CS 294-7: Cellular Telephony

Prof. Randy H. Katz

CS Division

University of California, Berkeley

Berkeley, CA 946720-1776

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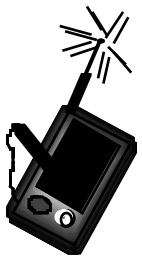
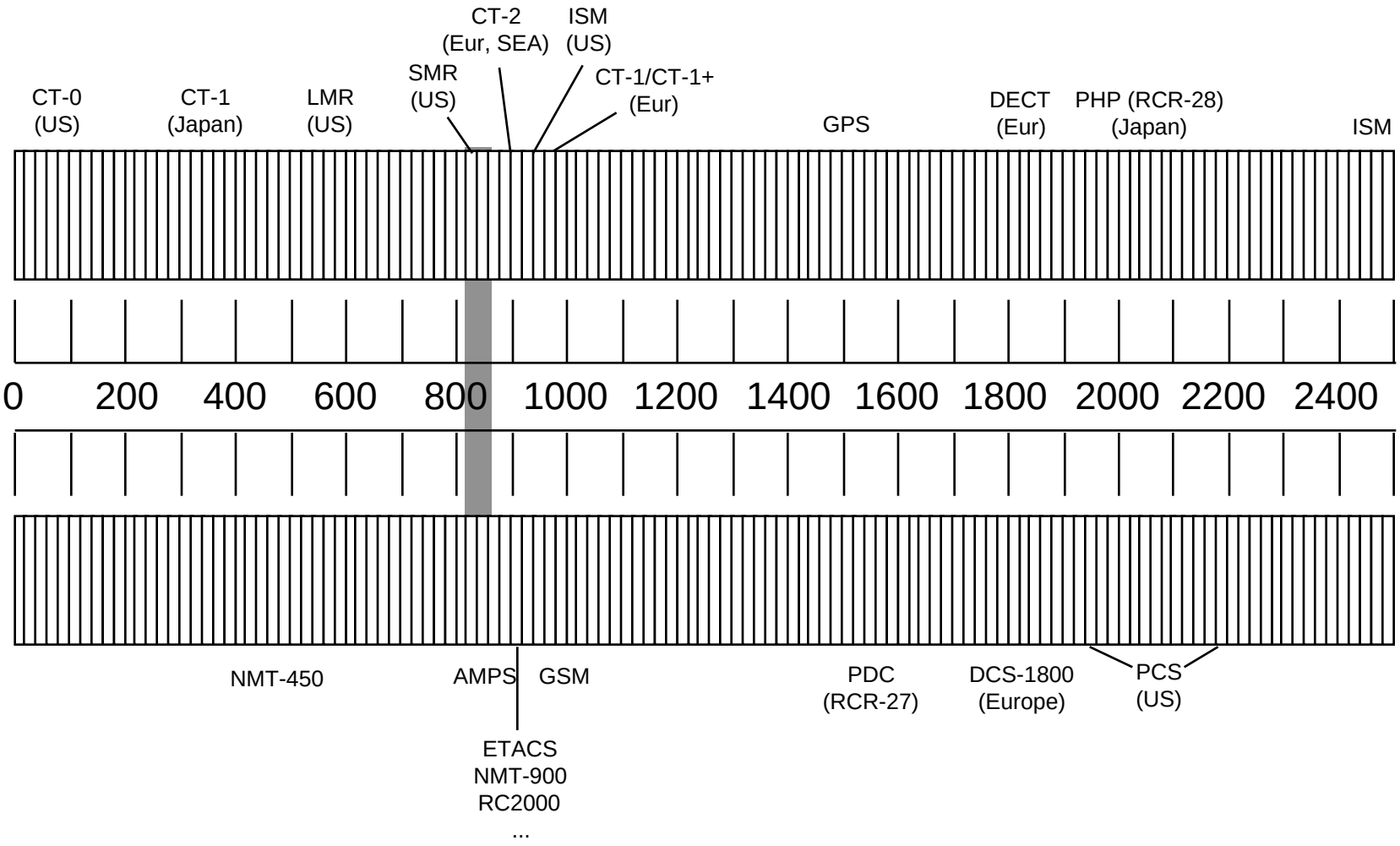


