Bandwidth, Layers Intro, Physical Layer, Framing

2 November 2025
Lecture 2

Slides Credits: Steve Zdancewic (UPenn)

Topics for Today

- Bandwidth
- Layers
- Physical Layer
- Link Layer
  - Framing

Source: Peterson and Davie 2.1 – 2.5

Some Units and Measurements

- $Mbps = 10^6\ bits/\text{sec}$
- $byte = 8\ bits$
- $KB = 2^{10}\ bytes\ (=\ 8{,}192\ bits)$
- $MB = 2^{20}\ bytes\ (=\ 8{,}388{,}608\ bits)$
- $ms = 10^{-3}\ seconds$
- $\mu s = 10^{-6}\ seconds$

- Speed of light:
  - Vacuum : $3\ x\ 10^8\ \frac{m}{\text{sec}}$
  - Copper or Fiber: $2\ x\ 10^8\ \frac{m}{\text{sec}}$

Key Equations

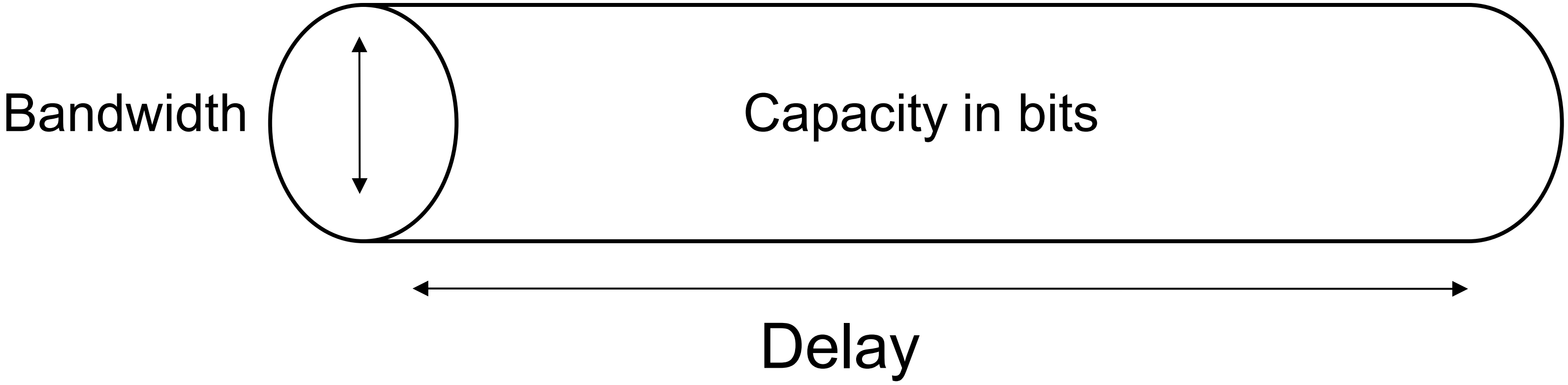
- `Total Sending Time = Propagation + Transmit + Queue`

- $Propagation = \frac{Distance}{SpeedOfLight}$

- $Transmit = \frac{Size}{Bandwidth}$

- $Queue = ?$

Performance: Delay x Bandwidth



Delay x Bandwidth determines the number of bits that can be “in flight”.

For efficient resource usage: keep the pipe full.

Total Sending Time: Direct Link

Data moves through the link at the speed of light.

Time	
$t = 0$	Data ready to be sent

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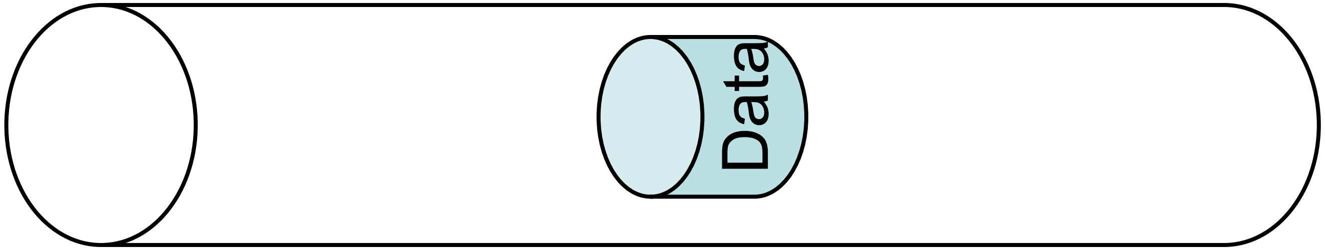
$\mathrm{t} = transmit$	Data finishes entering the link

Total Sending Time: Direct Link



Data moves through the link at the speed of light.

Time	
$t = 0$	Data ready to be sent
$t = transmit$	Data finishes entering the link
$t = transmit + k$	Data travels through the link ($\mathrm{transmit} + k < propagation$)

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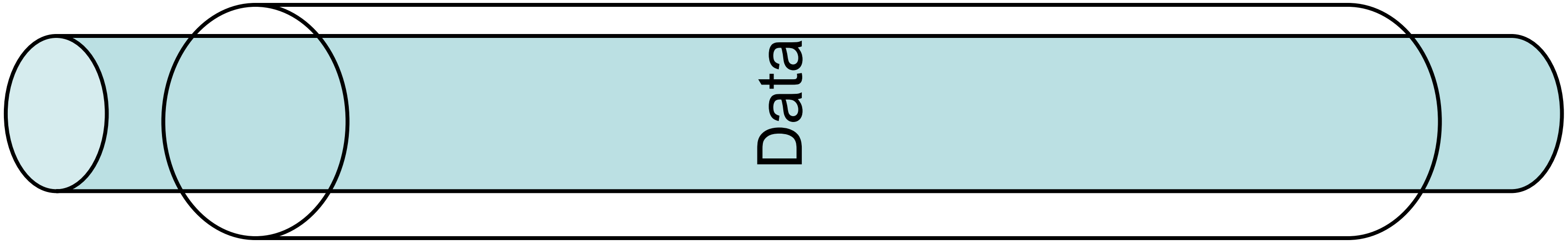
$t = propagation$	First bit arrives at the destination
$t = transmit + propagation$	Last bit arrives at the destination

If $transmit > propagation$

First bit exits the link before the last bit finishes entering it



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Still correct!

