Topics for Today

• More on Ethernet
  – Topology and Wiring
  – Switched Ethernet
  – Fast Ethernet
  – Gigabit Ethernet
• Wireless LANs
• Readings
  – 4.3 to 4.4
Original Ethernet Wiring

Heavy coaxial cable, called thicknet, 10Base5
Second Generation Ethernet Wiring

Thinner coaxial cable, called thinnet, 10Base2
Modern Ethernet Wiring

Uses a hub, called twisted pair Ethernet, 10BaseT
Switched Ethernet

• Connects multiple stations/segments
  – Frames copied between ports

• No collision any more?
  – What happens when a station and switch port transmit simultaneously?

• Full duplex switch
  – Point-to-point connection
  – Collision detection is no longer necessary
Fast Ethernet

• We want 100 Mbps bandwidth per host!
  – Servers and high performance work stations
• How to increase transmission speed by 10
• Keep the same Ethernet protocol
  – 100 Mbps $\rightarrow$ 1 bit-time = 10 ns
  – Minimum frame size still 64 bytes (512 bits)
    • Collision detection time = 5.12 $\mu$s
  – Signal propagation speed is still same
Fast Ethernet

efficiency \approx \frac{1}{1+5.4a}

a = \frac{PROP}{TRANS} = \frac{cablelength}{signalspeed} \times \frac{bandwidth}{framesize}

• Solution: reduce cable length by 10
  – Maximum network diameter: 250 m
  – Limit number of stations attached
Gigabit Ethernet

• We want 1 Gbps bandwidth per host!
• How to increase transmission speed by 100
• Keep the same Ethernet frame formats and sizes
  – 1 Gbps $\rightarrow$ 1 bit-time = 1 ns
  – Minimum frame size still 64 bytes
    • Collision detection time = 0.512 $\mu$s
• Reduce cable length by 100
  – Maximum network diameter: 25 m
  – Resulting LAN is too small to be useful
Gigabit Ethernet (cont’d)

• Gigabit Ethernet with diameter > 25m?
  – Switched full duplex network
  – One station per segment, no collision
    • CSMA/CD becomes void!

• How to maintain min/max frame sizes?
  – Carrier extension
    • Each frame is made at least 4096 bits (512 bytes)
    • Add some junk at the end (after checksum)
Carrier Extension

Fig 1. Ethernet Frame Format with Carrier Extension
Gigabit Ethernet (cont’d)

• If we have only small frames (64 bytes)
  – Max throughput will be $\frac{1000}{8} = 125$ Mbps
  – Only 25% increase over Fast Ethernet

• Can we do better?
  – Frame bursting
    • Allow multiple transmissions by a station
    • Need to preserve frame boundary
Frame Bursting

• First frame will always be carrier extended
  – Subsequent frames will not

• More frames to send after the first one
  – Send them one after the other
  – Inter-frame gap of 96 extended carrier bits
  – Stop sending when burst timer expires

• Performance: can achieve > 700 Mbps
Frame Bursting

Fig. 2. Packet Bursting
Wireless LAN
Hidden Terminal Effect
Hidden Terminal Problem

• Hidden terminals
  – A, C cannot hear each other
  – obstacles, signal attenuation
  – collisions at B

• Goal: avoid collisions at B

• CSMA/CA: CSMA with Collision Avoidance
Collision Avoidance

• Explicit channel reservation
• Sender sends short RTS
  – request to send
• Receiver reply with short CTS
  – clear to send
• CTS reserves channel for sender
  – notifying (possibly hidden) stations
RTS-CTS Exchange

source

DIFS

destination

RTS

SIFS

CTS

data

SIFS

ack

others

NAV. defer access

20
RTS-CTS Exchange

• Avoids hidden station collisions
• RTS and CTS are short
• Collisions less likely
  – Of shorter duration
• End result similar to collision detection
IEEE 802 LAN Std. Family

802.2 Logical Link Control (LLC)

| 802.3 CSMA/CD | 802.4 Token Bus | 802.5 Token Ring | 802.11 Wireless |

Layer 3-7
Layer 2 Data Link
Layer 1 Physical

MAC
PHY
What is IEEE 802.11?