Wireless Spectrum



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

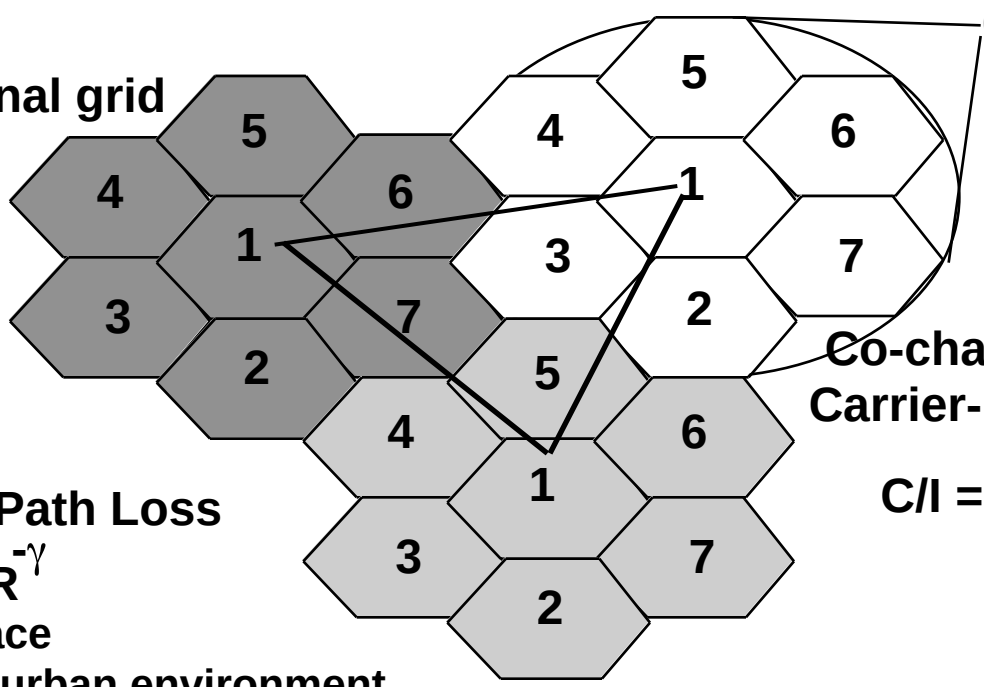
European GSM: 890-915 MHz, 935-960 MHz, 25 MHz system

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)**



Propagation Path Loss

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

$\gamma = 2$, free space

$\gamma = 5.5$, dense urban environment

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

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**

Cellular Phone Systems (GSM Terminology)

LE

PSTN

TSC (Transit Switching Center)

Operations Center

AuC

Authentication

VLR

HLR

EIR

VLR

MSC

aka MSTO

MSC

BSC

Cells

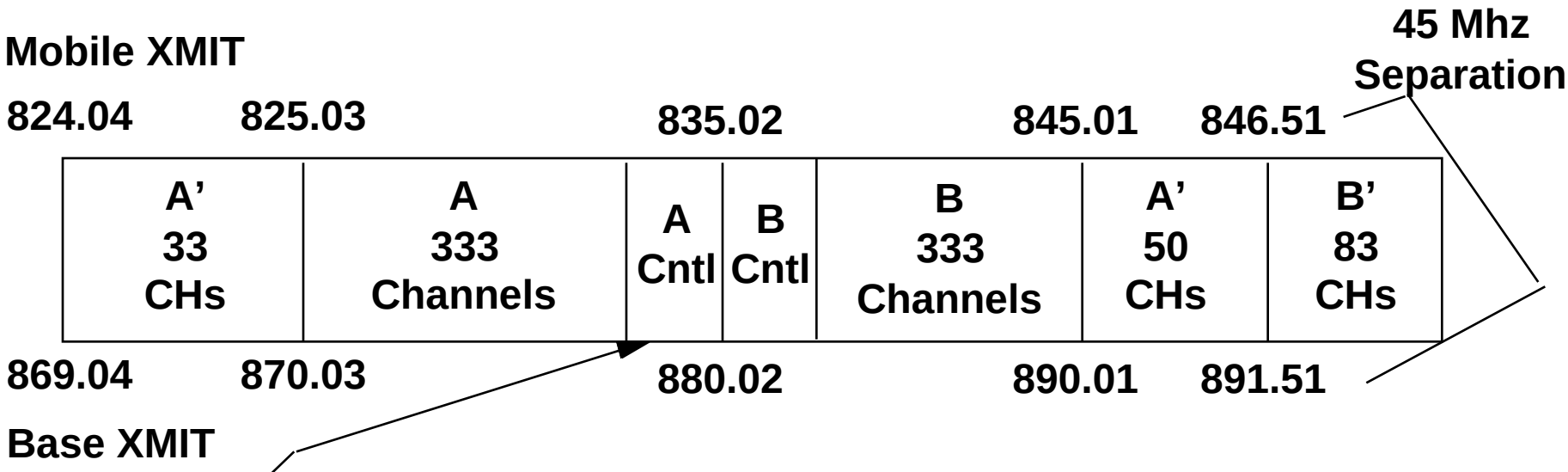
BSC

MS

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

North American Analog Cellular System (AMPS)



