CS 294-7: Cellular Telephony

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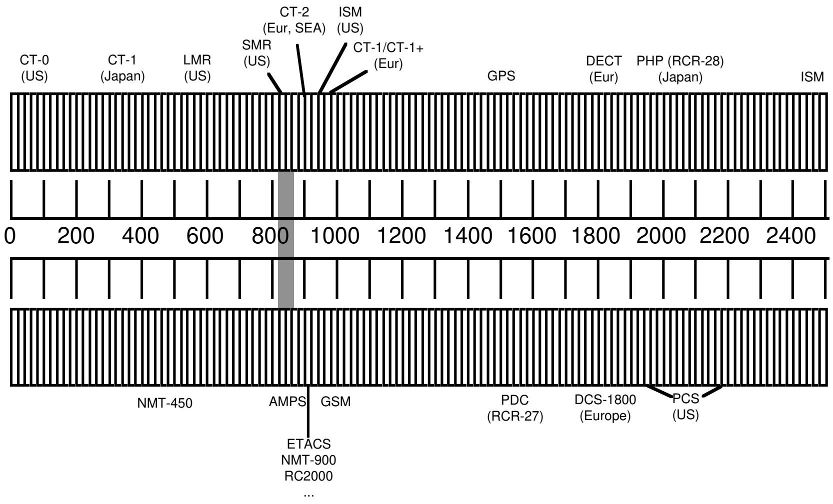
Wireless Spectrum



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North America Frequencies

Frequency Band	MS Xmit Band (MHz)	BS Xmit Band (MHz)	Bandwidth (MHz)
A”	824.0–825.0	869.0–870.0	1
A	825.0-835.0	870.0–880.0	10
A’	845.0–846.5	890.0–890.5	1.5
B	835.0–845.0	880.0–890.0	10
B’	846.5–849.0	891.5–894.0	2.5

European GSM: 890-915 MHz, 935-960 MHz, 25 MHz system

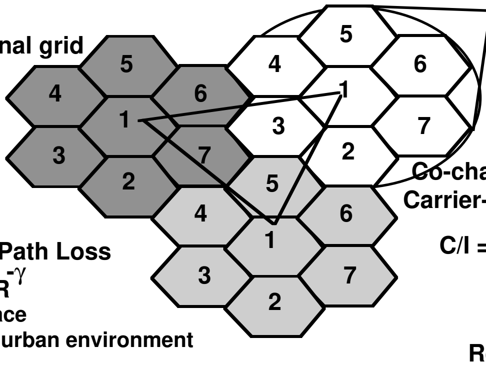
PCS Frequencies

Block Designator	MS Xmit Band (MHz)	BS Xmit Band (MHz)	Bandwidth (MHz)
A	1850–1865	1930–1945	15
D	1865–1870	1945–1950	5
B	1870–1885	1950–1965	15
E	1885–1890	1965–1970	5
F	1890–1895	1970–1975	5
C	1895–1910	1975–1990	15

Cellular Concept

- **Frequency Reuse (N = 7)**

Ideal hexagonal grid



Cluster

Co-channel Interference

Carrier-Interference Ratio

$$C/I = \frac{1}{\sum_{k=1}^{N} \left[\frac{D_k}{R}\right]^{-\gamma}}$$

Reuse Radius **Cell Radius**

18 dB rule of thumb for narrowband

Propagation Path Loss

$C \approx R^{-\gamma}$

$\gamma = 2$, free space

$\gamma = 5.5$, dense urban environment

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Cellular Concept

- **Assuming that the cell size is kept constant and fixed spectrum per cluster:**
  - More cells per cluster mean:
    - » Fewer channels per cell
    - » Less system capacity
    - » Less co-channel interference (co-channel cells farther apart)
  - Less cells per cluster mean:
    - » More channels per cell
    - » More system capacity
    - » More co-channel interference (co-channel cells closer together)
- **Choose reuse factor N is maximize capacity per area subject to interference limitations**

