ECE/COMPSCI 356 Computer Network Architecture

Lecture 7: Multi-access links

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Overview

- Multiple access links
  - Ethernet: CSMA/CD
  - Token ring
  - Wireless
    - 802.11 (WiFi): RTS/CTS
    - Bluetooth
    - Cell phone
  - Note: understand the concepts

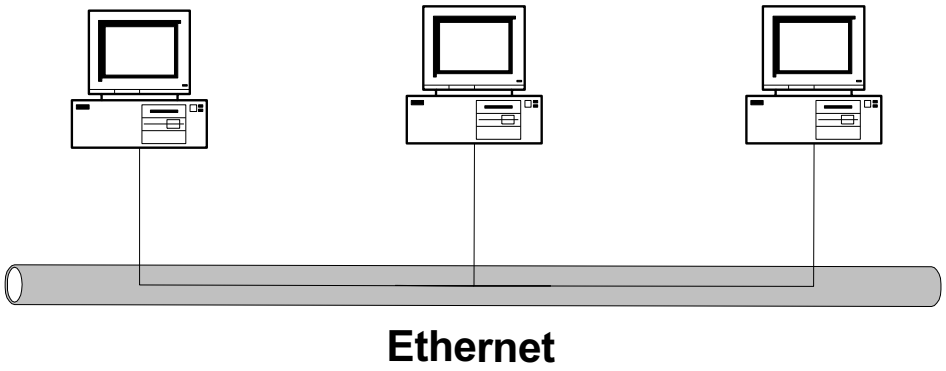
Ethernet

- Introduction
- Physical properties
  - How are nodes connected?
- Access control
  - Control access to the shared links
  - Frame format
  - Addresses
  - Transmitter algorithm

Ethernet -- introduction

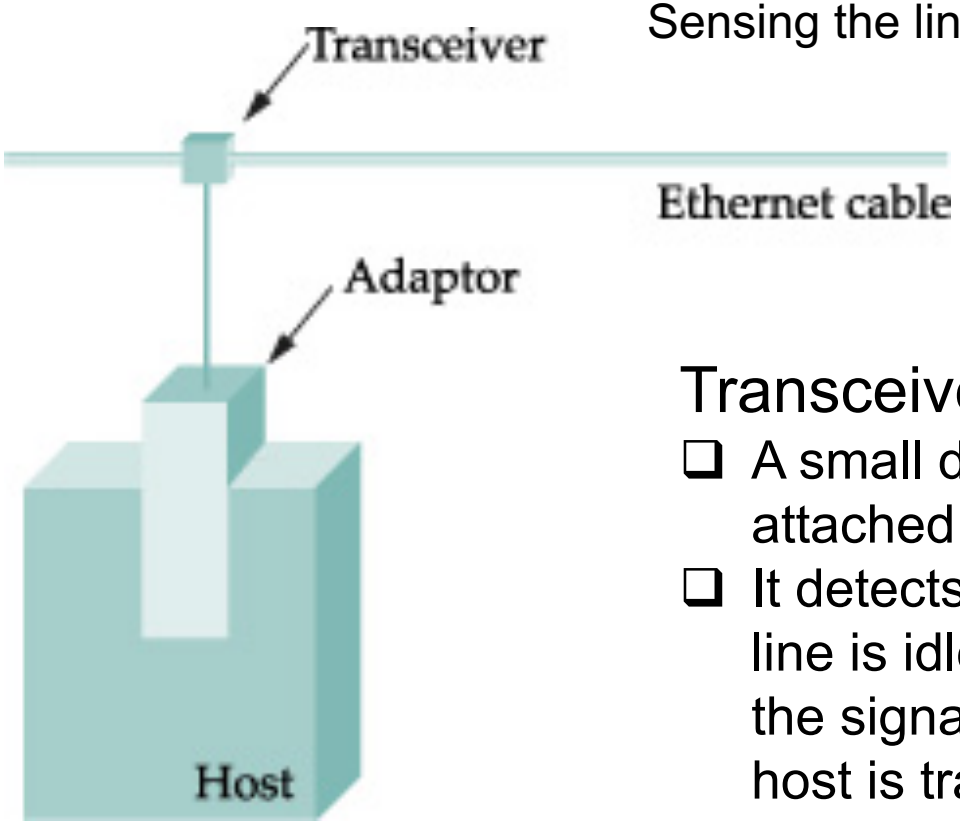
- Most successful local area networking technology of last 20 years.
- Developed in the mid-1970s by researchers at the Xerox Palo Alto Research Centers (PARC).
- Uses CSMA/CD technology
  - Carrier Sense Multiple Access with Collision Detection.
  - A set of nodes send and receive frames over a shared link.
  - Carrier sense means that all nodes can distinguish between an idle and a busy link.
  - Collision detection means that a node listens as it transmits and can therefore detect when a frame it is transmitting has collided with a frame transmitted by another node.
- Speed: 10Mbps – multi-Gbps
- IEEE standard 802.3 and its advanced versions

