Chapter 5:
Data Link Layer

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Learning Objectives

- Understand the functions of the data link layer.
- Understand the concept of the hop-to-hop delivery compared to host-to-host delivery and application-to-application delivery.
- Understand the concept of access method and define different access methods used in LANs and WANs.
- Understand how error control is handled at the data link layer.
- Understand the addressing mechanism used in the data link layer and how network layer addresses are mapped to data layer addresses.
**Data Link Layer**

**Hop-to-Hop Delivery**

The Data link layer provides hop-to-hop delivery in a closed network.

**Client Application:** Web browser

**Server Application:** Web Server

Internet Model

**Hop-to-hop delivery**

Hop-to-hop delivery means delivery of packets from the host’s network interface card (NIC) to the router’s interface.

Hop-to-hop delivery means delivery of packets from the one router interface to the other router’s interface.

Hop-to-hop delivery means delivery of packets from the one router interface to the host’s NIC.

Host to Host

Domain of underlying technology: hop-to-hop
Functions of the Data Link Layer

- Addressing
- Packetizing
- Flow control
- Error Detection and Control
- Medium Access Control

Addressing

- In hop-to-hop delivery, physical addresses of the devices are used to identify devices.
- The format of a physical address depends on the network type.
- For example, Ethernet LAN technology use 48-bit (6-byte) addresses.
- Each Ethernet network device has a Network Interface Card (NIC) with its own unique hardware address that is normally written in hexadecimal notation.

An Ethernet Physical Address in **Hexadecimal notation**

| 06-01-02-01-2C-4B |

| Ethernet Broadcast Address |

| FF-FF-FF-FF-FF-FF |
Address Resolution

- In the data link layer (hop-to-hop delivery), physical addresses are used to identify devices, but the IP header carries information only about IP address (network layer address).
- The Address Resolution Protocol (ARP) is responsible for finding the physical address of a given IP address in a LAN.

ARP Operation

Looking for the physical address of a node with IP address of 192.168.0.5

The node physical address is 12-23-EF-53-31-54

ARP Request
- Destination IP=192.168.0.5
- Source IP=192.168.0.2
- Destination MAC=FF-FF-FF-FF-FF-FF
- Source MAC=12-23-EF-78-50-00

ARP Response
- Destination IP=192.168.0.5
- Source IP=192.168.0.5
- Destination MAC=12-23-EF-78-50-00
- Source MAC=12-23-EF-53-31-54
Paketizing (Framing)

Data Link Header
Preamble Field, Source & Destination Physical Addresses, Length of the data, protocol....

IP Header
Source & Destination IP Addresses, Protocol, Time to live ....

Transport Layer Header (TCP or UDP)
Source & Destination port Numbers, Sequence number, Acknowledgment number, window size, checksum....

Data

Data Link Trailer
Cyclical Redundancy Check Number (used for error detection)....

Segment
Packet
Packet or Datagram
Frame

Error Control

- Data can be corrupted during transmission. For reliable communication, errors must be prevented, or detected and corrected.
- Source of Errors & How to prevent them:
  - White noise
  - Impulse noise
  - Crosstalk
  - Echo
  - Jitter
  - Attenuation
  - Distortion
Error Types

- **In a single-bit error**, only 1 bit in the data unit has changed.

- **A burst error** means that two or more bits in the data unit have changed.

Error Detection Methods

- **Error Detection Methods**
- **Using Redundancy Check**

- **Vertical Redundancy Check (VRC)**
- **Longitudinal Redundancy Check (LRC)**
- **Cyclic Redundancy Check (CRC)**

Data Bits

Redundant Bits
Vertical Redundancy Check (Parity Check)

In vertical redundancy check (VRC), a parity bit is added to every data unit so that the total number of 1s becomes even.

Data unit

Sum of bits is an even number?

Yes

No

Bits have not changed

Bits have changed

Retransmit

Even Parity Generator (Sender)

1

Data unit

Parity bit

Even Parity Checker (Receiver)

Sum of bits is an even number?

Yes

No

0

Longitudinal Redundancy Check (LRC)

Original data

11100111 11011101 00111001 10101001

LRC

10101010

Original data plus LRC
A. Konak IST 220/Ch5: Data link layer

Cyclic Redundancy Check (CRC)

Error Correction

- Error Correction Using Retransmission
  - If the sender has not receive positive acknowledgment in due time, the frame is retransmitted.
  - Stop-and-Wait Automatic Repeat Request (ARQ)
  - Sliding-Window ARQ

- Forward Error Correction
  - The receiver detects and fix errors without any retransmission. Usually requires complex algorithms and a lot redundancy. Therefore, it is used when retransmission requires long delays such as in satellite transmission.
Flow Control and Error Correction Using Retransmission & Positive Acknowledgment

Stop and Wait
Automatic Repeat Request (ARQ)

Sliding-Window ARQ

Medium Access Methods

Controlled

Random

Poll/Select (Mainframe Dummy Terminal Communication)

Token/Ring (Token/Ring LAN)

(CSMA/CD) Carrier Sense Multiple Access with Collision Detection (Ethernet LAN)

(CSMA/CA) Carrier Sense Multiple Access with Collision Avoidance (Wireless LAN)
Poll (Select/Poll)

- Poll procedure is used to receive data from secondary computers.

**Mainframe (Primary)**

1) A: Do you need data transmission?
   - Poll
   - NAK

3) B: Do you need data transmission?
   - Poll
   - NAK

5) C: Do you need data transmission?
   - Poll
   - Data
   - ACK

7) Ok. I got it.

2) No. Thank you!

4) Not this time.

6) Yes. Here is my data.

Select (Select/Poll)

- Select procedure is used to send data to secondary computers.

**Mainframe (Primary)**

1) B: I have got something for you? Are you available to accept data.
   - Select
   - ACK

3) Here you go.
   - Data
   - ACK

2) Yes. I am.

4) I got it. Thank you very much.
Token Ring

1. Comp. A wishes to begin transmitting. However, it can't since it does not have a token.

2. Comp. A detects and seizes the token. Then, it begins to transmit.

3. Comp. B wants to initialize a transition, but it can't since it does not have the token. Comp D receives the frame and copies it.

4. When Comp. A detects its returning frame, it releases the token.

5. Now, Comp C seizes the token, and it can begin to transmit.

CSMA/CD Algorithm

- Carrier Sense Multiple Access with Collision Detection (CSMA/CD) is a simple protocol used in Ethernet LANs to control the usage of the common medium by the stations on the same network.

- Start
- Listen the medium
- Wait a random amount of time
- Transmit immediately
- Is the medium idle?
- YES: Continue to listen the medium
- NO: Transmission is successful
- Collision detected?
- YES: Immediately cease transmitting
- NO: Transmit immediately
- Continue to listen medium for transmitting the next frame
CSMA/CD Operation

At time $t_0$, station A has a frame addressed D to transmit. It listens the bus medium, and it begins transmitting the frame since the bus is empty.

At $t_1$, stations B and C are ready to transmit. B senses a transmission and so defers. C, however, begins transmitting since it is still unaware of A's transmission.

When A's transmission reaches C, at $t_3$, C detects the collision and ceases transmission. However, A is still unaware of the collision and continues transmitting.

At $t_4$, C's transmission reaches A, and finally, A detects the collision and ceases transmission as soon as possible.