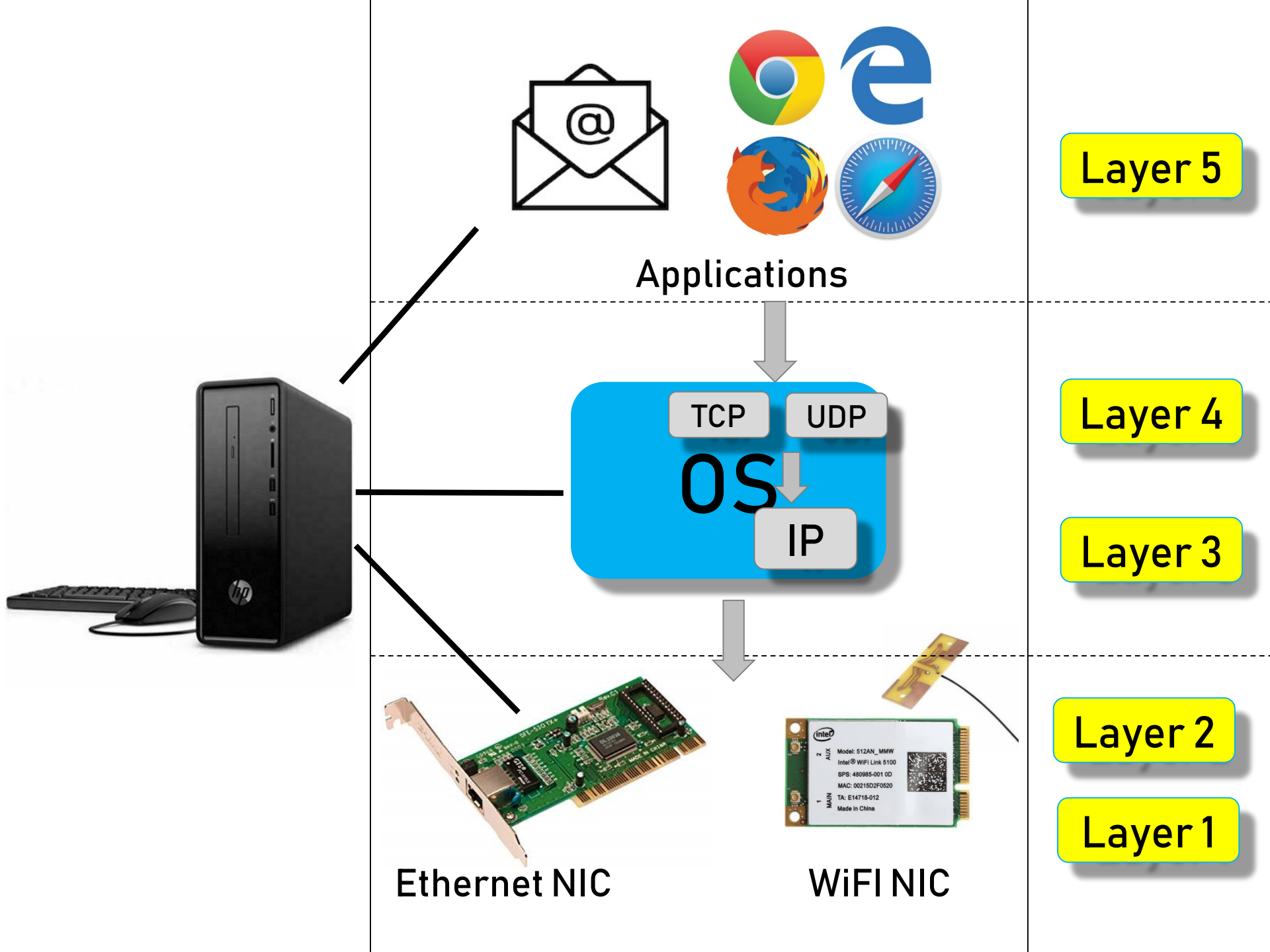
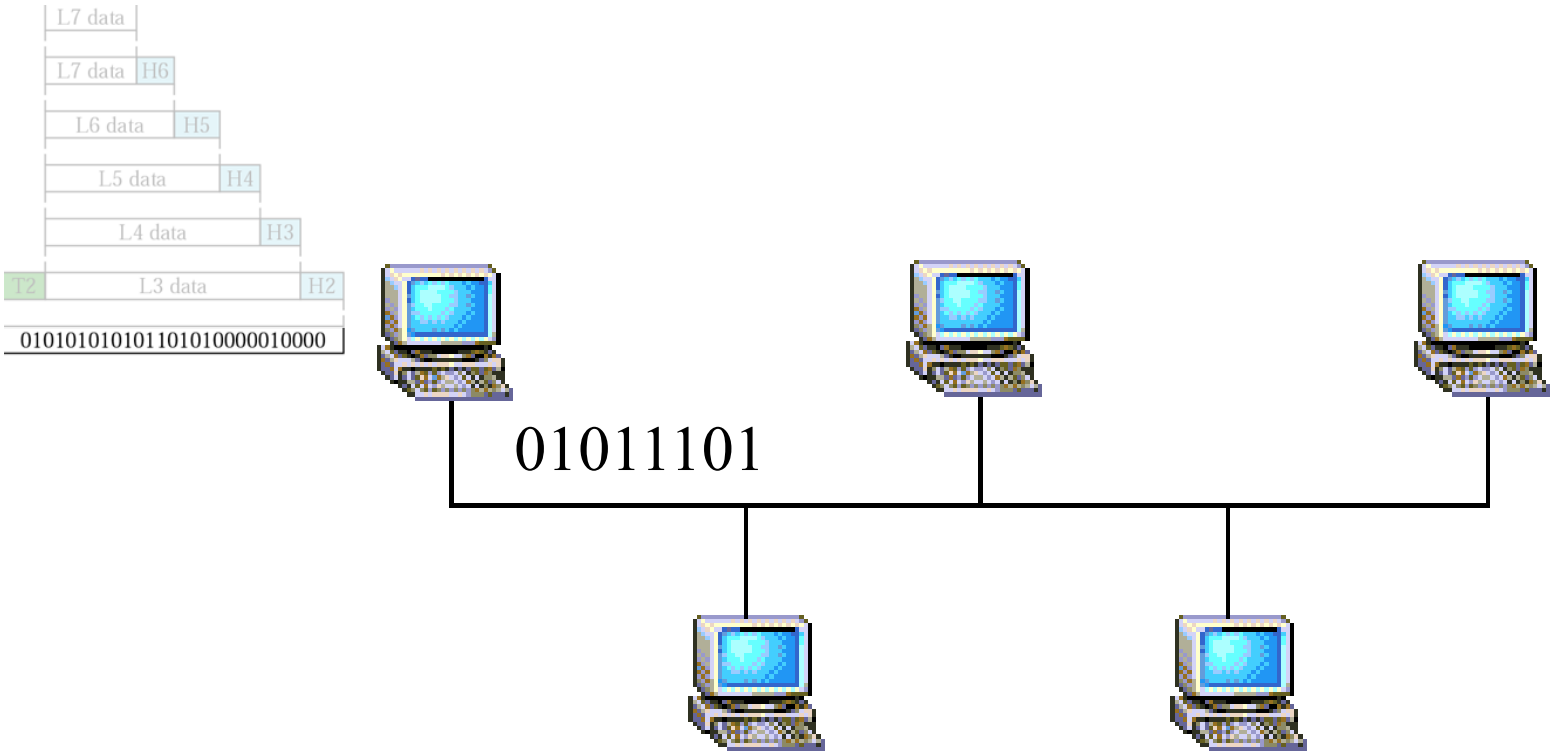

Layer 5
Applications
Layer 4
TCP
UDP
OS
Layer 3
IP
Layer 2
Layer 1
Ethernet NIC
WiFI NIC

Layered Internet Architecture (cont.)