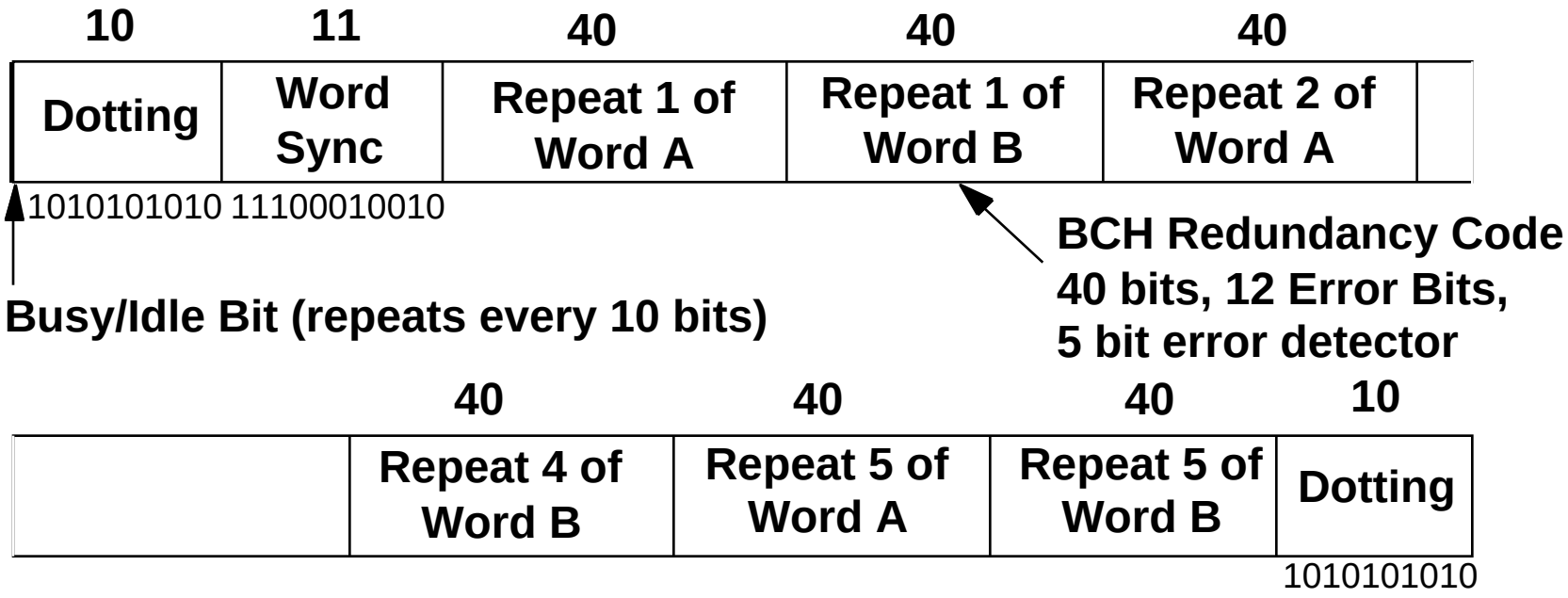
416 30 KHz channels for each of two operators (B wireline)

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)

AMPS Framing

Digital Control Channel (Forward Channel: BS to MH)

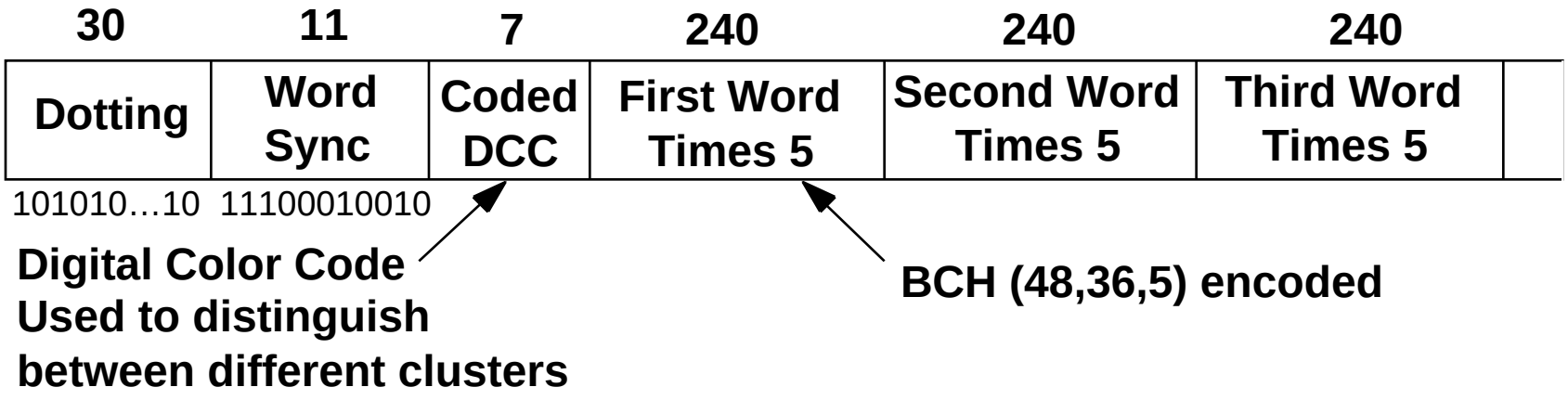


463 Bits Long

10 kbps

AMPS Framing

Digital Control Channel (Reverse Channel: MH to BS)



