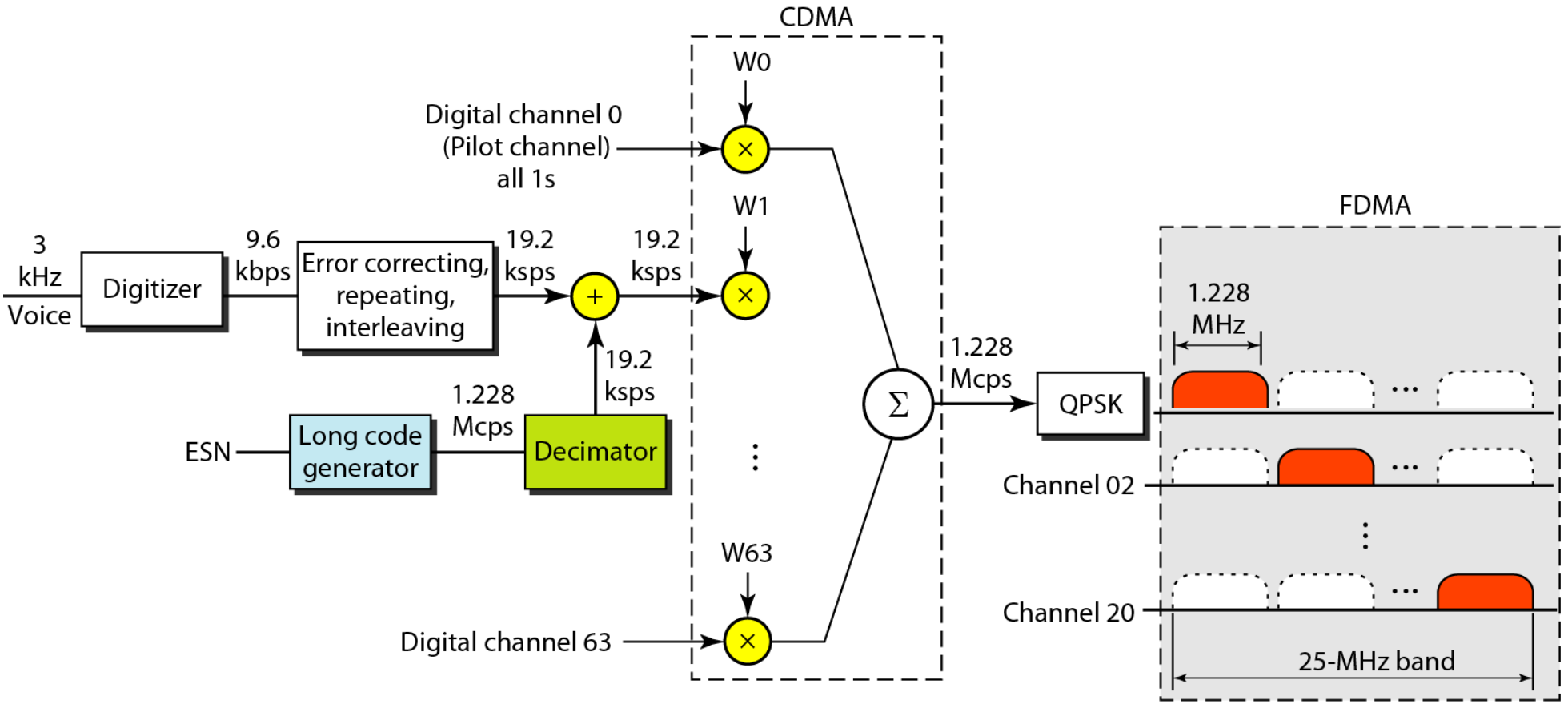
GSM is a digital cellular phone system using TDMA and FDMA.



