IMP Note to Self

IMP Note to Students

- It is important to know that just login to the session does not guarantee the attendance.
- Once you join the session, continue till the end to consider you as present in the class.
- IMPORTANTLY, you need to make the class more interactive by responding to Professors queries in the session.
- **Whenever Professor calls your number / name ,you need to respond, otherwise it will be considered as ABSENT**

Wireless & Mobile Communication (CSI ZG520)

Dr. Chandrashekhar P Chavan

chandrashekhar.chavan@wilp.bits-pilani.ac.in

+91- 9844556230, 9110291866

BITS Pilani

Pilani|Dubai|Goa|Hyderabad

http://taxila-aws.bits-pilani.ac.in/

innovate achieve lead

BITS Pilani

Pilani|Dubai|Goa|Hyderabad

Introduction

Course Objective

CO1 To learn the fundamentals of Mobile telecommunication systems and wireless networks.

CO2 To learn different modulation schemes and radio propagation models used in communication systems.

CO3 To learn multiple access techniques used in wireless networks.

CO4 To learn modern wireless communication systems.

CO5 To learn traffic routing in wireless networks.

Learning Outcomes

LO1 Students will be able to acquire the concepts of wireless and mobile communication systems.

LO2 Students will be able to differentiate various cellular technologies, modulation techniques and radio propagation models used in communication systems.

LO3 Students will be able to describe multiple access techniques and equalization, diversity and channel coding techniques used in wireless communication.

LO4 With the gained knowledge, students will be able to compare competitive technologies and the trade-offs associated.

Modular Content Structure

M1: Introduction to Wireless Systems and Modern Wireless Communication System.

M2:The Cellular Concept- System Design Fundamentals

M3: Cellular Network

M4: Mobile Radio Propagation: Large scale path Loss_ Part 1

M5: Mobile Radio Propagation: Large scale path Loss_ Part 2

M6: Mobile Radio Propagation: Large scale path Loss_ Part 3

M7: Small Scale fading_Part 1

M8: Small Scale fading_Part 1

Modular Content Structure

M9: Modulation Techniques for Mobile Radio_ Amplitude Modulation

M10: Modulation Techniques for Mobile Radio_ Angle Modulation

M11: Digital Modulation Techniques_1

M12: Digital Modulation Techniques_2

M13: Equalization & Diversity Techniques

M14: Concepts of OFDM & MIMO

M15: Multiple Access Techniques

M16: Wireless Networking

Text Book:

T1: "Wireless Communication Principles and Practice" by Theodore. S. Rappaport Second Ed., Prentice Hall of India, 2008.

T2: "Wireless Communications and Networks" by William Stallings – Pearson Education Ltd.

R1: "Mobile Communication" by Jochen H. Schiller, Addison –Wesley, Pearson Education Ltd., 2000.

R2: "Wireless and Mobile Network Architectures" by Yi-Bing Lin and Imrich Chaltamac, John Wiley and Sons, 2001.

M1: Introduction to Wireless Systems and Modern Wireless Communication System.

innovate achieve lead

Type Description/Plan/Reference

RL 1.1 Introduction to wireless and Mobile communication

RL 1.2 Types of wireless communication

RL 1.3 A Modern wireless communication system

CS 1 A brief summary of recorded lectures, Examples of wireless communication system- paging systems, wireless local loop, WLAN, Bluetooth, Prioritizing handoff

HW 1 T1: Problems: 1.2, 1.5, 1.9, 1.16, 2.1, 2.2, 2.8

LE 1 Introduction to MATLAB/Simulink

Programming Language:

1. MATLAB/SIMULINK.
2. Python - NumPy Package.

Introduction

- Wireless communications has been associated with cellular telephony, as this is the biggest market segment, and has had the highest impact on everyday lives.
- In recent times, wireless computer networks have also led to a significant change in working habits and mobility of workers – answering emails in a coffee shop has become an everyday occurrence.
- But besides these widely publicized cases, a large number of less obvious applications have been developed, and are starting to change our lives.

- This variety of new applications causes the technical challenges for the wireless engineers to become bigger with each day.
- To give an overview of the solution methods for current as well as future challenges.
- There are two paths to developing new technical solutions:
- Engineering Driven and Market Driven.
- In the first case, the engineers come up with a brilliant scientific idea – without having an immediate application in mind.

- As time progresses, the market finds applications enabled by this idea.
- In the other approach, the market demands a specific product and the engineers try to develop a technical solution that fulfills this demand.

- Market Demands.
- We start out with a brief history of wireless communications, in order to convey a feeling of how the science, as well as the market, has developed in the past 100 years.
- Then follows a description of the types of services that constitute the majority of the wireless market today.
- Each of these services makes specific demands in terms of data rate, range, number of users, energy consumption, mobility, and so on.
- A description of the interaction between the engineering of wireless devices and the behavioral changes induced by them in society.

How It All Started

- Wireless communication is the oldest form of communication like shouts and drums did not require any wires or cables to function.
- Wireless communications started only with the work of Maxwell and Hertz, who laid the basis for the understanding of the transmission of electromagnetic waves.
- In 1898, Marconi , made his well-publicized demonstration of wireless communications from a boat to the Isle of Wight in the English Channel.
- It is noteworthy that while Tesla was the first to succeed in this important endeavor, Marconi had the better public relations, and is widely cited as the inventor of wireless communications, receiving a Nobel prize in 1909.

Types of Services

- Broadcast
- Paging
- Cellular Telephony
- Trunking Radio
- Cordless Telephony
- Wireless Local Area Networks
- Personal Area Networks
- Fixed Wireless Access

Broadcast

The first wireless service was broadcast radio.

Four properties differentiate broadcast radio

1. The information is sent unidirectional, i.e., in one direction only.
2. The information transmitted is same for all receivers.
3. The information is transmitted continuously.
4. In many cases like TV

or radio, multiple transmitters send the same information

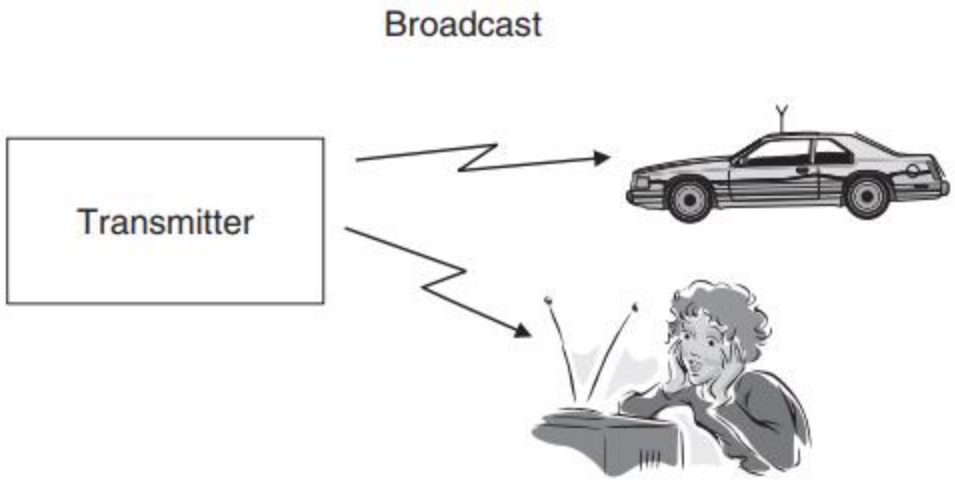


Figure Principle of broadcast transmission.

