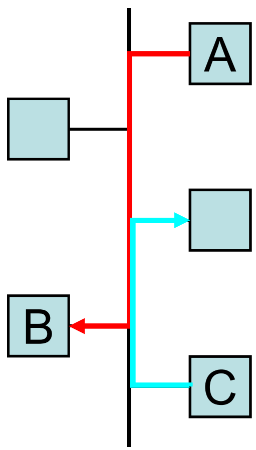
Random Access

1. Aloha
2. Slotted Aloha
3. CSMA
4. CSMA/CD

Background

Communication medium



No collision / Collision

- Modern Local Area Networks (LANs) operate as follows
  - Users are connected to communication medium, e.g. a wire, radio spectrum, etc.
  - When user A sends a message to user B, the message is **broadcast** to the medium and
    1. If no one else is broadcasting at the same time, every user on the LAN hears the message.
    2. If another user is broadcasting at the same time, then the message *interfere* (*collide*) with each other and no user on the LAN receives the individual message.

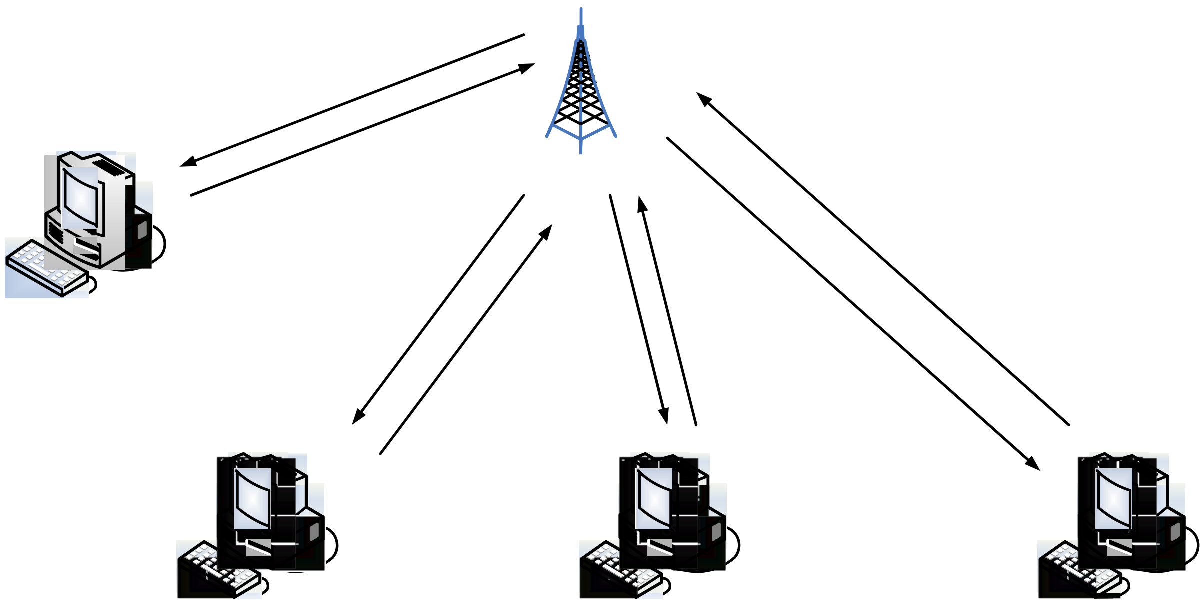
Communication Protocol

- Q: If there is a collision then there are (at least) two users that want to broadcast. How can we set up a *protocol* such that the users will rebroadcast and will not collide with each other again.

- A: Users wait a “random” amount of time before trying to rebroadcast.