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

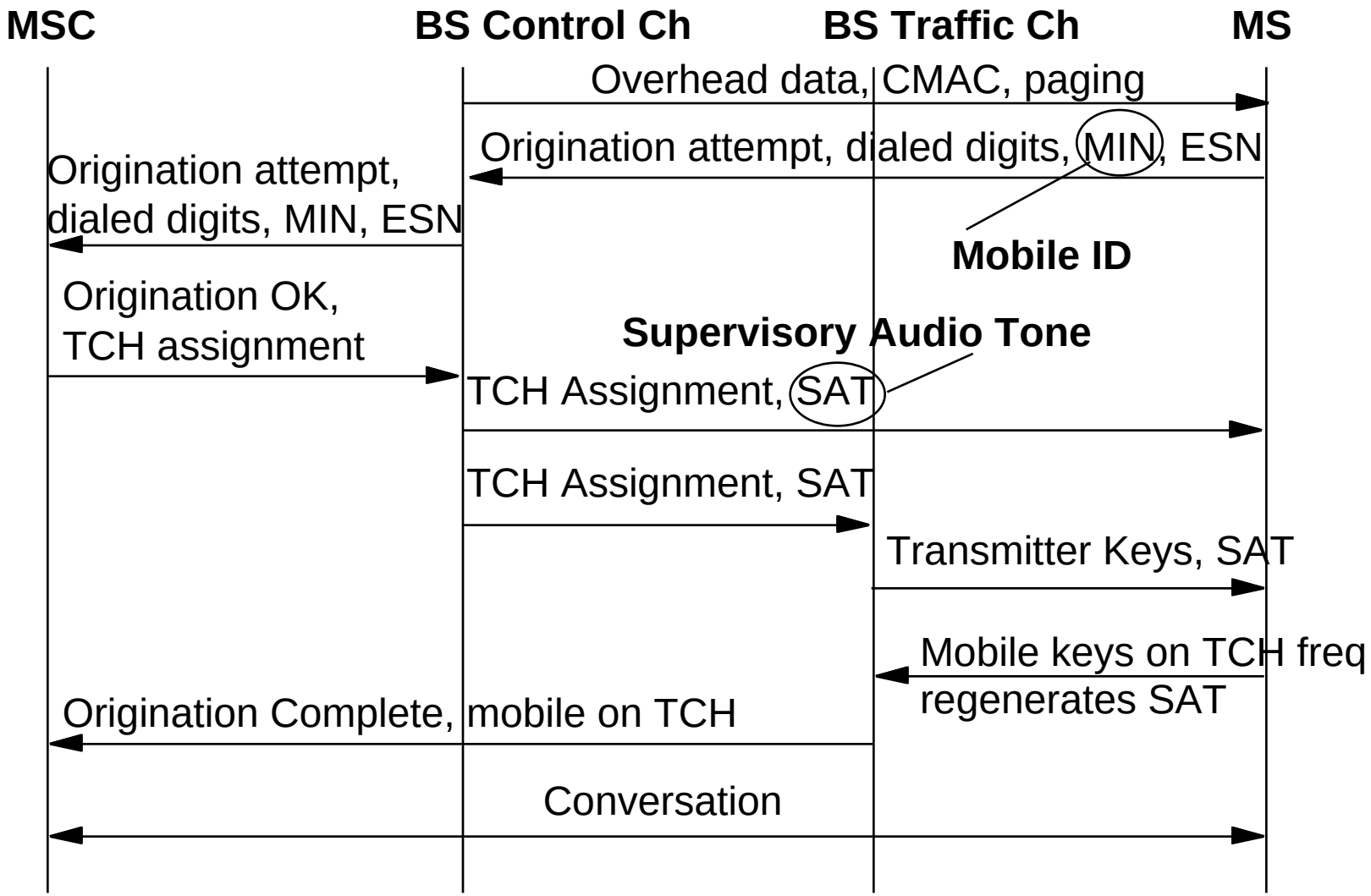
Reverse Voice Channel Framing

- 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

