Wireless Communications

Outline

- Introduction
  - What is Wireless Communication ?
  - Evolution of Mobile Radio Communications.
  - Classification of Wireless Communication.
  - Examples of Mobile Radio Systems.
  - Paging Systems.
  - Cordless Telephone Systems
  - Comparisons of Various Wireless Systems.

What is Wireless Communication?

Brief Introduction

Wireless Is Hot

- Billions of wireless devices are in use
- 4 wireless technologies in 10 communication technologies with most market potential:
  - Wi-Fi
  - UWB
  - Software Radio
  - Wireless Mesh
  - Other six are: Nanotech, PON, Soft Switching, MPLS, FSO, Optical Switching

Wireless Is Hot

Wireless operations permits services, such as long range communications, that are impossible or impractical to implement with the use of wires.

The term is commonly used in the telecommunications industry to refer to telecommunications systems (e.g. radio transmitters and receivers, remote controls, computer networks, network terminals, etc.) which use some form of energy (e.g. radio frequency (RF), infrared light, laser light, visible light, acoustic energy, etc.) to transfer information without the use of wires.

Information is transferred in this manner over both short and long distances.

Introductions to Wireless Communications

- Communication is an essential need of human being, e.g., conversation, letter
- "Wireless" used to be the only (limited and unreliable) way to communicate in ancient times: 烽火狼烟、摔杯为号、铜镜反光、鸣金收兵…
- Modern wireless communications are based on the electromagnetic field theory (Maxwell's equations, Marconi's invention)

Introductions to Wireless Communications (Cont'd)

Wireless is often prior to its wired counterpart and has become an important supplement:

- Marconi's Wireless Telegraph → Wired Telegraph &
- Telephone → Cordless, Cellular Telephone, and Wireless Local Loop
- Broadcast TV → Cable TV → Satellite TV
- Aloha Network → Ethernet → Wireless LAN

Characteristics of Wireless Comm.

- Convenience and reduced cost
  - Service can be deployed faster than fixed service
  - No cost of cable plant
  - Service is mobile, deployed almost anywhere
- Unreliable channel (attenuation, fading, shadowing, interference)
- Complicated design and management
- Device limitations (power supply, LCD)
- Limited bandwidth and expensive service

Why use wireless communication?

- Provides mobility
  - A user can send and receive messages no matter where he/she located
- Added convenience / reduced cost
  - Enables communications without adding expensive infrastructure
  - Can easily setup temporary wireless LANs (disaster situations)
- Developing nations use cellular telephony rather than laying wires to each home
- Use resources only when sending or receiving signal

Why is wireless different than wired?

- Noisy, time-varying channel
  - BER varies by orders of magnitude(Digital Communication)
  - Enviromental conditions affect transmission
- Shared medium
  - Other users create interference
  - Must develop ways to share the channel
- Bandwidth is limited
  - TÜK, FCC determines the frequency allocation
  - ISM band for unlicensed spectrum (902-928 MHz, 2.4-2.5 GHz, 5.725-5.875 GHz)
- Requires intelligent signal processing and communications to make efficient use of limited bandwidth in error-prone environment

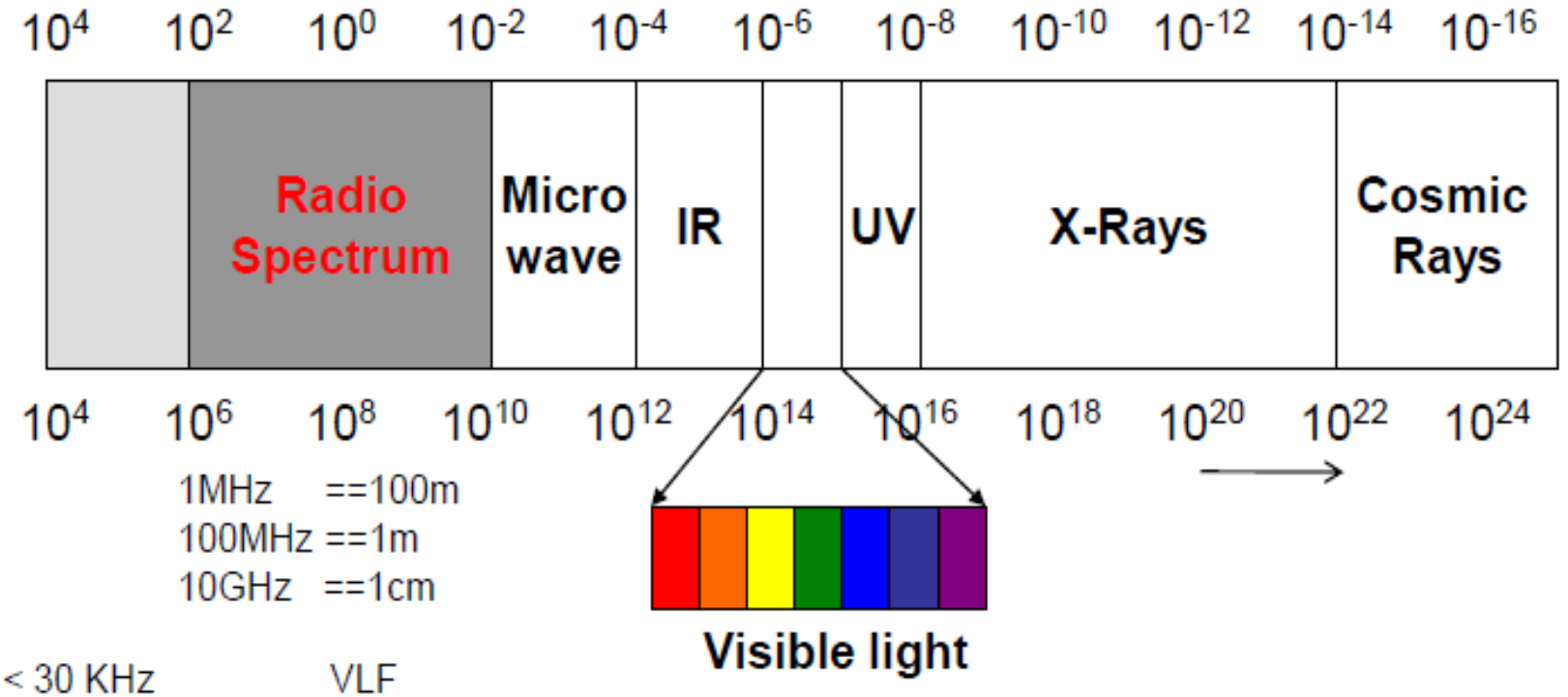
Limitations and Difficulties of Wireless

- Mobility brings unique challenges of its own
- Limitations from political and technical difficulties may inhibit wireless technologies (but doubtful today)
- Lack of an industry-wide standard, which should be a concern to the global community (but the global economy will mandate a solution)
- Device limitations
  - e.g., small LCD on a mobile telephone can only display a few lines of text
  - e.g., browsers of most mobile wireless devices use wireless markup language (WML) instead of HTML
- Security – Achilles heel of the technology
- RF Effects – long term effects on humans? Environment?

