Wireless and Mobile Networks

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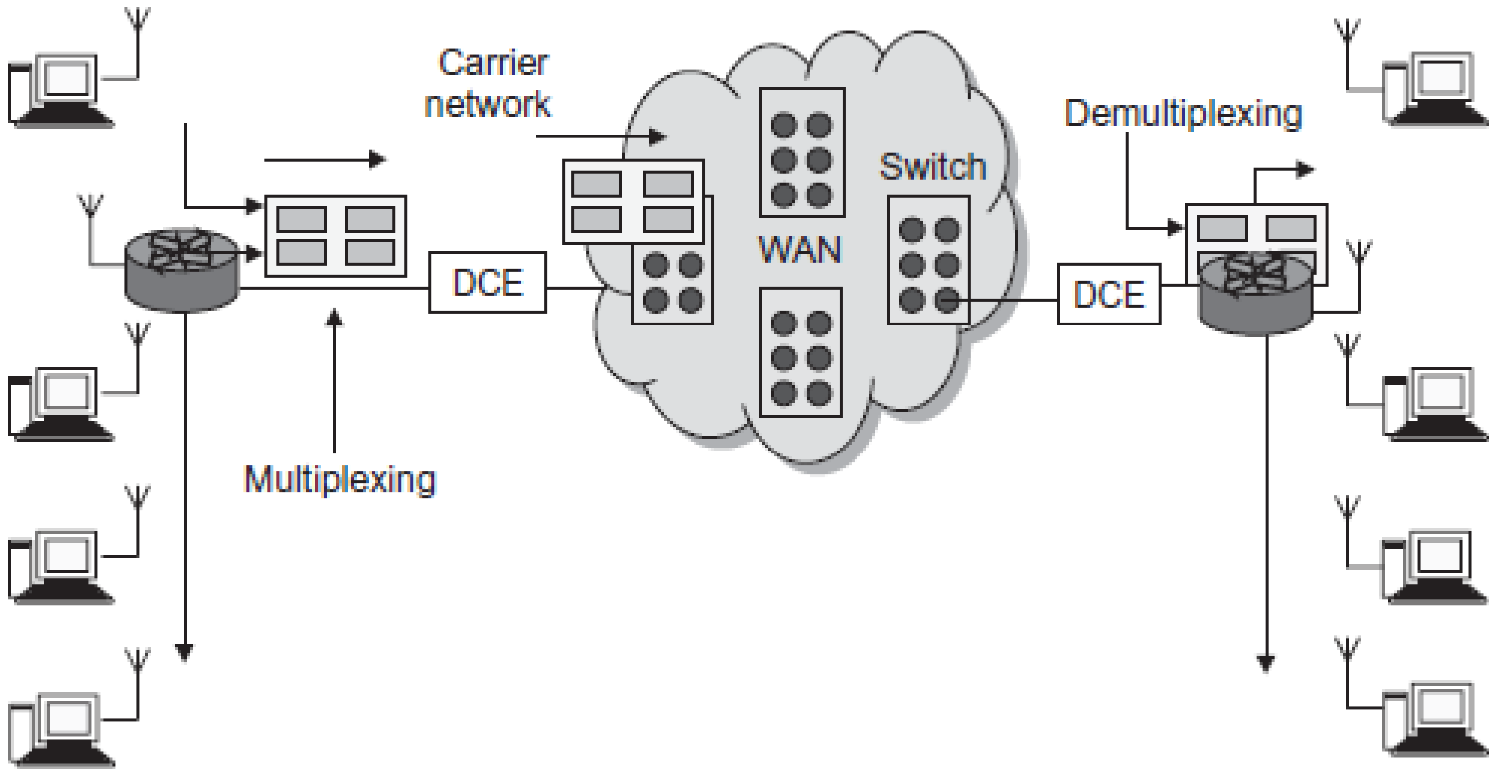
Chapter 1

Basics of Wireless Networks

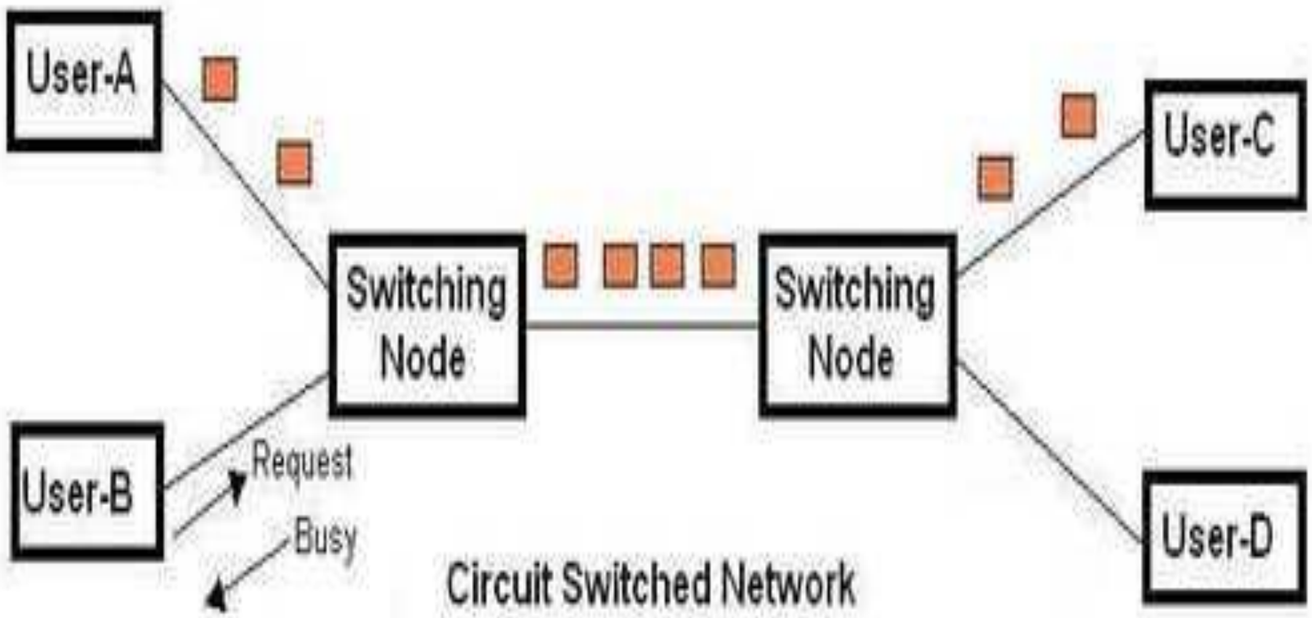
Wireless Switching Technology

Packet switching is the basic type of wireless switching technology. Packet-switched communication uses short bursts of information that use channels only for short periods of time. Wireless devices are ON with a specific address assigned to them. Data are sent to and from the address, routed using standardized protocols, and are essentially an extension of the standardized protocol.



