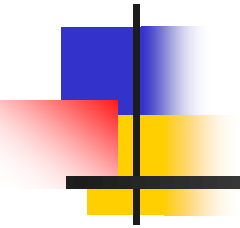
Wireless Mobile & Multimedia Networking (7COM1076)



Cellular Wireless Networks

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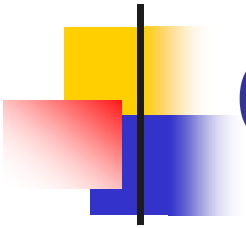
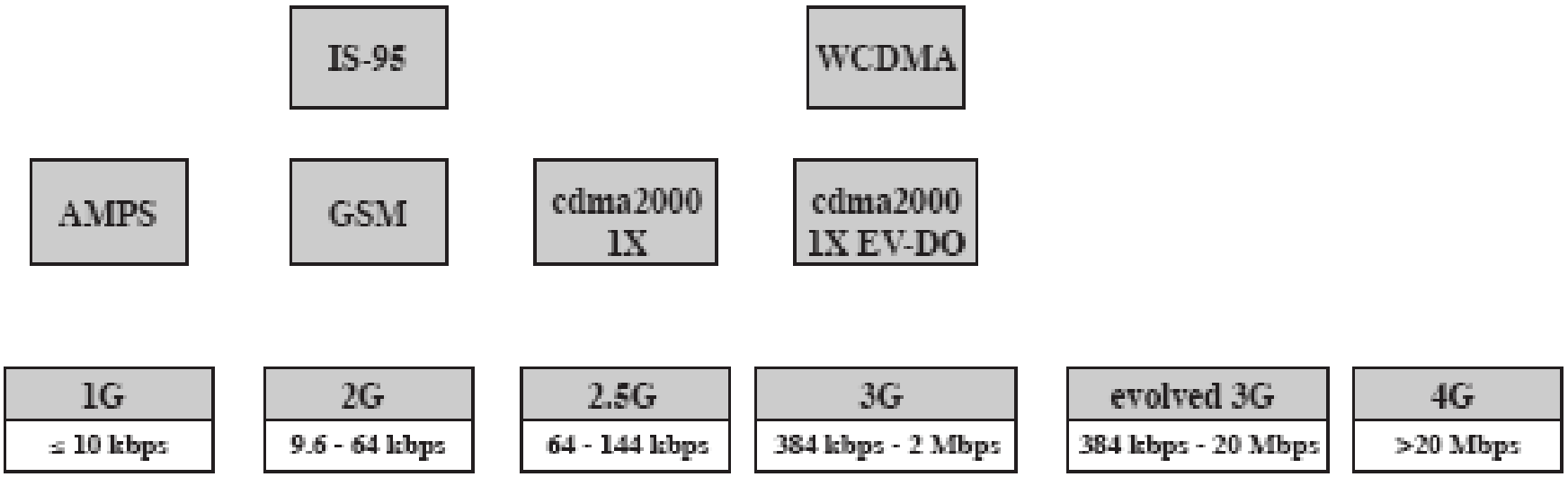


Overview

- *Principles of Cellular Networks*
- AMPS (1G)
- GSM (2G TDMA) and IS-95 (2G CDMA)
- WiMax and LTE (both 4G OFDM)

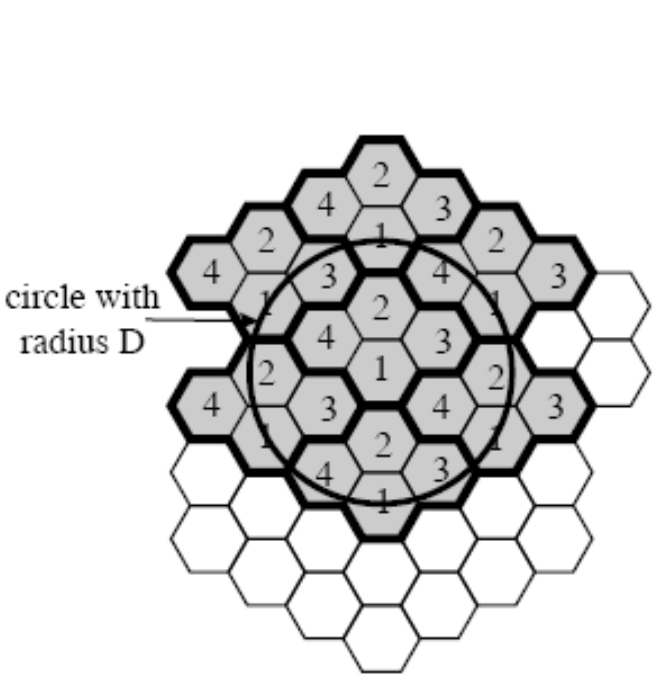
Evolution of Cellular Wireless Systems



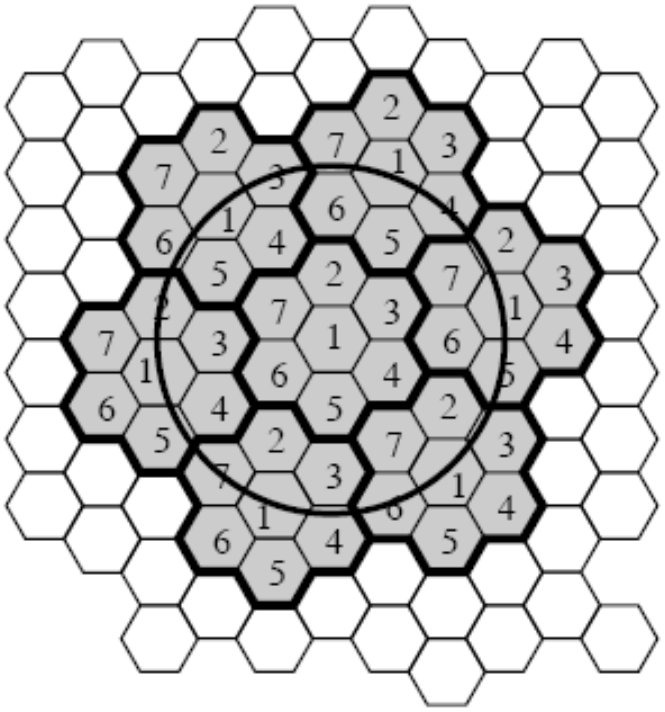
Cellular Network Organization

- Use multiple low-power transmitters (100 W or less)
- Areas divided into cells
  - Each served by its own antenna
  - Served by base station consisting of transmitter, receiver, and control unit
  - Band of frequencies allocated
  - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)

Frequency Reuse Patterns



(a) Frequency reuse pattern for $N = 4$



(b) Frequency reuse pattern for $N = 7$

Frequency Reuse

- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
  - 10 to 50 frequencies assigned to each cell
  - Transmission power controlled to limit power at that frequency escaping to adjacent cells
  - The issue is to determine how many cells must intervene between two cells using the same frequency

Reuse Factor

- Definitions
  - *D* = minimum distance between centers of cells that use the same frequency band (called cochannels)
  - *R* = radius of a cell
  - *d* = distance between centers of adjacent cells
  - *N* = number of cells in a repetitious pattern (each cell in the pattern uses a unique set of frequency bands), termed the **reuse factor.**
- Hexagonal cell pattern
  - *N = I^2+J^2+(I x J), I, J = 0, 1, 2, 3*
  - *D/R* = sqrt(3N)
  - *D/d* = sqrt(N)

Approaches to Cope with Increasing Capacity

- Adding new channels
- Frequency borrowing – frequencies are taken from adjacent cells by congested cells
- Cell splitting – cells in areas of high usage can be split into smaller cells
- Cell sectoring – cells are divided into a number of wedge-shaped sectors, each with their own set of channels
- Microcells – antennas move to buildings hills, and lamp posts

