LANs

Studying

Local Area Networks

Via

Media Access Control (MAC) SubLayer

Local Area Networks

- Aloha
- Slotted Aloha
- CSMA (non-persistent, 1-persistent, p-persistent)
- CSMA/CD
- Ethernet
- Token Ring

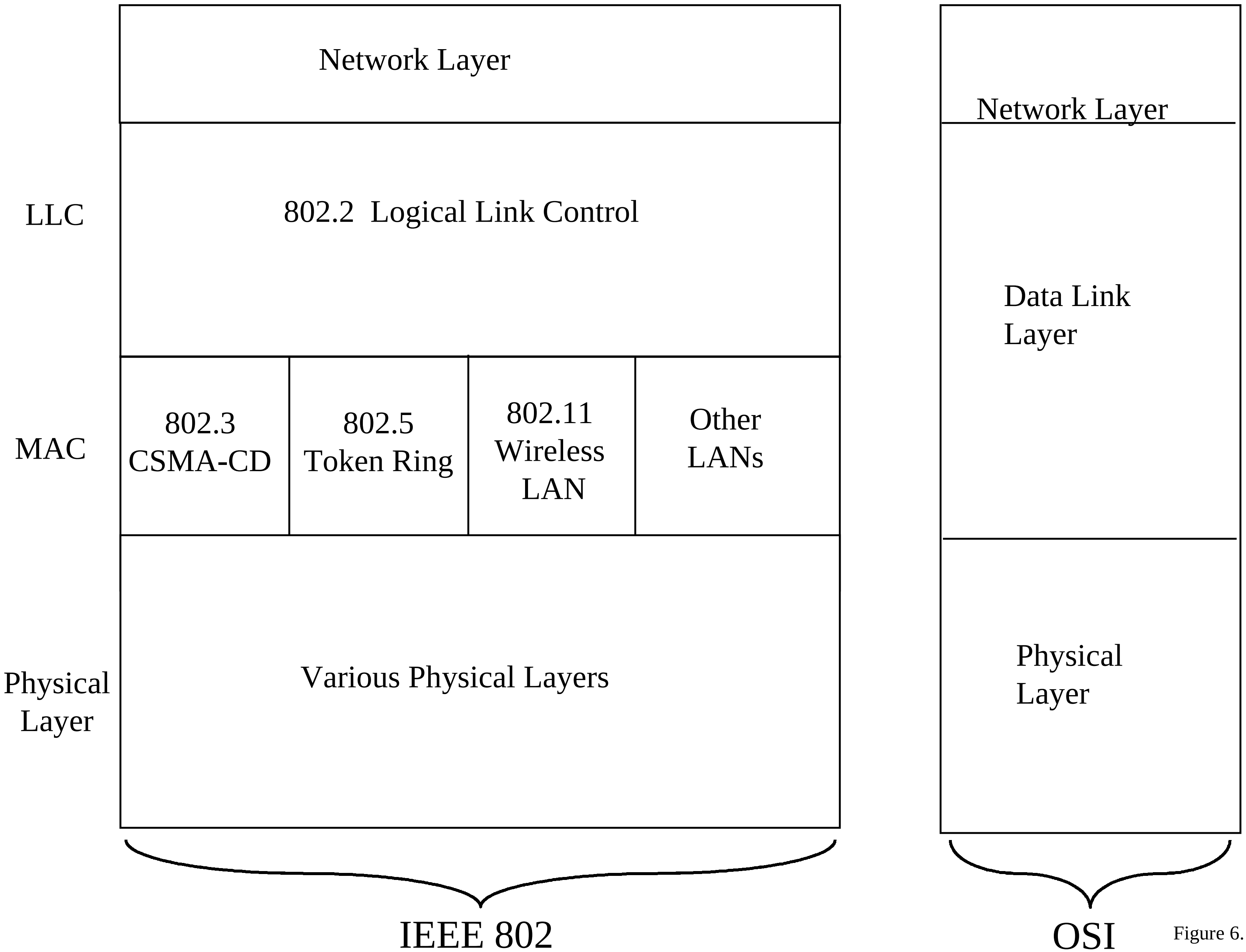
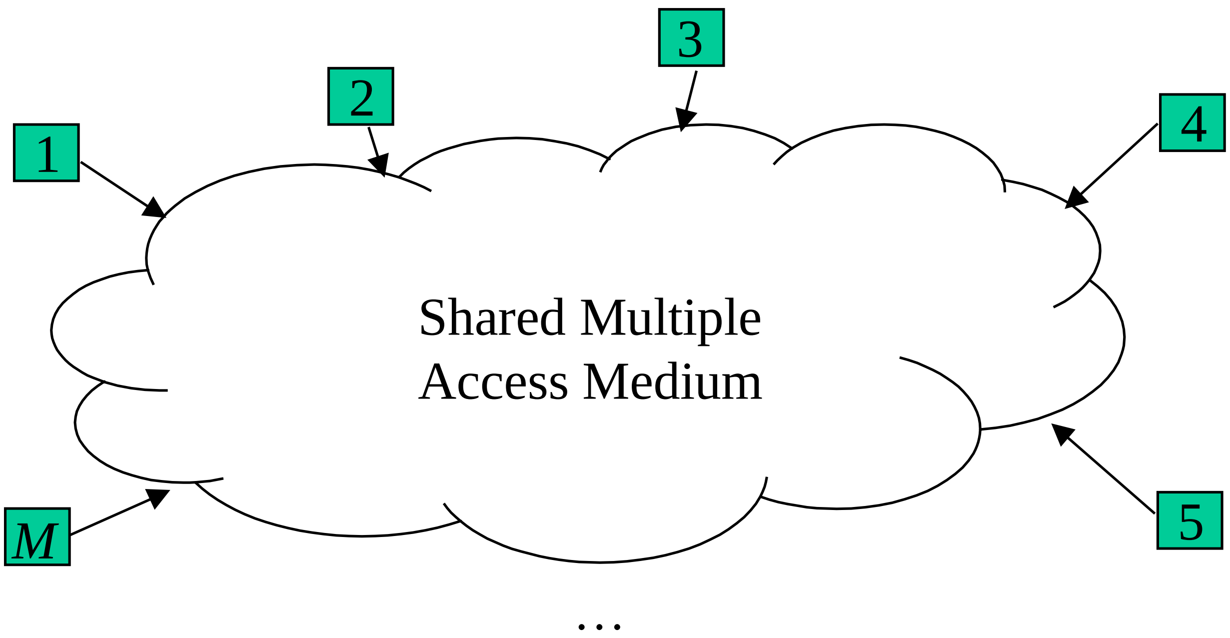

Network Layer
LLC
802.2 Logical Link Control
MAC
802.3
CSMA-CD
802.5
Token Ring
802.11
Wireless
LAN
Other
LANs
Physical
Layer
Various Physical Layers
IEEE 802
Network Layer
Data Link
Layer
Physical
Layer
OSI