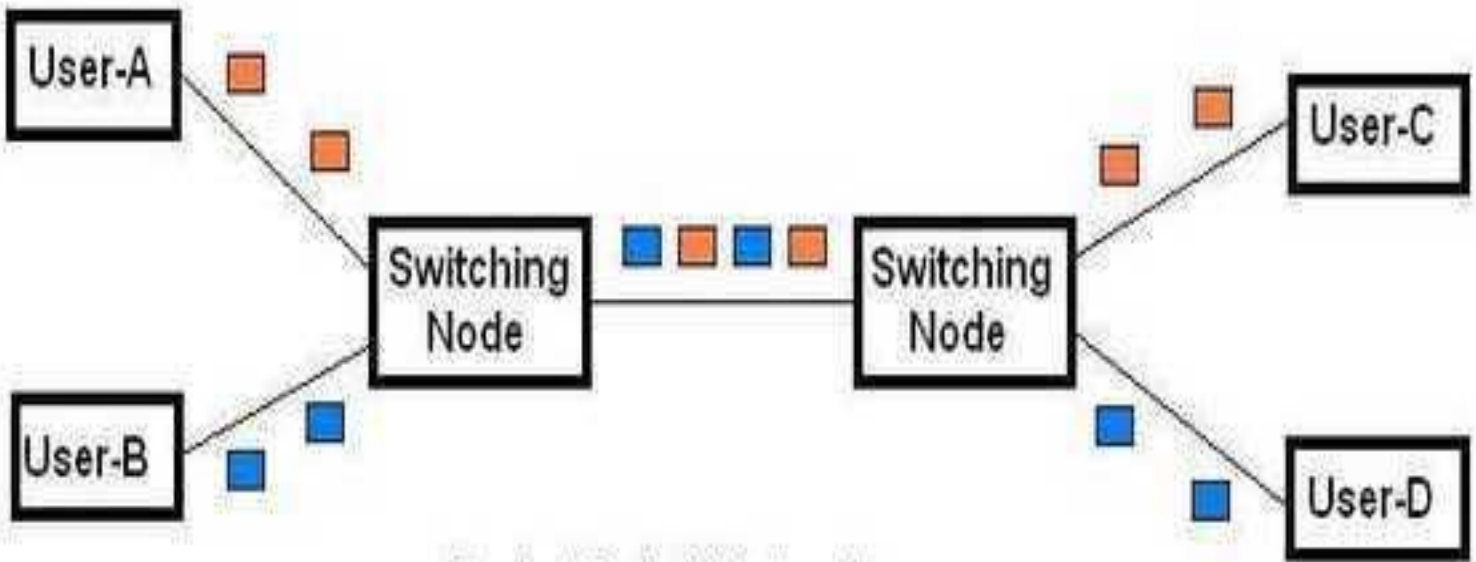
Packet switching.

The packet switching where the packets from all the computers of a premise moves in pipelined fashion over the network. The computers of specific premises are connected to the network. This network is connected to the switch of the WAN with the help of data circuit-terminating equipment (DCE).



User-A
User-B
Switching Node
Switching Node
User-C
User-D
Request
Busy
Circuit Switched Network

Switch establishes a connection from one network to the other network. Whenever the computers generate the packets, they are routed to the carrier network and pipelined with the help of multiplexing technique. At the receiving end (where the packets are destined), the packets are demultiplexed and delivered to the destination.



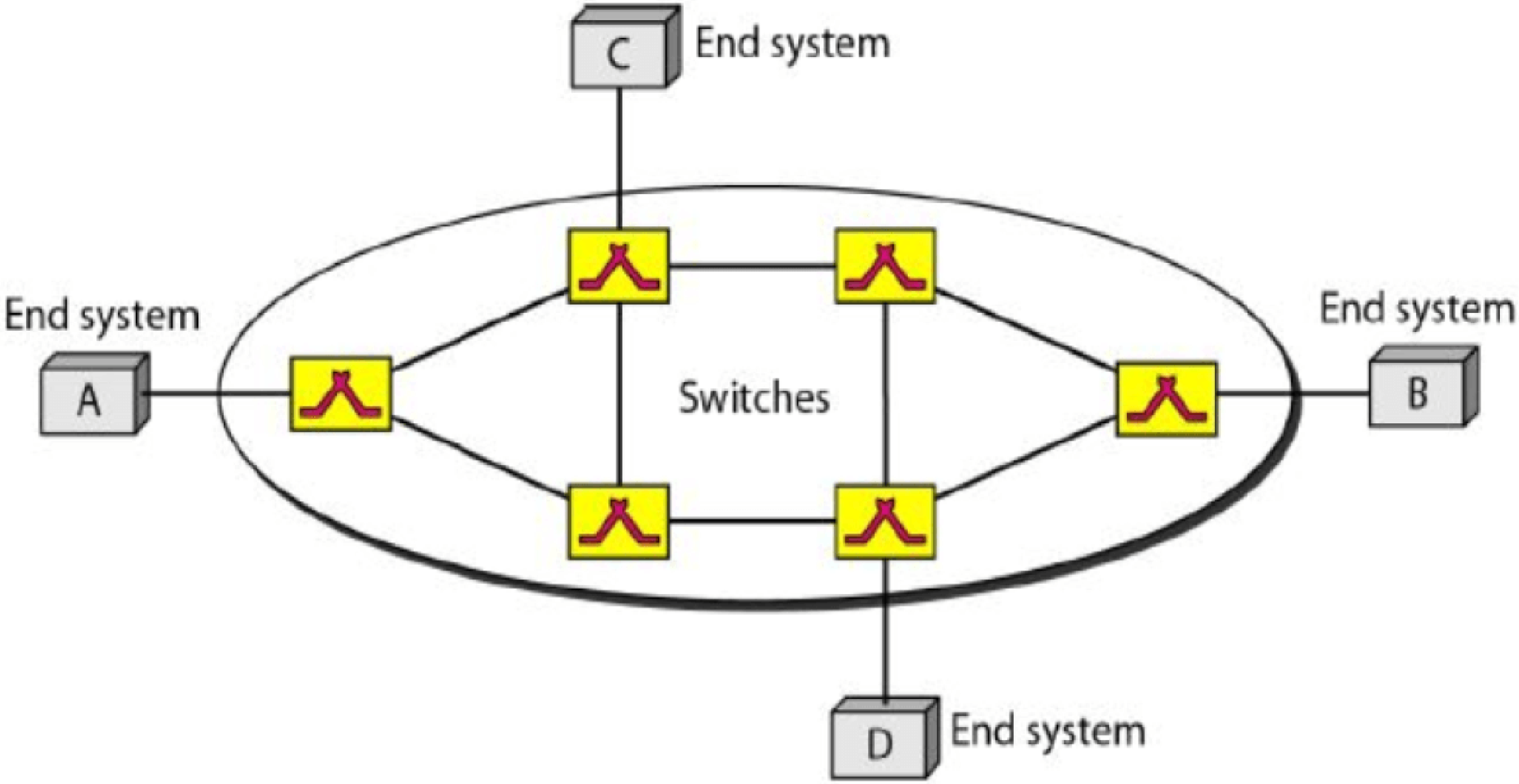
Packet Switch Network

Packet switching is a more efficient system for transmitting data, because it shares spectrum and bandwidth. By only using bandwidth when data is transmitted, and not holding a circuit open, many users can share capacity on a network more easily. Having an IP-type address for a device permits devices to act as part of the Internet, sending and receiving information automatically using standard protocols.

Another switching technology is based on **virtual circuits**. A virtual circuit is a logical circuit created within a shared network between two network devices. Two types of virtual circuits exist: switched virtual circuits (SVCs) and permanent virtual circuits (PVCs).

SVCs are virtual circuits that are dynamically established on demand and terminated when transmission is complete. Communication over an SVC consists of three phases: circuit establishment, data transfer, and circuit termination. The establishment phase involves creating the virtual circuit between the source and destination devices.

