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Communications & Networking
Laboratory

ECE 462 – Data and Computer Communications

Lecture 17/18: Medium Access Control

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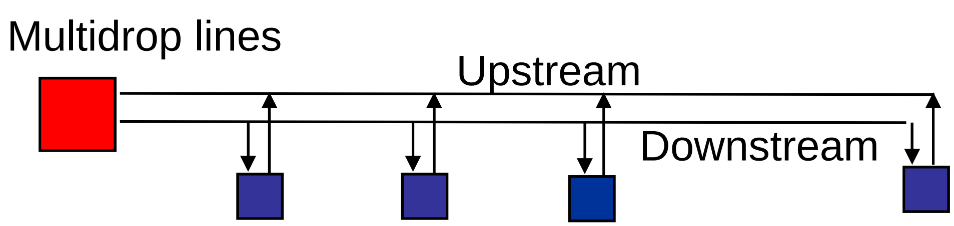
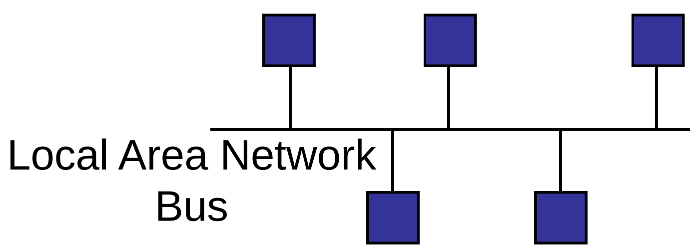
Outline

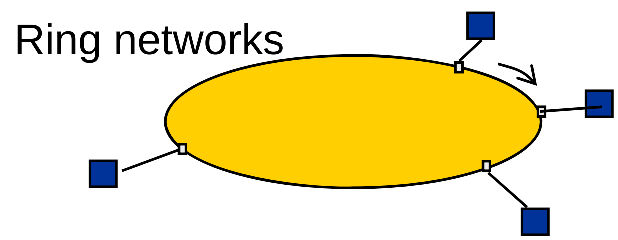
- Medium sharing techniques
- Types of polling
  - Cycle or Scan time
  - Access delay
- ALOHA
- S-ALOHA
- CSMA/CD

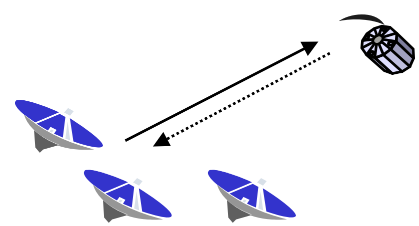
Medium Access Control

- So far we have considered a channel is being used as a Point-to-Point medium
- Now we consider sharing a channel
  - In the upstream it is many to one
  - In the downstream it is one to many
  - Examples:









Medium Sharing Techniques

- Medium sharing can be achieved
  - Static allocation
  - Dynamic Medium Access Control
    - Scheduling
    - Random Access