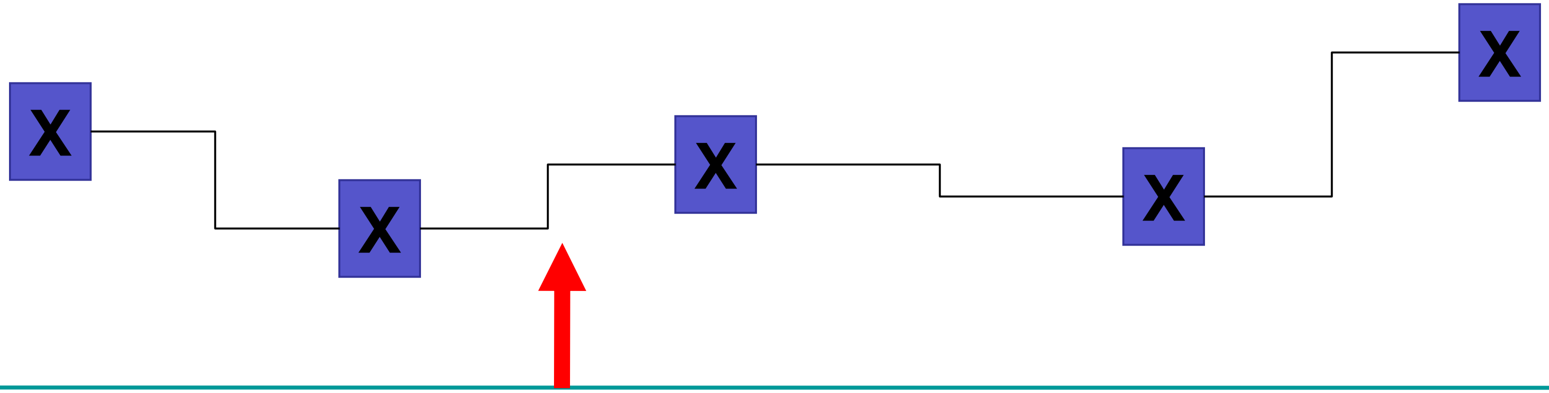
Paths Are Made of *Links*

Links are interconnected by zero or more *network elements*

- Switches, routers, hubs, bridges, etc.

Path delay is sum of link delays plus queuing (switching) delays

Path throughput = *bottleneck link* throughput



My internet is slow

What’s your package?

100Mbps, 100ms ping

Two offers for you:

1. Raise you to 1 Gbps
2. Lower your ping to 10ms

Which offer is better?

Latency Bound: Send 1 Byte

Transmit

Transmit Time: 1 Byte	
100 Mbps	0.00008ms
1 Gbps	0.000008ms

Propagation

Perceived Latency	100ms	10ms	Improvement?
100 Mbps	100.00008ms	10.00008ms	9.9x
1 Gbps	100.0000008ms	10.0000008ms	10x
Improvement?	0.0000008x	0.000008x	

Bandwidth Bound: Send 25 MB

Transmit Time: 25MB	
100 Mbps	2.097152 s
1 Gbps	0.2097152 s

Propagation

Perceived Latency: 25MB	100ms	10ms	Improvement?
100 Mbps	2.147152s	2.102152s	0.021406x
1 Gbps	0.2597152s	0.2147152s	0.20957x
Improvement?	8.26733x	9.8x	

So Far

- Bandwidth
- Layers
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- Link Layer
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Network Architecture

General blueprints that guide the design and implementation of networks

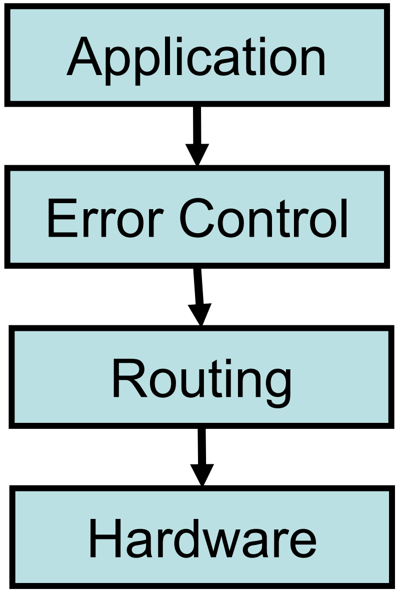
Goal: to deal with the complex requirements of a network

