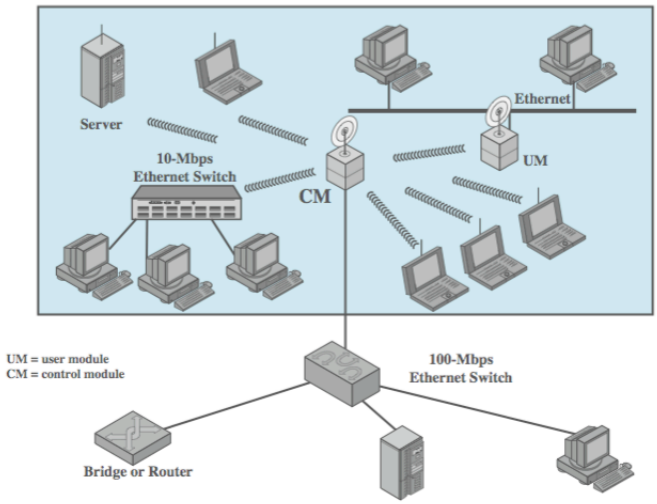
# Wireless LANs



# Overview of Wireless LANs

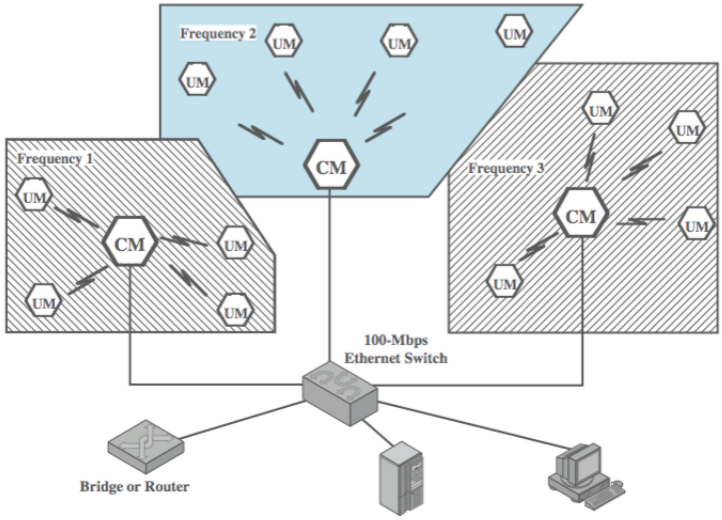
- use wireless transmission medium
- issues of high prices, low data rates, occupational safety concerns, & licensing requirements now addressed
- key application areas:
  - —LAN extension
  - —cross-building interconnect
  - —nomadic access
  - —ad hoc networking

# Single Cell LAN Extension






# Multi Cell LAN Extension



## Cross-Building Interconnect

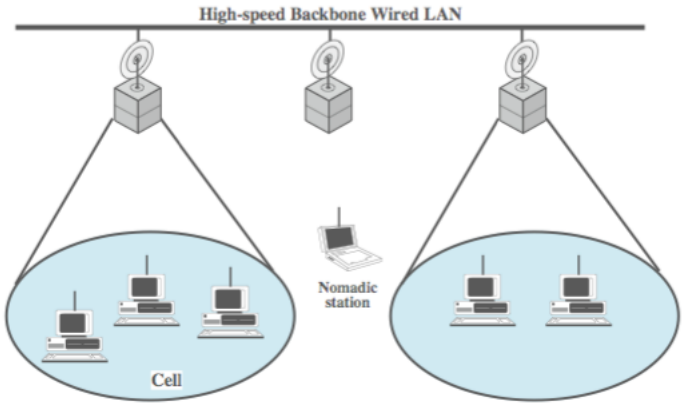
- connect LANs in nearby buildings
- point-to-point wireless link
  - —Not a LAN per se
- connect bridges or routers



## Nomadic Access

- link LAN hub & mobile data terminal
  - —laptop or notepad computer
  - —enable employee to transfer data from portable computer to server
- also useful in extended environment such as campus or cluster of buildings
  - —users move around with portable computers
  - —may wish access to servers on wired LAN