FREQUENCY SPECTRUM

- VICINITY OF 100 M Hz - FM Broadcasting
- 41M Hz – 960 M Hz - TV Broadcasting
- 118M Hz – 136 M Hz - Air to Ground System
- 225M Hz – 400 M Hz - Military Aircrafts
- Around 160 M Hz - Maritime Mobile Service
- 30M Hz – 100 M Hz - Fixed Station Service
- No spectrum was available between 30-400 M Hz lower portions as the services of this band had become very crowded. Above 10 G Hz , due to severe propagation path loss, multipath fading, and rain activity make the medium unsuitable for mobile comm.
- 800 M Hz was originally allotted to educational TV ch. Cable TV became a big factor in mid 70,s and shared the load of providing TV chs.
- This situation opened up the 800 M Hz band to some extent and FCC(USA) allocated a 40 M Hz system at 800 M Hz to Mobile Radio Cellular Systems.

Electromagnetic Spectrum



< 30 KHz	VLF
30-300KHz	LF
300KHz – 3MHz	MF
3 MHz – 30MHz	HF
30MHz – 300MHz	VHF
300 MHz – 3GHz	UHF
3-30GHz	SHF
> 30 GHz	EHF

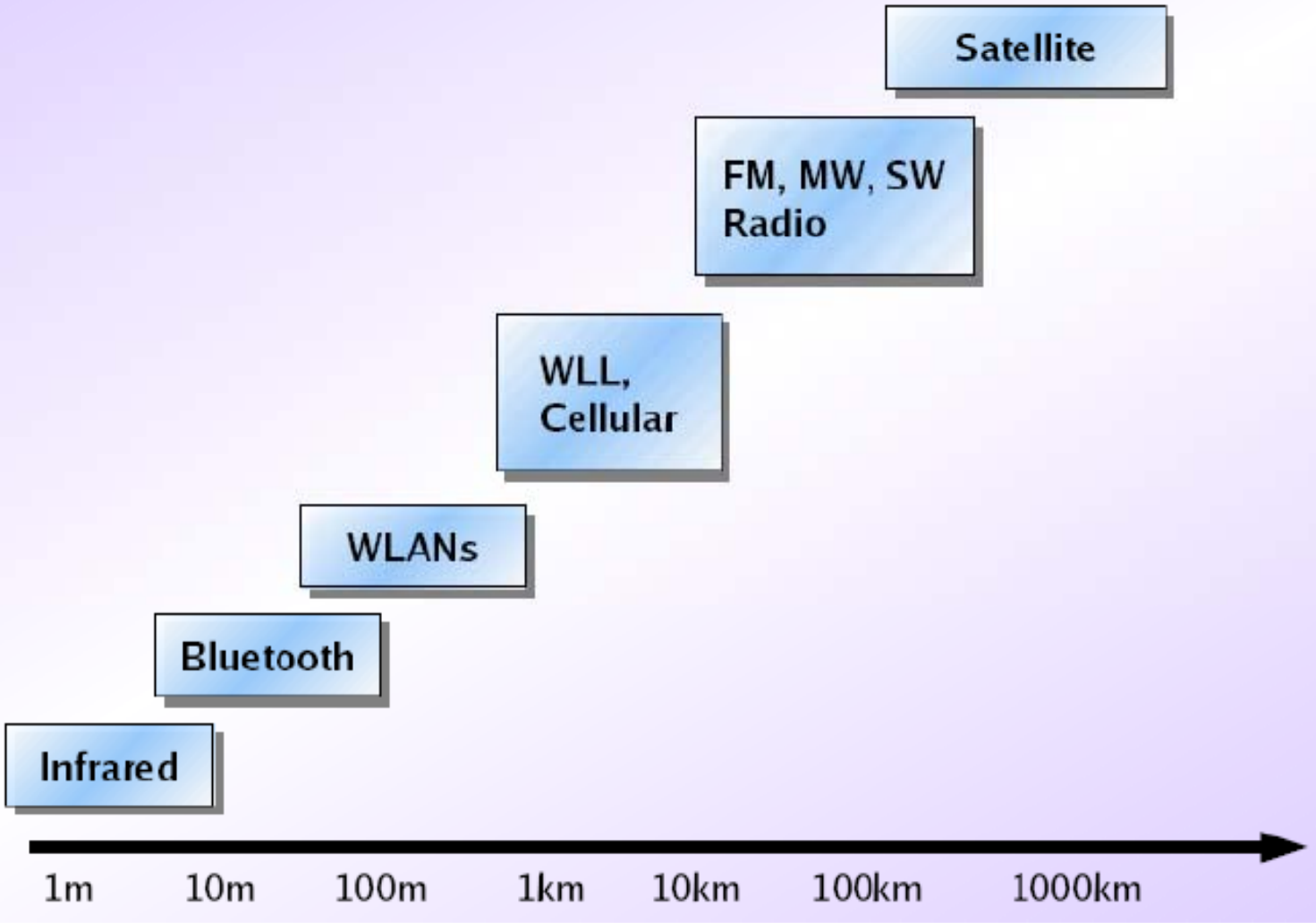
ELECTROMAGNETIC SPECTRUM
(Radio Waves Bands &their Uses)

Frequency	Band Name	Application
< 3 KHz	ELF	Submarine Communication
3-30 KHz	VLF	Marine Communication
30-300 KHz	LF	AM Radio
300 KHz-3 MHz	MF	-----do --
3 -30 MHz	HF/SHORT WAVE	-----do----
30 – 300 MHz	VHF	FM Radio
300 MHz- 3 GHz	UHF	TV , Cellular Telephony
3- 30 GHz	SUPER HF(SHF)	Satellite Communication, Radar
30 - 300 GHz	EXTRA HF (EHF)	Satellite Communication , Radar

ELECTROMAGNETIC SPECTRUM
(Microwave Bands &their Uses)

Frequency Ghz	Band Name	Application
1-2	L	Broadcasting , Cellular
2-4	S	Cellular , Radar
4-8	C	Satellite
8-12	X	Fixed Wireless- satellite , Radar
12-18	Ku	------Do-------
36-46	Q	Fixed Wireless
46-56	V	Fixed Satellite
56-100	w	Future Cellular
18-27 K , 27-46 Ka		