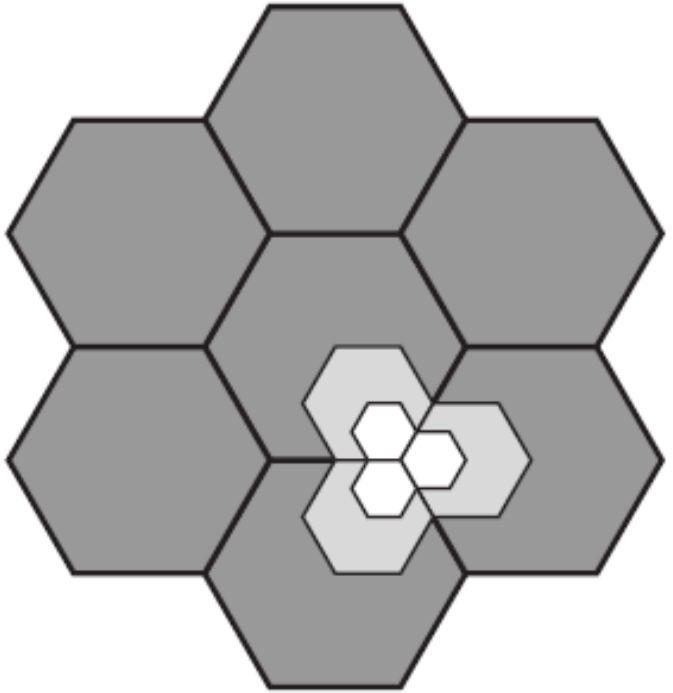
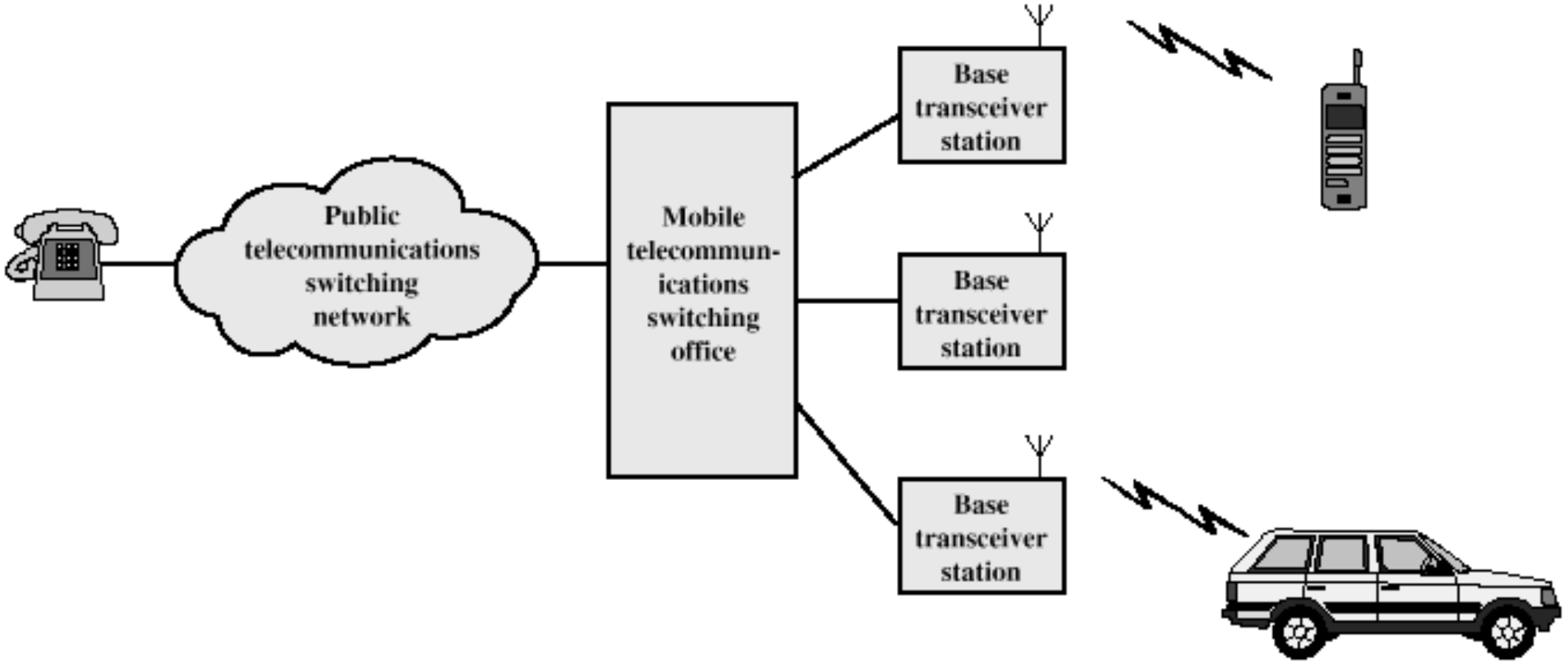


Figure 10.3 Cell Splitting

Cellular System Overview



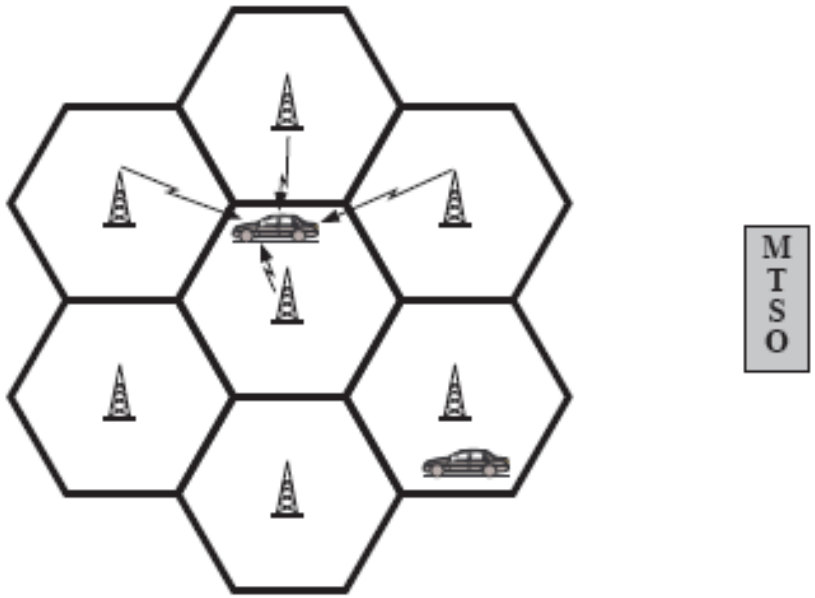
Cellular Systems Terms

- Base Station (BS) – includes an antenna, a controller, and a number of receivers
- Mobile telecommunications switching office (MTSO) – connects calls between mobile units
- Two types of channels available between mobile unit and BS
  - Control channels – used to exchange information having to do with setting up and maintaining calls
  - Traffic channels – carry voice or data connection between users

