INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-716-A
Mobile Communications Systems

Lecture #7
1G & 2G TDMA Mobile Systems

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NOVEMBER 2014

Agenda

- Zero Generation (Pre cellular)
- First Generation
- Second Generation TDMA

PRE CELLULAR (ZERO GENERATION)

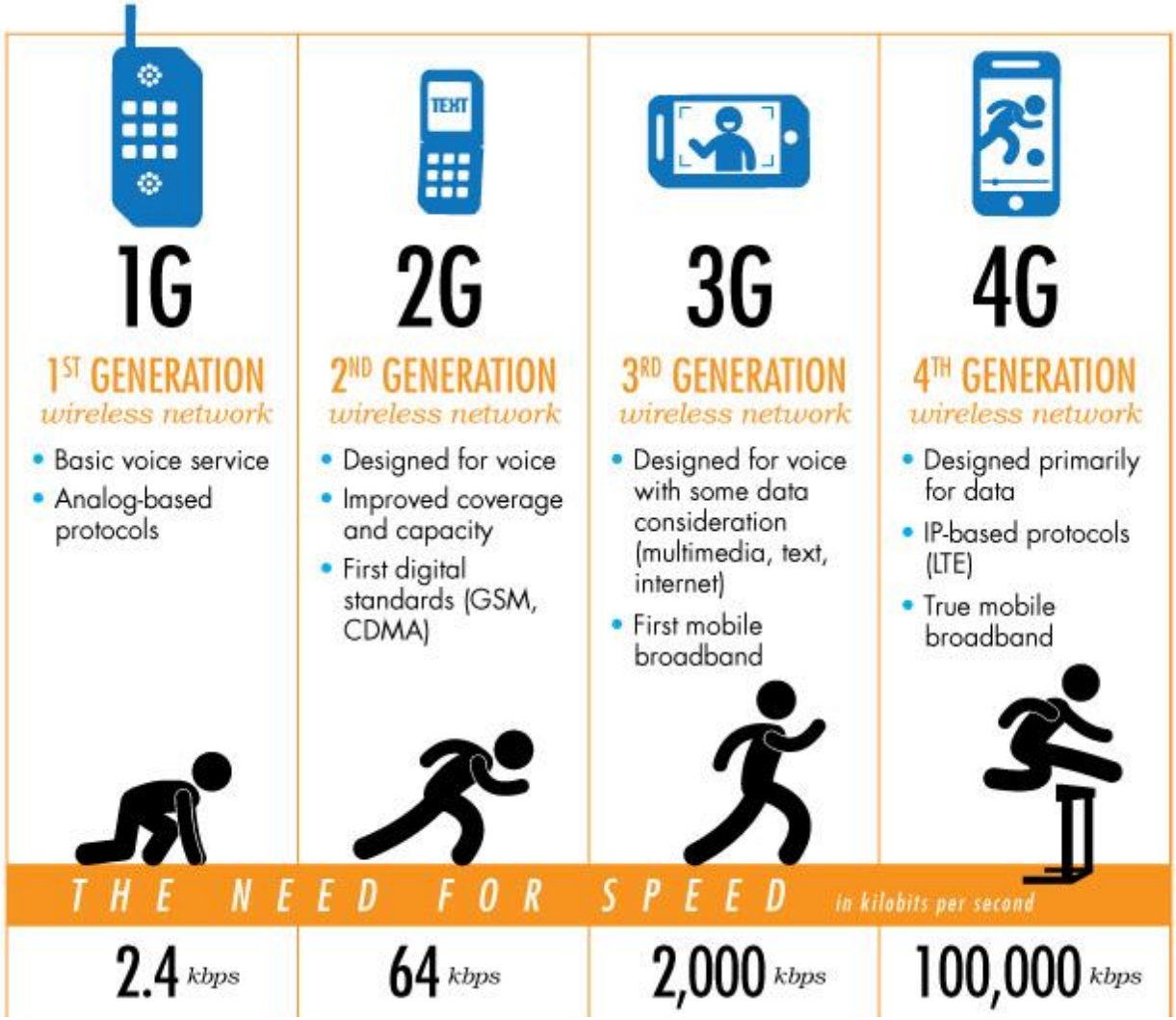
0G

- They are the mobile radio telephone systems preceded modern cellular mobile telephony technology.
- These systems are sometimes referred to as pre cellular (or sometimes zero generation) systems.
- Technologies used in pre cellular systems included
  - Push to Talk (PTT or manual),
  - Mobile Telephone System (MTS),
  - Improved Mobile Telephone Service (IMTS), and
  - Advanced Mobile Telephone System (AMTS) systems.

