Today's Lecture

- introduction to data link layer
  - in other words, how LANs work
- all about Ethernet today
- next time: other LANs
- why Ethernet?
  - almost everyone uses it
  - good way to cover many issues

Aloha, Parent of Ethernet

- built at Univ. of Hawaii in 1970's
- used radio to communicate between islands
- divide data into packets, use error detection and retransmission (as in first lecture)
- use a single radio frequency
  - one host at a time can broadcast
  - everyone hears the broadcast

Aloha Details

- to send a packet, just broadcast it
- put destination address in packet header, non-destination hosts ignore the packet
- no privacy (everybody hears everything)
  - ignored in Aloha design
  - still a problem in today's networks

Collisions

- problem: what if two hosts broadcast at the same time?
  - broadcasts interfere; packets are garbled
- non-solution: rely on timeout and retransmission
  - retransmissions can collide again, and again...
  - network can break down under heavy load
- a problem in any network not built from point-to-point links

Ethernet

- child of Aloha
- rather than using radio, sends waves down a coaxial cable
  - coax connection much cheaper than radio
- design issues are the same; approach is the same

Dealing with Collisions

- try to avoid collisions: don't start broadcasting unless network is quiet
- detect collisions early: when broadcasting, listen for interference
  - if interference, stop broadcasting
    - » don't use network resources for colliding broadcasts
- recover from collisions
  - this is the tricky part

Wire Length and Delays

- want broadcasters to detect collision while they are broadcasting
  - requirement: duration of broadcast greater than propagation delay between broadcasters
- to meet requirement
  - impose minimum broadcast duration
  - impose maximum cable length
  - proper choices are a compromise

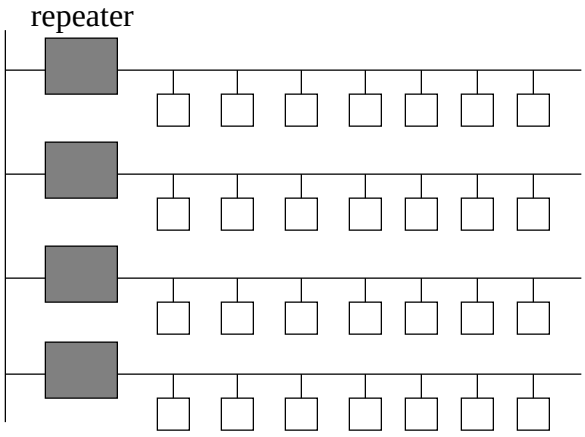
Dealing with Collisions

```
ethernetSend() {
        wait until cable is quiet
        if(trySend() == Success)    return;
        Time delay = 51.3 microseconds;
         forever {
                Time t = random between 0 and delay
                sleep(t);
                wait until cable is quiet
                if(trySend() == Success)    return;
                delay *= 2;
        }
}
```

"Classic" Ethernet

- also called "thick-net" or "10Base5"
  - 10 means 10 Mbits/second
  - 5 means 500m maximum cable length
- transceiver taps at least 2.5m apart
- connect multiple segments with repeaters
- no more than 2 repeaters on any path
- maximum of 1024 hosts

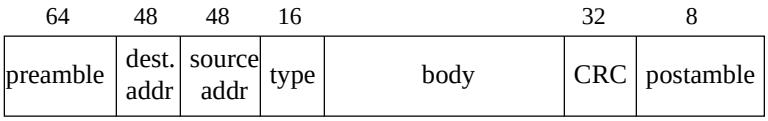
Typical Thick-Net Configuration



Ethernet Alternatives

- 10Base2 (“thin-net”)
  - 200m limit
  - daisy-chain configuration
- 10BaseT (“twisted-pair”)
  - 100m limit
  - star configuration
    - » hub connects point-to-point links
- can connect different types

Ethernet Frame Format



- preamble: alternate 0 and 1, for synch.
- various uses for type
- variable size body (max 1500 bytes)
- CRC: checksum to detect errors

Addresses

- 48 bit address ("MAC address") assigned to each adaptor
- unique across all adaptors, everywhere
  - a few bits to identify the manufacturer
  - other bits assigned by manufacturer
- special broadcast address ff:ff:ff:ff:ff:ff
- multicast addresses: first bit is 1

Multicast

- somewhere between broadcast (to everyone) and unicast (to one destination)
- receiving applications *subscribe* to a multicast address
- used for cooperating applications
- local administrator decides how to use multicast addresses

Receiving Frames

- Ethernet is a broadcast medium
- adaptor receives all frames
- it accepts a frame (passes it to the host) if
  - it is unicast and addressed to this adaptor
  - it is addressed to the broadcast address
  - it is addressed to a multicast address that the host has subscribed to
  - the adaptor is in "promiscuous mode"