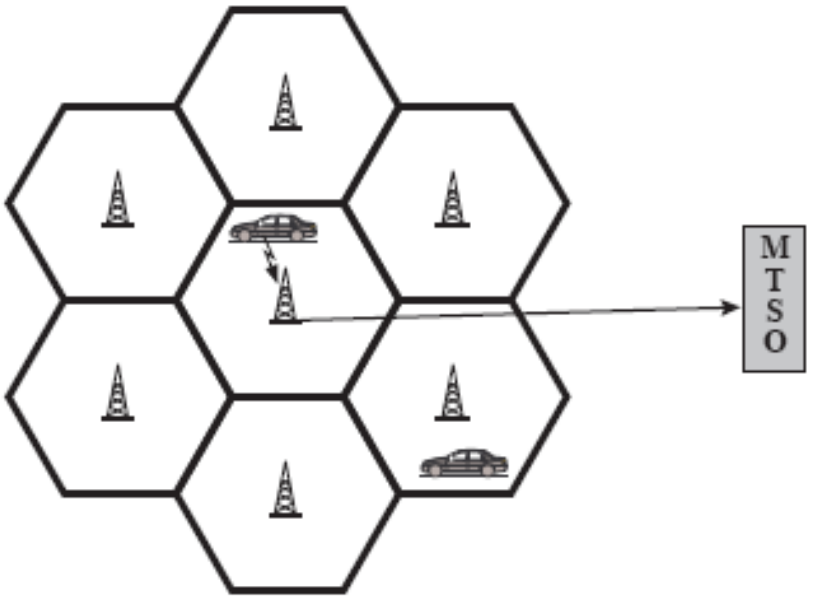
Steps in an MTSO Controlled Call between Mobile Users

(1) Mobile unit initialization

(2) Mobile-originated call



(a) Monitor for strongest signal

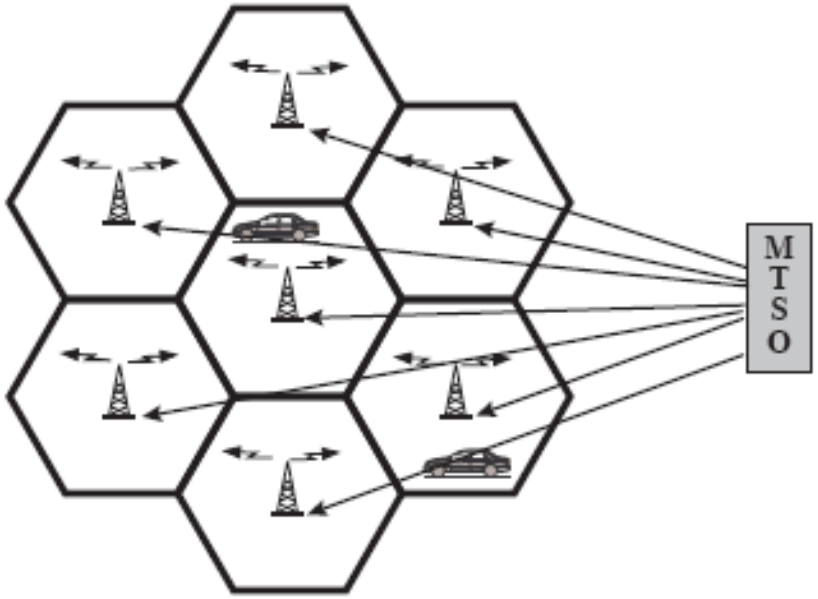


(b) Request for connection

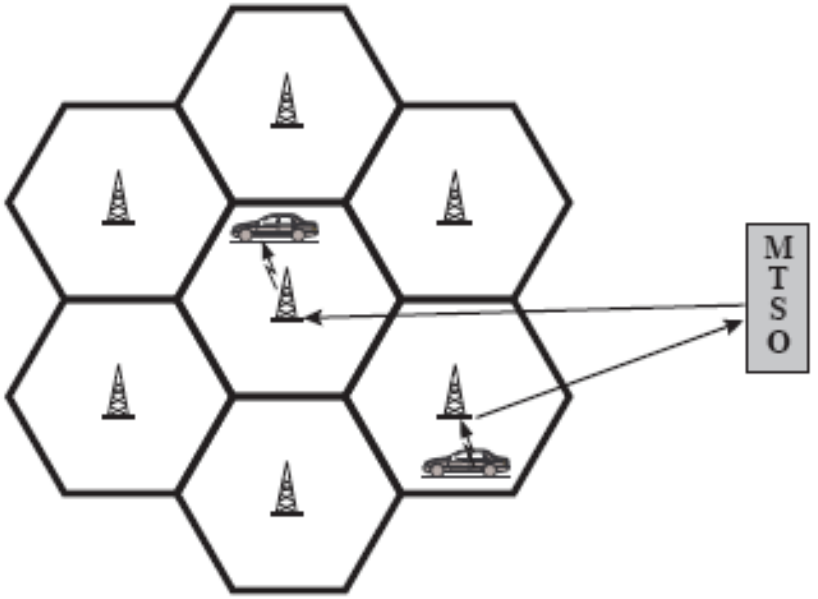
Steps in an MTSO Controlled Call between Mobile Users (Cont.)

(3) Paging

(4) Call accepted



(c) Paging

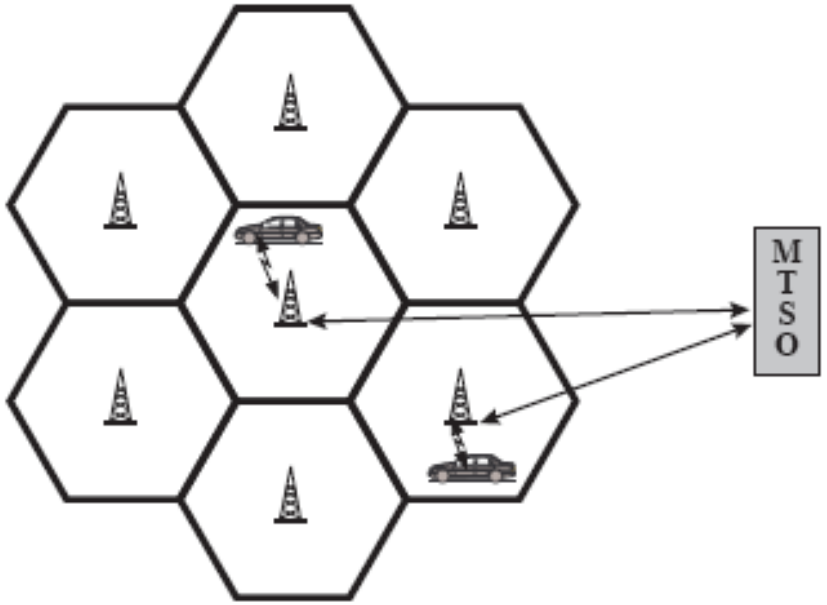


(d) Call accepted

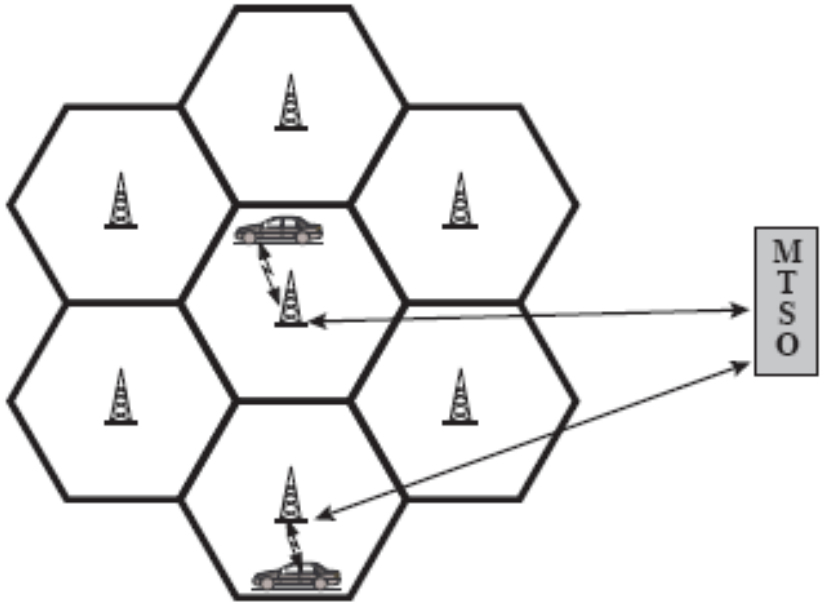
Steps in an MTSO Controlled Call between Mobile Users (Cont.)