# Infrastructure Wireless LAN

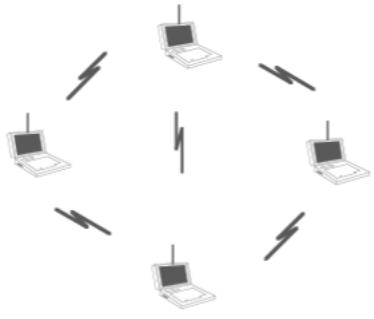



(a) Infrastructure Wireless LAN



# Ad Hoc Networking

- temporary peer-to-peer network



(b) Ad hoc LAN

## Wireless LAN Requirements

- throughput - efficient use wireless medium
- no of nodes - hundreds of nodes across multiple cells
- connection to backbone LAN - using control modules
- service area - 100 to 300 m
- low power consumption - for long battery life on mobiles
- transmission robustness and security
- collocated network operation
- license-free operation
- handoff/roaming
- dynamic configuration - addition, deletion, and relocation of end systems without disruption to users



## Technology

- infrared (IR) LANs
  - —individual cell of IR LAN limited to single room
  - —IR light does not penetrate opaque walls
- spread spectrum LANs
  - —mostly operate in ISM (industrial, scientific, and medical) bands
  - —no Federal Communications Commission (FCC) licensing is required in USA
- narrowband microwave
  - —microwave frequencies but not use spread spectrum
  - —some require FCC licensing

## Infrared LANs

- constructed using infrared portion of spectrum
- strengths
  - —spectrum virtually unlimited hence high rates possible
  - —unregulated spectrum
  - —infrared shares some properties of visible light
    - reflection covers room, walls isolate networks
  - —inexpensive and simple
- weaknesses
  - —background radiation, e.g. sunlight, indoor lighting
  - —power limited by concerns for eye safety and power consumption



## Infrared LANs Transmission Techniques

- directed-beam IR
  - —point-to-point links
  - —range depends on power and focusing
  - —for indoor use can set up token ring LAN
  - —IR transceivers positioned so data circulates in ring
- omnidirectional
  - —single base station with line of sight to other stations
  - —acts as a multiport repeater
  - —other stations use directional beam to it
- diffused configuration
  - —stations focused / aimed at diffusely reflecting ceiling

## Spread Spectrum LAN Configuration

- usually use multiple-cell arrangement
- adjacent cells use different center frequencies
- configurations:
  - —hub
    - connected to wired LAN
    - connect to stations on wired LAN and in other cells
    - may do automatic handoff
  - —peer-to-peer
    - no hub
    - MAC algorithm such as CSMA used to control access
    - for ad hoc LANs



## Spread Spectrum LANs Transmission Issues

- licensing regulations differ between countries
- USA FCC allows in ISM band:
  - —spread spectrum (1W), very low power (0.5W)
    - 902 - 928 MHz (915-MHz band)
    - 2.4 - 2.4835 GHz (2.4-GHz band)
    - 5.725 - 5.825 GHz (5.8-GHz band)
  - —2.4 GHz also in Europe and Japan
- interference
  - —many devices around 900 MHz: cordless telephones, wireless microphones, and amateur radio
  - —fewer devices at 2.4 GHz; microwave oven
  - —little competition at 5.8 GHz

