Chap 6 Medium Access Control Protocols and Local Area Networks

- Broadcast Networks: a single transmission medium is shared by many users. (Multiple access networks)
- User transmissions interfering or “colliding”
- Medium Access Control (MAC): to coordinate the access to the channel.

6.1 Multiple Access Communications

- Two schemes for sharing a transmission medium:
  - Channelization scheme (static): partition the medium into separate channels.
  - MAC scheme (dynamic): minimize or eliminate the incidence of collisions
    - Random access
    - Scheduling
- Examples:
  - Networks based on radio communications
    - two frequency bands:
      - one for transmitting
      - one for receiving
  - Ring networks
  - Shared buses and hub topology networks

Delay-Bandwidth Product and MAC Performance

- Propagation delay
  - $t_{prop} = \frac{d}{v}$
  - d: distance (meters)
  - v: 3×10^8 m/s
- Transmission bit rate
  - R: 10 Mbps, 100 Mbps, 1Gbps
  - L: number of bits in a frame
  - Then the sending station requires $X = \frac{L}{R}$ seconds to transmit the frame
- Throughput
  - the actual rate at which information is sent over the shared channel. (bit/second or frames/ second) R_{eff}
  - since the shared medium is the ONLY means available for the stations to communicate with each other. Some of the transmission resource will be utilized to transfer coordination information. So $R_{eff} < R$.
  - When a collision happens, resource is wasted.

Delay-Bandwidth Product and MAC Performance (continue)

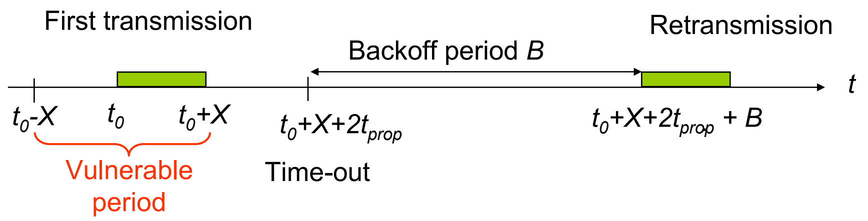
- Normalized maximum throughput or efficiency
  - $\rho_{max} = \frac{R_{eff}}{R} < 1$
- Normalized delay-bandwidth product α
  - $\alpha = \frac{t_{prop}R}{L} = \frac{t_{prop}}{X}$
  - ρ_{max} is related to α
  - E.g in Ethernet LAN. $\rho_{max} = \frac{1}{1+6.44\alpha}$
    - $\alpha \uparrow$, $\rho_{max} \downarrow$
      $\alpha=0.01$, $\rho_{max}=0.94$; $\alpha=1$, $\rho_{max}=0.13$
    - For desk area and local area networks. (t_{prop} small). α: acceptable.
    - For very high speed or long distance. α large. This is why broadcast techniques are used primarily in LANs.
- Normalized throughput or load
  - λ: aggregate rate of generated frames from all stations (frames/second)
  - λL: the average bit rate generated.
  - Load: $\rho = \frac{\lambda L}{R}$ $\rho < \rho_{max} < 1$.

6.2 Random Access
6.2.1 ALOHA

•Developed by university of Hawaii to interconnect terminals on different islands to the host computer: the network has a single central node (the host) and N terminal nodes
•Two channels: the broadcast channel and the random access channel
•The N terminal nodes share the random access channel for sending frames to the central node.
•The central node uses the broadcast channel to broadcast acknowledgement frames and clock signals to the terminal nodes.
•No direct communication between terminal nodes.
•No collision in the broadcast channel since only one node (the central node) transmits in the broadcast channel.
•In the random access channel, N terminal nodes use the ALOHA protocol to compete for the transmission resource.

6.2 Random Access
6.2.1 ALOHA

- The Protocol:
  1. Message are transmitted as soon as they become available.
  2. Frame transmissions may collide, treated as transmission errors
  3. Collided frames are recovered by retransmission
  4. Back off algorithm: when a collision happens, involved stations choose random numbers as time-out value to schedule their retransmissions
     (Spread out the retransmissions and reduce the likelihood of additional collisions)
- Performance Analysis of ALOHA
  See *Fig 6.10*
  - t_{prop}: the maximum one-way propagation delay
  - R: transmission bit rate.
  - L: number of bits in a frame
  - $X = \frac{L}{R}$: time needed to transmit a frame.
  - vulnerable period $t_0 - X$ to $t_0 + X$ (see F*ig 6.10*)



