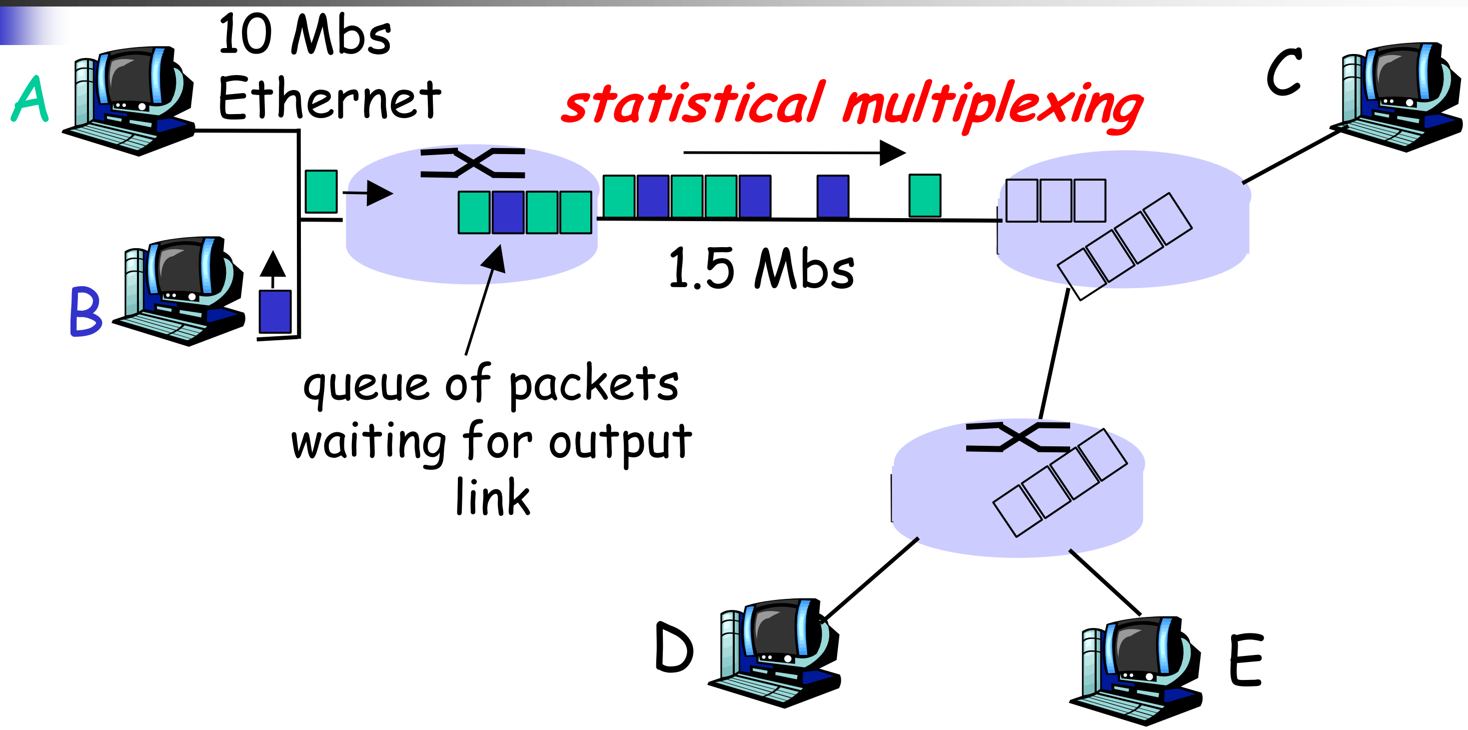
Building A Network: Cost Effective Resource Sharing

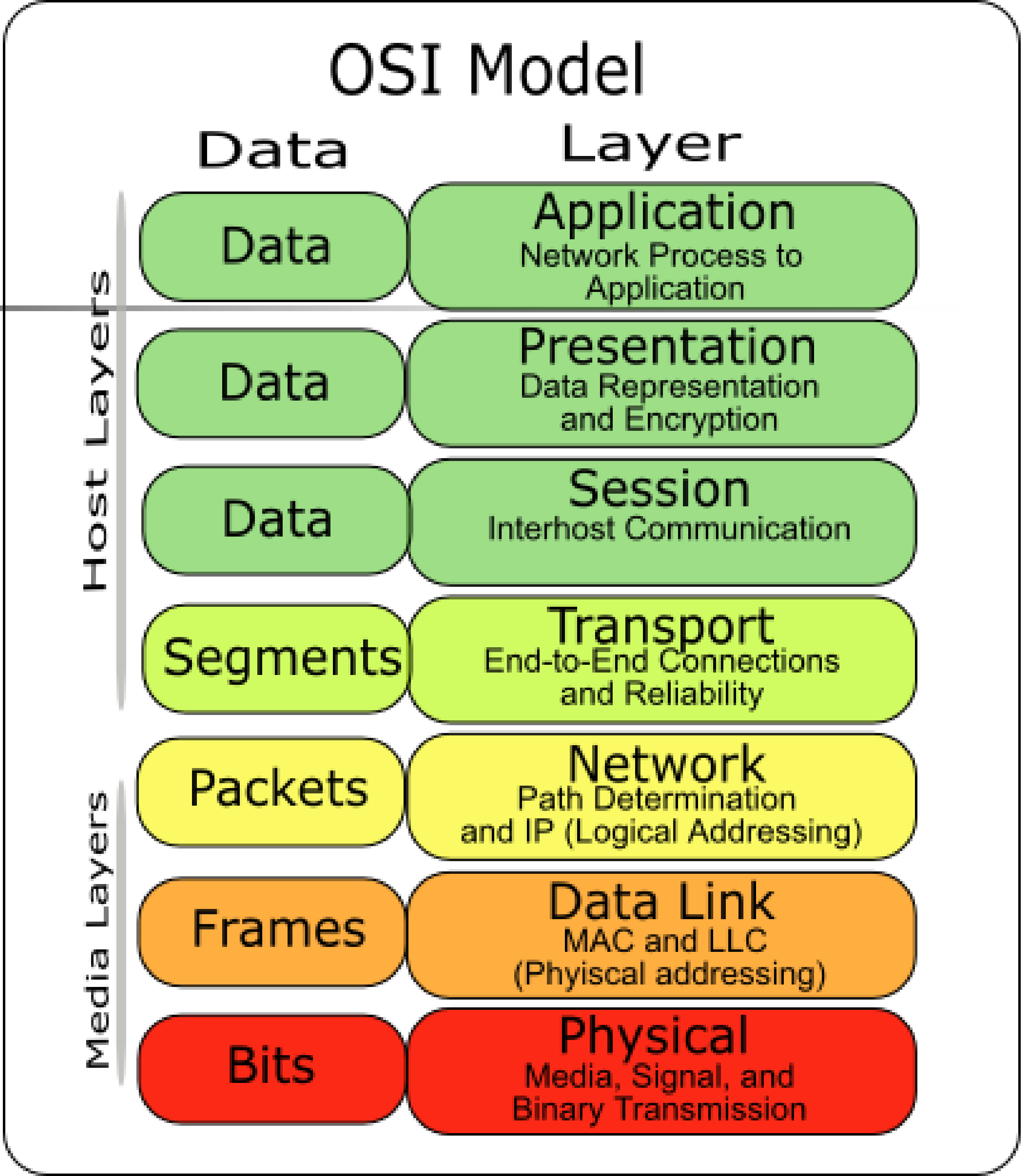
- Key requirement for computer networks is efficiency (Packet switching is the choice)
- A node when connected can send message to any other node at network
- What if all nodes want to exchange messages at same time
- ANS : Multiplexing

Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern ➔ ***statistical multiplexing***.

