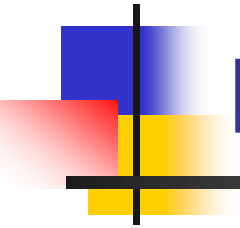


Networks & Data Communications

Wireless Voice Transmission & Cellular Standards

Wireless Voice Transmission

- Before cell phones, people who needed mobile-communications installed **radio telephones** in their cars
- The radio-telephone system had one central antenna tower per city, and perhaps **25 channels** available on that tower
- Using a **central antenna** meant that the phone in your car needed a powerful transmitter -- big enough to transmit 40 or 50 miles (about 70 km). It also meant that not many people could use radio telephones -- there just were not enough channels.

Wireless Voice Transmission

- The genius of the cellular system is the division of a city into small **cells**. This allows extensive **frequency reuse** across a city, so that millions of people can use cell phones simultaneously.
- A good way to understand the sophistication of a cell phone is to compare it to a CB radio or a walkie-talkie.

Wireless Voice Transmission

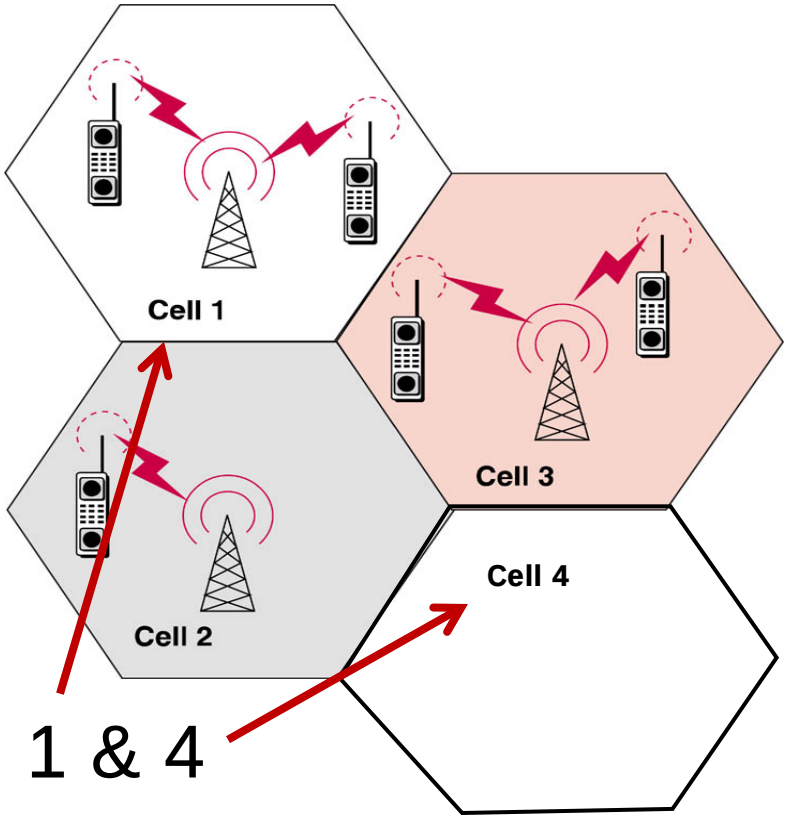
- Both walkie-talkies and CB radios are **half-duplex** devices
- Two people communicating on a CB radio or on walkie-talkies are using the same frequency, so only one person can talk at a time
- Cell phones are **full-duplex**. That means that you use one frequency for talking and a second, separate frequency for listening. Both people on the call can talk at once.

Wireless Voice Transmission

- **Channels** - A walkie-talkie typically has one channel, and a CB radio has 40 channels. A typical cell phone can communicate on 1,664 channels or more!
- **Range** - A walkie-talkie can transmit about 1 mile (1.6 km) using a 0.25-watt transmitter. A CB radio, because it has much higher power, can transmit about 5 miles (8 km) using a 5-watt transmitter. Cell phones operate within **cells**, and they can switch cells as they move around. Cells give cell phones incredible range. Someone using a cell phone can drive hundreds of miles and maintain a conversation the entire time because of the cellular approach.