Use *abstraction* to separate concerns

- Identify the useful service
- Specify the interface
- Hide the implementation

Layering

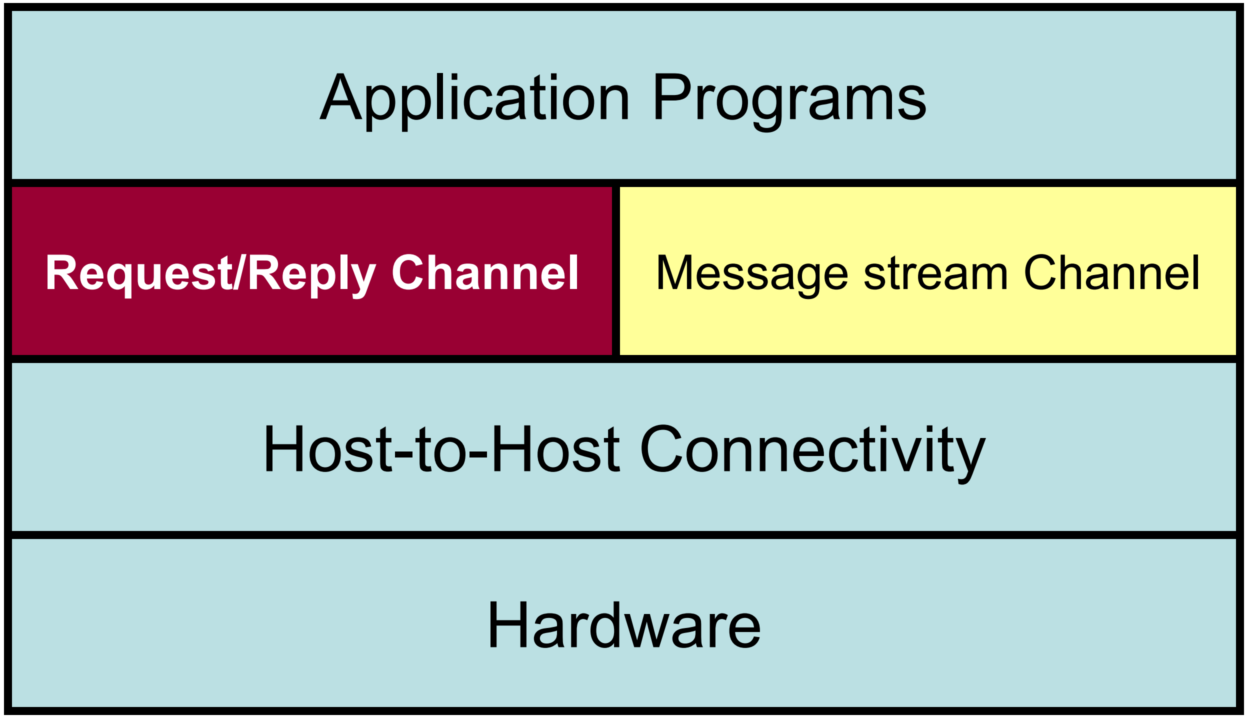
- A result of abstraction in network design
  - A stack of services (layers)
  - Hardware service at the bottom layer
  - Higher level services are implemented by using services at lower levels



