Chapter 2

Network Models

A Network is ..

- A combination of hardware (HW) and software (SW) that send *data* from one location to another.

  - HW: physical equipment that carries *signals* from one point of the network to another

  - SW: instruction sets that make possible the

Data transformed into the form of electromagnetic signals when sent along a transmission medium (link).

2-1   LAYERED TASKS

Topics discussed in this section:

- **Sender, Receiver, and Carrier**
- **Hierarchy**

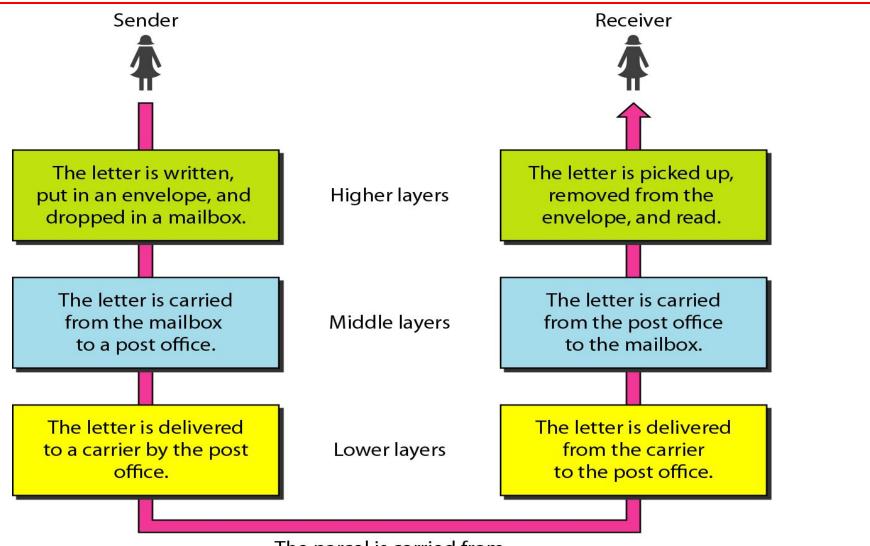# Network Architicture

- General blue prints that guide the design and implementation of networks.
- Examples:
    - OSI architicture
    - Internet architicture
- Abstraction of the different services and procedures.
- Abstraction naturally leads to layering.
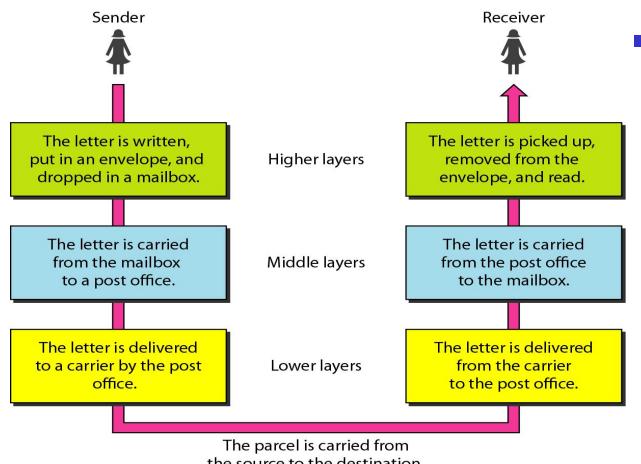
Concept of Layers

- We use the concept of layers in our daily life.

- As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.

Figure 2.1 Tasks involved in sending a letter

Sender

Receiver

The letter is written, put in an envelope, and dropped in a mailbox.

Higher layers

The letter is picked up, removed from the envelope, and read.

The letter is carried from the mailbox to a post office.

Middle layers

The letter is carried from the post office to the mailbox.

The letter is delivered to a carrier by the post office.

Lower layers

The letter is delivered from the carrier to the post office.

The parcel is carried from the source to the destination.

Hierarchy

Sender

Receiver

	Sender side		Receiver side

The letter is written, put in an envelope, and dropped in a mailbox.

Higher layers

The letter is picked up, removed from the envelope, and read.

The letter is carried from the mailbox to a post office.

Middle layers

The letter is carried from the post office to the mailbox.

The letter is delivered to a carrier by the post office.

Lower layers

The letter is delivered from the carrier to the post office.

The parcel is carried from the source to the destination.

- **The tasks must be performed in the order specified by the hierarchy of the layers!**

Concept of Layers

- Each layer provides a specific set of services.

- Services are provided through the definition of *protocols*.

- Each layer uses the services provided by the lower/above layers.

- Layers use protocols to communicate with each others.

Concept of Layers

- Each layer provides a specific set of services.

- Layering provides two nice features:
  - Decomposes the problem of building a network into more manageable components.
  - Provides a more modular design, modifying the functionality of the different layers without affecting the whole system!

2-2   THE OSI MODEL

Topics discussed in this section:

- **Layered Architecture**
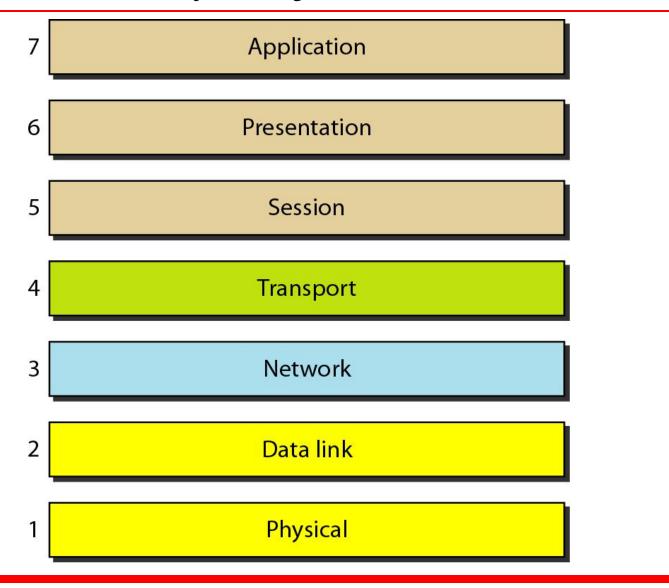- **Peer-to-Peer Processes**
- **Encapsulation**

The OSI Model

- An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model.

- An **open system** is a set of protocol that allows any two different systems to communicate regardless of their underlying architecture (H/W and S/W).

ISO is the organization.
OSI is the model.