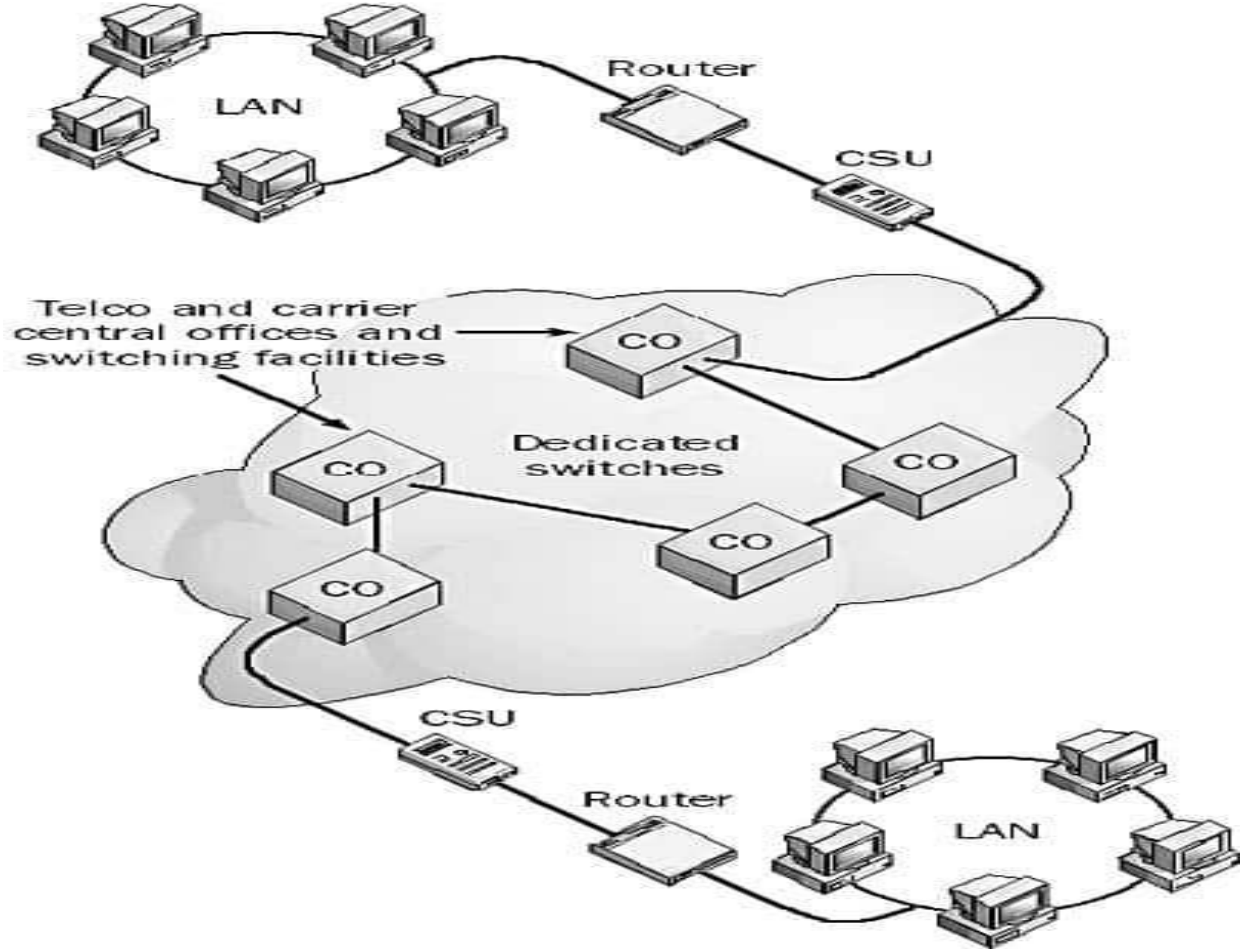
SVC



Data transfer involves transmitting data between the devices over the virtual circuit, and the circuit termination phase involves tearing down the virtual circuit between the source and destination devices. SVCs are used in situations in which data transmission between devices is sporadic, largely because SVCs increase bandwidth used due to the circuit establishment and termination phases, but they decrease the cost associated with constant virtual circuit availability.

PVC is a permanently established virtual circuit that consists of one mode: data transfer. PVCs are used in situations in which data transfer between devices is constant. PVCs decrease the bandwidth use associated with the establishment and termination of virtual circuits, but they increase costs due to constant virtual circuit availability. PVCs are generally configured by the service provider when an order is placed for service.

PVC



LAN
Router
CSU
Telco and carrier
central offices and
switching facilities
CO
Dedicated
switches
CO
CO
CO
CO
CSU
Router
LAN

Basis	Switched Virtual Circuit	Permanent Virtual Circuit
Definition	A virtual circuit is created when needed and is available only for the duration of the exchange	It is connection established permanently between two or more nodes.
Connection Termination	connection establishment and termination is required	connection establishment and termination is not needed
Route	Two SVC users may or may not get a distinct route for a connection.	Two PVC users get the same route always.

Wireless Communication Problems

The various problems encountered in wireless communication for wireless networks. The problems are, namely, shared media, increased bit error rate (BER), lower radio transmission power, scattering, reflection, diffraction, multipath propagation, fading, path loss, radio frequency (RF) signal interference, etc.

1- Shared media: The wireless media offers lower bandwidth in spite of the technologies coming up to support Mbps wireless networks. Therefore, the effective utilization of the bandwidth is necessary for wireless networks.

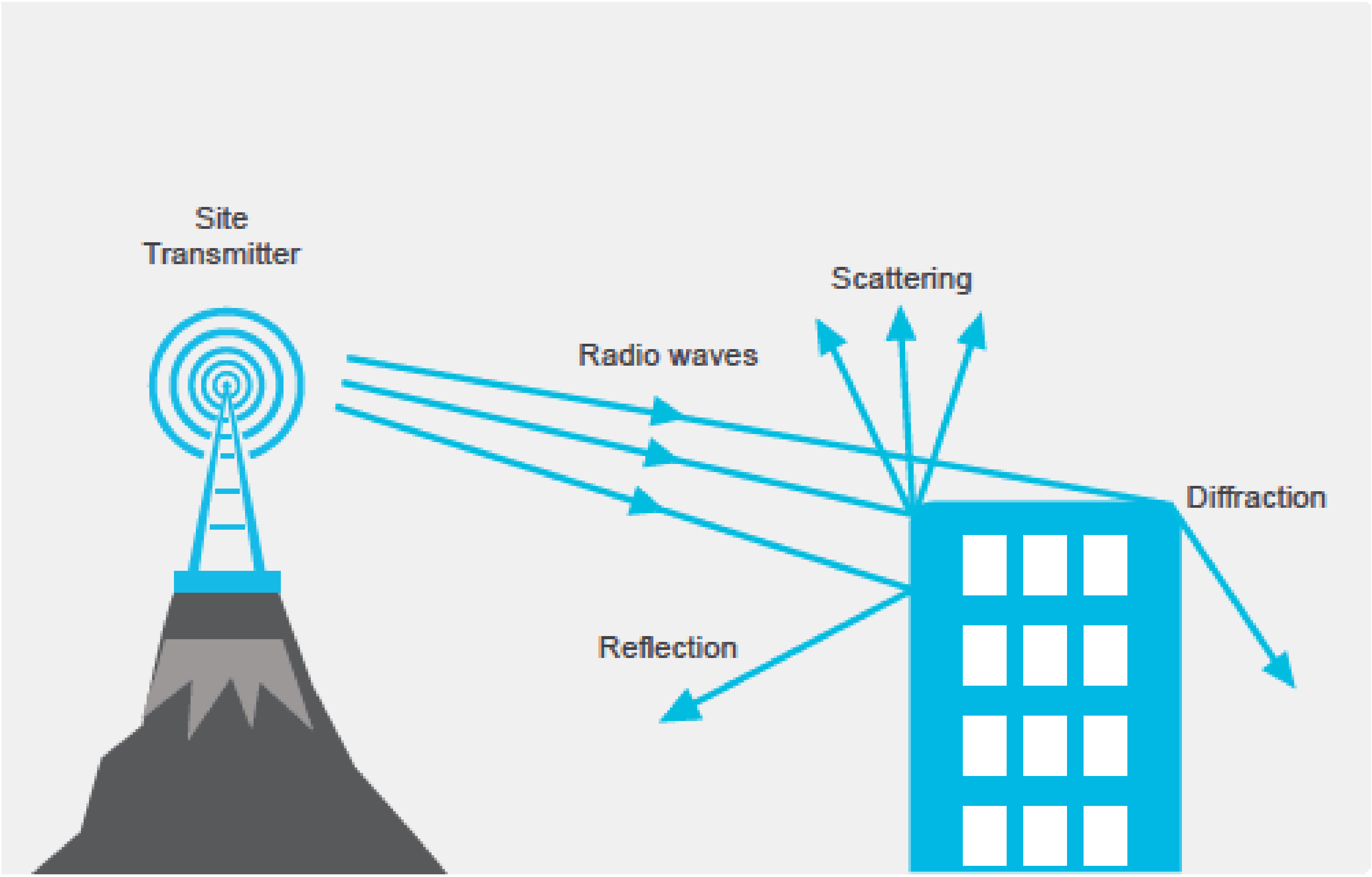
2- Increased bit error rate (BER): Wireless network media is more prone to errors due to obstacles coming in between the transmitter and the receiver, and the interference caused by neighboring transmitters. One can observe frequent disconnections causing loss of data and annoying the users especially in voice and video communications.