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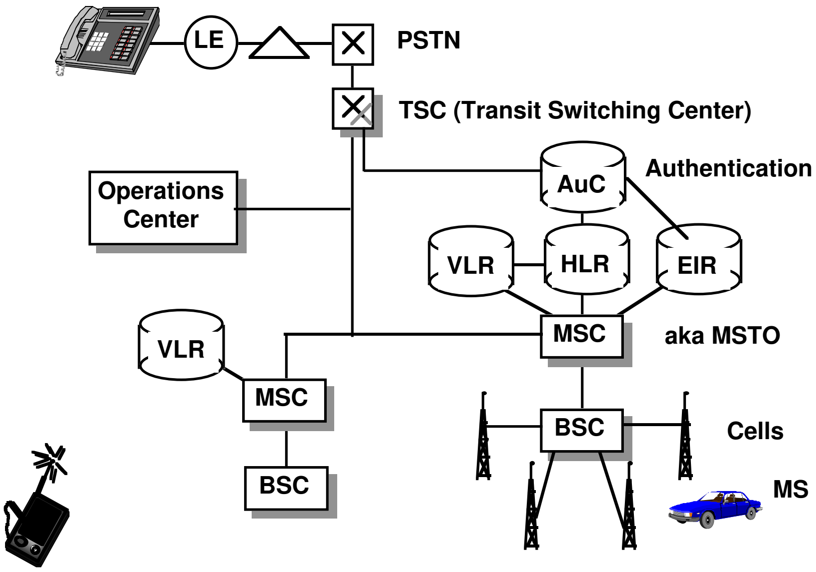
Cellular Phone Systems (GSM Terminology)



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GSM Terminology

- Mobile Service Switching Center (MSC)
  - Associated with a geographical area
  - Call routing and control
  - Interfacing with PSTN and ISDN
- Home Location Register (HLR)
  - Management of mobile subscribers
  - Subscriber info, call redirection/routing info
- Visitor Location Register (VLR)
  - Dynamic storage of subscriber information
  - Registration process
- Authentication Center (AuC)/Equip Ident Reg (EIR)
  - AuC used by HLR to grant service to MS
  - EIR maintains list of legitimate, fraudulent, faulty MS

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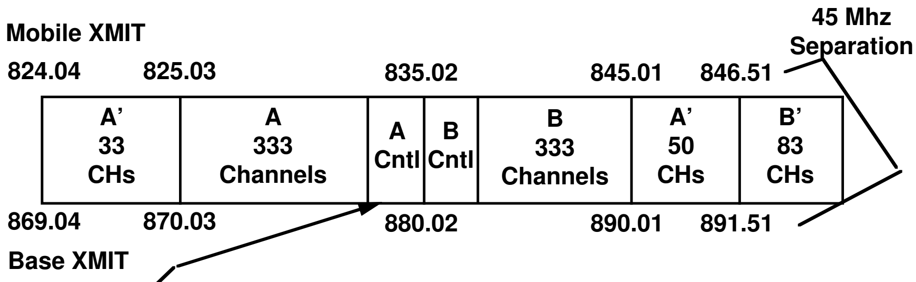
North American Analog Cellular System (AMPS)



416 30 KHz channels for each of two operators (B wireline)

Traffic Control Channels (TCH):
21 reserved control channels in each band

In-band Signaling Tones (e.g., disconnect, RTS dialed digits,
Ack handoff order, Alert, measured in 50-1800 ms)