(5) Ongoing call

(6) Handoff



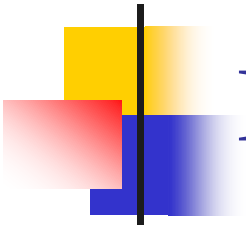
(e) Ongoing call



(f) Handoff

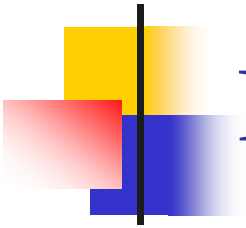
Additional Functions in an MTSO Controlled Call

- Call blocking
  - Busy
- Call termination
  - Hang up
- Call drop
  - Interference or weak signal
- Calls to/from fixed and remote mobile subscriber
  - Arranged by MTSO



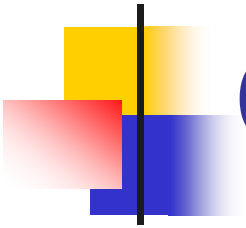
Handoff Performance Metrics

- Cell blocking probability – probability of a new call being blocked
- Call dropping probability – probability that a call is terminated due to a handoff
- Call completion probability – probability that an admitted call is not dropped before it terminates
- Probability of unsuccessful handoff – probability that a handoff is executed while the reception conditions are inadequate
- Handoff blocking probability – probability that a handoff cannot be successfully completed
- Handoff probability – probability that a handoff occurs before call termination
- Rate of handoff – number of handoffs per unit time
- Hard handoff and soft handoff



Power Control

- Design issues making it desirable to include dynamic power control in a cellular system
  - Received power must be sufficiently above the background noise for effective communication
  - Desirable to minimize power in the transmitted signal from the mobile
    - Reduce co-channel interference, alleviate health concerns, save battery power
  - In SS systems using CDMA, it's desirable to equalize the received power level from all mobile units at the BS

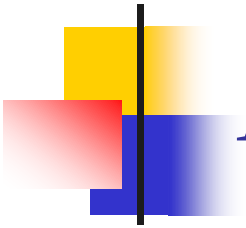


Overview

- Principles of Cellular Networks
- *AMPS (1G)*
- GSM (2G TDMA) and IS-95 (2G CDMA)
- WiMax and LTE (both 4G OFDM)

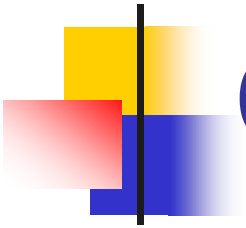
Advanced Mobile Phone Service (AMPS)

- Two 25-MHz bands allocated to AMPS
  - One for transmission from base to mobile unit (869-894 MHz)
  - One for transmission from mobile unit to base (824-849MHz)
- Each band split in two to encourage competition
  - Each 12.5MHz band is divided into 416 channels every 30KHz (21 for control and 395 for traffic)
  - All together 790 full-duplex voice channels and 42 full-duplex control channels
- Frequency reuse exploited



AMPS Operation

- Subscriber initiates call by keying in phone number and presses send key
- MTSO verifies number and authorizes user
- MTSO issues message to user's cell phone indicating send and receive traffic channels
- MTSO sends ringing signal to called party
- Party answers; MTSO establishes circuit and initiates billing information
- Either party hangs up; MTSO releases circuit, frees channels, completes billing



Overview

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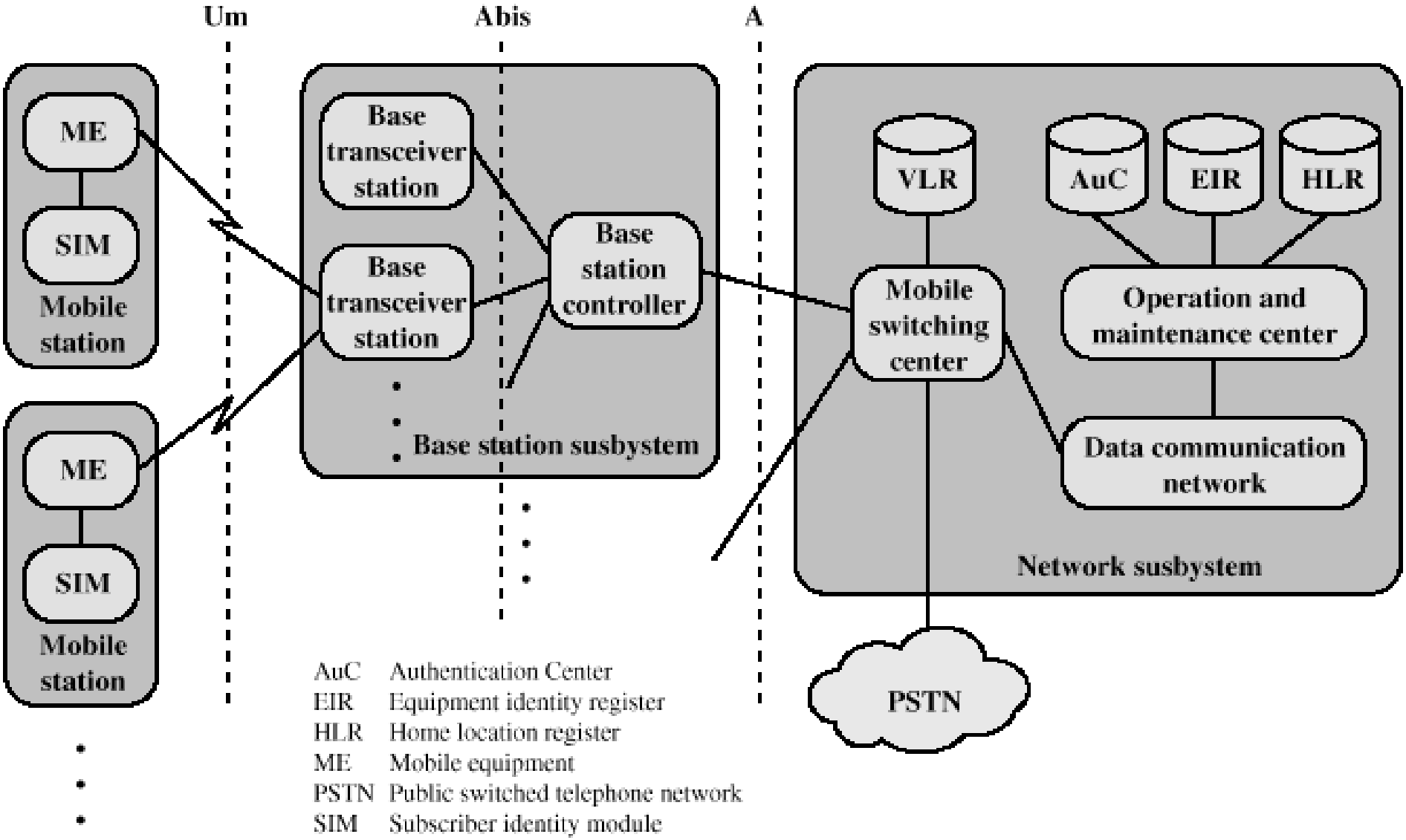
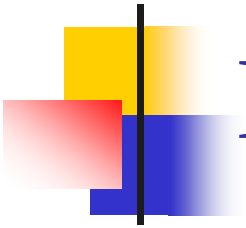
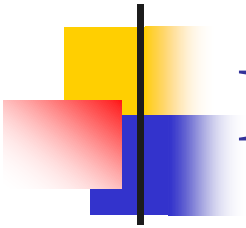


Figure 10.14 Overall GSM Architecture



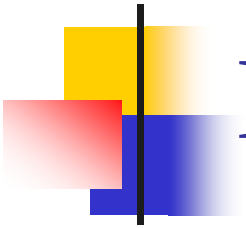
Mobile Station

- 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



Base Station Subsystem (BSS)

