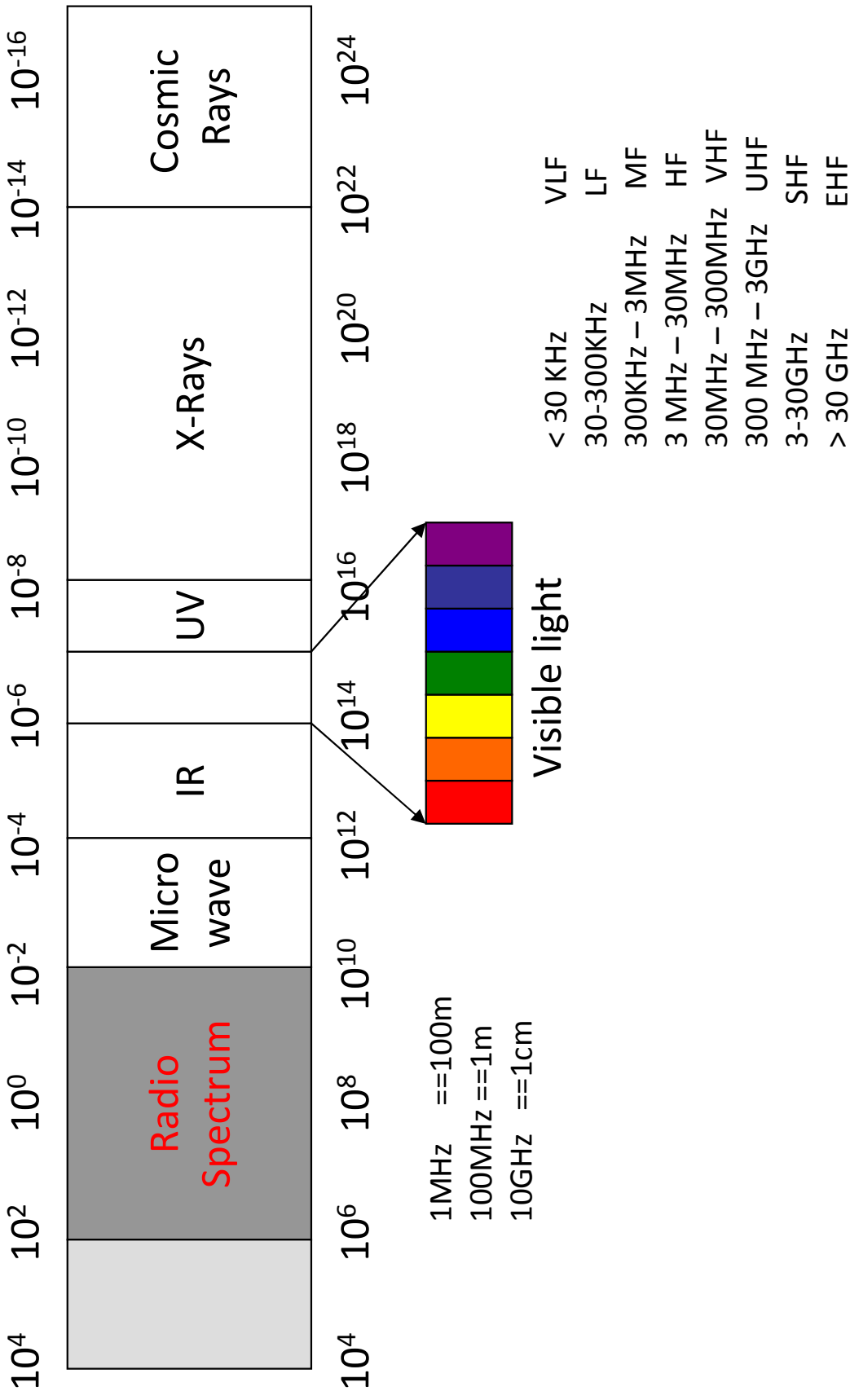


Introduction: What is Wireless and Mobile Communication?