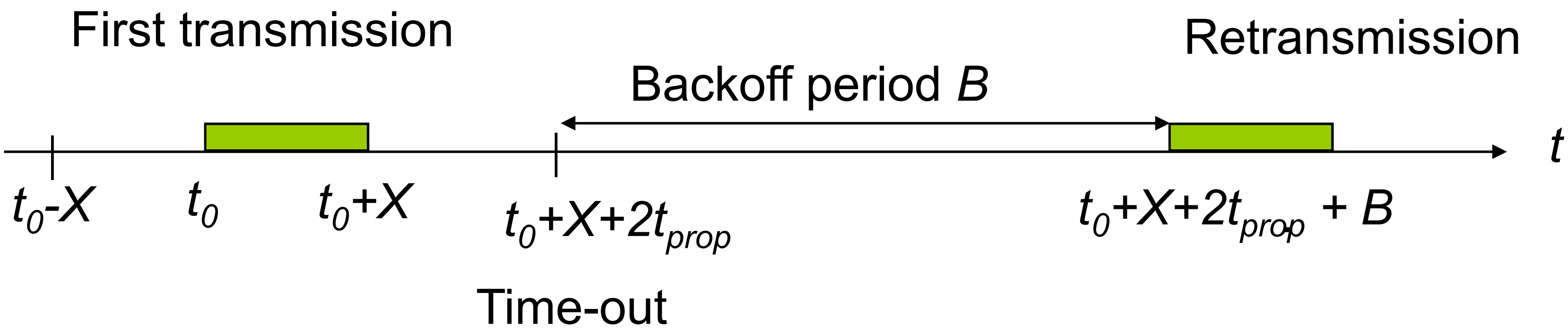
ALOHA (pure ALOHA or unslotted ALOHA)

- It was developed at the University of Hawaii in the early 1970s to connect computers situated on different Hawaiian islands.
- The computers of the ALOHA network transmit on the same radio channel whenever they have a packet to transmit.
- ALOHA is the father of multiple access protocols.



ALOHA protocol

1. A user transmits whenever it has data to transmit
2. If more than one frames are transmitted, they interfere with each other (collide) and are lost
3. If ACK not received within timeout, then a user picks random backoff time (to avoid repeated collision)
4. User retransmits frame after backoff time



ALOHA Model

- Definitions and assumptions
  - X: frame transmission time (assume constant)
  - S: throughput (average # successful frame transmissions per X seconds)
  - G: load (average # transmission attempts per X sec.)
  - Psuccess : probability a frame transmission is successful

$$S = GP_{success}$$

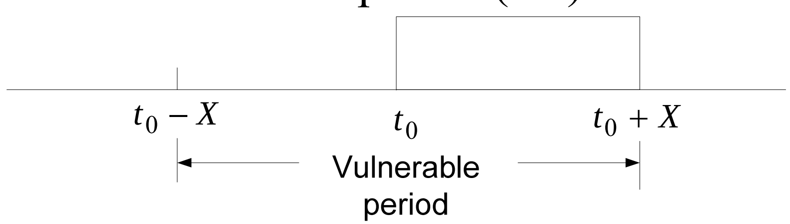
- Any transmission that begins during vulnerable period leads to collision
- Success if no arrivals during 2X seconds

Abramson's Assumption

- What is probability of no arrivals in vulnerable period?
- Abramson assumption: aggregate traffic arrival that result from new arrivals and retransmissions has a Poisson distribution with an average number of arrivals of G arrivals/X (Effect of backoff algorithm is that frame arrivals are equally likely to occur at any time interval)

$$\Pr\{k \text{ transmissions in 2X seconds}\} = \frac{(2G)^k}{k!} e^{-2G},\ k = 0,1,2,\ldots \text{(on average, 2G arrivals/2X seconds)}$$

The probability of a successful transmission is the probability that they are no additional packet transmission in the vulnerable period (2X).

