CIS 551 / TCOM 401

Computer and Network Security

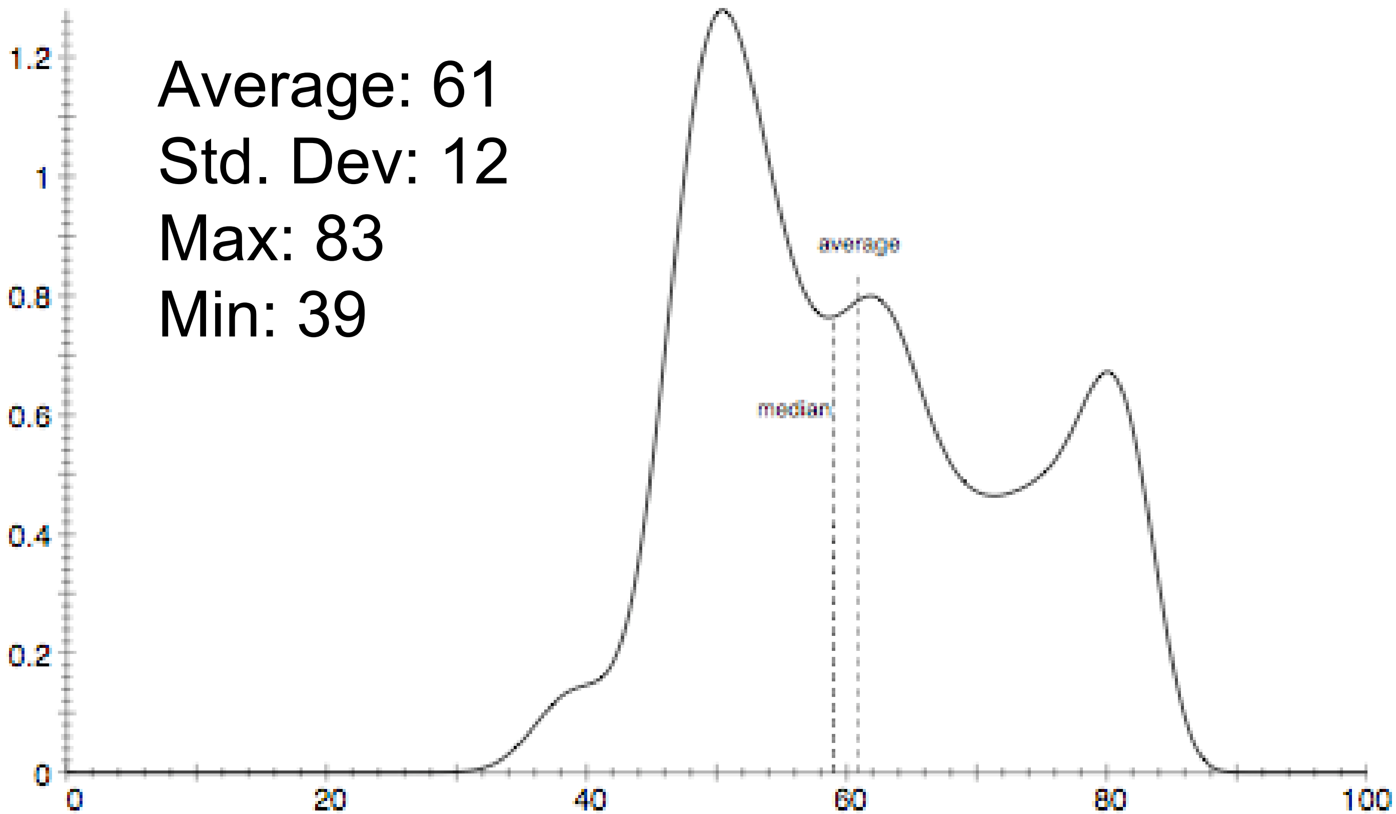
Spring 2008

Lecture 10

Announcements

- Project 2: Due March 7th
- Midterm 1 Distribution

Average: 61
Std. Dev: 12
Max: 83
Min: 39



Open Systems Interconnection (OSI)

Reference model – not actual implementation.