Dr. Yeffry Handoko Putra, M.T
Universitas Komputer Indonesia

- Transmitting voice and data using electromagnetic waves in open space
- Electromagnetic waves
 - Travel at speed of light ($c = 3 \times 10^8$ m/s)
 - Has a frequency (f) and wavelength (λ)
 - » $c = f \times \lambda$
 - Higher frequency means higher energy photons
 - The higher the energy photon the more penetrating is the radiation

Electromagnetic Spectrum



Wavelength of Some Technologies

- **GSM Phones:** (Global System for Mobile)
 - frequency \approx 900 MHz
 - wavelength \approx 33cm
- **PCS Phones** (Personal communication System)
 - frequency \approx 1.8 GHz
 - wavelength \approx 17.5 cm
- **Bluetooth:**
 - frequency \approx 2.4GHz
 - wavelength \approx 12.5cm

Frequency Carriers/Channels

- The information from sender to receiver is carrier over a well defined frequency band.
 - This is called a channel
- Each channel has a fixed frequency bandwidth (in KHz) and Capacity (bit-rate)
- Different frequency bands (channels) can be used to transmit information in parallel and independently.

Example

- Assume a spectrum of 90KHz is allocated over a base frequency b for communication between stations A and B
- Assume each channel occupies 30KHz.
- There are 3 channels
- Each channel is simplex (Transmission occurs in one way)
- For full duplex communication:
 - » Use two different channels (front and reverse channels)
 - » Use time division in a channel

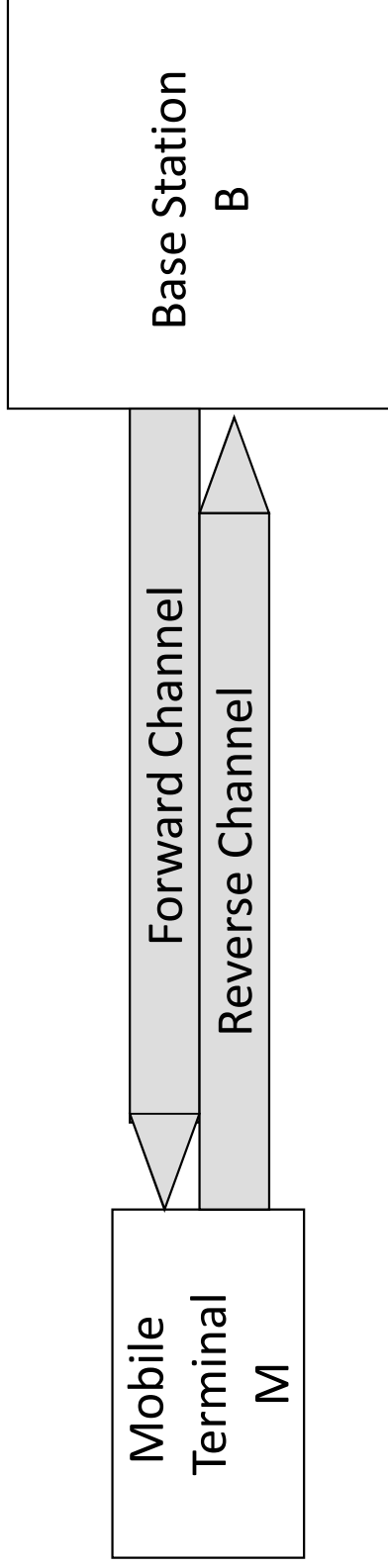
Station A	Channel 1 ($b - b+30$)	Station B
	Channel 2 ($b+30 - b+60$)	
	Channel 3 ($b+60 - b+90$)	

Simplex Communication

- Normally, on a channel, a station can transmit only in one way.
 - This is called simplex transmission
- To enable two-way communication (called full-duplex communication)
 - We can use Frequency Division Multiplexing
 - We can use Time Division Multiplexing

