PowerPoint Slides

Wireless Communications

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Evolution of Wireless Communication Systems

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Evolution of Wireless Communication Systems

- Brief History of Wireless Communications
- **Advantages of Wireless Communications**
- Disadvantages of Wireless Communications
- **Wireless Network Generations**
- Comparison of Wireless Systems
- **Evolution to Next Generation Networks**
- Applications of Wireless Communications
- **Potential Market Areas**
- Challenges for Research

What is Wireless Communications?

Wireless Communications – The transmission of user information such as human voice, digital data, e-mail messages, video and other multimedia services without the use of wires

Brief History of Wireless Communications

- Radio and Television Communications
- **Radar Communications**
- **Satellite Communications**
- **Wireless and Mobile Communications**
- **Cellular Communications**

Transition from Analog to Digital Systems

- System capacity
- **Quality aspects**
- Compatibility with other systems such as ISDN

Advantages of Wireless Communications

- ✓ Mobility
- ✓ **Increased reliability**
- ✓ Ease of installation
- ✓ **Rapid disaster recovery**
- ✓ Lower cost

Disadvantages of Wireless Communications

- Radio signal interference
- **Security**
- Health hazards

Wireless Network Generations

- First Generation Analog Cellular Systems
- **Second Generation Digital Cellular Systems**
- Evolution from 2G to 3G Cellular Networks
- **Third Generation Digital Cellular Systems**
- Wireless Networking Technologies

Existing 1G Analog Cellular Systems

- AMPS : Advanced Mobile Phone System
- **ETACS: Enhanced Total Access Communication System**
- NMT : Nordic Mobile Telephone
- **JTACS : Japanese Total Access Communication System**
- NTACS: Narrowband JTACS

Analog Cellular Systems

Standard	Frequency Band	Multiple Access	Modulation	Channel BW
AMPS	**824-894 MHz**	**FDMA**	**FM**	**30KHz**
NAMPS	**824-894 MHz**	**FDMA**	**FM**	**10KHz**
ETACS	900 MHz	FDMA	FM	25KHz
NMT-450	450-470 MHz	FDMA	FM	25KHz
NMT-900	890-960 MHz	FDMA	FM	12.5KHz
JTACS	860-925 MHz	FDMA	FM	25KHz
NTACS	843-925 MHz	FDMA	FM	12.5KHz
NTT	400/800 MHz	FDMA	FM	25KHz

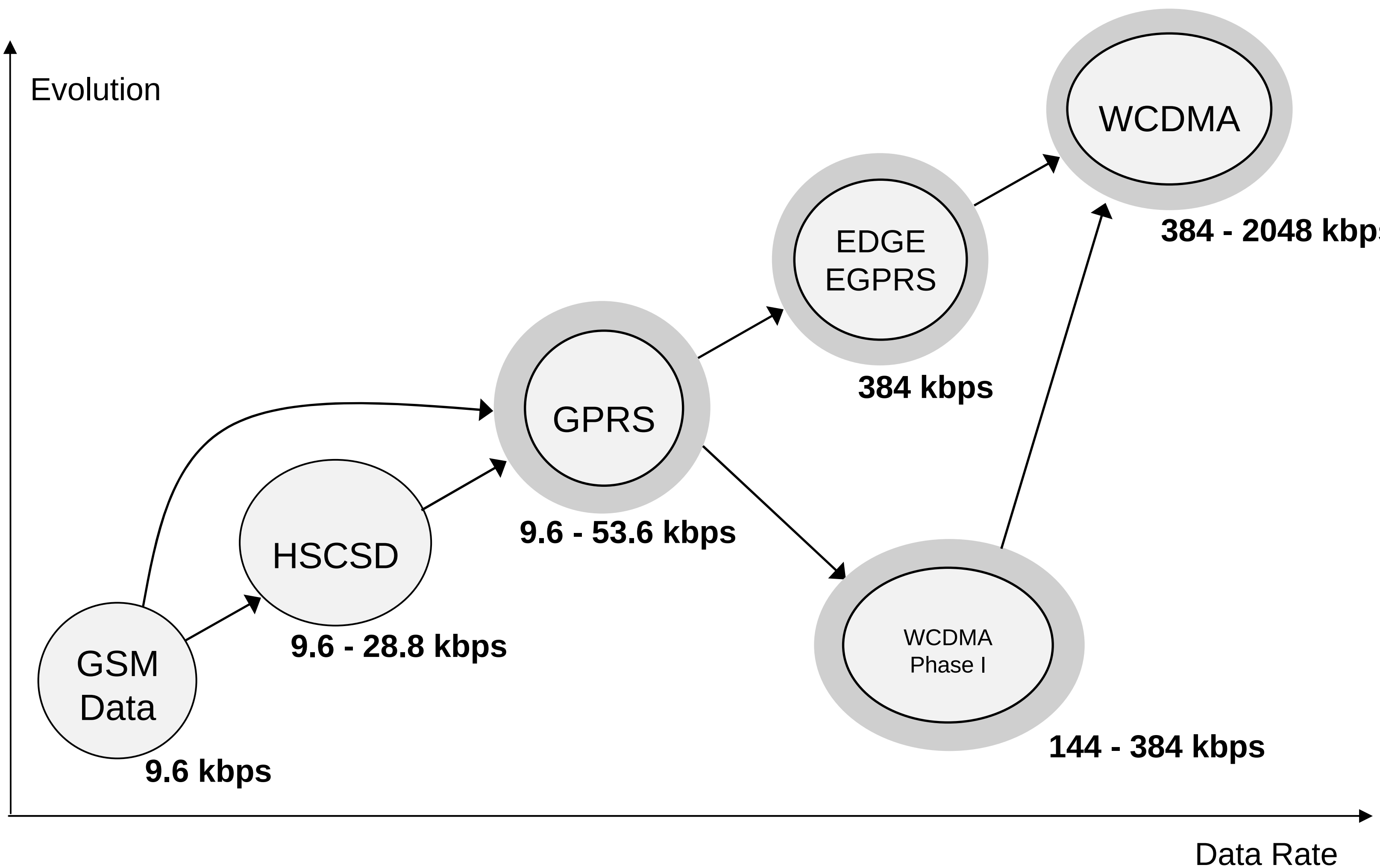
Second Generation Digital Cellular Systems

- IS-54/IS-136 : US Digital Cellular (USDC) - TDMA System
- **GSM : Global System for Mobile**
- PDC : Pacific Digital Cellular - A Japanese TDMA Cellular Standard
- **IS-95/cdmaOne : CDMA Cellular System**

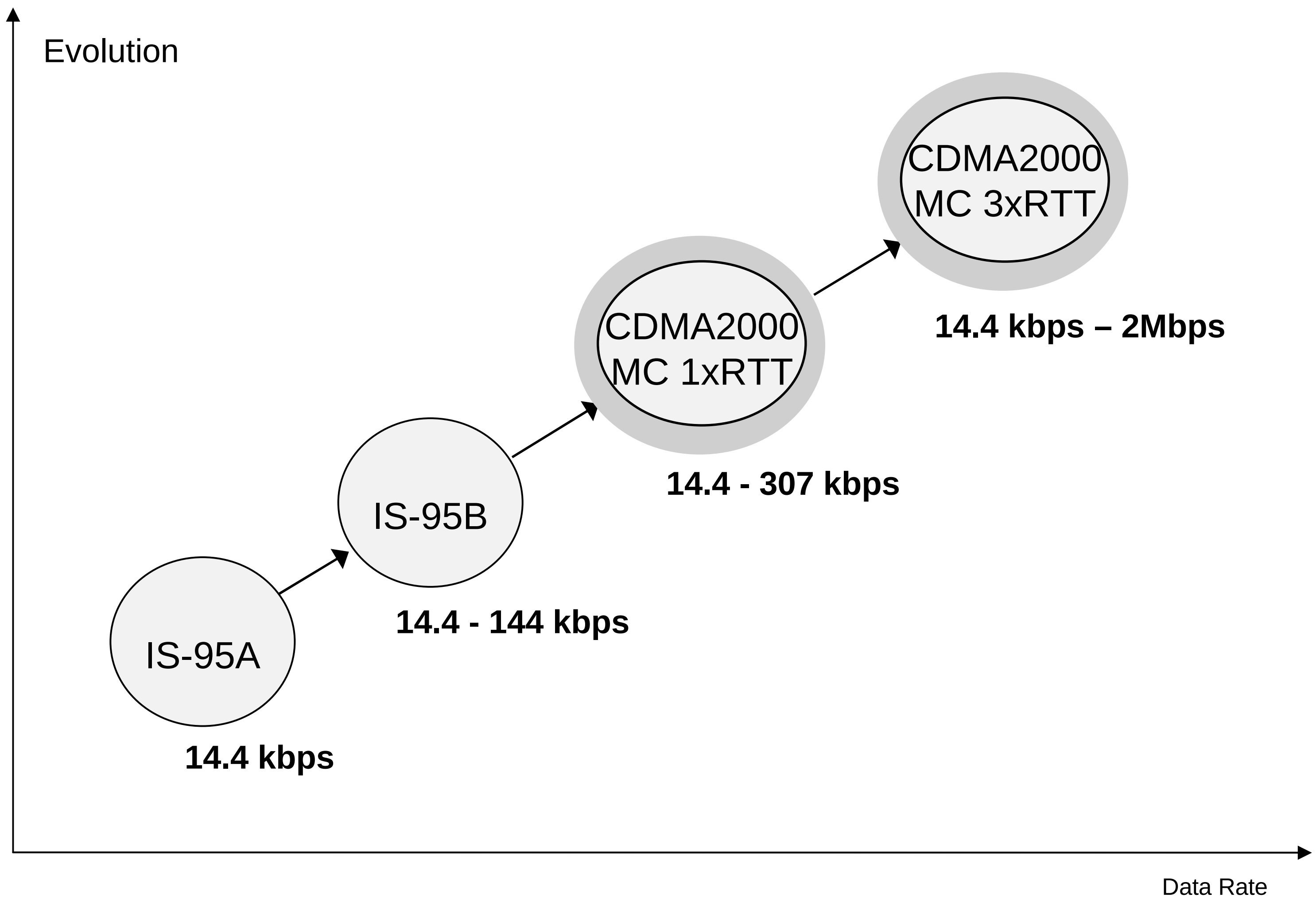
Digital Cellular Systems

Standard	Frequency Band	Multiple Access	Modulation	Channel BW
USDC	824-894 MHz	TDMA	π/4-DQPSK	30KHz
IS-95	824-894 MHz 1.8-2.0 GHz	CDMA	QPSK/ BPSK	1.25MHz
GSM	890-960 MHz	TDMA	GMSK	200KHz
PDC	810-1501 MHz	TDMA	Π/4-DQPSK	25KHz

