ECE 356/COMPSI 356
Computer Network Architecture

Lecture 6: Ethernet & WiFi MAC

Wednesday September 11, 2019

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Recap

- Last lecture:
  - Link layer functionality
  - Introduction to wireless communications
- Material for this lecture: **PD 2.6, 2.7**

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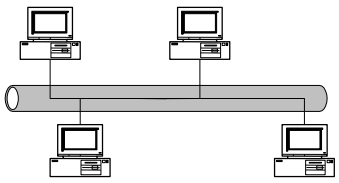
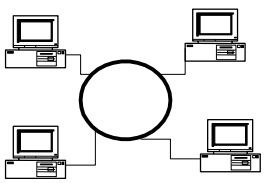
Lecture Outline

- Introduction to multiple-access links
- Ethernet: an introduction
- Ethernet Medum Access Control (MAC)
- Ethernet in practice
- WiFi Medium Access Control

Multiple-access Links (1/2)



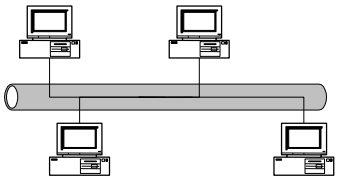
•Bus LAN



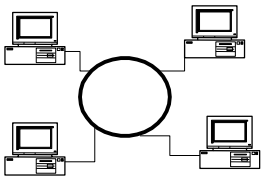
•Ring LAN

- Many nodes attached to the same link
  - Ethernet
  - Token rings
  - Wireless networks

Multiple-access Links (2/2)



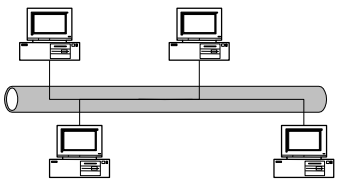
•Bus LAN



•Ring LAN

- Problem: who gets to send a frame?
  - Multiple senders transmitting at the same time leads to *collisions*

CSMA/CD and CSMA/CA



•Bus LAN

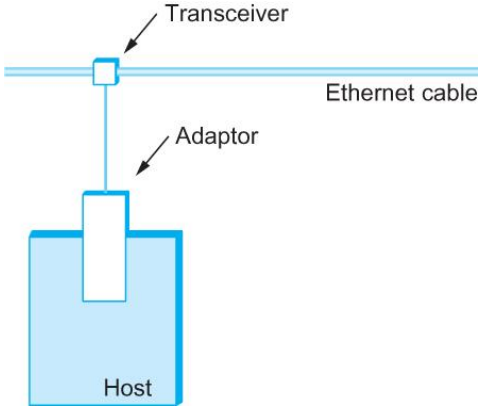
- Ethernet: Carrier Sense Multiple Access with **Collision Detection** (CSMA/CD)
- WiFi: Carrier Sense Multiple Access with **Collision Avoidance** (CSMA/CA)

Ethernet: An Introduction

- Most successful LAN technology of the last 20 years
- Developed in mid-1970s at Xerox PARC
- Speed: 10 Mbps – multi-Gbps
  - Industry roadmap expects 800 Gbps after 2020
- Standard: 802.3, Ethernet II (DIX, stands for Digital-Intel-Xerox)
- Bus topology

Physical Properties

Sensing the line; if idle, sends signals

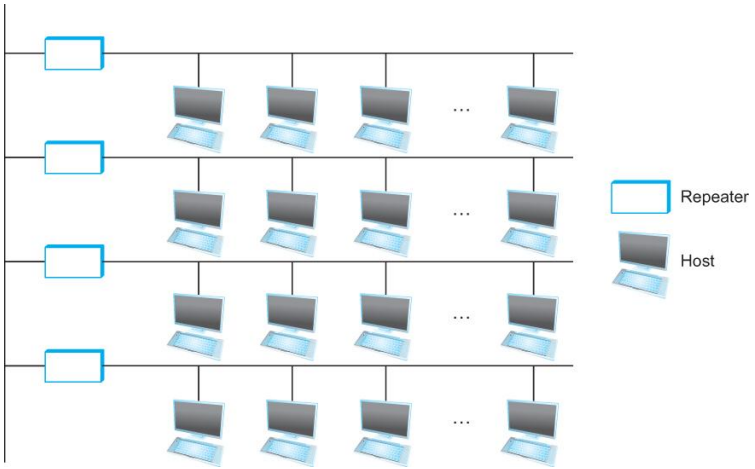


Transceiver

- A small device directly attached to the tap
- Detects when the line is idle and drives the signal when the host is transmitting
- Receives incoming signals

