

18-452/18-750
Wireless Networks and Applications

Lecture 10: Wireless LAN
802.11 MAC

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<http://www.cs.cmu.edu/~prs/wirelessS17/>

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Outline

- 802 protocol overview
- Wireless LANs – 802.11
 - » Overview of 802.11
 - » 802.11 MAC, frame format, operations
 - » 802.11 management
 - » 802.11*
 - » Deployment example
- Personal Area Networks – 802.15

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Features of 802.11 MAC protocol

- Supports MAC functionality
 - » Addressing
 - » CSMA/CA
- Error detection (FCS)
- Error correction (ACK frame)
- Flow control: stop-and-wait
- Fragmentation (More Frag)
- Collision Avoidance (RTS-CTS)

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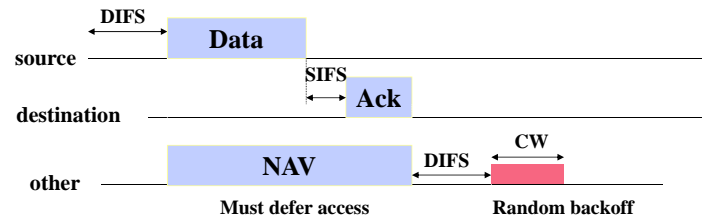
Carrier Sense Multiple Access

- Before transmitting a packet, sense carrier
- If it is idle, send
 - » After waiting for one DCF inter frame spacing (DIFS)
- If it is busy, then
 - » Wait for medium to be idle for a DIFS (DCF IFS) period
 - » Go through exponential backoff, then send (non-persistent solution)
 - » Want to avoid that several stations waiting to transmit automatically collide
 - » Cost of back off is high and expect a lot of contention
- Wait for ack
 - » If there is one, you are done
 - » If there isn't one, assume there was a collision, retransmit using exponential backoff

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DCF mode transmission without RTS/CTS



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Exponential Backoff

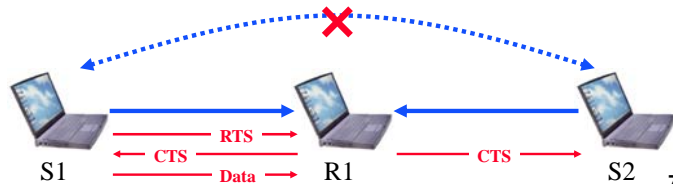
- **Force stations to wait for random amount of time to reduce the chance of collision**
 - » Backoff period increases exponential after each collision
 - » Similar to Ethernet
- **If the medium is sensed it is busy:**
 - » Wait for medium to be idle for a DIFS (DCF IFS) period
 - » Pick random number in contention window (CW) = backoff counter
 - » Decrement backoff timer until it reaches 0
 - But freeze counter whenever medium becomes busy
 - » When counter reaches 0, transmit frame
 - » If two stations have their timers reach 0; collision will occur;
- **After every failed retransmission attempt:**
 - » increase the contention window exponentially
 - » $2^i - 1$ starting with CW_{min} up to CW_{max} e.g., 7, 15, 31, ...

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Collision Avoidance

- **Difficult to detect collisions in a radio environment**
 - » While transmitting, a station cannot distinguish incoming weak signals from noise – its own signal is too strong
- **Why do collisions happen?**
 - » Near simultaneous transmissions
 - Period of vulnerability: propagation delay
 - » Hidden node situation: two transmitters cannot hear each other and their transmission overlap at a receiver



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Request-to-Send and Clear-to-Send

- **Before sending a packet, first send a station first sends a RTS**
 - » Collisions can still occur but chance is relatively small since RTS packets are short
- **The receiving station responds with a CTS**
 - » Tells the sender that it is ok to proceed
- **RTS and CTS use shorter IFS to guarantee access**
 - » Effectively priority over data packets
- **First introduced in the Multiple Access with Collision Avoidance (MACA) protocol**
 - » Fixed problems observed in Aloha