Sending 0 and 1 well is useful. But what if:

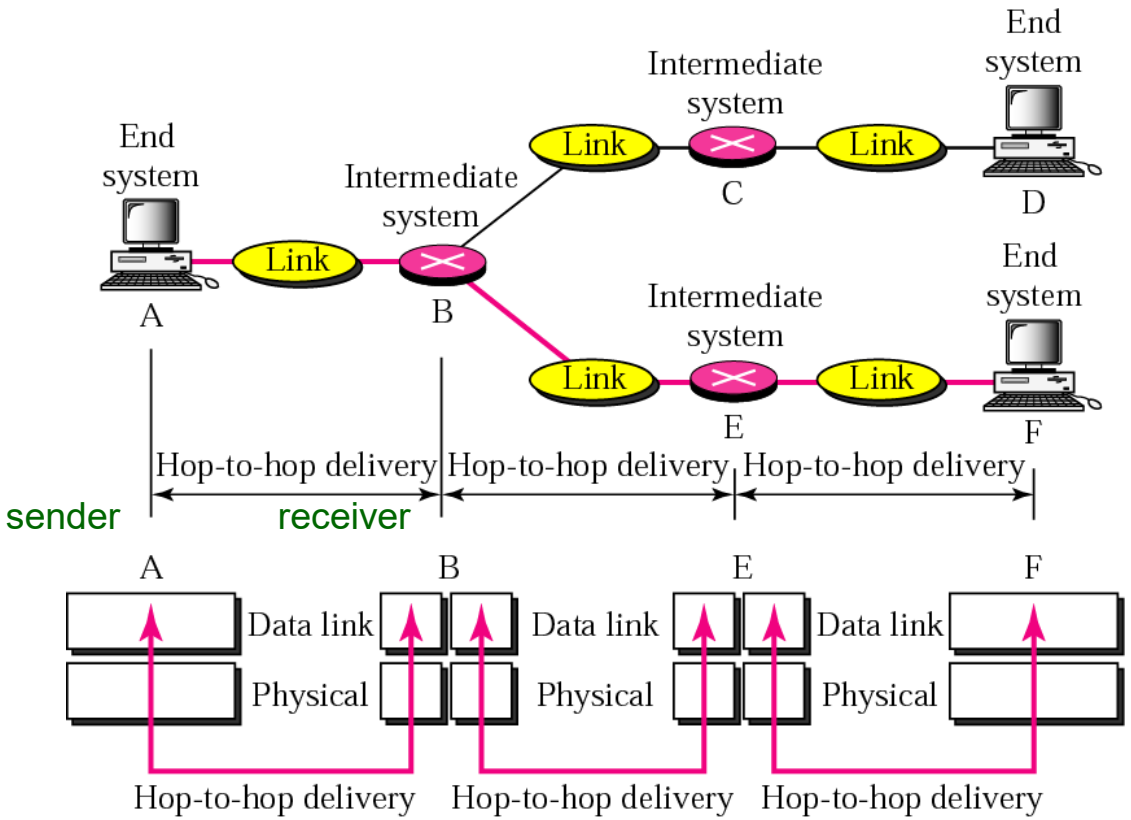
1) Multiple machines share the same communication medium?
(where should these bits go??)

2) Some of the bits get corrupted by noise?

Layered Internet Architecture (cont.)

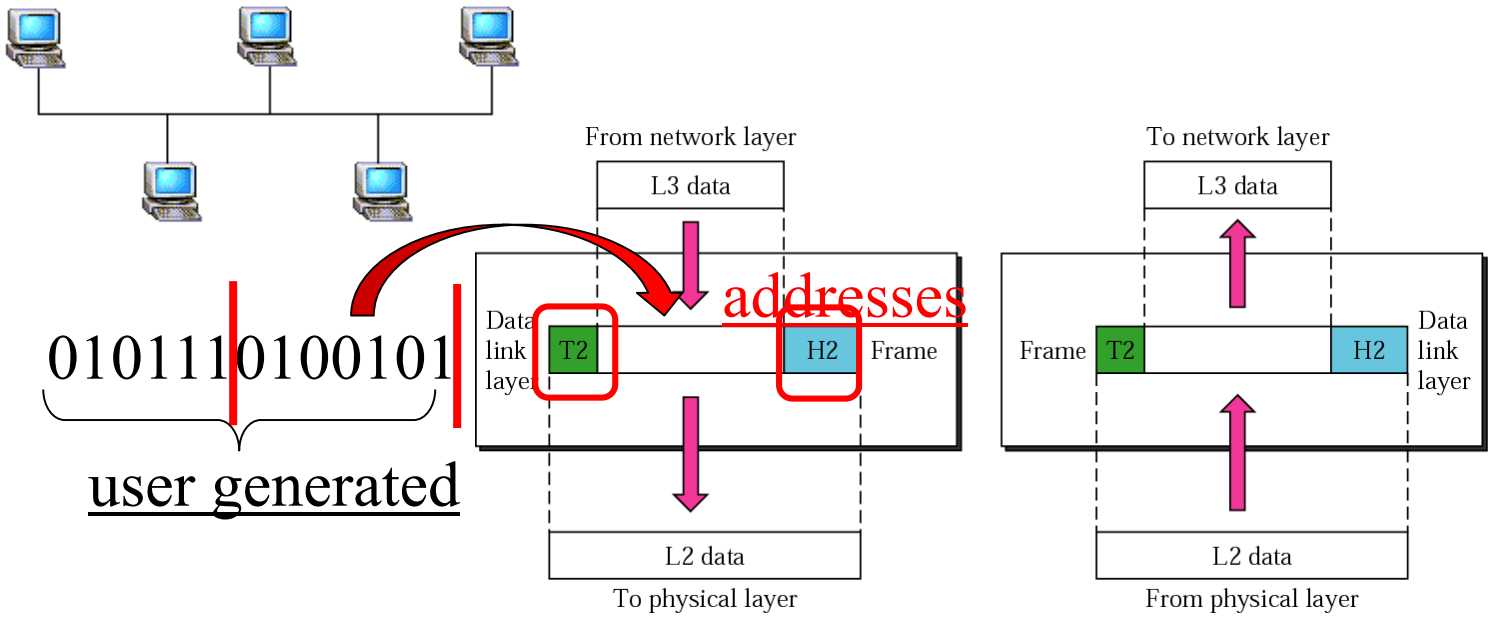
2. Data-Link Layer

The data link layer transforms the physical layer, a raw stream of bits, to a reliable link between two OR MORE devices on the same network. It makes the physical layer appear error-free to the upper layer.



Layered Internet Architecture (cont.)

- **framing**: The D.L.L divides the stream of bits received from the network layer into manageable data units called frames.
- **physical addressing**: The D.L.L adds a **header** to the frame to specify the NIC address of appropriate receiver on the other side (of wire).
- **error control**: The D.L.L adds reliability to the physical layer by adding a **trailer** with information necessary to detect / recover damaged or lost frames.
- **access control**: When two or more devices are connected to the same link, the D.L.L determines which device has control over the link at any given time.



Guide to

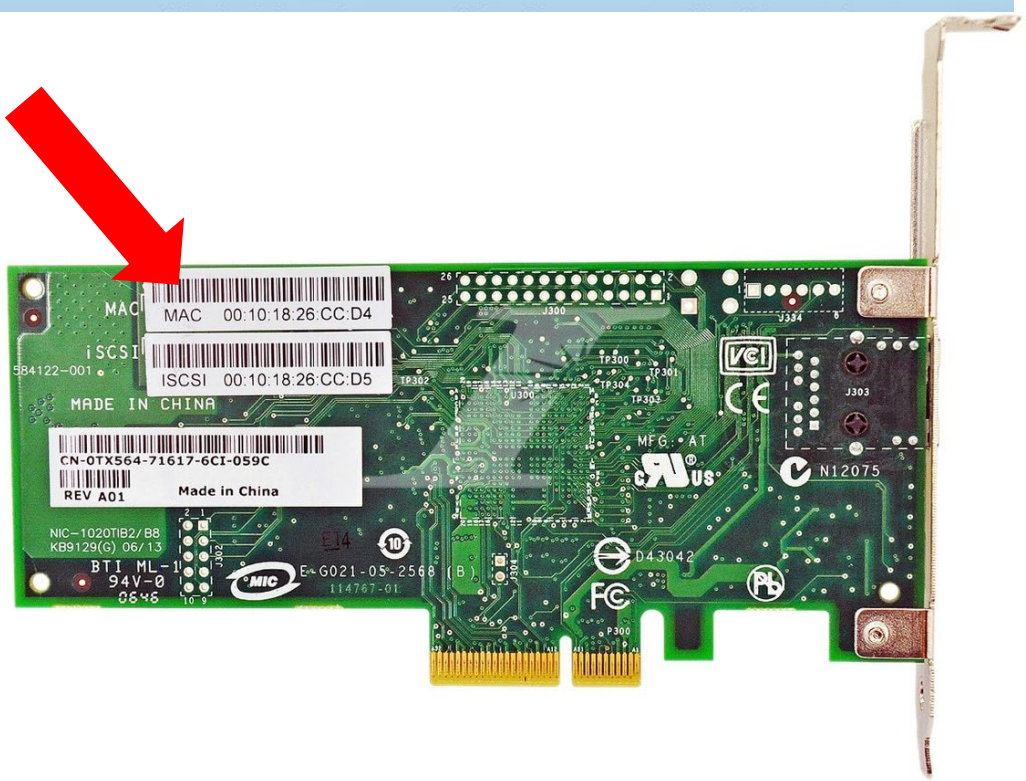
Networking Essentials

Simulations Developed by Greg Tomsho & Angela Poland

Replay Play Pause Menu

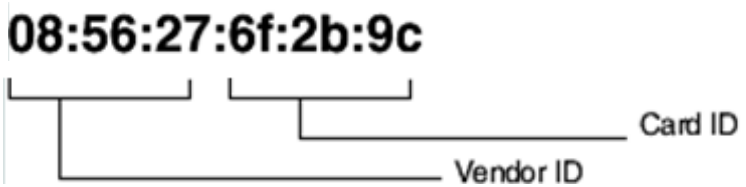
Summary:

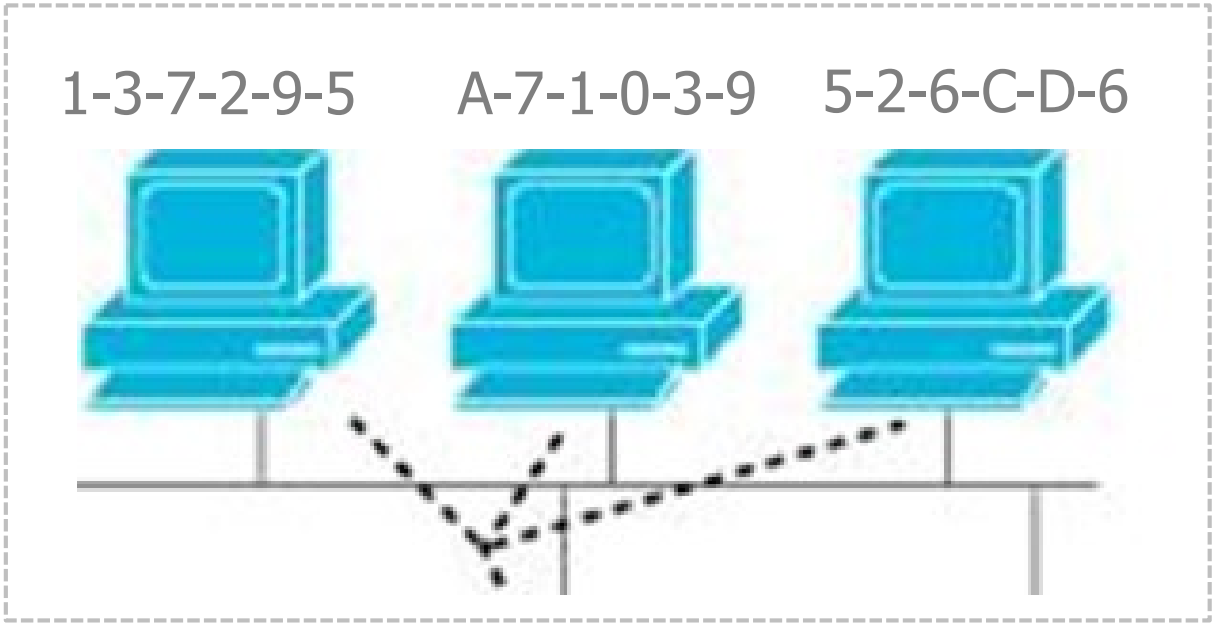
How a NIC Works



https://www.youtube.com/watch?v=QHoW3GEWLD8

MAC Address - 6-byte sequence assigned to NIC by the manufacturer ('name given at birth' that never changes)



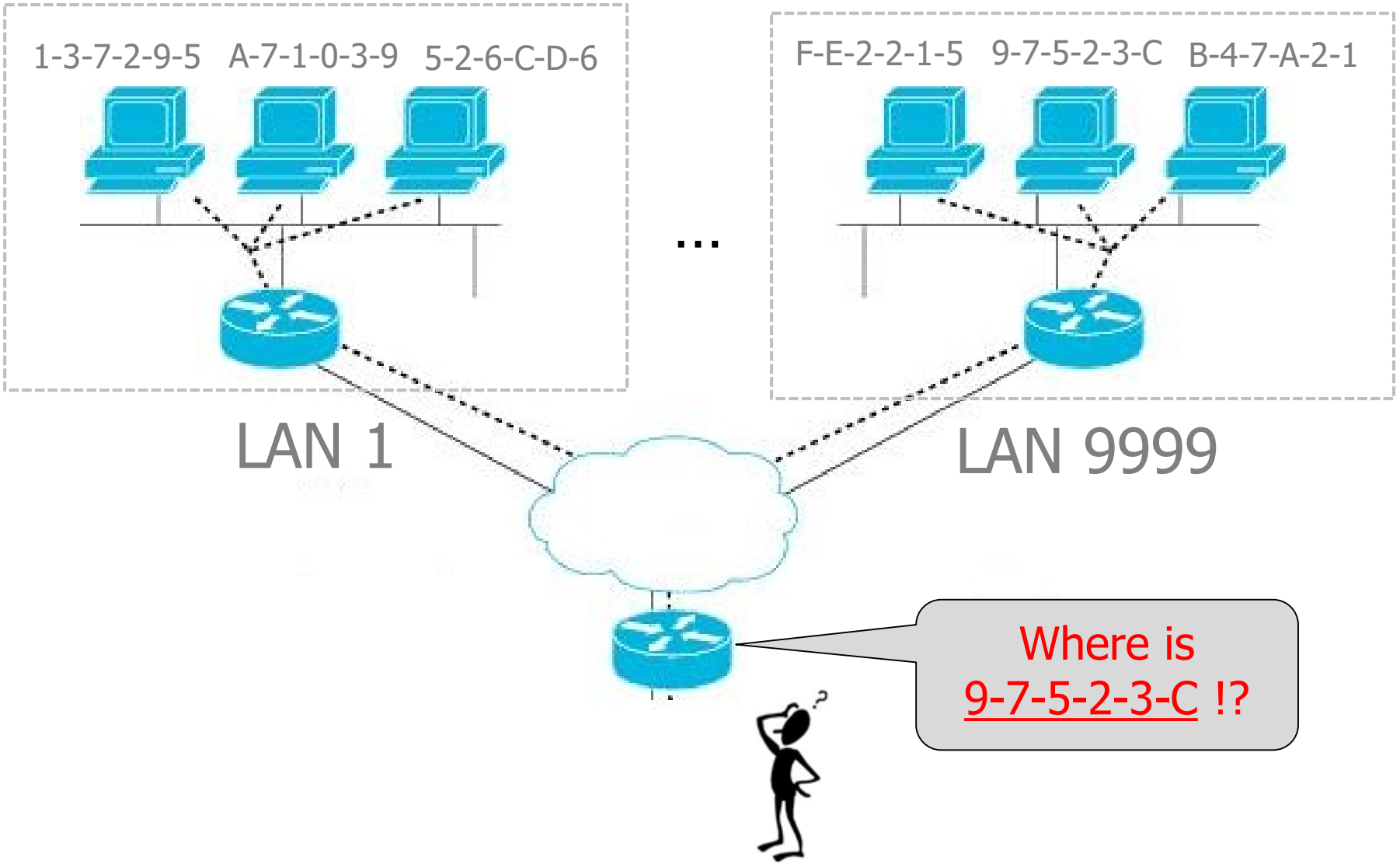


LAN 1

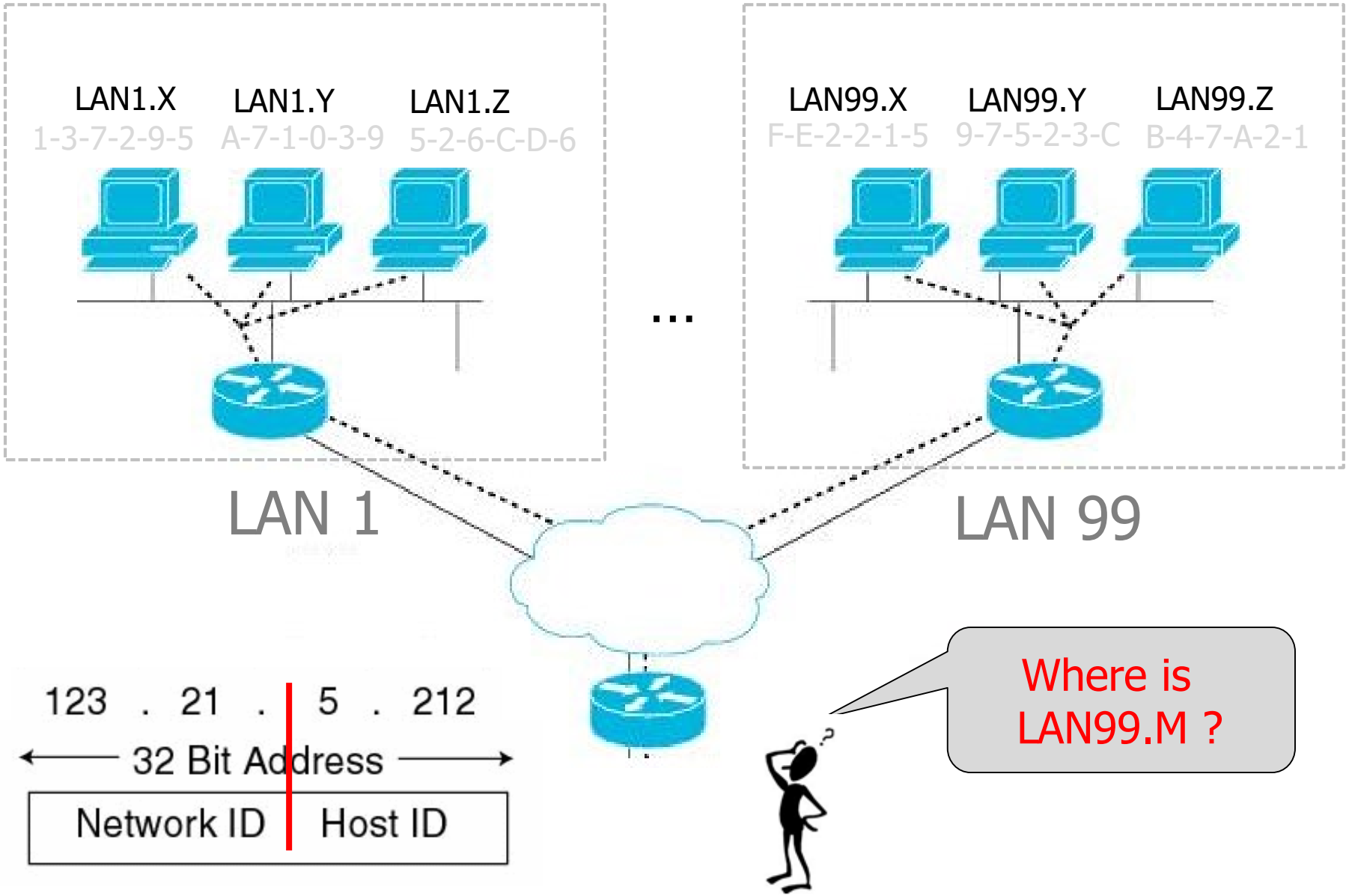
IMPORTANT:
MAC addr. of neighboring stations (may) have nothing in common !!!