How to Expand an Ethernet Segment: Repeaters (1/2)

- A repeater is a device that forwards digital signals
  - Like an amplifier
- Multiple segments can be joined together by repeaters



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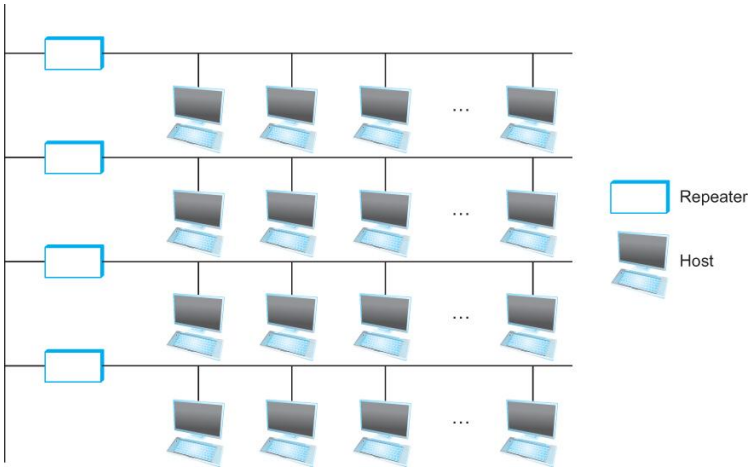
How to Expand an Ethernet Segment: Repeaters (2/2)

- No more than four repeaters between any host
  - <2500 meters
- < 1024 hosts
- Terminators are attached to each end of the segment
- Manchester encoding



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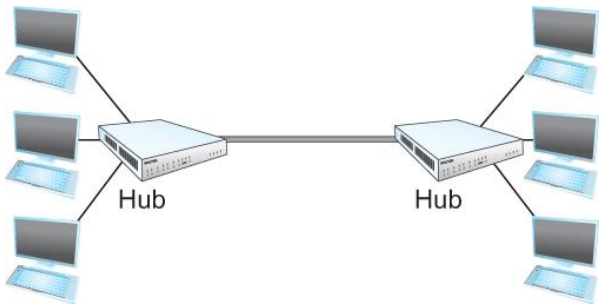
How to Expand an Ethernet Segment: Hubs

- Starting with 10Base-T, stations are connected to a hub (or a switch) in a star configuration
- 100 Mbps, 1000 Mbps



A hub is a multiway repeater

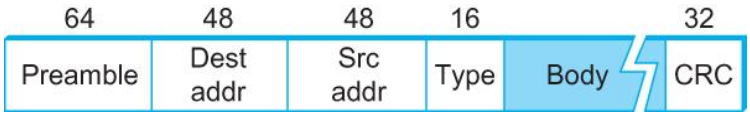
Collision Domain

- Any host hears any other host
  - A single segment
  - Multiple segments connected by repeaters
  - Multiple segments connected by a hub
- Hosts competing for access to the same link are the in the same *collision domain*

Lecture Outline

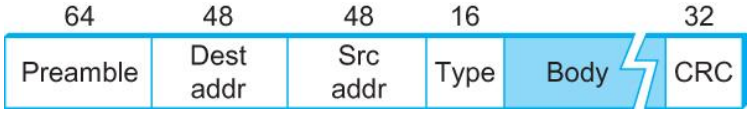
- Introduction to multiple-access links
- Ethernet: an introduction
- **Ethernet Medium Access Control (MAC)**
- Ethernet in practice
- WiFi Medium Access Control
-

Ethernet Frame Format (1/2)



