EITF25
Internet–Techniques and Applications
L4: Network Access

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Repetition

The link layer protocol should make sure that the data is correctly transmitted over the physical link using error detection and control.
Types of connections

a. Point-to-point

b. Multipoint
Local Area Networks (LAN)

- A Local Area Network (LAN) is usually privately owned and links the devices in a single office, building or campus.
- LAN size is limited to a few kilometers.
- Traditionally, LANs use a shared medium, which means that the stations share a common physical link.
- Wireless LANs (WLANs) are common everywhere.
Today, we usually don’t share a wired medium, however we all use wireless LANs (WLANs) that share a wireless medium. Therefore, the concept is still valid.
Characteristics for LANs with shared medium

- All data that is transmitted on the link, reaches all stations (broadcast).
- Due to attenuation on the link, the network has a limited size.
- The link can be extended with a **repeater** that amplifies the signal on the link.
LAN addresses

In a network, all stations need an address so that the data can reach the right destination.

All computers connected to standardized LANs have a unique physical address (called MAC-address).
The computer with the right destination address copies the packet and delivers it to the application.
Media Access Control (MAC)

- All computers in a multiple access network, need to have the same rules for sending and receiving data.
- This is called a Media Access Control (MAC) (or Multiple-Access Protocol).
Controlled access methods

• In **controlled access**, the stations consult one another to find which station has the right to send. A station cannot send unless it has been authorized by other stations.

• Controlled access is used in different parts of the mobile networks.
Reservation access method

In the *reservation method*, time is divided into intervals, and a reservation frame precedes the data frames. A station needs to make a reservation before sending data.
Polling

• In Polling, one station is designated as a Primary Station (Master) and the other stations are Secondary Stations (Slaves).

• The primary station controls the link, and the secondary stations follow its instructions. All data exchange must be made through the primary station.

• If the primary station has anything to send, it uses a Select function. If it wants to receive data it uses a Poll function.
Poll and Select functions
Token Passing

• In **Token passing** the stations are organized in a **logical ring**. Each station has a predecessor and a successor.

• A special packet, called a **token**, circulates through the ring. The possession of the token gives a station the right to access the link and send data.

• A station can only possess the token for a certain time, then it must release the token and pass it on.
Logical ring and physical topology

a. Physical ring

b. Bus ring
d. Star ring
Random access methods

• In random access or contention methods, no station is superior to another station and none is assigned the control over another. No station permits, or does not permit, another station to send.

• At each instance, a station that has data to send uses a procedure defined by the protocol to make a decision on whether or not to send.
ALOHA

• ALOHANET was developed by the University of Hawaii already in 1970.
• ALOHANET was a wireless LAN (one of the first).
• The multiple-access method in ALOHANET is called ALOHA.
ALOHANET

Mainframe
Pure ALOHA

- The stations share one frequency band. The mainframe sends data on another frequency (broadcast channel).
- A station sends a frame whenever it has a frame to send.
- If the station receives an ACK from the mainframe on the broadcast channel, the transmission is successful.
- If not, the frame needs to be retransmitted.
Frames in Pure ALOHA

Station 1
- Frame 1.1
- Frame 1.2

Station 2
- Frame 2.1
- Frame 2.2

Station 3
- Frame 3.1
- Frame 3.2

Station 4
- Frame 4.1
- Frame 4.2

Collision duration

Time

Collision duration

Time
Collisions in Pure ALOHA

B’s end collides with A’s beginning

A’s end collides with C’s beginning

Begin B End

Begin A End

Begin C End

$t - T_{fr}$ $t$ $t + T_{fr}$

Vulnerable time $= 2 \times T_{fr}$
Resend strategy

After a collision

• Wait a random time and resend \((T_B \text{ backoff time})\)
• After \(K_{max}\) attempts give up and try later (abort)
  • Often \(K_{max} = 15\).

**Example:** In **binary exponential backoff** the backoff time is chosen
\[
T_B \sim \mathcal{U}\left(0, (2^k - 1)T_f\right)
\]
where \(k\) is the attempt number.
Slotted ALOHA

• In Slotted ALOHA, the time is divided into slots, where each slot contains one frame in time.
• A station can only send in the beginning of a slot.
Frames in Slotted ALOHA

Station 1

Frame 1.1

Collision duration

Frame 1.2

Station 2

Frame 2.1

Collision duration

Frame 2.2

Station 3

Frame 3.1

Collision duration

Frame 3.2

Station 4

Frame 4.1

Collision duration

Frame 4.2

Slot 1

Slot 2

Slot 3

Slot 4

Slot 5

Slot 6

Time
Collisions in Slotted ALOHA

A collides with C

Vulnerable time = $T_{fr}$
Throughput of slotted ALOHA

Assume

• New packets with intensity $\lambda$ (acc to Poisson proc.)
• New and resent packets with intensity $G$ (Poisson)

Probability of $k$ packets in slot:

$$P(X = k) = \frac{G^k e^{-G}}{k!}$$

The mean throughput is

$$\text{Throughput} = E[\# \text{ success}] = Ge^{-G}$$
Throughput of slotted ALOHA

\[ Ge^{-G} \]

Stable system: \( \lambda < \frac{1}{e} \)
Throughput ALOHA

Slotted ALOHA

- $Ge^{-G}$ with maximum $\frac{1}{e} \approx 0.37$ at $G=1$

Pure ALOHA

- $Ge^{-2G}$ with maximum $\frac{1}{2e} \approx 0.18$ at $G=1/2$
Carrier Sense Multiple Access (CSMA)

- Before a station sends data, it ”listens” (senses) to the medium.
- If the medium is occupied, the station waits with the transmission.
- The vulnerable time is the propagation time (i.e. the time it takes for the signal to propagate from one of the medium to the other).
Vulnerable time in CSMA

Vulnerable time = propagation time

Frame propagation
Persistence methods

What if the channel is busy.

