Ethernet

Outline

- Multiple Access and Ethernet Intro
- Ethernet Framing
- CSMA/CD protocol
- Exponential backoff

Shared Access Networks are Different

- Shared Access Networks assume multiple nodes on the same physical link
  - Bus, ring and wireless structures
  - Transmission sent by one node is received by all others
  - No intermediate switches
- Need methods for moderating access (MAC protocols)
  - Fairness
  - Performance
  - How can this be done?

Multiple Access Methods

- Fixed assignment
  - Partition channel so each node gets a slice of the bandwidth
  - Essentially circuit switching – thus inefficient
  - Examples: TDMA, FDMA, CDMA (all used in wireless/cellular environments)
- Contention-based
  - Nodes contends equally for bandwidth and recover from collisions
  - Examples: Aloha, Ethernet
- Token-based or reservation-based
  - Take turns using the channel
  - Examples: Token ring

A Quick Word about Token Ring

- Developed by IBM in early 80's as a new LAN architecture
  - Consists of nodes connected into a ring (typically via concentrators)
  - Special message called a token is passed around the ring
    - When nodes gets the token it can transmit for a limited time
    - Every node gets an equal opportunity to send
  - IEEE 802.5 standard for Token Ring
- Designed for predictability, fairness and reliability
  - Originally designed to run at either 4Mbps and 16Mbps
- Still used and sold but beaten out by Ethernet

Our Focus is Ethernet

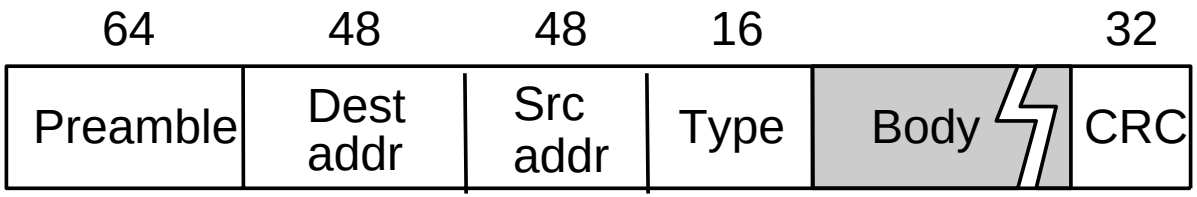
- History
  - Developed by Bob Metcalfe and others at Xerox PARC in mid-1970s
  - Roots in Aloha packet-radio network
  - Standardized by Xerox, DEC, and Intel in 1978
  - LAN standards define MAC and physical layer connectivity
    - IEEE 802.3 (CSMA/CD - Ethernet) standard – originally 2Mbps
    - IEEE 802.3u standard for 100Mbps Ethernet
    - IEEE 802.3z standard for 1,000Mbps Ethernet
- CSMA/CD: Ethernet's Media Access Control (MAC) policy
  - CS = carrier sense
    - Send only if medium is idle
  - MA = multiple access
  - CD = collision detection
    - Stop sending immediately if collision is detected

Ethernet Overview

- Most popular packet-switched LAN technology
- Bandwidths: 10Mbps, 100Mbps, 1Gbps
- Max bus length: 2500m
  - 500m segments with 4 repeaters
- Bus and Star topologies are used to connect hosts
  - Hosts attach to network via Ethernet transceiver or hub or switch
    - Detects line state and sends/receives signals
  - Hubs are used to facilitate shared connections
  - All hosts on an Ethernet are competing for access to the medium
    - Switches break this model
- Problem: Distributed algorithm that provides fair access

Ethernet Overview (contd.)