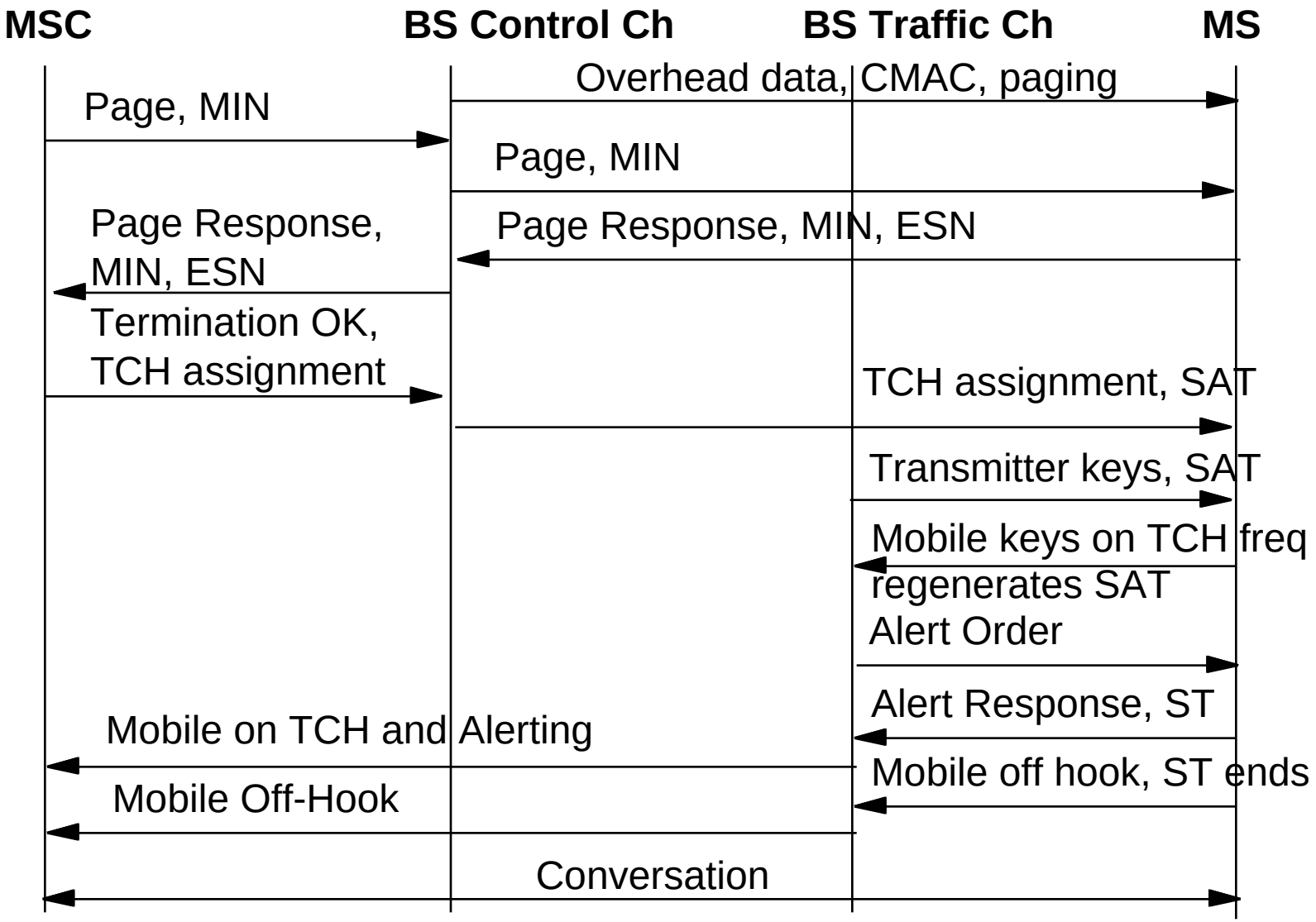
AMPS System

- **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**

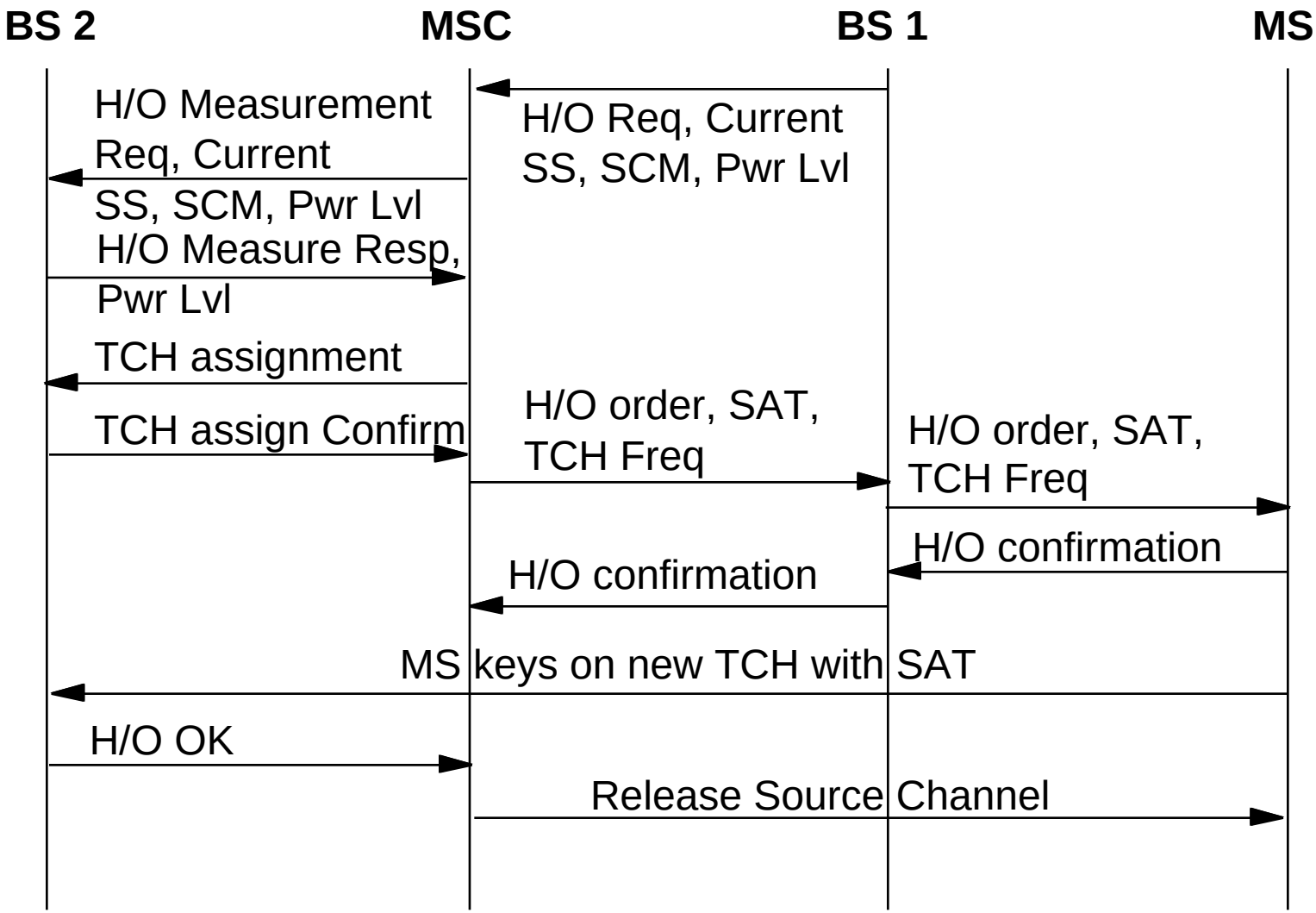
