Carrier Sense Multiple Access

IEEE 802.3 CSMA-CD ETHERNET

CSMA/CD

- Carrier Sensing: A node can hear whether other nodes are transmitting after a very small propagation and detection delay relative to a packet transmission time.
- A node will transmit only if the channel is detected idle.
- If one node starts transmitting and no other node starts before the first node's signal propagated throughout the cable, the first node is guaranteed to finish its packet without collision.
- We can view the first portion of a packet as making a reservation for the rest. (what is the vulnerable time period of a packet?)

CSMA/CD

- Collision Detection: In Ethernet, because of the physical properties of cable, it is possible to listen to the cable while transmitting.
- If two nodes start to transmit simultaneously, they will shortly detect a collision and both cease transmitting.

CSMA/CD

- Define τ_c to be the (propagation) delay of a packet from one end of the cable to the other and to be detected.
- Define τ_t to be the transmission delay for one packet.
- Typically $\tau_c << \tau_t$.
- Therefore, periods of transmission are separated by one or more *contention minislots* with duration τ_c .

Modeling CSMA/CD

1. Since the current state of the channel depends only on its immediate past history, we can model the channel using Markov chain analysis.
2. The states of the Markov chain represent the states of the channel: *idle*, *transmitting*, and *collided*.
3. The channel is shared among *N* stations.
4. There is a single station class (equal priority).
5. The time step of the Markov chain is chosen equal to the collision detection delay, i.e. $\mathrm{T} = \tau_c$
6. The carrier sense probability per minislot is a

Modeling CSMA/CD

6. All transmitted packets have equal lengths.
7. A packet duration is equal to the transmission delay of a packet τ_t
8. We define n as the ratio of transmission delay to propagation delay, i.e., $\mathrm{n} = \tau_t / \tau_c$
9. We assume that $n > 1$ which is true for small LANs carrying long packets or operating at low transmission speeds.

Modeling CSMA/CD

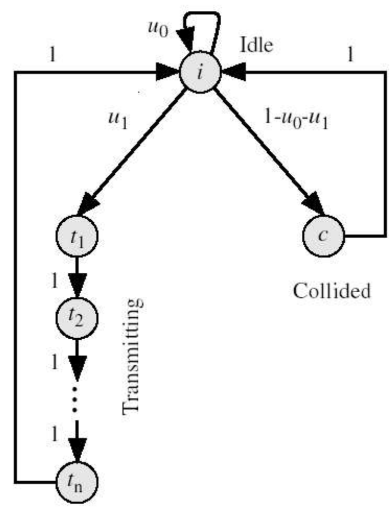
10. An *adaptive backoff strategy* is assumed where a collided user starts to sense the channel with probability α which is taken equal to the packet arrival probability, (i.e. α=a). In that sense, each collided user adapts its request probability to be proportional to its incoming traffic probability a.
11. A station can have at most one message waiting for transmission.
12. The transmission always begins at the beginning of each slot. (slotted CSMA/CD)

Modeling CSMA/CD

The probability that i users are active at a given collision time slot is given by

$$u_i = \binom{N}{i} a^i (1-a)^{N-i}$$

where a is the the probability that a station requests a transmission in a mini time slot:



Modeling CSMA/CD

We organize the distribution vector at equilibrium as follows.

$$\mathbf{s} = \begin{bmatrix} s_i & s_{t_1} & s_{t_2} & \cdots & s_{t_n} & s_c \end{bmatrix}^t$$

Modeling CSMA/CD

The corresponding transition matrix of the channel, when $n = 3$, is given by

$$\mathbf{P} = \begin{bmatrix} u_0 & 0 & 0 & 0 & \cdots & 0 & 1 & 1 \\ u_1 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 1 & 0 & 0 \\ 1-u_0-u_1 & 0 & 0 & 0 & \cdots & 0 & 0 & 0 \end{bmatrix}$$

Modeling CSMA/CD

Equilibrium distribution vector:

$$\mathbf{s} = \frac{1}{2 + u_1(n-1) - u_0} \times \begin{bmatrix} 1 \\ u_1 \\ u_1 \\ \vdots \\ u_1 \\ 1 - u_0 - u_1 \end{bmatrix}$$

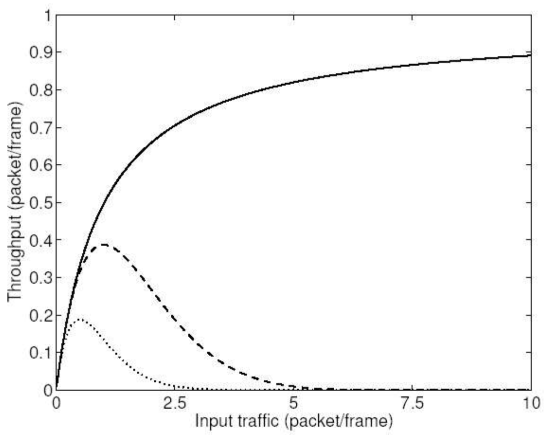
CSMA/CD Performance

The throughput is given by the equation

$$\begin{aligned} Th &= \sum_{i=1}^{n} s_{t_i} \\ &= \frac{n u_1}{2 + u_1(n-1) - u_0} \end{aligned}$$

For large values of n, the throughput approaches 100% which is expected since little time is wasted during the collision.