Figure 6.11



 Leon-Garcia & Widjaja: *Communication Networks* Figure 6.1

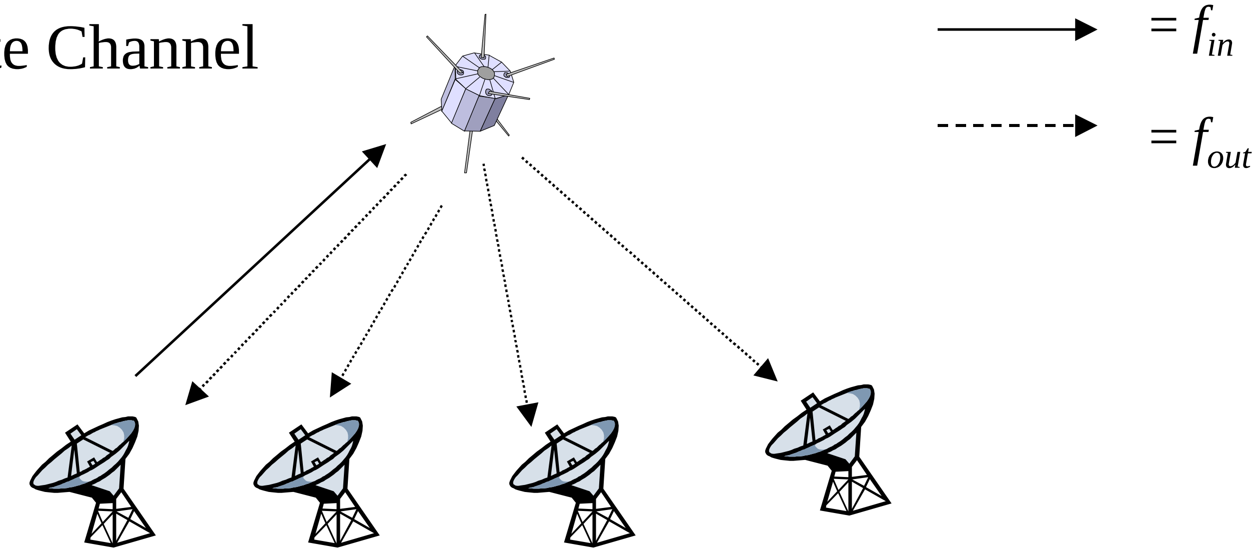
Static Channel Allocation Problem

The history of broadcast networks includes satellite and packet radio networks.

Let us view a satellite as a repeater amplifying and rebroadcasting everything that comes in.

To generalize this problem, consider networks where every frame sent is *automatically* received by every site (node).

Satellite Channel



 Leon-Garcia & Widjaja: *Communication Networks* Figure 6.3

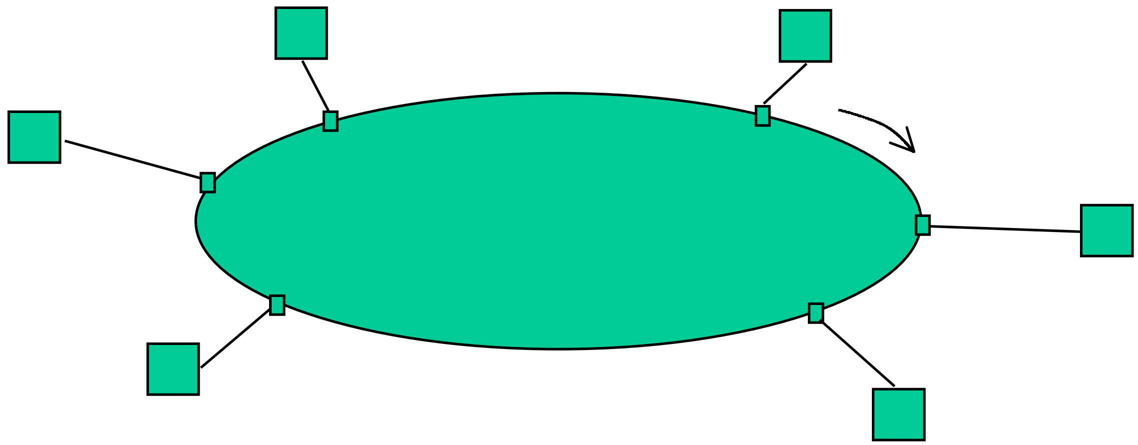
Static Channel Allocation Problem

We model this situation as n independent users (one per node), each wanting to communicate with another user and they have no other form of communication.

Channel Allocation Problem

To manage a single broadcast channel which must be shared *efficiently* and *fairly* among n uncoordinated users.

Ring networks



Multitapped Bus

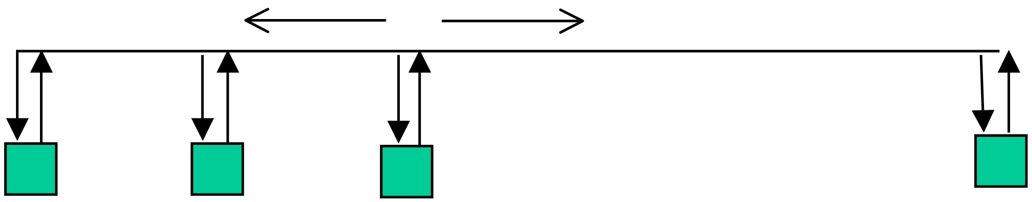


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Figure 6.5

Possible Model Assumptions for Channel Allocation Problem

0. *Listen property* :: (applies to satellites)

   The sender is able to *listen* to sent frame one round-trip after sending it.

   ➔ no need for explicit ACKs

1. Model consists of n *independent stations*.
2. A single channel is available for communications.

Possible Model Assumptions for Channel Allocation Problem

3. *Collision Assumption* :: If two frames are transmitted simultaneously, they overlap in time and the resulting signal is garbled. *This event is a collision.*

4a. *Continuous Time Assumption* :: frame transmissions can begin at any time instant.

4b. *Slotted Time Assumption* :: time is divided into discrete intervals (slots). Frame transmissions always begin at the start of a time slot.

Possible Model Assumptions for Channel Allocation Problem

5a. *Carrier Sense Assumption* ::

Stations can tell if the channel is busy (in use) before trying to use it. If the channel is busy, no station will attempt to use the channel until it is idle.

5b. *No Carrier Sense Assumption* ::

Stations are unable to sense channel before attempting to send a frame. They just go ahead and transmit a frame.

a :: Relative Propagation Time

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

-OR-

$$a = \frac{\text{propagation time (in seconds)}}{\text{transmission time (in seconds)}}$$

-OR-

$$a = \frac{\text{delay-bandwidth product}^{*}}{\text{average frame size}}$$ **[LG&W def p.346]**

