Computer Networks

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Chapter 2. Direct Link Networks

- Link Service and Framing
- Error Detection and Reliable Transmission
- HDLC, PPP, and SONET
- Token Ring
- Ethernet
- Bridges and Layer-2 switch
- Wireless Networks
- Network Performance

Network Performance

Network Performance

- Media Utilization
  - Time used for frame transmission vs. time the shared media is occupied

$$U = \frac{\text{Time for frame transmission}}{\text{total time for a frame}}$$

- Relative Propagation Time

$$a = \frac{\text{propagation time}}{\text{transmission time}} \quad or$$

$$a = \frac{\text{length of the data path (in bits)}}{\text{length of a standard frame (in bits)}}$$

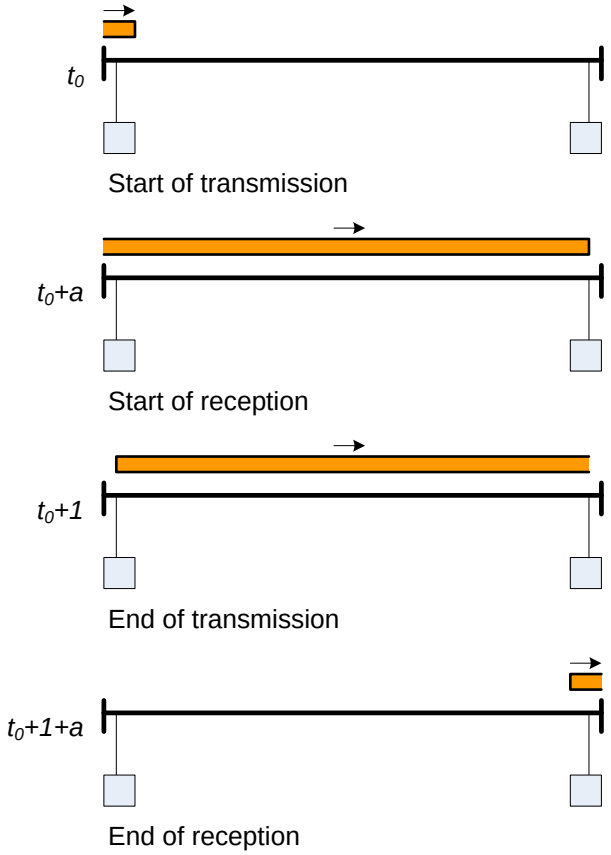
Different Networks

- Contention free
  - Point-to-Point Link
  - Ring LAN
- Random access
  - ALOHA
  - CSMA/CD

