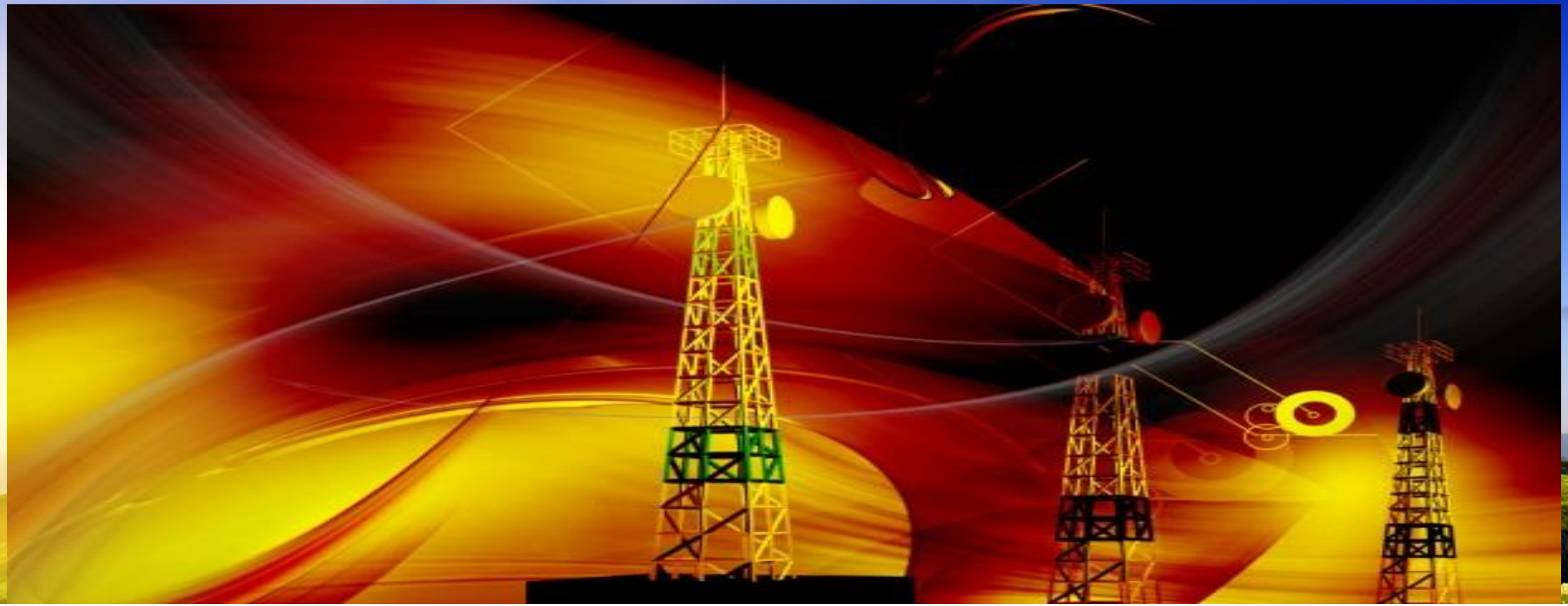


APPLICATIONS OF TELECOM

WIRELESS COMMUNICATION : Lecture 3

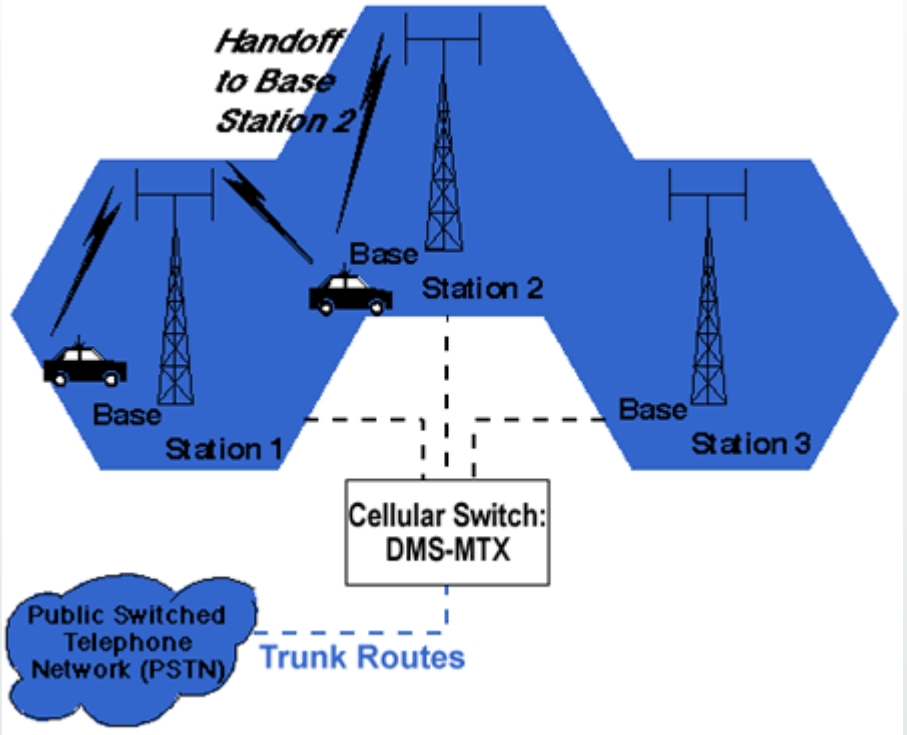
Ahmad Bilal
Ahmadbilal.webs.com

What is Mobility

- Initially Internet and Telephone Networks is designed assuming the user terminals are static
  - No change of location during a call/connection
  - A user terminals accesses the network always from a fixed location
- Mobility and portability
  - Portability means changing point of attachment to the network offline
  - Mobility means changing point of attachment to the network online

Degrees of Mobility : Challenge

- Walking Users
  - Low speed
  - Small roaming area
  - Usually uses high-bandwith/low-latency access
- Vehicles
  - High speeds
  - Large roaming area
  - Usually uses low-bandwidth/high-latency access
  - Uses sophisticated terminal equipment (cell phones)



What is PCS
Personal Communication Services

What is PCS

- Personal Communication Services
  - A wide variety of network services that includes wireless access and personal mobility services
  - Provided through a small terminal
  - Enables communication at any time, at any place, and in any form.
- The market for such services is tremendously big
  - Think of cell-phone market

Several PCS systems

- High-tier Systems
  - GSM: Global System for Mobile Communications
    - The mobile telephony system that we are using
  - IS-95 cdmaOne System
    - CDMA based multiple access

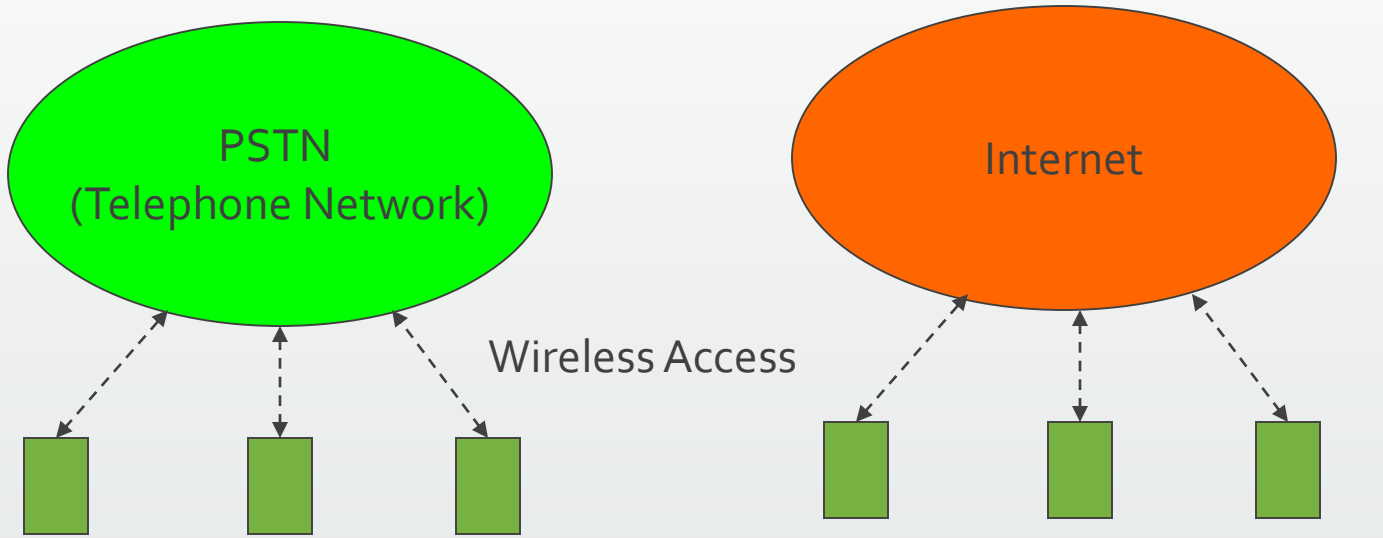
Several PCS systems

- Low-tier systems
  - Residential, business and public cordless access applications and systems
    - Cordless Telephone 2 (CT2)
    - Digital Enhanced Cordless Telephone (DECT)
    - Personal Access Communication Systems (PACS)

PCS Problems

- How to integrate mobile and wireless users to the Public Switched Telephone Network (PSTN) (Voice Network)
  - Cellular mobile telephony system
- How to integrate mobile and wireless users to the Internet (Data Network)
  - Mobile IP, DHCP, Cellular IP
- How to integrate all of them together and also add multimedia services (3G Systems)

Looking to PCS from different Angles



Mobile Users
-Cell phone users
-Cordless phone users

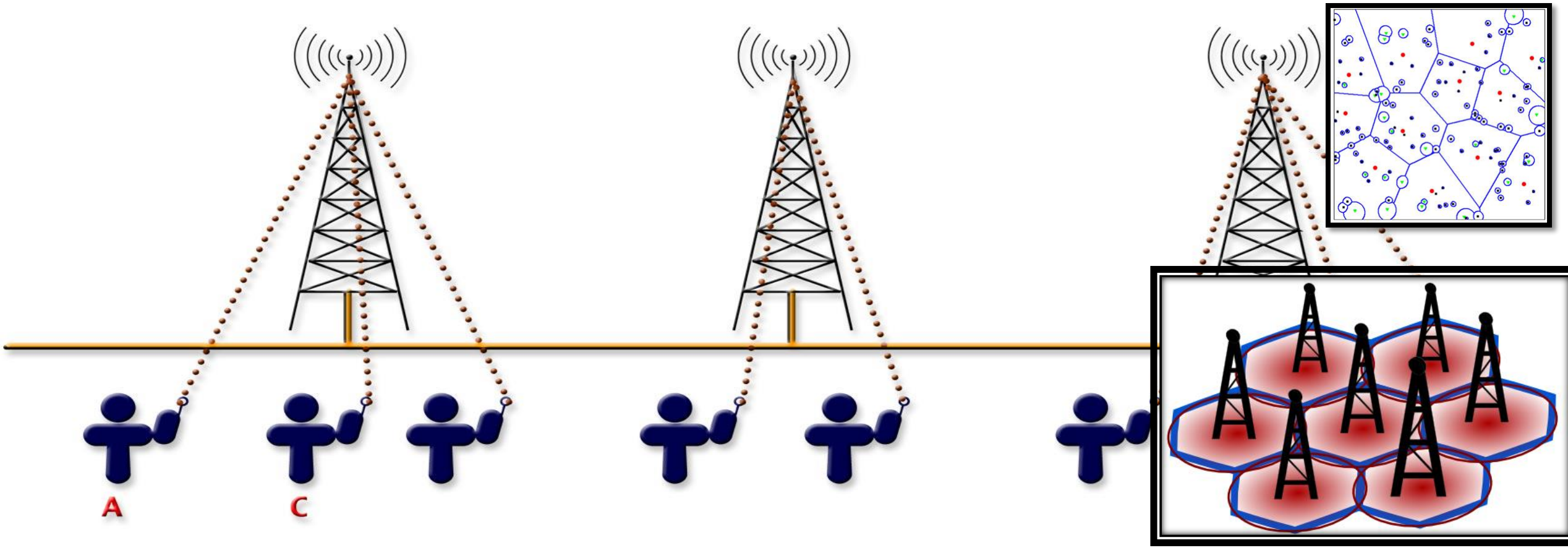
Telecom People View

Mobile Users
-Laptop users
-Pocket PC users
-Mobile IP, DHCP enabled computers

Data Networking People View

Major Mobile Radio Standards USA

Standard	Type	Year Intro	Multiple Access	Frequency Band (MHz)	Modulation	Channel BW (KHz)
AMPS	Cellular	1983	FDMA	824-894	FM	30
USDC	Cellular	1991	TDMA	824-894	DQPSK	30
CDPD	Cellular	1993	FH/Packet	824-894	GMSK	30
IS-95	Cellular/PCS	1993	CDMA	824-894 1800-2000	QPSK/BPSK	1250
FLEX	Paging	1993	Simplex	Several	4-FSK	15
DCS-1900 (GSM)	PCS	1994	TDMA	1850-1990	GMSK	200
PACS	Cordless/PCS	1994	TDMA/FDMA	1850-1990	DQPSK	300



Cellular System

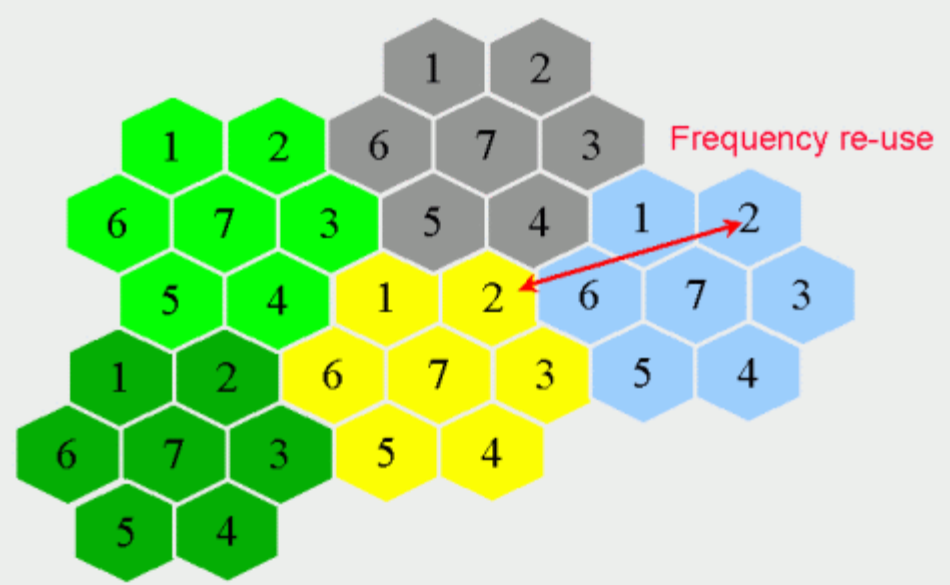
Introduction

Quick Answer

- Why it is called a cellular Service
- Is Wimax a cellular Service
- What are advantages of Cellular Services

Cellular Services

- Provide area Coverage to PSTN
- Limited Frequency Spectrum
- Geographical Region Divided in to cells
- Frequencies , Times, Codes reused to maximize Coverage



Cells should over Lap in real life ?