**** Delay-bandwidth product :: the product of the capacity (bit rate) and the delay.***

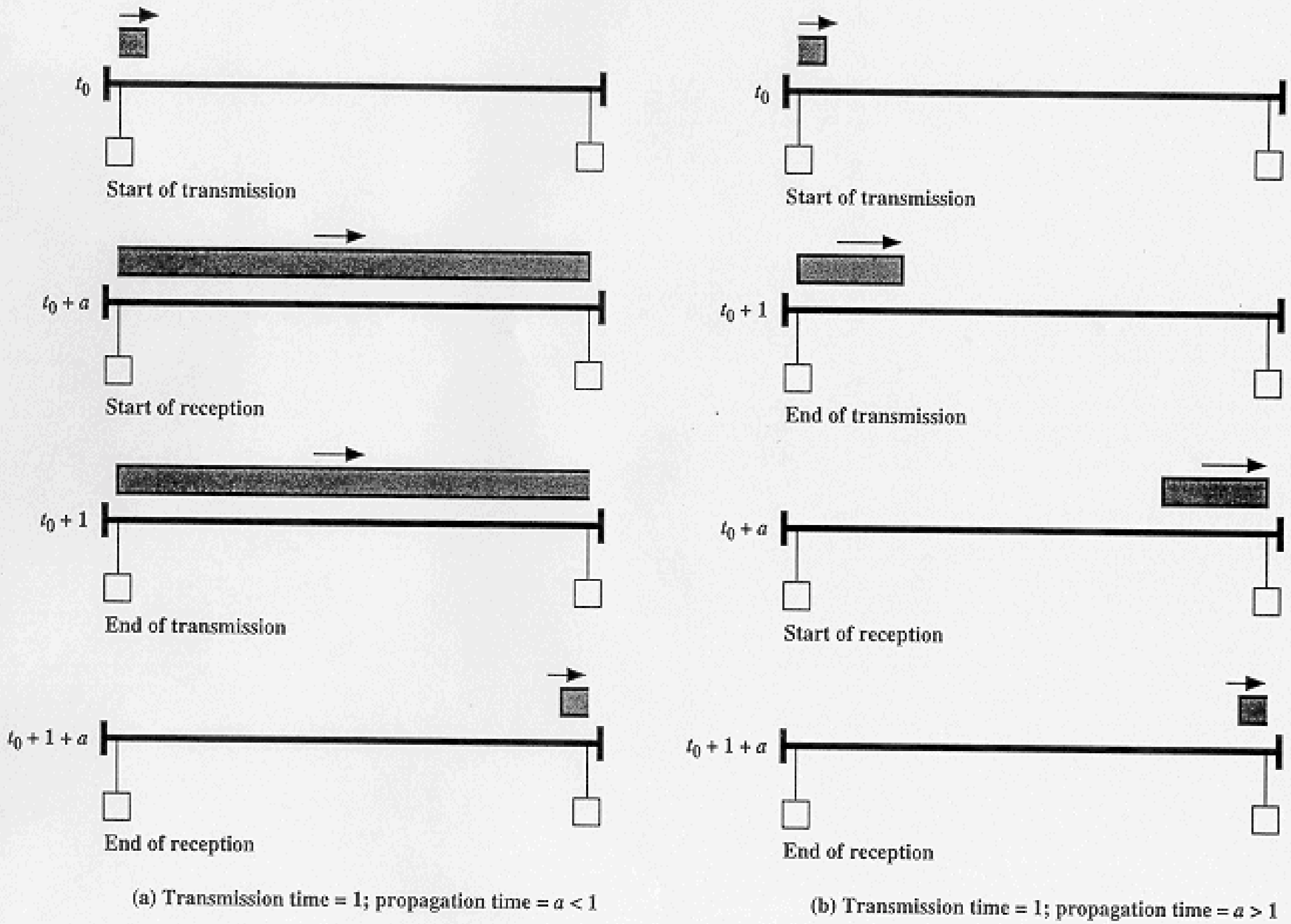

Figure 15.2 The Effect of a on Utilization for Baseband Bus

Relative Propagation Time

R = capacity (data rate)

d = maximum distance of communications path

v = propagation velocity (Assume v = 2/3 speed of light 2 x 10^8 meters/second)

L = frame length

$$a = \frac{d / v}{L/R} = \frac{Rd}{vL}$$

Upper Bound on Utilization for Shared Media LAN

Assume a perfect, efficient access that allows one transmission at a time where there are no collisions, no retransmissions, no delays between transmissions and no bits wasted on overhead. ***{These are best-case assumptions}***

$$Util = \frac{Tput}{Capacity} = \frac{L}{\dfrac{\text{propagation time} + \text{transmission time}}{R}}$$

Maximum Utilization for LANs

$$\text{max. Util} = \frac{\dfrac{L}{R}}{\dfrac{d}{v} + \dfrac{L}{R}} = \frac{L}{\dfrac{Rd}{v} + L} = \frac{1}{a + 1}$$

$$\text{max. Util} = \frac{1}{1 + a}$$

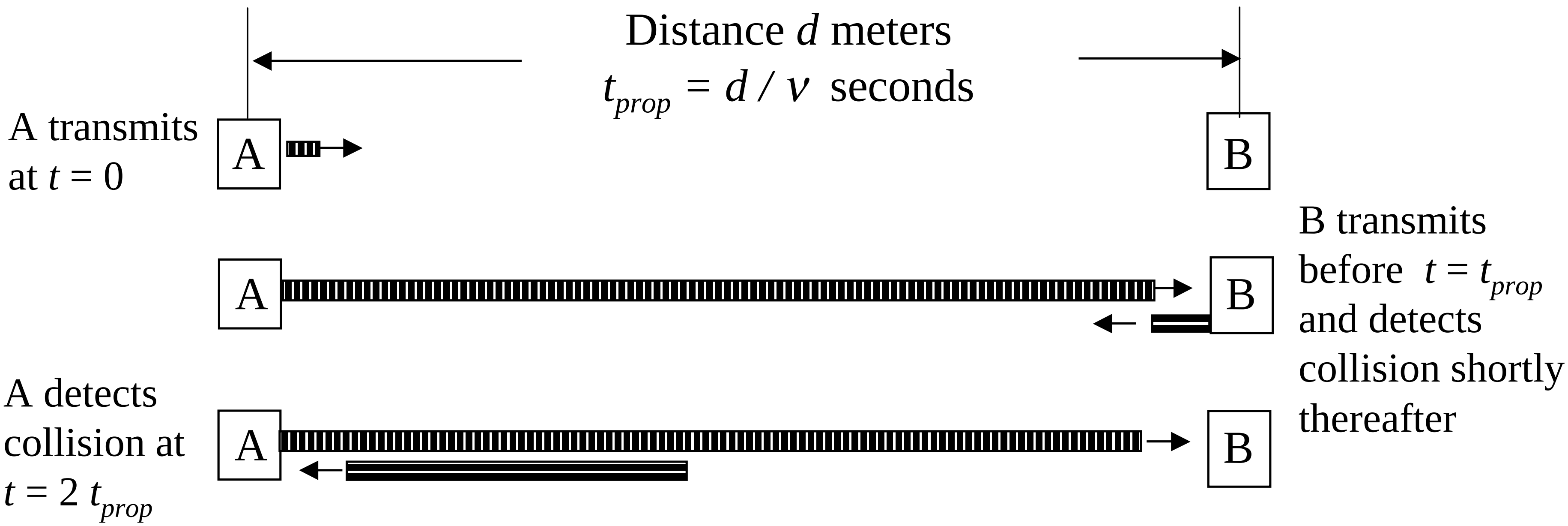

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Figure 6.7

Efficiency [LG&W p.346]

$$\text{Efficiency} = \frac{L}{L + 2t_{prop} R} = \frac{1}{1 + 2a}$$

Why is this result different?

LAN Design considering Performance

For broadcast LANs what are the factors under the designer's control that affect LAN performance?

- Capacity *{function of media}*
- Propagation delay *{function of media, distance}*
- Bits /frame (frame size)
- MAC protocol
- Offered load – depends on how retransmissions are handled
- Number of stations
- Error rate

Historic LAN Performance Notation

I :: input load - the total (normalized) rate of data generated by all n stations

G :: offered load – the total (normalized) data rate presented to the network *including retransmissions*

S :: throughput of LAN - the total (normalized) data rate transferred between stations

D :: average frame delay – the time from when a frame is ready for transmission until completion of a successful transmission.