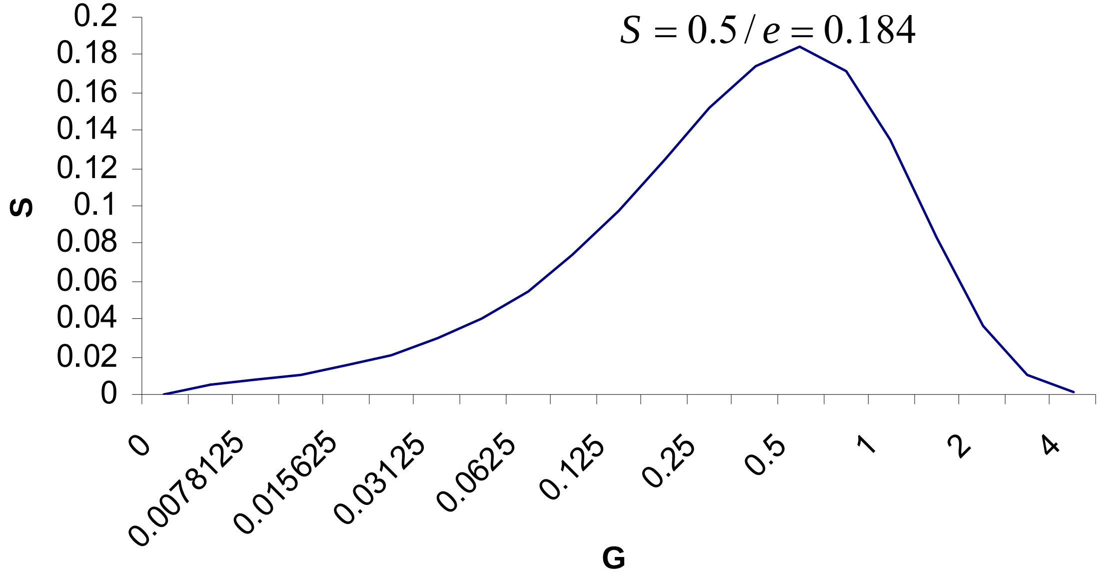


The throughput S = GPr{no collision}

$$= G\Pr\{0 \text{ transmissions in 2X seconds}\}$$

$$= G\frac{(2G)^0}{0!} e^{-2G}$$

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



Throughput S versus load G for pure ALOHA

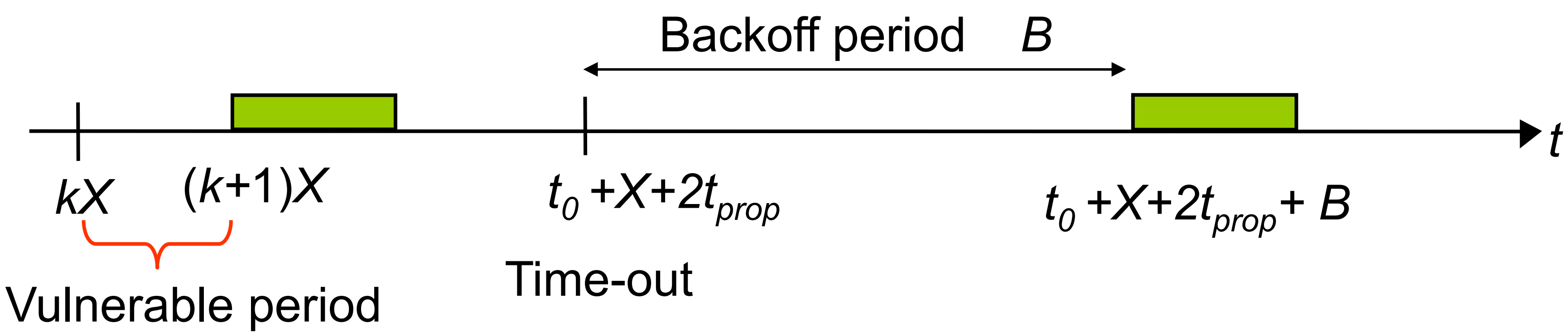
4. Observations

- Throughput S reaches a peak value of 0.5/*e* at load G = 0.5, and then declines back toward 0.
- Intuitively, two or more arrivals in a vulnerable period (2X) result in a collision
- For a given value of S there are two corresponding values for G. The system has two modes: for small G (i.e. S ≈ G, there is no collision) and for large G (i.e. G >>S, there are many backlogged users).
- ALOHA system cannot achieve throughput higher than 18.4 percent (0.5/*e*)