Features of Cellular Systems

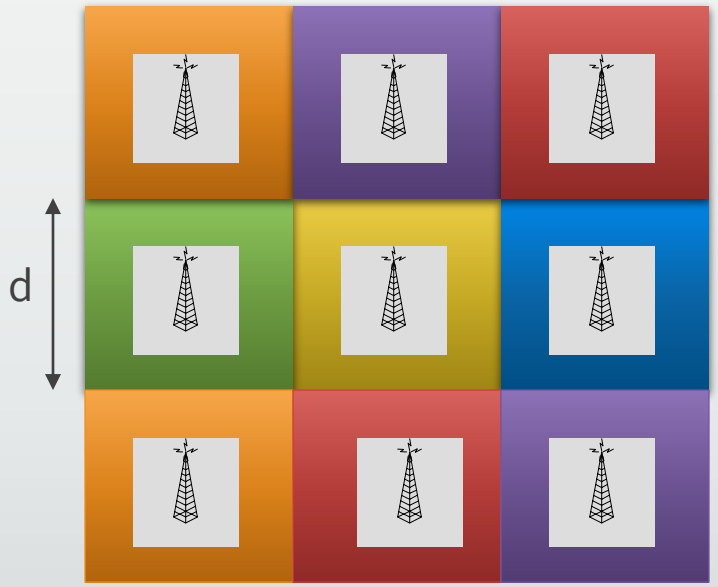
- High Capacity is achieved by limiting coverage of each Base station to a small geographical area called cell
- Hand off is a Important feature
- Cell - Cell Boundary
  - Users
  - Geo – Conditions
  - Link Budget
    - (Total Power Transmitted vs Total Power Recived)
  - (Cell boundaries are not fixed)- CDMA
  - Interference (Re using Phenomena)
    - Co Channel Interference (Worse at boundaries)

Features of Cellular Systems

System Capacity

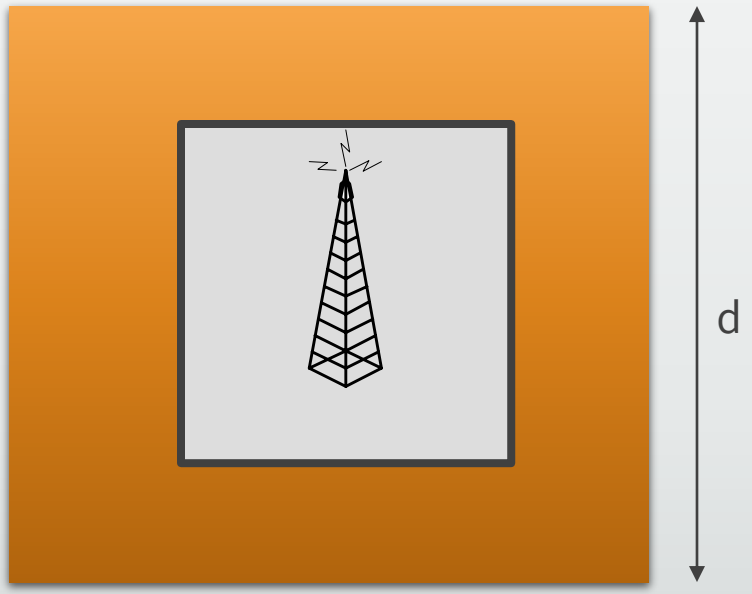
- System Capacity is the number all users that can communicate (use the system) at the same time
- A base station (cell) has a fixed number of channels available, hence at a given time a fixed number of users can talk simultaneously

System 1



Low cost base-stations covering a small area

System 2

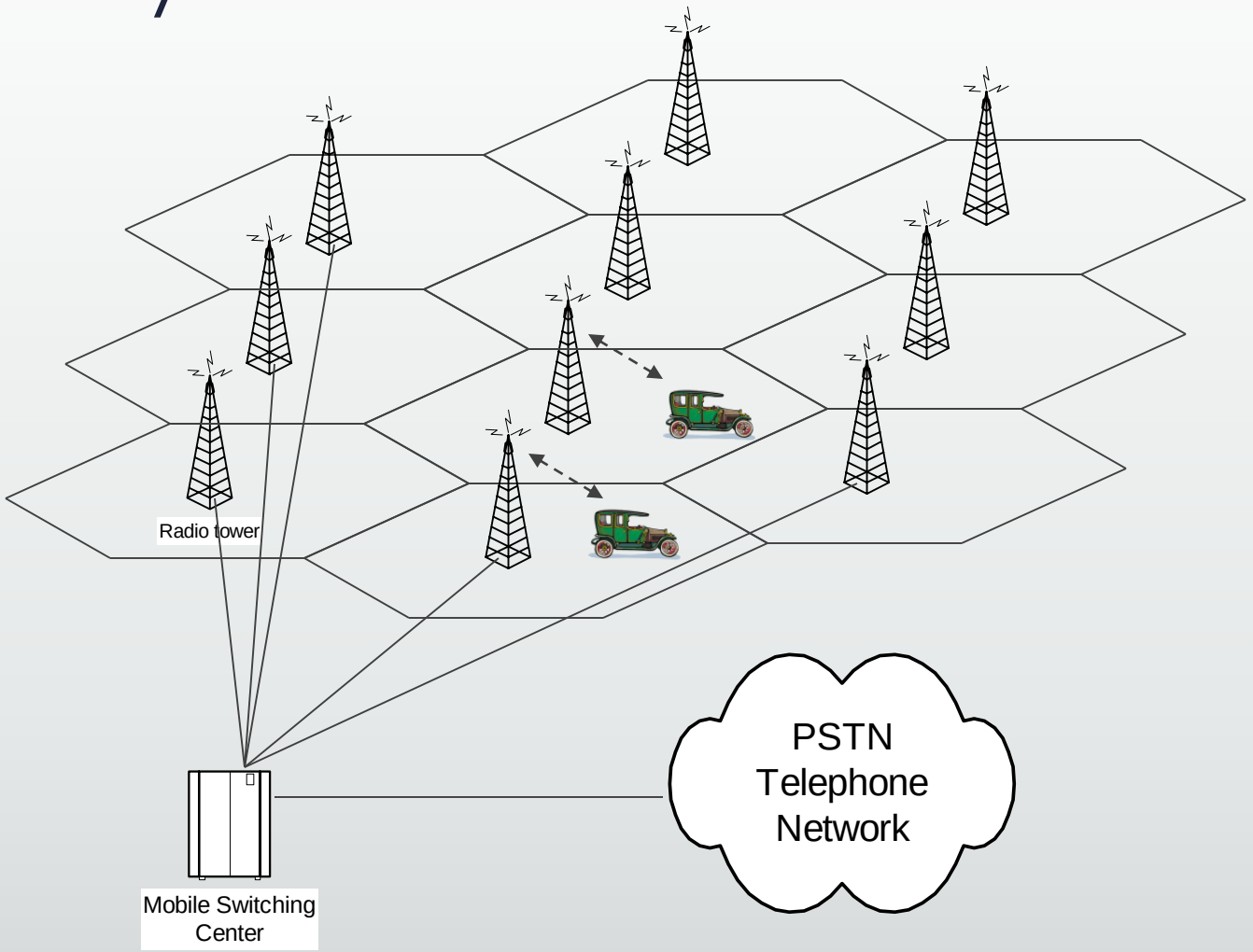


High cost base-stations covering a large area

Example : Cellular Telephony

- Characterized by
  - High mobility provision
  - Wide-range
  - Two-way voice communication
  - Handoff and roaming support
  - Integrated with sophisticated public switched telephone network (PSTN)
  - High transmit power requires at the handsets (~2W)

Cellular Telephony - Architecture



Wireless LANs (WLAN)

- Characterized by
  - Low mobility (not for vehicular use)
  - High speed data transmission
  - Confined regions – buildings and campuses
  - Coverage: 100m – 300m per base station
  - Nodes- Made by local Computer
  - Data is normally sent via Packet
  - Channel Access is Shared (Video)
  - Speed: 2-11Mbps, 20Mbps
  - Uses ISM bands
    - 902-928 MHz
    - 2400-2483.5 MHz
    - 5725-5850 MHz

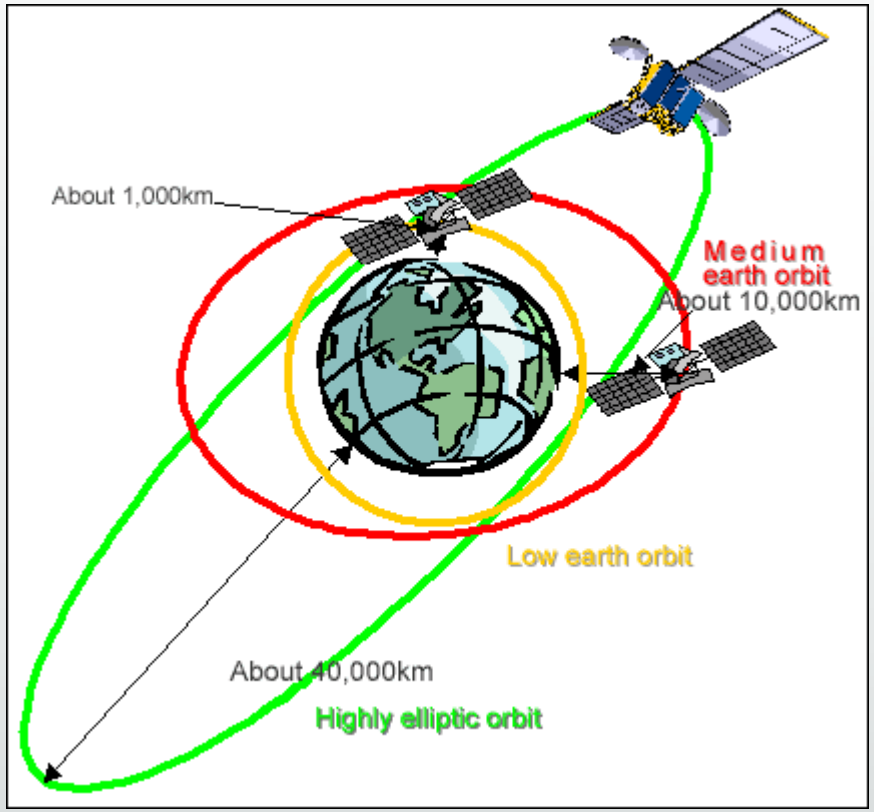
WLAN Standards

	Bitrate	Frequency Band	Range
IEEE 802.11b	5.5 – 11Mbps	2.4 GHz	~100m
IEEE 802.11a	54 Mbps	5 Ghz	~100m
HiperLAN (Europe)	20Mbps	5 GHz	~50m
HiperLAN/2	54 Mbps	5 GHz	~50m

Satellite Communication

Satellite Based Mobile Systems

- Categorized as
  - Two-way (or one-way) limited quality voice or data transmission
  - Very wide range and coverage
    - Large regions
    - Sometimes global coverage
    - Very useful in sparsely populated areas: rural areas, sea, mountains, etc.
  - Target: Vehicles and/or other stationary/mobile uses
  - Expensive base station (satellites) systems



Satellite based systems

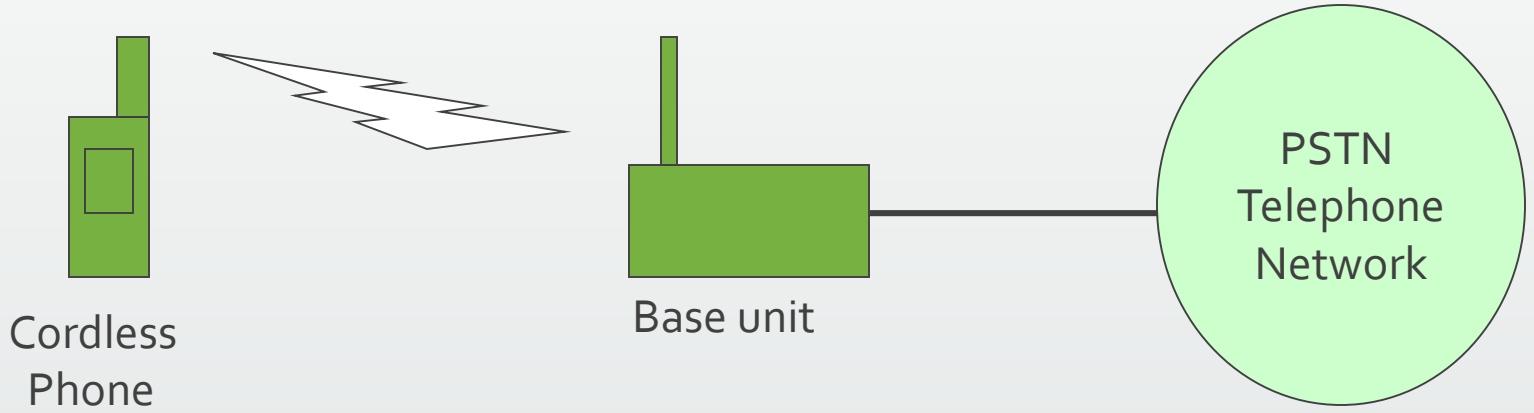
- Very large coverage
  - Low overall system capacity
- Expensive service
- Proposed Satellite Systems
  - LEOS: Low-earth orbit satellite systems
    - 10-100 satellites/system
    - High overall system capacity, low delay
    - Many but comparably less expensive satellites
  - MEOS: Medium-earth satellite systems
  - GEOS: Geostationary or Geosynchronous Orbit Systems
    - Fewer than 10 satellites/system
    - Low overall system capacity, high end-to-end delay (~0.5sec)
    - Very expensive satellites
- Iridium, Globalstar, Inmarsat are some example systems

Cordless System

Cordless Telephone

- Full Duplex
- Use radio Channel to Connect to BS
- BS is connected to PSTN via a telephone line
- May cover few meters

Cordless Telephones



Cordless Telephones

- Low power consumption
- Low cost equipment, small form factor and long talk-time
- No handoffs between base units

- Appeared as analog devices

Cordless Telephones

- Usage
  - At homes
  - At public places where cordless phone base units are available
- Design Choices
  - Few users per MHz
  - Few users per base unit
    - Many base units are connected to only one handset
  - Large number of base units per usage area
  - Short transmission range