- These mobile telephones were usually mounted in cars or trucks, though briefcase models were also made.
- Typically, the transceiver (transmitter-receiver) was mounted in the vehicle trunk and attached to the "head" (dial, display, and handset) mounted near the driver seat.

FIRST GENERATION

Mobile/Cellular System Evolution



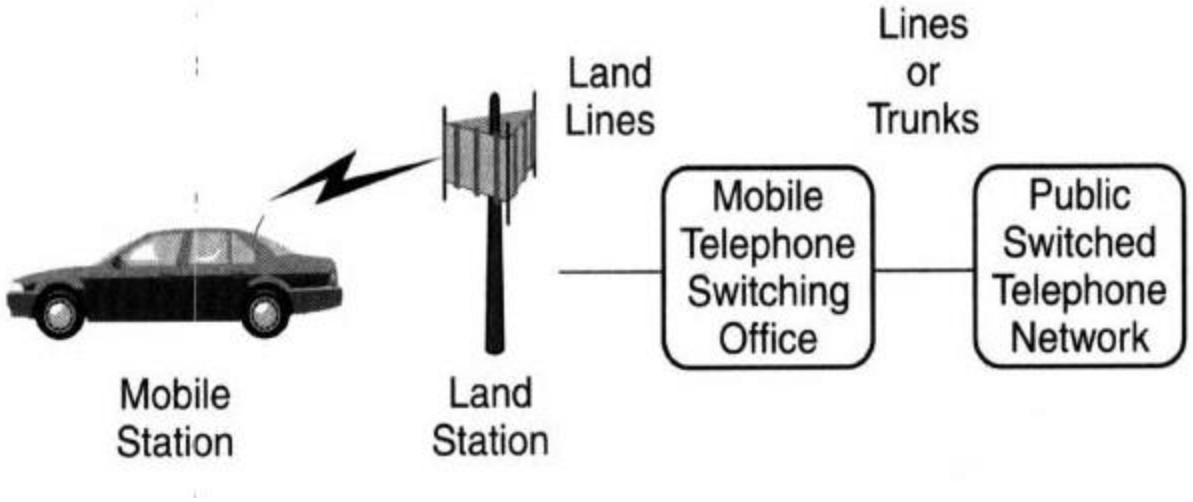
1G Analog

- Original cellular telephone networks
- Analog traffic channels
- Early 1980s in North America
- Advanced Mobile Phone Service (AMPS)
  - AT&T
- Also common in South America, Australia, and China

Spectral Allocation in North America

- Two 25-MHz bands are allocated to AMPS
  - One from BS to mobile unit (869–894 MHz)
  - Other from mobile to base station (824–849 MHz)
- Bands is split in two to encourage competition
  - In each market two operators can be accommodated
- Operator is allocated only 12.5 MHz in each direction
- Channels spaced 30 kHz apart
  - Total of 416 channels per operator
- Twenty-one channels allocated for control
- 395 to carry calls
- Control channels are 10 kbps data channels
- Conversation channels carry analog using frequency modulation
- Control information also sent on conversation channels in bursts as data
- Number of channels inadequate for most major markets
- For AMPS, frequency reuse is exploited

AMPS Architecture & Parameters



Base station transmission band	869 to 894 MHz
Mobile unit transmission band	824 to 849 MHz
Spacing between forward and reverse channels	45 MHz
Channel bandwidth	30 kHz
Number of full-duplex voice channels	790
Number of full-duplex control channels	42
Mobile unit maximum power	3 watts
Cell size, radius	2 to 20 km
Modulation, voice channel	FM, 12-kHz peak deviation
Modulation, control channel	FSK, 8-kHz peak deviation
Data transmission rate	10 kbps
Error control coding	BCH (48, 36,5) and (40, 28,5)

Operation

- AMPS-capable phone has numeric assignment module (NAM) in read-only memory
  - NAM contains number of phone
    - Assigned by service provider
  - Serial number of phone
    - Assigned by the manufacturer
  - When phone turned on, transmits serial number and phone number to MTSO
  - MTSO has database of mobile units reported stolen
    - Uses serial number to lock out stolen units
  - MTSO uses phone number for billing
  - If phone is used in remote city, service is still billed to user's local service provider