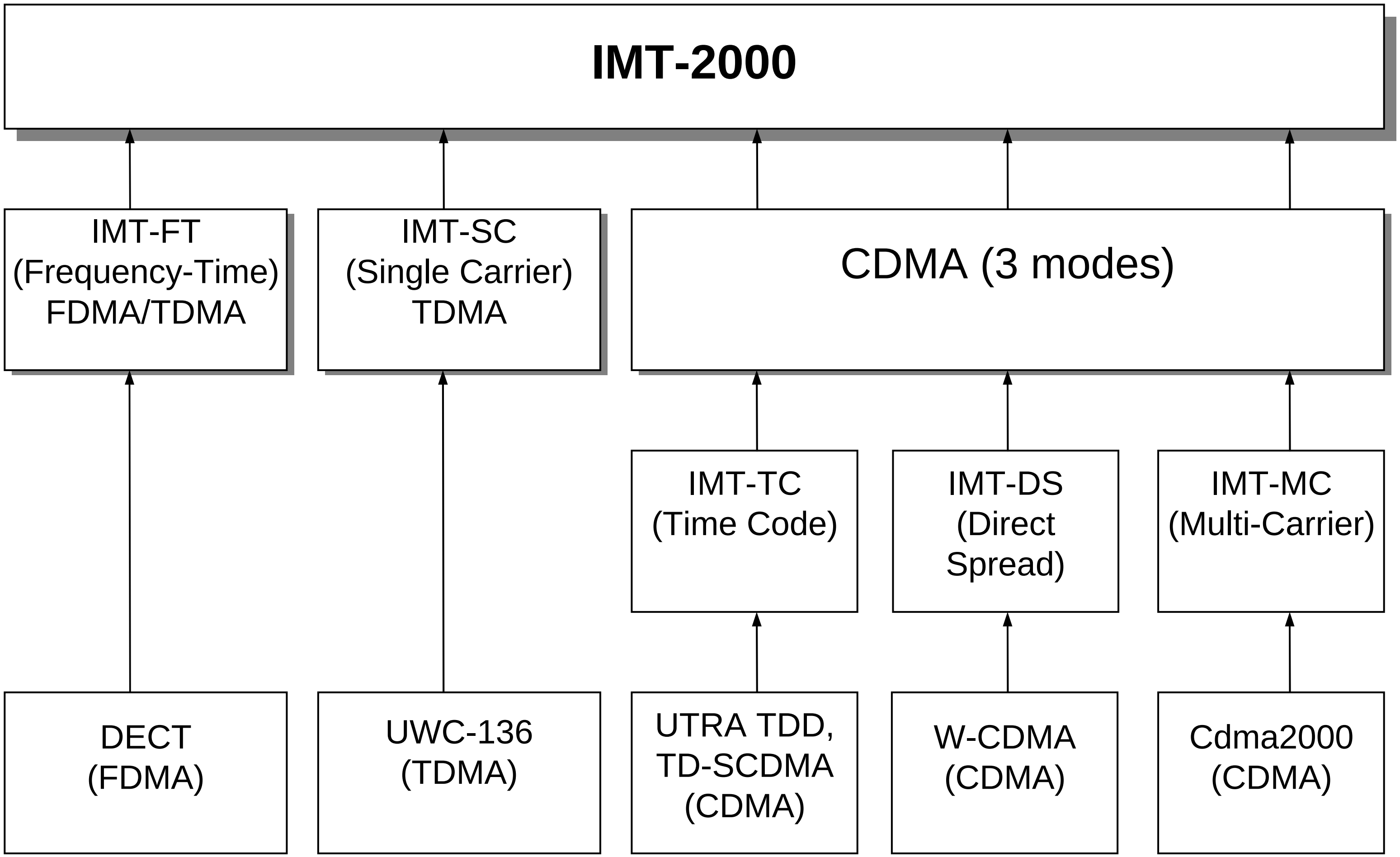
An Evolution Path from GSM to 3G Network



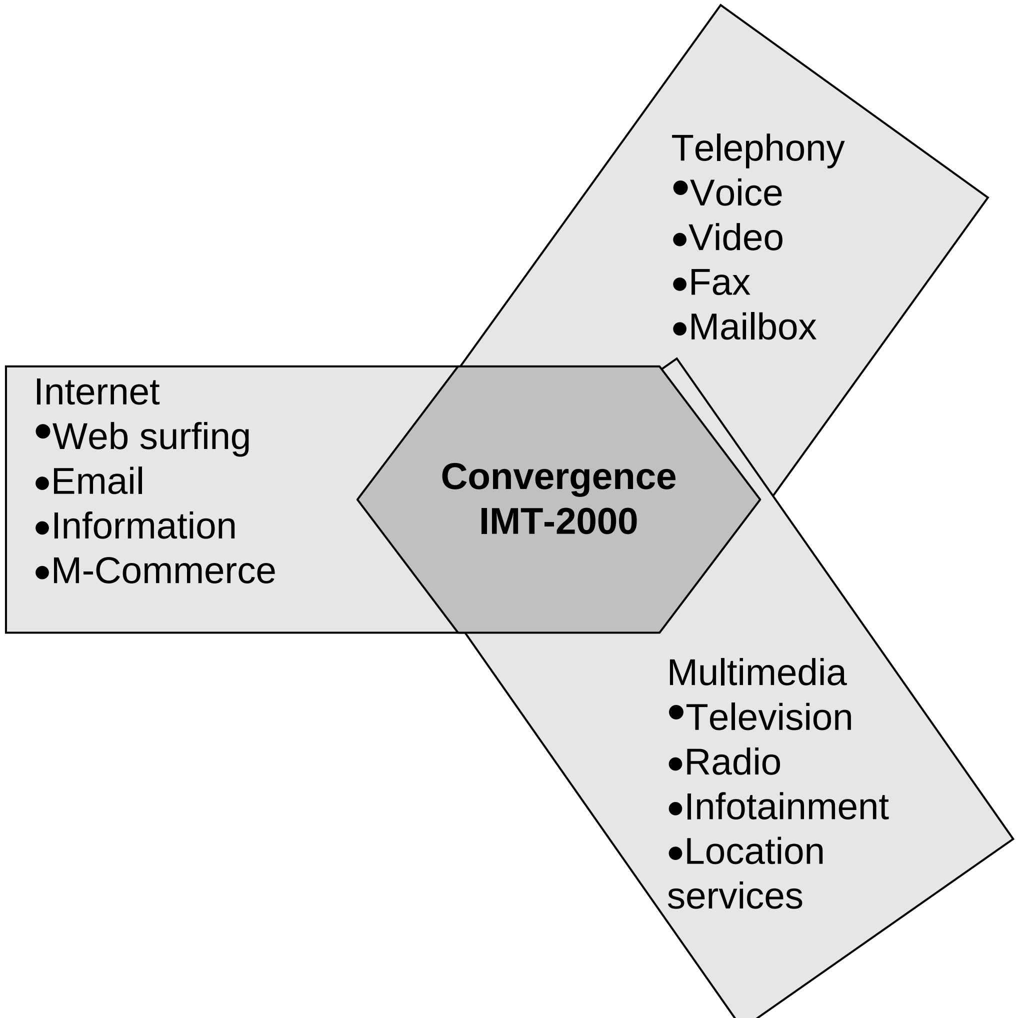
An Evolution Path from CDMA to 3G Network



Evolution of IMT-2000 standards



Convergence of Services in IMT-2000



IMT 2000 Services

- Voice
- **Switched Data**
- Messaging
- **Multimedia Messaging Service (MMS)**
- Immediate Messaging
- **Medium, High, and Interactive Multimedia**
- Sending multimedia postcards

Second Generation Digital Cellular Systems

- IS-54/IS-136 : US Digital Cellular (USDC) - TDMA System
- **GSM : Global System for Mobile**
- PDC : Pacific Digital Cellular - A Japanese TDMA Cellular Standard
- **IS-95/cdmaOne : CDMA Cellular System**

Wireless Networking Technologies

- **Wireless Local Area Network (WLAN)**
- **Wireless Personal Area Network (WPAN)**
- **Wireless Meteropolitan Area Network (WMAN)**

Wireless Communication Systems

Three most commonly used household wireless communication systems are:

- ✓ **Paging System**
- ✓ Cordless Phone System
- ✓ **Cellular Telephone System**

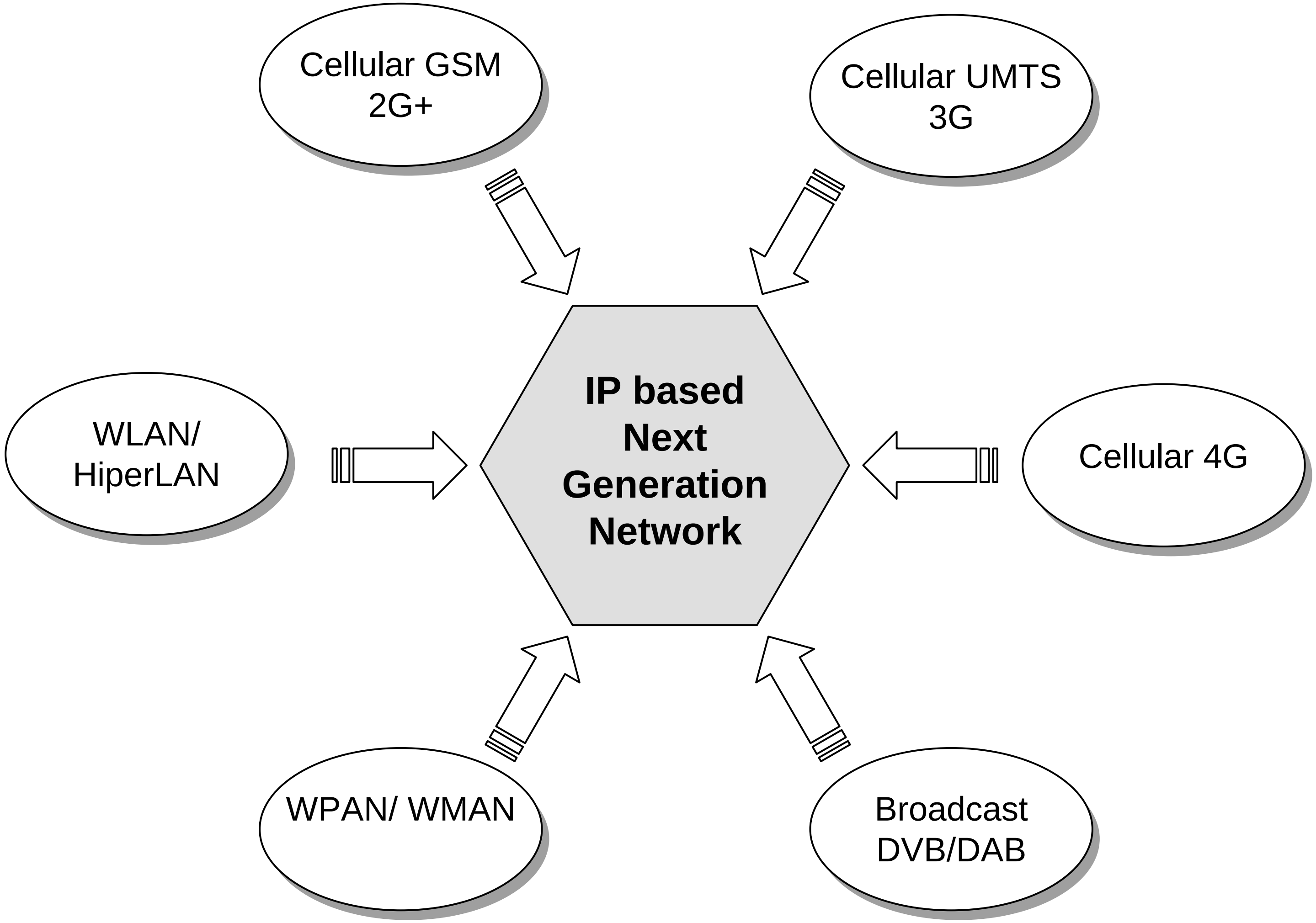
Comparison of Wireless Communication Systems