- Ethernet by definition is a broadcast protocol
  - Any signal can be received by all hosts
  - Switching enables individual hosts to communicate
- Network layer packets are transmitted over an Ethernet by encapsulating
- Frame Format



Ethernet Frames

- Preamble is a sequence of 7 bytes, each set to “10101010”
  - Used to synchronize receiver before actual data is sent
- Addresses
  - unique, 48-bit unicast address assigned to each adapter
    - example: **`8:0:e4:b1:2`**
    - Each manufacturer gets their own address range
  - broadcast: all **`1`**s
  - multicast: first bit is **`1`**
- Type field is a demultiplexing key used to determine which higher level protocol the frame should be delivered to
- Body can contain up to 1500 bytes of data

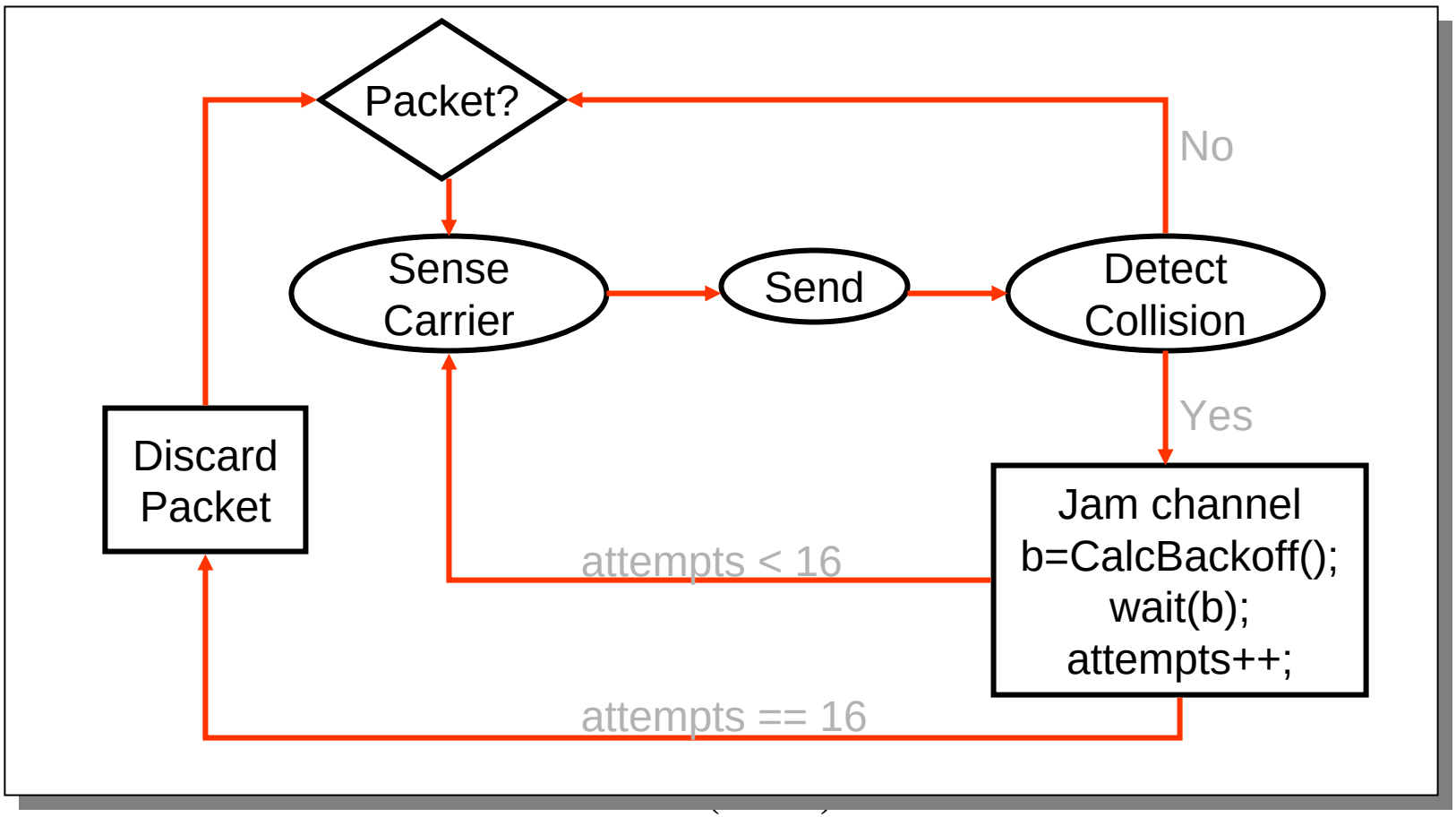
A Quick Word about Aloha Networks

- Developed in late 60's by Norm Abramson at Univ. of Hawaii (!!) for use with packet radio systems
  - Any station can send data at any time
  - Receiver sends an ACK for data
  - Timeout for ACK signals that there was a collision
    - What happens if timeout is poorly timed?
  - If there is a collision, sender will resend data after a random backoff
