Computer Networks

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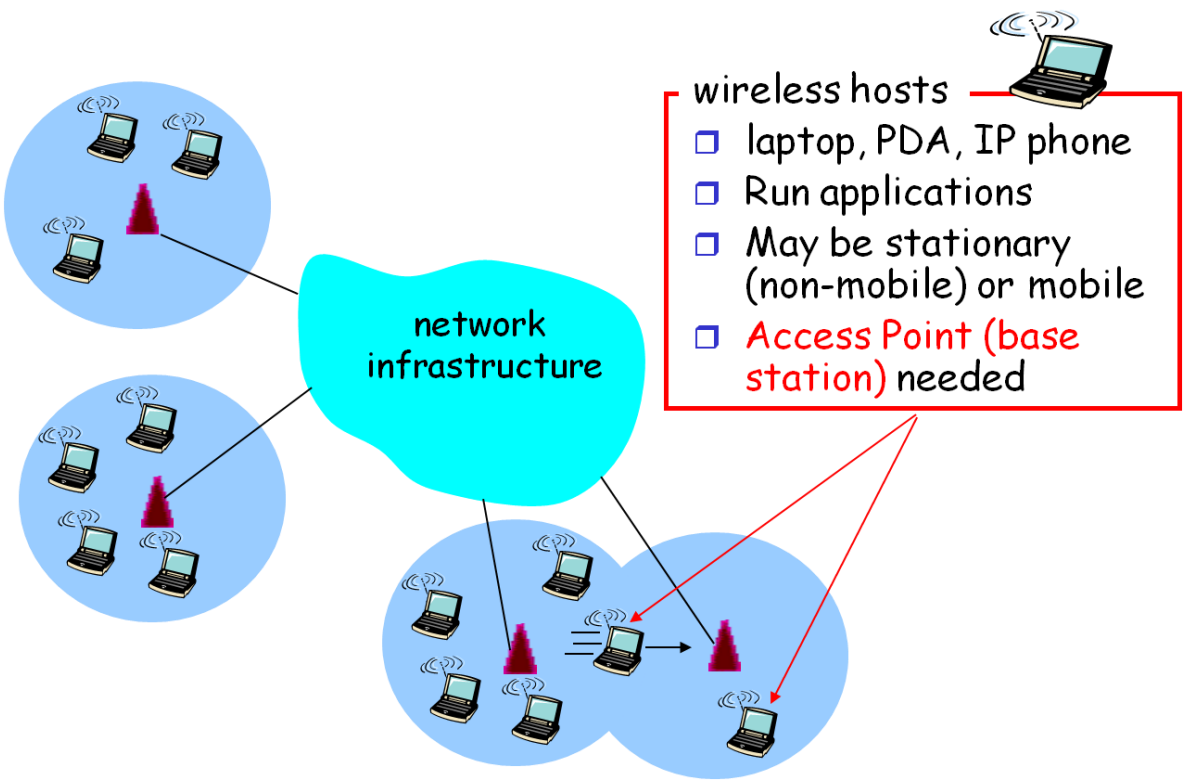
Chapter 2. Direct Link Networks

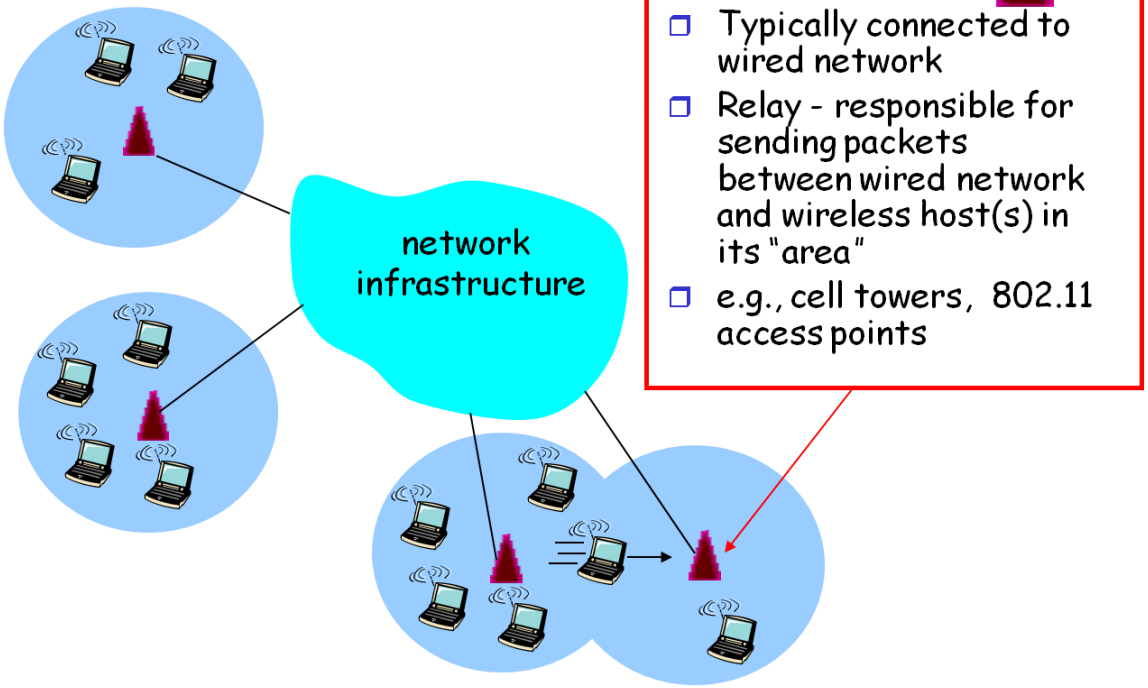
- Link Service and Framing
- Error Detection and Reliable Transmission
- HDLC, PPP, and SONET
- Token Ring
- Ethernet
- Bridges and Layer-2 switch
- Wireless Networks
- Network Performance

Wireless Networks

Wireless Networks



Elements of a Wireless Network



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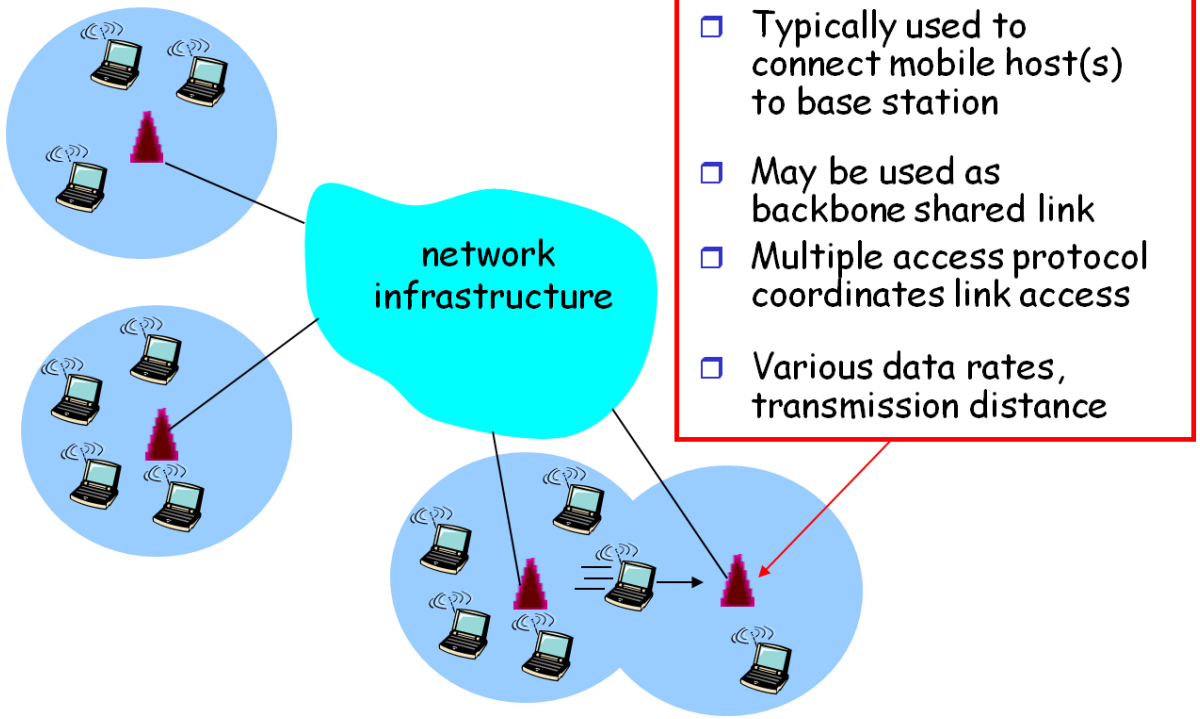
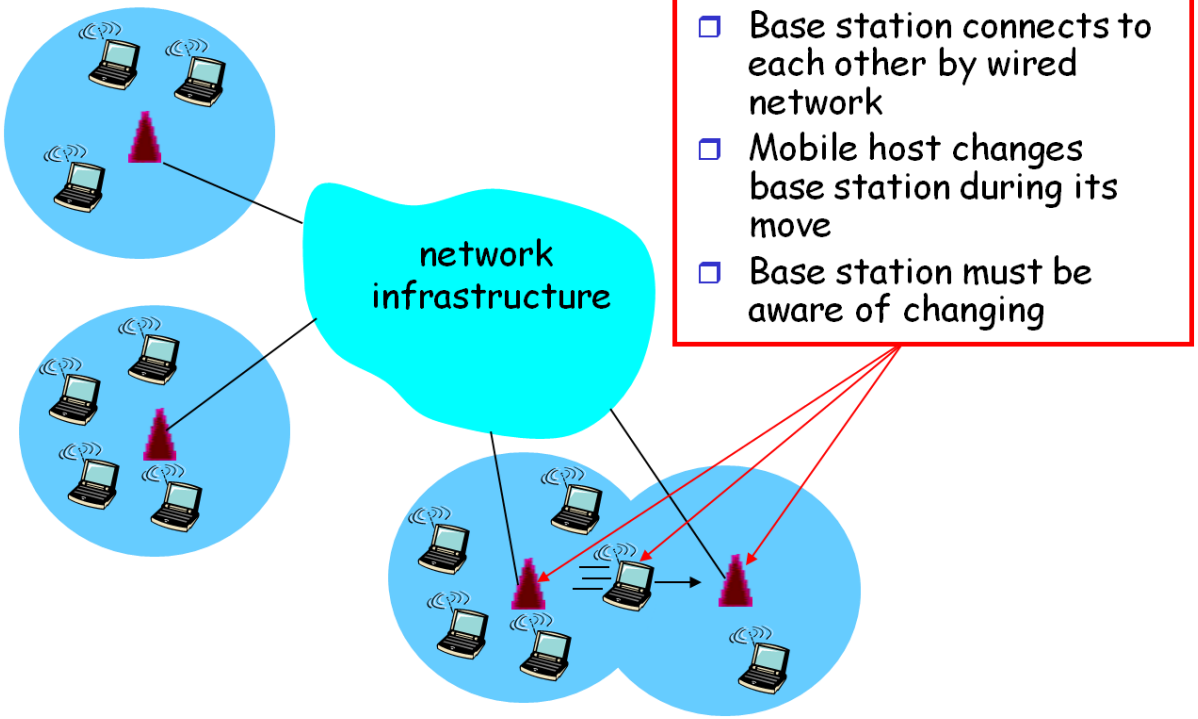