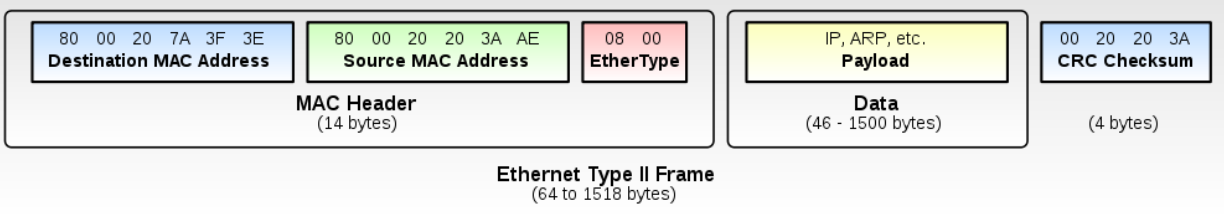
- Bit-oriented framing
- In a host's memory, Ethernet header is 14 bytes
- The adaptor adds the preamble and CRC
- Source, destination addresses: 48 bits
- The type field is the de-multiplexor

Ethernet Frame Format (2/2)



- 46-1500 bytes of data
  - Pad to minimum length
  - Minimum length is for collision detection

A Prettier Picture



- You will need to know this for Lab 2

Ethernet Addresses

- A flat unique 6-byte address per adaptor
  - E.g., 00:13:E8:6D:8C:3D
- Each manufacture is given a unique prefix
  - E.g.: **1C:5A:3E**:??:??:?? : Samsung Electronics
- An all 1s address is a broadcast address (FF:FF:FF:FF:FF:FF)
- An address with first bit 1 but not broadcast is multicast

Finding Ethernet Addresses of Your Device Interfaces

- Windows: *ipconfig /all*
- Linux/Unix: *ipconfig -a*
- Android: *settings -> about phone -> phone status*
- iPhone: *settings -> general -> about*
- Who manufactured your device?
  - hwaddress.com
  - macvendorlookup.com

Professor's Example

- Android phone Wi-Fi MAC c0:ee:fb:..: .. :..
- macvendorlookup:

Company	**OnePlus Tech (Shenzhen) Ltd**
Address	18F Tairan Building C, Tairan 8th Road Chegongmiao, Futian Shenzhen Guangdong 518040 CHINA
Range	`C0:EE:FB:00:00:00 - C0:EE:FB:FF:FF:FF`

Receiver Operation

- An adaptor receives
  - Frames with its address as a destination address
  - In promiscuous mode, all frames
  - Broadcast frames
  - Multicast frames if configured to

Transmitter Algorithm

1. The adaptor receives datagram from network layer, creates frame
2. If the adaptor senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.
3. If NIC transmits an entire frame without detecting another transmission, NIC is done with frame!
4. If NIC detects another transmission while transmitting, aborts and sends jam signal (collision!)

P-persistent Protocols

- Waits for the line to go idle, then: transmits with probability p, waits with probability $q = 1\text{-}p$
- Accommodates contention for the channel
- Ethernet is *1-persistent*

When a Collision Happens

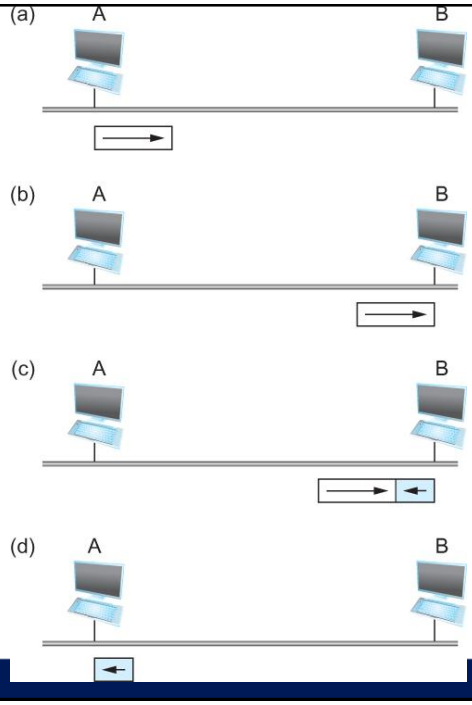
- Jam for 32 bits, then stop transmitting frame
- Wait and try again
  - *Exponential backoff:* doubling the delay interval of each collision
  - *After the nth* collision:: the adaptor waits for k x 51.2 μs, for randomly selected k=0, …, $2^n - 1$
    - 1st time: 0 or 51.2 μs
    - 2nd time: 0, 51.2, 102.4, or 153.6 μs
    - …
- Give up after several tries (usually 16)

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

- An adaptor senses the signals on the line and compares it with its own
  - If same, no collision; otherwise, collision
  - Sends 32-bit jamming sequence after collision
- In the worst case, a sender needs to send 512 bits (46+14+4 = 64B) to detect collision
  - Why?