MAC addresses are convenient for station addressing (packet/frame delivery) in small LAN environments.

What if we try to use MAC Address to address stations (deliver packets) in a WAN !?



What is the purpose of IP addresses !?

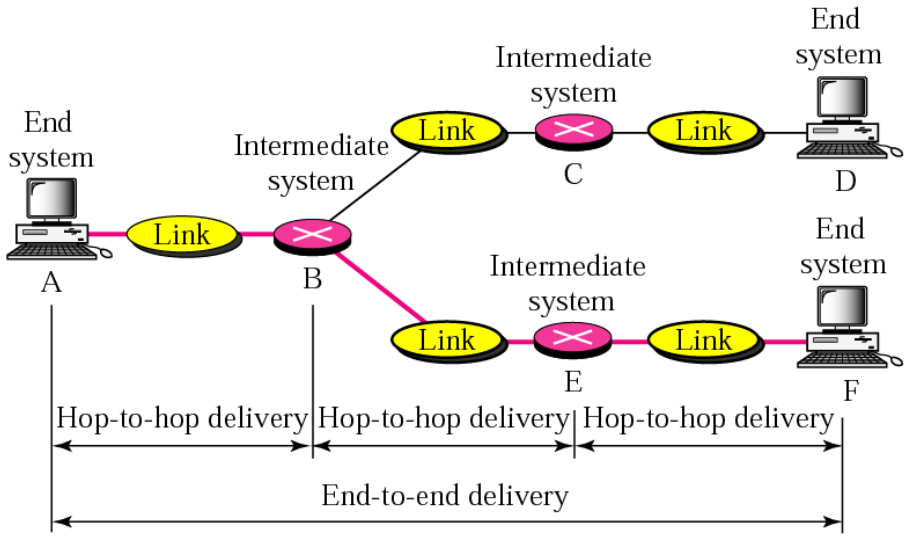


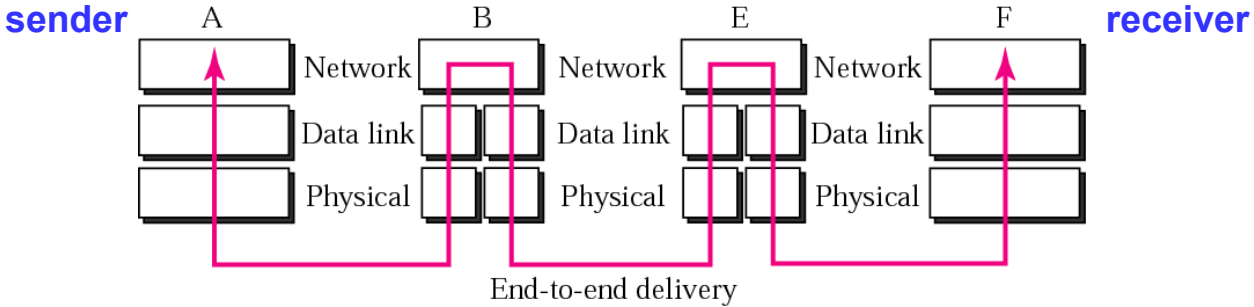
Layered Internet Architecture (cont.)

3. Network Layer

While the data link layer oversees the delivery of packets between two devices on the same network, the network layer is responsible for the source-to-destination delivery of packet across multiple networks / links.

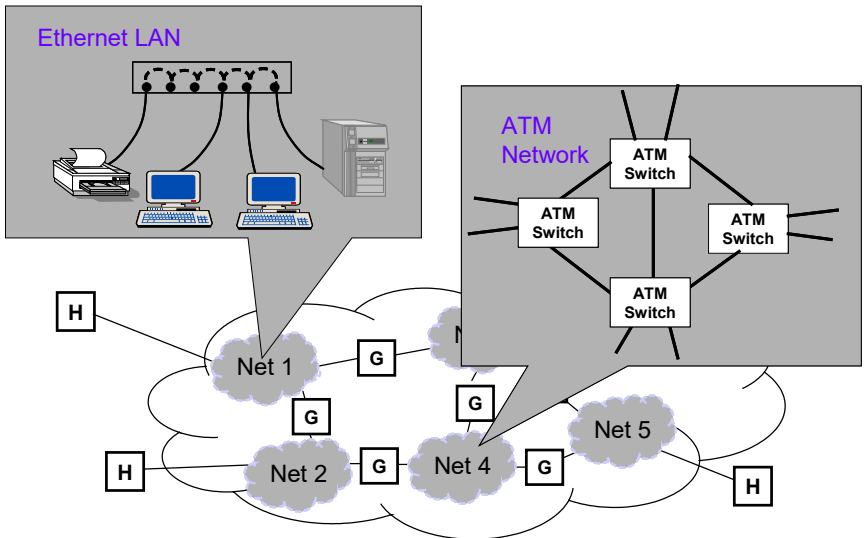
Routing over multiple networks:
1) in min time, AND
2) with min overhead.