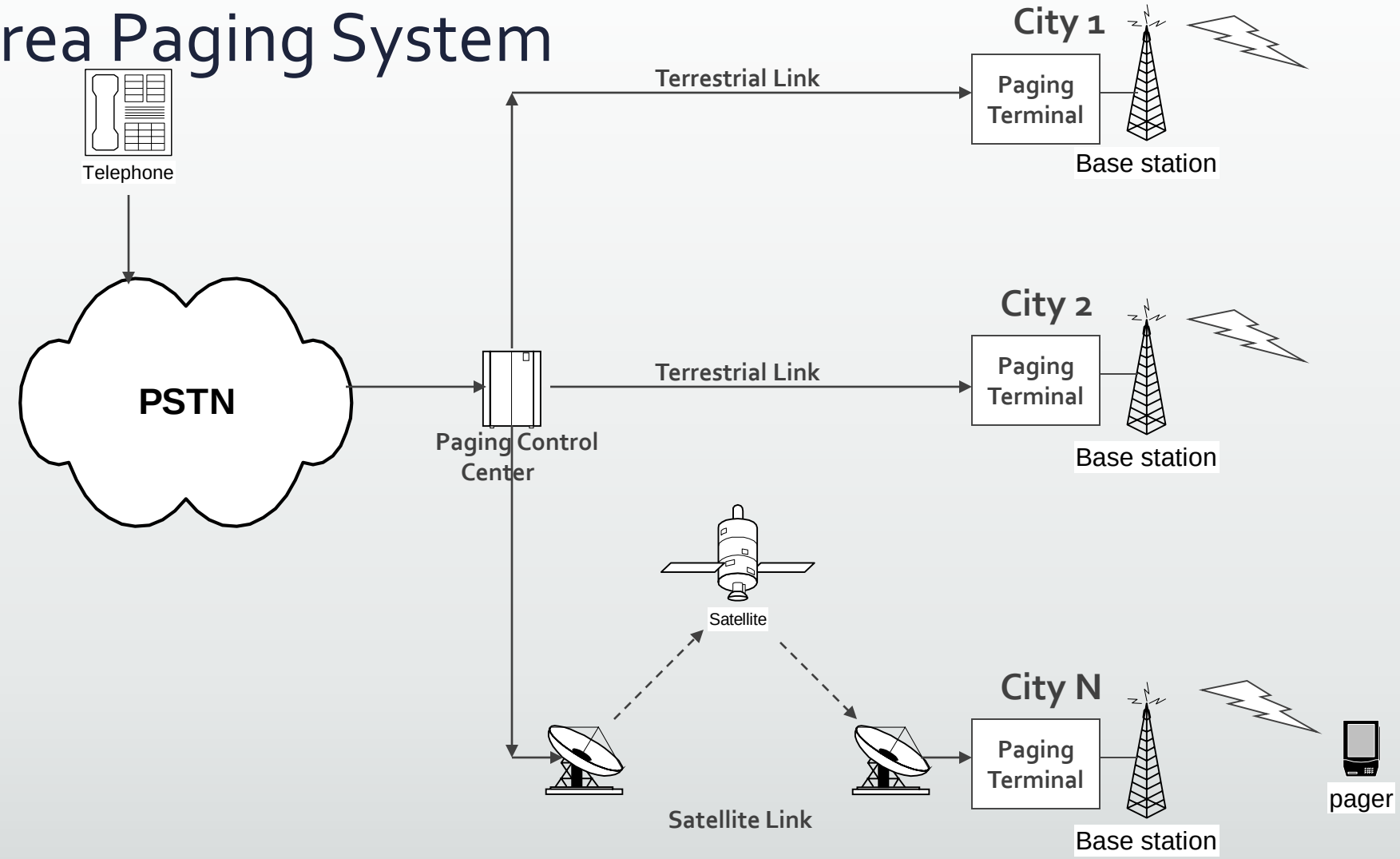
WIRELESS PAGING SYSTEM

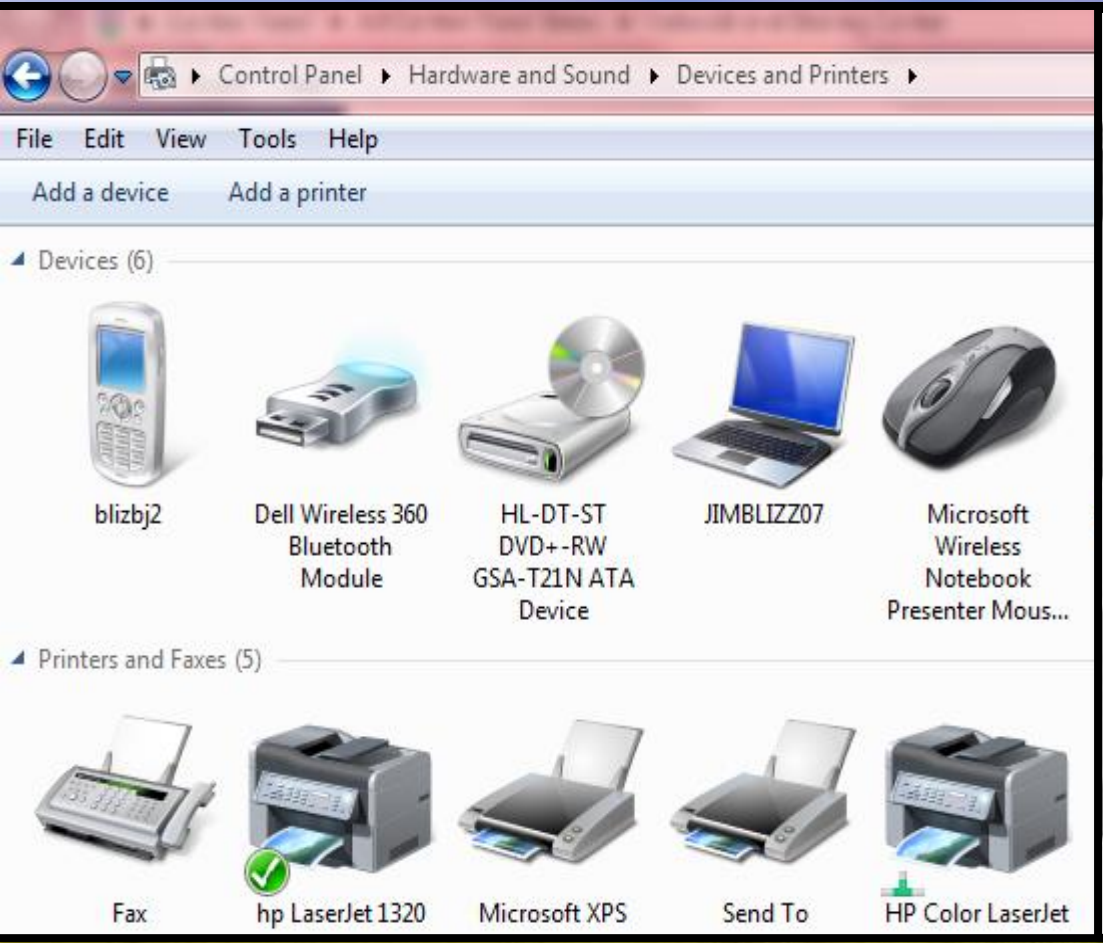
Paging System

Paging Systems

- Send brief message to subscriber. Message can be either numeric message, alpaha numeric message or voice message
- Categorized as
  - One-way messaging
  - Wide-area coverage (One cell may cover up to 2~5 KM)
  - Back bone may consist of satellites , Telephone lines
  - Low complexity, very low-power pager (receiver) devices
  - Being Replace by Mobile
  - Message(page) in Done in a Broad Cast Manner
  - Simple Terminals

Wide-Area Paging System




Control Panel ▸ Hardware and Sound ▸ Devices and Printers ▸
File Edit View Tools Help
Add a device
Add a printer
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blizbj2
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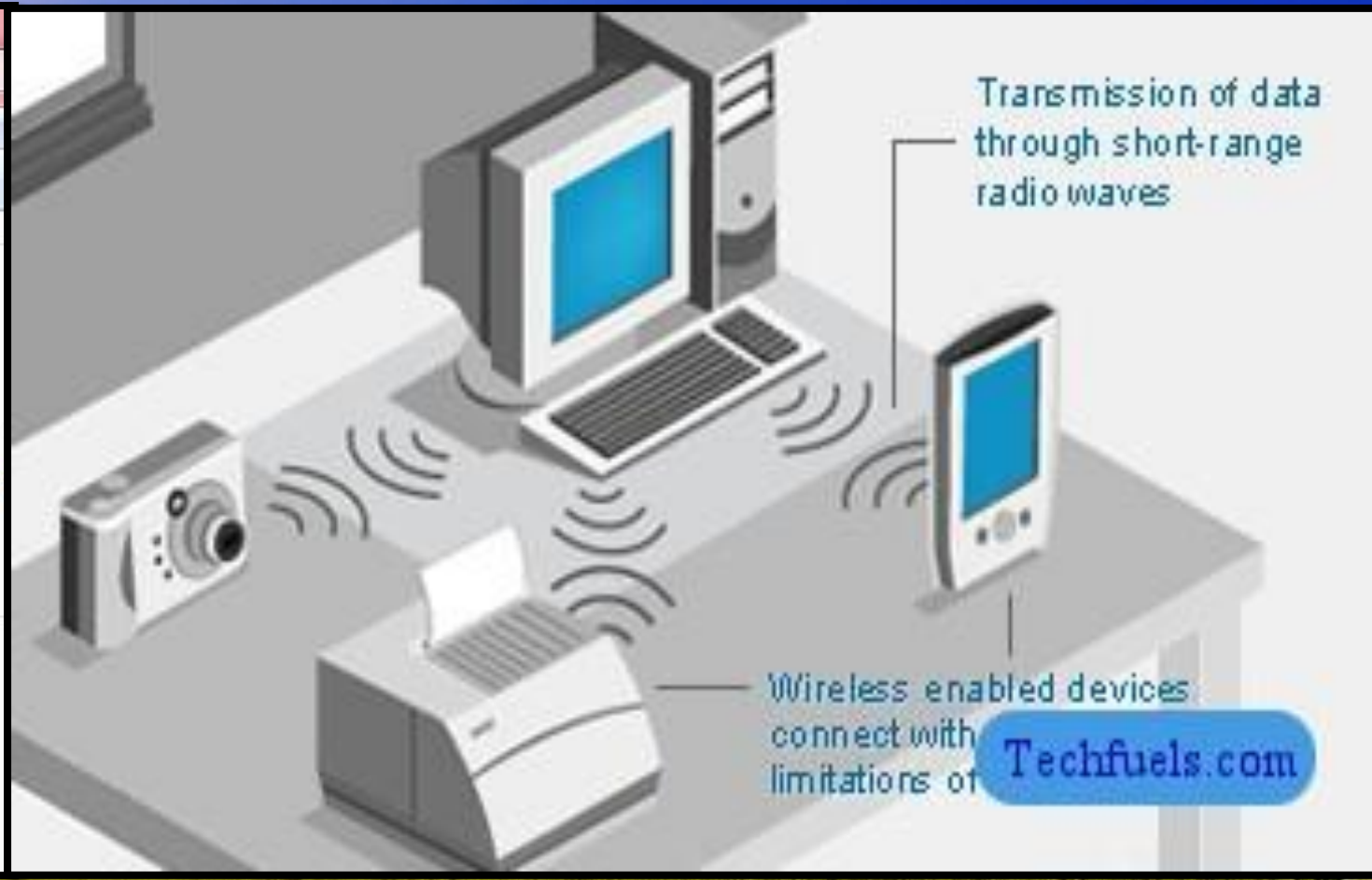
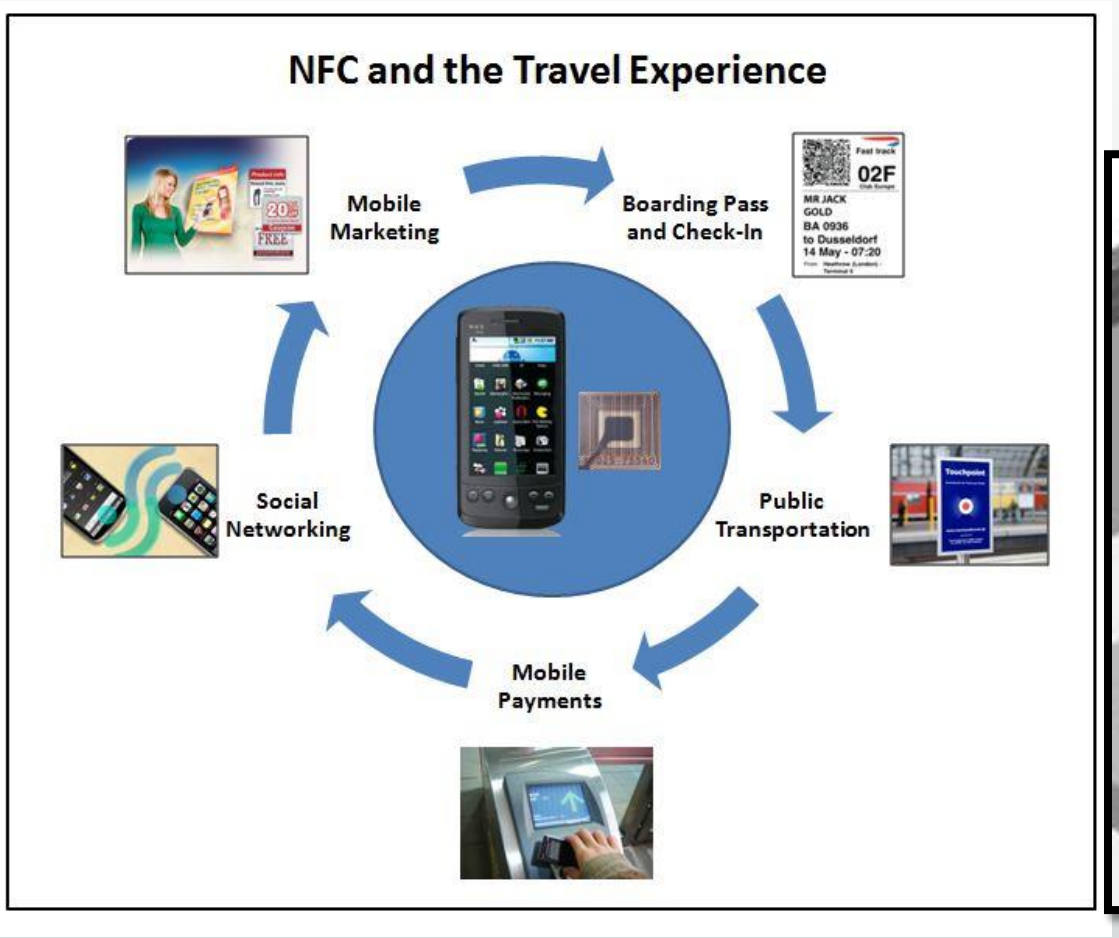

Transmission of data through short-range radio waves
Wireless enabled devices connect with
limitations of
Techfuels.com

PAN

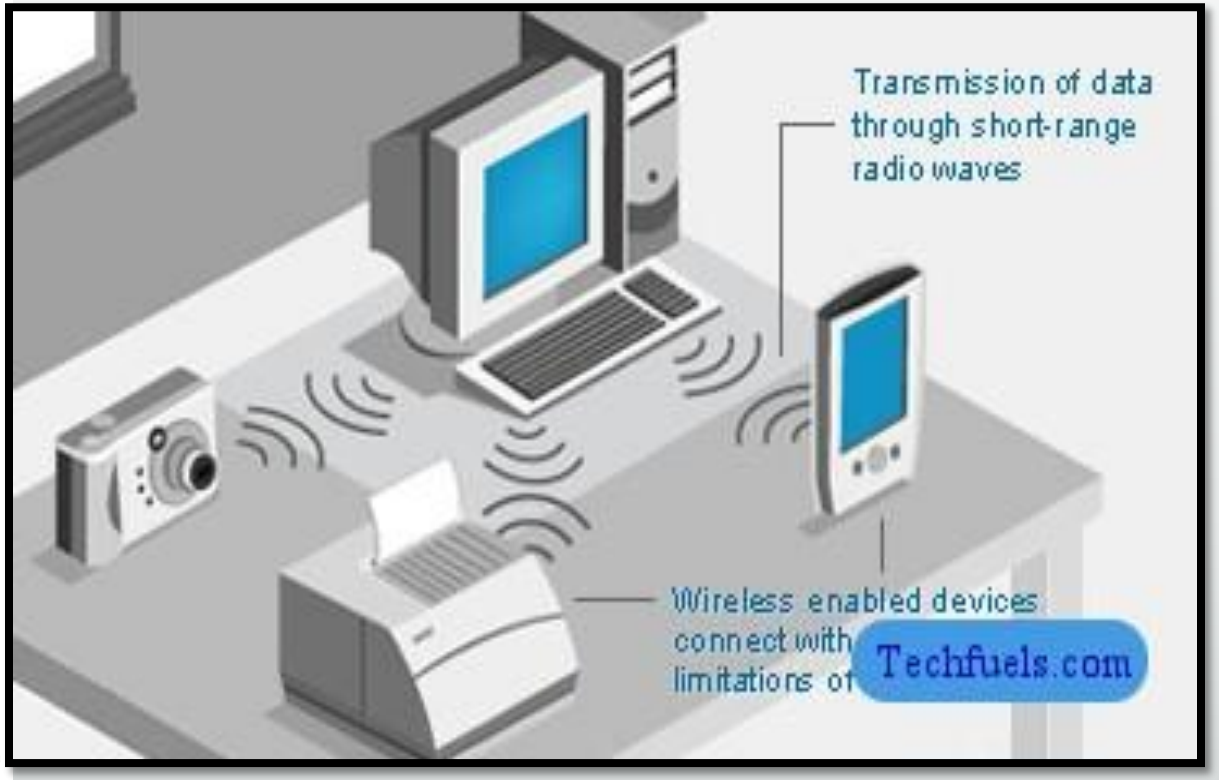
Personal Area Networks (PANs)