Call Sequence

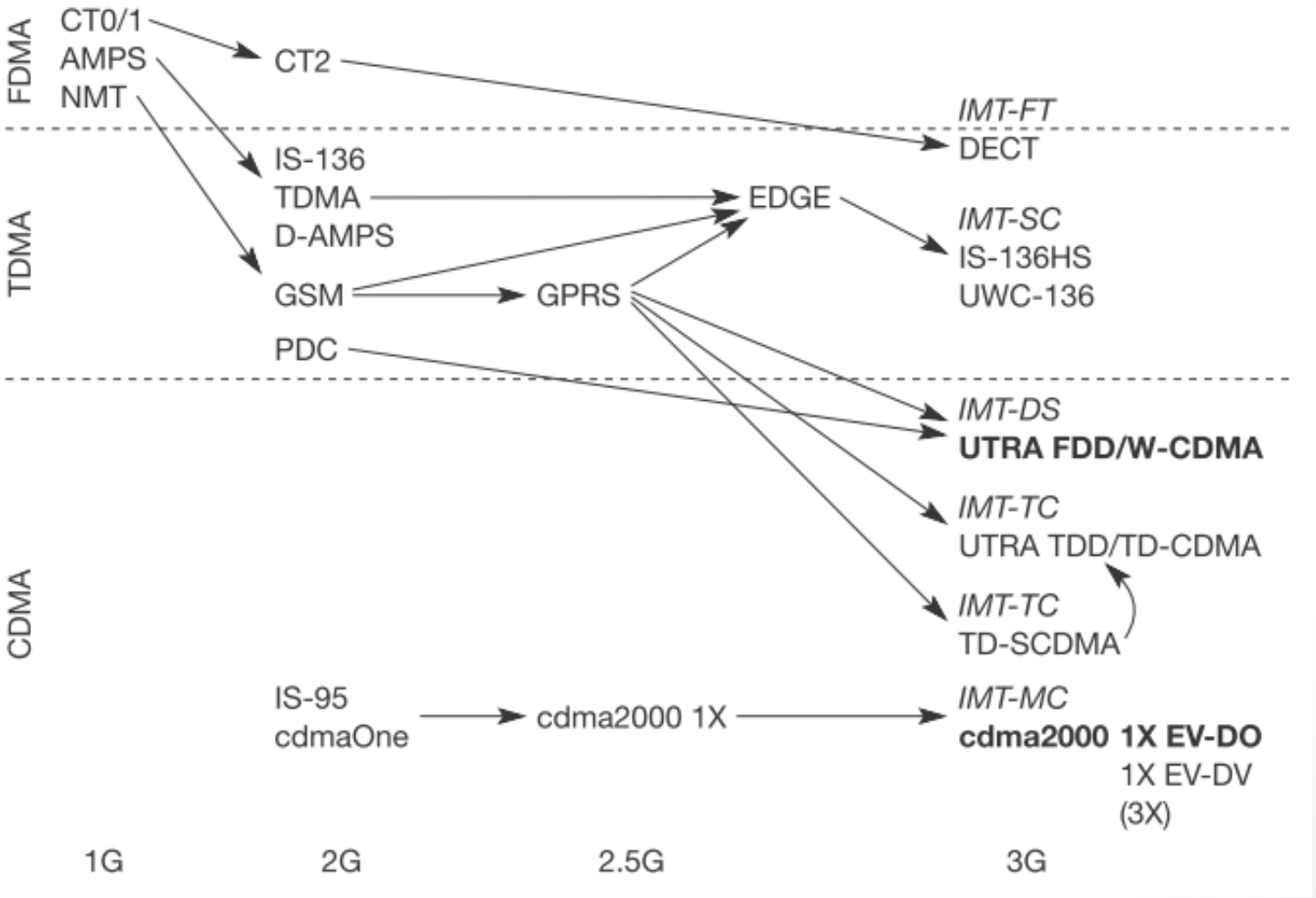
1. Subscriber initiates call by keying in number and presses send
2. MTSO validates telephone number and checks user authorized to place call
   - Some service providers require a PIN to counter theft
3. MTSO issues message to user's phone indicating traffic channels to use
4. MTSO sends ringing signal to called party
   - All operations, 2 through 4, occur within 10 s of initiating call
5. When called party answers, MTSO establishes circuit and initiates billing information
6. When one party hangs up MTSO releases circuit, frees radio channels, and completes billing information