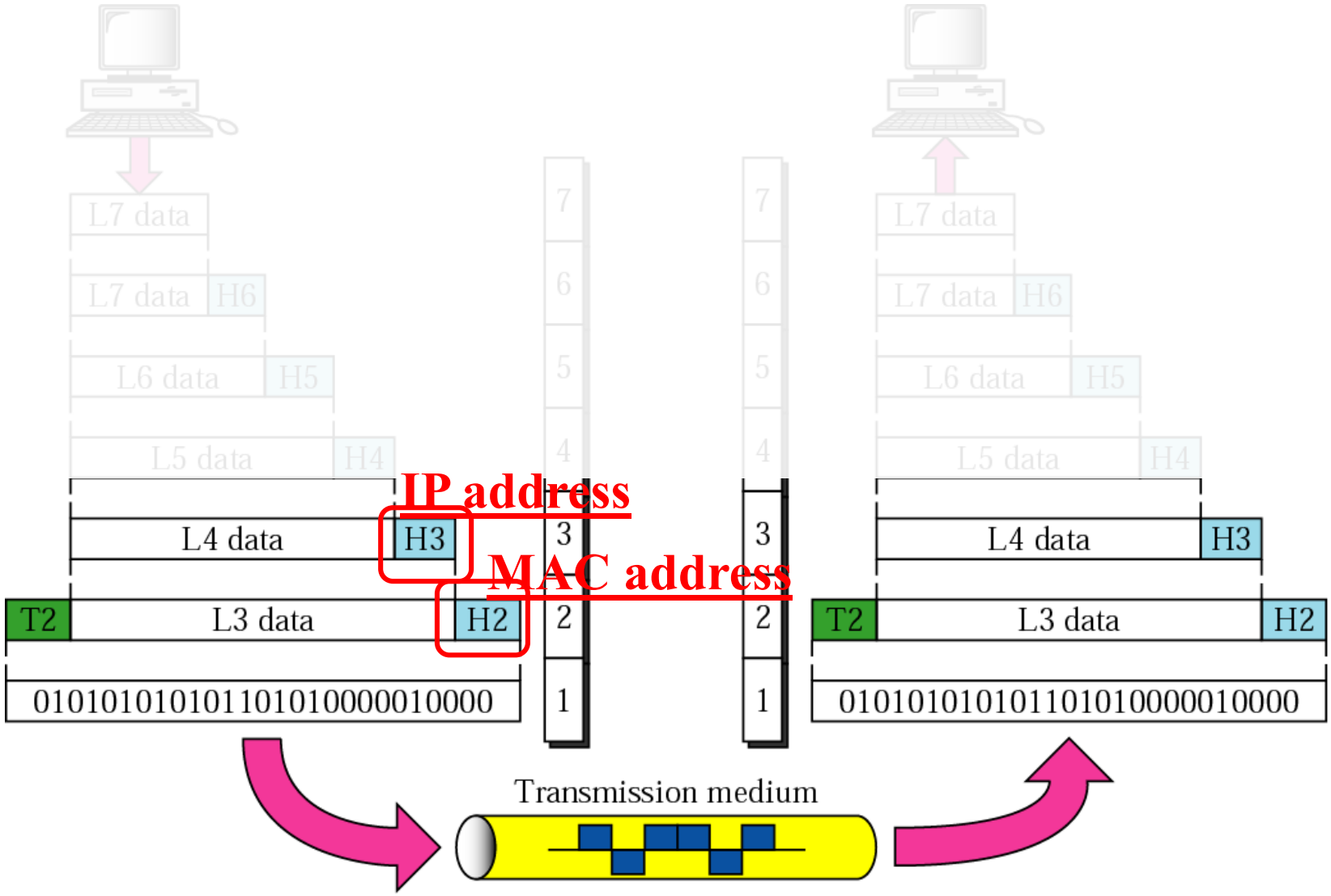


Layered Internet Architecture (cont.)

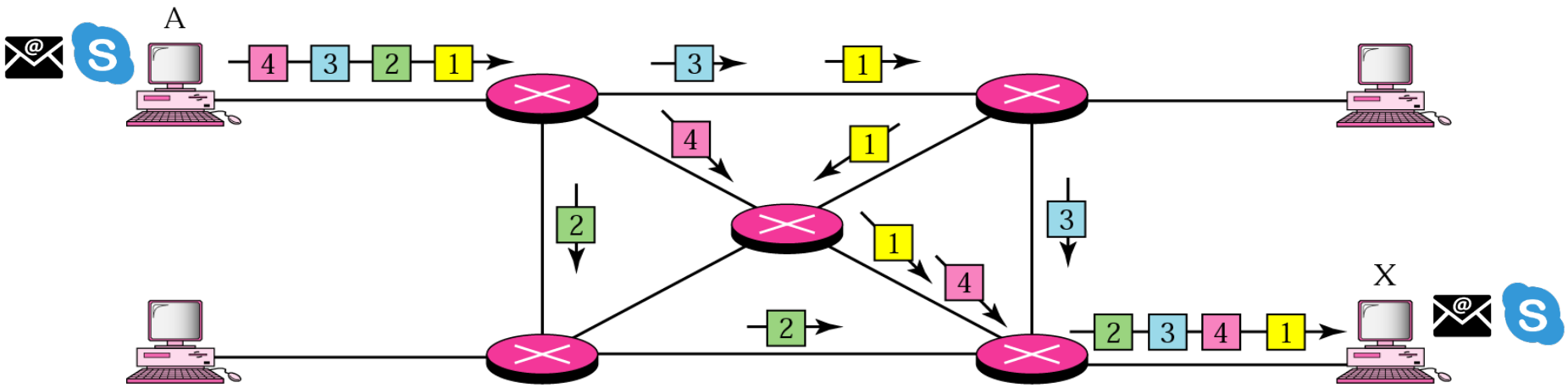
- **logical addressing**: **The physical addressing implemented by the data link layer handles the addressing / delivery problem locally – over a single wire. If a packet passes the network boundary another addressing system is needed to help distinguish between the source and destination network.**
- **routing**: **The N.L. provides the mechanism for routing/switching packets to their final destination, along the optimal path – across a large internetwork.**
- **fragmentation and reassembly**: The N.L. sends messages down to the D.L.L. for transmission. Some D.L.L. technologies have limits on the length of messages that can be sent. If the packet that the N.L. wants to send is too large, the N.L. must split the packet up, send each piece to the D.L.L, and then have pieces reassembled once they arrive at the N.L. on the destination machine.



Layered Internet Architecture (cont.)



Layered Internet Architecture (cont.)



Routing individual packets well (end-to-end) is useful. But what if:

1) Multiple 'programs' (applications) run at the same time on the same sending/receiving machine?

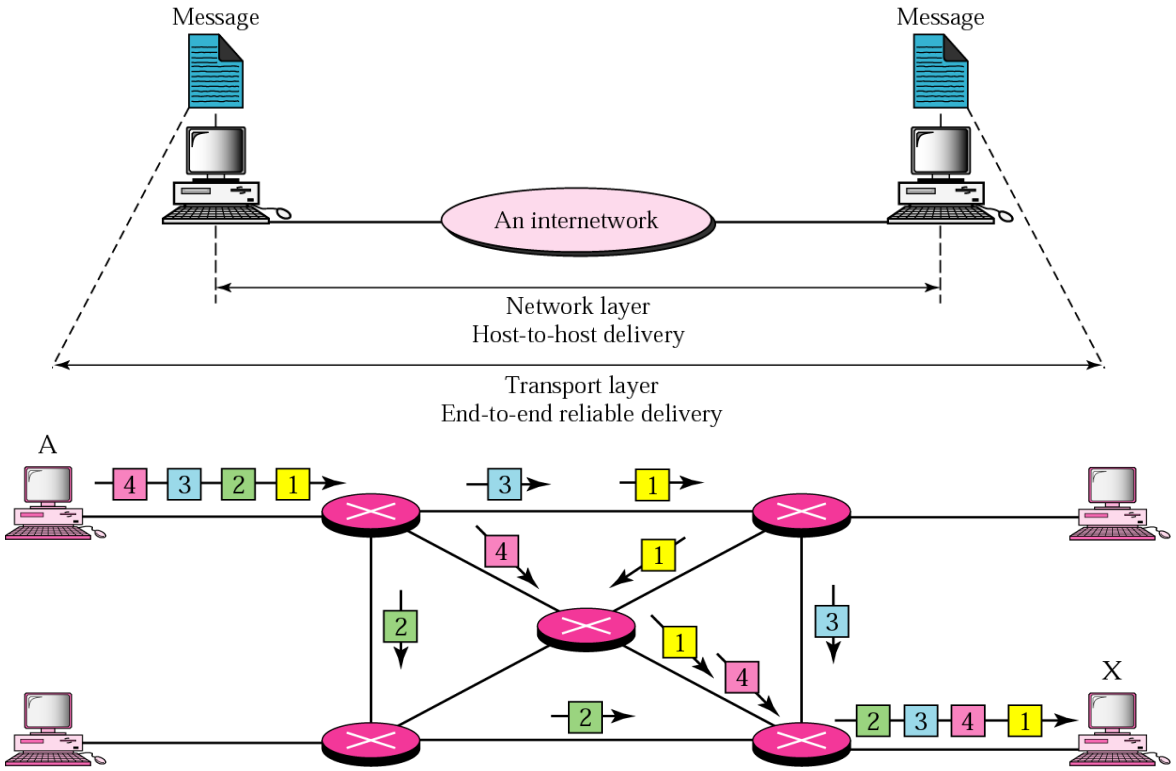
2) Packets come out of order?

3) Packets get lost?

Layered Internet Architecture (cont.)