- Bluetooth
  - 2.5GHz ISM band
  - 10m range, 1mW transmit power
  - 100m range, requires increase in transmit power
  - 1 Mbps data rate shared between 7 devices
  - FHSS spread spectrum use
  - TDD duplex scheme
  - Retricted start topology
    - 1 master connects to 7 slaves

NFC



BLUETOOTH

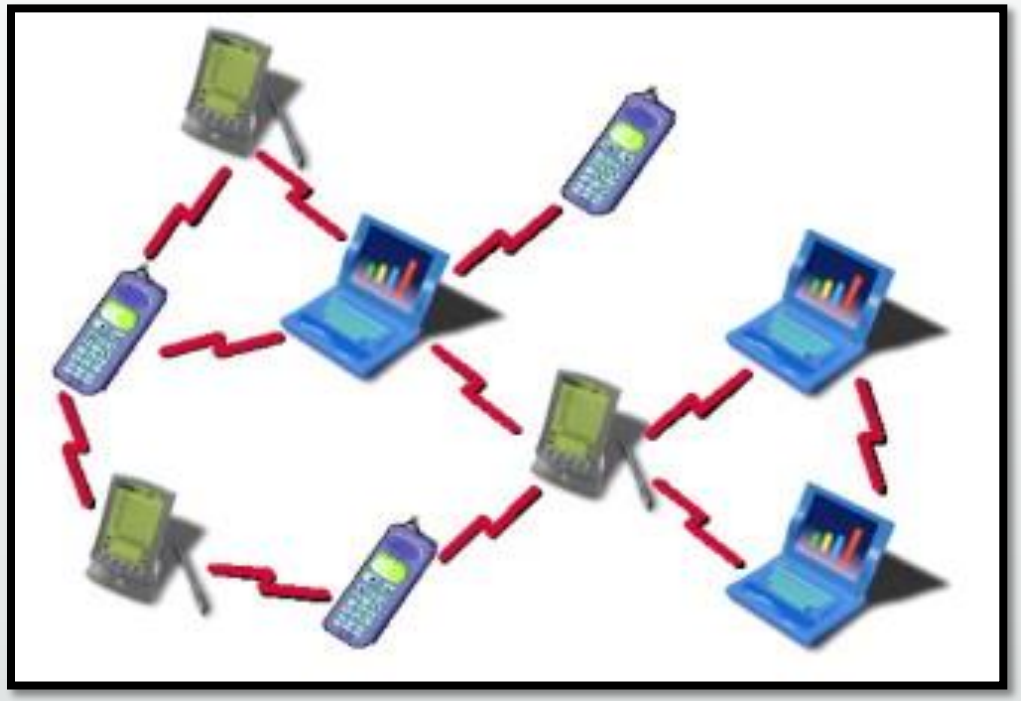


Emerging Wireless Technology

- Sensor Networks
- Ad- Hoc Networks
- Ultra Wideband

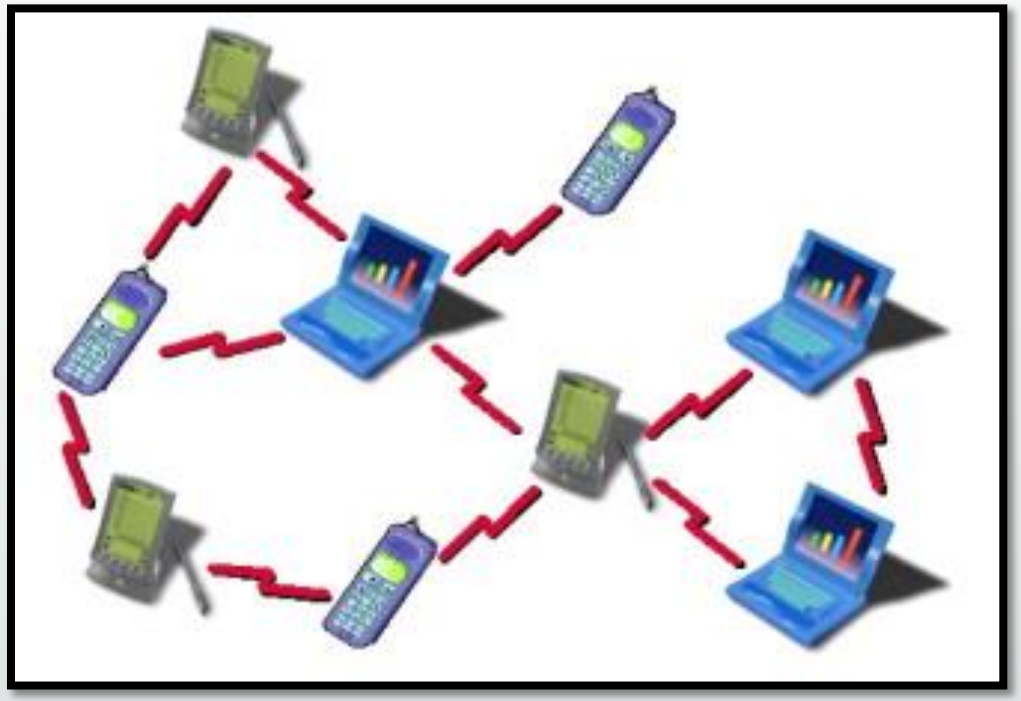
Ad-HOC NETWORK

- NO FIXED TECHNOLOGY – Dynamic Topology
- PEER TO PEER TECNOLOGY
- EVERY NODE ACTS A ROUTER
- RECONFIGUREABLE
- No Back Bone
- Multi Hope
- Fully Connected with Different SNR

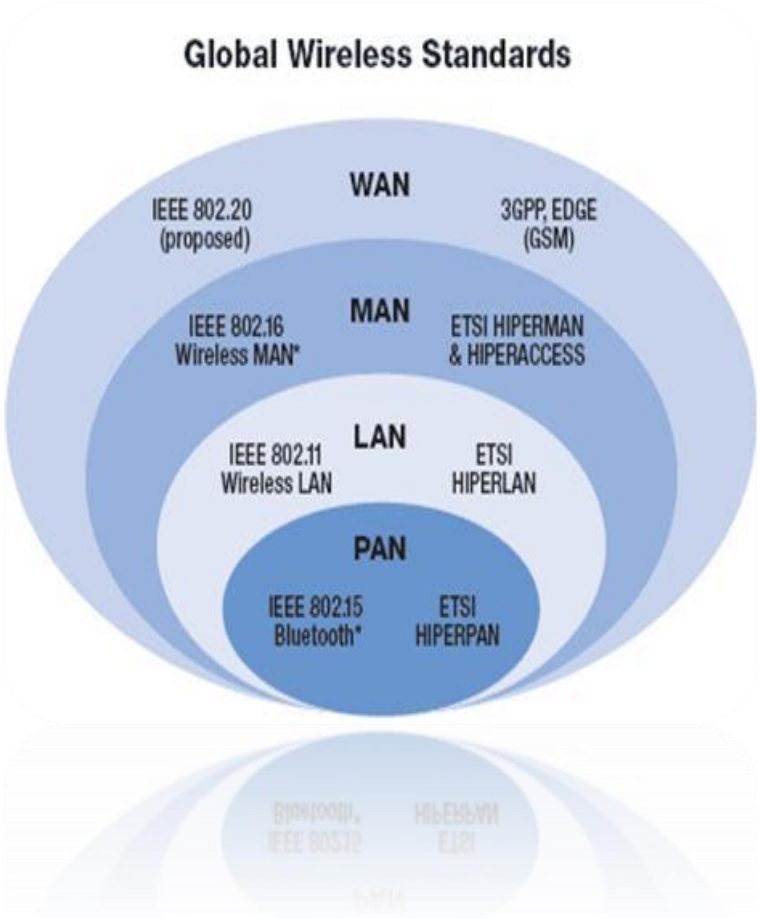


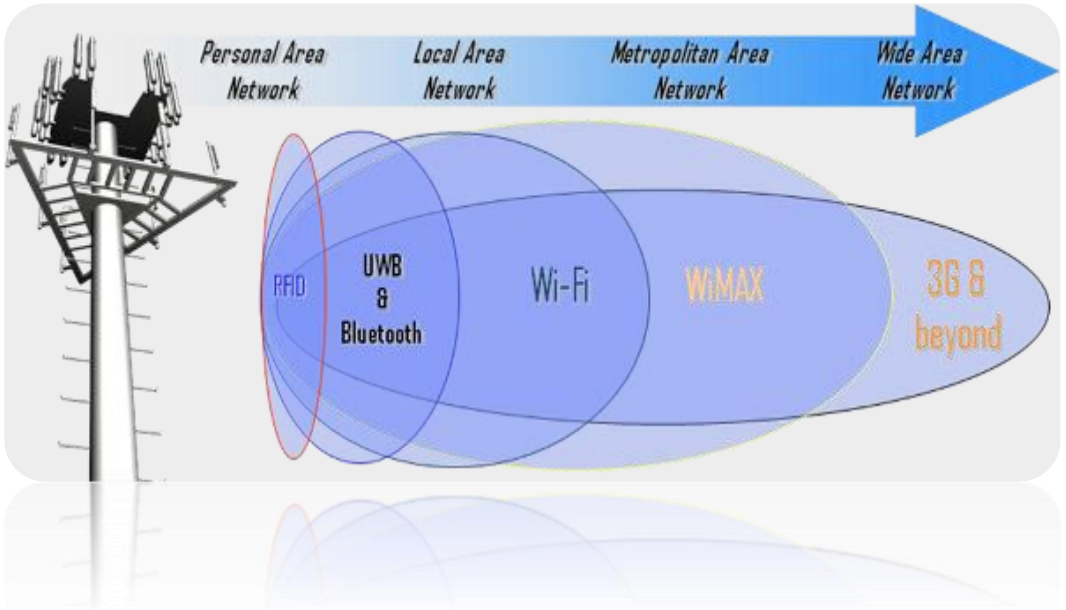
Ad-HOC NETWORK

- Capacity ~ Unknown
- Provides a Feasible Network
- Energy Constrains



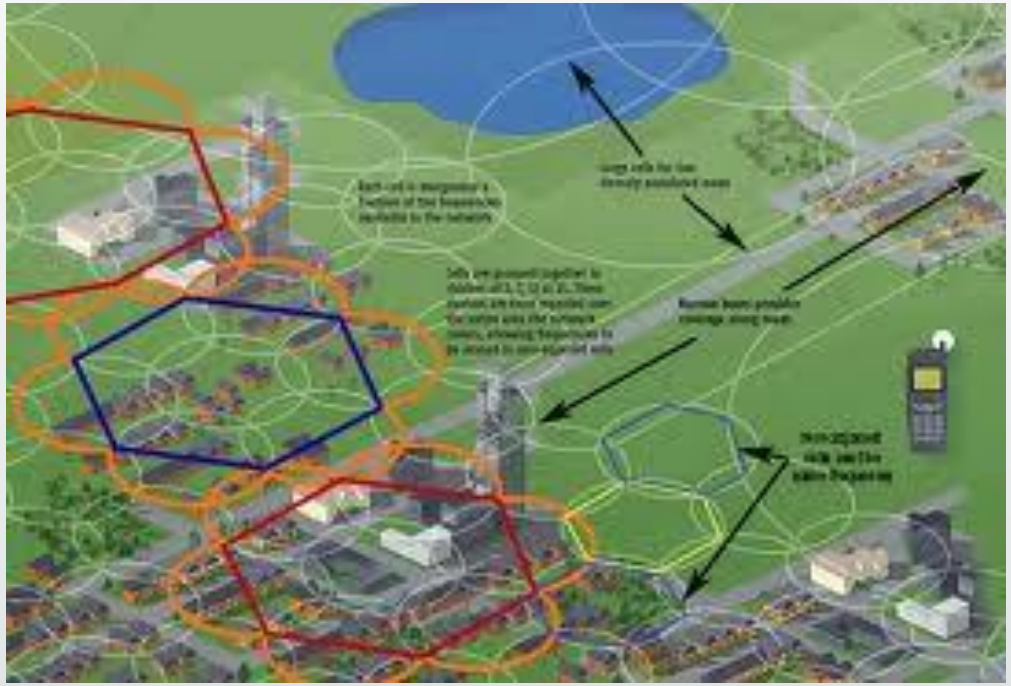
A Small Comparison





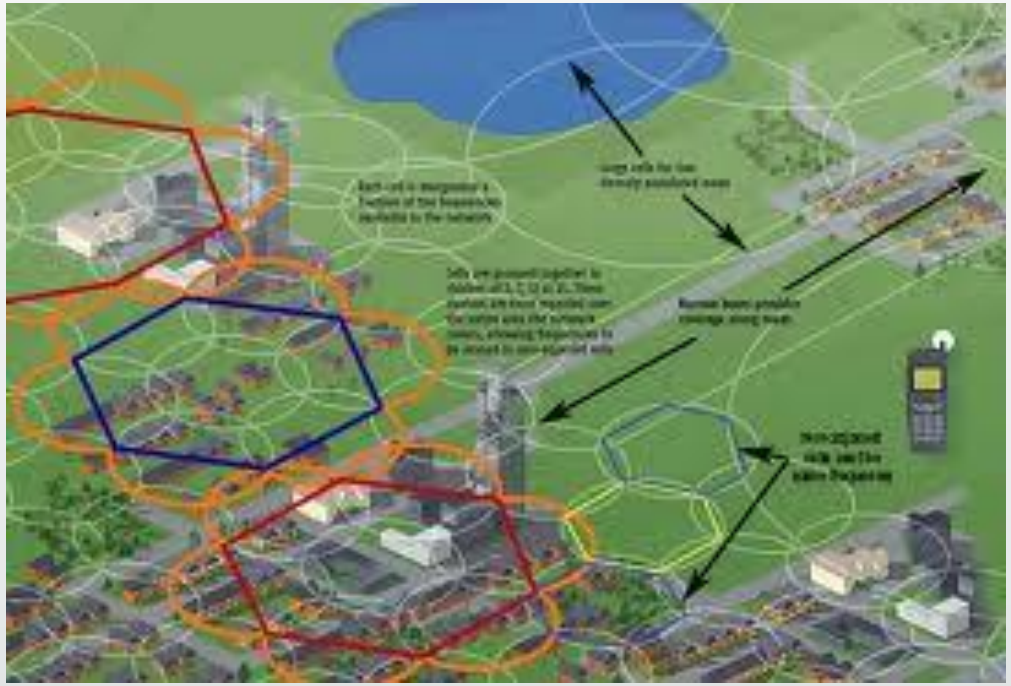
MAKING A MOBILE CALL

Pre Call Setup- Registering a Cell Phone



- Mobile phone is turned
- phone does not have an allocated channel,
- It is therefore necessary for there to be some methods or allocated means within the cellular telecommunications network, whereby a newly switched on mobile can communicate with the network and set up the standard communication.
- Even if a call is not to be made instantly, the network needs to be able to communicate with the mobile to know where it is