Wireless Voice Transmission

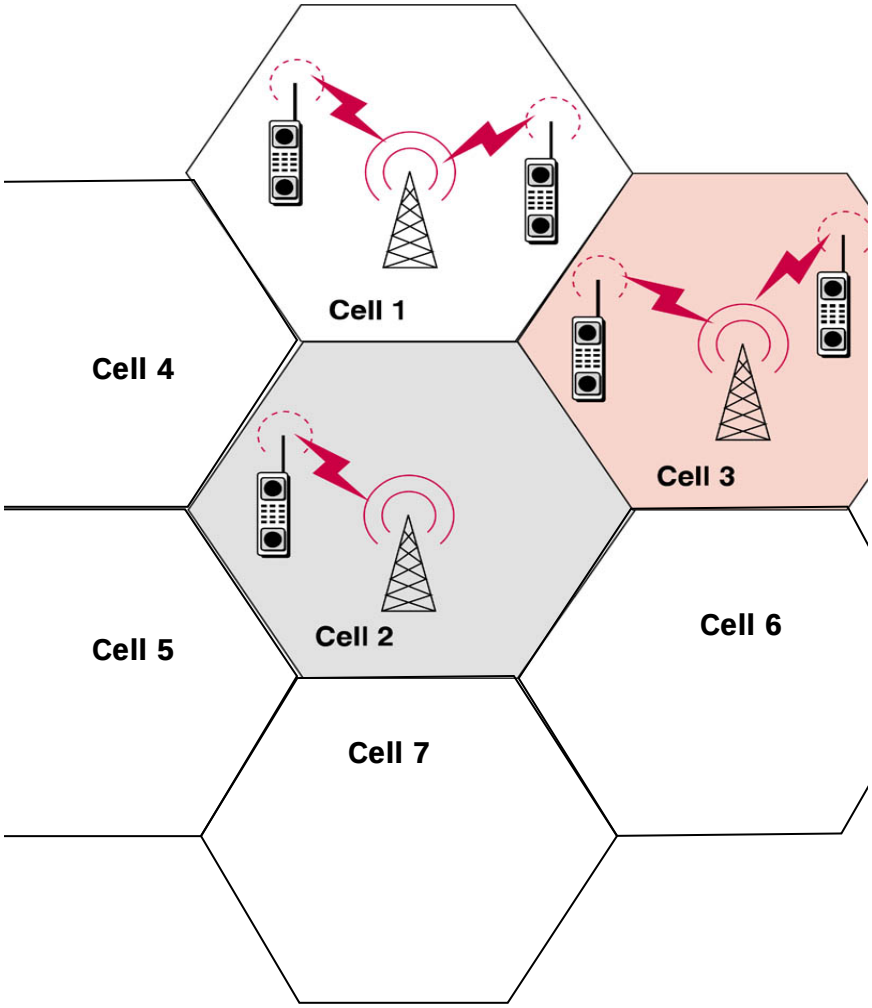
- **Cells** – Service provider chops up service area into 10 sq. mile “cells”
- Because cell phones and base stations use low-power transmitters, the same frequencies can be reused in non-adjacent cells, i.e. cell 1 & 4



- Each cell has a base station that consists of a tower and a small building containing the radio equipment.

