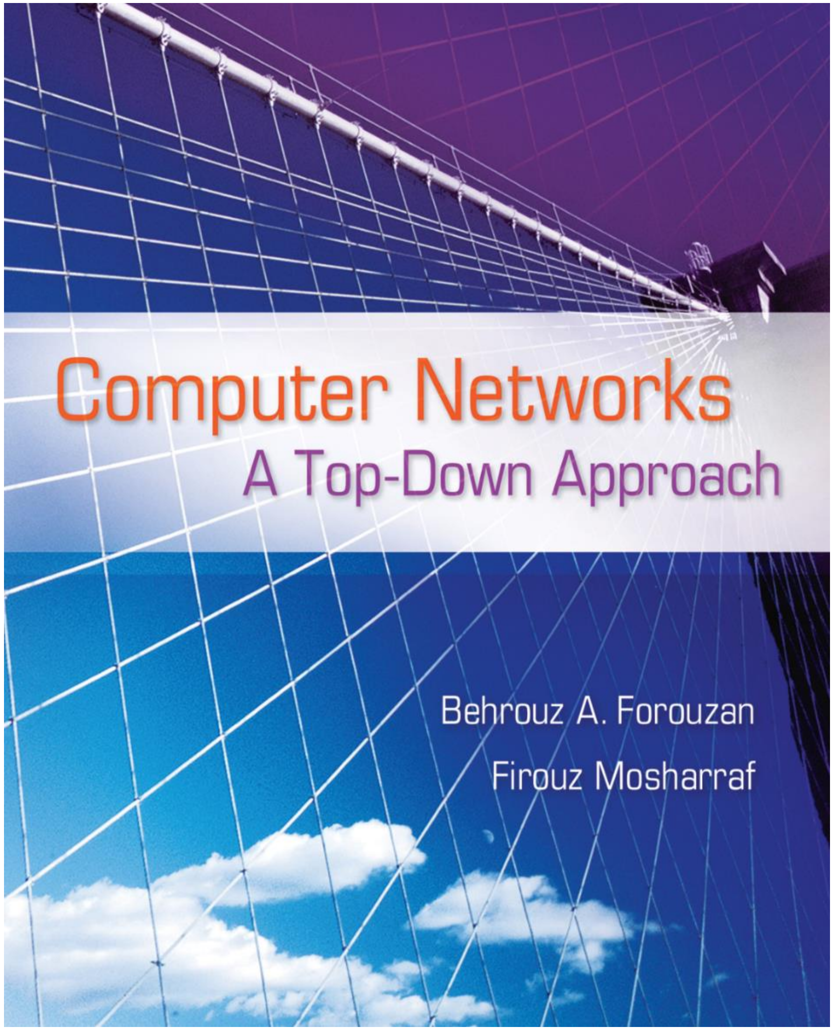
Chapter 6
WIRELESS NETWORKS



Chapter 6: Outline & Objective

WIRLESS LANS

OTHER WIRELESS NETWORKS

- ***We introduce wireless LANs, using IEEE project 802.11, the dominant standard.***
- ***We also discuss WiMAX technology, which is the counterpart of last-mile wired networks such as DSL or cable.***

6-1 WIRELESS LANS

- ***Wireless communication is one of the fastest-growing technologies.***
- ***The demand for connecting devices without the use of cables is increasing everywhere.***
- ***Wireless LANs can be found on college campuses, in office buildings, and in many public areas.***

6.1.1 Introduction

Before we discuss a specific protocol related to wireless LANs, let us talk about them in general.

- ***Architectural Comparison***
  - ***Medium***
  - ***Hosts***
  - ***Isolated LANs***
  - ***Connection to Other Networks***
  - ***Moving between Environments***

- ***Characteristics***
  - ***Attenuation***
  - ***Interference***
  - ***Multipath Propagation***
  - ***Error***

Figure 6.1: Isolated LANs: wired versus wireless

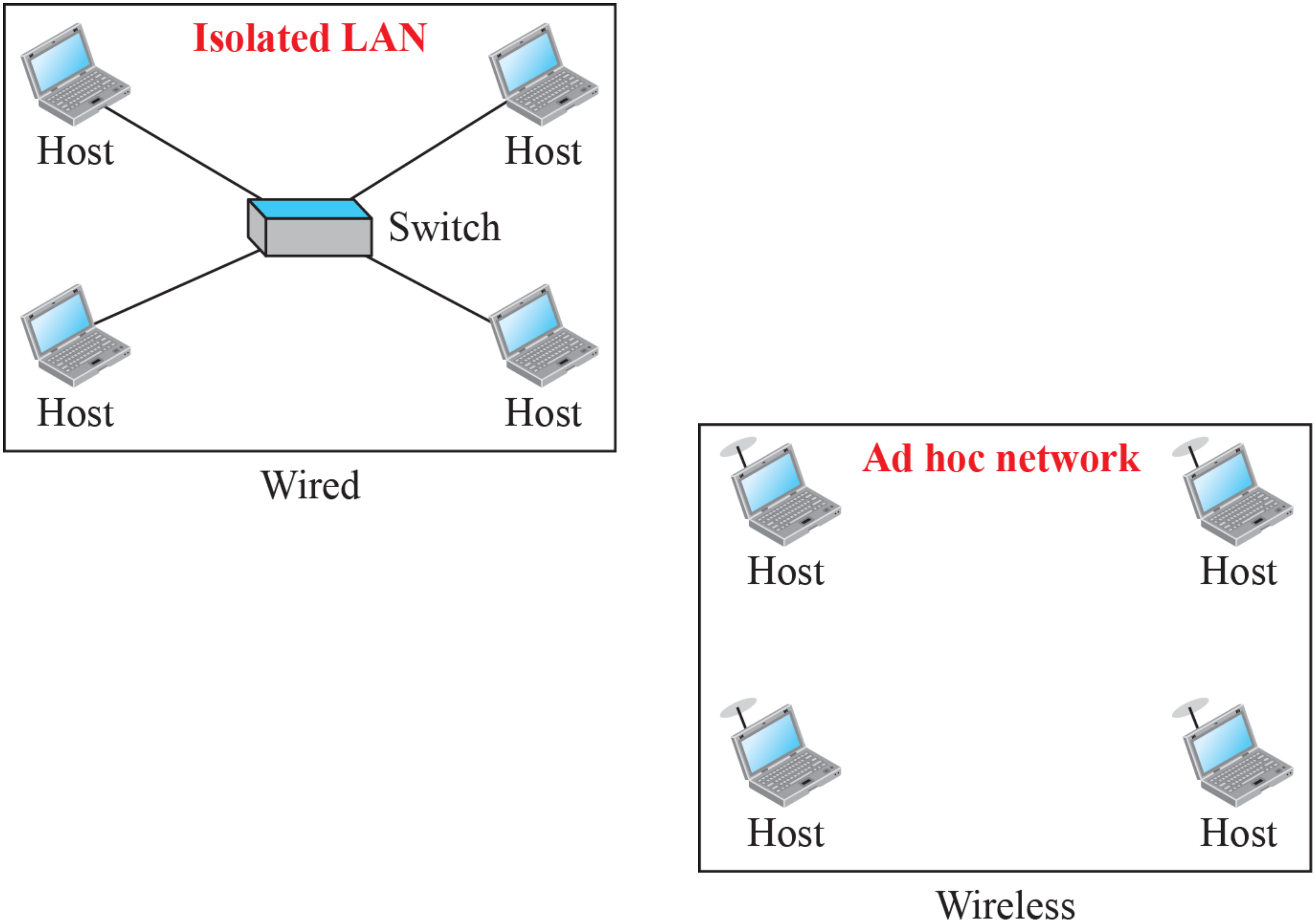


Figure 6.2: *Connection of a wired LAN and a wireless LAN to other networks*

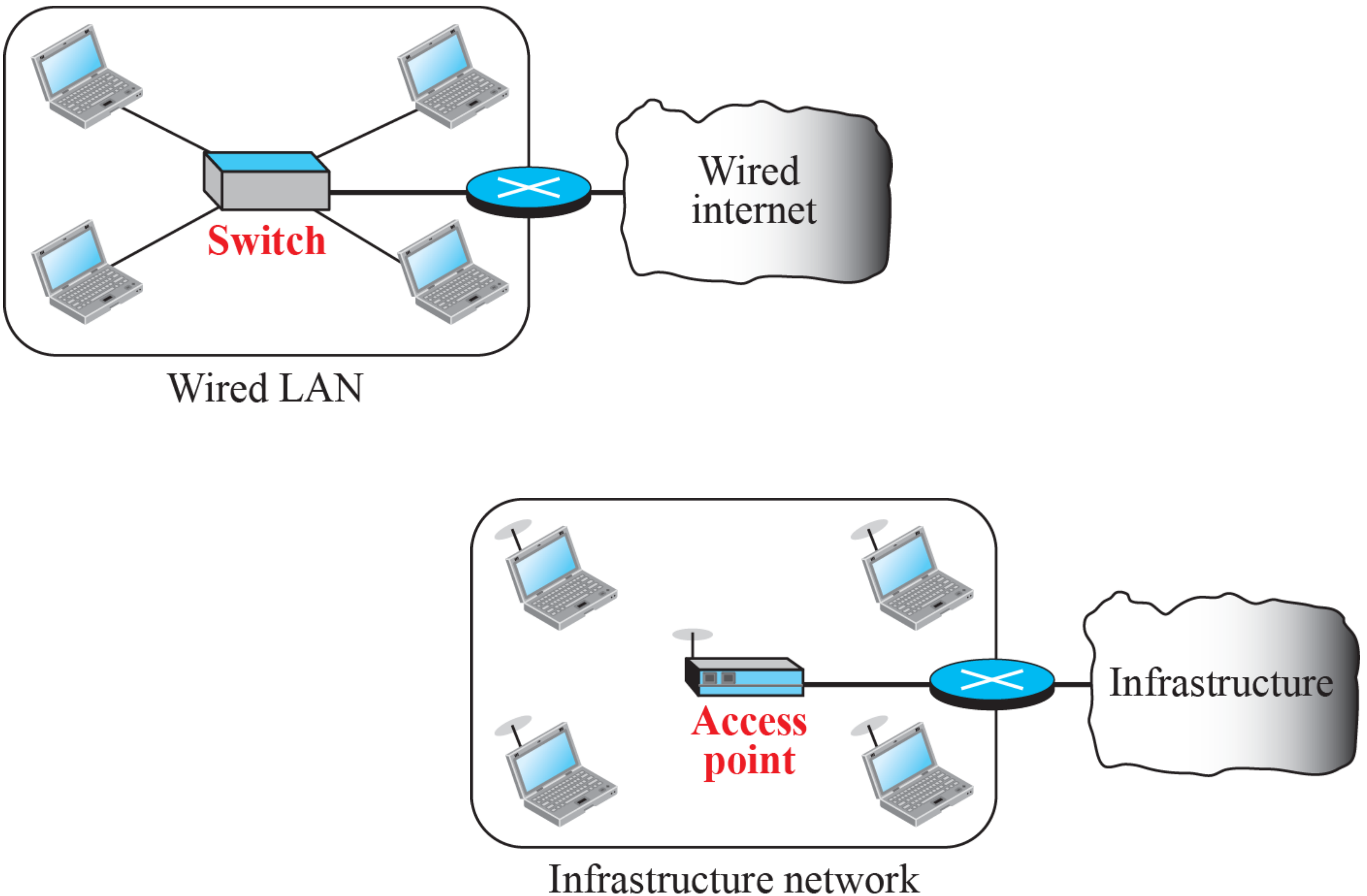
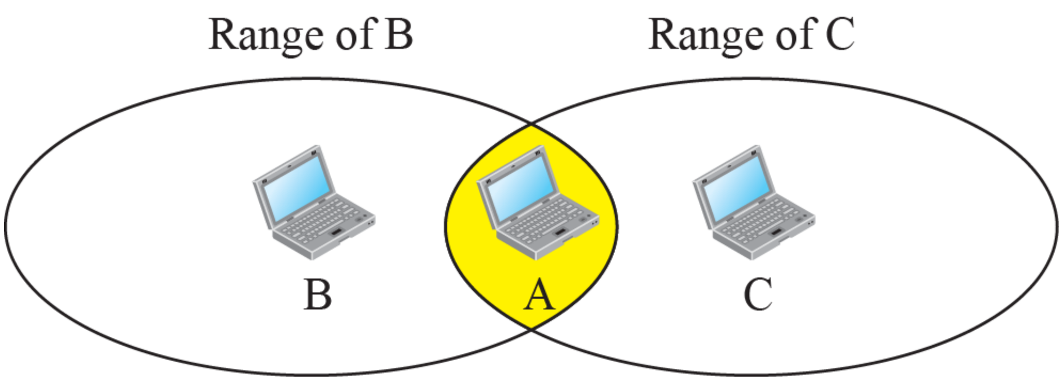
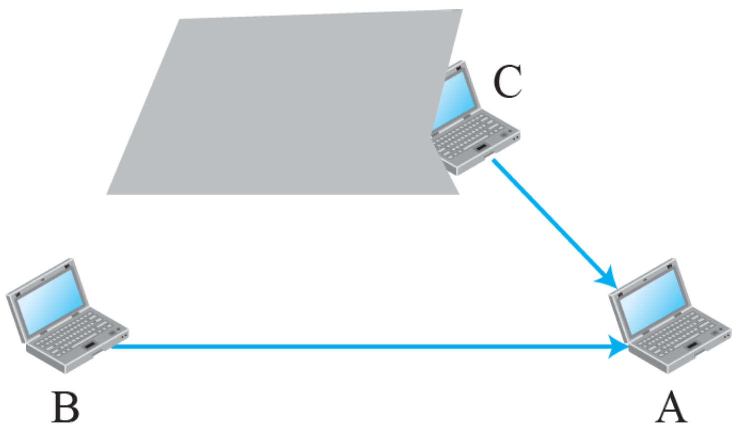