End Host	
Application	Transmits *messages* (e.g. FTP or HTTP)
Presentation	Data format issues (e.g. big- vs. little-endian)
Session	Manages multiple streams of data
Transport	Process to process protocols
Network	Routes *packets* among nodes in network
Data Link	Packages bit streams into *frames*
Physical	Transmits raw bits over link

IEEE 802 network standards

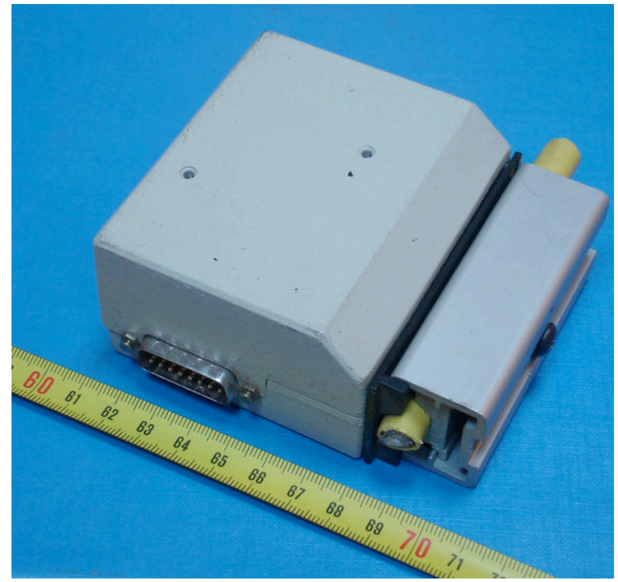
The IEEE 802 committee produces standards & specifications for Local Area Networks (LAN):

- **802.3 CSMA/CD Networks (Ethernet)**
- 802.4 Token Bus Networks
- 802.5 Token Ring Networks
- 802.6 Metropolitan Area Networks
- **802.11 Wireless LAN (Wifi) [Thursday]**

Ethernet (802.3)