Service Type	**Functionality**	**Operating Frequency**	**Level of infrast-ructure**	**Complexity**	**Hardware Cost**	**Range**
Paging System	BS: Tx only MS: Rx only	< 1 GHz	High	BS: High MS: Low	BS: High MS: Low	High
Cordless Phone System	Transceivers	1 – 3 GHz	Low	BS: Low MS: Medium	BS: Medium MS: Low	Low
Cellular Phone System	Transceivers	< 2 GHz	High	High	BS: High MS: Medium	High

Cellular Communication Standards

Analog or Digital	Cellular Systems Standard	Frequency Band	Multiple Access Technique	Modulation Scheme	Region
Analog	AMPS	824-894 MHz	FDMA	FM	North America
Analog	NMT-900	890-960 MHz	FDMA	FM	Europe
Analog	ETACS	900 MHz	FDMA	FM	Europe
Analog	JTACS	860-925 MHz	FDMA	FM	Japan
Digital	USDC/IS-54 or 136	824-894 MHz	TDMA	π/4-DQPSK	North America
Digital	IS-95	824-894 MHz; 1.8-2.0 GHz	CDMA	QPSK/ OQPSK	North America
Digital	GSM	890-960 MHz	TDMA	GMSK	Europe
Digital	PDC	810-1501 MHz	TDMA	π/4-DQPSK	Japan

Vision of Next Generation Network



Next Generation Wireless Network

Functional Requirements:

- ✓ **Very high-speed and high-quality transmission**
- ✓ Open platform
- ✓ **Flexible and varied service functions**

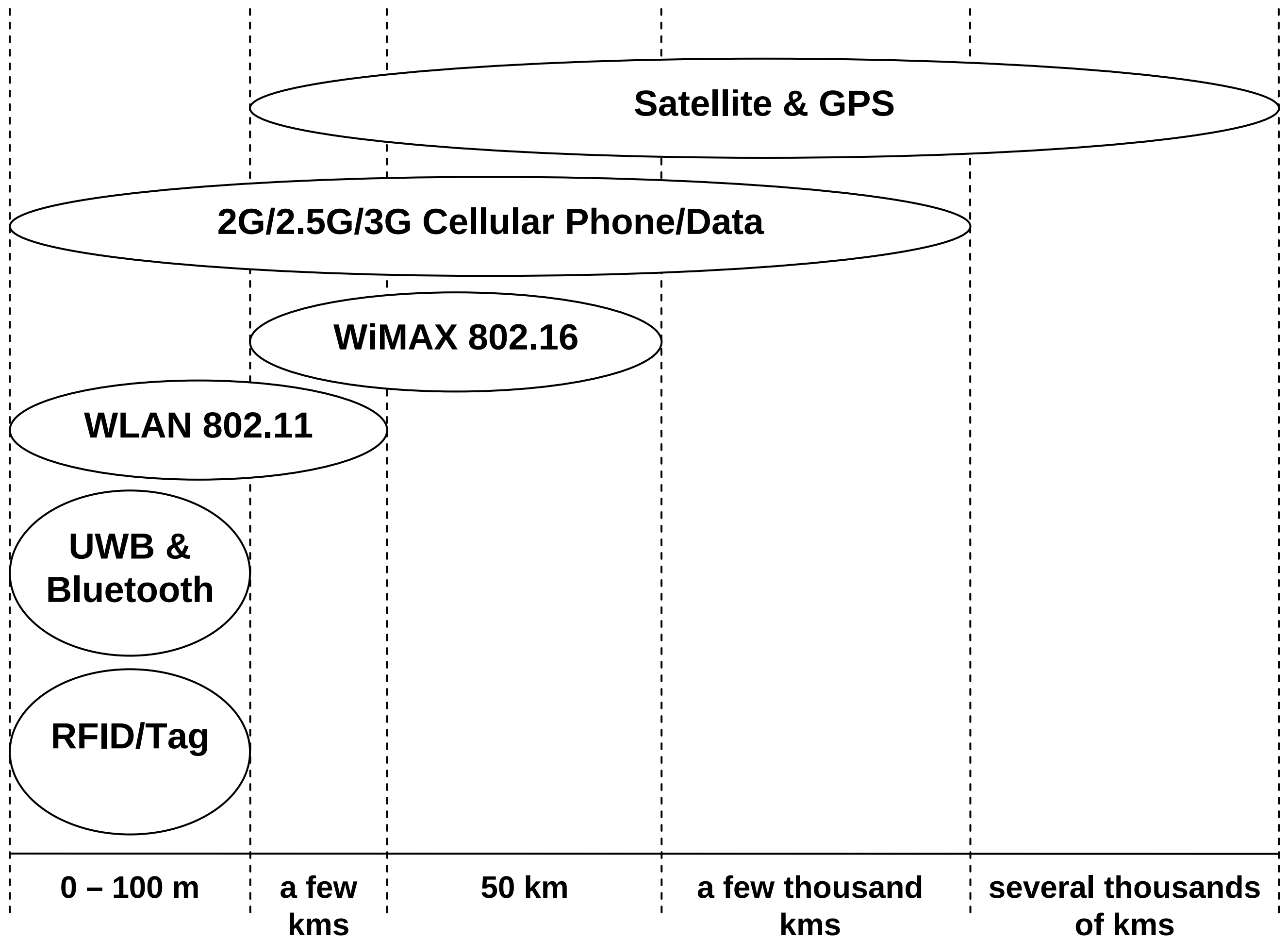
Comparison of Cellular Network Generations

First Generation	Second Generation	Third Generation	Next Generation
• Analog Transmission	• Digital Transmission	• Digital Transmission	• Digital Transmission
• Mainly Speech Communication	• Mainly Speech Communication	• Mainly Speech Communication	• Mainly Speech and Video Communication
• Voice Band Data	• Digital Data	• Increasing Digital Data	• Mainly Digital Data
• Circuit Switched	• Circuit Switched	• Increasingly Packet Switched	• Mainly Packet Switched
• Local Systems	• Global Roaming	• Global Roaming	• Global Roaming

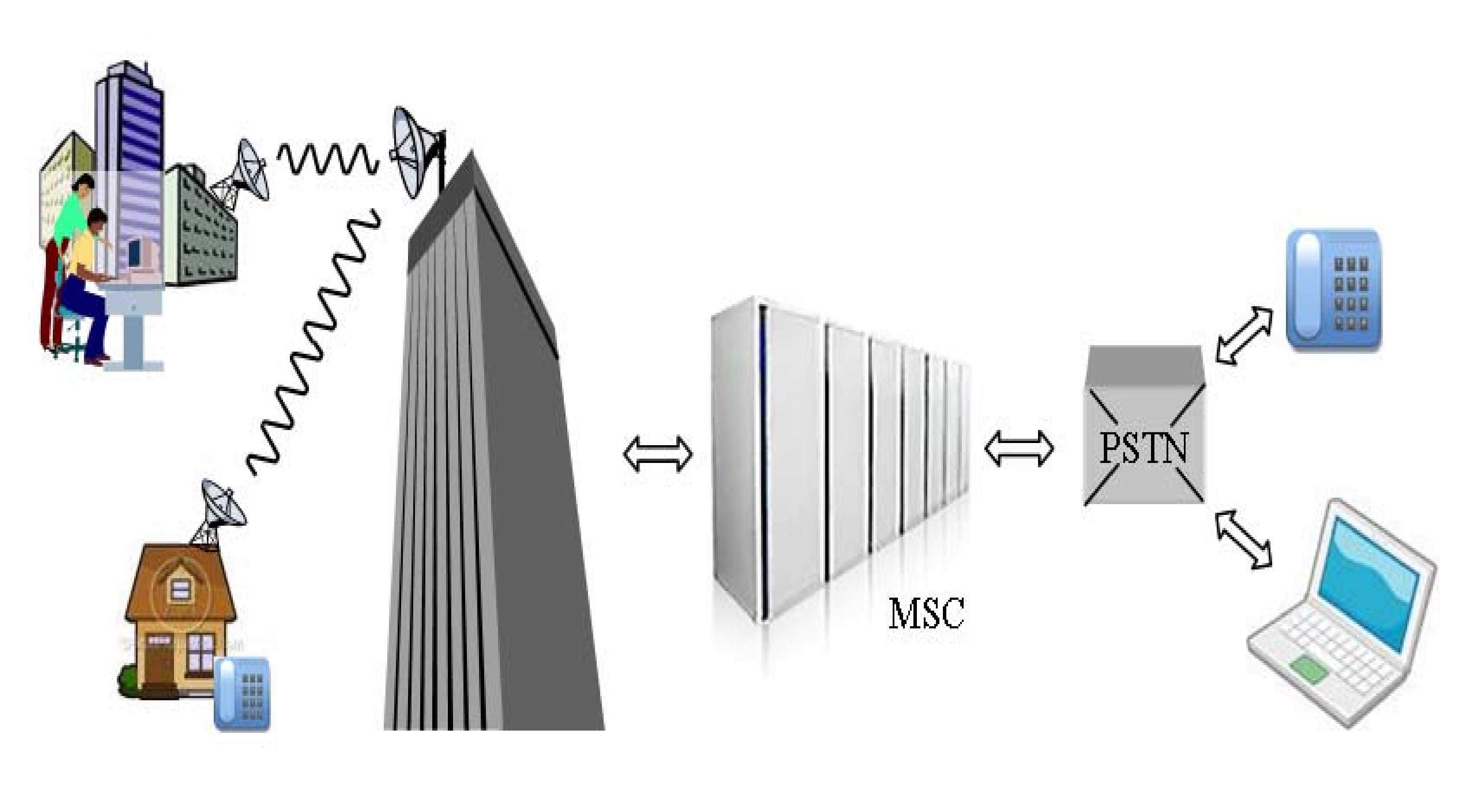
Wireless Data Communications Technologies