Range of Wireless Systems



Wavelength of Some Technologies

- GSM Phones:
  - frequency ~= 900 Mhz
  - wavelength ~= 33cm
- PCS Phones
  - frequency ~= 1.8 Ghz
  - wavelength ~= 17.5 cm
- Bluetooth:
  - frequency ~= 2.4Gz
  - wavelength ~= 12.5cm

The electronics booms

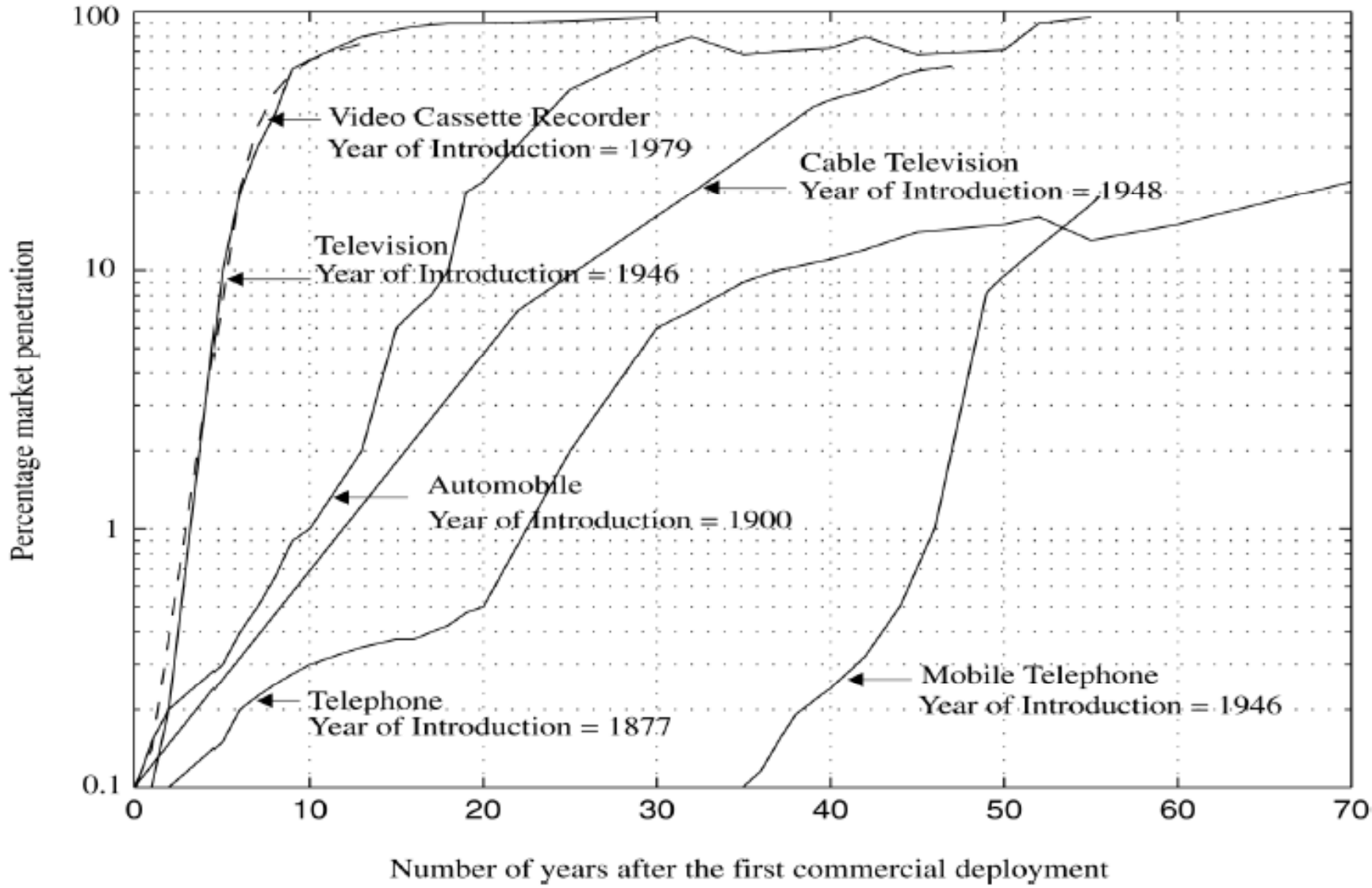


Figure 1.1 The growth of mobile telephony as compared with other popular inventions of the 20th century.

Wireless (Pre-)History

- "Pre-historic" times: smoke signals, bonfires, lighthouses, torches
- 1895: first radio transmission (Marconi, Isle of Wight, 18 mile distance)
- 1915: Wireless voice transmission established between San Francisco and New York
- 1945: Arthur C. Clarke(sci-fi writer) suggests *geostationary* satellites
- 1946: Public mobile telephony introduced in 25 US cities
- 1947: Invention of *cellular* concept (AT&T)
- 1957: First deployed communication satellite (Sputnik, Soviet Union)
- 1963: First deployed geostationary satellite (NASA)
- 1971: First packet-based radio network (ALOHANET, Univ. of Hawaii)
- 1983: First analog cellular system deployed (Chicago)
- 1985: Unlicensed frequency bands first authorized for WLAN use
- Ca. 1990: First digital cellular systems ("2G")
- 2000 - now: Standardization of 3rd generation mobile communication systems, WLANs, WPANs, sensor network radios,...