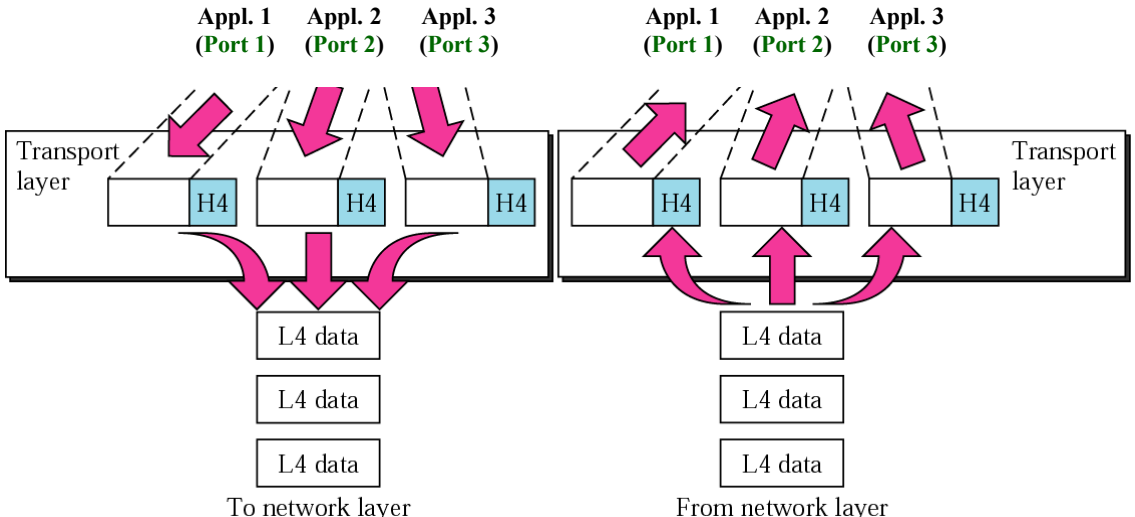
4. Transport Layer

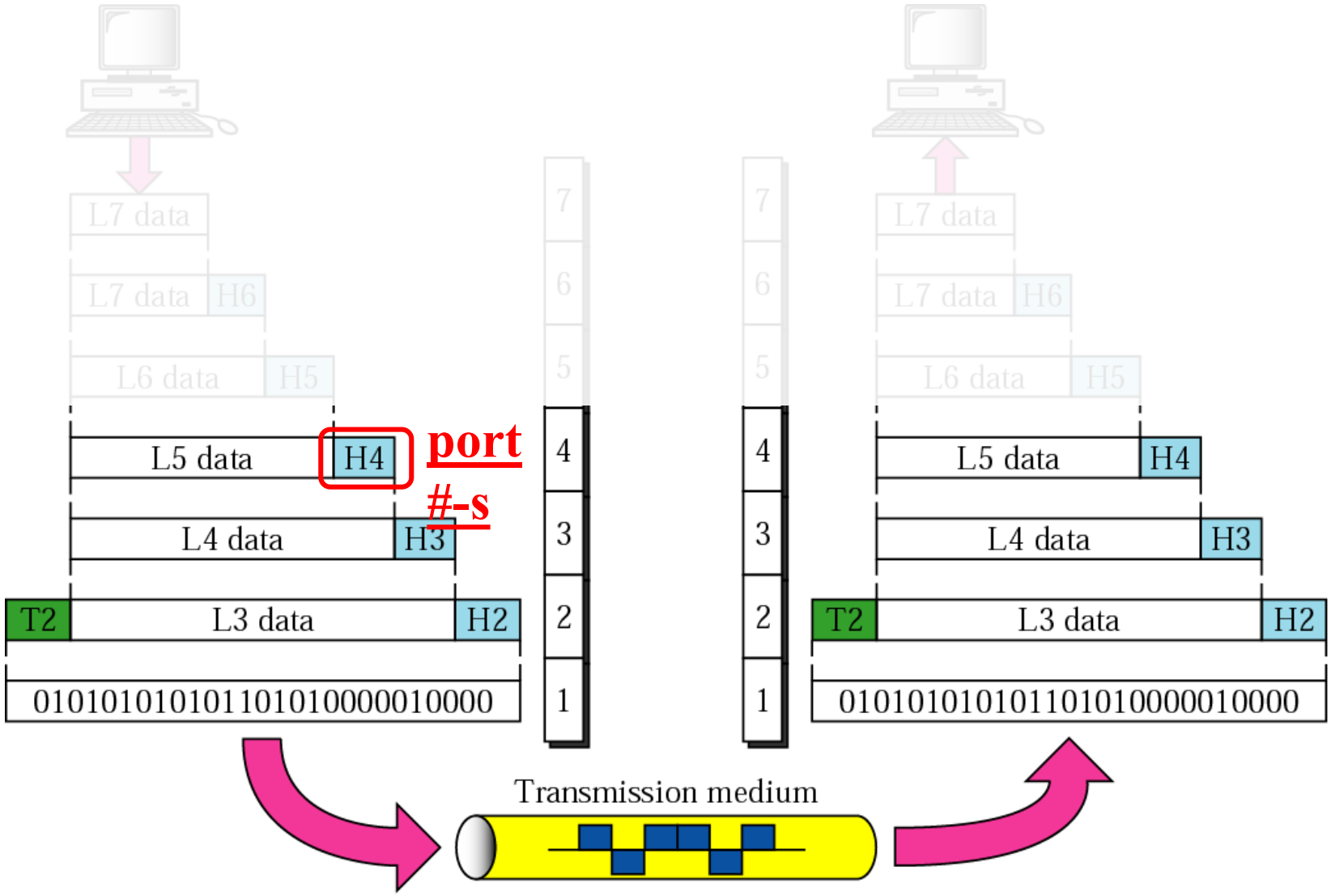
The transport layer is responsible for process-to-process delivery of entire message. While the network layer gets each packet to the correct computer, the transport layer gets the entire message to the correct process on that computer.



Layered Internet Architecture (cont.)

- **port addressing**: Computers often run several processes at the same time. For this reason, process-to-process delivery means delivery not only from one computer to the other but also from a specific process on one computer to a specific process on the other. The transport layer header therefore must include a type of address called a **port address**.
- **segmentation and reassembly**: A message is divided into segments, each segment containing a sequence number. These numbers enable the transport layer to reassemble the message correctly upon arrival at the destination, and to identify and replace packets that were lost in the transmission.
- **flow & error control**: Flow & error control at this layer are performed end-to-end rather than across a single link.



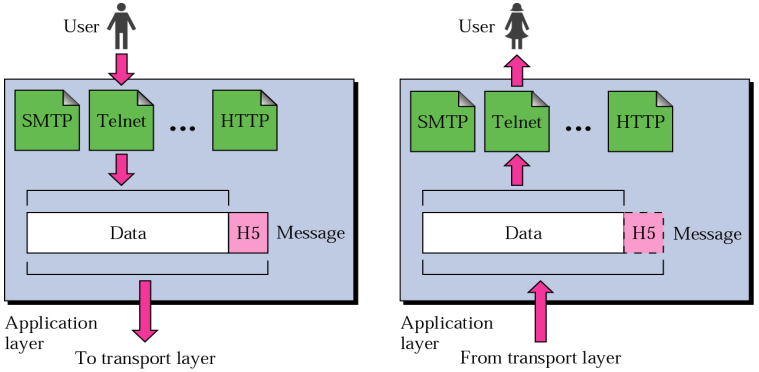

L7 data
L7 data H6
L6 data H5
L5 data H4
L4 data H3
T2 L3 data H2
0101010101011010100000010000
port #-s
7
6
5
4
3
2
1
Transmission medium

OSI Model: Application Layer

Application Layer (i.e. OSI Session + Presentation + Application Layer)

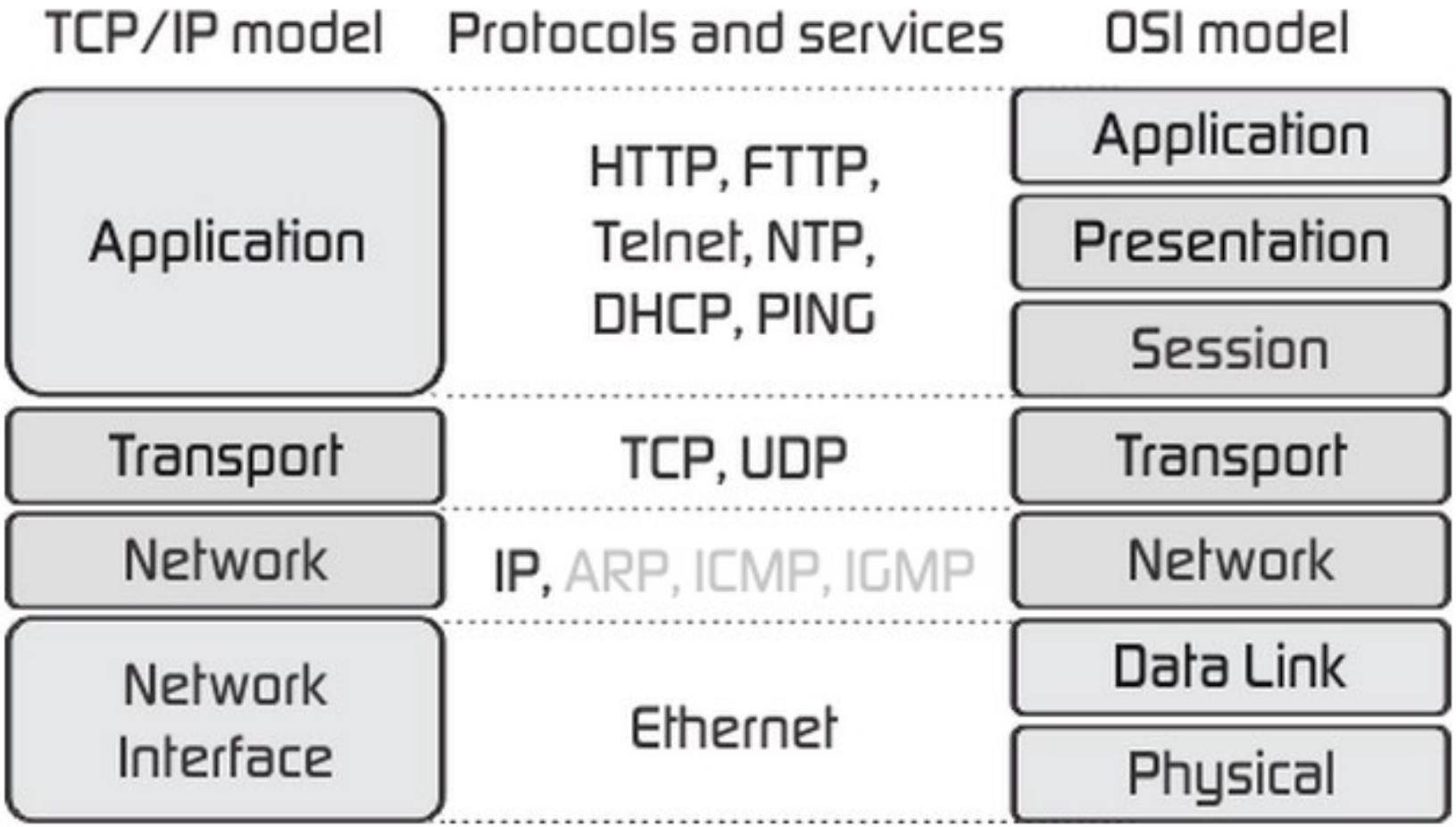
The application layer is responsible for providing the actual good-quality service to the user.