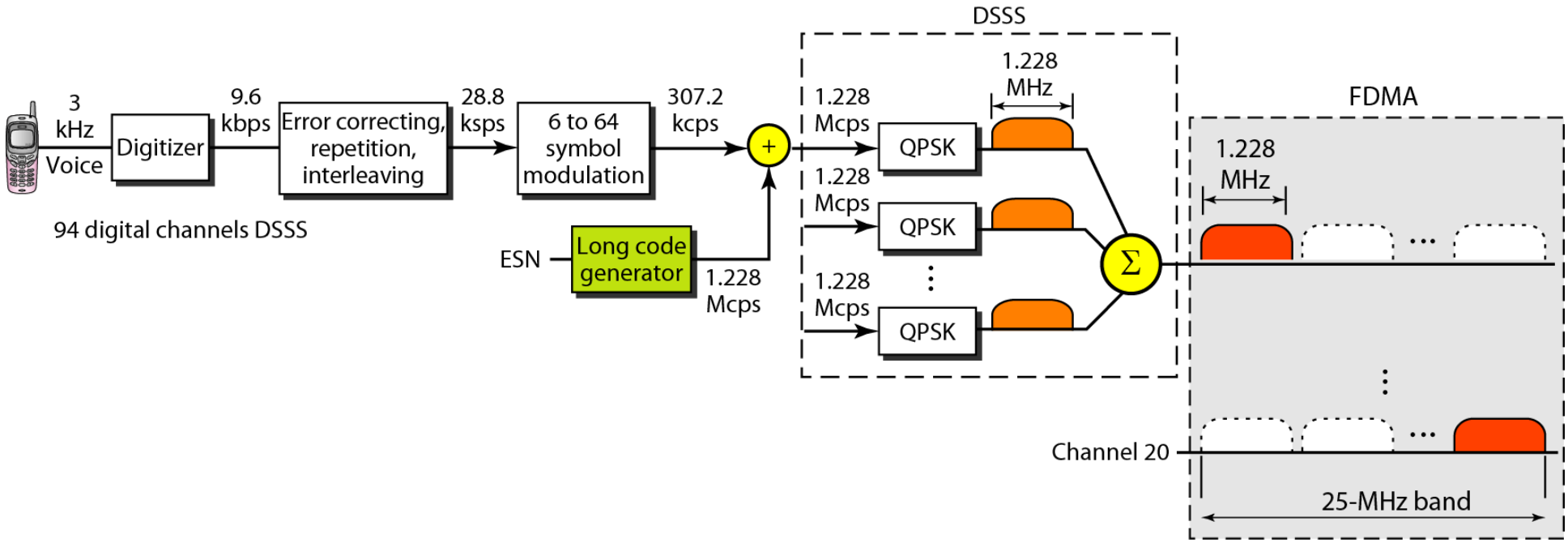

Band = 25 MHz = 124 channels
Channel: 200 kHz
890 MHz
Reverse band: 124 channels
915 MHz
935 MHz
Forward band: 124 channels
960 MHz

IS-95 forward transmission

IS-95 is a digital cellular phone system using CDMA/DSSS and FDMA.

