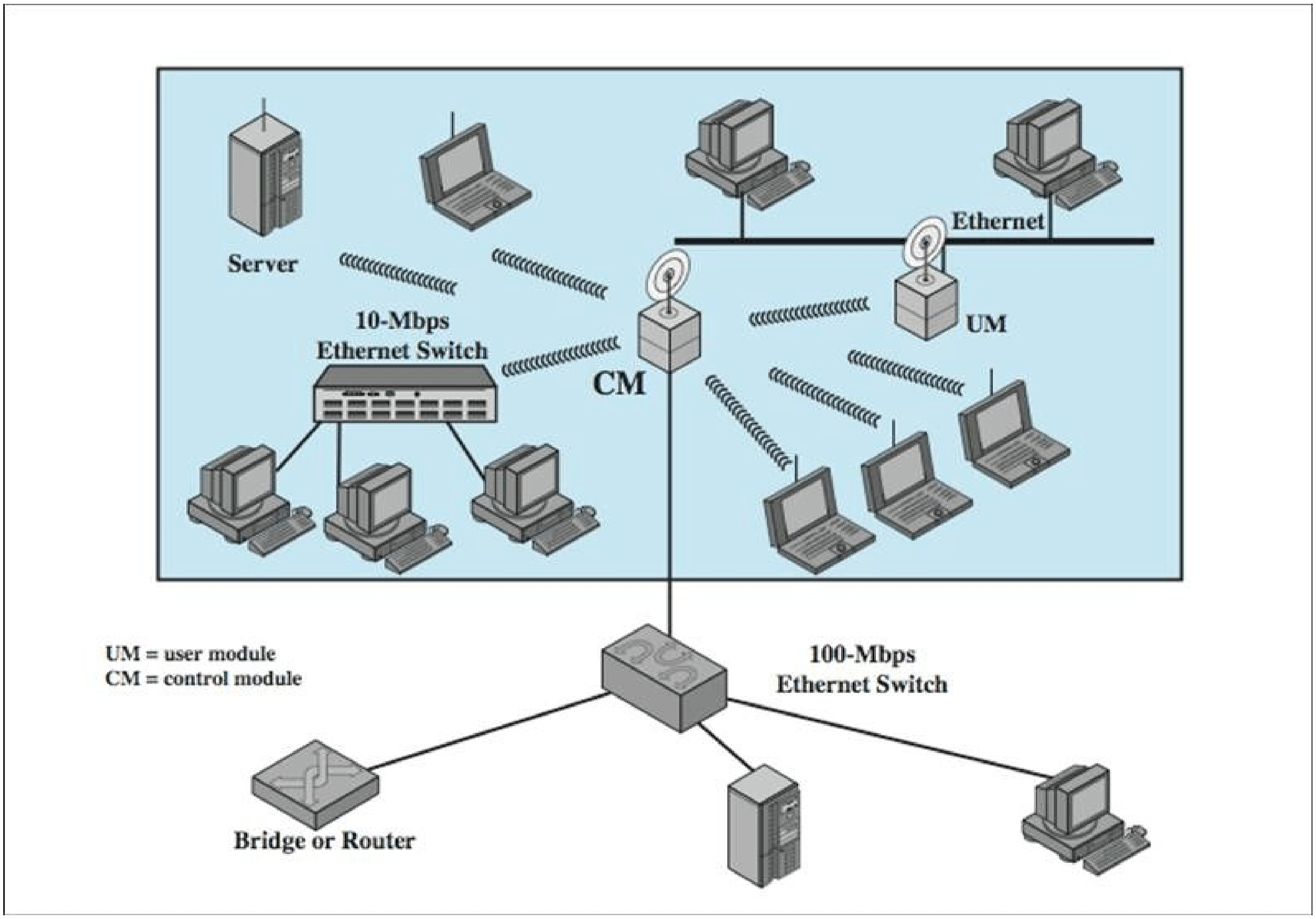
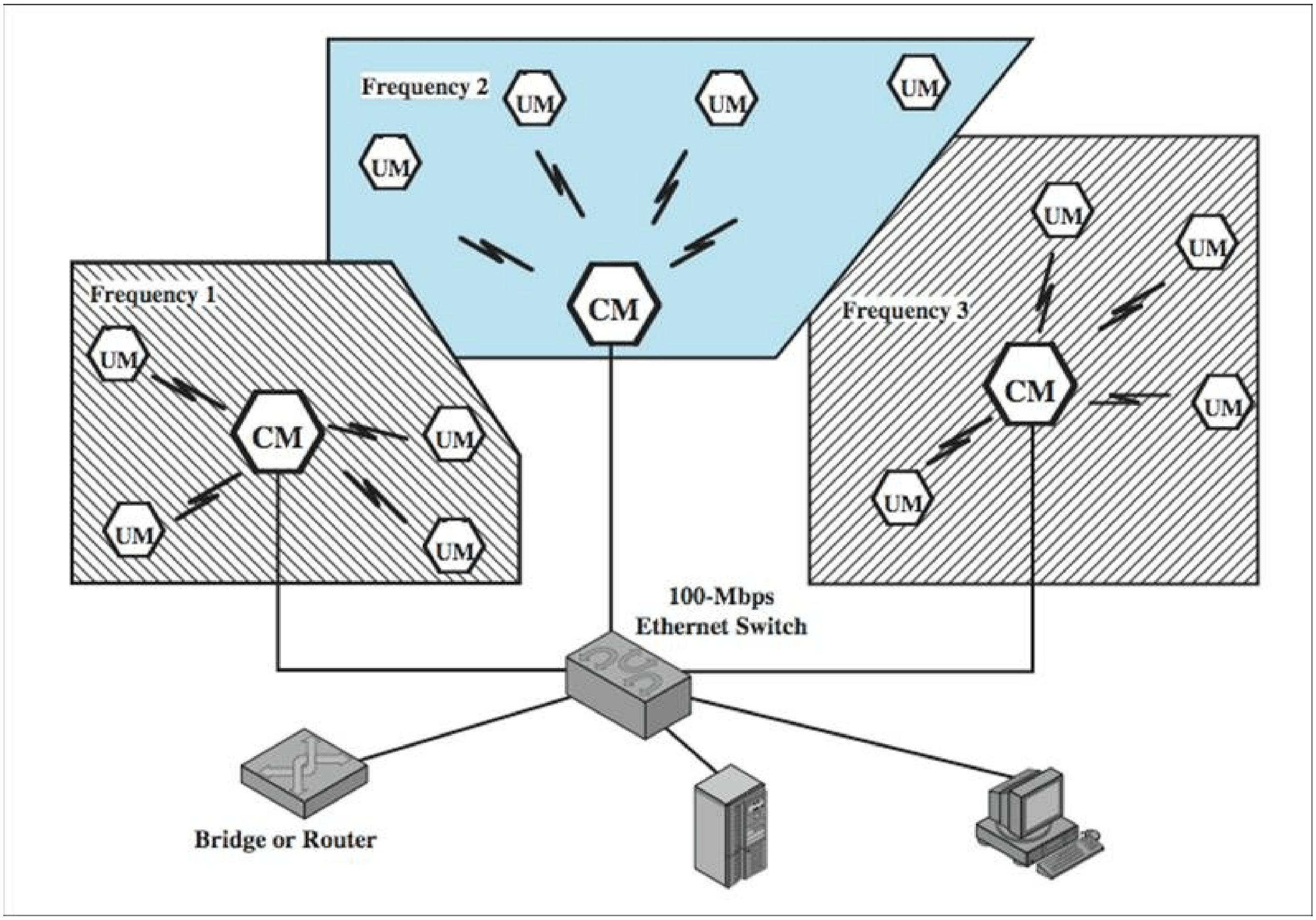
Wireless LANs

- **Wireless LAN Applications:**
  - **- LAN Extension:**
  - **- Cross-Building Interconnect:**
  - **- Nomadic Access:**
  - **- Ad-Hoc Networking:**

