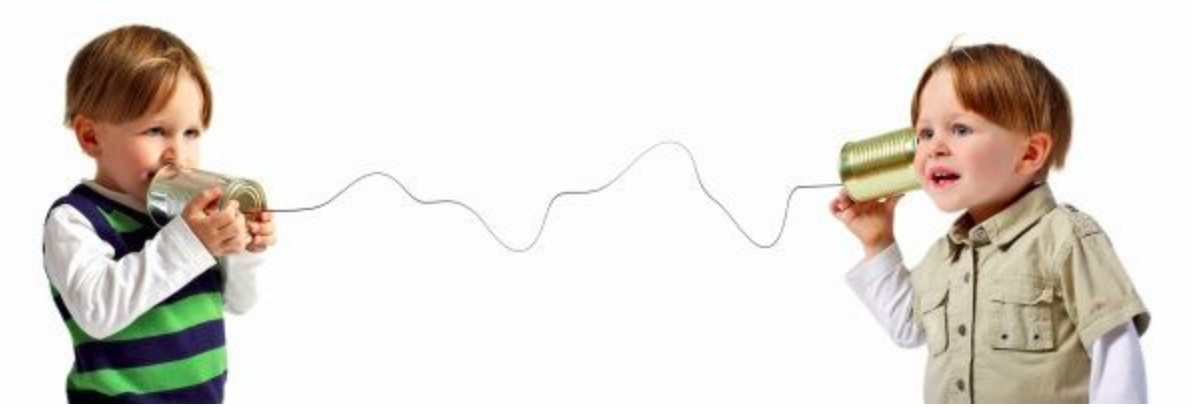
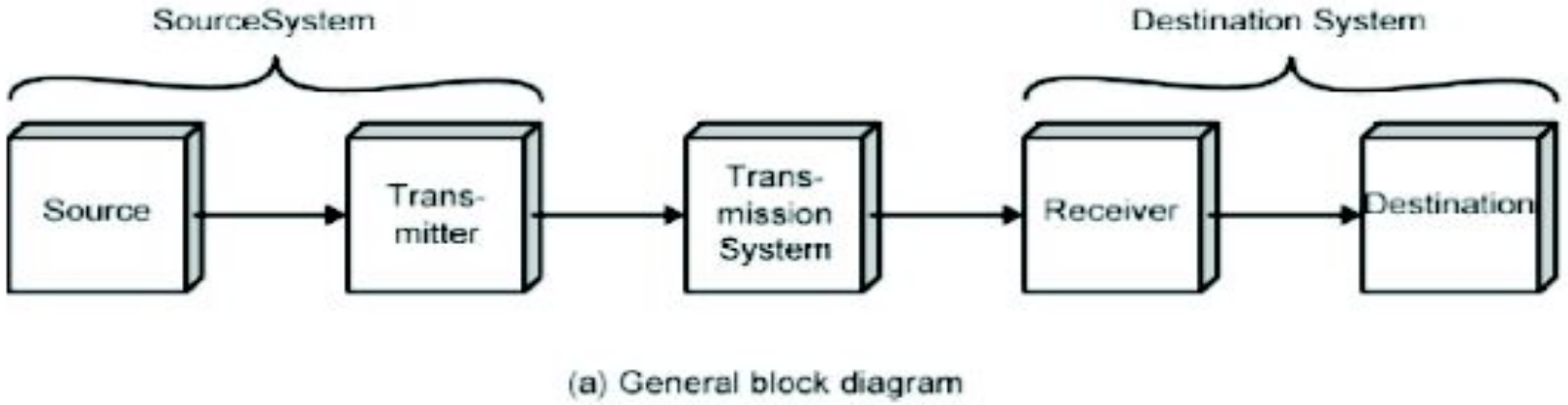
Basics of Data Communication