Paging

Similar to broadcast, paging systems are unidirectional wireless communications systems. The following properties characterize them:

1. The user can only receive information, but cannot transmit.
2. The information is intended for and received by, only a single user.
3. The amount of transmitted information is very small.

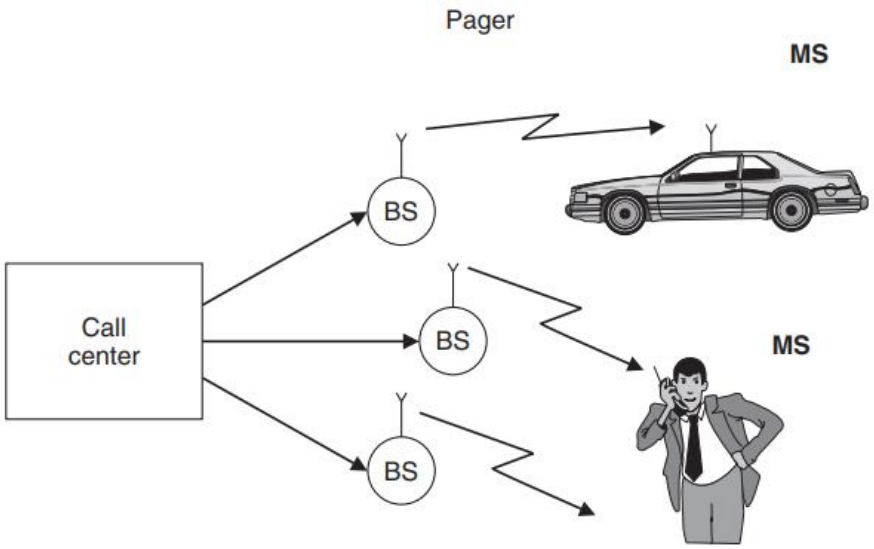


Figure Principle of a pager.

Cellular Telephony

Cellular telephony is the economically most important form of wireless communications. The information flow is bidirectional. A user can transmit and receive information at the same time.

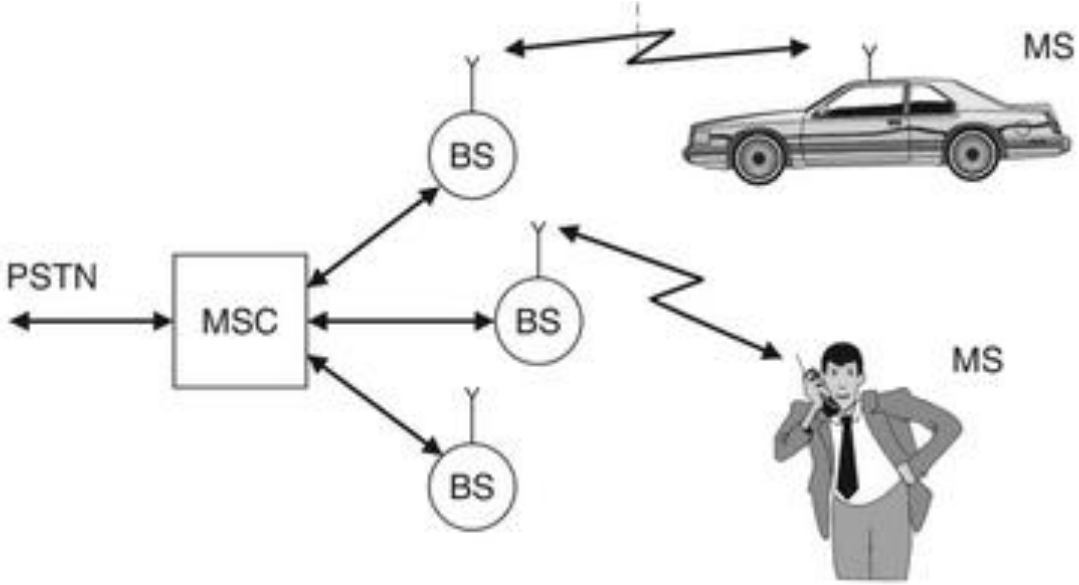


Figure Principle of a cellular system. *In this figure*: PSTN, Public Switched Telephone Network; MSC, Mobile Switching Center; BS, Base Station; MS, Mobile Station.

Trunking Radio

Trunking radio systems are an important variant of cellular phones, where there is no connection between the wireless system and the public switched telephone network (PSTN); therefore, it allows the communications of closed user groups. Obvious applications include police departments, fire departments, taxis, and similar services. The closed user group allows following operations

1. Group calls
2. Call priorities
3. Relay networks

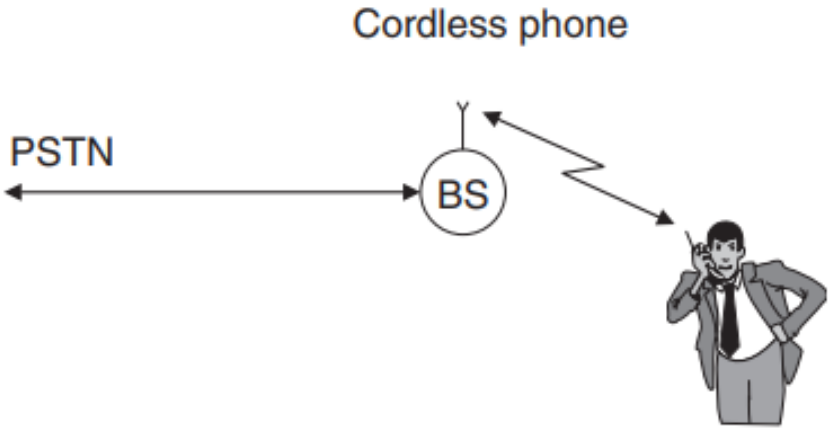


Figure Principle of a simple cordless phone.