The OSI Model

- The OSI model is a layered framework for the design of network systems that allows for communication between all types of computer systems.

- It consists of seven separate but related layers, each of which defines a part of the process of moving information across a network.

Figure 2.2 *Seven layers of the OSI model*

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data link
1	Physical

The ISO/OSI Reference Model

ISO: International Standards Organization

OSI: Open Systems Interconnection

The protocol *stack*:

The idea behind the model:
Break up the design to make implementation simpler. Each layer has a well-defined function. Layers pass to one another only the information that is relevant at each level. Communication happens only between adjacent layers.

Application
Presentation
Session
Transport
Network
Data link
Physical

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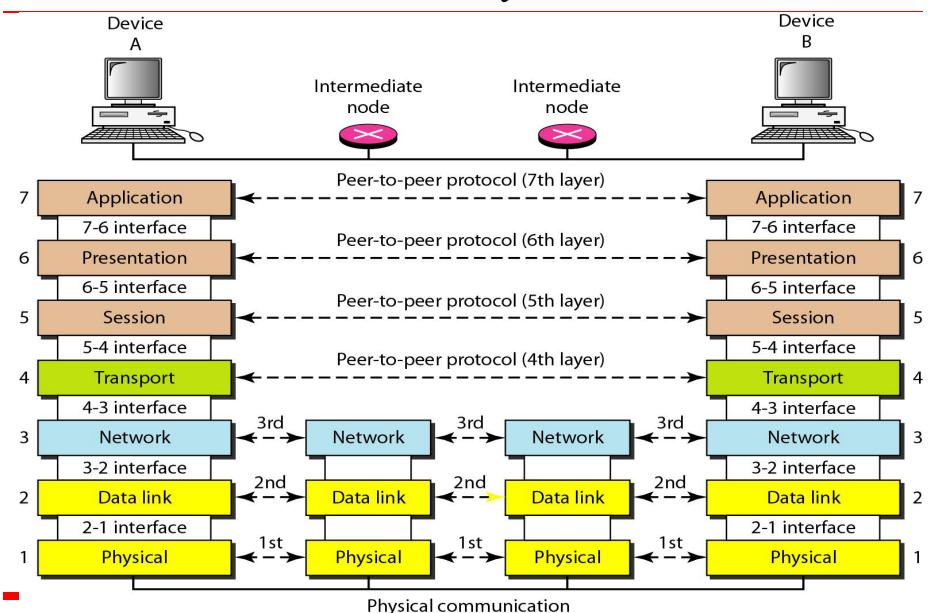
Layered Architecture

- OSI model consists of 7 layers.

- Each layer defines a family of functions distinct from those of the other layers.

- Within a single machine, each layer calls upon the services of the layer just below it.

  - *e.g. layer 3 uses the services provided by layer 2 and provides services for layer 4.*

Layered Architecture

- Between machines, layer x on one machine communicate with layer x on another machine.

- This communication is govern by an agreed-upon series of rules and convention called protocols.

- Communication between machines is a **peer-to-peer** process using the protocols appropriate to a given layer.

The interaction between layers in the OSI model

Device A — Device B

Intermediate node — Intermediate node

Peer-to-peer protocol (7th layer)

| 7 | Application | ← - - - → | Application | 7 |

7-6 interface

Peer-to-peer protocol (6th layer)

| 6 | Presentation | ← - - - → | Presentation | 6 |

6-5 interface

Peer-to-peer protocol (5th layer)

| 5 | Session | ← - - - → | Session | 5 |

5-4 interface

Peer-to-peer protocol (4th layer)

| 4 | Transport | ← - - - → | Transport | 4 |

4-3 interface

| 3 | Network | 3rd | Network | 3rd | Network | 3rd | Network | 3 |

3-2 interface

| 2 | Data link | 2nd | Data link | 2nd | Data link | 2nd | Data link | 2 |

2-1 interface

| 1 | Physical | 1st | Physical | 1st | Physical | 1st | Physical | 1 |

Physical communication

2.17

Peer-to-Peer Process

- At the physical layer, communication is direct where device A sends a stream of bits to device B. The bits must be converted to a form that can be transmitted to the receiving device.

- At the higher layers, communication must move down through the layers on device A over to device B and then back up through the layers.

Peer-to-Peer Process

- *Interfaces Between Layers*
    - The passing of the data and network information down/up through the layers in sending/ receiving require an **interface** between each pair of adjacent layers.
    - Well-defined interfaces and layer functions provide modularity to a network.
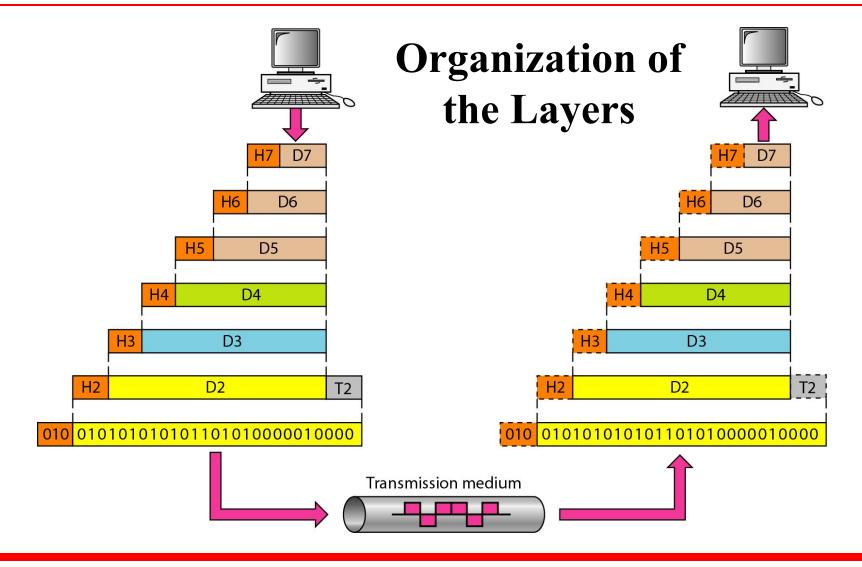
Organization of the Layers

- The seven layers can be thought of as belonging to three subgroups:

1) **Layers 1,2, and 3** – physical, data link, and network – are the network support layers.

2) **Layers 5,6, and 7** – session, presenation, and application – are user support layers; they allow interoperability among unrelated software systems.