Process of transmitting data from one point to another



Simplified Communications Model - Diagram



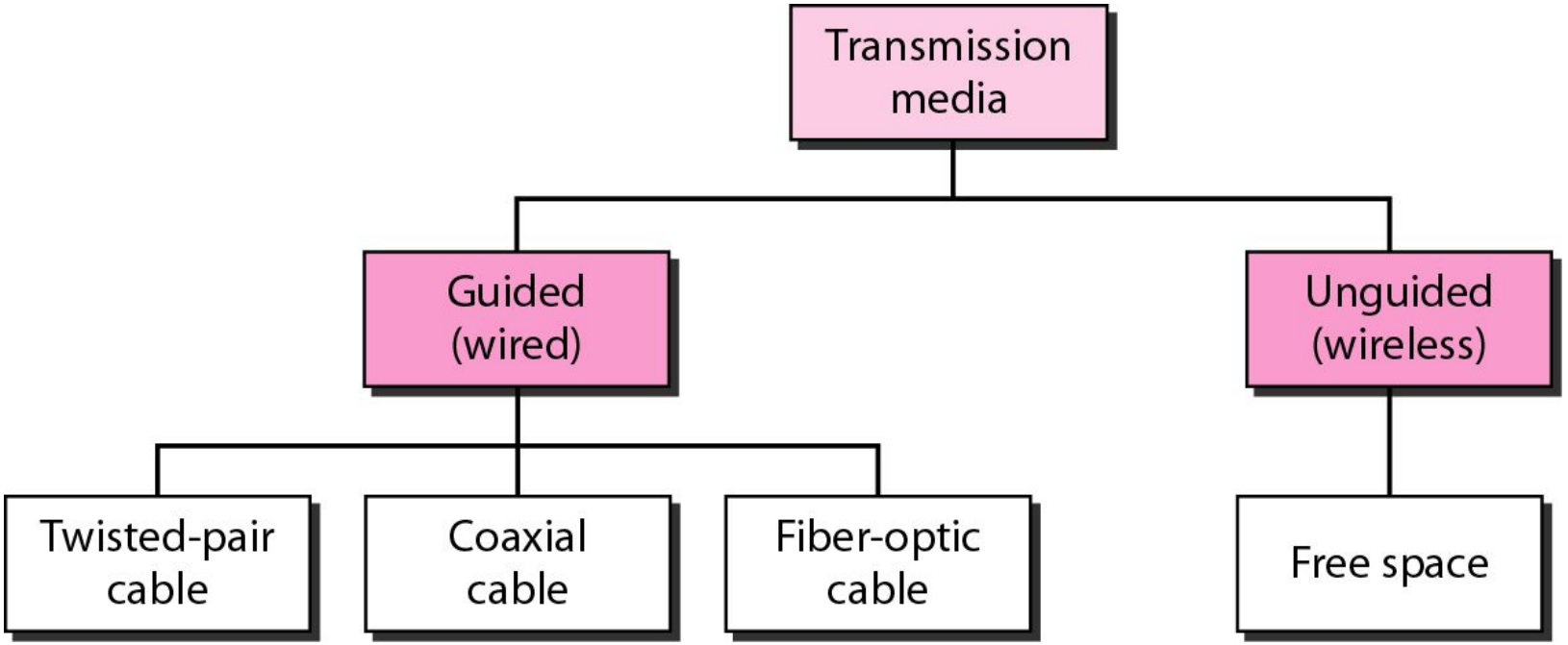
(a) General block diagram

(b) Example

Key elements in the model

- **Source**: Device which generates the data to be transmitted
- **Transmitter**: Device which transforms and encodes the information that needs to be transmitted
- **Transmission medium**: provides the path for data communication
- **Receiver**: Device which accepts the signal from the transmission media and converts in to a form that can be handled by the destination device
- **Destination**: Takes the incoming data from the receiver