Controlled Access versus Random Access

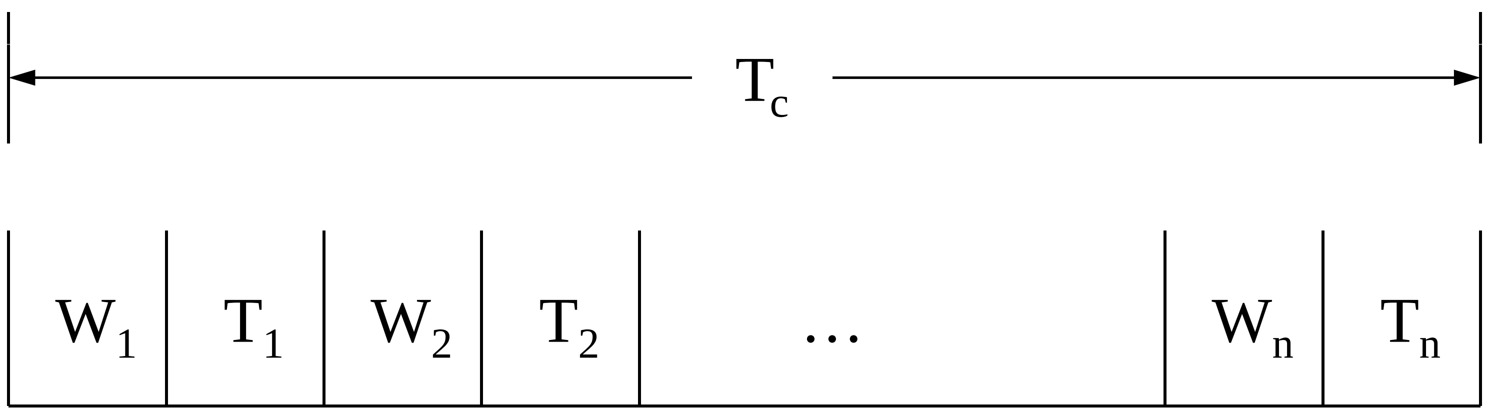
- Controlled Access protocols include hub and roll call polling, as well as token based (token ring and token bus) protocols
- Early hardware implementations of controlled access relied on frequency division multiplexing, which required duplicating the complicated hardware for each end user
- Time division multiplexing is simpler to implement from a hardware standpoint, and is commonly used
- Random Access based methods such as ALOHA or CSMA/CD are useful for providing faster access at low data rates
- Common applications include LANs, packet radio, satellite communications, and wireless PBX

Polling

- Types of Polling
  - Roll-Call Polling
  - Hub Polling
- In Roll-Call Polling stations get access to the channel for transmission on a round-robin fashion
- We need to evaluate the performance of Polling

Cycle Time

- Cycle time or scan time: time between subsequent polls at a particular station
- Derivation of cycle time
  - Ti   transmission time
  - Wi   walk time



Cycle time Derivation

Cycle time: $$T_c = \sum_{i=1}^{N} W_i + \sum_{i=1}^{N} T_i$$

Mean cycle time:

$$\overline{T_c} = \sum_{i=1}^{N} \overline{W_i} + \sum_{i=1}^{N} \overline{T_i}$$

$\sum_{i=1}^{N} \overline{W_i} = L$, then

$$\overline{T_c} = L + \sum_{i=1}^{N} \overline{T_i}$$

Average number of packets waiting to be transmitted when station *i* is polled:

$$\lambda_i \overline{T_c}$$

Time required to transmit these:

$$\overline{T_i} = \lambda_i \overline{T_c}\,\overline{m_i} = \rho_i \overline{T_c}$$

where

$$\rho_i = \lambda_i \overline{m_i}$$

Average scan time:

$$\overline{T_c} = L + \sum_{i=1}^{N} \overline{T_i}$$

$$= L + \overline{T_c} \sum_{i=1}^{N} \rho_i$$

$$= \frac{L}{1 - \sum \rho_i}$$

Total walk time for roll-call polling:

$$L = NT_p + NT_s + \tau'$$

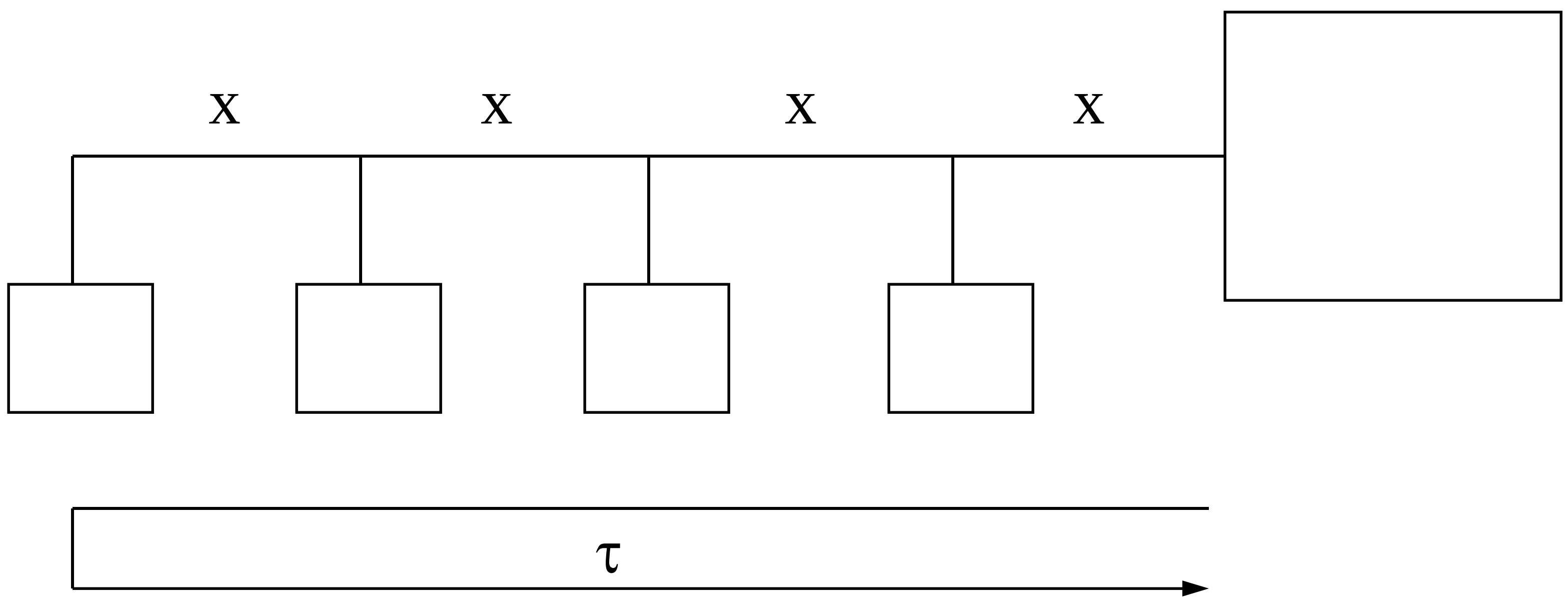
$$\tau' = \frac{\tau}{2}(1 + N)$$

In hub polling,

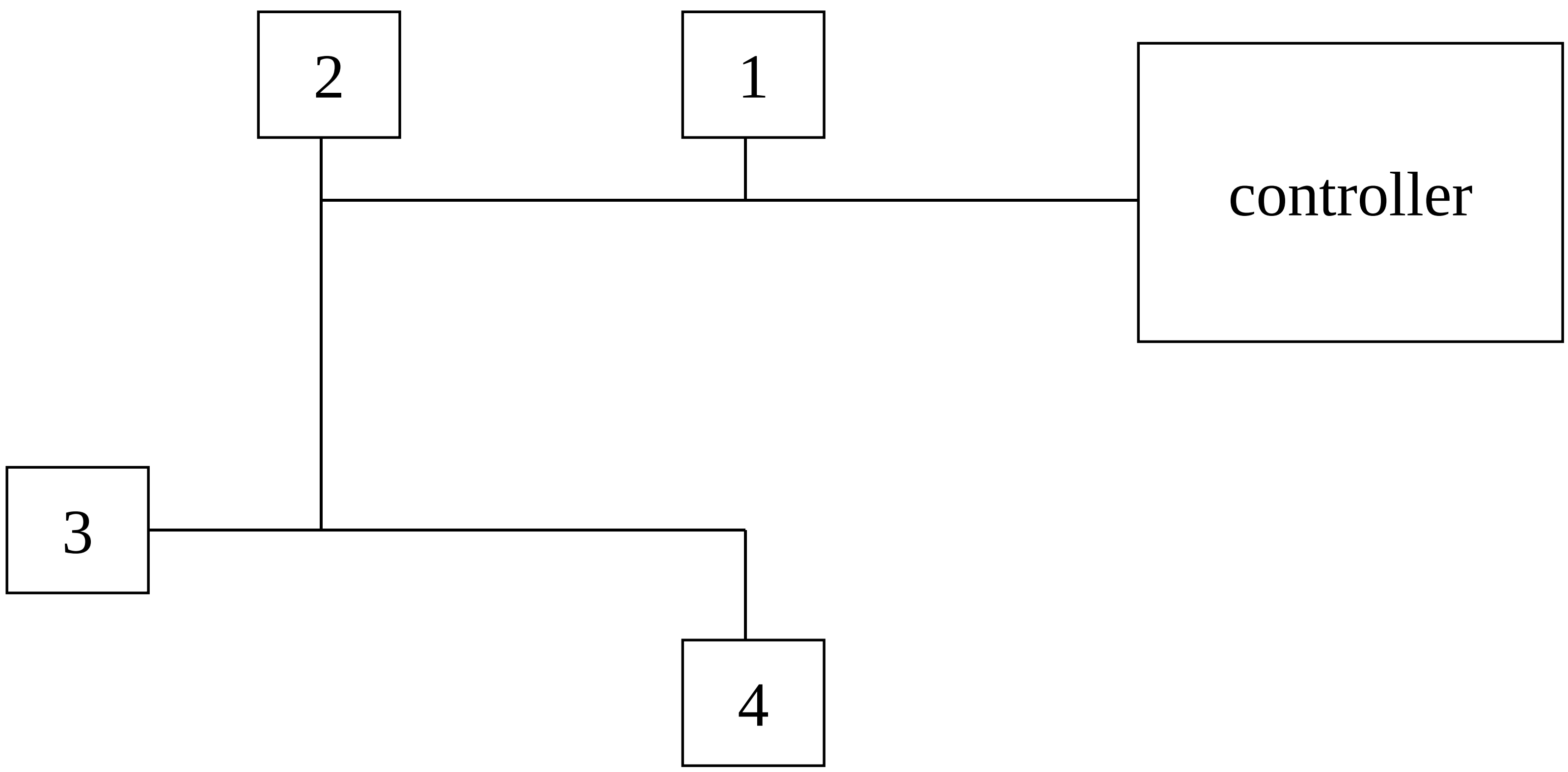
$$L_{hub} = \tau + NT_s$$

Special Case

- Uniform distribution of identical stations



Examples



Illustrating Example

Given:

λ_i = 75 frames/sec

frame length = 1000 bits

C = 600 Kbps

poll message = 60 bits

sync time = 0.1 msec

τ = 200 μsec

Solution

$$\tau' = \frac{\tau}{2}(1+N) = \frac{200}{2}(1+4) = 500\mu\sec$$

$$T_p = \frac{60}{600000} = 0.1m\sec$$

$$L = (4*0.1)+(4*0.1)+0.5 = 1.3m\sec$$

Solution (Cont'd)

$$m = \frac{1000}{600000} = 1.67 m\sec$$

$$\rho = N\lambda m = 4(75)(1.67 * 10^{-3}) = 0.5$$

$$\overline{T}_c = \frac{L}{1-\rho} = \frac{1.3}{1-0.5} = 2.6 \quad m\sec$$

ALOHA

- ALOHA - Additive Links On-line Hawaii Area System
- A random access protocol which yields a utilization of up to 18% at low data rates
- The derivation is probabilistic, based on the Poisson random variable for the traffic arrival
- For an infinite population, the probability of N frames in time T is given by

$$P[N,T] = \frac{(\lambda T)^N}{N!} e^{-\lambda T}$$

- Assumptions: The derivation is also based on the following
  - All users are independent
  - λ frame/second arrival rate
  - Frames are of fixed length
  - Frame transmit time = m
  - ρ total number of packets generated in m seconds
    - (Also referred to as **Normalized Throughput or *S***)
    - $N\lambda$ =total packets/second from N sources