S. No.	Wireless Technology	Data Speed	Radio Coverage
1.	2G digital cellular	10 kbps	Nationwide through roaming
2.	2.5G digital cellular	Up to 384 kbps	Nationwide through roaming
3.	3G digital cellular	Up to 2 Mbps	Nationwide through roaming
4.	WLAN 802.11b	11 Mbps	Building/campus, 100-120 meters
5.	WLAN 802.11g	54 Mbps	Building/campus, 90 meters
6.	WMAN 802.16 WiMax	75 Mbps	Metro city area, 56 kilometers
7.	Bluetooth	1 Mbps	Room/House, within 10 meters
8.	Ultra Wide Band (UWB)	100 Mbps	Auditorium, 50 meters
9.	RFID	Few kbps	Small area within a store room, 2.5 cm to 100 m
10.	GPS and Satellites	250 ms delay	Worldwide global

Wireless Data Communication Technologies



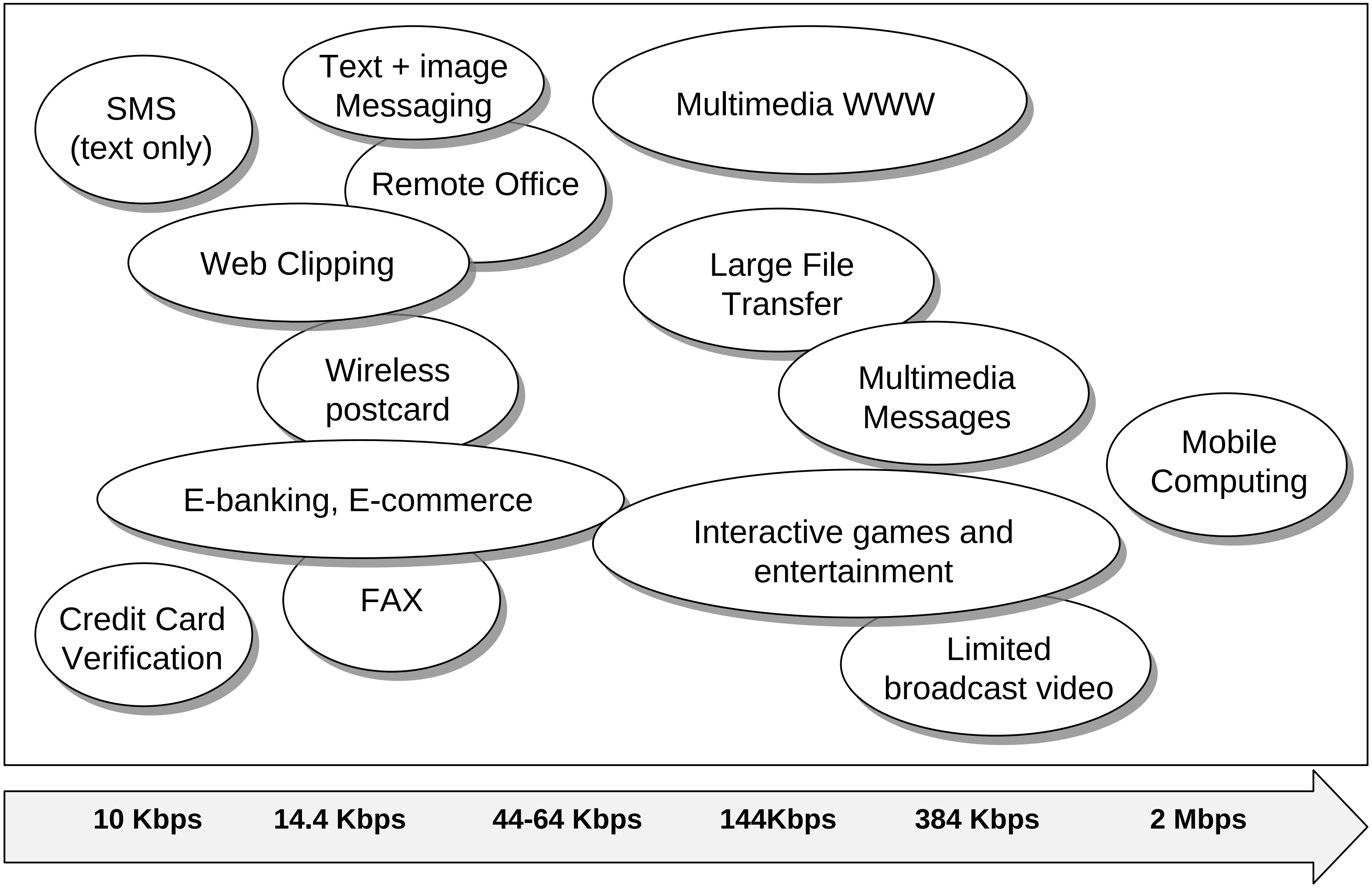
A Typical Fixed Wireless Network



Applications of Wireless Communications

- Office and household environments
- **Industrial control**
- Education sector
- **Health services**
- Government and military operations
- **Event and travel management**
- Home entertainment
- **Environmental and industrial research**

Potential Market Areas and Data Rates



Target Business Areas

- The Automotive Industry Market
- **The Fleet Management**
- Vehicle Positioning Market
- **The Utilities Market**
- The Security Systems Market
- **Vending Machines**

Challenges for Research

Wireless communications – a major technological areas for research as well as industrial applications.

True wireless multimedia services – required by highly mobile subscribers seamlessly on a global arena.

Diverse IP multimedia applications.

Summary

- Cellular Mobile Communications
- **Remote Wireless Internet Connections**
- Wireless Networks
- **Mobility, increased network reliability, easier and less expensive installation, and support for disaster recovery**

Thanks!

Mc Graw Hill Education

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Mobile Communication Engineering

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Mobile Communication Engineering

- Introduction
- **The Radio Paths**
- The Propagation Attenuation
- **Basic Propagation Mechanisms**
- Mobile Radio Channel
- **Simulation of Wireless Fading Channels**

Introduction

The mobile radio channel is

- extremely random in nature
- difficult to analyze
- places fundamental limitations on the performance of wireless communication systems

Mobile Communication Engineering?

- A study of signal propagation - vital to wireless communications
- **Basic Propagation Mechanisms**
- How wireless medium supports mobility of the users
- **Radio propagation characteristics**

Mobile Radio Environment

- Radio Propagation Paths
- **Propagation Attenuation**
- Multi-path Propagation
- **Basic Propagation Mechanisms**
- Mobile Radio Channel
  - **Multipath Fading**
  - Multipath Delay Spread
  - **Effect of Mobility: Doppler Shift**
  - Coherence Bandwidth and Time

Radio Propagation Paths

- **Direct wave Path** - a path which is clear form terrain contour.
- **Line of Sight (LOS) Path -** a path clear form buildings. In the mobile radio environment, line of sight condition is generally not met.
- **Obstructive Path** - a path when the terrain contour blocks the direct wave path. The signal may encounter diffraction resulting into shadow or diffraction loss.

The Propagation Attenuation

- In general, the propagation path loss increases with frequency of transmission, f_c and the distance between cell site and mobile, R.
- **In a real mobile radio environment, the propagation path-loss varies as $L_p \propto R^{\gamma}$, where γ is path-loss exponent which varies between 2 and 6, depending on the actual conditions.**
- γ= 2 is free-space condition and γ= 4 is typical value for mobile radio environment.

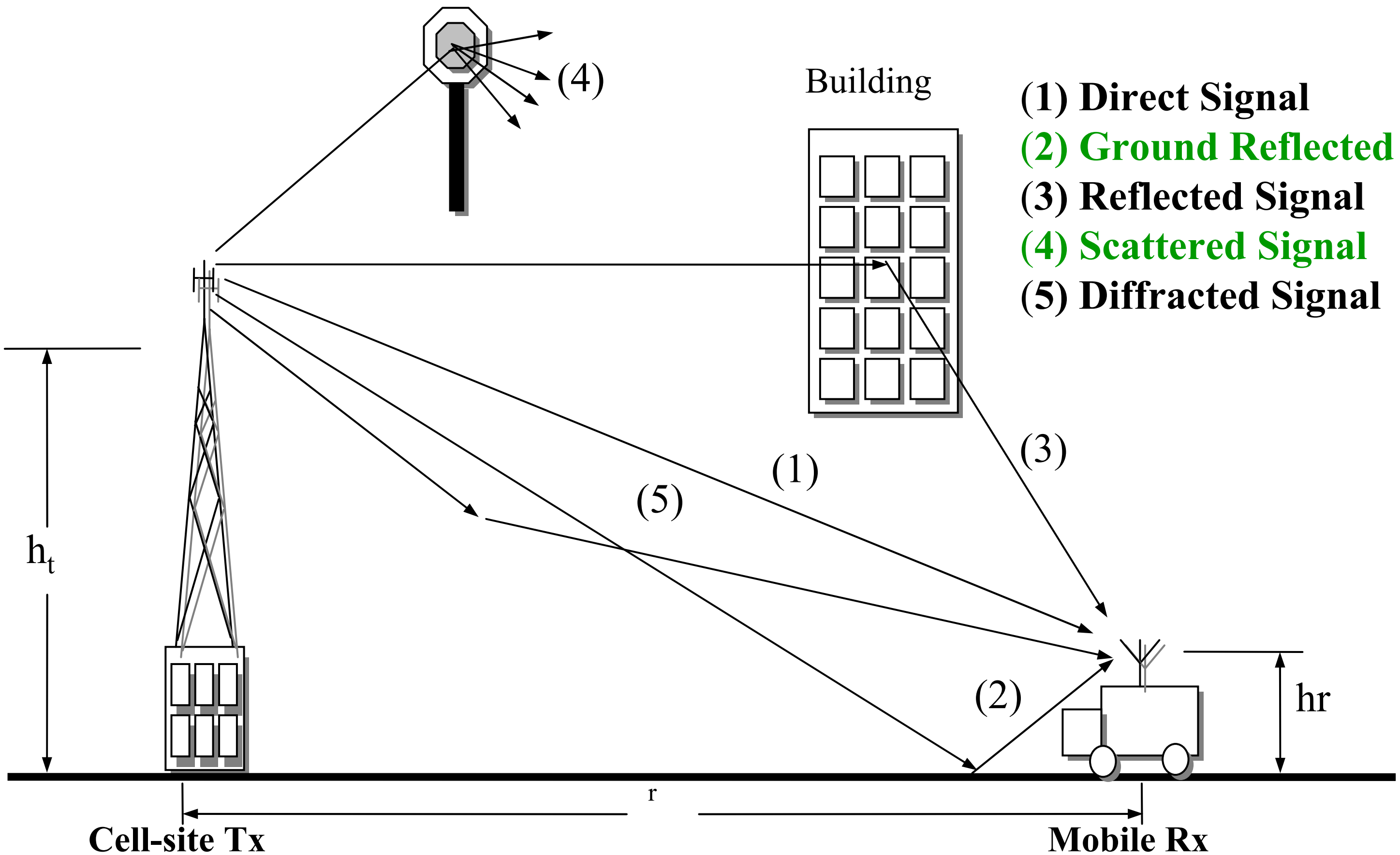
Path Loss Exponent Values

Mobile radio environment	Path loss exponent, γ
Free space condition	2
Flat rural area	3
Rolling terrain rural area	3.5
Typical urban areas	2.7 to 3.5
Suburban with low rise buildings	4
Shadowed urban areas	3 to 5
Dense urban with high rise buildings	4.5
In building – line-of-sight conditions	1.6 to 1.8
In building – obstructed conditions	4 to 6
In factories – obstructed conditions	2 to 3
Typical mobile radio environment	4