Organization of the Layers

- The seven layers can be thought of as belonging to three subgroups:

    3) Layer 4, the transport layer, links the two groups and ensures that what the lower layers have transmitted is in a form that the upper layers can use.

- The upper OSI layers almost implemented in S/W; lowers layers are combination of S/W and H/W except for the physical layer which is mostly H/W.

Figure 2.4 *An exchange using the OSI model*

Organization of the Layers

Encapsulation

- Another aspect of data communications in the OSI model is *encapsulation*.

    - The data protion of a packet at level *N-1* carries the whole packet (data and header and maybe trailer) from level *N*.

    - Level *N-1* is not aware of which part of the encapsulated packet is data and which part is the header or trailer.

    - For level N-1, the whole packet coming from level N is treated as one logical unit.

2-3   LAYERS IN THE OSI MODEL

In this section we briefly describe the functions of each layer in the OSI model.

Topics discussed in this section:

Physical Layer
Data Link Layer
Network Layer
Transport Layer
Session Layer
Presentation Layer
Application Layer

Physical layer
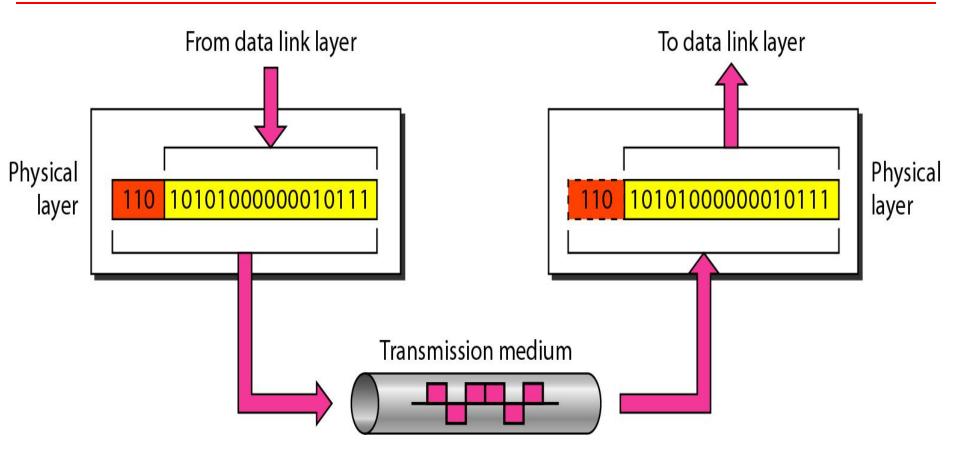
- The physical layer coordinate the functions required to carry a bit stream over a physical medium including:

  - Dealing with the mathematical and electrical specifications of the interfaces and transmission medium.

  - It defines the procedures and functions that physical devices and interfaces have to perform for transmission to occur.

Physical layer

- The physical layer is also concerned with:
  - Physical characteristics of interfaces and medium.
  - Representation of bits
  - Data rate
  - Synchronization of bits
  - Line configuration
  - Physical topology
  - Transmission mode
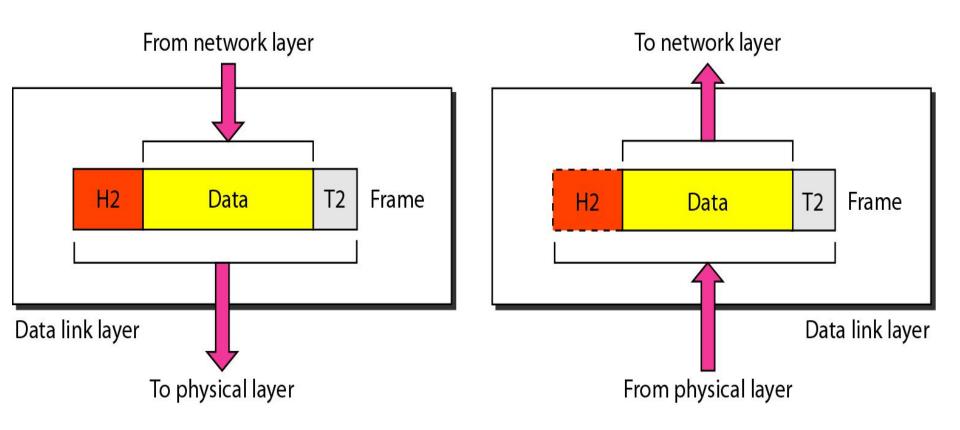
Figure 2.5 *Physical layer*

From data link layer

To data link layer

Physical layer

110 10101000000010111

Physical layer

110 10101000000010111

Transmission medium

Data Link layer

- The data link layer transforms the physical layer to reliable link.

- It makes the physical layer appear error-free to the upper layer (network layer).
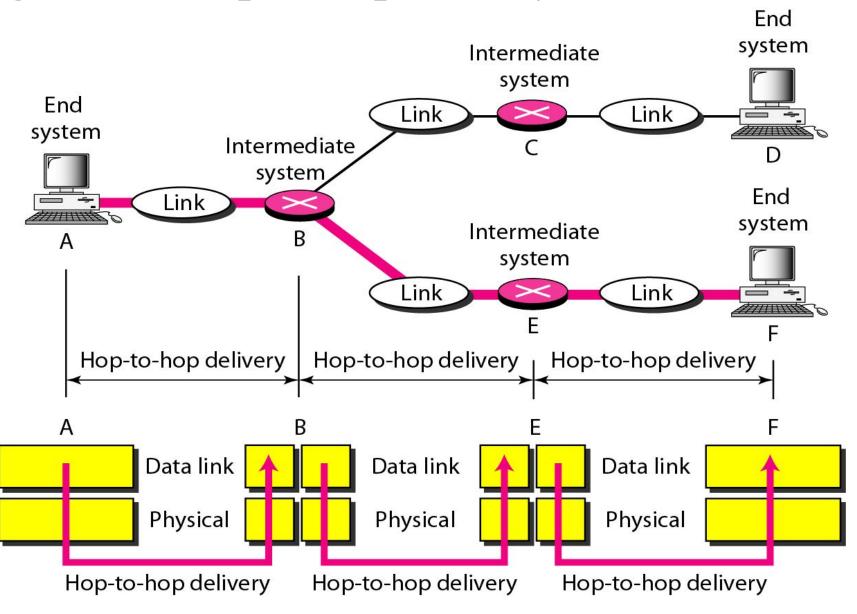
Figure 2.6 *Data link layer*

Data Link layer

- The data link layer provides *hop-to-hop delivery*.