- **Example: Single-Cell Wireless LAN Extension Configuration**

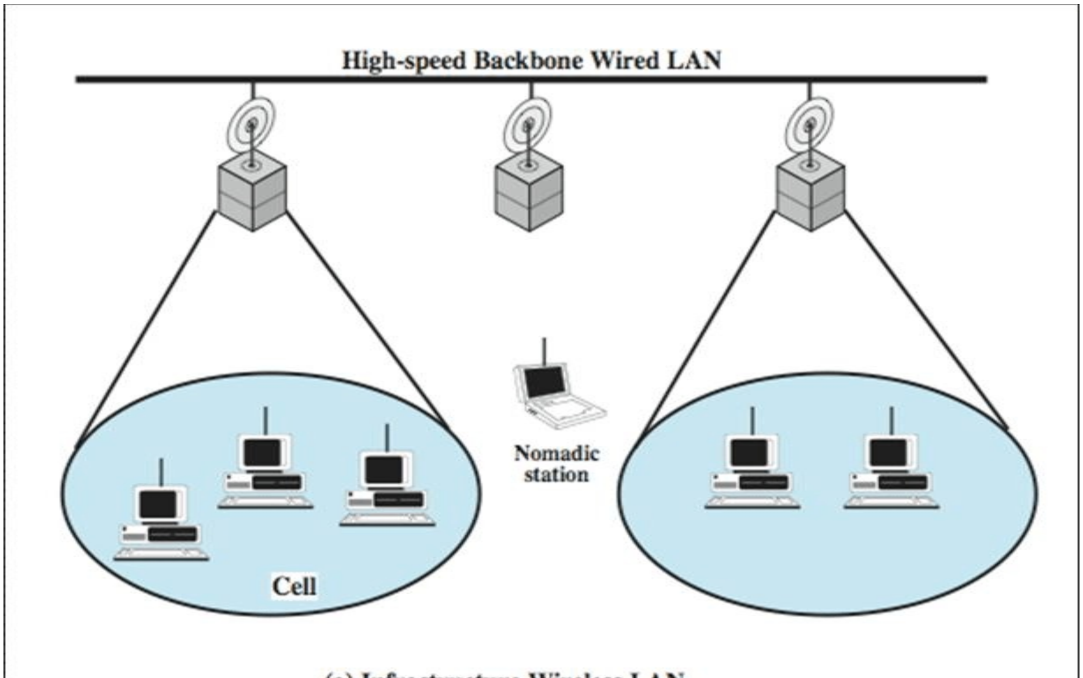


Example: Multiple-Cell Wireless LAN Extension Configuration



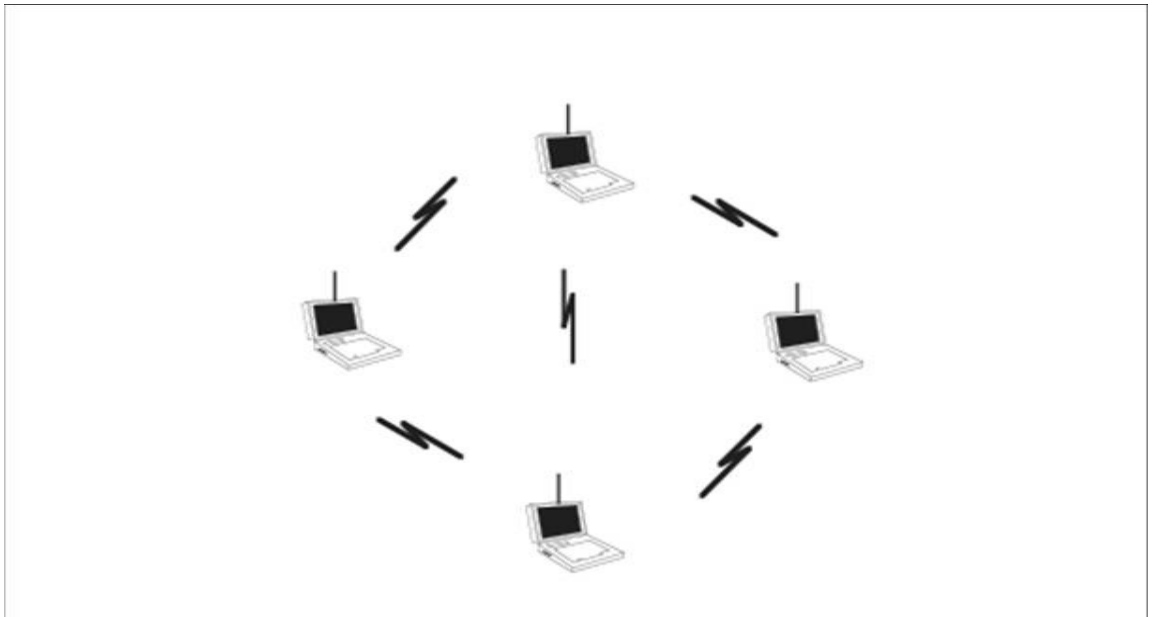
Additional Wireless LAN Configurations

- **Example: Infrastructure Wireless LAN - Nomadic Access**



(a) Infrastructure Wireless LAN

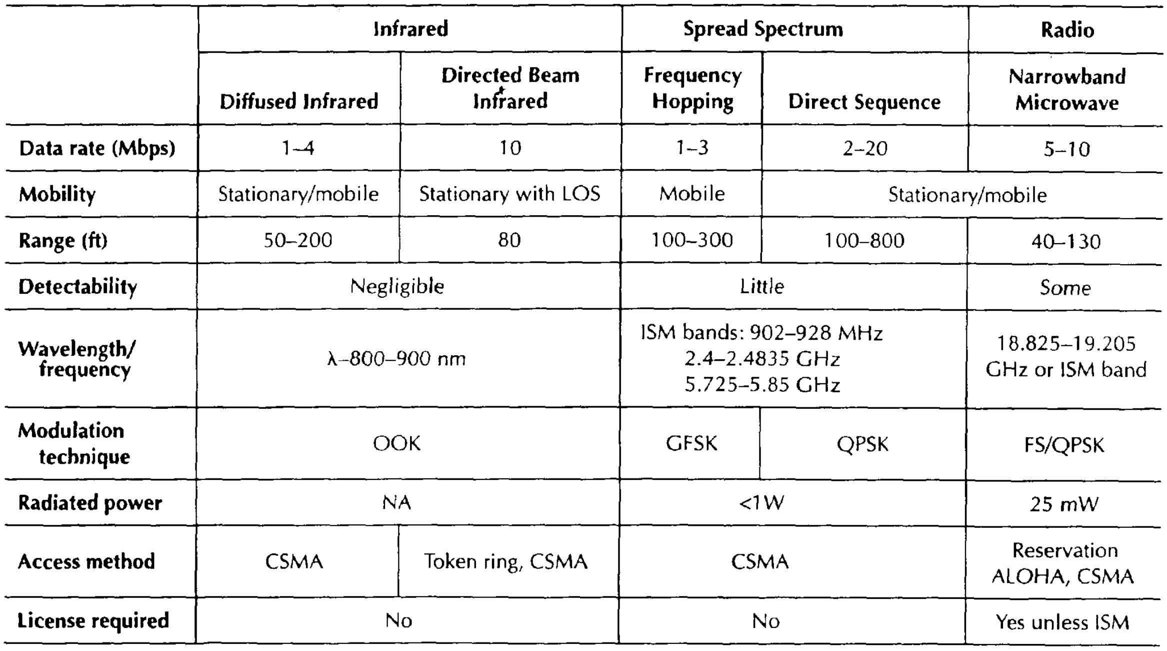
- **Example: Ad Hoc Wireless LAN**



(b) Ad hoc LAN

Wireless LAN Technologies

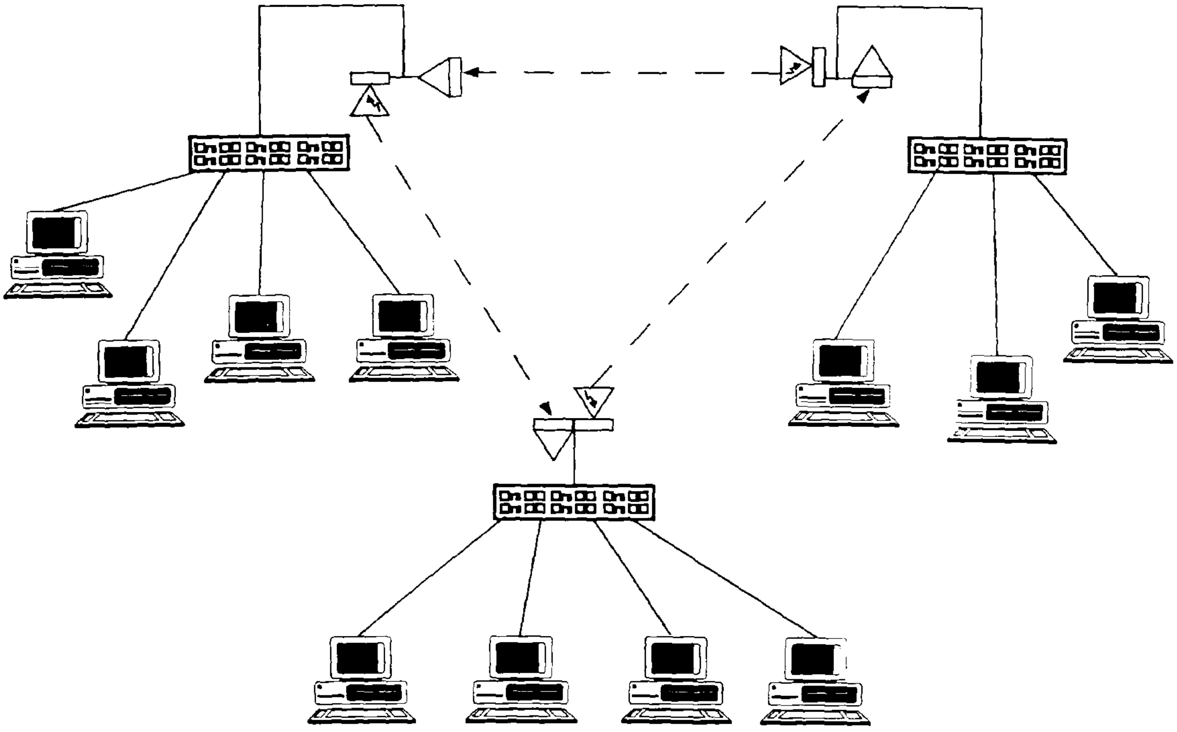
Comparison of Wireless LAN Technologies



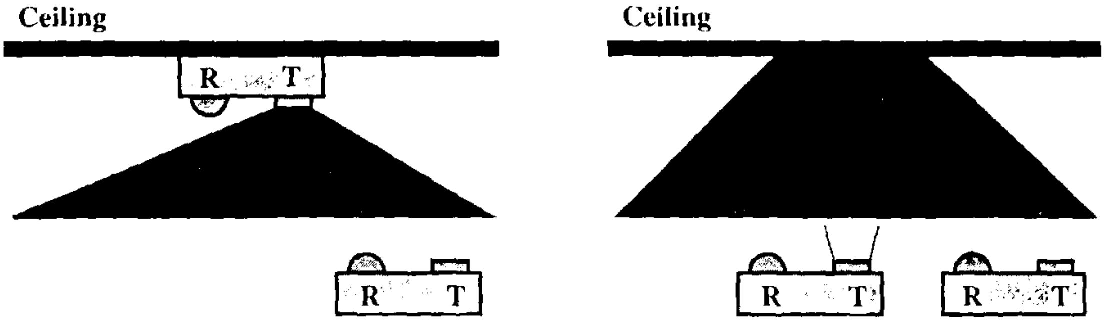
	Infrared		Spread Spectrum		Radio
	Diffused Infrared	Directed Beam Infrared	Frequency Hopping	Direct Sequence	Narrowband Microwave
Data rate (Mbps)	1–4	10	1–3	2–20	5–10
Mobility	Stationary/mobile	Stationary with LOS	Mobile	Stationary/mobile	
Range (ft)	50–200	80	100–300	100–800	40–130
Detectability	Negligible		Little		Some
Wavelength/ frequency	λ-800–900 nm		ISM bands: 902–928 MHz 2.4–2.4835 GHz 5.725–5.85 GHz		18.825–19.205 GHz or ISM band
Modulation technique	OOK		GFSK	QPSK	FS/QPSK
Radiated power	NA		<1W		25 mW
Access method	CSMA	Token ring, CSMA	CSMA		Reservation ALOHA, CSMA
License required	No		No		Yes unless ISM

Infrared LANs

- Transmission Techniques:
  - Direct Beam Infrared
  - Omnidirectional
  - Diffused



Token Ring LAN Using Point-to-Point Infrared Links

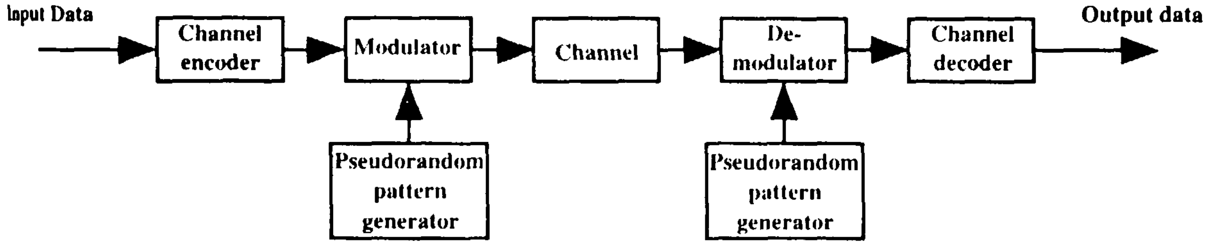


(a) Line of sight

(b) Diffuse

Configurations for Diffused Infrared LANs

Spread Spectrum LANs



General Model of Spread Spectrum Digital Communication System

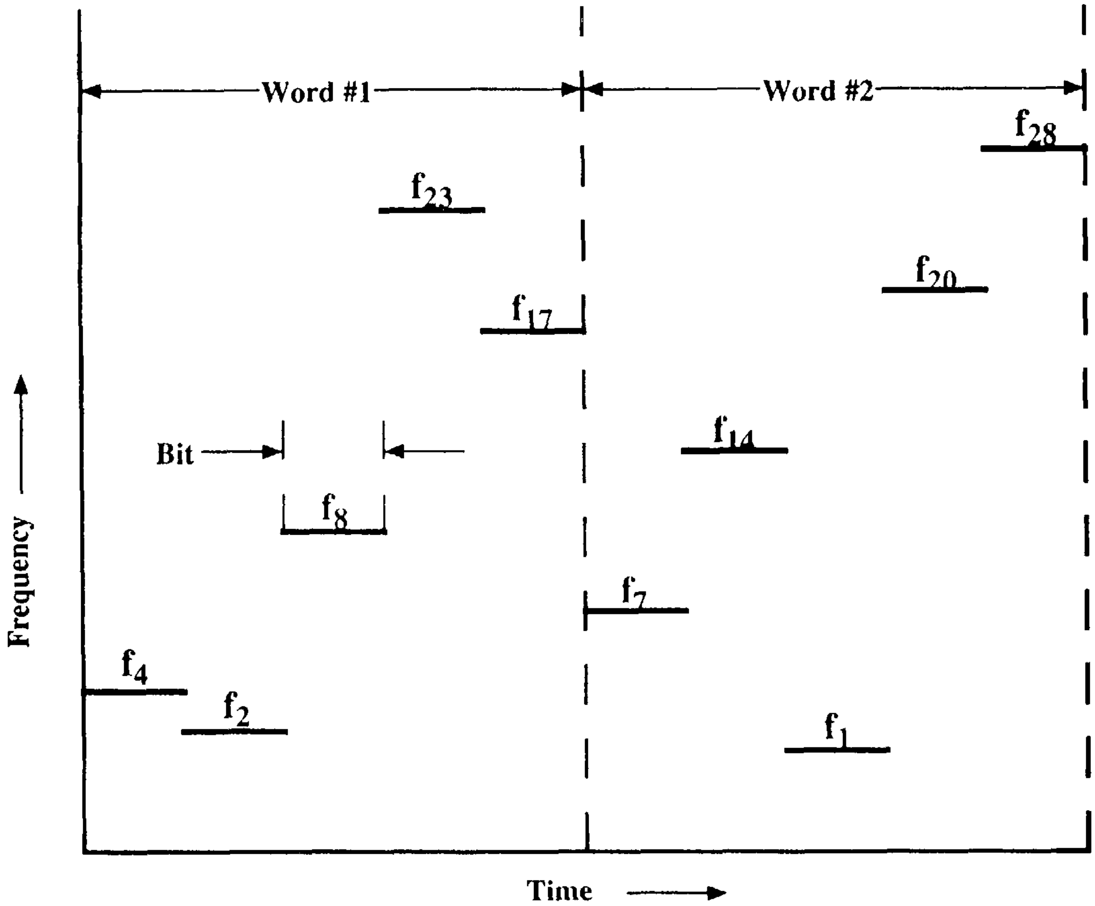
- Spread Spectrum communications was initially developed for military and intelligence requirements.

