Week 3 – Physical Layer Contd

COMP90007 Internet Technologies

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Maximum Data Rate of a Channel

- Nyquist's theorem relates the data rate to the bandwidth (B) and number of signal levels (V) (of a channel **without noise**):

$$\text{Max. data rate} = 2B \log_2 V \text{ bits/sec}$$

- Increase the bandwidth B can increase the data rate.
- If signal has V levels, each symbol can represent $\log_2 V$ bits.

Maximum Data Rate of a Channel

- If signal has V levels, each symbol can represent $\log_2 V$ bits.

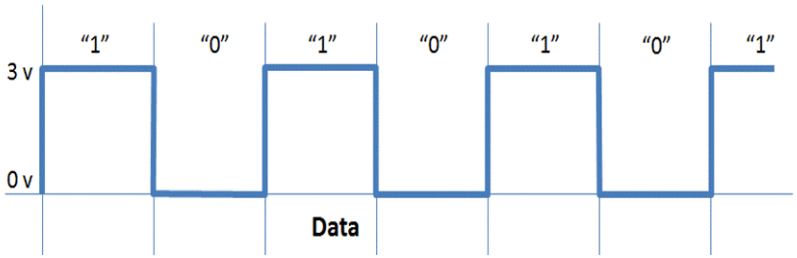


Figure 1. Data bits where logical "0" and "1" are represented by 0 volts and 3 volts respectively

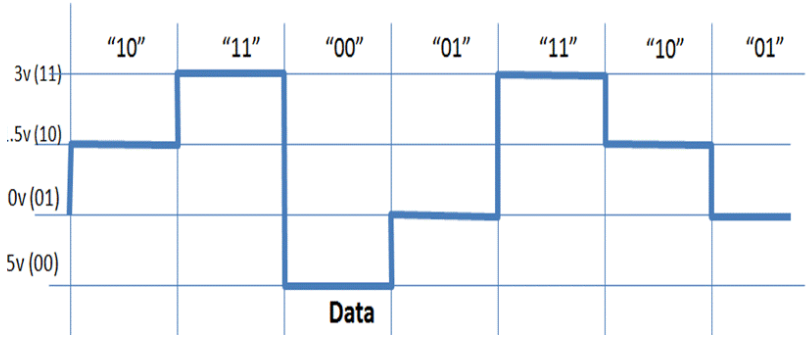


Figure 2. Four signaling levels per clock cycle can represent two data bits.

Image source: http://mason.gmu.edu/~rmorika2/Baud_Versus_Bits_per_second.htm

Maximum Data Rate of a Channel

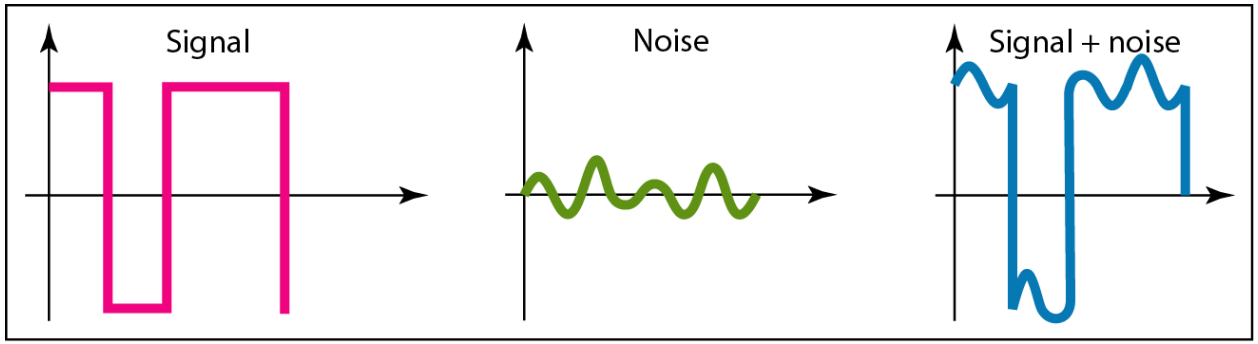
- Shannon's theorem relates the data rate to the bandwidth (B) and signal strength (S) relative to the noise (N):