Figure 2.7 *Hop-to-hop delivery*
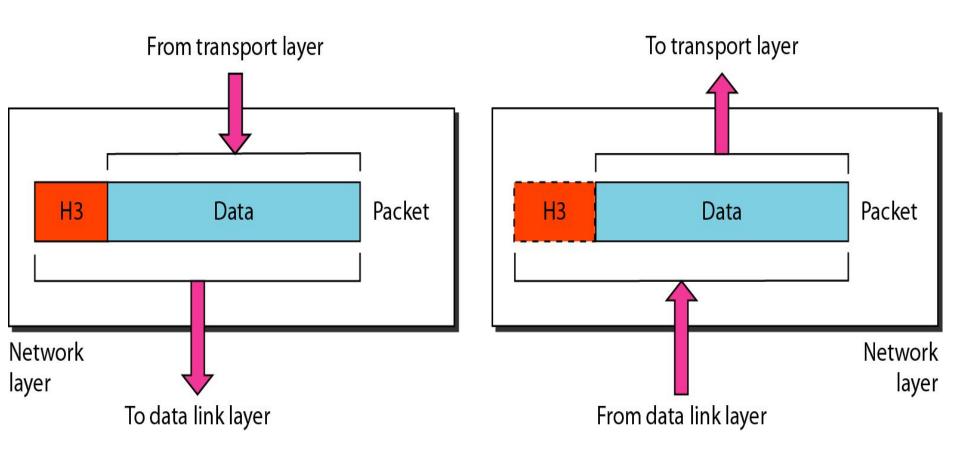
Data Link layer

- There are other responsibilities of data link layer include:
  - *Framing*
  - *Physical addressing*
  - *Flow control*
  - *Error control*
  - *Access control*

Network layer

- The network layer is responsible for the delivery of individual packets from the source host to the destination host.

- At the sender side, data is received from the higher layer (transport) and passed down to the lower layer (data link).

- At the sender side, data is received from the lower layer (data link) and passed up to the upper layer (transport).
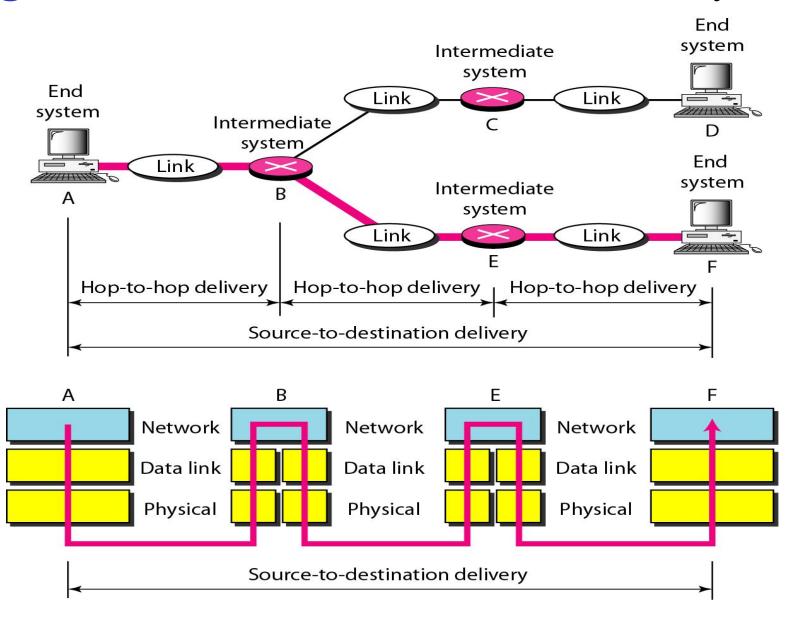
Figure 2.8 *Network layer*

Network layer

- Again, the network layer is responsible for the delivery of individual packets from source to destination.

- If two systems are connected to the same link, there is usually no need for a network layer.

- If the two systems are attached to different networks with connecting devices between the networks, there is often a need for the network layer to accomplish *source-to-destination delivery*.
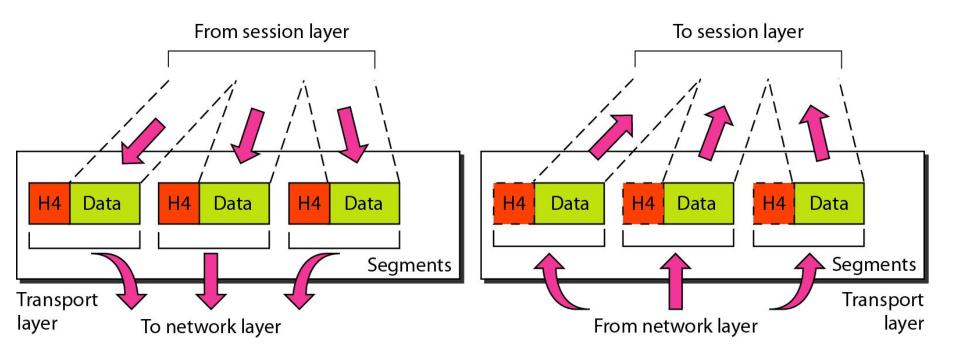
Figure 2.9 *Source-to-destination delivery*

Network layer

- Other responsibilities of network layer include:
    - *Logical addressing*
    - *Routing*

Transport layer

- The transport layer is responsible for the delivery of a message from one **process** to another.

- At the sender side, it receives application data and passes it down to the network layer.

