Introduction to Wireless LAN

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Overview

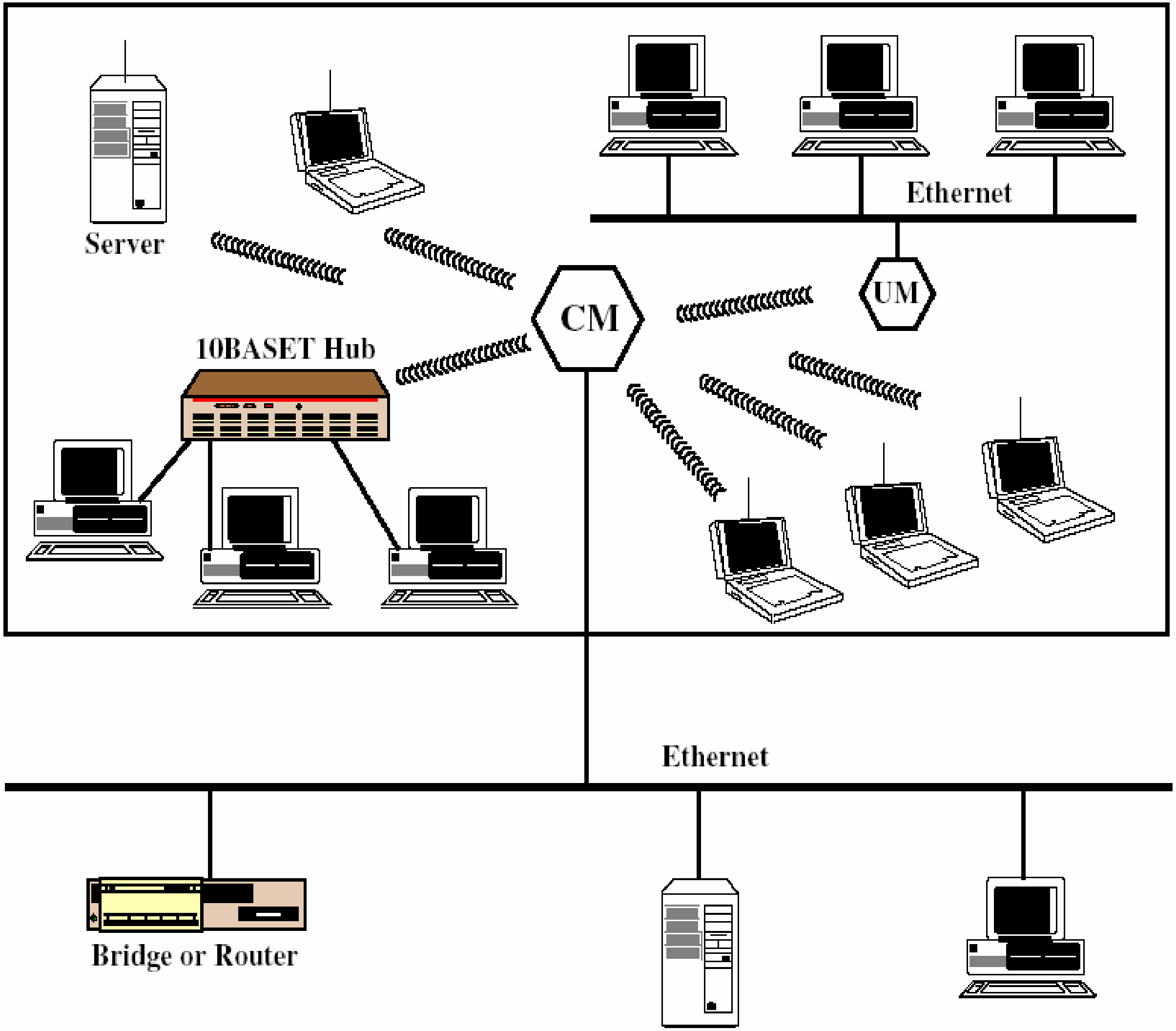
✓ Wireless LANs Applications

☞ LAN Extension

- Early wireless LAN products, introduced in the late of 1980s
- A role for the wireless LAN as an alternative to a wired LAN
  - **including buildings with large open areas, such as manufacturing plants, stock exchange trading floors, and warehouses and, historical building, and small offices where installation and maintenance of wired LANs is not economical.**
- Wireless LAN will be linked into a wired LAN on the same premises
  - referred to as LAN extension

Overview (cont'd)

✓ Single-Cell Wireless LAN Configuration



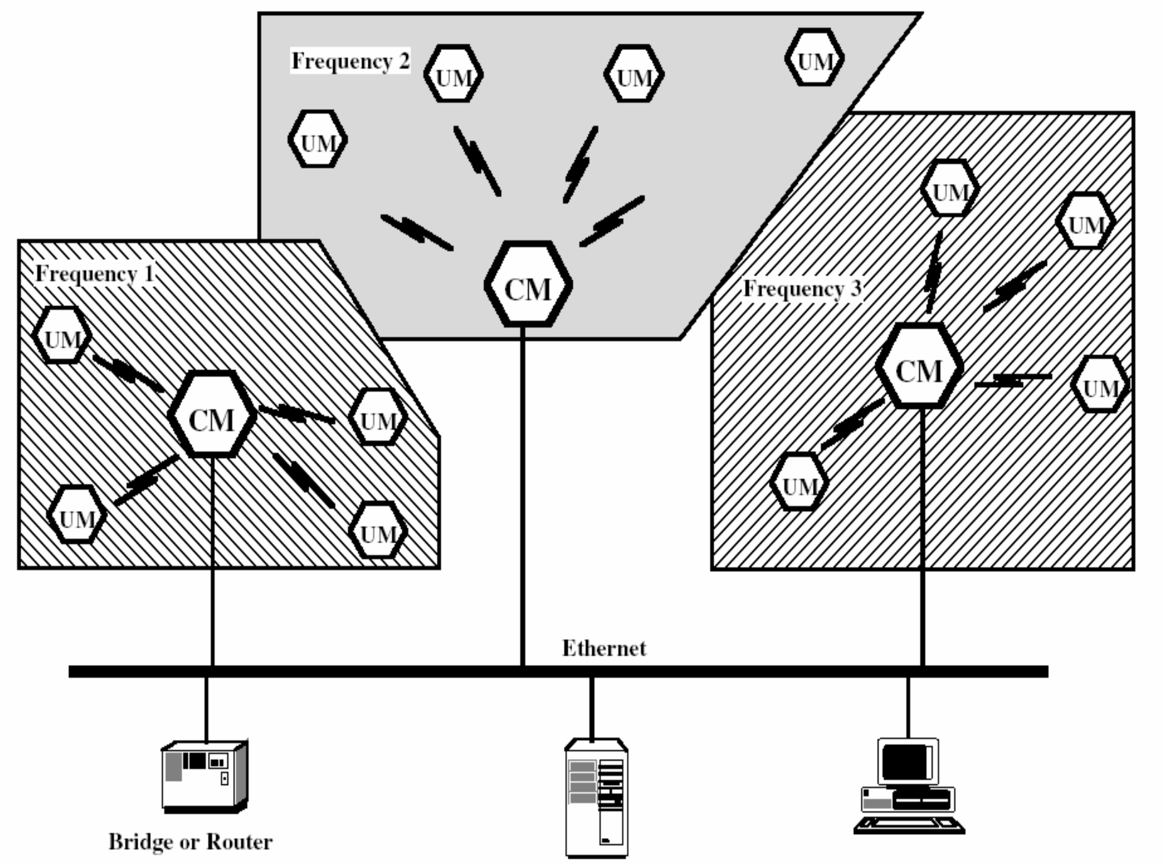
Overview (cont'd)

- Control Module (CM)
  - acting as an interface to a wireless LAN
  - Including either bridge or routers to link with other networks
  - some sort of access control logic, such as a polling or token-passing scheme, to regulate the access from the end systems
- Hub or UM (user module)
  - Controlling a number of stations

Overview (cont'd)

✓ Multiple-Cell Wireless LAN Configuration

☞ **With an infrared LAN, transmission is limited to a single room; therefore, one cell is needed for each room in an office building that requires wireless support**



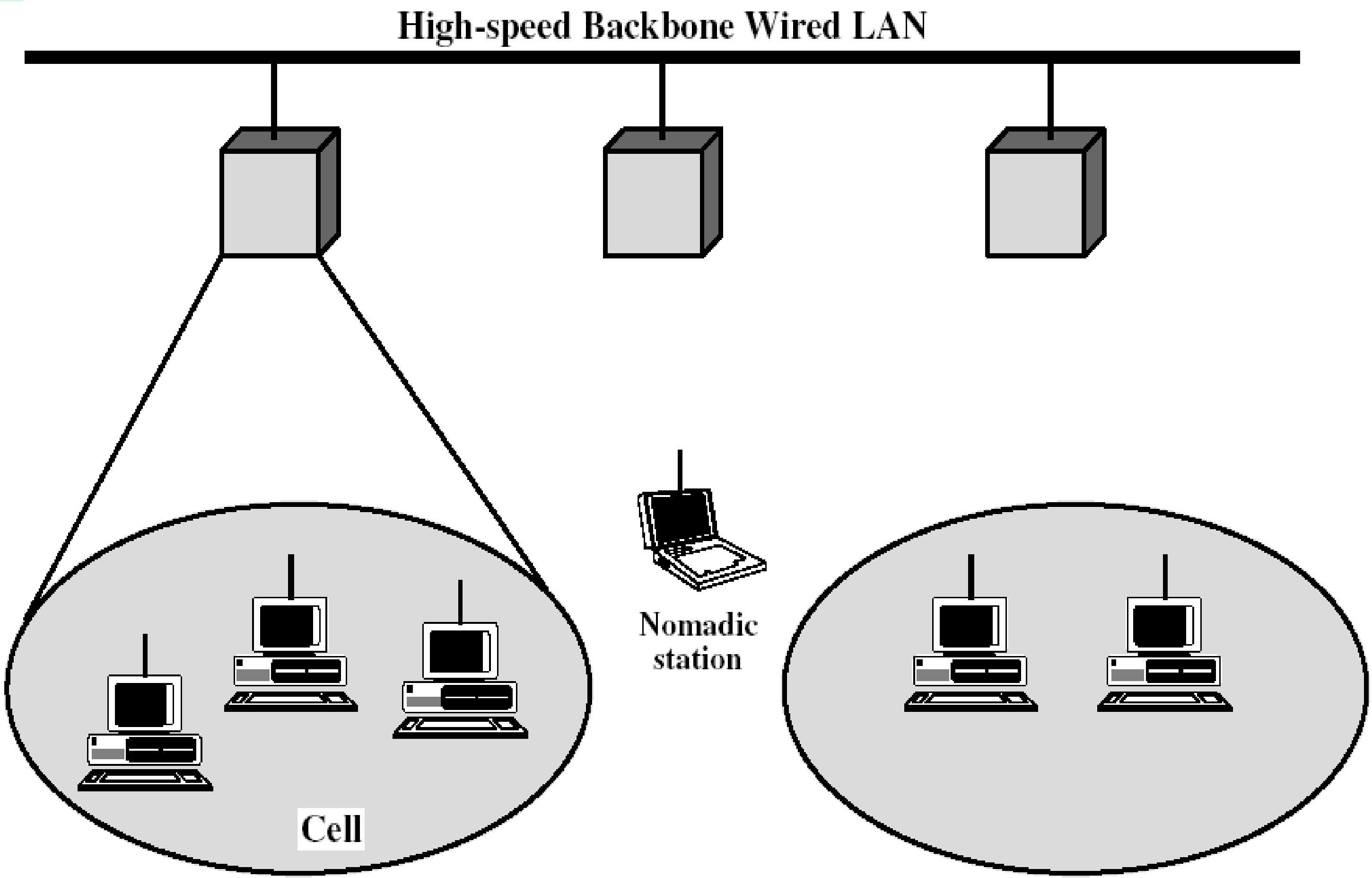
Overview (cont'd)

✓ Wireless LANs Applications (cont'd)

