Getting Connected
(Chapter 2 Part 4)

Networking
CS 3470, Section 1
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Five Problems

- Encoding/decoding
- Framing
- Error Detection
- Error Correction
- Media Access
Five Problems

- Encoding/decoding
- Framing
- Error Detection
- Error Correction
- Media Access
Core Ethernet

- Ethernet standard is 802.3
- Legacy multiple-access network
  - Set of nodes sends and receives frames over shared link
  - Kind of like a bus
Core Ethernet

Ethernet is CSMA/CD, which stands for “Carrier Sense, Multiple Access with Collision Detection.”

- **Carrier sense**: all nodes can distinguish between idle and busy link
- **Collision detection**: node listens as it transmits can tell if it collides with another frame
Core Ethernet

- By standard, Ethernet is implemented using Coax, on segments limited to 500m.
- Hosts joined by “tapping into” segment.
- Multiple Ethernet segments joined together by **repeaters**.
  - What do you think a repeater does?
- No more than four repeaters allowed.
Core Ethernet

- Total reach: 2500m
- All physical limitations considered, an Ethernet is limited to 1024 hosts maximum.
- Any signal emitted by a host on the ethernet is broadcast over the entire network.
- Terminators attached to the end absorb the signal and prevent bounce-back.
Ethernet Technologies: 10Base2

- **10**: 10Mbps; **2**: under 200 meters max cable length
- thin coaxial cable in a bus topology
- repeaters used to connect up to 5 multiple segments
- repeater repeats bits it hears on one interface to its other interfaces: physical layer device only!
Core Ethernet

Cable Types:

- 10Base2
  - 10Mbps peak, Baseband, with 200m limit
- 10Base5
  - 10Mbps peak, Baseband, with 500m limit
- 10BaseT
  - 10Mbps peak, Baseband, Twisted-Pair cable, 100m limit
Core Ethernet

- Encoding schemes
  - Original specification used Manchester encoding
  - Higher-speed Ethernet uses 4B/5B or the similar 8B/10B encoding
Shared Access

- Everyone speaks at the same time
- Competition for the same link, speaking at the same time produces the notion of a \textit{collision domain}. 
Ethernet Frame Structure

- Sending adapter encapsulates IP datagram (or other network layer protocol packet) in **Ethernet frame**

  - Preamble:
    - 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
    - used to synchronize receiver, sender clock rates
Ethernet Frame Structure (more)

- **Addresses**: 6 bytes
- **Type**: indicates the higher layer protocol, mostly IP but others may be supported
- **CRC**: checked at receiver, if error is detected, the frame is simply dropped
MAC Addresses

- Every Ethernet adapter in the world has a unique address
  - Media Access Control (MAC)
- Burned into ROM in hardware
- Sequence of six numbers separated by colons
  - Six binary numbers
  - Usually displayed in hex for humans
MAC Addresses

- Binary representation
  - 00001000 00000000 00101011 11100100
  - 10110001 00000010

- Human (hex) representation
  - 8:0:2b:e4:b1:2

- How do we go from binary to hex (and back)?
Hex Exercise

- What is the following hex mac address in binary?
  E0:DB:55:E7:AD:1D

- What is the following binary mac address in hex?
  11001010:00101011:11001101 (first half)
  00000111:00101111:01010100 (second half)
MAC Addresses

- How do we find them on our machines?
  - Windows
    - cmd -> “ipconfig /all”
  - Linux
    - $> /sbin/ifconfig –a

- Can a machine have more than one MAC address?
- Is it changeable?
MAC Addresses

- Ethernet adapter receives all frames and accepts frames that are addressed to
  - Its own address
  - Broadcast address (all 1’s)
  - Multicast address that it has been programmed to accept
- Can also be put into promiscuous mode to accept all frames
  - Only used in network debugging and hacking
So if a MAC address is unique, can every packet sent be traced back to a unique user?
CSMA (Carrier Sense Multiple Access)

- Ethernet is CSMA/CD, which stands for “Carrier Sense, Multiple Access with Collision Detection.”
  - **Carrier sense**: all nodes can distinguish between idle and busy link
  - **Collision detection**: node listens as it transmits can tell if it collides with another frame
CSMA (Carrier Sense Multiple Access)

- CSMA: listen before transmit:
  - If channel sensed idle: transmit entire frame
  - If channel sensed busy, defer transmission

- Human analogy: don’t interrupt others!
CSMA collisions

collisions can still occur: propagation delay means two nodes may not hear each other’s transmission

collision: entire packet transmission time wasted

note: role of distance & propagation delay in determining collision probability
CSMA/CD (Collision Detection)

- CSMA/CD: carrier sensing, deferral as in CSMA
  - collisions detected within short time
  - colliding transmissions aborted, reducing channel wastage
CSMA/CD collision detection
Collisions