- At the receiver side, it receives data from the network layer and passes it up to the appropriate process.
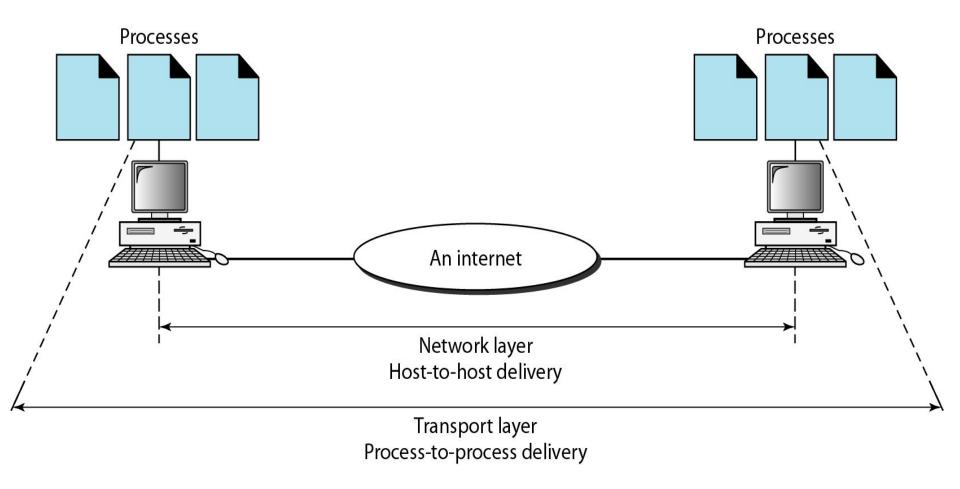
Figure 2.10   *Transport layer*

Transport layer

- Again, the transport layer is responsible for the delivery of a message from one **process** to another.

- Unlike the network layer which is source-to-destination delivery, the transport layer is *process-to-process delivery* of the entire message.

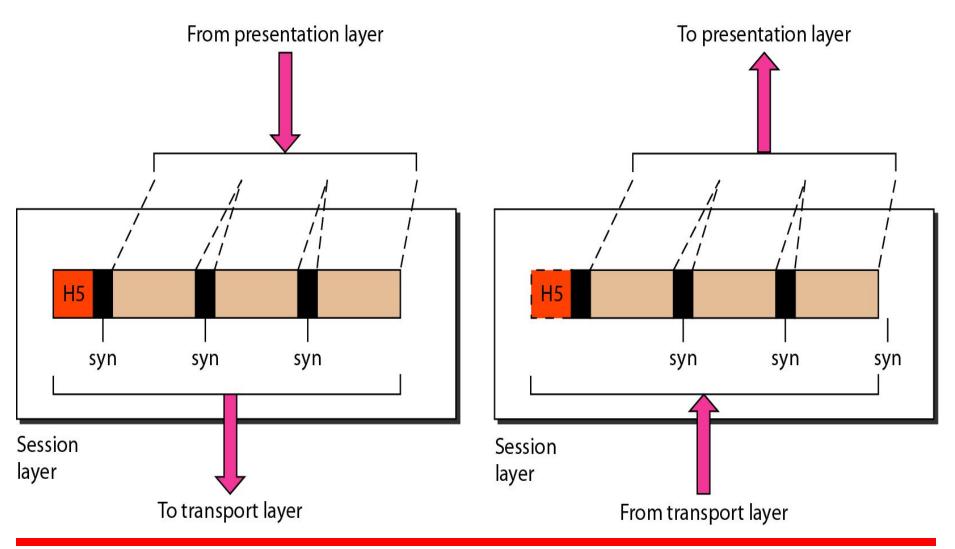# Figure 2.11   *Reliable process-to-process delivery of a message*

Processes

Processes

An internet

Network layer
Host-to-host delivery

Transport layer
Process-to-process delivery

Transport layer

- Other responsibilities of transport layer:
  - *Service-point addressing*
  - *Segmentation and reassembly*
  - *Connection control*
  - *Flow control*
  - *Error control*

Session layer

- The session layer is responsible for dialog control and synchronization.

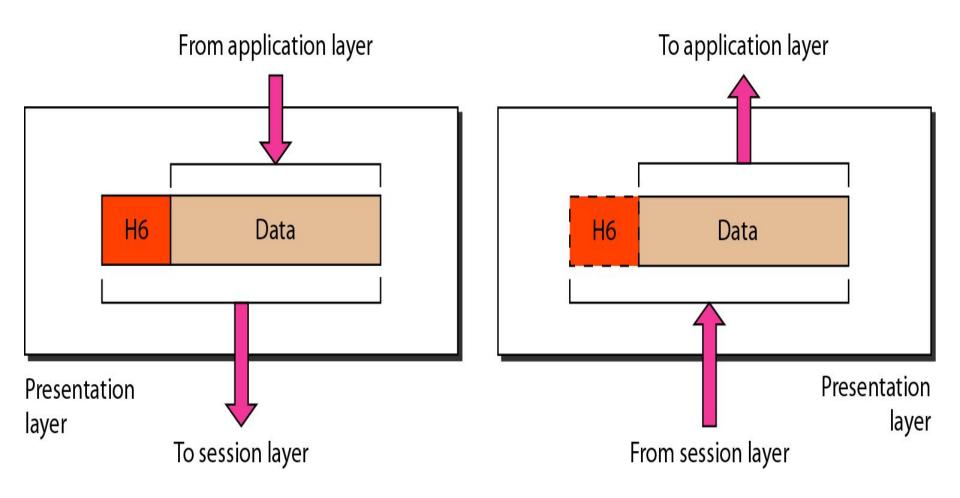# Figure 2.12 *Session layer*

Session layer

- Specific responsibilities of the session layer include:
  - *Dialog control*
  - *Synchronization*

Presentation layer

- The presentation layer is concerned with syntax and semantics of the information exchange between two systems.
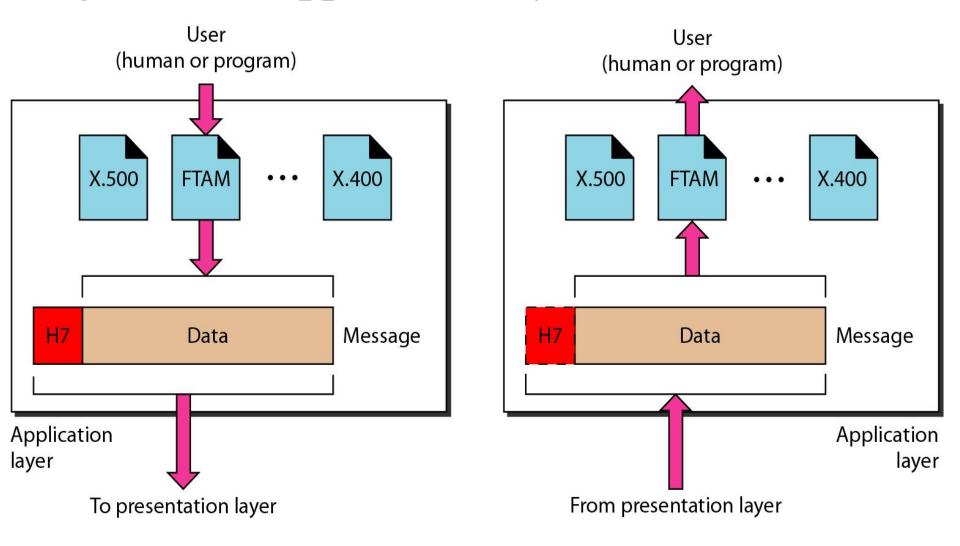
Figure 2.13 *Presentation layer*

Presentation layer

- Specific responsibilities of presentation layer:
  - *Translation*
  - *Encryption*
  - *Compression*

Application layer

- The application layer enables user, weather human or software, to access the network.

