Review - Slotted Aloha

What did we learn?

- $\lambda_{max} = e^{-1} \approx 0.368$
- q_r should dynamically change

Binary Exponential Backoff

- $q_r = 2^{-k}$, when a packet experienced k collisions.

Next Step

Questions:

- Can we do better than Slotted Aloha?
- How close to the maximal throughput can we get?

To improve Slotted Aloha:

- Where do we waste time?

Improving Slotted Aloha

Approaches

- Carrier Sensing (CSMA)
- Collisions Detection (CD)

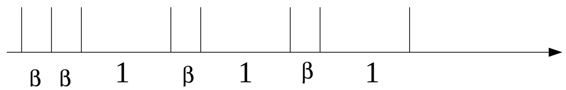
Ethernet uses CSMA/CD

Goal

- Understand CSMA
- Understand CD
- Understand Ethernet

Model - CSMA

- Time is divided into slots (unit time = $\frac{L}{C}$ seconds):



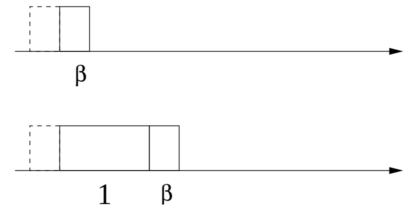
Length of idle slot $\beta = \tau \frac{C}{L}$ seconds

- Packet arrival rate (over all nodes) of λ packets/time unit
- Collision or Perfect Reception
- Immediate Feedback: $0, 1, e$
- Transmission Probability: q_r

Note: Stations only transmit after an idle slot !

Observations - CSMA

Events



Average Length of Events

$$
\begin{aligned}
E[T] &= E[T \mid \text{no transmission attempt}]P\{\text{no transmission attempt}\} + \\
&\quad E[T \mid \text{transmission attempt}]P\{\text{transmission attempt}\}
\end{aligned}
$$

Using the Poisson approximation with

$$g(n) = nq_r$$

we obtain

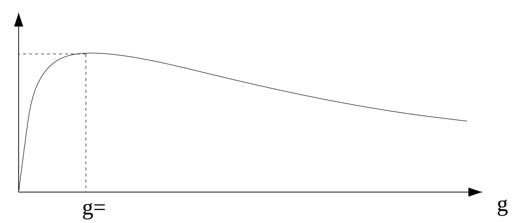
$$
\begin{aligned}
E[T] &= \beta \cdot e^{-g(n)} + (1+\beta) \cdot \left(1 - e^{-g(n)}\right) \\
&= \beta + 1 - e^{-g(n)}
\end{aligned}
$$

and

$$
\begin{aligned}
throughput(n) = \frac{P_{succ}}{E[T]} &= \frac{g(n)e^{-g(n)}}{E[T]} \\
&= \frac{g(n)e^{-g(n)}}{\beta + 1 - e^{-g(n)}}
\end{aligned}
$$

Results - CSMA

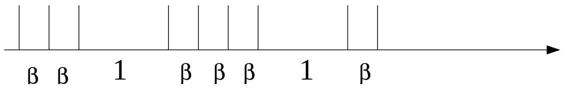
For β very small



- Maximal throughput for $g = \sqrt{2\beta}$
- Maximal throughput is $\frac{1}{1+\sqrt{2\beta}}$
- Stability is an issue

Model - CSMA/CD

- Time is divided into slots:

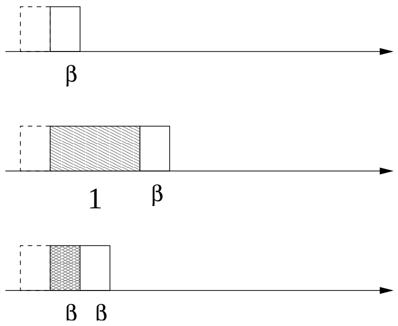


Length of collision slot $\beta = \tau \frac{C}{L}$ seconds

- Packet arrival rate (over all nodes) of λ packets/time unit
- Collision or Perfect Reception
- Immediate Feedback: $0, 1, e$
- Transmission Probability: q_r

Observations - CSMA/CD

Events



Average Length of Events

$$\begin{aligned} E[T] &= E[T \mid \text{no trans. attempt}]P\{\text{no trans. attempt}\} + \\ &\quad E[T \mid \text{one trans. attempt}]P\{\text{ one trans. attempt}\} + \\ &\quad E[T \mid > \text{one trans. attempt}]P\{ > \text{one trans. attempt}\} \end{aligned}$$