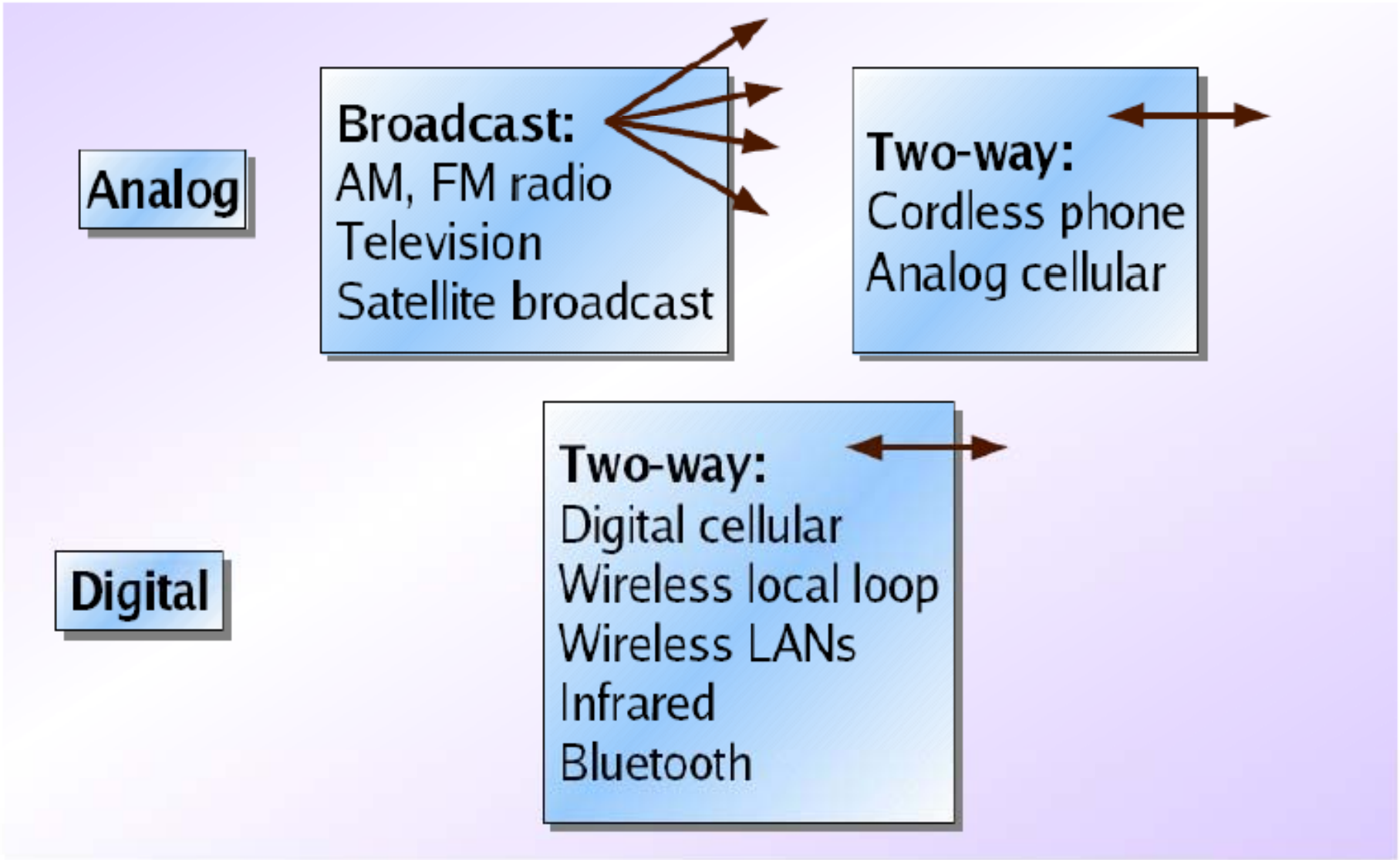
Wireless Comes of Age

- 1893: Nikola Tesla demonstrated the first ever wireless information transmission in New York City
- 1897: Marconi demonstrated transmission of radio waves to a ship at sea 29 km away
- 1915: Wireless telephony established-- VA and Paris
- 1920's: Radio broadcasting became popular
- 1930's: TV broadcasting began
- 1946: First public mobile telephone service in US
- 1960's: Bell Labs developed cellular concept-- brought mobile telephony to masses
- 1960's: Communications satellites launched
- Late 1970's: IC technology advances enable affordable cellular telephony-- ushers in modern cellular era
- Early 1990's: Cellular telephony in Türkiye
- 2007: İŞTCell cellular service is introduced by TürkCell