AMPS Control Channels

- 21 full-duplex 30-kHz control channels
  - Transmit digital data using FSK
  - Data are transmitted in frames
- Control information can be transmitted over voice channel during conversation
  - Mobile unit or the base station inserts burst of data
    - Turn off voice FM transmission for about 100 ms
    - Replacing it with an FSK-encoded message
  - Used to exchange urgent messages
    - Change power level
    - Handoff

SECOND GENERATION TDMA

Development of Mobile Telecommunication Systems



Popular 2G Systems

	GSM	IS-136	IS-95
Year introduced	1990	1991	1993
Access method	TDMA	TDMA	CDMA
Base station transmission band	935 to 960 MHz	869 to 894 MHz	869 to 894 MHz
Mobile station transmission band	890 to 915 MHz	824 to 849 MHz	824 to 849 MHz
Spacing between forward and reverse channels	45 MHz	45 MHz	45 MHz
Channel bandwidth	200 kHz	30 kHz	1250 kHz
Number of duplex channels	125	832	20
Mobile unit maximum power	20 W	3 W	0.2 W
Users per channel	8	3	35
Modulation	GMSK	$\pi/4$ DQPSK	QPSK
Carrier bit rate	270.8 kbps	48.6 kbps	9.6 kbps
Speech coder	RPE-LTP	VSELP	QCELP
Speech coding bit rate	13 kbps	8 kbps	8, 4, 2, 1 kbps
Frame size	4.6 ms	40 ms	20 ms
Error control coding	Convolutional 1/2 rate	Convolutional 1/2 rate	Convolutional 1/2 rate forward; 1/3 rate reverse

Differences Between 1G and 2G Systems

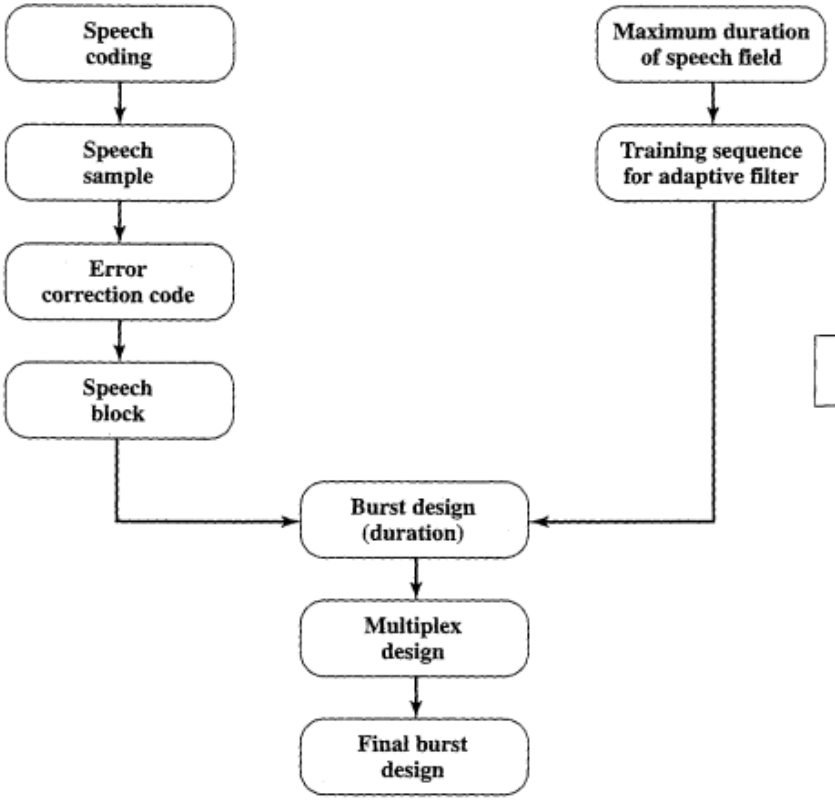
- Digital traffic channels – first-generation systems are almost purely analog; second-generation systems are digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Error detection and correction – second-generation digital traffic allows for detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users