- Utilization (fraction of transmitted frames avoiding collision for N nodes) was pretty bad
  - Max utilization = 18%
- Slotted Aloha (dividing transmit time into windows) helped
  - Max utilization increased to 36%

Ethernet's MAC Algorithm

- In Aloha, decisions to transmit are made without paying attention to what other nodes might be doing
- Ethernet uses CSMA/CD – listens to line before/during sending
- If line is idle (no carrier sensed)
  - send packet immediately
  - upper bound message size of 1500 bytes
  - must wait 9.6us between back-to-back frames
- If line is busy (carrier sensed)
  - wait until idle and transmit packet immediately
    - called *1-persistent* sending
- If collision detected
  - Stop sending and jam signal
  - Try again later

State Diagram for CSMA/CD

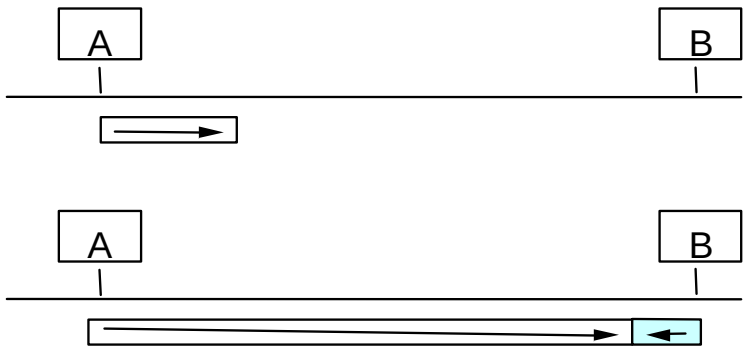


Collisions

Collisions are caused when two adaptors transmit at the same time (adaptors sense collision based on voltage differences)

- Both found line to be idle
- Both had been waiting to for a busy line to become idle

A starts at time 0



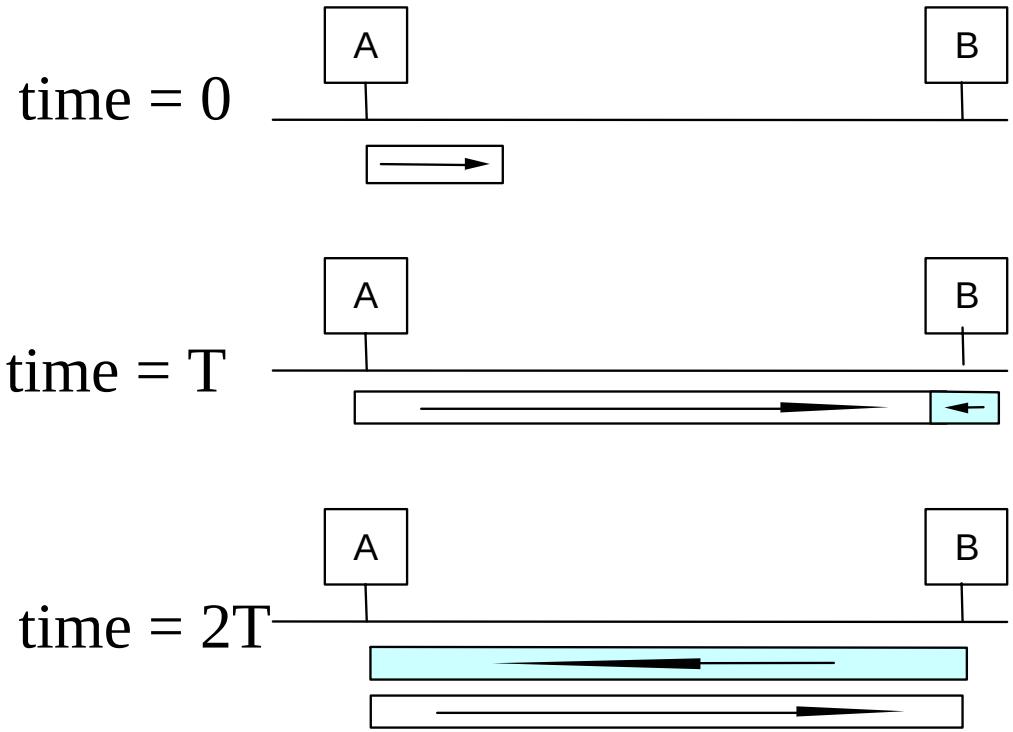
Message almost there at time T when B starts – collision!