Duplex Communication - FDD

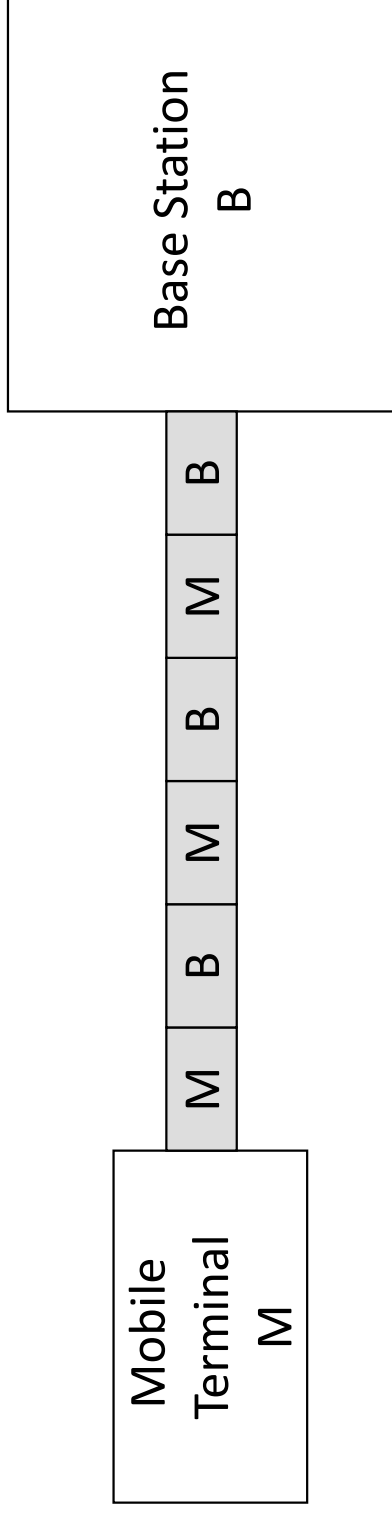
- FDD: Frequency Division Duplex



Forward Channel and Reverse Channel use different frequency bands

Duplex Communication - TDD

- TDD: Time Division Duplex



A single frequency channel is used. The channel is divided into time slots. Mobile station and base station transmit on the time slots alternately.

Example - Frequency Spectrum Allocation in U.S. Cellular Radio Service

Reverse Channel

991	992	...	1023	1	2	...	799
-----	-----	-----	------	---	---	-----	-----

824-849 MHz

Forward Channel

991	992	...	1023	1	2	...	799
-----	-----	-----	------	---	---	-----	-----

869-894 MHz

Channel Number

Reverse Channel $1 \leq N \leq 799$
 $991 \leq N \leq 1023$

Forward Channel $1 \leq N \leq 799$
 $991 \leq N \leq 1023$

(Channels 800-990 are unused)

Channels (Forward and Reverse) are separated by 45 MHz

Center Frequency (MHz)

$0.030N + 825.0$
 $0.030(N-1023) + 825.0$

$0.030N + 870.0$
 $0.030(N-1023) + 870.0$

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

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

The Need for Wireless/Mobile Networking

- Demand for Ubiquitous Computing
 - Anywhere, anytime computing and communication
 - You don't have to go to the lab to check your email
 - Pushing the computers more into background
 - Focus on the task and life, not on the computer
 - Use computers **seamlessly** to help you and to make your life more easier.
 - Computers should be location aware
 - Adapt to the current location, discover services

Some Example Applications of Ubiquitous Computing

- You walk into your office and your computer automatically authenticates you through your active badge and logs you into the Unix system
- You go to a foreign building and your (**Personal Digital Assistant**) PDA automatically discovers the closest public printer where you can print your schedule and give to your friend

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-136 (Interim State)
 - USA digital cellular mobile telephony system
 - TDMA based multiple access
 - Personal Digital Cellular
 - 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)
 - Personal Handy Telephone System (PHS)

Several PCS systems

- Wideband wireless systems
 - For Internet access and multimedia transfer
 - Cdma2000
 - W-CDMA, proposed by Europe
 - SC-DMA, proposed by China/Europe