- 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

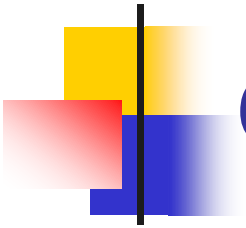


Network Subsystem (NS)

- 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)

Mobile Switching Center (MSC) Databases

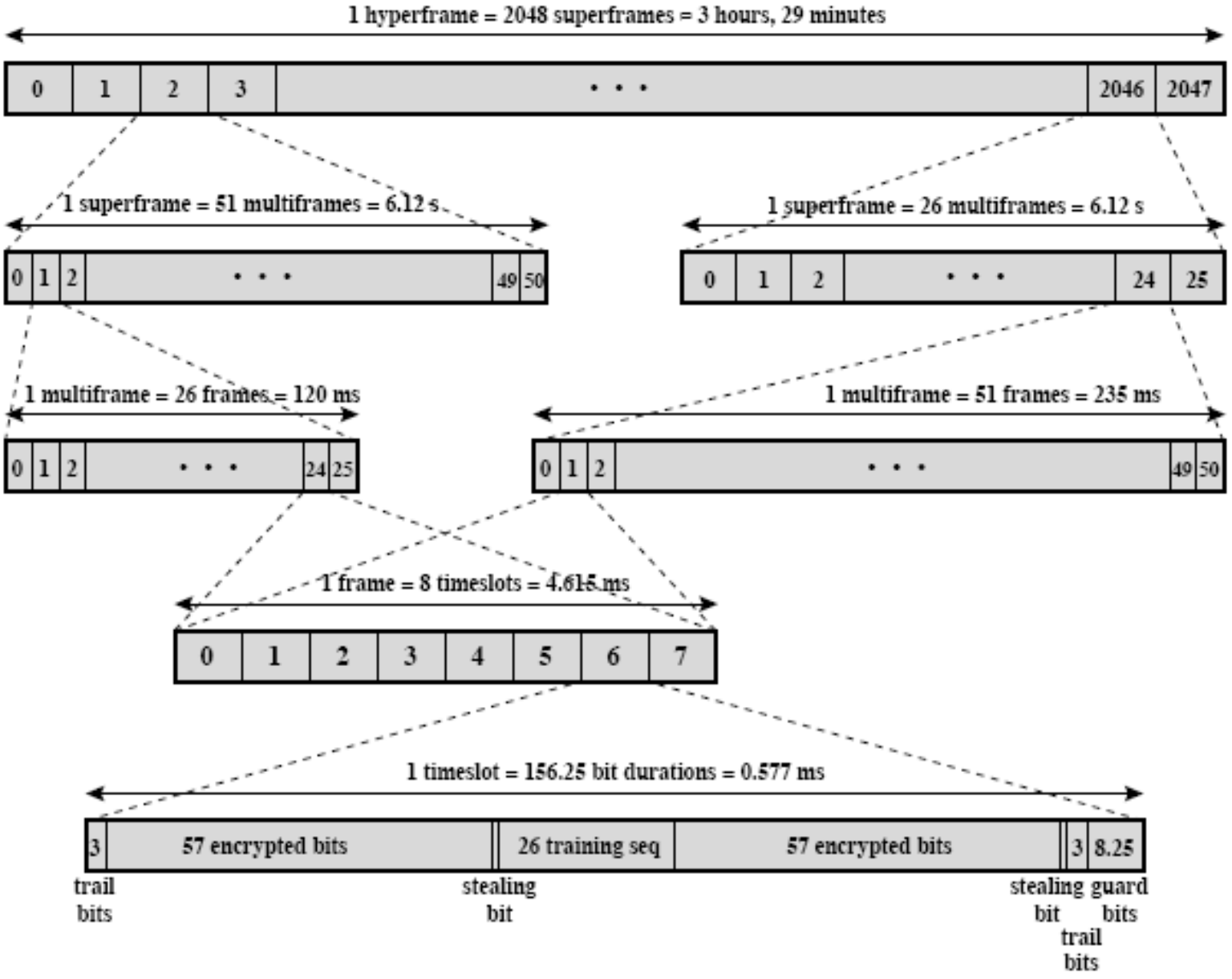
- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds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

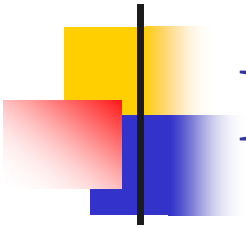


GSM Radio Link Aspects

- Two 25-MHz bands allocated to GSM
  - One for transmission from base to mobile unit (935-960 MHz)
  - One for transmission from mobile unit to base (890-915MHz)
  - Each 25MHz band is divided into 125 radio-frequency carriers every 200kHz, provides for 125 full-duplex channels.
  - Each 200KHz frequency carrier is divided into 8 logical channels defined by the repetitive occurrence of time slots.

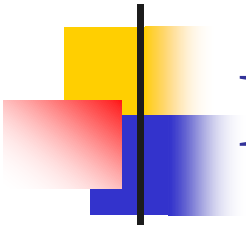
GSM Frame Format





IS-95

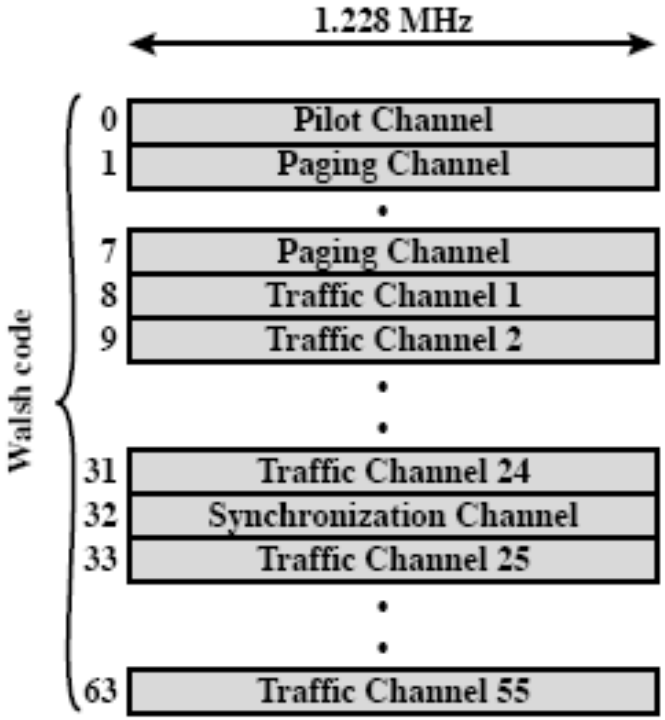
- Most widely used second-generation CDMA system.
- Using DSSS on forward and reverse links.
- All forward channels use the same bandwidth. The chipping code is used to distinguish among the different channels.
  - For the forward channel, chipping codes are the 64 orthogonal 64-bit codes
  - For the reverse channel, chipping codes are still 64 bits, but are not guaranteed orthogonal, but the orthogonarity of signals are guaranteed by an orthogonal modulation scheme.