Figure 6.3: Hidden station problem



a. Stations B and C are not in each other's range.



b. Stations B and C are hidden from each other.

Characteristics

- *There are several characteristics of wireless LANs that either do not apply to wired LANs or the existence of which is negligible and can be ignored.*
- *We discuss some of these characteristics here to pave the way for discussing wireless LAN protocols.*
- *Wired LANs uses shared medium a dedicated medium (point-to-point communication). So the MAC protocol, such as CSMA/CD, is not needed anymore.*
- *In the case of a wireless LAN, the medium (air) is still shared between the users. We need MAC protocols such as CSMA/CA or channelization protocols to control sharing the medium.*

15.15.3 Access Control

Maybe the most important issue we need to discuss in a wireless LAN is access control—how a wireless host can get access to the shared medium (air). The CSMA/CD algorithm does not work in wireless LANs for three reasons:

1. ***Wireless hosts do not have enough power to send and receive at the same time.***
2. ***The hidden station problem prevents collision detection***
3. ***The distance between stations can be great.***

6.1.2 IEEE 802.11 Project

- ***IEEE has defined the specifications for a wireless LAN, called IEEE 802.11, which covers the physical and data-link layers.***
- ***In some countries, including the United States, the public uses the term WiFi (short for wireless fidelity) as a synonym for wireless LAN.***
- ***WiFi, however, is a wireless LAN that is certified by the WiFi Alliance, a global, nonprofit industry association of more than 300 member companies devoted to promoting the growth of wireless LANs.***

802	Overview	Basics of physical and logical networking concepts.
802.1	Bridging	LAN/MAN bridging and management. Covers management and the lower sub-layers of OSI Layer 2, including MAC-based bridging (Media Access Control), virtual LANs and port-based access control.
802.2	Logical Link	Commonly referred to as the LLC or Logical Link Control specification. The LLC is the top sub-layer in the data-link layer, OSI Layer 2. Interfaces with the network Layer 3.
802.3	Ethernet	"Grandaddy" of the 802 specifications. Provides asynchronous networking using "carrier sense, multiple access with collision detect" (CSMA/CD) over coax, twisted-pair copper, and fiber media. Current speeds range from 10 Mbps to 10 Gbps. Click for a list of the "hot" 802.3 technologies.
802.11	Wi-Fi	Wireless LAN Media Access Control and Physical Layer specification. 802.11a,b,g,etc. are amendments to the original 802.11 standard. Products that implement 802.11 standards must pass tests and are referred to as "Wi-Fi certified."
802.11a		Specifies a PHY that operates in the 5 GHz U-NII band in the US - initially 5.15-5.35 AND 5.725-5.85 - since expanded to additional frequencies
		Uses Orthogonal Frequency-Division Multiplexing
		Enhanced data speed to 54 Mbps Ratified after 802.11b
802.11b		Enhancement to 802.11 that added higher data rate modes to the DSSS (Direct Sequence Spread Spectrum) already defined in the original 802.11 standard
		Boosted data speed to 11 Mbps 22 MHz Bandwidth yields 3 non-overlaping channels in the frequency range of 2.400 GHz to 2.4835 GHz. Beacons at 1 Mbps, falls back to 5.5, 2, or 1 Mbps from 11 Mbps max.
802.11g		Extends the maximum data rate of WLAN devices that operate in the 2.4 GHz band, in a fashion that permits interoperation with 802.11b devices. Uses OFDM Modulation (Orthogonal FDM). Operates at up to 54 megabits per second (Mbps), with fall-back speeds that include the "b" speeds
802.11n		Higher-speed standards. Several competing and non-compatible technologies; often called "pre-n"
		Top speeds claimed of 108, 240, and 350+ MHz. Competing proposals come from the groups, EWC, TGn Sync, and WWiSE and are all variations based on MIMO (multiple input, multiple output)
802.14	Cable modems	Withdrawn PAR. Standards project no longer endorsed by the IEEE.
802.15	Wireless Personal Area Networks	Communications specification that was approved in early 2002 by the IEEE for wireless personal area networks (WPANs).
802.15.1	Bluetooth	Short range (10m) wireless technology for cordless mouse, keyboard, and hands-free headset at 2.4 GHz.
802.16	Wireless Metropolitan Area Networks	This family of standards covers Fixed and Mobile Broadband Wireless Access methods used to create Wireless Metropolitan Area Networks (WMANs.) Connects Base Stations to the Internet using OFDM in unlicensed (900 MHz, 2.4, 5.8 GHz) or licensed (700 MHz, 2.5 – 3.6 GHz) frequency bands. Products that implement 802.16 standards can undergo WiMAX certification testing.

6.1.2 (continued)

- ***Architecture:*** ***The standard defines two kinds of services: the basic service set (BSS) and the extended service set (ESS).***
  - ***Basic Service Set***
  - ***Extended Service Set***
  - ***Station Types***

- ***MAC Sublayer***
  - ***Distributed Coordination Function (DCF)***
  - ***Point Coordination Function (PCF)***
  - ***Fragmentation***
  - ***Frame Format***
  - ***Frame Types***

- ***Addressing Mechanism***
- ***Exposed Station Problem***
- ***Physical Layer***
  - ***IEEE 802.11 FHSS***
  - ***IEEE 802.11 DSSS***
  - ***IEEE 802.11 Infrared***
  - ***IEEE 802.11a OFDM***
  - ***IEEE 802.11b DSSS***
  - ***IEEE 802.11g***
  - ***IEEE 802.11n***

Figure 6.4: Basic service sets (BSSs)

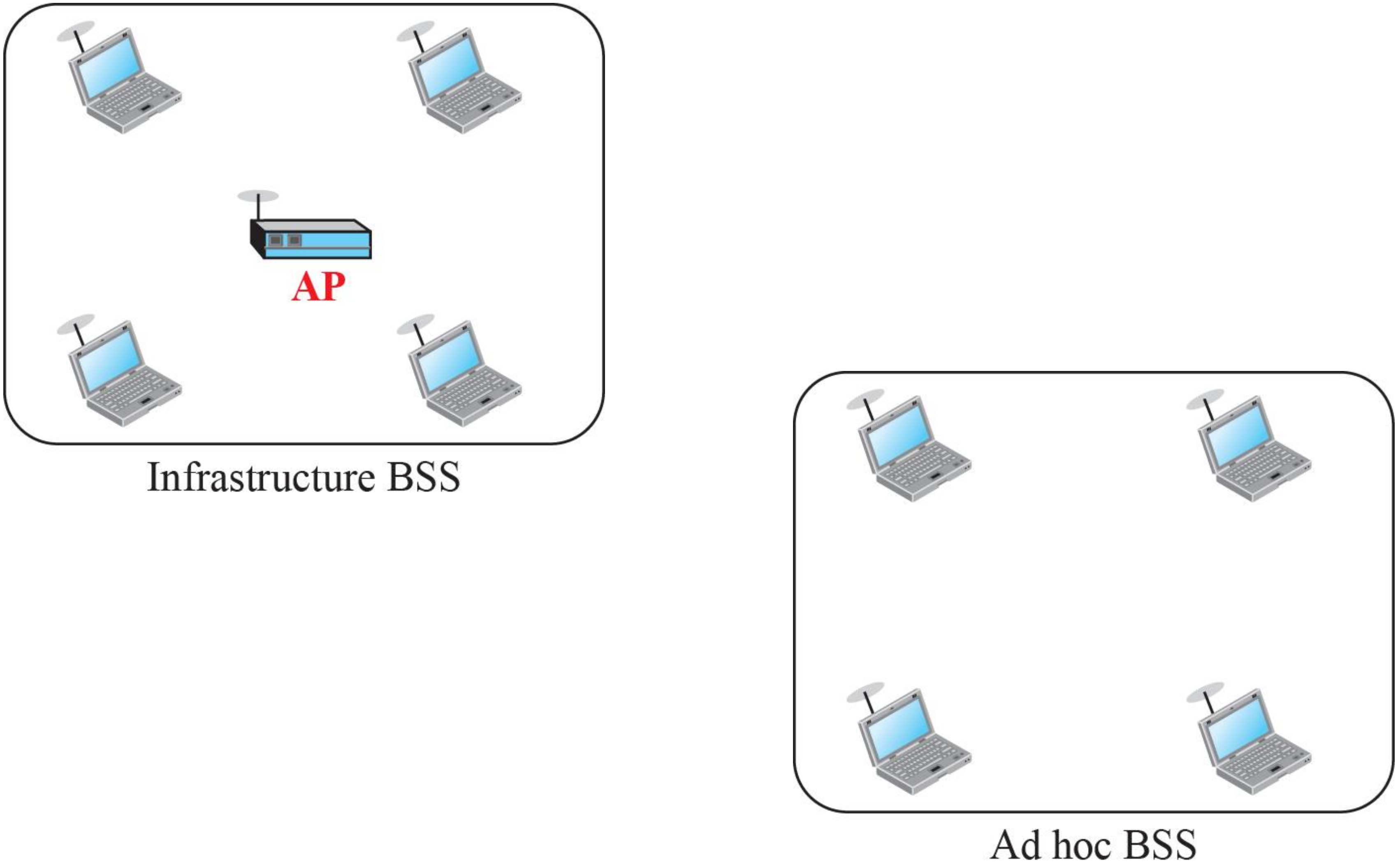
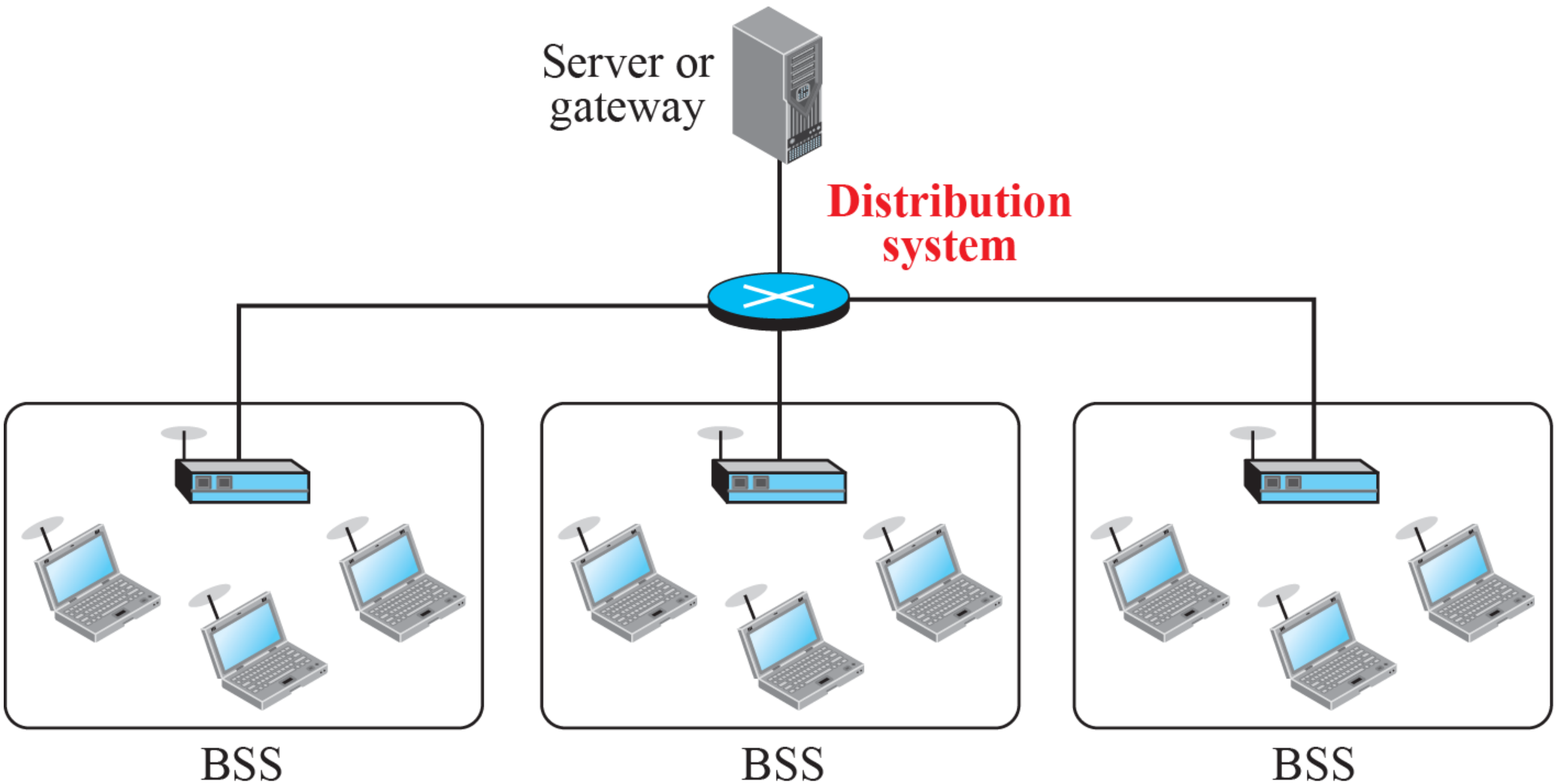