Normalizing Throughput (S)

[*assuming one packet = one frame*]

Throughput (S) is normalized using packets/packet time where

packet time :: the time to transmit a *standard* fixed-length packet

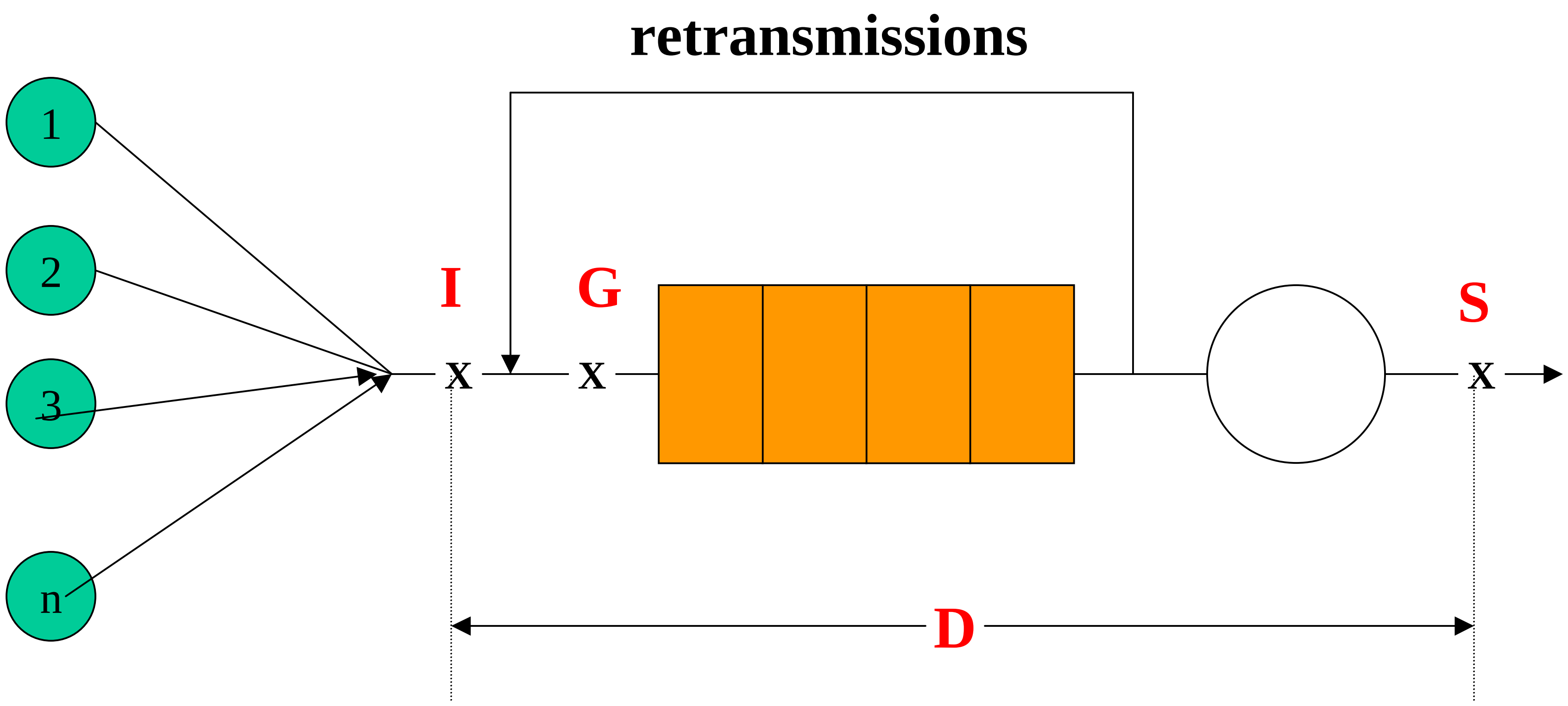
i.e.,

$$\textbf{packet time} = \frac{\textbf{packet length}}{\textbf{bit rate}}$$

NOTE: Since the channel capacity is one packet /packet time, S can be viewed as *throughput as a fraction of capacity.*

Represented in LG&W by ρ in later graphs.