3- Lower radio transmission power: Mobile units are compact in size and work on battery with scarce energy resources. The mobile nodes limit transmission power to avoid interference. Signal strength decreases with inverse square of distance. Higher frequency (3–5 GHz) usage increases attenuation and decreases range of communication.

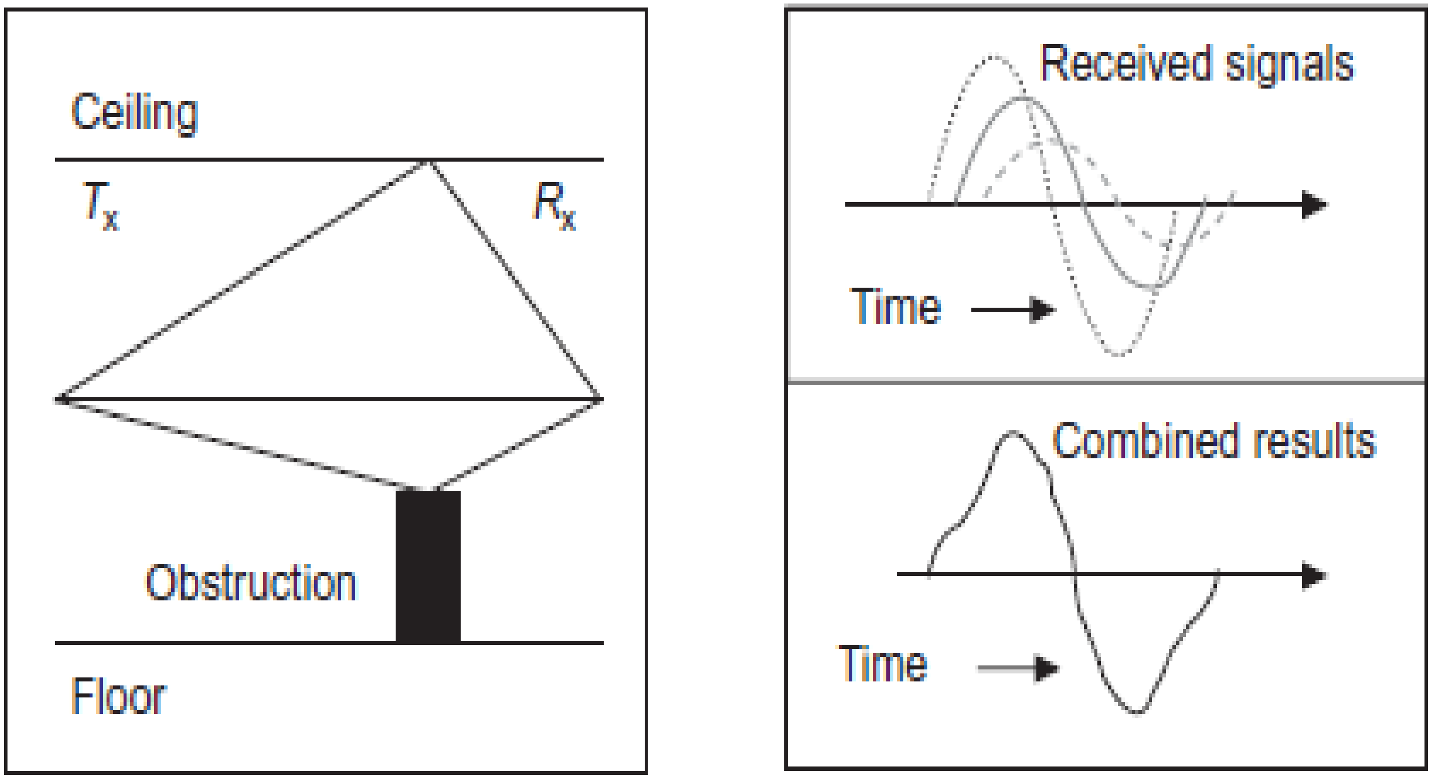
4- Scattering: Scattering occurs when the material through which the wave travels has objects with dimensions that are small compared to the wavelength, and where the number of obstacles per unit volume is large. Scattered waves are produced by rough surfaces, small objects, or other irregularities in the channel. To provide proper functioning of radio devices in this kind of environment, it is necessary that the radio network design utilizes the correct deployment methodologies (placement and antenna selection) to minimize this effect.

5- Reflection: Reflection occurs when a propagating electromagnetic wave strikes an object which has very large dimensions compared to the wavelength of the propagating wave, for example, walls, furniture, building structure, etc.

6- Diffraction: Diffraction occurs when the radio path between the transmitter and the receiver is obstructed by a surface that has sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle.