TDMA Design Considerations

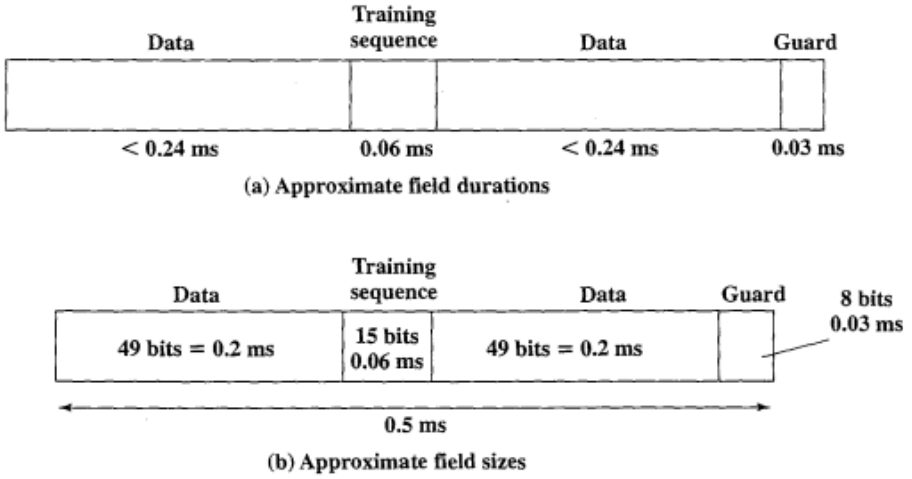
- Number of logical channels (number of time slots in TDMA frame): 8
- Maximum cell radius (R): 35 km
- Frequency: region around 900 MHz
- Maximum vehicle speed (V_m):250 km/hr
- Maximum coding delay: approx. 20 ms
- Maximum delay spread (Δ_m): 10 μs
- Bandwidth: Not to exceed

  200 kHz (25 kHz per channel)