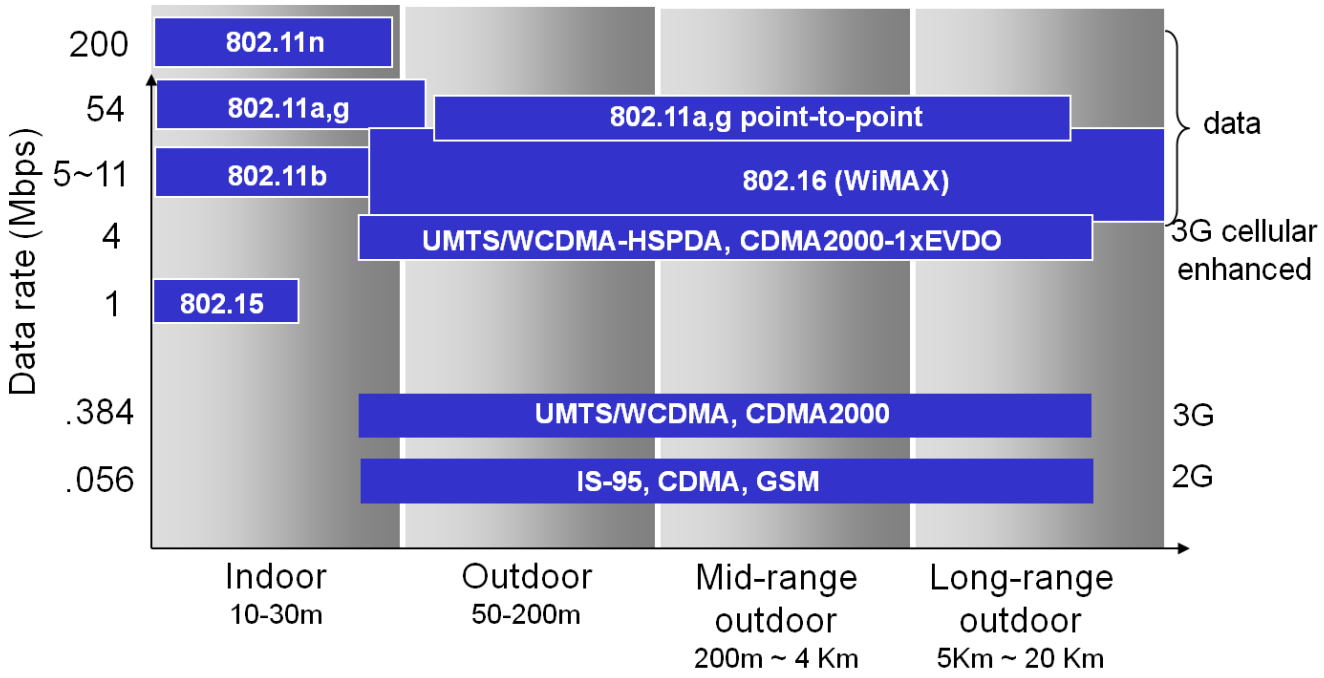
Elements of a Wireless Network



Handoff

- Base station connects to each other by wired network
- Mobile host changes base station during its move
- Base station must be aware of changing

Various Wireless Link Standards



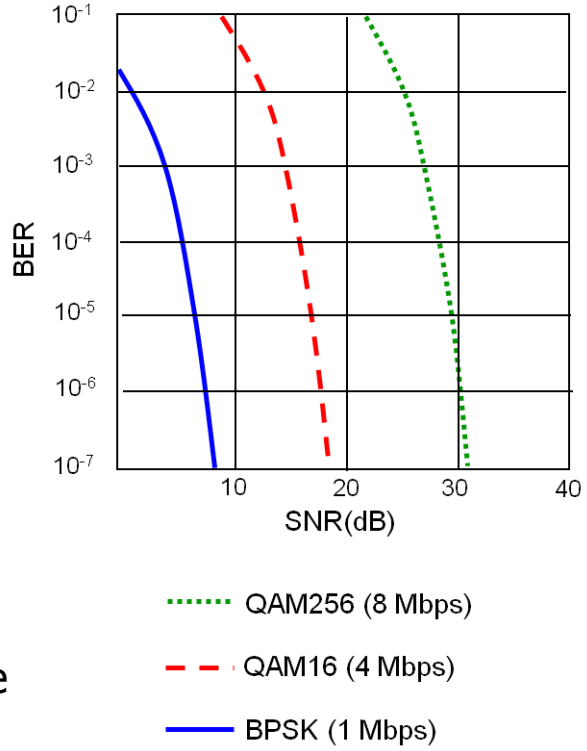
Wireless Link Characteristics

Different from wired link

- Decreased signal strength:
  - Radio signal attenuates fast as it propagates through air
- Multipath propagation:
  - Radio signal reflects off ground objects, arriving at destination by different times (self-interfering)
- Interference from other sources:
  - Standard wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g. phone, oven)
- Robustness and security:
  - Interference prone and easily eavesdropped

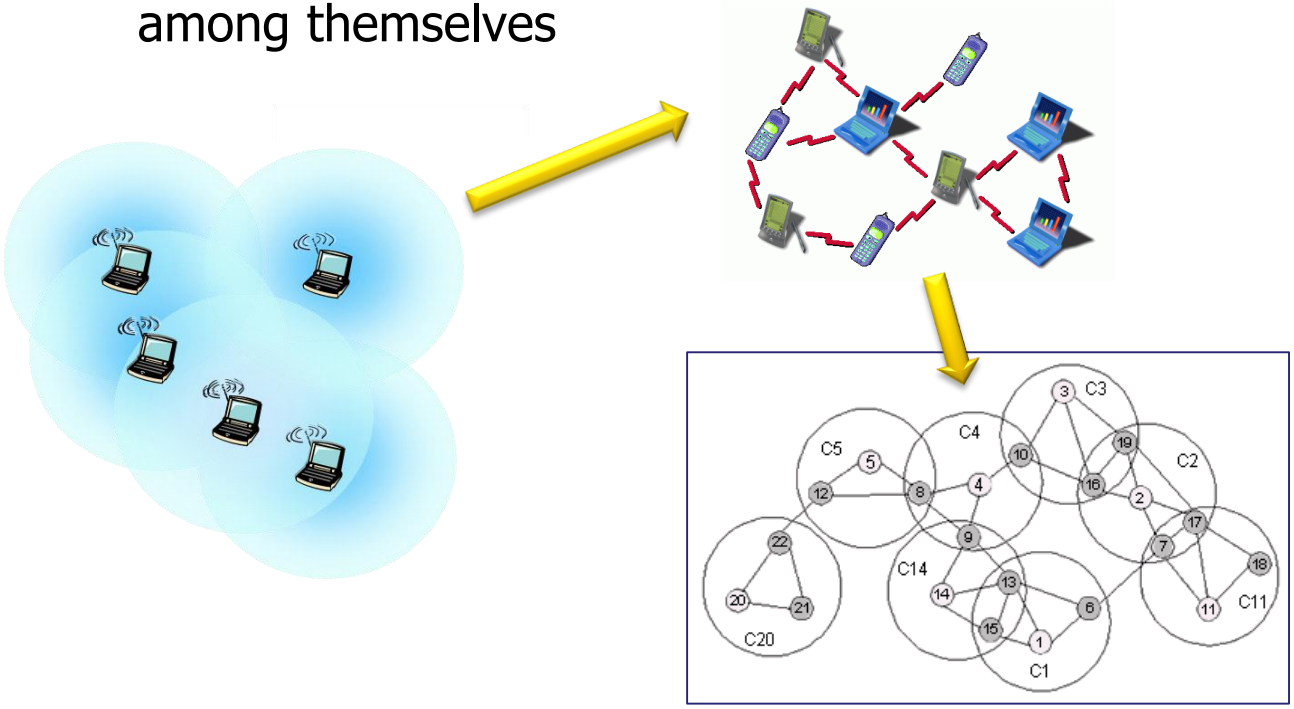
SNR vs. BER

- SNR: signal-to-noise ratio
  - larger SNR → easier to extract signal from noise
- BER: bit error rate
  - The lower the better
- Transmission rate
  - Determined by physical layer (modulation technique)
- Given physical layer
  - increase power -> increase SNR->decrease BER
  - But power is limited by battery life on mobile stations



Ad-hoc Networking

- Peer-to-peer communication, no base stations
- Nodes organize themselves into a network: route among themselves