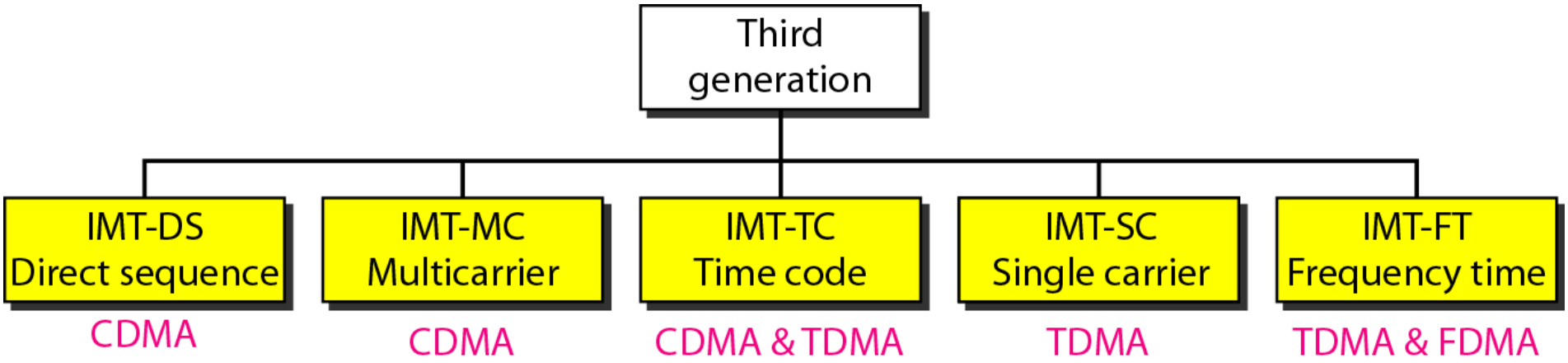


IS-95 reverse transmission

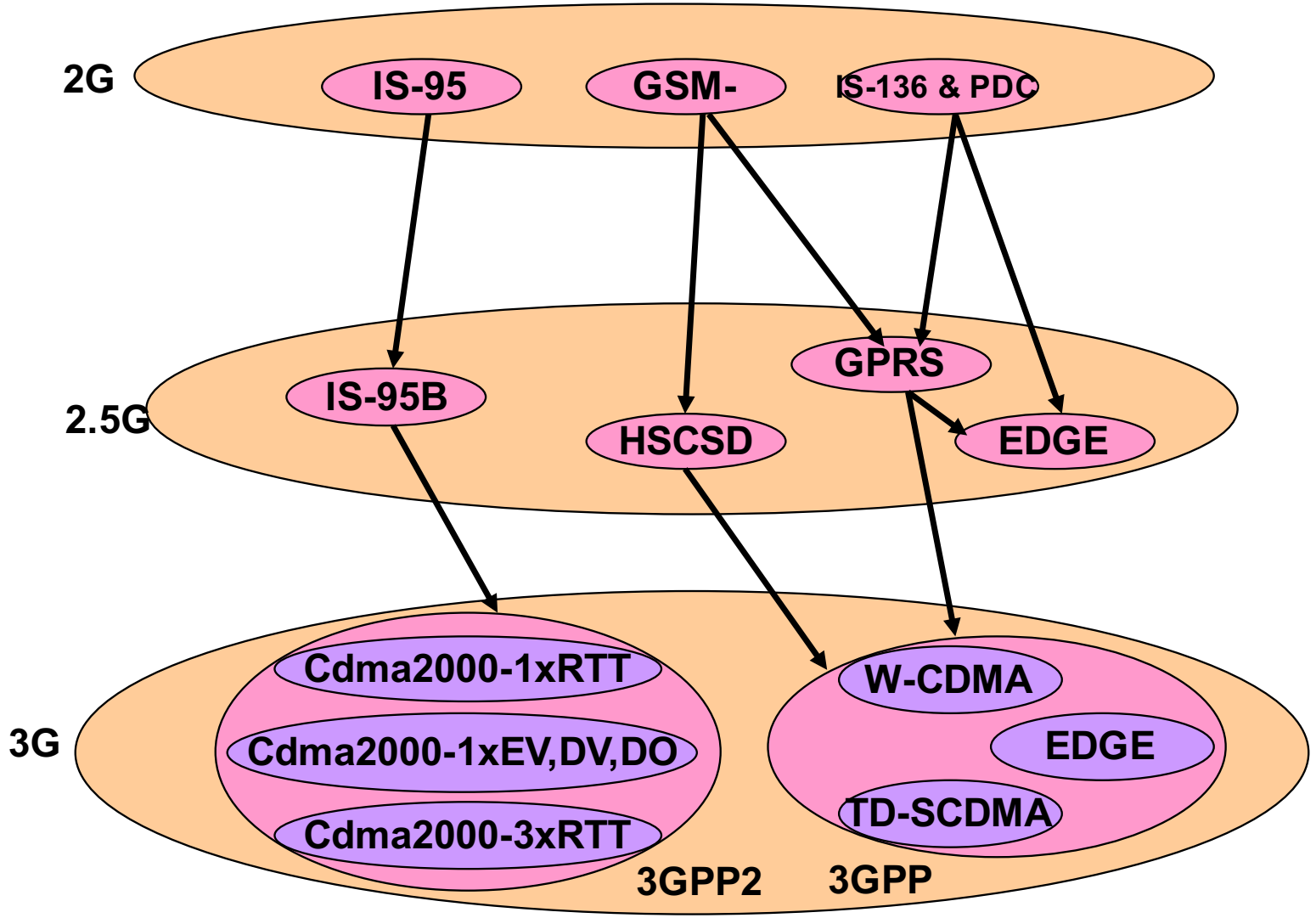


3rd Generation

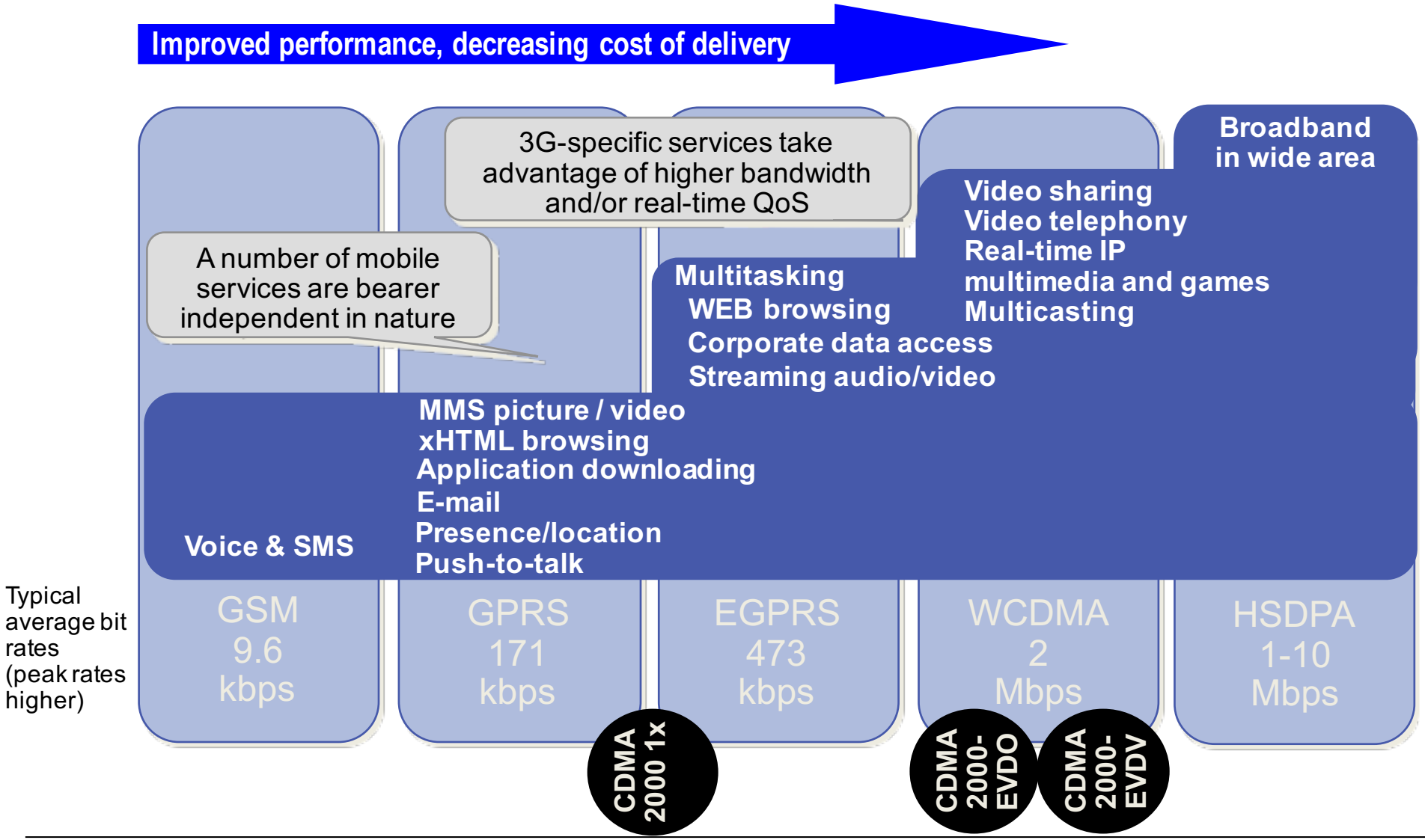
- Third Generation (3G) is created by ITU-T and is called IMT-2000