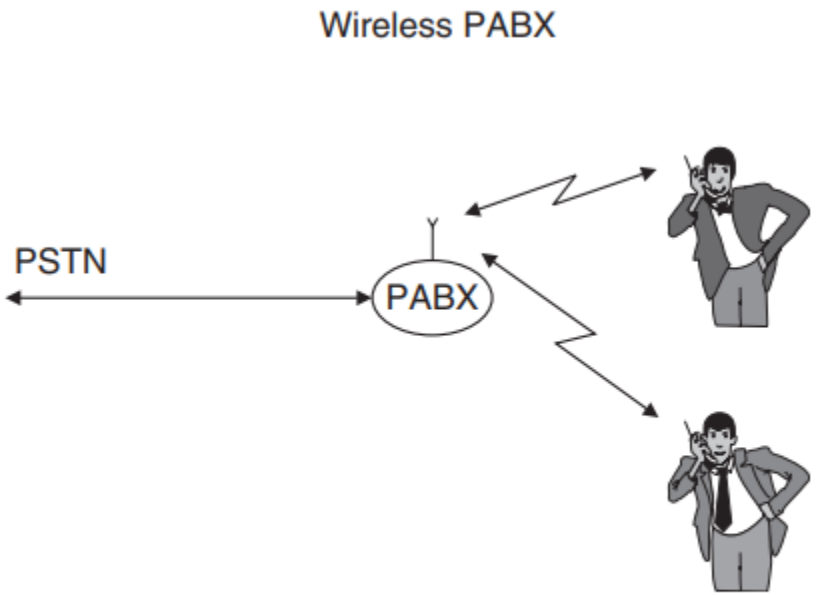


Figure Principle of a wireless private automatic branch exchange.

Wireless Local Area Networks

- The functionality of Wireless Local Area Networks (WLANs) is very similar to that of cordless phones connecting a single mobile user device to a public landline system.
- A major difference between wireless LANs and cordless phones is the required data rate. While cordless phones need to transmit (digitized) speech, which requires at most 64 Kbit/s, wireless LANs should be at least as fast as the Internet that they are connected.

Personal Area Networks

- When the coverage area becomes even smaller than that of WLANs, we speak of Personal Area Networks (PANs).
- Such networks are mostly intended for simple cable replacement duties.

For example, devices following the Bluetooth standard allow connecting a hands-free headset to a phone without requiring a cable; in that case, the distance between the two devices is less than a meter.

Fixed Wireless Access

- Fixed wireless access systems can also be considered as a derivative of cordless phones or WLANs, essentially replacing a dedicated cable connection between the user and the public landline system.

The main difference from a cordless system is that

(i) there is no mobility of the user devices and

(ii) the BS almost always serves multiple users.

Requirements for the Services

- Data Rate
- Range and Number of Users
- Mobility
- Energy Consumption
- Use of Spectrum

Data Rate

Data rates for wireless services ranges from few bits per second to several gigabits per second, depending on the application.

Type of application	Data rate
Sensor networks	1 Kbit/s
Speech communications	5 and 64 Kbit/s
Elementary data services	10 and 100 Kbit/s
Computer peripherals and similar devices	1Mbit/s
High-speed data services	0.5 to 100 Mbit/s
Personal Area Networks	100 Mbit/s

Range and Number of Users

Another distinction among the different networks is the range and the number of users that they serve. By range, we mean here the distance between transmitter and receiver.

The coverage area of a system can be made almost independent of the range by just combining a larger number of BSs into one big network.

Type of network	Range
Body Area Networks (BANs)	1meter
Personal Area Networks	10 meter
WLANs	up to 100 meter
Cellular systems	10 or even 30 km
Satellite systems	1,000 km radius
Fixed wireless access services	100 m and several tens of kilometers

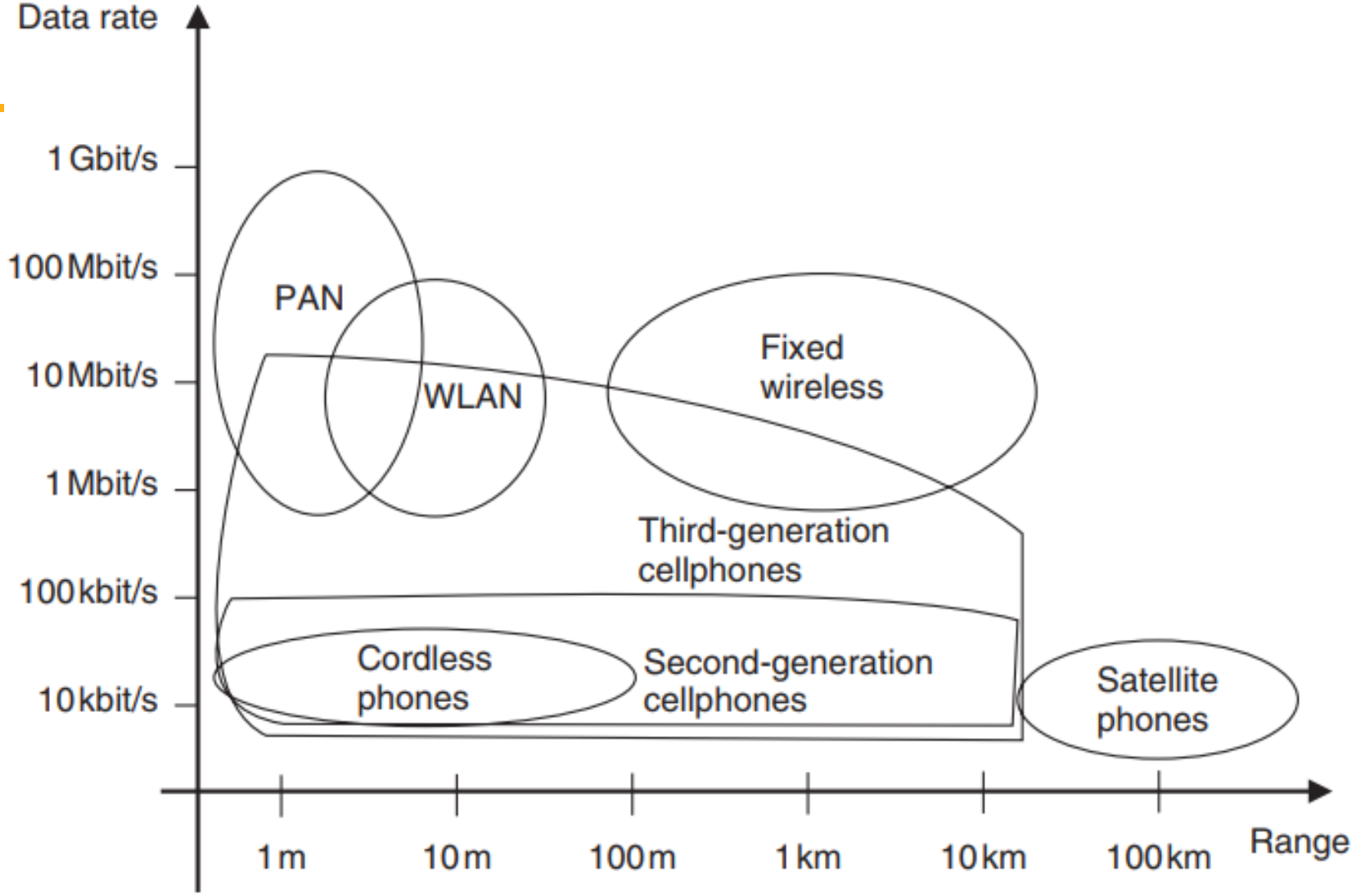


Figure Data rate versus range for various applications.