# IEEE 802 Standards

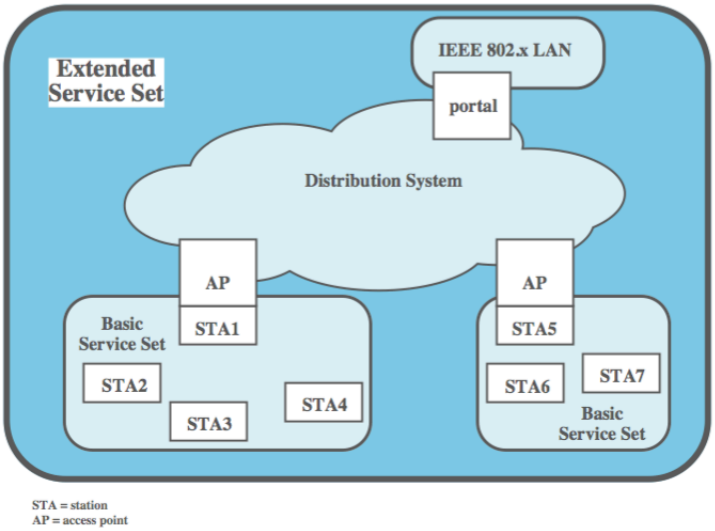
| Standard | Scope |
|---|---|
| IEEE 802.11 | Medium access control (MAC): One common MAC for WLAN applications |
| | Physical layer: Infrared at 1 and 2 Mbps |
| | Physical layer: 2.4-GHz FHSS at 1 and 2 Mbps |
| | Physical layer: 2.4-GHz DSSS at 1 and 2 Mbps |
| IEEE 802.11a | Physical layer: 5-GHz 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 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 Architecture






# IEEE 802.11 - BSS

- basic service set (BSS) building block
- may be isolated
- may connect to backbone distribution system (DS) through access point (AP)
- BSS generally corresponds to cell
- DS can be switch, wired network, or wireless network
- have independent BSS (IBSS) with no AP

# Extended Service Set (ESS)

- possible configurations:
  - —simplest is each station belongs to single BSS
  - —can have two BSSs overlap
  - —a station can participate in more than one BSS
  - —association between station and BSS dynamic
- ESS is two or more BSS interconnected by DS
- appears as single logical LAN to LLC



# IEEE 802 Services

| Service | Provider | Used to support |
|---|---|---|
| Association | Distribution system | MSDU delivery |
| Authentication | Station | LAN access and security |
| Deauthentication | Station | LAN access and security |
| Dissassociation | Distribution system | MSDU delivery |
| Distribution | Distribution system | MSDU delivery |
| Integration | Distribution system | MSDU delivery |
| MSDU delivery | Station | MSDU delivery |
| Privacy | Station | LAN access and security |
| Reassocation | Distribution system | MSDU delivery |

## Services - Message Distribution

- distribution service
  - —primary service used by stations to exchange MAC frames when frame must traverse DS
  - —if stations in same BSS, distribution service logically goes through single AP of that BSS
- integration service
  - —enables transfer of data between 802.11 LAN station and one on an integrated 802.x LAN



## Association Related Services

- DS requires info about stations within ESS
- provided by association-related services
- station must associate before communicating
- 3 mobility transition types:
  - —no transition - stationary or in single BSS
  - —BSS transition - between BSS in same ESS
  - —ESS transition: between BSS in different ESS

## Association Related Services

- DS needs identity of destination station
  - —stations must maintain association with AP within current BSS
- 3 services relate to this requirement:
  - —Association - establishes initial association between station and AP
  - —Reassociation - to transfer an association to another AP
  - —Disassociation - by station or AP



## Medium Access Control

- MAC layer covers three functional areas
  - —reliable data delivery
  - —access control
  - —security

## Reliable Data Delivery

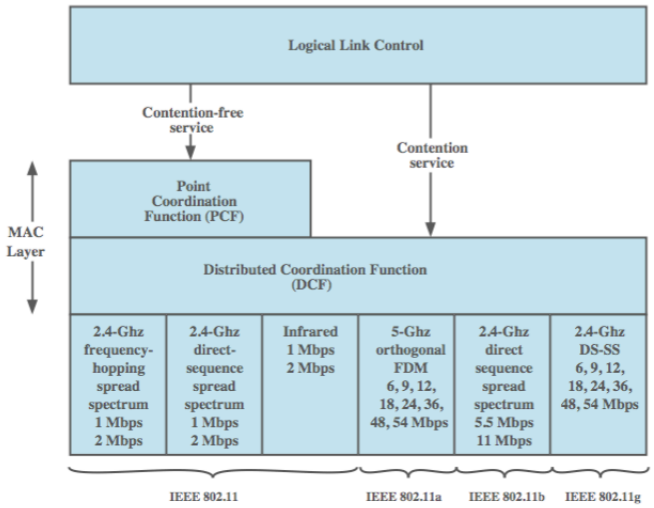
- 802.11 physical / MAC layers unreliable
  - —noise, interference, and other propagation effects result in loss of frames
  - —even with error-correction codes, frames may not successfully be received
- can be dealt with at a higher layer, e.g. TCP
- more efficient to deal with errors at MAC level
- 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