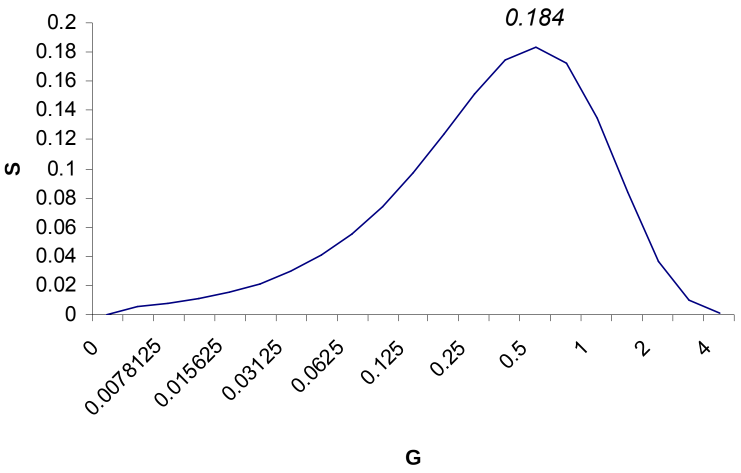
6.2.1 ALOHA (continue)

- The probability of a successful transmission is the probability that there are no additional frame transmissions in t_0-X to t_0+X
  - *S*: arrival rate of new frames per *X* seconds. (also the throughput)
  - *G*: total arrival rate (new arrivals + retransmissions) (or total load) per X seconds.
- Assume that the back off algorithm spreads the retransmission, so that frame transmissions are equally likely to occur at any instant in time. ⇒

  number of frames transmitted in a time interval has a Poisson distribution with average number of arrivals of *2G arrivals/2X* seconds.
  - *P[K transmissions in 2X seconds]*= $\frac{(2G)^k}{k!}e^{-2G}$ *k=0, 1, 2 ……*
  - *S = GP[no collision] = GP[0 transmission in 2X seconds] = G*· $\frac{(2G)^k}{0!}e^{-2G}$ $=G\,e^{-2G}$

    Fig 6.11

  When $G=0.5$, $S_{max}=\frac{1}{2e}\approx 18.4\%$



6.2.2 Slotted ALOHA

1. Frames are assumed to be constant and to occupy one time slot ($X = \frac{L}{R}$ one time slot)
2. Stations are allowed to initiate transmissions only at the beginning of a time slot

   See *Fig 6.12*

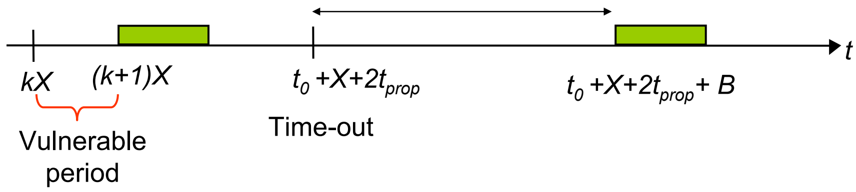
   - The vulnerable period is t_0-X to t_0, the average arrivals in t_0-X to t_0 is G.

   So:

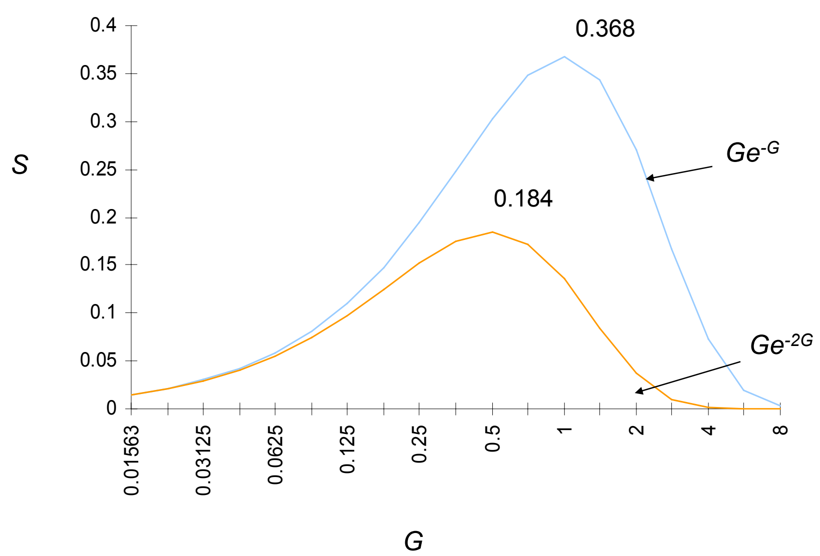
   S=GP[0 transmission in X seconds]

   $= G \cdot \frac{G^0}{0!} e^{-G} = G e^{-G}$

   When $G=1$, $S_{max} = \frac{1}{e} = 36.8\%$.