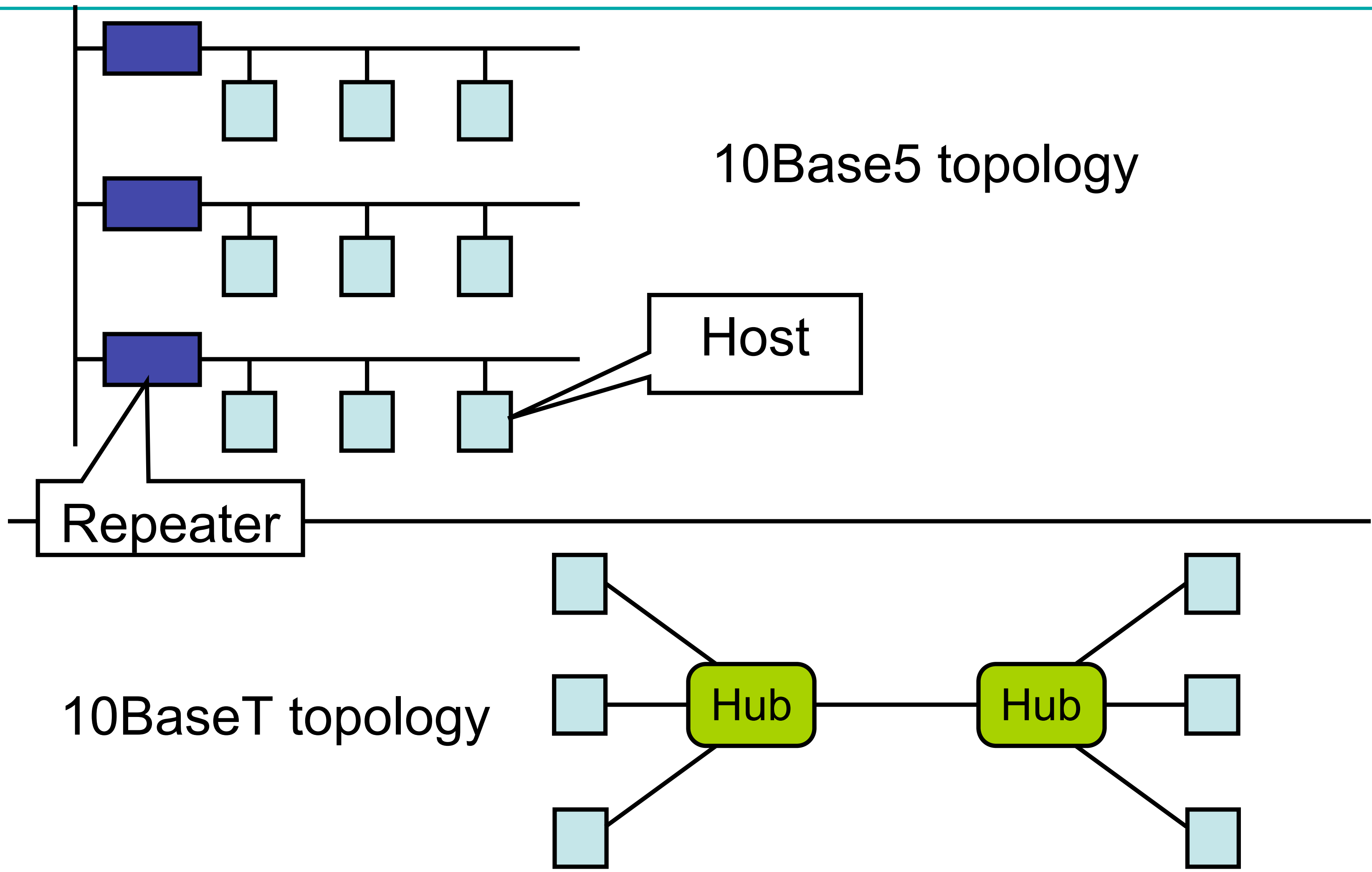
- A standard for local area networks (LAN)
- Developed in mid-70's at Xerox PARC
  - Descendent of Aloha, a U. of Hawaii radio packet network
  - DEC, Intel, and Xerox standard: 1978 for 10Mbps
  - IEEE 802.3 standard grew out of that
- Physical implementations:
  - 10Base5, 10BaseT, 100BaseT, 1000BaseT…
  - Speed: 10Mbps,100Mbps, 1000Mbps, …

Ethernet Physical links



- Originally used “Thick-net” 10Base5
  - 10 = 10Mbps
  - 5 = maximum of 500 meters segments
  - Up to 4 repeaters between two hosts
    =2500m max
- More common: 10BaseT
  - 10 = 10Mbps
  - T = Twisted pair (typically Category 5), Maximum of 100 meter segments
  - Connected via *hubs* (still 2500m max)
- Today’s standards: 100BaseT, 1000BaseT

Ethernet topologies



How the ethernet works

- The Ethernet link is *shared*
  - A signal transmitted by one host reaches *all* hosts
- Method of operation: **CSMA/CD**
  - Carrier Sense, Multiple Access, with Collision Detection
- Hosts competing for the same link are said to be in the same ***collision domain***
  - Good news: easy to exchange data
  - Bad news: have to regulate link access
- Procotol: *Media Access Control* ***(MAC)***

Ethernet Addresses

- Every adapter manufactured has a unique address
  - 6 bytes (48 bits) usually written in Hex.
  - Examples: 00-40-50-B1-39-69 and 8:0:2b:e4:b1:2
  - Each manufacturer is assigned 24bit prefix
  - Manufacturer ensures unique suffixes