$$\text{Max. data rate} = B \log_2(1 + S/N) \text{ bits/sec}$$

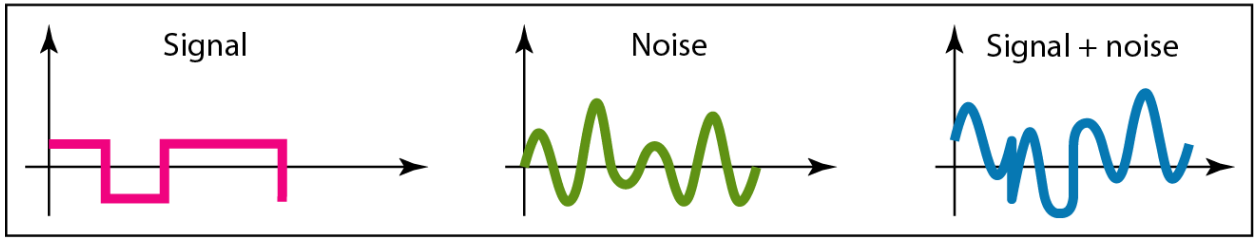
How fast signal can change

How many levels can be seen

Maximum Data Rate of a Channel



a. Large SNR



b. Small SNR

Example 1: Lets Consider Nyquist first

Q: If a binary signal is sent over a 3-kHz channel, what is the maximum data rate?

Ans:

Nyquist limit is:

$2B \log_2 V = 2 \times 3000 \times \log_2 2 = 6$ kbps.

… but there is no mention of noise here!

Example 2

Q: Given the signal-to-noise ratio (SNR) of 20 dB, and the bandwidth of 4kHz (using phone line), what is the maximum data rate according to Shannon's theorem?

Ans:

SNR(dB) = $10*\log_{10}(S/N)$

SNR of 20 dB is equivalent to S/N = 100

$4 * \log_2(1 + 100) = 4 * \log_2 (101) = 26.63$ kbps.

Example 3

Q: If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?

Ans:

SNR of 20 dB = S/N = 100.

The Shannon limit is: $3^* \log_2(101) \approx 19.975$ kbps

The Nyquist limit is:
$2B \log_2 V = 2 \times 3 \times \log_2 2 = 6$ kbps.
The bottleneck is therefore the Nyquist limit, giving a **maximum channel capacity of 6 kbps**

Summary

- Timing aspect
  - Bandwidth and Latency
- Mechanical aspect: transmission media
  - Twisted pair
  - Co-axial
  - Fibre optics
  - Wireless: EM waves, satellites
- Electrical aspect
  - Data communication using signals
  - Digital modulation
- Capacity of a channel
  - Maximum data rate