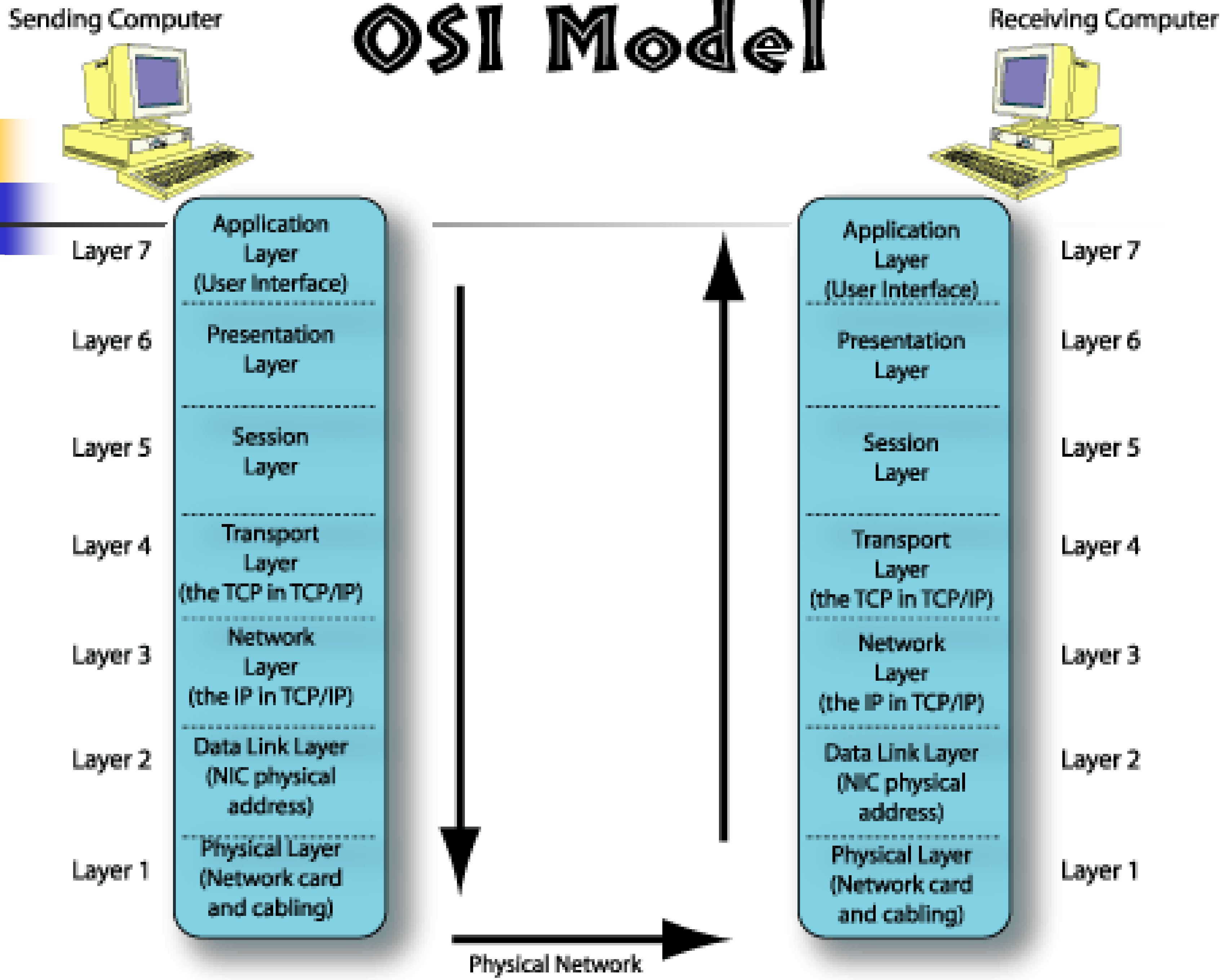
OSI Model


OSI Model
Data
Layer
Host Layers
Media Layers
Data
Application
Network Process to Application
Data
Presentation
Data Representation and Encryption
Data
Session
Interhost Communication
Segments
Transport
End-to-End Connections and Reliability
Packets
Network
Path Determination and IP (Logical Addressing)
Frames
Data Link
MAC and LLC (Phyiscal addressing)
Bits
Physical
Media, Signal, and Binary Transmission

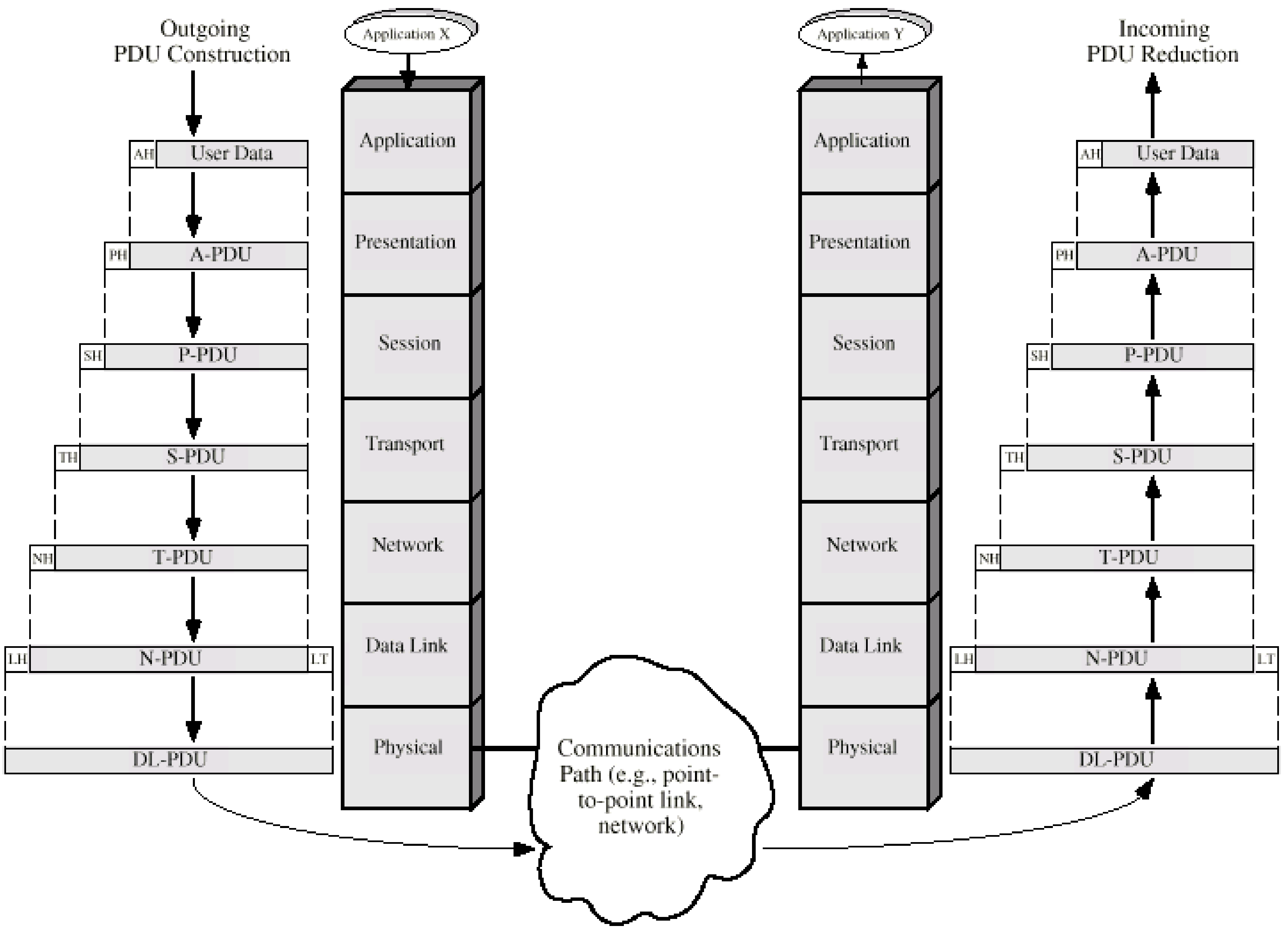
OSI - The Model

- A layer model
- Each layer performs a subset of the required communication functions
- Each layer relies on the next lower layer to perform more primitive functions
- Each layer provides services to the next higher layer
- Changes in one layer should not require changes in other layers