Classification of Wireless Communication

Brief Introduction

Wireless Systems: Classification



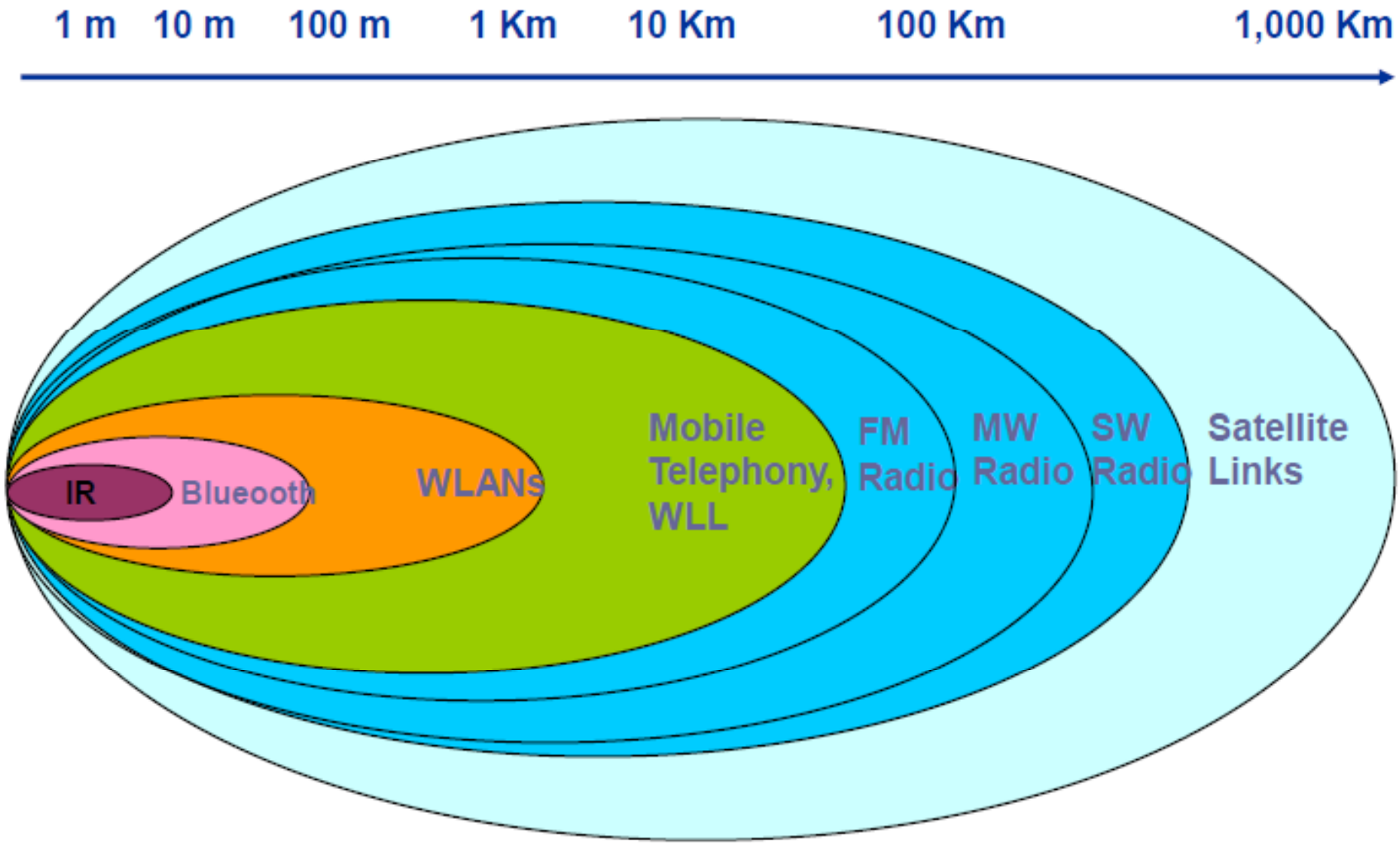
DIGITAL TRANSMISSION VS ANALOG TRANSMISSION

- Primary Advantage : **Noise Immunity** Exact amplitude, frequency, phase of received signal not important.
- Digital signals are better suited to processing and multiplexing than analog. DSP is the processing of analog signals using digital methods. Signal processing includes filtering, equalizing and phase shifting.
- Digital systems use signal regeneration rather than signal amplification. Noise produced in electronic amplifier is additive. Therefore, S/N ratio deteriorates each time an analog signal is amplified.
- Digital signals are simpler to measure and evaluate.
- Digital systems are better suited to evaluate error performance.
- Tx errors in digital signal scan be detected and corrected more easily and accurately than is possible with analog signals.
- --BUT--- They require more bandwidth, more precise time synchronization between Tx & Rx clocks. They require expensive clock recovery circuits in all receivers. Digital Tx systems are incompatible with older analog Tx facilities.

DIGITAL TRANSMISSION

- Noise Immunity : data transmitted as ones and zeros. It is easier to differentiate the signals from noise.
- Reliability : With digital data, parameters such as checksums, error correcting codes or redundnant data to ensure that ones and zeros that are transmitted are the same that are received.
- Compression : Repeating patterns of zeros and ones from an information stream can be removed in order to conserve bandwidth .Silence is suppressed in various conversations.
- **Security** : With binary data we can apply various encryption and authentication algorithms to ensure that a third party cannot view or tamper with the info stream. Even without encryption, digital signals travelling over public airwaves have an inherent obsecurity to them especially if the modulation, multiplexing and encoding techniques are not known.

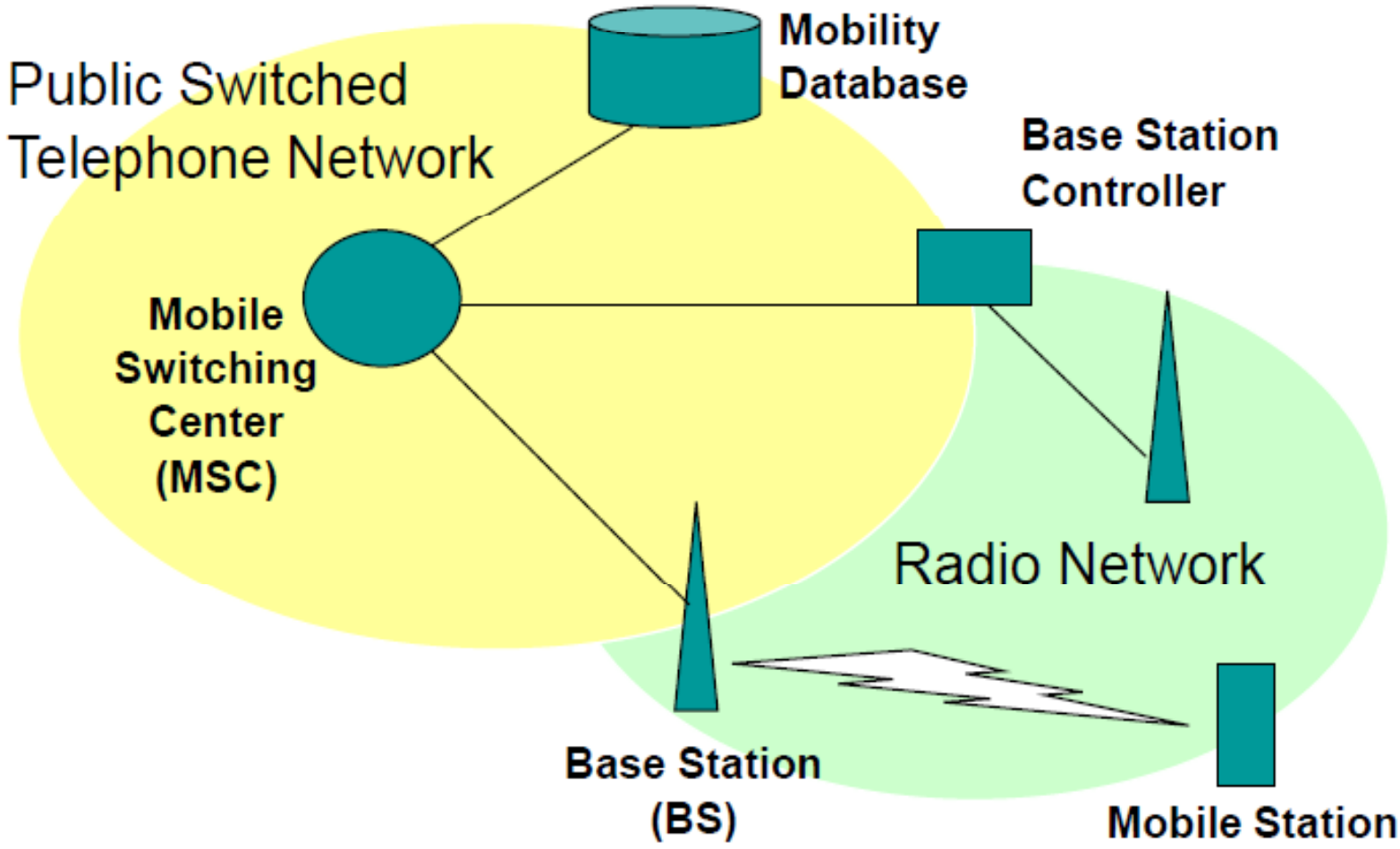
Wireless Systems: Range Comparison



Examples of Mobile Radio Systems

Most people are familiar with a number of mobile radio communication systems used in everyday life. Garage door openers, remote controllers for home entertainment equipment, cordless telephones, hand-held walkie-talkies, pagers (also called paging receivers or "beepers"), and cellular telephones are all examples of mobile radio communication systems. However, the cost, complexity, performance, and types of services offered by each of these mobile systems are vastly different.

Basic Cellular



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 connections 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

- Control Channel
  - Radio channel used for transmission of call setup, call request, call initiation and other beacon and control purposes.
- Forward Channel ("Downlink")
  - Radio channel used for transmission of information from the base station to the mobile
- Reverse Channel ("Uplink")
  - Radio channel used for transmission of information from mobile to base station

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 (“Handover’’)
- The process of transferring a mobile station from one channel or base station to an other.
- 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.