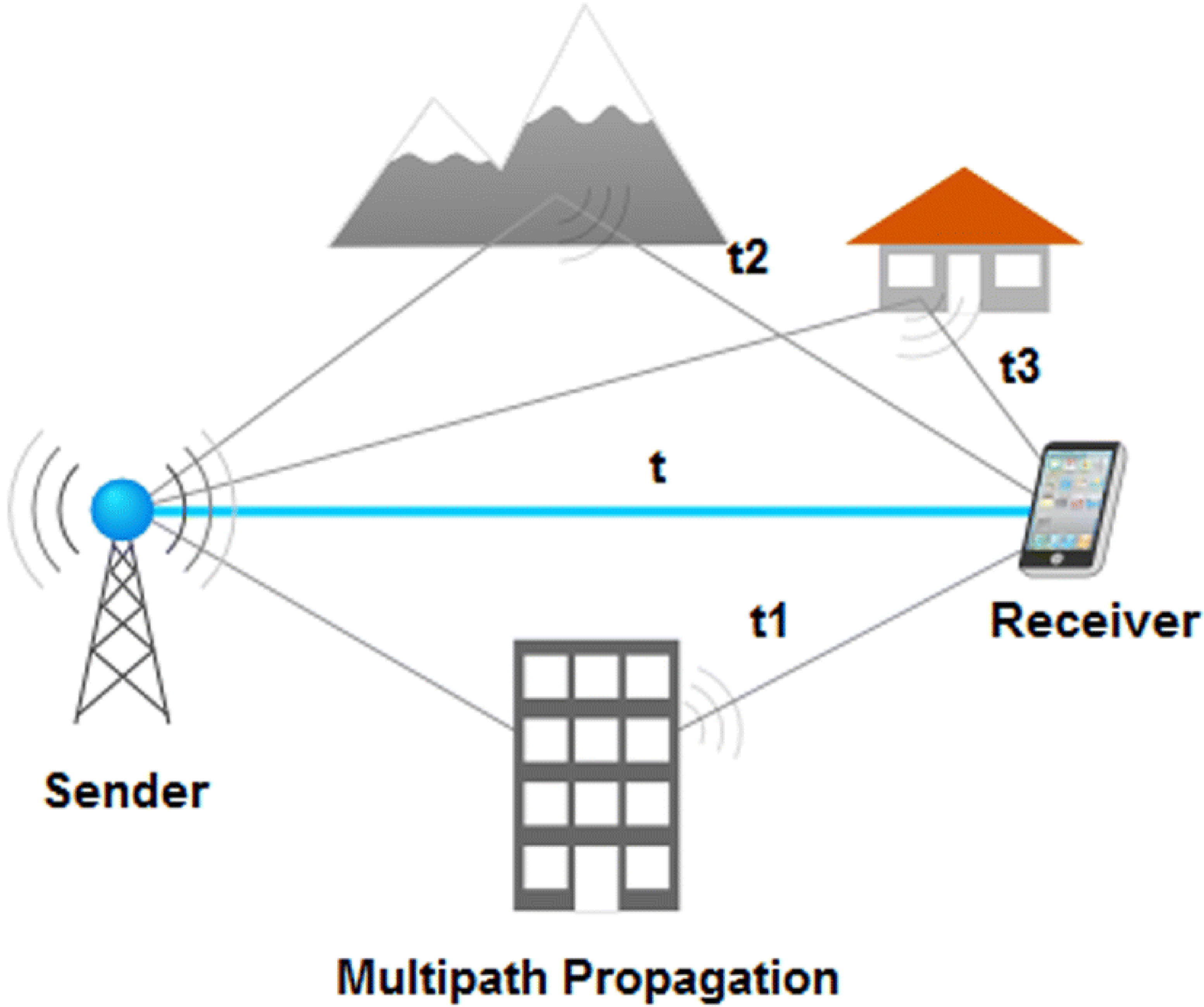

Site
Transmitter
Scattering
Radio waves
Diffraction
Reflection

7- Multipath propagation: The multipath problem in mobile radio is caused by reflection and scattering from buildings, trees, and other obstacles along the radio path. Radio waves arrive at a mobile receiver from many different directions, with different time delays. Together with a possible direct ray, a ground-reflected ray, and other possible scattered rays, these combine vectorially at the receiver antenna to give a resultant signal which depends on the differences in path length that exist in this multipath field.



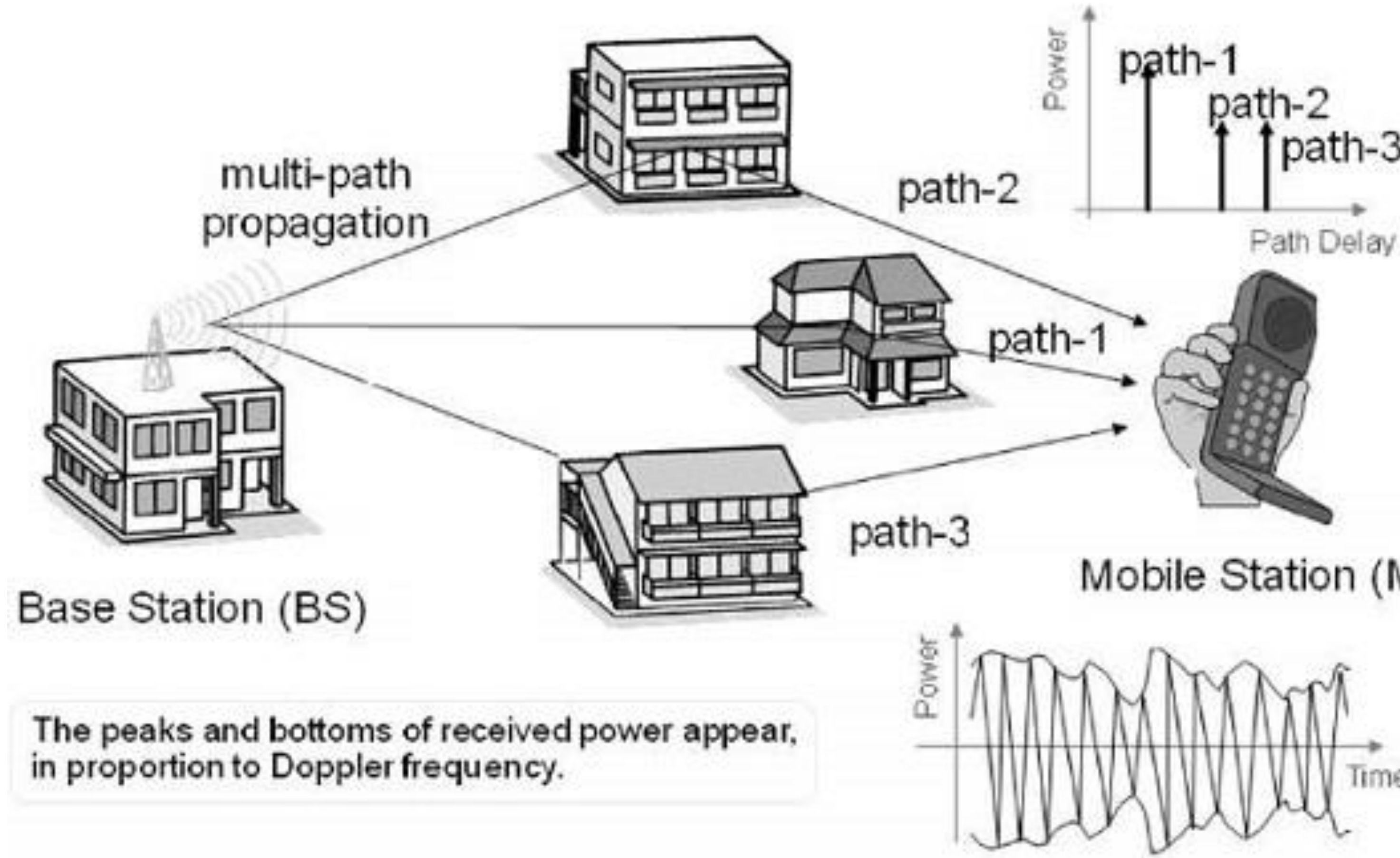
Multipath propagation of a signal. R_x: receiver; T_x: transmitter.

The multipath propagation of a signal from transmitter to receiver in a room where the signal gets reflected by the ceiling and obstructions. Signals are received from various paths with time delays and the final signal is the summation of the all received signals. As vehicle-borne, or handheld, receiver moves from one location to another, the phase relationship between the components of the various incoming waves changes, so the resultant signal changes.


t2
t3
t
t1
Receiver
Sender
Multipath Propagation

8- Fading: Signal-fading phenomena can drastically affect the performance of a wireless communications system. Often caused by multipath conditions, fading can degrade the BER performance of a digital communications system, resulting in the data loss. A key to preventing loss of radio performance is to understand the nature of multipath fading phenomena and how to anticipate when such phenomena may be a concern.