- The essential idea is to spread the information signal over a wider bandwidth in order to make jamming and interception more difficult.

- More recently, spread spectrum techniques are being used in commercial wireless communication systems (e.g., telephony, LANs).

- Spread Spectrum Methods:
  - Frequency Hopping (FH) Modulation
  - Direct Sequence (DS) Modulation

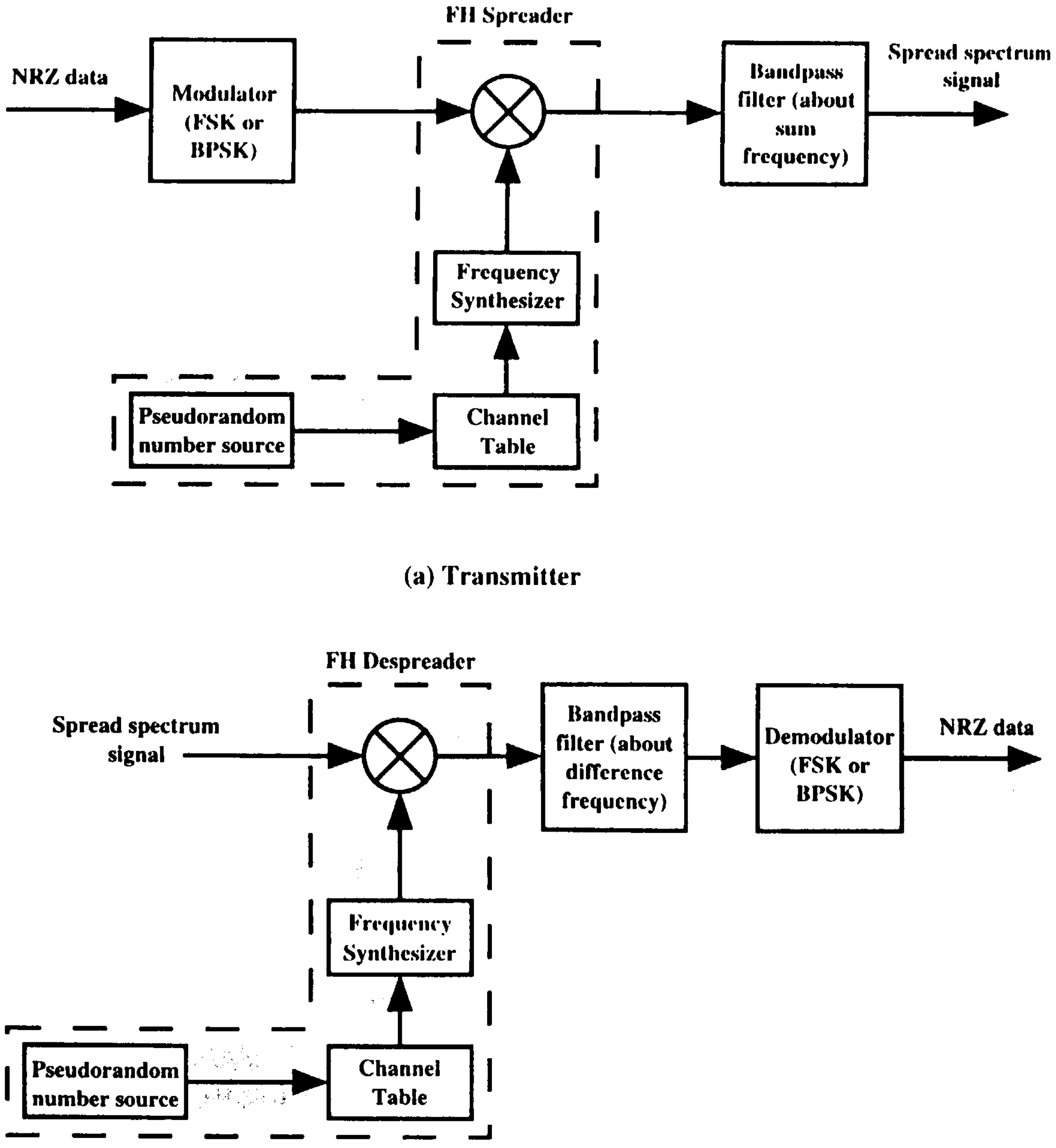
Frequency Hopping (FH) Modulation



Example of a Frequency-Hopped Signal

- The signal is broadcast over a pseudorandom series of frequencies.
- A receiver hopping in synchronization with the transmitter, picks up the message.
- An eavesdropper hears only unintelligible blips.
- Fast Frequency Hopping:
  - One or mode hops per data symbol.
- Slow Frequency Hopping:
  - More than one symbol per hop.

Frequency Hopping Spread Spectrum System

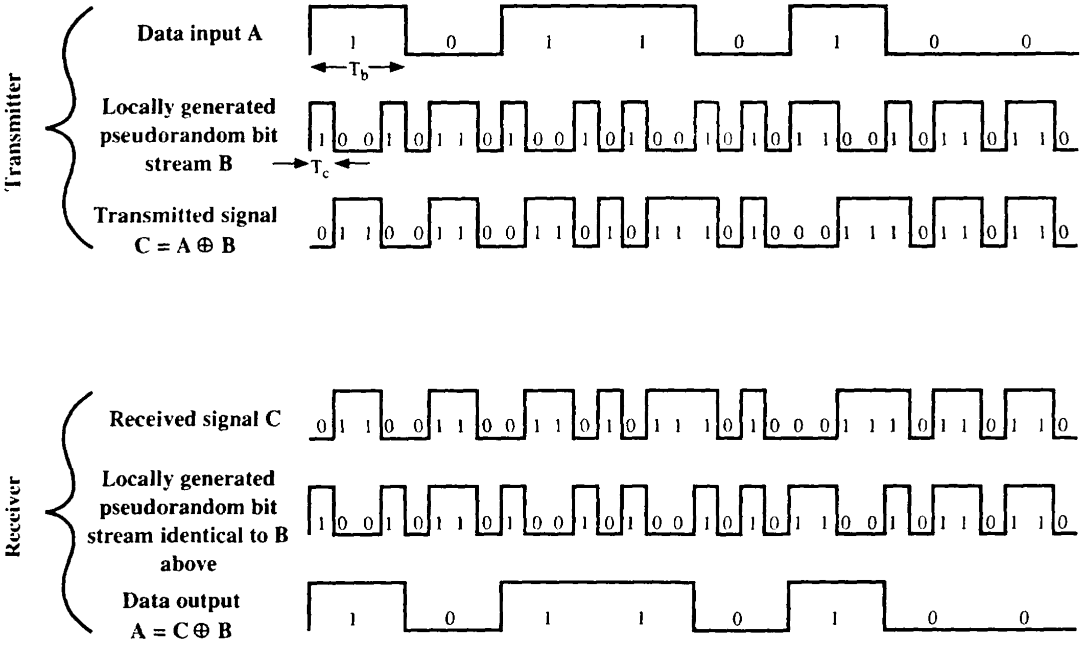


(a) Transmitter

(b) Receiver

Frequency-Hopping Spread Spectrum System

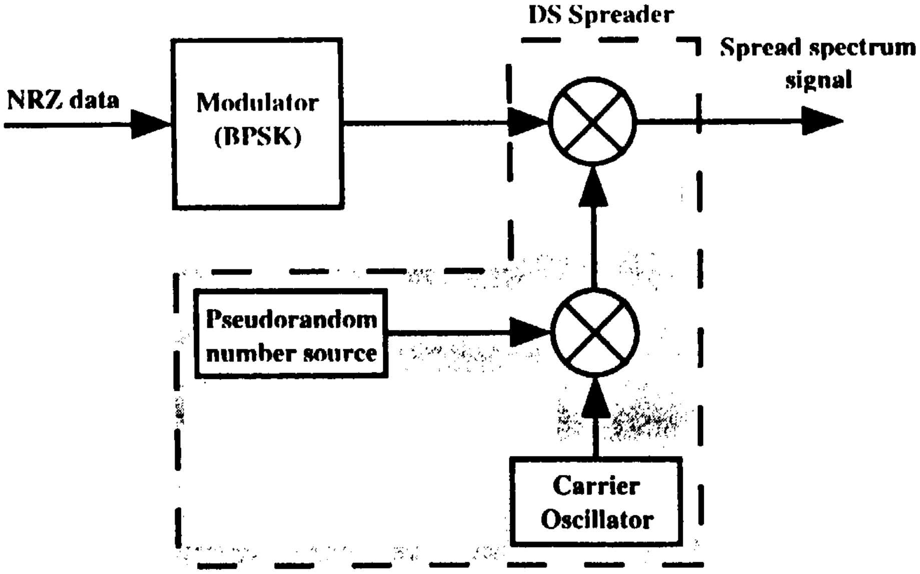
Direct Sequence (DS) Modulation



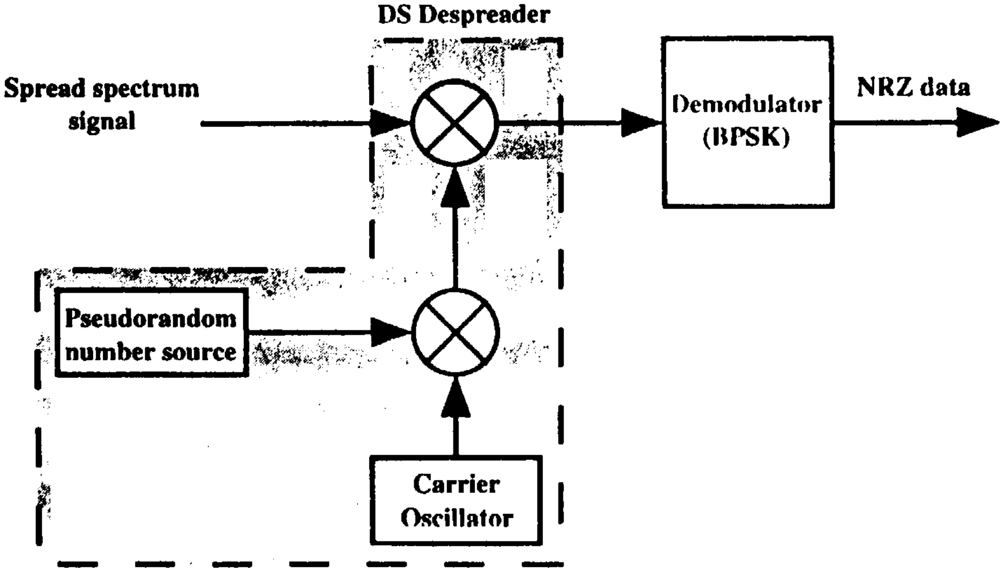
Example of Direct Sequence Spread Spectrum

- Each bit in the original signal is modulated by a higher rate pseudorandom bit stream
- The pseudorandom code is known as the chipping code and runs at the chip rate.
- The receiver knows the chipping code and uses a correlator to receive the transmitted data.

