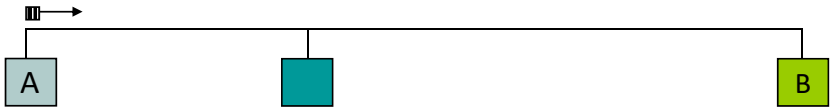
3. CSMA (Carrier Sensing Multiple Access)

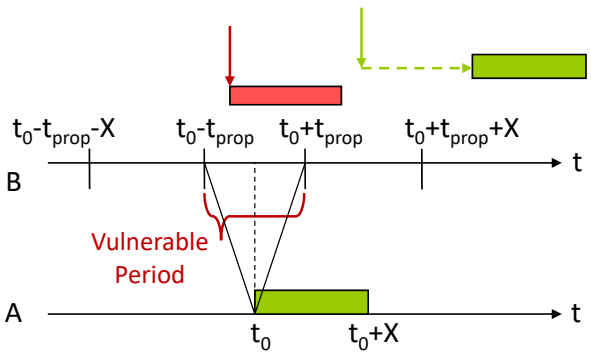
- A station senses the channel before it starts transmission
  - If idle, start transmission
  - If busy, either wait or schedule backoff (different options)

Station A begins transmission at t_0



Station A captures channel at $t_0 + t_{prop}$

Vulnerable Period

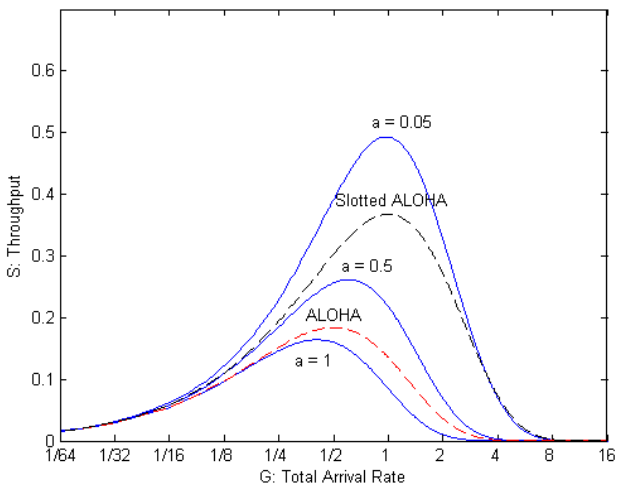


Vulnerable period is now $2t_{prop}$ seconds long

Three CSMA Options

- 1-Persistent CSMA
- Non-Persistent CSMA
- P-Persistent CSMA

Throughput of 1-Persistent CSMA

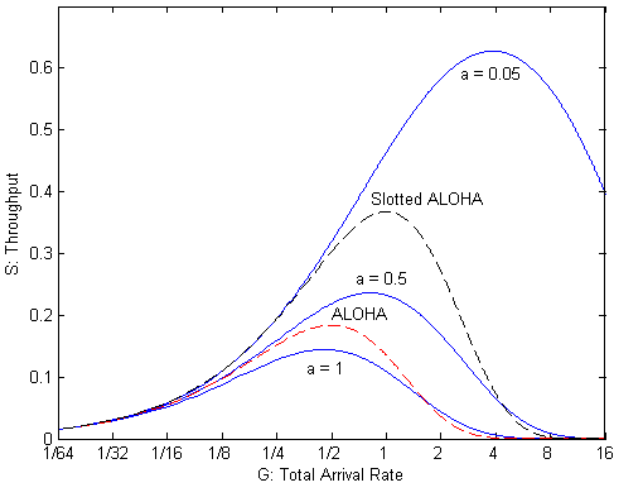


- Normalized one-way delay-bandwidth product (denote by a)

$$a = \frac{t_{prop} R}{L} = \frac{t_{prop}}{X}$$

- It is better than ALOHA & Slotted ALOHA for small a
- It is worse than ALOHA when a > 1
- It is worse than Slotted ALOHA when a > 0.5

Throughput of Non-Persistent CSMA



- It achieves higher throughput than 1-persistent CSMA
- It is worse than ALOHA when a > 1
- It is worse than Slotted ALOHA when a > 0.5