Signal Attenuation Rate

- **Free-Space conditions:** Signal strength decays at the rate of 6 dB/octave or 20 dB/decade
- **Mobile Radio Propagation Environment condition:** Signal strength decays at the rate of 12 dB/octave or 40 dB/decade

Radio Propagation Mechanisms

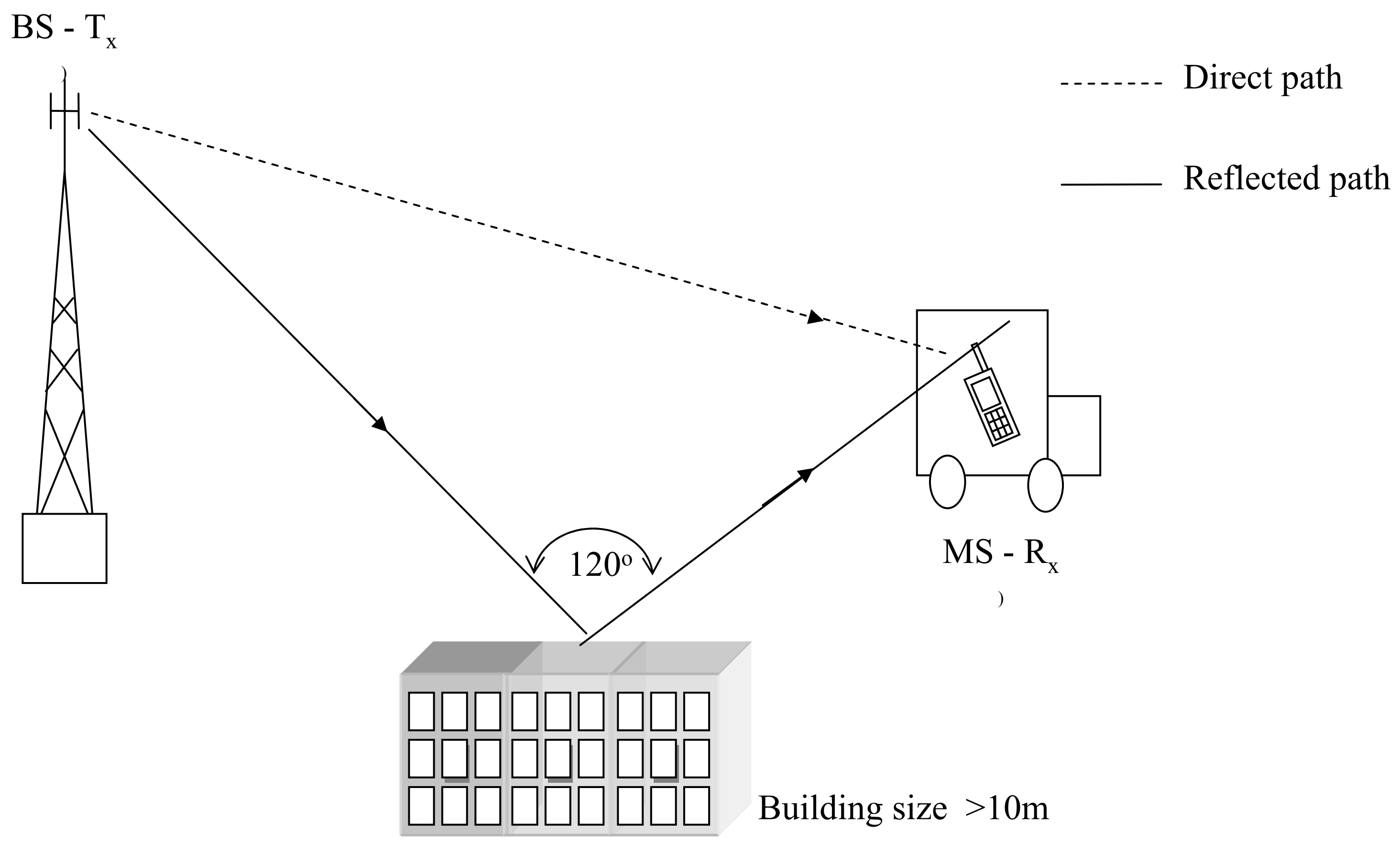


(1) Direct Signal
(2) Ground Reflected Signal
(3) Reflected Signal
(4) Scattered Signal
(5) Diffracted Signal

Propagation Mechanisms

- **Reflection** : Propagating wave impinges on an object which is large compared to wavelength, such as the surface of the Earth, buildings, walls, etc.
- **Diffraction** : Radio path between transmitter and receiver obstructed by surface with sharp irregular edges. Waves bend around the obstacle, even when LOS does not exist
- **Scattering** : Objects smaller than the wavelength of the propagating wave, e.g. foliage, street signs, lamp posts.

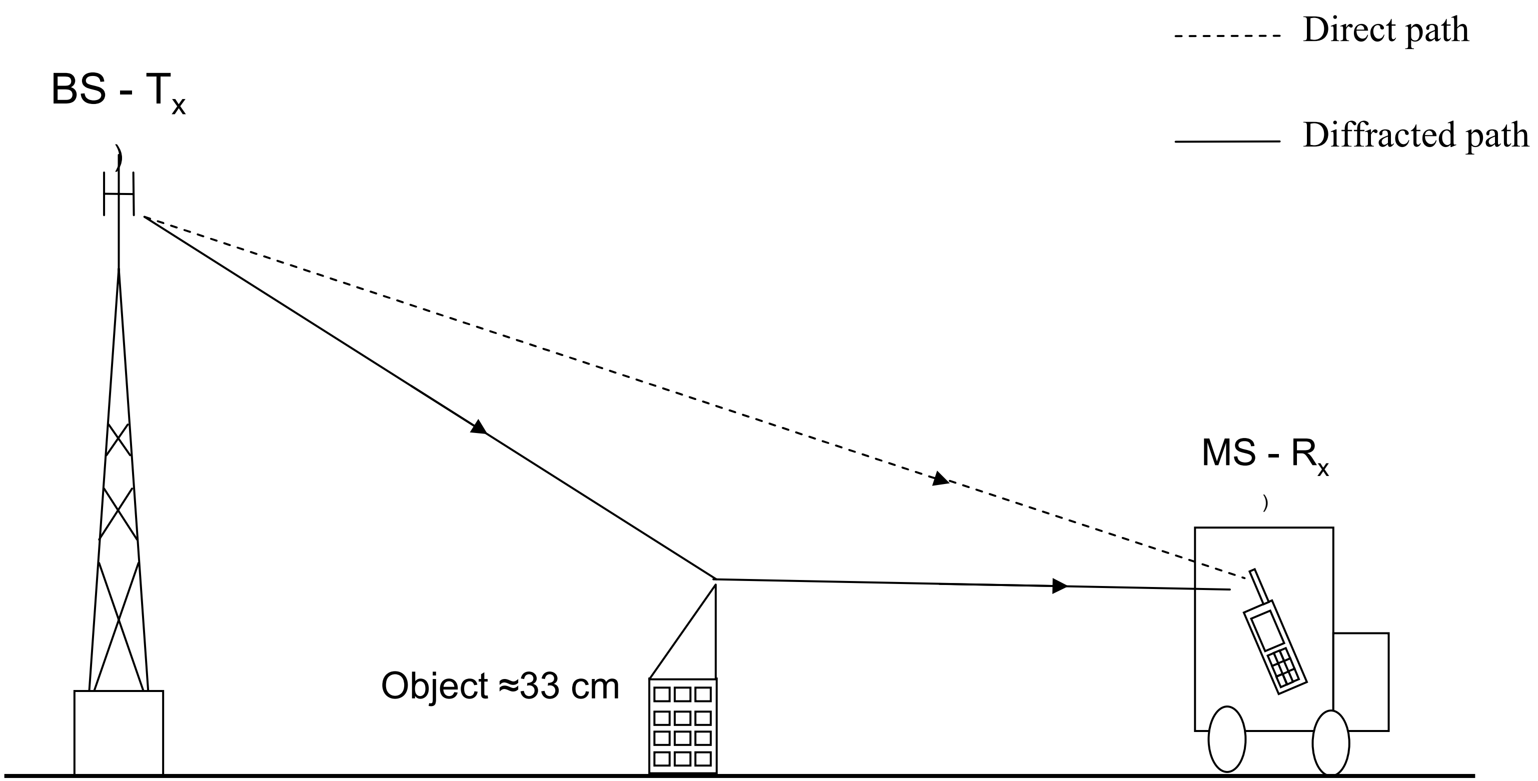
Effects of Reflection on Signal Propagation