Ethernet Frame Format

64	48	48	16		32
Preamble	Dest	Src	Type	Body	CRC

- Preamble – repeating pattern of 0’s & 1’s
  - Used by receiver to synchronize on signal
- Dest and Src – Ethernet Addresses
- Type – demultiplexing key
  - Identifies higher-level protocol
- Body – payload
  - Minimum 46 Bytes
  - Maximum 1500 Bytes

Addresses in an ethernet frame

- All bits = 1 indicates a *broadcast* address
  - Sent to all adapters
- First bit = 0 indicates *unicast* address
  - Sent to only one receiver
- First bit = 1 indicates *multicast* address
  - Sent to a group of receivers

An Ethernet Adapter Receives:

- Frames addressed to the broadcast address
- Frames addressed to its own address
- Frames sent to a multicast address
  - If it has been programmed to listen to that address
- All frames
  - If the adapter has been put into *promiscuous mode*

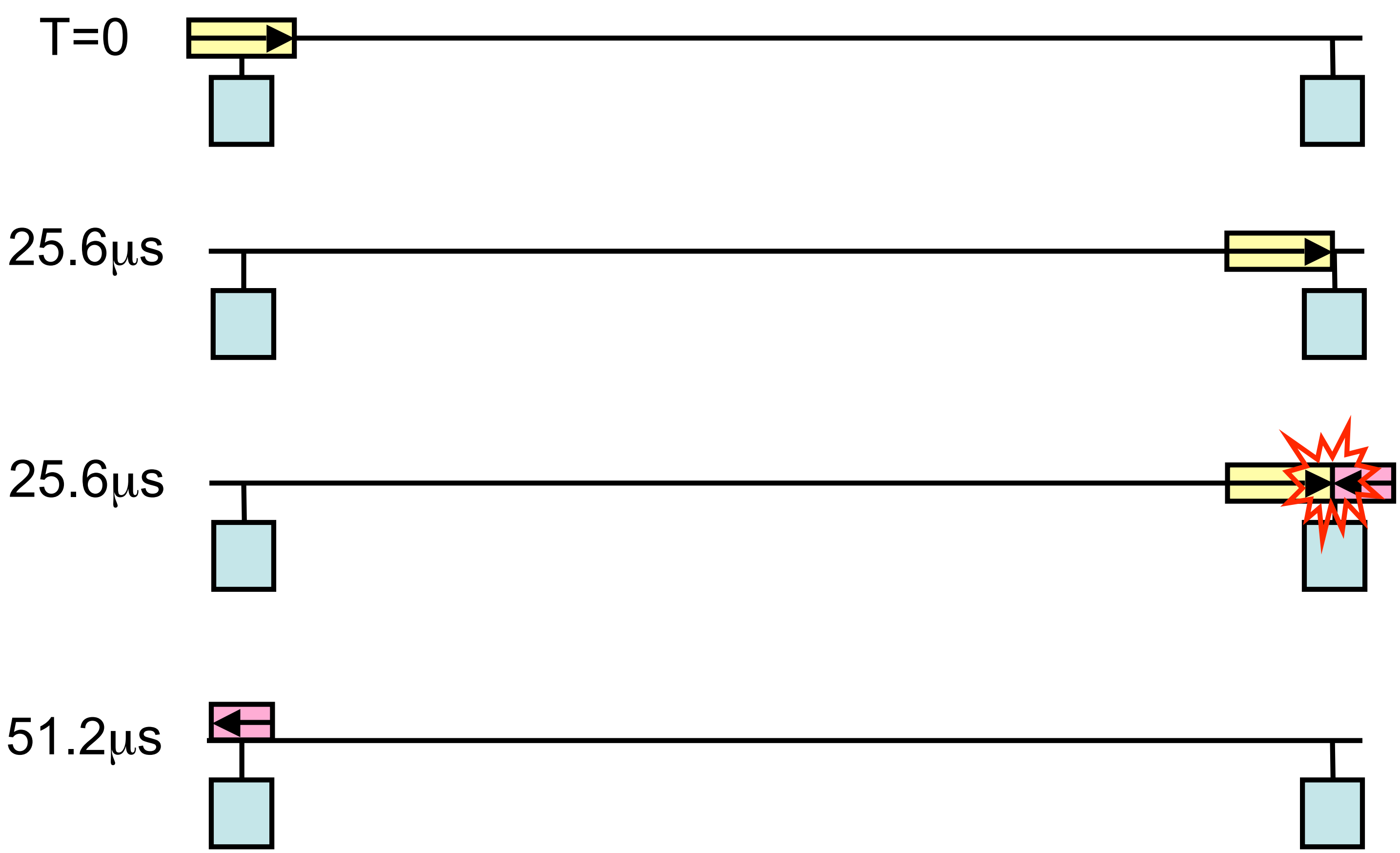
Ethernet Transmitter Algorithm

- If the link is idle transmit the frame immediately
  - Upper bound on frame size means adapter can't hog the link
- If the link is busy
  - Wait for the line to go idle