Collision Detection: Worst Case

- Best case: A,B close by
- Worst case: A and B are at opposite ends of the network
- One-way delay is d
- A needs to send for $2d$ (round-trip delay) to detect collision
- $2d$ = 51.2 μs. On a 10 Mbps Ethernet, corresponds to 512 bits



Maximum Distance Between the Nodes

- Five physical segments between any two nodes
- Four repeaters between the nodes.
- Each segment < 500m → Total < 2500m

Maximum Distance to Minimum Frame Size

- Propagation delay for this maximum-extent Ethernet network is ~25.6 μs (5000 m / speed of light in copper)
- $2d$ = 51.2 μs (a factor of two for error margin)
  - Protocol specification is twice as strict as it needs to be
- Minimum Ethernet packet frame is 512 bits (64B)
  - Header 14B, payload 46B, CRC 4B

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- **Ethernet in practice**
- WiFi Medium Access Control

Ethernet Experience

- Work best under lightly loaded conditions
  - Over 30% utilization is considered heavy
- Used conservatively
  - Fewer than 200 hosts, far shorter than 2500 m
- Very successful
  - Easy to maintain
  - Price: does not require a switch which used to be expensive

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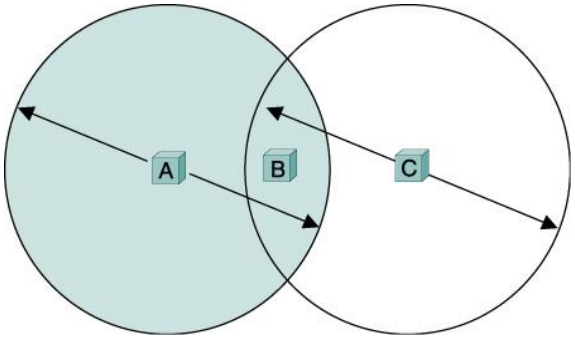
Wireless Access Control: Additional Considerations

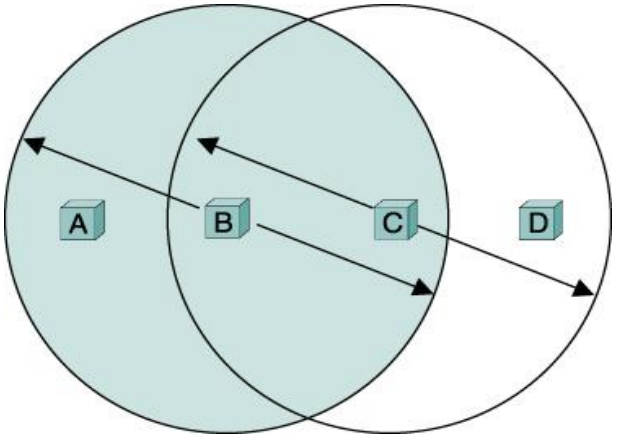
- Wireless nodes do not receive each node's transmissions
- Wireless nodes cannot transmit and receive at the same time on the same frequency
  - Strong signal generated by the transmitter "drowns out" weaker signals received from other nodes
- Uses *collision avoidance* instead of *collision detection*

Wireless Nodes Do Not All Hear Each Other: Hidden Node Problem



- A, C cannot hear each other
- Transmissions to B collide
  - A,C are not aware of a collision
  - A,C *hidden* with respect to one another

Wireless Nodes Do Not All Hear Each Other: Exposed Node Problem



- Simultaneously B can send to A, C can send to D
- C overhearing B's transmission does not mean C cannot transmit to D

802.11 (WiFi) Multiple Access with Collision Avoidance (1/2)

- Sender and receiver exchange control messages
- Sender → receiver: Request to Send (RTS)
  - Specifies the length of frame
- Receiver → sender: Clear to Send (CTS)
  - Echoes length of frame

802.11 (WiFi) Multiple Access with Collision Avoidance (2/2)