AMPS Signaling: Mobile Origination



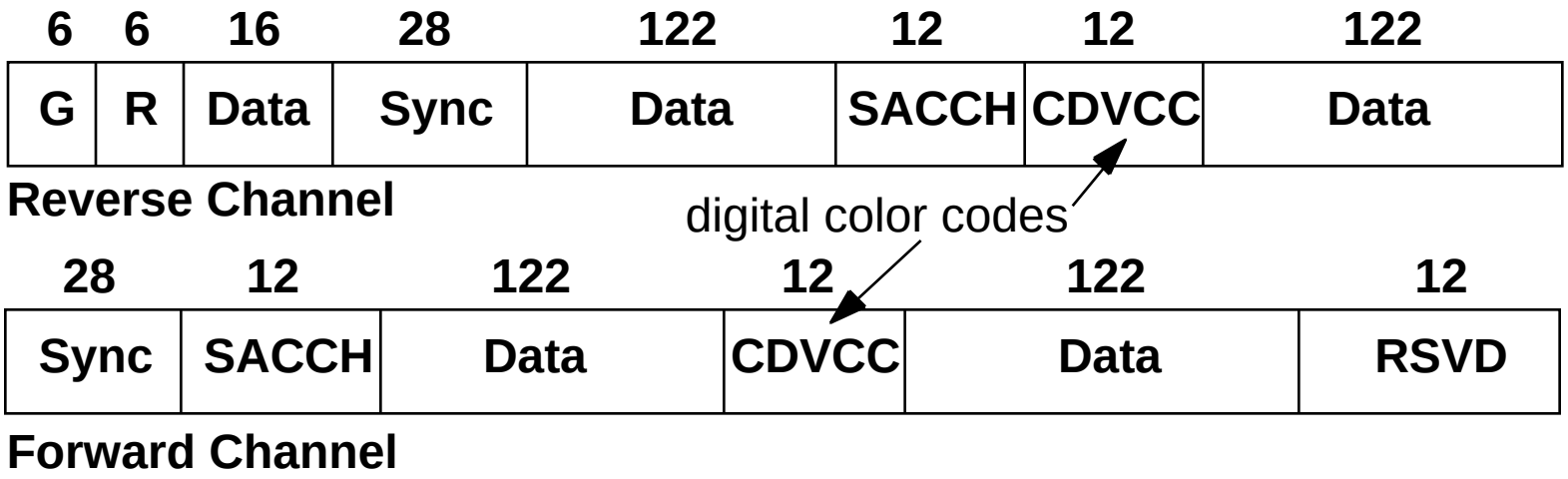
AMPS Signaling: Mobile Termination



AMPS Signaling: Handoff



Digital Cellular TDMA (IS-54)