Direct Sequence Spread Spectrum System



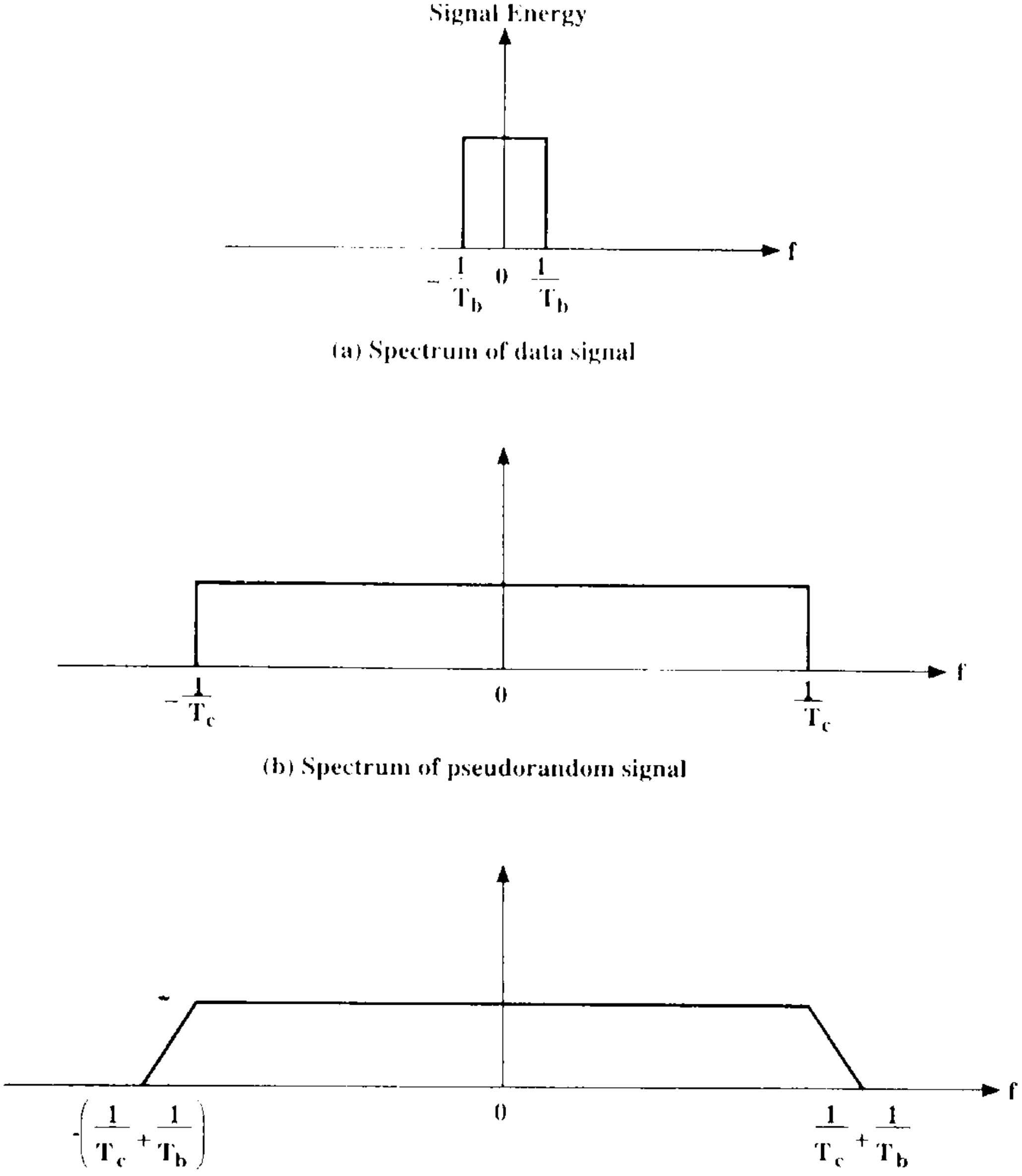
(a) Transmitter



(b) Receiver

Direct Sequence Spread Spectrum System

Spectrum of a Direct Sequence Spread Spectrum Signal



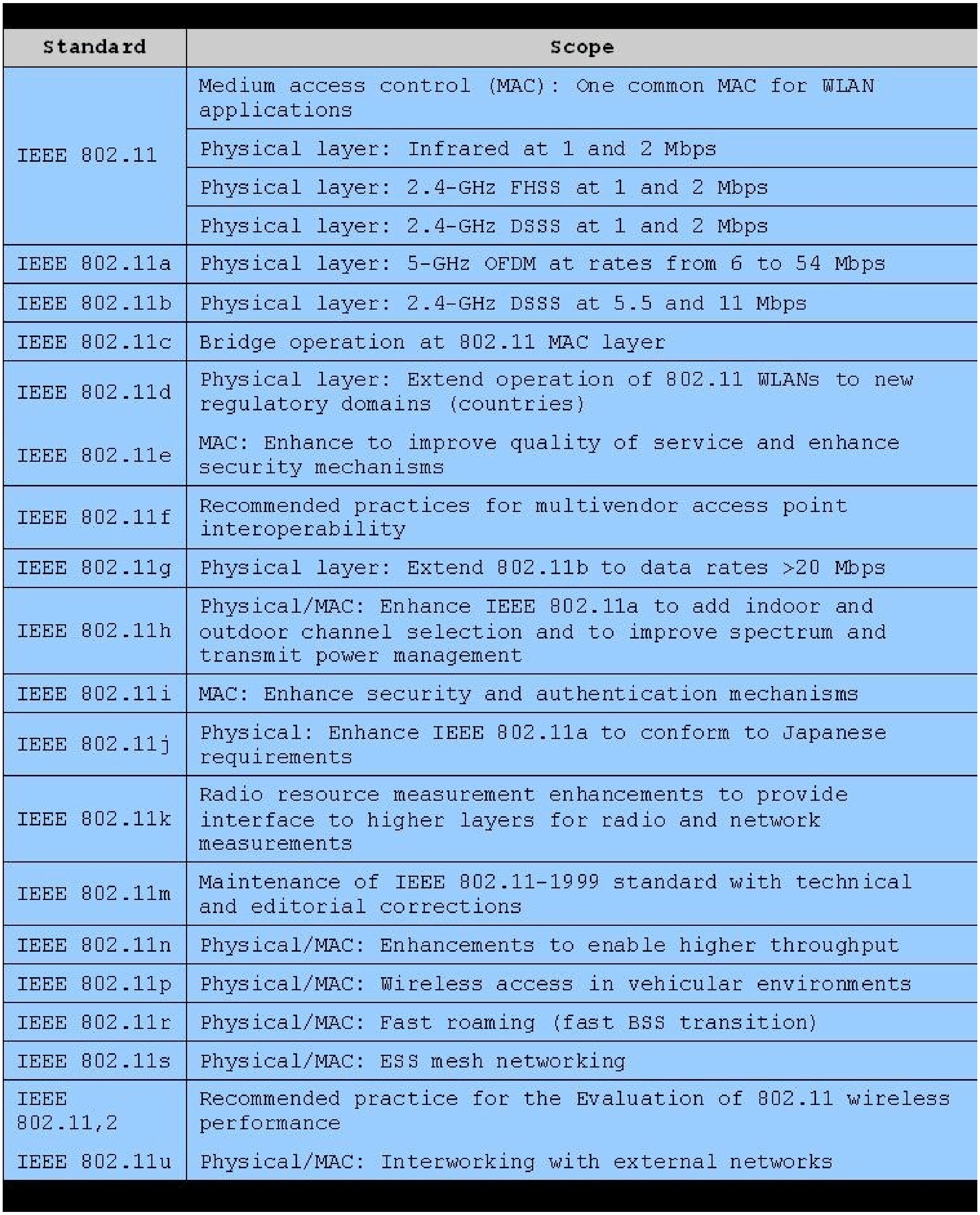
(a) Spectrum of data signal

(b) Spectrum of pseudorandom signal

(c) Spectrum of combined signal

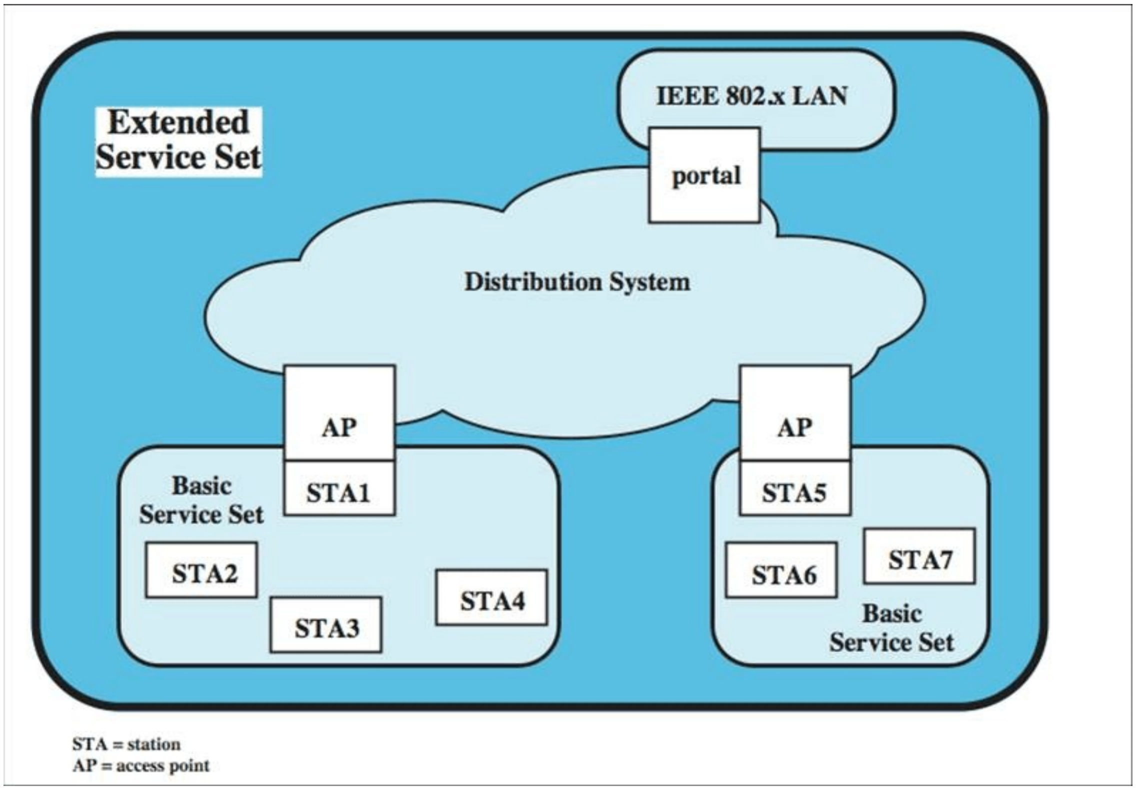
Spectrum of a Direct Sequence Spread Spectrum Signal

IEEE 802.11 Wireless LAN Standards



Standard	Scope
IEEE 802.11	Medium access control (MAC): One common MAC for WLAN applications
	Physical layer: Infrared at 1 and 2 Mbps
	Physical layer: 2.4-GHz FHSS at 1 and 2 Mbps
	Physical layer: 2.4-GHz DSSS at 1 and 2 Mbps
IEEE 802.11a	Physical layer: 5-GHz OFDM at rates from 6 to 54 Mbps
IEEE 802.11b	Physical layer: 2.4-GHz DSSS at 5.5 and 11 Mbps
IEEE 802.11c	Bridge operation at 802.11 MAC layer
IEEE 802.11d	Physical layer: Extend operation of 802.11 WLANs to new regulatory domains (countries)
IEEE 802.11e	MAC: Enhance to improve quality of service and enhance security mechanisms
IEEE 802.11f	Recommended practices for multivendor access point interoperability
IEEE 802.11g	Physical layer: Extend 802.11b to data rates >20 Mbps
IEEE 802.11h	Physical/MAC: Enhance IEEE 802.11a to add indoor and outdoor channel selection and to improve spectrum and transmit power management
IEEE 802.11i	MAC: Enhance security and authentication mechanisms
IEEE 802.11j	Physical: Enhance IEEE 802.11a to conform to Japanese requirements
IEEE 802.11k	Radio resource measurement enhancements to provide interface to higher layers for radio and network measurements
IEEE 802.11m	Maintenance of IEEE 802.11-1999 standard with technical and editorial corrections
IEEE 802.11n	Physical/MAC: Enhancements to enable higher throughput
IEEE 802.11p	Physical/MAC: Wireless access in vehicular environments
IEEE 802.11r	Physical/MAC: Fast roaming (fast BSS transition)
IEEE 802.11s	Physical/MAC: ESS mesh networking
IEEE 802.11,2	Recommended practice for the Evaluation of 802.11 wireless performance
IEEE 802.11u	Physical/MAC: Interworking with external networks