Wireless Voice Transmission

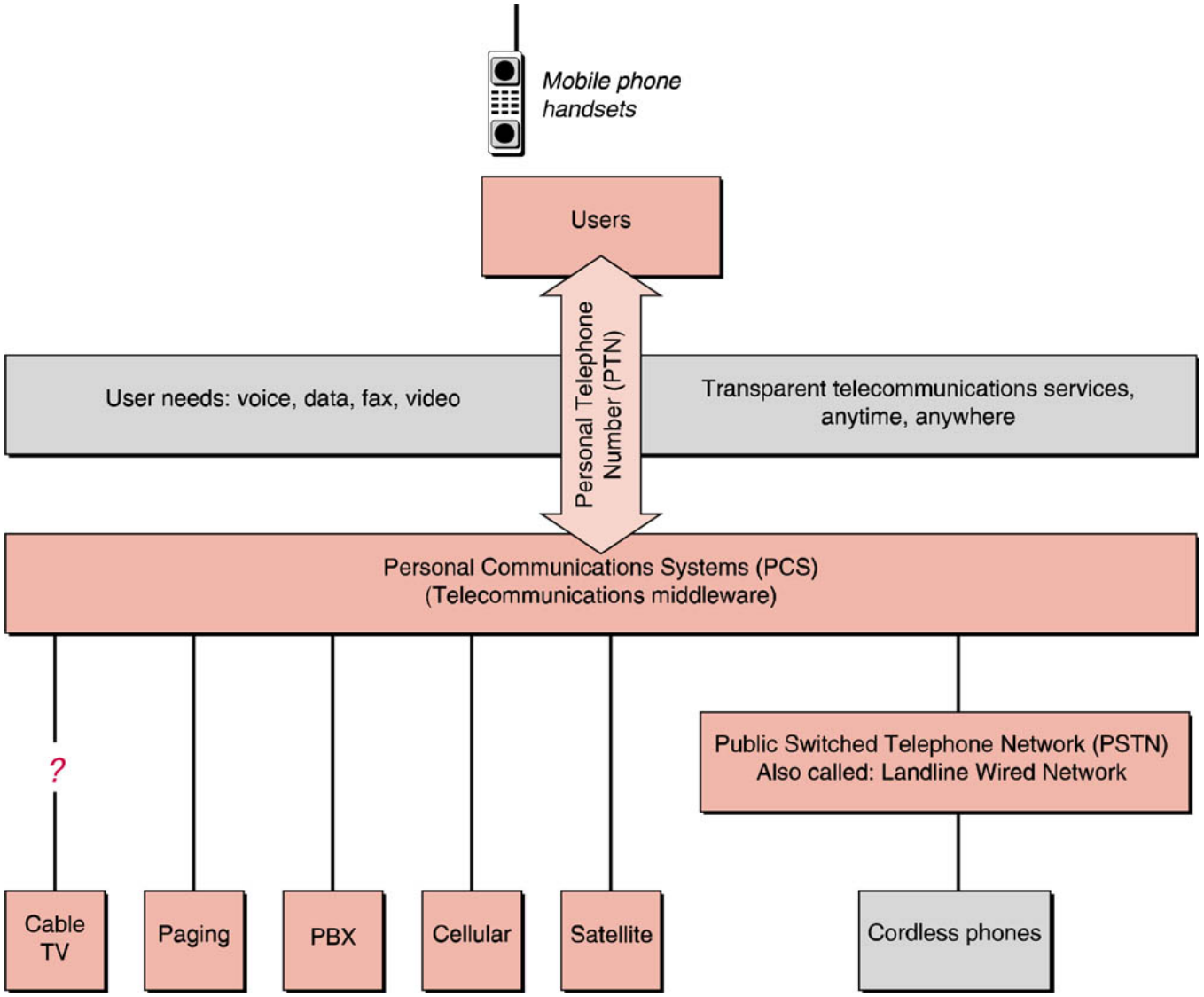
- Cells have 6 sides & each cell is surrounded by 6 other cells
- A single cell in an analog cell-phone system uses one-seventh of the available duplex voice channels so it has a unique set of frequencies and there are no collisions
- A service provider typically gets **832 radio frequencies** to use in a city
- Each cell phone uses two frequencies per call -- a duplex channel -- so there are typically **395 voice channels** per carrier. (The other 42 frequencies are used for **control channels**)

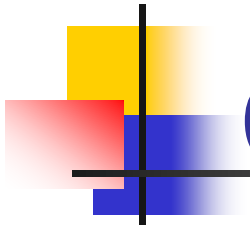


Wireless Voice Transmission

- Therefore, each cell has about **56 voice channels** available. In other words, in any cell, 56 people can be talking on their cell phone at one time.
- Each carrier in each city also runs one central office called the **Mobile Telephone Switching Office** (MTSO).