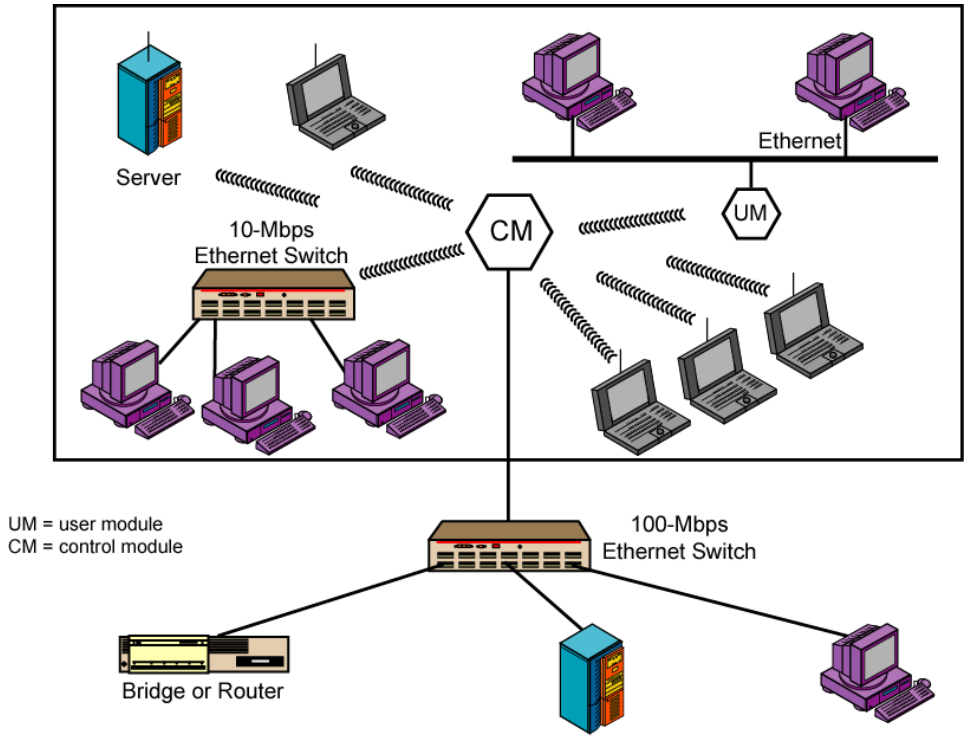


Wireless Network Taxonomy

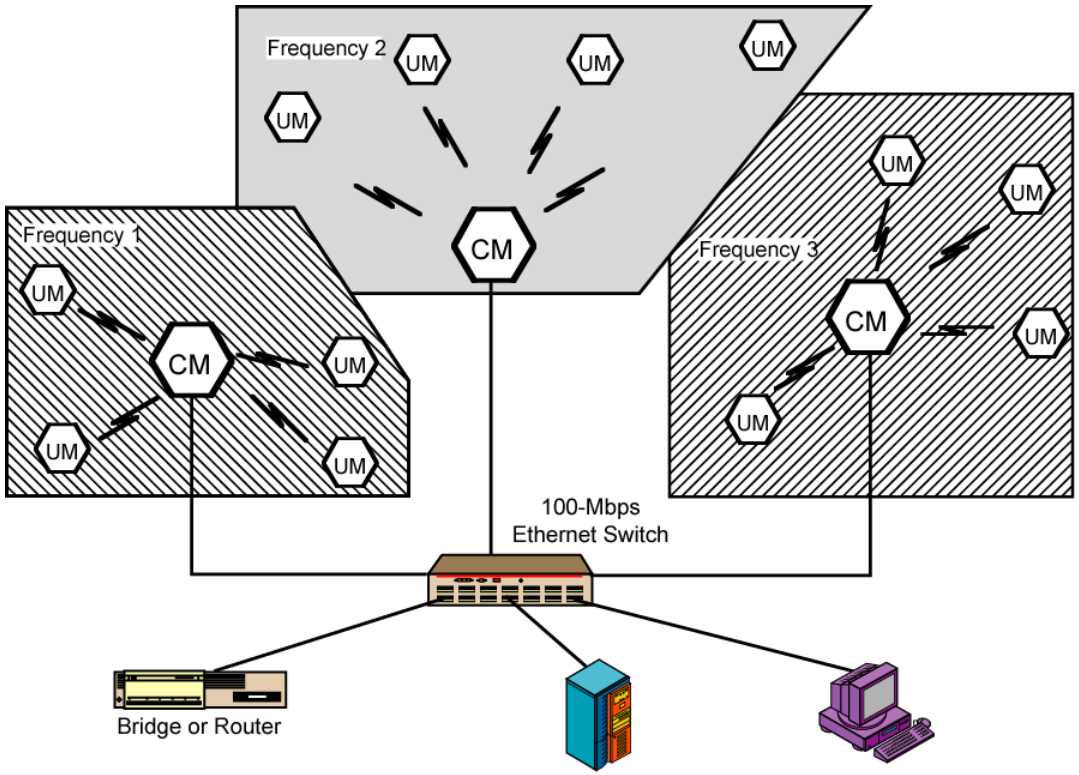
	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

IEEE 802.11 Wireless LANs

- A single-cell configuration

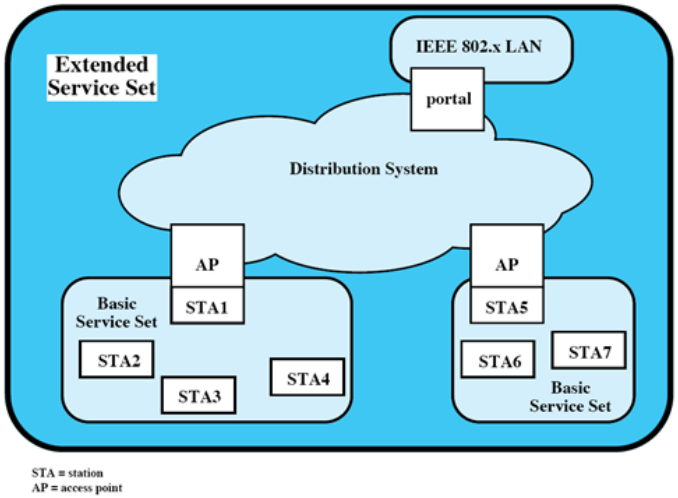


A Multi-Cell Configuration

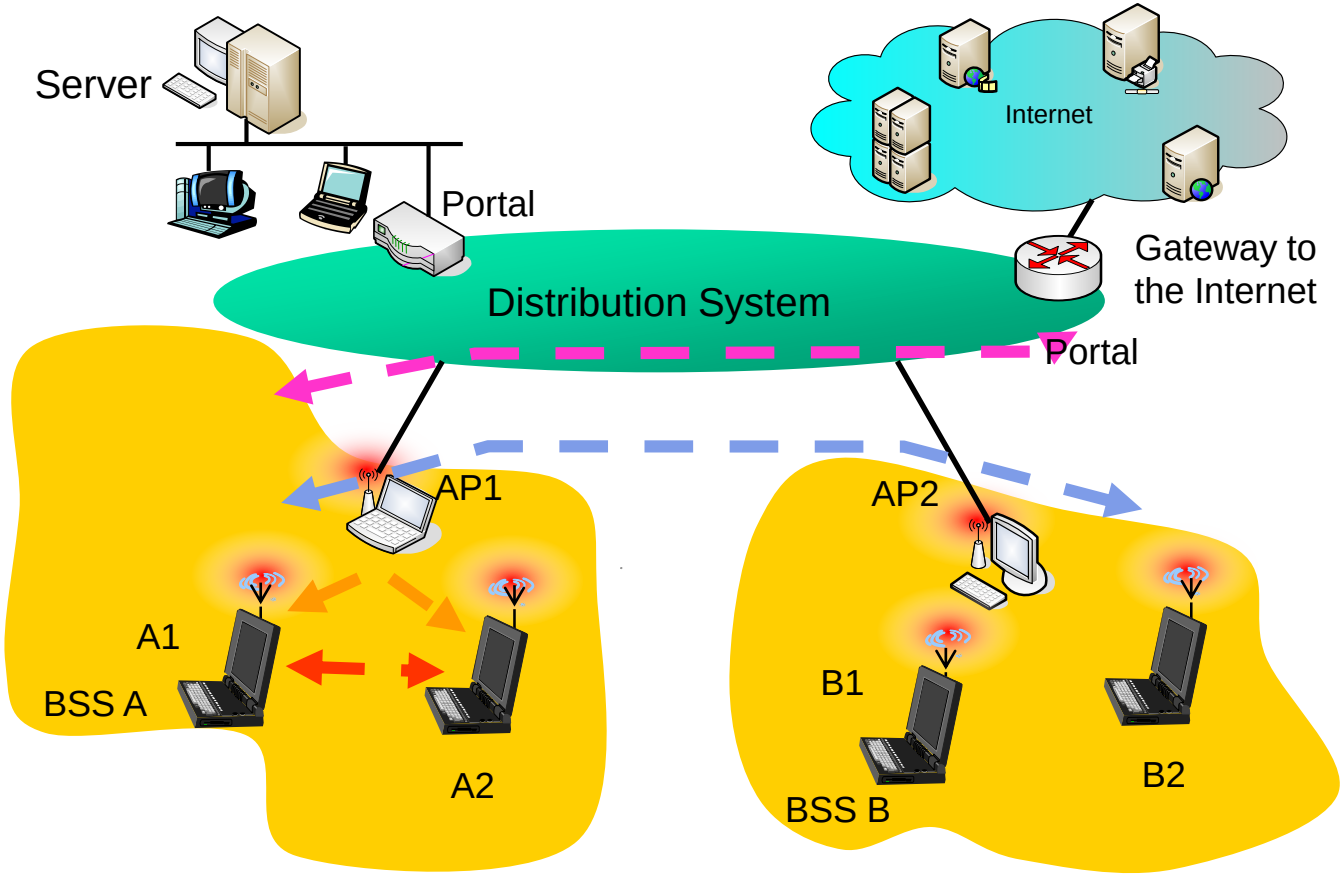


IEEE 802.11 Architecture

- Basic Service Set (BSS)
  - A single cell coordinated by one access point (base station)
- Extended Service Set (ESS)
  - Multiple BSSs interconnected by Distribution System (DS)
  - DS can be a switch, wired network, or wireless network
  - An ESS appears as a single logical LAN
  - Portals (routers) provide access to Internet



Possible Communications



IEEE 802.11 Services

Service	Provider	Support
Authentication	Station	LAN access and security
Deauthentication	Station	LAN access and security
Privacy	Station	LAN access and security
MSDU send/receive	Station	MSDU delivery
Association	Distribution system	MSDU delivery
Disassociation	Distribution system	MSDU delivery
Reassociation	Distribution system	MSDU delivery
Distribution	Distribution system	MSDU delivery
Integration	Distribution system	MSDU delivery

MSDU: MAC service data units

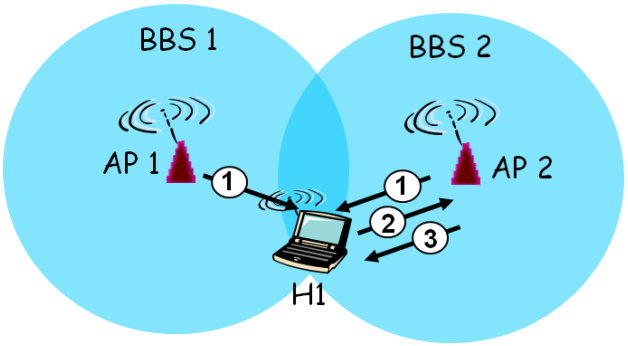
Different Services

- Distribution service
  - Exchange MAC frames that should traverse DS
- Integration service
  - Enables transfer of data between station on 802.11 LAN and one on integrated 802.x LAN
- Authentication/Deauthentication
  - Used to establish identity of stations to each other
  - Optional required before association
- Privacy
  - Prevent messages being read by others (encryption)

Supporting Handoff

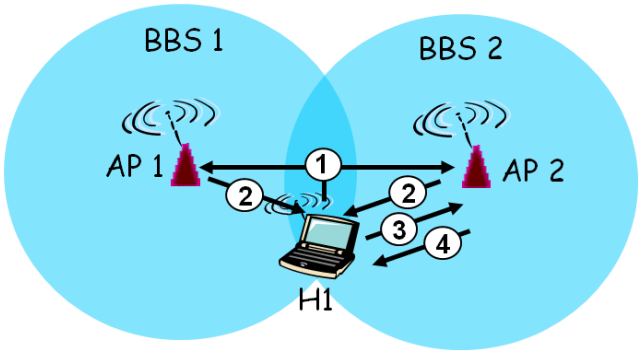
- Association
  - Establishes initial association between station and AP
  - To make identity and address known
  - AP can communicate information to other APs within ESS
- Reassociation
  - Transfer established association to another AP
  - Allows station to move from one BSS to another
- Disassociation
  - From either station or AP that association is terminated
  - Given before station leaves ESS or shuts
  - i.e. handoff between ESS is unsupported