Only frames that arrive during prior X seconds collide



6.2.2 Slotted ALOHA

Example:

In a radio system, R=9600 bps, frame length L=120 bits, what is the max throughput possible with ALOHA and slotted ALOHA

Answer: The frame rate is: $\frac{9600}{120}$ =80 frames/sec.

The max throughput is:

80*0.184≈15 frames/sec (ALOHA)

80*0.368≈30 frames/sec (Slotted ALOHA)

6.2.3 Carrier Sense Multiple Access (CSMA)

•When a station wants to transmit a frame, it first sense the medium for the presence of a carrier signal from other stations to determine whether there is an ongoing transmission. If the medium is idle, the station begins the transmission.

•Otherwise:

➢1-persistent CSMA: sense the channel continuously. As soon as the channel is sensed idle, transmit frames.

“greedy”. → high collision rate

➢Non-persistent CSMA: run the back off algorithm and reschedule a future resensing time. → longer delay

➢P-persistent CSMA: sense until the channel becomes idle, then:

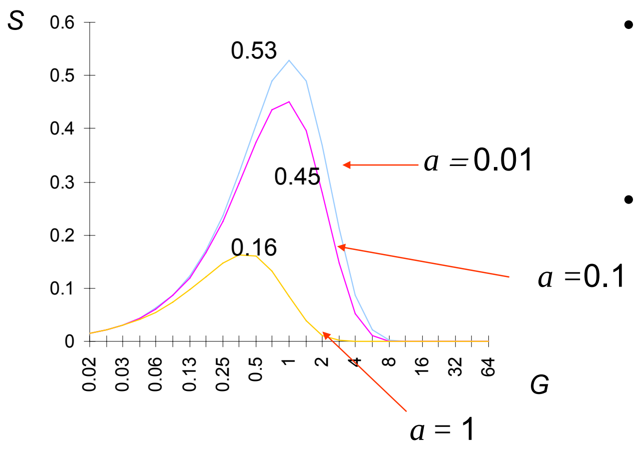
with prob. *p*, transmits the frame

with prob. *1-p*, waits an additional *tprop* before resensing

CSMA is sensitive to the end-to-end propagation delay.

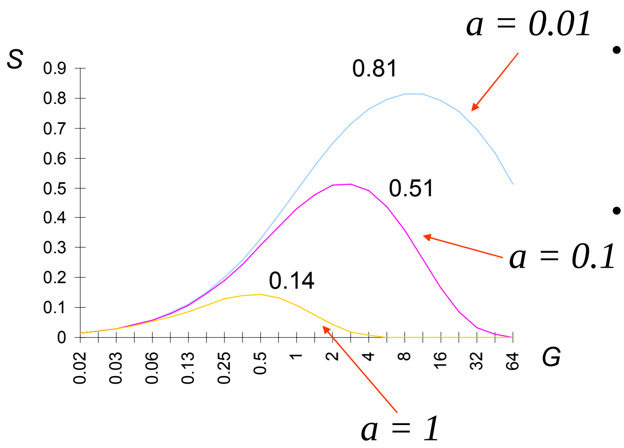
See *Fig 6.15* for *S* versus *G*

1-Persistent CSMA Throughput



- Better than Aloha & slotted Aloha for small a
- Worse than Aloha for $a > 1$

Non-Persistent CSMA Throughput

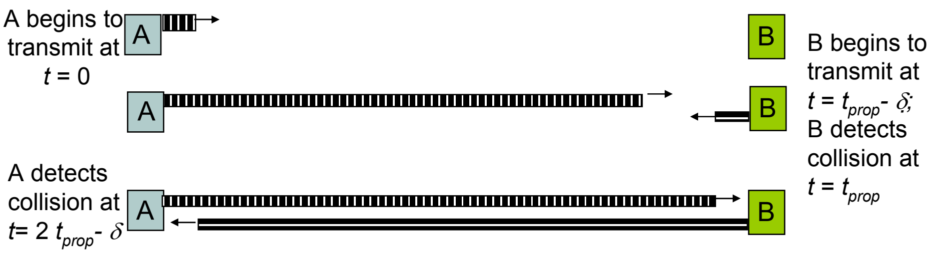


- Higher maximum throughput than 1-persistent for small a
- Worse than Aloha for $a > 1$