  - Wait for 9.6μs after end of last frame (sentinel)
  - Transmit the frame
- Two (or more) frames may *collide*
  - Simultaneously sent frames interfere

Collision Detection

- When an adapter detects a collision
  - Immediately sends 32 bit *jamming signal*
  - Stops transmitting
- A 10MBps adapter may need to send 512 bits in order to detect a collision
  - Why?
  - 2500m + 4 repeaters gives RTT of 51.2μs
  - 51.2μs at 10Mbps = 512 bits
  - Fortunately, minimum frame (excluding preamble) is 512 bits = 64 bytes
    - 46 bytes data + 14 bytes header + 4 bytes CRC

Ethernet Collision (Worst Case)



Exponential Backoff

- After it detects 1st collision
  - Adapter waits either 0 or 51.2μs before retrying
  - Selected randomly
- After 2nd failed transmission attempt
  - Adapter randomly waits 0, 51.2, 102.4, or 153.6μs
- After n^{th} failed transmission attempt
  - Pick k in 0 … 2^n-1
  - Wait k x 51.2μs
  - Give up after 16 retries (but cap n at 10)

Ethernet Security Issues

- Promiscuous mode
  - *Packet sniffer* detects all Ethernet frames

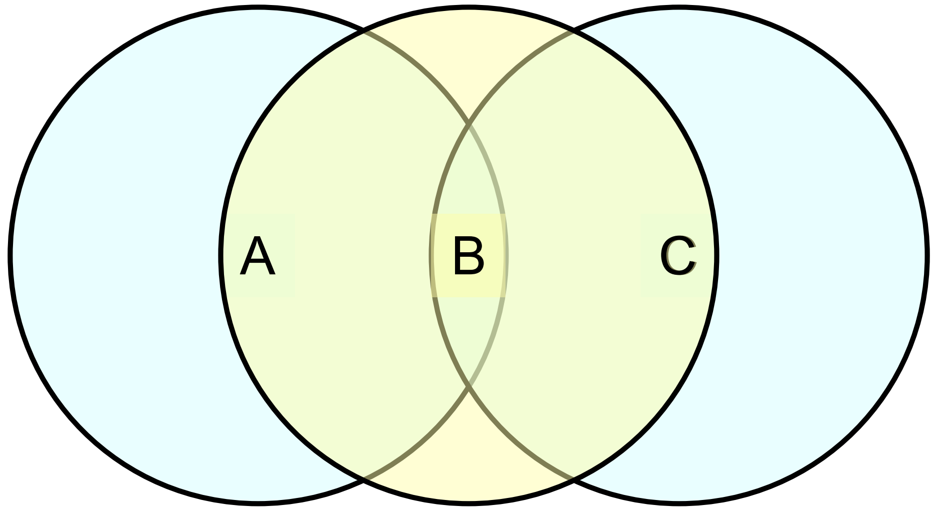
- Less of a problem in *switched* Ethernet
  - Why?