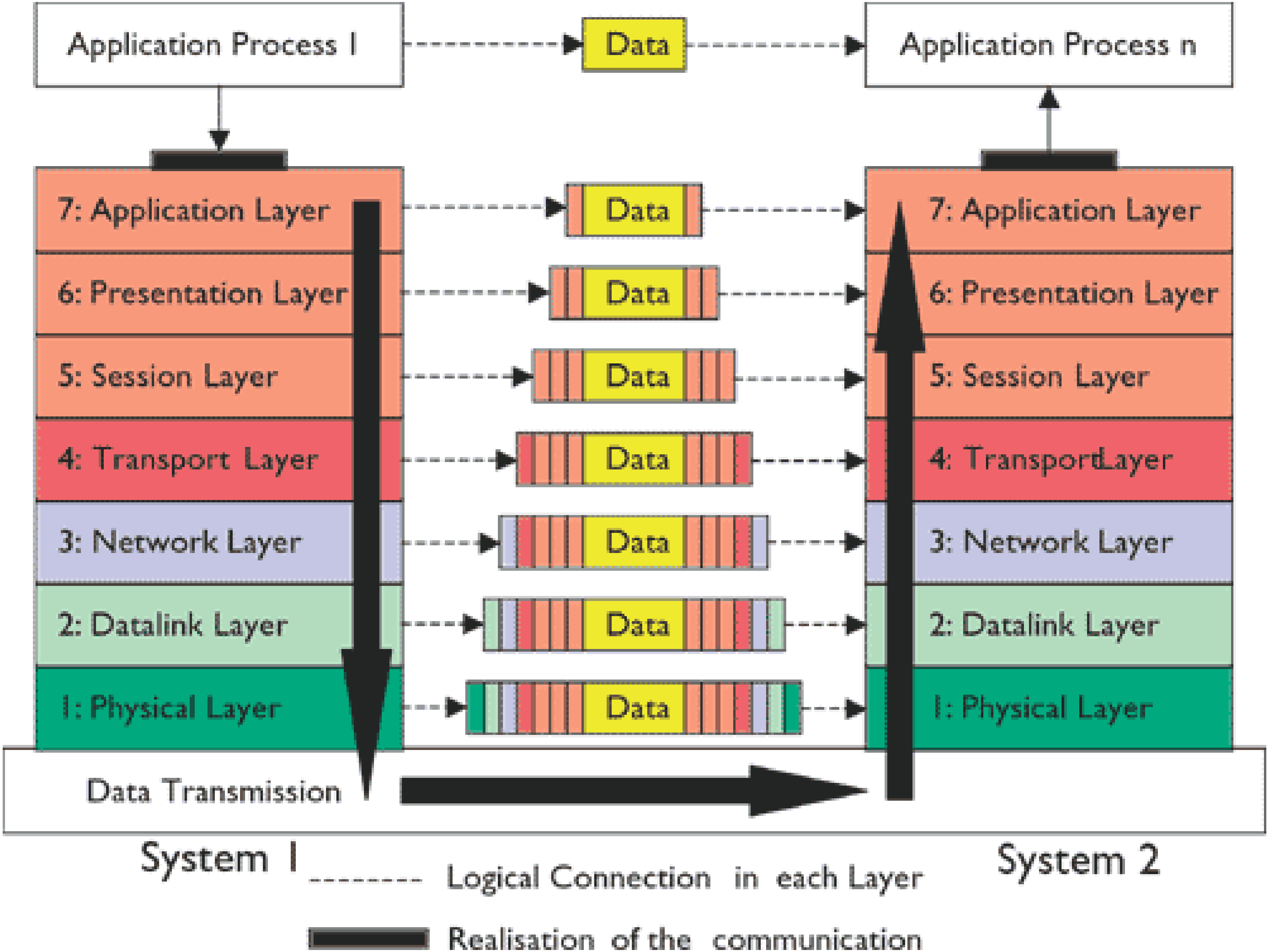
OSI Model



Sending Computer
Receiving Computer
Layer 7
Application Layer (User Interface)
Layer 6
Presentation Layer
Layer 5
Session Layer
Layer 4
Transport Layer (the TCP in TCP/IP)
Layer 3
Network Layer (the IP in TCP/IP)
Layer 2
Data Link Layer (NIC physical address)
Layer 1
Physical Layer (Network card and cabling)
Physical Network



Outgoing
PDU Construction
Application X
Application Y
Incoming
PDU Reduction
AH
User Data
PH
A-PDU
SH
P-PDU
TH
S-PDU
NH
T-PDU
LH
N-PDU
LT
DL-PDU
Application
Presentation
Session
Transport
Network
Data Link
Physical
Communications
Path (e.g., point-
to-point link,
network)

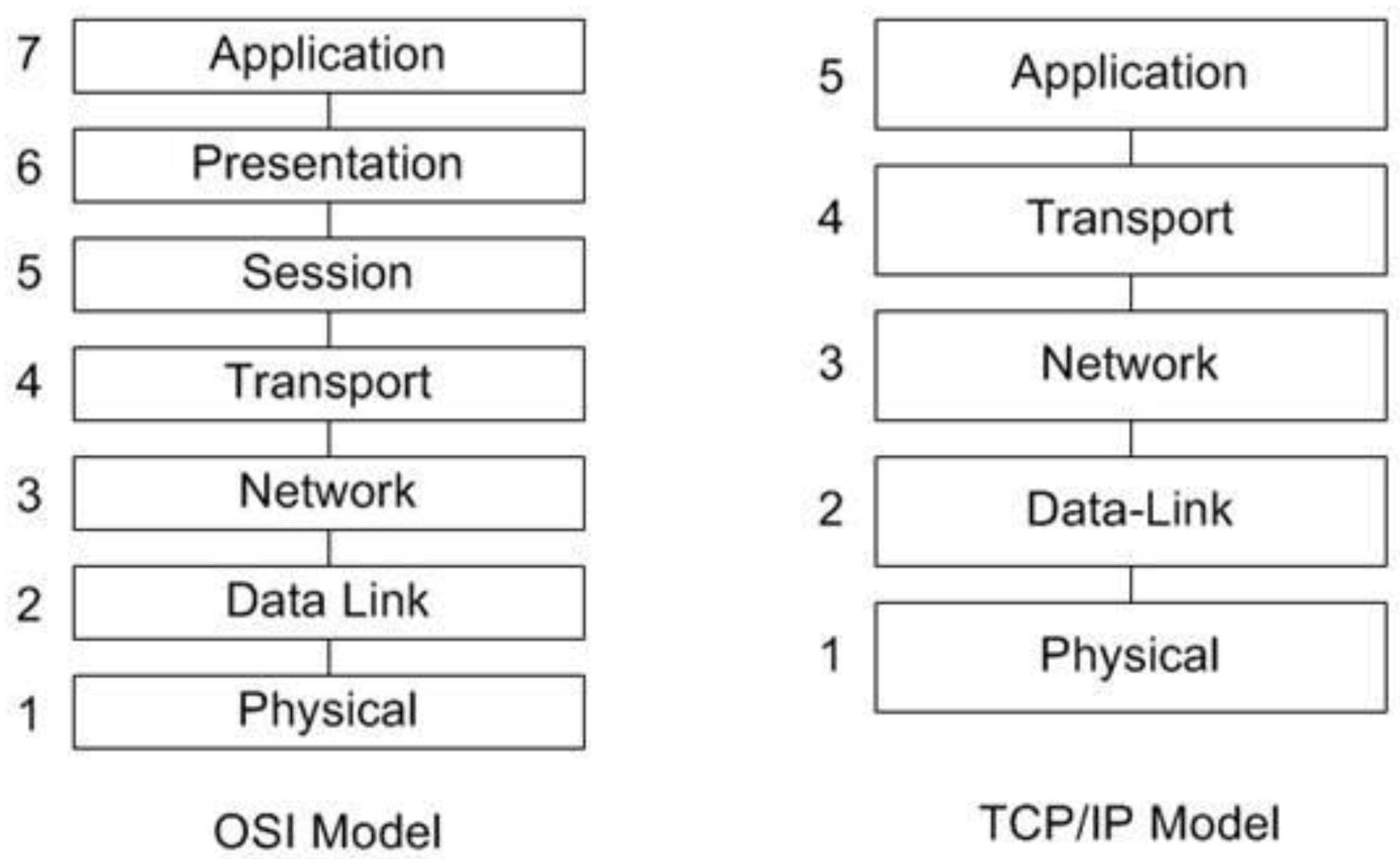


Application Process I
Data
Application Process n
7: Application Layer
6: Presentation Layer
5: Session Layer
4: Transport Layer
3: Network Layer
2: Datalink Layer
1: Physical Layer
Data Transmission
7: Application Layer
6: Presentation Layer
5: Session Layer
4: TransportLayer
3: Network Layer
2: Datalink Layer
1: Physical Layer
System 1
System 2
Logical Connection in each Layer
Realisation of the communication