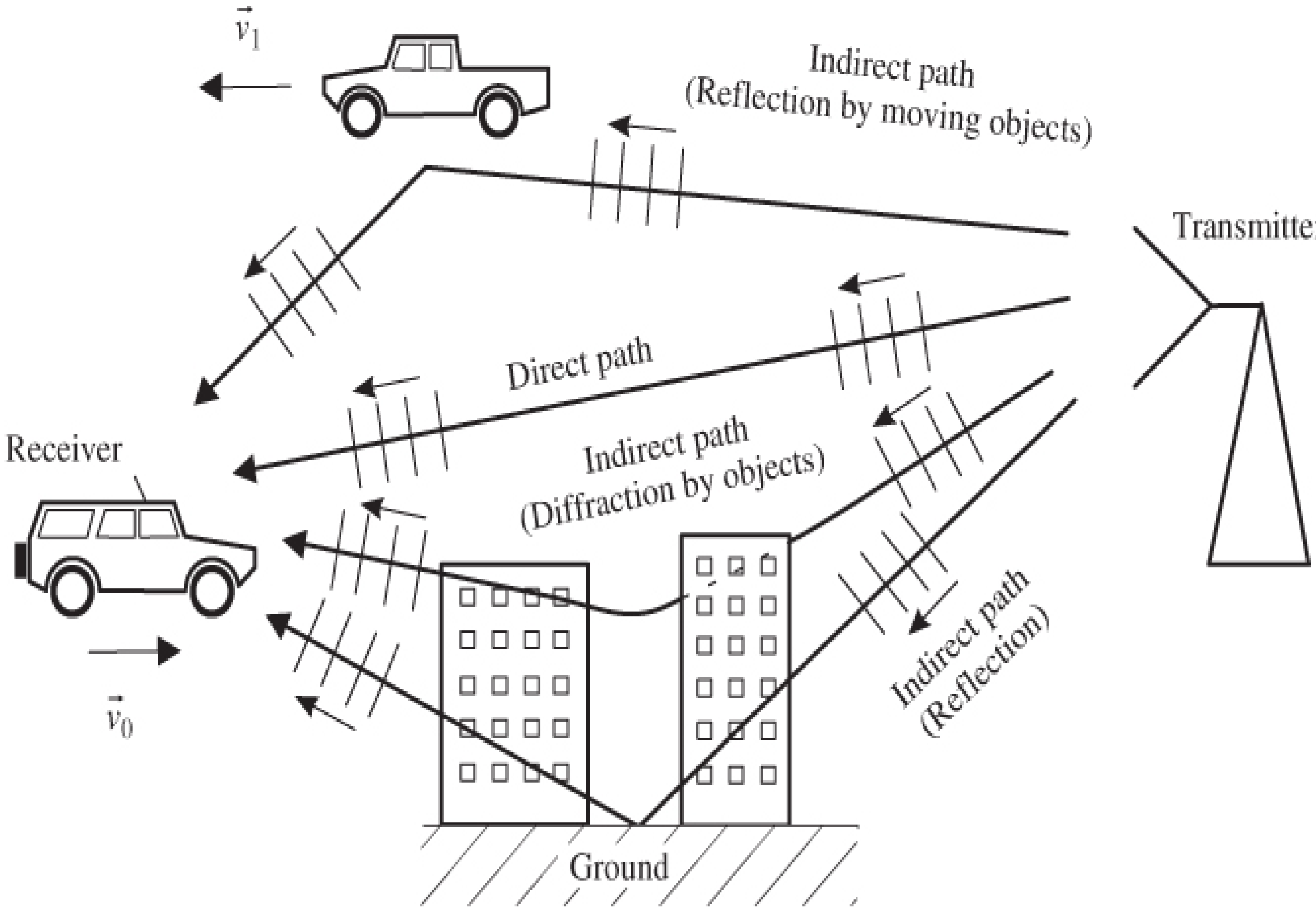
Fading can occur in many forms, including a phenomenon called **flat fading**. In flat fading, the same degree of fading takes place for all the frequency components transmitted through a radio channel and within the channel bandwidth. That is, all the frequency components of the transmitted signal rise and fall in unison.


multi-path
propagation
path-1
path-2
path-3
Power
Path Delay
Base Station (BS)
Mobile Station (MS)
The peaks and bottoms of received power appear,
in proportion to Doppler frequency.
Power
Time

In contrast, **frequency-selective fading** causes different frequencies of an input signal to be attenuated and phase shifted differently in a channel. Frequently, channels experiencing frequency-selective fading may require an equalizer to achieve the desired performance. Frequency-selective fading gives rise to notches in the frequency response of the channel.

Equalization techniques attempt to restore the memoryless (flat fading) nature of the channels. With proper equalization, it is possible to transmit at higher data rates before the onset of inter symbol interference (ISI) is apparent in the time domain.

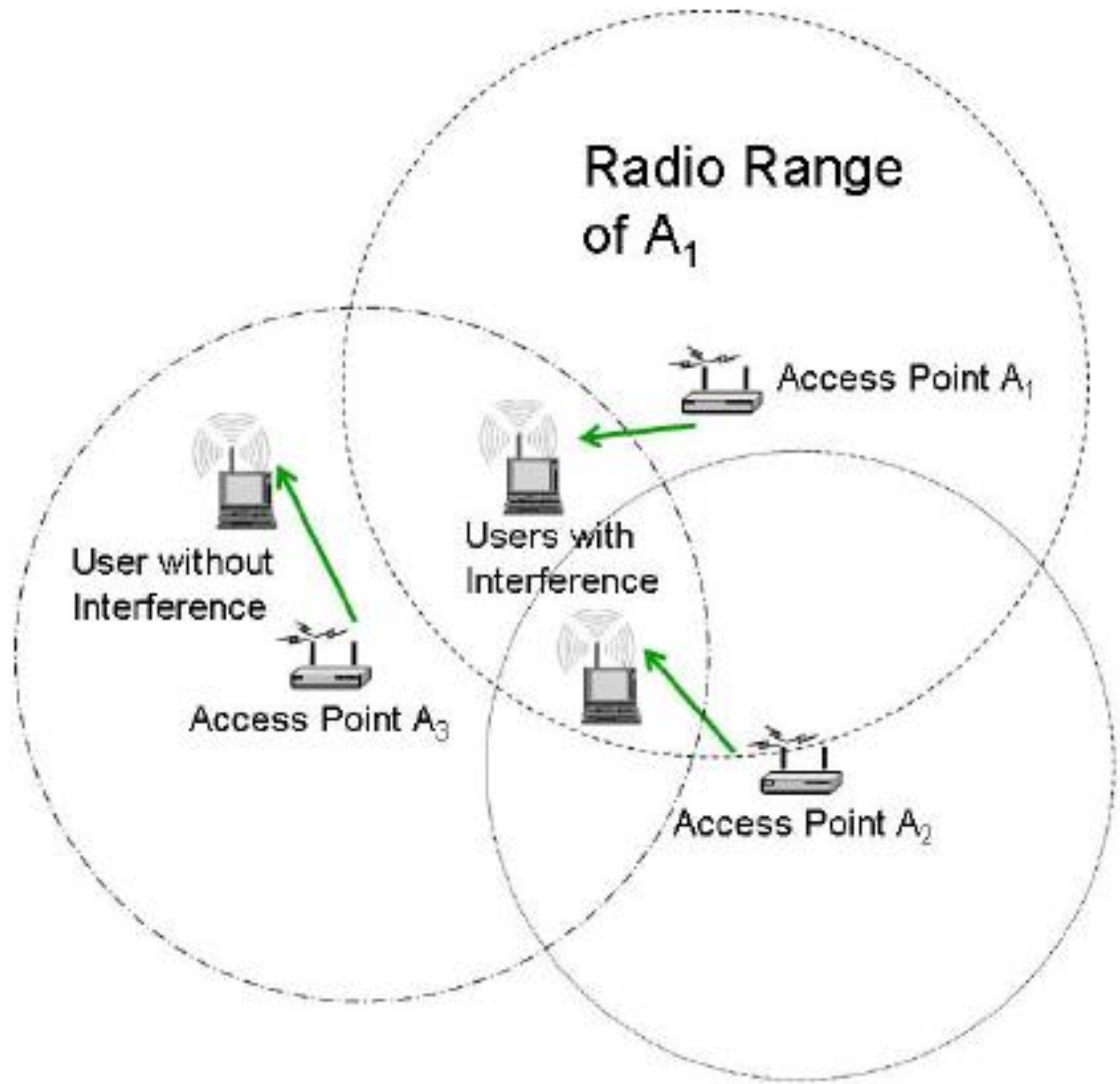
9- Path loss: Path loss between the transmitter and the receiver is a key consideration when designing a wireless network. Expected levels of path loss, based on the range between the transmitter and the receiver, provide valuable information when determining requirements for transmit power levels, receiver sensitivity, and signal-to-noise ratio (SNR).