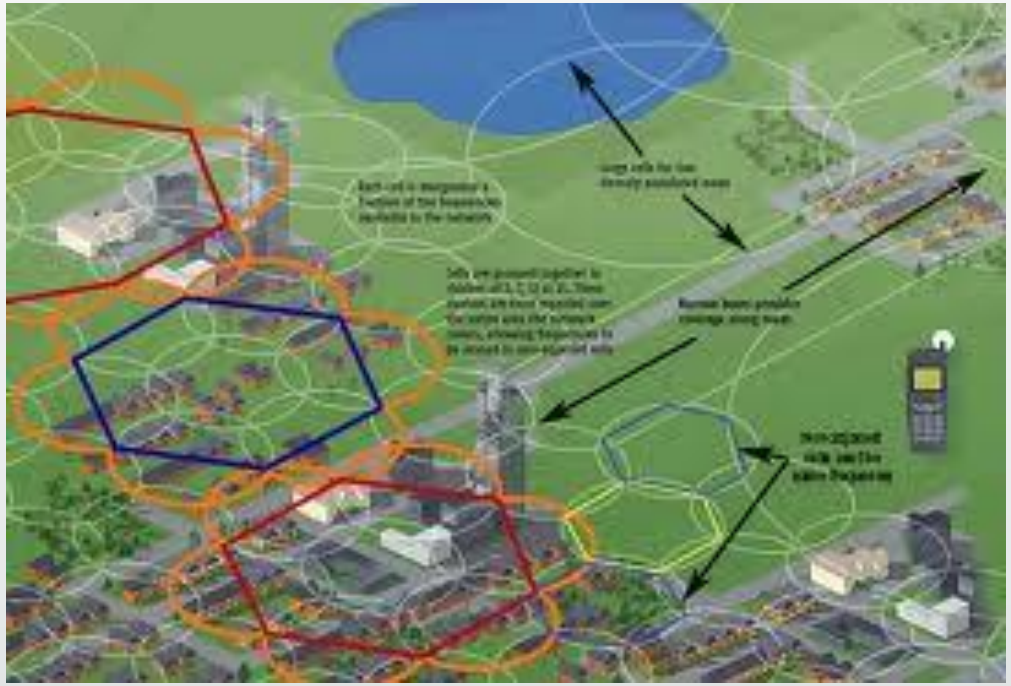
STEP 1 : Switch on The Phone



- Phone is turned on.
- Scan the Strongest Forward channel
- Monitors Control Chanel (Scan Channel).
- Scans for Strongest BS

Remember : Control Channel makes up normally 5 % of total allocated frequency . Rest of frequency is used for data and voice

Calling a Mobile Phone



- Phone is turned on.
- Scan the Strongest Forward channel
- Monitors Control Chanel.
- Scans for Strongest BS

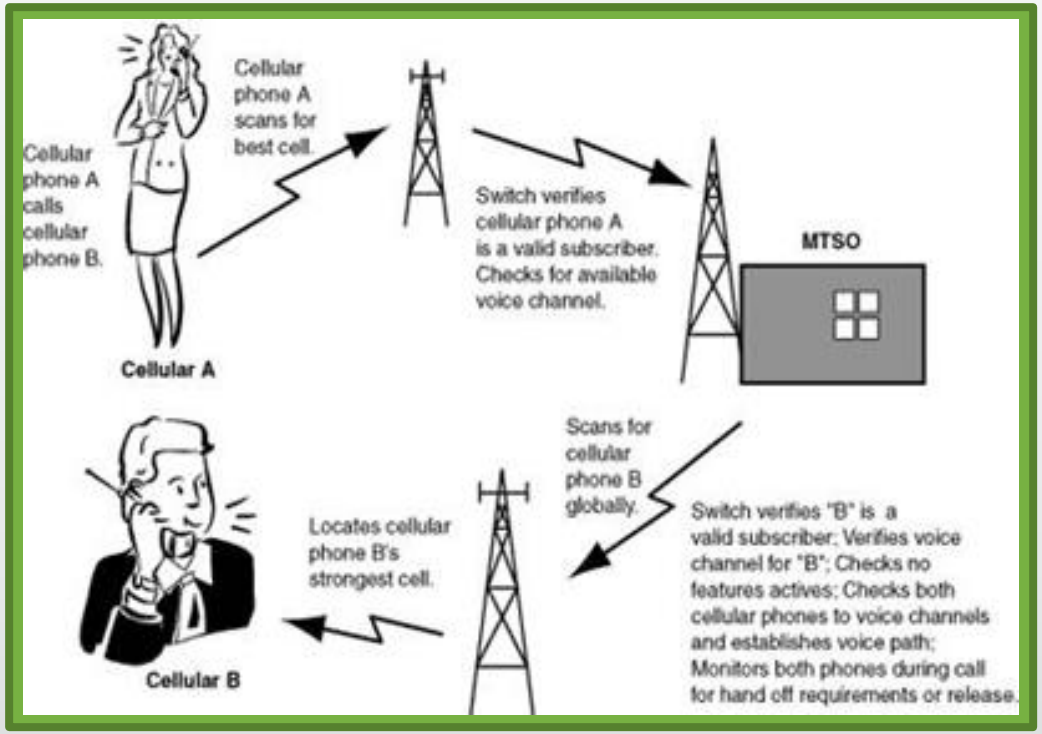
Remember : Control Channel makes up normally 5 % of total allocated frequency . Rest of frequency is used for data and voice

Calling a Mobile Phone

- MSC dispatches a Request to all BS in cellular System
- MIN is broadcasted as a paging message on all FCH
- Mobile Identifies it self over reverse channel.
- BS→ MSC : Informs of handshake
- MSC instruct the BS to move the call to unused voice channel **(TYPICALLY 6)**
- BS→ Mobile : Change frequency
- Data message (Alert is transmitted) over FCH

Calling from Mobile Phone

- Call initiation request is sent
  - Transmits → (MIN, ESN, and Number to be called)
  - SCM –Station Class mark also Transmitted
- BS → Receives data and route it to MSC
- MSC validates request , initiate Billing
- Move call to PSTN/MSC
- MSC instruct the BS to move the call to unused voice channel **(TYPICALLY 6)**

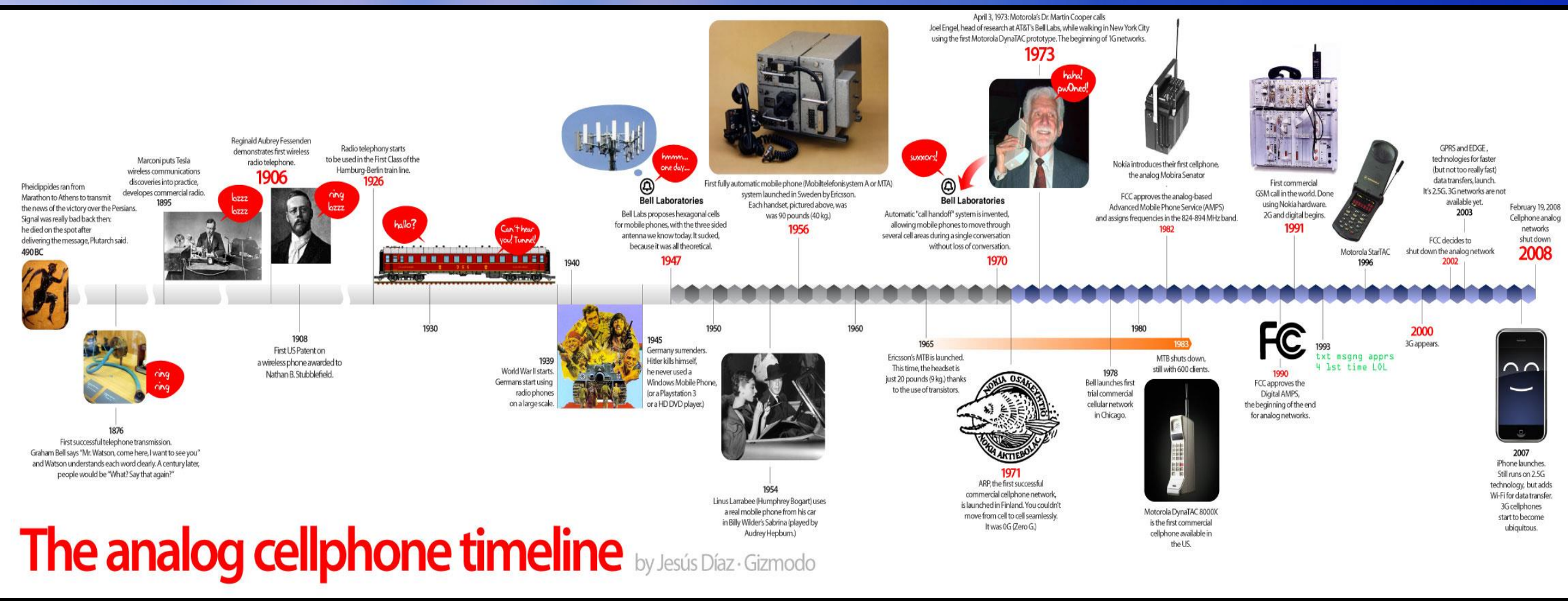


ROLE OF MSC during call

- MSC Adjust transmitted power of Mobile Unit and BS
- Handoff

The Roaming

- In wireless telecommunications, **roaming** is a general term referring to the extension of connectivity service in a location that is different from the home location where the service was registered. Roaming ensures that the wireless device is kept connected to the network, without losing the connection.
- When a customer Enters a new geographical area , that is different From his HLR area, he is registered as a ROAMER
- This is Accomplished by
- MSC transmits (FCC)request to all unregistered mobiles to report the MIN and ESN over (RCC)
- Mobile Reports back
- Data is verified from HLR (billing Status)
- Allow Registration and Calling Facility



Modern Wireless Communication

History of Wireless and Mobile Communication

History

- 1831: Faraday had first started experimenting with electromagnetic waves.
  - Electromagnetic wave:
    - one of the waves that are propagated by simultaneous periodic variations of electric and magnetic field intensity and that include
      - radio waves
      - infrared
      - visible light
      - ultraviolet,
      - X rays
      - Gamma rays

History – Mathematics and EM

- 1864: Maxwell who had been working on a mathematical model for electromagnetic waves finally published his paper on the subject.
  - One of the consequences of his theories was that E.M. waves would travel at near the speed of light.
  - This had also been experimentally determined by others at the time.

History

- At the time very few people fully understood Maxwell's equation.

History – Existence of EM Waves

- At the same time that Lodge was carrying out his experiments, Heinrich Hertz in Germany was also doing some of his own concerning Maxwell's equations.
    - Hertz's investigations into Maxwell's equations involved generation, detection, and measurement of waves in free space, rather than along wires.
- 1887: Hertz proves existence of EM waves; first spark transmitter generates a spark in a receiver several meters away
    - The units of frequency waves is named after him, 1 cycle/second equals a Hertz.

History – Wireless Telegraph

- 1896: Guglielmo Marconi demonstrates wireless telegraph to English telegraph office
- 1897: ``The Birth of Radio'' - Marconi awarded patent for wireless telegraph
- 1897: First ``Marconi station'' established on Needles island to communicate with English coast
- 1898: Marconi awarded English patent no. 7777 for tuned communication
- 1898: Wireless telegraphic connection between England and France established

History – Frequency Tuning

- In 1898: Tesla gave one of the first wireless demonstrations with a what we would call a remote control boat.
  - He realized that things of this nature would need to only respond to their own frequency, and remain inactive otherwise.
  - This was Tesla's fundamental radio tuning invention, which he had first described several years earlier.

History – Transoceanic Communication

- 1901: Marconi successfully transmits radio signal across Atlantic Ocean from Cornwall to Newfoundland
- 1902: First bidirectional communication across Atlantic
- 1909: Marconi awarded Nobel prize for physics

History – Voice over Radio

1914: First voice over radio transmission

1920s: Mobile receivers installed in police cars in Detroit

1930s: Mobile transmitters developed; radio equipment occupied most of police car trunk

by 1934: Amplitude Modulation (AM) systems used by police cars and stations

1935: Edwin Armstrong demonstrated frequency modulation (FM) for the first time. Majority of police systems converted to FM

History – Mobile Telephony

- 1946: First public mobile telephone service was introduced. First interconnection of mobile users to public switched telephone

  network (PSTN)
- 1949: FCC (Federal Communications Commission) of US recognizes mobile radio as new

  class of service
- 1950-1960: AT&T Bell Labs developed theory and techniques for cellular telephony

History - Pager

- 1959: The term "pager" was first used, referring to a Motorola radio communications product
- 1968: AT&T proposed cellular telephony to FCC of US.
- 1974: The first pager was introduced by Motorola.
- 1977: Public cell phone testing began.
- 1979: World's first cellular system was implemented by NTT Japan.
- 1980: 3.2 million pagers used wordwide. They had limited range.

History – Cordless Phones and Cellular Telephony

- 1980: Cordless phones started to emerge.
- Early 1980s: Wireless modems emerged.
- 1981: European Nordic Mobile Telephone (NMT) System was developed
- 1983: FCC allocated wireless spectrum for mobile telephony.
- 1983: AMPS, first USA analog cellular telephony standard was developed

History – Wireless Data

- 1983: Intoduction of ARDIS wireless data service
- 1985: European Total Access Cellular System (ETACS) was deployed.
- 1985: In Germany, cellular standard C-450 was introduced.
- 1985: ISM bands defined for commercial spread spectrum applications

History – Wireless LANs, GSM

- 1987: IEEE 802.11 Wireless LAN working grup founded.
- 1989: In Europe, GSM was defined.
- 1990: In Europe, GSM deployed.
- by 1990: Wide-area paging had been invented and over 22 million pagers were in use
- 1990: FCC allocated spctrum in 900 Mhz for cordless phones.
- 1990: Announcement of Wireless LAN products

History

- 1991: First US digital cellular hardware was installed. IS-54 and IS-136 emerged.
- 1991: RAM mobile (mobitex) data service
- 1992: HyperLAN in Europa
- 1992: World Radio Conference in Malaga (WRC-92) allocated frequencies for future UMTS use.
  - Frequencies 1885 - 2025 and 2110 - 2200 MHz were identified for IMT2000 use

History

- 1993: First GSM 1800 system in commercial operation in UK
- 1993: IS-95 code-division multiple-access (CDMA) spread- spectrum digital cellular system deployed in US
- 1993: CDPD (Cellular Digital Packet Data) over AMPS was realized
- 1994: GSM system deployed in US
- 1994: there were over 61 million pagers in use and pagers became popular for personal use.

History – Bluetooth, PCS

- 1994: Ericsson starts investigating a low-power, low-cost radio technology to remove cables around cell phones (born of Bluetooth idea)
- 1995: FCC auctions off frequencies in Personal Communications System (PCS) band at 1.8 GHz for mobile telephony
- 1995: DSS started to be used for cordless phones

History – Third Generation

- 1995 The UMTS Task Force was established
- 1996: The UMTS Forum was established in Zurich.
- 1997 the UMTS Forum produced its first report entitled
- 1997: IEEE 802.11 has been standardized (2 Mbps)
- 1997: IS-95B standard complete; includes 64 kbps data

History – Personal Area Networks

- 1998: Bluetooth was born. SIG for Bluetooth has been established by the leadership of 5 companies: Ericsson, IBM, Intel, Toshiba, Nokia
- 1998: HomeRF Working Group was formed.
- 1998: FCC gave 2.5 GHz spectrum for cordless phones
- 1998 ETSI SMG meeting in Paris both W-CDMA and TD-CDMA proposals were combined to UMTS air interface specification.

History – 3G Trials and Progress

- 1998: The first call using a Nokia W-CDMA terminal in DoCoMo's trial network was completed at Nokia's R&D unit near Tokyo in Japan.
- Jun 1998: CDMA2000 submitted to ITU for IMT-2000
- Dec 1998: The first meetings of the 3GPP Technical Specification Groups in France.
- 1999: IEEE 802.11b approved (11 Mbps)
- 1999: The first open Bluetooth specification 1.0 is released.