Wireless Voice Transmission





Cellular Standards

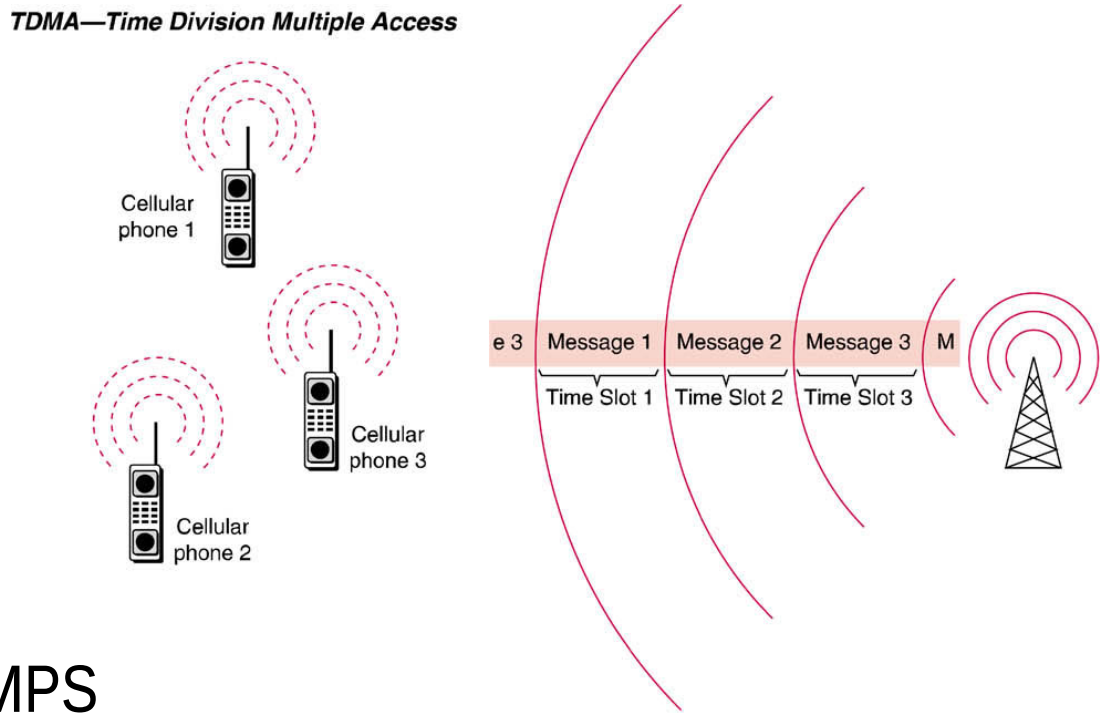
- **Frequency division multiple access** (FDMA)
  - puts each call on a separate **frequency**
- **Time division multiple access** (TDMA)
  - assigns each call a certain portion of **time** on a designated frequency
- **Code division multiple access** (CDMA)
  - gives a unique **code** to each call and spreads it over the available frequencies

Cellular Standards - FDMA

- FDMA separates the spectrum into distinct voice channels by splitting it into **uniform chunks of bandwidth** like radio stations
- Each station sends its signal at a different frequency within the available band
- FDMA is used mainly for **analog transmission**. While it is certainly capable of carrying digital information, FDMA is not considered to be an efficient method for digital transmission
- Used in Advanced Mobile Phone Service (AMPS)