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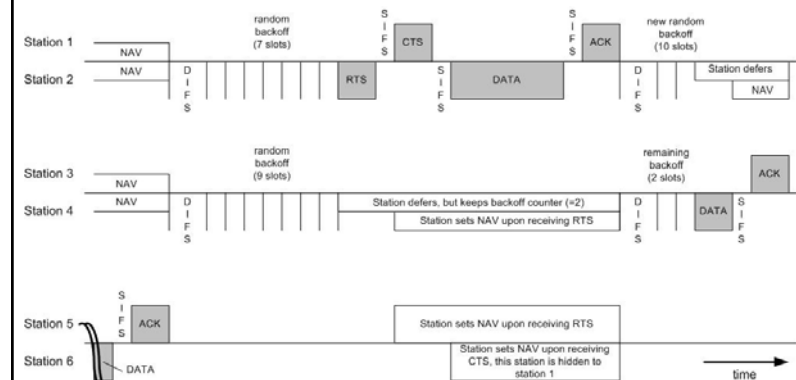
Virtual Carrier Sense

- RTS and CTS notify nodes within range of sender and receiver of upcoming transmission
- Stations that hear either the RTS or the CTS “remember” that the medium will be busy for the duration of the transmission
 - » Based on a Duration ID in the RTS and CTS
 - » Note that they may not be able to hear the data packet!
- Virtual Carrier Sensing: stations maintain Network Allocation Vector (NAV)
 - » Time that must elapse before a station can sample channel for idle status
 - » Consider the medium to be busy even if it cannot sense a signal

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Use of RTS/CTS



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Some More MAC Features

- Use of RTS/CTS is controlled by an RTS threshold
 - » RTS/CTS is only used for data packets longer than the RTS threshold
 - » Pointless to use RTS/CTS for short data packets – high overhead!
- Number of retries is limited by a Retry Counter
 - » Short retry counter: for packets shorter than RTS threshold
 - » Long retry counter: for packets longer than RTS threshold
- Packets can be fragmented.
 - » Each fragment is acknowledged
 - » But all fragments are sent in one sequence
 - » Sending shorter frames can reduce impact of bit errors
 - » Lifetime timer: maximum time for all fragments of frame

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Features of 802.11 MAC protocol

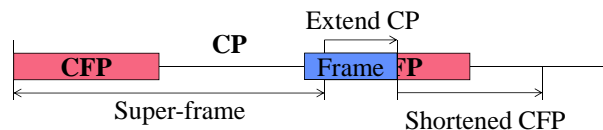
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Now What about PCF?

- IEEE 802.11 combines random access with a “taking turns” protocol
 - » DCF (Distributed Coordination Mode) – Random access
 - CP (Contention Period): CSMA/CA is used
 - » PCF (Point Coordination Mode) – Polling
 - CFP (Contention-Free Period): AP polls hosts



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Playing Games with Inter Frame Spacing

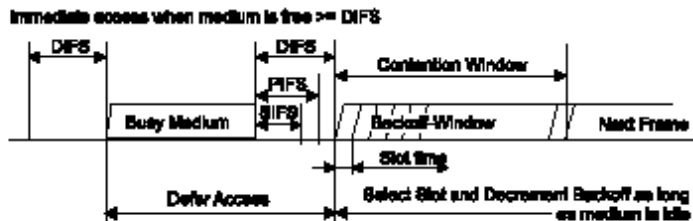
- Assigning different IFS effectively provides a mechanism for prioritizing packets and events
- SIFS - short IFS: for high priority transmissions
- PIFS – PCF IFS: used by PCF during contention-free period
- DIFS – DCF IFS: used for contention-based services
- EIFS – extended IFS: used when there is an error



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Effect of Different IFS



- PCF transmissions effectively get priority over DCF transmission because they use a shorter IFS

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PCF Operation Overview

- PC – Point Coordinator
 - » Uses polling – eliminates contention
 - » Polling list ensures access to all registered stations
 - » Over DCF but uses a PIFS instead of a DIFS – gets priority
- CFP – Contention Free Period
 - » Alternate with DCF
- Periodic Beacon – contains length of CFP
 - » NAV prevents transmission during CFP
 - » CF-End – resets NAV
- CF-Poll – Contention Free Poll by PC
 - » Stations can return data and indicate whether they have more data
 - » CF-ACK and CF-POLL can be piggybacked on data

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And What about Ad Hoc?