OSI vs TCP/IP

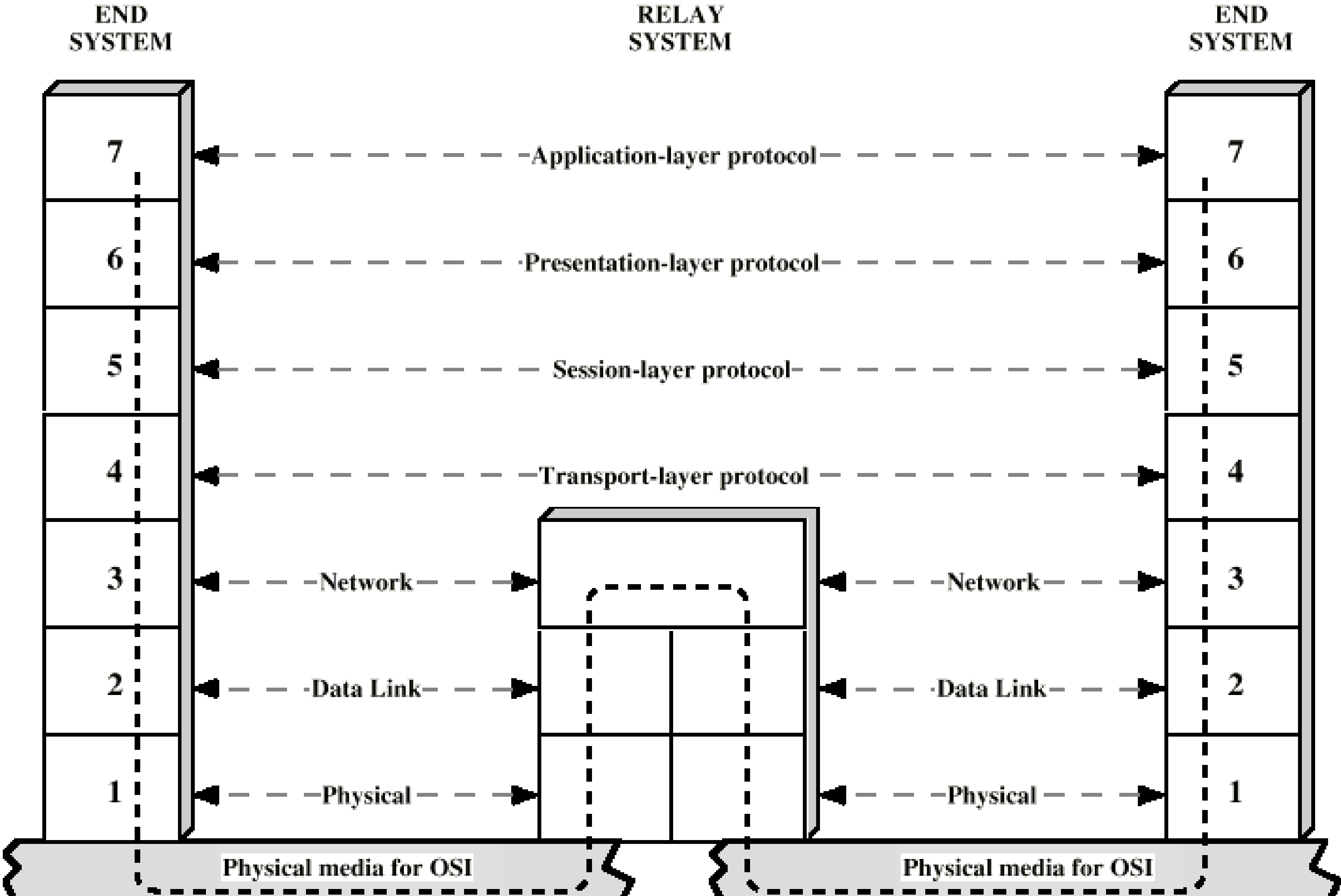
OSI Model	TCP/IP Model (DoD Model)	TCP/IP – Internet Protocol Suite
Application	Application	Telnet, SMTP, POP3, FTP, NNTP, HTTP, SNMP, DNS, SSH, …
Presentation		
Session		
Transport	Transport	TCP, UDP
Network	Internet	IP, ICMP, ARP, DHCP
Data Link	Network Access	Ethernet, PPP, ADSL
Physical		

OSI vs TCP/IP



7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical
OSI Model
5 Application
4 Transport
3 Network
2 Data-Link
1 Physical
TCP/IP Model

Use of a Relay



OSI Layers

- Physical
  - Mechanical
  - Electrical
  - Functional
  - Procedural
- Data Link
  - Means of activating, maintaining and deactivating a reliable link
  - Error detection and control
  - Higher layers may assume error free transmission

OSI Layers

- Network
  - Transport of information
  - Higher layers do not need to know about underlying technology
  - Not needed on direct links
- Transport
  - Exchange of data between end systems
  - Error free
  - In sequence
  - No losses
  - No duplicates
  - Quality of service

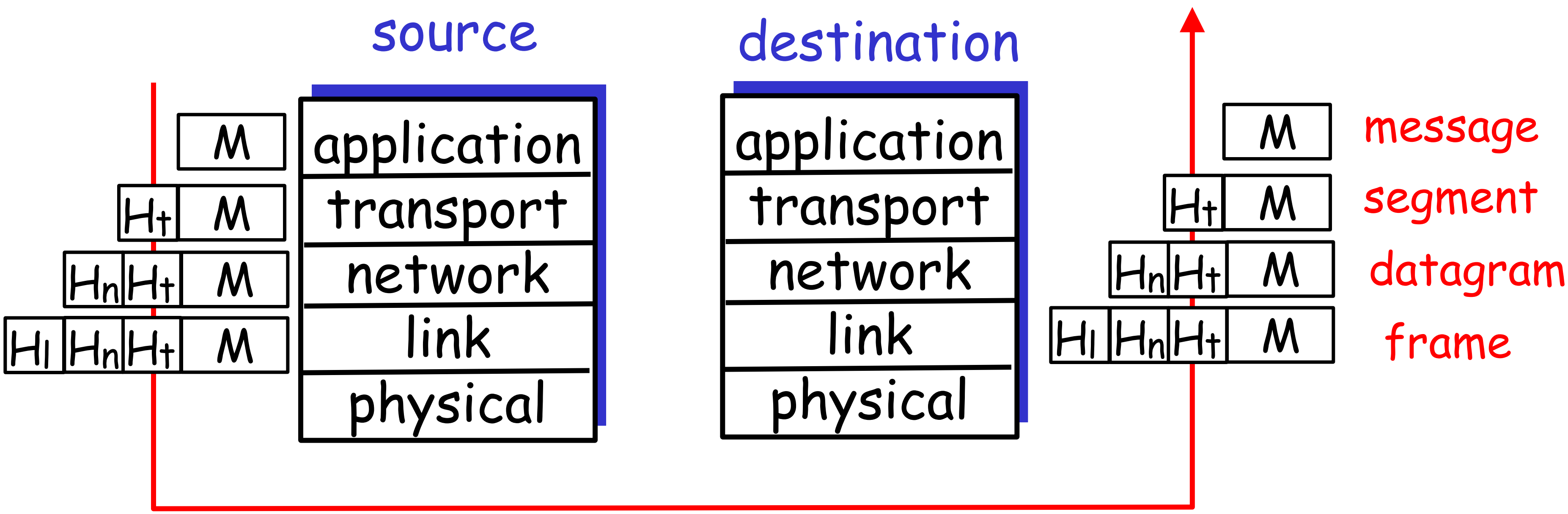
OSI Layers

- **Session**
  - Control of dialogues between applications
  - Dialogue discipline
  - Grouping
  - Recovery
- **Presentation**
  - Data formats and coding
  - Data compression
  - Encryption
- **Application**
  - Means for applications to access OSI environment