- **1-persistent**: As soon as the channel becomes idle, the station transmits its data.

- **Nonpersistent**: The station waits a random amount of time and then senses the channel again.

- **p-Persistent**: The station transmits with probability $p$. With probability $1-p$, check line
  - Idle: Restart (and transmit with prob $p$)
  - Busy: Wait $T_B$ and then restart
Behavior of the persistence methods

a. 1-persistent

b. Nonpersistent

c. p-persistent
CSMA with Collision Detection (CSMA/CD)

The original CSMA method does not specify the procedure following a collision.

• CSMA/CD was developed to better handle collisions.

• After a station monitors the medium after it sends a frame to see if the transmission was successful. A station that detects a collision, immediately aborts the transmission and sends a jamming signal.
Energy levels on link
Minimum frame size

A sending station must be able to detect a collision before transmitting the last bit of a frame. Therefore, the frame transmission time must be at least two times the maximum propagation time on the link, so that the colliding signal can propagate back to the sending station before the last bit is transmitted.
CSMA with Collision Avoidance (CSMA/CA)

- CSMA/CD was developed for wired networks that have low attenuation. Therefore, the energy level during a collision can easily be detected.

- In a wireless network much of the energy is lost in transmission. A collision may add only 5-10% additional energy, which is not useful for effective collision detection as in CSMA/CD.

- Therefore, CSMA/CA tries to avoid collisions.
Collision avoidance strategies

CSMA/CA has three collision avoidance strategies:

1. Interframe space (IFS)
2. Contention Window
3. Acknowledgment
Interframe space

A station does not send immediately after finding the medium idle. Instead it waits a period of time, called Interframe space (IFS), since a distant station may have already started transmitting. If, after the IFS time the channel is still idle, the station can send.
Contestation window

The contention window is an amount of time divided into slots.
A station that is ready to send chooses a random number of slots as its wait time.
During the wait time, the station monitors the channel. If the channel is found busy, the timer is stopped and then restarted when the channel is idle.
When a station has sent a frame, there is a time-out on the channel (no other station can send a frame). During this time-out the receiving station sends an ACK if the data is received correctly.

If the sending station has not received an ACK within the time-out period, the data is assumed to be lost (either due to collision or bit errors).
Collision avoidance in CSMA/CA
The IEEE project 802 started in 1985. Ethernet was originally developed in the 1970s at Xerox, and it was inspired by ALOHAnet.
Wired LAN topologies

Mesh

Star

Bus

Ring
Physical address (MAC address)

06:01:02:01:2C:4B

6 bytes = 12 hex digits = 48 bits

All hosts with a network card for an IEEE 802.x-network have a unique physical address.
# Ethernet MAC frame

**Preamble**: 56 bits of alternating 1s and 0s

**SFD**: Start frame delimiter, flag (10101011)

<table>
<thead>
<tr>
<th></th>
<th>Preamble</th>
<th>SFD</th>
<th>Destination address</th>
<th>Source address</th>
<th>Type</th>
<th>Data and padding</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 bytes</td>
<td>1 byte</td>
<td>6 bytes</td>
<td>6 bytes</td>
<td>2 bytes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Minimum payload length: 46 bytes
Maximum payload length: 1500 bytes

Minimum frame length: 512 bits or 64 bytes
Maximum frame length: 12,144 bits or 1518 bytes

Physical-layer header

45
Unicast and Broadcast addresses

- Data transfer is usually performed in *unicast*, that is there is one source and one destination.
- Some messages need to be sent in *broadcast*, that is one source sends the message to all hosts on the network.
- In 802-networks, the broadcast address is defined as all 1:s.
Medium Access method for standard Ethernet: 1-persistent CSMA/CD

a. 1-persistent
Encoding: Manchester

Early Ethernet standard uses Manchester encoding.
Bus topology

The first versions of Ethernet used a bus topology where all hosts were connected to the same cable using taps.

a. A LAN with a bus topology using a coaxial cable
Later versions of Ethernet used hubs. A hub transfers packets from an incoming link to all other links. It therefore works on the physical layer.
Collision domain

All hosts that share the same medium belong to a collision domain. This adds constraints on the size of the shared link.

a. Without bridging
Bridges

Bridges were developed to separate the shared links into two collision domains. The bridge acts as a host on all links and can transfer packets between links.
Basic principle for a switch

The switch keeps an address table for forwarding of packets.

<table>
<thead>
<tr>
<th>Address</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>71:2B:13:45:61:41</td>
<td>1</td>
</tr>
<tr>
<td>71:2B:13:45:61:42</td>
<td>2</td>
</tr>
<tr>
<td>64:2B:13:45:61:12</td>
<td>3</td>
</tr>
<tr>
<td>64:2B:13:45:61:13</td>
<td>4</td>
</tr>
</tbody>
</table>
Full-duplex communication

Modern Ethernets uses full-duplex communication.
Switched Ethernets

Ethernet switches can be used to build larger access networks. Broadcast messages are sent to all hosts in the network (defined by the router).
Ethernet (IEEE 802.3) evolution

- Standard Ethernet (10 Mbps)
- Fast Ethernet (100 Mbps)
- Gigabit Ethernet (1 Gbps)
- Ten-Gigabit Ethernet (10 Gbps)

Access networks

Backbone networks
Gigabit Ethernet (IEEE 802.3z)

- Used as
  - Metropolitan Area Network (MAN)
  - Access network

- Ethernet frames over optic fibre (or twisted pair)
- full duplex, no collisions
- Forward Error Correction on physical layer
Topologies

a. Point-to-point

b. Star

c. Two stars

d. Hierarchy of stars