Histor – 3G Progress

- Jul 1999: Phase 1 CDMA2000 standard complete and approved for publication
- Jul 1999: Korea Telecom Freetel launches world's first IS-95B network in Korea
- 1999: Nokia Oyj said that it has completed what it claims to be the first WCDMA call through the public switched telephone network in the world
- Nov 1999: ITU-R Task Group 8/1 endorses CDMA2000 standards (three modes) for IMT-2000

History – 3G Progress

- 1999: ETSI Standardization finished for UMTS Release 1999 specifications both for FDD and TDD in Nice, France.
- Mar 1999: March 1999 ITU approves radio interfaces for third generation mobile systems
- 1999: World Radio Conference (WRC-99) handled spectrum and regulatory issues for advanced mobile communications applications in the context of IMT-2000
- June 2000: Telstra and Nortel complete first 3G CDMA2000 1X data transmission

History – Bluetooth on the Market

- 2000: The first certified Bluetooth products on the market
- Oct 2000: SK Telecom and LG Telecom (Korea) launch world's first 3G commercial services using CDM2000
- Mar 2001: 3GPP approves UMTS Release 4 specification in Palm Springs, CA.
- 2001: The latest Bluetooth protocol 1.1 is released.

History – 3G Progress

- 2001 Ericsson and Vodafone UK claim to have made the world's first WCDMA voice call over commercial network.
- Jun 2001: NTT DoCoMo launched a trial 3G service
- June 2001: CDMA2000 1xEV-DO recognized as part of the 3G IMT-2000 standard

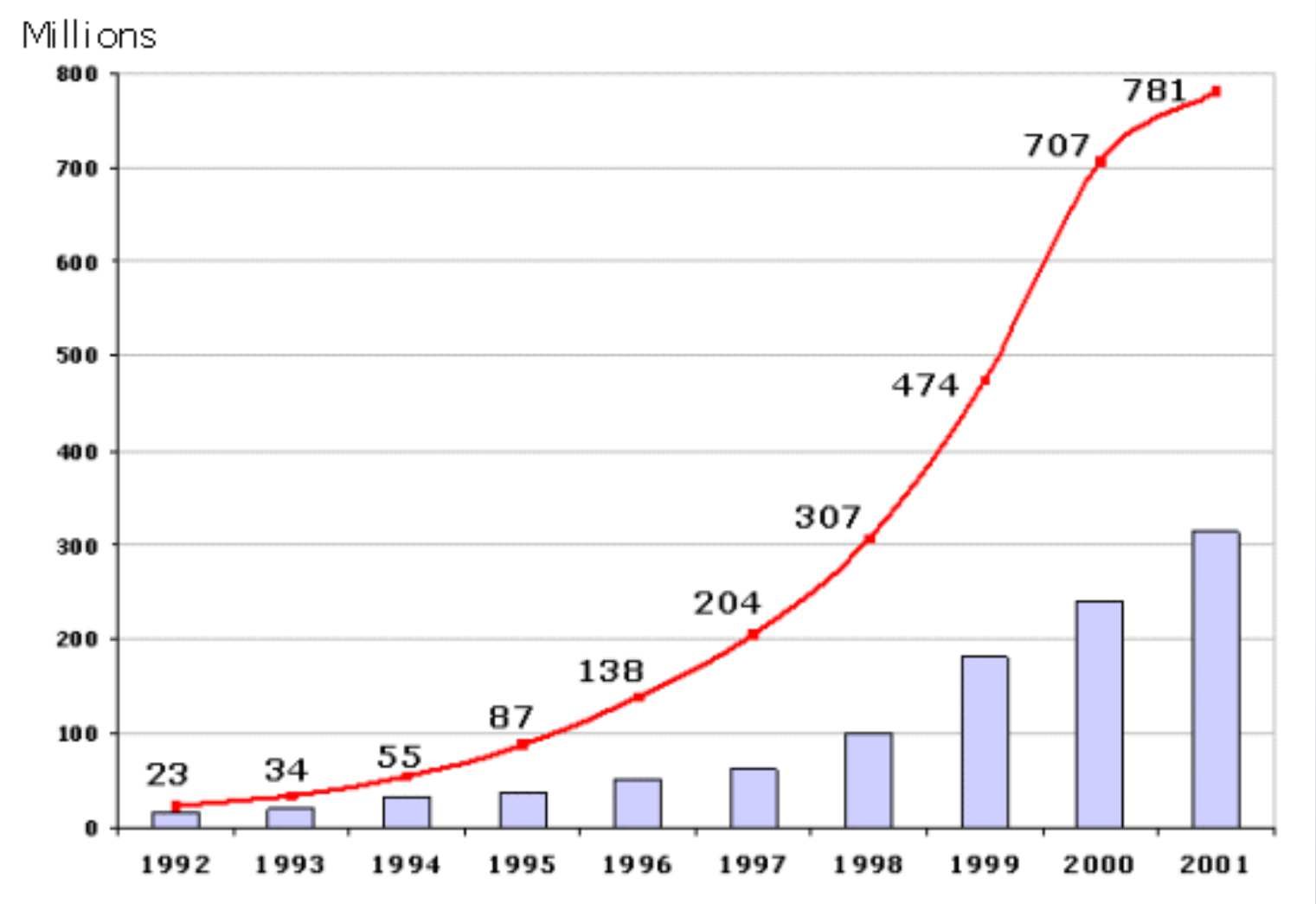
History – 3G Commercial Services

- Aug 2001: 1 million commercial CDMA2000 1X subscribers
- Oct 2001 NTT DoCoMo launched the first commercial WCDMA 3G mobile network
- Nov 2001: Nokia and AT&T Wireless complete first live 3G EDGE call.
- Dec 2001: Telenor launched in Norway the first commercial UMTS network
- Jan 2002: Verizon Wireless (US) launches commercial CDMA2000 1X service

Future

- Jan 2002: Verizon Wireless (US) launches commercial CDMA2000 1X service
- Feb 2002: Nokia and Omnitel Vodafone claims to have made the first rich call in an end-to-end All-IP mobile network at the 3GSM World Congress in Cannes, France.
- May 2002: 10 million commercial CDMA2000 1X subscribers
- Jun 2003: Target date for UMTS Release 6
- 2005: UMTS service will be world-wide

World Cellular Subscriber Growth



2G Technologies

	cdmaOne (IS-95)	GSM, DCS-1900	IS-54/IS-136 PDC
Uplink Frequencies (MHz)	824-849 (Cellular) 1850-1910 (US PCS)	890-915 MHz (Eurpe) 1850-1910 (US PCS)	800 MHz, 1500 Mhz (Japan) 1850-1910 (US PCS)
Downlink Frequencies	869-894 MHz (US Cellular) 1930-1990 MHz (US PCS)	935-960 (Europa) 1930-1990 (US PCS)	869-894 MHz (Cellular) 1930-1990 (US PCS) 800 MHz, 1500 MHz (Japan)
Deplexing	FDD	FDD	FDD
Multiple Access	CDMA	TDMA	TDMA
Modulation	BPSK with Quadrature Spreading	GMSK with BT=0.3	$\pi/4$ DQPSK
Carrier Seperation	1.25 MHz	200 KHz	30 KHz (IS-136) (25 KHz PDC)
Channel Data Rate	1.2288 Mchips/sec	270.833 Kbps	48.6 Kbps (IS-136) 42 Kbps (PDC)
Voice Channels per carrier	64	8	3
Speech Coding	CELP at 13Kbps EVRC at 8Kbps	RPE-LTP at 13 Kbps	VSELP at 7.95 Kbps

Cellular Networks

- First Generation
  - Analog Systems
  - Analog Modulation, mostly FM
  - AMPS
  - Voice Traffic
  - FDMA/FDD multiple access
- Second Generation (2G)
  - Digital Systems
  - Digital Modulation
  - Voice Traffic
  - TDMA/FDD and CDMA/FDD multiple access
- 2.5G
  - Digital Systems
  - Voice + Low-datarate Data
- Third Generation
  - Digital
  - Voice + High-datarate Data
  - Multimedia Transmission also

2G and Data

- 2G is developed for voice communications
- You can send data over 2G channels by using modem
- Provides a data rates in the order of ~9.6 Kbps
- Increased data rates are requires for internet application
- This requires evolution towards new systems: 2.5 G

2.5 Technologies

- Evolution of TDMA Systems
  - GPRS for GSM and IS-136
    - Up to 171.2 Kbps data-rate
  - EDGE for 2.5G GSM and IS-136
    - Up to 384 Kbps data-rate
- Evolution of CDMA Systems
  - IS-95B
    - Up to 64 Kbps

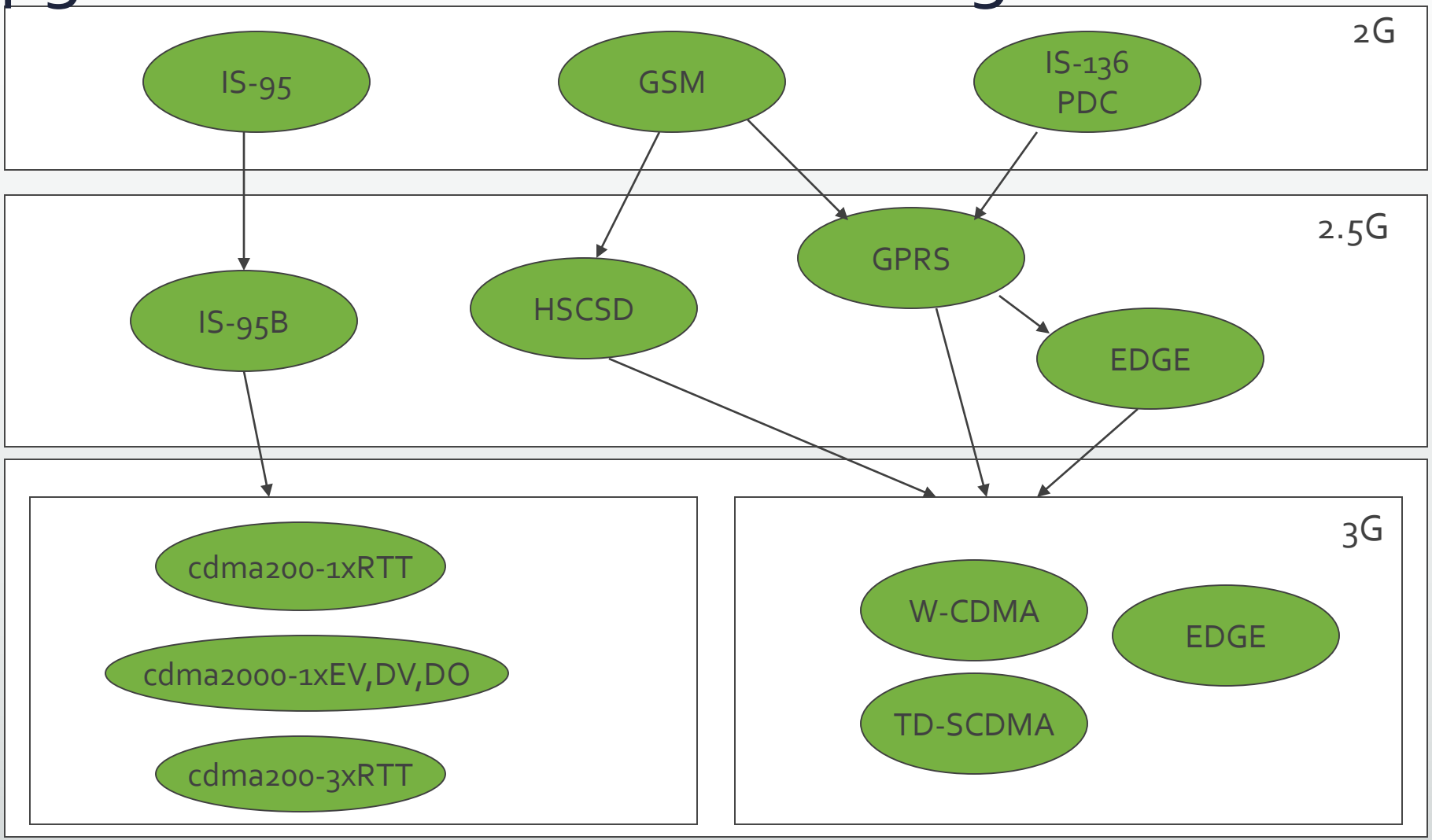
3G Systems

- Goals
  - Voice and Data Transmission
    - Simultanous voice and data access
  - Multi-megabit Internet access
    - Interactive web sessions
  - Voice-activated calls
  - Multimedia Content
    - Live music

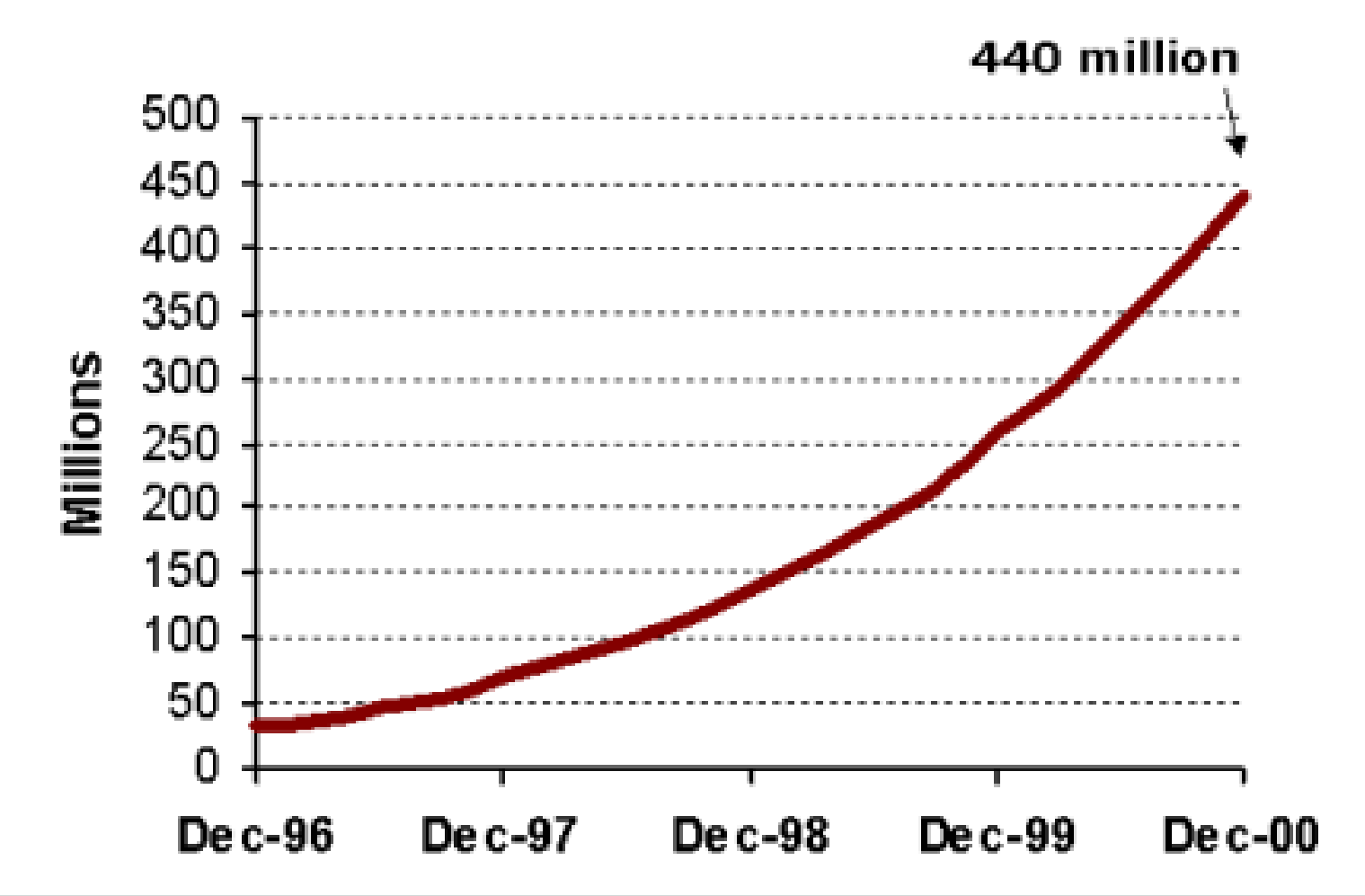
3G Systems

- Evolution of Systems
  - CDMA sysystem evaolved to CDMA2000
    - CDMA2000-1xRTT: Upto 307 Kbps
    - CDMA2000-1xEV:
    - CDMA2000-1xEVDO: upto 2.4 Mbps
    - CDMA2000-1xEVDV: 144 Kbps datarate
  - GSM, IS-136 and PDC evolved to W-CDMA (Wideband CDMA) (also called UMTS)
    - Up to 2.048 Mbps data-rates
    - Future systems 8Mbps
    - Expected to be fully deployed by 2010-2015
  - New spectrum is allocated for these technologies