TDMA Design

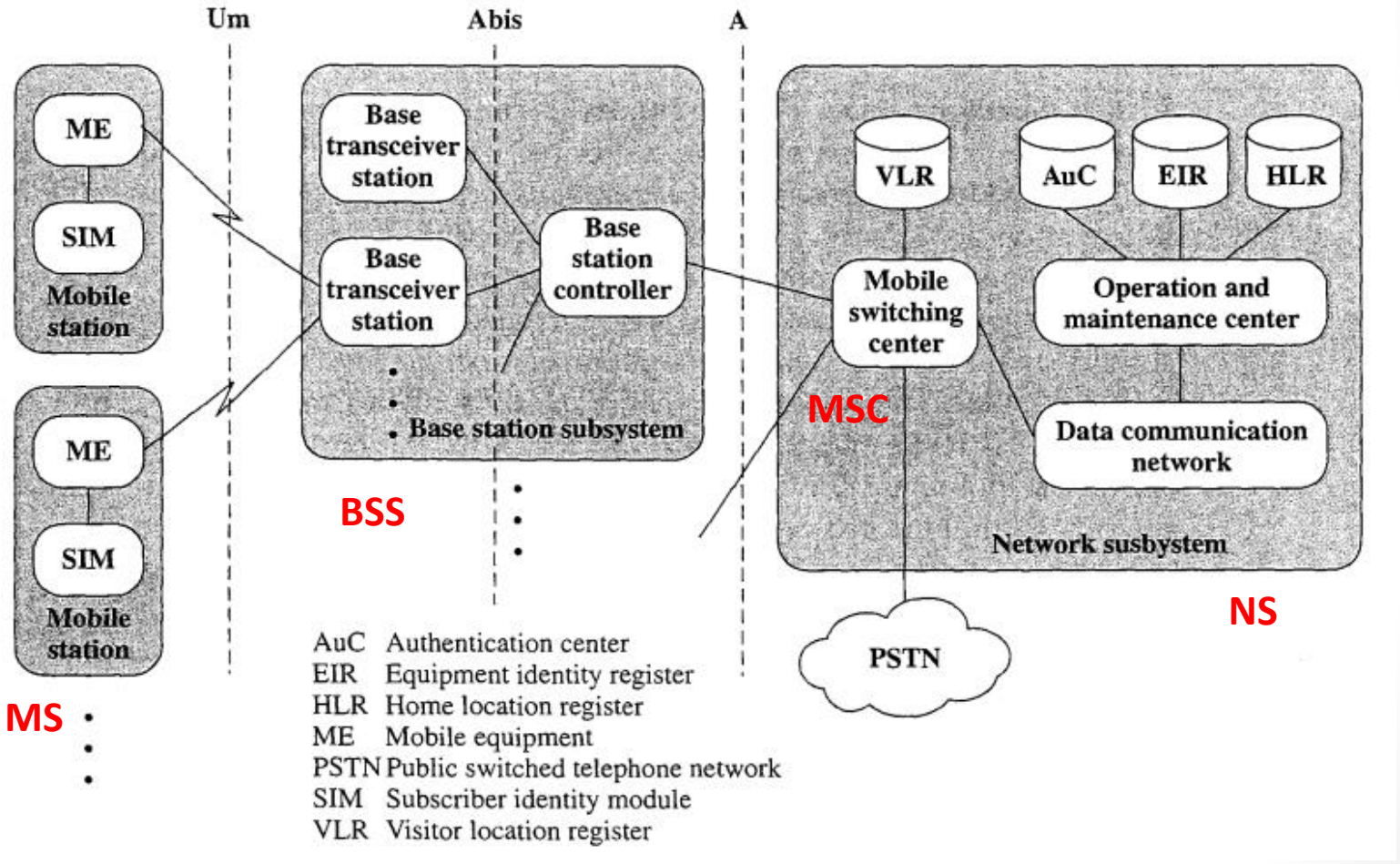


Steps in Design of TDMA Time Slot



TDMA Time Slot

GSM Network Architecture



MS & BSS

- Mobile station communicates across Um interface (air interface) with base station transceiver in same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a telephone or PCS
  - ME includes radio transceiver, digital signal processors and subscriber identity module (SIM)
- GSM subscriber units are generic until SIM is inserted
  - SIMs roam, not necessarily the subscriber devices

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

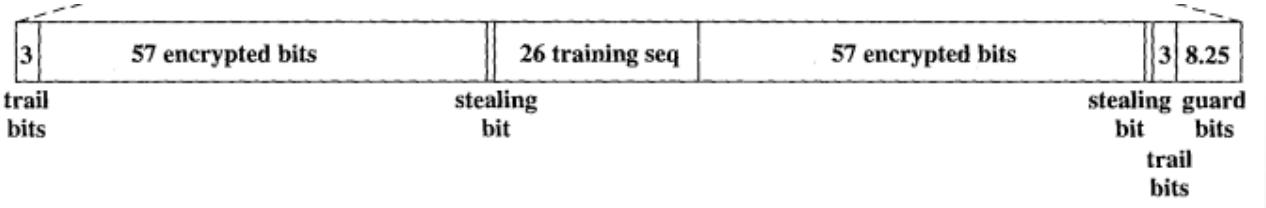
NS & MSC

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

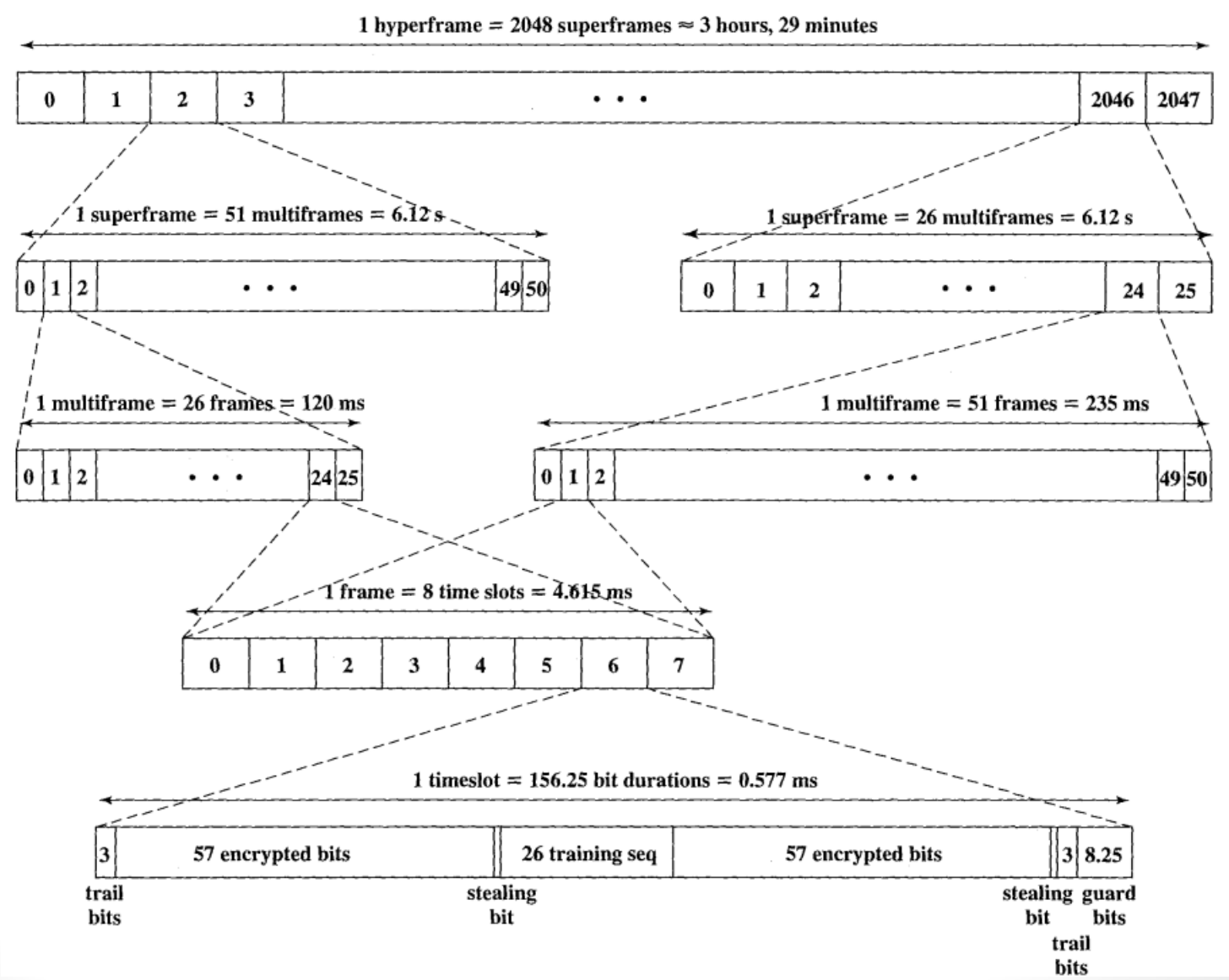
- MSC components:
  - Home location register (HLR) database – stores information about each subscriber that belongs to it
  - Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
  - Authentication center database (AuC) – used for authentication activities, holds encryption keys
  - Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