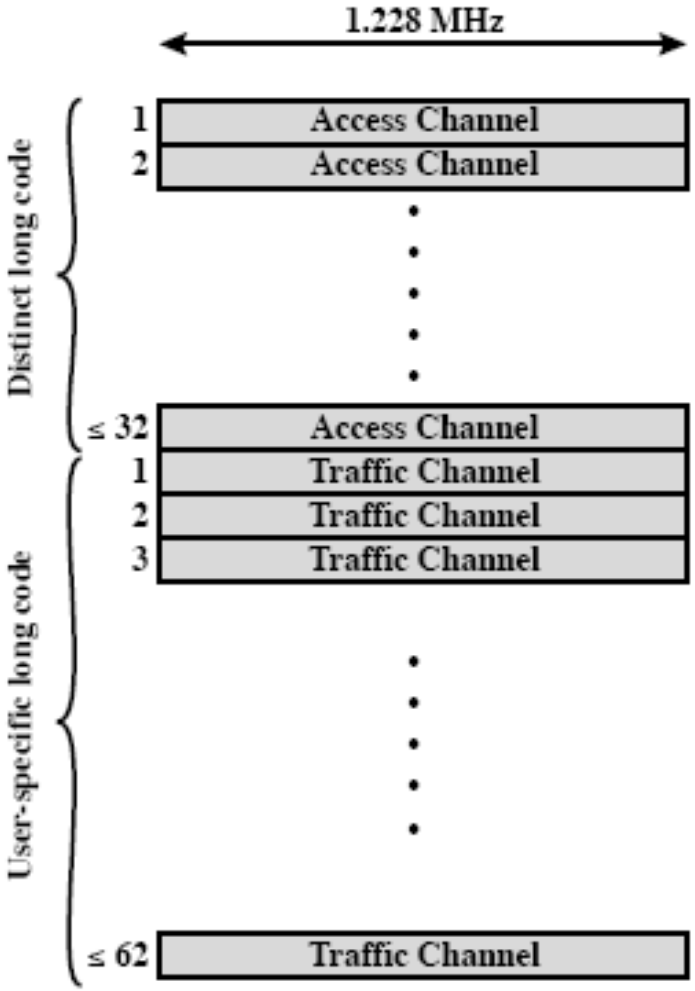
IS-95 Radio Link Aspects

- Two 25-MHz bands allocated to IS-95
  - One for transmission from base to mobile unit (869-894 MHz), the forward link
  - One for transmission from mobile unit to base (824-849MHz), the reverse link
  - Each 25MHz band is divided into 20 radio-frequency carriers every 1250kHz, provides for 20 full-duplex channels.
  - Each 1250KHz frequency carrier is divided into 64 logical channel on the forward link or up to 94 logical channel on the reverse link

IS-95 Channel Structure



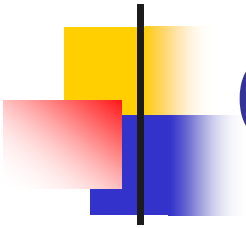
(a) Forward channels



(b) Reverse channels

Advantages of CDMA Cellular

- Frequency diversity – frequency-dependent transmission impairments have less effect on signal
- Multipath resistance – chipping codes used for CDMA exhibit low cross correlation and low autocorrelation
- Privacy – privacy is inherent since spread spectrum is obtained by use of noise-like signals
- Graceful degradation – system only gradually degrades as more users access the system



Overview

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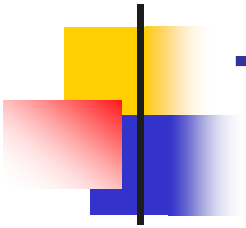
- GSM (2G TDMA) and IS-95 (2G CDMA)
- *WiMax and LTE (both 4G OFDM)*

Third-Generation Capabilities

- An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic
- More efficient use of the available spectrum in general
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

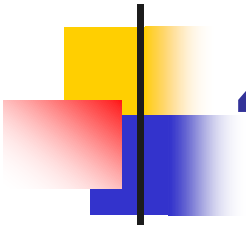
Why 4G ?

Current	4G
Voice communication	VoIP, high quality video conferencing
SMS, MMS	Video messaging
Internet browsing	Super-fast internet
Downloadable games	Online gaming with mobility
Downloadable video	High quality audio & video streaming
No TV service	Broadcast TV on-demand
Peer-to-peer messaging	Wide-scale distribution of video clips
	Mobile payment
	File transfer
	Many other innovative ideas



Technical Requirements

- Increase data rate
  - About 100 Mbps downlink and 50 Mbps uplink
- Improve wireless performance
  - Better signal reception and better coverage
- Increase spectrum efficiency
  - More subscribers and more data transfer in the same spectrum
- High flexibility of allocation
  - Quickly adjust data rate to subscriber according to need



4G Enabling Technology

- Some key technologies made 4G possible
- Both WiMAX (Worldwide Interoperability for Microwave Access and LTE (Long Term Evolution) use:
  - OFDM, OFDMA and SC-FDMA
  - Channel dependent scheduling
  - Adaptive coding and modulation (ACM)
  - Multiple-In-Multiple-Out (MIMO) antenna processing
  - Turbo coding and decoding
- Need to fight the fading channel

Battle of the Megabytes

- WiMAX vs LTE- Clash of the Titans
- WiMAX- An IP based wireless broadband access technology that provides performance similar to Wi-Fi with coverage and QoS (Quality of Service) of cellular networks.
- Cellular-backed LTE, with overwhelming support from cellular operators, looks to be late starting favorite
- Intel, Samsung, Cisco etc. are supporting WiMAX whereas, NSN, Ericsson, Alcatel Lucent etc. are supporting LTE

WiMAX introduction

- Need for the extension of the range of Wi-Fi
- Key to Wi-Fi's success:

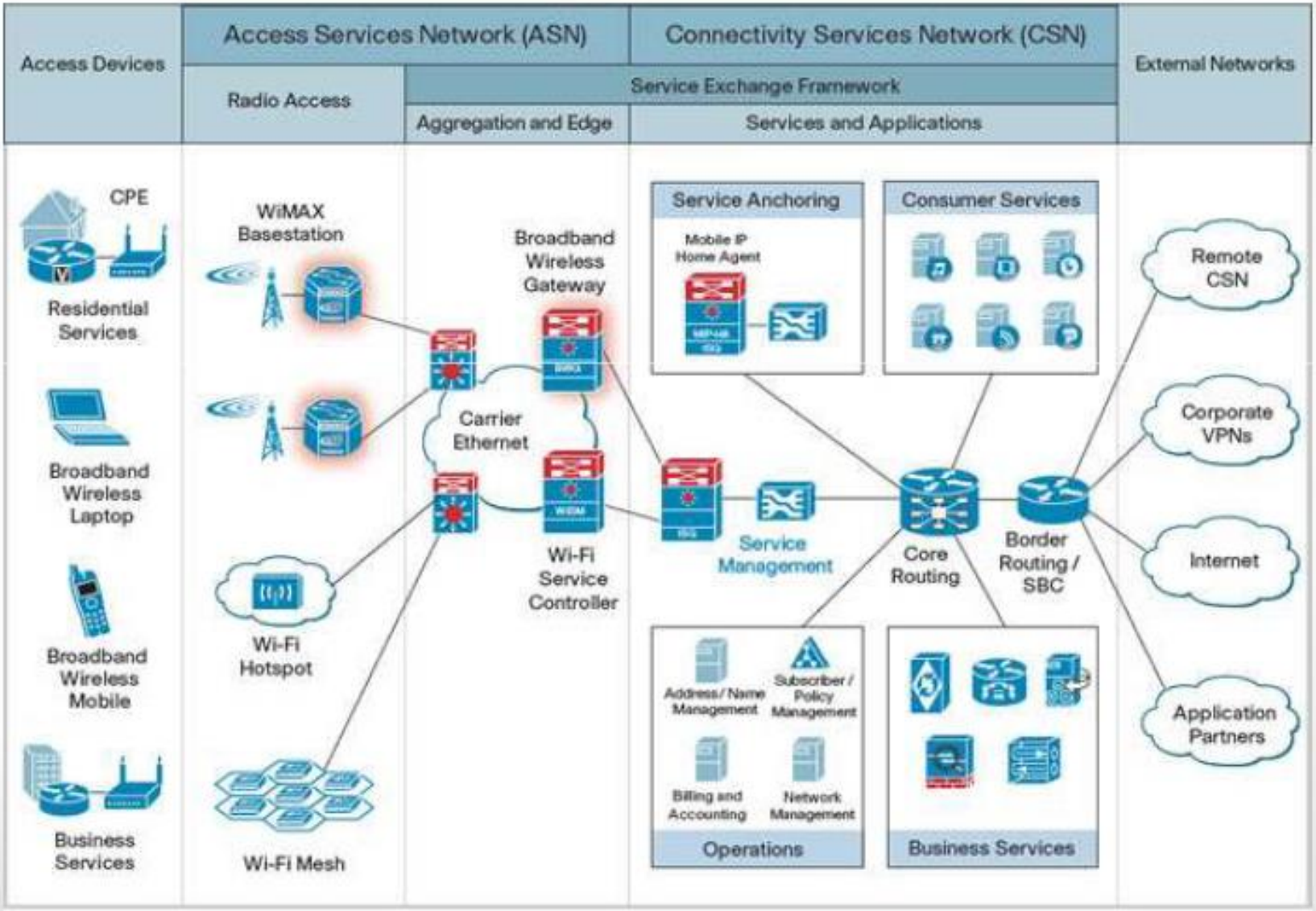
1. Simple Time Division Duplex protocol and flat IP architecture.
2. Base station could be plugged into simple DSL line.