- **Infrastructure mode: access points relay packets**
 - » Based on an Infrastructure BSS
 - » APs are connected through a distribution system
- **Ad-hoc mode: no fixed network infrastructure**
 - » Based on an Independent BSS
 - » A wireless endpoint sends and all nodes within range can pick up signal
 - » Each packet carries destination and source address
 - » Effectively need to implement a “network layer”
 - How do know who is in the network?
 - Routing?
 - Security?
 - » Research area – discussed later in the course

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Summary WiFi

- **Supports infrastructure and ad hoc mode**
- **Uses ACKs to detect collisions**
- **Uses RTS-CTS to avoid hidden terminals**
 - » Adds virtual carrier sense to physical carrier sense
 - » Almost never used because of overhead
- **Supports a point control function in addition to distributed control**
 - » Supports scheduled access in addition to random access
 - » Almost never used because of overhead

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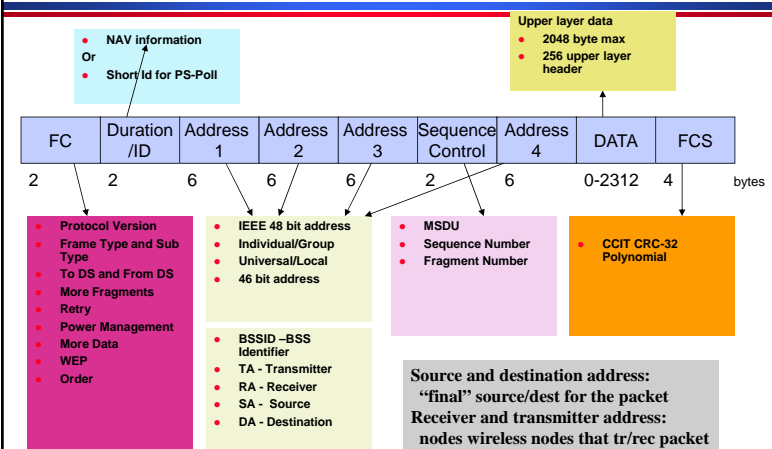
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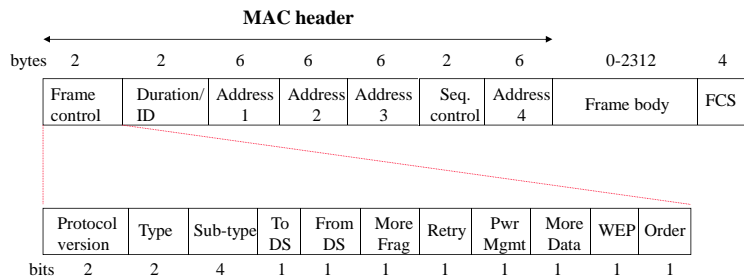
Frame Format (802.11b)



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Detailed 802.11 MAC Frame Format



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Packet Types

- **Type/sub-type field is used to indicate the type of the frame**
- **Management:**
 - » Association/Authentication/Beacon
- **Control**
 - » RTS, CTS, CF-end, ACK
- **Data**
 - » Data only, or Data + CF-ACK, or Data + CF-Poll or Data + CF-Poll + CF-ACK

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Addressing Fields

To DS	From DS	Message	Address 1	Address 2	Address 3	Address 4
0	0	station-to-station frames in an IBSS; all mgmt/control frames	DA	SA	BSSID	N/A
0	1	From AP to station	DA	BSSID	SA	N/A
1	0	From station to AP	BSSID	SA	DA	N/A
1	1	From one AP to another in same DS	RA	TA	DA	SA

RA: Receiver Address TA: Transmitter Address
 DA: Destination Address SA: Source Address
 BSSID: MAC address of AP in an infrastructure BSS

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Some More Fields

- **Duration/ID:** Duration in DCF mode/ID is used in PCF mode
- **More Frag:** 802.11 supports fragmentation of data
- **More Data:** In polling mode, station indicates it has more data to send when replying to CF-POLL
- **RETRY** is 1 if frame is a retransmission; **WEP** (Wired Equivalent Privacy)
- **Power Mgmt** is 1 if in Power Save Mode; **Order** = 1 for strictly ordered service