Figure 6.5: Extended service set (ESS)



Wireless Network Components & Architecture

- **Basic Service Set (BSS)**
  – Smallest WLAN block
- **Distribution System (DS)**
  – Connects BSS blocks
- **Access Points (AP)**
  – Functions as a bridge or relay point
- **Extended Service Set (ESS)**
  – Two or more BSS interconnected by a DS

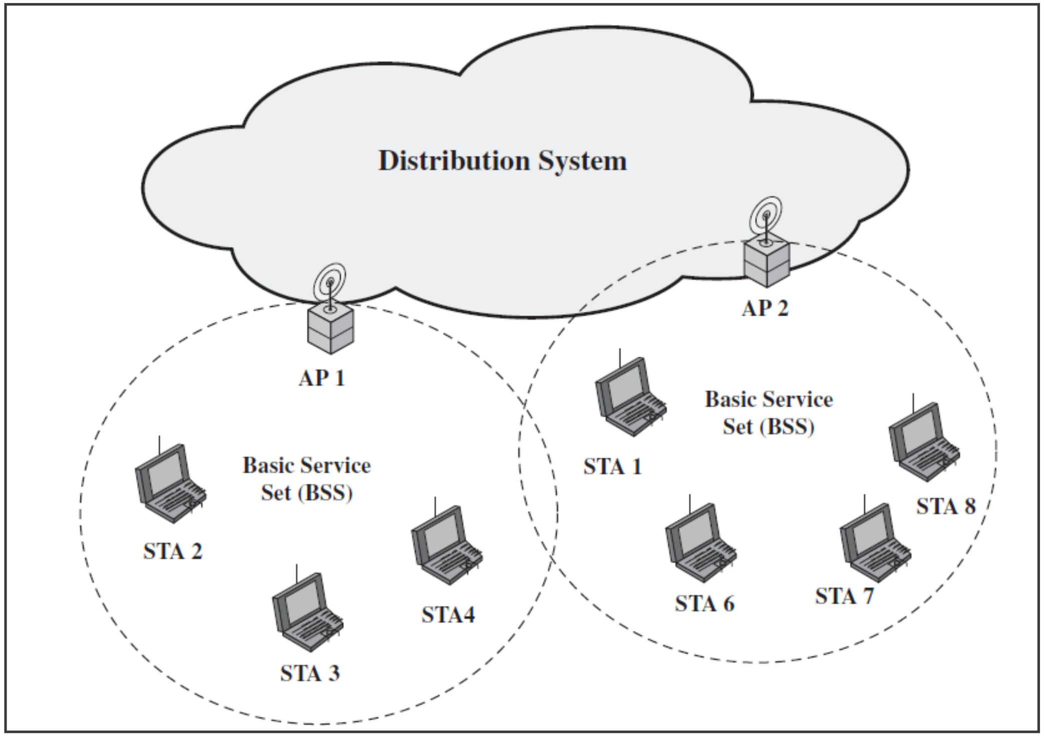
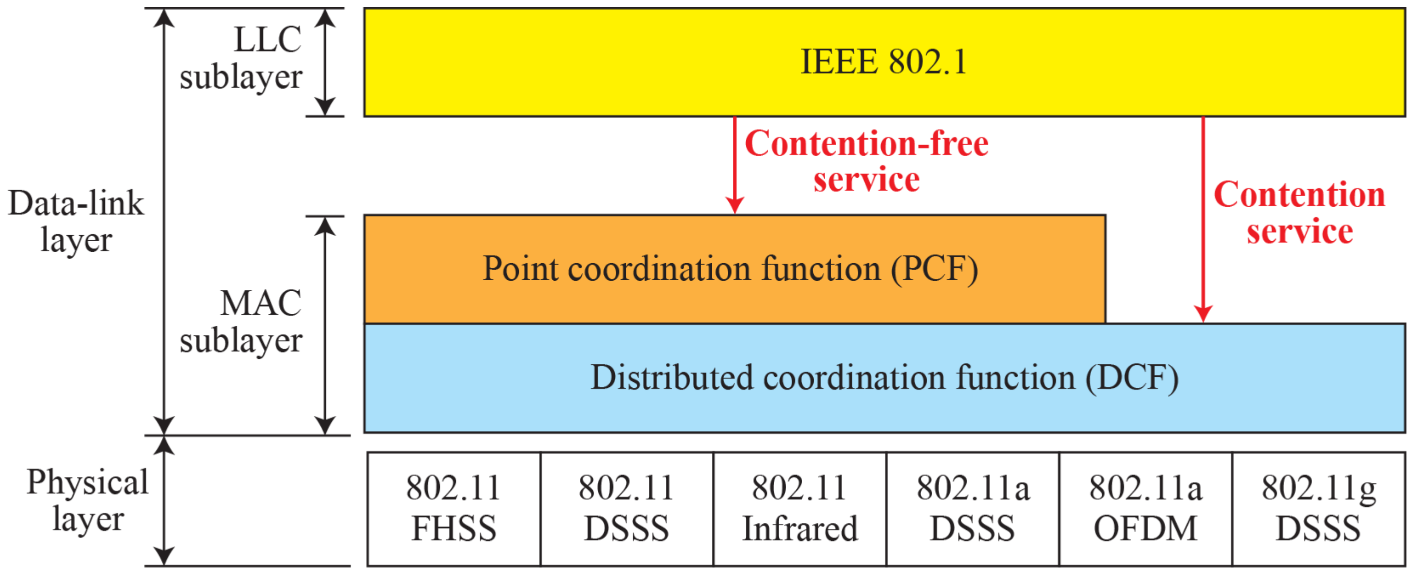


Figure 6.6: MAC layers in IEEE 802.11 standard



MAC Sublayer: IEEE 802.11 defines two MAC sublayers: the distributed coordination function (DCF) and point coordination function (PCF). Figure shows the relationship between the two MAC sublayers, the LLC sublayer, and the physical layer. We discuss the physical layer implementations later in the chapter and will now concentrate on the MAC sublayer.

Wireless LAN has four frame types:
Wired LAN, the medium access process is achieved using the collision detection mechanism.
Wireless LAN, the same task is done using the RTS, CTS, and ACK frames. We need all of these as well as data frames.