Scanning for Association



Passive Scanning:

- Beacon frames sent from Aps
- Association Request frame sent: H1 to selected AP
- Association Response frame sent: selected AP to H1

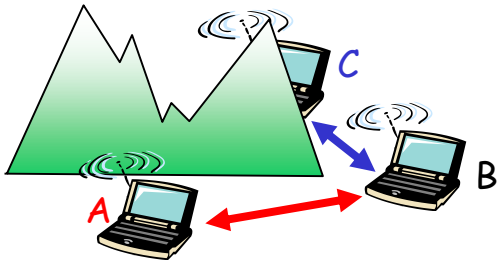


Active Scanning:

- Probe Request frame broadcast from H1
- Probe response frame sent from Aps
- Association Request frame sent: H1 to selected AP
- Association Response frame sent: selected AP to H1

Wireless Communication

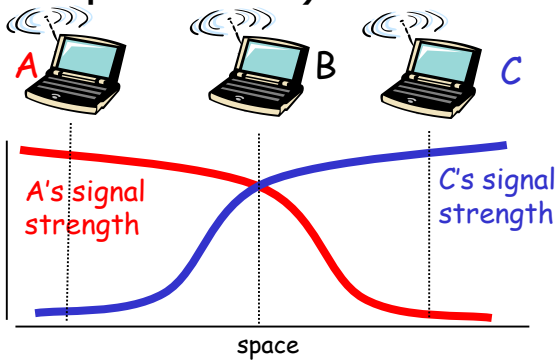
- Multiple wireless senders and receivers create additional problems (beyond multiple access)



Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other

A, C unaware of their interference at B



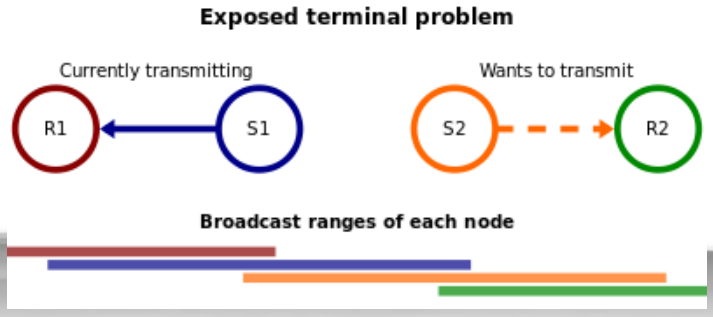
Signal fading problem

- B, A hear each other
- B, C hear each other

A, C can not hear each other interfering at B

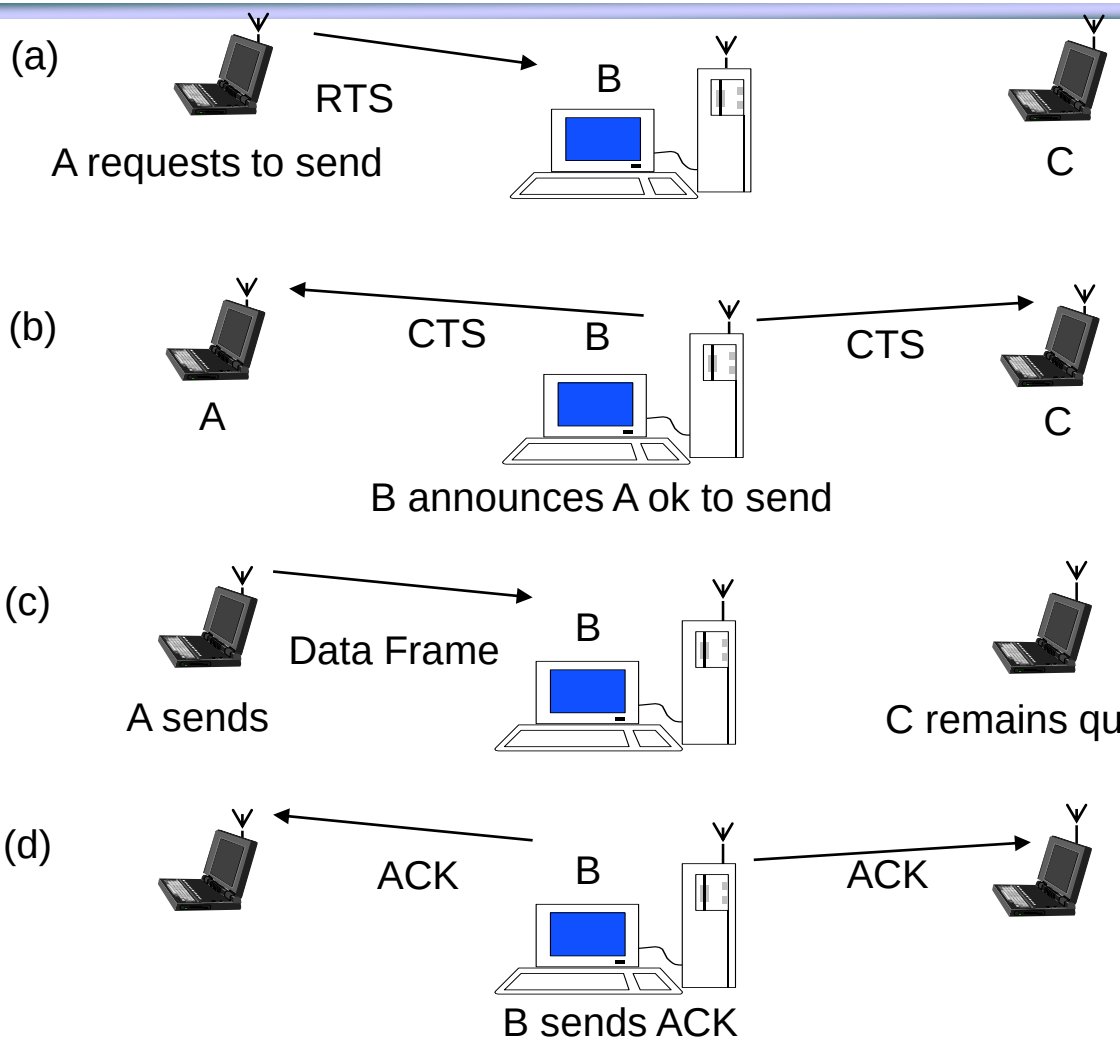
Exposed terminal problem

- S1, S2 hear each other
- S2 waits when it hears S1 transmitting
- But S1->R1 and S2->R2 can transfer simultaneously since they are not interference

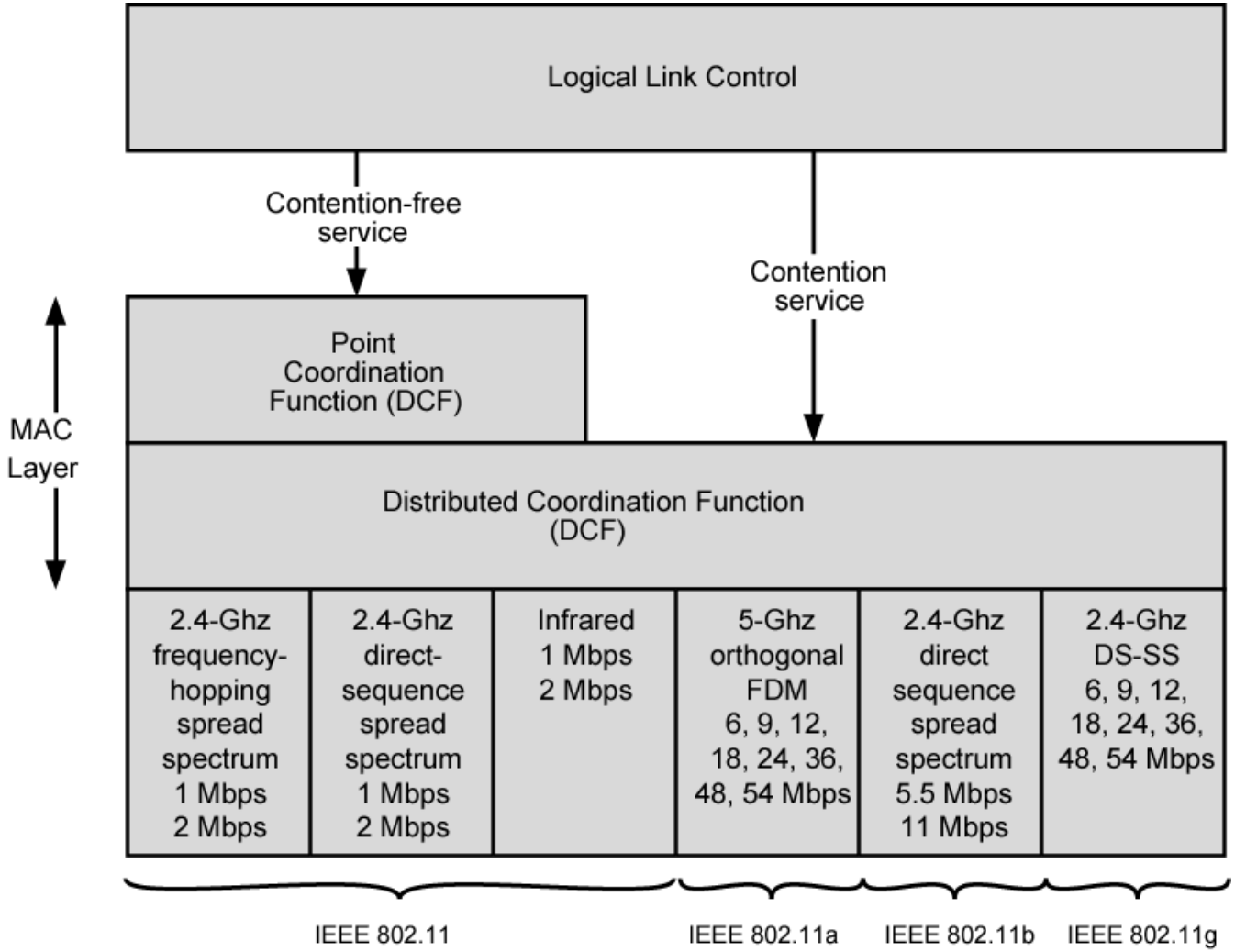


4 Frame Exchange

- To enhance wireless reliability, 4-frame exchange may be used
  - Source issues a Request to Send (RTS) frame to destination
  - Destination responds with Clear to Send (CTS)
  - After receiving CTS, source transmits data
  - Destination responds with ACK
- Stations refrain from transmission to avoid collision
  - RTS alerts all stations within range of source that exchange is under way
  - CTS alerts all stations within range of destination
- RTS/CTS exchange is a required function, but can be disabled