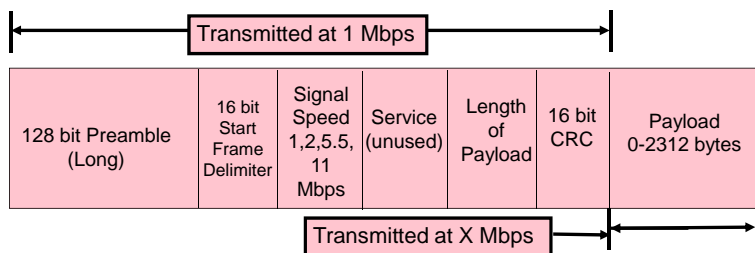
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Long Preamble

Long Preamble = 144 bits

- Interoperable with older 802.11 devices
- Entire Preamble and 48 bit PLCP Header sent at 1 Mbps



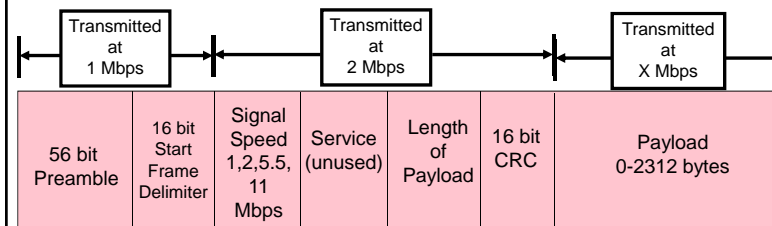
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Short Preamble

Short Preamble = 72 bits

- Preamble transmitted at 1 Mbps
- PLCP Header transmitted at 2 Mbps
- more efficient than long preamble



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Multi-bit Rate

- 802.11 allows for multiple bit rates
 - » Allows for adaptation to channel conditions
 - » Specific rates dependent on the version
- Algorithm for selecting the rate is not defined by the standard – left to vendors
 - » Still a research topic!
 - » More later in the semester
- Packets have multi-rate format
 - » Different parts of the packet are sent at different rates
 - » Why?

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Data Flow Examples

- Case 1: Packet from a station under one AP to another in same AP's coverage area
- Case 2: Packet between stations in an IBSS
- Case 3: Packet from an 802.11 station to a wired server on the Internet
- Case 4: Packet from an Internet server to an 802.11 station

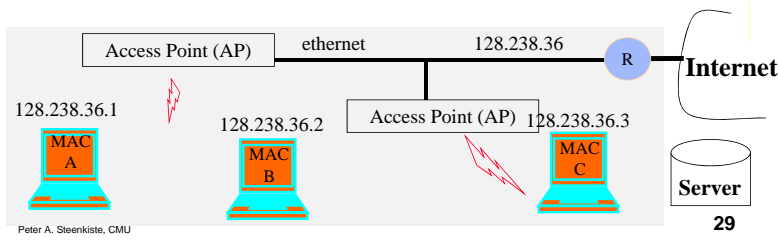
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Some Background: Forwarding Logic

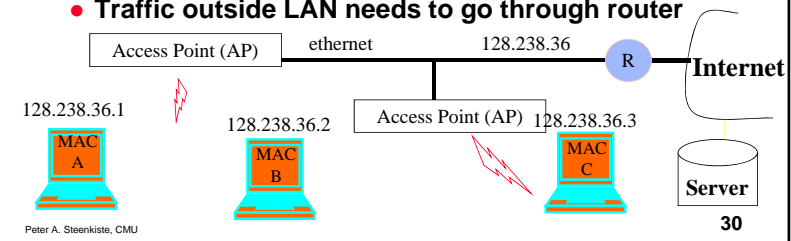
- When node needs to send an IP packet:
 - » In the same IP network?
 - Check destination IP address
 - » Yes: forward based on MAC address
 - Uses ARP protocol to map IP to MAC address
 - » No: forward packet to “gateway” router
 - Uses MAC address of the router