Physical properties -- Ethernet segment



- Most popular physical links for Ethernet
  - Last digital shows segment length
    - 10Base5 **Thick Ethernet:** 10 Mbps coax cable. A segment < 500m
    - 10Base2 **Thin Ethernet:** 10 Mbps coax cable. < 200 m
    - 10Base-T 10 Mbps T: Twisted Pair < 100m
    - 100Base-TX 100 Mbps over Category 5 twisted pair < 100m
    - 100Base-FX 100 Mbps over Fiber Optics (for wide area links) > 500m
    - 1000Base-FX 1Gbps over Fiber Optics > 500m
    - 10000Base-FX 10Gbps over Fiber Optics > 500m

Physical properties -- transceiver

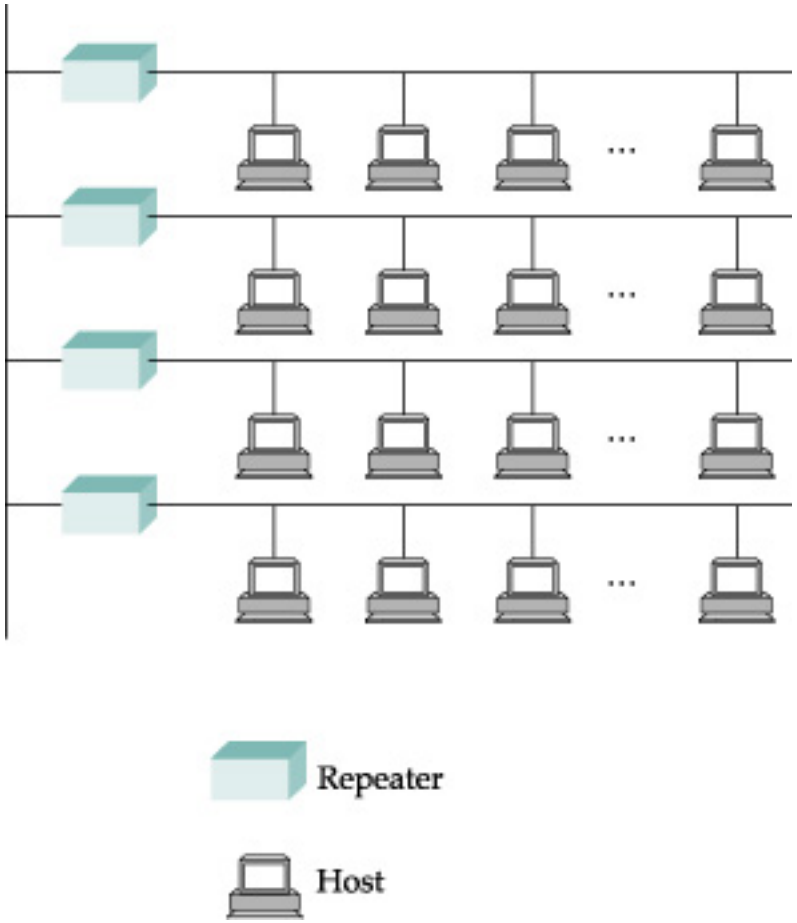


Sensing the line; if idle, sends signals

Transceiver

- A small device directly attached to the tap
- It detects when the line is idle and drives the signal when the host is transmitting
- It also receives incoming signals.