Historic LAN Performance Notation



Typical frame delay versus throughput performance

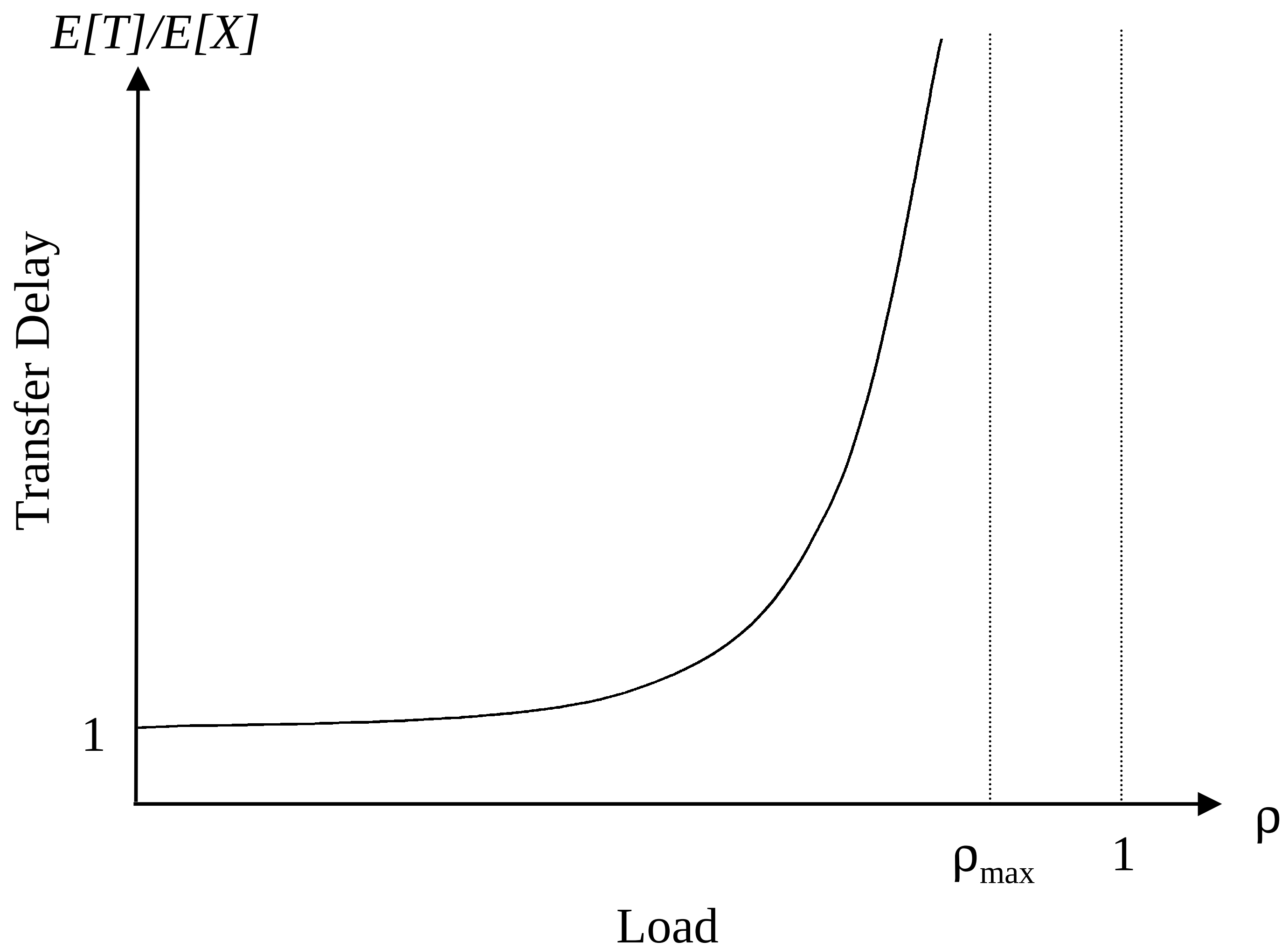


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Figure 6.8

Delay-Throughput Performance Dependence on a

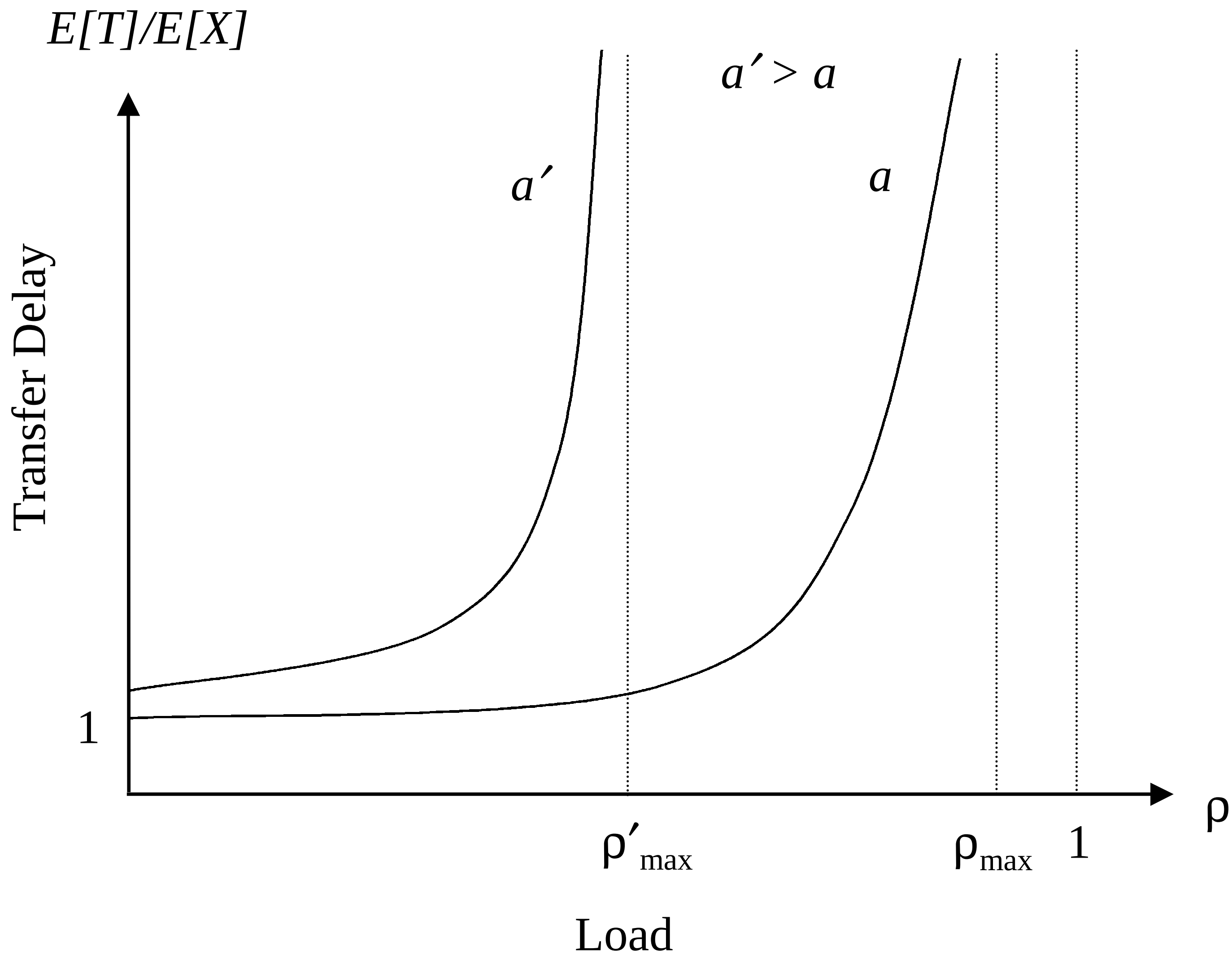


Figure 6.9

ALOHA

- Abramson solved the channel allocation problem for ground radio at University of Hawaii in 1970’s

Aloha Transmission Strategy

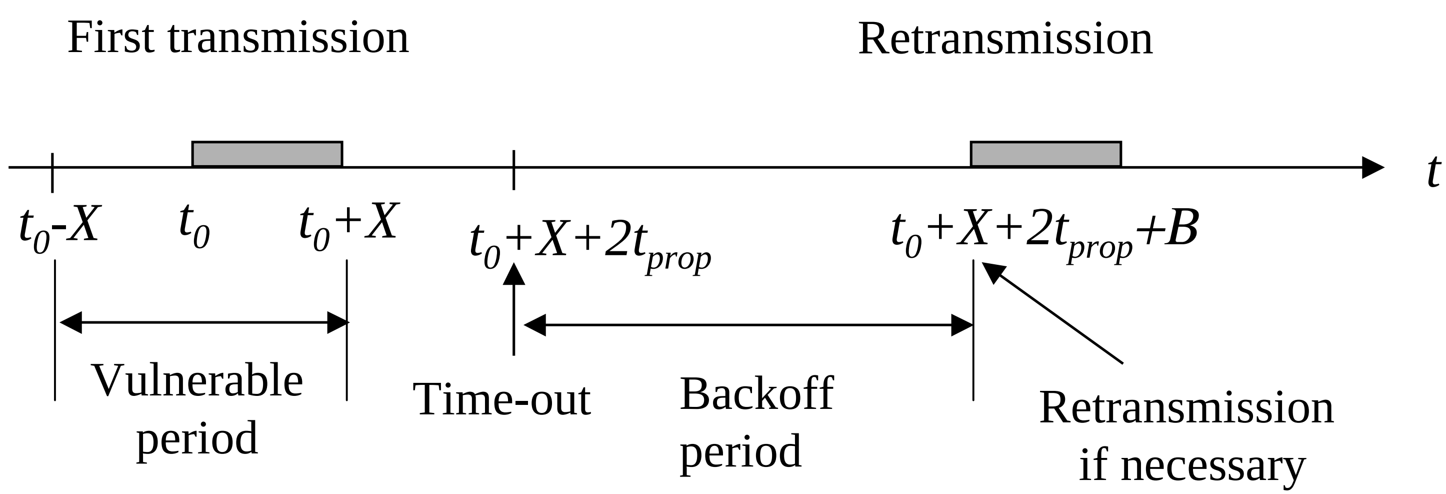
Stations transmit whenever they have data to send

- Collisions will occur and colliding frames are destroyed

Aloha Retransmission Strategy

Station waits a *random amount of time before sending again*

ALOHA



random backoff period *B*

 Leon-Garcia & Widjaja: *Communication Networks* Figure 6.16

Slotted ALOHA (Roberts 1972)

- uses discrete time intervals as *slots (i.e., slot = one packet transmission time)* and synchronize send time (e.g., use "pip" from a satellite)