- **synchronization**: If a system is sending a large file, insert checkpoints every 100 pages to ensure that each 100-page unit is received and acknowledged independently. Thus, if a crash happens during the transmission of page 523, the only pages that need to be resend are pages 501 to 523.
- **encryption**: To carry sensitive information, a system must be able to ensure privacy. Encryption transforms the original information to another form, while decryption reverses the received message back to its original form.
- **compression**: Data compression reduces the number of bits contained in the information – it is particularly important in the transmission of multimedia.



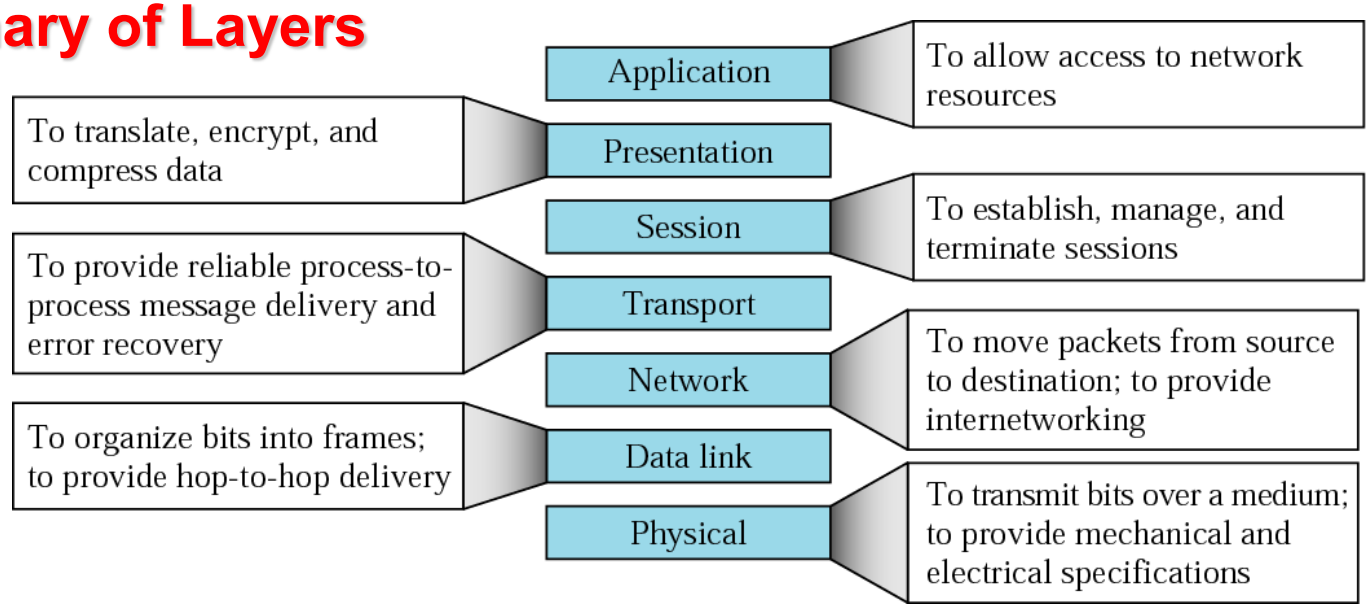
Layered Internet Architecture (cont.)

TCP/IP vs. OSI Model



Layered Internet Architecture (cont.)

Summary of Layers



Why 5 (7) Layers?

- **physical and application layer** = bottom and top
- **data link layer** – bundles all link-dependent details
- **network layer** – responsible for hop-to-hop routing
- **transport layer** – responsible for end-to-end flow control
- **session and presentation layer** – provide some useful features; these can be easily provided in application layer

Why did OSI Model Fail in Practice?

(1) Bad Timing

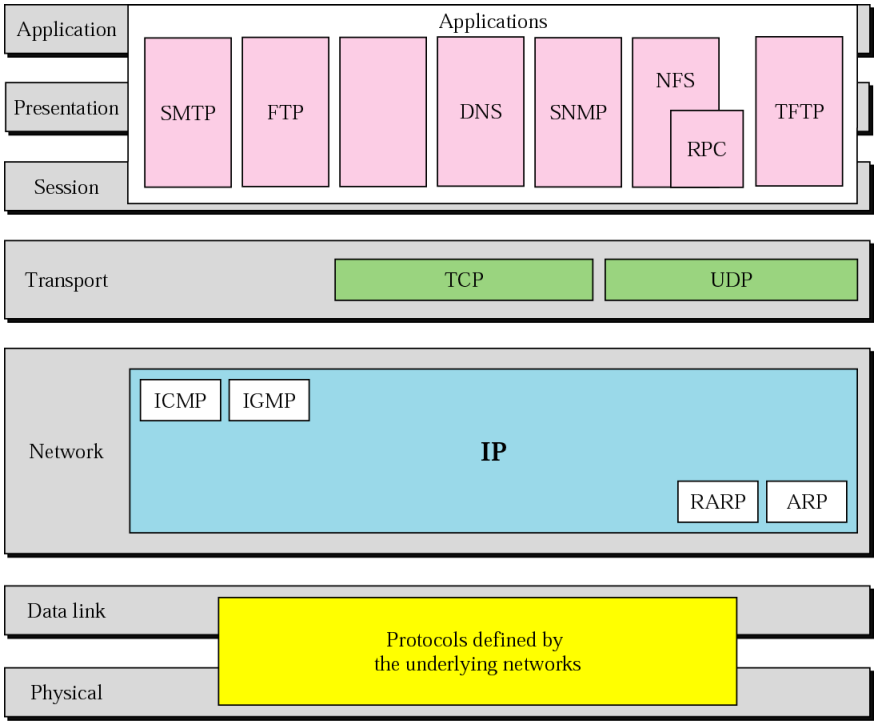
- although essential elements of OSI model were in place quickly, final standard (model + protocols) was not published until 1984
- by the time it took to develop OSI protocol standards, TCP/IP network architecture emerged as an alternative for open system interconnection
- free distribution of TCP/IP as part of Berkeley UNIX system ensured widespread use and development of numerous applications at various academic institutions

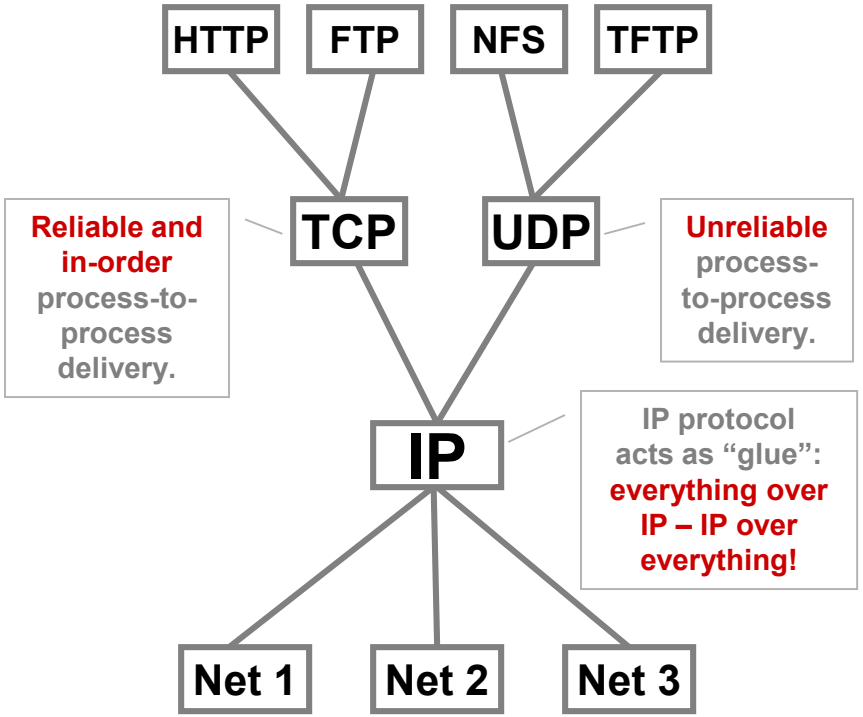
(2) Complexity and Inefficiency

- 7-layer OSI model was specified before there was much experience in designing large-scale OSI networks – several design choices were made in absence of concrete evidence of their effectiveness
- some functions, e.g. error control, appear in several layers (data link, transport, application) $\Rightarrow$ overall efficiency reduced