Figure 6.7: WLAN Flow diagram of CSMA/CA

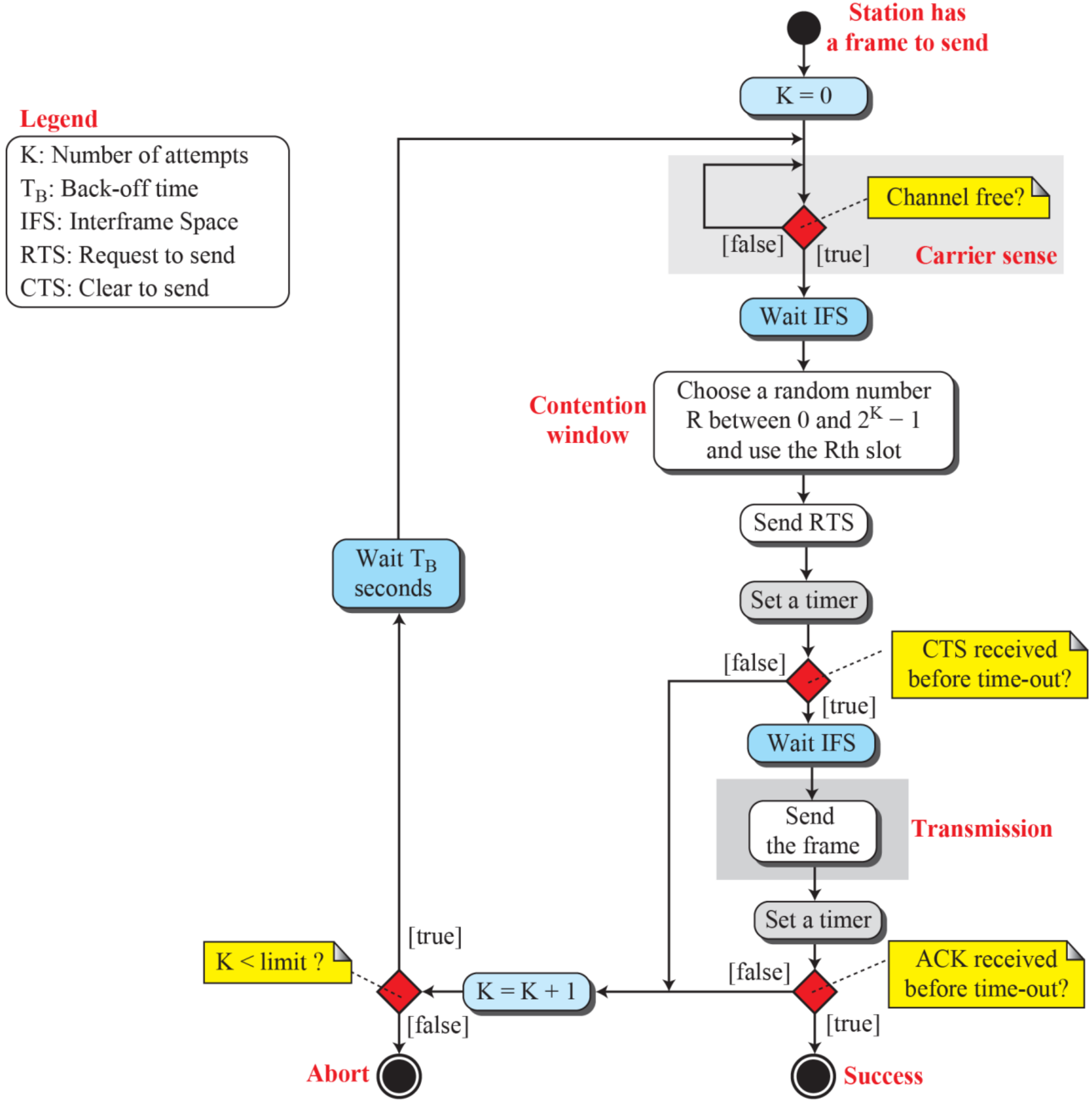


Figure 6.8: Contention window

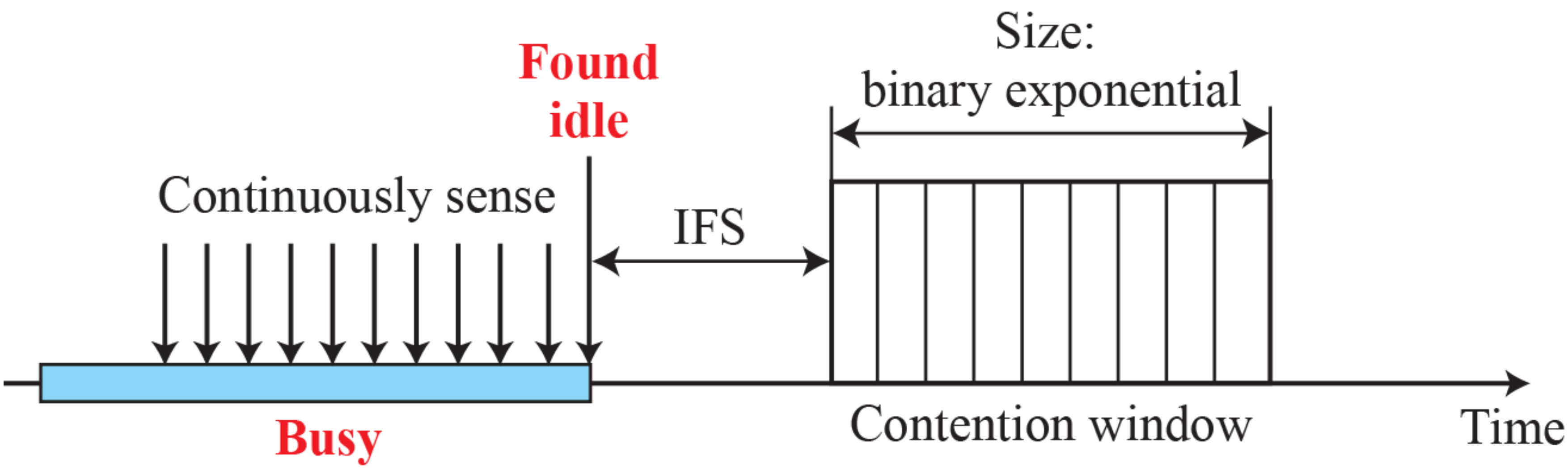


Figure 6.9: CSMA/CA and NAV

DIFS = Distributed interframe space
RTS = request to send (RTS).
SIFS = short interframe space (SIFS)
CTS = Clear to send
NAV = network allocation vector No carrier Sensing
RTS = Request to Send
CTS = Clear to Send
ACK = Acknowledgment

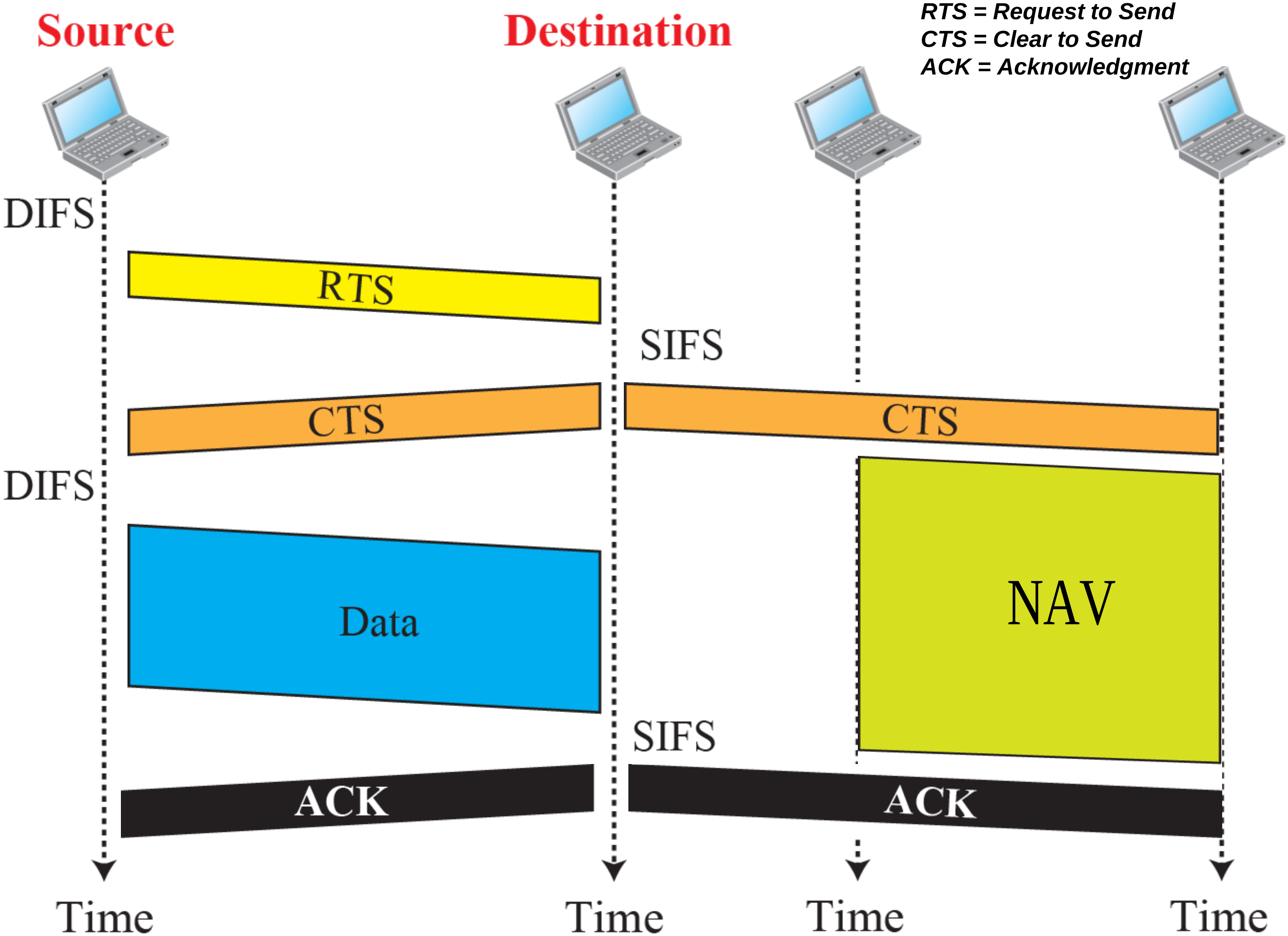


Figure 6.10: Example of repetition interval

PIFS =Point Coordination Function Inter-FrameSpace.
DIFS = Distributed interframe space
RTS = request to send (RTS).
SIFS = short interframe space (SIFS)
CTS = Clear to send
NAV = network allocation vector No carrier Sensing
RTS = Request to Send
CTS = Clear to Send
ACK = Acknowledgment

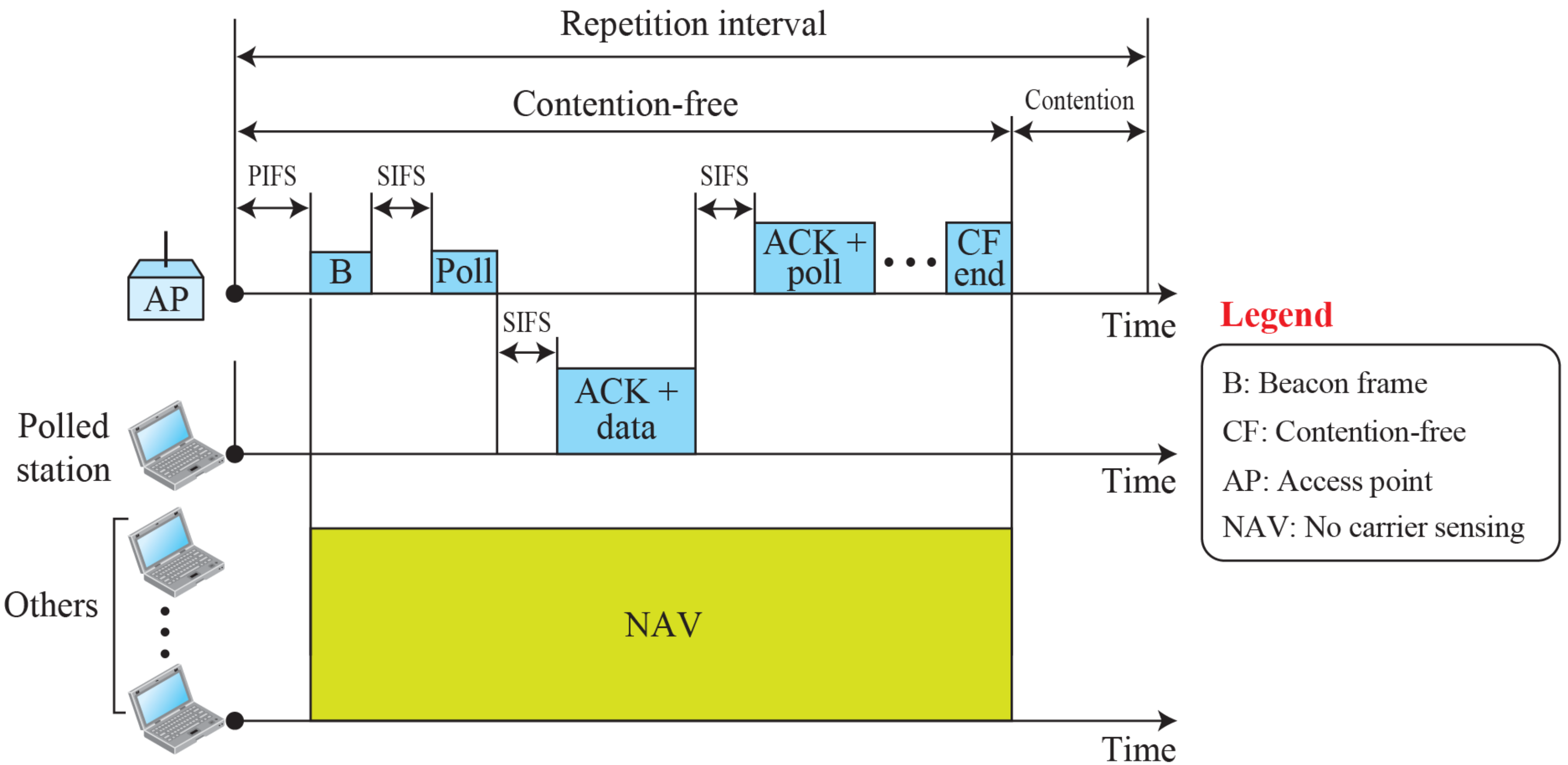
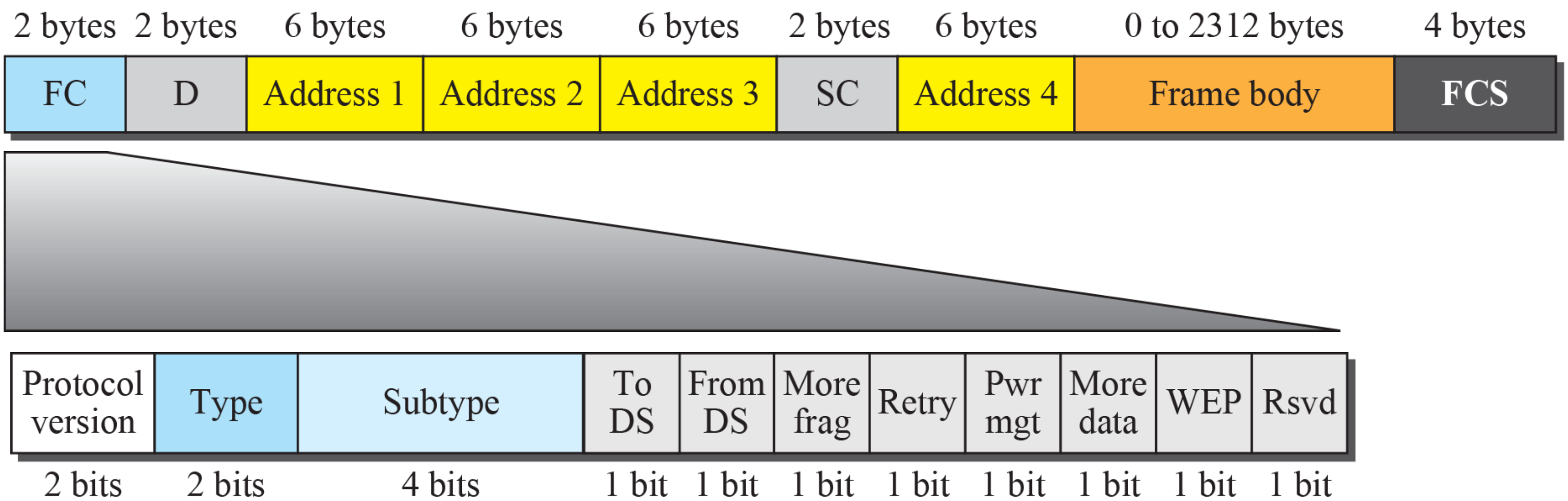