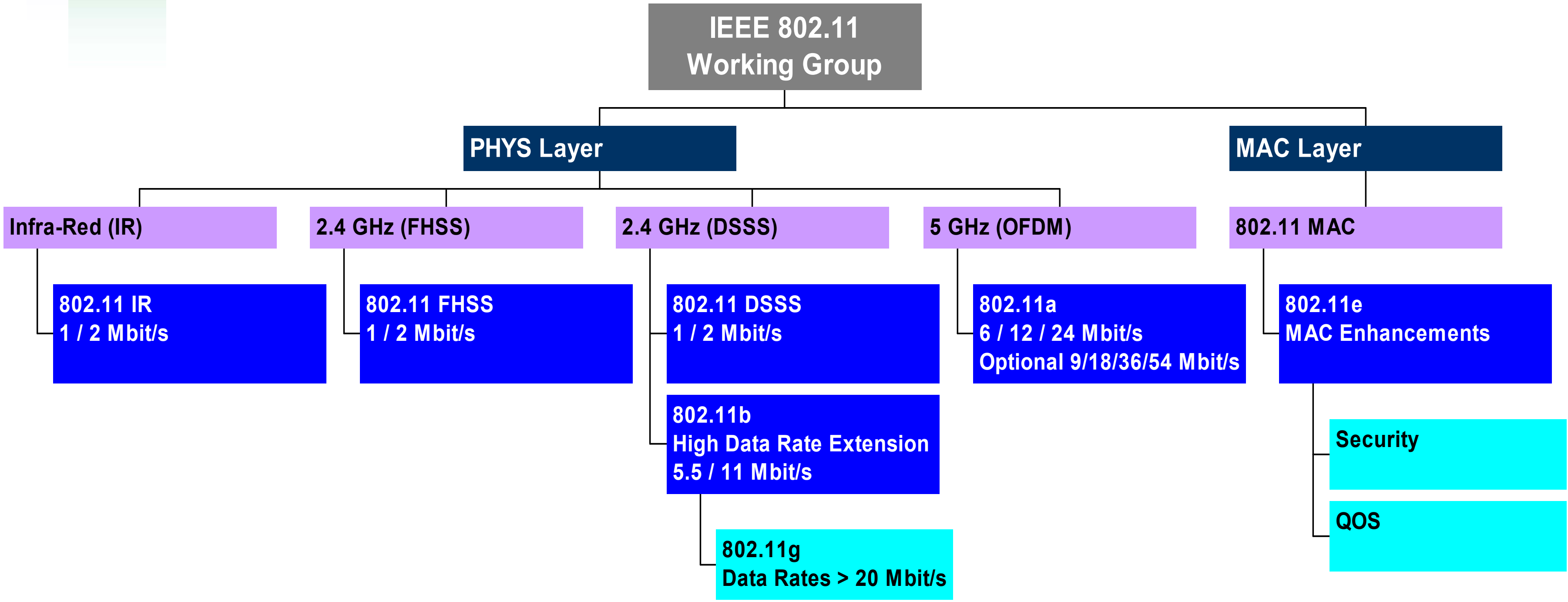
- ☞ Cross-Building Interconnect
  - Point-to-point wireless link between two buildings
- ☞ Normadic Access
  - Providing a wireless link between a LAN hub and a mobile data terminal equipped with an antenna, such as a laptop computer or notepad computer
  - Useful in an extended environment such as a campus or a business operating out of a cluster of buildings
- ☞ Ad Hoc Networking
  - Setting up Peer-to-peer network (no centralized server) to meet some immediate need
  - For example, useful for employees, each with a laptop or palmtop computer in a conference room for a business or classroom meeting.
  - Dynamically configuring stations into a temporary network

Overview (cont'd)

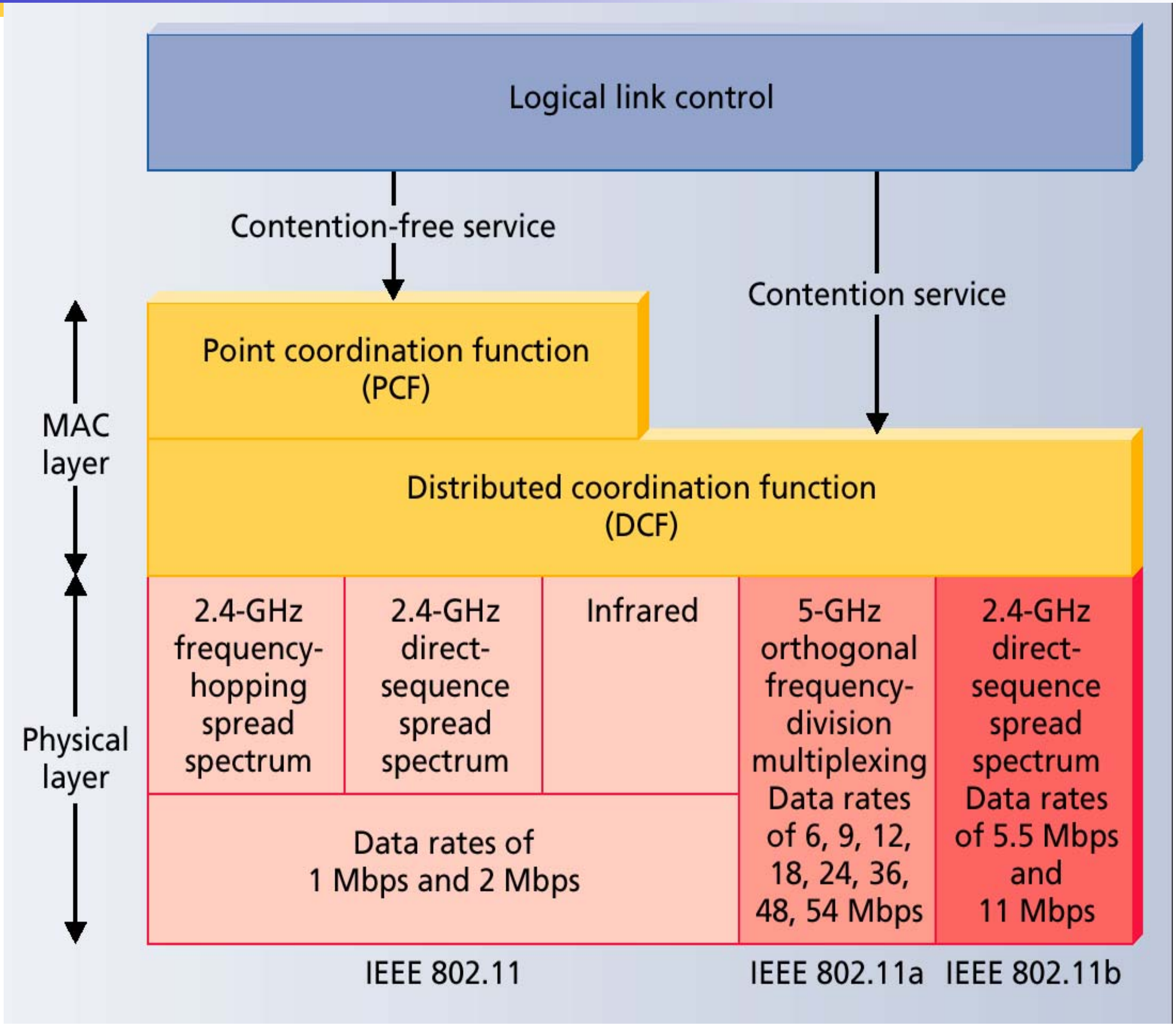
✓ Infrastructure wireless LAN



IEEE 802.11 Organization Tree



IEEE 802.11 Protocol Architecture



802 versions

11	**1 Mbps or 2 Mbps,** so was too slow.
11a	**FHSS; 5-GHz band**; **54 Mbps**; **OFDM (48 data+4 Sync) ch. 18-54 Mbps, =With Europ. HiperLAN/2**
11b	DSSS; Uses the **same frequency band as 802.11**, but uses **different modulation technique** achieve 1,2,5.5, **11 Mbps**.
11g	Uses the **OFDM modulation= of 802.11a** but the **frequency band =of 802.11b**. (Theory-54 Mbps)??
11n	High speed, > 100Mbps, mostly indoor use; **MIMO antennas and OFDM radios**
11e	Same as 11b, but **QoS support**

Where Does Wireless RF Live?

ISM Band: Industrial, Scientific, Medical

902-928 MHz	2400-2483.5 MHz	5725-5850 MHz
Old Wireless	802.11/802.11b	802.11a
	Bluetooth	
	Cordless Phones	
	Home RF	
	Baby Monitors	
	Microwave Ovens	

IEEE 802.11 Specifications

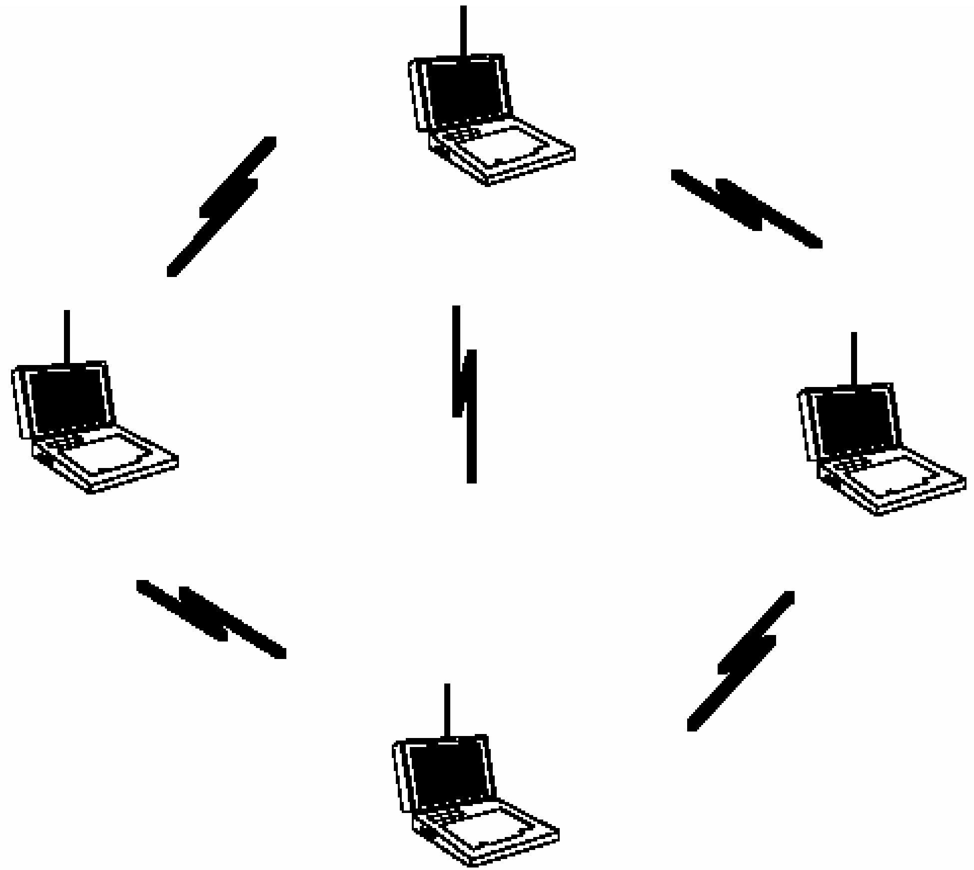
- IEEE 802.11 spec
  - 802.11 (2.4GHz)
    - MAC protocol
      - DCF (Distributed Coordination Function) : CSMA-CA
        - » Adaptation to wireless environment of Ethernet mode
        - » Contention among Stations
      - PCF (Point Coordination Function)
        - » Data transfer by polling methods
      - Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS), Infrared based PHY layer
    - Data rate: 1, 2Mbps

IEEE 802.11 Specifications (cont'd)

- IEEE 802.11 Spec.
  - 802.11b (2.4GHz)
    - MAC : CSMA-CA
    - Physical layer based on CCK (complementary code keying)
    - Data rate: 5.5, 11Mbps
    - up to 100m
  - 802.11a (5GHz)
    - MAC: CSMA-CA
    - Physical layer based on OFDM
    - Data rate: 6, 9, 12, 18, 24, 36, 48, 54Mbps
    - Up to 20m
  - Operating modes:
    - Infrastructure mode (access point)
    - Ad hoc mode

Overview (cont'd)

✓ Ad hoc LAN



Overview (cont'd)

- Wireless LAN Requirements
  - High capacity, ability to cover short distances, full connectivity among attached stations, and broadcast capability
  - Requirements specific to the wireless LAN environment
    - Throughput : MAC protocol for making as efficient use as possible of the wireless medium to maximize capacity
    - Number of Nodes : supporting hundreds of nodes across multiple cells
    - Connection to backbone LAN : using Control Module
    - Service Area : diameter of 100 to 300 m
    - Battery power consumption : mobile nodes that monitor access points constantly
    - Transmission robustness and security : in noisy environment and from eavesdropping