Internet Model

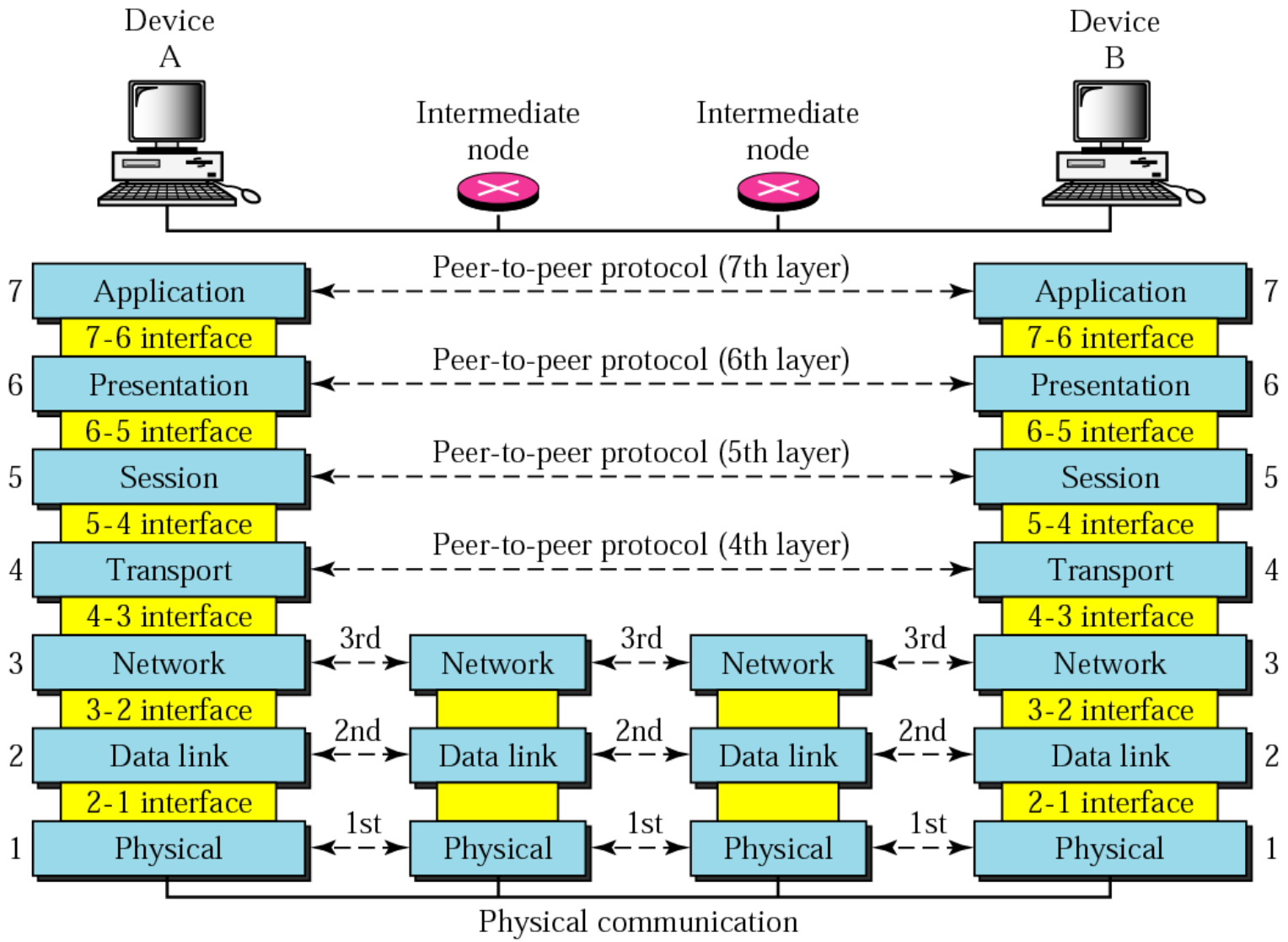
Internet Model and Hourglass Protocol Stack





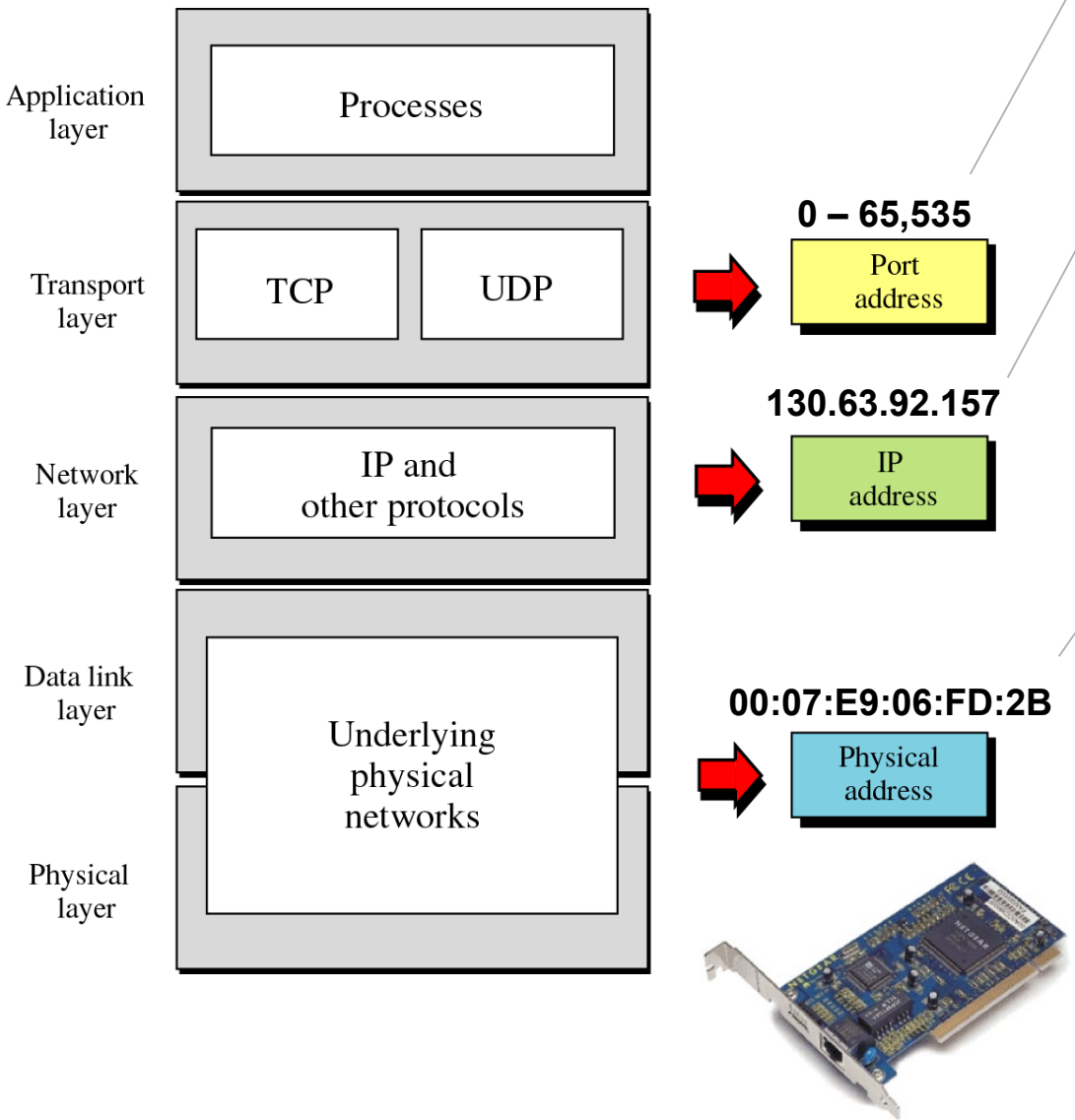
The operation of one single protocol at the network layer (IP protocol) over various networks provides independence from the underlying network technologies.
IP over anything, anything over IP!

OSI Model: Summary



Internet Model (cont.)

Addresses in TCP/IP Model



- **locally unique** logical address used to differentiate between applications sharing the same IP address

- **globally unique** logical address used to locate corresponding node in the entire Internet
- hierarchical addresses that can be easily aggregated in routing tables ⇒ **fast routing !**

- **globally unique** NIC address used to located corresponding node on a LAN
- each NIC on a subnetwork may have different manufactures ⇒

  we cannot aggregate physical addresses in routing tables ⇒

  large networks cannot use these addresses to identify hosts !