Slotted Aloha Strategy

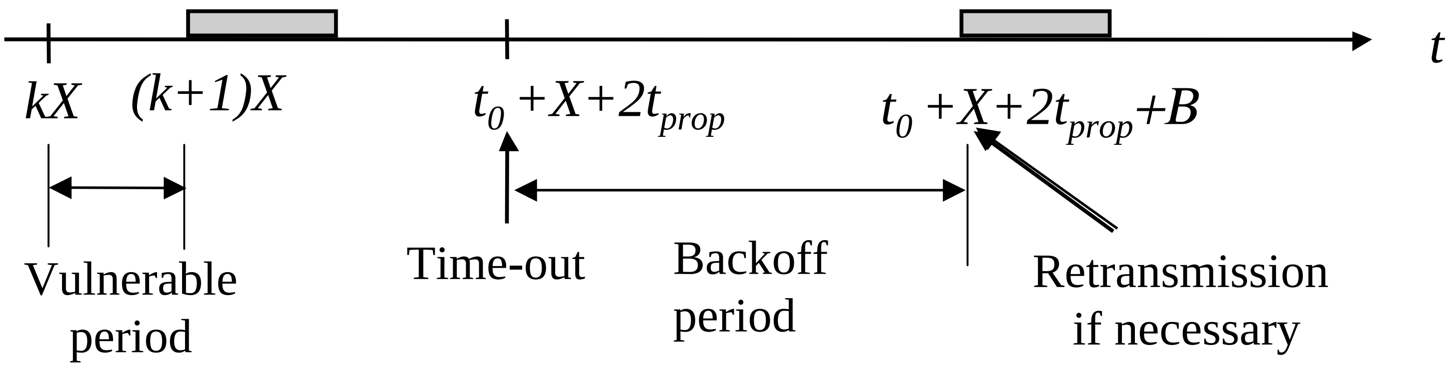
Stations transmit ONLY at the beginning of a time slot

- Collisions will occur and colliding frames are destroyed

Slotted Aloha Retransmission Strategy

Station waits a *random amount of time before sending again*

Slotted ALOHA



random backoff period *B* slots

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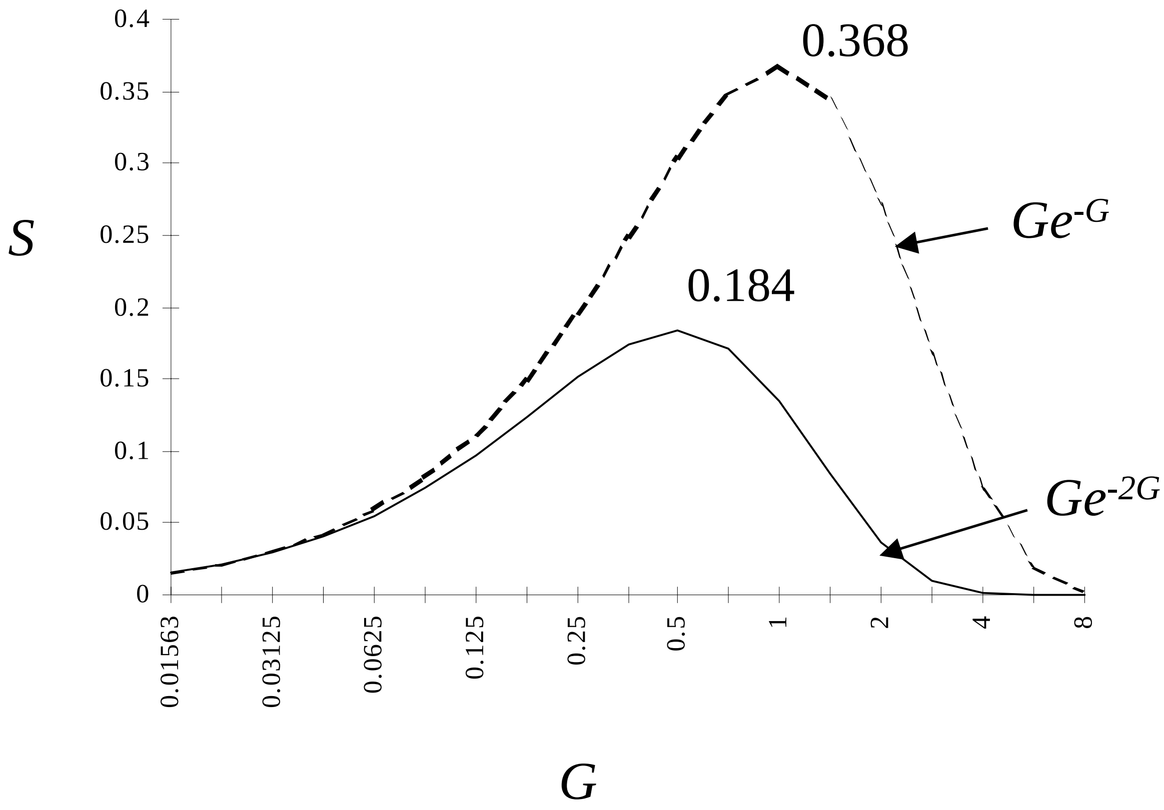
ALOHA and Slotted ALOHA Throughput versus Load



 Leon-Garcia & Widjaja: *Communication Networks* Figure 6.17

Non-Persistent CSMA (Carrier Sense with Multiple Access)

nonpersistent CSMA {less greedy}

1. Sense the channel.
2. IF the channel is ***idle***, THEN transmit.

3. IF the channel is ***busy*****,** THEN wait a <u>random amount of time</u> and start over.

1 - Persistent CSMA (Carrier Sense with Multiple Access)

1 - persistent CSMA {selfish}

1. Sense the channel.
2. IF the channel is ***idle***, THEN transmit.
3. IF the channel is ***busy***, THEN continue to listen until channel is ***idle.*** Now transmit immediately.

P - Persistent CSMA (Carrier Sense with Multiple Access)

p - persistent CSMA {a slotted approximation}

1. Sense the channel.

2. IF the channel is ***idle***, THEN with probability **p** transmit and with probability **(1-p)** delay for one time slot and start over.

3. IF the channel is ***busy***, THEN delay ***one time-slot*** and start over.

P – Persistent CSMA details

- the time slot is usually set to the maximum propagation delay.
- as **p** decreases, stations wait longer to transmit but the number of collisions decreases
- Considerations for the choice of **p:**
- **(n x p)** must be **< 1** for stability, where **n** is maximum number of stations, i.e.,

$$p < 1/n$$

CSMA Collisions

- In all three cases a collision is possible.

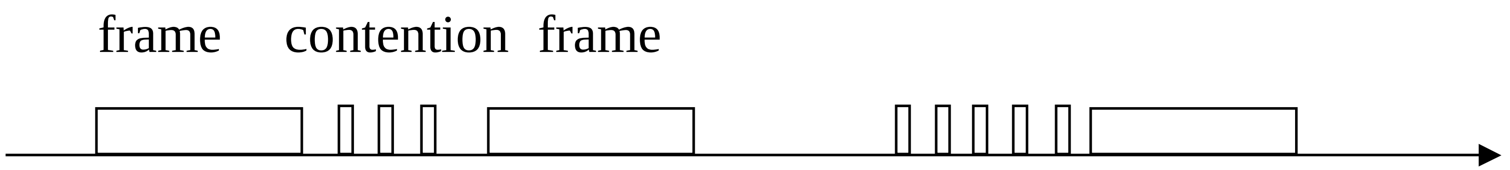
- CSMA determines collisions by the lack of an ACK which results in a TIMEOUT. *{This is extremely expensive with respect to performance.}*
- If a collision occurs, THEN wait a random amount of time and start over.
  –

CSMA/CD Collisions

- If a collision is detected during transmission, THEN immediately cease transmitting the frame.
- The first station to detect a collision sends a ***jam signal*** to all stations to indicate that there has been a collision.
- After receiving a ***jam signal***, a station that was attempting to transmit waits a random amount of time before attempting to retransmit.
- The maximum time needed to detect a collision = 2 x propagation delay.