- **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)**

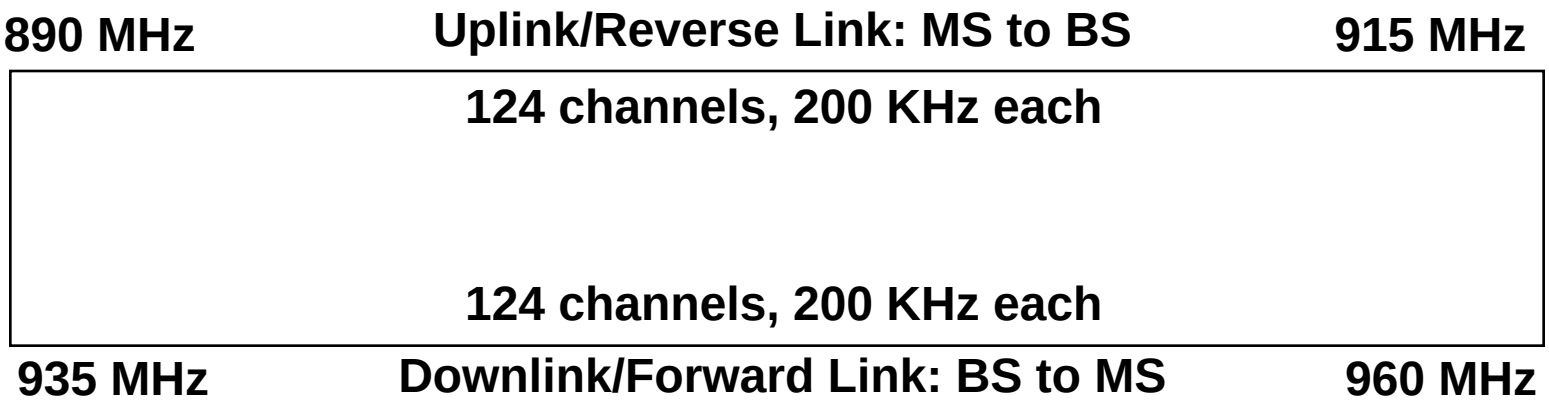
Digital Cellular TDMA (IS-54)

- **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**

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



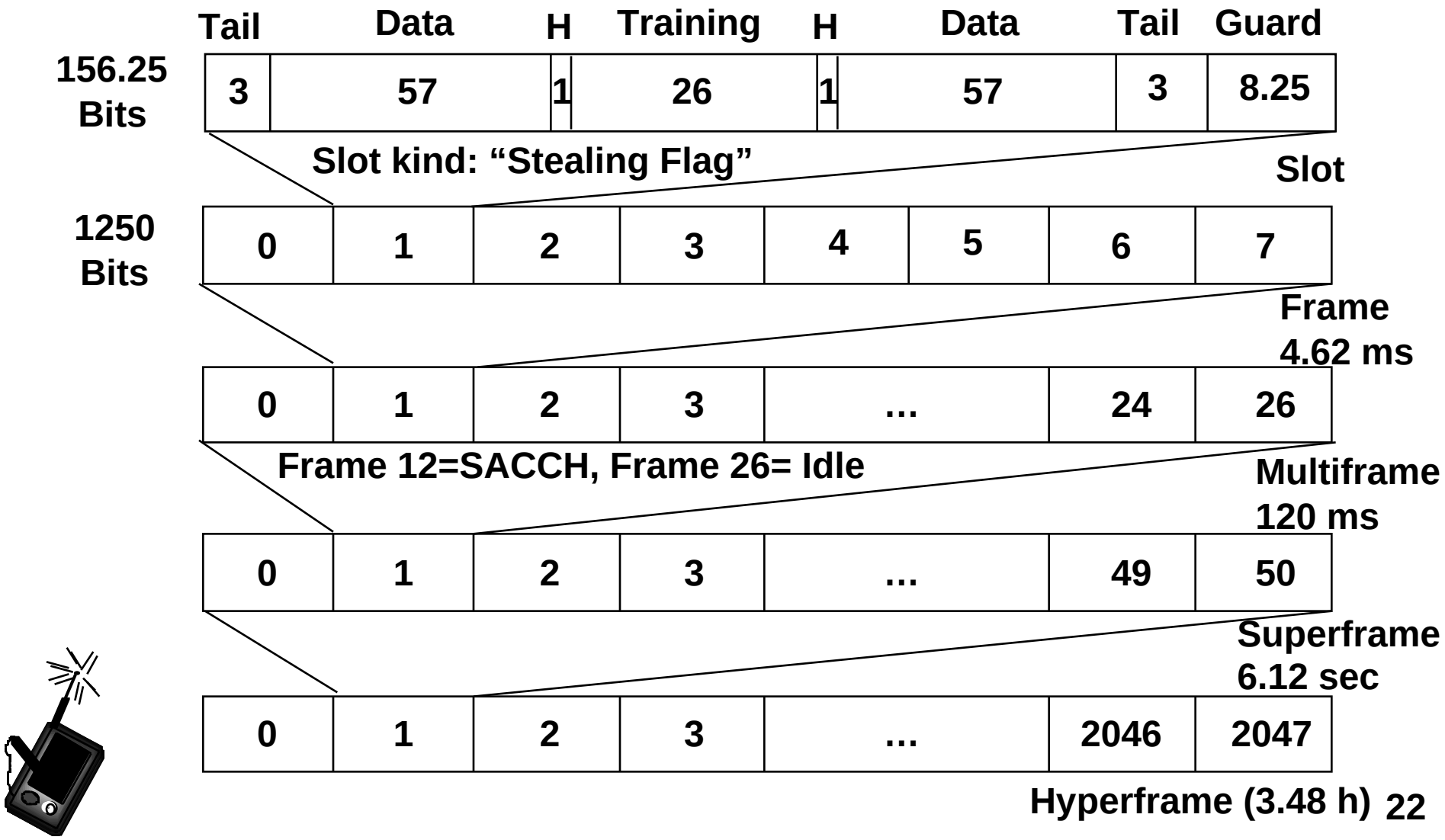
124 Traffic Channels x 8 Slots/Ch = 992 simultaneous conversations