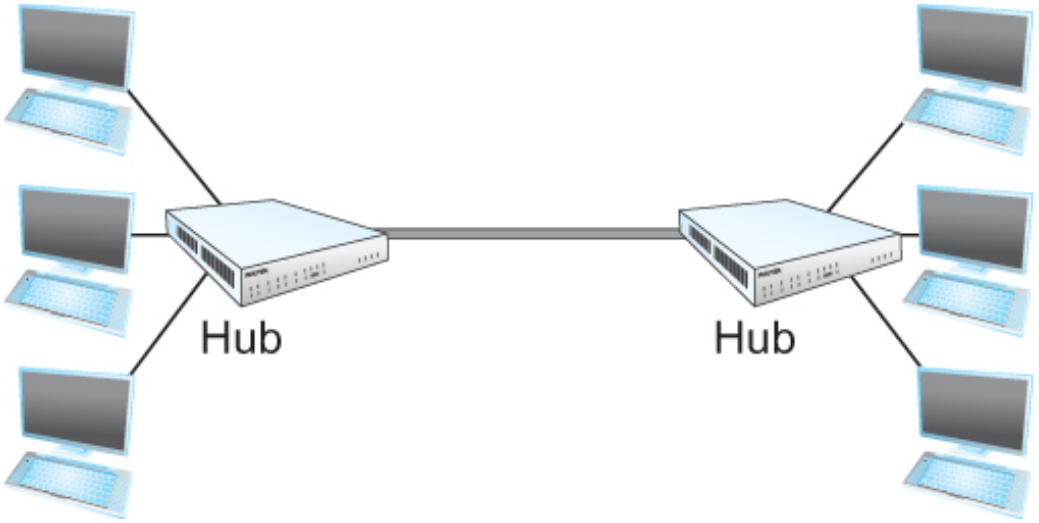
Connecting Ethernet segments via repeater



- A repeater is a device that forwards digital signals
  - Multiple segments can be joined together by repeaters
- No more than four repeaters between any host
  - <2500 meters
- < 1024 hosts
- Terminators are attached to each end of the segment
- Manchester encoding

Connecting Ethernet segments via hub

- Starting with 10Base-T, stations are connected to a hub in a star configuration



A hub is a multiway repeater

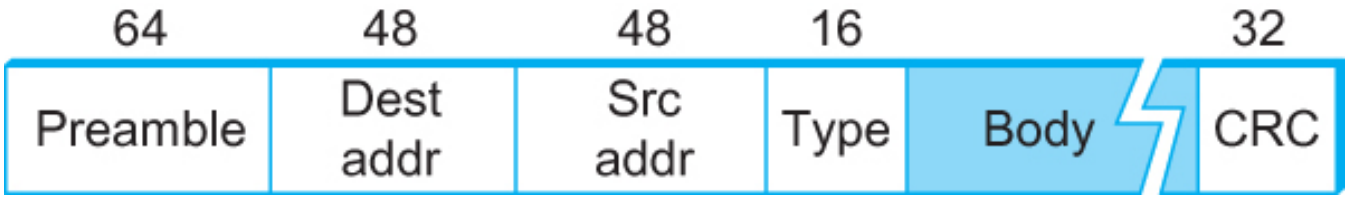
Access control

- Any host hears any other host
  - A single segment
  - Multiple segments connected by repeaters
  - Multiple segments connected by a hub
- The physical link is shared
- How to control access of the physical link?
- The algorithm is commonly called Ethernet's Media Access Control (MAC).
  - It is implemented in Hardware on the network adaptor.