TDMA Format – Time Slot Fields

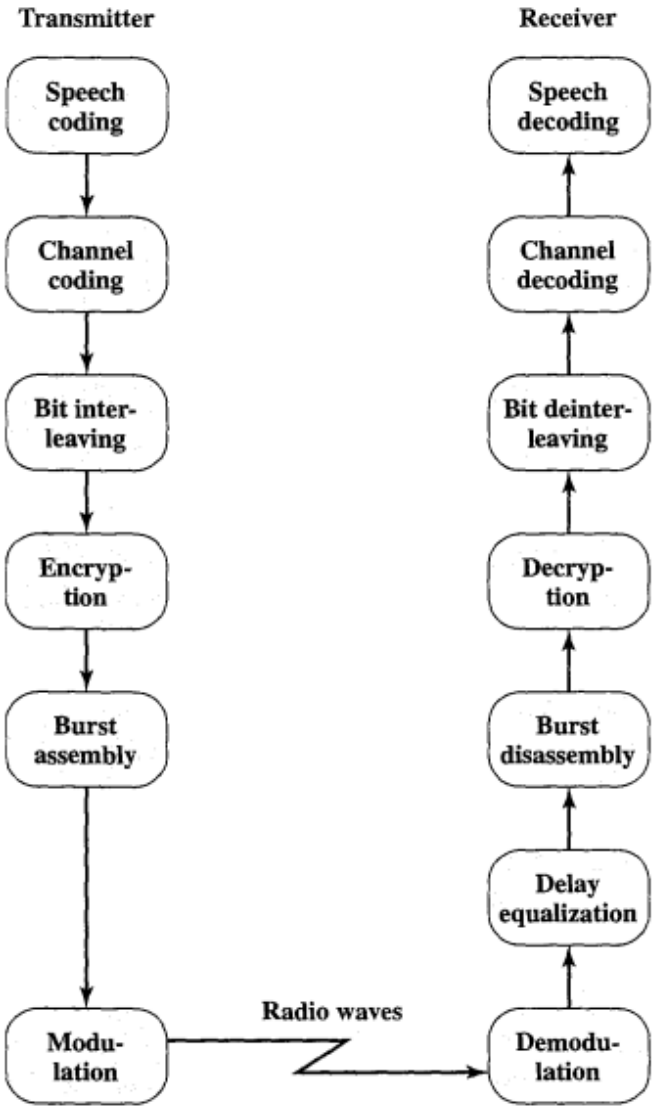
- Trail bits – allow synchronization of transmissions from mobile units
- Encrypted bits – encrypted data
- Stealing bit - indicates whether block contains data or is "stolen"
- Training sequence – used to adapt parameters of receiver to the current path propagation characteristics
  - Strongest signal selected in case of multipath propagation
- Guard bits – used to avoid overlapping with other bursts