- Advantages
  - Decompose problems
  - Modular changes

- **Protocols** implement the layers

Example Protocol Stack



Application Programs

Request/Reply Channel

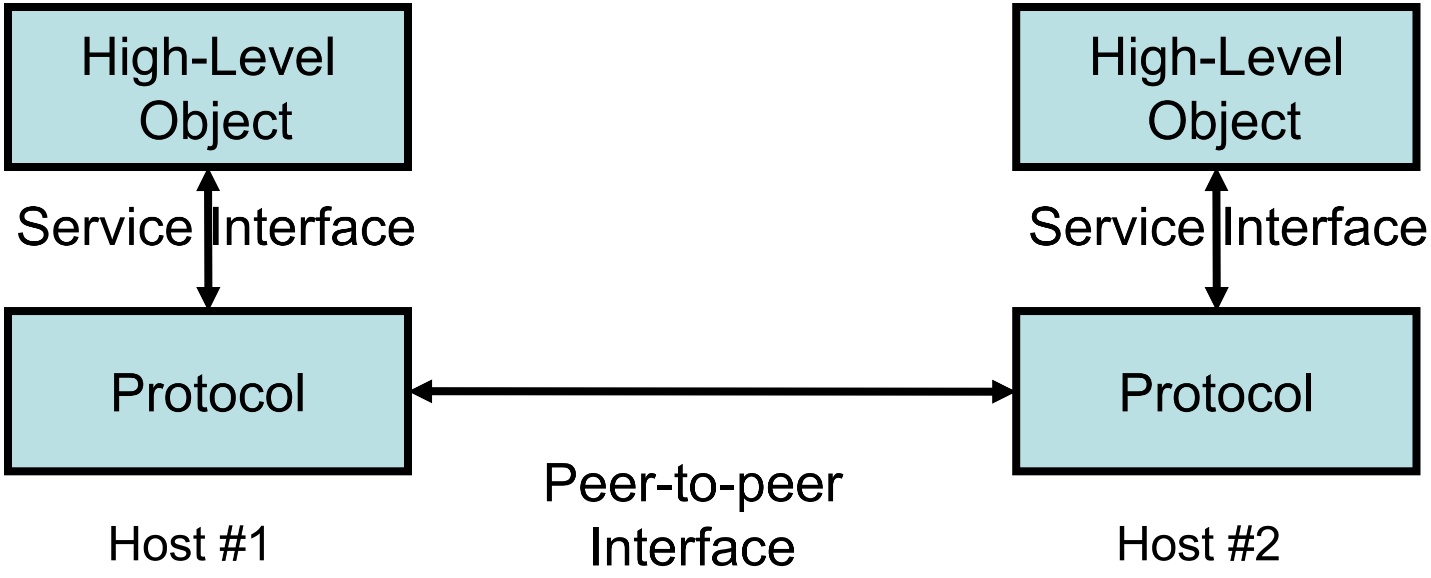
Message stream Channel

Host-to-Host Connectivity

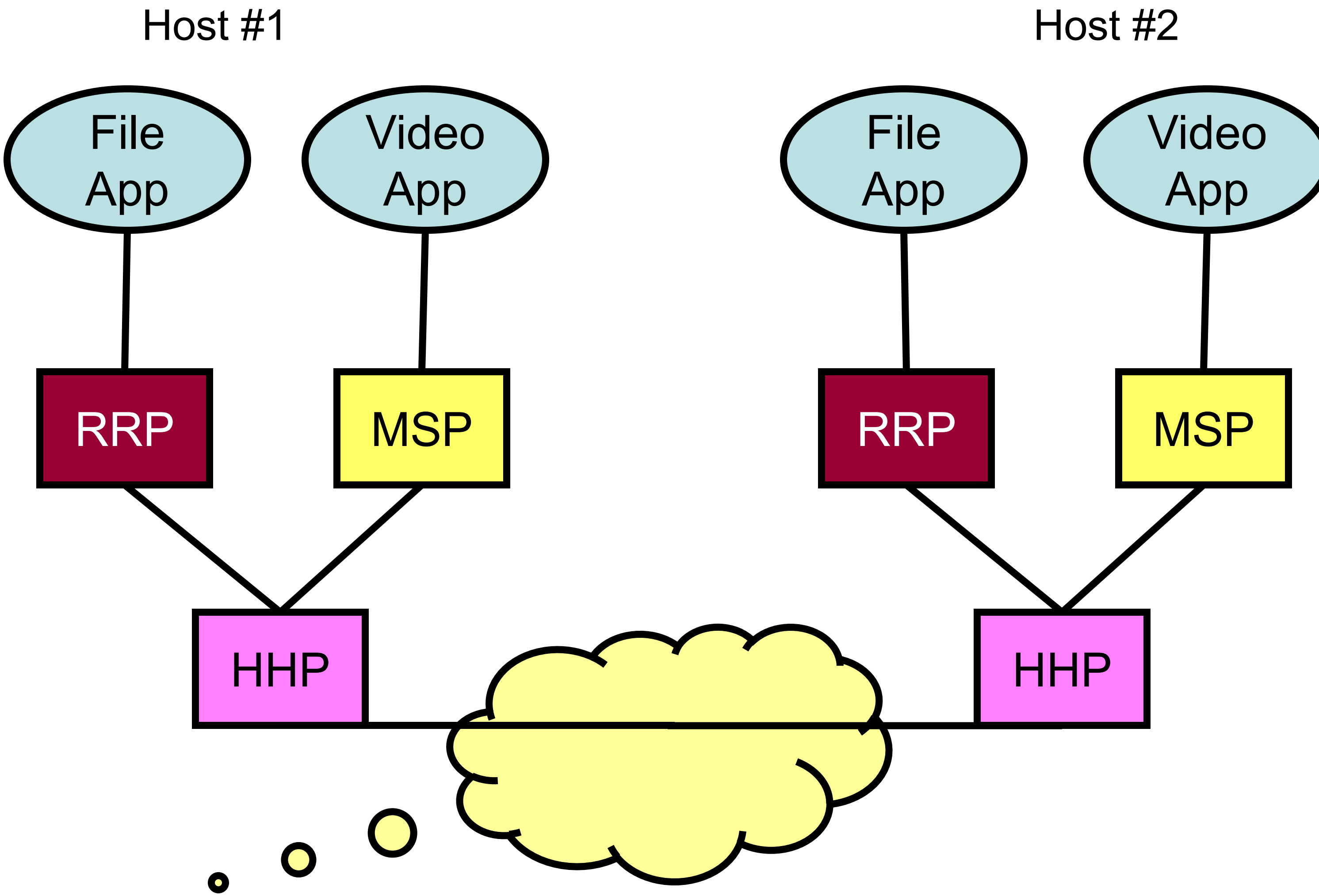
Hardware

Protocol Interfaces

- Service Interfaces
  - Communicate up and down the stack
- Peer Interfaces
  - Communicate to counterpart on another host