Point-to-Point Link with No ACK

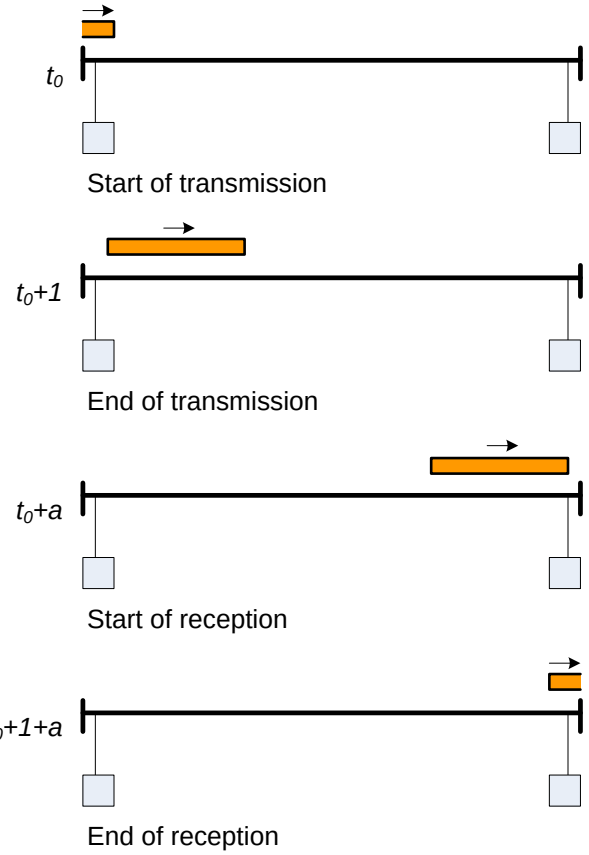
Large frame

(a) transmission time = 1
propagation time = a<1



Small frame

(b) transmission time = 1
propagation time = a>1

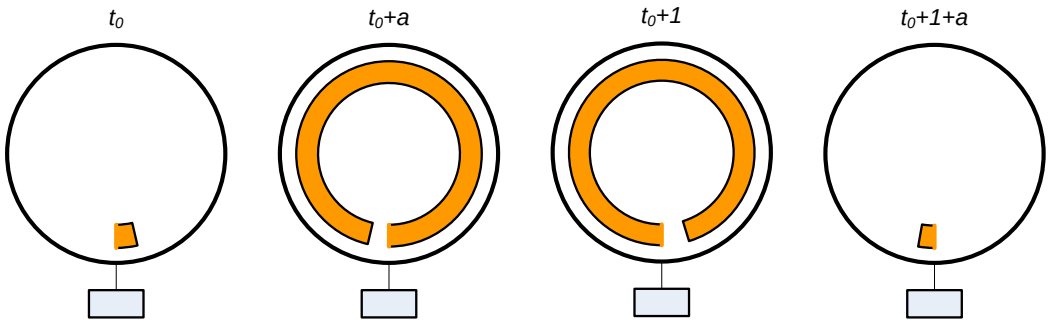


Max Utilization for Point-to-Point Link

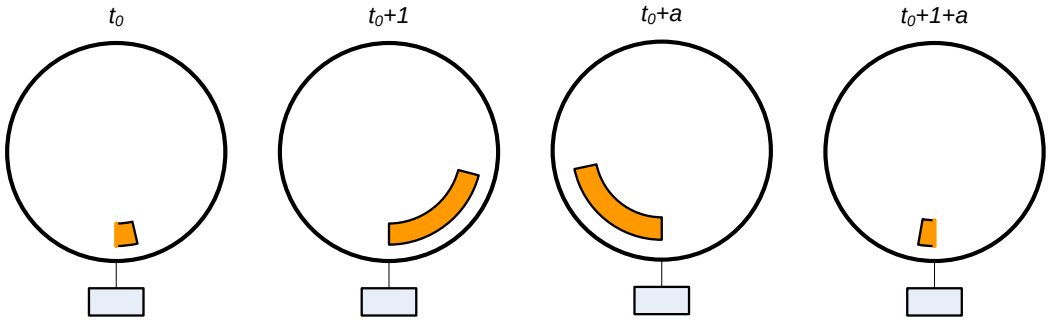
- Parameters and assumptions
  - 1: normalized frame transmission time
  - a: end to end propagation delay
  - N: number of stations
- Each station has frames to transmit
- Total frame time=transmission delay + propagation delay: $1+a$
- Max Utilization:

$$U = \frac{1}{1+a}$$

Ring LAN



(a) transmission time = 1, propagation time = a<1



(b) transmission time = 1, propagation time = a>1

Max Utilization for Ring LAN

- Define
  - T_1 : Average time to transmit a frame, i.e. $T_1 = 1$
  - T_2 : Average time to pass the token after frame transmission
- Max Utilization: $U = T_1/(T_1+T_2)$

2 cases

- Case 1: $a<1$ (frame longer than ring)
  - T_2 = time to pass token to the next station = a/N
- Case 2: $a>1$ (frame shorter than ring)
  - T_2 = sender wait for frame returns after transmission = $a-1+a/N$

$$U = \begin{cases} \dfrac{1}{1+a/N} & a<1 \\ \dfrac{1}{a+a/N} & a>1 \end{cases}$$

Slotted ALOHA

- Suppose:
  - N nodes with many frames to send, each transmits in slot with probability p
- Probability of successful transmission
  - One node has success in a slot $= p(1-p)^{N-1}$
  - Any node has a success $A = Np(1-p)^{N-1}$
- Maximize value of A

$$p = \frac{1}{N} \implies A = \left(1 - \frac{1}{N}\right)^{N-1}$$

Slotted ALOHA

- Utilization if a slot is successfully used

$$U_s = \frac{1}{1+2a} \approx 1 \quad (a \ll 1)$$

- Since A is the rate of success slot

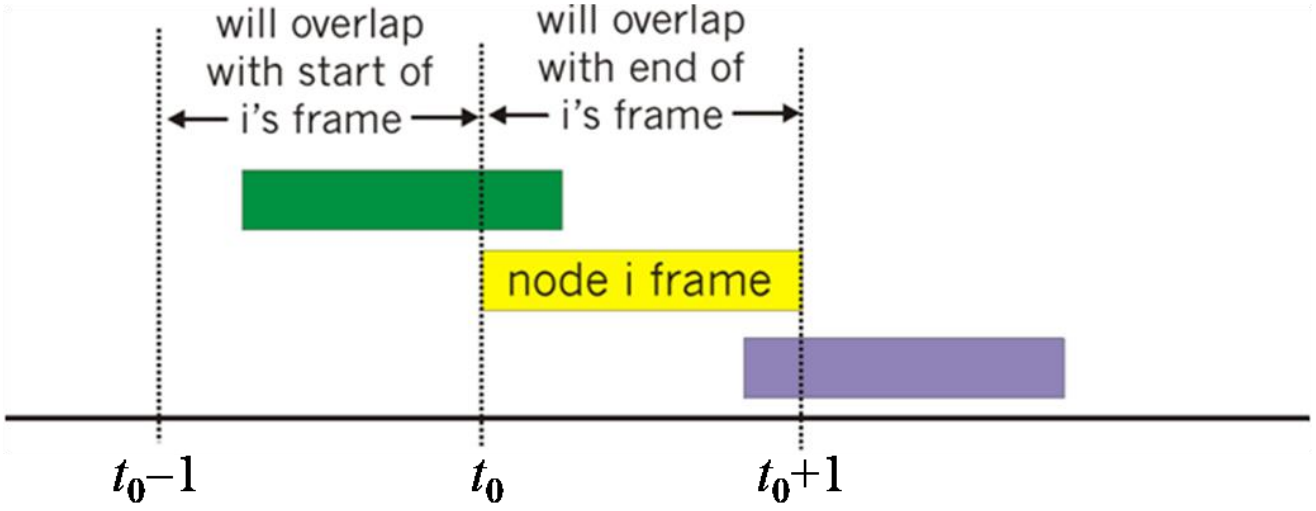
$$U = U_s \times A \approx \left(1 - \frac{1}{N}\right)^{N-1}$$