- It provides user interfaces and support for services such as e-mail, remote file access and transfer, shared database management, and other types of distributed information services.
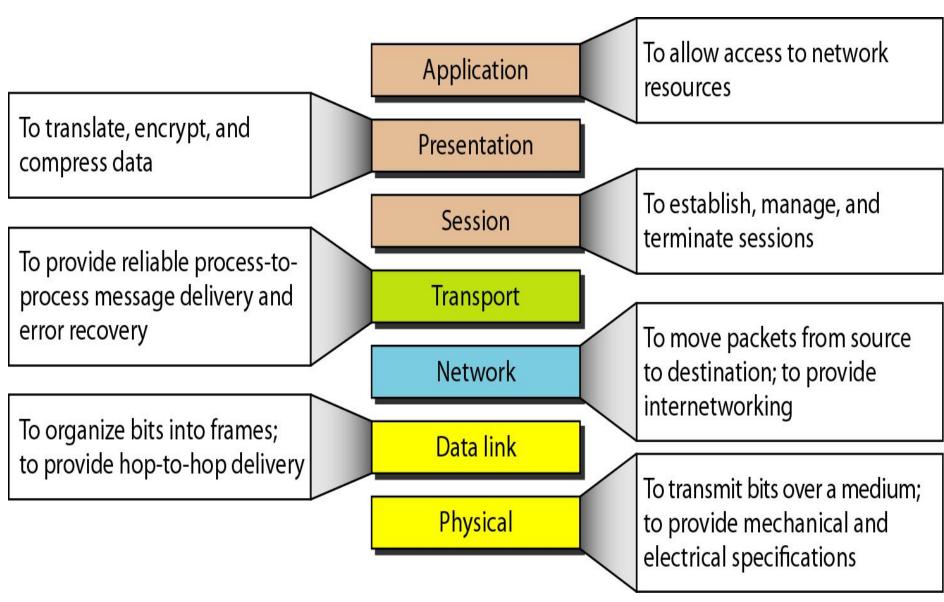
Figure 2.14 *Application layer*

Application layer

- Specific responsibilities of presentation layer:
  - *Network virtual terminal*
  - *File transfer, access, and management*
  - *Mail services*
  - *Directory services*

Figure 2.15 *Summary of layers*

	Layer	
	Application	To allow access to network resources
To translate, encrypt, and compress data	**Presentation**	
	Session	To establish, manage, and terminate sessions
To provide reliable process-to-process message delivery and error recovery	**Transport**	
	Network	To move packets from source to destination; to provide internetworking
To organize bits into frames; to provide hop-to-hop delivery	**Data link**	
	Physical	To transmit bits over a medium; to provide mechanical and electrical specifications

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- *The layers in the TCP/IP protocol suite do not exactly match those in the OSI model.*

- *The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application.*

- *When TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers: physical, data link, network, transport, and application.*

The Layers in the TCP/IP Protocol Suite

Application					
Presentation	FTP	HTTP	DNS	NFS	**• • •**
Session					

Transport	TCP	UDP

ICMP IGMP

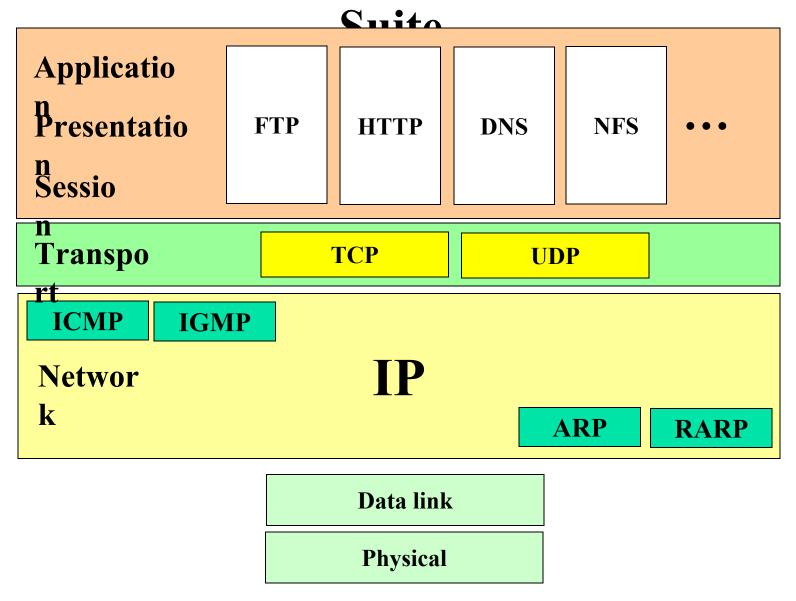**Network** **IP**

ARP RARP

Data link

Physical

Figure 2.16 *TCP/IP and OSI model*

- TCP/IP is a hierarchical protocol made up of interactive modules, each of which provides a specific functionality.
- The layers of the TCP/IP protocol suite contain relatively independent protocols.
- The term hierarchical means that each upper-level protocol is supported by one or more lower-level protocols.

- **Physical and Data Link Layers**
  - No specific protocol is defined at this layer, rather, TCP/IP model supports all the standard and proprietary protocols.
  - For instance, a network in a TCP/IP internetwork can be a local-area network or a wide-area network.

Network layer (internetwork layer)

- TCP/IP at this layer supports the Internetworking Protocol (IP)

- There are also some other protocols that support data movement in this layer. Including: ARP, RARP, ICMP, and IGMP.