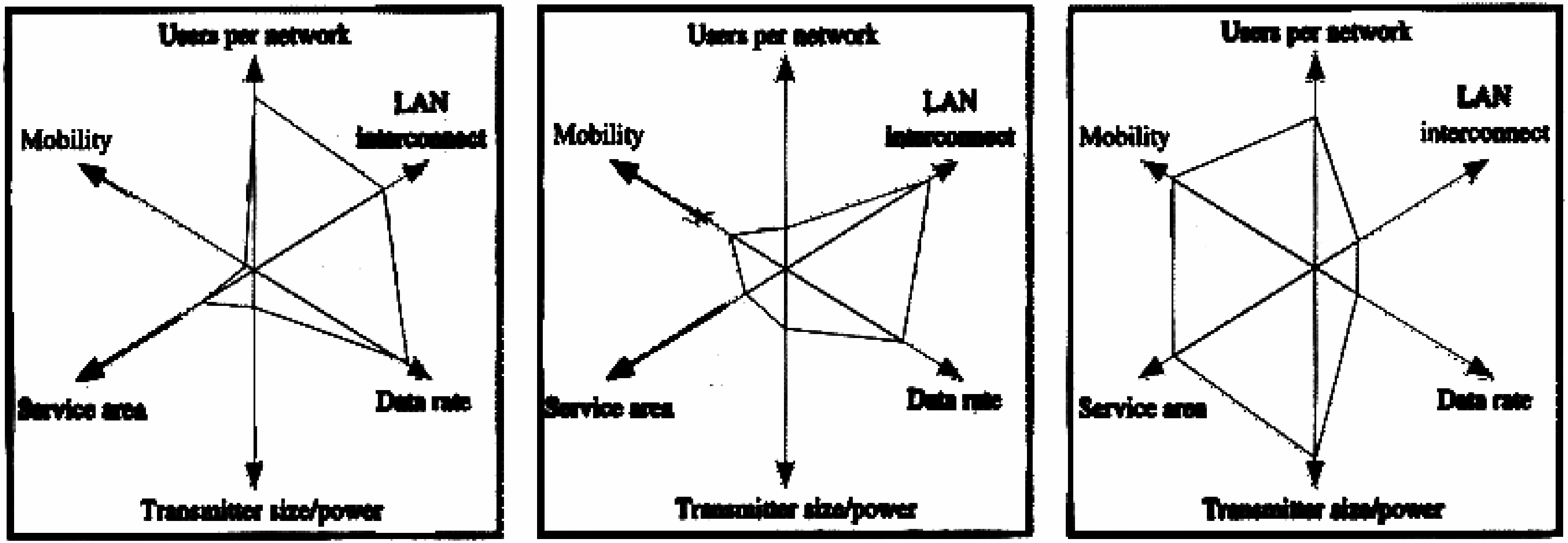
Overview (cont'd)

☞ Requirements specific to the wireless LAN environment (cont'd)

- Collaborated network operation : two or more wireless LAN to operate in the same area or in some area where interference between the LANs
- License-free operation
- Handoff/roaming : from one cell to another
- Dynamic configuration : permitting dynamic and automated addition, deletion and relocation of end systems without disruption to other users

Overview (cont'd)

✓ Kiviat Graphs for Data Networks



(a) Wired LANs (b) Wireless LANs (c) Mobile Data Networks

Overview (cont'd)

✓ Wireless LAN Technology

☞ Categorized according to the transmission technique that is used

- Infrared (IR) LANs : limited to a single room because infrared light does not penetrate opaque walls
- Spread spectrum LANs : operating ISM (industrial, scientific, and medical) bands
- Narrowband microwave : operating at microwave frequencies but not using spread spectrum (in licensing or ISM bands)

Overview (cont'd)

✓ Comparison of wireless LAN Technologies

	Infrared		Spread Spectrum		Radio
	Diffused Infrared	Directed Beam Infrared	Frequency Hopping	Direct Sequence	Narrowband Microwave
Data Rate (Mbps)	1 to 4	1 to 10	1 to 3	2 to 20	10 to 20
Mobility	Stationary/mobile	Stationary with LOS	Mobile	Stationary/mobile	
Range (ft)	50 to 200	80	100 to 300	100 to 800	40 to 130
Detectability	Negligible		Little		
Wavelength/ frequency	λ: 800 to 900 nm		902 to 928 MHz 2.4 to 2.4835 GHz 5.725 to 5.85 GHz		902 to 928 MHz 5.2 to 5.775 GHz 18.825 to 19.205 GHz
Modulation technique	ASK		FSK	QPSK	FS/QPSK
Radiated power	—		< 1 W		25 mW
Access method	CSMA	Token Ring, CSMA	CSMA		Reservation ALOHA, CSMA
License required	No		No		Yes unless ISM

Infrared LANs

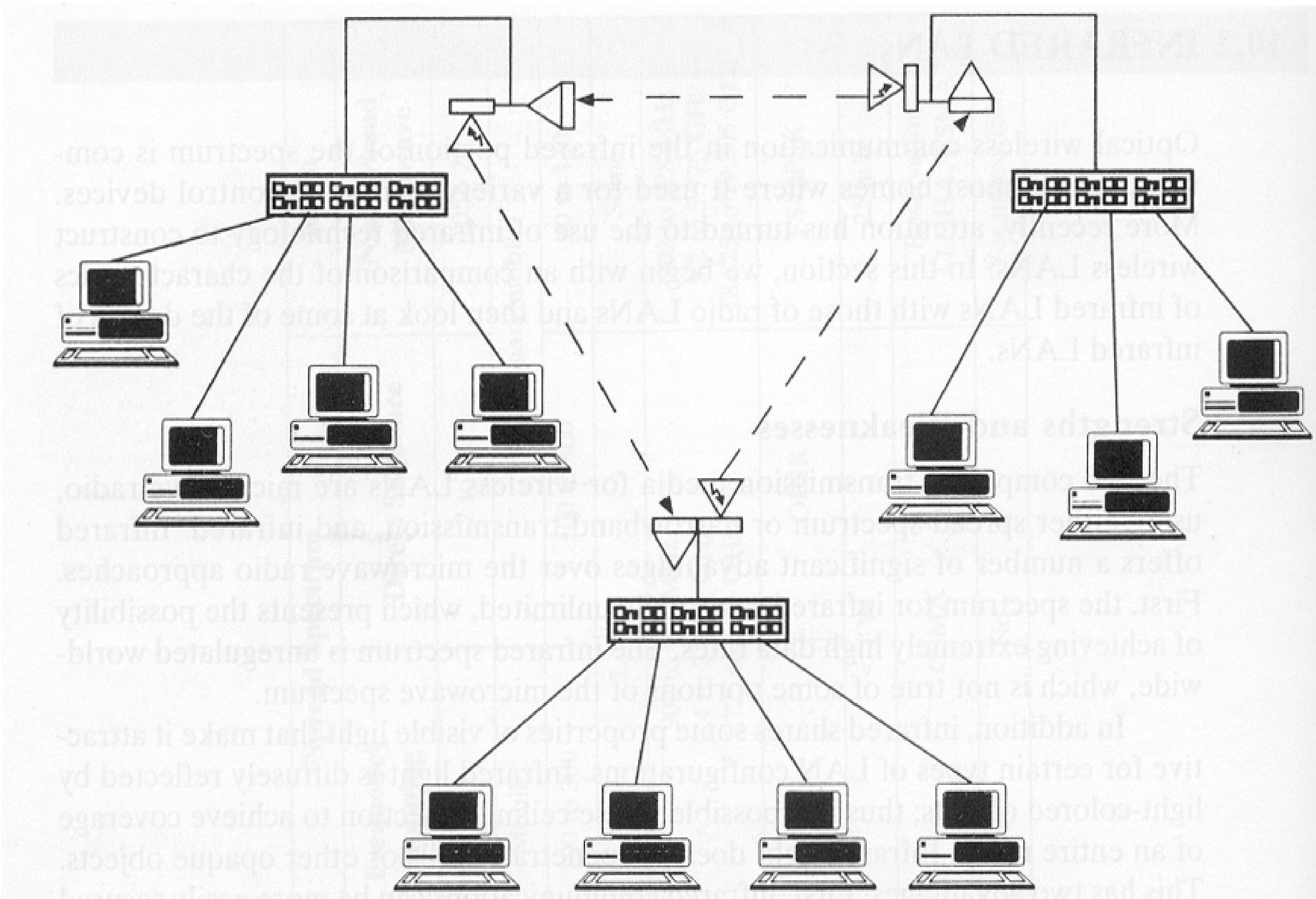
- ✓ Optical wireless communication in the infrared portion of the spectrum
  - ☞ **in most homes, used for a variety of remote control devices**
- ✓ Strength of Infrared
  - ☞ **The spectrum for infrared is virtually unlimited, which presents the possibility of achieving extremely high data rates**
  - ☞ **Possible to use ceiling reflection to achieve coverage of an entire room**
    - **can be more easily secured against eavesdropping than microwave**
    - **a separate infrared installation can be operated in every room in a building without interference**
  - ☞ **Infrared equipment is relatively inexpensive and simple**
    - **IR receivers need to detect only the amplitude of optical signals, but most microwave receivers must detect frequency or phase**

Infrared LANs (cont'd)

- Weaknesses of Infrared
  - Noise caused by intense background radiation, from sunlight and indoor lighting
  - So, need to use high power transmitter
- Transmission Techniques
  - Direct Beam Infrared
    - Used to create point-to-point links
    - Depending on the emitted power and on the degree of focusing
    - Used for cross-building inter-connect between bridges or routers located in buildings within a line of sight of each other
    - For example, setting up a token ring LAN

Infrared LANs (cont'd)

- ✓ Token ring LAN using point-to-point infrared Links

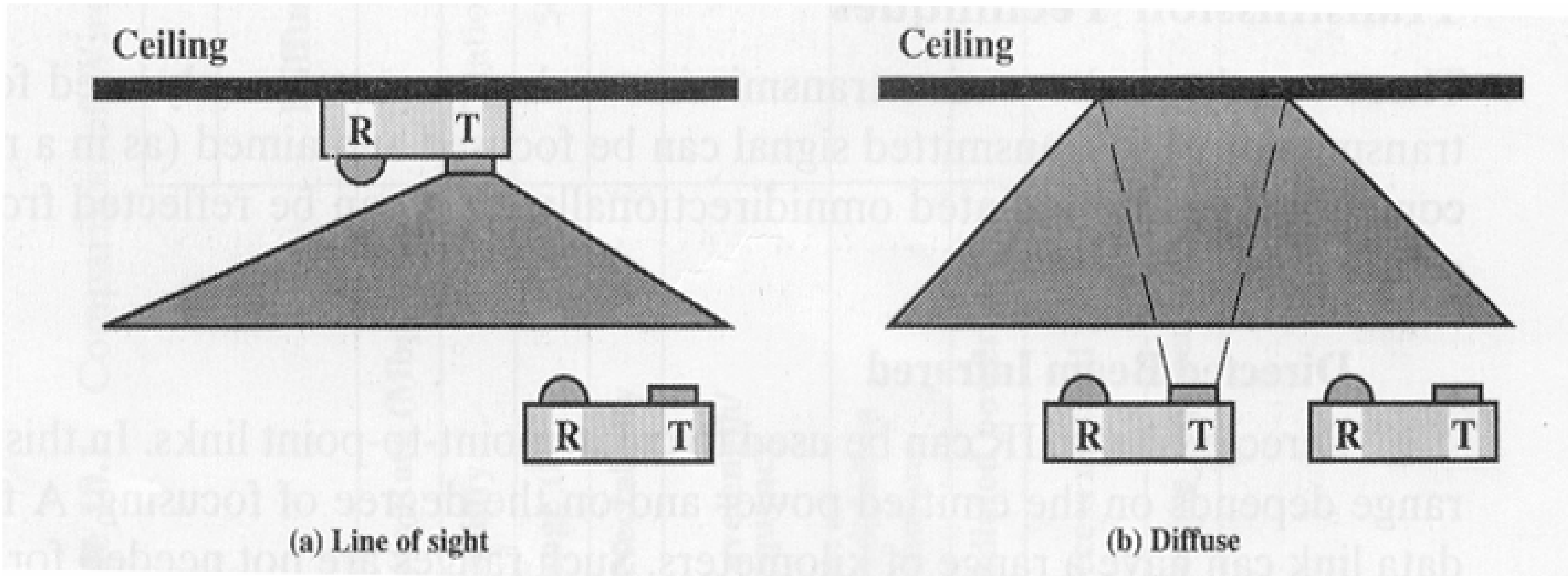


Infrared LANs (cont'd)

- Omnidirectional
  - Omnidirectional configuration involves a single base station that is within line of sight of all other stations on the LAN
    - The base station acts as a multiport repeater similar to the type for 10BASE-T and 100BASE-T
- Diffused
  - All of IR transmitters are focused and aimed at a point a diffusely reflecting ceiling
  - IR radiation striking the ceiling is reradiated omnidirectionally and picked up by all of the receivers in the area