Wireless (802.11)

- Spread spectrum radio
  - 2.4GHz frequency band
- Bandwidth ranges 1, 2, 5.5, 11, 22, … Mbps

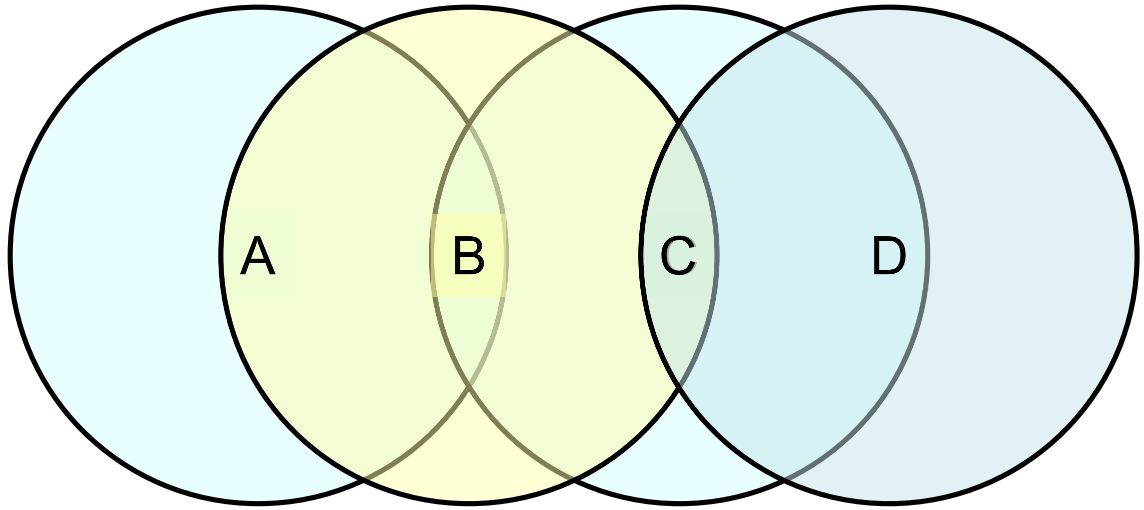
- Like Ethernet, 802.11 has shared medium
  - Need MAC (uses exponential backoff)
- Unlike Ethernet, in 802.11
  - No support for collision detection
  - Not all senders and receivers are directly connected

Hidden nodes



- A and C are *hidden* with respect to each other
  - Frames sent from A to B and C to B simultaneously may collide, but A and C can't detect the collision.