(a)
RTS
B
A requests to send
C
(b)
CTS
B
CTS
A
C
B announces A ok to send
(c)
Data Frame
B
A sends
C remains quiet
(d)
ACK
B
ACK
B sends ACK

IEEE 802.11 Protocol Architecture



Media Access Control

- Distributed wireless foundation MAC (DWFMAC)
  - Distributed access control mechanism
  - Optional centralized control on top
- The lower sub-layer is distributed coordination function (DCF)
  - Contention algorithm to provide access to all traffic
  - CSMA/CA (collision avoidance)
- The upper is point coordination function (PCF)
  - Centralized MAC algorithm, Contention free
  - Built on top of DCF

Distributed Coordination Function

- The DCF sub-layer uses CSMA/CA
  - Station senses medium before transmitting
  - Don't collide with ongoing transmission by other station
- DCF includes delays
  - Inter-frame space (IFS), station wait for IFS before transmitting
  - Accounts for priority scheme
- No collision detection, why?
  - Difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - Transmitting station cannot distinguish incoming weak signals from noise and effects of own transmission
  - Can't sense all collisions in any case: hidden terminal, fading
  - *ACK* is used for success transmission

IEEE 802.11 MAC Protocol: CSMA/CA

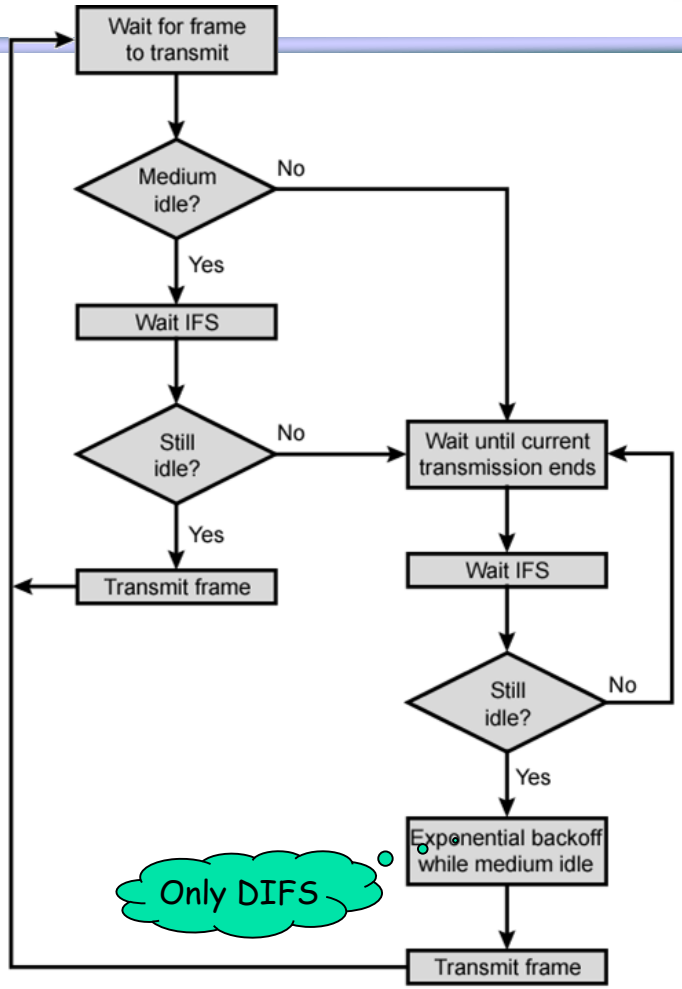
Sender:

1. Station with frame senses medium
   - If idle, wait to see if remains idle for 1 IFS (Inter-Frame Space). If so, may transmit immediately (No Collision Detection)
   - If busy (either initially or becomes busy during IFS), monitor until current transmission is over
   - Once current transmission over, delay another IFS
     - If remains idle, backoff random time and again sense (to ensure stability, binary exponential backoff used)
     - If medium idle, station may transmit
     - During backoff time, if medium busy, backoff timer is halted and resumes when medium becomes idle
     - Transmit if timer expires
     - if no ACK, increase random backoff interval and try to retransmit

Receiver:

- if frame received OK
  - return ACK after SIFS (ACK needed due to hidden terminal problem)

IEEE 802.11 Medium Access Control Logic



3-level Priority

- SIFS (short IFS)
  - Shortest IFS – highest priority
  - For all immediate responses
- PIFS (point coordination function IFS)
  - Mid-length IFS
  - Used by the centralized controller in PCF scheme when issuing polls
- DIFS (distributed coordination function IFS)
  - Longest IFS
  - Used for other asynchronous frames contending for access

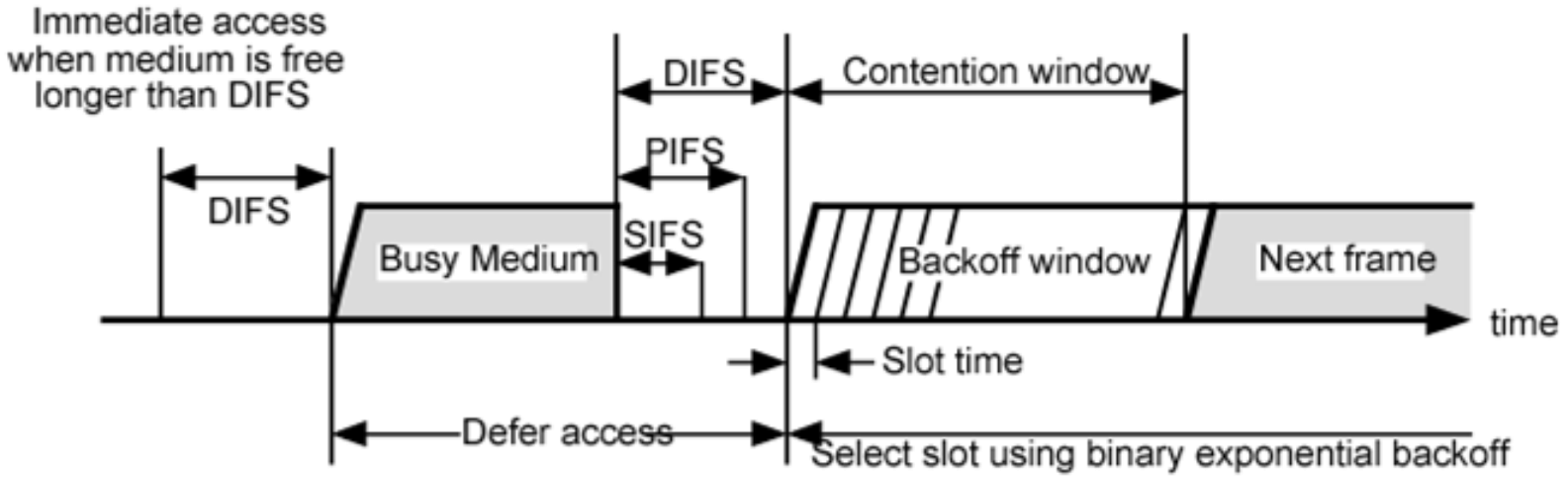
SIFS Use

- Acknowledgment (ACK)
  - Station responds with ACK after waiting SIFS gap
- Delivery of multiple frame LLC PDU
  - Station with multi-frame LLC PDU to transmit sends out 1st MAC frame using normal IFS
  - Each subsequent frames sent after SIFS
- Poll response
  - Response frame after poll
- Clear to Send (CTS)
  - Station can ensure data frame will get through by issuing RTS with normal IFS
  - Destination station should respond with CTS using SIFS if ready to receive

PIFS and DIFS

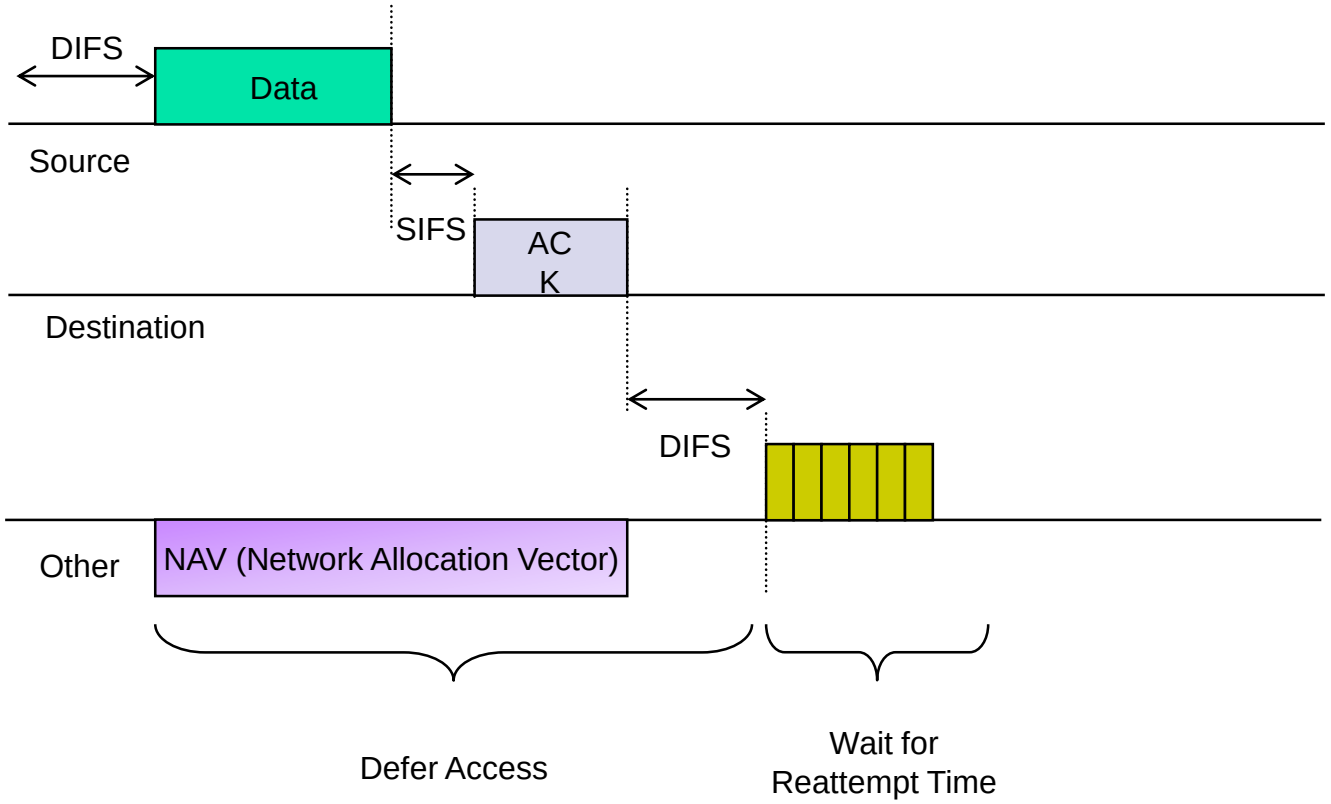
- PIFS used by centralized controller
  - Issuing polls
  - Takes precedence over normal contention traffic
  - Frames using SIFS have precedence over PCF poll
- DIFS used for all ordinary asynchronous traffic