CSMA/CD Performance



CSMA/CD Performance

The success probabillity for a transmission in the CSMA/CD protocol is given by

$$p_a = (1-a)^{N-1}$$

CSMA/CD Performance

The average number of attempts for a successful transmission is

$$\begin{aligned} n_a &= \sum_{i=0}^{\infty} i\,(1-p_a)^i\, p_a \\ &= \frac{1-p_a}{p_a} \end{aligned}$$

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

CSMA/CA

- Carrier sense multiple access with collision avoidance (CSMA/CA) is used in *wireless LANs* where a transmitting station is unable to determine if a collision occurred while transmitting or not.

CSMA/CA Modeling Assumptions

1. Since the current state of the channel depends only on its immediate past history, we can model the channel using Markov chain analysis.
2. The states of the Markov chain represent the states of the channel: *idle*, *transmitting*, and *collided*.
3. The channel is shared among *N* stations.
4. There is a single station class (equal priority).
5. The packet arrival probability per time step is a.

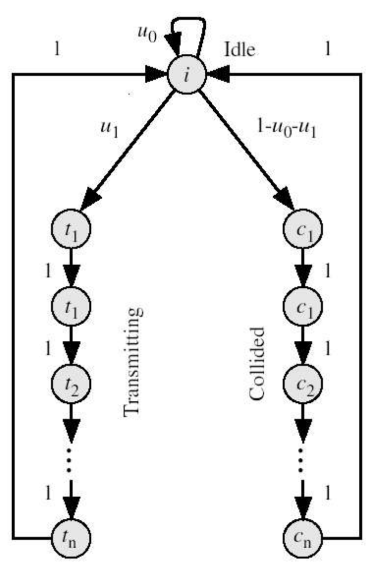
CSMA/CA Assumptions

6. All transmitted packets have equal lengths.
7. A packet duration is equal to the transmission delay of a packet τ_t.
8. The time step of the Markov chain is chosen equal to the propagation delay, i.e. T= τ_p .
9. We define n as the ratio of transmission delay to propagation delay, i.e., n = τ_t / τ_p. We assume that n>1 which is true for small LANs carrying long packets or operating at low transmission speeds.
10. A station can have at most one message waiting for transmission.

CSMA/CA Modeling

The probability that i users are active at a given time step is given by

$$u_i = \binom{N}{i} a^i (1-a)^{N-i}$$



CSMA/CA Modeling

We organize the distribution vector at equilibrium as follows.

$$\mathbf{s} = \begin{bmatrix} s_i & s_{t_1} & s_{t_2} & \cdots & s_{t_n} & s_{c_1} & s_{c_2} & \cdots & s_{c_n} \end{bmatrix}^t$$

CSMA/CA Modeling

The corresponding transition matrix of the channel, when $n = 3$, is given by

$$\mathbf{P} = \begin{bmatrix} u_0 & 0 & 0 & 1 & 0 & 0 & 1 \\ u_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1-u_0-u_1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

CSMA/CA Modeling

Equilibrium distribution vector:

$$\mathbf{s} = \frac{1}{n(1-u_0)+1} \times \begin{bmatrix} 1 \\ u_1 \\ u_1 \\ \vdots \\ u_1 \\ 1-u_0-u_1 \\ 1-u_0-u_1 \\ \vdots \\ 1-u_0-u_1 \end{bmatrix}$$

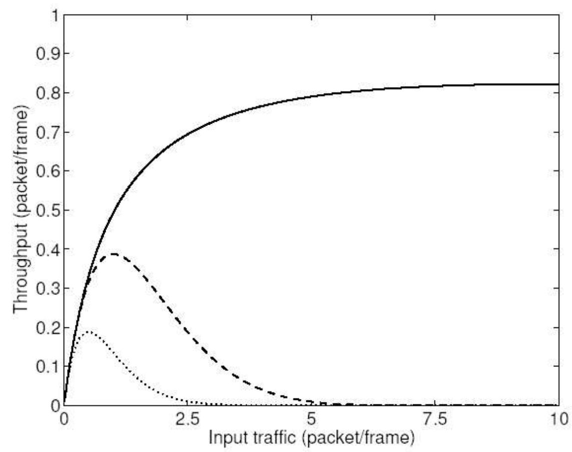
CSMA/CA Performance

The throughput is given by the equation

$$\begin{aligned} Th &= \sum_{i=1}^{n} s_{t_i} \\ &= \frac{n u_1}{n(1-u_0)+1} \end{aligned}$$

For large values of n, the throughput approaches $u_1/(1-u_0) < 100\%$ which is expected since time is wasted during collisions.

CSMA/CA Performance



CSMA/CA Performance

The success probabillity for a transmission in the CSMA/CA protocol is given by

y

$$p_a = (1\text{-}a)^{N-1}$$

CSMA/CA Performance

The average number of attempts for a successful transmission is

$$\begin{aligned} n_a &= \sum_{i=0}^{\infty} i\,(1-p_a)^i\,p_a \\ &= \frac{1-p_a}{p_a} \end{aligned}$$