Exposed nodes

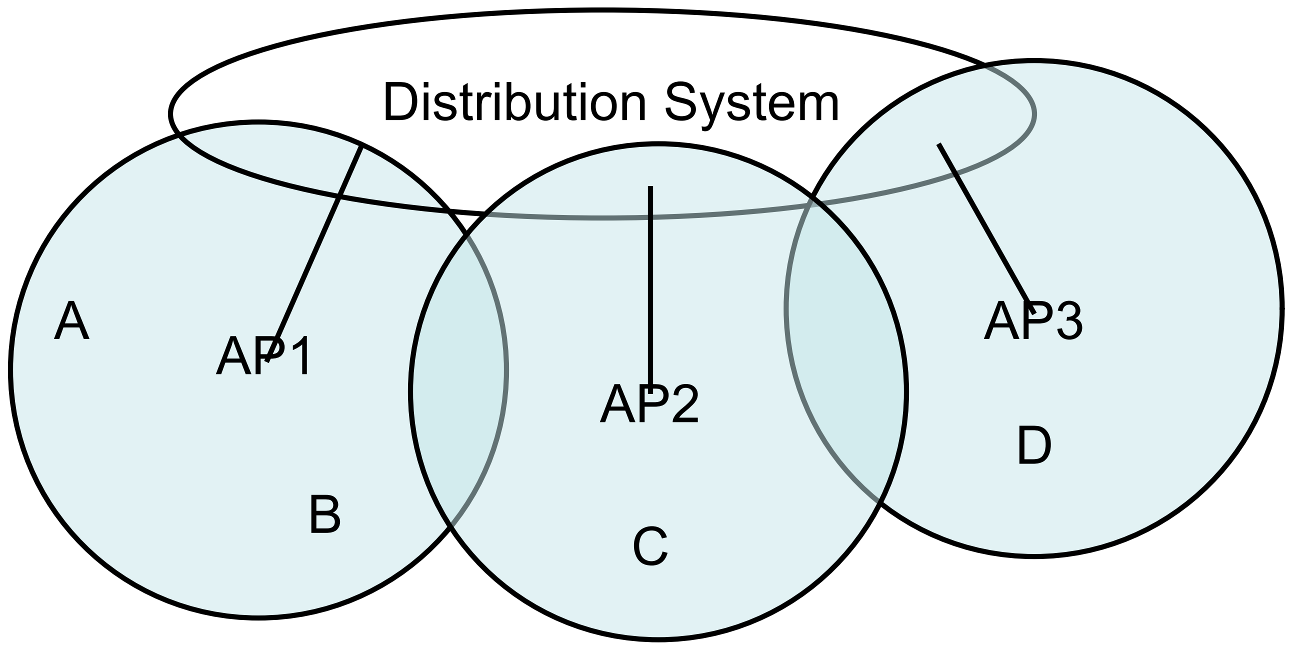


- B is exposed to C
  - Suppose B is sending to A
  - C should still be allowed to transmit to D
  - Even though C—B transmission would collide
  - (Note A to B transmission would cause collision)

Multiple Access Collision Avoidance

- Sender transmits Request To Send (RTS)
  - Includes length of data to be transmitted
  - Timeout leads to exponential backoff (like Ethernet)
- Receiver replies with Clear To Send (CTS)
  - Echoes the length field
- Receiver sends ACK of frame to sender
- Any node that sees CTS cannot transmit for durations specified by length
- Any node that sees RTS but not CTS is not close enough to the receiver to interfere
  - It’s free to transmit

Wireless Access Points



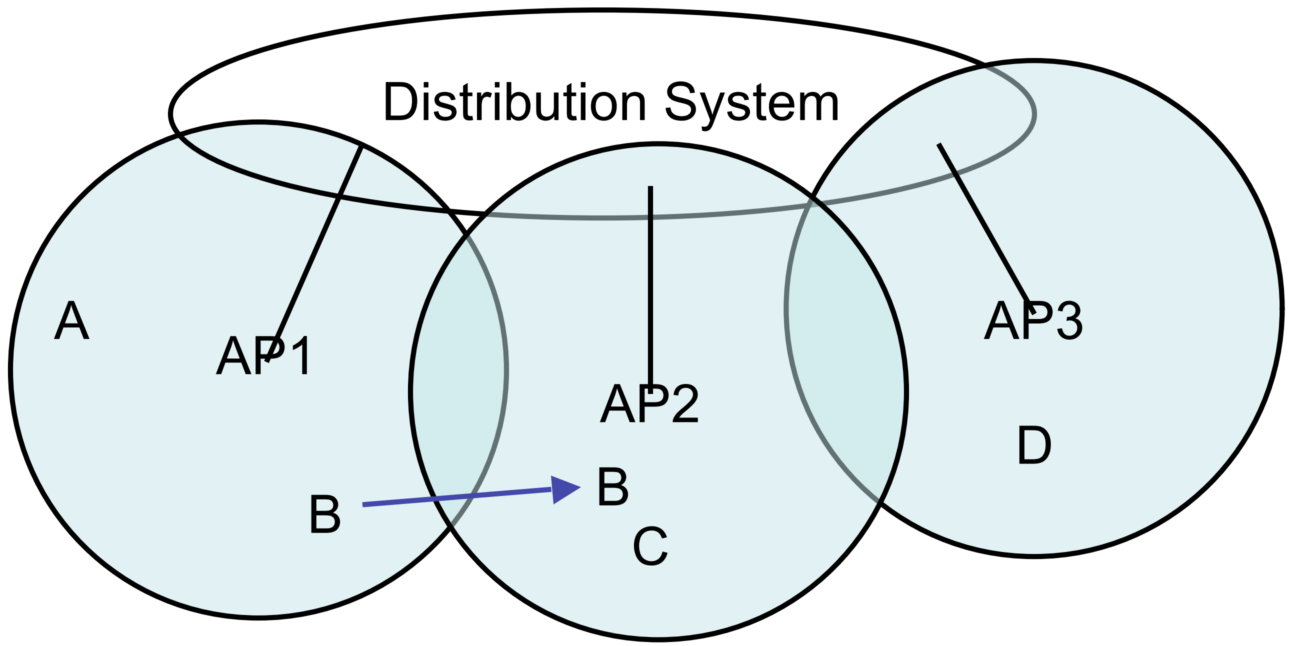
- Distribution System – wired network infrastructure
- Access points – stationary wireless device
- Roaming wireless