IEEE 802.11 MAC Timing – DCF



(a) Basic Access Method

Transmission of MPDU without RTS/CTS

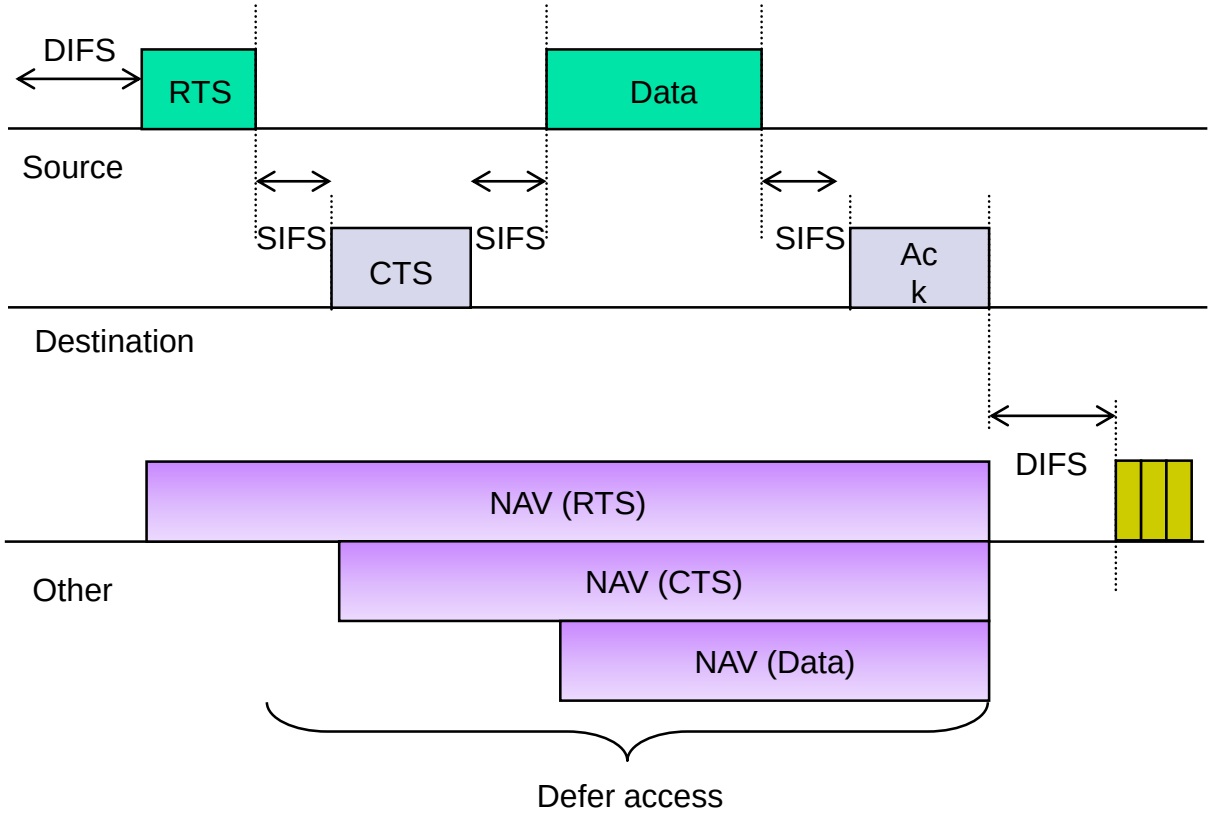


MPDU：Mac Protocol Data Unit

NAV: Source stations informs other stations of transmission time (in υsec) for an MPDU (a field in it)

Saving Energy：no need to listen CTS/RTS for the whole time

Transmission of MPDU with RTS/CTS



Point Coordination Function (PCF)

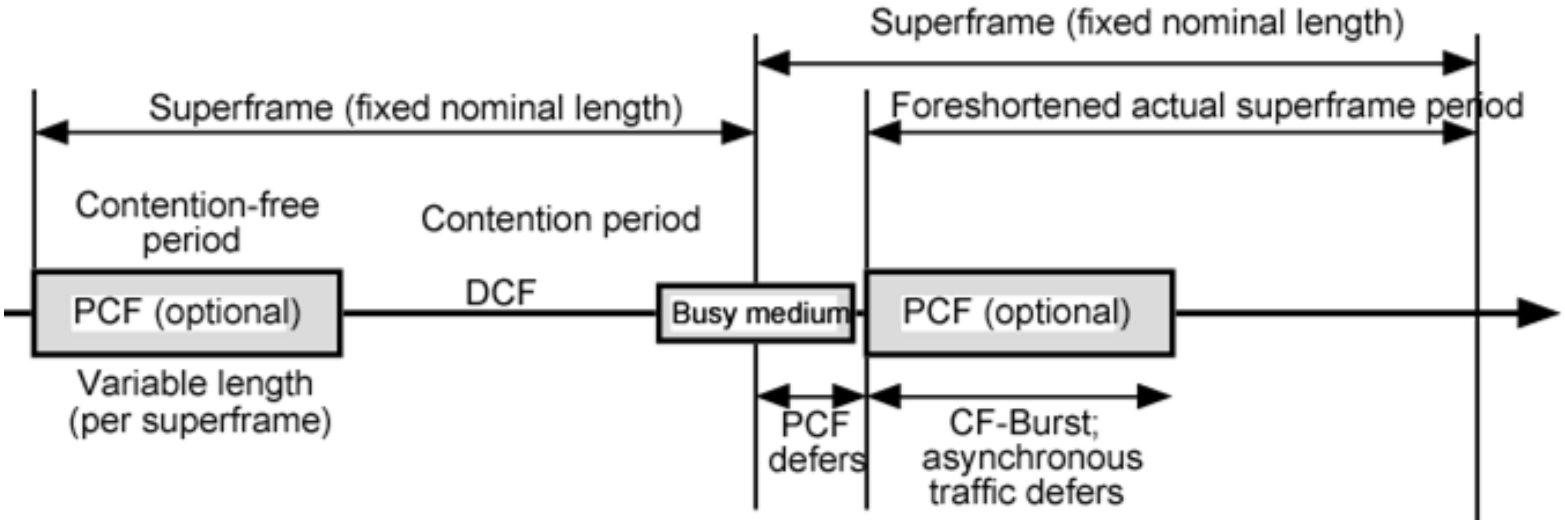
- Polling by centralized polling master (point coordinator)
  - Uses PIFS (<DIFS) when issuing polls
  - Can seize medium and lock out all asynchronous traffic while it issues polls and receives responses
- Wireless network configured so number of stations with time-sensitive traffic are controlled by point coordinator
  - 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 another poll
  - Repeat until current round ended

Super-frame

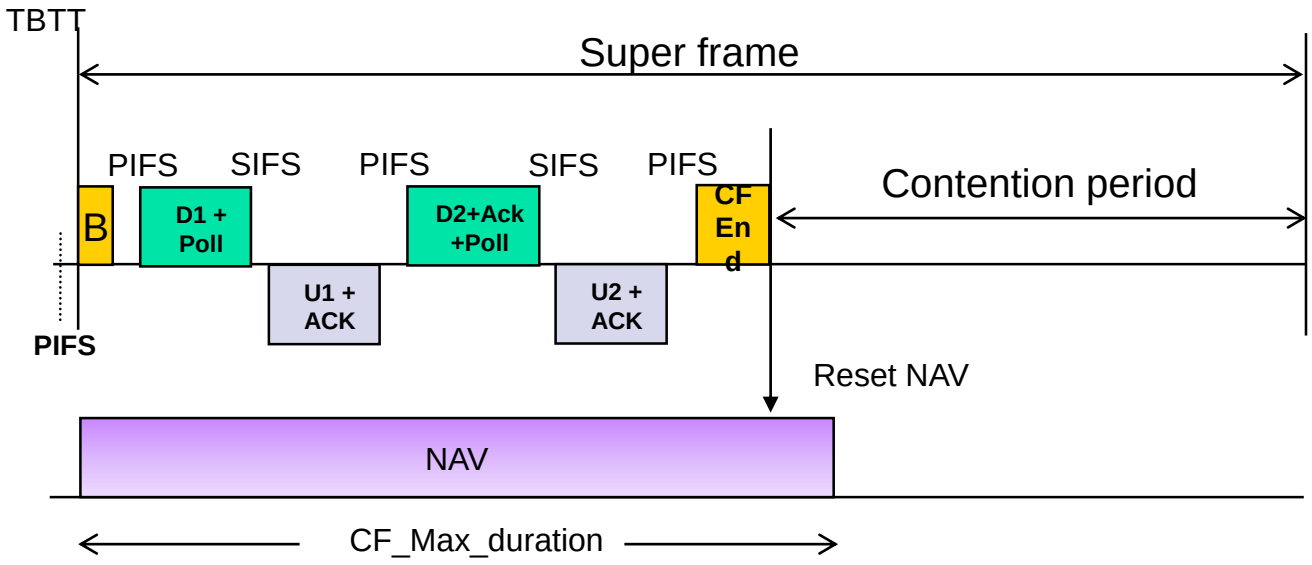
- Super-frame defined by PCF
  - During first part of super-frame interval, point coordinator polls round-robin to all polling stations
  - Remainder of super-frame allows contention period for asynchronous access
- At beginning of super-frame, point coordinator creates a contention-free period
  - Time varies because of variable frame size issued by responding stations
  - Rest of super-frame available for contention-based access
- At end of super-frame interval, point coordinator contends for access using PIFS
  - By beacon frame, results in super-frame period for next cycle

超级帧：
点协调器不断发布轮询，会封锁所有异步通信量。为了避免这种情况，在超帧时间的前一部分，有点协调器轮询，在超帧时间的后一部分，允许异步通信量争用接入。

IEEE 802.11 MAC Timing – PCF



PCF Frame Transfer



D1, D2 = frame sent by point coordinator
U1, U2 = frame sent by polled station
TBTT = target beacon transmission time
B = beacon frame

IEEE 802.11 MAC Frames

- Management frames
- Control frames
- Data frames

Management Frames

- Manage communications between stations and APs
  - Station association & disassociation with AP
  - Authentication & deauthentication
  - Timing & synchronization