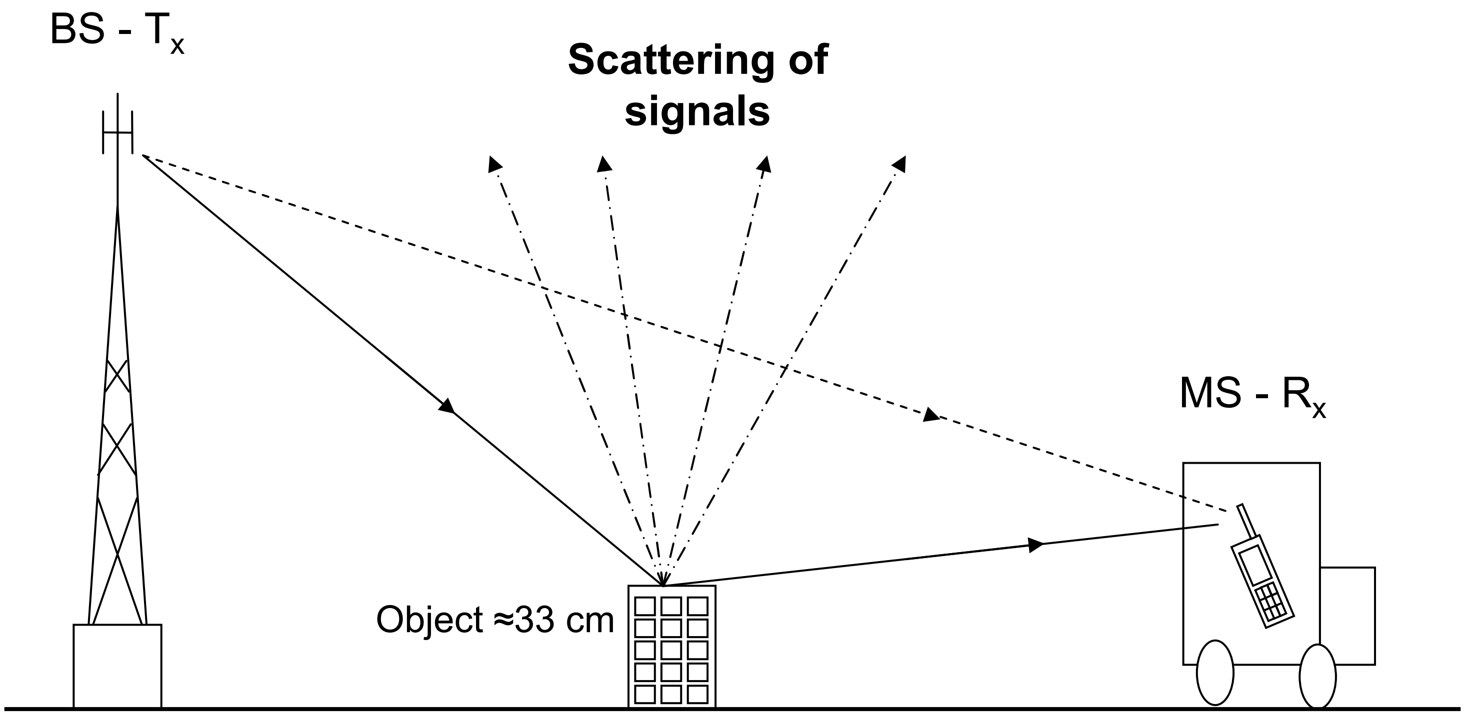
Diffraction

- **A change in wave pattern caused by interference between waves that have been reflected from a surface or a point**
- **Causes regions of waves strengthening and weakening**
- **Results in bending of the wave**
- **Can occur in different situations when waves**
  - √ Pass through a narrow slit
  - √ **Pass the edge of a reflector**
  - √ Reflect off two different surfaces approximately one wavelength apart

Diffraction of Radio Signal

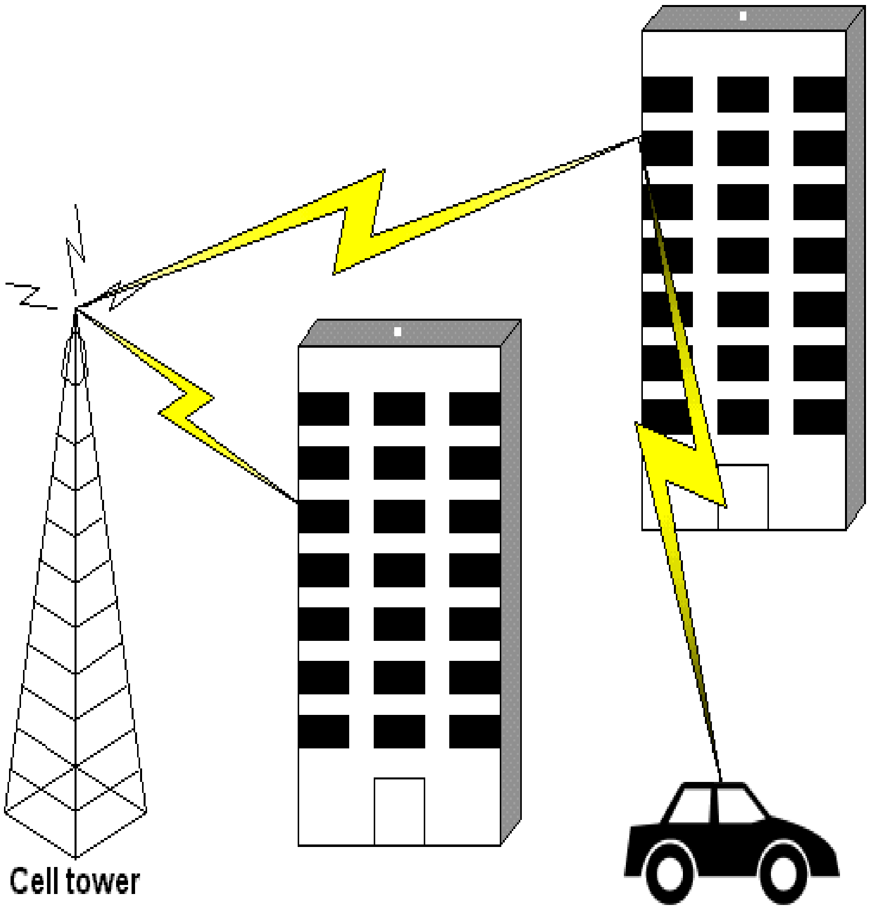


Scattering of Radio Signal



Blocking and Absorption

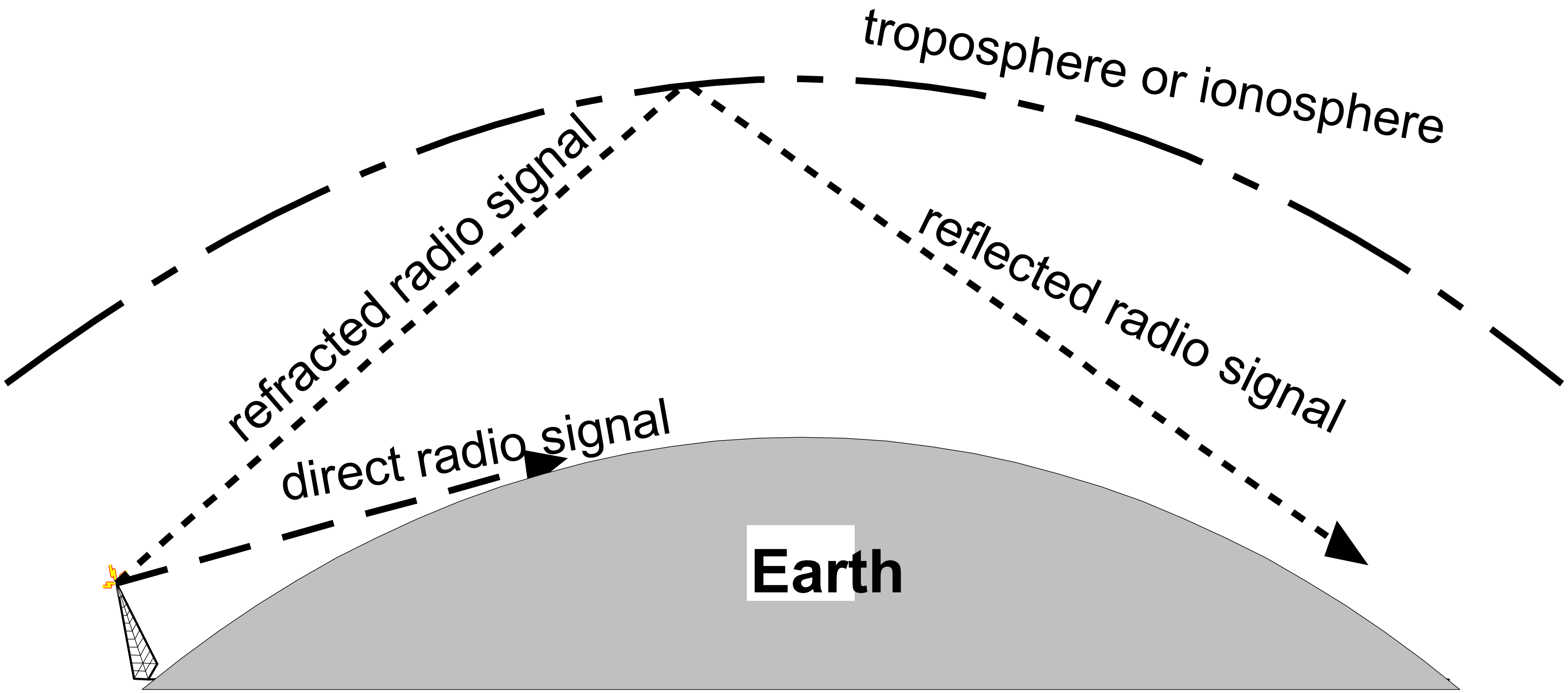
- Some substances like trees and shrubs, clouds, mist and other atmospheric moisture and dust, metal screen, human body near a hand held **absorb** radio waves
- **Higher frequency radio waves are absorbed more than lower frequency radio waves**



Refraction

- Refraction is the bending of electromagnetic waves as they pass from medium of one density into medium of another density.
- **Radio waves typically bend due to changes in density of air caused by changes in humidity, temperature or pressure.**
- Dielectric constant describes how the wave will propagate through the material.