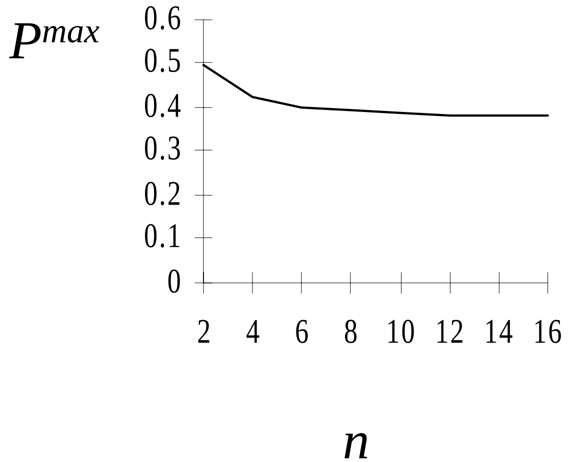
CSMA vs CSMA/CD

- CSMA is essentially a historical technology now.
- If propagation time is short compared to transmission time, station can be *listening before sending* with CSMA
- Collision detection (CD) accomplished by detecting voltage levels outside acceptable range. Thus attenuation limits distance without a repeater.
- If the collision time is short compared to packet time (i.e., small *a*), performance will increase due to CD



Probability of 1 successful transmission:

$$P_{success} = np(1-p)^{n-1}$$



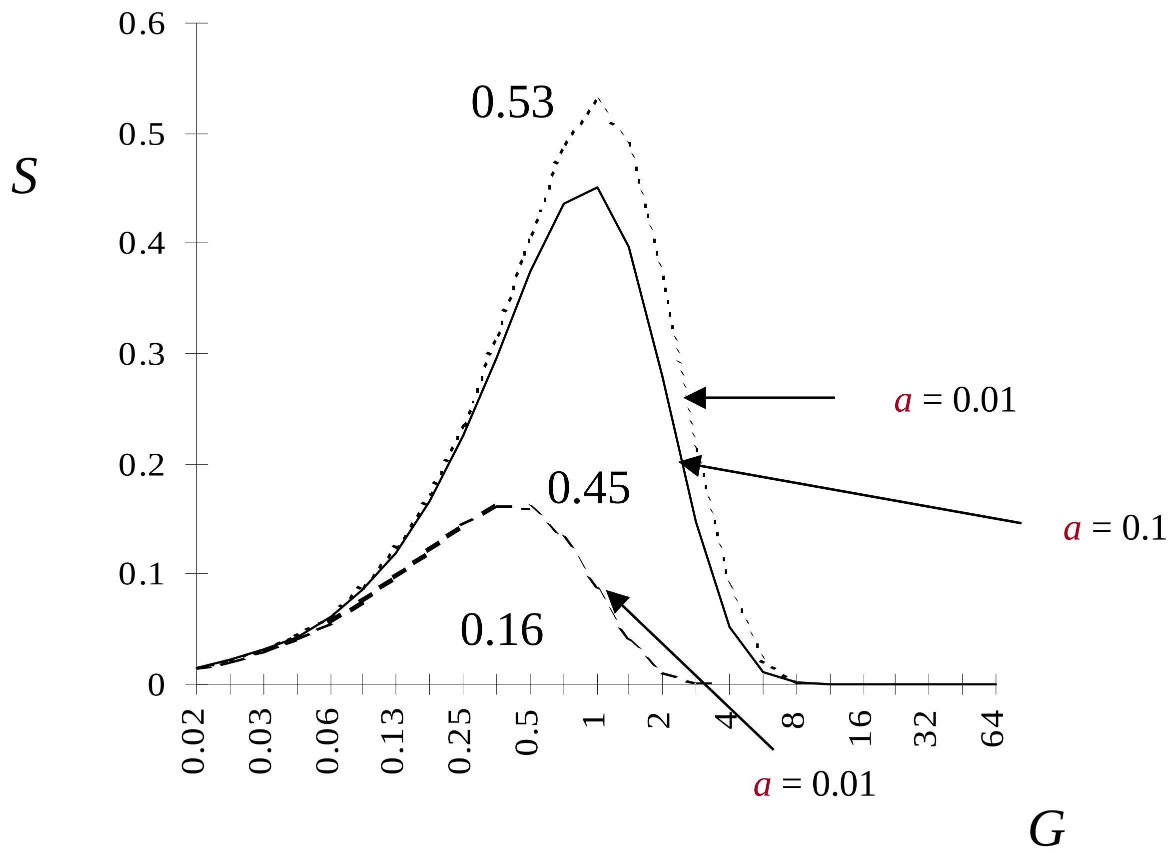
$P_{success}$ is maximized at p=1/n:

$$P_{success}^{\max} = n(1-\frac{1}{n})^{n-1} \rightarrow \frac{1}{e}$$

Figure 6.23

Throughput vs Load varying *a*

1-Persistent CSMA



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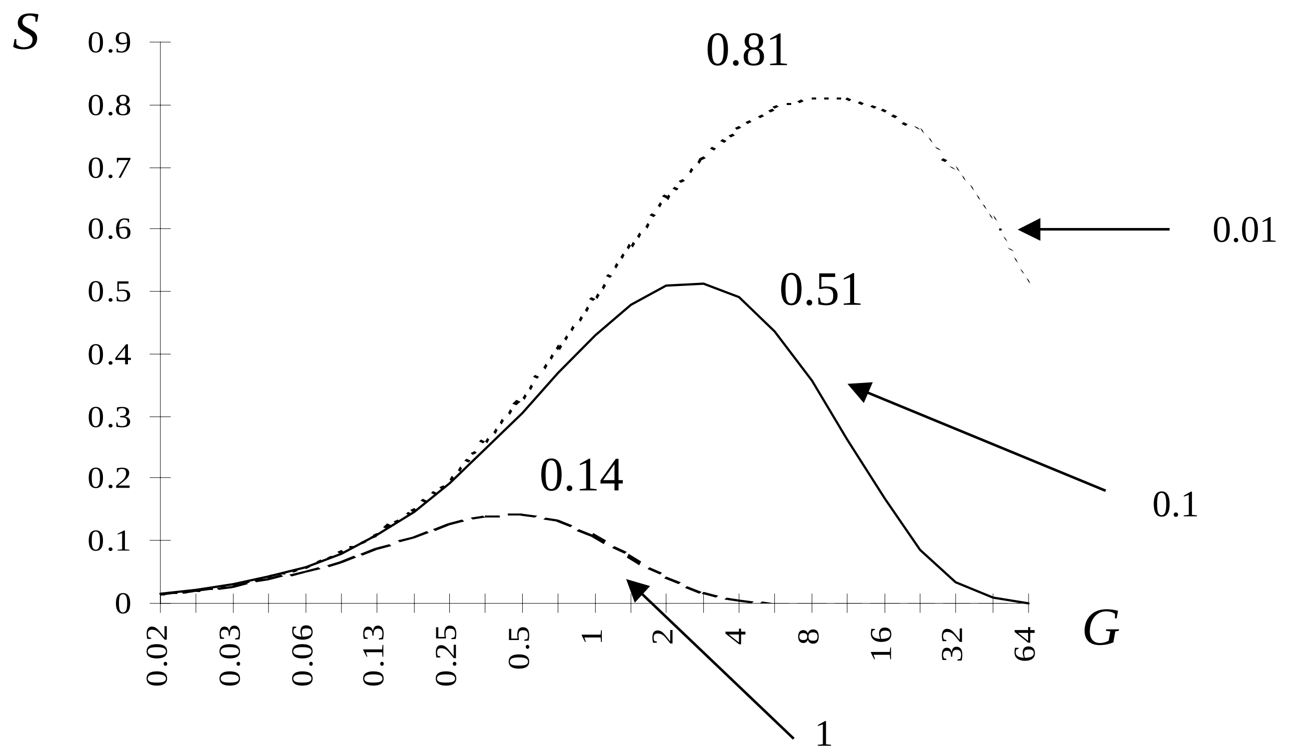
Throughput vs Load varying *a*

