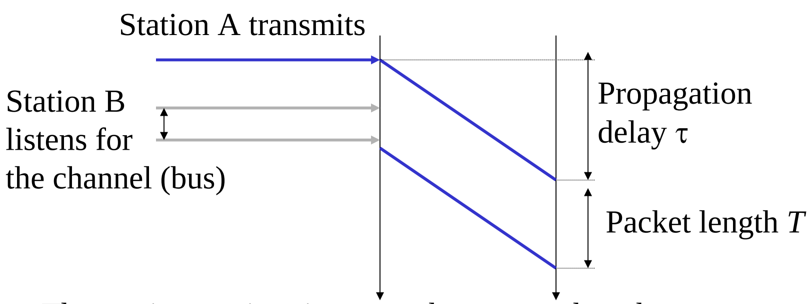
Lecture 7 CSMA

CSMA

Carrier Sense Medium Access

- Station that has data to transmit will first listen for the bus. If detects the channel unoccupied it will start transmitting data; otherwise
  - **1-persistent**: Transmission is tried immediately when the channel is sensed to be free.
  - **nonpersistent**: Channel is sensed and transmission is attempted after some random back-off time.
  - **p-persitent**: When ever the channel is sensed to be free transmission is tried with probability p (Geometric back-off time)

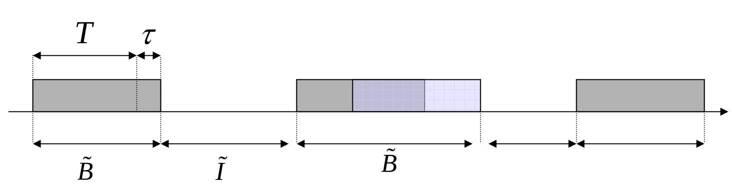
Nonpersistent CSMA



- The carrier sensing time must be greater than the maximum propagation delay of the bus, in order to detect ongoing transmission.
- Collision can happen, if another station starts transmission while the station B is listening for the channel. Due to the propagation delay, B is not able to detect this transmission.

CSMA

- Assume that the carrier sensing time is equal to maximum propagation delay. Packet arrival process is Poisson with intensity g.



- Idle period

  $$\Pr\{\tilde{I} \le x\} = 1 - \Pr\{\tilde{I} > x\} = 1 - \Pr\{0 \text{ packets arrive in } x\} = 1 - e^{-gx}$$

  is exponentially distributed

  Expected value:

  $$I = \mathrm{E}\{\tilde{I}\} = \frac{1}{g}$$

CSMA

- Useful time: Time duration during which packets are transmitted successfully

$$\tilde{U} = \begin{cases} T & \text{No collision} \\ 0 & \text{Collision} \end{cases}$$

$$U = \mathrm{E}\{\tilde{U}\} = T \Pr\{0 \text{ packets in } \tau\} = Te^{-g\tau}$$

- Busy period

$$\tilde{B} = T + \tau + \tilde{Y}$$

$$B = \mathrm{E}\{T + \tau + \tilde{Y}\}$$

- Time lost due to a collision $\tilde{Y}$

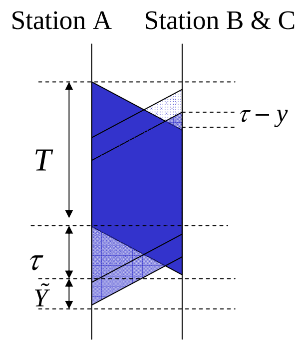
Consider the last colliding packet

$$\Pr\{\tilde{Y} \le y\} = \Pr\{0 \text{ arrivals in } \tau - y\} = e^{-g(\tau - y)}$$

$$\mathrm{E}\{\tilde{Y}\} = \tau - \frac{1 - e^{-g\tau}}{g}$$

To guarantee that the packet is last.