$\vec{v}_1$
Indirect path
(Reflection by moving objects)
Transmitter
Direct path
Receiver
Indirect path
(Diffraction by objects)
Indirect path
(Reflection)
$\vec{v}_0$
Ground

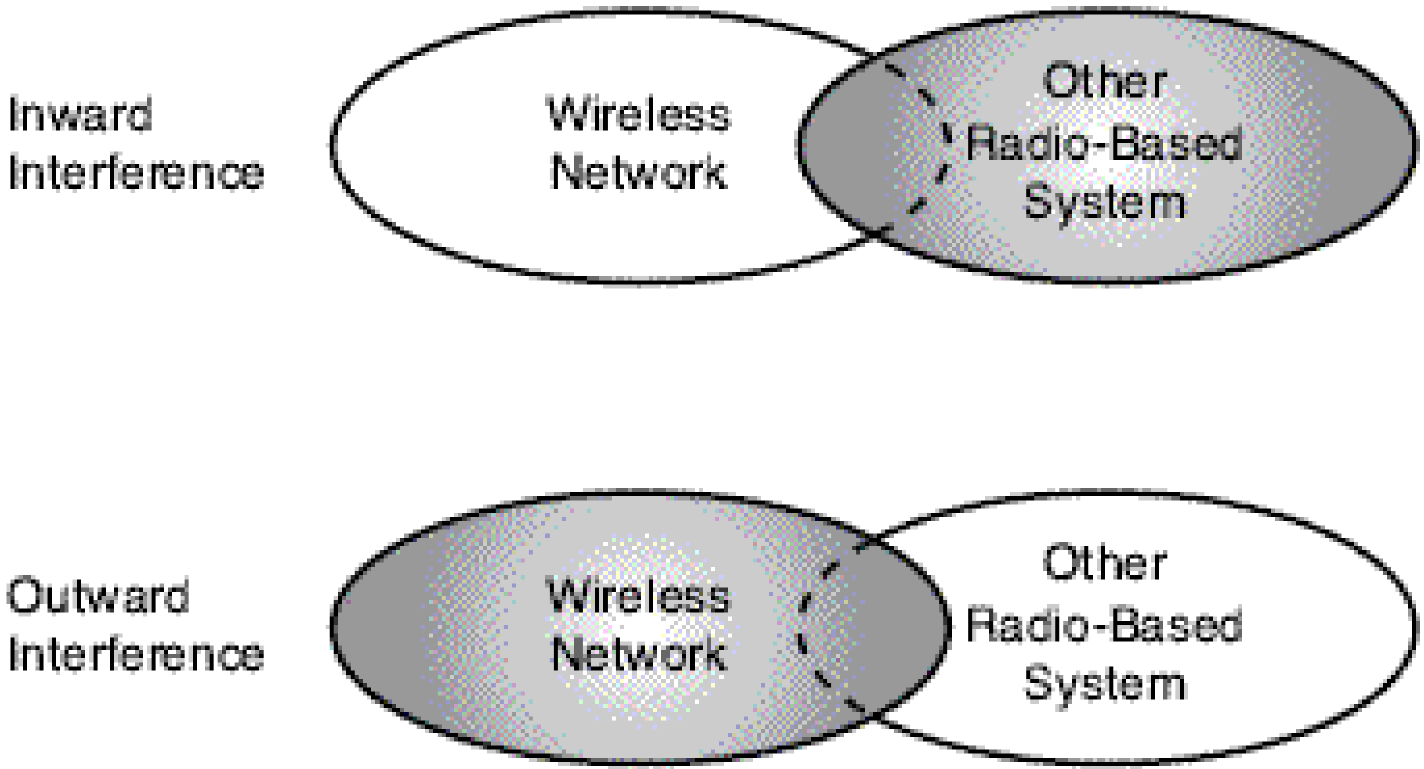
Actual path loss depends on the transmit frequency, and it grows exponentially as range increases between the transmitter and the receiver. With typical indoor applications, the path loss increases at approximately 20 dB every 100 ft. Multipath propagation can cause signal fading, which effectively increases path loss. The primary method for countering the effects of path loss is to utilize additional access points in a wireless network to provide adequate coverage throughout the facility where the wireless networks will operate.

10- RF signal interference: The process of transmitting and receiving radio and laser signals through the air makes wireless systems vulnerable to atmospheric noise and transmissions from other systems. In addition, wireless networks can interfere with other nearby wireless networks and radio wave equipment. Interference can take on an inward or outward direction.


Radio Range
of A_1
Access Point A_1
Users with
Interference
User without
Interference
Access Point A_3
Access Point A_2

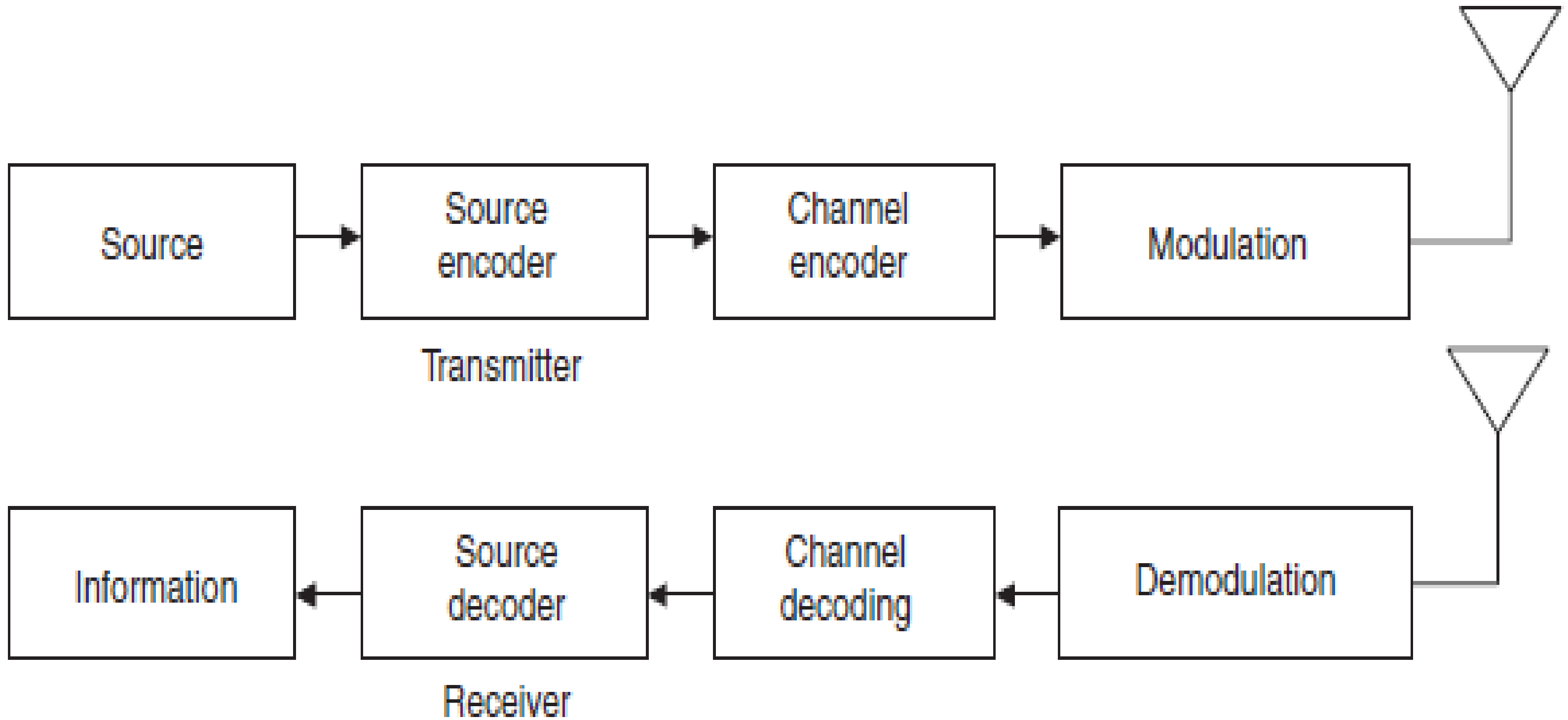
A radio-based network, for example, can experience **inward interference** or co-channel interference either from the harmonics of transmitting systems or from other products by using similar radio frequencies in the local area. Microwave ovens operate in the S-band (2.4 GHz) that many wireless LANs use to transmit and receive. These signals result in delays to the user by either blocking transmissions from stations on the LAN or by causing bit errors to occur in data being sent. These types of interference can limit the areas where the deployment of wireless network takes place.