- Goal of WiMAX- to extend Wi-Fi like services to an entire community by using inexpensive components and licensed or unlicensed frequencies.
- Roger Marks founded 802.16 (WiMAX) working group in 1998 and has chaired the committee since then.
- WiMAX combines the cellular range with the Wi-Fi speed. It plugs into Ethernet like Wi-Fi and provides roaming voice and data like cellular.

WiMAX standards

- First wireless MAN air interface standard in 2001 (use above 10GHz)- approved WiMAX 802.16a original WiMAX specs in January 2003
- Followed by 802.16d (fixed WiMAX) in 2004 which added the MIMO.
- Further came in 802.16e (mobile WiMAX) which added the mobility factor
- Current version is 802.16j which added multihop relay
- Future standards of 802.16m, 802.16n and 802.16p are in progress which will bring in advanced air interface with higher data rates of 100mbps for mobile and 1Gbps for fixed services along with higher reliability of network and FDD along with TDD.

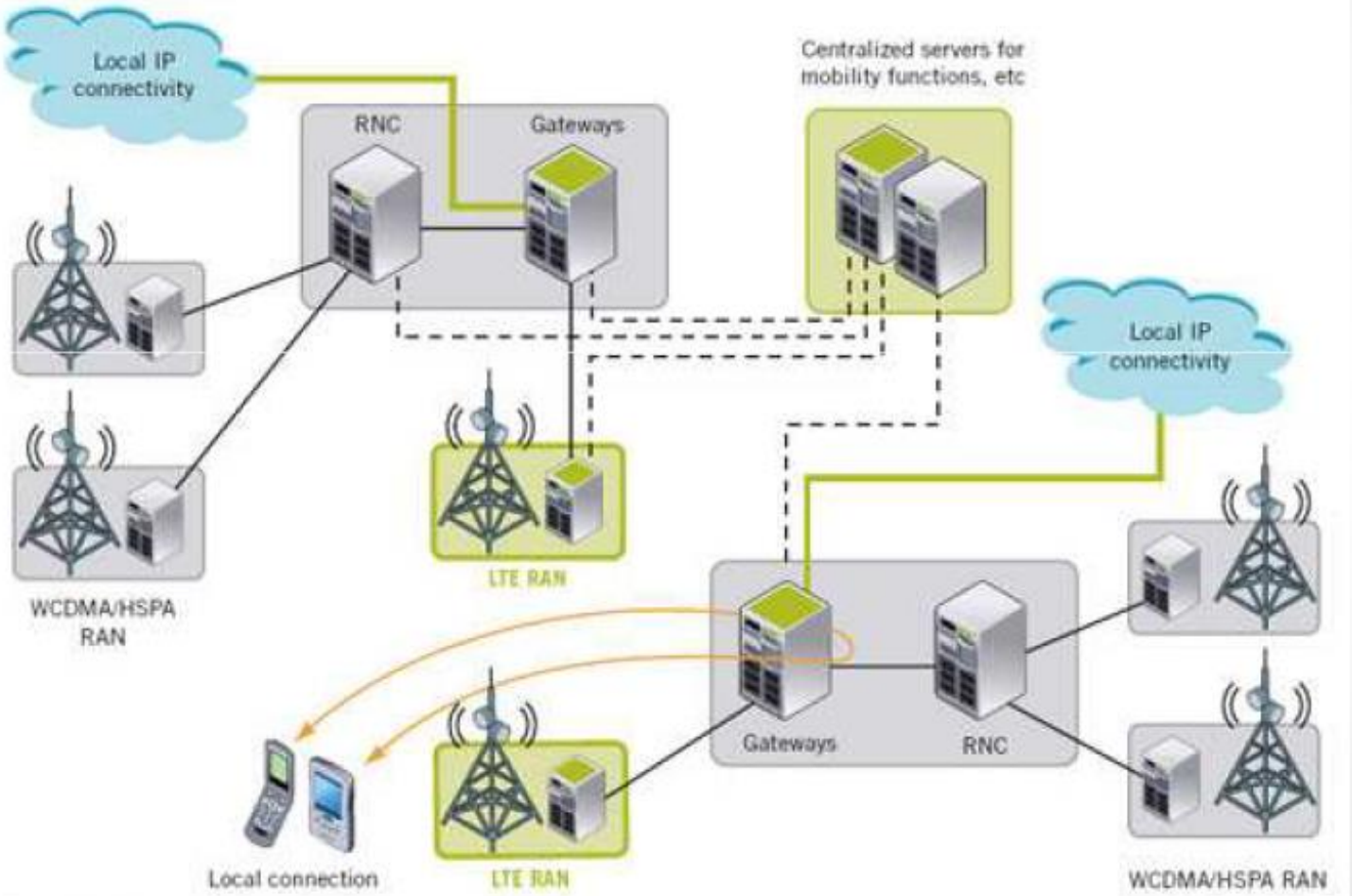
WiMAX architecture



LTE explained

- Evolves form third generation technology based on WCDMA.
- Supports higher peak data rate through wider bandwidth.
- Provides Low Latency and Overhead (Radio Delay<5mSec)
- Implements Scheduling at Base station to maintain Channel Quality.
- All IP based network with reduction in cost per bit
- Flexibility in use of new and existing frequency bands (Spectrum Flexibility)
- Lower power consumption
- Supports mobility speeds up to 350km/hr with 500km/hr under consideration.

LTE architecture



LTE specifications

- Higher Peak data rates(20MHz operation):
  downlink: 100Mbps
  (150Mbps peak based on 2x2 MIMO)
  (300Mbps peak based on 4x4 MIMO)
  uplink: 50Mbps(75Mbps peak) (5Mbps individually)
- Improved latency (UE-RNC-UE) below 10ms (round trip time)
- Support of scalable B.W. – 1.4,3,5,10,15,20MHz
- Support of paired and unpaired spectrum (FDD and TDD)
- Uplink: QPSK, 16-QAM and 64-QAM (optional for handset)
- Downlink: QPSK, 16-QAM and 64-QAM
- Uplink- SC-FDMA and Downlink- OFDMA

Similarities

- OFDMA(Orthogonal Frequency Division Multiple Access) on downlink
- MIMO(Multiple Input Multiple Output) and beam forming
- Backward compatibility
- Speed
- Error correcting codes- Viterbi and turbo coding
- IP based technologies
- Scalable Bandwidth