Protocols at The Network Layer

- *Internetworking Protocol (IP)*
  - Most important protocol of the TCP/IP network stack!
  - Implements internetworking.
  - IP is an unreliable and connectionless protocol- a best-effort delivery.
  - It is host-to-host protocol.

Protocols at The Network Layer

- ***Address Resolution Protocol (ARP)***
  - It is used to find the physical address (NIC) of the node after its Network address is known.

- ***Reverse Address Resolution Protocol (RARP)***
  - It is used to find the Internet address of the node after its physical address is known.

Protocols at The Network Layer

- *Internet Control Message Protocol (ICMP)*
  - It is used by hosts and gateways to send notification of datagrams (packets) problem back to the sender.
- *Internet Group Message Protocol (IGMP)*
  - It is used to facilitate the simultaneous transmission of messages to a group of recipients.

Transport Layer

- In this layer, the protocol is responsible for delivery of message from a process to another process.

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Protocols at The Transport Layer

- ***User Datagram Protocol (UDP)***

  - It adds port addresses, checksum error control, and length information to the data from the upper layer.

- ***Transmission Control Protocol (TCP)***

  - It is reliable and connection-oriented.

Protocols at The Transport Layer

- ***Stream Control Transmission Protocol (STCP)***

- It supports the newer application e.g. voice over the Internet.

- It combine best features of UDP and TCP.

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Application Layer

- The application layer in TCP/IP is equivalent to the combined session, presentation, and application.

2-5   ADDRESSING

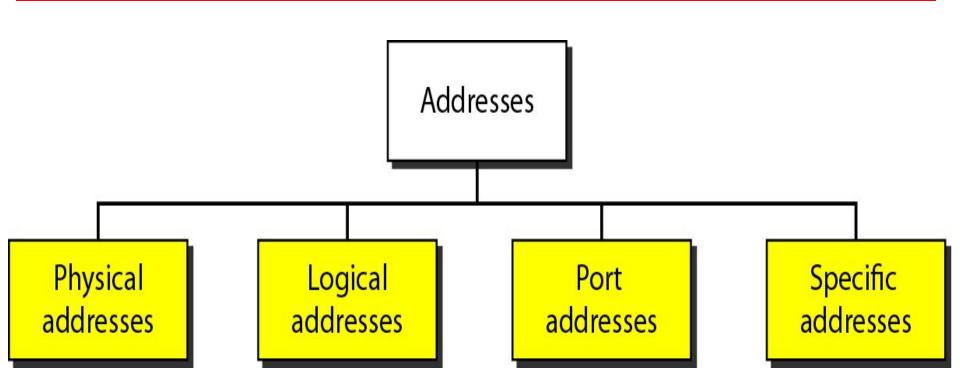*Four levels of addresses are used in an internet employing the TCP/IP protocols:*
- *physical (link) addresses ,*
- *logical (IP) addresses,*
- *port addresses, and*
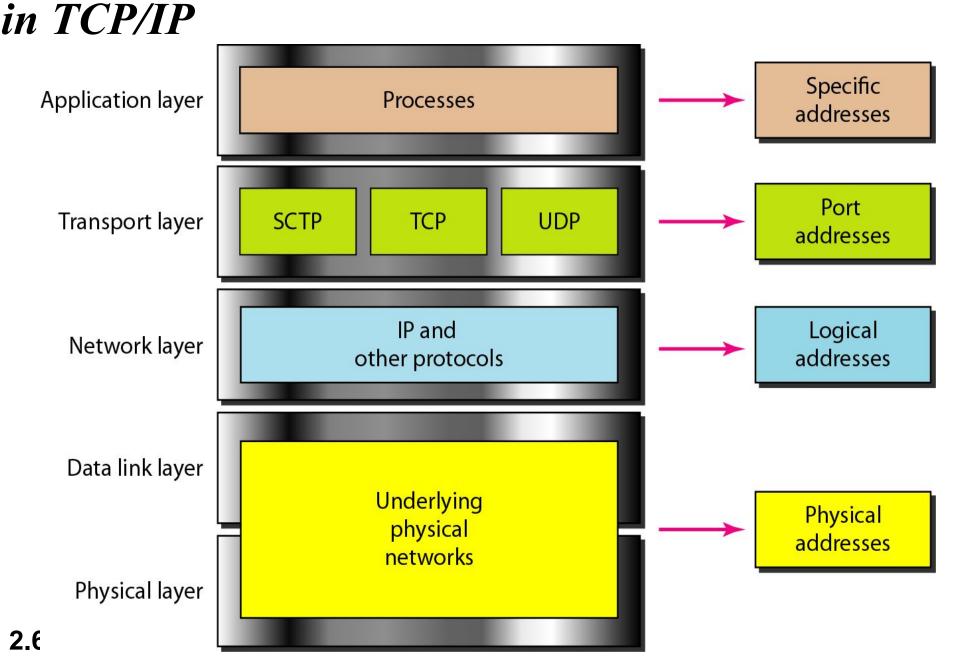- *specific addresses.*

2-5   ADDRESSING

Topics discussed in this section:

Physical Addresses
Logical Addresses
Port Addresses
Specific Addresses

Figure 2.17 *Addresses in TCP/IP*
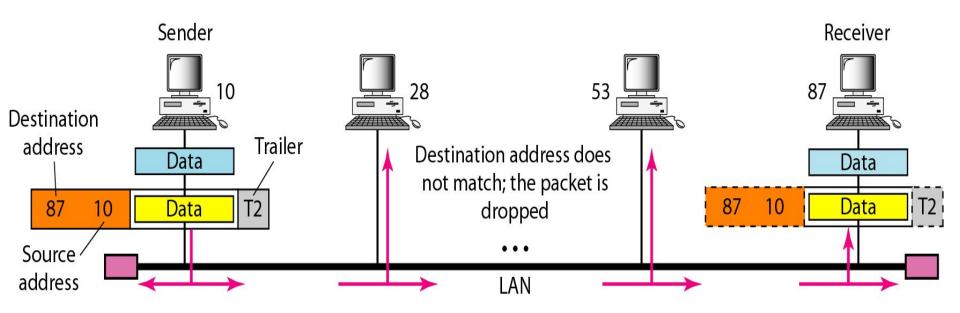
Figure 2.18 *Relationship of layers and addresses in TCP/IP*

Application layer	Processes	→ Specific addresses
Transport layer	SCTP TCP UDP	→ Port addresses
Network layer	IP and other protocols	→ Logical addresses
Data link layer	Underlying physical networks	→ Physical addresses
Physical layer		

- *Physical Addresses*
  - It is knwon as link address .
  - It is the address of a node as defined by its LAN or WAN.
  - The size and format of the address depends on the network.
    - Ethernet uses 6-bytes (48-bits) □ NIC
    - LocalTalk (Apple) uses 1-byte dynamic address

Example 2.1

In Figure 2.19 a node with physical address 10 sends a frame to a node with physical address 87. The two nodes are connected by a link (bus topology LAN). As the figure shows, the computer with physical address 10 is the sender, and the computer with physical address 87 is the receiver.

