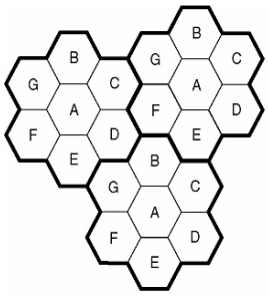
Mobile Telephones

- Introduction
  - Cells, Handoff
  - AMPs
- 2nd Generation
  - D-AMPS
  - GSM
  - CDMA
- Future
  - UMTS, CDMA2000
  - 2.5G

Cellular Structure

- Divide into cells
  - Frequencies: Reuse frequencies
  - Size cells vary in size. In 1st generation 10-20km diameter, digital systems are smaller in diameter
  - Capacity: To increase capacity we increase the number of cells
    - Microcells within cells



- MTSO / MSC Mobile Telephone Switching Office/Mobile Switching Center
  - Base stations at the center of each cell
  - Normally connected to a MTSO/MSC

Handoff

- The movement of users requires the system to support calls from cell to cell,
  - Handoff process takes 300msec
  - Transfer call to the base station which gets the max power from the mobile phone
  - The phone may have to change channel
- Two types of handoff:
  - Soft handoff: new base station acquired before old one is dropped,
    - This provides call continuity
    - Requirements: we need to be able to tune to 2 frequencies
  - Hard handoff: Old base station drops the line, before the new one acquires it
    - Possibility of disconnection if the new BS can't acquire the call

AMPS (1st generation)

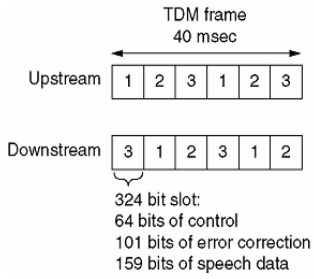
- FDM – 832 Frequency Division Multiplexing with 832 full duplex channels
  - 824-849MHz & 869-894MHz
  - 4 kinds of channel:
    - Control: (base to mobile) 21 channels to manage the system,
    - Paging: (base to mobile) alert mobile users for calls,
    - Access: (bidirectional) call setup and channel assignment,
    - Data: (bidirectional) voice, fax, data
- Phone ID: identified by a 32bit serial number and a 10 digit phone number

AMPS (1st generation)

- Joining a cell:
  - Control channel scan to find the one with the strongest signal
  - Broadcast its IDs
- Outgoing calls:
  - Access channel phone transmits the number to be called and its own ID on the access channel
  - Control channel transmits the channel number and the phone switches to the relevant channel
  - Collision back off and try again
- Incoming calls:
  - Paging channel Phones listen to the paging channel for arriving calls and switch to the channel the call is transmitted
- Problems:
  - Eavesdropping analog means anyone can tune in
  - Cloning phone id could be copied as it was transmitted on the control channel

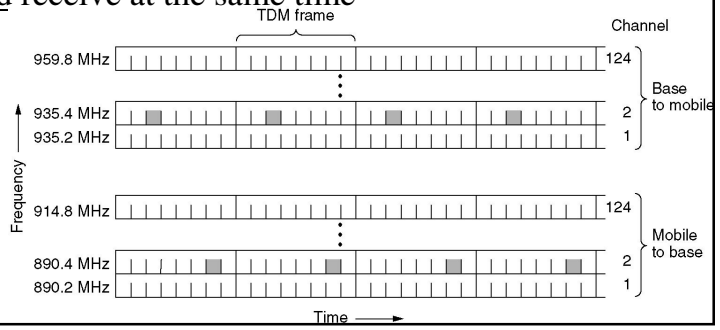
D-AMPS (2nd generation)

- Extension on AMPS. Uses the same frequencies plus 1850-1910MHz, 1930-1990MHz
- Compressed digitised voice using predictive modeling and a complex modulation scheme to reduce normal 56kbps PCM to 8 kbps
  - 3 users / 6 users with better compression using TDM
- Control similar to AMPS
- Handoff when line quality deteriorates
  - MAHO Mobile Assisted HandOff

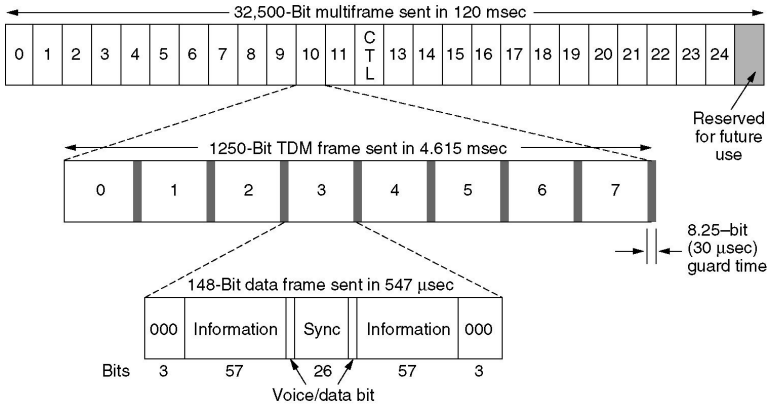


GSM (2nd generation)