How can we be sure A knows about the collision?

Collision Detection

- How can A know that a collision has taken place?
  - There must be a mechanism to insure retransmission on collision
  - A's message reaches B at time T
  - B's message reaches A at time 2T
  - So, A must still be transmitting at 2T
- IEEE 802.3 specifies max value of 2T to be 51.2us
  - This relates to maximum distance of 2500m between hosts
  - At 10Mbps it takes 0.1us to transmit one bit so 512 bits (64B) take 51.2us to send
  - So, Ethernet frames must be at least 64B long
    - 14B header, 46B data, 4B CRC
    - Padding is used if data is less than 46B
- Send jamming signal after collision is detected to insure all hosts see collision
  - 48 bit signal

Collision Detection contd.



Exponential Backoff

- If a collision is detected, delay and try again
- Delay time is selected using binary exponential backoff
  - 1st time: choose K from {0,1} then delay = K * 51.2us
  - 2nd time: choose K from {0,1,2,3} then delay = K * 51.2us
  - *nth* time: delay = K x 51.2us, for K=0..$2^n - 1$
    - Note max value for k = 1023
  - give up after several tries (usually 16)
    - Report transmit error to host
- If delay were not random, then there is a chance that sources would retransmit in lock step
- Why not just choose from small set for K
  - This works fine for a small number of hosts
  - Large number of nodes would result in more collisions

MAC Algorithm from the Receiver Side

- Senders handle all access control
- Receivers simply read frames with acceptable address
  - Address to host
  - Address to broadcast
  - Address to multicast to which host belongs
  - All frames if host is in promiscuous mode

Fast and Gigabit Ethernet

- Fast Ethernet (100Mbps) has technology very similar to 10Mbps Ethernet
  - Uses different physical layer encoding (4B5B)
  - Many NIC's are 10/100 capable
    - Can be used at either speed
- Gigabit Ethernet (1,000Mbps)
  - Compatible with lower speeds
  - Uses standard framing and CSMA/CD algorithm
  - Distances are severely limited
  - Typically used for backbones and inter-router connectivity
  - Becoming cost competitive
  - How much of this bandwidth is realizable?

Experiences with Ethernet

- Ethernets work best under light loads
  - Utilization over 30% is considered heavy
    - Network capacity is wasted by collisions
- Most networks are limited to about 200 hosts
  - Specification allows for up to 1024
- Most networks are much shorter
  - 5 to 10 microsecond RTT
- Transport level flow control helps reduce load (number of back to back packets)
- Ethernet is inexpensive, fast and easy to administer!

Ethernet Problems

- Ethernet's peak utilization is pretty low (like Aloha)
- Peak throughput worst with
  - More hosts
    - More collisions needed to identify single sender
  - Smaller packet sizes
    - More frequent arbitration
  - Longer links
    - Collisions take longer to observe, more wasted bandwidth
  - Efficiency is improved by avoiding these conditions

Why did Ethernet Win?

- There are LOTS of LAN protocols
- **Price**
- Performance
- Availability
- Ease of use
- Scalability
- Tomorrow we will talk about physical layer stuff…