MULTIACCESS CHANNELS

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MULTIACCESS PROTOCOLS

- **Protocol Candidates**
  - Channel Partitioning (Frequency, Time, or Code Division Multiplexing)
  - Random Access (e.g., CSMA/CD)
  - Round-Robin (e.g., Token Passing)

- **The Ideal Protocol**
  - A single active node will get the entire channel bandwidth
  - N active nodes will get 1/N of the channel bandwidth
  - The protocol is distributed (no master node)
  - The protocol is simple to implement

FRAME TRANSMISSION

- 10 Mbps ⇒ 1 bit is injected onto the medium every 0.1 μsec
FRAME PROPAGATION AND TRANSMISSION

- **Frame Latency** = \(
\frac{3D}{2c} + \frac{L}{R}
\)
  
  *Propagation time + Transmission time*
- **Propagation Time** over the distance \(D\) in copper wire
  
  \[
  \tau = \frac{D}{\frac{3}{2}c} = \frac{3D}{2c}
  \]
  
  *\(D\): Distance traveled by a bit (electrical pulse)*
  *\(c\): Speed of light in a vacuum (3 \(\times\) \(10^8\) m/sec)*
  *\(c' = \frac{2}{3}c\): Speed of an electron in copper (200 m/\(\mu\)sec)*
- **Transmission Time** = \(
\frac{L}{R}
\)
  
  *\(L\): Packet Length*
  *\(R\): Transmission Rate*

FRAME LATENCY EXAMPLE

- **Given**
  
  * Bandwidth of 10 Mb/s*
  * Frame (Packet) size of 1,500 bytes*
  * Distance of 2,500 meters*
  * Sending and receiving overhead = 0 \(\mu\)sec*
  * Assume no signal attenuation*
- **What is the interbit time?** 0.1 \(\mu\)sec
- **What is the total latency of the frame from sender to receiver?**
  
  \(2,500/200 \mu\)sec + 12,000 \(\times\) 0.1 \(\mu\)sec = 12.5 + 1,200 = 1.2125 ms
  
  *The transmission time dominates the propagation time!*
- **What is the maximum collision time?**
  
  \(2 \times \frac{D}{c'} = 25 \mu\)sec

SPACE-TIME DIAGRAM (THE PARAMETER \(a\))

- **The performance of a packet-mode multiaccess channel is heavily influenced by \(a\)**
  
  \[
  a = \frac{\text{Max propagation delay}}{\text{Time to transmit average size packet}}
  \]
  
  *The number of packets that a transmitting station can place on the medium before the farthest station receives the first bit*
- **Small \(a\) (**<<** 1)**
  
  *Propagation delay is a small fraction of the packet transmission time*
  *Every station receives at least part of the packet before source finishes transmission*
  *Usually small (0.01) for wired and wireless LANs, cellular telephony, packet radio*
- **Large \(a\)**
  
  *Source may transmit many packets before receiver sees the first bit*
  *Satellite links can have \(a\) as large as 100*
PERFORMANCE METRICS

- Normalized Goodput
  - The fraction of a link’s capacity devoted to carrying non-retransmitted packets
  - Excludes time lost to protocol overhead, collisions, and retransmissions
  - Example
    - It takes 16 seconds to transmit a 10 MB (Kilobyte) file over a 10 Mbps link
    - Link capacity is 10 Mbps
    - Effective transmission rate (goodput) is 80/16 = 5 Mbps
    - Normalized goodput is 5/10 = 0.5
- Mean Delay: Mean time required to successfully transmit a packet
  - Collisions may require several transmission attempts
- Stability: Throughput doesn’t decrease with increasing offered load
- Fairness
  - Minimal fairness: No starvation (finite mean delay)
  - Stricter fairness: Equal share of bandwidth

THE MULTIACCESS PROBLEM

- What happens if two senders separated by 2000 meters on a wired LAN transmit at the same time?
  - First bit collides midway between the two hosts.
  - Collision occurs 5 μsec after first bit is sent
  - Collision causes a noisy signal which is detected 10 μsec after start of transmission
- Some Options for Single-Channel Transmissions
  - Transmitter listens on the bus for a collision (carrier sense)
    - Wired LANs generally have carrier sense (listen during transmission)
    - Wireless LANs generally do not since some hosts may be out of range
  - Transmitter receives a packet acknowledging receipt of the transmitted packet
  - Pass a around one special token that grants the holder access to the medium

PURE ALOHA

- Multiple access protocol for ground-based radio broadcasting
  - Transmit at any time
  - No ACK received ⇒ Collision ⇒ Wait a random time interval before resending
  - Throughput is maximized when all frames are the same size
- Vulnerability Period
  - Fixed length frames (t = time to transmit 1 frame)

P单纯ALOHA

- Pure Aloha
  - Start
  - Wait 1 RTT for ACK
  - RTT expired
  - No Collision
  - Max backoff
  - Done
  - Abort

- Slotted Aloha
  - Synchronize senders and send only at the beginning of a slot time
**ALOHA CHANNEL UTILIZATION**

- **Channel Utilization**: Fraction of time channel is busy transmitting a successful packet.
- **Performance Model Assumptions**
  - An infinite population Poisson source
  - Mean aggregate packet attempt rate: \( \lambda \) frames per second (includes retries)
  - One frame time is \( t \)
- **Note**: Channel utilization is maximized for fixed-length frames.