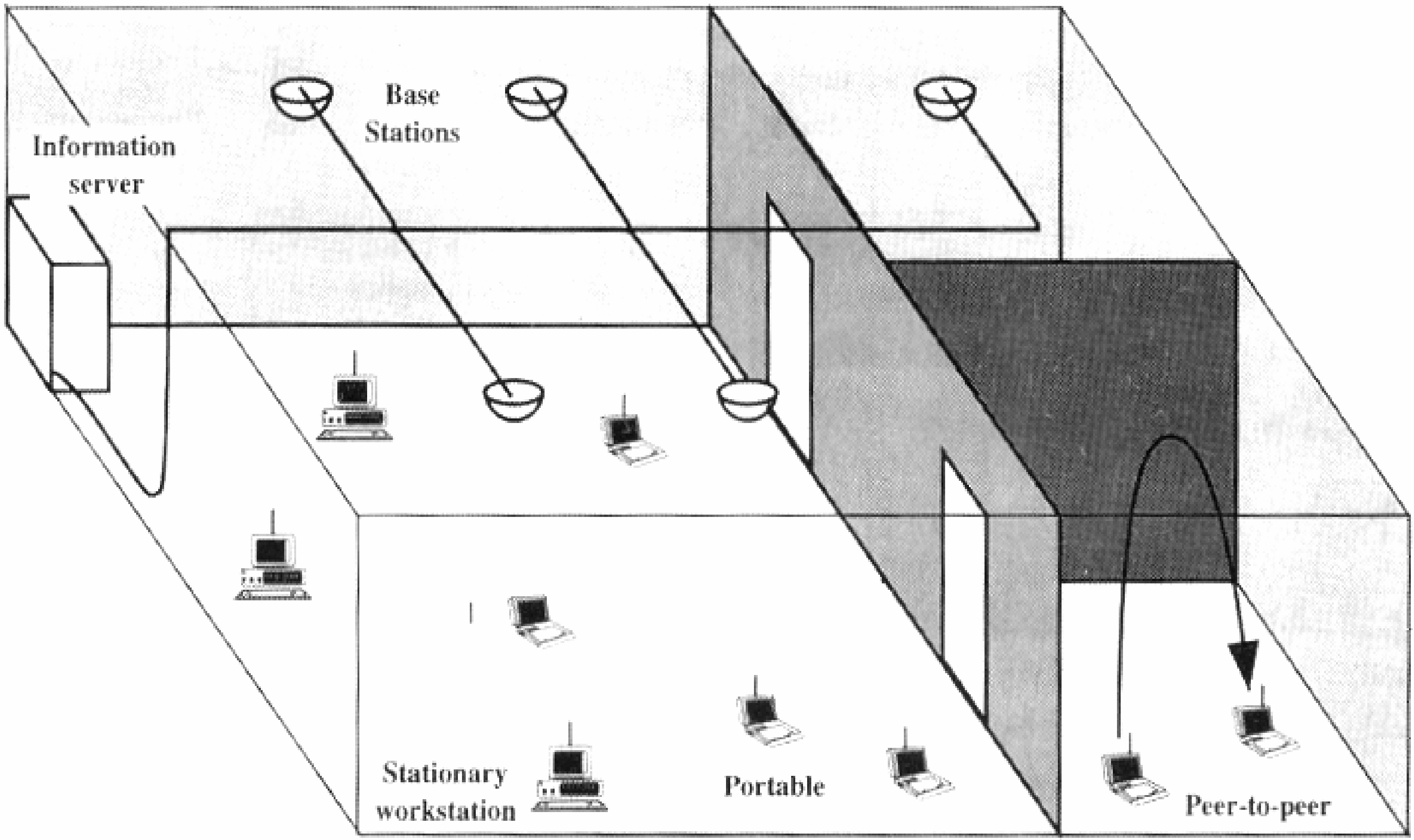
Infrared LANs (cont'd)

- ✓ Configurations for Diffused Infrared LANs



Infrared LANs (cont'd)

- Network of Portable Terminals Using Infrared



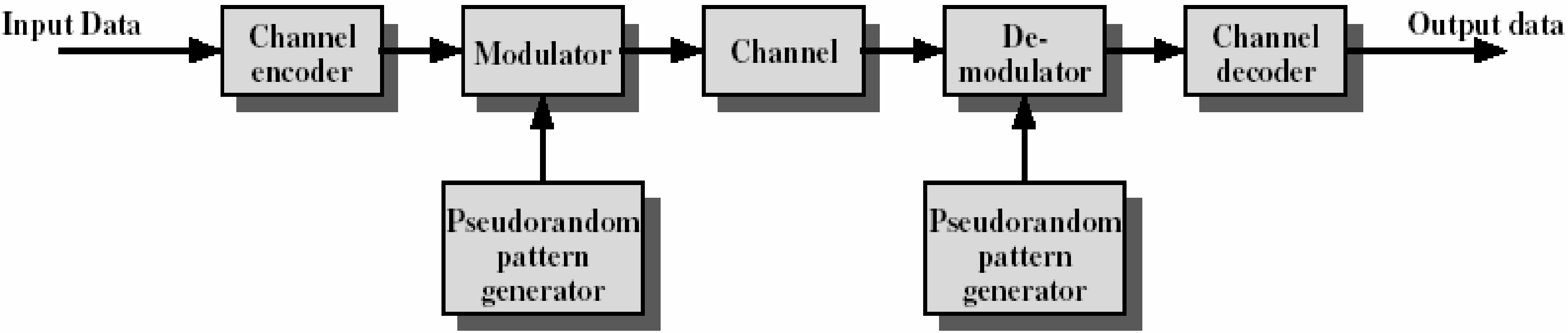
Spread Spectrum LANs

The most popular type of wireless LAN uses spread spectrum techniques

- ✓ Spread Spectrum Communications
  - ☞ Developed initially for military and intelligence requirements
  - ☞ Essential idea : spreading the information signal over a wider bandwidth to make jamming and interception more difficult
    - Frequency hopping
    - Direct sequence spread spectrum

Spread Spectrum LANs (cont'd)

✓ General Model of Spread Spectrum Digital Communication System



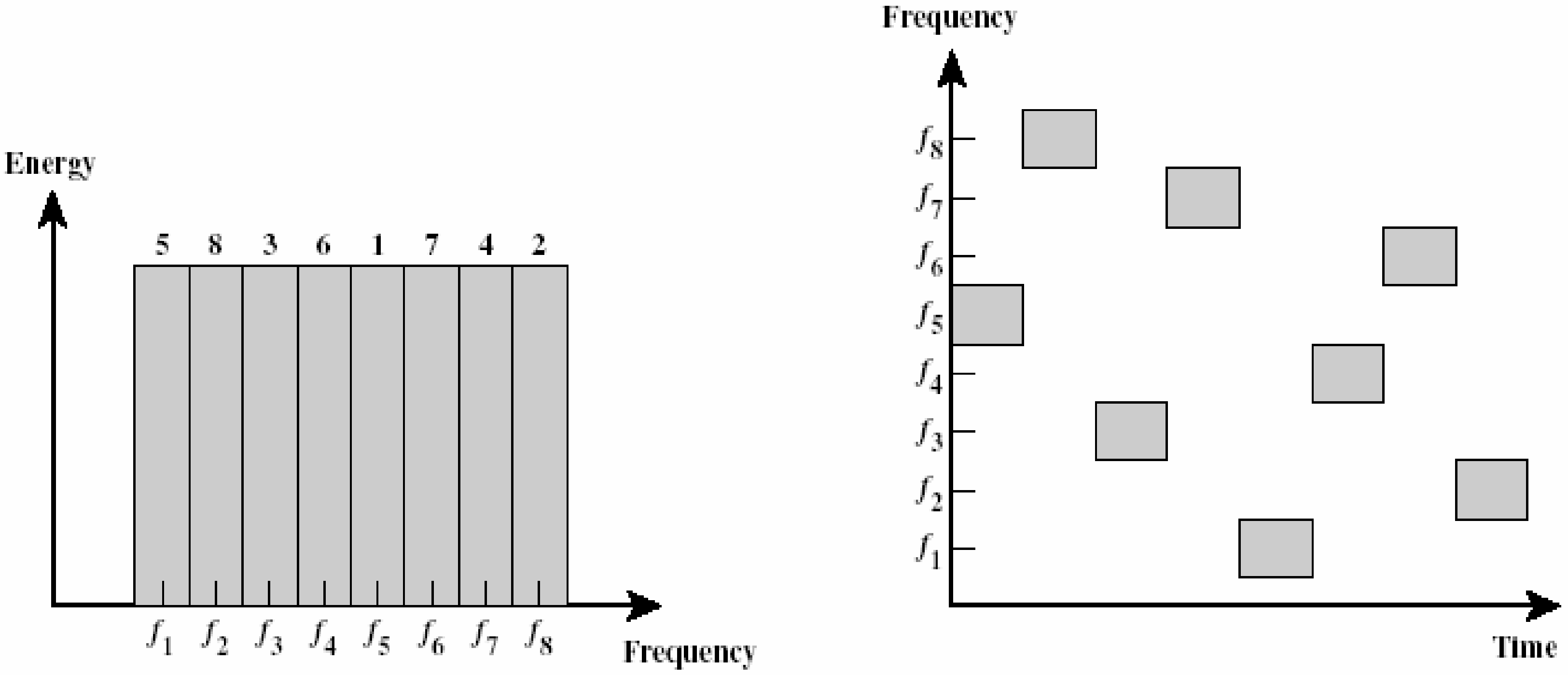
- Channel encoder : producing an analog signal with a relatively narrow bandwidth around some center frequency
- The effect of modulation is to increase significantly the bandwidth (spread spectrum) of the signal to be transmitted
- Transmitter and receiver shares the algorithm of pseudorandom pattern generator

Spread Spectrum LANs (cont'd)

- Frequency Hopping
  - The signal is broadcast over a seemingly random series of radio frequencies, hopping from frequency to frequency at fixed intervals
  - IEEE 802.11 standard uses a 300-ms interval
  - The sequence of channels used is detected by a pseudorandom code
  - Both transmitter and receiver use the same code to tune into a sequence of channels in synchronization

Spread Spectrum LANs (cont'd)