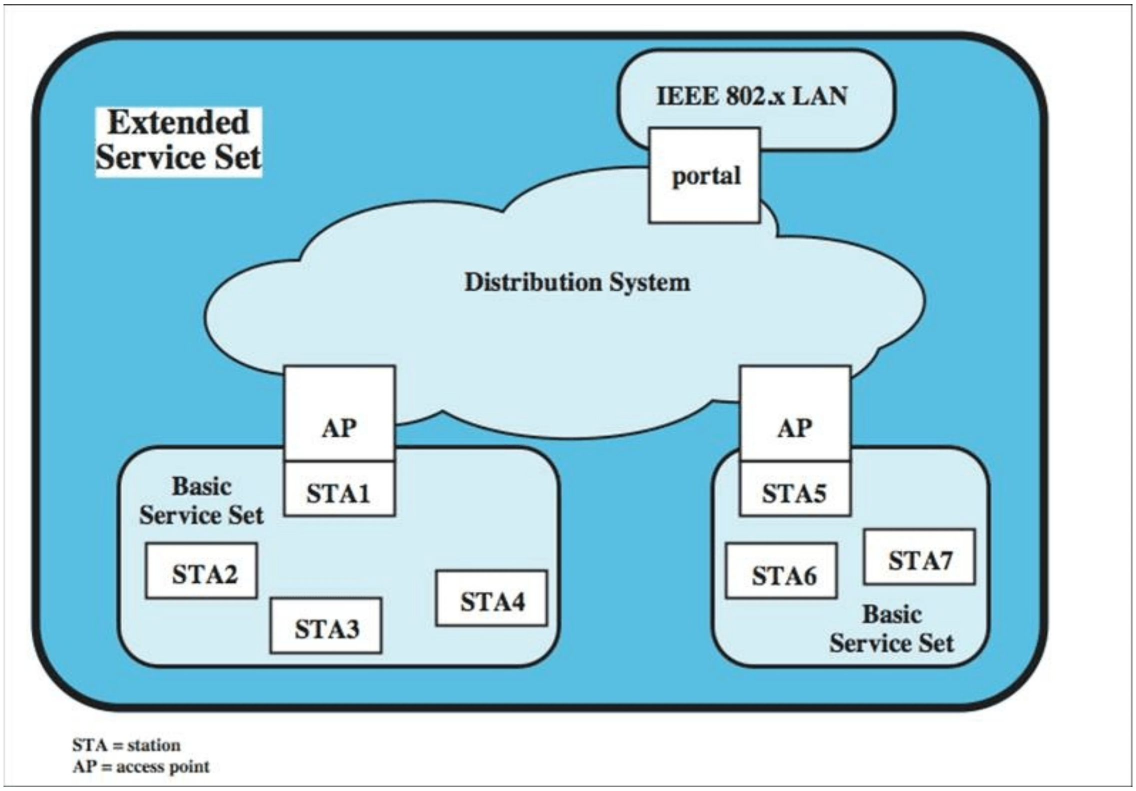
IEEE 802.11 Wireless LAN Architecture



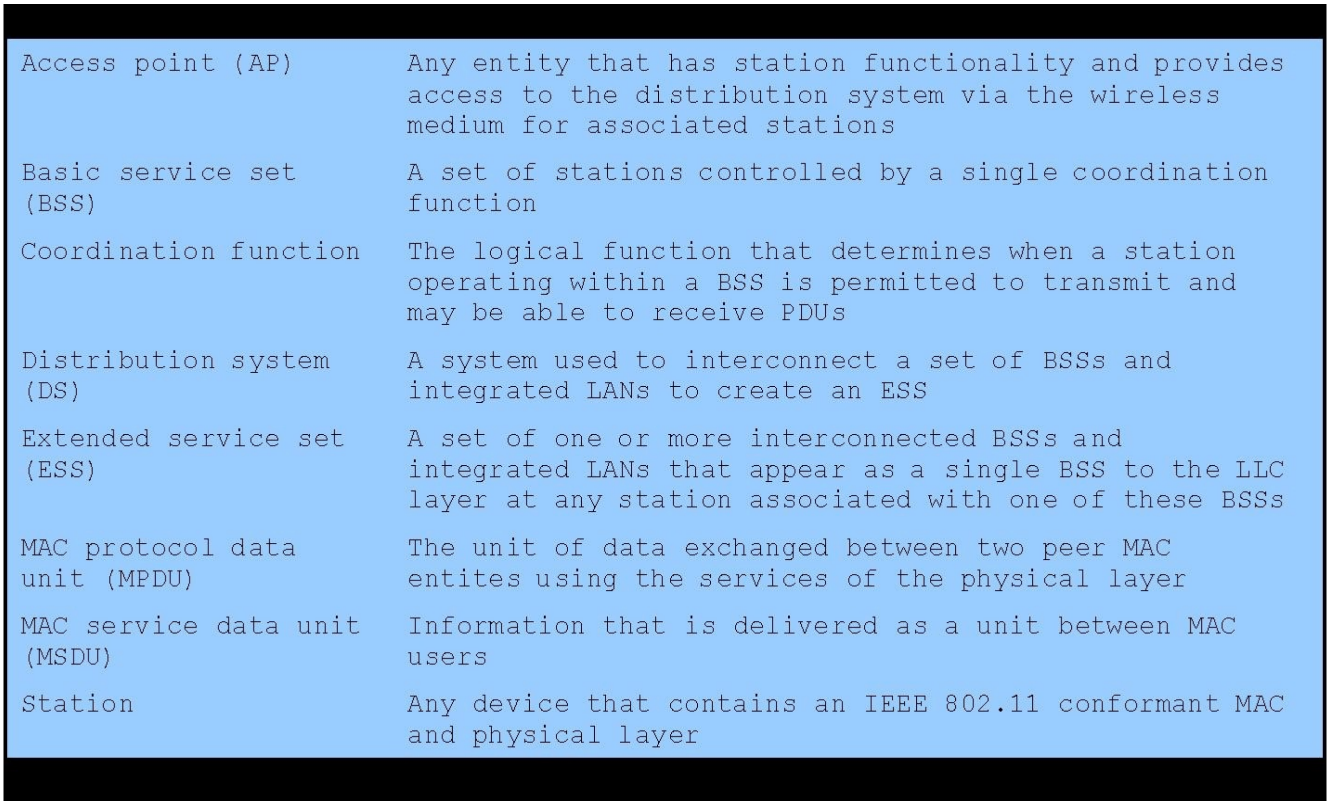
- Service Sets:
  - BSS (Basic Service Set):
    Consists of a number of stations executing the same MAC protocol sharing the same medium.
  - ESS (Extended Service Set):
    Two or more interconnected BSSs.

- Station Types (based on mobility):
  - No Transition
    station stays within its own BSS.
  - BSS Transition
    station moves between BSSs in a single ESS.
  - ESS Transition
    station moves between multiple ESSs.

IEEE 802.11 Wireless LAN Architecture



- ## IEEE 802.11 Terminology:



Access point (AP)	Any entity that has station functionality and provides access to the distribution system via the wireless medium for associated stations
Basic service set (BSS)	A set of stations controlled by a single coordination function
Coordination function	The logical function that determines when a station operating within a BSS is permitted to transmit and may be able to receive PDUs
Distribution system (DS)	A system used to interconnect a set of BSSs and integrated LANs to create an ESS
Extended service set (ESS)	A set of one or more interconnected BSSs and integrated LANs that appear as a single BSS to the LLC layer at any station associated with one of these BSSs
MAC protocol data unit (MPDU)	The unit of data exchanged between two peer MAC entites using the services of the physical layer
MAC service data unit (MSDU)	Information that is delivered as a unit between MAC users
Station	Any device that contains an IEEE 802.11 conformant MAC and physical layer

IEEE 802.11 Services

- MSDU Delivery:
  The basic service used by a station to transfer data.

- Distribution:
  The primary service used by stations to exchange MAC frames when the frame must traverse the DS to get from a station in one BSS to a station in another BSS.

- Integration:
  Enables transfer of data between a station on an IEEE 802.11 LAN and a station on an integrated IEEE 802.x LAN (through a portal).

- Association:
  Establishes an association between a station and an access point. The identity and address of the station become known to the access point.

- Reassociation:
  Enables an established association to be transferred from one access point to another access point. This allows a mobile station to move from one BSS to another.

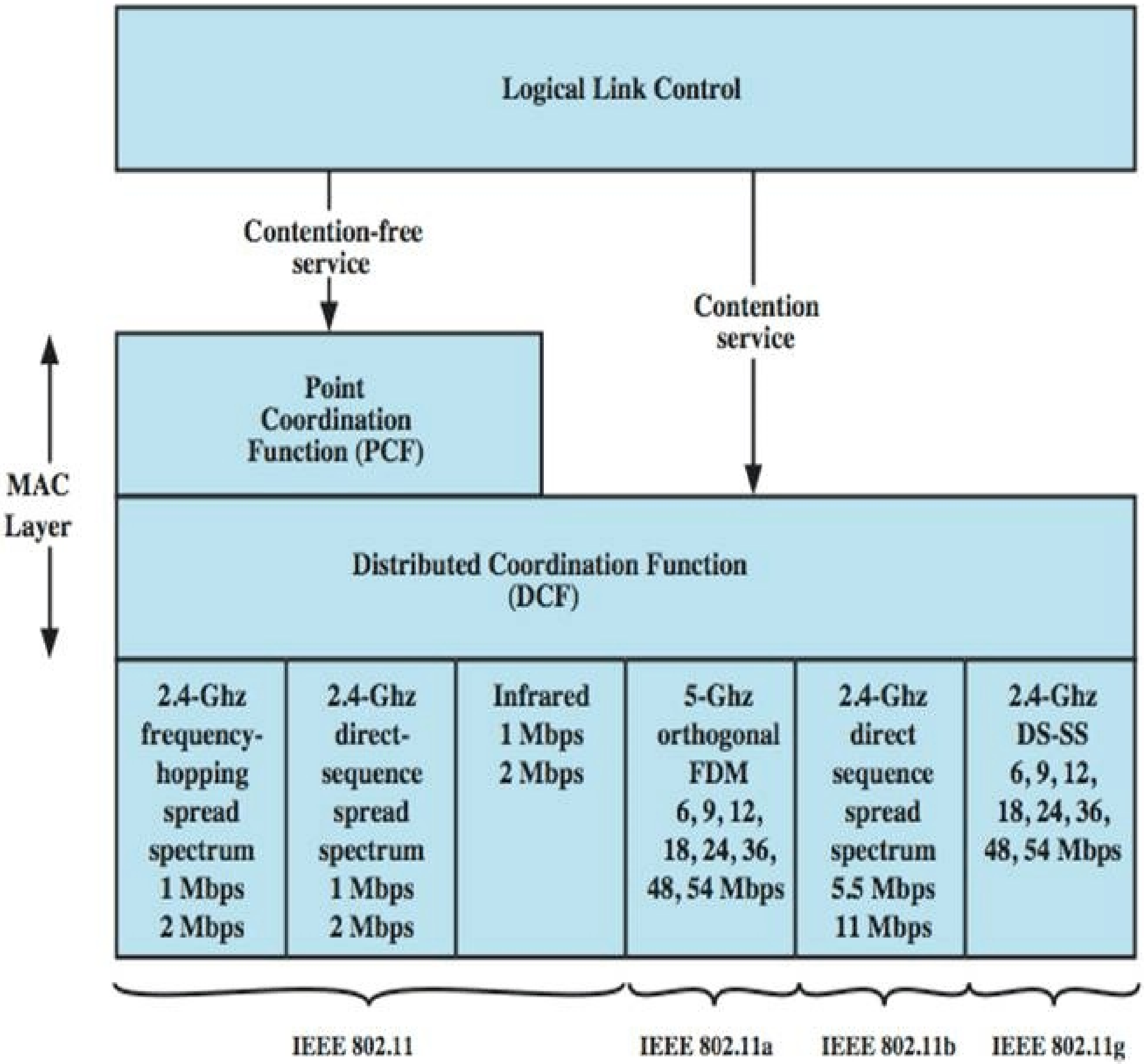
- Disassociation:
  A notification from either a station or an access point that an existing association is terminated. A station should give this notification before leaving an ESS or shutting down.

- Authentication:
  Establishes the identity of stations to each other.

- Deauthentication:
  Invoked whenever an existing authentication is to be terminated.