Using the Poisson approximation with

$$g(n) = nq_r$$

we obtain

$$\begin{aligned} E[T] &= \beta \cdot e^{-g(n)} + \\ &\quad (1+\beta) \cdot \left(g(n)e^{-g(n)}\right) + \\ &\quad 2\beta \cdot \left(1 - e^{-g(n)} - g(n)e^{-g(n)}\right) \\ &= \beta + g(n)e^{-g(n)}\beta\Big[1 - (1 + g(n))e^{-g(n)}\Big] \end{aligned}$$

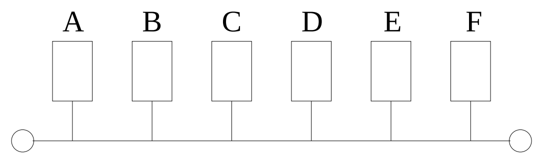
and

$$throughput(n) = \frac{P_{succ}}{E[T]} = \frac{g(n)e^{-g(n)}}{\beta + g(n)e^{-g(n)}\beta\Big[1 - (1+g(n))e^{-g(n)}\Big]}$$

Results - CSMA/CD

- Maximal throughput for $g = 0.77$
- Maximal throughput is $\frac{1}{1+3.31\beta}$
- Stability is an issue

Ethernet



- Uses CSMA/CD
- Uses Binary Backoff
- Does not use time slots

Ethernet Frame

Preamble	Dest. Address	Source Address	Type	Data	CRC

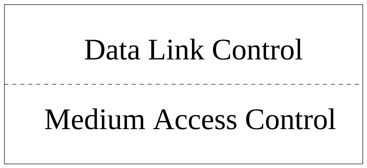
- **Preamble (8 bytes)**: Synchronization
- **Destination Address (6 bytes) - Source Address (6 bytes)**
  MAC-Address (hexadecimal notation): 1A-3B-0D-08-9B
- **Type (2 bytes)**: Multiplexing (of Network protocols)
- **Data (46-1500 bytes)**
- **Cyclic-Redundancy Check (4 bytes)**: Error detection

Ethernet Protocol

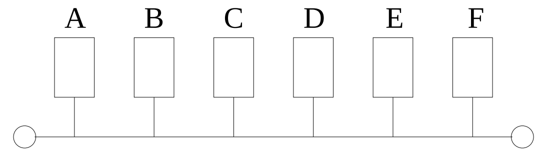
- If the adapter senses that the channel is idle and has a frame to transmit, it starts to transmit the frame. If the adapter senses that the channel is busy, it waits until it senses no signal (plus 96 bit times) and then starts to transmit.
- If the adapter detects a signal from other adapters while transmitting, it stops transmitting its frames and instead transmits a 48-bit jam signal.
- After aborting, the adapter enters an **exponential backoff** phase.
- After experiencing the nth collision in a row for this frame, the adapter chooses at random a value K from $\{0, 1, ..., 2^{m-1}\}$ where $m := \min(n, 10)$. The adapter then waits $K \cdot 512$ bit frames and then tries to retransmit the frame.

$- >$ Connectionless Service

Data Link Layer for Random Access

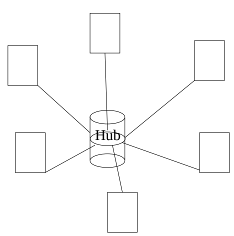


10Base2 Ethernet



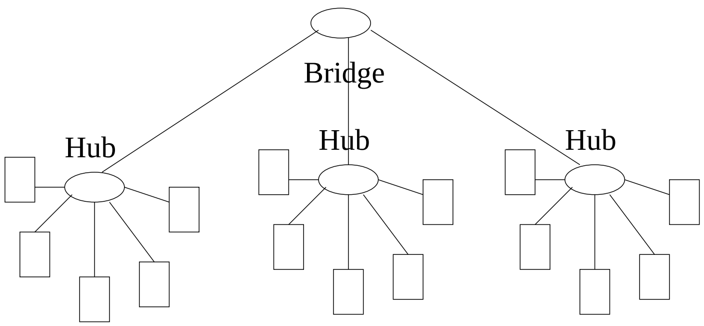
- 10 Mbps
- Thin coaxial wire
- Maximal Length (without repeaters) is 185m.

10BaseT and 100BaseT Ethernet

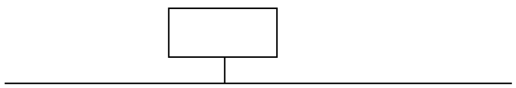


- 10 Mbps / 100 Mbps
- Twisted-pair copper wire
- Maximal Length (host to hub) is 100m.

Interconnecting Ethernets



WaveLAN's: IEEE 802.11



Basestation/Access Point (AP)

- Hidden-Terminal Problem: ACK
- CSMA/CA