Access control

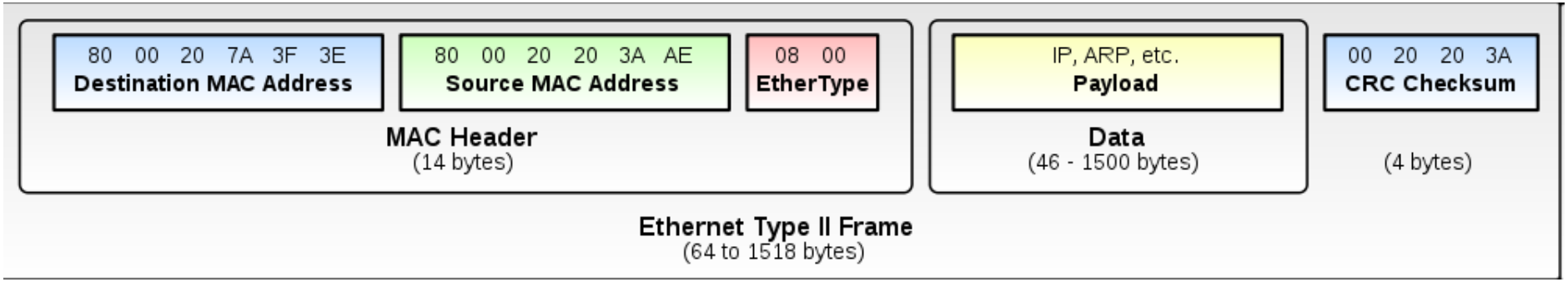
- Frame format
- Ethernet address
- Ethernet transmitter algorithm

Frame format



- Bit-oriented protocol
- Preamble (64bit): allows the receiver to synchronize with the signal (sequence of alternating 0s and 1s).
- Host and Destination Address (48bit each).
- Packet type (16bit): acts as demux key to identify the higher level protocol.
- Data (up to 1500 bytes)
  - Minimally a frame must contain at least 46 bytes of data.
  - Frame must be long enough to detect collision.
- CRC (32bit)

A prettier picture



- You'll need to know this for Lab 2

Ethernet Addresses

- Each host on an Ethernet (in fact, every Ethernet host in the world) has a unique Ethernet Address.
- The address belongs to the adaptor, not the host.
  - It is usually burnt into ROM.
- Ethernet addresses are typically printed in a human readable format
  - As a sequence of six numbers separated by colons.
  - Each number corresponds to 1 byte of the 6 byte address and is given by a pair of hexadecimal digits.
  - Leading 0s are dropped.
  - For example, 8:0:2b:e4:b1:2 is
    - 00001000 00000000 00101011 11100100 10110001 00000010

Ethernet Addresses

- To ensure that every adaptor gets a unique address, each manufacturer of Ethernet devices is allocated a different prefix that must be prepended to the address on every adaptor they build
    - AMD has been assigned the 24bit prefix 8:0:20

Ethernet Addresses

- Each frame transmitted on an Ethernet is received by every adaptor connected to that Ethernet.
- Each adaptor recognizes those frames addressed to its address and passes only those frames on to the host.
- In addition to *unicast* address, an Ethernet address consisting of all 1s is treated as a *broadcast* address.
  - All adaptors pass frames addressed to the *broadcast* address up to the host.
- Similarly, an address that has the first bit set to 1 but is not the *broadcast* address is called a *multicast* address.
  - A given host can program its adaptor to accept some set of *multicast* addresses.

Ethernet Addresses

- To summarize, an Ethernet adaptor receives all frames and accepts
  - Frames addressed to its own address
  - Frames addressed to the broadcast address
  - Frames addressed to a multicast addressed if it has been instructed

Ethernet Transmitter Algorithm

- When the adaptor has a frame to send and the line is idle, it transmits the frame immediately.
  - The upper bound of 1500 bytes in the message means that the adaptor can occupy the line for a fixed length of time.
- When the adaptor has a frame to send and the line is busy, it waits for the line to go idle and then transmits immediately.