DEFINITIONS (CONTD)

- HANDOFF → THE PROCESS OF TRANSFERRING A MOBILE STATION FROM ONE CHANNEL OR BASE STATION TO ANOTHER.
- STD → SUBSCRIBER TRUNK DIALING.
- PCO → PUBLIC CALL OFFICE.
- FCC → FEDERAL COMMUNICATIOON COMMUNICATION.(USA).
- TRAI → TELECOMMUNICATION REGULATORY AUTHORITY OF INDIA.
- MOBILE HAND SET BATTERY → 3.6/3.7 V RECHARGABLE.
- SIM → SUBSCRIBER IDENTIFICATION MODULE.

Cellular Call Completion (Definitions)

- **Components of a signal:**
  - **Mobile Identification Number (MIN)** - an enclosed representation of the mobile telephone's 10-digit telephone number.
  - **Electronic Serial Number (ESN**) - a fixed 32 digits number assigned to the telephone by the manufacturer.
  - **System Identification Number (SID)** - a number assigned to the particular wireless carrier to which the telephone's user has subscribed by regulatory authority.
  - **Station Class Mark(SCM)-** Indicates the max transmitter power level for particular user.
  - **ESN**- permanent number of phone
  - **MIN & SID** are programmed when service plan is activated during purchase.

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

Major Mobile Radio Standards - Europe

Standard	Type	Year Intro	Multiple Access	Frequency Band (MHz)	Modulation	Channel BW (KHz)
ETACS	Cellular	1985	FDMA	900	FM	25
NMT-900	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	Paging	1993	FDMA4	Several	4-FSK	25
CT2	Cordless	1989	FDMA	864-868	GFSK	100
DECT	Cordless	1993	TDMA	1880-1900	GFSK	1728
DCS-1800	Cordless/PCS	1993	TDMA	1710-1880	GMSK	200

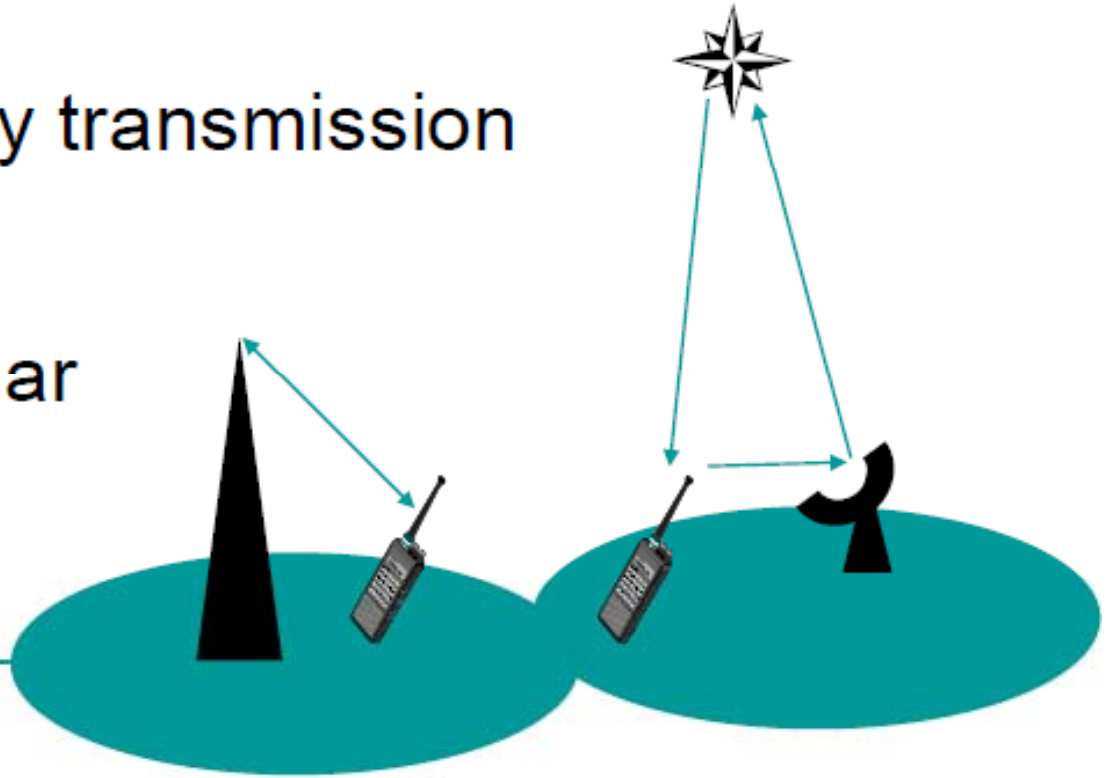
Paging systems

- Traditional paging is one-way ,personal wireless alerting /
- messaging system.
- The first paging system was developed by Charles F. Neergard,a radio engineer.
- Information delivered in paging system can be done in the following four types:

- **Alert tone**
- **Voice messages**
- **Digit string(Numeric pager)**
- **Text string (Alphanumeric pager)**

Paging Systems

- Broad coverage for short messaging
- Message broadcast from all base stations
- Simple terminals
- Optimized for 1-way transmission
- Answer-back hard
- Overtaken by cellular



FEATURES OF PAGING SYSTEM

FEATURE	MOBILE UNIT	BASE STATION
COVERAGE RANGE	HIGH	HIGH
REQUIRED INFRA-STRUCTURE	HIGH	HIGH
COMPLEXITY	LOW	HIGH`
HARDWARE COST	LOW	HIGH
CARRIER FREQUENCY	< 1 GHz	< 1 GHz
FUNCTIONALITY	RECEIVER	TRANSMITTER

Paging systems

- Paging systems are comm. Systems that can send brief alert/message to a subscriber.
- Depending on the type of service , the message can either be numeric message, an alphanumeric message, or a voice message.
- Paging systems are typically used to notify a subscriber of the need to call a particular telephone no. or travel to a known location to receive further instructions.

Paging systems

- In modern paging systems news headlines, stock quotations & faxes can be sent.
- A message can be sent to a paging subscriber via the paging system access number with a telephone keypad or modem. The issued message is called a page.
- The paging system then transmits the page throughout the service area using base stations which broadcast the page on a radio carrier.

Paging systems

- While a simple paging system can cover a limited range of 2km to 5km or may even be confined to within individual buildings, wide area paging systems can provide world wide coverage.