Slotted ALOHA

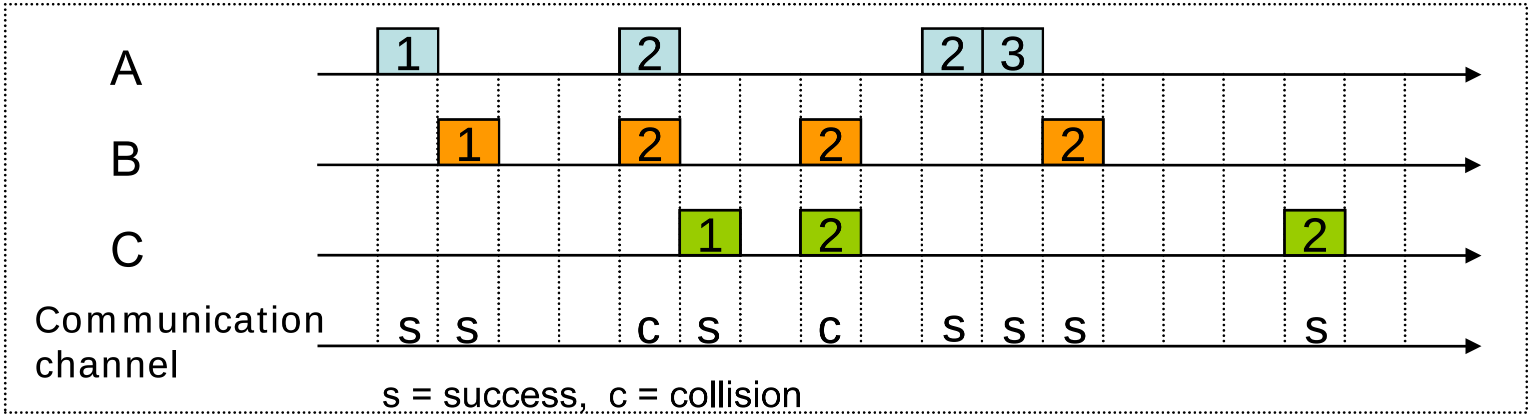
Protocol

1. Time is slotted in X seconds slots
2. Users synchronized to frame times
3. Users transmit frames in first slot after frame arrival
4. Backoff intervals in multiples of slots



Only frames that arrive during prior X seconds collide.

Example of Slotted Aloha



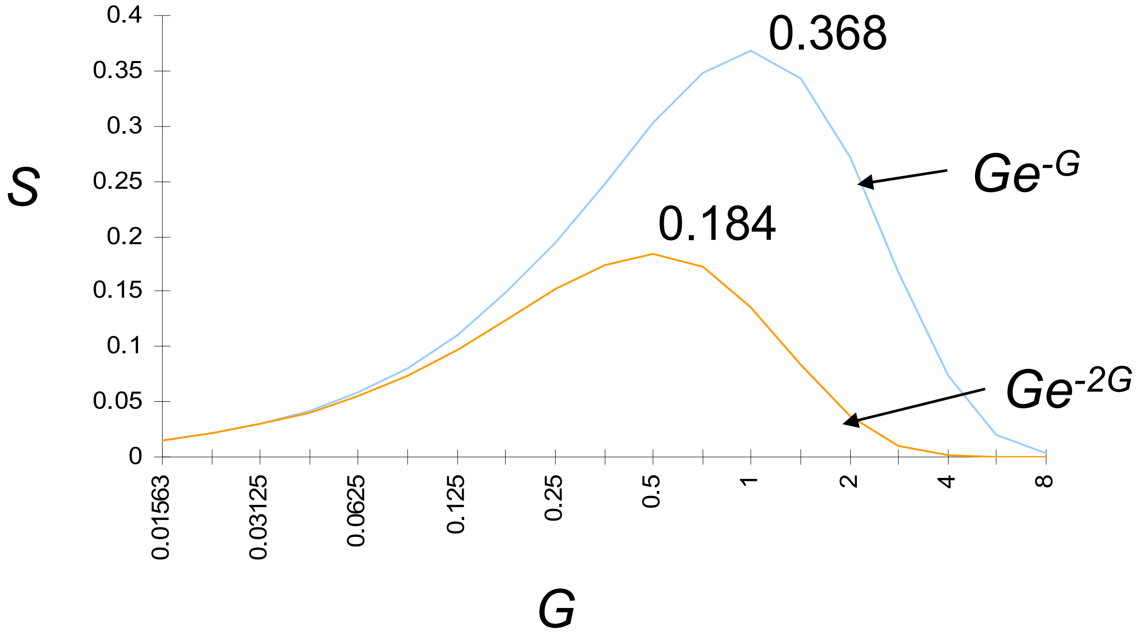
Throughput Analysis

1. The throughput S

$$S = GP[\text{no collision}] = GP[\text{no arrivals in X seconds}] = G \cdot \frac{(G)^0}{0!} e^{-G} = G \cdot e^{-G}$$