Several PCS systems

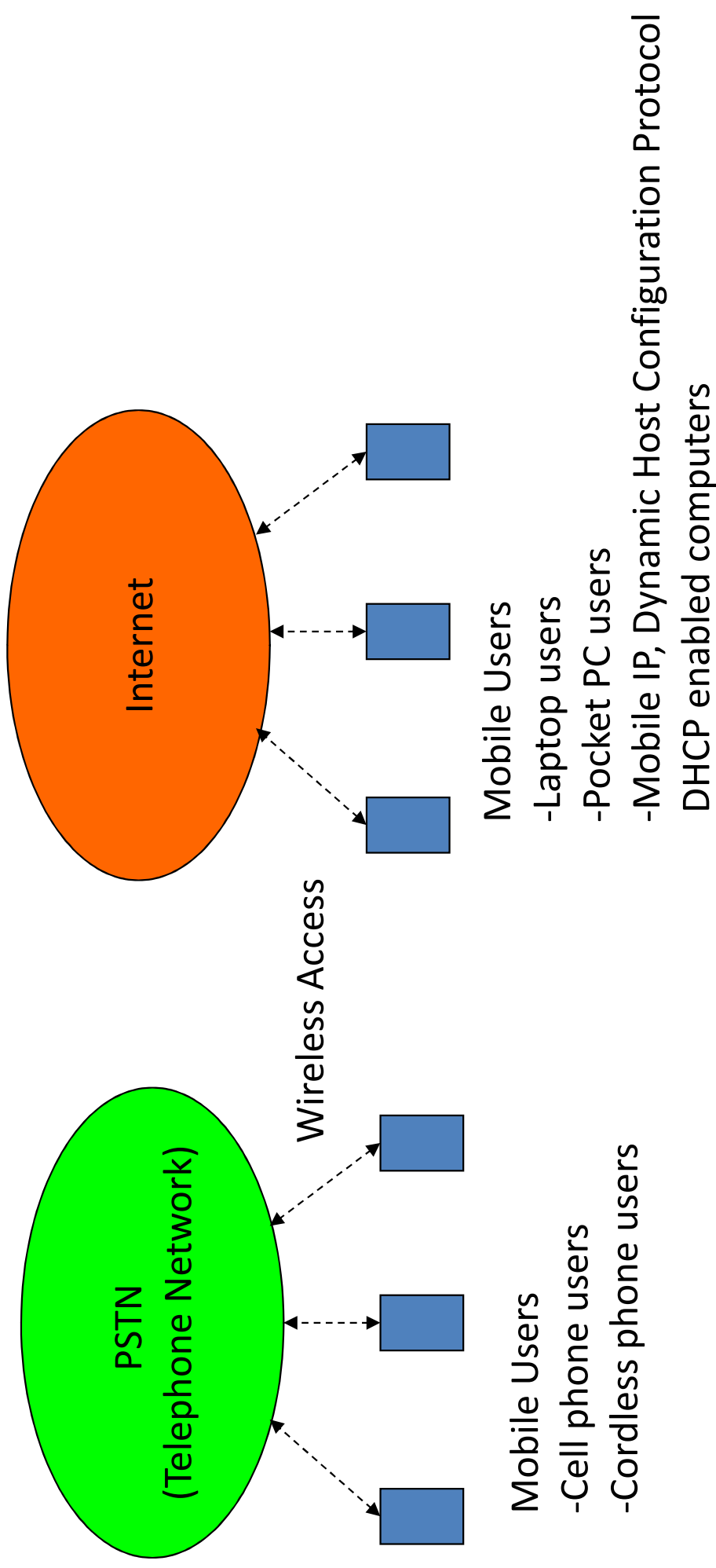
- Other PCS Systems
 - Special data systems
 - CDPD: Cellular Digital Packet Data
 - RAM Mobile Data
 - Advanced Radio Data Information System (ARDIS)
 - Paging Systems
 - Mobile Satellite Systems
 - LEO, MEO, HEO satellites for data/voice
 - ISM band systems: Bluetooth, 802.11, etc.