Upgrade Paths for 2G Technologies



GSM Subscriber Growth



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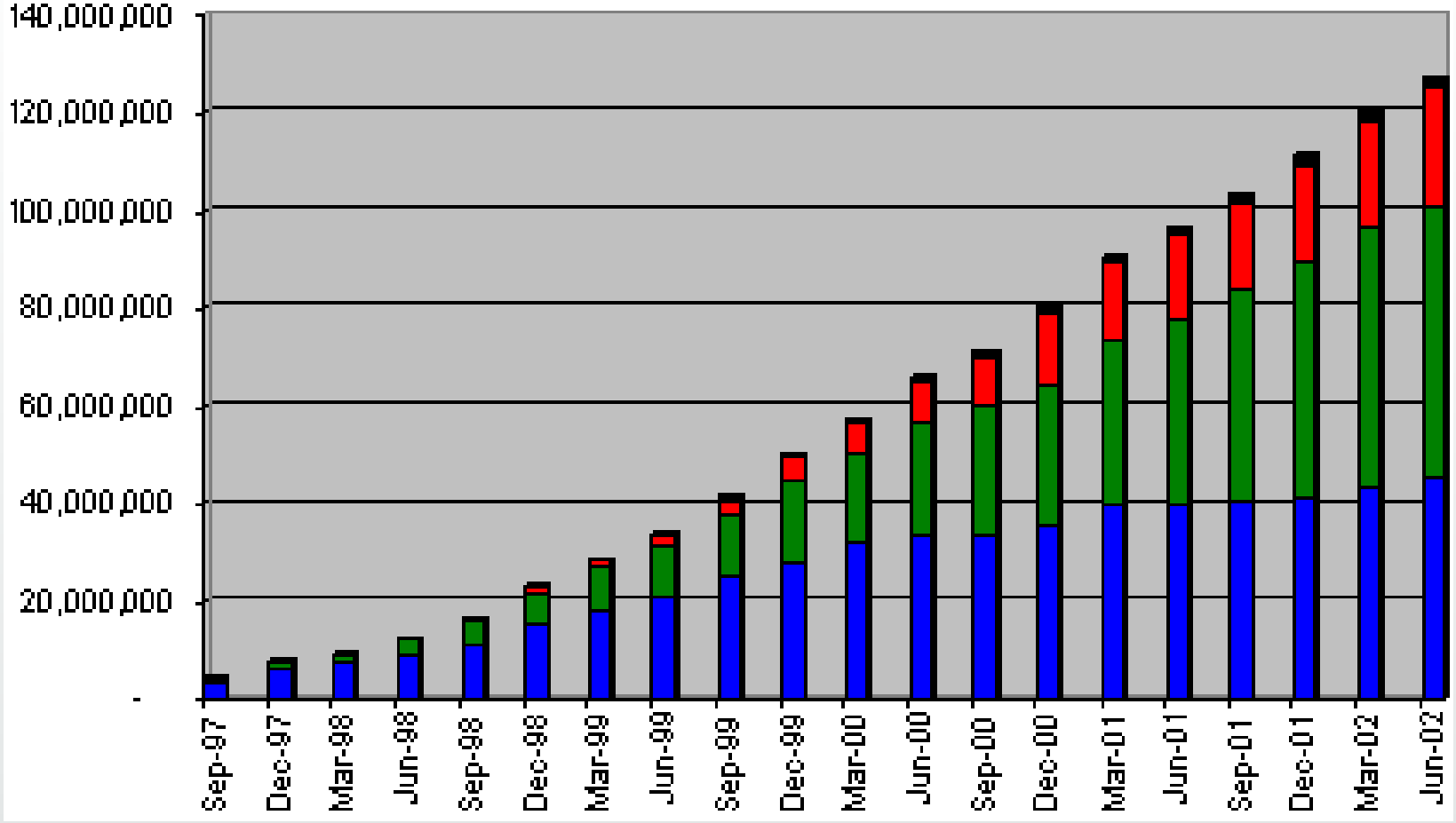
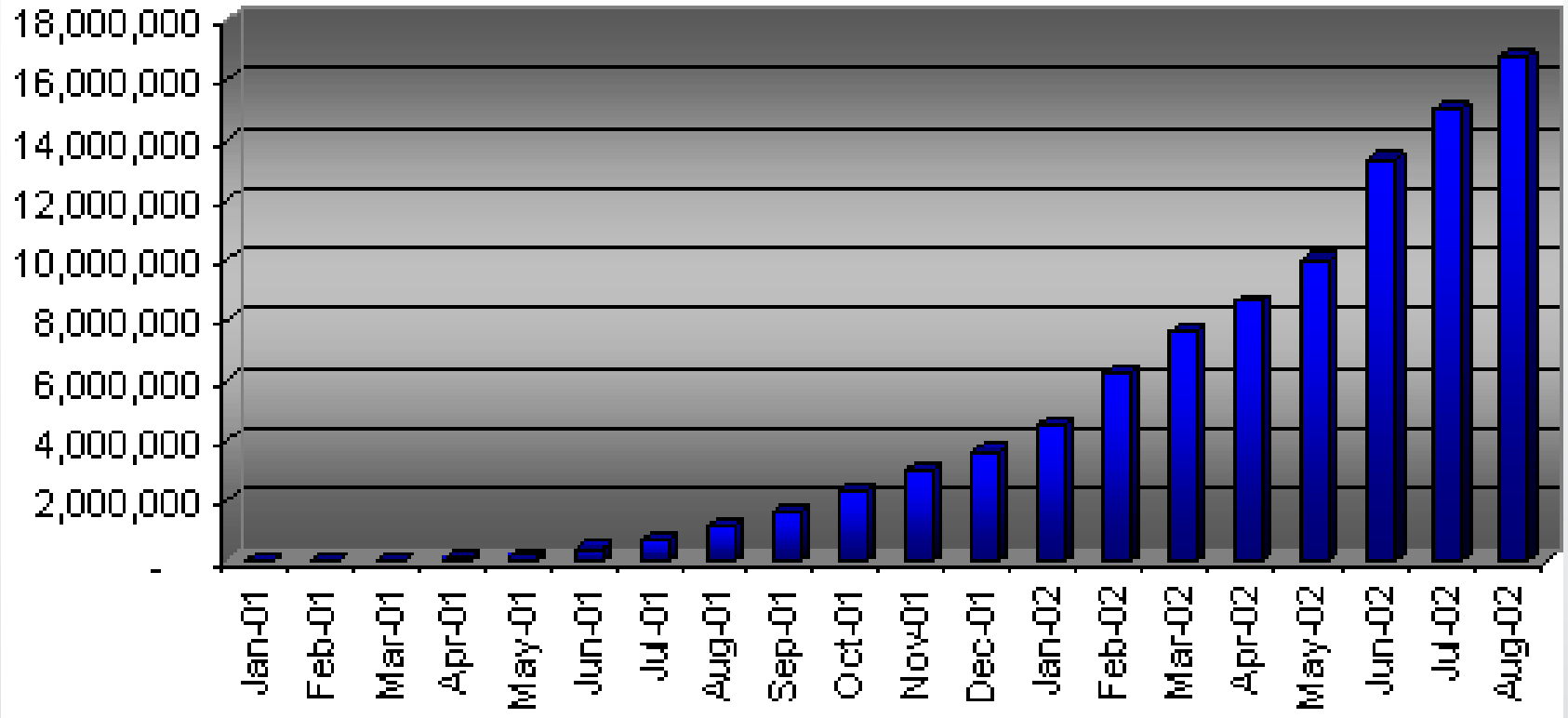
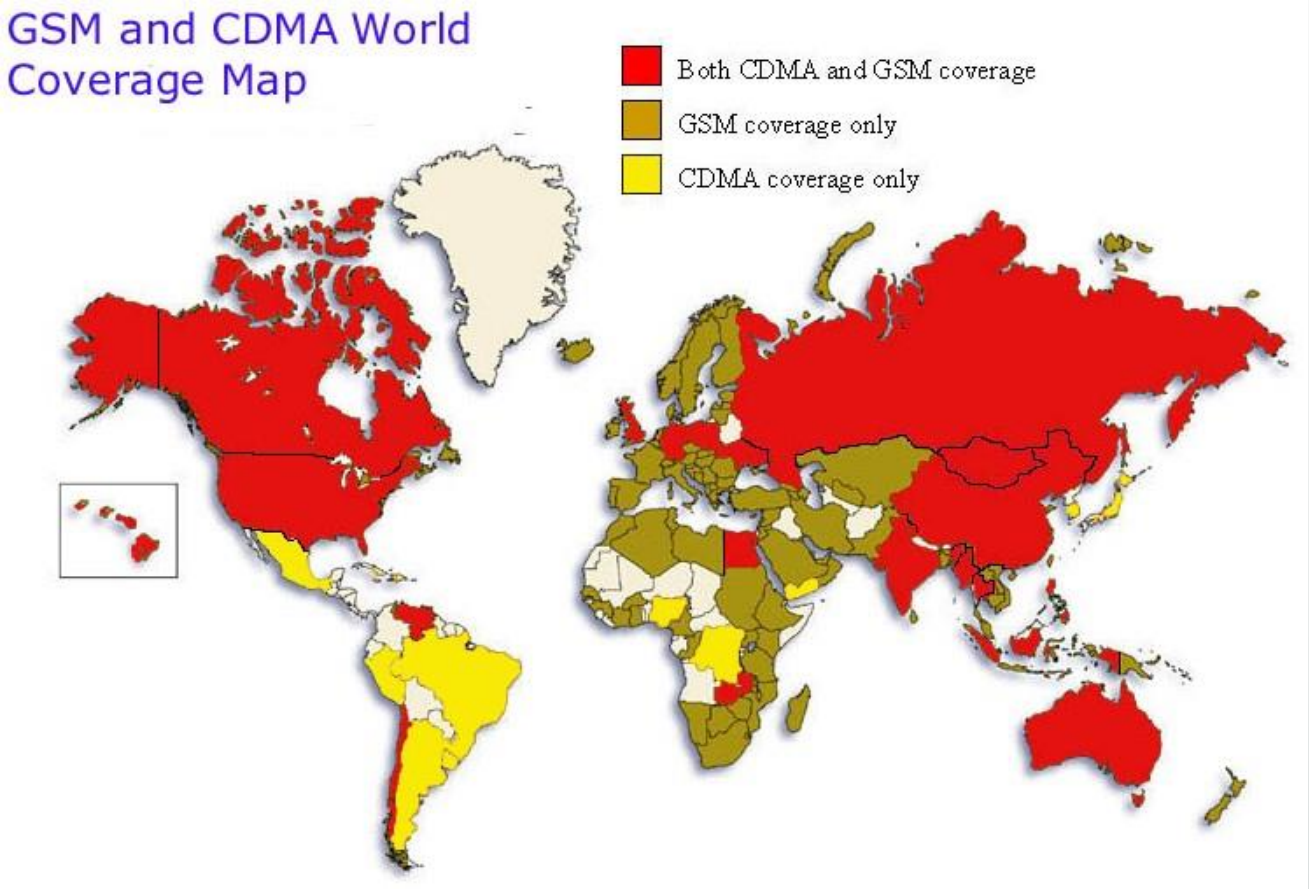