Example Protocol Graph

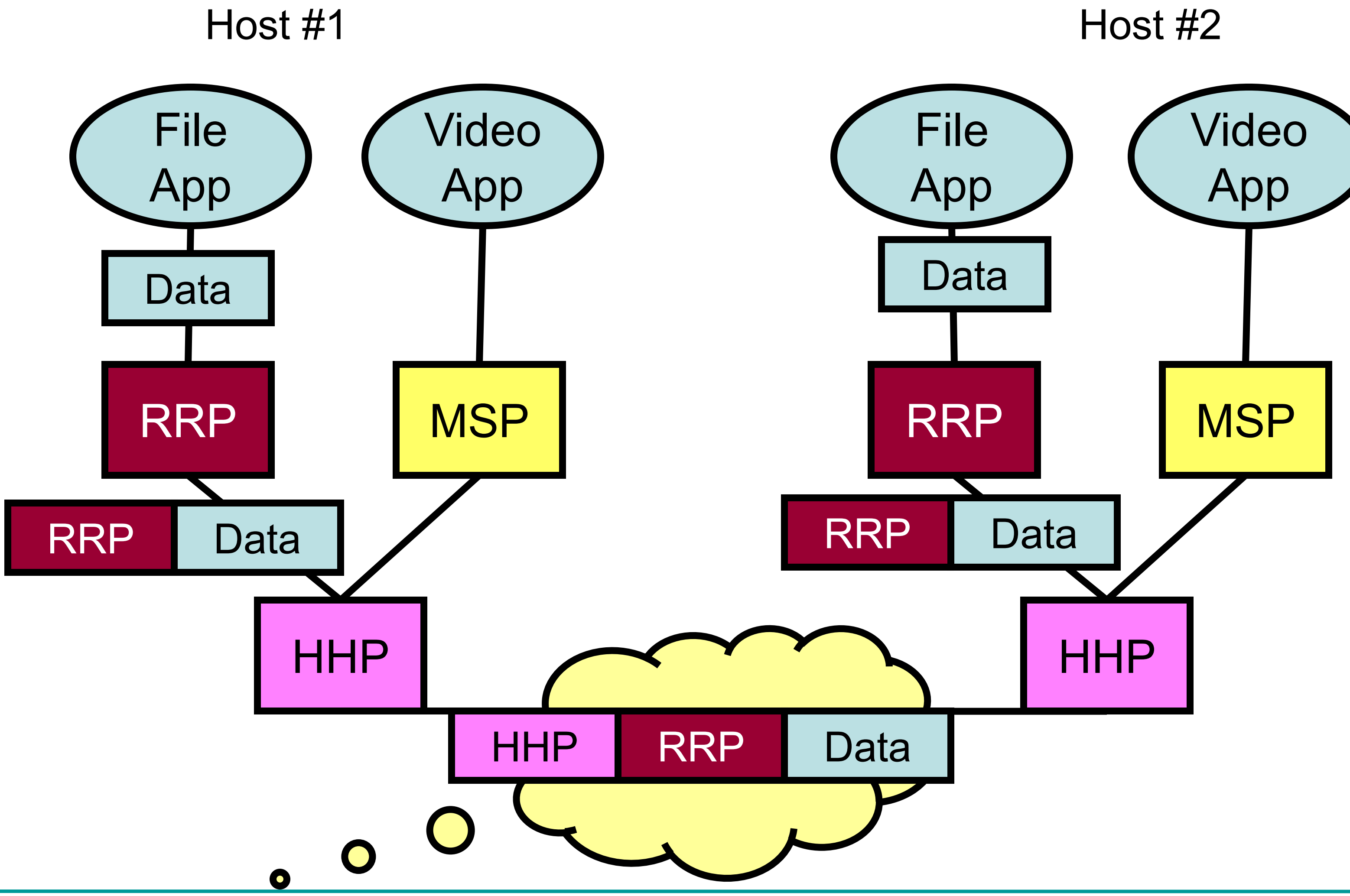


HHP: Host-to-Host Protocol

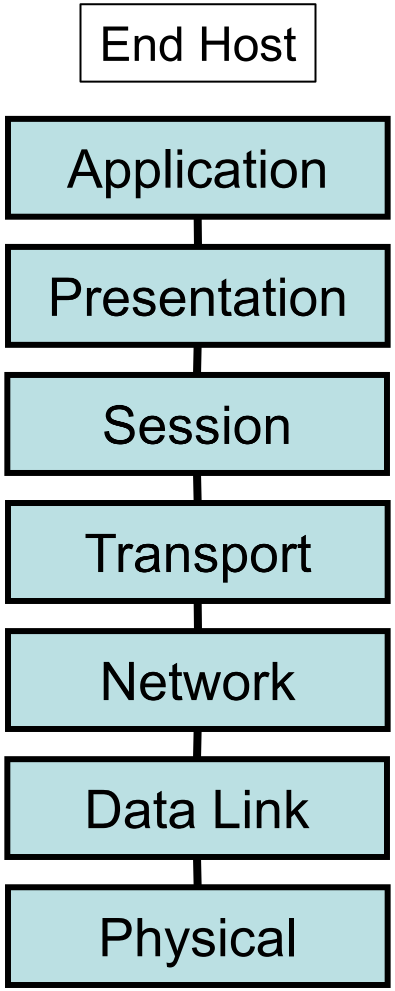
RRP: Request-Reply Protocol

MSP: Message Streaming Protocol

Example Protocol Graph



Open Systems Interconnection (OSI)



End Host

Application

Presentation

Session

Transport

Network

Data Link

Physical

Reference model-not actual implementation

Transmits *messages* (e.g. FTP or HTTP)

Data format issues (e.g. big- vs. little-endian)

