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
Figure 6.11

IEEE 802

Networks: Local Area Networks

Copyright ©2000 The McGraw Hill Companies
Figure 6.1} Leon-Garcia & Widjaja: Communication Networks

Copyright ©2000 The McGraw Hill Companies

Networks: Local Area Networks

Shared Multiple Access Medium
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
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 \textit{efficiently} and \textit{fairly} among $n$ uncoordinated users.
Ring networks

Multitapped Bus
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-

\[ a = \frac{\text{delay-bandwidth product}^*}{\text{average frame size}} \]

* Delay-bandwidth product :: the product of the capacity (bit rate) and the delay.
(a) Transmission time = 1; propagation time = \(a < 1\)

(b) Transmission time = 1; propagation time = \(a > 1\)

Figure 15.2  The Effect of \(a\) on Utilization for Baseband Bus
Relative Propagation Time

\[ R = \text{capacity (data rate)} \]
\[ d = \text{maximum distance of communications path} \]
\[ v = \text{propagation velocity (Assume} v = \frac{2}{3} \text{speed of light} \quad 2 \times 10^8 \text{meters/second)} \]
\[ L = \text{frame length} \]

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

\[
\frac{\text{Util}}{\text{Capacity}} = \frac{L}{\text{propagation time} + \text{transmission time} \over R}
\]
Maximum Utilization for LANs

\[
\text{max. Util} = \frac{L}{d + \frac{L}{v} + \frac{L}{Rd} + \frac{L}{v}} = \frac{1}{a + 1}
\]
A transmits at $t = 0$

Distance $d$ meters

$t_{prop} = d / v$ seconds

B transmits before $t = t_{prop}$ and detects collision shortly thereafter

A detects collision at $t = 2t_{prop}$
Efficiency [LG&W p.346]

\[
\frac{L}{L + 2t_{\text{prop}} R} = \frac{1}{1 + 2a}
\]

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.,

```
packet length
--------------
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 $\rho$ in later graphs.
Historic LAN Performance Notation

retransmissions

Networks: Local Area Networks
Typical frame delay versus throughput performance

\[ E[T]/E[X] \]

Transfer Delay

Load

\[ \rho_{\text{max}} \]

\[ \rho \]

Copyright ©2000 The McGraw Hill Companies

Leon-Garcia & Widjaja: Communication Networks

Networks: Local Area Networks
Delay-Throughput Performance Dependence on $a$

$E[T]/E[X]$ vs. Load

Transfer Delay

1

$\rho_{\text{max}}$  $\rho_{\text{max}}$  1

$a' > a$

$a'$  $a$

Copyright ©2000 The McGraw Hill Companies

Leon-Garcia & Widjaja: *Communication Networks*

Networks: Local Area Networks
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

First transmission

\[ t_{0} - X \quad t_{0} \quad t_{0} + X \]

Vulnerable period

Retransmission

\[ t_{0} + X + 2t_{prop} \quad t_{0} + X + 2t_{prop} + B \]

Time-out

Backoff period

Retransmission if necessary

random backoff period \( B \)
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
ALOHA and Slotted ALOHA
Throughput versus Load

Figure 6.17 Leon-Garcia & Widjaja:
Communication Networks
Copyright ©2000 The McGraw Hill Companies

Networks: Local Area Networks
Non-Persistent CSMA (Carrier Sense with Multiple Access)

nonpersistent CSMA \{less greedy\}

1. Sense the channel.
2. IF the channel is \textit{idle}, THEN transmit.
3. IF the channel is \textit{busy}, THEN wait a random amount of time and start over.
1 - Persistent CSMA (Carrier Sense with Multiple Access)

1 - persistent CSMA \{selfish\}

1. Sense the channel.

2. IF the channel is \textit{idle}, THEN transmit.

3. IF the channel is \textit{busy}, THEN continue to listen until channel is \textit{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 $p$:
  - $(n \times p)$ must be $< 1$ for stability, where $n$ is maximum number of stations, i.e.,
    \[ p < \frac{1}{n} \]
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 \( p = \frac{1}{n} \):

\[ P_{\text{max}}^{success} = n \left(1 - \frac{1}{n}\right)^{n-1} \rightarrow \frac{1}{e} \]
Figure 6.21 - Part 2

Throughput vs Load varying \( a \)

1-Persistent CSMA

\[ S \]

\[ G \]
Throughput vs Load varying $a$

Non-Persistent CSMA

$S$

$G$

Figure 6.21 - Part 1
Maximum Achievable Throughputs

![Diagram showing Maximum Achievable Throughputs for different access methods: Aloha, Slotted Aloha, 1-P CSMA, Non-P CSMA, and CSMA/CD.](image)

- **Aloha**
- **Slotted Aloha**
- **1-P CSMA**
- **Non-P CSMA**
- **CSMA/CD**

**Axes:**
- **x-axis:** \( \alpha \) ranging from 0.01 to 1
- **y-axis:** \( \rho_{\text{max}} \) ranging from 0 to 1
Frame Delay varying $a$

![Diagram showing frame delay varying $a$.](image)