- ✓ Frequency-Hopping example

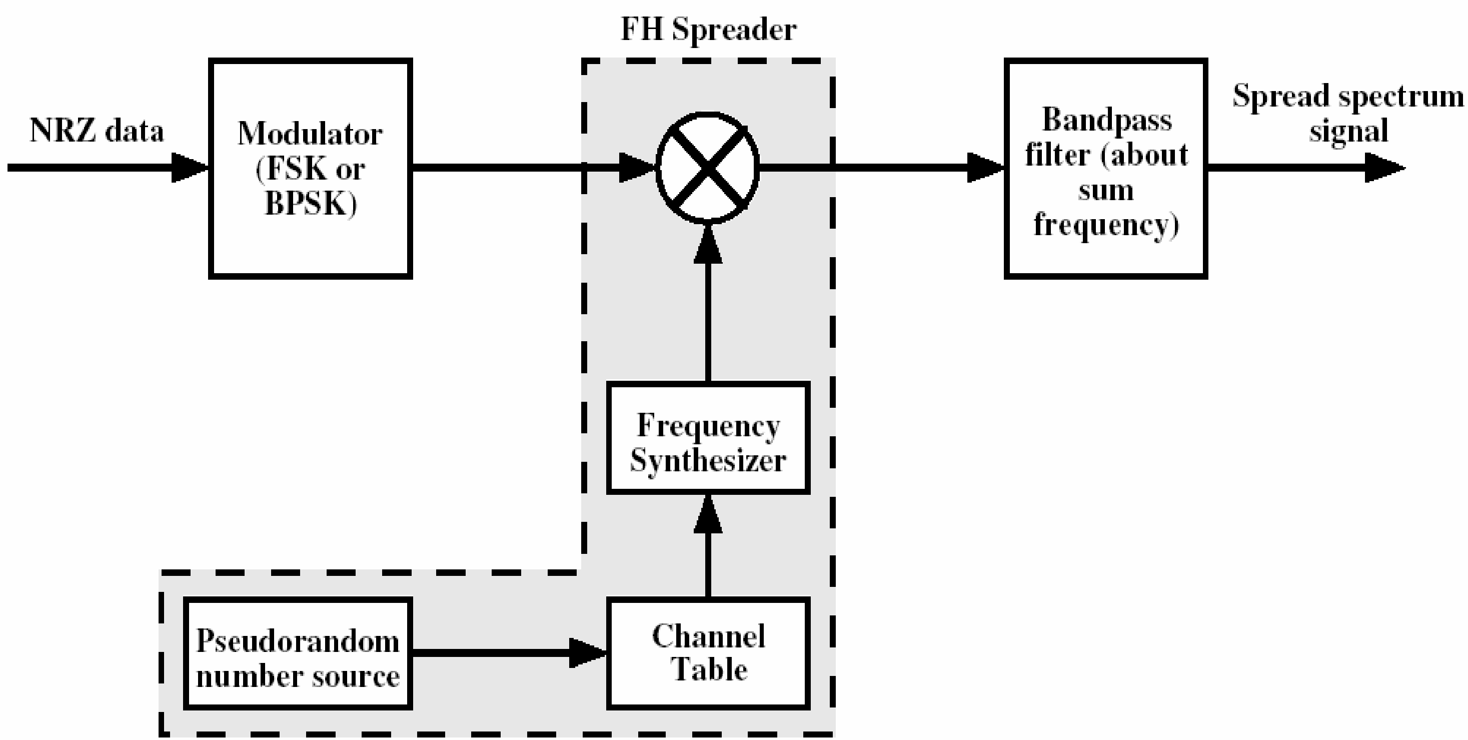


(a) Channel assignment

(b) Channel use

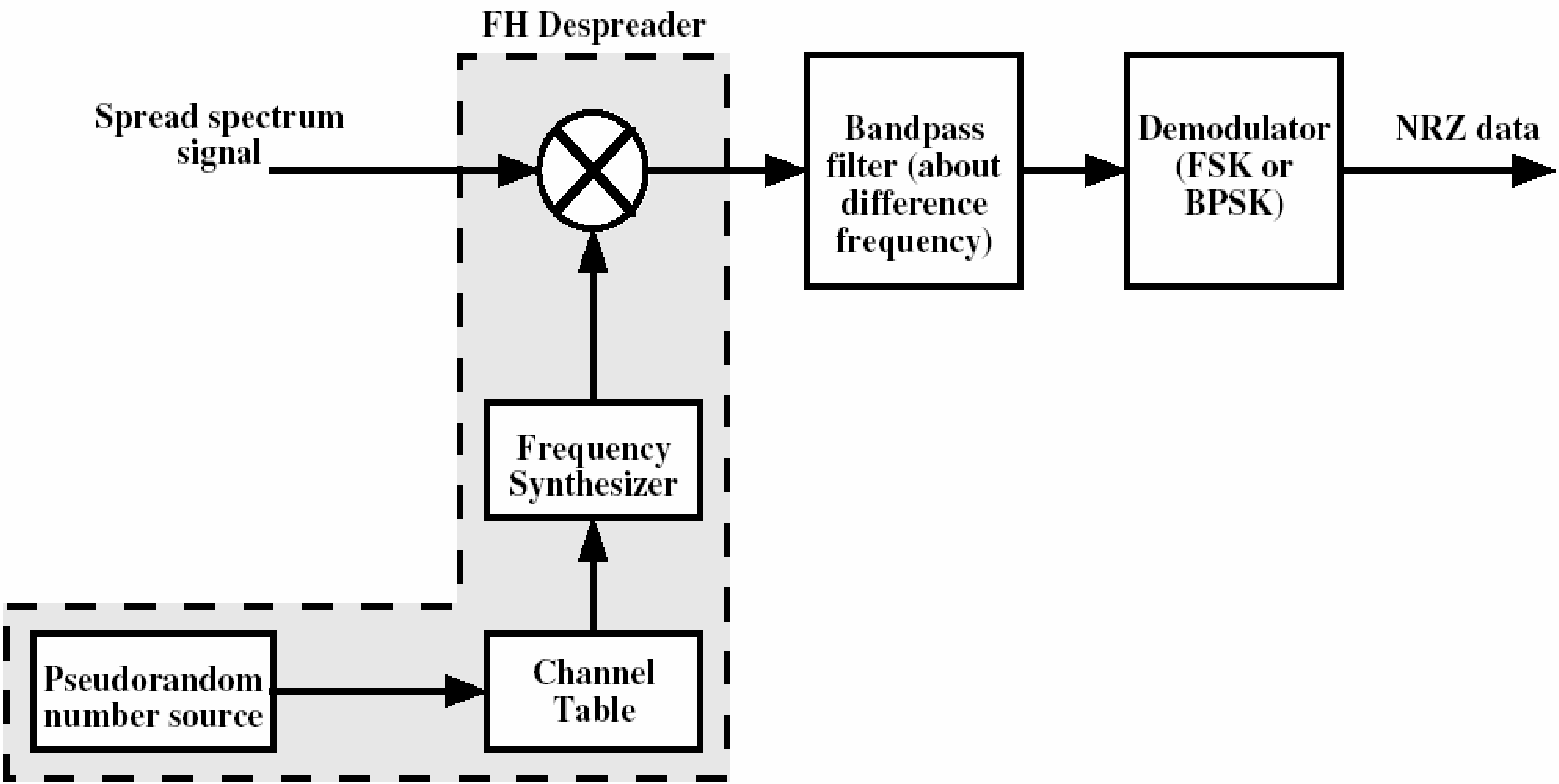
Spread Spectrum LANs (cont'd)

- A typical block diagram for a frequency-hopping system



(a) Transmitter

Spread Spectrum LANs (cont'd)



(b) Receiver

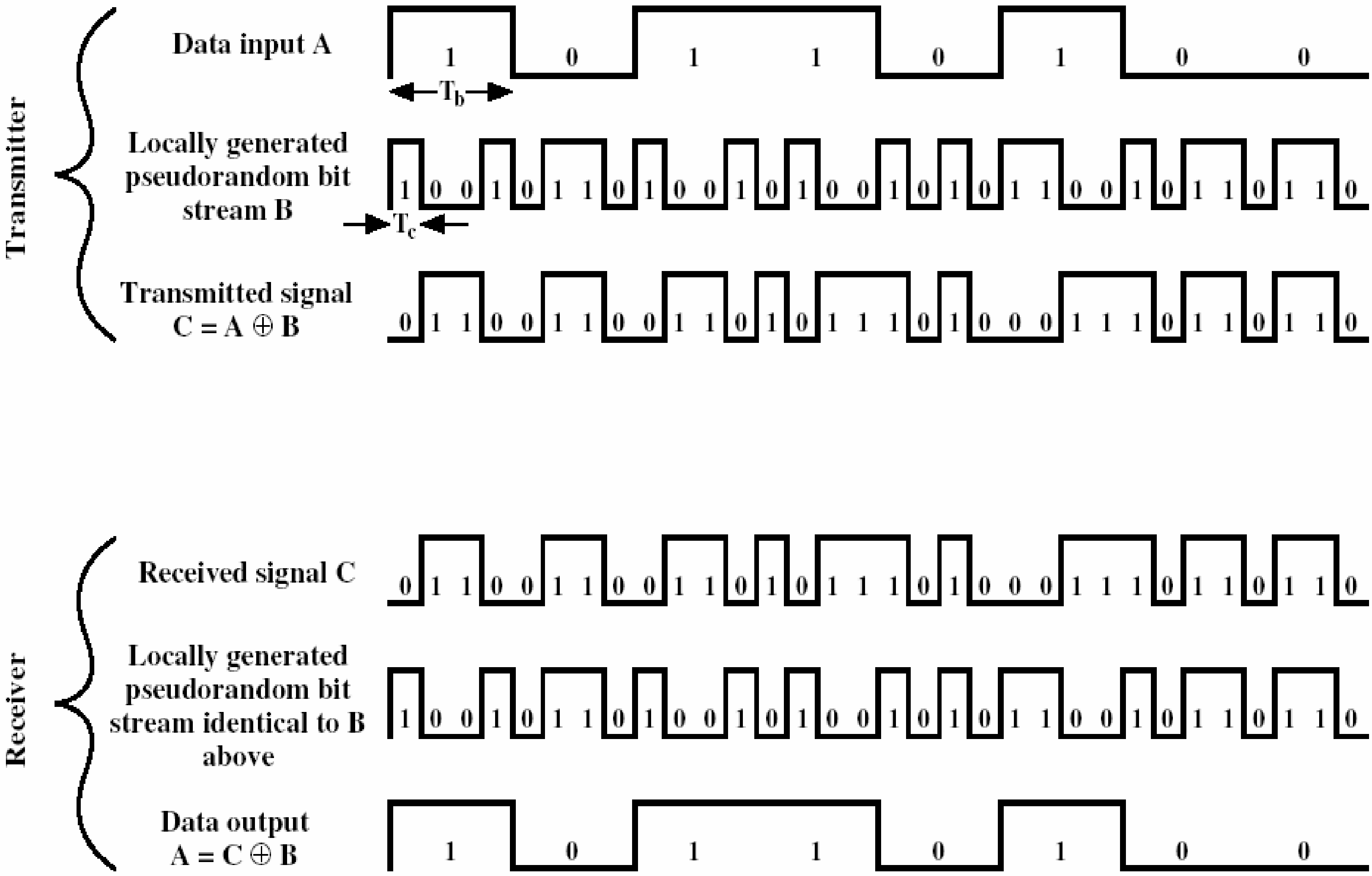
Spread Spectrum LANs (cont'd)

✓ Direct Sequence

- ☞ Each bit in the original signal is represented by multiple bits in the transmitted signal, known as a chipping code.
- ☞ Chipping code spreads the signal across a wider frequency band in direct proportion to the number of bits used
  - A 10-bit chipping code spreads the signal across a frequency band that is 10 times greater than a 1-bit chipping code
- ☞ Combining the digital information stream with the pseudorandom bit stream using an exclusive-OR

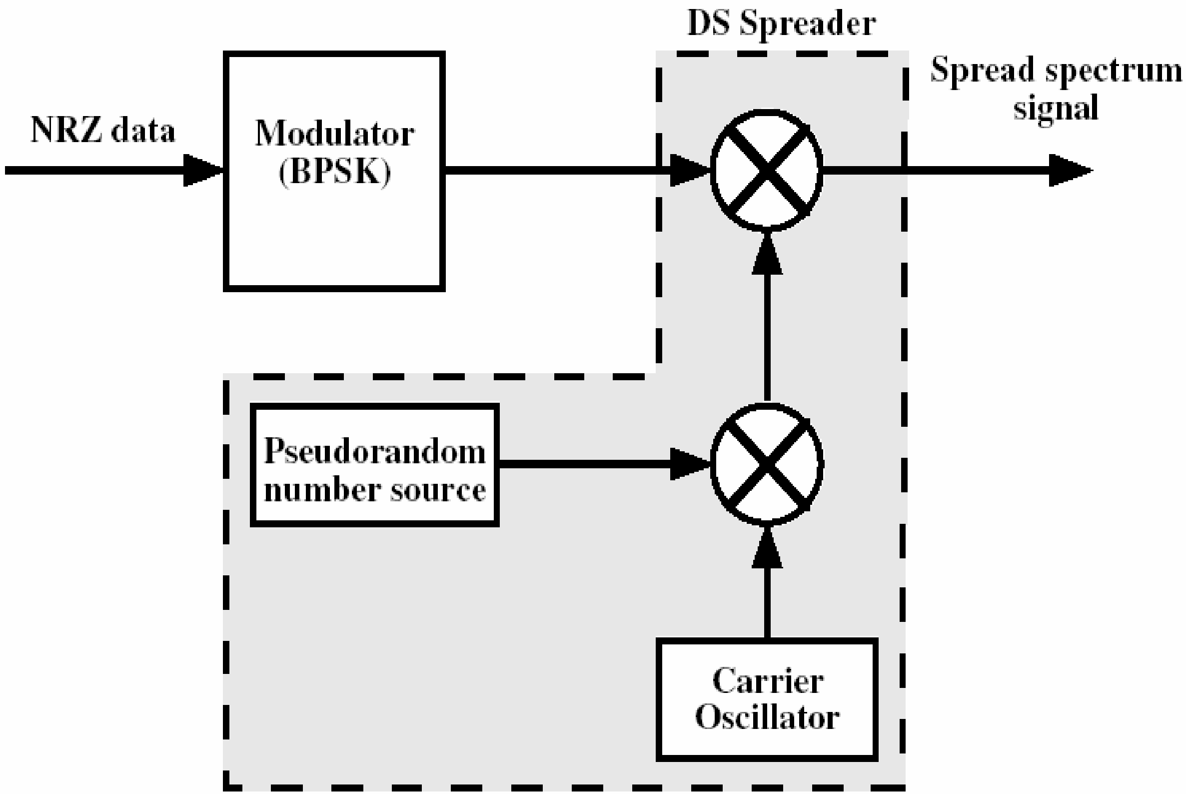
Spread Spectrum LANs (cont'd)

