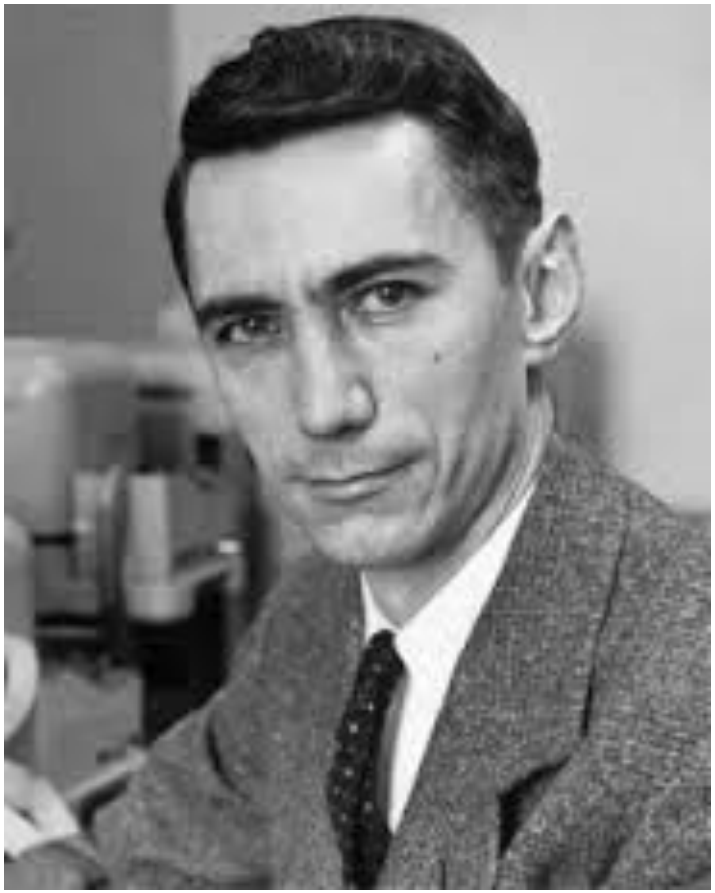
Week 3 – First: Wrapping Up The Physical Layer with Two Theorems

COMP90007
Internet Technologies

How much can we put on a link?