Figure 6.11: Frame format



Field	*Explanation*
Version	Current version is 0
Type	Type of information: management (00), control (01), or data (10)
Subtype	Subtype of each type (see Table 6.2)
To DS	Defined later
From DS	Defined later
More flag	When set to 1, means more fragments
Retry	When set to 1, means retransmitted frame
Pwr mgt	When set to 1, means station is in power management mode
More data	When set to 1, means station has more data to send
WEP	Wired equivalent privacy (encryption implemented)
Rsvd	Reserved

Table 6.1: Subfields in FC field

Figure 6.12: Control frames

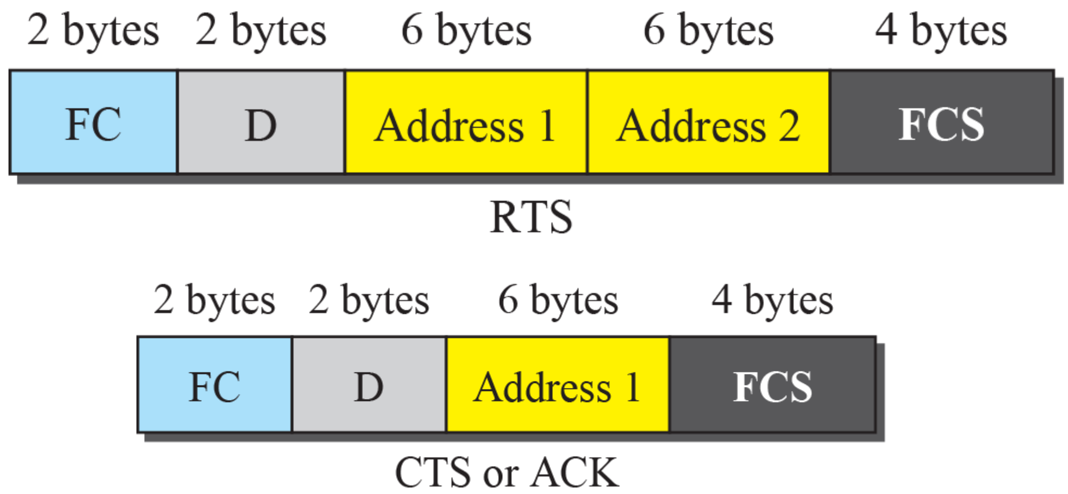


Table 6.2: Values of subfields in control frames

Subtype	*Meaning*
1011	Request to send (RTS)
1100	Clear to send (CTS)
1101	Acknowledgment (ACK)

Table 6.3: Addresses

To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source

To DS	*From DS*	*Address 1*	*Address 2*	*Address 3*	*Address 4*
0	0	Destination	Source	BSS ID	N/A
0	1	Destination	Sending AP	Source	N/A
1	0	Receiving AP	Source	Destination	N/A
1	1	Receiving AP	Sending AP	Destination	Source

Figure 6.13: Addressing mechanisms

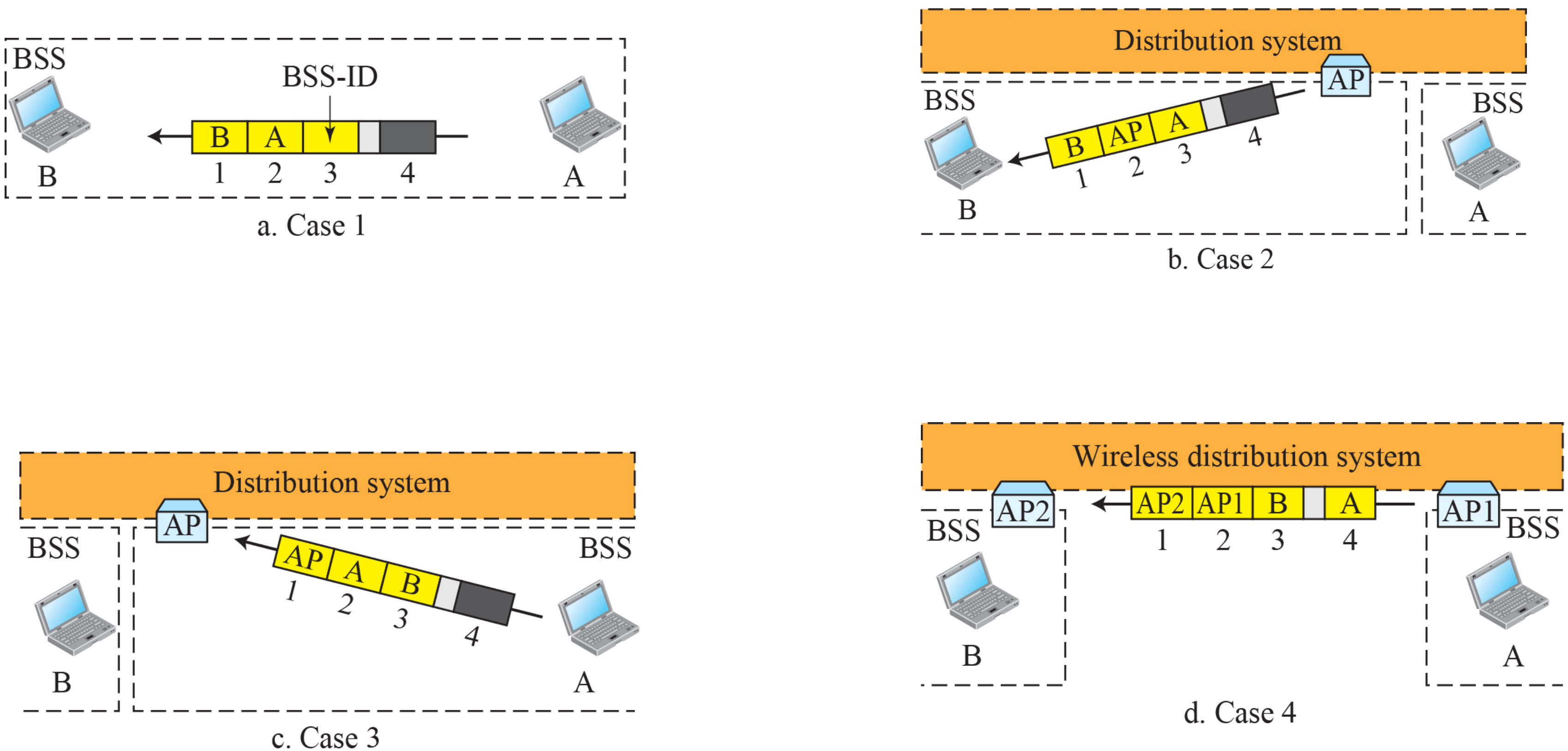


Table 6.4: Specifications

IEEE	*Technique*	*Band*	*Modulation*	*Rate (Mbps)*
802.11	FHSS	2.400–4.835 GHz	FSK	1 and 2
	DSSS	2.400–4.835 GHz	PSK	1 and 2
	None	Infrared	PPM	1 and 2
802.11a	OFDM	5.725–5.850 GHz	PSK or QAM	6 to 54
802.11b	DSSS	2.400–4.835 GHz	PSK	5.5 and 11
802.11g	OFDM	2.400–4.835 GHz	Different	22 and 54
802.11n	OFDM	5.725–5.850 GHz	Different	600

Physical Layer: We discuss six specifications, as shown in Table 15.4. All implementations, except the infrared, operate in the industrial, scientific, and medical (ISM) band, which defines three unlicensed bands in the three ranges 902–928 MHz, 2.400–4.835 GHz, and 5.725–5.850 GHz.