Manages multiple streams of data

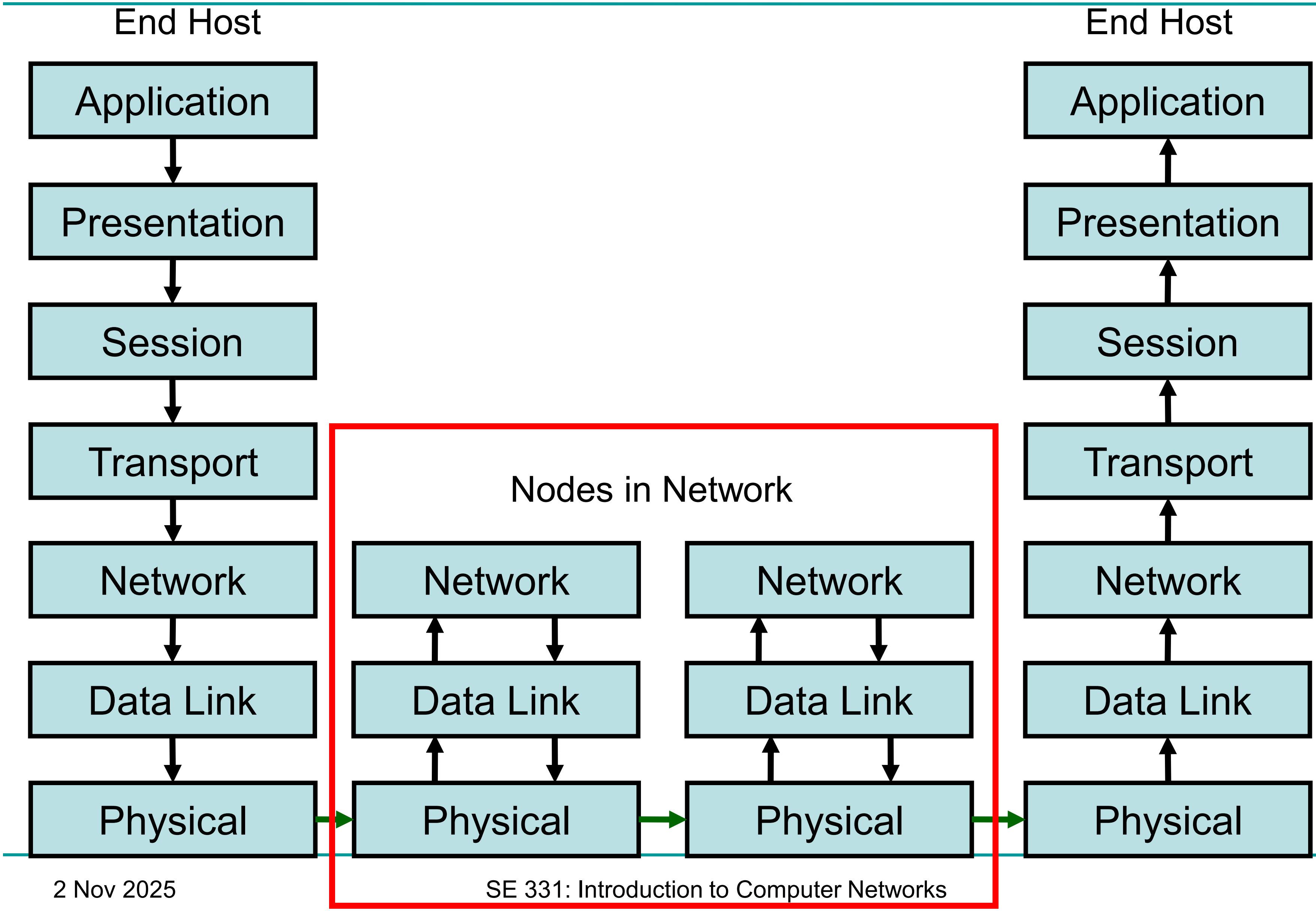
Process to process protocols

Routes *packets* among nodes in network

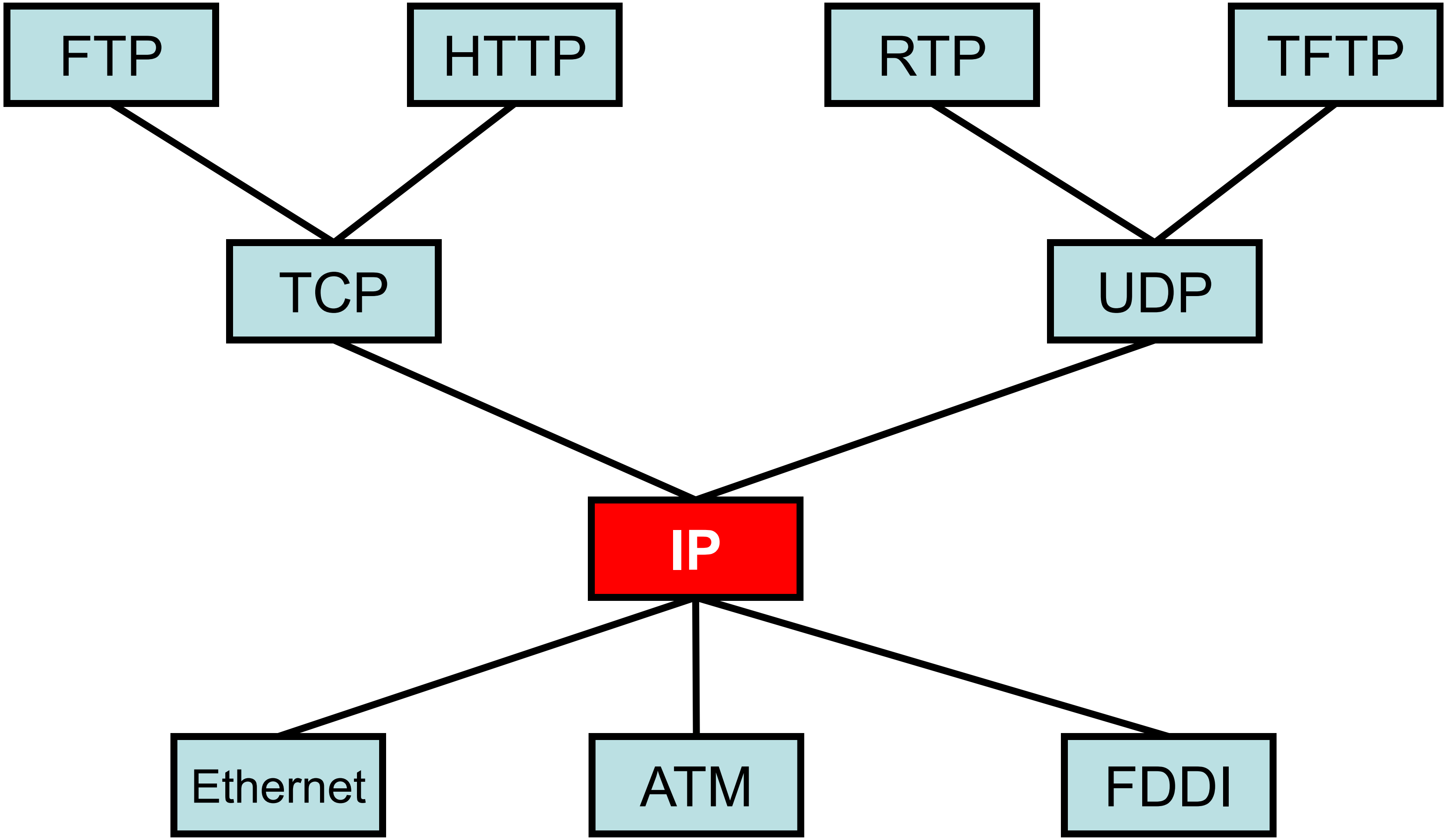
Packages bit streams into *frames*

Transmits raw bits over link

Open Systems Interconnection (OSI)



Internet Protocol Graph



So Far

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Problem: Physical connection