✓ Example of Direct Sequence Spread Spectrum



Spread Spectrum LANs (cont'd)

- ✓ Direct Sequence Spread Spectrum System

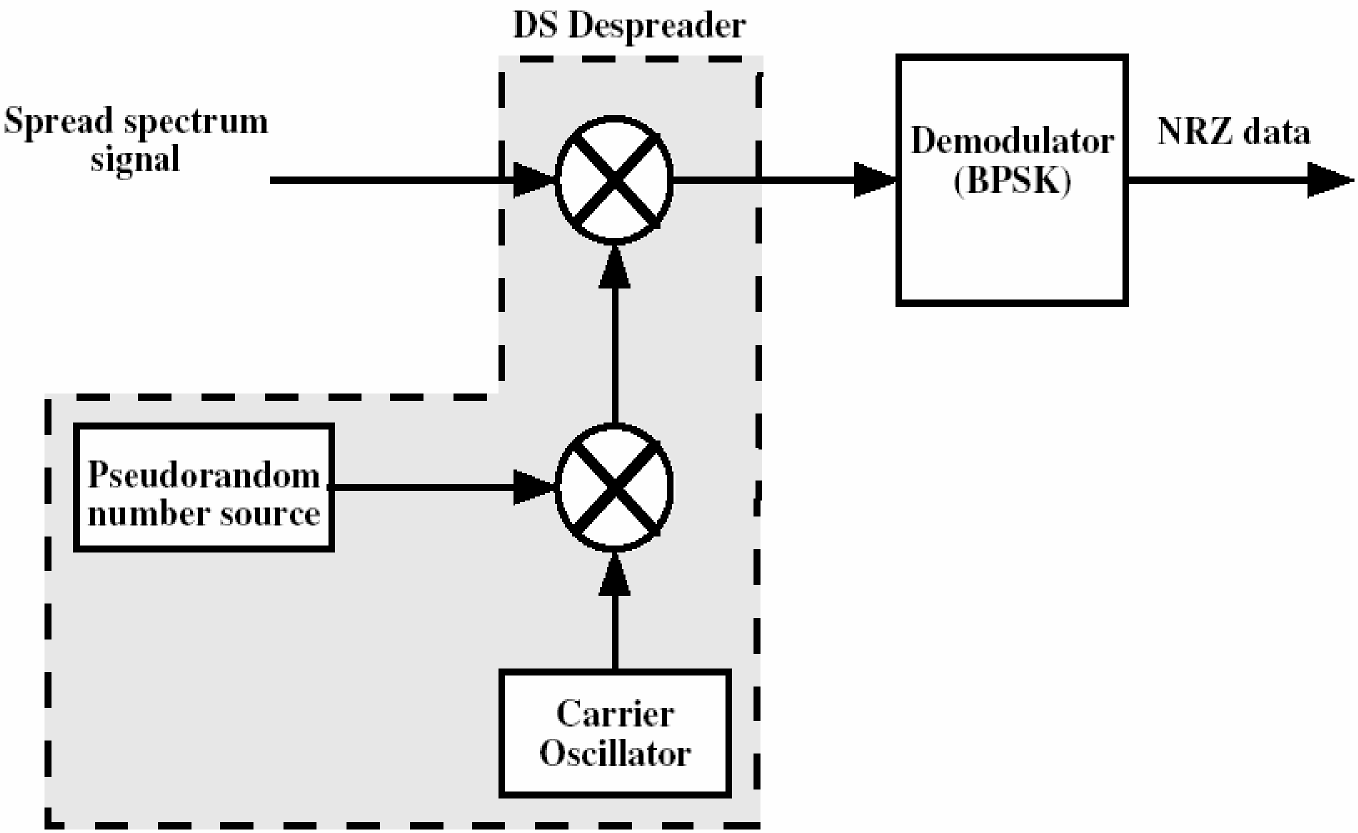


(a) Transmitter

- ☞ The information stream and the pseudorandom stream are both converted to analog signals and then combined

Spread Spectrum LANs (cont'd)

- ✓ Direct Sequence Spread Spectrum System



(b) Receiver

Spread Spectrum LANs (cont'd)

- Transmission issues
  - 2.4 GHz wireless LAN (TGb)
    - use of Frequency hopping
    - 11 Mbps (1999 standard)
  - 5 GHz wireless LAN (TGa)
    - use of Orthogonal Frequency Division Multiplexing (OFDM)
    - 6 to 54 Mbps (2001)

Narrowband Microwave LANs

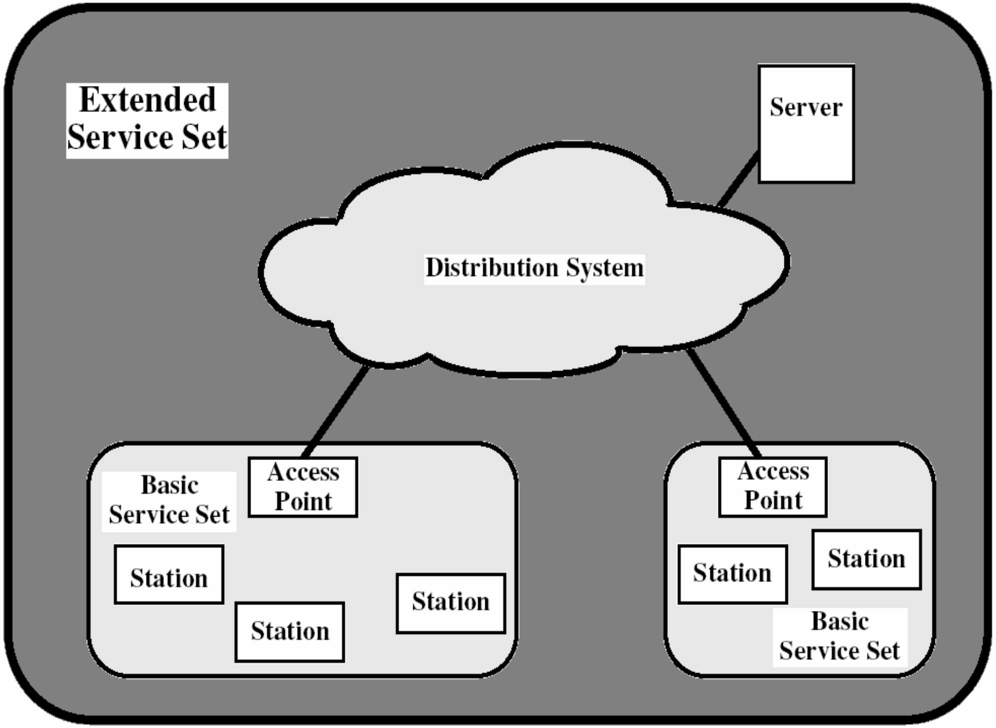
- ✓ Using a microwave radio frequency band for signal transmission, with a relatively narrow bandwidth
- ✓ Licensed Narrowband RF
  - ☞ Licensed and coordinated within specific geographic areas to avoid potential interference between systems
  - ☞ Each geographic area has a radius of 28 km
  - ☞ To provide security from eavesdropping, all transmissions are encrypted.
  - ☞ One advantage of the licensed narrowband LAN is that it guarantees interference-free communication

Narrowband Microwave LANs (cont'd)

- Unlicensed Narrowband RF
  - In 1995, Radio LAN became the first vendor to introduce a narrowband wireless LAN using the unlicensed ISM spectrum
  - This spectrum can be used for narrow-band transmission at lower power (0.5W or less)
  - 10 Mbps at 5.8 GHz band : 50 m in semiopen office and 100m in an open office

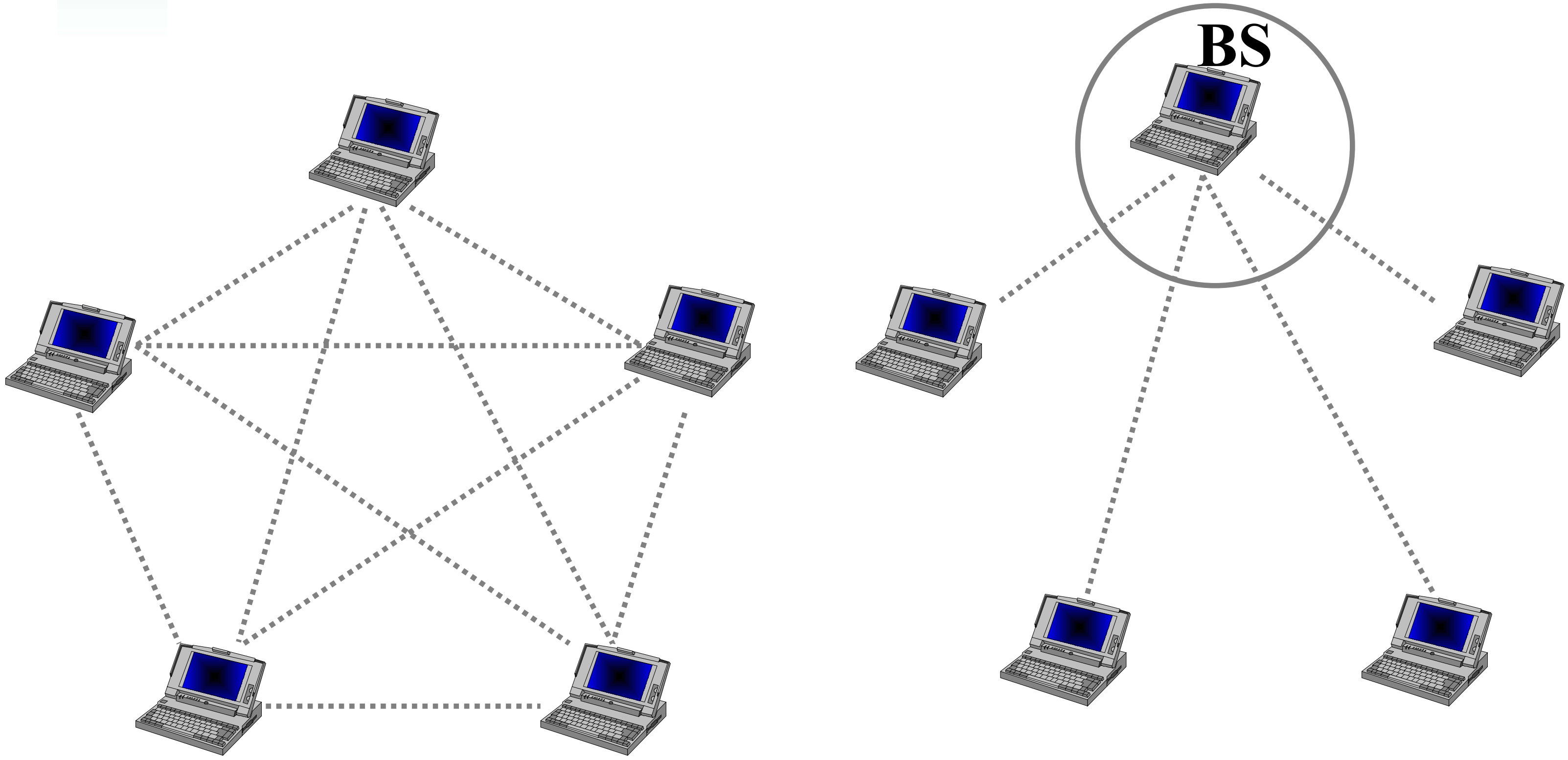
Wireless LAN Standards

- ✓ Started in 1987 within the IEEE 802.4 group
- ✓ Decided in 1990 to form a new working group, IEEE 802.11
- ✓ IEEE 802.11 Architecture



802.11 Wireless LAN Configurations

1. Ad-Hoc Networking 2. Infrastructure Networking



Wireless LAN Standards (cont'd)

- Basic Service Set (BSS) : cell
  - consists of some number of stations executing the same MAC protocols and competing for access to the same shared medium
  - Access point : functioning as a bridge
- Extended Service Set (ESS)
  - consists of two or more basic service sets interconnected by a distribution system
- Distribution System
  - Wired backbone LAN

Wireless LAN Standards (cont'd)

- Three types of stations based on mobility
  - No transition : stationary or in BSS
  - BSS transition : Between BSS
  - ESS transition : movement from a BSS in one ESS to a BSS within another ESS
- IEEE 802.11 Services
  - Association : establishing initial association between a station and an access point
  - Reassociation : handoff from one BSS to another
  - Disassociation : a notification from either a station or an access point that an existing association is terminated.
  - Authentication : Used to establish the ID of stations to each other
  - Privacy : optional use of encryption to assure privacy