Transmission Medium *medium and physical layer*



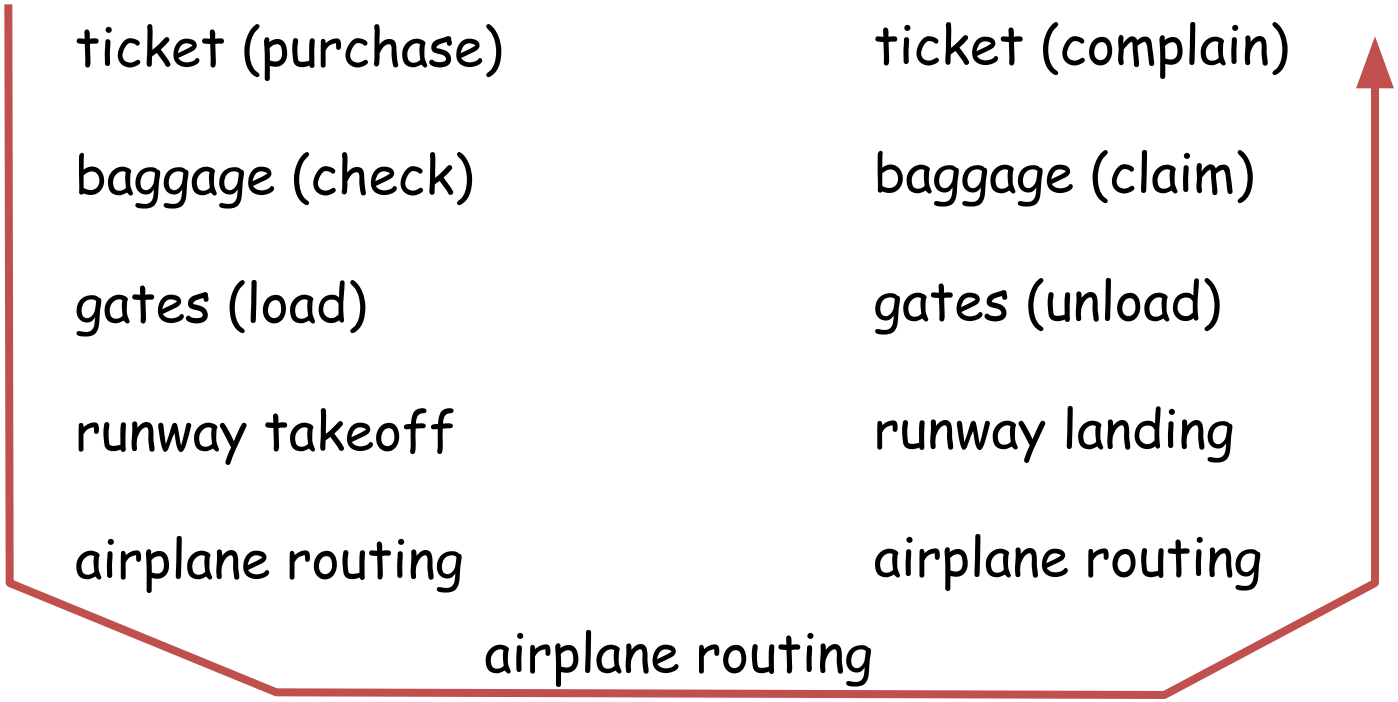
Protocol “Layers”

Networks are complex!