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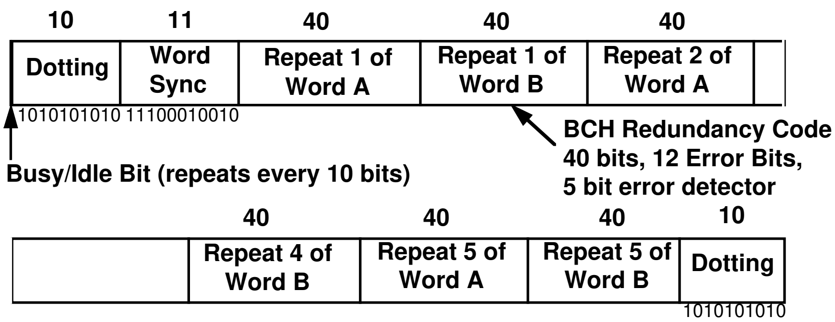
AMPS Framing

Digital Control Channel (Forward Channel: BS to MH)



463 Bits Long

10 kbps

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AMPS Framing

Digital Control Channel (Reverse Channel: MH to BS)

30	11	7	240	240	240	
Dotting	Word Sync	Coded DCC	First Word Times 5	Second Word Times 5	Third Word Times 5	
101010...10	11100010010					

Digital Color Code Used to distinguish between different clusters

BCH (48,36,5) encoded

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AMPS Framing

Forward Voice Channel Framing

101	11	40	37	11	40	37	11	40	
Dotting	Word Sync	Word Repeat 1	Dot	WS	Word Repeat 2	Dot	WS	Word Repeat 3	
101010...01	11100010010								

	37	11	40	37	11	40
	Dot	WS	Word Repeat 10	Dot	WS	Word Repeat 11

Reverse Voice Channel Framing

– similar, except consisting of two data words each repeated five times
– data words encoded in BCH (48,36,5) rather than BCH (40,28,5)
– yields 300-600 bps from 20 kbps signaling

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AMPS System

- Call Processing Steps
  - e.g., Mobile terminated call: somebody calling the MS
    - » MSC dispatches request to all BSs in system
    - » MIN broadcast as paging message over all forward control channels
    - » MS responds to page on reverse control channel
    - » BS relays MS ack to MSC
    - » MSC instructs BS to move call to unused voice channel
    - » BS signals MS to tune to its assigned channel
    - » Alert signal sent to mobile to commence ringing
    - » Call is now in progress
    - » MSC modifies transmit power and assigned frequency to maintain call quality (e.g., handoff)
    - » Control signalling is sent in-band

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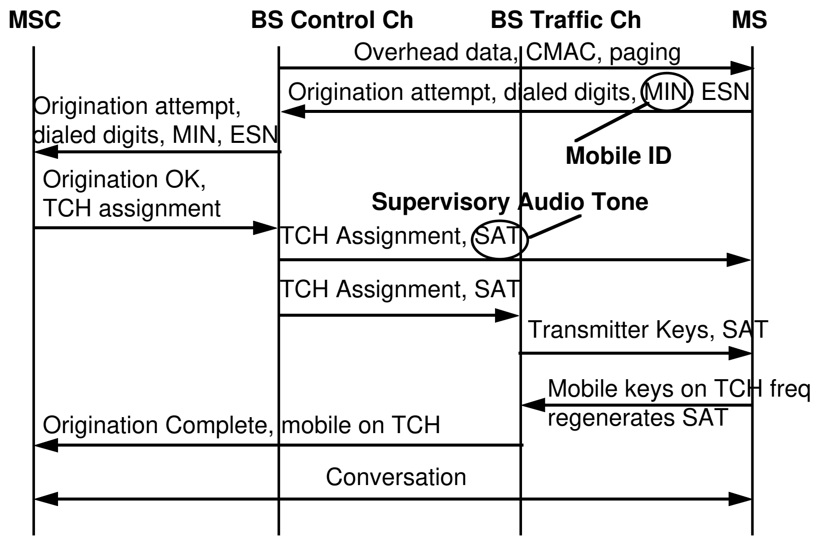
AMPS Signaling: Mobile Origination