ALOHA

$$\rho = N\lambda \ m$$

The following results are obtained

$$P(no.collision) = e^{-2G}$$

- Where $G = N\lambda' \ m$ and T=2m (collision period)

$$P(collision) = 1 - e^{-2G}$$

$$G = S + G(1 - e^{-2G})$$

- or

$$S = Ge^{-2G}$$

ALOHA

- The constraint of equilibrium (what goes in must exit at the same rate) requires

$$dS/dG = 0$$

- The optimum traffic for ALOHA is *G*=1/2, which yields a throughput of

$$S = \frac{1}{2}e^{-1} = 0.1839$$

- Note that the value of *G* =1/2 total frame in m seconds includes *S*=.184 successful frames per *m* seconds, leaving 0.316 frames per *m* seconds as retransmissions
- So even at the optimum utilization, the majority of frames are retransmissions
- The mean number of retransmissions per successful transmission is given by

$$E = \frac{G}{S} - 1$$

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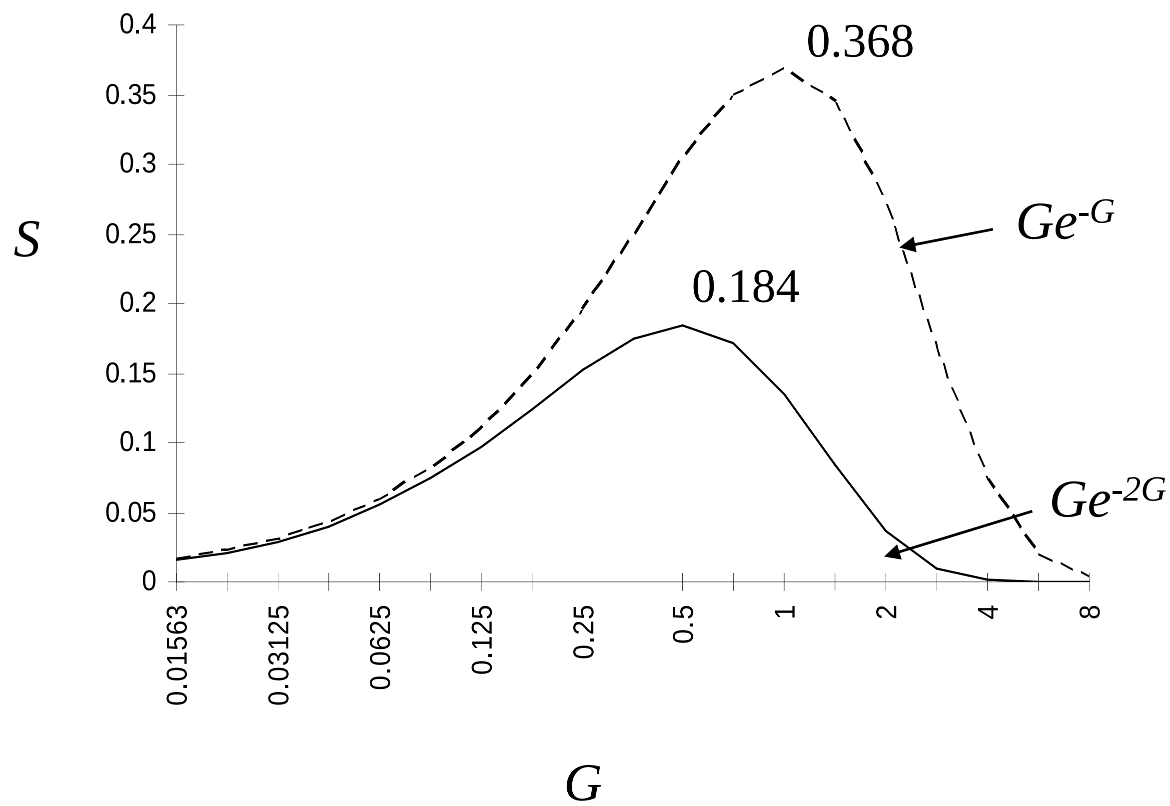
Slotted-ALOHA

- Slotted ALOHA is another random access protocol which restricts the transmissions to certain discrete "slots”
- This has the effect of reducing the collision interval from 2*m* to *m*
- The equations are modified as follows

$$S = Ge^{-G}$$

- G (optimum) = 1
- S (optimum) = e^{-1} = 0.368
- The net effect of Slotted ALOHA is to yield a twofold increase in utilization