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

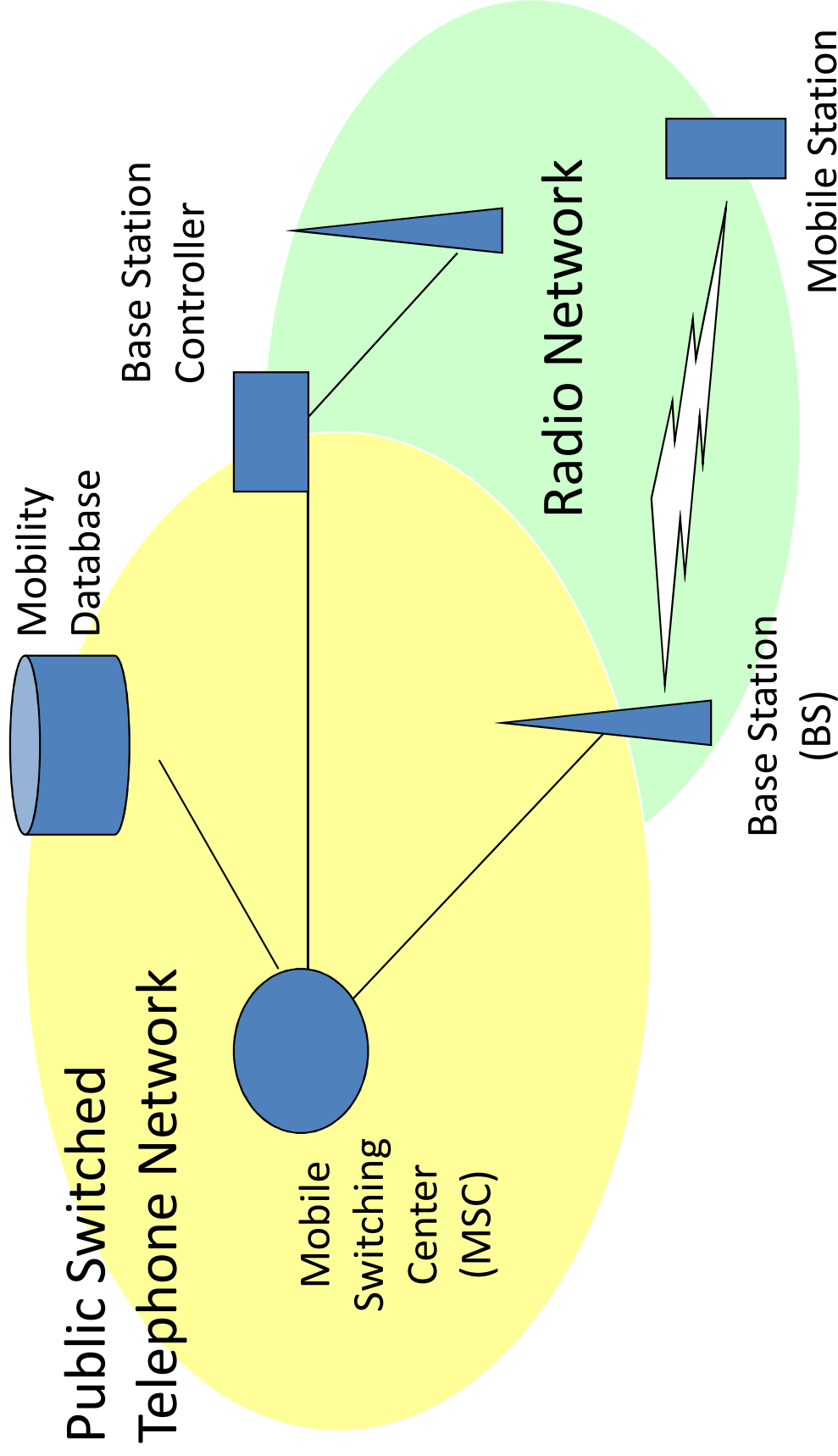
Angles



Telecom People View

Data Networking People View

Very Basic Cellular/PCS Architecture



Wireless System Definitions

- **Mobile Station**

- A station in the cellular radio service intended for use while in motion at unspecified locations. They can be either hand-held personal units (portables) or installed on vehicles (mobiles)

- **Base station**

- A fixed station in a mobile radio system used for radio communication with the mobile stations. Base stations are located at the center or edge of a coverage region. They consists of radio channels and transmitter and receiver antennas mounted on top of a tower.