2. Observations

Throughput S reaches a peak value of $1/e = 0.368$ at load G = 1



Example: ALOHA and Slotted ALOHA

Suppose that a radio system uses a 9600 bps channels for sending call setup request messages to a base station. Suppose that packets are 120 bits long. What is the maximum throughput possible with ALOHA and with slotted ALOHA?

- The system transmits packets at a rate

  = (9600 bits/second) x (1 packet/120bits)

  = 80 packets/second.

- The maximum throughput for ALOHA

  = 80 x (0.184)

  ≈ 15 packets/second

- The maximum throughput for slotted ALOHA

  = 80 x (0.368)

  ≈ 30 packets/second

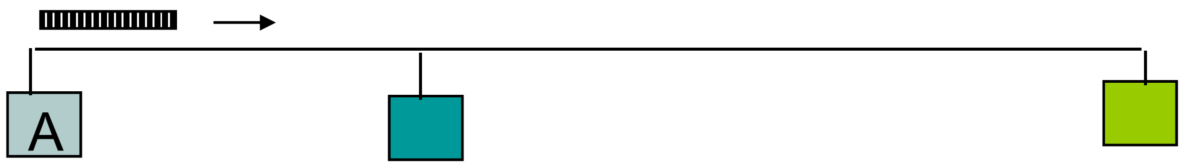
Carrier Sense Multiple Access (CSMA)

Protocol

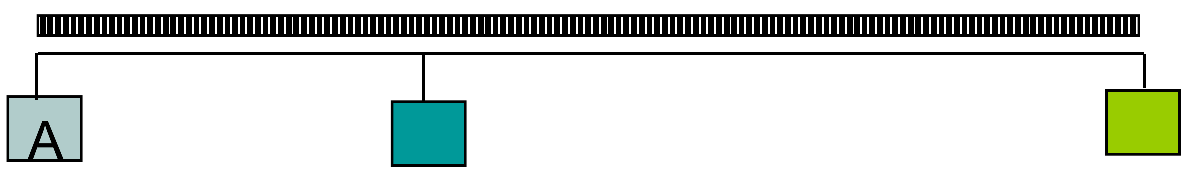
A station senses the channel (by checking for a voltage) before it starts transmission

- If busy, either wait or schedule backoff (different options)
- If idle (no voltage sensed), start transmission
- When collisions occur they involve entire frame transmission times
- Vulnerable period is reduced to t_{prop}

Station A begins transmission at $t = 0$



Station A captures channel at $t = t_{prop}$

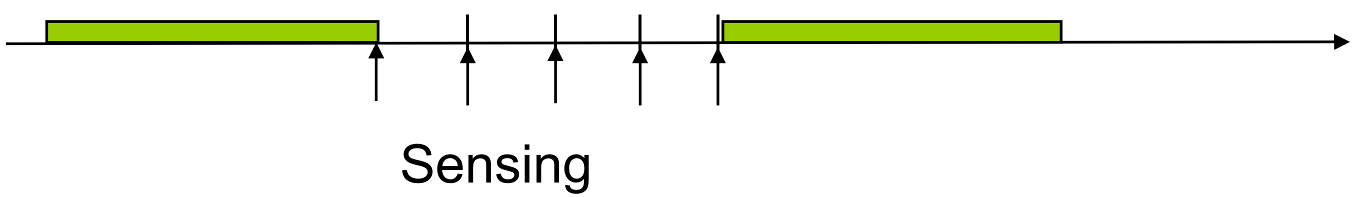


- If $t_{prop} > X$ (or if $a = t_{prop}/X > 1$), no gain compared to ALOHA or slotted ALOHA