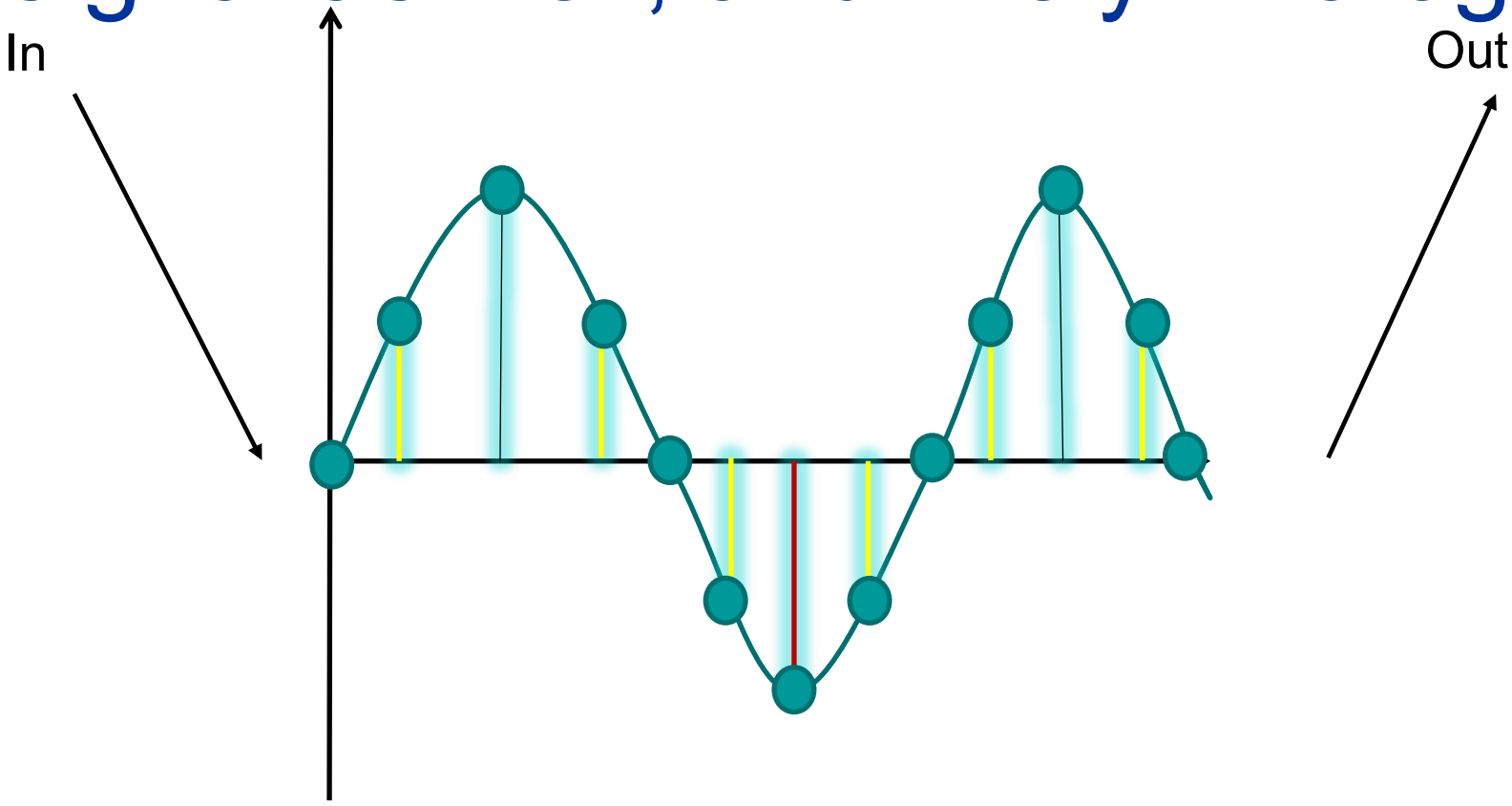
- Nyquist's Theorem first

Claude Shannon: Adds Noise Considerations…



- Shannon's theorem next

Original Data would likely be a signal as well, and likely Analog…



E.g., voice, video, etc.

Maximum Data Rate of a Channel

- "If a function contains no frequencies higher than B hertz then it is completely determined by looking at a set of points spaced 1/2B apart"
- Thus, **Nyquist's theorem** relates the data rate to the bandwidth (B) in Hz of a signal (and number of signal levels V used):

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

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

- For example if N is too high data rate approaches 0

Lets try an Example with Shannon's

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

Ans:

$= 4000 \log_2(1 + 100) = 4000 \log_2 (101) = 26.63$ kbit/s. Note that the value of S/N = 100 is equivalent to the SNR of 20 dB

Lets Consider Both

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:

Recall SNR of 20 dB = S/N = 100.

The Shannon limit is about 19.975 kbps but the Nyquist limit is:

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

The bottleneck is therefore the Nyquist limit, giving a **maximum channel capacity of 6 kbps**