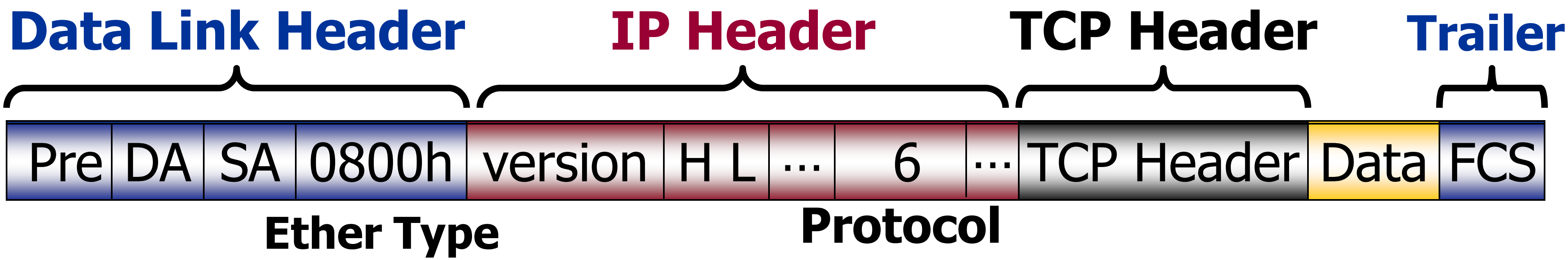
Protocol layering and data

Each layer takes data from above

- adds header information to create new data unit
- passes new data unit to layer below



Protocol Headers



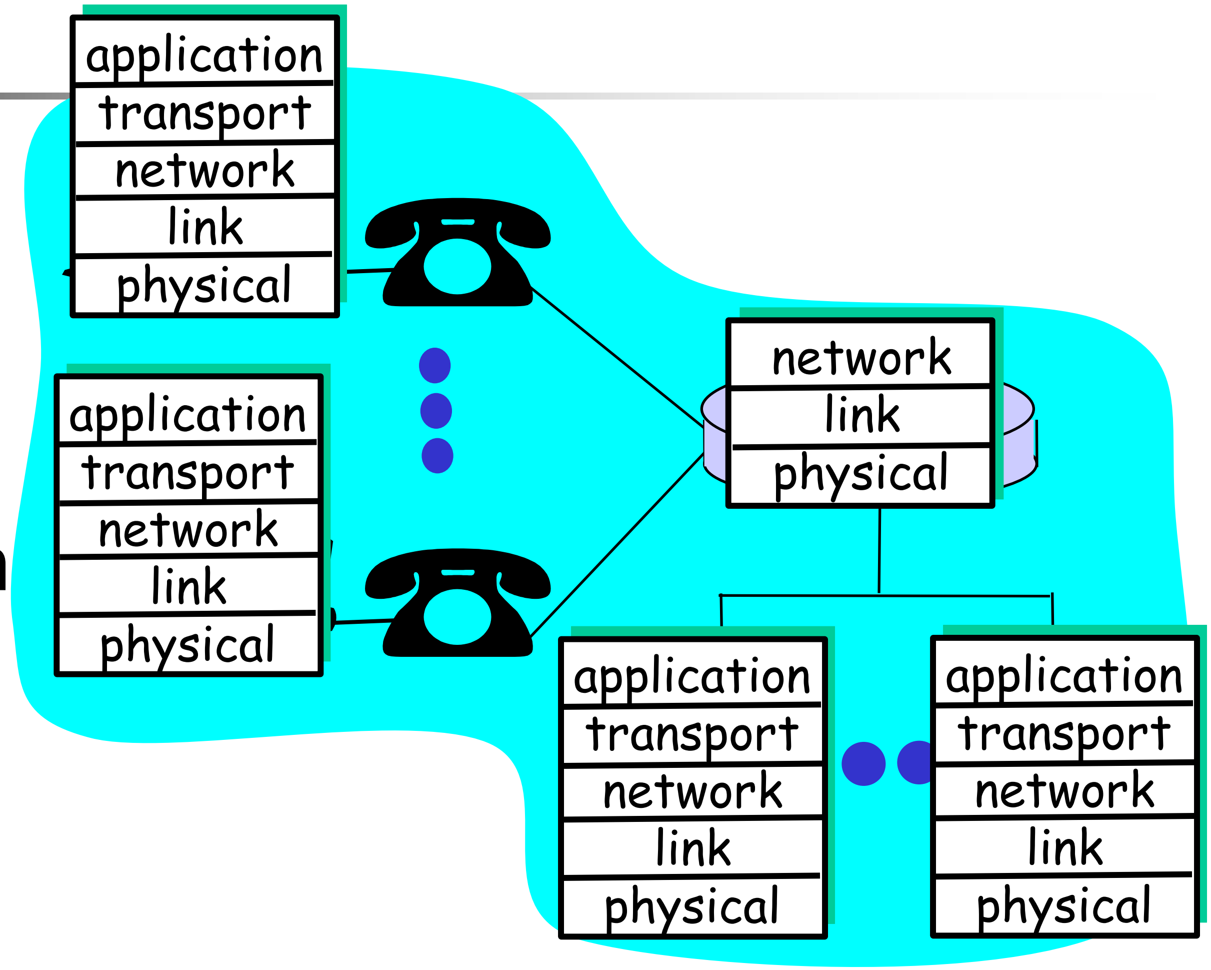
0x0800 Internet Protocol, Version 4 (IPv4)
0x0806 Address Resolution Protocol (ARP)
0x8100 IEEE 802.1Q-tagged frame
0x86DD Internet Protocol, Version 6 (IPv6)
0x8847 MPLS unicast
0x8848 MPLS multicast

1: Internet Control Message Protocol (ICMP)
2: Internet Group Management Protocol (IGMP)
6: Transmission Control Protocol (TCP)
17: User Datagram Protocol (UDP)
89: Open Shortest Path First (OSPF)

Layering: logical communication

Each layer:

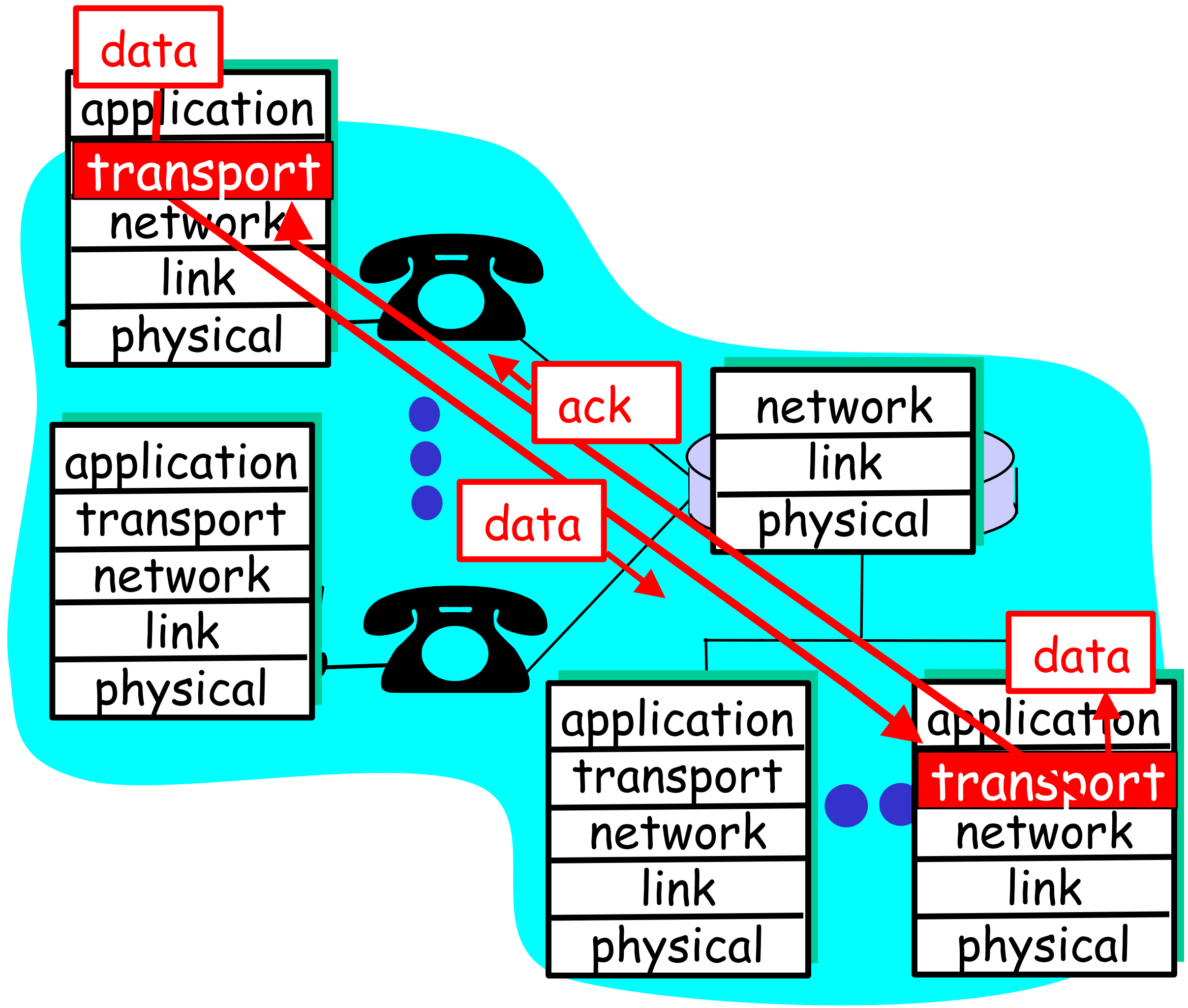
- distributed
- "entities" implement layer functions at each node
- entities perform actions, exchange messages with peers