Figure 6.15: Physical layer of IEEE 802.11 FHSS

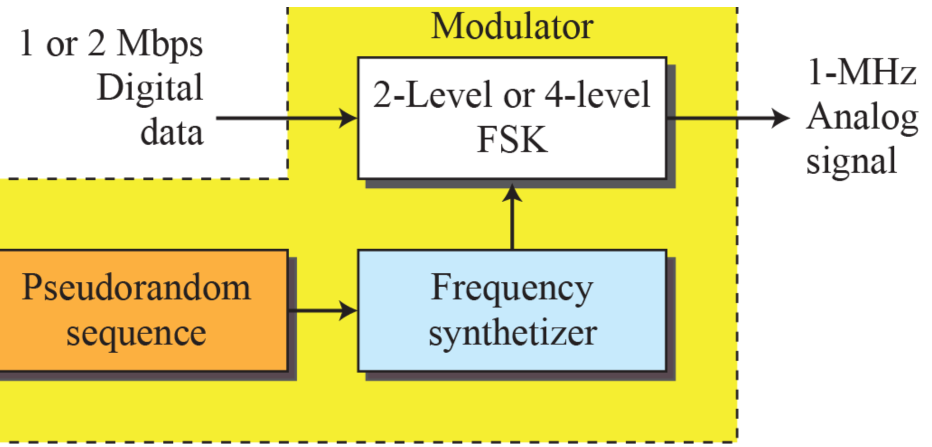


Figure 6.16: Physical layer of IEEE 802.11 DSSS

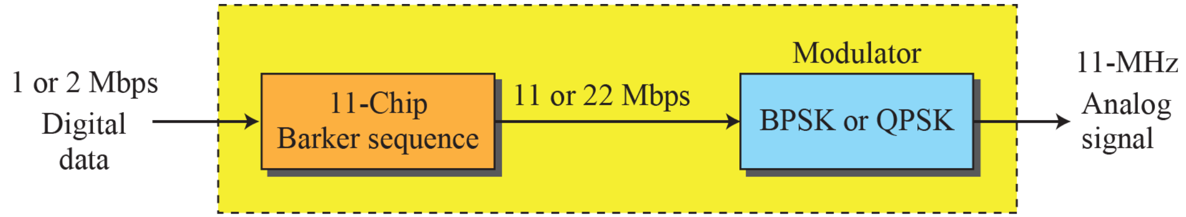
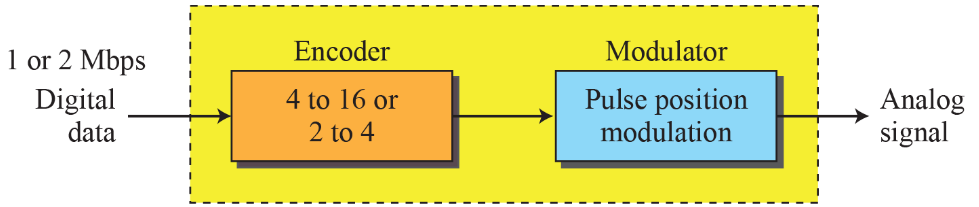
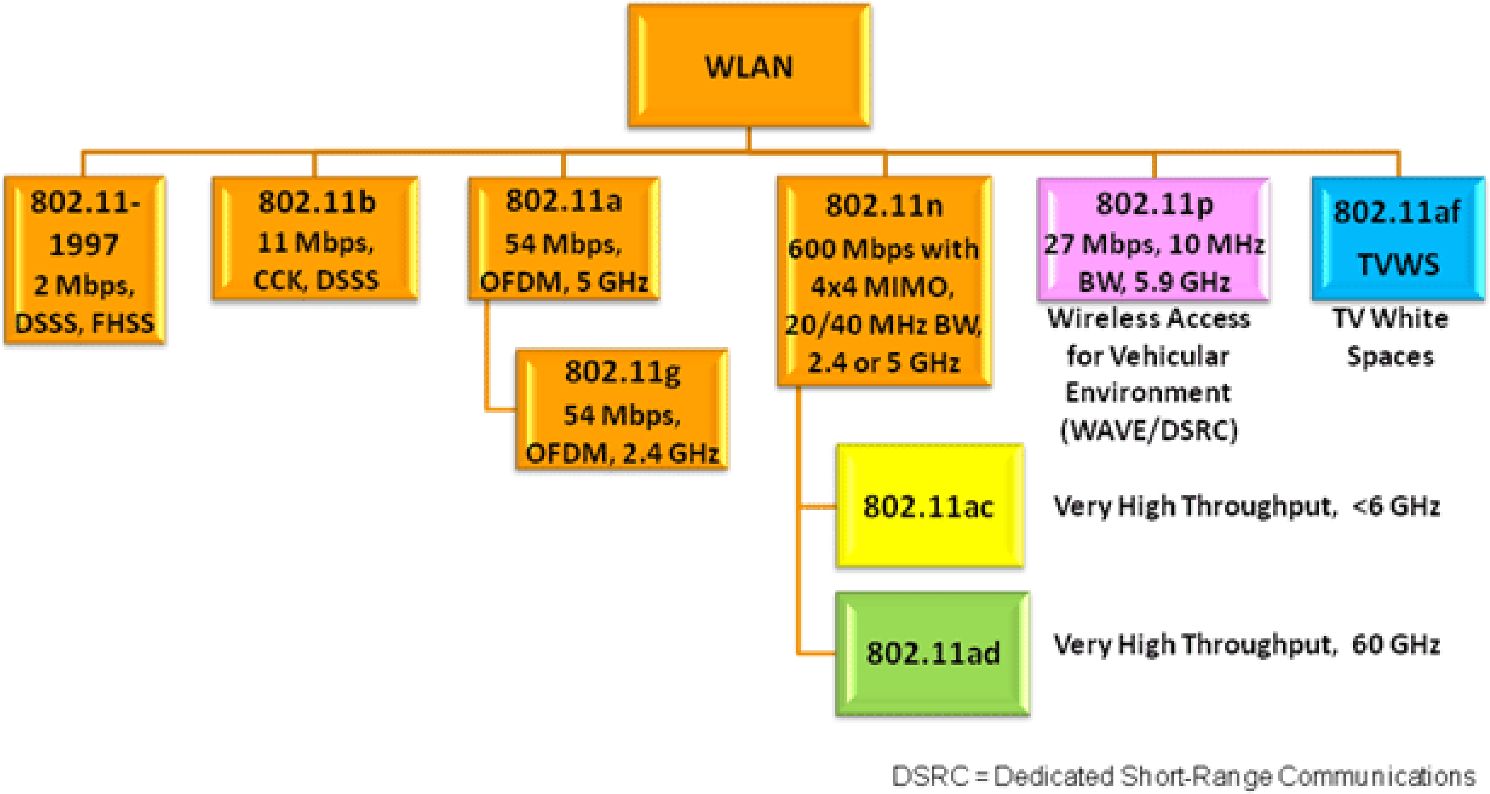


Figure 6.17: Physical layer of IEEE 802.11 infrared




WLAN
802.11-1997
2 Mbps,
DSSS, FHSS
802.11b
11 Mbps,
CCK, DSSS
802.11a
54 Mbps,
OFDM, 5 GHz
802.11g
54 Mbps,
OFDM, 2.4 GHz
802.11n
600 Mbps with
4x4 MIMO,
20/40 MHz BW,
2.4 or 5 GHz
802.11p
27 Mbps, 10 MHz
BW, 5.9 GHz
Wireless Access
for Vehicular
Environment
(WAVE/DSRC)
802.11af
TVWS
TV White
Spaces
802.11ac
Very High Throughput, <6 GHz
802.11ad
Very High Throughput, 60 GHz
DSRC = Dedicated Short-Range Communications

- ***IEEE 802.11b DSSS:*** describes the **high-rate direct-sequence spread spectrum (HRDSSS)** method for signal generation in the 2.400–4.835 GHz ISM band. HR-DSSS is similar to DSSS except for the encoding method, DSSS, HR-DSSS defines four data rates: 1, 2, 5.5, and 11 Mbps.
- ***IEEE 802.11g:*** This new specification defines forward error correction and OFDM using the 2.400–4.835 GHz ISM band. The modulation technique achieves a 22- or 54-Mbps data rate. It is backward-compatible with 802.11b, but the modulation technique is OFDM.
- ***IEEE 802.11n:*** An upgrade to the 802.11 project is called 802.11n (the next generation of wireless LAN). The goal is to increase the throughput of 802.11 wireless LANs. This standard has higher bit rate of 600 Mpbs. The standard uses what is called **MIMO (multiple-input multiple-output antenna)** to overcome the noise problem in wireless LANs. The idea is that if we can send multiple output signals and receive multiple input signals.
- **802.11ac:** IEEE 802.11ac physical layer is an extension of 802.11n, The theoretical 802.11ac maximum data rate is 6.93 Gb/s using 160-MHz bandwidth, eight spatial streams.

6.1.4 WiMax

- *Worldwide Interoperability for Microwave Access (WiMAX) is an IEEE standard 802.16 (for fixed wireless) and 802.16e (for mobile wireless) that aims to provide the "last mile" broadband* ***wireless access alternative to cable modem, telephone DSL service***..

WiMAX

People want to have access to the Internet from home or office (fixed) where the wired access to the Internet is either not available or is expensive.

People also need to access the Internet when they are using their cellular phones.

WiMAX has been designed for these types of applications.

Services

WiMAX provides two types of services to subscribers:

- ***fixed and***
- ***mobile.***

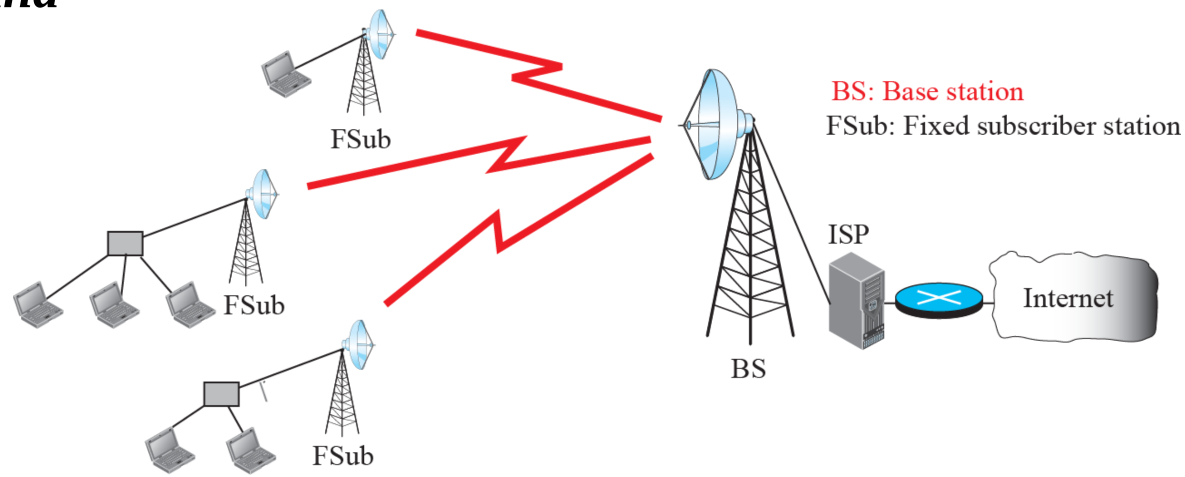


Figure 16.1:* *Fixed WiMAX

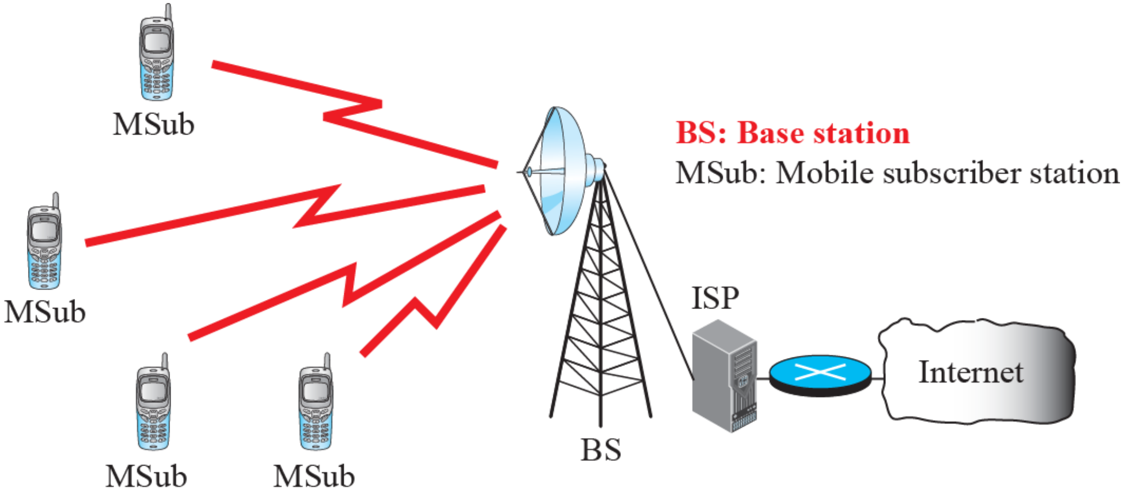


Figure 16.2:* *Mobile WiMAX

Wireless Impairments

- Atmospheric absorption – water vapour and oxygen contribute to attenuation
- Multipath – obstacles reflect signals so that multiple copies with varying delays are received
- Refraction – bending of radio waves as they propagate through the atmosphere