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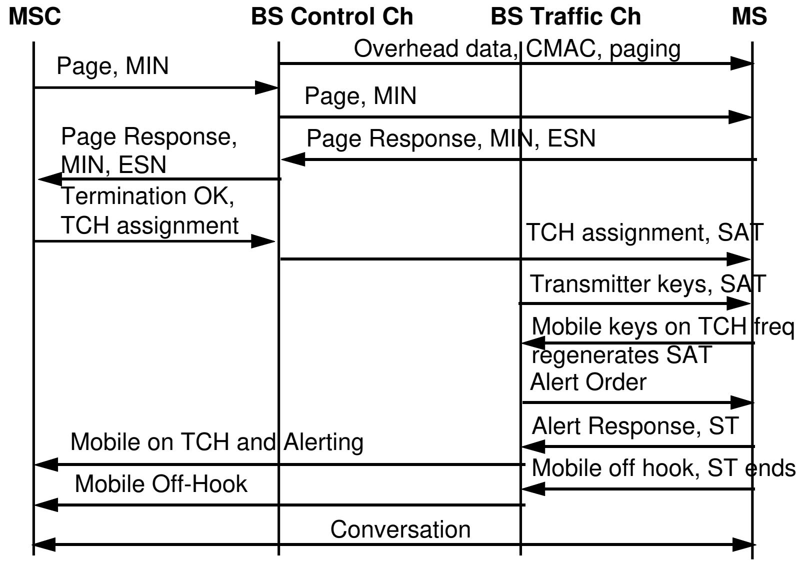
AMPS Signaling: Mobile Termination



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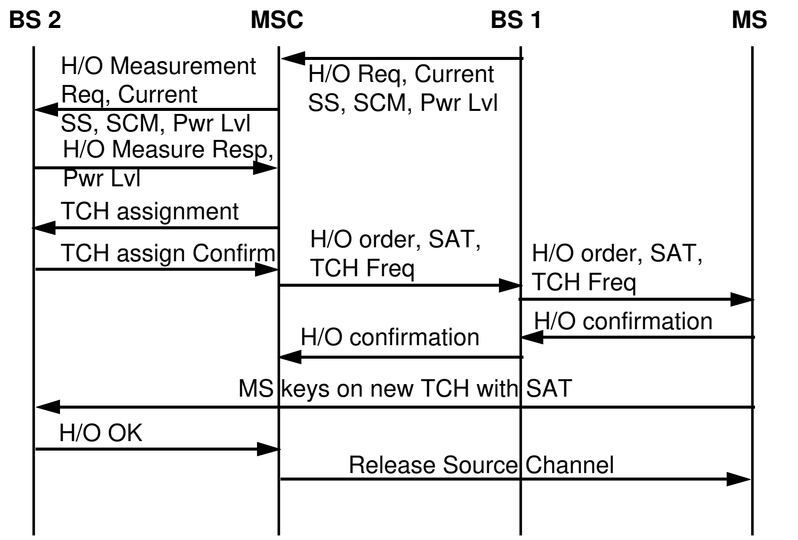
AMPS Signaling: Handoff



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Digitial Cellular TDMA (IS-54)

6	6	16	28	122	12	12	122
G	R	Data	Sync	Data	SACCH	CDVCC	Data

Reverse Channel

digital color codes

28	12	122	12	122	12
Sync	SACCH	Data	CDVCC	Data	RSVD

Forward Channel

- 48.6 kbps in 30 Khz voice channel
- 6 time slots (324 bits/6.67 ms each), 40 ms frame
- Control channels
  - Fast Associated Control Channel (FACCH): Stolen speech frames (65 data bits/frame)
  - Slow Associated Control Channel (SACCH): 12 bits in each slot for signaling information (300 data bps)

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Digital Cellular TDMA (IS-54)