## Four Frame Exchange

- 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

# Media Access Control

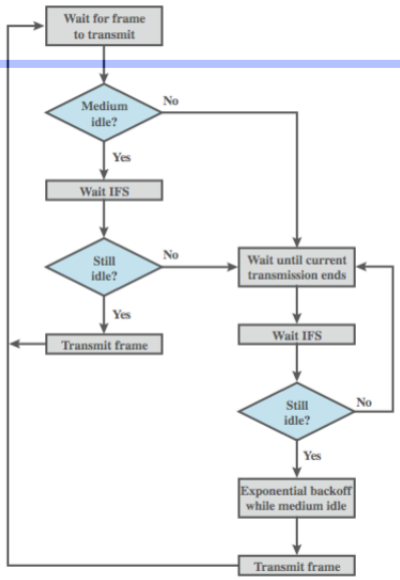





# Distributed Coordination Function

- DCF sublayer uses CSMA
  - —if station has frame to send it listens to medium
  - —if medium idle, station may transmit
  - —else waits until current transmission complete
- no collision detection since on wireless network
- DCF includes delays that act as a priority scheme

# IEEE 802.11 Medium Access Control Logic






# Priority IFS Values

- IFS (**I**nter **F**rame **S**pace)
- SIFS (short IFS)
  - —for all immediate response actions (see later)
- PIFS (point coordination function IFS)
  - —used by the centralized controller in PCF scheme when issuing polls
- DIFS (distributed coordination function IFS)
  - —used as minimum delay for asynchronous frames contending for access

## SIFS Use

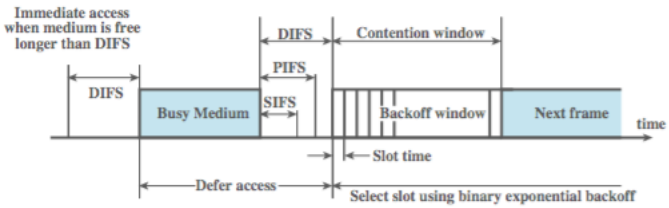
- SIFS gives highest priority
  - —over stations waiting PIFS or DIFS time
- SIFS used in following circumstances:
  - —Acknowledgment (ACK)
    - station responds with ACK after waiting SIFS gap
    - for efficient collision detect & multi-frame transmission
  - —Clear to Send (CTS)
    - station ensures data frame gets through by issuing RTS
    - and waits for CTS response from destination
  - —Poll response
    - see Point coordination Function (PCF) discussion next



## PIFS and DIFS Use

- PIFS used by centralized controller
  - —for issuing polls
  - —has precedence over normal contention traffic
  - —but not SIFS
- DIFS used for all ordinary asynchronous traffic

# IEEE 802.11 MAC Timing Basic Access Method



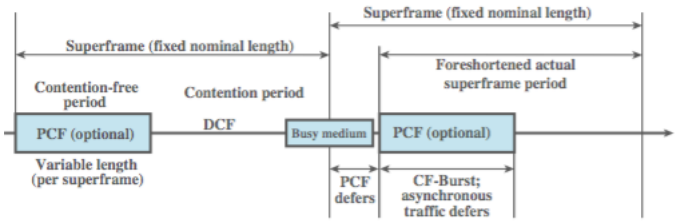

(a) Basic Access Method



# Point Coordination Function (PCF)

- alternative access method implemented on top of DCF
- polling by centralized polling master (point coordinator)
- uses PIFS when issuing polls
- point coordinator polls in round-robin to stations configured for polling
- when poll issued, polled station may respond using SIFS
- if point coordinator receives response, it issues another poll using PIFS
- if no response during expected turnaround time, coordinator issues poll
- coordinator could lock out async traffic by issuing polls
- have a superframe interval defined