- many “pieces”:
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

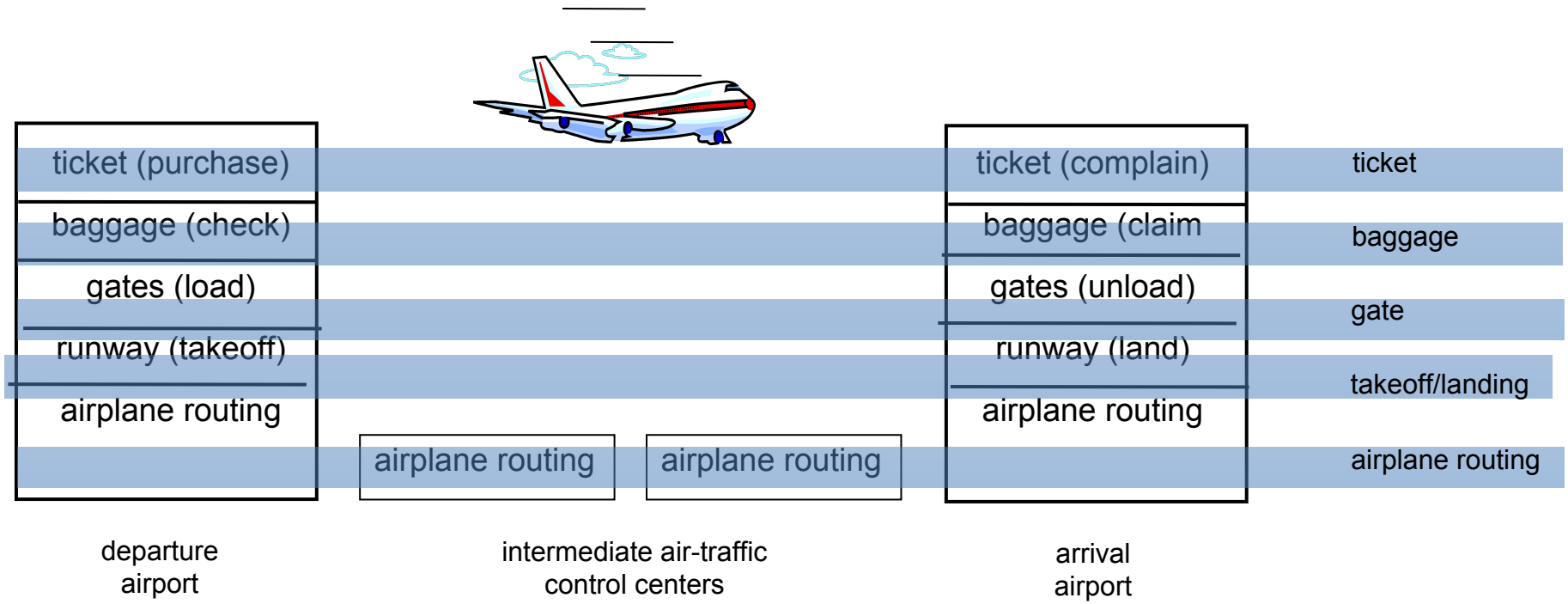
Protocol is a set of rules that govern a data communication.

Organization of air travel



- a series of steps

Layering of airline functionality



Layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

Why layering?

Dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

Protocol Stack

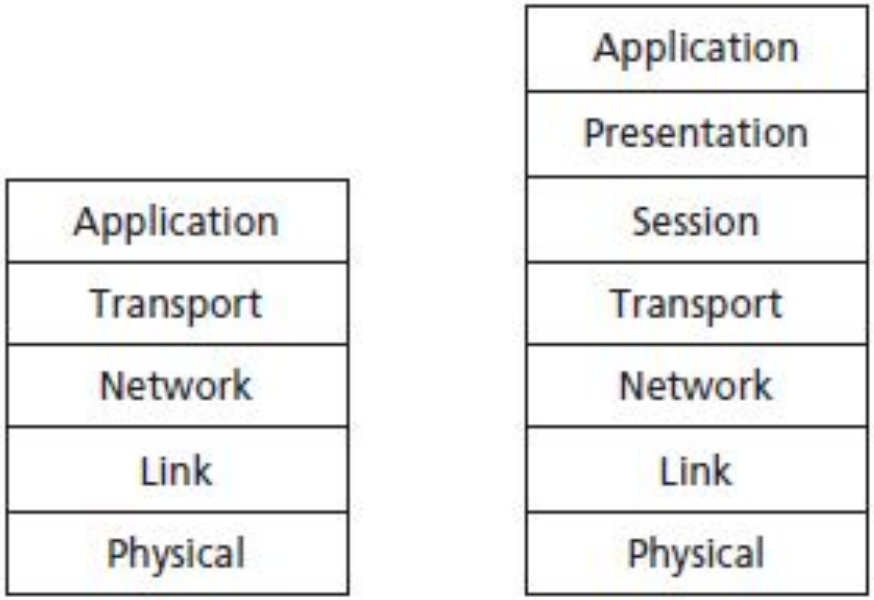
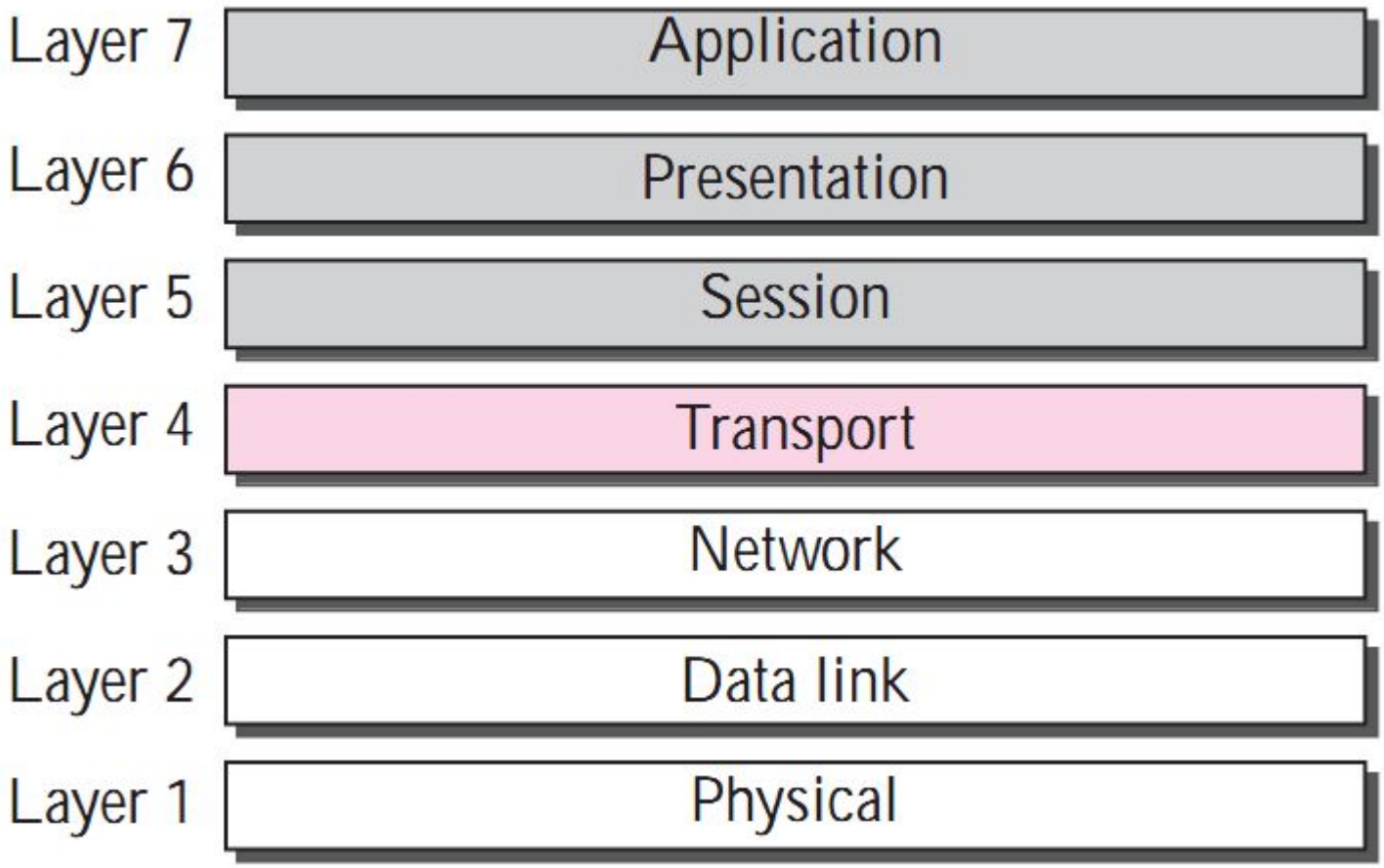


Figure 1.23 ♦ The Internet protocol stack (a) and OSI reference model (b)