Mobility

- Wireless systems also differ of mobility that they have to allow for the users.
- The ability to move around while communicating is one of the main factors of wireless communication for the user.

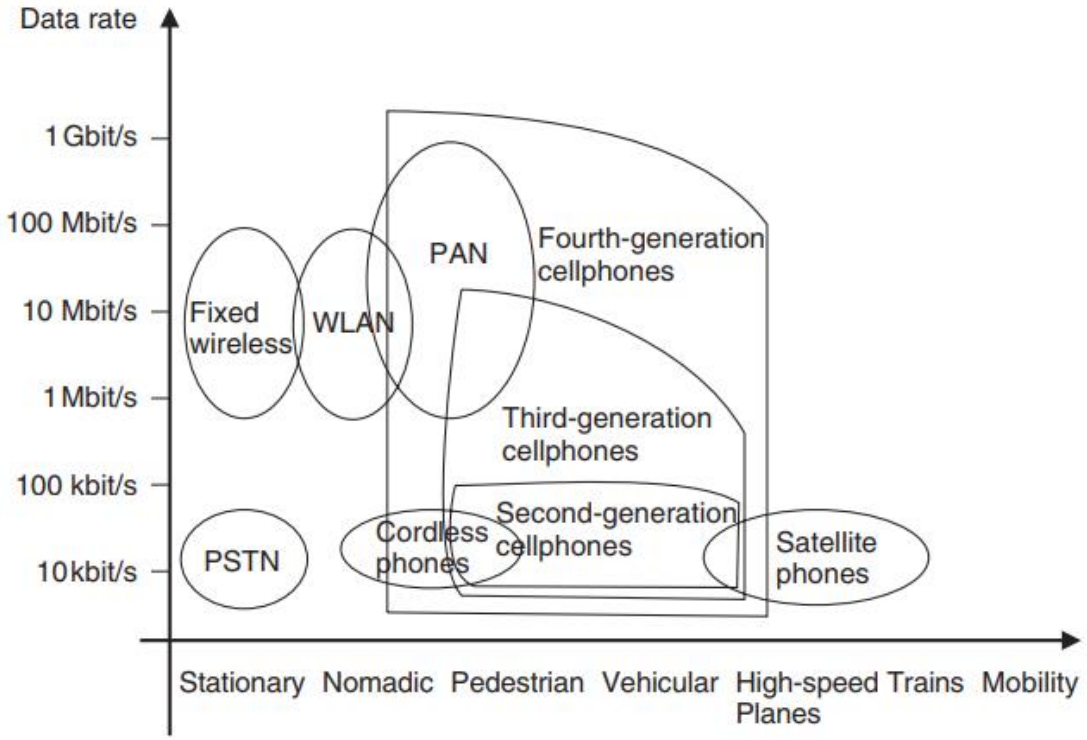


Figure Data rate versus mobility for various applications.

Energy Consumption

Energy consumption is a critical aspect of wireless devices. Most wireless devices use (one way or rechargeable) batteries, as they should be free of any wires both the ones used for communication and the ones providing the power supply.

- Rechargeable batteries
- One way batteries
- Power mains

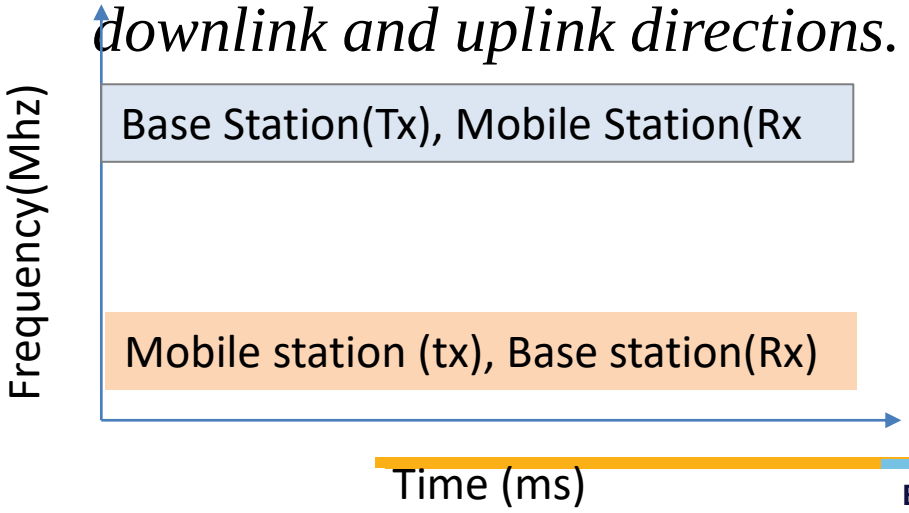
Use of Spectrum

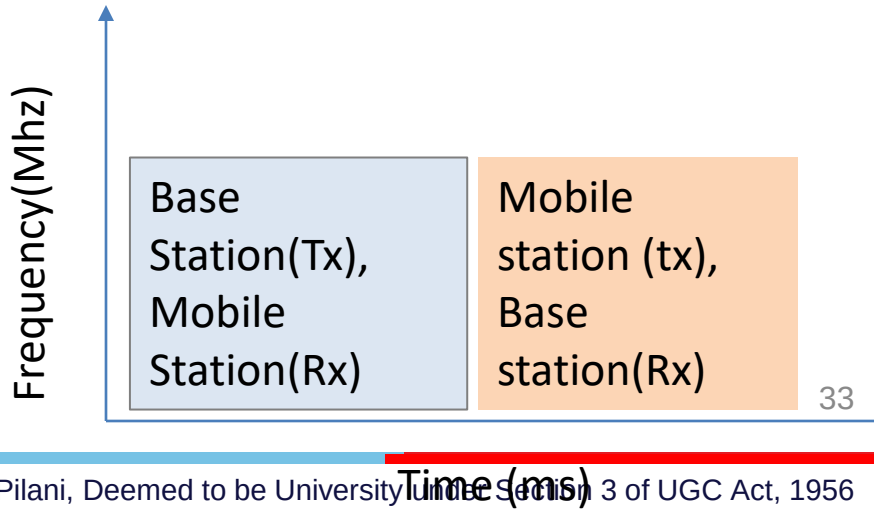
Spectrum can be assigned on an exclusive basis, or on a shared basis. That determines to a large degree the multiple access scheme and the interference resistance that the system has to provide:

- Spectrum dedicated to service and operator
- Spectrum allowing multiple operators
- Spectrum dedicated to a service
- free spectrum
- Adaptive spectral usage

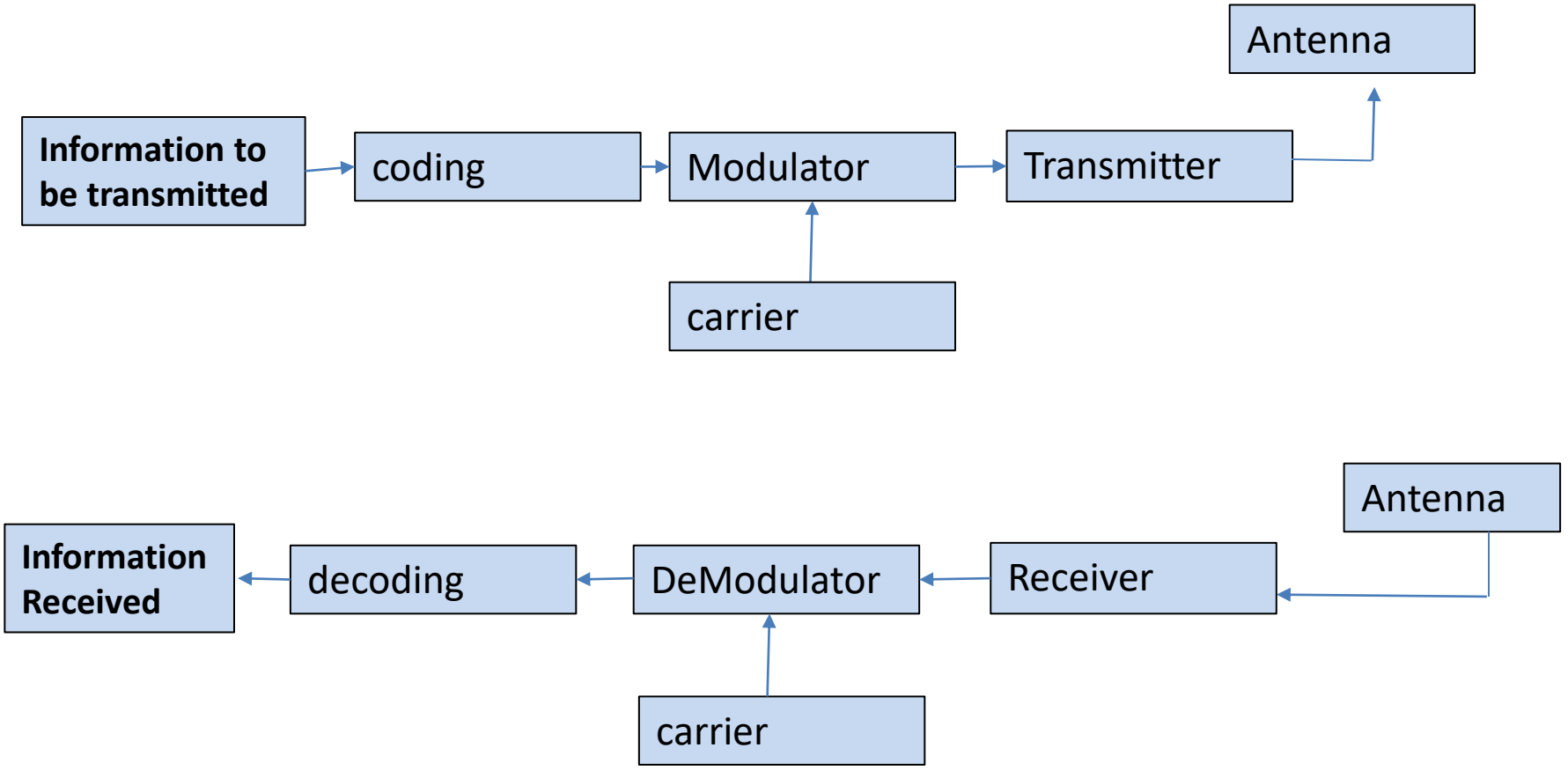
Direction of Transmission (The duplex concept)

- *Simplex systems*– e.g., broadcast systems and pagers.
- *Semi-duplex systems – e.g.*,Walkie-talkies
- *Full-duplex systems* – e.g., cellphones and cordless phones.
- ***FDD*** *uses two separate frequencies for the uplink (from the mobile to the BS) and the downlink (from the BS to the mobile).*
  TDD *uses a single frequency to transmit signals in both the downlink and uplink directions.*