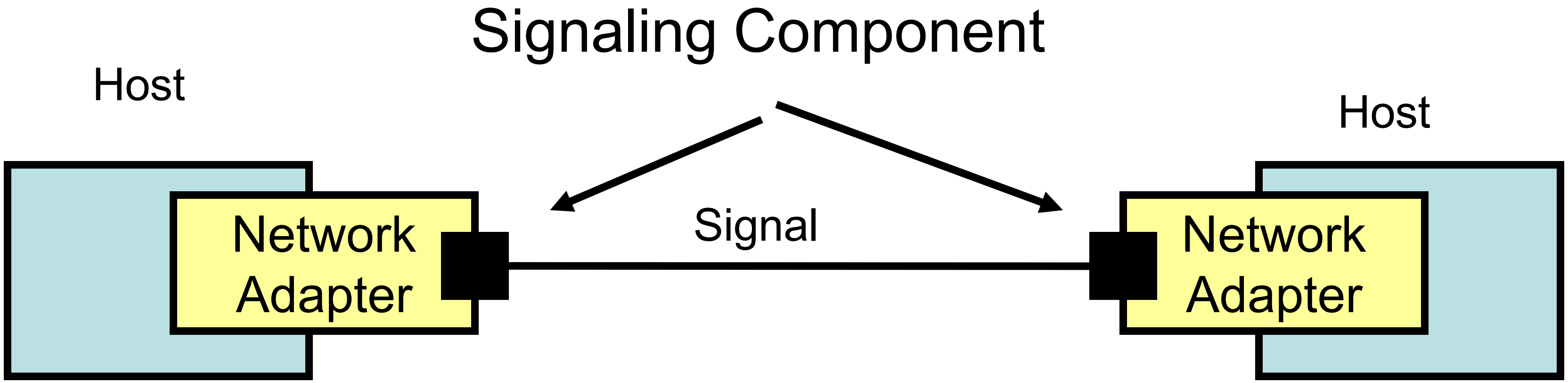
Transmitting signals

Encoding & decoding bits

Error detection and correction

Reliable transmission

Signaling Components



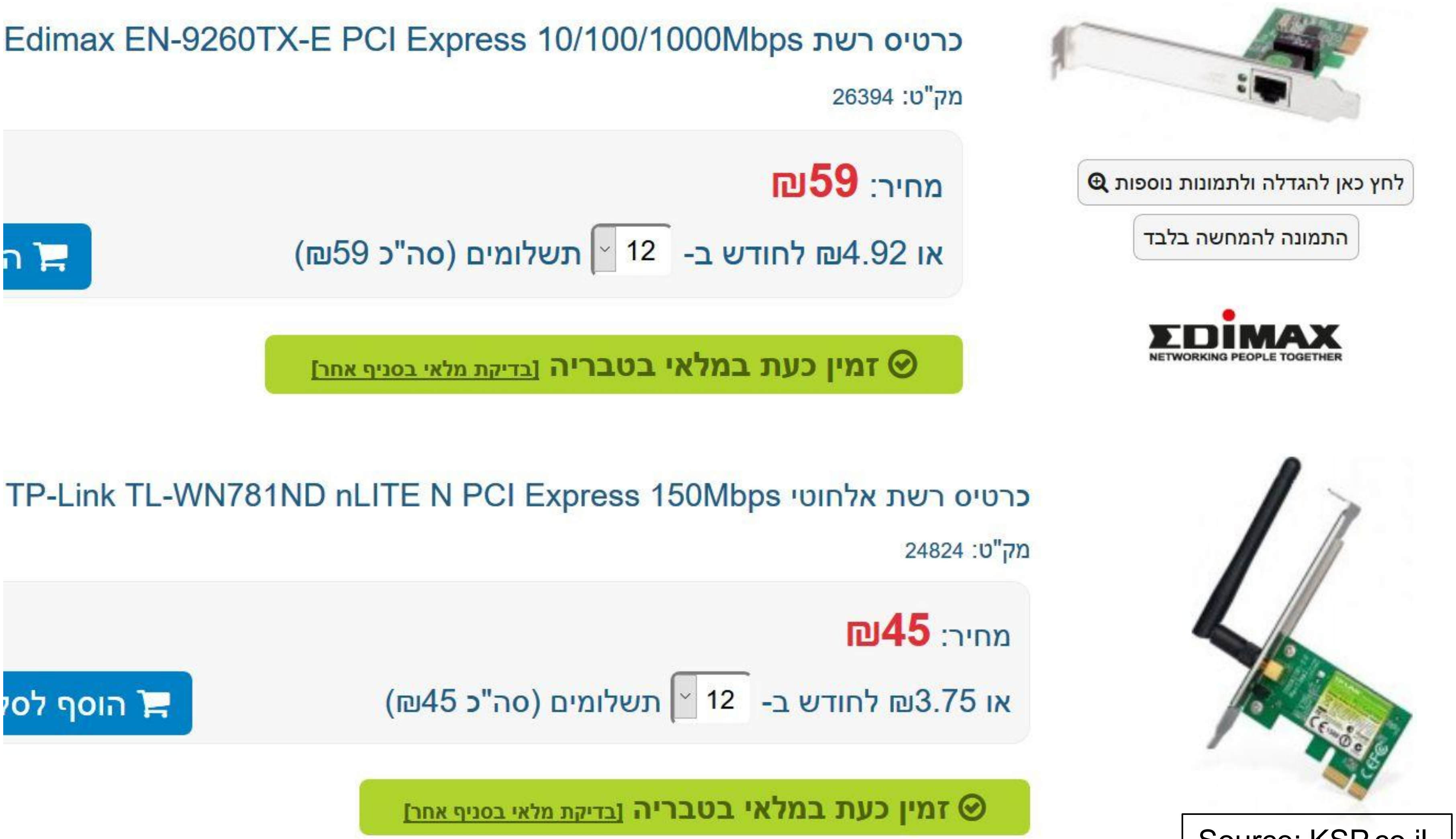
Network adapters encode streams of bits into signals.

Simplification: Assume two discrete signals—high and low.

Practice: Different voltages on copper link.