Data Link Layer

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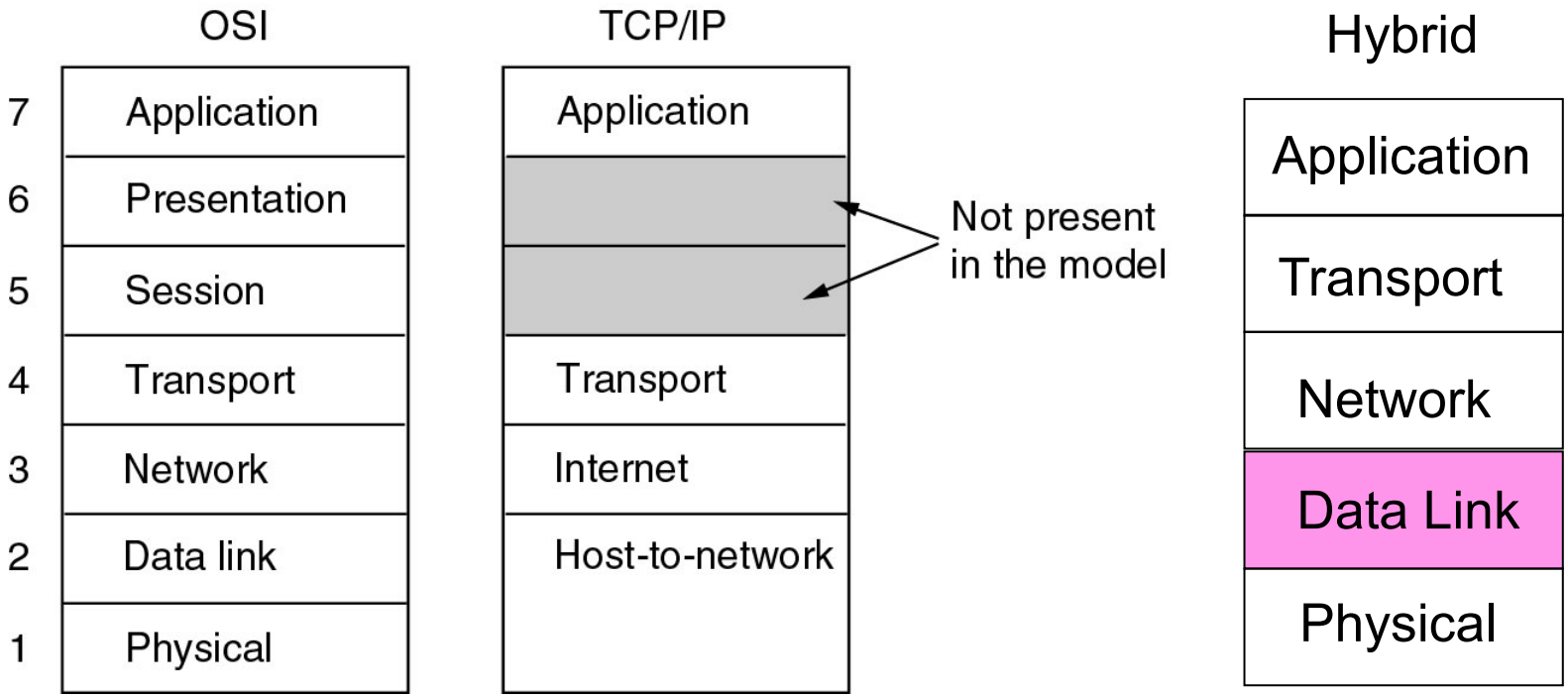
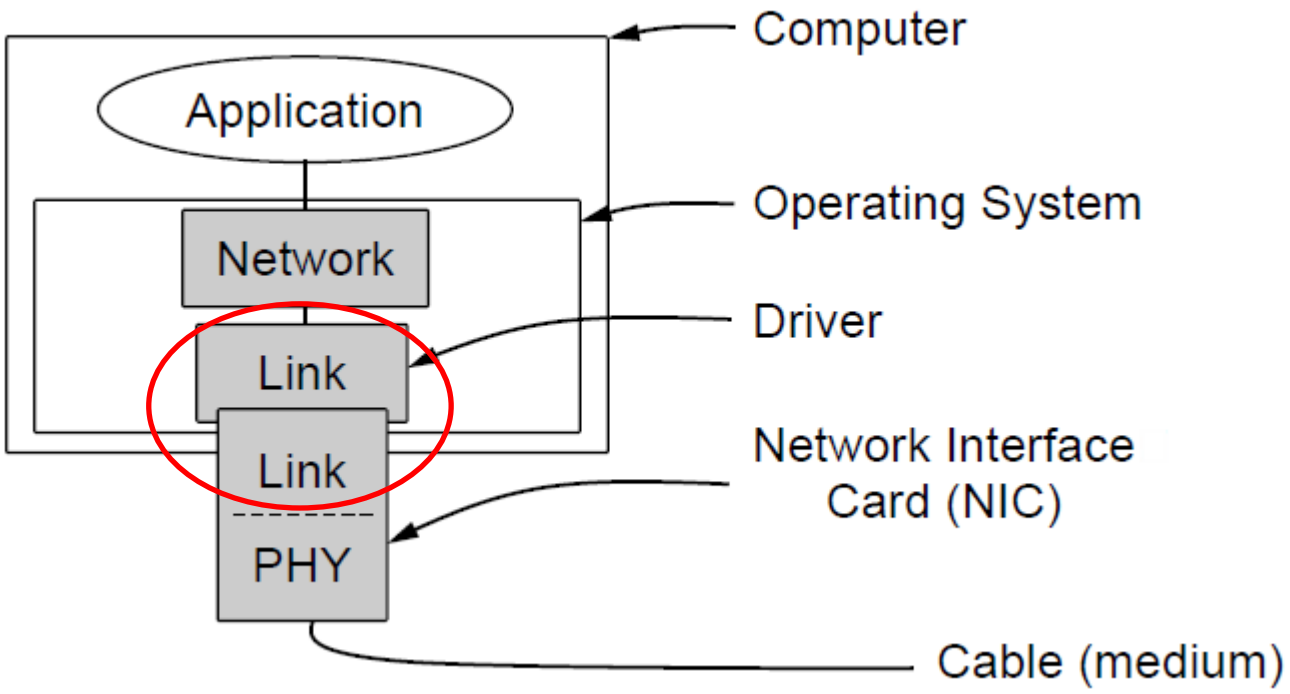
The Data Link Layer in OSI and TCP/IP



- **Reliable**, **efficient** communication of "**frames**" between two adjacent machines.
- Handles transmission errors and flow control.