Cellular Standards - TDMA

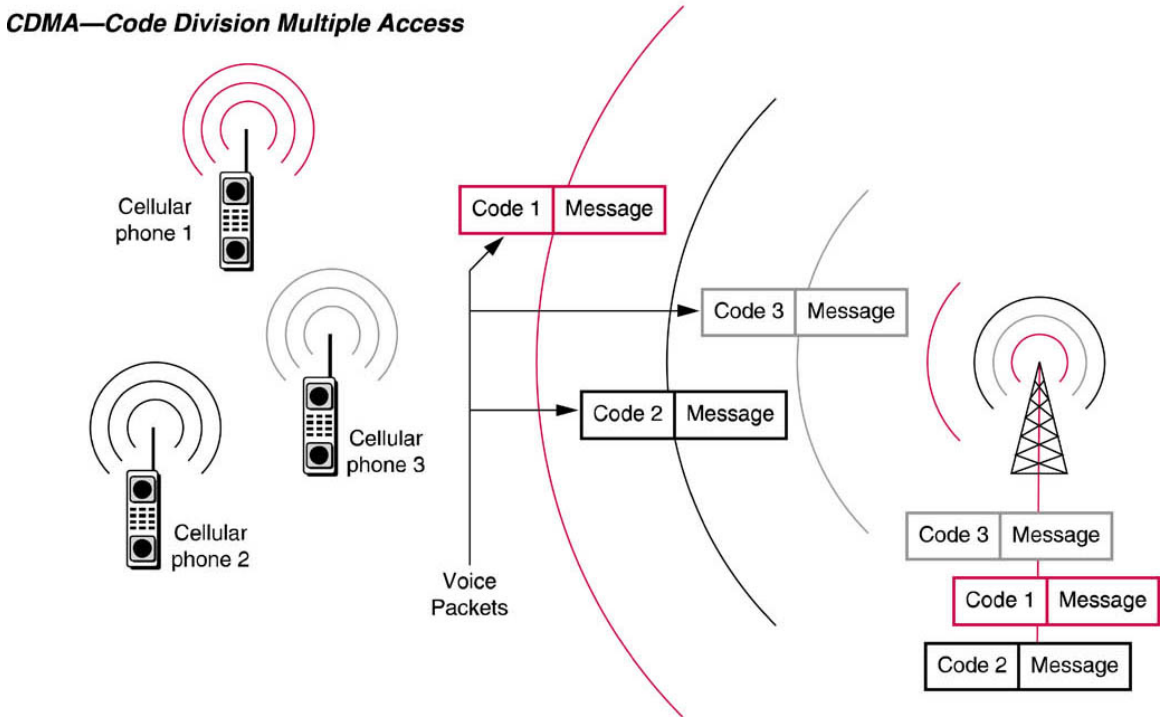
AT&T
and
T-Mobile



- Aka D-AMPS
- TDMA achieves more than one conversation per frequency by assigning timeslots to individual conversations
- 3-times as many calls as AMPS (168 channels/cell)
- Data transmission rate = 9.6 Kbps
- More technically limited than CDMA

Cellular Standards - CDMA

Verizon
and
Sprint

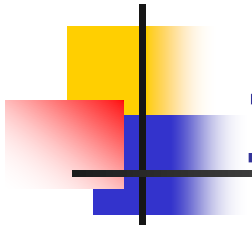


- CDMA attempts to maximize the number of calls transmitted within a limited bandwidth by using a spread spectrum transmission technique
- Packets for each call are marked with a code
- Patented by Qualcom – requires 8% royalty

Wireless Data Service Generations

See table on page 193

- Pre-G Technologies (aka 0G)
  - Enhanced Paging and two-way text messaging (pagers)
  - Private Packet Radio (proprietary modem)
- 1G
  - Circuit-switched analog cellular (AMPS) [Introduced in U.S. in 1983 by AT&T]
  - Cellular Digital Packet Radio (CDPD) [AT&T - service ended in 2004]
- 2G
  - Time Division Multiple Access (TDMA) [AT&T and T-Mobile]
  - Code Division Multiple Access (CDMA) [Verizon and Sprint]
- 2.5G
  - General Packet Radio Service (GPRS) [AT&T and T-Mobile]
    - Based on TDMA standard
  - 1xRTT [Verizon and Sprint]
    - Based on CDMA standard
- 3G
  - Enhanced Data for GSM Evolution (EDGE) [AT&T and T-Mobile]
  - Evolution Data Optimized or Evolution Data Only (EvDO) [Verizon and Sprint]