Wireless LAN Standards (cont'd)

- Physical Medium Specification
  - Infrared at 1 Mbps and 2 Mbps operating at a wavelenth between 850 and 950 nm
  - Direct-sequence spread spectrum operating in the 2.4 GHz ISM band. Up to 7 channels, each with a data rate of 1 Mbps or 2 Mbps, can be used
  - Frequency-hopping spread spectrum operating in the 2.4 GHz ISM band, at data rate of 1 Mbps and 2 Mbps

Wireless LAN Standards (cont'd)

✓ Medium Access Control

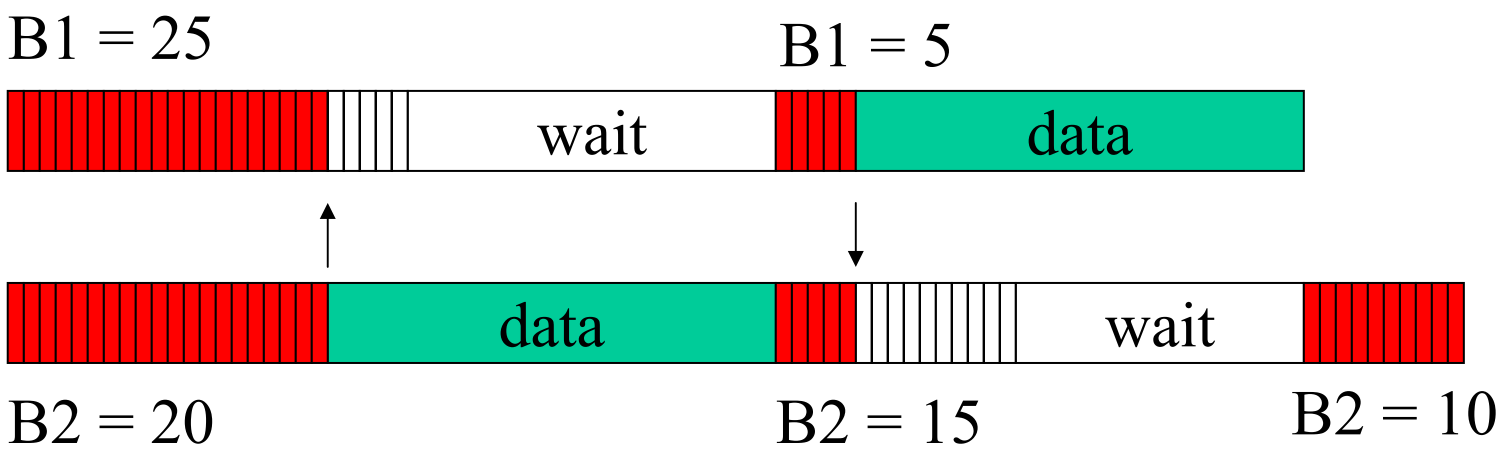
- ☞ DFWMAC (Distributed Foundation Wireless MAC)
  - Distributed access control mechanism with optional centralized control
- ☞ Distributed Coordination Function (DCF)
  - uses a contention algorithm to provide access to all traffic.
  - ordinary asynchronous traffic directly uses DCF
  - use of a simple CSMA algorithm
- ☞ Point Coordination Function
  - is centralized MAC algorithm used to provide contention-free service

Congestion Avoidance: in IEEE 802.1 DCF

- Before transmitting a packet, randomly choose a backoff interval in the range [0,cw]
  - **cw** is the contention window
- "Count down" the backoff interval when medium is idle
  - Count-down is suspended if medium becomes busy
- When backoff interval reaches 0, transmit packet (or RTS)

DCF Example

Let cw = 31



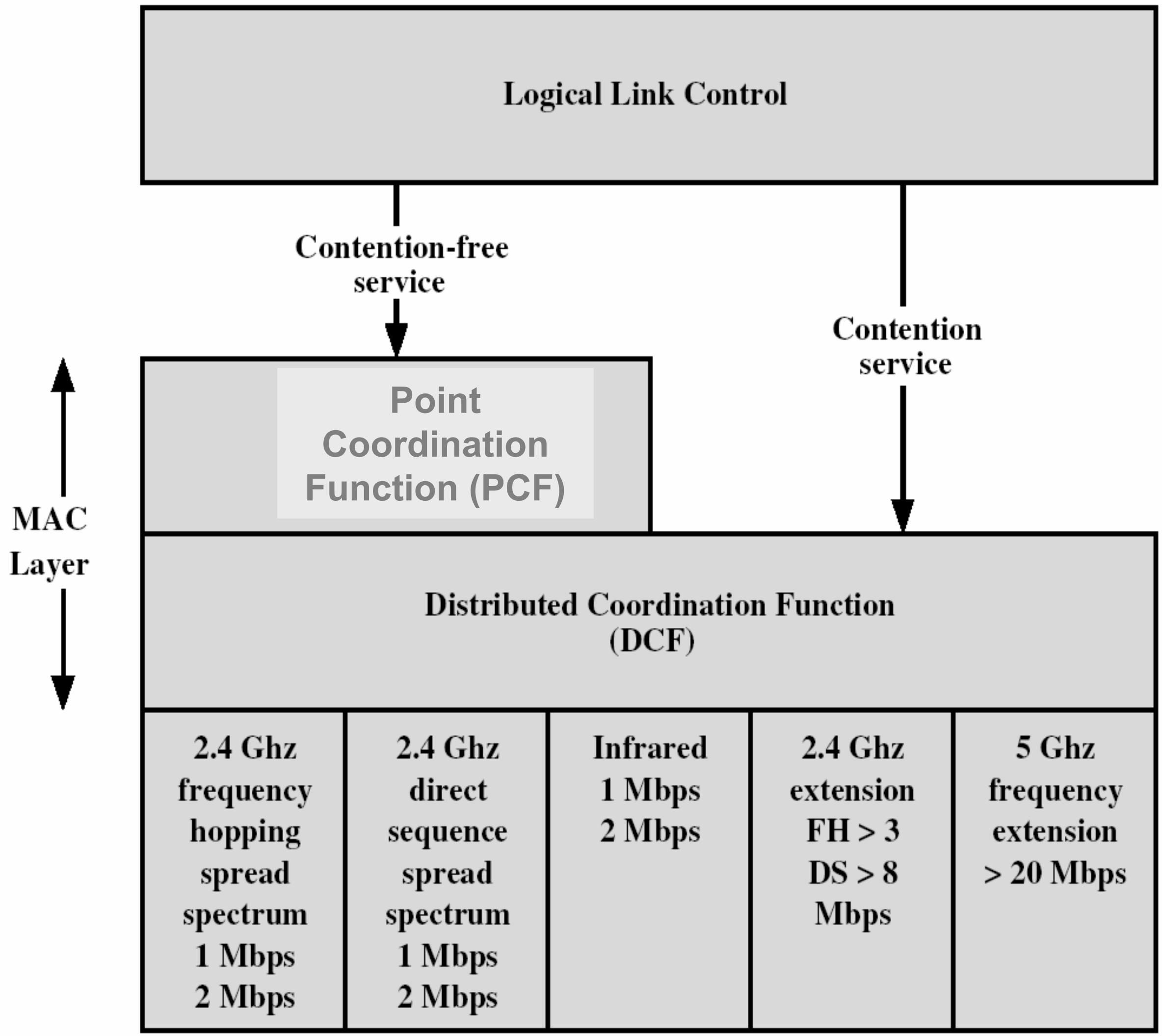
B1 and B2 are backoff intervals at nodes 1 and 2

Congestion Avoidance

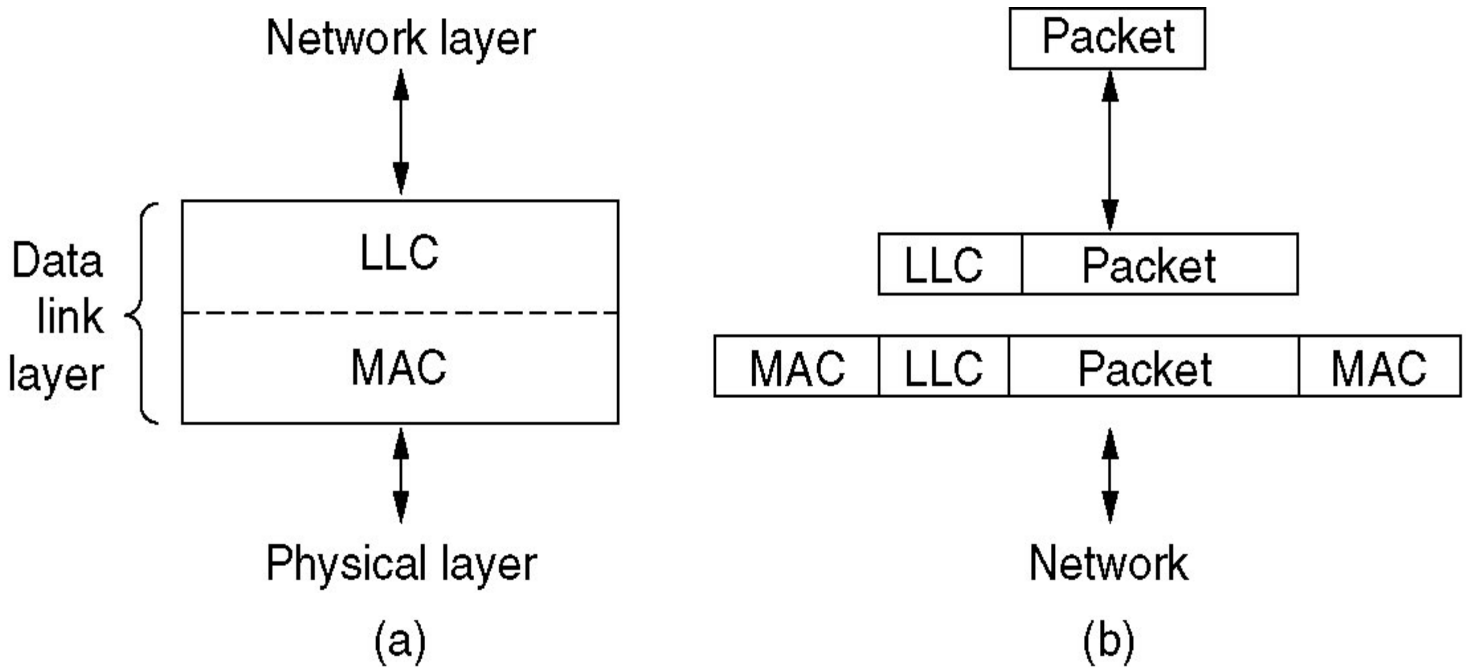
- ✓ The time spent counting down backoff intervals contributes to MAC overhead
- ✓ Choosing a ***large cw*** leads to large backoff intervals and can result in larger overhead
- ✓ Choosing a ***small cw*** leads to a larger number of collisions (more likely that two nodes count down to 0 simultaneously)

Wireless LAN Standards (cont'd)