ALOHA and S-ALOHA Performance



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CSMA/CD

- Carrier Sense Multiple Access with Collision Detect improves on ALOHA access method when the propagation delay is less than frame transmission time.
  - Carrier sensing inhibits a node from initiating transmission if the bus or ring is in use
  - As a station transmits its own packet it listens to the transmission and, if it detects a collision, it aborts that transmission with a jamming signal
  - Thus, when a collision does occur, CSMA/CD is able to detect it

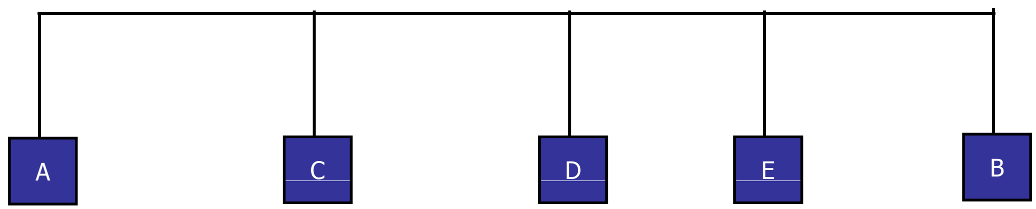
CSMA /CD Protocol

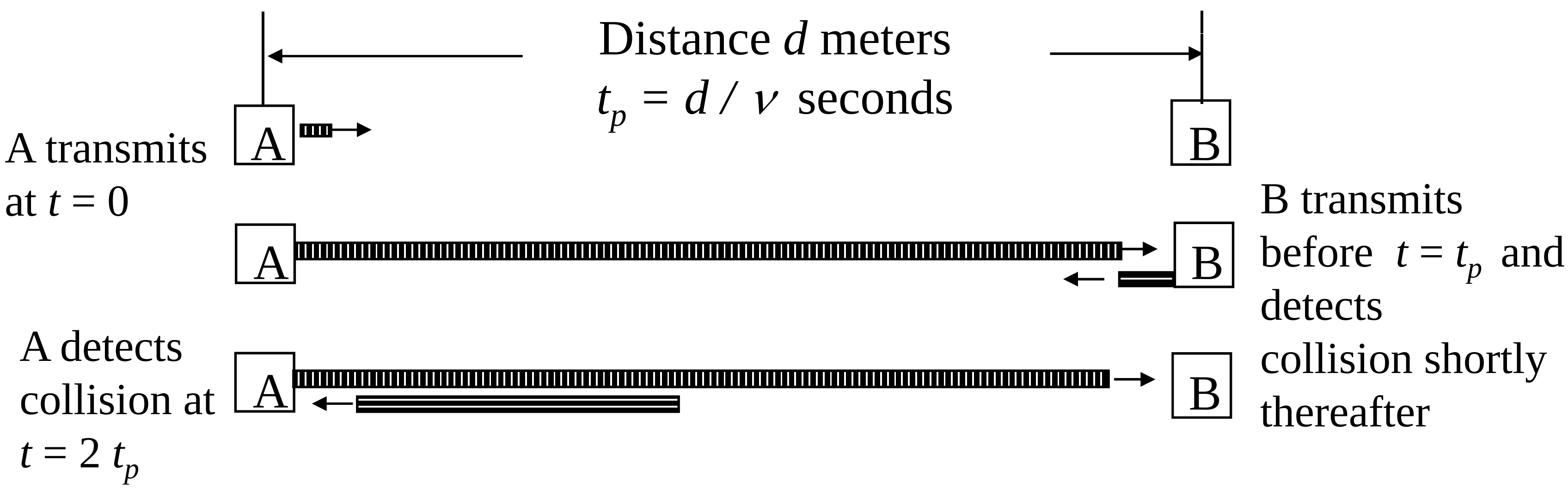
- CSMA/CD operation
  - If the channel is busy, then defer transmission to the next slot with some probability
  - If the channel is quiet, then send the packet
    - continue listening to the transmission
  - If a collision occurs, then abort the transmission and send a short jamming signal
  - Wait a random number of slots before trying again