- Mobile Assisted Handoff (MAHO)
  - Use signal measurements at subscriber unit to decide when to handoff
  - Use unused time slots to tune to adjacent base stations to take signal strength measurements (indicated by MSC over control channels)
  - Stores measurements for up to 12 stations, plus SS, BER on assigned traffic channel
  - MSC obtains measurements on demand from subscriber units
- Compare to AMPS:
  - SS measurements of reverse voice channels made by BS, collected by MSC
  - Locator Receiver: monitors signal strength of users in neighboring cells--could trigger handover for MS near edge of cell

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Other Handoff Issues

- **Fixed vs. Dynamic Channel Assignment**
  - Fixed: each cell has a fixed # of channels
    - » Calls can be blocked if all channels in use
    - » Cells can borrow channels from adjacent cells if not in use
    - » Or cells can reserve guard channels for handed over calls
  - Dynamic: channels allocated to cells on a call by call basis
    - » MSC allocation must consider probability of blocking, implications for co-channel and adjacent channel interference
    - » MSC collects channel occupancy, traffic distribution, SS measurements on continuous basis
    - » Could be combined with guard concept to minimize the number of channels reserved for this purpose

GSM TDMA System

890 MHz — Uplink/Reverse Link: MS to BS — 915 MHz

124 channels, 200 KHz each

124 channels, 200 KHz each

935 MHz — Downlink/Forward Link: BS to MS — 960 MHz

124 Traffic Channels x 8 Slots/Ch = 992 simultaneous conversations

13 kbps speech coding data rate
9.6 kbps data rate
half rate coders being developed

GSM Control Channels

- Control Channels (scheduled within multiframes)
  - BCH: Broadcast Channels
    - » BCCH: Broadcast Control Channel—
      Broadcast cellid, common control channels, etc.
    - » FCCH: Frequency Correction Channel—
      Constant frequency shift of RF carrier
    - » SCH: Synchronization Channel—
      Time synchronization, frame #, BS id
  - CCCH: Common Control Channels
    - » PCH: Paging Channel—for paging MS
    - » AGCH: Access Grant Channel—assign MS to SDCCH
    - » RACH: Random Access Channel—MS to BS requests
  - DCCH: Dedicated Control Channels
    - » SDCCH: Stand-Alone Dedicated Control Channels—
      Service rqst, subscriber authentication, cipher init, etc.
    - » ACCH: Associated Control Channels—out of band
      signaling, e.g., to exchange SS measurements
      Fast (FACCH) and slow (SACCH) control channels

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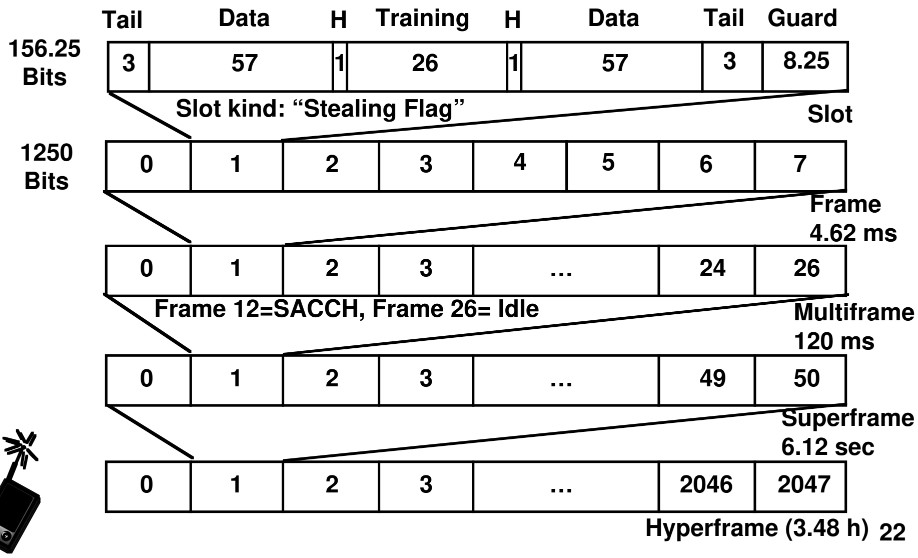
GSM Framing