Paging systems

- Wide area paging systems consist of a network of telephone lines, many base stations transmitters and large radio towers that simultaneously broadcast a page from each base station(known as simulcasting)
- Simulcast transmitters may be located within the same service area or in different cities or countries.
- Paging systems are designed to provide reliable comm. to subscribers wherever they are; whether inside a building, driving on a highway, or flying in an airplane.

Paging systems

- This necessitates larger transmitter powers(kilowatts) & low data rates(a couple of thousand bits/sec) for max. coverage from each BS.

Wide area paging networks

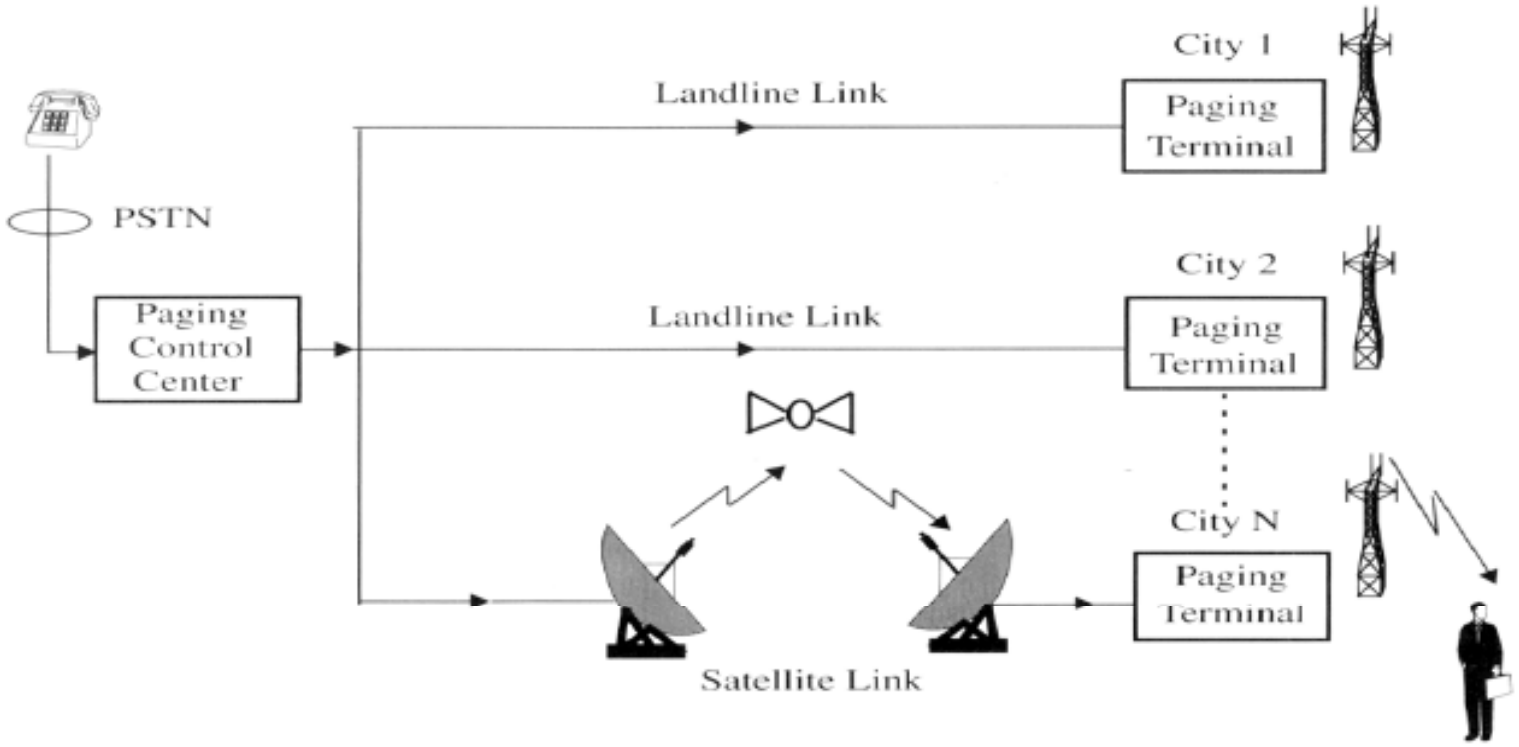
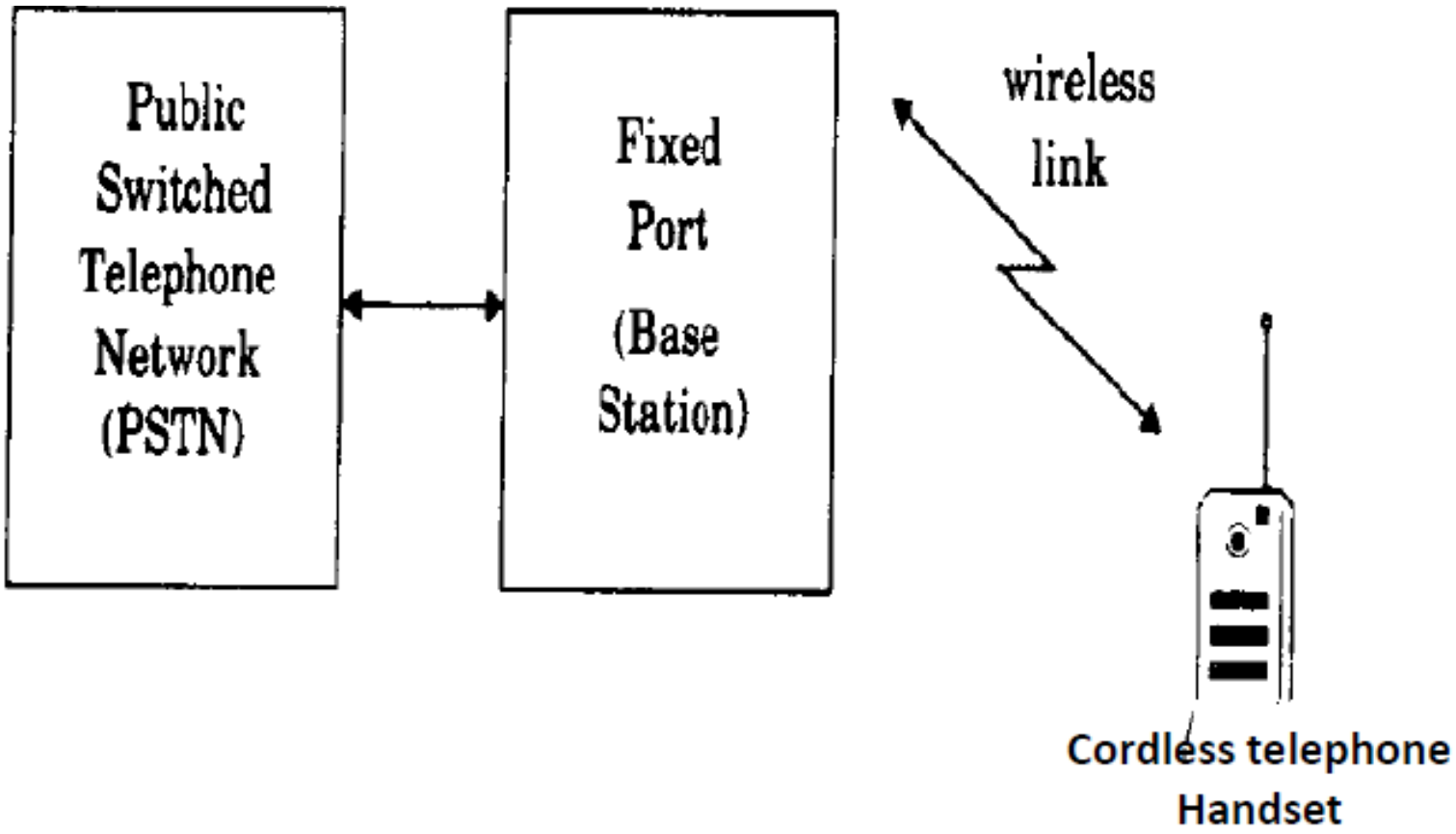