$0 \le y \le \tau$



CSMA

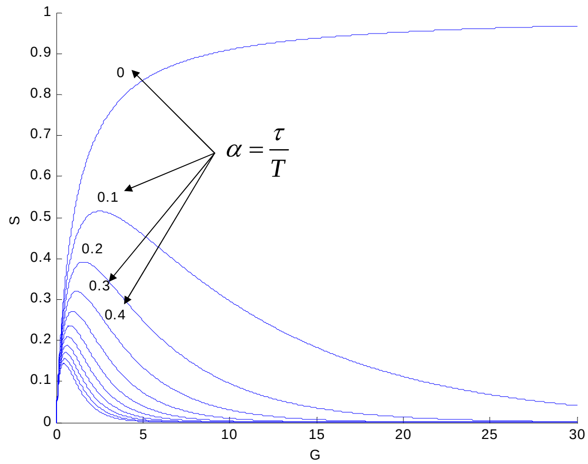
- Throughput: Useful Time/ Total Time

$$S = \frac{U}{B + I} = \frac{Te^{-g\tau}}{T + 2\tau - \frac{1 - e^{-g\tau}}{g} + \frac{1}{g}}$$

$$= \frac{Ge^{-\alpha G}}{G(1 + 2\alpha) + e^{-\alpha G}}, \quad \alpha = \frac{\tau}{T}$$

- The longer the packet length compared to the propagation delay the higher the capacity.

CSMA



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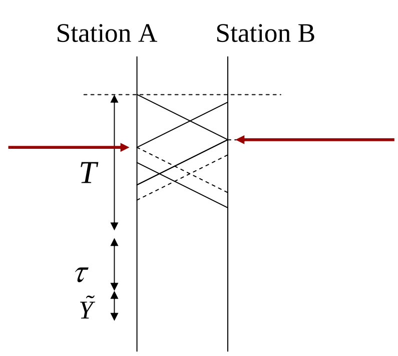
CSMA/CD

Carrier Sense Medium Access with Collision Detection

- Collision is detected by listening for the channel. When a station detects collision it will send a jamming message to help other stations to detect collision.
- After detecting the collision the transmission will be aborted and the collided stations will back-off.



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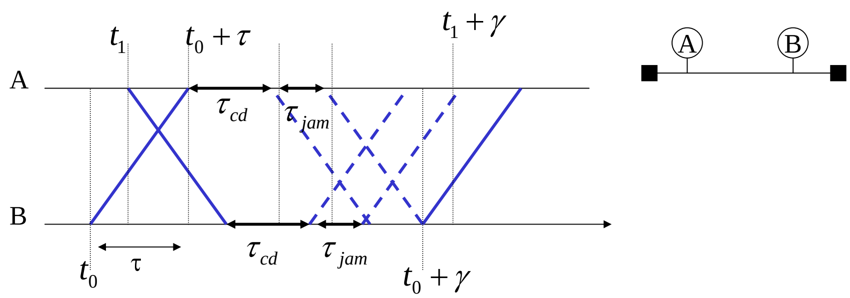
CSMA/CD

- τ Propagation delay
- τ_{cd} Time to detect collision
- τ_{jam} Length of the jamming message
- Time lost due to the collection by station A: $\gamma = 2\tau + \tau_{cd} + \tau_{jam}$



CSMA/CD

- Transmission time

$$\tilde{x} = \begin{cases} \tau + T & \text{Successful} \\ \gamma + \tau & \text{Unsuccessful} \end{cases}$$

Geometric distribution

$$\Pr\{X = k\} = (1-p)^{k-1} p, \quad k = 0,1,2,...$$

$$E\{X\} = \sum_{k=0}^{\infty} k \Pr\{X = k\} = \frac{1}{p}$$

- Slotted system: Slot time is equal to the propagation time τ.
- Probability of k slot idle time:

$$\Pr\{\tilde{I} = k\tau\} = \left(e^{-g\tau}\right)^{k-1}\left(1-e^{-g\tau}\right)$$