(leads to some interesting encoding issues)

Network Interface Cards



כרטיס רשת Edimax EN-9260TX-E PCI Express 10/100/1000Mbps

מק"ט: 26394

מחיר: ₪59

או ₪4.92 לחודש ב- 12 תשלומים (סה"כ ₪59)

ה

זמין כעת במלאי בטבריה [בדיקת מלאי בסניף אחר]

לחץ כאן להגדלה ולתמונות נוספות

התמונה להמחשה בלבד

EDIMAX
NETWORKING PEOPLE TOGETHER

כרטיס רשת אלחוטי TP-Link TL-WN781ND nLITE N PCI Express 150Mbps

מק"ט: 24824

מחיר: ₪45

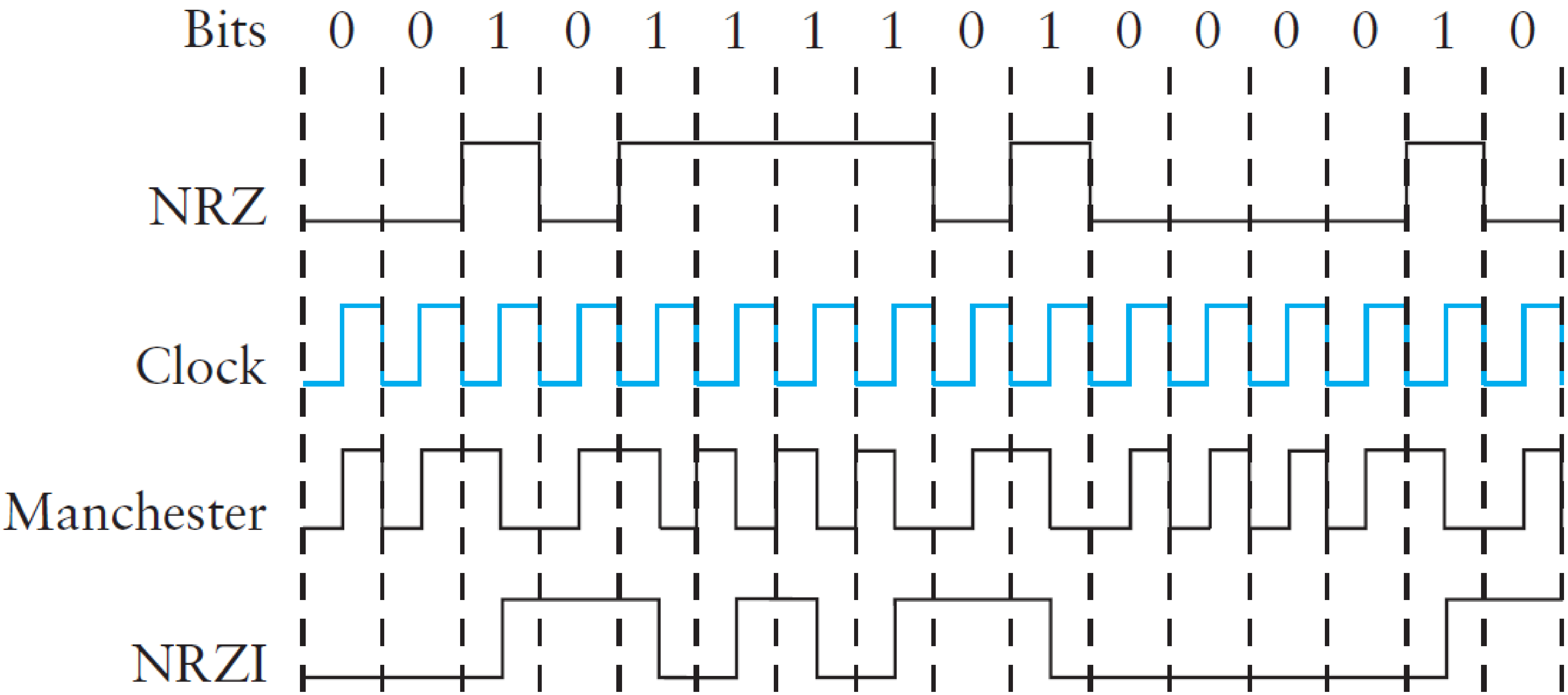
או ₪3.75 לחודש ב- 12 תשלומים (סה"כ ₪45)

הוסף לס

זמין כעת במלאי בטבריה [בדיקת מלאי בסניף אחר]

Source: KSP.co.il

Encoding Schemes



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Framing

- Need a way to send blocks of data.
  - How does the network adapter detect when the sequence begins and ends?

- *Frames* are link layer unit of data transmission
  - Byte oriented vs. Bit oriented
  - Point-to-point (e.g. PPP) vs. Multiple access (Ethernet)

Byte-oriented Protocols

- View each frame as a sequence of bytes

BISYNC

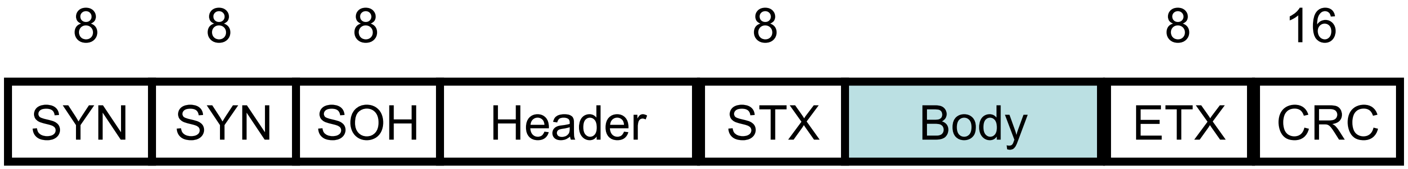
- *Binary Synchronous Communication* protocol
- Developed by IBM in late 1960's

DDCMP

- *Digital Data Communication Message Protocol*
- Used in Digital Equipment Corporation's DECNET

- Primary question: Which bytes are in the frame?

Sentinel Approach: BISYNC



8	8	8		8		8	16
SYN	SYN	SOH	Header	STX	Body	ETX	CRC

BISYNC frame format

- SYN – synchronization
- SOH – start of header
- STX – start of text
- ETX – end of text
- CRC – cyclic redundancy check

Sentinels

Character Stuffing

- What happens if ETX code (0x03) occurs in BODY?

- Use an “escape character”

- DLE – Data-link-escape (0x10)

- Used just as \ in C- or Java-style strings
  - **“quotes in \”quotes\”””**
  - **“slash is \\”**

Conclusion

- Bandwidth
- Layers
- Physical Layer
- Link Layer
    - Framing