Wireless communication systems



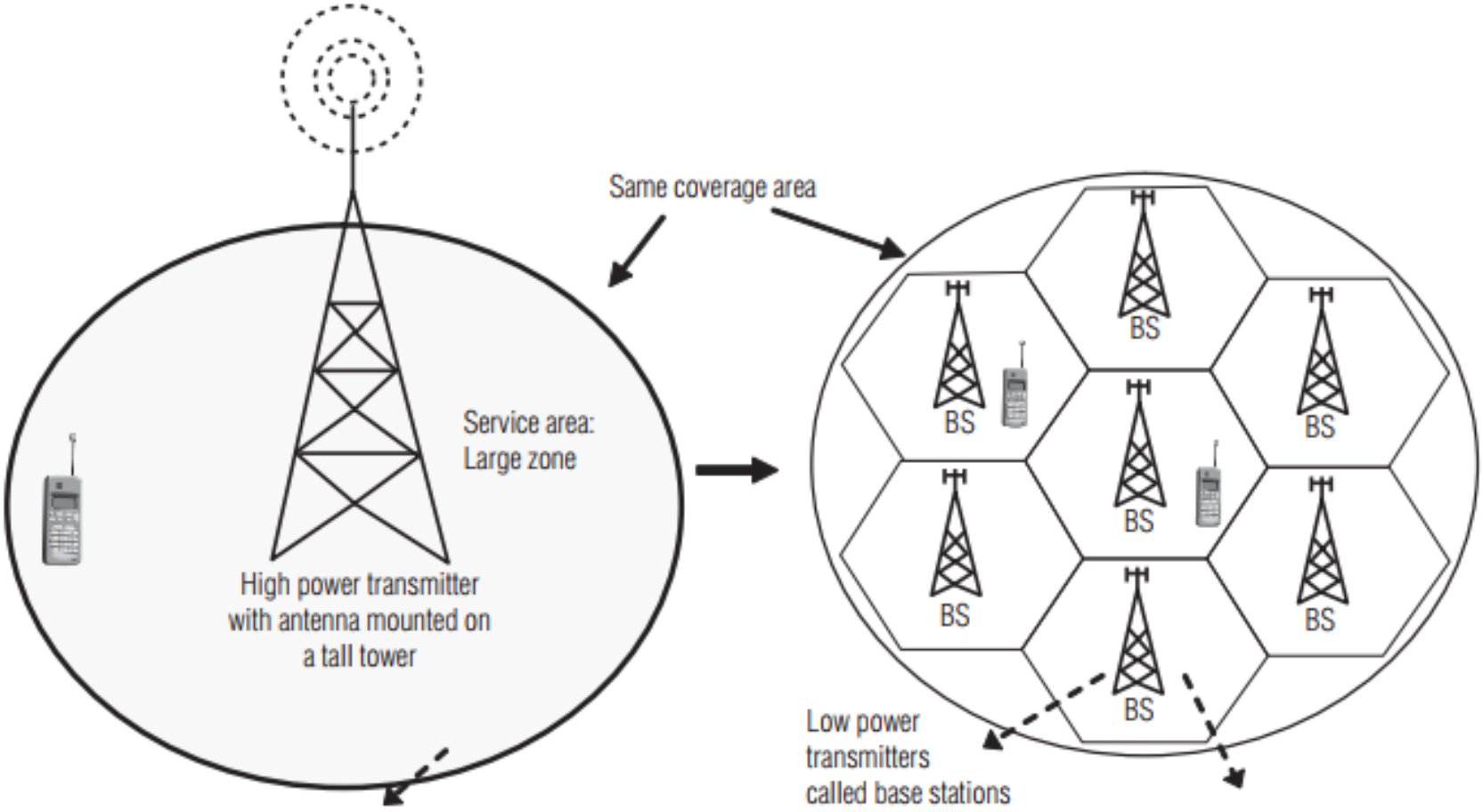


Figure : Early mobile radio system and cellular system

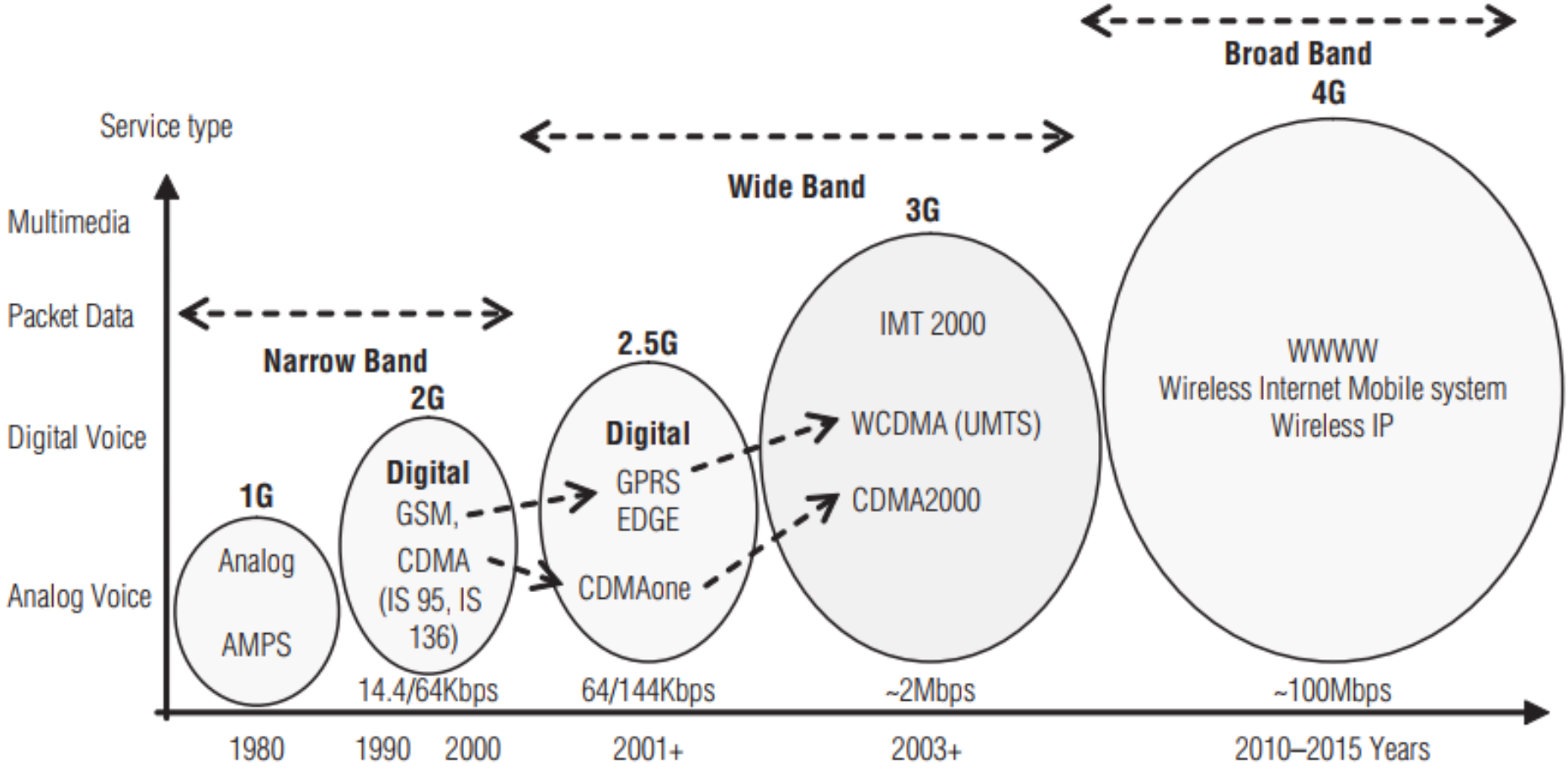


Figure : Evolution of cellular systems

Cellular Network- 1G

Goal: To develop a working system that could provide basic voice service

Time frame: 1980s in US

Technology: FDMA/FDD

Speed: 2.4Kbps

1G network used Analogue circuit-switched technology with FDMA 800–900 MHz frequency bands.

Example Systems:

- Analogue Mobile Phone System (AMPS-USA)
- Total Access Communication System (TACS-UK)
- Nordic Mobile Telephone (NMT-Europe)

In AMPS, two 25-MHz bands are allocated. One 25-MHz band is for communication from BS to mobile unit and the other for communication from mobile unit to BS.

The following are the limitations of 1G:

- Supports only speech
- Low traffic capacity
- Unreliable handover
- Long-call setup time and frequent call drops
- Inefficient use of bandwidth and poor battery life
- Poor voice quality and large phone size
- Allows users to make voice calls in 1 country only

- the first handheld device from Motorola Company which was available in 1984 in 1G network.