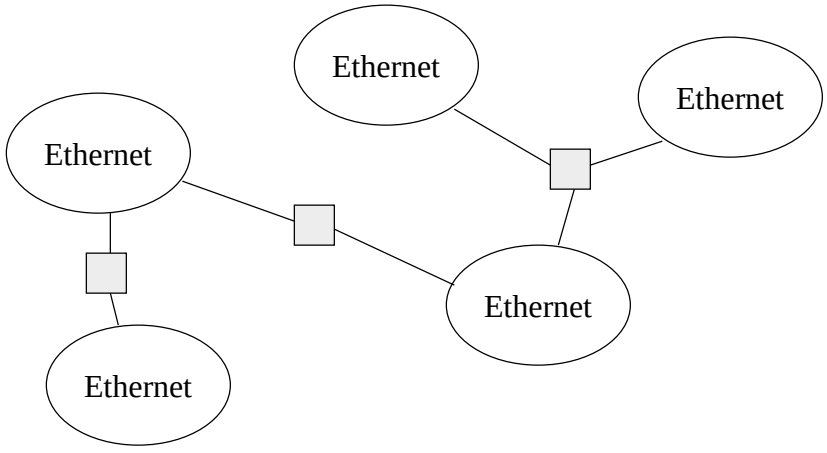
Experience with Ethernet

- works well with 10-200 hosts per net
- 150m length more typical than 1500m
- packet length is bimodal
- very cheap to add a host
  - PC adaptor costs $20
  - 8-port hub costs $70

Ethernet Bridges

- bridge: a box that connects to two or more ethernets, forwarding packets between them
  - repeater is an electrical amplifier
  - bridge understands frames
- allows multiple Ethernets to be connected
  - treat the combination like a single Ethernet
  - scales better than using repeaters

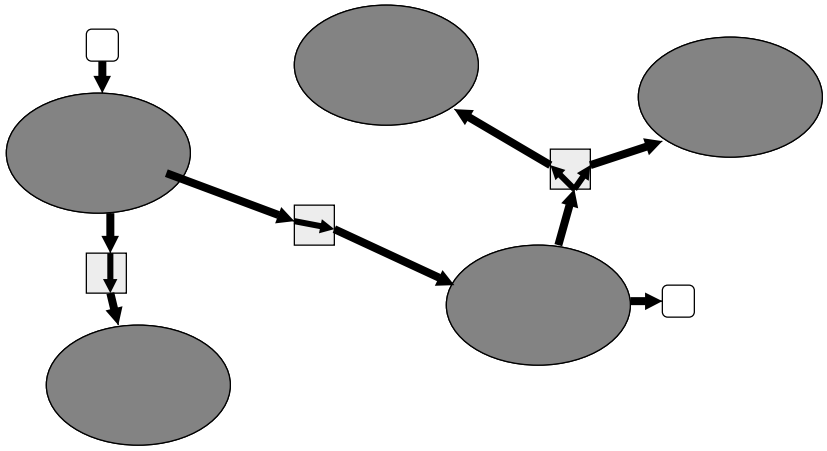
Bridges



Simple (“Dumb”) Bridges

- receives all frames
  - except those it sent itself
- on receiving a frame, forwards it onto all Ethernets except the one it came from
- forwarding gets frame to its destination, wherever the destination is

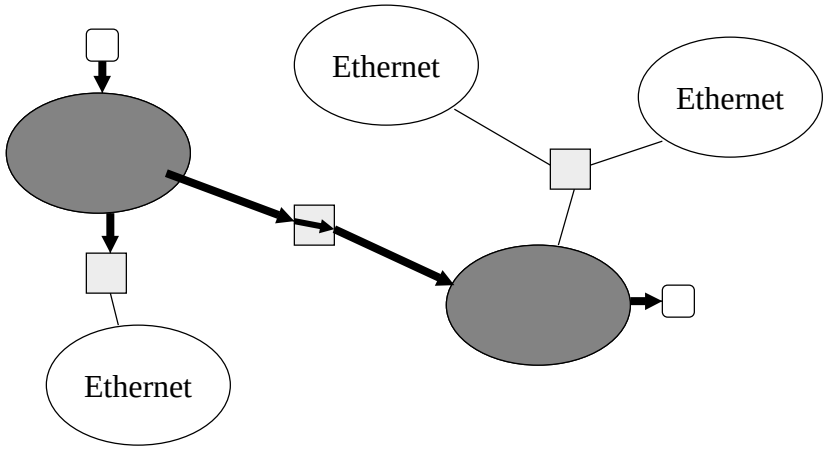
Dumb Bridges at Work



Smart Bridges

- dumb bridges flood all frames to everywhere, wasting resources.
- smart bridges forward frames only when necessary
  - keep list of destinations with action for each
- list and actions programmed by a person

Smart Bridges in Action



Smart Bridges: Problems

- relies on programming being right
- network mysteriously "malfunctions" if
  - machine plugged in without reprogramming
  - machine moved without reprogramming
  - machine gets new adaptor without reprogramming
  - etc.
- problems happen all the time

Learning Bridges

- bridge learns which machines are where
- keep action table (like smart bridge)
  - entries initialized to "flood"
- learn from sender-address fields in frames
  - when frame sent by S observed on net N, set action for S to "forward to net N"
- handles single-hop or multi-hop routing
- over time, net becomes more efficient

Handling Changes

- What if the net configuration changes?
- handle by forgetting old information
  - forget after (say) five minutes
  - normally, re-learn quickly
  - optimization: use new packets to corroborate known information
- "soft state" (learning with periodic forgetting) is a common trick in net protocols

Fast Ethernet

- 100 Mbit/sec Ethernet widely available
  - "100BaseT", etc.
- still cheap and easy to use
- 1 Gbit/sec Ethernet on the way

- Will Ethernet crush other fast networks?