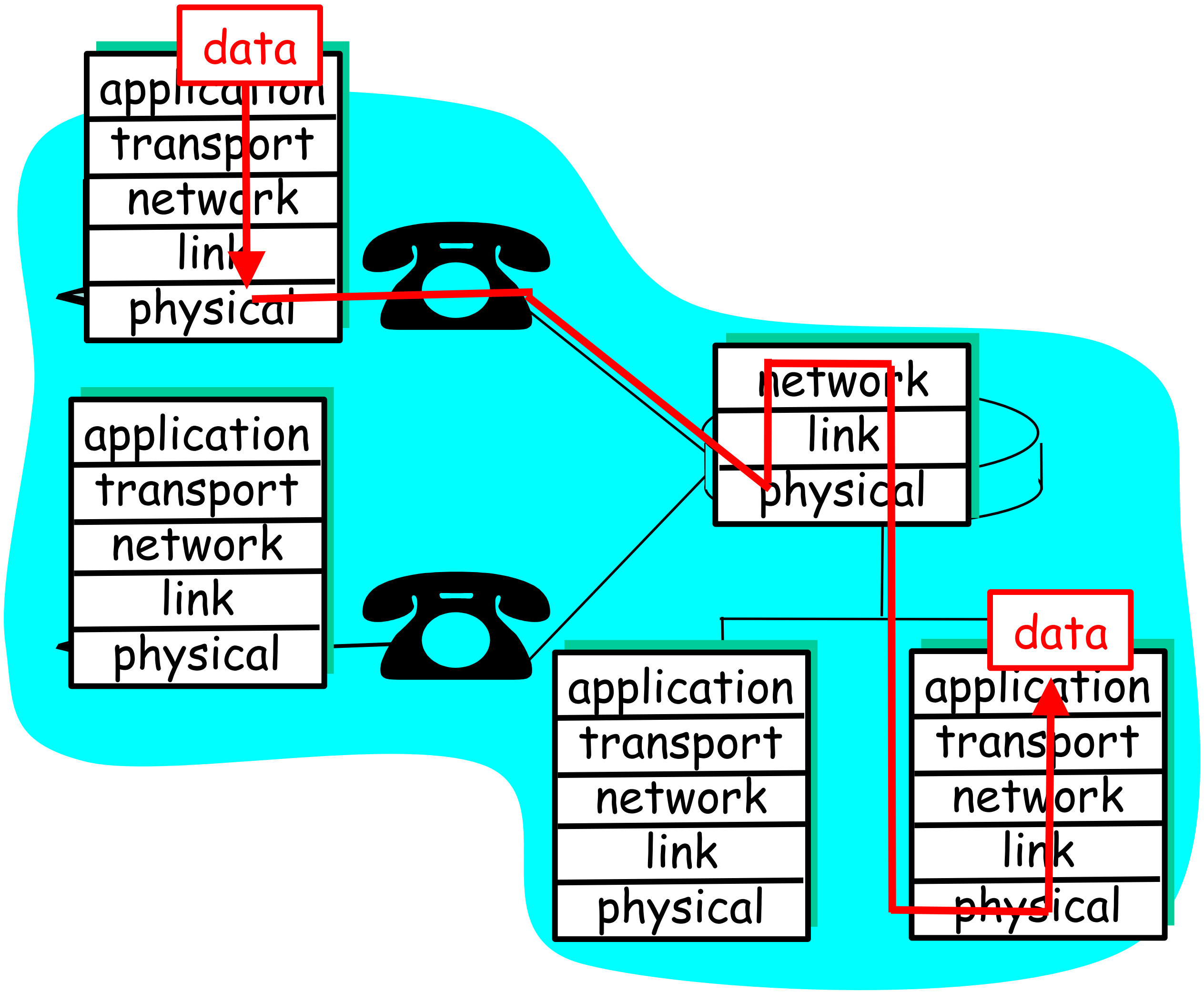
Layering: logical communication

E.g.: transport

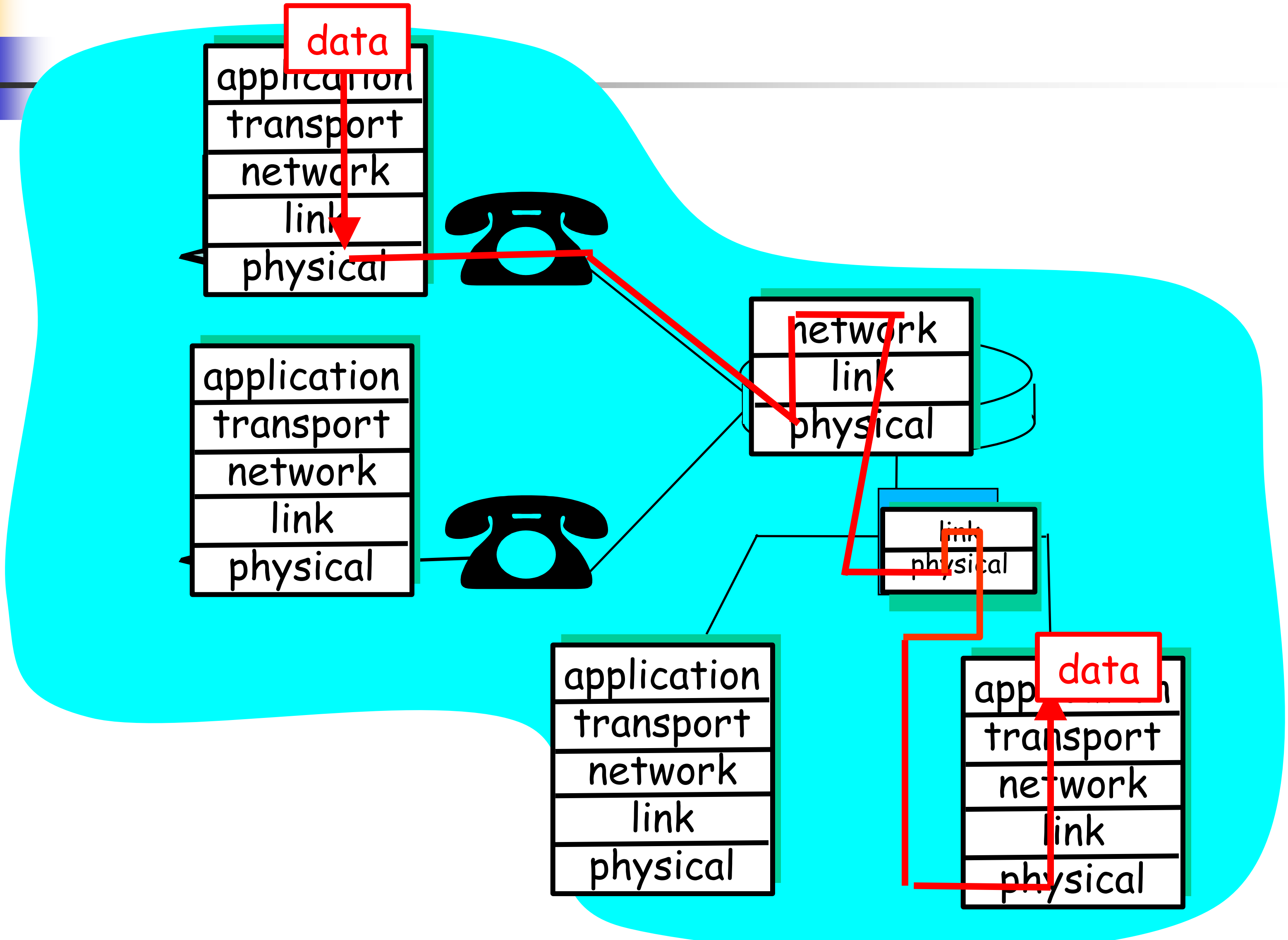
- take data from app
- add addressing, reliability check info to form “datagram”
- send datagram to peer
- wait for peer to ack receipt
- analogy: post office