6.2.4 CSMA with Collision Detection (CSMA/CD)

- If a collision is detected, during transmission, aborting the frame transmission to reduce the wasted bandwidth.
- *Fig 6.16*: A station need $2t_{prop}$ seconds to find out whether it has successfully capture the channel.
- In CSMA collisions result in wastage of X seconds spent transmitting an entire frame
- CSMA-CD reduces wastage to time to detect collision and abort transmission

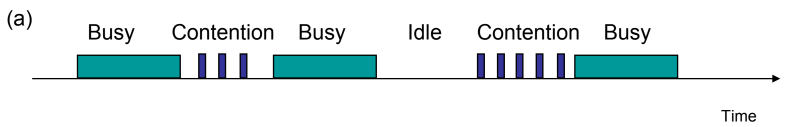
CSMA/CD reaction time



It takes $2\,t_{prop}$ to find out if channel has been captured

CSMA-CD Model

- Assumptions
  - Collisions can be detected and resolved in $2t_{prop}$
  - Time slotted in $2t_{prop}$ slots during contention periods
  - Assume n stations, and each may transmit with probability p in each contention time slot
  - Once the contention period is over (a station successfully occupies the channel), it takes X seconds for a frame to be transmitted
  - It takes t_{prop} before the next contention period starts.



Contention Resolution

- How long does it take to resolve contention?
- Contention is resolved ("success') if exactly 1 station transmits in a slot:

$$P_{success} = np(1-p)^{n-1}$$

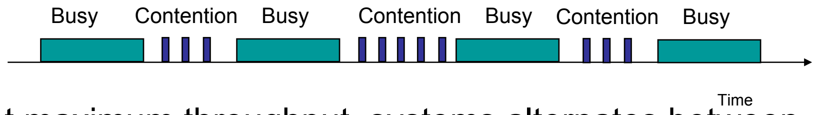
- By taking derivative of $P_{success}$ we find max occurs at p=1/n

$$P_{success}^{\max} = n\frac{1}{n}(1-\frac{1}{n})^{n-1} = (1-\frac{1}{n})^{n-1} \rightarrow \frac{1}{e}$$

- On average, $1/P^{max} = e = 2.718$ time slots to resolve contention

$$\textit{Average Contention Period} = 2t_{prop}e \textit{ seconds}$$

CSMA/CD Throughput



- At maximum throughput, systems alternates between contention periods and frame transmission times

$$\rho_{\max} = \frac{X}{X + t_{prop} + 2et_{prop}} = \frac{1}{1 + (2e+1)a} = \frac{1}{1 + (2e+1)Rd/\nu L}$$

- where:

  R bits/sec, *L* bits/frame, X=*L/R* seconds/frame

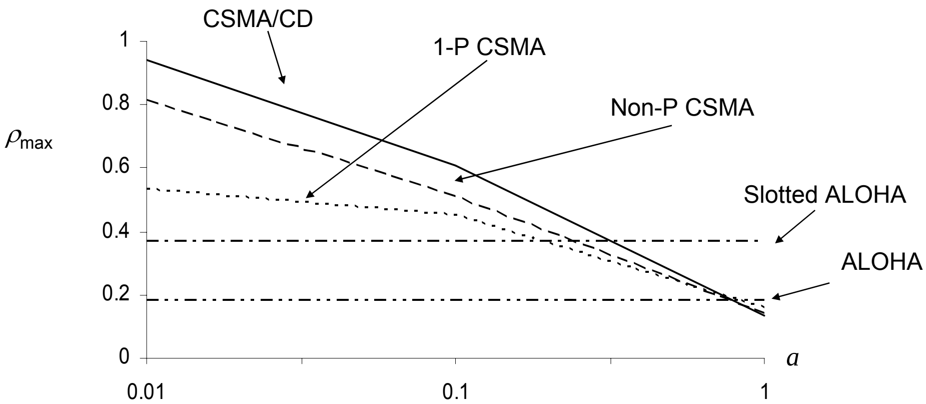
  $a = t_{prop}/X$

  ν meters/sec. speed of light in medium

  d meters is diameter of system

  2*e*+1 = 6.44

Throughput for Random Access MACs



- For small a: CSMA-CD has best throughput
- For larger a: Aloha & slotted Aloha better throughput
- ALOHA, slotted ALOHA are not sensitive to α