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

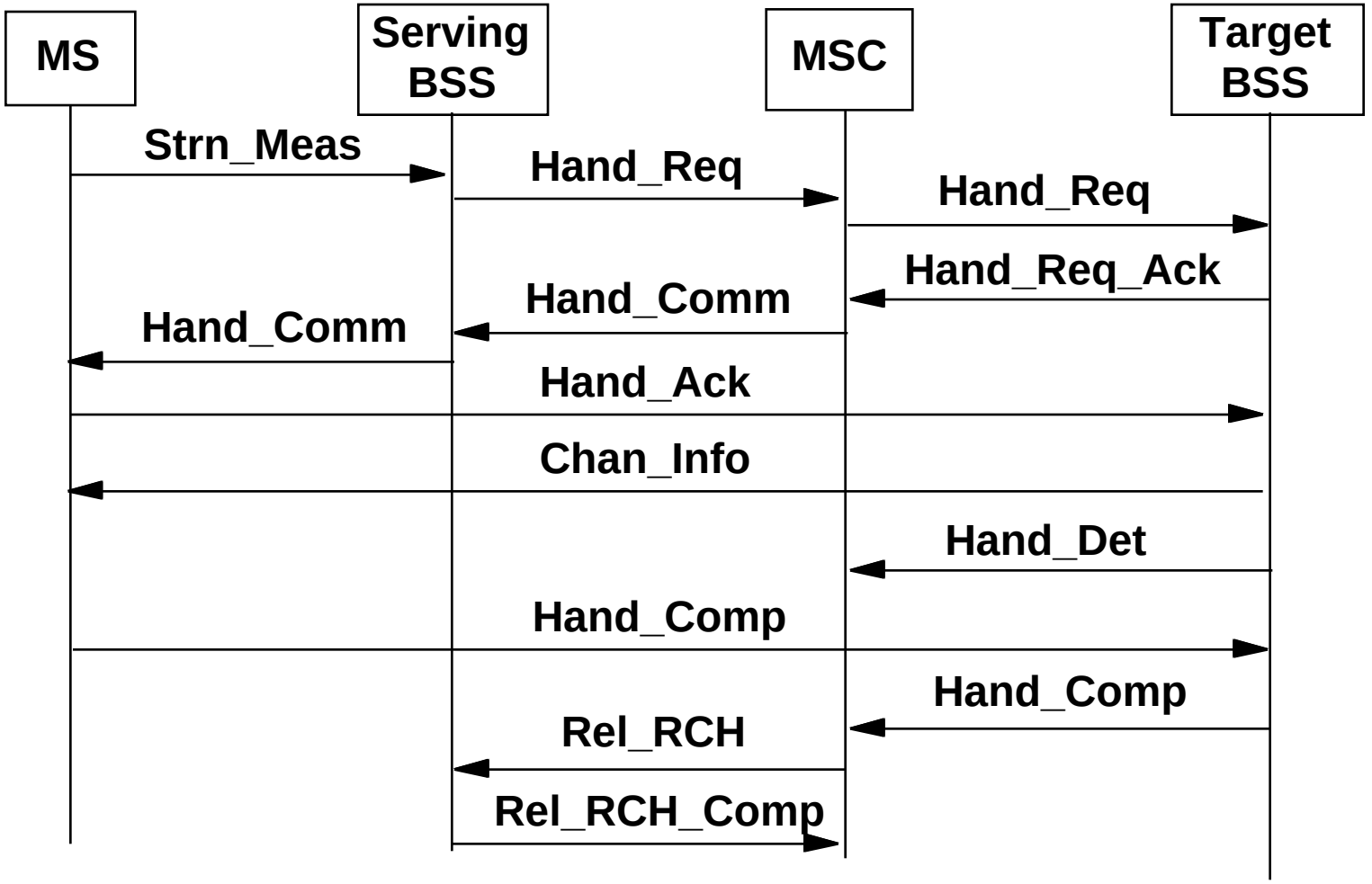
GSM Control Channels

- **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

GSM Framing


Tail
Data
H
Training
H
Data
Tail
Guard
156.25 Bits
3
57
1
26
1
57
3
8.25
Slot kind: “Stealing Flag”
Slot
1250 Bits
0
1
2
3
4
5
6
7
Frame 4.62 ms
0
1
2
3
…
24
26
Frame 12=SACCH, Frame 26= Idle
Multiframe 120 ms
0
1
2
3
…
49
50
Superframe 6.12 sec
0
1
2
3
…
2046
2047
Hyperframe (3.48 h)

GSM Mobile Initiated Handoff



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

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**

IS-95 CDMA System