- Privacy:
  Used to prevent the contents of messages from being read by other than the intended recipient. (uses encryption)

IEEE 802.11 Protocol Architecture



Logical Link Control
Contention-free service
Contention service
MAC Layer
Point Coordination Function (PCF)
Distributed Coordination Function (DCF)
2.4-Ghz frequency-hopping spread spectrum 1 Mbps 2 Mbps
2.4-Ghz direct-sequence spread spectrum 1 Mbps 2 Mbps
Infrared 1 Mbps 2 Mbps
5-Ghz orthogonal FDM 6, 9, 12, 18, 24, 36, 48, 54 Mbps
2.4-Ghz direct sequence spread spectrum 5.5 Mbps 11 Mbps
2.4-Ghz DS-SS 6, 9, 12, 18, 24, 36, 48, 54 Mbps
IEEE 802.11
IEEE 802.11a
IEEE 802.11b
IEEE 802.11g

- Distributed Coordination Function (DCF):
  - uses CSMA contention to provide access to all stations
- Point Coordination Function (PCF):
  - provides contention-free access using polling.

IEEE 802.11 MAC Layer Reliable Data Delivery

- 802.11 physical / MAC layers unreliable
  - noise, interference, and other propagation effects result in loss of frames
  - even with error-correction codes, frames may not successfully be received
- can be dealt with at a higher layer, e.g. TCP
- more efficient to deal with errors at MAC level
- 802.11 includes frame exchange protocol
  - station receiving frame returns acknowledgment (ACK) frame
  - exchange treated as atomic unit
  - if no ACK within short period of time, retransmit
- can use four-frame exchange for better reliability
  - source issues a Request to Send (RTS) frame to dest
  - destination responds with Clear to Send (CTS)
  - after receiving CTS, source transmits data
  - destination responds with ACK
- RTS alerts all stations within range of source that exchange is under way
- CTS alerts all stations within range of destination
- other stations don't transmit to avoid collision
- RTS/CTS exchange is required function of MAC but may be disabled

Distributed Coordination Function (DCF)

- Uses CSMA contention to provide access to all stations. (Note: no CD)

- To insure fairness, DCF includes a set of delays that provide a priority scheme.

- A station with a frame to transmit, senses the medium. If idle, it waits to see if the medium remains idle for a time equal to IFS (interframe space). If yes, the station transmits.

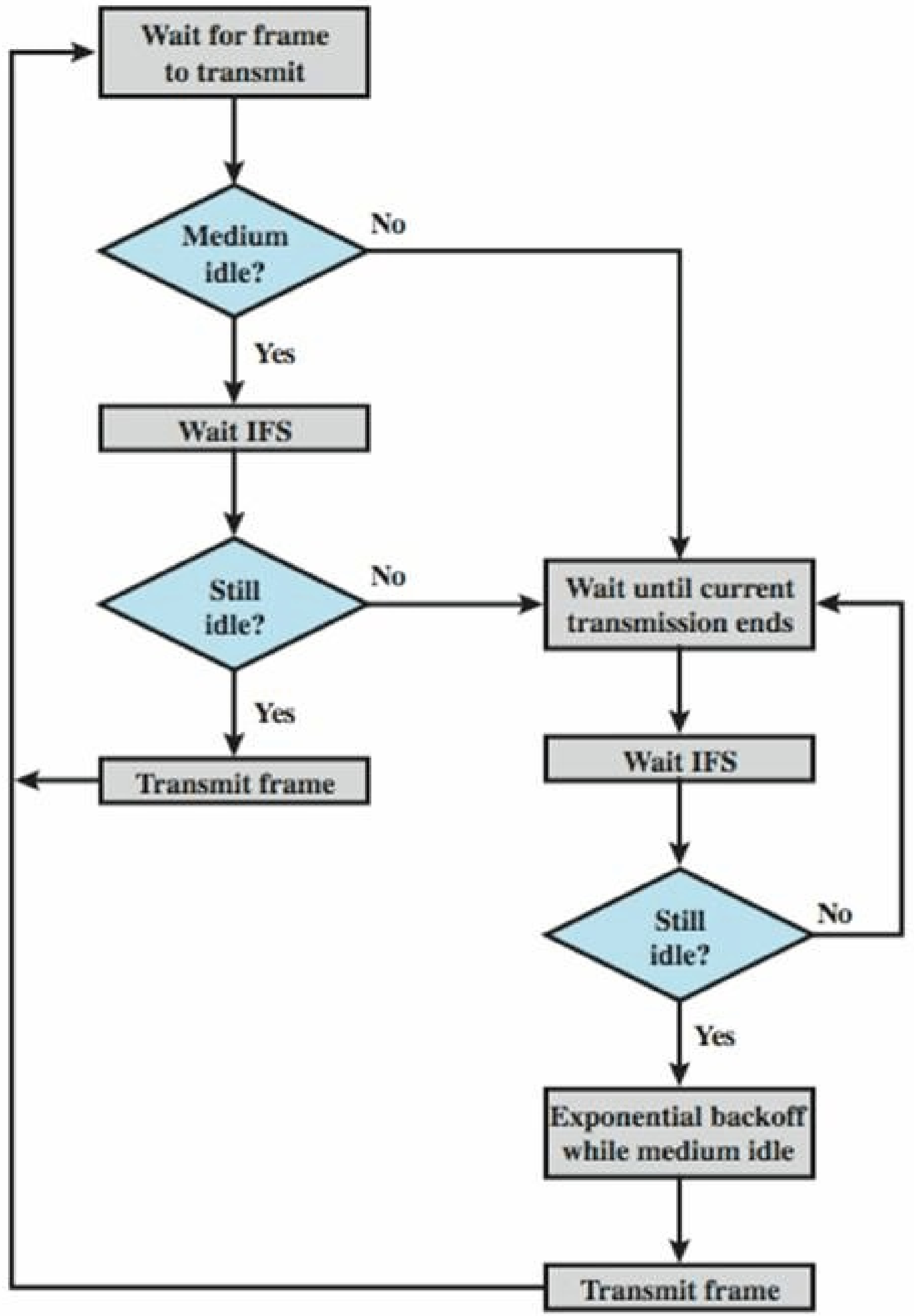
- If the medium is busy, (either initially or it became busy within IFS), the stations defers transmission and continues to monitor the medium until the current transmission is over.

- Once the current transmission ends, the station delays another IFS. If the medium remains idle, the station backs off using a binary exponential backoff scheme and again senses the medium. if the medium is still idle, the station transmits.

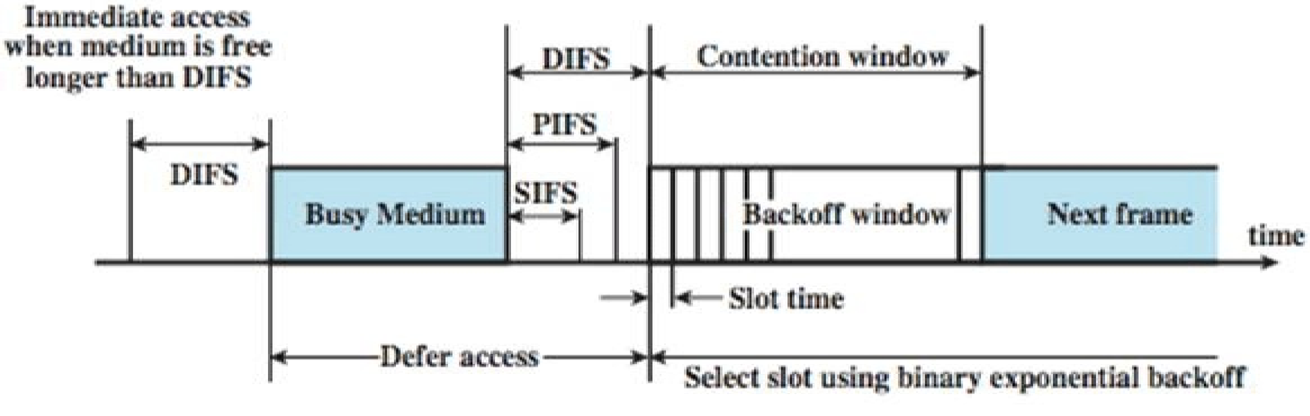
- Types of IFS:
  - SIFS (short IFS):
    The shortest IFS. Used for all immediate response actions.
  - PIFS (PCF IFS):
    A midlength IFS. Used by the centralized controller in the PCF scheme when issuing polls.
  - DIFS (DCF IFS):
    The longest IFS. Used as a minimum delay for asynchronous frames contending for access.

- Any station using SIFS has, in effect, highest priority. SIFS is used for:
  - Acknowledgement (ACK):
    to ACK a received unicast frame.
  - Clear to send (CTS):
    sent in response to a Request to Send frame (RTS) to indicate station's readiness to receive a data frame.
  - Poll Response:
    used in the PCF.

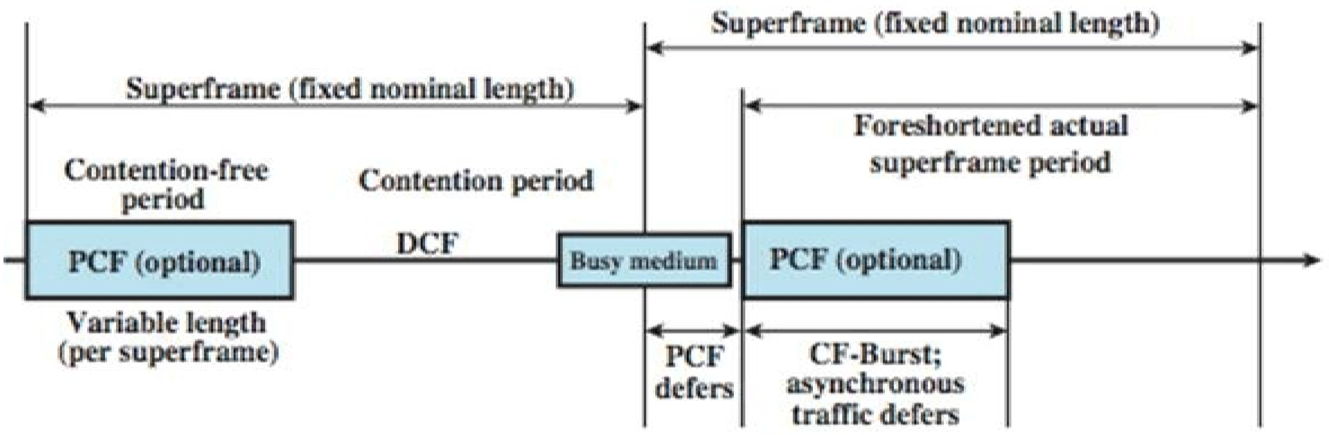
IEEE 802.11 Medium Access Control Logic


Wait for frame to transmit
Medium idle?
No
Yes
Wait IFS
Still idle?
No
Yes
Transmit frame
Wait until current transmission ends
Wait IFS
Still idle?
No
Yes
Exponential backoff while medium idle
Transmit frame

IEEE 802.11 MAC Timing


Immediate access when medium is free longer than DIFS
DIFS
DIFS
Contention window
PIFS
SIFS
Busy Medium
Backoff window
Next frame
time
Slot time
Defer access
Select slot using binary exponential backoff

(a) Basic Access Method

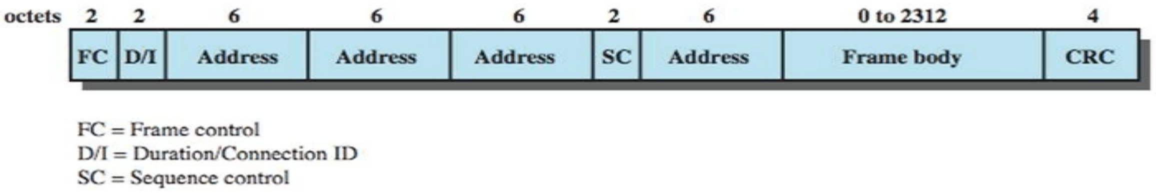

Superframe (fixed nominal length)
Superframe (fixed nominal length)
Foreshortened actual superframe period
Contention-free period
Contention period
PCF (optional)
DCF
Busy medium
PCF (optional)
Variable length (per superframe)
PCF defers
CF-Burst; asynchronous traffic defers

(b) PCF Superframe Construction

Point Coordination Function (PCF)

- **PCF is an alternate access method on top of DCF.**
- **Uses polling by the centralized polling master (point coordinator).**
- **PIFS is used when issuing polls. This locks out asynchronous traffic during the polling and response process.**
- **To prevent the lockout of all asynchronous traffic, an interval known as a superframe is used.**
- **During the first part of the interval, the point coordinator issues polls in a round-robin fashion to all stations configured for polling. The point coordinators idles for the remainder of the interval, allowing a contention period for asynchronous traffic.**

IEEE 802.11 MAC Frame Structure



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

- **Frame Control (2 octets):**
  Indicates type of frame and provides control information.
- **Duration/Connection ID (2 octets):**
  As a duration field, it indicates the time (in microseconds) the channel will be allocated for successful transmission of a MAC frame. In some control frames, this field contains an association or connection identifier.
- **Addresses (6 octets each):**
  The number of and meaning is context dependent. types include: source, destination, transmitting station, and receiving station.
- **Sequence Control (2 octets):**
  4-bit fragment number: for fragmentation of frames.
  12-bit frame sequence number between sender and receiver.
- **Frame Body 90 to 2312 octets):**
  Contains an LLC PDU or MAC control information.
- **Frame Check Sequence (4 octets):**
  32-bit CRC.