Week 3 – Next: Data Link Layer

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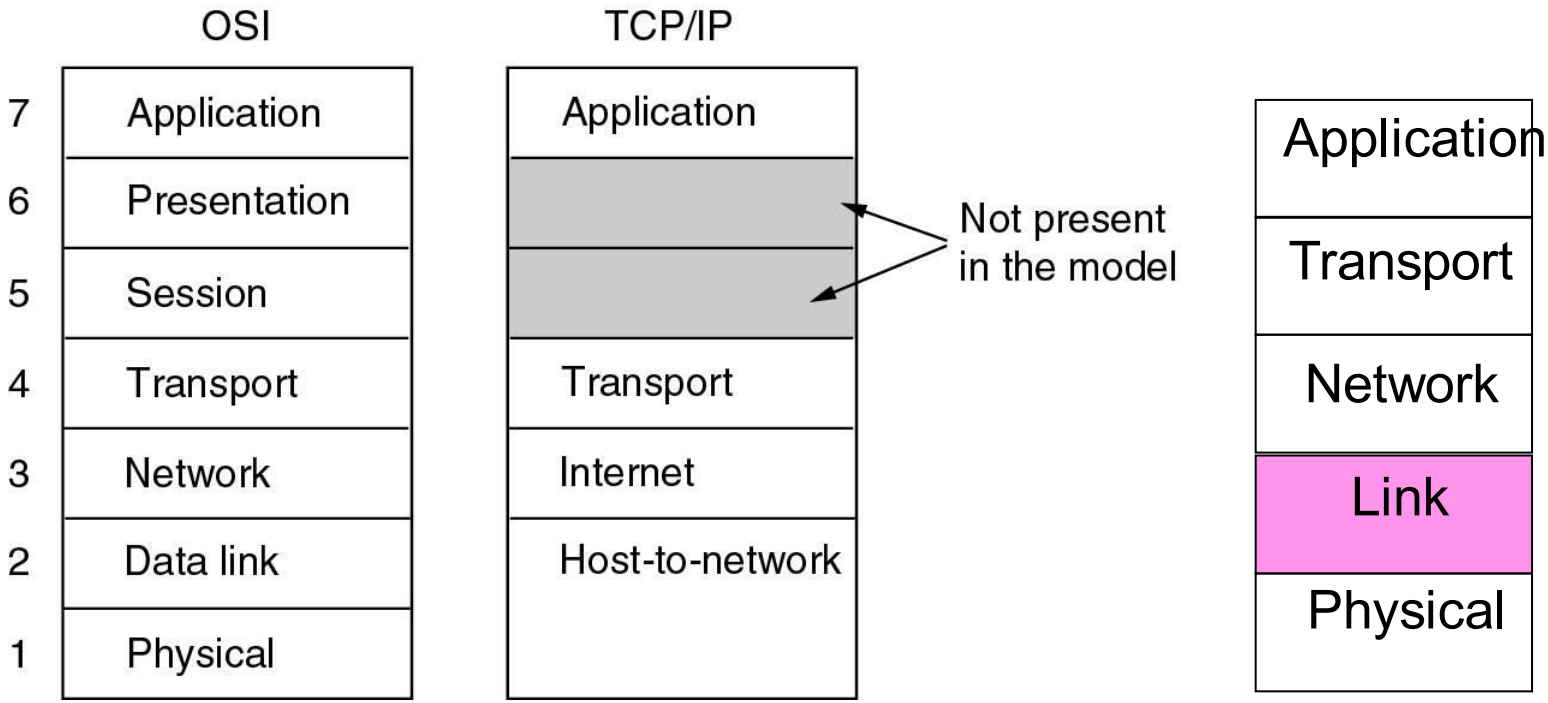
The Data Link Layer in OSI and TCP/IP



- *Reliable, efficient* communication of “frames” between two *adjacent* machines.

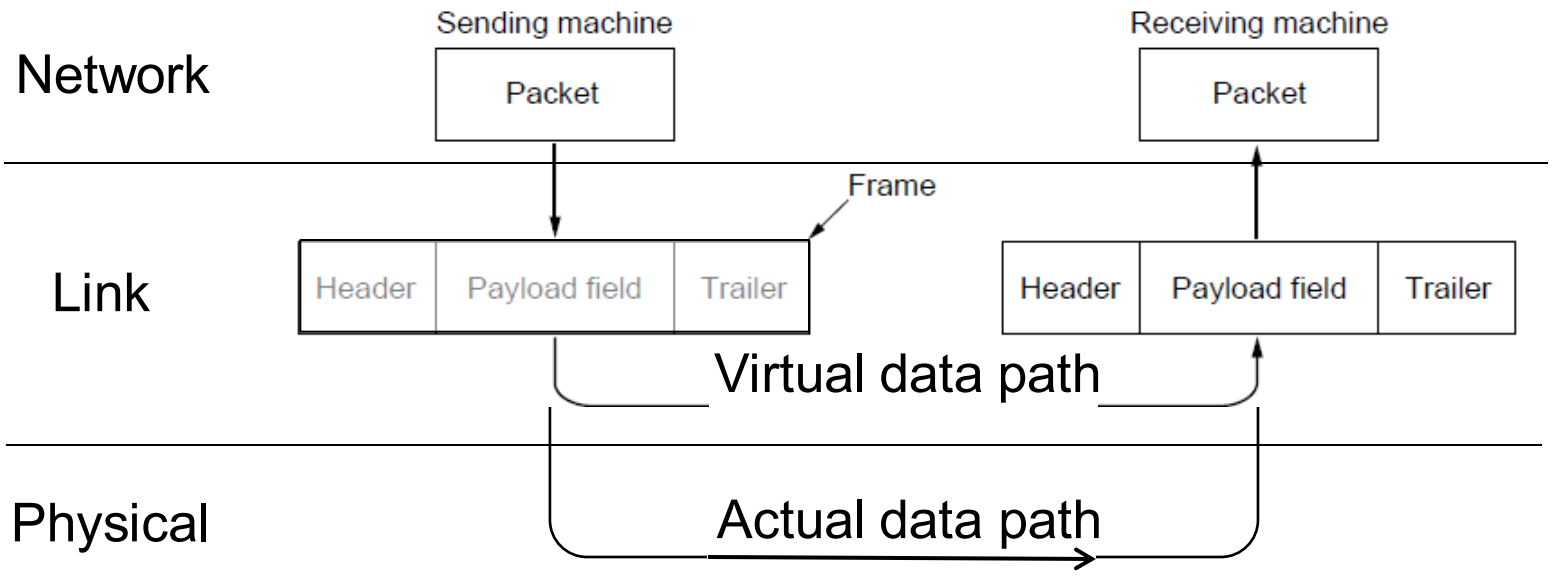
>> Handles transmission errors and flow control.