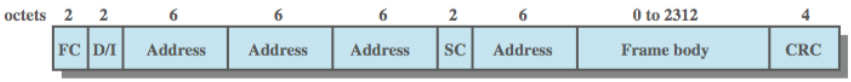
# PCF Superframe Timing




(b) PCF Superframe Construction



# IEEE 802.11 MAC Frame Format




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

## Control Frames

- Power Save-Poll (PS-Poll)
  - request AP transmit buffered frame when in power-saving mode
- Request to Send (RTS)
  - first frame in four-way frame exchange
- Clear to Send (CTS)
  - second frame in four-way exchange
- Acknowledgment (ACK)
- Contention-Free (CF)-end
  - announces end of contention-free period part of PCF
- CF-End + CF-Ack:
  - acknowledges CF-end to end contention-free period and release stations from associated restrictions



## Data Frames – Data Carrying

- eight data frame subtypes, in two groups
- first four carry upper-level data
- Data
  - simplest data frame, contention or contention-free use
- Data + CF-Ack
  - carries data and acknowledges previously received data during contention-free period
- Data + CF-Poll
  - used by point coordinator to deliver data & req send
- Data + CF-Ack + CF-Poll
  - combines Data + CF-Ack and Data + CF-Poll

## Data Frames – Not Data Carrying

- other four data frames do not carry user data
- Null Function
  - —carries no data, polls, or acknowledgments
  - —carries power mgmt bit in frame control field to AP
  - —indicates station is changing to low-power state
- other three frames (CF-Ack, CF-Poll, CF-Ack + CF-Poll) same as corresponding frame in preceding list but without data



## Management Frames

- used to manage communications between stations and Aps
- such as management of associations
  - —requests, response, reassociation, dissociation, and authentication

# 802.11 Physical Layer

| | 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 802.11 Physical Layer - DSSS

- Direct-sequence spread spectrum (DSSS)
- 2.4 GHz ISM band at 1 Mbps and 2 Mbps
- up to seven channels, each 1 Mbps or 2 Mbps, can be used
- depends on bandwidth allocated by various national regulations
  - —13 in most European countries
  - —one in Japan
- each channel bandwidth 5 MHz
- encoding scheme DBPSK for 1-Mbps and DQPSK for 2-Mbps using an 11-chip Barker seq

## Original 802.11 Physical Layer - FHSS

- Frequency-hopping spread spectrum
  - —2.4 GHz ISM band at 1 Mbps and 2 Mbps
  - —23 channels in Japan
  - —70 channels in USA
  - —signal hopping between multiple channels based on a pseudonoise sequence
  - —1-MHz channels are used
- hopping scheme adjustable
- two-level Gaussian FSK modulation for 1 Mbps
- four-level GFSK modulation used for 2 Mbps



## Original 802.11 Physical Layer – Infrared

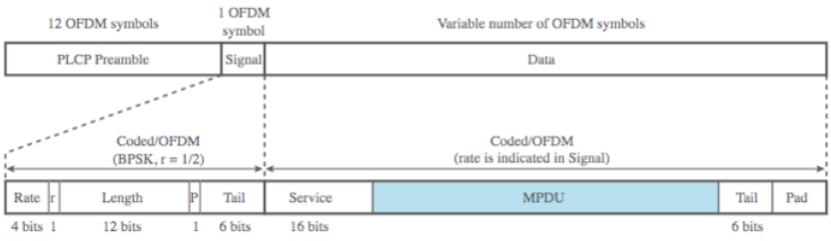
- omnidirectional
- range up to 20 m
- 1 Mbps uses 16-PPM (pulse position modulation)
  - —4 data bit group mapped to one of 16-PPM symbols
  - —each symbol a string of 16 bits
  - —each 16-bit string has fifteen 0s and one binary 1
- 2-Mbps has each group of 2 data bits is mapped into one of four 4-bit sequences
  - —each sequence consists of three 0s and one binary 1
- intensity modulation is used for transmission