- **<u>Frame Control Field</u>**
  - Protocol Version (2 bits): currently version 0
  - Type (2 bits): control, management, or data.
  - Subtype (4 bits):
  - To DS (1 bit): frame to the distribution system.
  - From DS (1 bit): frame leaving the distribution system.
  - More Fragment (1 bit): if set to 1, more fragments to follow
  - Retry (1 bit): set to 1 to indicate retransmission.
  - Power Management (1 bit): set to indicate sender in sleep mode.
  - More Data (1 bit): set to 1 to indicate that station has more data to send.
  - Wired Equivalent Privacy (WEP) bit (1 bit): set if WEP protocol in use. Used to exchange encryption keys.
  - Order (1 bit): set in any data frame sent using the Strictly Ordered service. This service tells the receiving station that frames must be processed in order.

IEEE 802.11 MAC Control Frames

- Power Save-Poll (PS-Poll):
  This frame is sent by any station to the station that includes the AP (access point). Its purpose is to request that the AP transmit a frame that has been buffered for this station while the station was in power-saving mode.

- Request to Send (RTS):
  This is the first frame in the four-way frame exchange. The station sending this message is alerting a potential destination, and all other stations within reception range, that it intends to send a data frame to that destination.

- Clear to Send (CTS):
  This is the second frame in the four-way exchange. It is sent by the destination station to the source station to grant permission to send a data frame.

- Acknowledgment:
  Provides an acknowledgment from the destination to the source that the immediately preceding data, management, or PS-Poll frame was received correctly.

- Contention-Free (CF)-end:
  Announces the end of a contention-free period that is part of the point coordination function (PCF).

- CF-End + CF-Ack:
  Acknowledges the CF-end. This frame ends the contention-free period and releases stations from the restrictions associated with that period.

IEEE 802.11 MAC Data Frames

There are eight data frame subtypes, organized into two groups. The first four subtypes define frames that carry upper-level data from the source station to the destination station. The four data-carrying frames are:

- Data:
  This is the simplest data frame. It may be used in both a contention period and a contention-free period.

- Data + CF-Ack:
  May only be sent during a contention-free period. In addition to carrying data, this frame acknowledges previously received data.

- Data + CF-Poll:
  Used by a point coordinator to deliver data to a mobile station and also to request that the mobile station send a data frame that it may have buffered.

- Data + CF-Ack + CF-Poll:
  Combines the functions of the Data + CF-Ack and Data + CF-Poll into a single frame.

The remaining four subtypes of data frames do not in fact carry any user data:

- Null Function:
  Carries no data, polls, or acknowledgments. It is used only to carry the power management bit in the frame control field to the AP, to indicate that the station is changing to a low-power operating state.

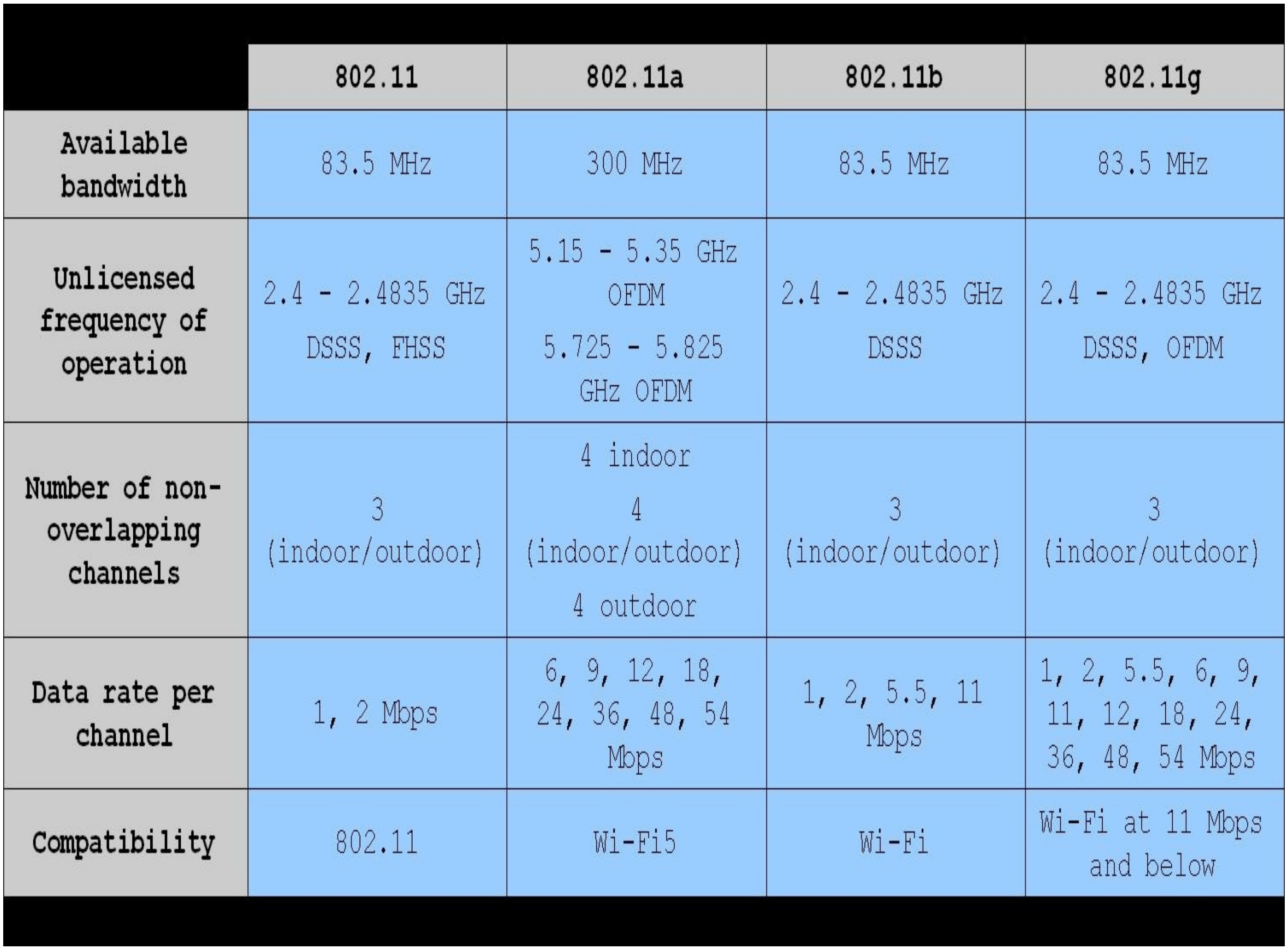
- CF-Ack:
- CF-Poll:
- CF-Ack + CF-Poll:
  Have the same functionality as the corresponding data frame subtypes in the preceding list (Data + CF-Ack, Data + CF-Poll, Data + CF-Ack + CF-Poll) but without the data.

IEEE 802.11 MAC Management Frames

- Management frames are used to manage communications between stations and APs.

- Functions covered include management of associations (request, response, reassociation, dissociation, and authentication.

IEEE 802.11 Physical Layer Standards



	802.11	802.11a	802.11b	802.11g
Available bandwidth	83.5 MHz	300 MHz	83.5 MHz	83.5 MHz
Unlicensed frequency of operation	2.4 - 2.4835 GHz DSSS, FHSS	5.15 - 5.35 GHz OFDM 5.725 - 5.825 GHz OFDM	2.4 - 2.4835 GHz DSSS	2.4 - 2.4835 GHz DSSS, OFDM
Number of non-overlapping channels	3 (indoor/outdoor)	4 indoor 4 (indoor/outdoor) 4 outdoor	3 (indoor/outdoor)	3 (indoor/outdoor)
Data rate per channel	1, 2 Mbps	6, 9, 12, 18, 24, 36, 48, 54 Mbps	1, 2, 5.5, 11 Mbps	1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48, 54 Mbps
Compatibility	802.11	Wi-Fi5	Wi-Fi	Wi-Fi at 11 Mbps and below

Original IEEE 802.11 Physical Layer Standard

Three physical media are defined in the original 802.11 standard:

- **Direct sequence spread spectrum (DSSS):**
    - Operating in the 2.4-GHz ISM band, at data rates of 1 Mbps and 2 Mbps.
    - In the United States, the FCC (Federal Communications Commission) requires no licensing for the use of this band.
    - The number of channels available depends on the bandwidth allocated by the various national regulatory agencies. This ranges from 13 in most European countries to just one available channel in Japan.
    - Up to three nonoverlapping channels, each with a data rate of 1 Mbps or 2 Mbps, can be used in the DSSS scheme. Each channel has a bandwidth of 5 MHz.

- **Frequency-hopping spread spectrum (FHSS):**
    - Operating in the 2.4-GHz ISM band, at data rates of 1 Mbps and 2 Mbps.
    - The number of channels available ranges from 23 in Japan to 70 in the United States.
    - FHSS system makes use of a multiple channels, with the signal hopping from one channel to another based on a pseudonoise sequence. In the case of the IEEE 802.11 scheme, 1-MHz channels are used.
    - The details of the hopping scheme are adjustable. For example, the minimum hop rate for the United States is 2.5 hops per second. The minimum hop distance in frequency is 6 MHz in North America and most of Europe and 5 MHz in Japan.

- **Infrared:**
    - Operating at a wavelength between 850 and 950 nm, at data rates of 1 Mbps and 2 Mbps .
    - The IEEE 802.11 infrared scheme is omnidirectional rather than point to point.
    - A range of up to 20 m is possible.

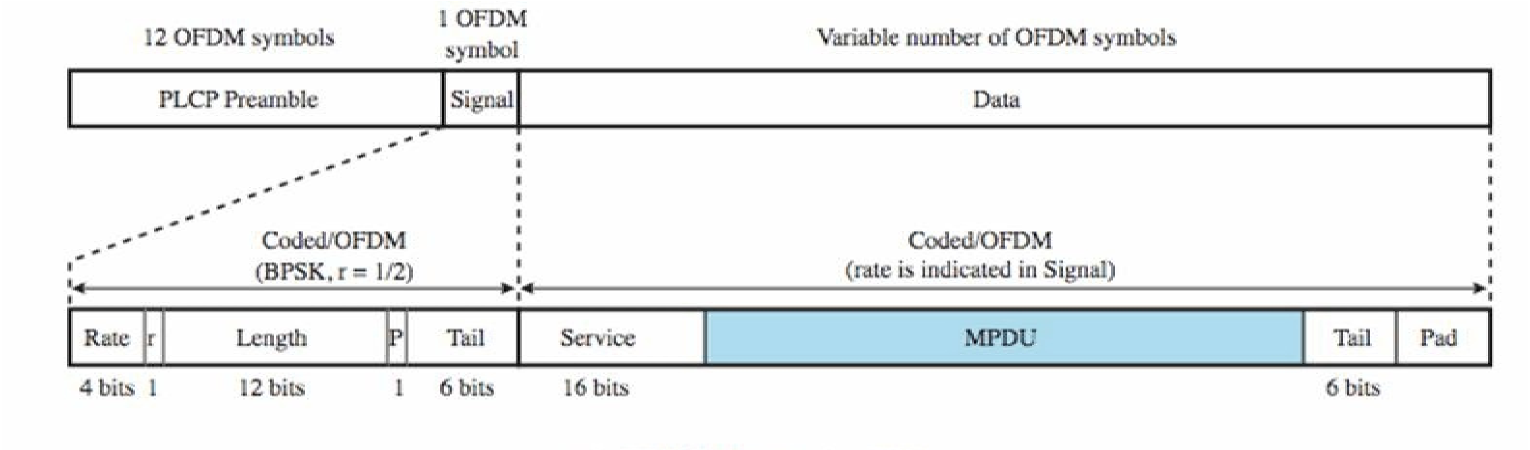
IEEE 802.11a

- Uses of the frequency band called the Universal Networking Information Infrastructure (UNNI), which is divided into three parts.