CSMA Options

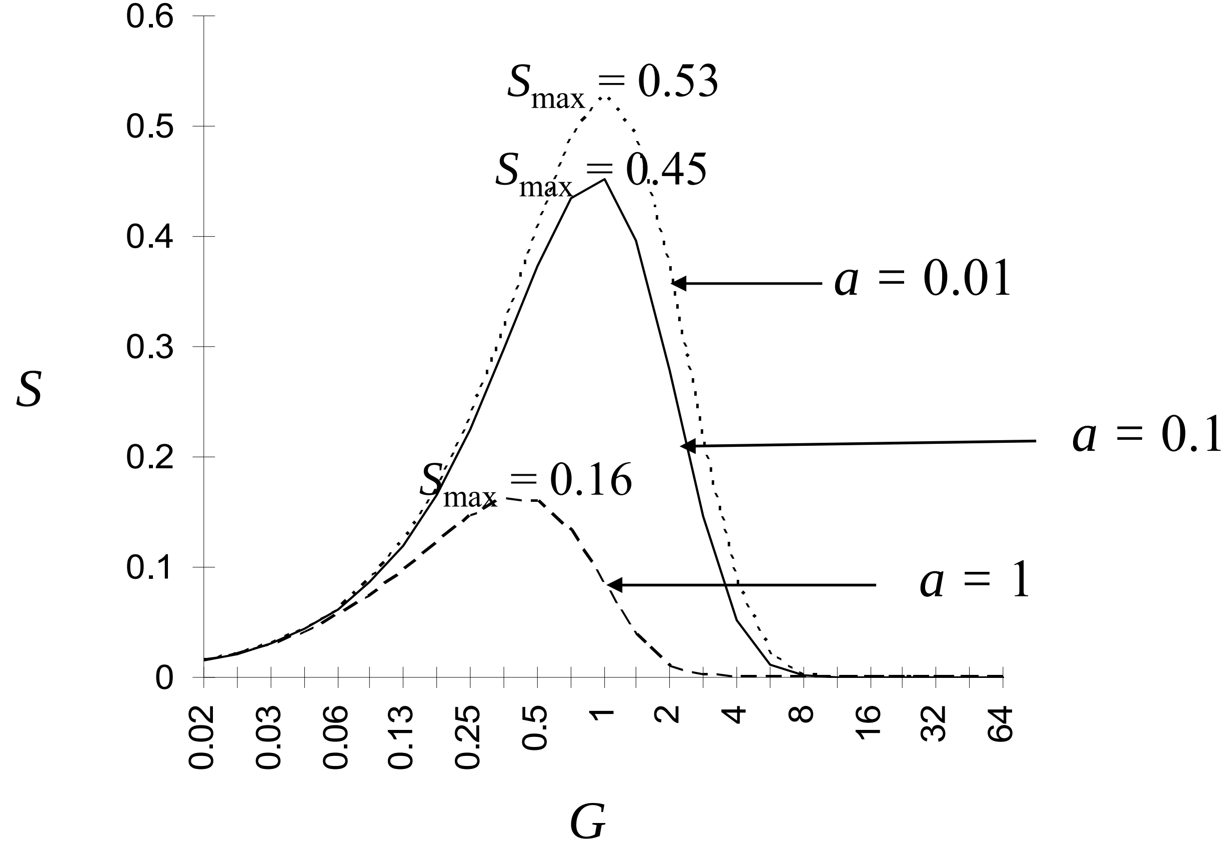
CSMA options differ when a station has a frame to transmit but the channel is busy

- 1-persistent CSMA (most greedy)
  - Start transmission as soon as the channel becomes idle
  - Low delay and low efficiency
- Non-persistent CSMA (least greedy)
  - Wait a backoff period, then sense carrier again
  - High delay and high efficiency
- p-persistent CSMA (adjustable greedy)
  - Wait till channel becomes idle, transmit with prob. p; or wait one t_{prop} time & re-sense with probability 1-*p*
  - Delay and efficiency can be balanced