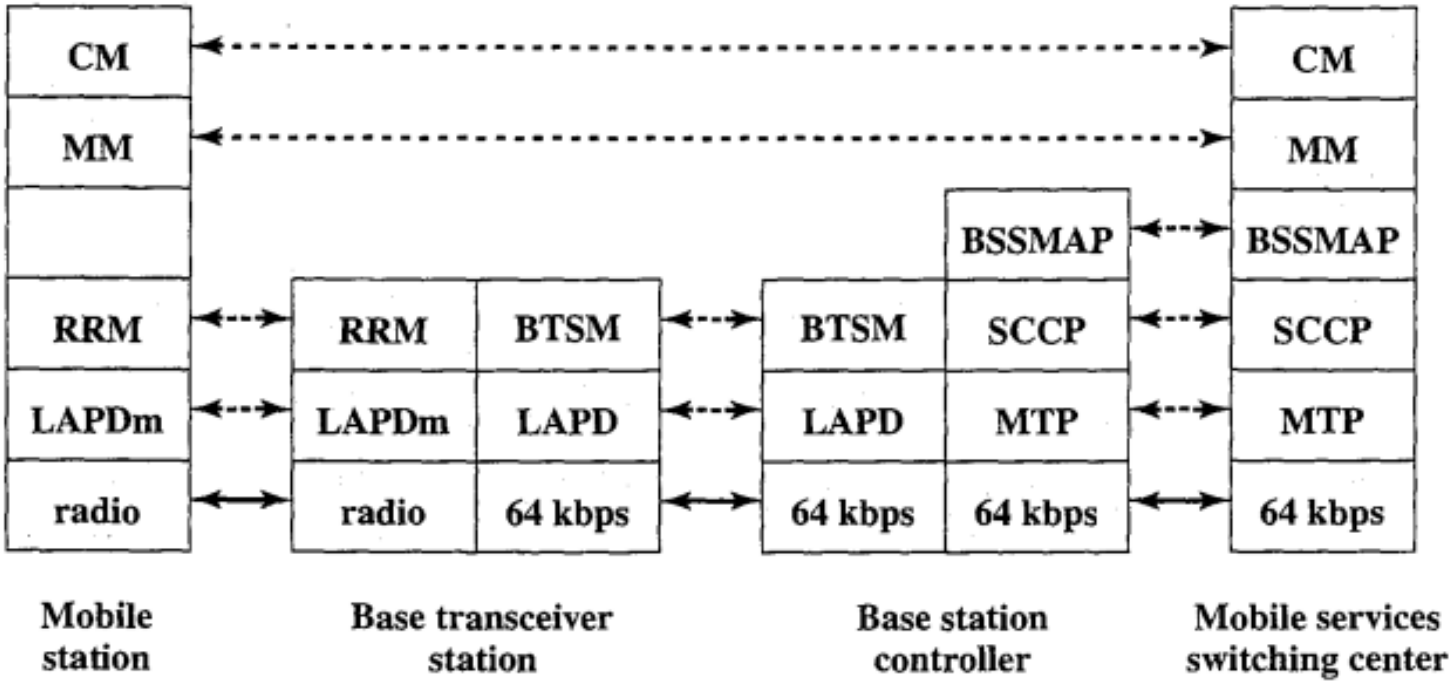
GSM Frame Format



GSM Speech Signal Processing



GSM Signaling Protocol Architecture



BSSMAP = BSS mobile application part
BTSM = BTS management
CM = connection management
LAPD = link access protocol, D channel
MM = mobility management
MTP = message transfer part
RRM = radio resources management
SCCP = signal connection control part

Functions Provided by Protocols

- Protocols above the link layer of the GSM signaling protocol architecture provide specific functions:
  - Radio resource management
  - Mobility management
  - Connection management
  - Mobile application part (MAP)
  - BTS management

- For more details, refer to:
  - Chapter 4, J. Chiller, Mobile Communications, 2003.
  - Chapter 10, W. Stallings, Wireless Communications and Networks, 2005.
- The lecture is available online at:
  - https://speakerdeck.com/ahmad_elbanna
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