

# Computer Networks

## ICS 651

- Wireless sensor networks
- Ethernet
- ARP
- Ethernet collisions

# Wireless Sensor Network

## More General Data Forwarding

- some applications may require general communication, e.g. communication in the local area, transmit images and sound, debugging and reconfiguration
- geographic routing: move the packet in the direction of the destination. Often fails. Many workarounds, including Geometric Routing, which keeps track of overall network topology.
- gradient routing: source or destination sends a broadcast, everyone keeps track of distance. Grad, Lusus.
- sender can send a broadcast, which builds a reverse route back to the sender. Receiver uses this route to reply, building a route back to itself. Multipath On-Demand Routing (MOR).
- keeping multiple paths (MOR) lets you dynamically load balance (each node may have multiple next hops) and try to avoid congestion (if one transmission fails, try transmitting to a different next hop)

# Wireless Sensor Network Physical Layers

- wanted: long range and low power
- directional focus: lasers, infrared, phased array antennas, directional antennas. All require aiming, but some could be automatic
- omnidirectional: no focus needed, but more power needed for same range
- if antenna is high off the ground, power  $\sim r^2 \times \text{distance}$
- if antenna is near the ground, power  $\sim r^4 \times \text{distance}$

# ISM bands

- Industrial, Scientific, Medical (ISM) bands are generally free from licensing restrictions
- ISM bands are available in the 800-900MHz range (but different frequencies e.g. for US and Europe) and 2.4GHz range (worldwide, same frequency as microwave ovens, resonant frequency of water) and other ranges
- good selection of radios: systems, circuits, chips
- maximum power level usually determined by regulation, e.g. FCC in the US
- serial radios, 802.11, Bluetooth, Zigbee, and many other up-and-coming standards all use ISM bands

# Ethernet

- Carrier Sense Multiple Access
- Frame Format
- Ethernet address
- Address Resolution Protocol
- Collision Detection and Random Binary Backoff
- Then and now: coaxial to hubs, 3Mb/s to Gigabit
- Learning bridges
- Designing a small network

# Ethernet Concepts

- broadcast medium ("Ether") is a physical wire
- sender can monitor medium for other transmissions, hold off until there is silence
- after current transmission (if any is over), sender can transmit
- sender can monitor its own transmission for errors (most likely due to collision)
- CRC in frame allows all receivers to detect collisions
- Ethernet is usually described as Carrier Sense Multiple Access (CSMA) with Collision Detection (CSMA/CD)
- collision detection depends on:
  - finite speed of light
  - maximum network diameter

# Ethernet Collision Detection

- if speed of light is  $c$  m/s
- if minimum frame size is  $b$  bits
- if bandwidth is  $B$  b/s
- in-class exercise: what is the maximum network diameter (in meters -- find the formula) that still allows us to detect collisions?
- also compute for the specific case  $c = 2 * 10^8$  m/s,  $b = 256$  bits,  $B = 100$  Mb/s

# Ethernet Frame

preamble	dest	source	type	data	CRC
8	6	6	2	46-1500	4

- destination comes first: very little buffering/intelligence needed to discard a frame that is not for me
- address ff:ff:ff:ff:ff:ff is the broadcast address
- source address is generally ignored
- ethertype is 0x0800 for IP packets, 0x0806 for ARP packets, 0x86DD for IPv6 packets
- if ethertype is 1500 or less, it encodes the frame length, and other protocols (LLC/Logical Link Control) must be used to determine next higher layer

# Ethernet Addresses

- every Ethernet interface must have a globally unique address
- unlike IP, this address is not used for routing, so does not need to have global significance (no need to be hierarchical)
- Ethernet addresses are sold in blocks of  $2^{24} = 16,777,216$  (value of the first three bytes belongs to each manufacturer)
- `arp -a` to see some addresses with which your computer is communicating

# Ethernet and IP

- use ethernet to carry IP packet
- IP host/router knows: IP address of next hop, interface on which to send it
- must fragment if header + data > 1500 bytes
- must pad packet if header + data < 46 bytes
- could broadcast packet, let all but one IP on the network discard it
- instead, broadcast a request, let the specific host reply:  
Address Resolution Protocol

# ARP

dest FFFFFFFFFFFFFF				source sender Ethernet		type 806	
htype 01	proto 800	hl 6	pl 4	op 1 (2)			
sender hw sender Ethernet				sender proto sender IP			
target hw FFFFFFFFFFFFFF				target proto target IP			

- request (op 1) is sent to broadcast address, reply (op 2) to sender hardware address
- only 28 bytes, padding needed to get to 46
- hardware and protocol lengths (hl, pl) make ARP flexible enough for lots of protocols (e.g. IPv6)

# ARP Cache

- don't want to send a request for every IP packet
- when I get a reply, I cache the address
- IP is connectionless, so use a timer (15 minutes) to discard old entries
- if ARP cache fills, can do LRU discard
- if I get an ARP request from someone, I will assume:
  - they plan to send me a packet
  - I will eventually send them some reply
- so I add them to my cache

# Ethernet Collision Algorithm

- If there is a collision, it will be detected in the first 512 bits of the frame
- if a sender detects a collision, it must jam the wire
- receivers and other senders detect jamming, stop listening
- all senders must do binary exponential backoff
- randomization for backoff algorithm comes from my Ethernet address

# Ethernet Evolution and Summary

- Xerox
- 3 Mb/s system with 2- or 6-byte addresses
- 10-Base 5: coaxial 10Mb/s with vampire taps
- 10-Base 2 (thinwire): coaxial 10Mb/s with point-to-point
- 10-Base T: CAT-5 to hubs, no actual shared medium
- 100- and 1000 Mb/s Ethernet(s) over twisted pair or fiber
- Gigabit and 10-Gigabit Ethernet
- Ethernet is usually classified as: Carrier Sense Multiple Access (CSMA) with Collision Detection: CSMA/CD