- ✓ IEEE 802.11 Protocol Architecture



IEEE 802.2: Logical Link Control



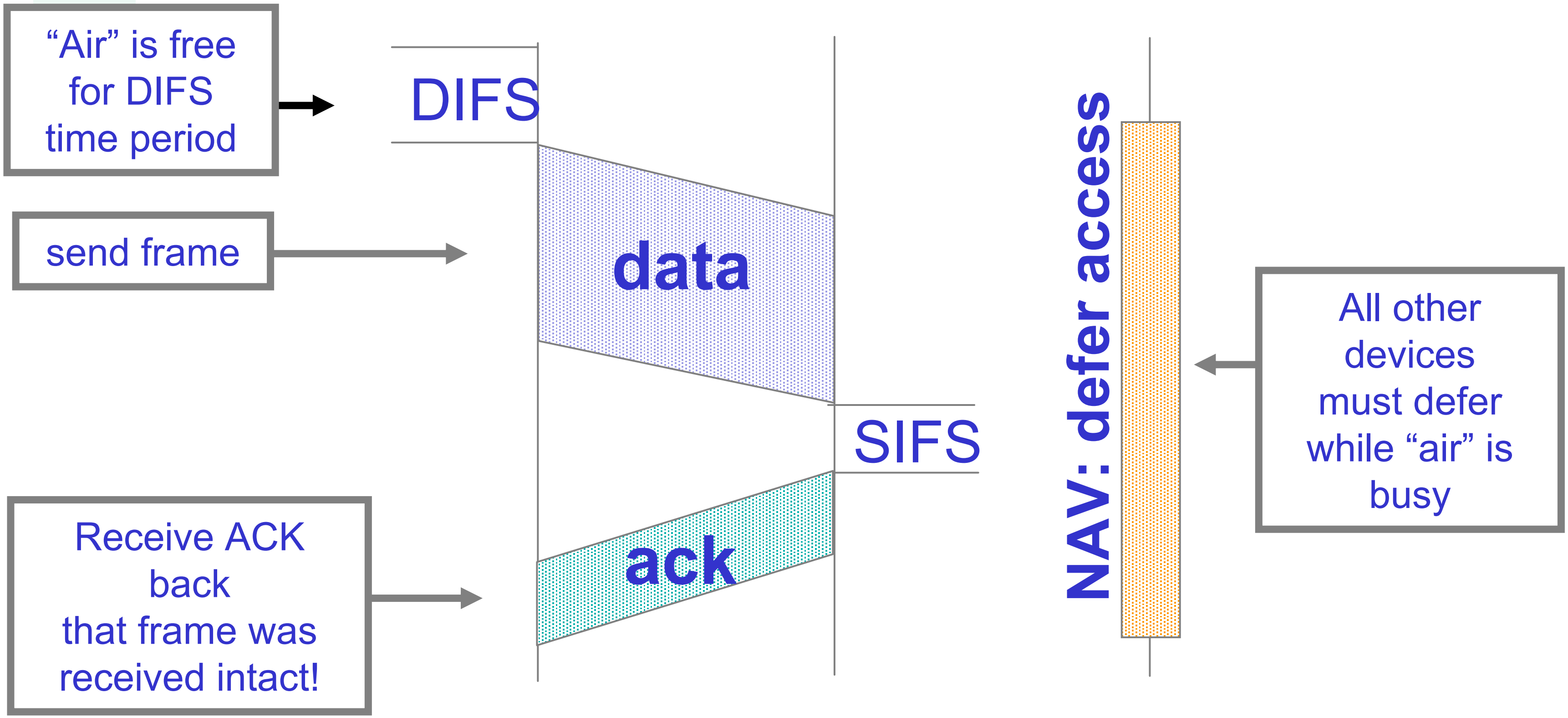
CSMA-CA + Acknowledgement

- ✓ Carrier Sense Multiple Access with *Collision Avoidance*
- ✓ _How CSMA-CA works:
  - **Device wanting to transmit senses the medium (Air)**
  - **If medium is busy – defers**
  - **If medium is free for certain period (DIFS) - *transmits frame***
- ✓ Latency can increase if "air" is very busy! Device has hard time finding "open air" to send frame !

* DIFS - Distributed Inter-Frame Space (approx 128 µs)

CSMA-CA + Acknowledgement

- Carrier Sense Multiple Access with <u>*Collision Avoidance*</u>



- **Every frame is ack'ed - except broadcast and multicast!**

Distributed Coordination Function

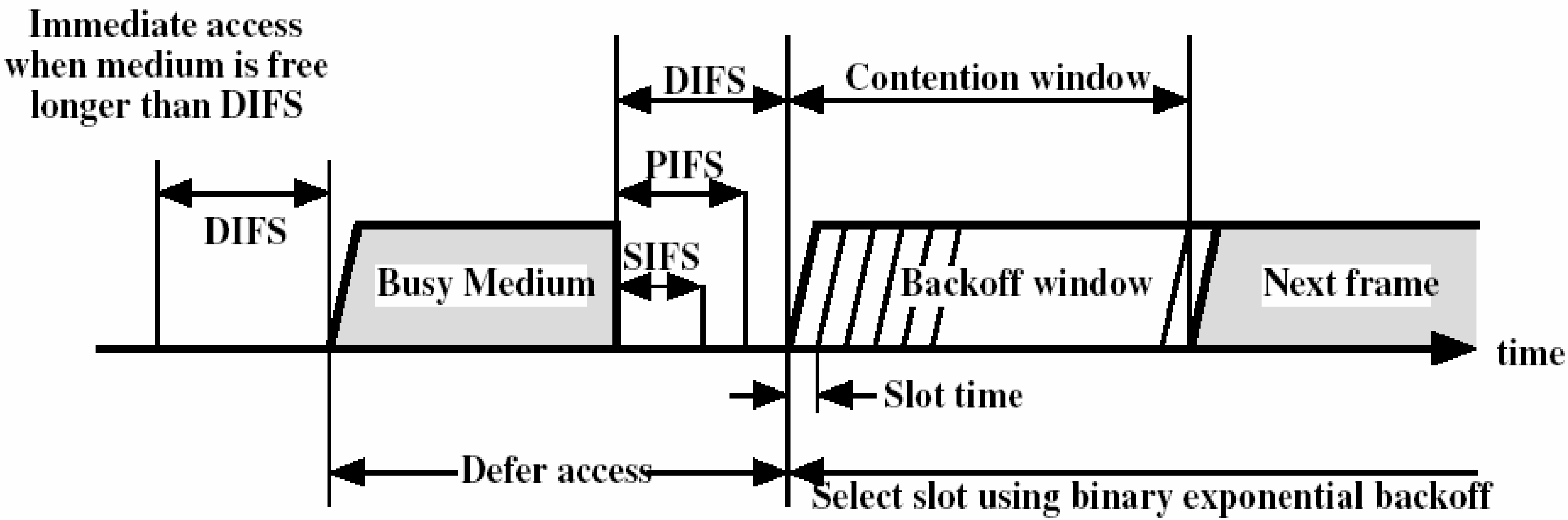
- ✓ does not include a collision detection function (i.e. CSMA/CD) because collision detection is not practical on a wireless network.
- ✓ For the smooth and fair functioning, DCF includes a set of delays that amounts to a priority scheme.
- ✓ IFS (interframe space) : considering single delay
  - ☞ If the medium is idle, it waits to see if the medium remains idle for a time equal to IFS. If so, STA may transmit immediately.
  - ☞ If busy, STA defers transmission and continues to monitor the medium until the current transmission is over.
  - ☞ Once the current transmission is over, the STA delay another IFS. If the medium remains idle for this period, then the station backs off using a binary exponential backoff scheme and senses the medium. If medium is still idle, the station may transmit.

DCF (cont'd)

- SIFS (short IFS)
  - Used for all immediate response actions
- PIFS (point coordination function IFS)
  - A midlelength IFS, used by the centralized controller in the PCF scheme when issuing polls.
- DIFS (distributed coordination function IFS)
  - The longest IFS, used as a minimum delay for asynchronous frames contending for access

IEEE 802.11 MAC Timing

✓ Basic Access Method



IEEE 802.11 MAC Timing (cont'd)

- Considering SIFS
  - Any station using SIFS has highest priority
  - Acknowledgment (ACK): STA responds with an ACK frame after waiting only for an SIFS gap
    - collision detection is not used, the likelihood of collisions is greater than with CSMA/CD, and the MAC-level ACK provides for efficient collision recovery .
    - SIFS can be used to provide efficient delivery of an LLC protocol data unit (PDU) that requires multiple MAC frames.
    - A scenario
      - A STA with a multiframe LLC to transmit sends out the MAC Frames one at a time
      - Each frame is acknowledged after SIFS by the recipient
      - When source receives an ACK, it immediately (after SIFS) sends the next frame in the sequence
      - The result is that once a station has contended for the channel, it will maintain control of the channel until it has sent all of the fragments of an LLC PDU

IEEE 802.11 MAC Timing (cont'd)

- Clear to Send (CTS) :
  - A STA can ensure that its data frame will get through by first issuing a small Request to Send (RTS) frame
  - The STA to which this frame is addressed should immediately respond with a CTS frame if it is ready to receive.
  - All other stations receive the RTS and defer using the medium until they see a corresponding CTS or until a timeout occurs.

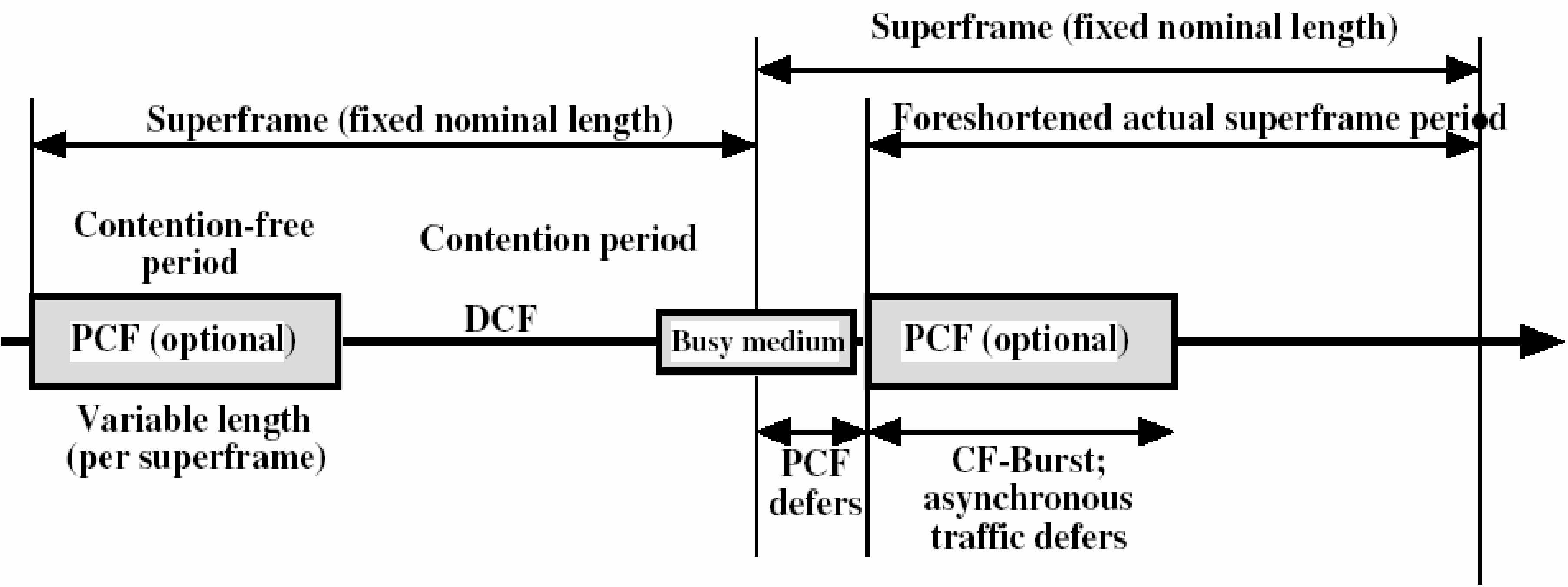
- ✓ The PIFS is used by the centralized controller in issuing polls and takes precedence over normal contention traffic
- ✓ The DIFS interval is used for all ordinary asynchronous traffic

IEEE 802.11 MAC Timing (cont'd)

- Point Coordination Function
  - Point coordinator makes use of PIFS when issuing polls
    - Because PIFS is smaller than DIFS, pointer coordinator can seize the medium and lock out all asynchronous traffic while it issues polls and receives responses
  - To prevent for the point coordinator to lock out all asynchronous traffic by repeatedly issuing polls, an interval known as the super frame is defined
    - During the first part of this interval, the point coordinator issues polls in a round –robin fashion to all stations configured for polling. The point coordinator then idles for the remainder of the superframe, allowing a contention period for asynchronous access

IEEE 802.11 MAC Timing (cont'd)

✓ PCF Superframe Construction



Wireless LAN Standards (cont'd)

✓ MAC Frame Format

octets	2	2	6	6	6	2	6	0 to 2312	4
	FC	D/I	Address	Address	Address	SC	Address	Frame body	CRC

FC = Frame control
D/I = Duration/Connection ID
SC = Sequence control

(a) MAC frame

bits	2	2	4	1	1	1	1	1	1	1	1
	Protocol version	Type	Subtype	To DS	From DS	MF	RT	PM	MD	W	O

DS = Distribution system
MF = More fragments
RT = Retry
PM = Power management

MD = More data
W = Wired equivalent privacy bit
O = Order

(b) Frame control field

Other Wireless LAN standards

- ✓ IEEE 802.15.1
  - ☞ IEEE standard of Bluetooth specification
  - ☞ Version 1.1 (2001. 4)
- ✓ IEEE 802.15.2
  - ☞ Spec. for IEEE 802.11 Wireless LAN and Bluetooth in 2.4 GHz
    - Some mutual interference
- ✓ IEEE 802.15.3
  - ☞ WPAN spec. for more speed than 20 Mbps (The end of 2001)
- ✓ Bluetooth
  - ☞ Data rate : 1 Mbps
  - ☞ 10 m Watt
  - ☞ Range : > 10 m