Figure 2.19 *Physical addresses*

Example 2.2

As we will see in Chapter 13, most <u>local-area networks</u> use a 48-bit (6-byte) physical address written as 12 hexadecimal digits; every byte (2 hexadecimal digits) is separated by a colon, as shown below:

07:01:02:01:2C:4B

A 6-byte (12 hexadecimal digits) physical address.

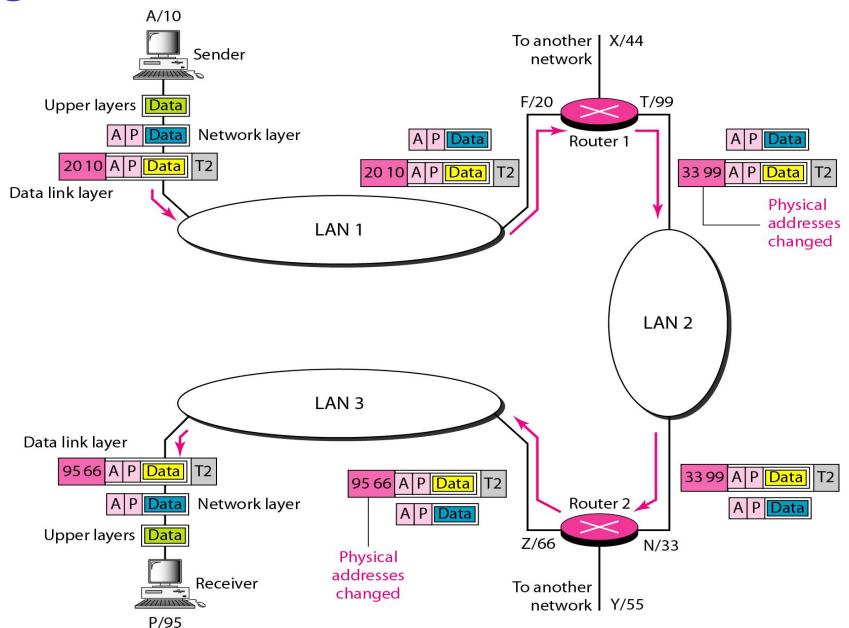**Also known as a MAC address**

2-5   ADDRESSING

- *Logical Addresses*

  - Necessary for universal communications that are independent of underlying physical networks.

  - *Physical address is not enough in an internetwork environment where the different network can have different address formats.*

  - A logical address in the Internet is **32-bits**.

Example 2.3

Figure 2.20 shows a part of an internet with two routers connecting three LANs. Each device (computer or router) has a pair of addresses (logical and physical) for each connection. In this case, each computer is connected to only one link and therefore has only one pair of addresses. Each router, however, is connected to three networks (only two are shown in the figure). So each router has three pairs of addresses, one for each connection.

Figure 2.20 IP addresses

Note

- The physical addresses will change from hop to hop, but the logical addresses usually remain the same.
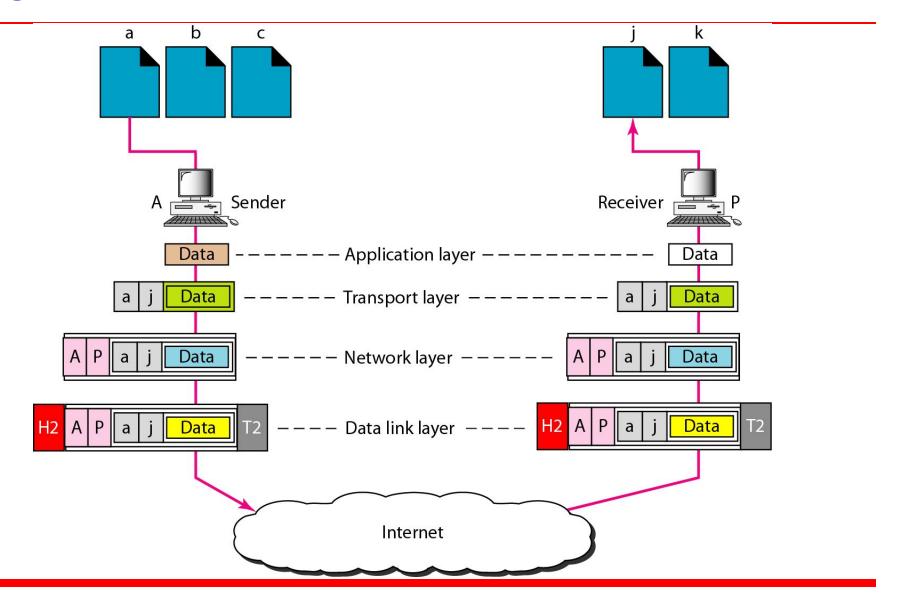- No two hosts on the Internet have the same IP address.

2.76

- *Port Addresses*
  - It is necessary for the receiver device that runs multiple process to receive data simultaneously □ this make a need to label each process
  - A port address is **16-bits**.

Example 2.4

Figure 2.21 shows two computers communicating via the Internet. The sending computer is running three processes at this time with port addresses a, b, and c. The receiving computer is running two processes at this time with port addresses j and k. Process a in the sending computer needs to communicate with process j in the receiving computer. Note that although physical addresses change from hop to hop, logical and port addresses remain the same from the source to destination.

Figure 2.21 Port addresses

Example 2.5

As we will see in Chapter 23, a port address is a 16-bit address represented by one decimal number as shown.

753

**A 16-bit port address represented
as one single number.**

Note

The physical addresses change from hop to hop,
but the logical and port addresses usually remain the same.

- *Specific Adresses*
  - Examples
    - *e-mail address*
    - *URL address*

  - Those addresses get changed to the corresponding port and logical address by the sending computer.