$$\text{Let } N \to \infty$$

$$U \approx e^{-1} = 0.367879$$

Pure ALOHA

- Simpler but collision probability increases
  - Frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$



Pure ALOHA

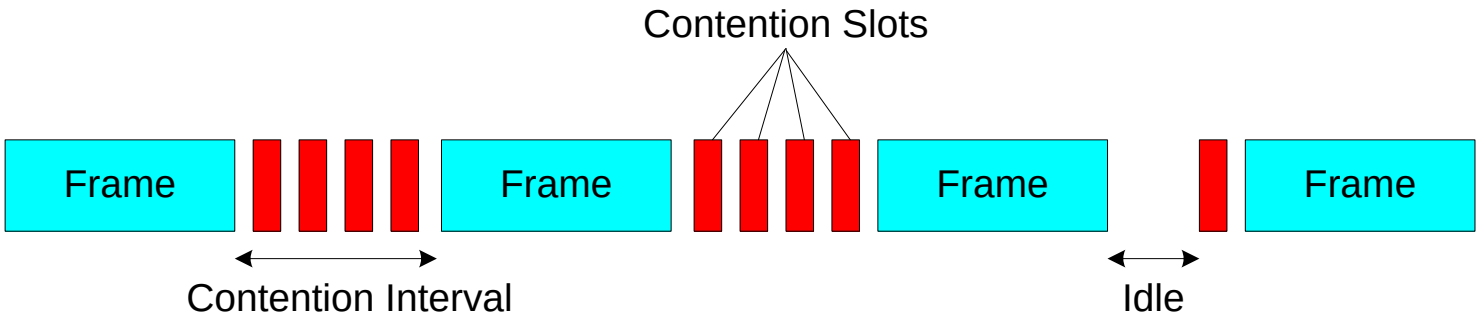
- Suppose:
  - N nodes with many frames to send, each transmits in a slot with probability p

- Probability of successful transmission

$$
\begin{aligned}
A =& N \cdot P(\text{one transmits in the slot}) \cdot \\
& P(\text{no other node transmits in } [t_{0-1}, t_0] \cdot \\
& P(\text{no other node transmits in } [t_0, t_{0+1}]
\end{aligned}
$$

$$
\begin{aligned}
U \approx A &= Np \cdot (1-p)^{2N-1} \\
&\approx \frac{1}{2}(1-\frac{1}{2N})^{2N-1} \quad (p = \frac{1}{2N}) \\
&\approx 1/(2e) = 0.183940 \quad (N \to \infty)
\end{aligned}
$$

CSMA/CD



- Contention slots end in a collision
- Contention interval is a sequence of contention slots

- Length of a slot in contention interval is $2a$
- Suppose the probability that a station attempts to transmit in a slot is p

Max Utilization for CSMA/CD (1)

- Let A be the probability that some station can successfully transmit in a slot, then:

$$A = \binom{N}{1} p^1 (1-p)^{N-1} = Np(1-p)^{N-1}$$

- In above formula, A is maximized when $p=1/N$, thus:

$$A = \left(1 - \frac{1}{N}\right)^{N-1}$$

Max Utilization for CSMA/CD (2)

- Probability of a contention interval with j slots

$$Prob[\,j \text{ unsuccessful attempts}] \times Prob[1 \text{ successful attempt}] = A(1-A)^j$$

- The expected number of slots in a contention interval is then calculated as:

$$\sum_{j=1}^{\infty} jA(1-A)^j = \frac{1-A}{A}$$

Max Utilization for CSMA/CD (3)

- Maximum Utilization

$$U = \frac{\text{Frame time}}{\text{Frame time+Propagation time+Average contention interval}}$$

$$= \frac{1}{1+a+2a\frac{1-A}{A}} = \frac{1}{1+\frac{2-A}{A}a}$$

- Let $N \rightarrow \infty$, $A = (1-1/N)^{N-1} = 1/e$ (e=2.718)

$$U = \frac{1}{1+\frac{2-A}{A}a} = \frac{1}{1+(2e-1)a} \approx \frac{1}{1+4.44a}$$

Summary

- 网络性能分析
  - Point-to-point link
  - Ring LAN
  - ALOHA, Slotted ALOHA
  - CSMA/CD