• 802.11 is the standard for Wireless Local Area Networks (WLAN)
• Original Specification 1997, revised in 1999
• Operating Range: 10-100m inside, 300m outside
• Frequency
  – 2.4 Ghz (802.11 and 802.11b)
  – 5 Ghz (802.11a)
• Transmission rates of 1/2Mbps
802.11 Variations

• 802.11a
  – Speed: 6-54Mbps
  – Uses 5GHz ISM band (5.15-5.35 GHz)
  – OFDM (Orthogonal Frequency Division Multiplexing)

• 802.11b
  – Speed: 5.5/11 Mbps
  – DSSS (Direct Sequence Spread Spectrum)
  – Most common implementation of wireless LAN

• 802.11e
  – QoS (Quality of Service) Enhancement
802.11 Variations (Cont’d)

• 802.11f
  – Improve the interoperability of Access Point

• 802.11g
  – Develop higher speed extension for 802.11b
  – Speed: > 20Mbps

• 802.11h
  – Enhance the 802.11 and 802.11a standard to enable regulatory acceptance of 5GHz products

• 802.11i
  – Improve the security and authentication mechanism
Ad-Hoc Network

- Ad-Hoc Mode supports mutual communication among wireless clients only

- Basic Service Set (BSS) - BSSID
Infrastructure Network

• Provides the communication between wireless clients and wired network through AP (Access Point).
Infrastructure Network (Cont’d)

• **BSS**
  – Basic Service Set
  – A single cell in the 802.11 standard

• **DS**
  – Distribution System
  – Interconnects a set of BSS and any integrated LAN

• **ESS**
  – Extended Service Set
  – A set of BSSs joined together
MAC and Physical Layer

- The 802.11 is divided into a MAC and Physical Layer
- Four different Physical Layers (PHY)
  - DSSS or Direct Sequence Spread Spectrum
  - FHSS or Frequency Hopping Spread Spectrum
  - OFDM (Orthogonal Frequency Division Multiplexing)
  - IR or Infrared
- A common MAC layer accesses the three different PHY layers

<table>
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<th>LLC</th>
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<tr>
<td>MAC</td>
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<tr>
<td>FHSS (2.4GHz)</td>
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</tbody>
</table>
Medium Access Control

- **DCF (Distributed Coordination Function)**
  - Contention-Based Medium Access Control
  - CSMA/CA

- **PCF (Point Coordination Function)**
  - Contention Free Medium Access Control
  - Optional access method works like polling
  - Suited for Time Bound Services like Voice or Multimedia

- **Carrier Sensing**
  - Physical carrier sensing
  - Virtual carrier sensing
    - Set Network Allocation Vector (NAV) to the duration field value in the data, RTS or CTS frame
    - NAV indicates the amount of time elapsed until the current transmission completes
Basic Transmission Algorithm

1. Sense the medium (perform physical channel assessment)
2. If NAV=0, yes, go to step 3. Otherwise, go to step 4.
3. If Medium Idle, yes, Transmit Frame. Otherwise, go to step 4.
4. If Collision, yes, go to Random Backoff Time. Otherwise, go to step 2.
Medium Access and IFS

- **IFS (Inter-Frame Spacing)**
  - DIFS
  - PIFS: PCF IFS = SIFS + slot time
  - DIFS: DCF IFS = SIFS + 2*slot time

- **Exponential Back-off**
  - Random back-off time within a contention window [0, CW]
  - Contention window size increases with retransmission
  - Back-off time = random() * slot time
  - Random() = a pseudo random integer in [0,CW]
  - CWmin <= CW <= CWmax, CW starts with CWmin and increases by every retransmission up to CWmax, and is reset after successful transmission
DCF
(Distributed Coordination Function)

• Listen before-talk scheme based on the CSMA
• Stations transmits when medium is free for time greater than a DIFS period
• Random backoff is issued when medium busy
  – All backoff slots occur after a DIFS
DCF (Cont’d)

- Defer access based on *Carrier Sense*
- Direct access when medium is sensed free longer than DIFS, otherwise defer and backoff.
- Receiver of directed frames to return an ACK immediately when CRC correct
PCF
(Point Coordination Function)

- Contention-free frame transfer
- Single Point Coordinator (PC) controls access to the medium.
  - AP acts as PC
- PC transmits beacon packet when medium is free for time greater than PIFS
  - PCF has higher priority than the DCF
- During PCF mode,
  - PC polls each station for data
  - After a transmission of a MPDU, move on to the next station
  - Ineffective on large networks
PCF (Cont’d)

Station 2 sets NAV (Network Allocation Vector).