Typical Implementation

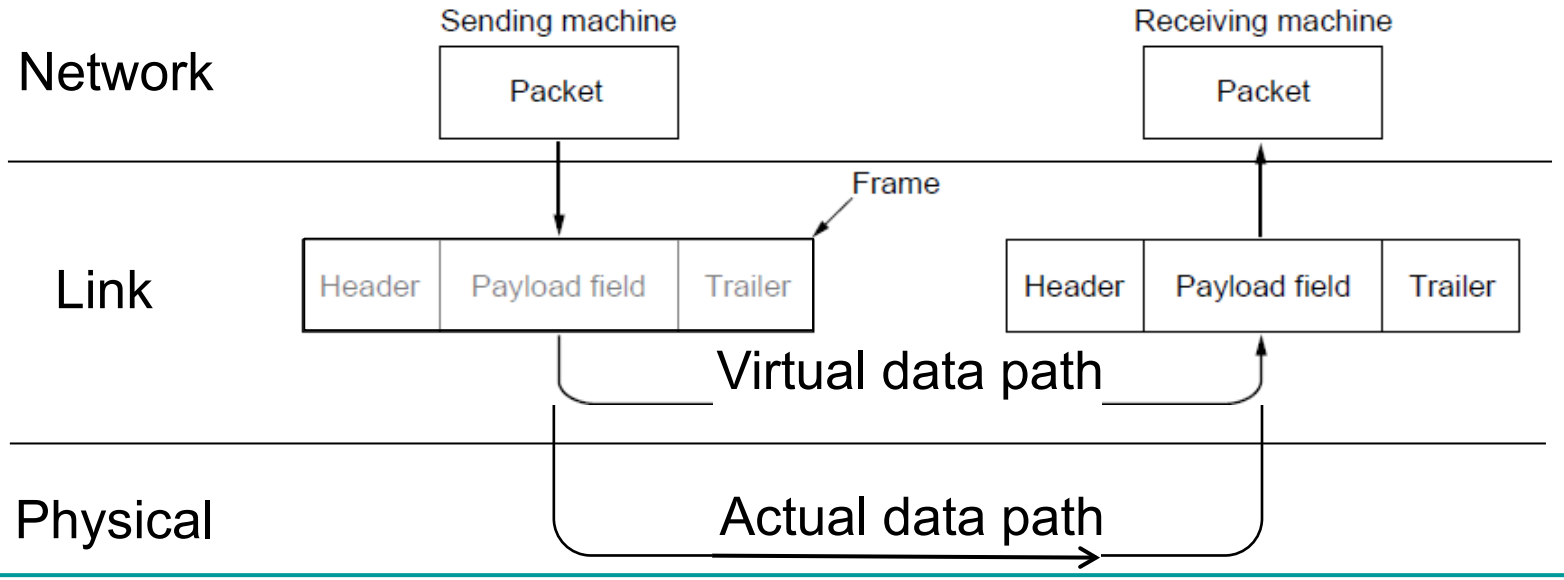


Functions of the Data Link Layer

- Functions of the data link layer:
  1. Provide a well-defined service interface to network layer
  2. Handling transmission errors
  3. Data flow regulation
- Primary process:
  - Take **packets** from network layer, and encapsulate them into **frames**

Relation Between Packets and Frames

- Each frame contains a header, a payload and a trailer
- Link layer accepts packets from the network layer, and encapsulates them into frames that it sends using the physical layer; reception is the opposite process



Type of Services

- **Connection-Oriented vs Connectionless**:

  Whether a connection is setup before sending a message

- **Acknowledged vs Unacknowledged**:

  Whether the receiver gives the sender an acknowledgement upon receiving the message

Services Provided to Network Layer

- Transferring data from the network layer on source host to the network layer on destination host

- Services provided:
  - Unacknowledged connectionless service
  - Acknowledged connectionless service
  - Acknowledged connection-oriented service

Unacknowledged Connectionless Service

- Source host transmits independent frames to recipient host with no acknowledgement
- No logical connection establishment or release
- No lost frame recovery mechanism (or left to higher levels)
- Applications:
  - Ethernet LANs
  - Real-time traffic, e.g. voice

Acknowledged Connectionless Service

- Source host transmits independent frames to recipient host with acknowledgement
- No logical connection establishment or release
- Each frame is individually acknowledged, and retransmitted if lost or errors
- Application: Wireless – IEEE 802.11 WiFi

Acknowledged Connection-Oriented Service

- Source host transmits independent frames to recipient host after connection establishment and with acknowledgement
- Connection established and released (communicate rate and details of message)
- Frames are numbered, counted, acknowledged with logical order enforced
- Application: Unreliable links such as satellite channel

Framing (1)

- Framing: breaks raw bit stream into discrete units
- Physical layer provides no guarantee a raw stream of bits is error free
- The primary purpose of framing is to provide some level of reliability over the unreliable physical layer
- Checksums can be computed and embedded at the source, then computed and compared at the destination

checksum = f(payload)

Framing (2)

- Methods:
  - Character (Byte) count
  - Flag bytes with byte stuffing
  - Start and end flags with bit stuffing
- Most data link protocols use a combination of character count and one other method