The other half of the issue, **outward or adjacent channel interference**, occurs when a wireless network's signal disrupts other systems, such as adjacent wireless LANs and navigation equipment on aircraft. This disruption results in the loss of some or all of the system's functionality. Interference is uncommon with wireless LAN products operating in the public spread spectrum bands because they operate on such a little power (less than 1 W). The transmitting components must be very close and must be operating in the same band for either one to experience inward or outward interference.


Inward Interference
Wireless Network
Other Radio-Based System
Outward Interference
Wireless Network
Other Radio-Based System

Wireless Communication System

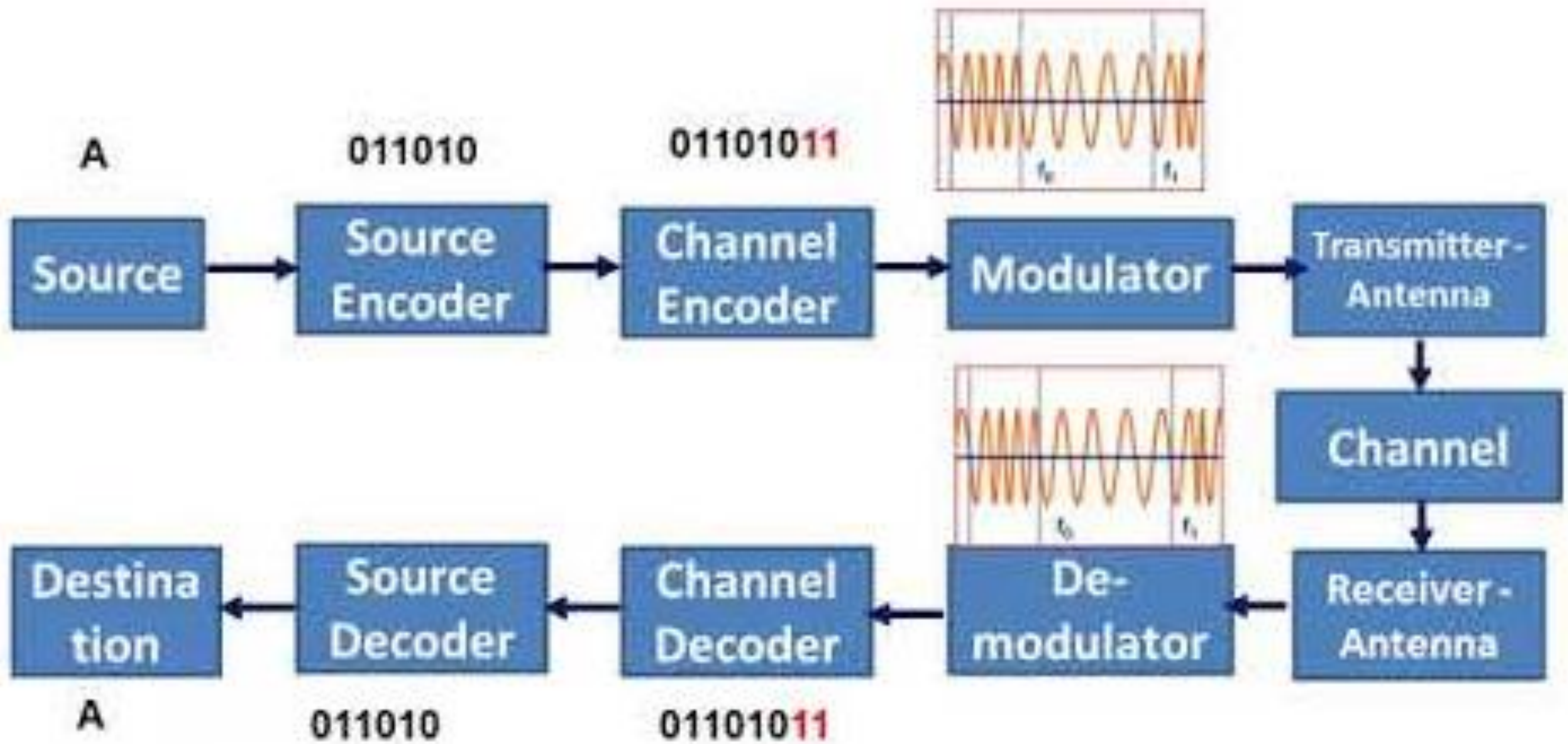
Wireless communication systems exchange electronic data among different users through a wireless media. Analog communication systems convert (modulate) analog signals into modulated (analog) signals whereas digital communication systems convert information in the form of bits into digital signals. Analog signals can be converted into bits by quantizing and digitizing for use in digital communications.



Wireless communication system.

A typical wireless system communication consisting of transmitter and receiver. The transmitter receives the information from the source and encodes it by using a source encoder. The source encoder is used to encode the message from the source into a continuous stream of bits. Methods for source encoding are waveform coding, linear predictive coding, etc.

The channel encoder encodes the signal for error correction and detection by adding some redundant bits. The encoded signal is modulated by using the digital modulation schemes. The modulated signal is sent over the wireless medium. The receiver demodulates and decodes (channel decoding and source decoding) the signal to obtain the transmitted information.


A
011010
01101011
Source
Source Encoder
Channel Encoder
Modulator
Transmitter - Antenna
Channel
Receiver - Antenna
De-modulator
Channel Decoder
Source Decoder
Destina tion
A
011010
01101011

Source coding deals with the time and amplitude discretization of the analog source signal. Typical analog source signals in communication systems are speech and image signals. Thus, source coding techniques can be classified into speech and image coding.

The output of the transmitter encoder is further digitally processed and encoded for the error control during the transmission through the communication channel. This process is called **channel coding**. The following are examples of commonly used error detection and error correction techniques: cyclic redundancy check (CRC), block coding, and interleaving.