Station 3 is hidden to the PC, it does not set the NAV. It continues to operate in DCF.
Limitations of PCF

- Unknown transmission time of the polled stations
  - Delays the transmission of time-bounded traffic
  - Unpredictable time delays in each CFP

- Hidden station problem
  - It could transmit interfering frames during CFP
What does Bluetooth do for you?

- Data/Voice Access Points
- Personal Ad-hoc Networks
- Cable Replacement

Bluetooth
What is Bluetooth?

- A hardware description
- An application framework

Latest Version on Bluetooth Website: www.Bluetooth.com
### What does Bluetooth Do?

<table>
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<tr>
<th>Topology</th>
<th>Supports up to 7 simultaneous links</th>
<th>Each link requires another cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexibility</td>
<td>Goes through walls, bodies, cloths...</td>
<td>Line of sight or modified environment</td>
</tr>
<tr>
<td>Data rate</td>
<td>1 MSPS, 720 Kbps</td>
<td>Varies with use and cost</td>
</tr>
<tr>
<td>Power</td>
<td>0.1 watts active power</td>
<td>0.05 watts active power or higher</td>
</tr>
<tr>
<td>Size/Weight</td>
<td>25 mm x 13 mm x 2 mm, several grams</td>
<td>Size is equal to range. Typically 1-2 meters. Weight varies with length (ounces to pounds)</td>
</tr>
<tr>
<td>Cost</td>
<td>Long-term $5 per endpoint</td>
<td>~ $3-$100/meter (end user cost)</td>
</tr>
<tr>
<td>Range</td>
<td>10 meters or less</td>
<td>Range equal to size. Typically 1-2 meters</td>
</tr>
<tr>
<td></td>
<td>Up to 100 meters with PA</td>
<td></td>
</tr>
<tr>
<td>Universal</td>
<td>Intended to work anywhere in the world</td>
<td>Cables vary with local customs</td>
</tr>
<tr>
<td>Security</td>
<td>Very, link layer security, SS radio</td>
<td>Secure (its a cable)</td>
</tr>
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**Cable Replacement**
Basic Baseband Protocol

- **Spread spectrum frequency hopping radio**
  - 79/23 one MHz channels
  - Hops every packet
    - Packets are 1, 3 or 5 slots long
  - Frame consists of two packets
    - Transmit followed by receive
  - Nominally hops at 1600 times a second (1 slot packets)
Network Topology

- **Radio Designation**
  - Connected radios can be master or slave
  - Radios are symmetric (same radio can be master or slave)

- **Piconet**
  - Master can connect to 7 simultaneous or 200+ active slaves per piconet
  - Each piconet has maximum capacity (1 MSPS)
    - Unique hopping pattern/ID

- **Scatternet**
  - High capacity system
    - Minimal impact with up to 10 piconets within range
  - Radios can share piconets!
The Piconet

- All devices in a piconet hop together
  - In forming a piconet, master gives slaves its *clock* and *device ID*
    - Hopping pattern determined by *device ID* (48-bit)
    - Phase in hopping pattern determined by *Clock*
- Non-piconet devices are in standby
- Piconet Addressing
  - *Active Member Address* (AMA, 3-bits)
  - *Parked Member Address* (PMA, 8-bits)
**Master Paging a slave**

- **Master pages slave (packet has slave ID) at slave page frequency (1 of 32)**
  - Master sends page train of 16 most likely frequencies in slave hop set
    - Slave ID sent twice a transmit slot on slave page frequency
    - Master listens twice at receive slot for a response
  - If misses, master sends second train on remaining 16 frequencies

- **Slave listens for 11 ms (page scan)**
  - If correlator triggers, slave wakes-up and relays packet at response frequency
  - Master responds with FHS packet (provides master’s **Device ID** and **Clock**)
  - Slave joins piconet