Probability that there are no arrivals in slots k-1 and one arrival during the last slot of the idle time interval

$$\mathrm{E}\{\tilde{I}\} = \frac{\tau}{1-e^{-g\tau}}$$

CSMA/CD

- Consider a single time slot τ. Transmission is successful with probability

$$P_s = \Pr\left\{\text{only one packet arrives} \,\middle|\, \text{at least one packet arrives}\right\}$$

$$= \frac{g\tau e^{-g\tau}}{1-e^{-g\tau}}$$

- Probability that busy period consist of up to l transmissions

$$e^{-g\tau}\left(1-e^{-g\tau}\right)^{l-1} \Rightarrow \text{expected number of transmissions in a busy period} = \frac{1}{e^{-g\tau}}$$

- Probability that the busy period takes $k(T+\tau)+(l-k)(\gamma+\tau)$ seconds with *l*-*k* collisions and *k* successful transmissions

$$\Pr\left\{\tilde{B} = k(T+\tau)+(l-k)(\gamma+\tau)\right\}$$

$$= \binom{l}{k} P_s^k \left(1-P_s\right)^{l-k} \left(e^{-g\tau}\right)^{k-1}\left(1-e^{-g\tau}\right)$$

CSMA/CD

- Expected length of the busy period is then

$$B = \sum_{l=0}^{\infty}\sum_{k=0}^{l}\left(k(T+\tau)+(l-k)(\gamma+\tau)\right)\Pr\left\{\tilde{B} = k(T+\tau)+(l-k)(\gamma+\tau)\right\}$$

$$= \sum_{l=0}^{\infty}\sum_{k=0}^{l}\left(k(T+\tau)+(l-k)(\gamma+\tau)\right)\binom{l}{k} P_s^k \left(1-P_s\right)^{l-k}\left(e^{-g\tau}\right)^{k-1}\left(1-e^{-g\tau}\right)$$

$$= \frac{1}{e^{-g\tau}}\left(P_s\,(T+\tau)+\left(1-P_s\right)(\gamma+\tau)\right)$$

Expected length of a transmission

Number of transmissions in a busy period

CSMA/CD

- Useful time

$$\Pr\left\{\tilde{U}=kT\right\}=\Pr\left\{k \text{ successful transmissions during the busy period}\right\}$$

$$=\sum_{l=k}^{\infty}\Pr\left\{\tilde{B}=k\left(T+\tau\right)+\left(l-k\right)\left(\gamma+\tau\right)\right\}$$

$$U=\Pr\left\{\tilde{U}=kT\right\}=\frac{1}{e^{-g\tau}}P_sT$$

Transmission time of the packet

Fraction of transmissions that are succesful

number of transmissions

CSMA/CS

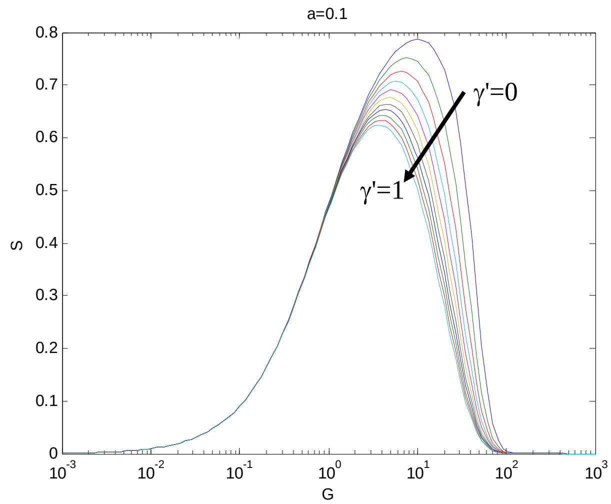
- Throughput

$$S=\frac{U}{B+I}=\frac{g\tau Te^{-g\tau}}{g\tau Te^{-g\tau}+\left(\left(1-e^{-g\tau}\right)-g\tau e^{-g\tau}\right)\gamma+\tau}$$

$$=\frac{aGe^{-aG}}{aGe^{-aG}+\left(\left(1-e^{-aG}\right)-aGe^{-aG}\right)\gamma'+a},$$

$$a=\frac{\tau}{T},\quad \gamma'=\frac{\gamma}{T},\quad G=gT$$

CSMA/CD



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