Non-Persistent CSMA



 Leon-Garcia & Widjaja: *Communication Networks* Figure 6.21 - Part 1

Maximum Achievable Throughputs

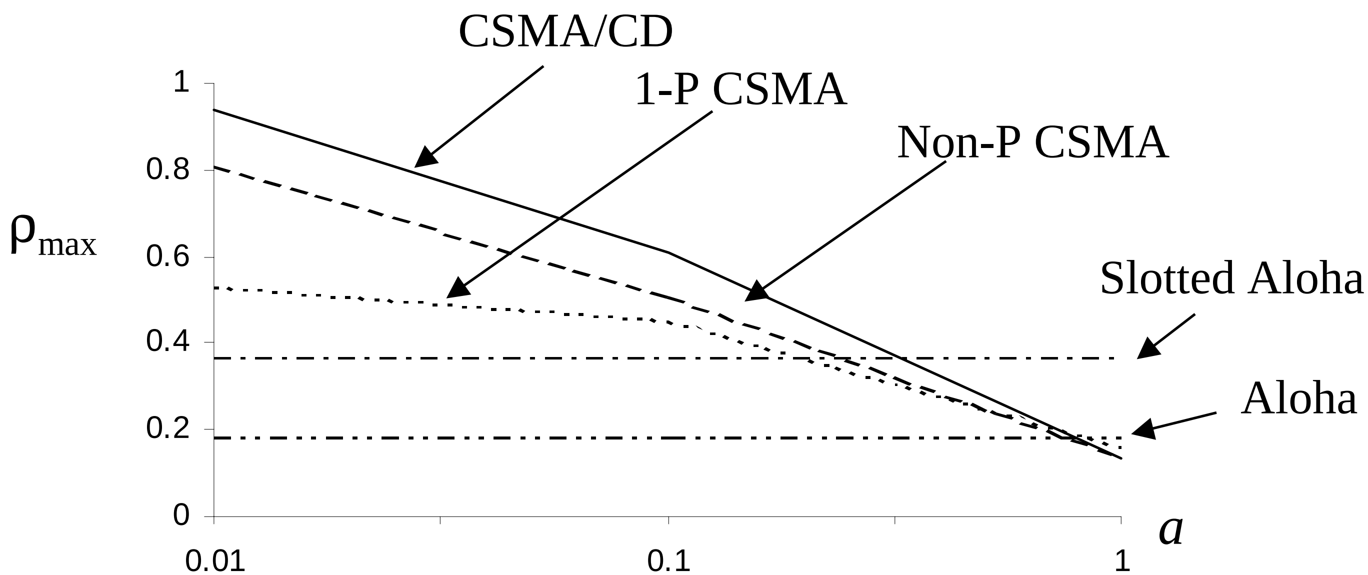


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Figure 6.24

Frame Delay varying *a*

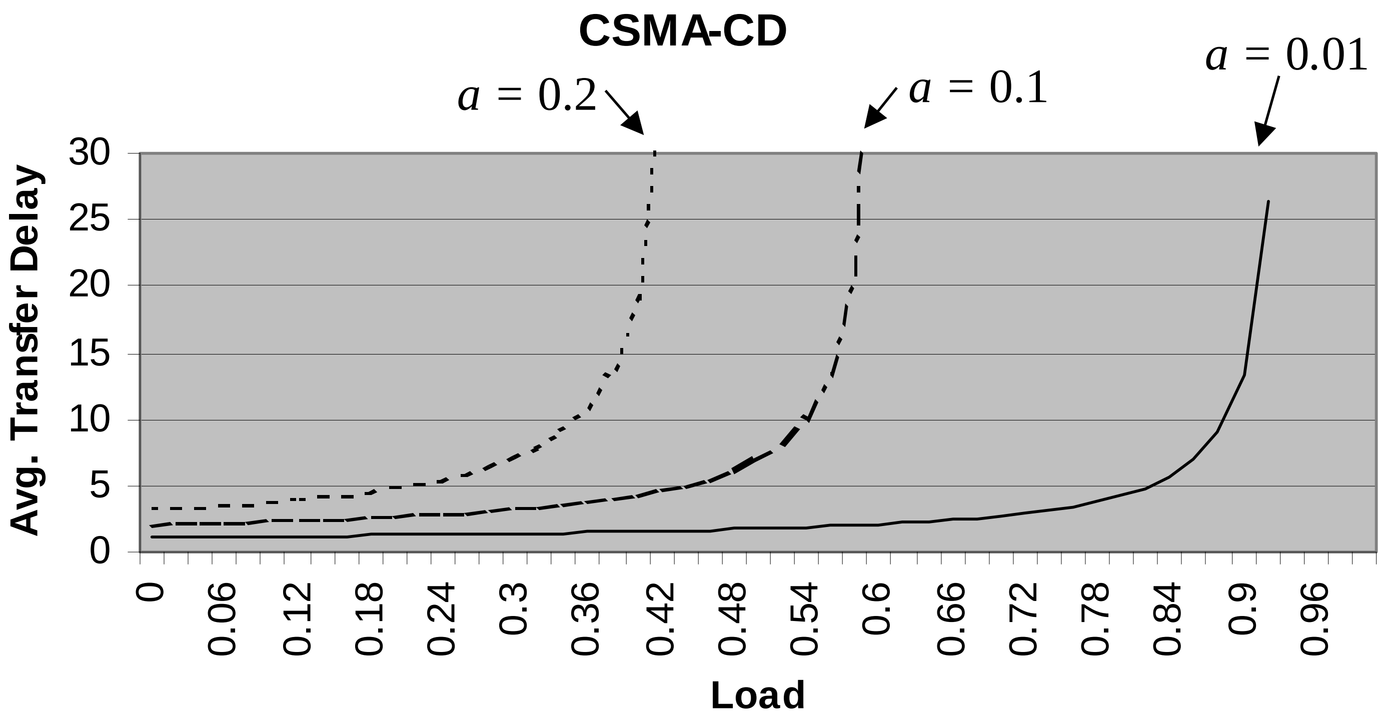

Figure 6.51