  - UNNI-1 band (5.15 to 5.25 Ghz):
    Intended for indoor use
  - UNNI-2 band (5.25 to 5.35 Ghz):
    Can be used either indoor or outdoor,
  - UNNI-3 band (5.725 to 5.825 Ghz):
    For outdoor use.

- IEEE 802.11a advantages over IEEE 802.11b/g:
  - Utilizes more available bandwidth than 802.11b/g. each UNNI channel band provides four non-overlapping channels for a total of 12 across the allocated spectrum
  - Provides a much higher data rates than 802.11b
  - Provides the same maximum data rate as 802.11g,
  - Uses a different, relatively uncluttered frequency spectrum (the 5 Ghz band).

IEEE 802.11a Physical Layer Frame Format



(a) IEEE 802.11a physical PDU

- **PLCP Preamble:**
  Enables the receiver to acquire an incoming OFDM signal and synchronize the demodulator.
- **Signal:**
  Consists of 24 bits encoded as a single OFDM symbol.
  Signal field subfields:
  - **Rate: the data rate at which the data field portion of the frame is transmitted**
  - **r: reserved for future use**
  - **Length: Number of octets in the MAC PDU**
  - **P: An even parity bit for the 17 bits in the Rate, r, and Length subfields**
  - **Tail: Consists of 6 zero bits to bring the convolutional encoder to the zero state**
- **Data:**
  Consists of a variable number of OFDM symbols transmitted at the data rate specified in the Rate subfield.
  Prior to transmission, all of the bits of the Data field are scrambled.
  Data field consists of four subfields:
  - **Service: 16 bits, with first 7 bits set to zeros to synchronize the descrambler in the receiver, and the remaining 9 bits (all zeros) reserved for future use.**
  - **MAC PDU: Handed down from the MAC layer.**
  - **Tail: Produced by replacing the six scrambled bits following the MPDU end with 6 bits of all zeros; used to reinitialize the convolutional encoder.**
  - **Pad: The number of bits required to make the Data field a multiple of the number of bits in an OFDM symbol (48, 96, 192, or 288).**

IEEE 802.11b

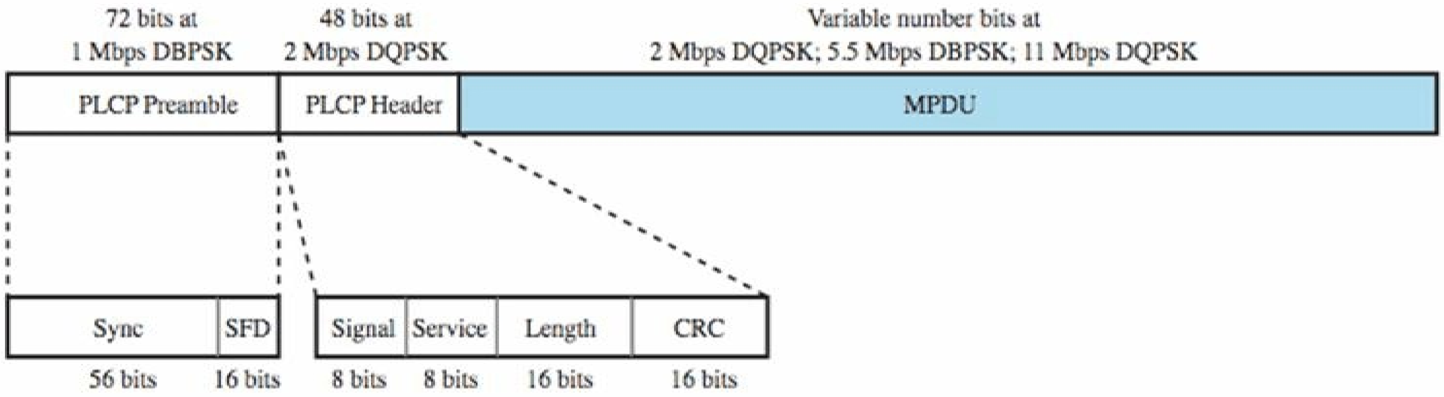
- IEEE 802.11b is an extension of the IEEE 802.11 DSSS scheme, providing data rates of 5.5 and 11 Mbps in the ISM band.

- The chipping rate is 11 MHz, which is the same as the original DSSS scheme, thus providing the same occupied bandwidth.

- To achieve a higher data rate in the same bandwidth at the same chipping rate, a modulation scheme known as complementary code keying (CCK) is used.

- An optional alternative to CCK is known as packet binary convolutional coding (PBCC). PBCC provides for potentially more efficient transmission at the cost of increased computation at the receiver. PBCC was incorporated into 802.11b in anticipation of its need for higher data rates for future enhancements to the standard.

IEEE 802.11b Physical Layer Frame Format



(b) IEEE 802.11b physical PDU

- **PLCP Preamble - 72 bits (or 144 bits for legacy interoperability):**
  Enables the receiver to acquire an incoming signal and synchronize the demodulator.
  Consists of two subfields:
  - **- 56-bit Sync field:**
    Used for synchronization
  - **- 16-bit start-of-frame delimiter (SFD):**
- **PLCP Header:**
  - **- Signal:**
    Indicates the data rate at which the MPDU portion of the frame is transmitted.
  - **- Service:**
    Only 3 bits are used.
    1st bit indicates whether transmit frequency and symbol clocks use the same local oscillator.
    2nd bit indicates whether CCK or PBCC encoding is used.
    3rd bit acts as an extension to the Length subfield.
  - **- Length:**
    Indicates the length of the MPDU field by specifying the number of microseconds necessary to transmit the MPDU.
  - **- CRC:**
    A 16-bit error-detection code used to protect the Signal, Service, and Length fields.
- **MPDU:**
  Consists of a variable number of bits transmitted at the data rate specified in the Signal subfield. Prior to transmission, all of the bits of the physical layer PDU are scrambled.

IEEE 802.11g

- IEEE 802.11g extends 802.11b to data rates up to 54 Mbps.

- Like 802.11b, 802.11g operates in the 2.4-GHz (ISM) range and thus the two are compatible.

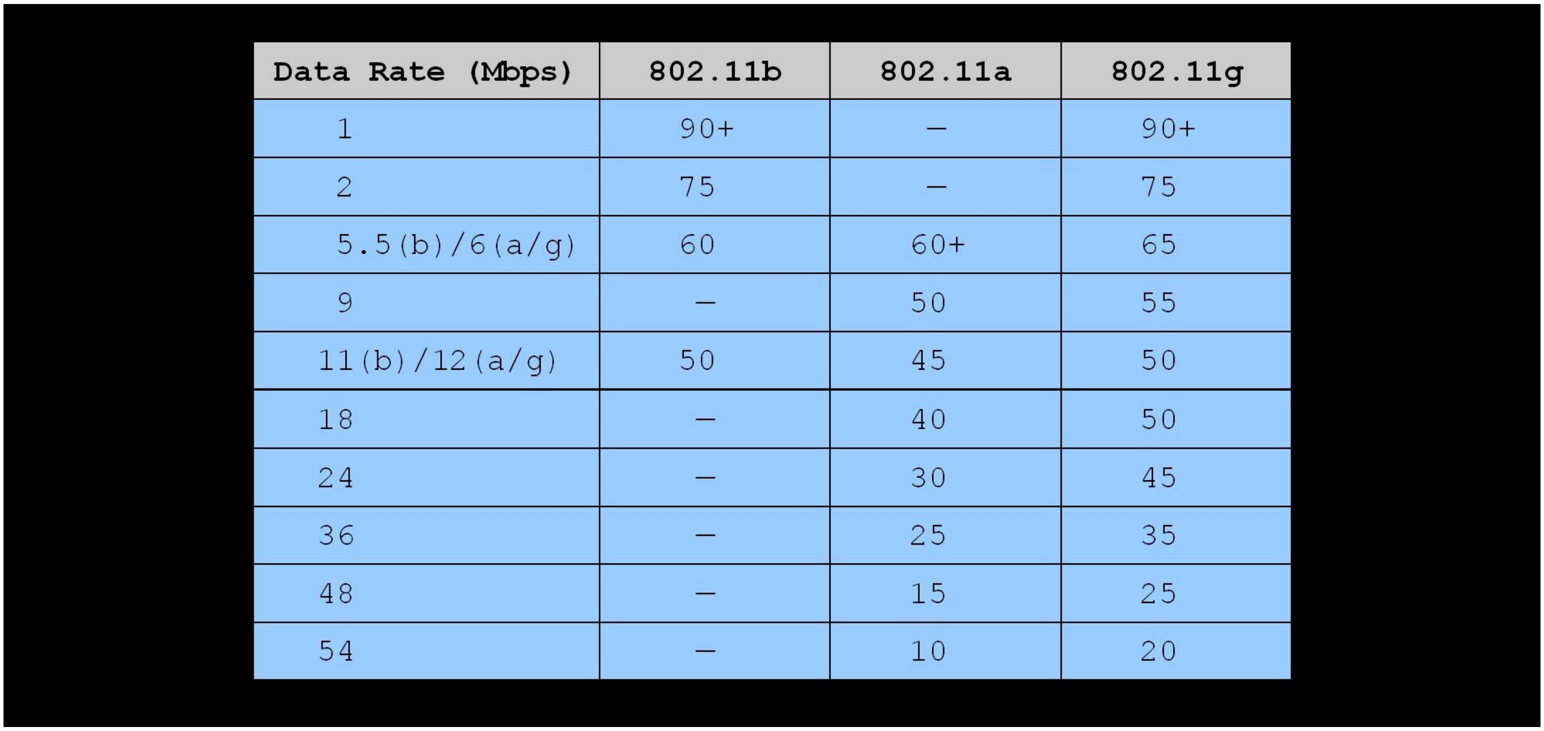
- The standard is designed so that 802.11b devices will work when connected to an 802.11g AP, and 802.11g devices will work when connected to an 802.11b AP, in both cases using the lower 802.11b data rate.

- IEEE 802.11g provides compatibility with 802.11 and 802.11b by specifying the same modulation and framing schemes as these standards for 1, 2, 5.5, and 11 Mbps.

- At data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps, 802.11g adopts the 802.11a OFDM scheme, adapted for the 2.4 GHz rate; this is referred to as ERP-OFDM, with ERP standing for extended rate physical layer.

- ERP-PBCC is also used to provide data rates of 22 and 33 Mbps.

Estimated Distance (m) vs. Data Rate



Data Rate (Mbps)	802.11b	802.11a	802.11g
1	90+	–	90+
2	75	–	75
5.5(b)/6(a/g)	60	60+	65
9	–	50	55
11(b)/12(a/g)	50	45	50
18	–	40	50
24	–	30	45
36	–	25	35
48	–	15	25
54	–	10	20

IEEE 802.11 Security Considerations

IEEE 802.11 defines three services that provide a wireless LAN with access and privacy services.

- **Authentication:**
  - **Used to establish the identity of stations to each other.**
  - **Supports several authentication schemes and allows for expansion of the functionality of these schemes.**
  - **The standard does not mandate any particular authentication scheme, which could range from relatively unsecure handshaking to public-key encryption schemes.**
  - **Requires mutually acceptable, successful authentication before a station can establish an association with an AP.**

- **Deauthentication:**
  - **Invoked whenever an existing authentication is to be terminated.**

- **Privacy:**
  - **Used to prevent the contents of messages from being read by other than the intended recipient.**
  - **The standard provides for the optional use of encryption to assure privacy.**

The original 802.11 specification included a set of security features for privacy and authentication that, unfortunately, were quite weak.

- **For privacy, 802.11 defined the Wired Equivalent Privacy (WEP) algorithm. The privacy portion of the 802.11 standard contained major weaknesses.**

- **In order to accelerate the introduction of strong security into WLANs, the Wi-Fi Alliance promulgated Wi-Fi Protected Access (WPA) as a Wi-Fi standard.**

- **WPA is a set of security mechanisms that eliminates most 802.11 security issues.**