- FDM:
  - 124 channels (890-915MHz, 935-960MHz)
- TDM:
  - 8 users per 200kHz
  - Different Slots used as GSM phones cannot transmit and receive at the same time



GSM framing hierarchy



- Data rates per channel 270833bps, per user 33.854 kbps
- 51 slot multiframe 26 frames per 120msec

CDMA (2nd generation)

- Use entire frequency range for each transmission
  - Need to be able to tune into just one transmission
- Encoding
  - Divide each bit time into m short intervals, called chips
    - Typically there are 64 or 128 chips
    - Each station has a unique chip sequence
  - Transmission
    - 1 → Transmit its chip sequence
    - 0 → Transmit the complement of the sequence

CDMA example

A: 0 0 0 1 1 0 1 1	A: (–1 –1 –1 +1 +1 –1 +1 +1)
B: 0 0 1 0 1 1 1 0	B: (–1 –1 +1 –1 +1 +1 +1 –1)
C: 0 1 0 1 1 1 0 0	C: (–1 +1 –1 +1 +1 +1 –1 –1)
D: 0 1 0 0 0 0 1 0	D: (–1 +1 –1 –1 –1 –1 +1 –1)
(a)	(b)

Six examples:

– – 1 –	**C**	S_1 = (–1 +1 –1 +1 +1 +1 –1 –1)
– 1 1 –	**B** + $\overline{\mathbf{C}}$	S_2 = (–2 0 0 0 +2 +2 0 –2)
1 0 – –	**A** + $\overline{\mathbf{B}}$	S_3 = (0 0 –2 +2 0 –2 0 +2)
1 0 1 –	**A** + **B** + **C**	S_4 = (–1 +1 –3 +3 +1 –1 –1 +1)
1 1 1 1	**A** + **B** + $\overline{\mathbf{C}}$ + **D**	S_5 = (–4 0 –2 0 +2 0 +2 –2)
1 1 0 1	**A** + **B** + $\overline{\mathbf{C}}$ + $\overline{\mathbf{D}}$	S_6 = (–2 –2 0 –2 0 –2 +4 0)

(c)

$S_1 \bullet C$ = (1 +1 +1 +1 +1 +1 +1 +1)/8 = 1
$S_2 \bullet C$ = (2 +0 +0 +0 +2 +2 +0 +2)/8 = 1
$S_3 \bullet C$ = (0 +0 +2 +2 +0 –2 +0 –2)/8 = 0
$S_4 \bullet C$ = (1 +1 +3 +3 +1 –1 +1 –1)/8 = 1
$S_5 \bullet C$ = (4 +0 +2 +0 +2 +0 –2 +2)/8 = 1
$S_6 \bullet C$ = (2 –2 +0 –2 +0 –2 –4 +0)/8 = –1

(d)

CDMA Orthogonality

- Chip sequences need to be special…
  - Pairwise Orthogonal: $S \bullet T = \sum S_i T_i = 0$
- Limitations
  - Sychronisation: senders sends a known sequence which is long enough for the receiver to lock onto it,
  - Power Levels: Stations have to adjust their power level according to instructions from the base station
  - Knowledge of Sender: Assumption of known receiver, so that the relevant chip sequence is know
- Available bandwidth typically outstrips GSM.

3rd generation

- IMT-2000: International Mobile Telecommunications
  - Voice High-quality voice transmission
  - Messaging replace email, fax, SMS, chat, etc
  - Multimedia music, videos, films, TV, etc
  - Internet Web Surfing, w/multimedia
- Proposals – both based on 5MHz CDMA
  - UMTS: W-CDMA Universal Mobile Telecommunications System
    - Compatible with GSM so that it could handle handoffs to/from GSM cells,
  - CDMA2000 was proposed by Qualcomm

2.5G technology

- 3G Cost vs. Benefit? The license and infrastructure costs are very serious, which us (the users) will have to pay

- Alternatives
  - EDGE: GSM with more bits per baud
  - GPRS: General Packet Radio Service
    - Operates on top of D-AMPS or GSM
    - Transmits IP packets in a cell running a voice system
    - Higher data rates: twice GSM