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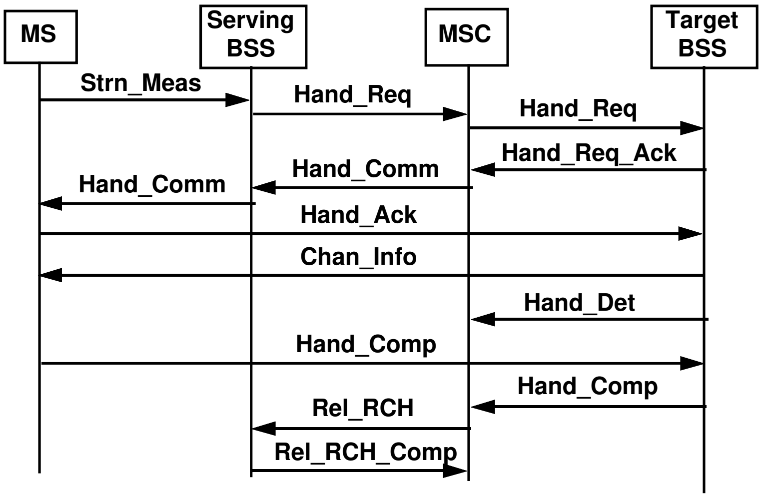
GSM Mobile Initiated Handoff



Within single regional area, somewhat more complex for inter-MSC handoff

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IS-95 CDMA System

- Single 1.25 MHz bandwidth (41 AMPs channels), channelized via orthogonal spreading codes
  - Walsh functions: 64 possible codes/channels
  - Forward Channel
    - » Pilot Channel (channel 0): sequence of 0s
    - » Sync Channel (channel 32): 1200 bps
      System ID, time of day, access procedures
    - » (Upto) Seven Paging Channels (channels 1-7): 9600/4800 bps
    - » 55 channels are available for voice traffic—
      9600, 4800, 2400, 1200 bps based on dynamic needs
  - Reverse Channel
    - » Access signals
    - » Reverse traffic signals
- Frequency division multiplexing for additional CDMA channel groups

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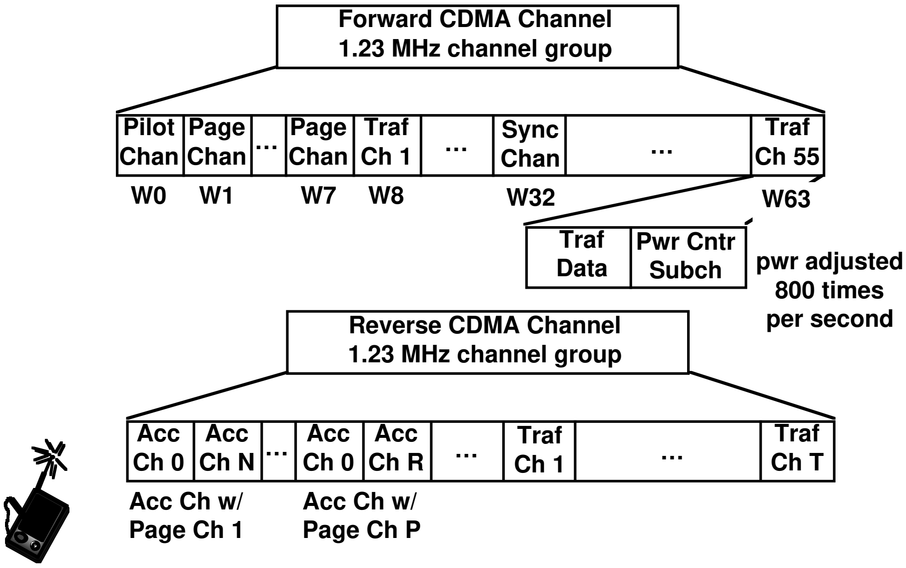
IS-95 CDMA System



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