1G Cellular

- **Advanced Mobile Phone Service** (**AMPS**)
  - **Analog** cellular systems
  - Operate in the 800MHz frequency range
  - Uses separate frequencies, or "channels", for each conversation (FDMA)
  - Have significant limitations ...
    - offer relatively poor signal quality
    - static and interference are inherent with the system
    - can handle relatively few concurrent calls per cell
  - FCC ended service requirement on 2/18/2008

1G Cellular

- **Cellular Digital Packet Radio (CDPD)**
  - used unused bandwidth normally used by AMPS mobile phones between 800 and 900 MHz.
  - Speeds up to 19.2 kbit/s were possible.
  - The service was discontinued in conjunction with the retirement of the parent AMPS service.

2G – Digital Cellular

- **Digital Cellular** offers significant capacity increases compared to AMPS analog cellular systems.
- Carriers have steadily moved to digital cellular systems.

2G – Digital Cellular

- **Call is digitized at the telephone handset** and sent in a digital format to the tower
- Digital conversations can be **compressed** which allows between three to 10 digital cell-phone calls to occupy the space of a *single* analog call.
- More calls to share the common bandwidth in a cell concurrently
- Quality is greatly improved
- Better equipped to support wireless **data** transmission
- 2GHz band allocated to digital cellular
- Conversations are multiplexed using TDMA or CDMA

2.5G – Cellular

- General Packet Radio Services (GPRS) [AT&T and T-Mobile]
  - Based on TDMA model
  - Wireless, packet-based communication service
  - Until recently was the standard 2.5G protocol used in most smartphones
  - Unlike a circuit-switched voice connection, this is a packet-switched, "always on" connection that remains active as long as the phone is within range of the service. It allows smartphones to do things like run applications remotely over a network, interface with the Internet, participate in instant messenger sessions, act as a wireless modem for a computer and transmit and receive e-mails
- Theoretical data transfer rate of >200 Kbps (56Kbps actual)
- Some smartphones in the United States still use this protocol, though newer, faster protocols are available

2.5G – Cellular

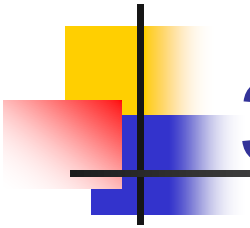
- 1vRTT
- Based on CDMA model
- Data transfer rate of 100Kbps

3G – Digital Cellular

- **3G** technology is intended for the true multimedia cell phone -- typically called “smartphones”
- Features increased bandwidth and transfer rates to accommodate Web-based applications and phone-based audio and video files.

3G – Digital Cellular

- **Enhanced Data GSM Environment (EDGE)**. EDGE can transmit data at more than three times the rate of GPRS (384 Kbps)
- Many smartphones in the United States are now using EDGE protocol
- Used by AT&T and T-Mobile



3G – Digital Cellular

- **EvDO (CDMA 2000)**
- Data transmission rates:
  - 2.4 Mbit/s with Rev. 0
  - up to 3.1 Mbit/s with Rev. A (4G)
- Used by Verizon and Sprint

Wireless Data Services - GSM

- Originally, the acronym GSM stood for **Groupe Spécial Mobile**, a group formed by the **Conference of European Posts and Telegraphs (CEPT)** in 1982 to research the merits of a European standard for mobile telecommunications.
- Commercial service using the GSM system did not actually start until 1991. Instead of using analog service.
- **Global System for Mobile communications (GSM)** is an international standard. If you travel in Europe and many other parts of the world, GSM is the only type of cellular service available.
- Service layer that overlies **TDMA** (original draft was for CDMA, however vendors & carriers weren't willing to standardize on a patented technology)

4G - Digital Cellular

- Being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth.
- Some 4G protocols are:
  - Universal Mobile Telecommunication Service (UMTS)
  - Wideband Code-Division Multiple Access (WCDMA)
  - High-Speed Downlink Packet Access (HSDPA) [AT&T]
  - Evolution Data Optimized (EvDO rev. A) [Verizon & Sprint]

Coverage Maps

- Verizon
- Sprint
- AT&T technology
- T-Mobile