Binary Exponential Backoff

- When collision occurs the stations wait a random number of slots before retransmitting
  - On first collision wait either 0 or 1 time slots before retrying
  - On second collision, wait either 0, 1, 2, or 3 time slots before retrying
  - On third collision, wait 0 to 7 time slots before retrying
  - In general, after n collisions, wait anywhere from 0 to $2^n - 1$ slots, if $n \leq 10$; or between 0 and 1023 slots if $n > 10$
  - After 16 collisions, give up and report that packet could not be sent
  - After a period of no collisions, start backing down number of slots

Contention Period





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CSMA/CD Performance

- CSMA/CD is most effective for applications with a small coefficient *a*
- CSMA/CD is the basis for the Ethernet-based LANs
- The equation performance of CSMA/CD is

$$\rho_{MAX} = S_{CSMA/CD} = N\lambda m = \frac{1}{1+(2e^{1}+1)a} = \frac{1}{1+6.4a}$$

  - where $a = t_p / m$
  - t_p = longest point-to-point propagation delay
  - and m = message transmission time

CDMA/CD Performance

- Note that $a = t_p / t_I = t_p / m << 1$

- For example, when L=1000 bits, R=10 Mbps and a bus length of 200 meters

$t_I = m =$1000/10 Mbps = 100 μs

T_p=0.200 Km X5 μs/Km=1 μs

$a = t_p / m$ =1/100=0.01 <<1

Deriving CSMA/CD Performance (1)

- Consider max collision interval (A and B) denoted by $2t_p$
- Consider the the time to get a frame through, t_V
- Divide this time to N mini-slots of $2t_p$
  - $2t_p = t_V / N$
- *The time* t_V *includes* transmission and contention intervals
  - transmission interval is $t_I / t_p = 1/2a$ slots
  - whereas each contention interval has either a collision or no transmissions
  - Need to find the average length of a contention interval

Deriving CSMA/CD Performance (2)

- Assume that the probability that a node transmits is p
- The probability that there is only one transmission on the bus (ie, exactly one station transmits), p_s, is given by

$$p_s = \binom{n}{1} p^1 (1-p)^{n-1} = np(1-p)^{n-1}$$

- This is maximized when $p = 1/N$ and thus $p_s = \left(1 - \frac{1}{N}\right)^{N-1}$
- But note that the mean contention interval is

$$t_C = t_p \cdot \sum_{i=1}^{\infty} i p_s (1-p_s)^{n-1}$$

- and we find in the limit $\lim_{N \to \infty} \left(1 - \frac{1}{N}\right)^{N-1} = \frac{1}{e}$
- Thus t_c=(1+2e)t_I=(1+2e)at_p

Deriving CDMA/CD Performance (3)

- The utilization can be written as

$$S = \rho_{Max} = \frac{t_I}{t_I + t_C}$$

$$\rho_{Max} = \frac{1}{1 + a(1 + 2e)}$$

$$S_{CSMA/CD} = \rho_{Max} = N\lambda m = \frac{1}{1 + 6.4a}$$

IEEE 802 LAN Standards

- 802.1 Service Interface
- 802.2
  - Type I – connectionless
  - Type 2 - connection-oriented
- 802.3 CSMA/CD
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 DQDB (Dual-Queue Dual Bus) Metropolitan Area Network

IEEE 802.3 CSMA/CD (based on Ethernet LAN)

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- Coaxial Cable:
  - thick, with cut-in tap (10BASE5)
  - thin, with BNC connector (10BASE2)
- Transceiver Hardware (on workstation or external interface)
  - senses carrier: busy, idle, or collision
  - sends/receives frames
  - contains a hardwired address
- Ethernet protocol software/firmware (on workstation)
  - formats header
  - performs random backoff after collision
  - implements binary exponential backoff algorithm
- No master station

Ethernet Frame

64 bits	48 bits	48 bits	16 bits	368 to 12,000 bits	32 bits
Preamble	Destination	Source	Type	Frame Data	CRC

- 48-bit address is installed at the factory for each interface
- Destination must be on the same LAN as the Source
- Frame Type describes the payload; thus each frame is self-identifying (example: TCP/IP packet)
- Minimum frame size = slot time = 512 bits
- Interframe gap = 96 bits
- Jamming signal size = 32 - 48 bits