Functions & Methods of the Data Layer

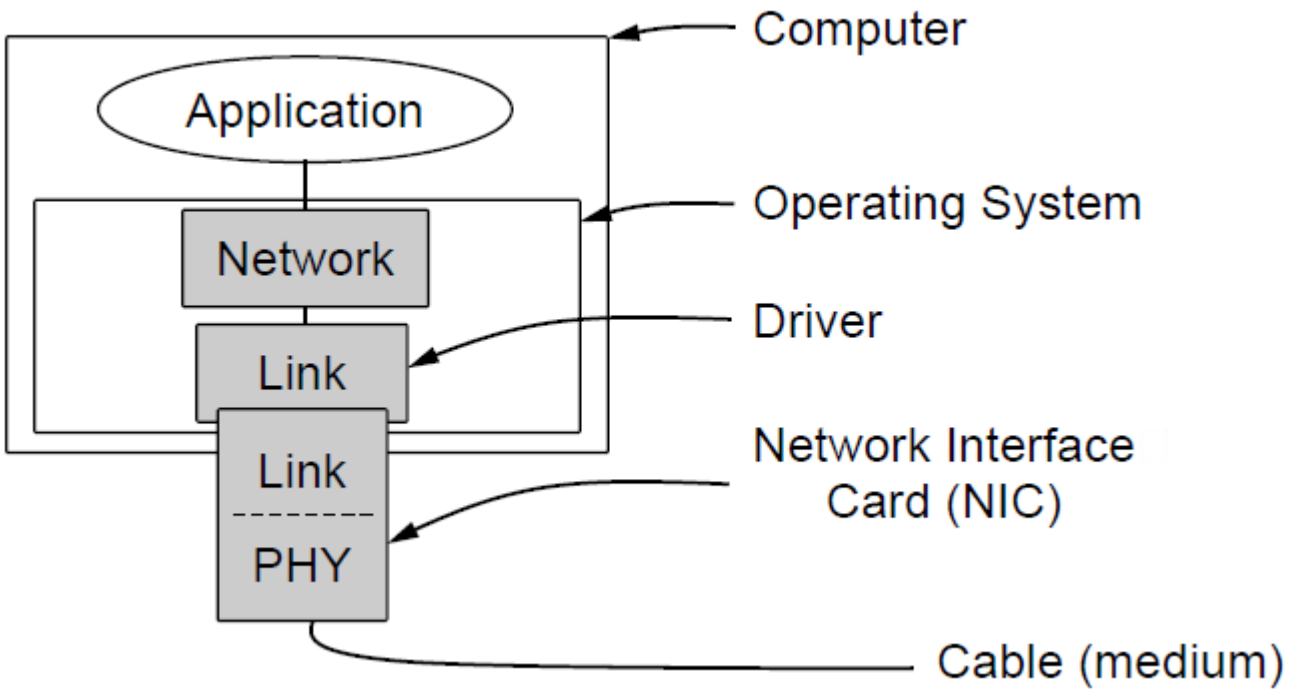
- Functions of the data link layer:
  1. Provide a well-defined service interface to network layer
  2. Handling *transmission errors*
  3. *Data flow* regulation
- First:
  - Take **packets from network layer**, and encapsulate them **into frames** (containing a header, a payload, a trailer)

Relation Between Packets and Frames

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



Typical Implementation



Type of Services

- **Connection-Oriented vs Connectionless**: Whether a connection is setup before sending a message
- **Acknowledged vs Unacknowledged**: Whether the service provider give the service user an acknowledgement upon delivering the message