- When an adapter detects its frame in a collision, it transmits a 32-bit jamming sequence and stops
  - Will minimally send 96 bits – 64 bit preamble and 32 bits of jamming
  - Also called a runt frame
- What sort of configuration will cause the most runt frames?
Transmitter Algorithm

- So that’s great that we can detect collisions, but lot’s of collisions are probably bad
- How can we minimize collisions?
  - *Exponential backoff*
Transmitter Algorithm

- Maximum distance between any two end hosts is 2500m.
- At most four repeaters in any Ethernet segment.
- Transmitters are required to send 512 bits per frame.
  - Consider A and B at opposite ends of the network.
  - A sends at time “t.” One link latency, d, is required to reach host B.
  - First bit of A's transmission reaches B at time “t+d.” B still sees an idle line and begins to transmit.
  - B's frame immediately collides with A's. B sends a 96-bit jamming sequence (a runt frame), arriving at time t +2d.
Some Physical Specifications to the 802 Standard ...

... So A must still be talking when the runt frame comes back.

- Max distance = 2500m
- Round-trip delay assuming four repeaters and “low” propagation speed is 51.2µs.
- At 10-Mbps, this “pipe” is exactly 512 bits.

Falloff:

- 51.2µs to send. Whoa! Collision.
- Either send next frame or not... (Backoff 0 or 51.2µs)
- Still busy? Double your choices and pick randomly (e.g., pick randomly from 0µs, 51.2µs, 102.4µs, 153.6µs)
“Taking Turns” MAC protocols

Polling
- master node “invites” slave nodes to transmit in turn
- concerns:
  - polling overhead
  - latency
  - single point of failure (master)

Token Passing
- control token passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)
IEEE 802.11 Wireless LAN

- **802.11b**
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - Greater tolerance of interference by adding more redundancy
    - Each bit is represented by multiple bits – if some bits are damaged, can recover
    - All hosts use same chipping code for decoding
  - widely deployed, using base stations
IEEE 802.11 Wireless LAN

- **802.11a**
  - 5-6 GHz range
  - up to 54 Mbps

- **802.11g**
  - 2.4-5 GHz range
  - up to 54 Mbps

- All use CSMA/CA for multiple access
  - Cannot sense collision detection!

- All have base-station and ad-hoc network versions
Base station approach

- Wireless host communicates with a base station
  - base station = access point (AP)
- Basic Service Set (BSS) (a.k.a. “cell”) contains:
  - wireless hosts
  - access point (AP): base station
- BSS’s combined to form distribution system (DS)
Ad Hoc Network approach

- No AP (i.e., base station)
- Wireless hosts communicate with each other
  - To get packet from wireless host A to B may need to route through wireless hosts X, Y, Z
- Applications:
  - “laptop” meeting in conference room, car
  - Interconnection of “personal” devices
  - Battlefield
- IETF MANET (Mobile Ad hoc Networks) working group
IEEE 802.11: multiple access

- Collision if 2 or more nodes transmit at same time
- CSMA makes sense:
  - get all the bandwidth if you’re the only one transmitting
  - shouldn’t cause a collision if you sense another transmission
- Collision detection doesn’t work: hidden terminal problem
IEEE 802.11 MAC Protocol: CSMA/CA

- 802.11 CSMA: sender
  - if sense channel idle for DIFS (distribute inter-frame space) sec.
  - then transmit entire frame (no collision detection)
  - if sense channel busy then binary backoff

- 802.11 CSMA: receiver
  - if received OK
  - return ACK after SIFS (short inter-frame space)

SIFS required because of hidden terminal problem
Collision avoidance mechanisms

Problem:
- Two nodes, hidden from each other, transmit complete frames to base station
- Wasted bandwidth for long duration!

Solution:
- Small reservation packets
- Nodes track reservation interval with internal “network allocation vector” (NAV)
Collision Avoidance: RTS-CTS exchange

- Sender transmits short RTS (request to send) packet: indicates duration of transmission
- Receiver replies with short CTS (clear to send) packet
  - Notifying (possibly hidden) nodes
- Hidden nodes will not transmit for specified duration: NAV

![Diagram showing RTS-CTS exchange with DIFS, SIFS, and NAV]
Collision Avoidance: RTS-CTS exchange

- RTS and CTS short:
  - collisions less likely, of shorter duration
  - end result similar to collision detection
- IEEE 802.11 allows:
  - CSMA
  - CSMA/CA: reservations
  - polling from AP
Summary of MAC protocols

- What do you do with a shared media?
  - Channel Partitioning, by time, frequency or code
  - Random partitioning (dynamic),
  - Taking Turns
End of Notes for Exam 1