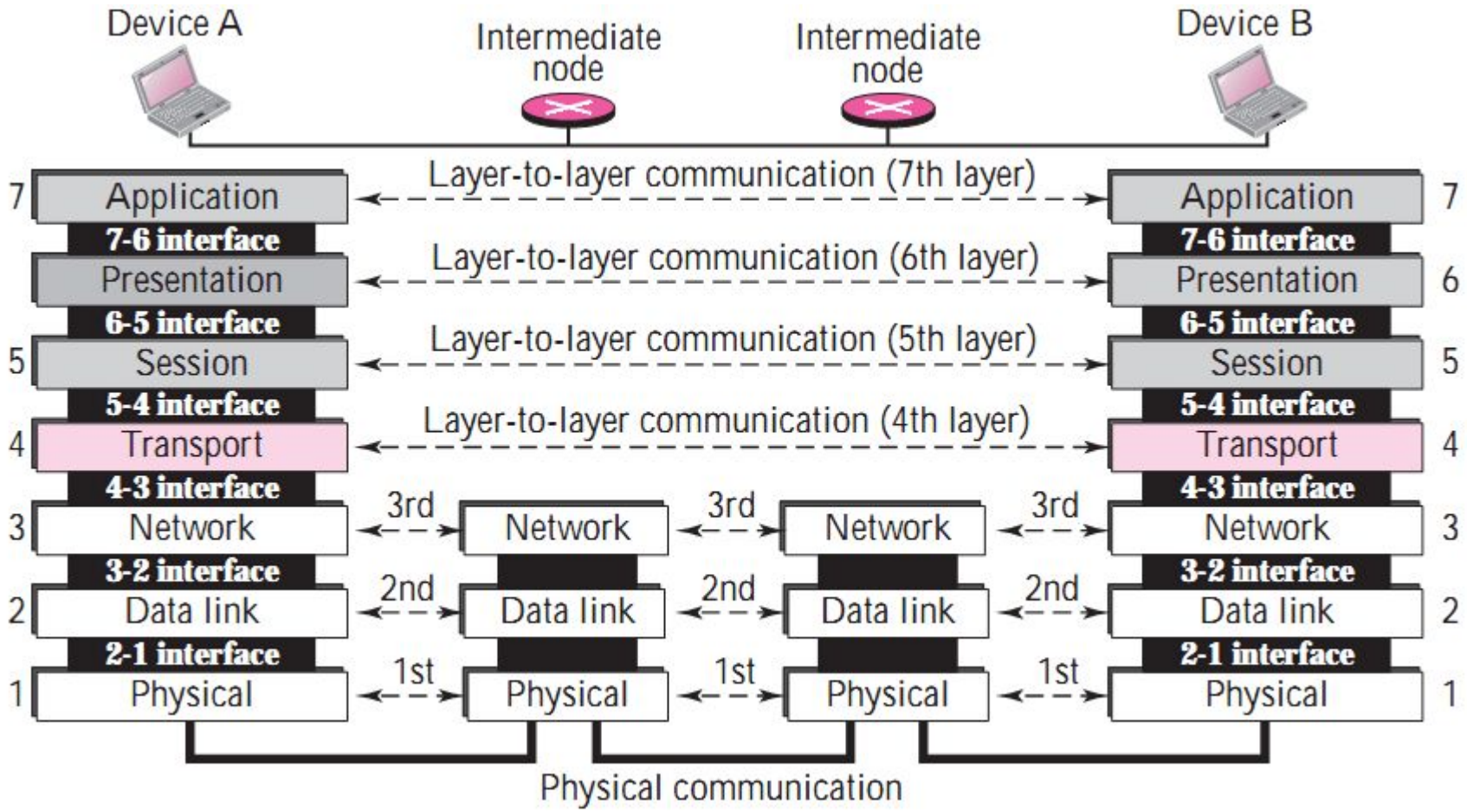
OSI MODEL

- **An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model**.
- It was first introduced in the late 1970s.
- An open system is a set of protocols that allows any two different systems to communicate regardless of their underlying architecture.
- The OSI model is not a protocol;
- it is a model for understanding and designing a network architecture that is flexible, robust, and interoperable.

Layered Architecture



OSI layers


Device A
Intermediate node
Intermediate node
Device B
Layer-to-layer communication (7th layer)
Layer-to-layer communication (6th layer)
Layer-to-layer communication (5th layer)
Layer-to-layer communication (4th layer)
7
Application
7-6 interface
Presentation
6
6-5 interface
5
Session
5-4 interface
4
Transport
4-3 interface
3
Network
3rd
3-2 interface
2
Data link
2nd
2-1 interface
1
Physical
1st
Physical communication

Organization of the Layers

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

- Layers 1, 2, and 3- physical, data link, and network - are the **network support layers;** they deal with the physical aspects of moving data from one device to another (such as electrical specifications, physical connections, physical addressing, timing **).**

- Layers 5, 6, and 7- session, presentation, and application - can be thought of as the **user support layers; they allow interoperability among unrelated software systems**.