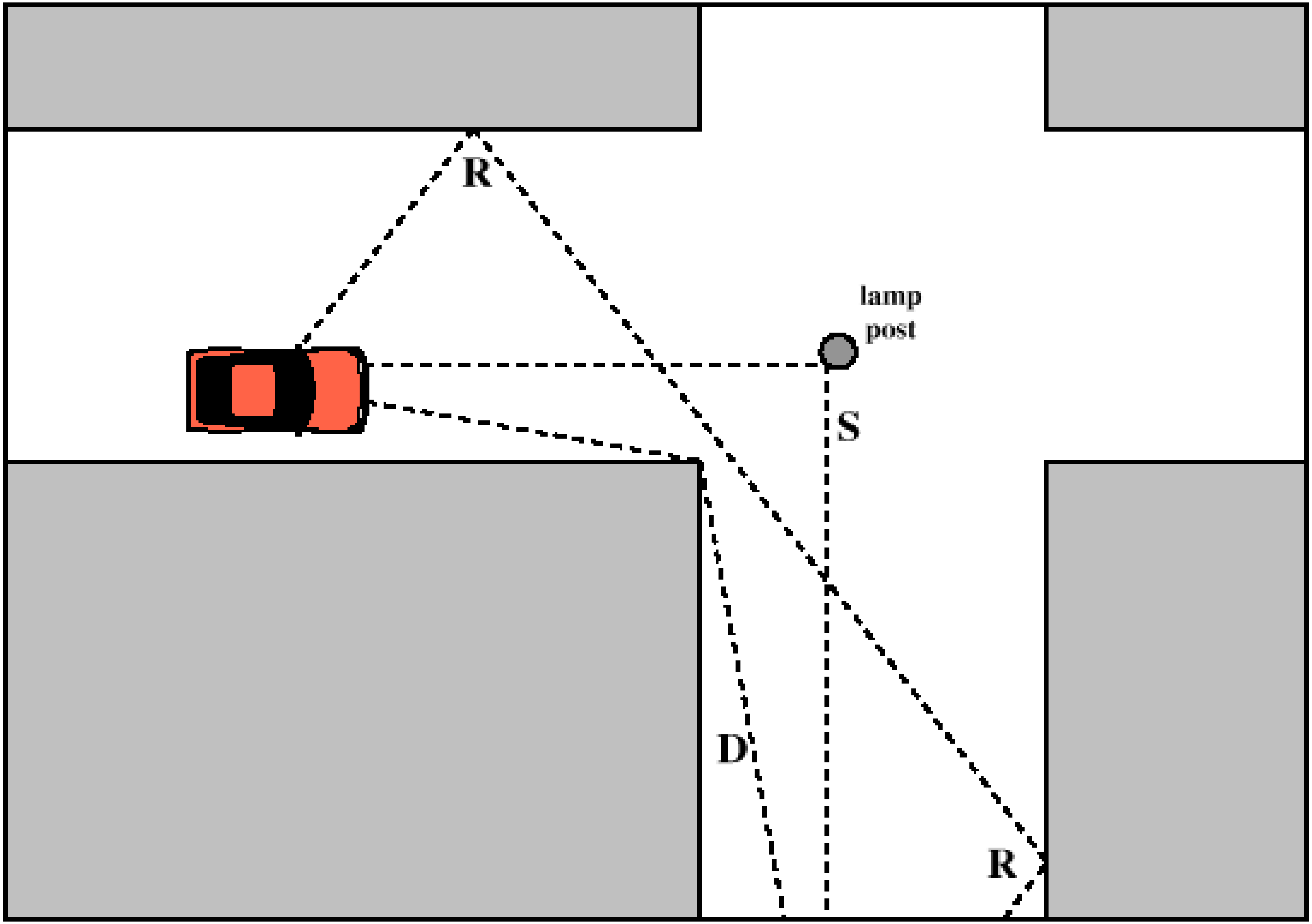


Figure 5.10 Sketch of Three Important Propagation Mechanisms: Reflection (R), Scattering (S), Diffraction (D) [ANDE95]

Multipath Propagation

- Reflection - occurs when signal encounters a surface that is large relative to the wavelength of the signal
- Diffraction - occurs at the edge of an impenetrable body that is large compared to wavelength of radio wave
- Scattering – occurs when incoming signal hits an object whose size is nearly equal to or less than the wavelength of the signal

The Effects of Multipath Propagation

- Multiple copies of a signal may arrive at different phases (i.e.. at different times due to different path length)
  - If phases add destructively, the signal level relative to noise declines, making detection more difficult
- Inter-Symbol Interference (ISI)
  - One or more delayed copies of a pulse may arrive at the same time as the primary pulse for a subsequent bit
- SNR is the ratio of the signal power to the noise power.
  - If the signal power is decreased or the noise power is increased, SNR will decrease.
  - In a wireless LAN, the signal power is less (using batteries). The noise power is higher in a wireless LAN because the noise is not controlled. The noise from any source can affect the signal exchanged between the sender and the receiver.

Types of Fading

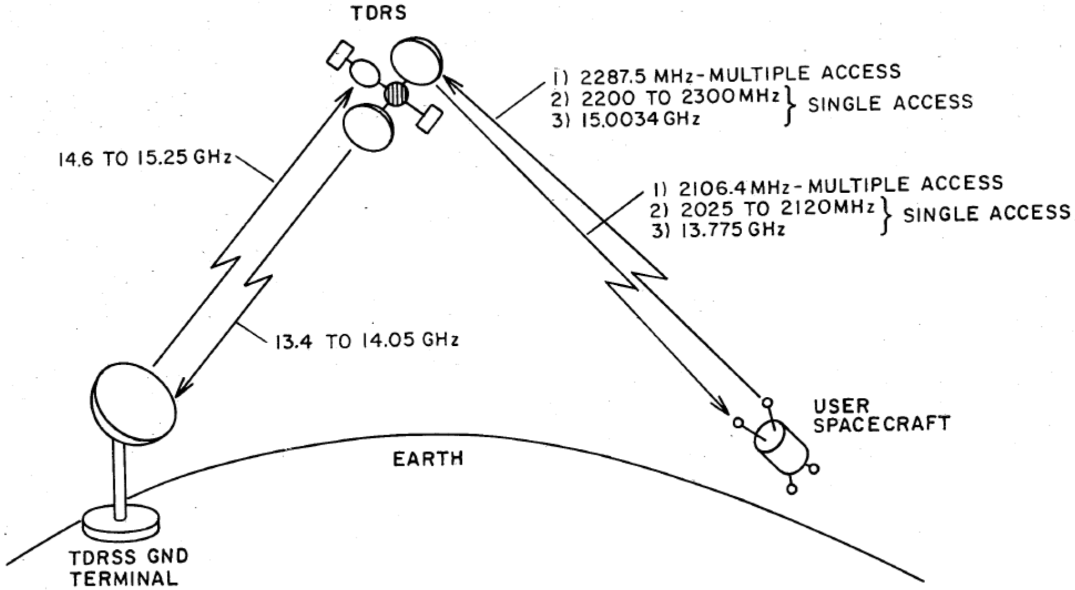
- Fast fading
- Slow fading
- Flat fading
- Selective fading
- Rayleigh fading – statistical model, random, r-dist
- Rician fading – random-stochastic model, radio propagation anomaly caused by partial cancellation of a radio signal by itself

MONASH University

Information Technology

Satellite Communications

Stallings - Chapter 9



Satellite Networks

A satellite network is a combination of nodes, some of which are satellites, that provides communication from one point on the Earth to another. A node in the network can be a satellite, an Earth station, or an end-user terminal or telephone.

- ***Orbits***
- ***Footprints***
- ***Three Categories of Satellites***
  - ***Frequency Bands for Satellite Communication***
- ***GEO Satellites***
- ***MEO Satellites***
  - ***Global Positioning System (GPS)***
- ***LEO Satellites***

Satellite-Related Terms

- **Earth Stations**

  antenna systems on or near earth
- **Uplink**

  transmission from an earth station to a satellite
- **Downlink**

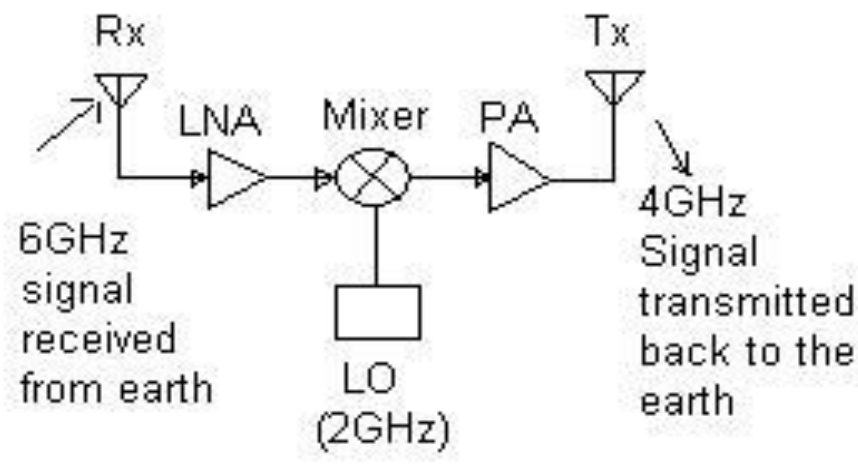
  transmission from a satellite to an earth station
- **Transponder**

  electronics in the satellite that convert uplink signals to downlink signals

Transponder

- **Transponder** is a component in the satellite that takes an uplink signal and converts it to a downlink signal is called a transponder. More broadly speaking a transponder gathers signals over a range of uplink frequencies and re-transmits them on a different set of downlink frequencies to receivers on Earth, often without changing the content of the received signal or signals.

- As shown in the figure, satellite transponder receives signal of 6175 MHz from the earth,
- It converts the 6175 MHZ to 3950 MHz by subtracting it using LO of 2225 MHz
- This is for C band satellite.
- It does amplification of the signal in addition to the frequency translation.
- Typically there will be about 12 or 24 transponders available in a satellite.



Satellite Transponder

Ways to Categorize Communications Satellites

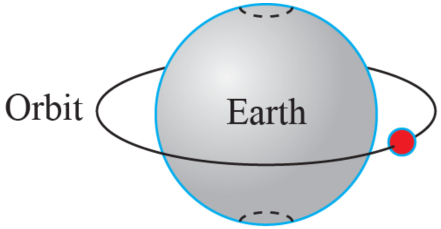
- **Coverage area**
  - Global, regional, national
- **Service type**
  - Fixed service satellite (FSS)
  - Broadcast service satellite (BSS)
  - Mobile service satellite (MSS)
- **General usage**
  - Commercial, military, amateur, experimental

Satellite vs Terrestrial Wireless links

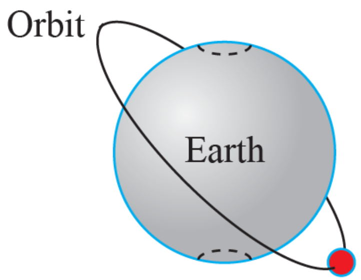
- Much larger reception area for satellite systems
- Spacecraft power and bandwidth - very limited
- Satellite to Satellite comms not as bad as terrestrial
- Broadcast, Multicast and Point-to-point applications
- Very high bandwidths/data-rates available
- Except for short-term outages, transmission quality is usually high
- Propagation delay to geo-stationary orbit is 0.25 sec
- Earth station transmissions often receives its own transmission as echo

Classification of Satellite Orbits

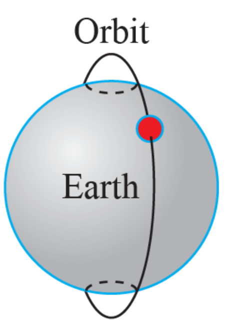
- **Circular or elliptical orbit**
  - **Circular** with center at earth's center
  - **Elliptical** with one foci at earth's center
- **Orbit around earth in different planes**
  - **Equatorial** orbit above earth's equator
  - **Other orbits** referred to as inclined orbits
  - **Polar** orbit passes over both poles
- **Altitude of satellites**
  - **Geostationary orbit (GEO)**
  - **Medium earth orbit (MEO)**
  - **Low earth orbit (LEO)**



a. Equatorial-orbit satellite



b. Inclined-orbit satellite



c. Polar-orbit satellite

GEO Orbit

- **Advantages** of the GEO orbit
  – Tracking of the satellite is simplified
  – High coverage area
- **Disadvantages** of the GEO orbit
  – Weak signal after traveling over 35,000 km
  – Polar regions are poorly served
  – Signal sending delay is substantial. Satellite latency and time delay 240ms - 279ms

MEO Satellite Characteristics

- Circular orbit at altitude range of 5,000 to 12,000 km
- Orbit period of 6 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 50ms
- Maximum satellite visible time is a **few hours**

LEO Satellite Characteristics

- Circular/slightly elliptical polar orbit under 2000 km
- Orbit period ranges from 1.5 to 2 hours
- Diameter of coverage is about 8000 km
- Round-trip signal propagation delay less than 20ms
- Maximum satellite visible time up to 20 min

LEO Categories

- Little LEOs
  - Frequencies below 1 GHz
  - 5MHz of bandwidth
  - Data rates up to 10 kbps
  - Aimed at paging, tracking, and low-rate messaging
- Big LEOs
  - Frequencies above 1 GHz
  - Support data rates up to a few megabits per sec
  - Offer same services as little LEOs in addition to voice and positioning services

Kepler's law?