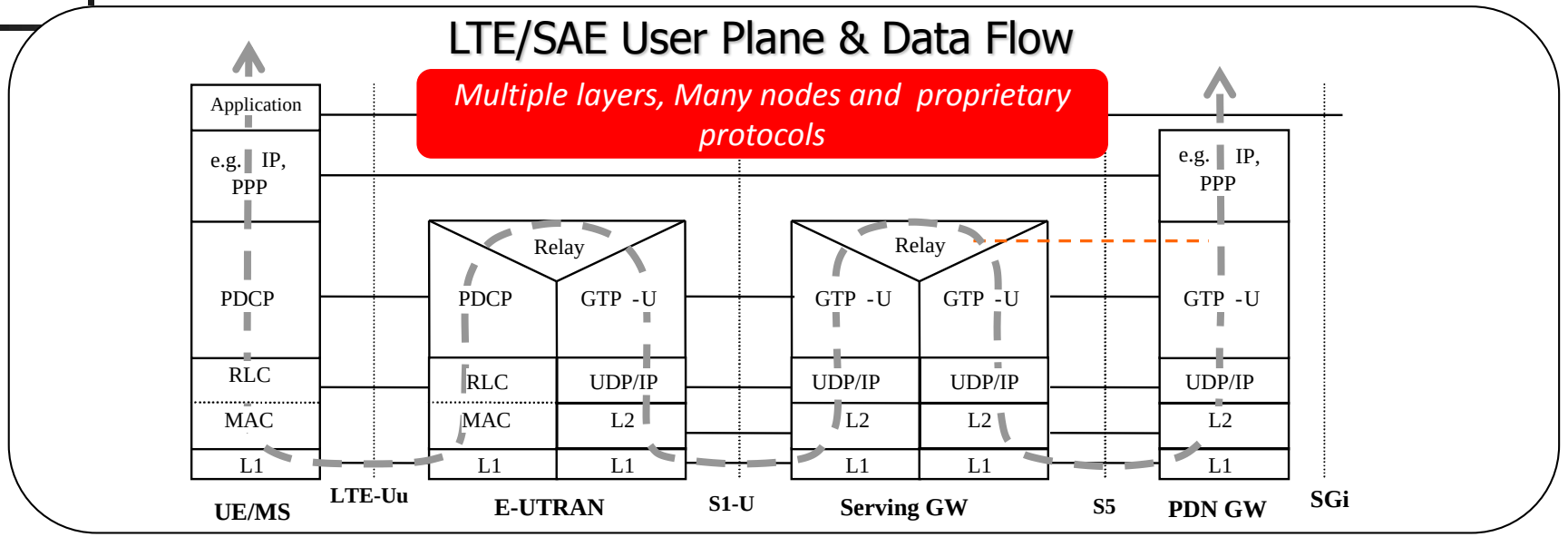
Differences

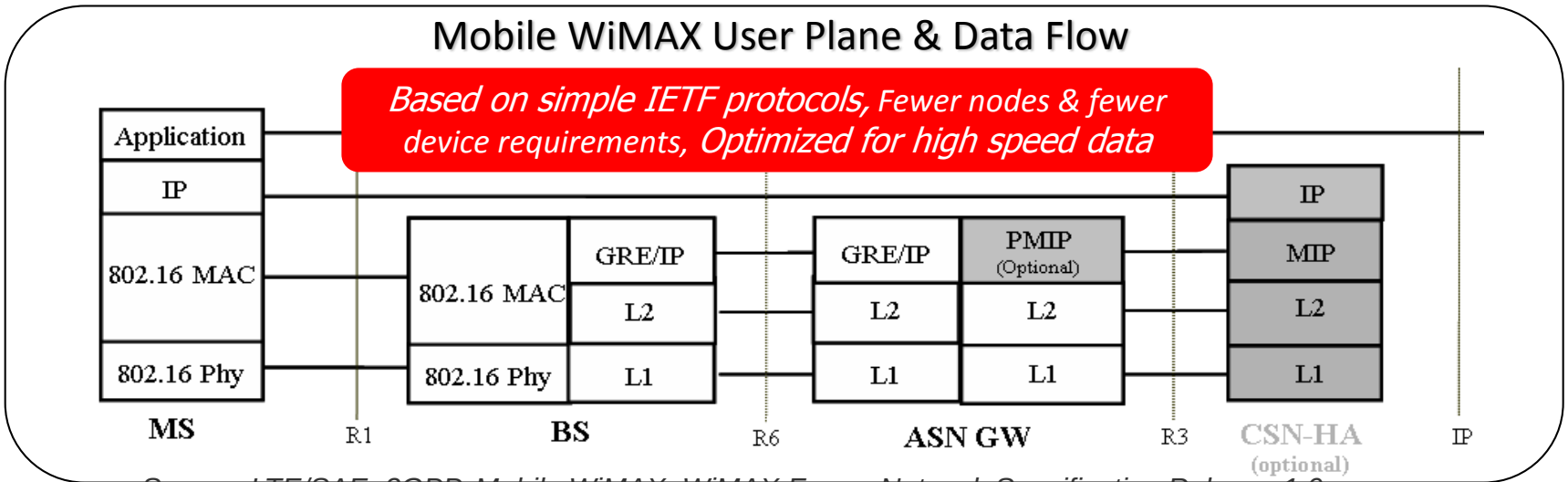
Point of difference	WiMAX	LTE
Subcarrier Spacing	The subcarrier spacing can be variable due to which capacity can be varied.	Constant at 15kHz.
Latency	The time between the user-B.S.-user is 50msec.	The time between UE-RNC-UE is10msec.
Channel utilization	optimizes for maximum channel usage by processing all the information in a wide channel.	organizes the available spectrum into smaller chunks.
FFT	Due to High channel utilization, processing that much information requires 1000-point Fast Fourier Transform.	Organization of data into smaller chunks makes it process the information by a lower point FFT (like 16-point FFT).
Evolution	It is a completely new technology with upgrading in generations but not an exact evolution.	It has evolved from WCDMA to HSPA to LTE with a core backbone of GSM.

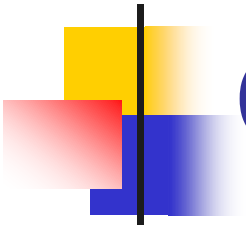
Differences

Point of difference	WiMAX	LTE
Duplexing mode	Uses only TDD(Time Division Duplexing). However 802.16m release 1.5 added FDD feature due to growing market opportunities and to avoid interference.	Uses FDD(Frequency Division Duplexing) and TDD(Time Division Duplexing).
Uplink signaling	WiMAX uses Orthogonal Frequency Division Multiple Access (OFDMA) for uplink signaling.	LTE uses single-carrier frequency division multiple access (SC-FDMA) for uplink signaling.
Power consumption	Due to OFDMA on the uplink signaling the PAPR (Peak to Average Power ratio) hence more power consumption at the handset.	Due to SC-FDMA on the uplink signaling the PAPR is lower and PA efficiency is high hence less power consumption and improved battery life.

Comparing the End-to-End Network

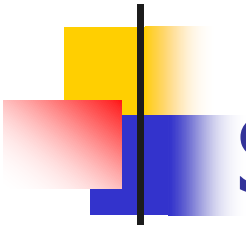






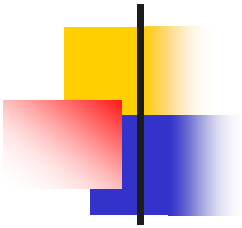
Comparison

- WiMAX and LTE employ similar technologies
- Both will achieve very high data rates
- Both will provide new services
- Both use: OFDMA, MIMO, TURBO
- LTE has the advantage of large GSM/UMTS customer base
- WiMAX has the advantage of being already in service in few places in USA



Summary

- Principles of Cellular Networks
  - Frequency reuse
  - Cellular system overview
  - Steps of setting-up a call and maintaining it
  - Handoff & power control
- First-Generation FDMA
  - AMPS
- Second-Generation TDMA and CDMA
  - GSM
  - IS-95
- Forth-Generation Systems
  - WiMAX & LTE



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