Wireless System Definitions

- **Mobile Switching Center**
 - Switching center which coordinates the routing of calls in a large service area. In a cellular radio system, the MSC connects the cellular base stations and the mobiles to the PSTN (telephone network). It is also called Mobile Telephone Switching Office (MTSO)
- **Subscriber**
 - A user who pays subscription charges for using a mobile communication system
- **Transceiver**
 - A device capable of simultaneously transmitting and receiving radio signals

Wireless System Definitions

- Simplex Systems

- Communication systems which provide only one-way communication

- Half Duplex Systems

- Communication Systems which allow two-way communication by using the same radio channel for both transmission and reception. At any given time, the user can either transmit or receive information.

- Full Duplex Systems

- Communication systems which allow simultaneous two-way communication. Transmission and reception is typically on two different channels (FDD).

Wireless System Definitions

- Handoff
 - The process of transferring a mobile station from one channel or base station to another.
- Roamer
 - A mobile station which operates in a service area (market) other than that from which service has been subscribed.
- Page
 - A brief message which is broadcast over the entire service area, usually in simulcast fashion by many base stations at the same time.

PCS Systems Classification

- Cordless Telephones
- Cellular Telephony (High-tier)
- Wide Area Wireless Data Systems (High-tier)
- High Speed Local and Personal Area Networks
- Paging Messaging Systems
- Satellite Based Mobile Systems
- 3G Systems

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 Digital Packet Data)	Cellular	1993	FH/Packet	824-894	GMSK	30
IS-95 (Interim standard)	Cellular/PCS	1993	CDMA	824-894 1800-2000	QPSK/BPSK	1250
FLEX(free Open source for web appl)	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

Major Mobile Radio Standards - Europe

Standard	Type	Year Intro	Multiple Access	Frequency Band (MHz)	Modulation	Channel BW (KHz)
ETACS(Extended total access commn sys	Cellular	1985	FDMA	900	FM	25
NMT-900 (Nordic mobile tech	Cellular	1986	FDMA	890-960	FM	12.5
GSM	Cellular/PCS	1990	TDMA	890-960	GMSK	200KHz
C-450	Cellular	1985	FDMA	450-465	FM	20-10
ERMES (European radio messaging sys	Paging	1993	FDMA4	Several	4-FSK	25
CT2 (cordless telephony 2	Cordless	1989	FDMA	864-868	GFSK	100
DECT(digital enhancedCommun Sys)	Cordless	1993	TDMA	1880-1900	GFSK	1728
DCS-1800 (digital cellular sys)	Cordless/PCS	1993	TDMA	1710-1880	GMSK	200

Cordless Telephones

- Characterized by
 - Low mobility (in terms of range and speed)
 - Low power consumption
 - Two-way tetherless (wireless) voice communication
 - High circuit quality
 - Low cost equipment, small form factor and long talk-time
 - No handoffs between base units
- Appeared as analog devices
- Digital devices appeared later with CT2, DECT standards in Europe and ISM band technologies in USA