Ethernet Transmitter Algorithm

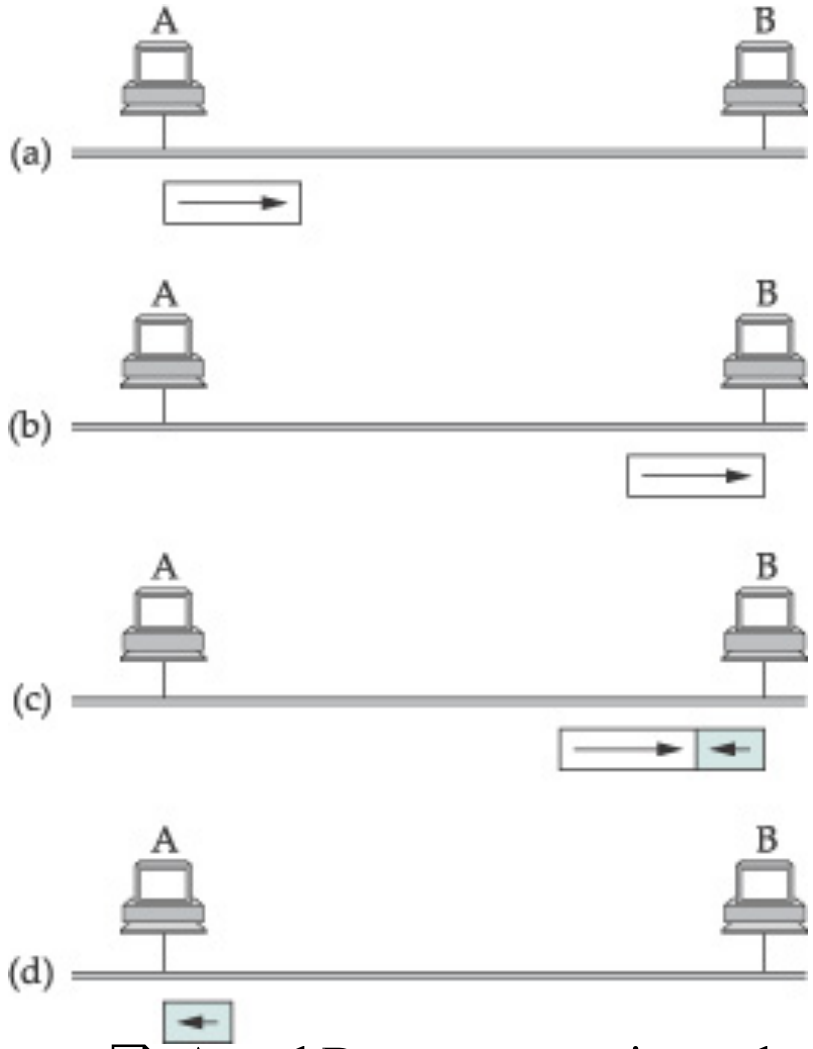
- Since there is no centralized control it is possible for two (or more) adaptors to begin transmitting at the same time,
  - E.g., both found the line to be idle
- When this happens, the two (or more) frames are said to be *collide* on the network.
- Each sender is able to determine that a collision is in progress.
  - The adapter senses the signal and checks whether it's the same as its own signal

Ethernet Transmitter Algorithm

- If collision…
  - transmit 64-bit preamble + a 32-bit jamming sequence
    - Called *runt frame*
  - stop transmitting frame
  - Wait and try again
    - *After the nth* collision
      - The adaptor waits for k x 51.2us, where k is randomly selected among 0, …, $2^n - 1$
      - 1st time: 0 or 51.2us
      - 2nd time: 0, 51.2, 102.4, or 153.6us
      - …
    - give up after several tries (usually 16)
    - *Exponential backoff*

Ethernet Transmitter Algorithm

- Support collision detection
  - Every Ethernet frame must be at least 512 bits (64 bytes) long.
    - 14 bytes of header + 46 bytes of data + 4 bytes of CRC
- Consider that a maximally configured Ethernet is 2500 m long, and there may be up to four repeaters between any two hosts, the round trip delay has been determined to be 51.2 μs
  - Which on 10 Mbps Ethernet corresponds to 512 bits



(a) A sends a frame at time t ;

(b) A's frame arrives at B at time t + d;

(c) B begins transmitting at time t + d and immediately collides with A's frame;