# 802.11a

- uses 5-GHz band (different to other variants)
  - —supports higher data rates, is less cluttered
- orthogonal frequency division multiplexing (OFDM)
  - —multiple carrier signals at different frequencies
  - —some bits on each channel
- up to 48 subcarriers modulated using BPSK, QPSK, 16-QAM, or 64-QAM
  - —subcarrier frequency spacing 0.3125 MHz
  - —convolutional code at rate of 1/2, 2/3, or 3/4 provides forward error correction
  - —combination of modulation technique and coding rate determines data rate



# 802.11a Physical Frame



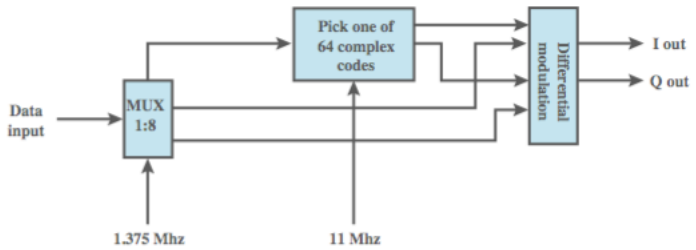

(a) IEEE 802.11a physical PDU

# 802.11b

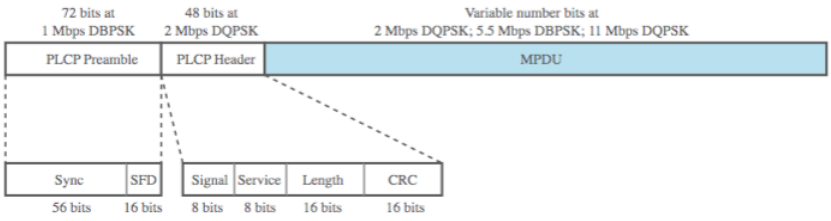
- extension of 802.11 DS-SS scheme
  - —with data rates of 5.5 and 11 Mbps
- chipping rate 11 MHz
  - —same as original DS-SS scheme
  - —Complementary Code Keying (CCK) modulation gives higher data rate with same bandwidth & chipping rate
  - —also Packet Binary Convolutional Coding (PBCC) for future higher rate use



# 11-Mbps CCK Modulation Scheme



# 802.11b Physical Frame




(b) IEEE 802.11b physical PDU



# 802.11g

- higher-speed extension to 802.11b
- operates in 2.4GHz band
- compatible with 802.11b devices
- combines physical layer encoding techniques used in 802.11 and 802.11b to provide service at a variety of data rates
  - —ERP-OFDM for 6, 9, 12, 18, 24, 36, 48, 54Mbps rates
  - —ERP-PBCC for 22 & 33Mbps rates

## Data Rate vs Distance (m)

| 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 |



## Access and Privacy Services - Authentication

- authentication used to establish station identity
- wired LANs assume physical connection gives authority to use LAN
- not a valid assumption for wireless LANs
- 802.11 supports several authentication schemes
- does not mandate any particular scheme
- from relatively insecure handshaking to public-key encryption
- 802.11 requires mutually acceptable, successful authentication before association

## Access and Privacy Services Deauthentication & Privacy

- Deauthentication
  - —invoked whenever an existing authentication is to be terminated
- Privacy
  - —used to prevent messages being read by others
  - —802.11 allows optional use of encryption
- Original WEP security features were weak
- Subsequently 802.11i and WPA alternatives evolved giving better security



## Summary

- Wireless LAN alternatives
- IEEE 802.11 architecture and services
- 802.11 Media Access Control
- 802.11 Physical Layers
  - —802.11, 802.11a, 802.11b, 802.11g
- Security considerations