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

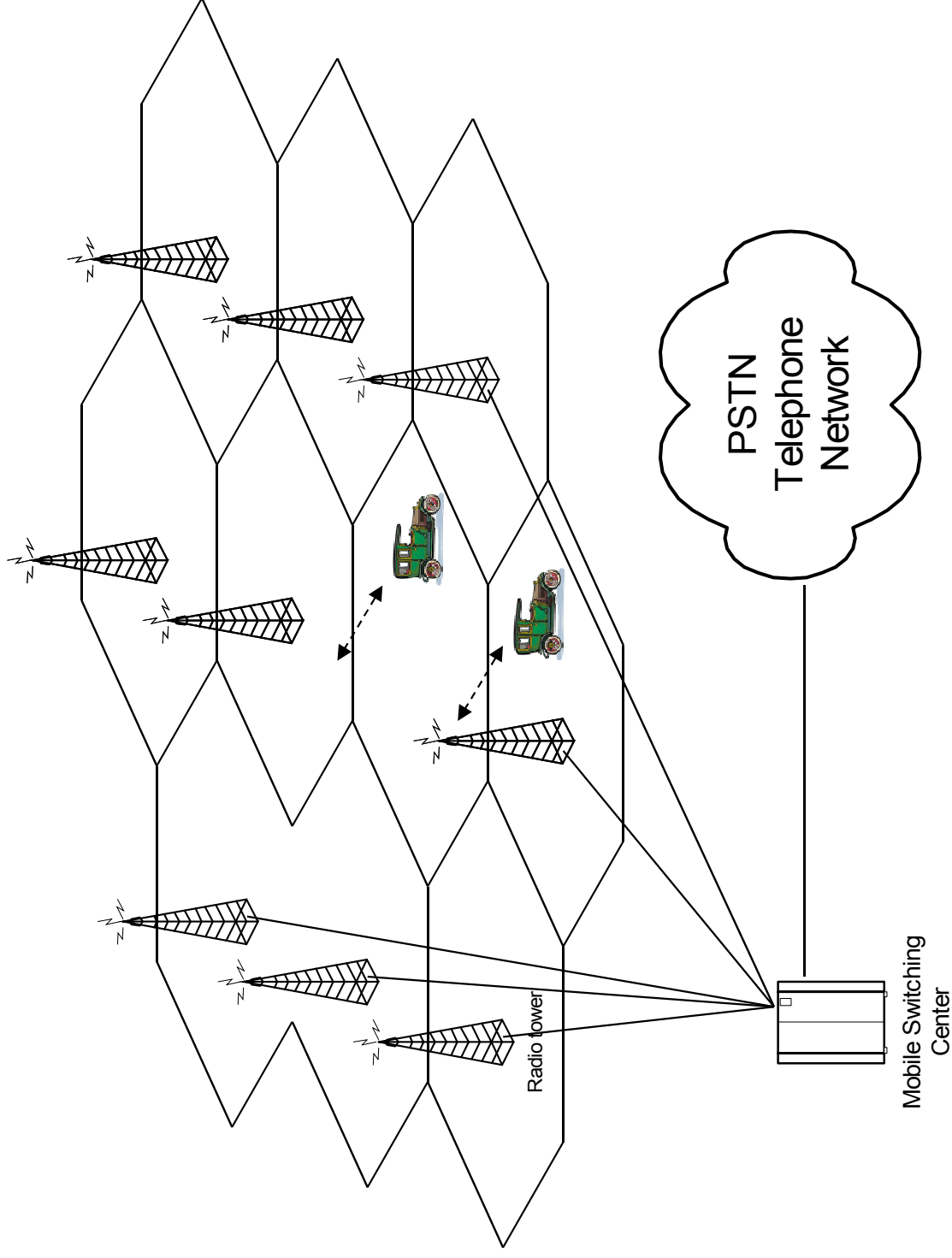
Cordless Phone

- Some more features
 - 32 Kb/s adaptive differential pulse code modulation (ADPCM) digital speech encoding
 - Tx power ≤ 10 mW
 - Low-complexity radio signal processing
 - No forward error correction (FEC) or whatsoever.
 - Low transmission delay < 50 ms
 - Simple Frequency Shift Modulation (FSK)
 - Time Division Duplex (TDD)

Cellular Telephony

- Characterized by
 - High mobility provision
 - Wide-range
 - Two-way tetherless 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



Cellular Telephony Systems

- Mobile users and handsets
 - Very complex circuitry and design
- Base stations
 - Provides gateway functionality between wireless and wireline links
- Mobile switching centers
 - Connect cellular system to the terrestrial telephone network

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 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 (Europe) 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

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 required for internet application
- This requires evolution towards new systems:
2.5 G

2.5 Technologies

- Evolution of TDMA Systems
 - HSCSD (High speed Circuit Switched Data) for 2.5G GSM
 - Up to 57.6 Kbps data-rate
 - GPRS (General Packet Radio Services) for GSM and IS-136
 - Up to 171.2 Kbps data-rate
 - EDGE (Enhanced Data For Global Evolution) 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
 - Simultaneous voice and data access
 - Multi-megabit Internet access
 - Interactive web sessions
 - Voice-activated calls
 - Multimedia Content
 - Live music

3G Systems

- Evolution of Systems
 - CDMA system evolved to CDMA2000
 - » CDMA2000-1xRTT: Upto 307 Kbps
 - » CDMA2000-1xEV:
 - » CDMA2000-1xEVDO: upto 2.4 Mbps
 - » CDMA2000-1xEVDO: 144 Kbps data rate
 - GSM, IS-136 and IS-54 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