Refraction of Radio Signal



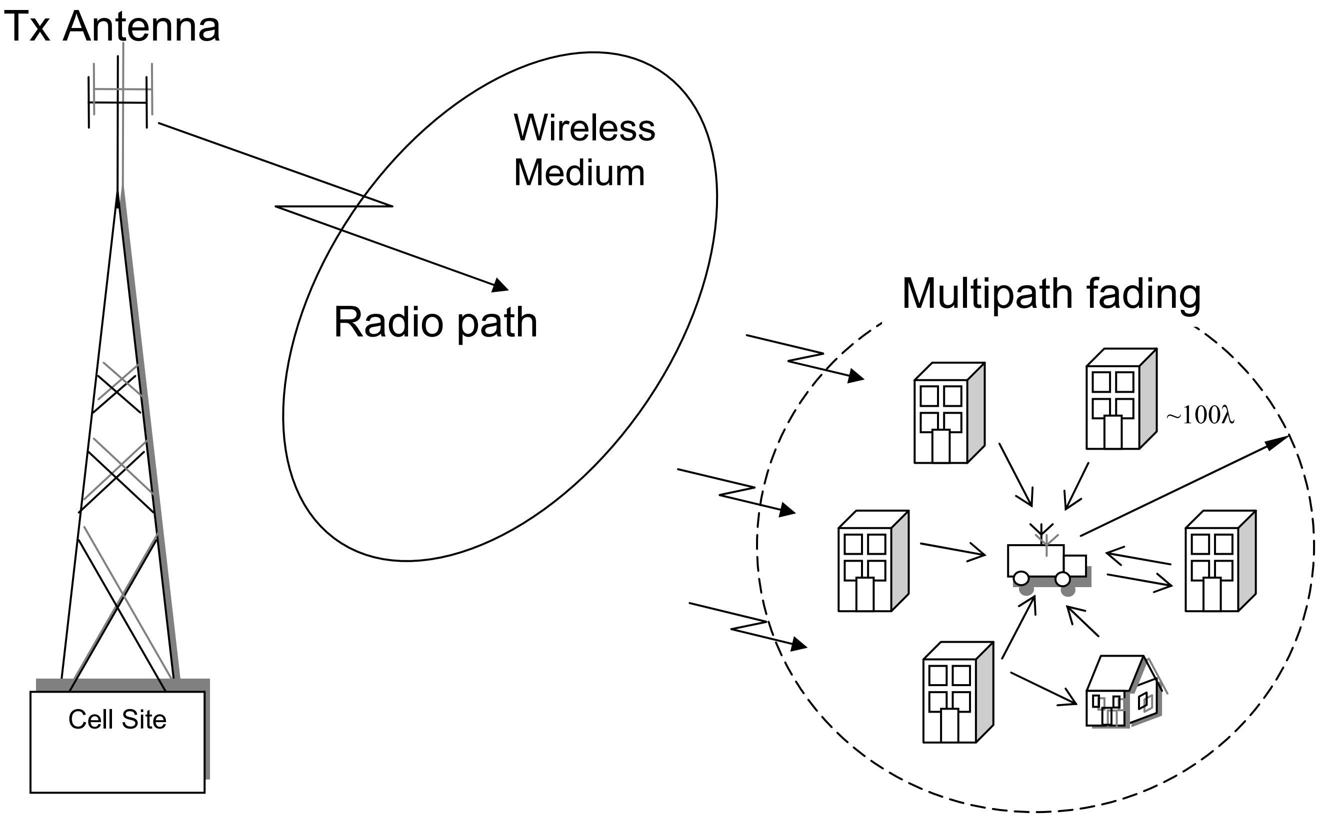
Mobile Radio Channel

- Mobile radio channels introduce noise, fading, interference, and other distortions into the signals that they transmit.
- **In mobile communication system, a signal experiences multipath propagation which causes rapid signal level fluctuations of the amplitude of a radio signal in a short time over a short distance called *fading*.**

Impairment to Radio Channel - Fading

- Multipath waves are generated because the antenna height of mobile is lower than its typical surroundings, and the operating wave length is much less than the sizes of the surrounding structures at mobile.
- **The sum of multipath waves causes a signal fading phenomenon.**
- The signal may fade in range of about 40 dB (10 dB above and 30 dB below the average signal). If the mobile moves fast, the rate of signal fluctuations is fast.

Multipath Fading in a Mobile Radio Environment



Types of Fading

- Fading effects due to multipath time delay spread
  - Flat (non-frequency selective) fading
  - Frequency selective fading
- **Fading effects due to Doppler spread**
  - **Fast fading (Rayleigh fading)**
  - **Slow fading (Rician fading)**

Flat (Non-frequency Selective) Fading

- When radio channel has a constant gain and linear phase response but its bandwidth is **greater** than that of the transmitted signal
- ***All* frequency components of the received signal fluctuates in the *same* proportions simultaneously**
- Described by **Rayleigh distribution**
- **Typical flat fading channels cause *deep fades*, (20 or 30 dB)**

Frequency Selective Fading

- When radio channel has a constant gain and linear phase response but its bandwidth is **less** than that of the transmitted signal
- **Affects the different spectral components of a radio signal unequally**
- Due to time dispersion of the transmitted symbols within the channel, the channel induces intersymbol interference
- **Frequency selective fading channels are also known as wideband channels**

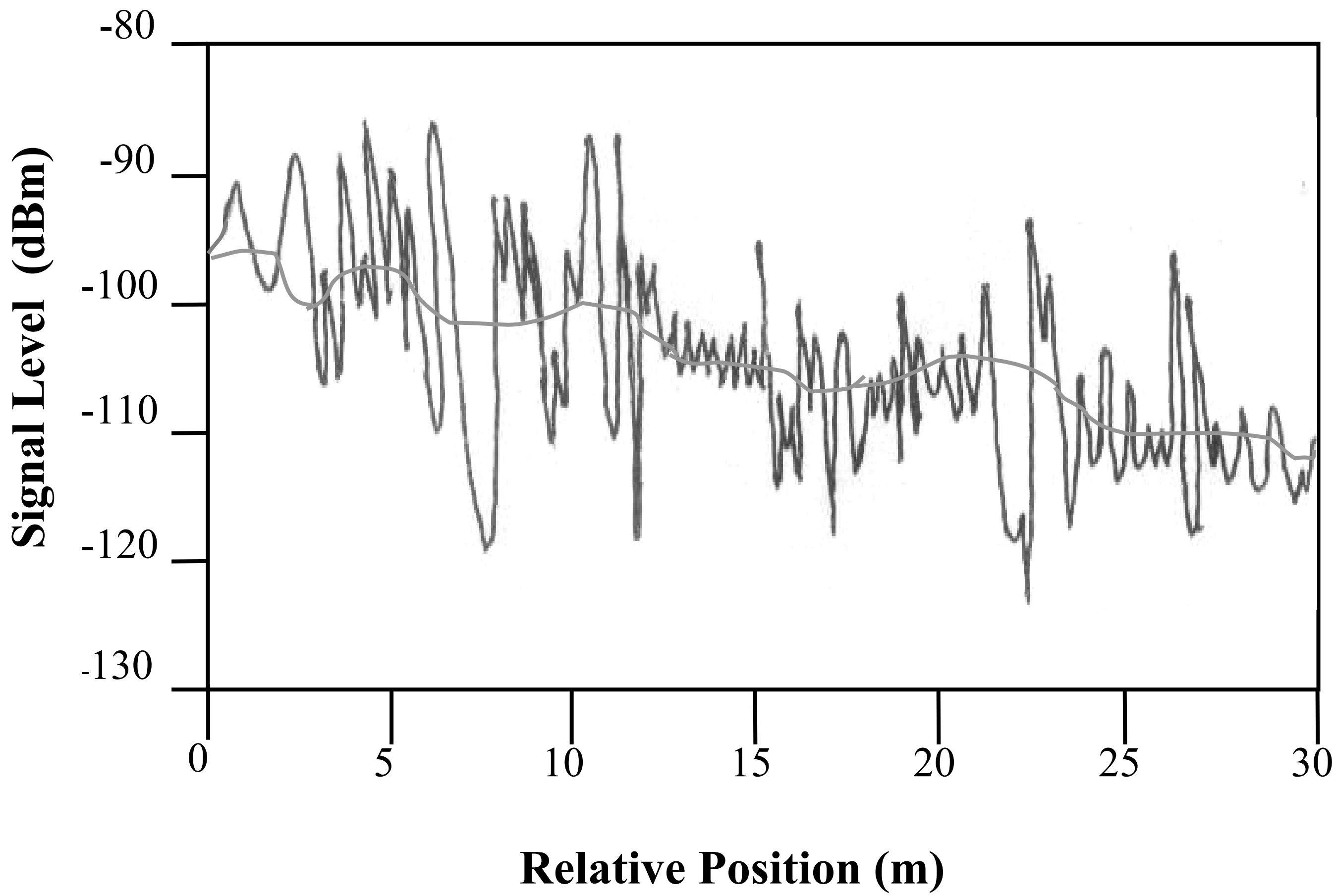
Fast Fading (Rayleigh fading)

- Rapid fluctuations in received signal strength occur over distances of about one-half a wavelength.
- **The channel impulse response changes rapidly within the symbol duration.**
- The coherence time of the channel is smaller than symbol period of the transmitted signal.
- **This causes frequency dispersion, also called time selective fading, due to Doppler spreading.**

Slow Fading (Rician fading)

- Rapid fluctuations in received signal strength occur over distances of about one-half a wavelength.
- **The channel impulse response changes rapidly within the symbol duration.**
- The coherence time of the channel is smaller than symbol period of the transmitted signal.
- **This causes frequency dispersion, also called time selective fading, due to Doppler spreading.**

A Typical Fading Signal Received



Shadow Fading

- The variation of the signal strength due to location
- **Similar to slow fading**
- Typically modeled by attenuation in signal amplitude that follows a log-normal distribution
- **The variation in shadow fading is specified by the standard deviation of the logarithm of this attenuation**