Layering: physical communication

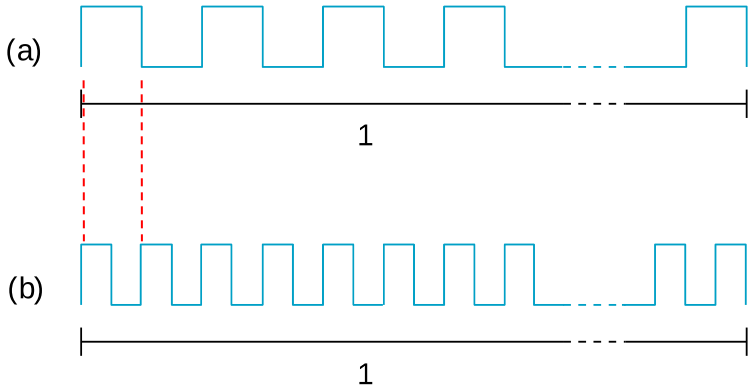


Layering: physical communication



Building A Network: Performance

Bandwidth: number of bits per time unit.



We can talk about bandwidth at the physical level, but we can also talk about logical process-to-process bandwidth.

Latency: time taken for a message to travel from one end of the network to the other.

Again, we can consider a single-link or an end-to-end channel.

Latency

$$\text{Latency} = \text{Propagation} + \text{Transmit} + \text{Queue}$$

$$\text{Propagation} = \text{Distance} / \text{Speed of light}$$

$$\text{Transmit} = \text{Size} / \text{Bandwidth}$$

$$\text{Speed of light} = \begin{cases} 2.0 \times 10^8 m/s \text{ in a fiber} \\ 2.3 \times 10^8 m/s \text{ in a cable} \\ 3.0 \times 10^8 m/s \text{ in a vaccum} \end{cases}$$

Throughput

$$\text{Throughput} = \text{Transfer size} / \text{Transfer time}$$

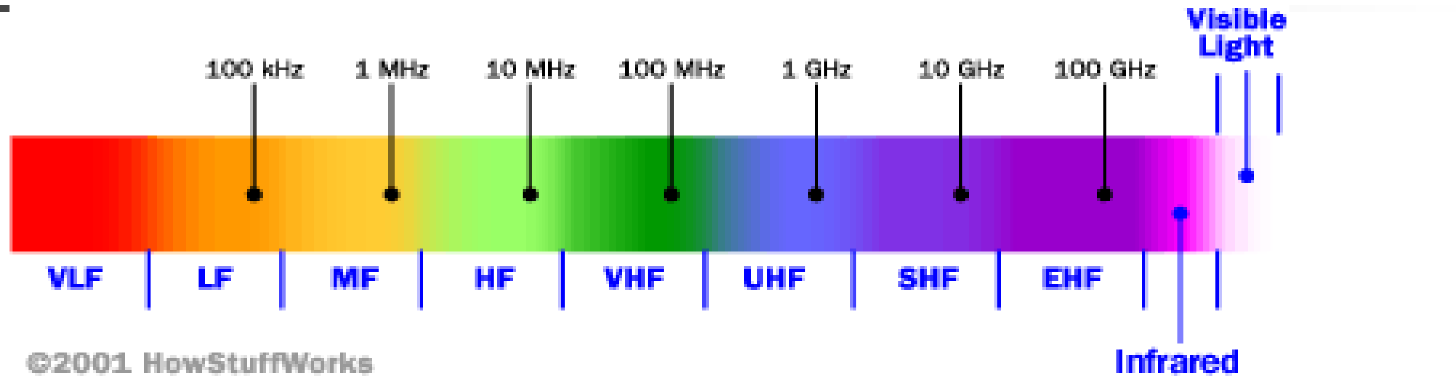
(effective end-to-end throughput)

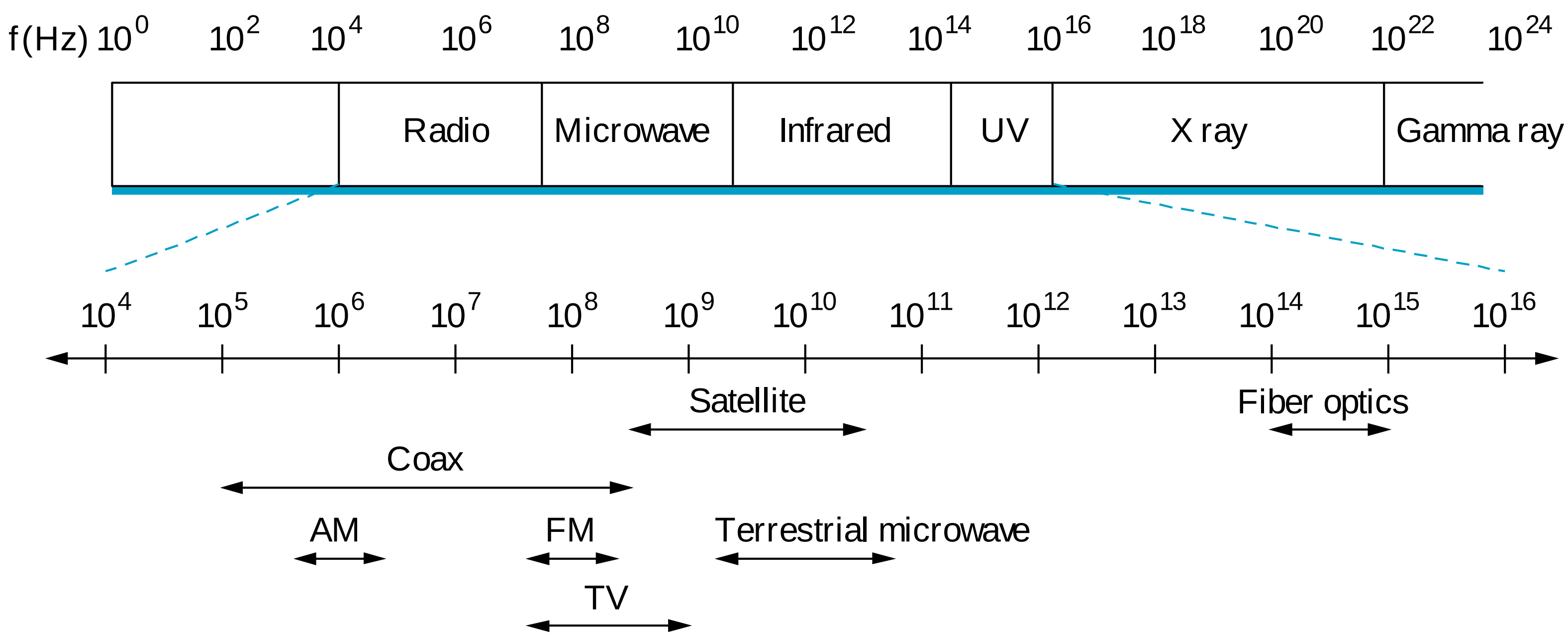
$$\text{Transfer time} = \text{RTT} + 1/\text{Bandwidth} \times \text{Transfer size}$$

Jitter

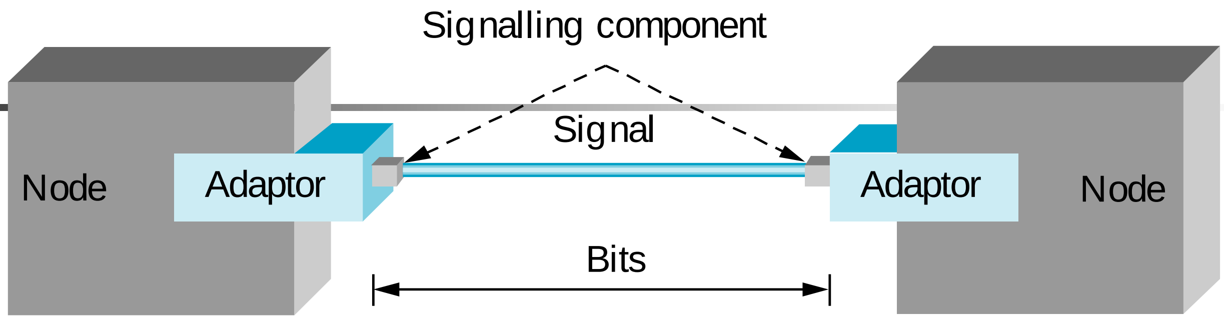
Jitter is a variation (somewhat random) of the latency from packet to packet. Jitter is most often observed when packets traverse multiple *hops* from source to destination.