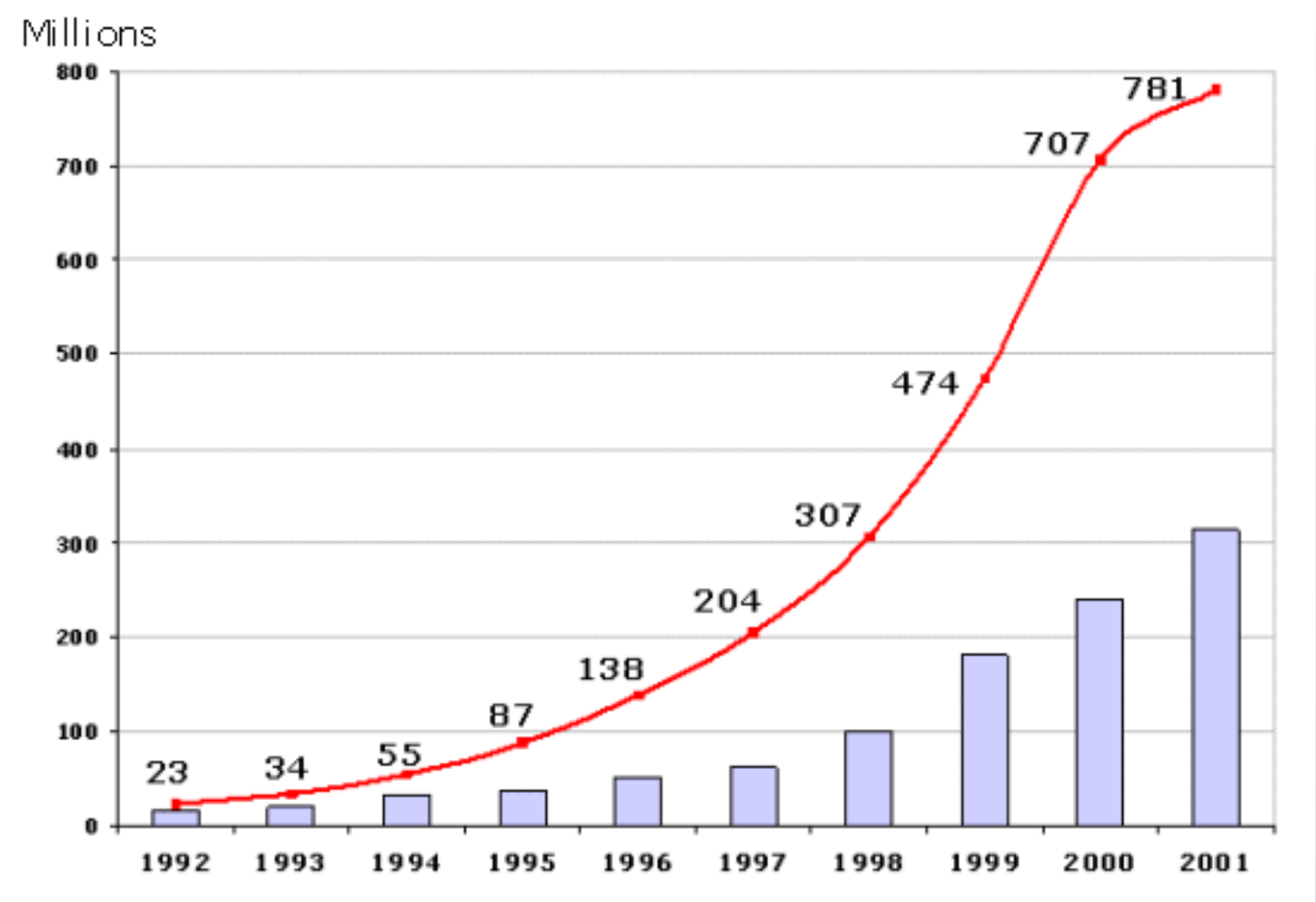
CDMA2000 Subscriber Growth



GSM and CDMA Coverage Map Worldwide



World Cellular Subscriber Growth



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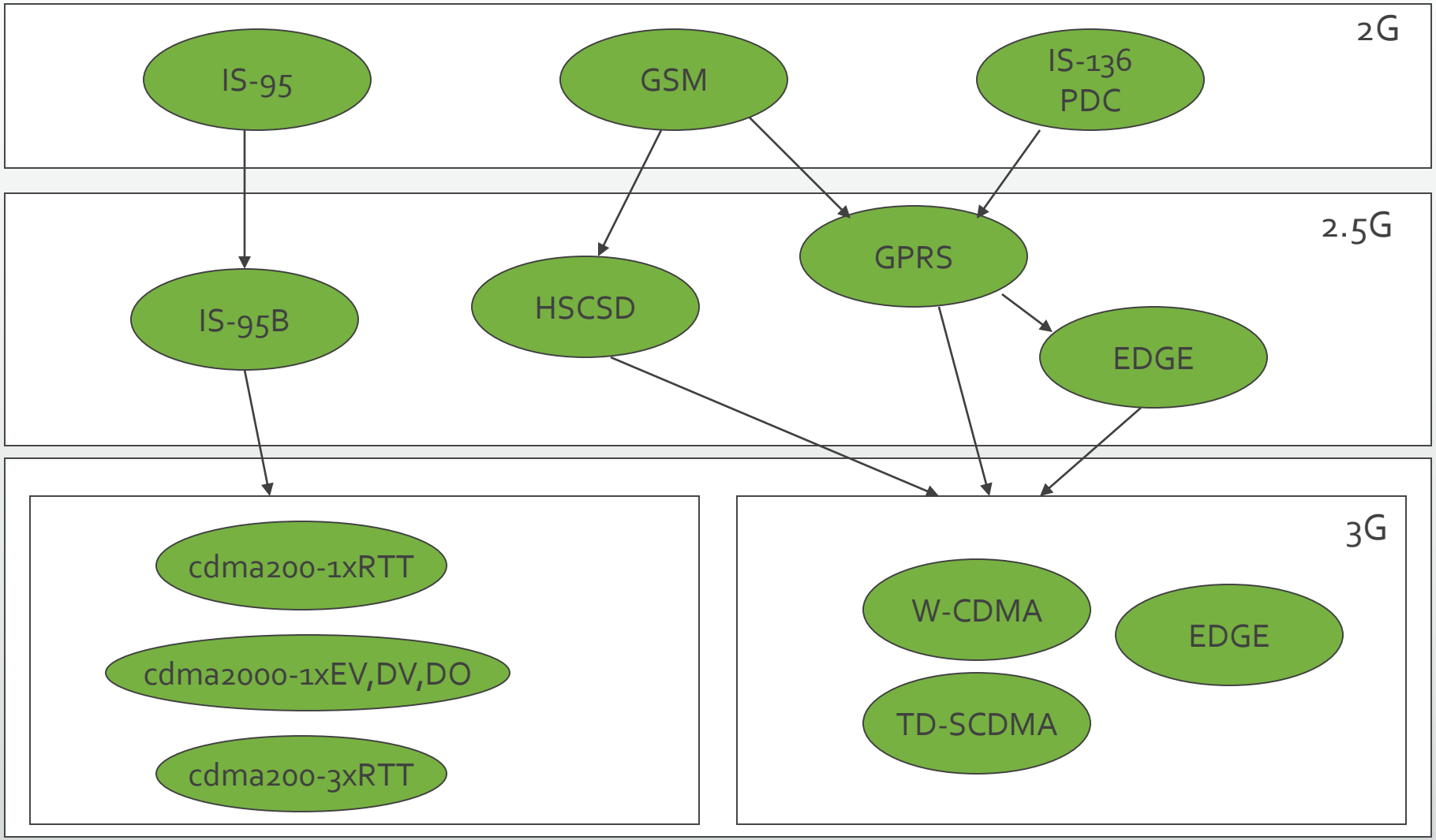
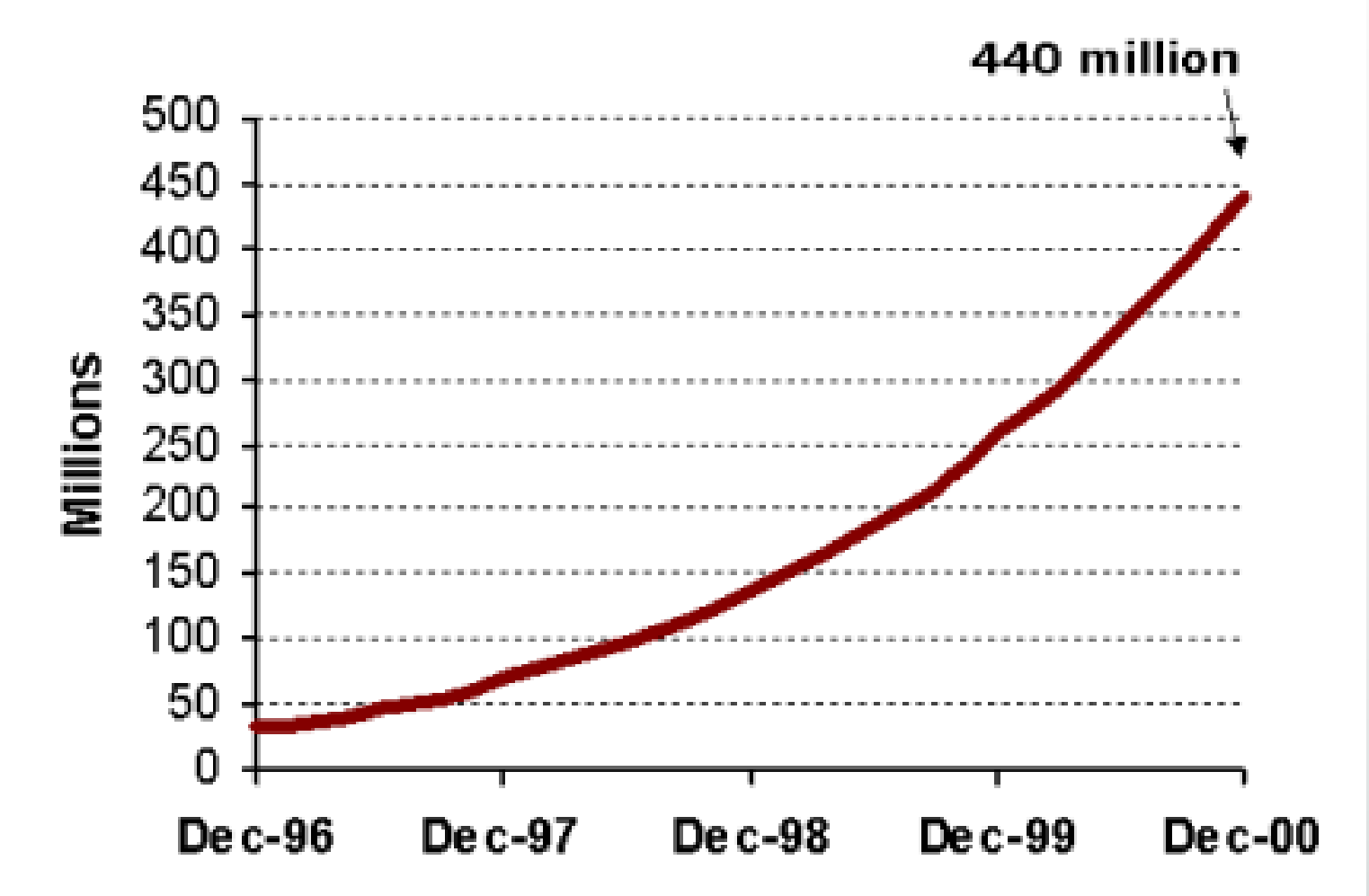


GSM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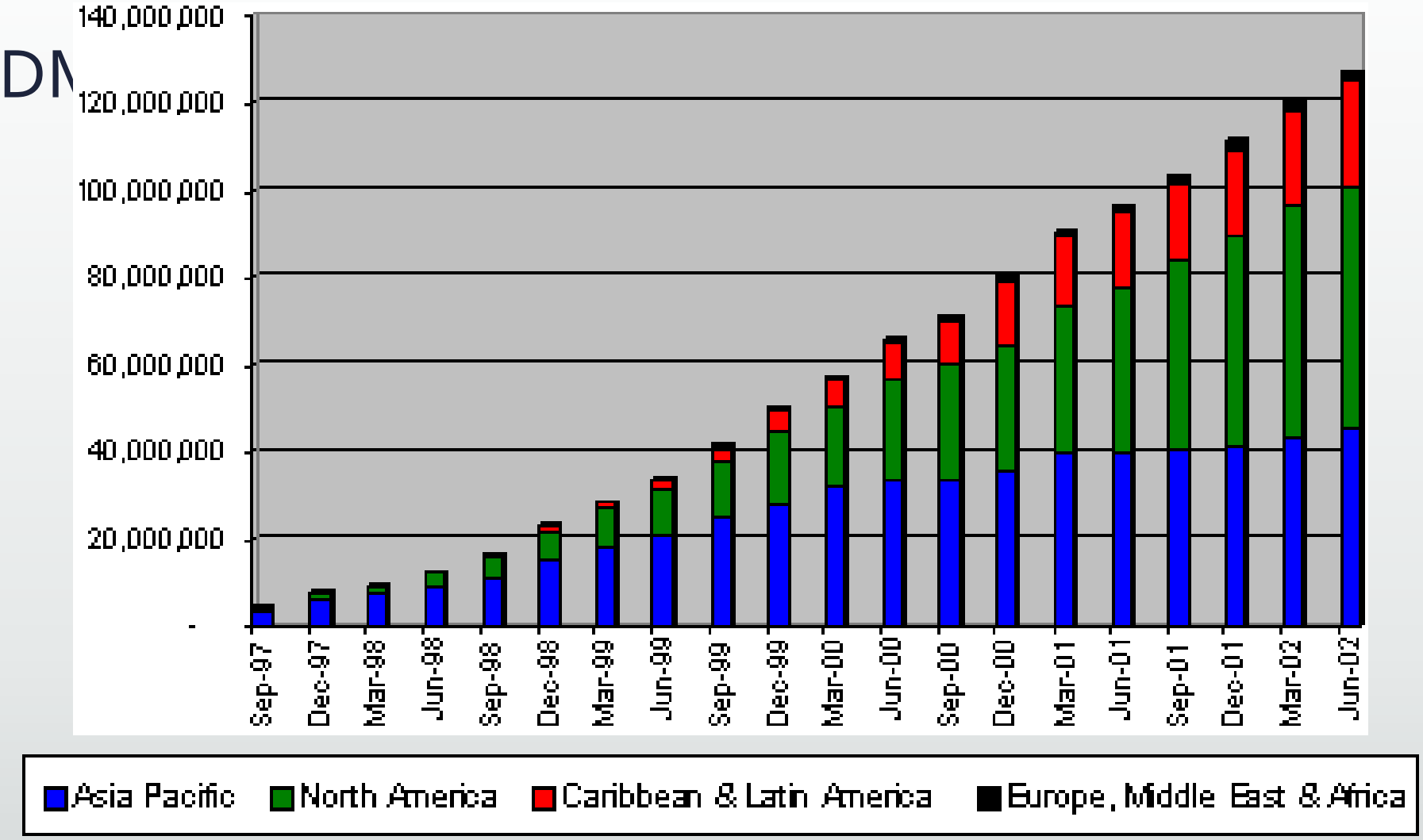
CDM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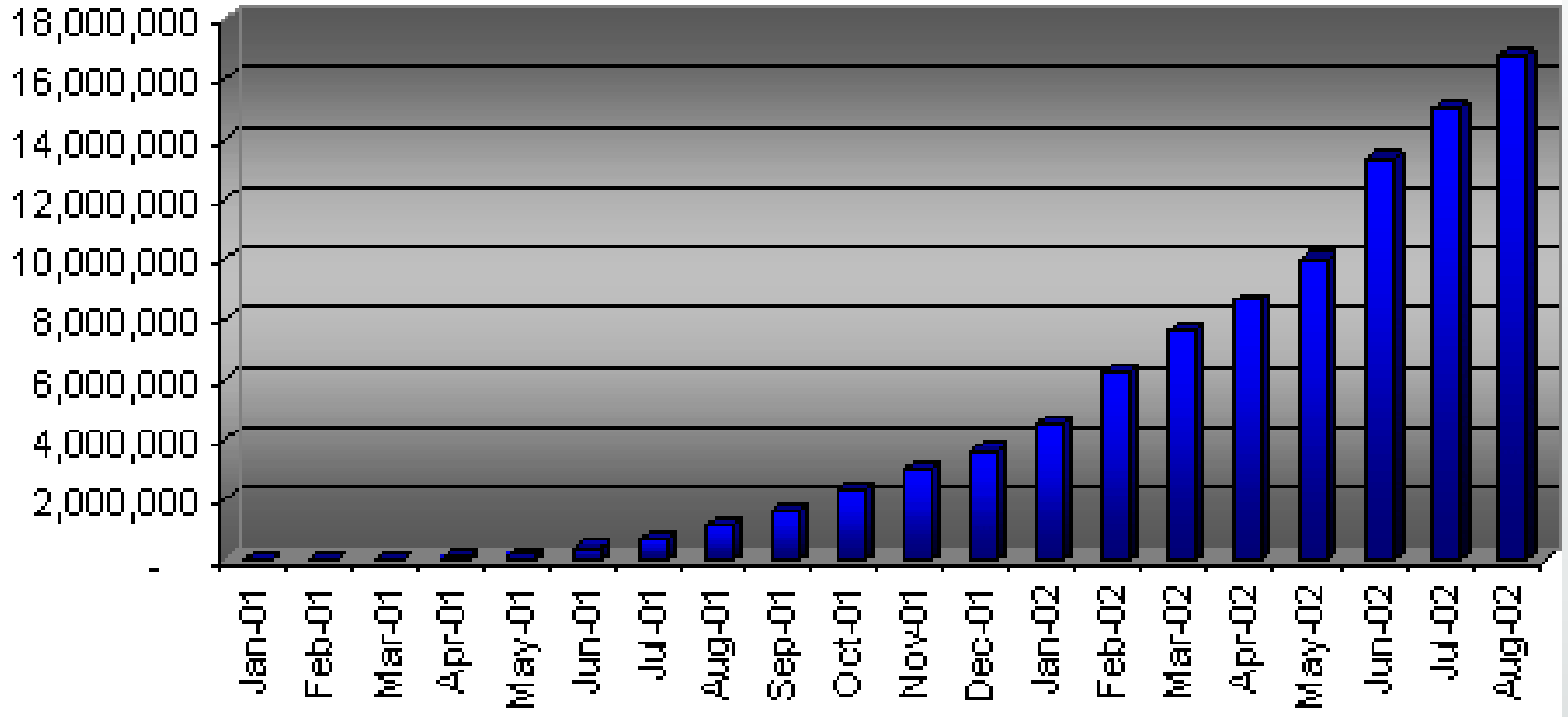
Dec-99
Mar-00
Jun-00
Sep-00
Dec-00
Mar-01
Jun-01
Sep-01
Dec-01
Mar-02
Jun-02
Asia Pacific
North America
Caribbean & Latin America
Europe, Middle East & Africa

CDMA2000 Subscriber Growth



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