Selecting an Access Point

- *Active scanning*
  - Node sends a Probe frame
  - All AP's within reach reply with a Probe Response frame
  - Node selects an AP and sends Association Request frame
  - AP replies with Association Response frame

- *Passive scanning*
  - AP periodically broadcasts Beacon frame
  - Node sends Association Request

Node Mobility



- B moves from AP1 to AP2
- B sends Probes, eventually prefers AP2 to AP1
- Sends Association Request

802.11 Security Issues

- Packet Sniffing is *worse*
  - No physical connection needed
  - Long range (6 blocks)
  - Current encryption standards (WEP, WEP2) not that good
- Denial of service
  - Association (and Disassociation) Requests are not authenticated

Wired Equivalent Privacy (WEP)

- Designed to provide same security standards as wired LANs (like Ethernet)
  - WEP uses 40 bit keys
  - WEP2 uses 128 bit keys
- Uses shared key authentication
  - Key is configured manually at the access point
  - Key is configured manually at the wireless device
- WEP frame transmission format:

$$802.11Hdr, IV, K_{S+IV}\{DATA, ICV\}$$

  - S = shared key
  - IV = 24 bit "initialization vector"
  - ICV = "integrity checksum" uses the CRC checksum algorithm
  - Encryption algorithm is RC4

Problem with WEP

- RC4 generates a keystream
  - Shared key S plus IV generates a long sequence of pseudorandom bytes RC4(IV,S)
  - Encryption is: $C = P \oplus RC4(IV,S)$ $\oplus$ = "xor"
- IV's are public -- so it's easy to detect their reuse
- Problem: if IV ever repeats, then we have
  - $C1 = P1 \oplus RC4(IV,S)$
  - $C2 = P2 \oplus RC4(IV,S)$
  - So $C1 \oplus C2 = P1 \oplus P2$
  - Statistical analysis or known plaintext can disentangle P1 and P2

Finding IV Collisions

- How IV is picked is not specified in the standard:
  - Standard "recommends" (but does not require) that IV be changed for every packet
  - Some vendors initialize to 0 on reset and then increment
  - Some vendors generate IV randomly per packet
- Very active links send ~1000 packets/sec
  - Exhaust 24 bit keyspace in < 1/2 day
- If IV is chosen randomly, probability is > 50% that there will be a collision after only 4823 packets

Other WEP problems

- Replay attacks
  - Standard requires the protocol to be stateless
  - Expensive to rule out replay attacks. (The sender and receiver can't keep track of expected sequence numbers)

- Integrity violations
  - Attacker can inject or corrupt WEP encrypted packets
  - CRC (Cyclic Redundancy Check) is an error detection code commonly used in internet protocols
  - CRC is good at detecting random errors (introduced by environmental noise)
  - But, CRC is not a hash function -- it is easy to find collisions
  - Attacker can arbitrarily pass off bogus WEP packets as legitimate ones