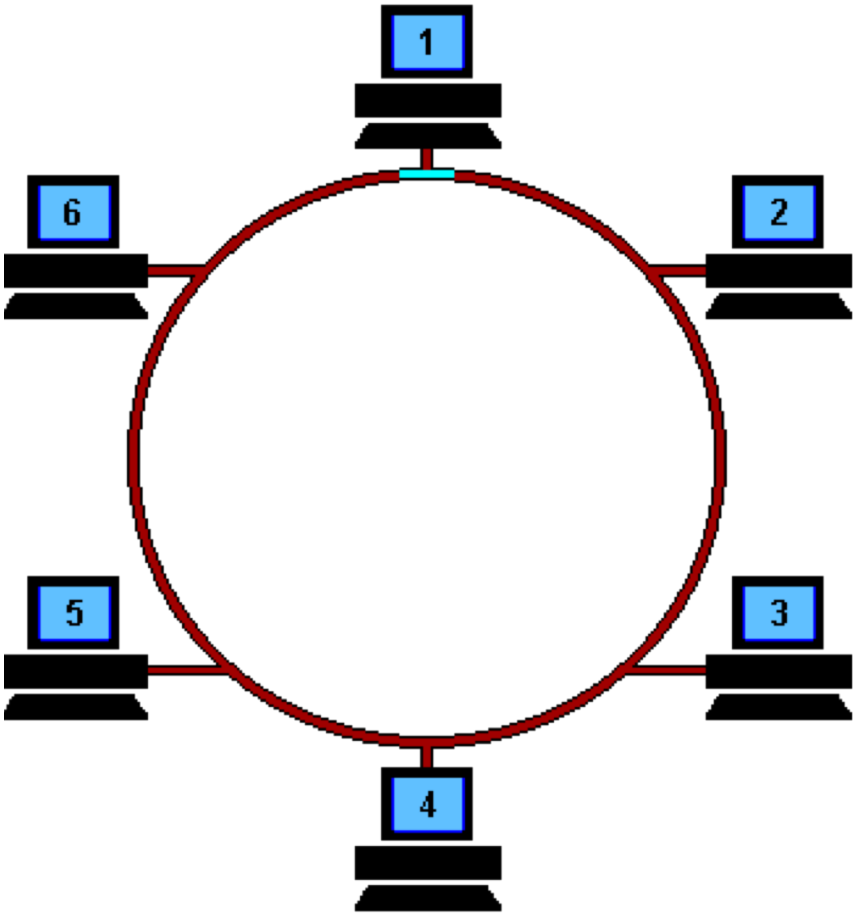
(d) B's runt (32-bit) frame arrives at A at time t + 2d.

- 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 **μ**s. On a 10Mps Ethernet, corresponds to 512 bits

Ethernet experience

- 30% utilization is heavy
- Most Ethernets are light loaded
- Very successful
  - Easy to maintain
  - Cheap: just need an adapter to each host

Token rings



- A token circulates the ring
- If a node has something to send, take the token off the ring, and send the frame
  - Node 1
- Each node along the way simply forwards the frame
- Receiver copies the frame
  - Node 4
- Frame comes back to sender
  - Sender removes the packet and puts the token back

Wireless Links

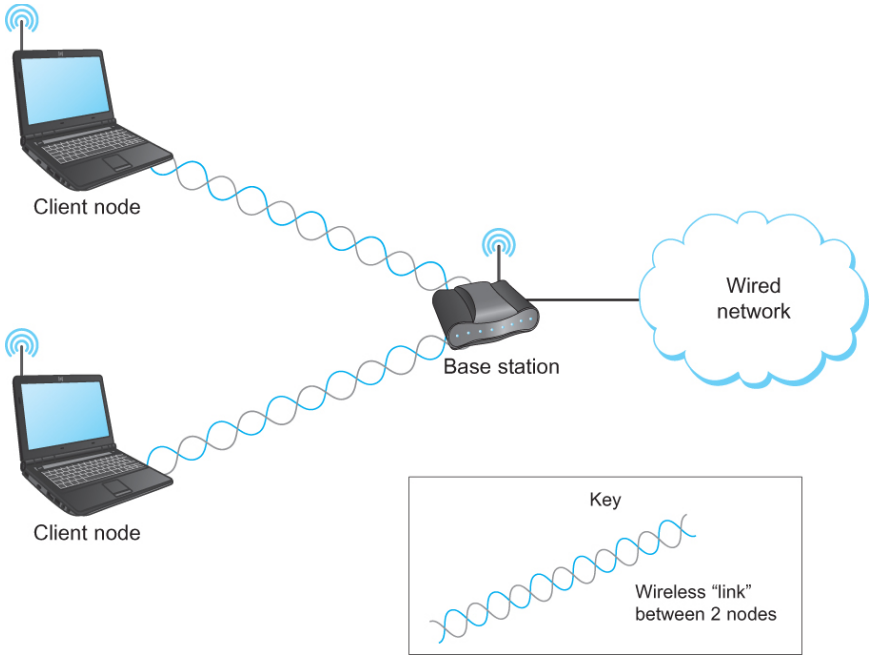
- Wireless links transmit electromagnetic signals in air
- Wireless links all share the same “wire” (so to speak)
  - The challenge is to share it efficiently without interfering with each other
  - Most of this sharing is accomplished by dividing the “wire” along the dimensions of frequency and space
- Exclusive use of a particular frequency in a particular geographic area may be allocated to an individual entity such as a corporation