Control Frames

- Power Save-Poll (PS-Poll)
  - Sent by any station to AP
  - Request AP transmission frame buffered for this station while station in power-saving mode
- Request to Send (RTS)
- Clear to Send (CTS)
- Acknowledgment (ACK)
- Contention-Free-End (CF-End)
  - Announces end of contention-free period (PCF)
- CF-End + CF-Ack:
  - Acknowledges CF-End
  - Releases stations from associated restrictions

Data Frames – Data Carrying

- 8 data frame subtypes, in two groups

First 4 carry upper-level data from source station to destination station

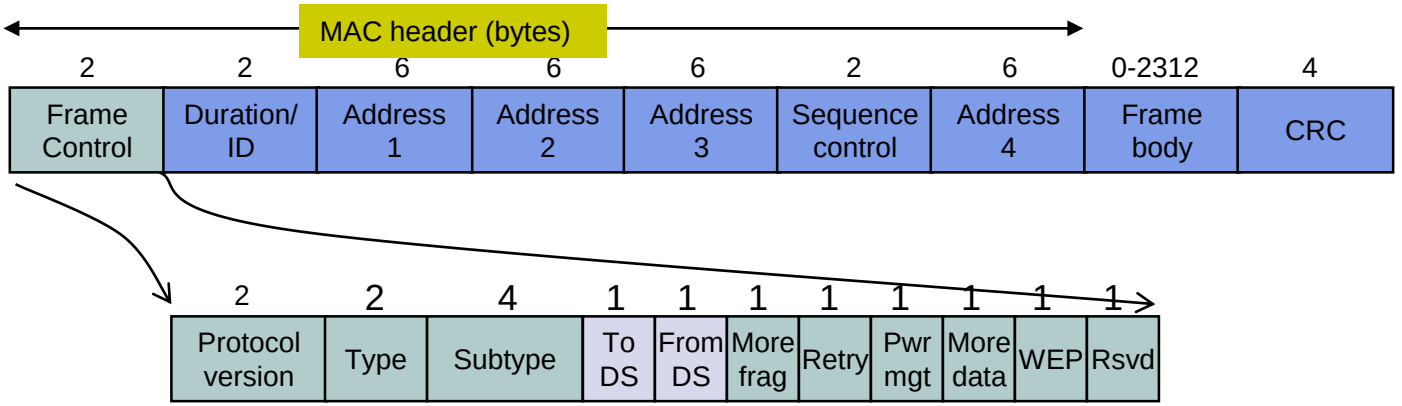
- Data
  - Pure data frame
- Data + CF-Ack
  - Sent during contention-free period
  - Carries data and acknowledges previously received data
- Data + CF-Poll
  - Used by point coordinator to deliver data
  - Also to request station send data frame it may have buffered
- Data + CF-Ack + CF-Poll
  - Combines Data + CF-Ack and Data + CF-Poll

Data Frames – No Data Carrying

Last 4 data frames do not carry user data

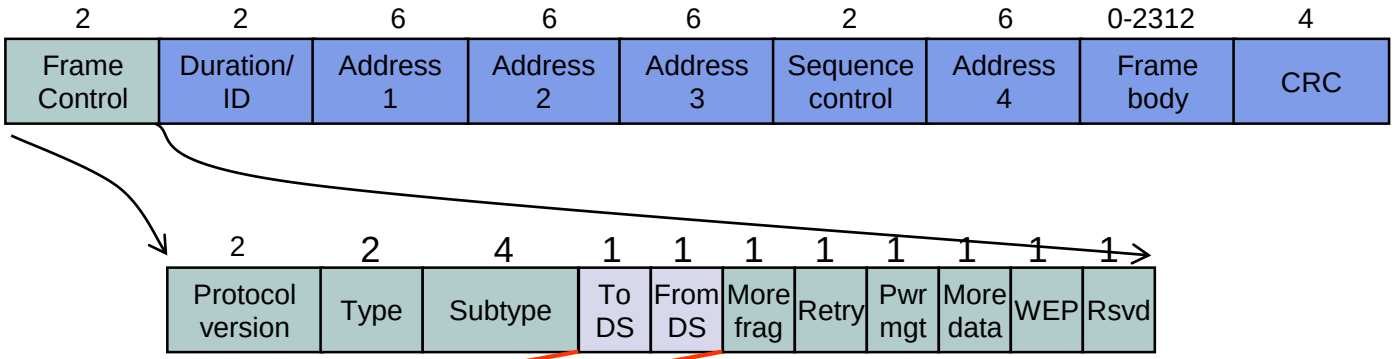
- Null Function
  - Carries no data, polls, or acknowledgments
  - Carries power management bit in frame control field to AP
  - Indicates station is changing to low-power state
- Other 3 frames
  - CF-Ack, CF-Poll, CF-Ack + CF-Poll
  - Same as corresponding frame in preceding list but without data

Frame Control Fields (1)



- Protocol version = 0
- Type: Management (00), Control (01), Data (10)
- Subtype within frame type, e.g.
  - Type=00, subtype=association; Type=01, subtype=ACK
- MoreFrag=1 if another fragment of MSDU to follow

Frame Control Fields (2)

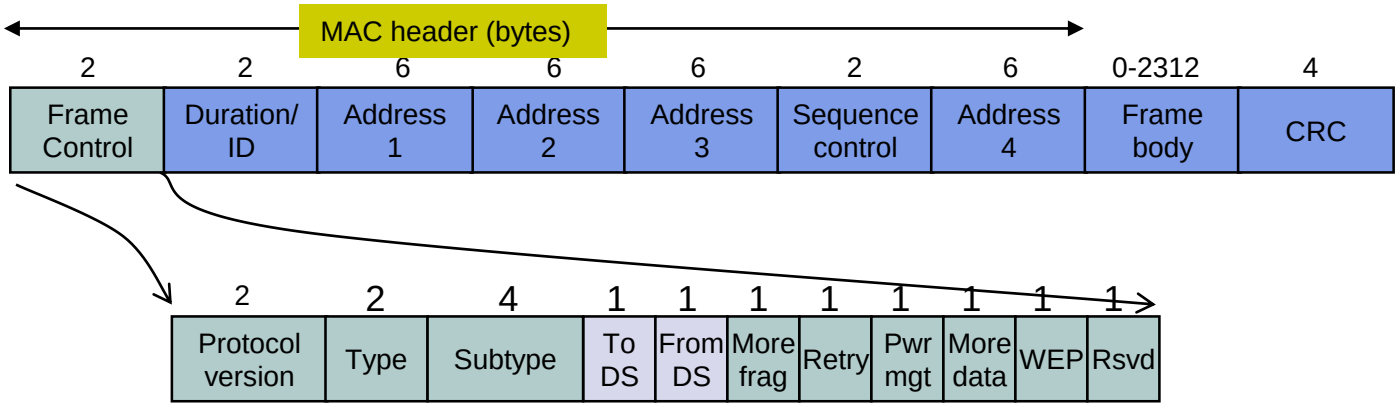


To DS	From DS	Address 1	Address 2	Address 3	Address 4	Meaning
0	0	Destination address	Source address	BSS ID	N/A	Data frame from station to station within a BSS
0	1	Destination address	BSS ID	Source address	N/A	Data frame exiting the DS
1	0	BSS ID	Source address	Destination address	N/A	Data frame destined for the DS
1	1	Receiver address	Transmitter address	Destination address	Source address	WDS frame being distributed from AP to AP

To DS = 1 if frame goes to DS; From DS = 1 if frame exiting DS

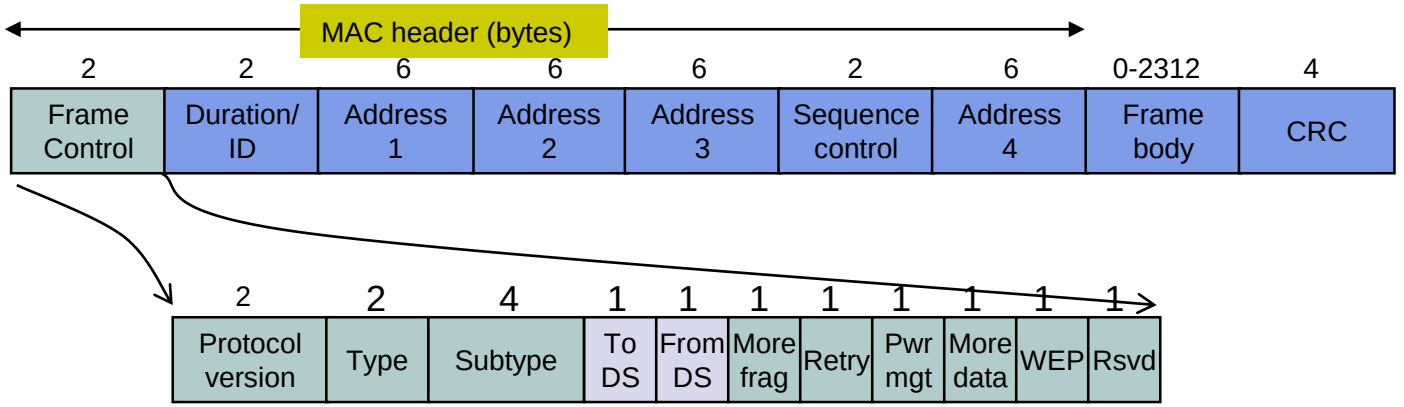
- Address 4: used only in ad hoc mode

Frame Control Fields (3)



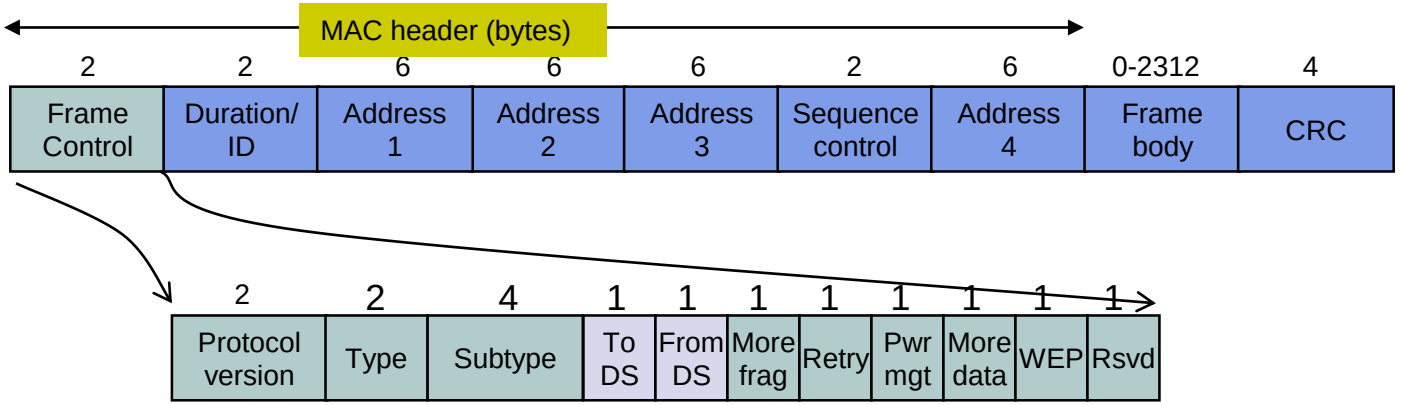
- Retry =1 if mgmt/control frame is a retransmission
- Power Management used to put station in/out of sleep mode
- More Data =1 to tell station in power-save mode more data buffered for it at AP
- WEP =1 if frame body encrypted