Spectrum


Visible Light
100 kHz
1 MHz
10 MHz
100 MHz
1 GHz
10 GHz
100 GHz
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
Infrared
©2001 HowStuffWorks

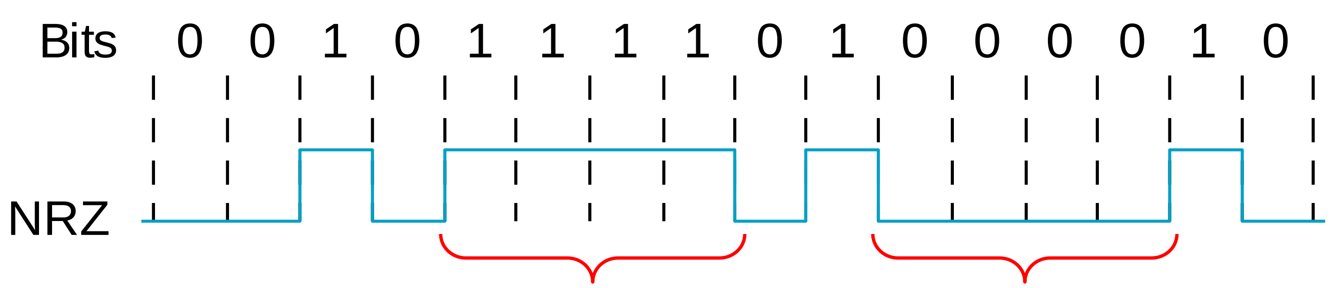

f (Hz) 10^0
10^2
10^4
10^6
10^8
10^10
10^12
10^14
10^16
10^18
10^20
10^22
10^24
Radio
Microwave
Infrared
UV
X ray
Gamma ray
10^4
10^5
10^6
10^7
10^8
10^9
10^10
10^11
10^12
10^13
10^14
10^15
10^16
Satellite
Fiber optics
Coax
AM
FM
Terrestrial microwave
TV

Encoding – NRZ (Non-Return to Zero)



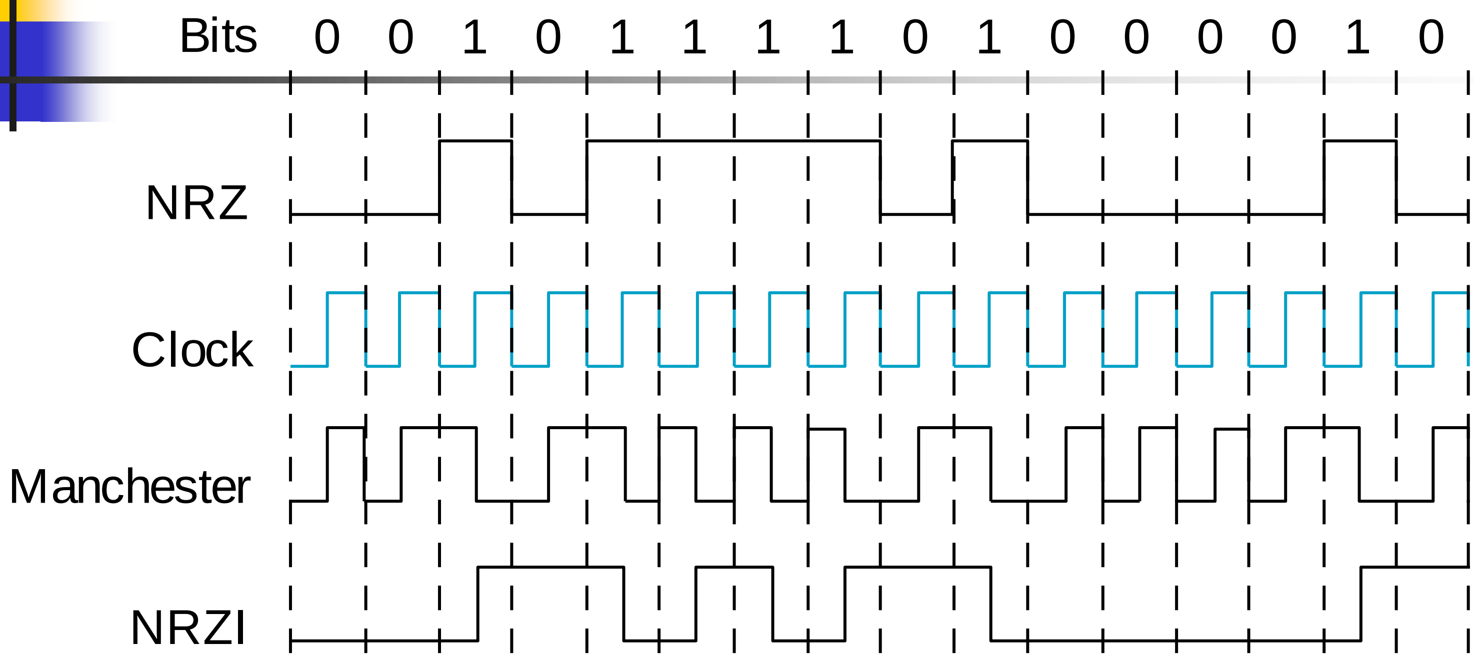
NRZ: Encode 0s and 1s using two different "levels".

Problem 1: The signal is synchronous; that is, there's a reference clock marking the "length" of each bit.



Problem 2: Separating 0's from 1's is not trivial.

NRZI and Manchester Encoding



Clock recovery depends on ***transitions***. To keep clocks in sync, the more transitions the better; too few and clocks will drift.

NRZI: Encode 1s using "transitions"; 0s keep current level.

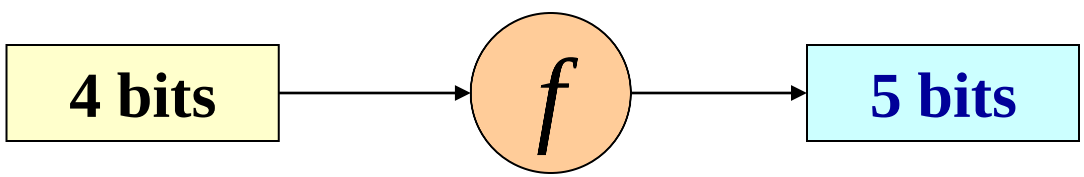
Manchester: low to high signals a 0, high to low signals a 1.

Summary

- **NRZ:** *Clock recovery* is problem.
- **NRZI:** 0s have no transitions and thus they won't help with clock recovery.
- **Manchester:** <u>Doubles the rate of transitions</u> making clock recovery easier, on the other hand, since there are 2 transitions for every single bit, the <u>efficiency (information per unit of time) drops by 50%.</u>

4B/5B Encoding

Basic idea: Insert extra bits into the stream to break up long sequences of 0s and 1s. Doesn't allow more than one leading 0 and no more than two trailing 0s.



4B/5B Encoding

4-bit Data Symbol	5-bit Code
0000	11110
0001	01001
0010	10100
0011	10101
0100	01010
0101	01011
0110	01110
0111	01111
1000	10010
1001	10011
1010	10110
1011	10111
1100	11010
1101	11011
1110	11100
1111	11101

$$2^4 = 16$$

$$2^5 = 32$$

16 codes are "left over" and some can be used for purposes other than encoding data. For instance:

11111 = idle line

00000 = dead line

00100 = halt

7 codes violate the "one leading 0, two trailing 0s rule".