What is the period of the moon, according to Kepler's law?
Here C is a constant approximately equal to 1/100. The period is in seconds and the distance in kilometers.

The radius of the Earth is 6378 km

$$\boxed{\textbf{Period} = C \times \textbf{distance}^{1.5}}$$

Solution

The moon is located approximately 384,000 km above the Earth. The radius of the Earth is 6378 km. Applying the formula, we get the following.

$$\textbf{Period} = (1/100) \times (384{,}000 + 6378)^{1.5} = 2{,}439{,}090 \text{ s} = 1 \text{ month}$$

According to Kepler's law, what is the period of a Geo Stationary satellite that is located at an orbit approximately 35,786 km above the Earth?

The radius of the Earth is 6378 km

Solution

Applying the formula, we get the following.

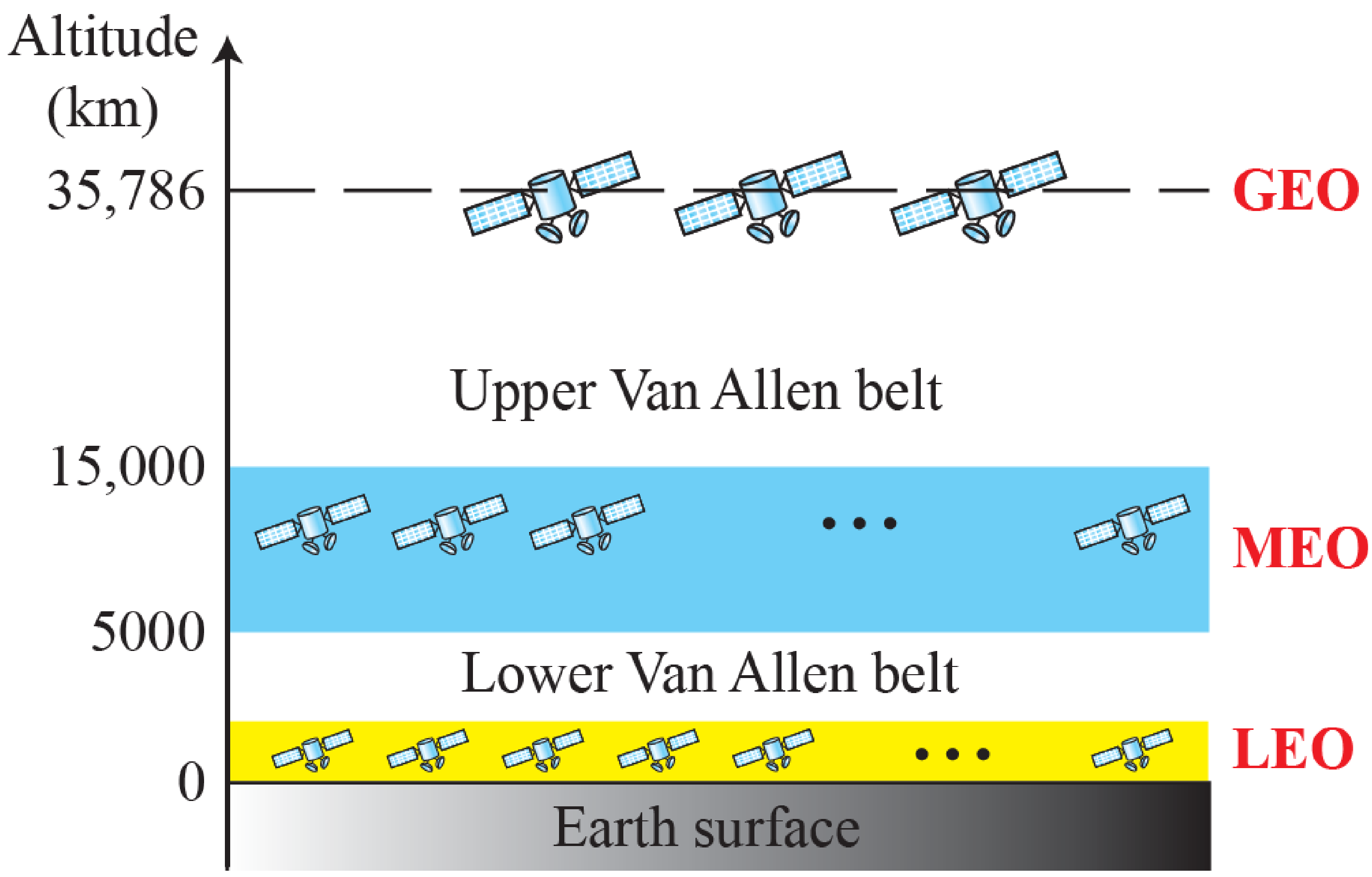
$$\textbf{Period} = (1/100) \times (35{,}786 + 6378)^{1.5} = 86{,}579 \text{ s} = 24 \text{ h}$$

This means that a satellite located at 35,786 km has a period of 24 h, which is the same as the rotation period of the Earth. A satellite like this is said to be *stationary* to the Earth. The orbit, as we will see, is called a *geostationary orbit*.

Orbital Comparisons

Orbits	LEO	MEO	GEO
Orbital period	1.5 to 2 hr	5 to 10 hr	24 hr
Altitude range	500 to 1500 km	8000 to 18,000 km	35,863 km
Visibility duration	15 to 20 min/pass	2 to 8 hr/pass	Permanent
Elevation	Rapid variations; high and low angles	Slow variations; high angles	No variations; Low angles @ high latitudes
Round-trip propagation delay	Several mS	10's of mS	~250 ms
Ground coverage (diameter @10º)	~6000 km	~12,000 to 15,000 km	16,000 km
Examples of Systems	Iridium, GlobalStar, Teledesic, Skybridge, Orbcomm	Odyssey, Inmarsat	Intelsat, Intersputnik, Inmarsat

Figure 6.47: Satellite orbit altitudes

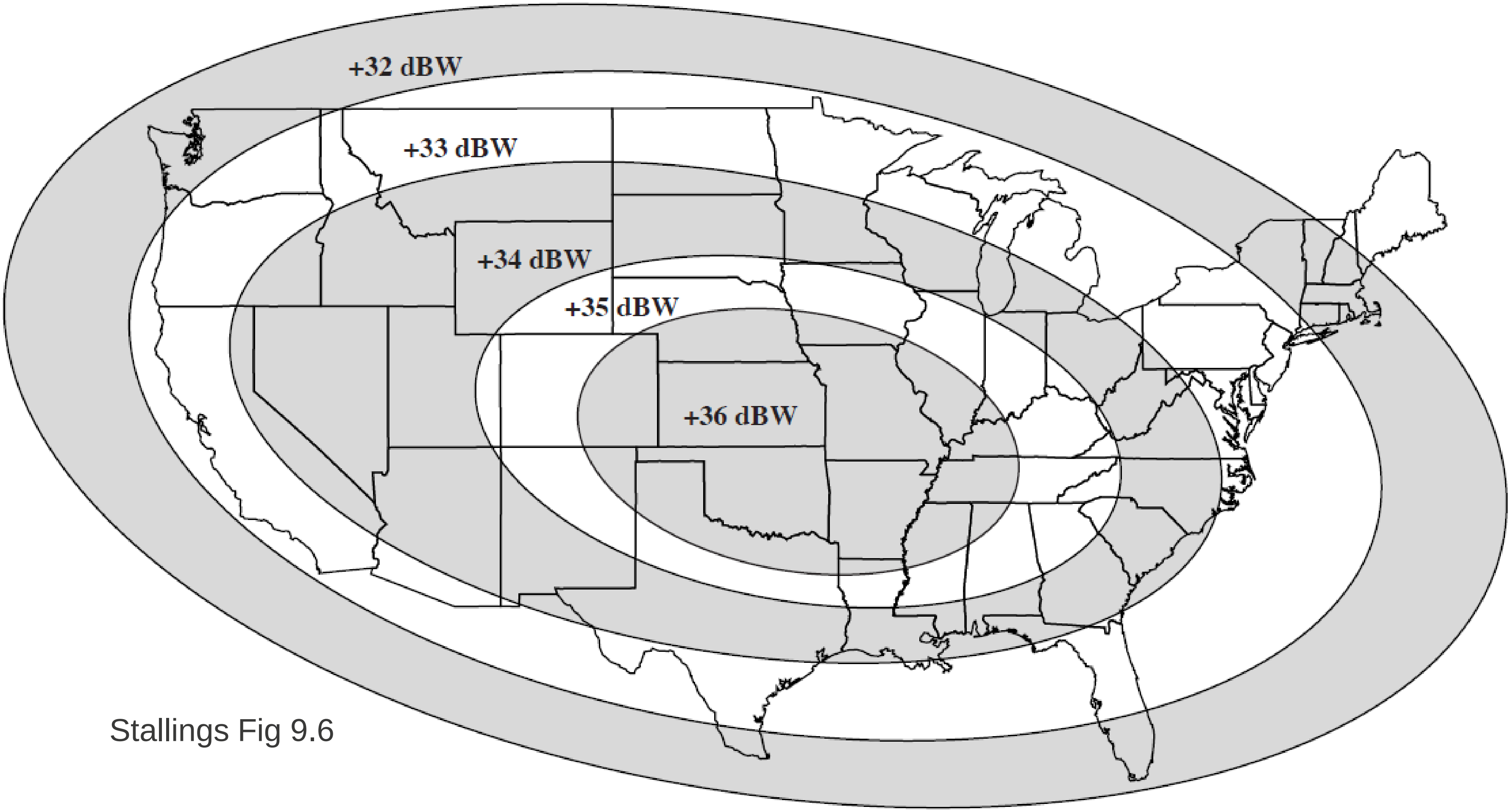


Satellite Frequency Bands Available for Satellite Comms

Band	Frequency range	General Application
L	1 to 2 GHz	Mobile satellite service (MSS)
S	2 to 4 GHz	MSS, NASA, deep space research
C	4 to 8 GHz	Fixed satellite service (FSS)
X	8 to 12.5 GHz	FSS military, terrestrial earth exploration and meteorological satellites
Ku	12.5 to 18 GHz	FSS, Broadcast satellite (BSS)
K	18 to 26.5 GHz	BSS, FSS
Ka	26.5 to 40 GHz	FSS

Band	*Downlink, GHz*	*Uplink, GHz*	*Bandwidth, MHz*
L	1.5	1.6	15
S	1.9	2.2	70
C	4.0	6.0	500
Ku	11.0	14.0	500
Ka	20.0	30.0	3500

Satellite Footprint



Stallings Fig 9.6

Chapter 6: Summary

- ***Wireless LANs became formalized with the IEEE 802.11 standard, which defines two services: basic service set (BSS) and extended service set (ESS). The access method used in the distributed coordination function (DCF) MAC sublayer is CSMA/CA. The access method used in the point coordination function (PCF) MAC sublayer is polling. WiMAX is a wireless access network that may replace DSL and cable in the future.***

- ***A satellite network uses satellites to provide communication between any points on Earth. We have discussed several systems: including GEO, MEO, and LEO.***