Other MAC Frame Fields (1)



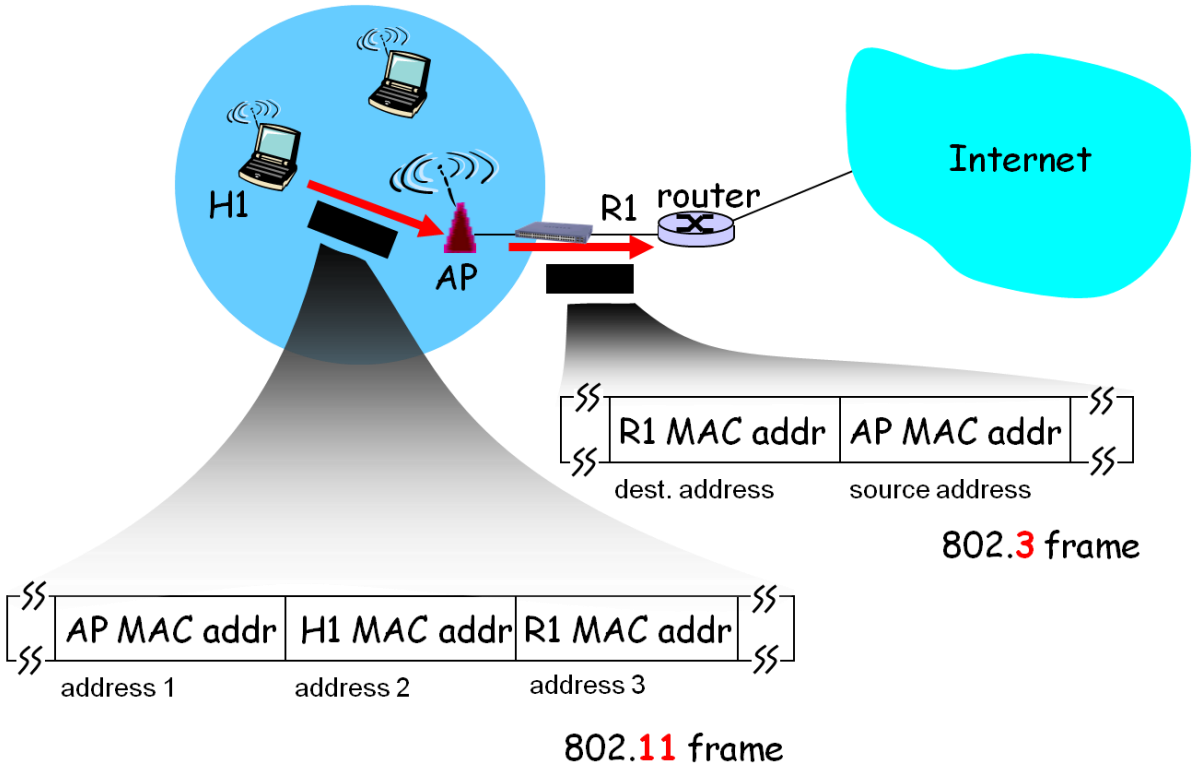
- Duration/Connection ID
  - If used as duration, indicates time (in μs) channel will be allocated for successful transmission of MAC frame
  - In some management frames, contains association or connection identifier
- Addresses
  - Number and meaning of address fields depend on context
  - Types include source, destination, transmitting station, and receiving station

Other MAC Frame Fields (2)



- Sequence Control
  - 4-bit fragment number subfield
    - For fragmentation and reassembly
  - 12-bit sequence number
  - Number frames between given transmitter and receiver
- Frame Body
  - MSDU, or a fragment of MSDU
  - LLC PDU or MAC control information
- Frame Check Sequence
  - 32-bit cyclic redundancy check

Integrate 802.11 and 802.3 nets

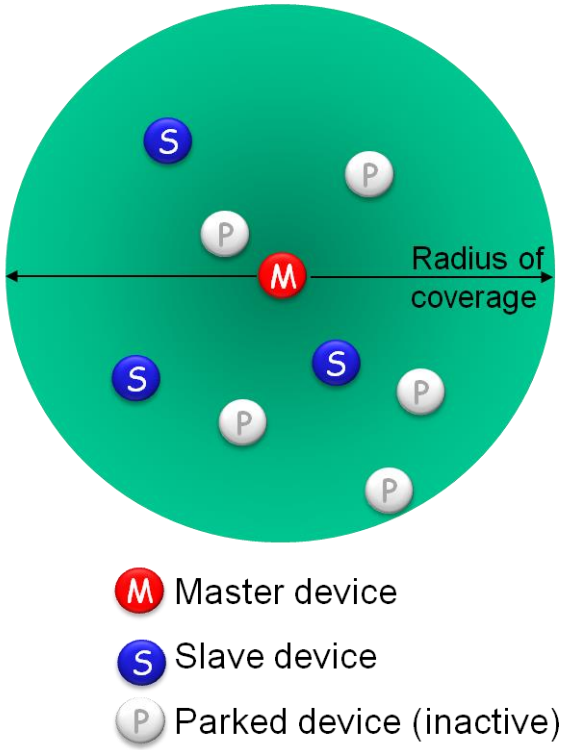


802.11 Physical Layer

- 1997
  - IEEE 802.11, includes MAC layer and 3 physical layer specifications
  - Two in 2.4-GHz band and one infrared
  - All operating at 1 and 2 Mbps
- 1999
  - IEEE 802.11a, 5-GHz band up to 54 Mbps
  - IEEE 802.11b, 2.4-GHz band at 5.5 and 11 Mbps
- 2003 and later
  - IEEE 802.11g, extends IEEE 802.11b, up to 54 Mbps
  - IEEE 802.11n, improves 802.11a and 802.11g using multiple antennae (MIMO, multiple-input multiple-output)

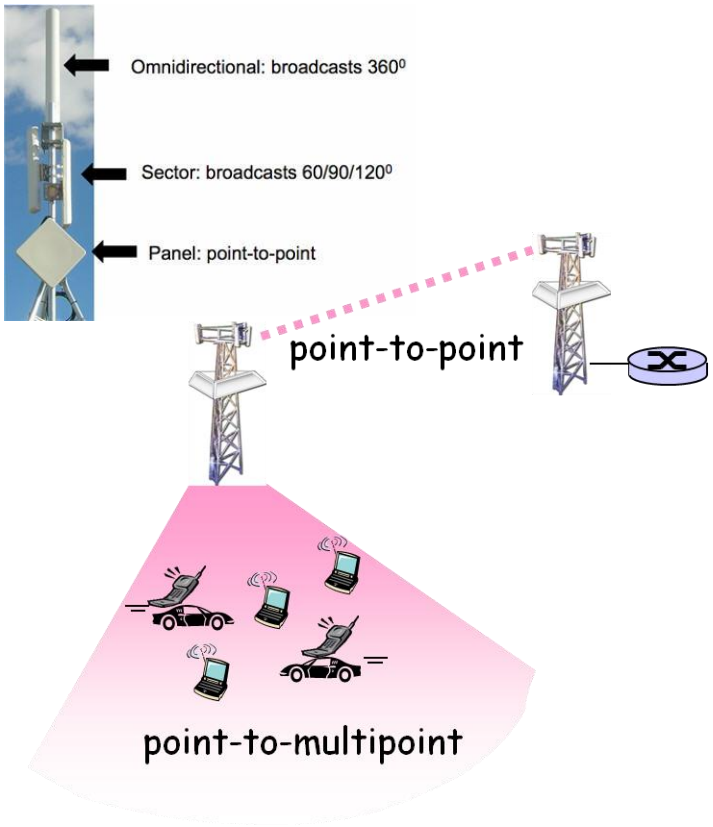
802.15: Personal Area Network

- 802.15
  - Evolved from Bluetooth specification
  - 2.4 GHz radio band
  - <10m diameter, Up to 721 kbps
- Functions
  - Replacement for cables (mouse, keyboard, headphones)
- Master/Slaves:
  - Slaves request permission to send (to master)
  - Master grants requests



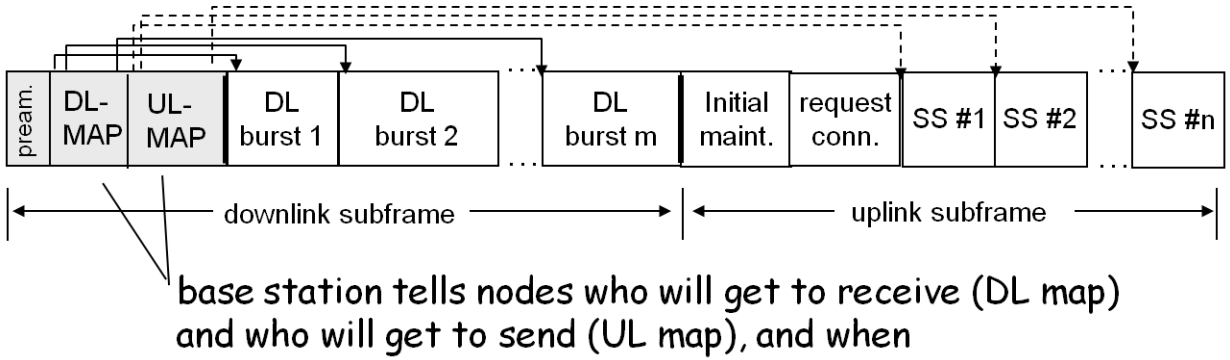
802.16: WiMAX

- Worldwide Interoperability for Microwave Access
- Like 802.11 & cellular: base station model
  - Transmissions to/from base station by hosts with omnidirectional antenna
  - Base station-to-base station backhaul with point-to-point antenna
- Unlike 802.11
  - Range ~ 6 miles ("city area")
  - ~14 Mbps



802.16: WiMAX

- Channel partitioning
  - The subscriber station (SS) cannot transmit data until allocated a channel by the Base Station (BS)
- Transmission frame
  - Down-link subframe: base station to node
  - Uplink subframe: node to base station



Summary

- 无线局域网的组成
- 802.11的服务
- 802.11的MAC协议：CSMA/CA
  - 与CSMA/CD作比较
- 802.11的帧类型和帧格式
  - 与以太网帧格式比较

Homework

- 书第17章习题：17.1，17.11，17.8