![Probability of Success vs. Number of Attempts](image)

**ALOHA CHANNEL UTILIZATION**

- **Number of Successful Transmissions in time \( T \)**
  \[
  n_{\text{Successful}} = \lambda T \times \text{Prob}[\text{Success}]
  \]
- **Channel Busy Time (due to successful packets)**
  \[
  t_{\text{Busy}} = t \times n_{\text{Successful}} = t \lambda T \text{Prob}[\text{Success}]
  \]
- **Utilization**:
  \[
  U = \frac{t_{\text{Busy}}}{T} = \lambda T \text{Prob}[\text{Success}]
  \]
- **Maximum utilization** is \( \frac{1}{2\lambda} = 0.184 \)
  - Method: Find \( \lambda \) such that \( \frac{dU}{d\lambda} = 0 \)
  - *How can we improve on this utilization?*

**CSMA PROTOCOLS**

- **IEEE 802.3**: A family of 1-persistent CSMA/CD with truncated binary exponential backoff
- **Carrier Sense Protocol**
  - Avoid "some" collisions by detecting "some" transmissions
  - Stations listen for a carrier (transmission) before transmitting
  - Frame transmission time > \( 2T_{\text{MAX}} \), the max. round-trip propagation delay
- **Nonpersistent CSMA**
  - If medium is busy, station waits a random time interval and retries
  - Effect: Randomly probe the medium until it is idle
- **Persistent CSMA**
  - Station waits for the medium to become idle
PERSISTENT CSMA

- Clustering
  - If 2 stations find the medium busy, a collision is guaranteed when they both retry!
- \( p \)-persistence (slotted channels)
  - When channel becomes idle, either:
    - Send a frame with probability \( p \); or
    - Wait one time slot with probability \( 1-p \) before repeating process.
- Idea: \( \Pr \{2 \text{ waiting stations will cause a collision}\} = p^2 \)
- Choice of \( p \): A tradeoff between 1) Performance under heavy load, and 2) Mean message delay
  - \( n \) waiting stations \( \Rightarrow \) Mean number of simultaneous sends is \( np \)
  - Want \( np < 1 \)

EXPOSENTIAL BACKOFF

- Each station checks if transmission was successful
- If a collision occurs, wait \( W \) time slots (\( 2 \tau_{MAX} \))
  - Choose \( W \) equiprobably from \( 0 \leq W < 2^B \), \( B = \min(n, 10) \)
  - Increment backoff count (\( B = 1, 2, 3, \ldots, 10 \))
  - \( 2 \tau_{MAX} \): Maximum round-trip (two-way) propagation delay
- Backoff at most 15 times: \( B = 1, 2, \ldots, 10, 10, 10, 10, 10, 10 \)

CHANNEL UTILIZATION

IEEE 802.3

- IEEE 802.3: specifies a family of 1-persistent CSMA/CD with truncated binary exponential backoff running at speeds from 1 Mbps to 10 Mbps on various media
- Ethernet is a specific product that attempts to implement IEEE 802.3
- Minimum packet length is 64 bytes
- Every interface has a MAC address (e.g., 08:00:20:8d:65:80)
- IEEE 802.3 Frame Format (Ethernet uses Type Field in place of length field)
MEDIA OPTIONS

<table>
<thead>
<tr>
<th>Name</th>
<th>Cable</th>
<th>Max Segment</th>
<th>Nodes/Seg.</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>10Base5</td>
<td>Thick Coax</td>
<td>500 m</td>
<td>100</td>
<td>Good for backbones</td>
</tr>
<tr>
<td>10Base2</td>
<td>Thin Coax</td>
<td>200 m</td>
<td>30</td>
<td>Cheap system</td>
</tr>
<tr>
<td>10Base-T</td>
<td>Twisted Pair</td>
<td>100 m</td>
<td>1024</td>
<td>Easy maintenance</td>
</tr>
<tr>
<td>10Base-F</td>
<td>Fiber Optics</td>
<td>2000 m</td>
<td>1024</td>
<td>Between buildings</td>
</tr>
</tbody>
</table>

- **Nomenclature**: xBASEy (e.g., 10BASE5)
  - x indicates network data rate in Mbps (e.g., 10 Mbps)
  - y indicates maximum segment length in 100 meters (e.g., 500 meters)
  - BASE indicates baseband signaling
- **Attenuation**: Signal loses strength as it travels through a lossy medium

CSMA/CA (WIRELESS LANS) (1)

- **Wireless LANs**
  - Use radio (or infrared) signals (2-3 Mbps or 11-54 Mbps)
  - Are noisy and unreliable
- **Multiple transmissions can occur simultaneously if signals don’t interfere**

![Diagram of A, B, C, D]

- **Problems**
  - Hidden Station: Can’t detect competitor because it is too far away
  - Exposed Station: A strong transmitter masks other stations

CSMA/CA (WIRELESS LANS) (2)

- **IEEE 802.11 (CSMA/CA)**
  - p-persistence but when idle, wait one interframe spacing before contending
  - Waits for random value chosen in [0, Contention Window]
  - Then, transmits packet and waits for ACK from receiver
  - If no ACK, use binary exponential backoff
  - If someone is transmitting, stop timer and resume it when transmission is done
- **IEEE 802.11 (MACAW, Multiple Access with Collision Avoidance for Wireless)**

![Diagram of A, B, C]

TOKEN-RING NETWORK

- Stations are logically ordered into a ring
- **One station holds a token packet**
  - Token gives right to send packets
  - Passes token after transmission
  - Transmitted packets return to sender and serve as implicit ACK
- **A second counterrotating ring serves as a backup**
- **Need to monitor for ring/host failure and lost token**
- **Fiber Distributed Data Interface (FDDI) is an example of a 100 Mbps token-ring**