Wireless Links

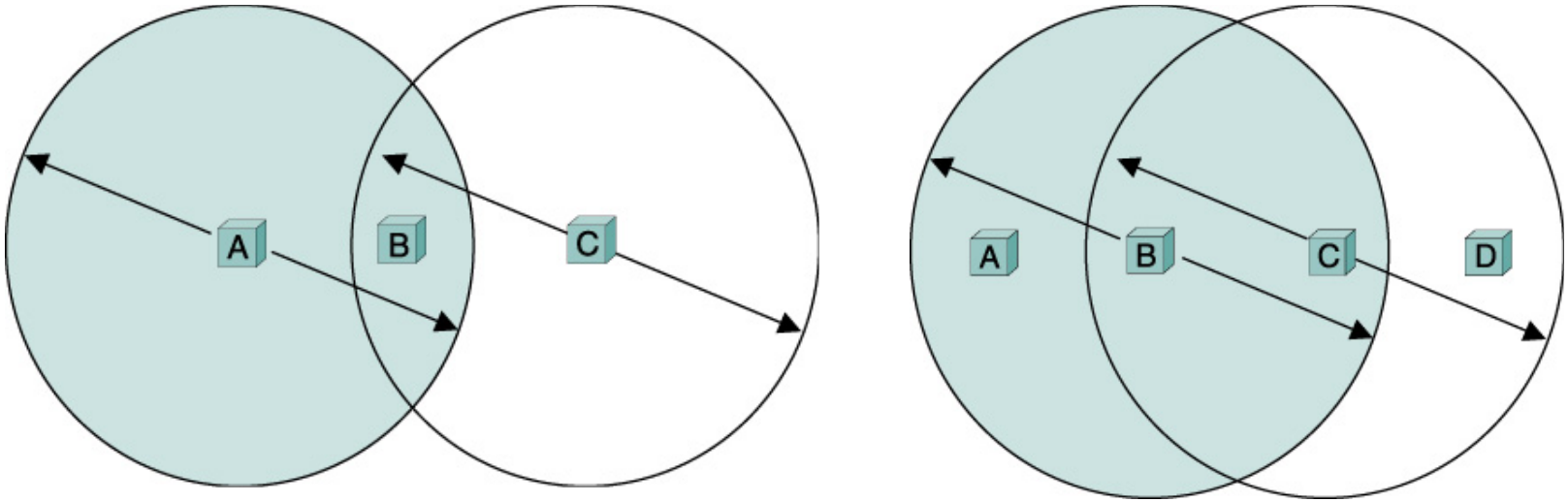
- These allocations are determined by government agencies such as FCC (Federal Communications Commission) in USA
- Specific bands (frequency) ranges are allocated to certain uses.
  - Some bands are reserved for government use
  - Other bands are reserved for uses such as AM radio, FM radio, televisions, satellite communications, and cell phones
  - Specific frequencies within these bands are then allocated to individual organizations for use within certain geographical areas.
  - Finally, there are several frequency bands set aside for “license exempt” usage
    - Bands in which a license is not needed

Wireless Links

- Mostly widely used wireless links today are usually asymmetric
  - Two end-points are usually different kinds of nodes
    - One end-point usually has no mobility, but has wired connection to the Internet (known as base station)
    - The node at the other end of the link is often mobile



Wireless access control



- Can't use Ethernet protocol
  - Hidden node
    - A and C can't hear each other's collision at B
  - Exposed node
    - B can send to A; C can send to D

802.11 (WiFi) Multiple access with collision avoidance (CSMA/CA)