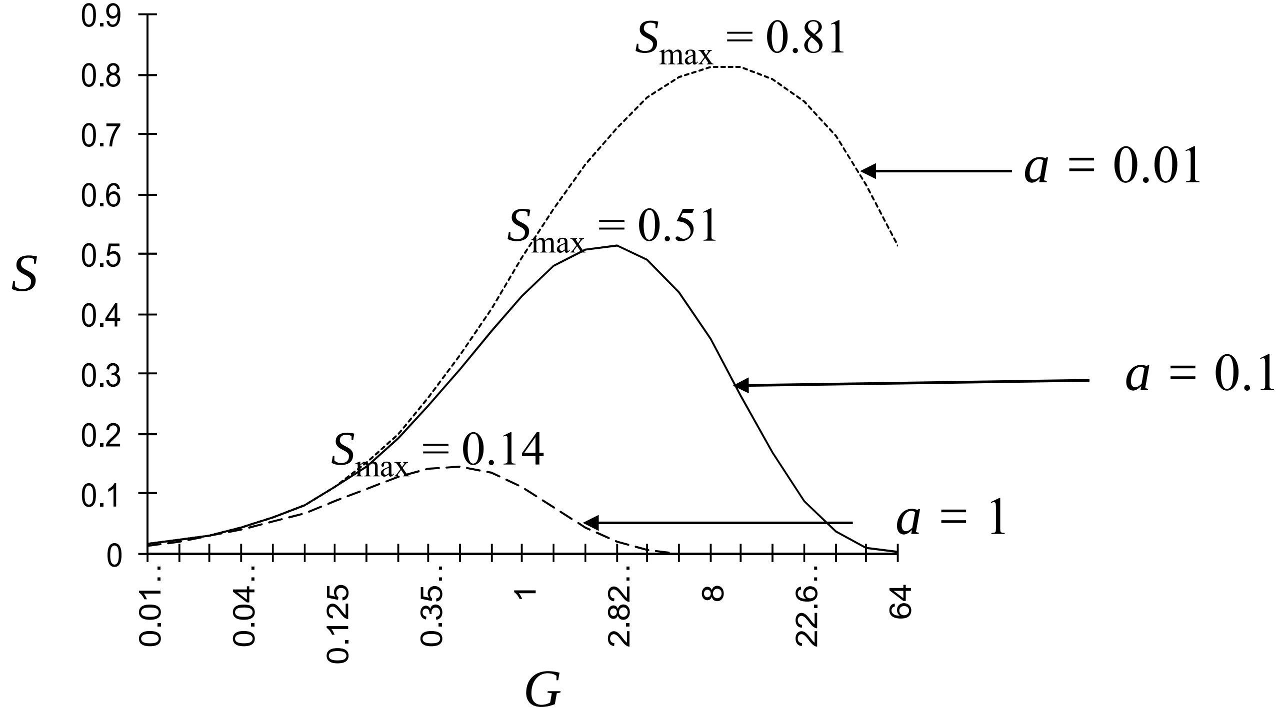


Throughput Analysis

- Throughput S versus load G for **1-Persistent CSMA** (three different $a = t_{prop}/X$)



- Throughput S versus load G for **Non-Persistent CSMA** (three different $a = t_{prop}/X$)



- Observations
  - 1-persistent is sharper than non-persistent.
  - $a=t_{prop}/X$ has import impact on the throughput.
  - When a approaches 1, both 1-persistent and non-persistent is worse than ALOHAs

Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

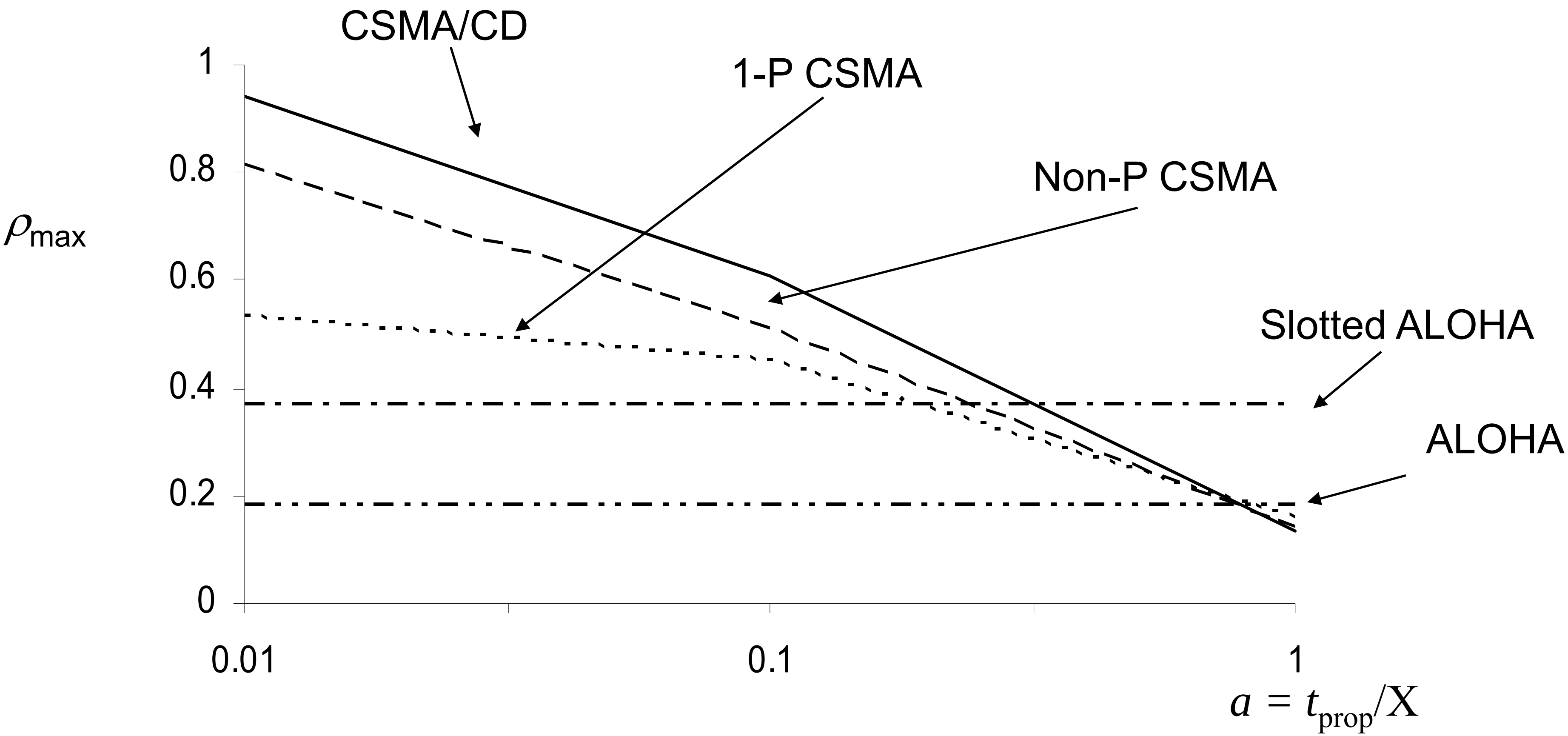
Protocol

- In CSMA/CD protocol, nodes with packets to transmit must sense the channel and proceed as follow:
  1. If the channel is idle, transmit and listen while transmitting
  2. If the channel is busy (similar to CSMA) persist, backoff immediately, or persist and attempt transmission with probability *p*.
  3. In case of a collision, a node transmits a short jamming signal so that other nodes know there is a collision and abort the transmission. Then, the backoff algorithm is used to schedule a future re-sensing time.
- In CSMA, collisions result in wastage of X seconds spent in transmitting an entire frame
- CSMA/CD reduces the wastage of time by aborting the transmission after detecting the collision
- CSMA/CD scheme provides the basis for the Ethernet LAN protocol

CSMA/CD reaction time

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

Maximum Achievable Throughputs of Random Access MAC Techniques



- For small *a*: CSMA-CD has best throughput
- For larger *a*: Aloha & slotted Aloha better throughput