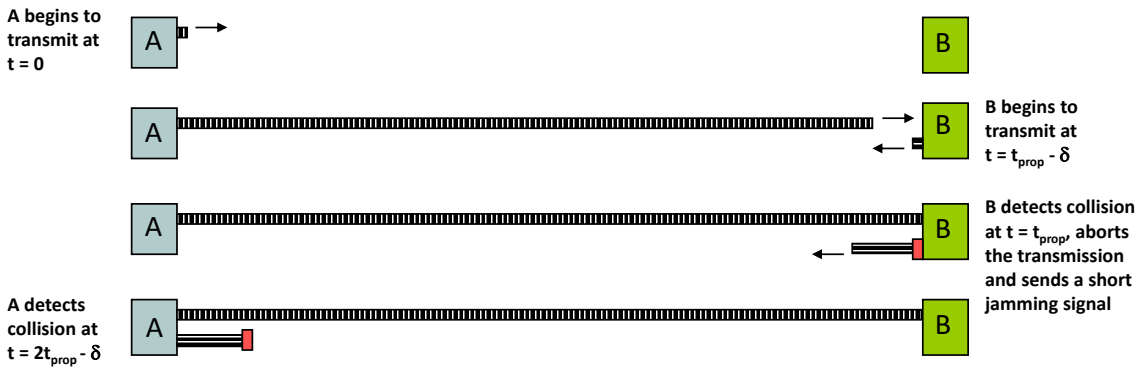
4. CSMA/CD (CSMA with Collision Detection)

- In both ALOHA and CSMA schemes, collisions involve entire frame transmissions
- The amount of the wasted bandwidth can be reduced by aborting the transmission as soon as a collision is detected
  - If a collision is detected during the transmission, the station
    - aborts the transmission
    - sends a short jamming signal to ensure that other stations know that a collision has occurred, and
    - use a backoff algorithm to schedule a future re-sensing time

IEEE 802.3 MAC Protocol

- 1-Persistent CSMA/CD with Truncated Binary Exponential Backoff
  - Collision resolution: Truncated Binary Exponential Backoff
    - If a station has experienced the n^{th} collision in a row for a frame, it selects an integer value (K) at random from {0, 1, … …, 2^m-1} where m = min(n, 10) and waits for K mini-slots (each mini-slot = $2t_{prop}$) before sensing again
    - The increasing range of selection for backoff after each collision is intended to increase the likelihood that re-transmission will succeed
    - Up to 16 re-transmission attempts will be allowed, after which the system gives up

CSMA/CD Reaction Time



- It takes A up to $2t_{prop}$ time to find out whether it has captured the channel successfully

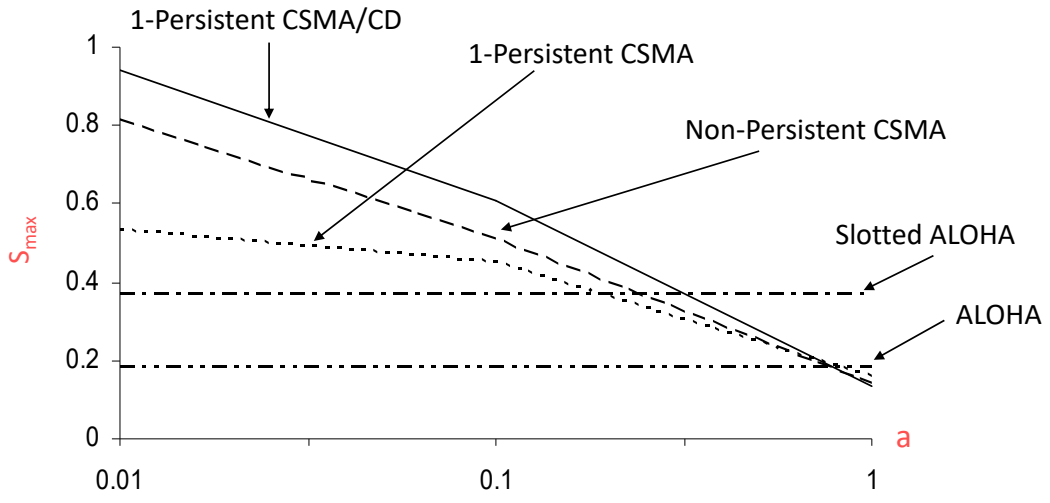
Minimum Frame Size in IEEE 802.3 Ethernet

- Observation: the transmitter must keep transmitting (i.e., hold the carrier) for the entire $2t_{prop}$ period, in order to detect whether its own frame is involved in a collision

- Example:
  - Transmission rate = 10 Mbps
  - Maximum distance = 2500 m (500 m segments & 4 repeaters)
  - Mini-slot time = $2t_{prop}$ = 2 × 2500 m / (2 × 10^8 m/s) = 25 µs
    - Absolute minimum frame size is 25 µs x 10 Mbps = 250 bits
  - IEEE 802.3 standard requires 512 bits = 64 bytes

- So, when the transmission rate increases, in order for CSMA/CD to operate correctly, we need to
  - Increase the minimum frame size, or
  - Reduce the maximum distance between two stations

Throughput Comparison of Random Access Approaches



- For small a: CSMA/CD has the best throughput
- For large a: ALOHA & Slotted ALOHA yield better throughput