Figure 1.3 A wide area paging system. The paging control center dispatches pages received from the PSTN throughout several cities at the same time.

CORDLESS TELEPHONE SYSTEMS

- Cordless telephone systems are full duplex comm. systems that use radio to connect a portable handset to a dedicated BS,which is then connected to a dedicated telephone line with a specific telephone no on the PSTN.
- In first generation cordless telephone systems(manufactured in 1980s) ,the portable unit communicates only to the dedicated base unit and only over distances of a few tens of meters.
- Early cordless telephones operate solely as extension telephones to a transceiver connected to subscriber line on the PSTN & are primarily for in-home use.

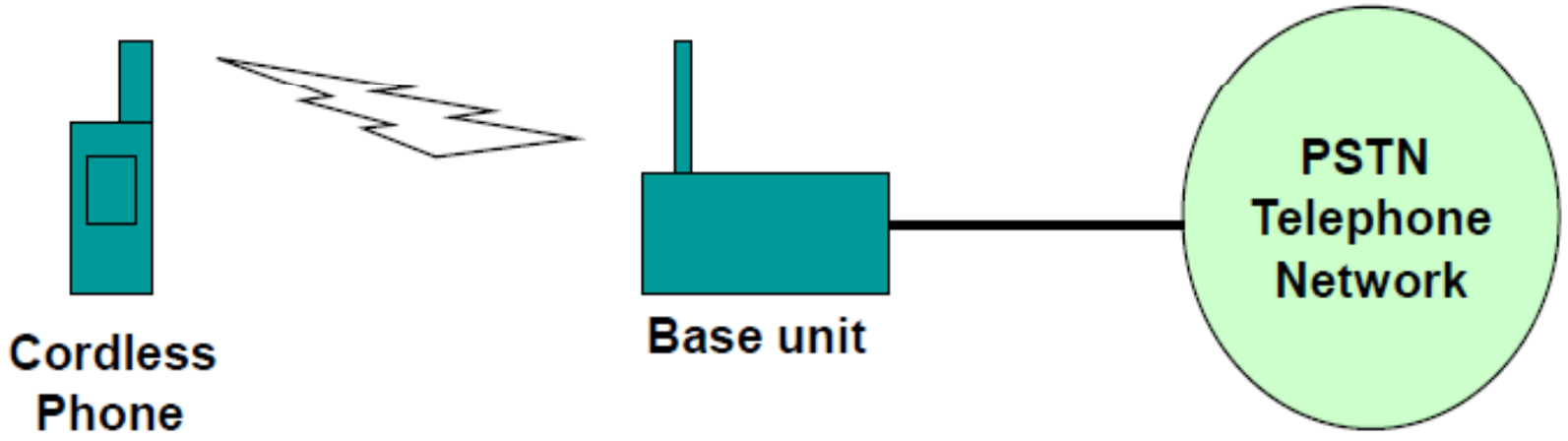
Diagram of Cordless Telephone System



CORDLESS TELEPHONE SYSTEMS…..

- Second generation cordless telephone have introduced which allow subscribers to use their handsets at many outdoor locations within urban centers such as London or Hong Kong.
- Modern cordless telephones are sometimes combined with paging receivers so that a subscriber may first be paged & then respond to the page using the cordless telephone.
- Cordless telephone system provide the user with limited range of mobility, as it is usually not possible to maintain a call if the user travels outside the range of the BS.
- Typical second generation base stations provide coverage ranges up to a few hundred meters.

Cordless Telephones



FEATURES OF CORDLESS PHONE SYSTEM

FEATURE	MOBILE UNIT	BASE STATION
COVERAGE RANGE	LOW	LOW
REQUIRED INFRA-STRUCTURE	LOW	LOW
COMPLEXITY	MODERATE	`LOW
HARDWARE COST	LOW	MODERATE
CARRIER FREQUENCY	1-3 GHz	1-3 GHz
FUNCTIONALITY	TRANS-RECEIVER	TRANS-RECEIVER

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 < 50ms
  - Simple Frequency Shift Modulation (FSK)
  - Time Division Duplex (TDD)

Comparison of Various WirelessSystems

Table 1.5 Comparison of Mobile Communication Systems—Mobile Station

Service	Coverage Range	Required Infra-structure	Complexity	Hardware Cost	Carrier Frequency	Functionality
TV Remote Control	Low	Low	Low	Low	Infrared	Transmitter
Garage Door Opener	Low	Low	Low	Low	< 100 MHz	Transmitter
Paging System	High	High	Low	Low	< 1 GHz	Receiver
Cordless Phone	Low	Low	Moderate	Low	< 1 GHz	Transceiver
Cellular Phone	High	High	High	Moderate	< 2 GHz	Transceiver

Comparison of Various Wireless Systems

Table 1.6 Comparison of Mobile Communication Systems—Base Station

Service	Coverage Range	Required Infra-structure	Complexity	Hardware Cost	Carrier Frequency	Functionality
TV Remote Control	Low	Low	Low	Low	Infrared	Receiver
Garage Door Opener	Low	Low	Low	Low	< 100 MHz	Receiver
Paging System	High	High	High	High	< 1 GHz	Transmitter
Cordless Phone	Low	Low	Low	Moderate	< 1 GHz	Transceiver
Cellular Phone	High	High	High	High	< 2 GHz	Transceiver