Cellular Network-2G

- Goal: Digital voice service with improved quality and also provide better services
- Time Frame: Launched in Finland in 1991
- 2G technology supports data, speech, FAX, SMS, and WAP services.
- The frequency bands used by GSM are 890–960 MHz and 1710–1880 MHz. (890–915 MHz - uplink MS to BS, 935–960 MHz downlink BS to MS)
- Used digital signals

Digital modulation formats were introduced in this generation with the main technology as TDMA/FDD

Data Speed: upto 64kbps

Services like text message, picture message was included.

Example Systems:

- Global System for Mobile Communications (GSM) (TDMA and FDMA)
- IS-95(Interim Standard) (CDMA)

Ericsson GH218 which was introduced in 1994 and operated in 2G networks.

The following are limitations of 2G:

- Provides low data rates ranging from 9.6 kbps to 28.8 kbps.
- Circuit-switched network, where the end systems are dedicated for the entire call session. This causes reduction in usage of bandwidth and resources.
- Too many 2G standards globally (e.g. GSM, CDMA, PDC, and PHS)

Interim generation (2.5G)

- Goal: To provide better data rates and wider range of data services and it was a transition from 2G to 3G
- Time frame: 2000-2002
- *The mobile technology using GPRS standard has been termed as 2.5G.*
- The 2.5G was started in 1998 with added GPRS and enhanced data rates for GSM evolution (EDGE).

Cellular Network- 3G

- The aim of 3G systems is to provide communication services from person-to-person at any place (global roaming) and at any time through any medium with guaranteed quality of service.
- high-speed internet access, live video communications, and simultaneous data and voice transmission .
- The 3G technology has added multimedia facilities to 2.5G phones.
- 3G operates in the frequency band of 1710–2170 MHz.
- It provides high transmission rates from 348 Kbps in a moving vehicle to 2 Mbps for stationary or mobile users.

- Examples of 3G system are universal mobile telecommunication systems (UMTS) and international mobile telecommunications at 2,000 MHz (IMT-2000).
- UMTS are designed to provide different types of data rates, based on the following circumstances:

  up to 144 kbps for moving vehicles

  384 kbps for pedestrians

  2 Mbps for indoor or stationary users

LG U8110 that was introduced in 2004 and is operating in 3G networks.

The following are the drawbacks of 3G system:

- High bandwidth requirement
- High spectrum licensing fees
- Expense and bulk size of 3G phones
- Lack of 2G mobile user buy in for 3G wireless service
- Lack of network coverage because it is still a new service
- High prices of 3G mobile services in some countries

Cellular Network- 4G

- Goal: High mobility, High data rate
- Frequency Band: 2 to 8 Ghz.
- Download speed is upto 100 Mbps for moving users and 1GPS for stationary users.

The following modulation techniques are proposed to be used in the 4G cellular phones.

Variable spreading factor-orthogonal frequency and code division multiplexing (VSF-OFCDM).

Variable spreading factor code-division multiple access (VSF- CDMA).

LTE (Long Term Evolution)

- ✓ Uses Orthogonal Frequency Division Multiplexing (OFDM)
- ✓ Uses Multi-input Multi-output(MIMO) for enhanced throughput

Features of 4G

- Support for interactive multimedia, voice, streaming video, Internet, and other broadband services
- Fully IP based mobile system
- High speed, high capacity, and low cost-per-bit
- Global access, service portability, and scalable mobile services
- Seamless switching, and a variety of Quality of Service
- Better scheduling and call-admission-control techniques
- Better spectral efficiency
- Interoperability with existing wireless standards
- Packet switched network

Advantages of 4G

- Affordable communication services.
- High speed, high capacity and low cost per bit.
- Support for interactive multimedia, voice , streaming video, Internet and other broadband services.
- Global access, Service portability and scalable mobile services and variety of quality of services provided.
- Better spectral efficiency.
- seamless network of multiple protocol and air interfaces.

Table History of 1G, 2G, 3G, and 4G technologies

Technology	Various generations				
	1G	**2G**	**2.5G**	**3G**	**4G**
Design began	1970	1980	1985	1990	2000
Implementation	1984	1991	1999	2002	2012–2015
Service	Analogue voice	Digital voice	High-capacity packets, MMS	High-capacity broadband data	Higher capacity, completely IP, Multimedia
Multiple access	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	OFDMA
Standards	AMPS, TACS, NMT	CDMA, GSM, PDC	GPRS, EDGE	WCDMA, CDMA2000	Single standard
Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Core network	PSTN	PSTN	PSTN, Packet network	Packet network	Internet

Handoff: A crucial component of the cellular concept is the notion of handoffs. Handoff is the process of transferring an active call from one cell to another as the mobile unit moves from one cell to the other.

Handoff operation involves identifying a new BS and allocation of voice and control signals associated.

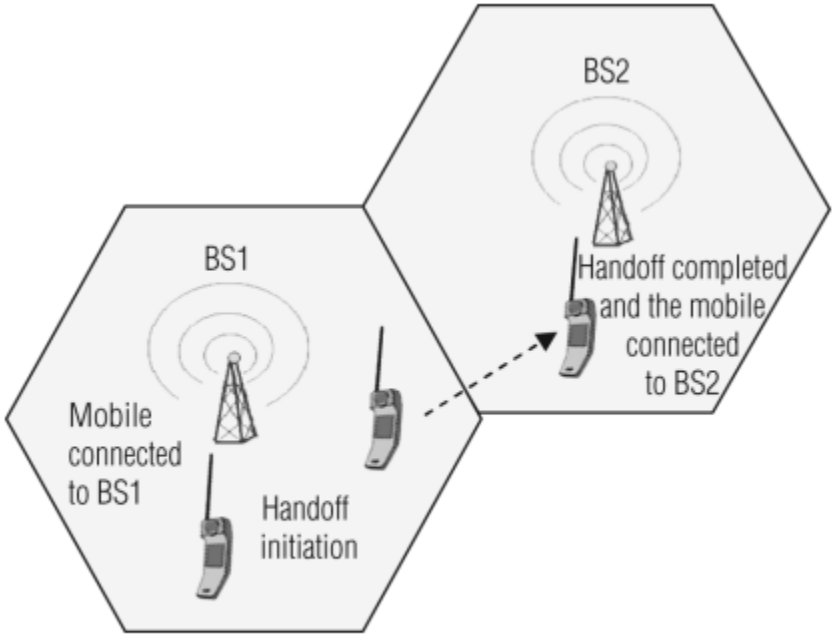


Figure Call handoff process

Handoff –

- high priority over call initiation requests
- must be performed successfully
- Infrequently
- be imperceptible.
- The margin $\Delta = P_{r\ handoff} - P_{r\ minimum\ usable}$ cannot be too large or too small.