Application
Presentation
Session
Transport
Network
Data link
Physical

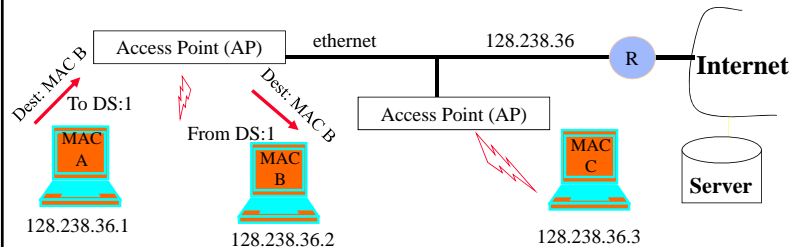


Communication in LANs

- Every interface to the network has a IEEE MAC and an IP address associated with it
 - » True for both end-points and routers
- IP address inside a LAN share a prefix
 - » Prefix = first part of the IP address, e.g., 128.238.36
 - » Can be used to determine whether devices are on same LAN
- Traffic outside LAN needs to go through router



Case 1: Communication Inside BSS

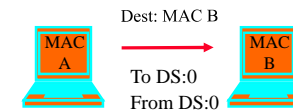


- AP knows which stations are registered with it so it knows when it can send frame directly to the destination
- Frame can be set directly to the destination by AP

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Case 2: Ad Hoc

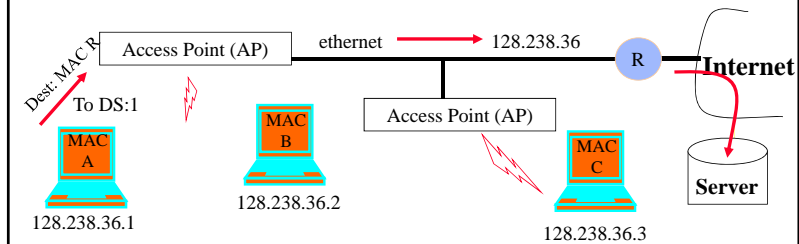


- Direct transmit only in IBSS (Independent BSS), i.e., without AP
- Note: in infrastructure mode (i.e., when AP is present), even if B can hear A, A sends the frame to the AP, and AP relays it to B

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Case 3: To the Internet

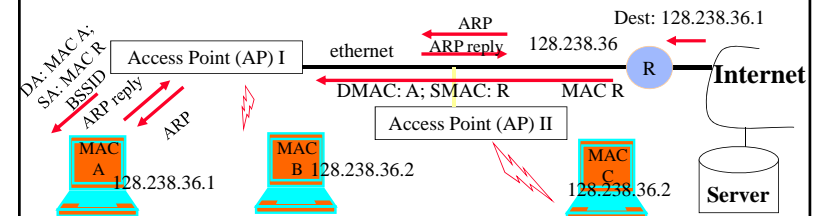


- MAC A determines IP address of the server (using DNS)
- From the IP address, it determines that server is in a different subnet
- Hence it sets MAC R as DA;
- » Address 1: BSSID, Address 2: MAC A; Address 3: DA
- AP will look at the DA address and send it on the ethernet
- » AP is an 802.11 to ethernet bridge
- Router R will relay it to server

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Case 4: From Internet to Station



- Packet arrives at router R – uses ARP to resolve destination IP address
 - » AP knows nothing about IP addresses, so it will simply broadcast ARP on its wireless link
 - » DA = all ones – broadcast address on the ARP
- MAC A host replies with its MAC address (ARP reply)
 - » AP passes on reply to router
- Router sends data packet, which the AP simply forwards because it knows that MAC A is registered
- Will AP II broadcast the ARP request on the wireless medium? How about the data packet?

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Summary

- Wifi packets have 4 MAC addresses
- Needed to support communication inside a LAN, across access points connected by a wired LAN
- WiFi frames have a multi-rate format, i.e., different parts are sent at different rates
 - » The header is sent at a lower rate to improve chances it can be decoded by receivers
 - » Contains critical information such as virtual carrier sense, and the bit rate used for the data

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