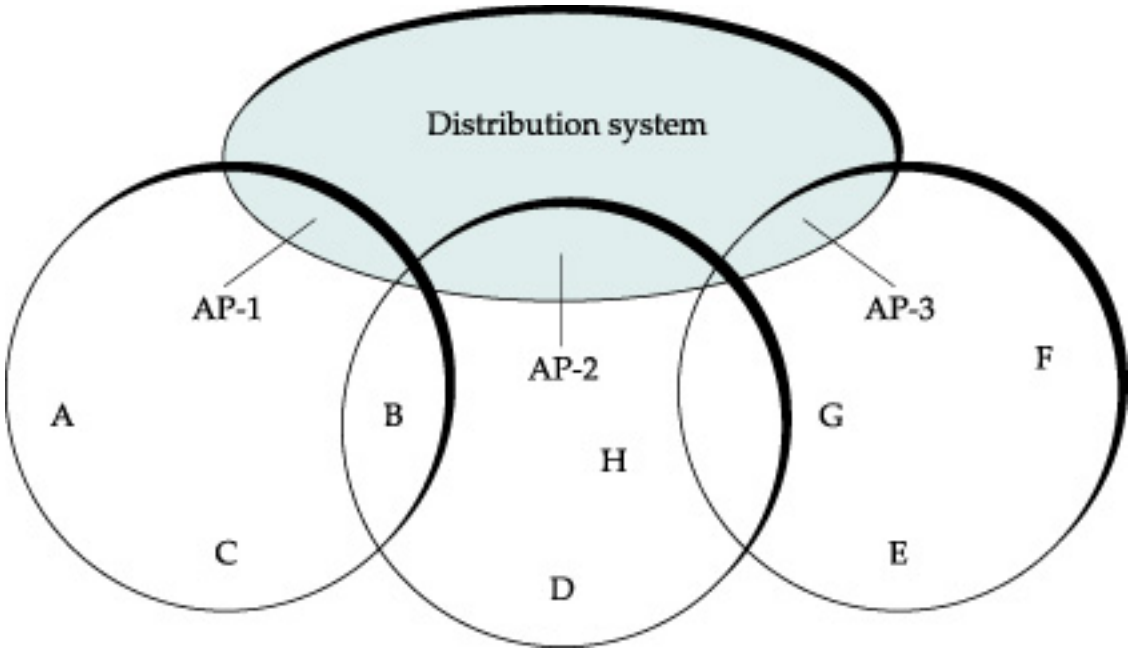
- Sender and receiver exchange control
  - Sender → receiver: Request to send (RTS)
    - Specifies the length of frame
  - Receiver → sender: Clear to send (CTS)
    - Echoes length of frame
  - Sender → receiver: frame
  - Receiver → sender: ack

- Node sees CTS
  - Too close to receiver, can't transmit
  - Addressing hidden nodes
- Node only sees RTS
  - Okay to transmit
  - Addressing exposed nodes

How to resolve collision

- Sender cannot do collision detection
  - Single antenna can't send and receive at the same time
- If no CTS, then RTS collide
- Exponential backoff to retransmit

Distribution system



- Hosts associate with Aps
  - AP: access point
- APs connect via the distribution system
  - Wired network
    - Ethernet

AP association

- Active scanning
  - Node: Probe
  - APs: Probe response
  - Node selects one of APs, send Association request
  - AP replies Association Response
- Passive scanning
  - AP sends Beacon to announce itself
  - Node sends Association Request

Bluetooth

- Connecting devices: mobile phones, headsets, keyboards
  - Very short range communication
  - Low power
- License exempt band 2.45 Ghz
- 1~3Mpbs
- Specified by Bluetooth Special Interest Group

Cell phone technologies

- Using licensed spectrum
- Different bands using different frequencies
- Base stations form a wired network
- Geographic area served by a base station's antenna is called a cell
  - Similar to wifi
- Phone is associated with one base station
- Leaving a cell entering a cell causes a handoff

Summary

- Multiple access links
  - Ethernet: CSMA/CD
  - Token ring
  - Wireless
    - 802.11 (WiFi): RTS/CTS
    - Bluetooth
    - Cell phone