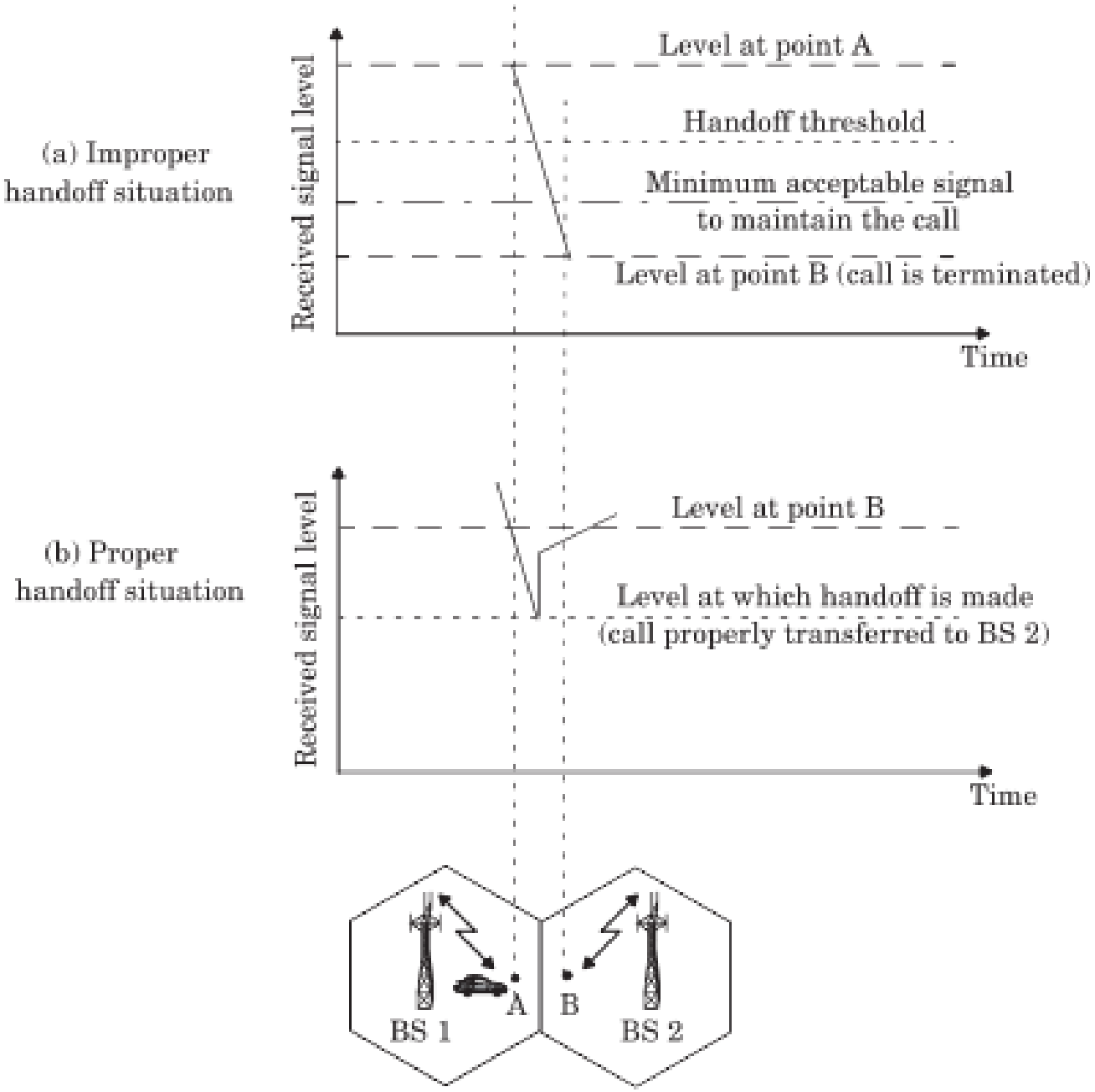


Figure Illustration of a handoff scenario at cell boundary.

- In deciding when to handoff, it is important to ensure that the drop in the measured signal level is not due to momentary fading.
- Information about the vehicle speed is useful in handoff decisions.
- Dwell time –The time over which a call may be maintained within a cell without handoff.
- The statistics of dwell time are important in the practical design of handoff algorithm.

- In first generation analog cellular system, the locator receiver is used for handoff.
- In second generation system, handoff decisions are mobile assisted –mobile assisted handoff (MAHO).
- Intersystem handoff –different cellular systems –roamer.

Prioritizing Handoffs

- Guard channel concept –can be used with dynamic channel assignment strategies to increase spectrum utilization.
- Queuing of handoff –possible due to the fact that there is a finite time interval between handoff threshold time and call-terminated time

Practical Handoff Considerations

innovate achieve lead

- Several handoff schemes have been devised to handle the simultaneous traffic of high speed and low speed users – minimizing the handoff intervention from the MSC

HOME WORK

1.2 If 0 dBm is equal to 1 mW (10^{-3} W) over a 50Ω load; express 10W in units of dBm.

1.5 In simulcasting paging systems, there usually is one dominant signal arriving at the paging receiver. In most, but not all cases, the dominant signal arrives from the transmitter closest to the paging receiver. Explain how the FM capture effect could help reception of the paging receiver. Could the FM capture effect help cellular radio systems? Explain how

1.9 Assume a I Amp-hour battery is used on a cellular telephone (often called a cellular subscriber unit). Also assume that the cellular telephone draws 35 mAin idle mode and 250 mA during a call. How long would the phone work (i.e., what is the battery life) if the user leaves the phone on continually and has one 3-minute call every day? Every 6 hours? Every hour? What is the maximum talk time available on the cellular phone in this example?

1.16 Discuss the similarities and differences between a conventional cellular radio system and a space-based (satellite) cellular radio system. What are the advantages and disadvantages of each system? Which system could support a larger number of users for a given frequency allocation? Why? How would this impact the cost of service for each subscriber?

2.1 In your place of work, how many modern wireless communications networks are available to you? Identify the types of services, the types of technologies, the commercial names of the service providers, and the commercial names of the equipment manufacturers that offer these wireless access capabilities.

2.2 In your home, how many modern wireless communications networks are available to you? Identify the types of services, the types of technologies, the commercial names of the service providers, and the commercial names of the equipment manufacturers that offer these wireless access capabilities.

2.8 How would multicarrier transmissions impact an operator's approach to allocating resources to accommodate a growing subscriber database that increasingly desires data connectivity over voice? How would heavy HSCSD usage impact a cellular carrier's strategy in allocating channels in the base stations of a cellular network? How would the rapid adoption of Voice over Internet Protocol (VoIP) impact cellular congestion? Explain.

IMP Note to Self