- Sender → receiver: frame
- Receiver → sender: ACK
- Other nodes can send after hearing ACK

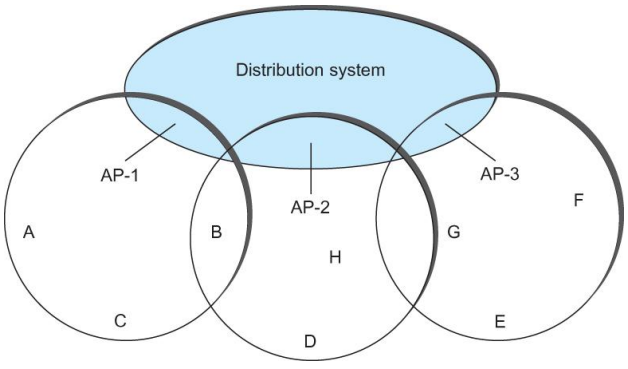
Addressing Hidden and Exposed Node Problems

- Node sees CTS
  - Too close to receiver, cannot transmit
  - Addressing hidden terminals
- Node only sees RTS
  - Okay to transmit
  - Addressing exposed terminals

How to Resolve a Collision

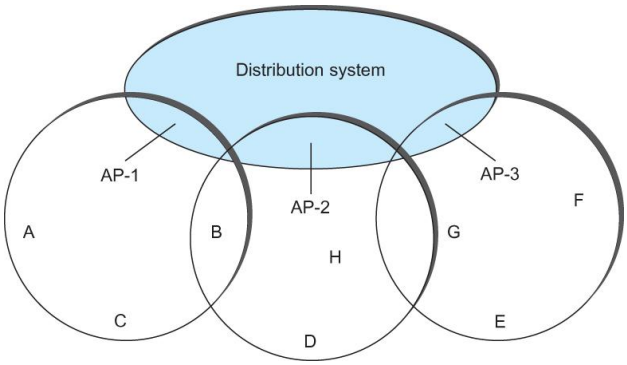
- If no CTS, then RTS collide
- Exponential backoff to retransmit

Typically 802.11 Nodes Connect to Base Stations (Access Points)



- Base stations are called Access Points (APs)
- Each node associates with one AP
- APs connect via the *distribution system*

Communications Between Individual Nodes are via Access Points

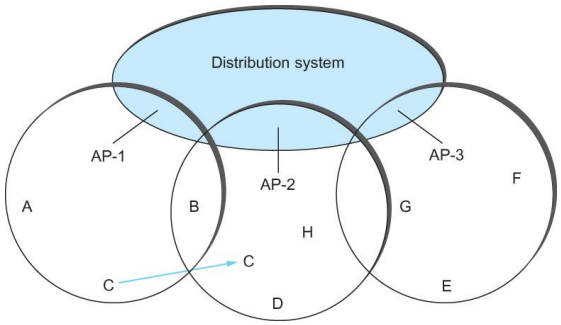


- When A communicates with E, traffic flows from A to AP-1 to AP-3 to E

Node-Access Point Association (1/2)

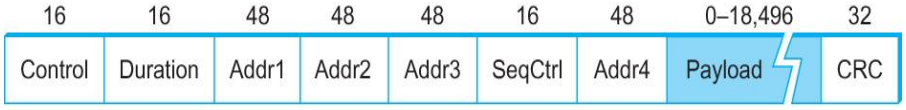
- *Active scanning*
  - Node: a *Probe*
  - All APs within reach: a *Probe Response*
  - Node selects one of APs, send an *Association Request*
  - AP replies with an *Association Response*
- *Passive scanning*
  - AP sends a *Beacon* to announce itself
  - Node sends an *Association Request*

Node-Access Point Association (2/2)



- Nodes associate with APs when joining the network and when network conditions change
- E.g., when C moves, it will change its association from AP-1 to AP-2
- Happens many times as you walk across campus

802.11 Frame Format



4 addresses

- Same AP
  - Addr1: dst
  - Addr2: src
- Different APs
  - ToDS and FromDS in control field set
  - Add1: dst, Addr2: AP_dst
  - Addr3: AP_src, Add4: src

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Next Lecture

- Wireless and mobile networking