Effects of Multipath Fading

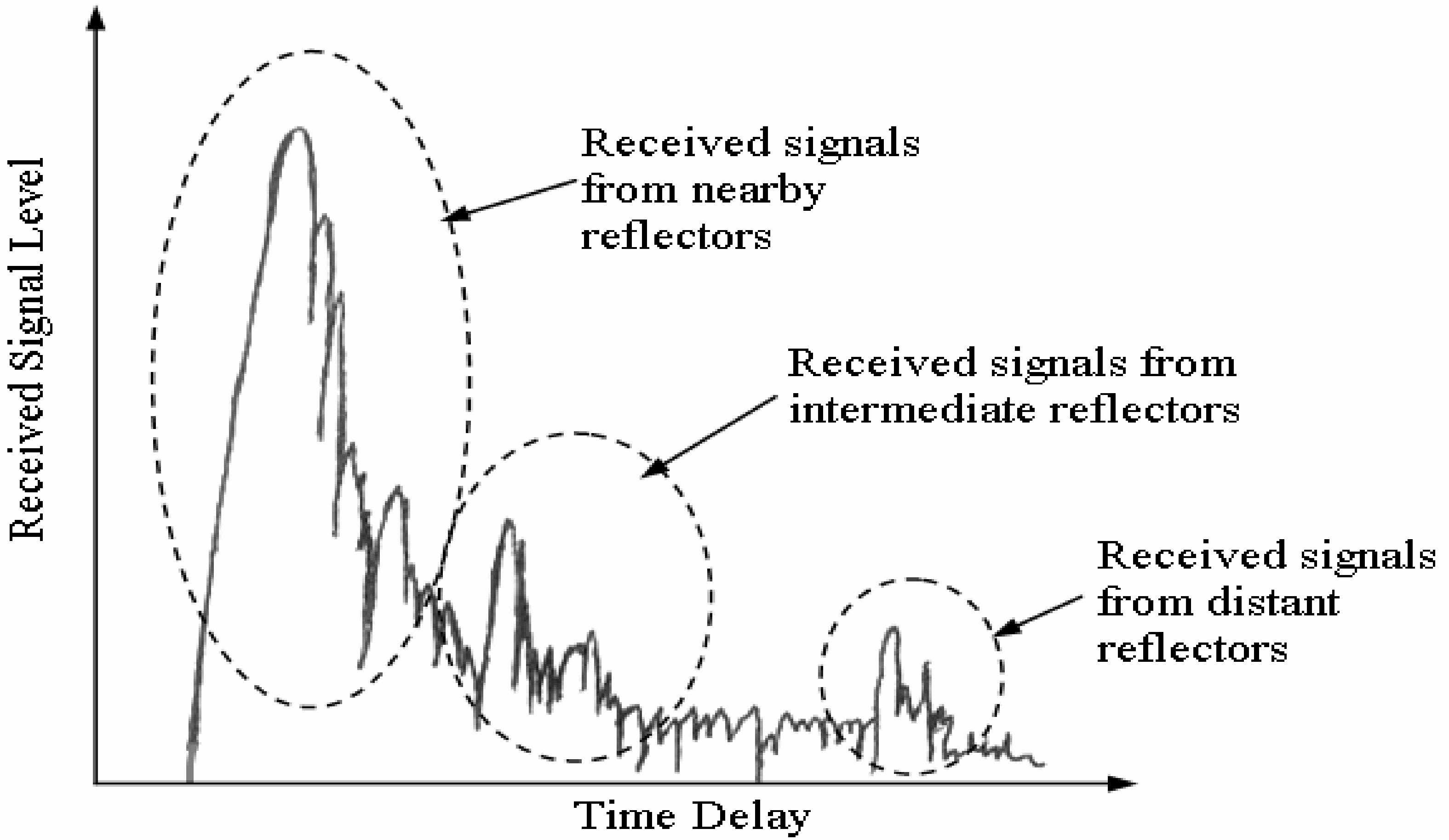
(as noticed by the listener)

- ✓ Rapid change in volume
- ✓ **Random frequency modulation**
- ✓ Echoes
- ✓ **Distortion**
- ✓ Dropped call

Multipath Delay Spread

- Multipath propagation yields signal paths of different paths with different times of arrival at the receiver.
- **Spreads/smears the signal, could cause inter-symbol interference, limits maximum symbol rate**
- Delay Spread also occurs due to Rayleigh fading which results from the signal's amplitude and phase being altered by reflections.

Delay spread of a received signal



Typical Delay Spread Values

Type of environment	Delay spread (μs)
Inside the building	<0.1
Open area	<0.2
Sub-urban area	0.5
Urban area	3

Doppler Shift

- The relative motion between the cell site and mobile results in random frequency change due to different Doppler shifts on each of the multipath components.
- **The Doppler shift, f_d is given by**

$$f_d = (1/\lambda_c)\, V_m \cos\theta$$

where λ_c is the wavelength of the carrier signal, V_m is the relative velocity of the mobile, the angle θ is between the motion of the mobile and direction of arrival of the scattered waves.

Doppler Spread

- Doppler shift will be positive or negative depending on whether the mobile receiver is moving towards or away from the cell site.
- **In mobile radio applications, the Doppler spectrum or Doppler spread for a Rayleigh fading channel is usually modeled by**

$$D(\lambda) = (0.16/f_{dm}) \times [1-(\lambda_c / f_{dm})^2]^{-0.5} \quad \text{for } -f_{dm} \leq \lambda_c \leq f_{dm}$$

where f_{dm} is the maximum Doppler frequency possible

$f_{dm} = V_m / \lambda_c$

Level Crossing Rate

- It is possible to relate the time rate of change of the received signal to the signal level and velocity of the mobile.

- **The level crossing rate, N_L is defined as the expected rate at which the Rayleigh fading envelope, normalized to the local RMS signal level, crosses a specified threshold level in a positive-going direction.**

$$N_L = 2.5\, f_{dm}\, \rho\, e^{-\rho^2}$$

ρ is the value of the specified level L, normalized to the local rms amplitude of the fading envelope, that is, L/Lrms.

Fade Rate and Fade Duration

- **Fade rate** is defined as the number of times that the signal envelope crosses the threshold value in a positive going direction per unit time.

Average fade rate = 2 V_m / λ_c

- The **average fade duration** is defined as the average period of time for which the received signal is below a specified level L.

Average fade duration, Ť = $0.4(e^{\rho^2}-1)/(f_{dm}\ \rho)$

Coherence Bandwidth

- The coherence bandwidth is a statistical measure of the range of frequencies over which the channel can be considered flat.
- **The coherence bandwidth, B_c represents the correlation between two fading signal envelopes at frequencies f_1 and f_2 and is a function of delay spread Ŧ$_d$.**

$$B_c \approx 1 / (2 \pi \text{Ŧ}_d)$$

Where Ŧ$_d$ is the delay spread.

Coherence Time

- Coherence time is the time duration over which two received signals have a strong potential for amplitude correlation.
- **It is used to characterize the time varying nature of the frequency dispersiveness of the channel in the time domain.**
- Coherence time, $Ŧ_c$ is inversely proportional of Doppler spread.

$$Ŧ_c \approx 0.423 / f_{dm}$$

Where f_{dm} is the maximum Doppler shift given by V_m / λ_c.

Wireless Fading Channels

- Simulating a wireless communication system involves modeling a mobile radio channel based on mathematical descriptions of the channel.
- **Even when a mobile receiver is stationary, the received signal may fade due to movement of surrounding objects in the radio channel.**
- Rayleigh and Rician fading channels are useful models of real-world phenomena in wireless communications.

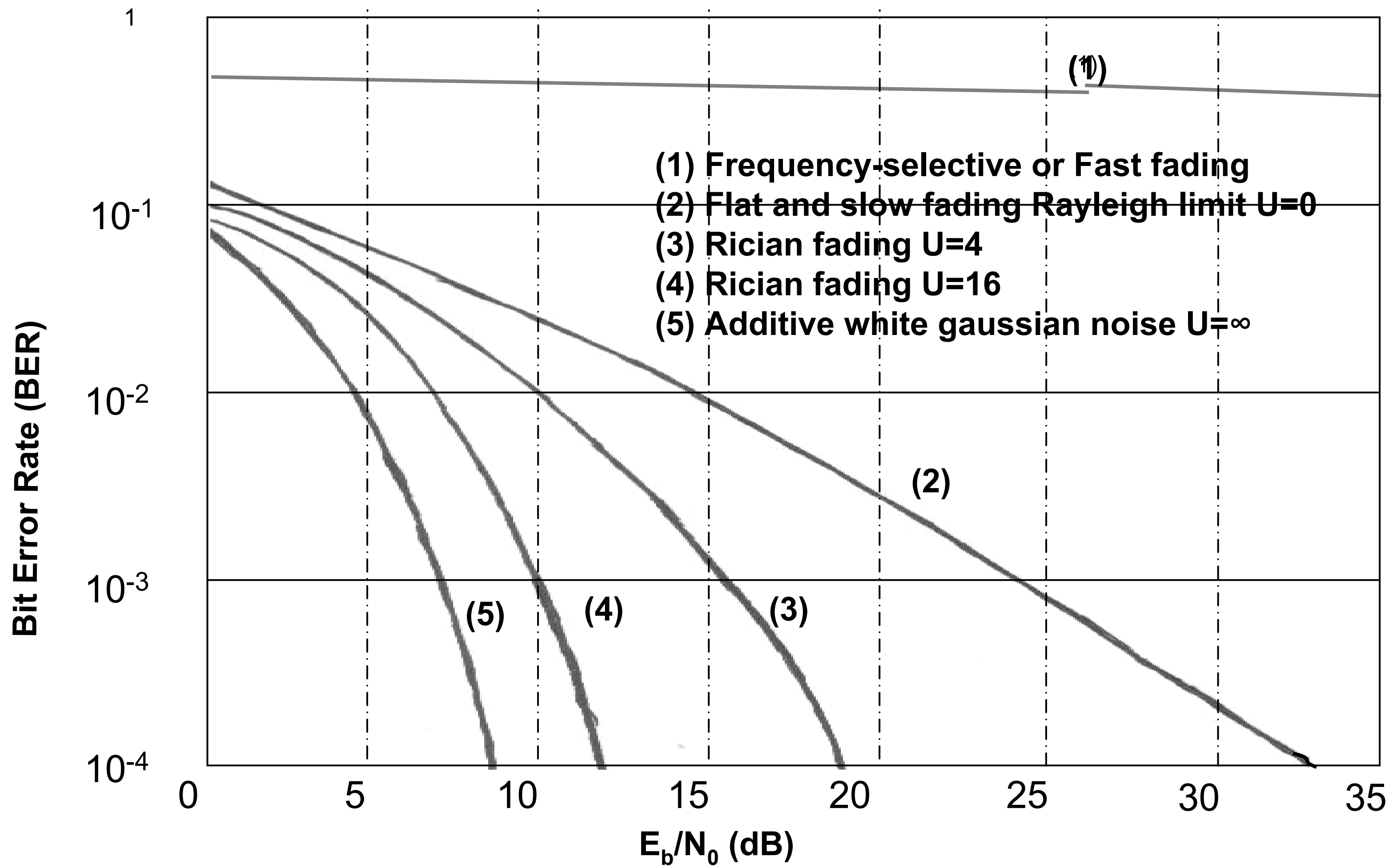
Impulse Response of Channel

- The wireless channels can be characterized by a parameter U, defined as ratio of the power in the dominant path to the power in the scattered path.
  - ✓ **When U = 0 (that is, power in the dominant path is zero), the channel is Rayleigh channel.**
  - ✓ When U is equal to infinity (that is, power in the scattered path is zero), the channel is AWGN.
- **The impulse response is a wideband channel characterization and contains all information necessary to simulate any type of radio transmission through the channel.**

Simulating a Fading Channel

- The BERTool of Communications ToolBox of technical computing simulation software MATLAB implements a baseband channel model for multipath propagation conditions.
- **A mobile radio channel may be modeled as a linear filter with a time varying impulse response, where the time variation is due to receiver motion in space.**
- The Communications Toolbox models a fading channel as a linear Finite Impulse Response (FIR) filter.

BER Plot for Fading Channels



Summary

- Impairments to propagation include reflection, diffraction, scattering, and many other similar phenomena.
- **Channel impairments cause multipath propagation and mobile signal fading.**
- Multipath propagation results in delay spread, which causes intersymbol interference limiting the bandwidth of the channel, and irreducible error rates.

Thanks!