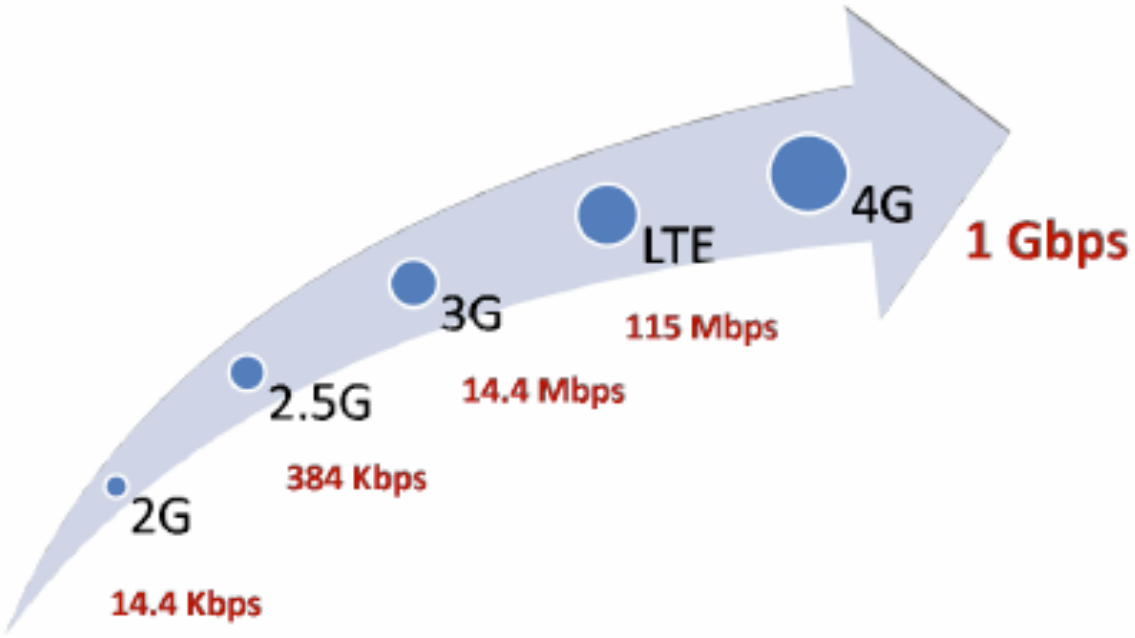
Evolution from 2G



Service Roadmap



2G – 4G Data download rates



- 2.5G speed is based on the maximum offered by EDGE
- 3G speed is based on the maximum offered by HSDPA