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

OSI Application Layer

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

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

Application Layer protocols example

- Application Layer
  - There is a need for support protocols, to allow the applications to function
- Some network applications
  - DNS: handles naming within the Internet
  - POP – IMAP – SMTP: handle electronic mail
  - FTP: File Transfer over the Internet
  - WWW – HTTP: Web world
  - Multimedia

OSI Presentation Layer

- The presentation layer is concerned with the **syntax and semantics of the information exchanged between two systems.**

OSI Presentation Layer

- Translation
- Encryption
- Compression

OSI Presentation Layer

- Specific responsibilities of the presentation layer include the following:

Translation.

The presentation layer at the sender changes the information from its sender-dependent format into a common format.

The presentation layer at the receiving machine changes the common format into its receiver-dependent format.

OSI Presentation Layer

Encryption

To carry sensitive information a system must be able to assure privacy.

Encryption means that the sender transforms the original information to another form and sends the resulting message out over the network.

Decryption reverses the original process to transform the message back to its original form.

OSI Presentation Layer

Compression.

Data compression reduces the number of bits contained in the information.

Data compression becomes particularly important in the transmission of multimedia such as text, audio, and video.

OSI: **Session Layer**

- It establishes, maintains, and synchronizes the interaction between communicating systems. (applications).

- The session layer defines how to start, control and end conversations (called sessions) between applications.

- Specific responsibilities of the session layer include the following:

OSI: **Session Layer**

- **Dialog control.**
- **Synchronization.**

OSI: **Session Layer**

- **Dialog control.** The session layer allows two systems to enter into a dialog.
- It allows the communication between two processes to take place in either half- duplex (one way at a time) or full-duplex (two ways at a time) mode.

- **Synchronization.** The session layer allows a process to add checkpoints (synchronization points) into a stream of data.

OSI: **Transport Layer**

- The transport layer is responsible for process-to-process delivery of the entire message.
- A process is an application program running on the host.

- Whereas the network layer oversees source-to-destination delivery of individual packets, it does not recognize any relationship between those packets.

- It treats each one independently, as though each piece belonged to a separate message, whether or not it does.

OSI: **Transport Layer**

- The transport layer, on the other hand, ensures that the whole message arrives intact and in order, overseeing both error control and flow control at the source-to-destination level.

OSI: **Transport Layer**

- **Service-point addressing**
- **Segmentation and reassembly**
- **Connection control**
- **Flow control**
- **Error control**

OSI: **Transport Layer**

- Other responsibilities of the transport layer include the following:

1. Service-point addressing

- Computers often run several programs at the same time.
- For this reason, source-to-destination delivery means delivery not only from one computer to the next but also from a specific process (running program) on one computer to a specific process (running program) on the other.

OSI: **Transport Layer**

Service-point addressing

- The transport layer header must therefore include a type of address called **a service-point address (or port address).**

- The network layer gets each packet to the correct computer; the transport layer gets the entire message to the correct process on that computer.

OSI: **Transport Layer**

- **Segmentation and reassembly**

A message is divided into transmittable segments, with each segment containing a sequence number.

- These numbers enable the transport layer to reassemble the message correctly upon arriving at the destination and to identify and replace packets that were lost in transmission.

OSI: **Transport Layer**

- **Connection control**
- The transport layer can be either connectionless or connection- oriented.

- A **connectionless transport layer** treats each segment as an independent packet and delivers it to the transport layer at the destination machine.

- A **connection- oriented transport layer** makes a connection with the transport layer at the destination machine first before delivering the packets. After all the data are transferred, the connection is terminated.

OSI: **Transport Layer**

- **Flow control.**

Like the data link layer, the transport layer is responsible for flow control.

However, flow control at this layer is performed end to end rather than across a single link.

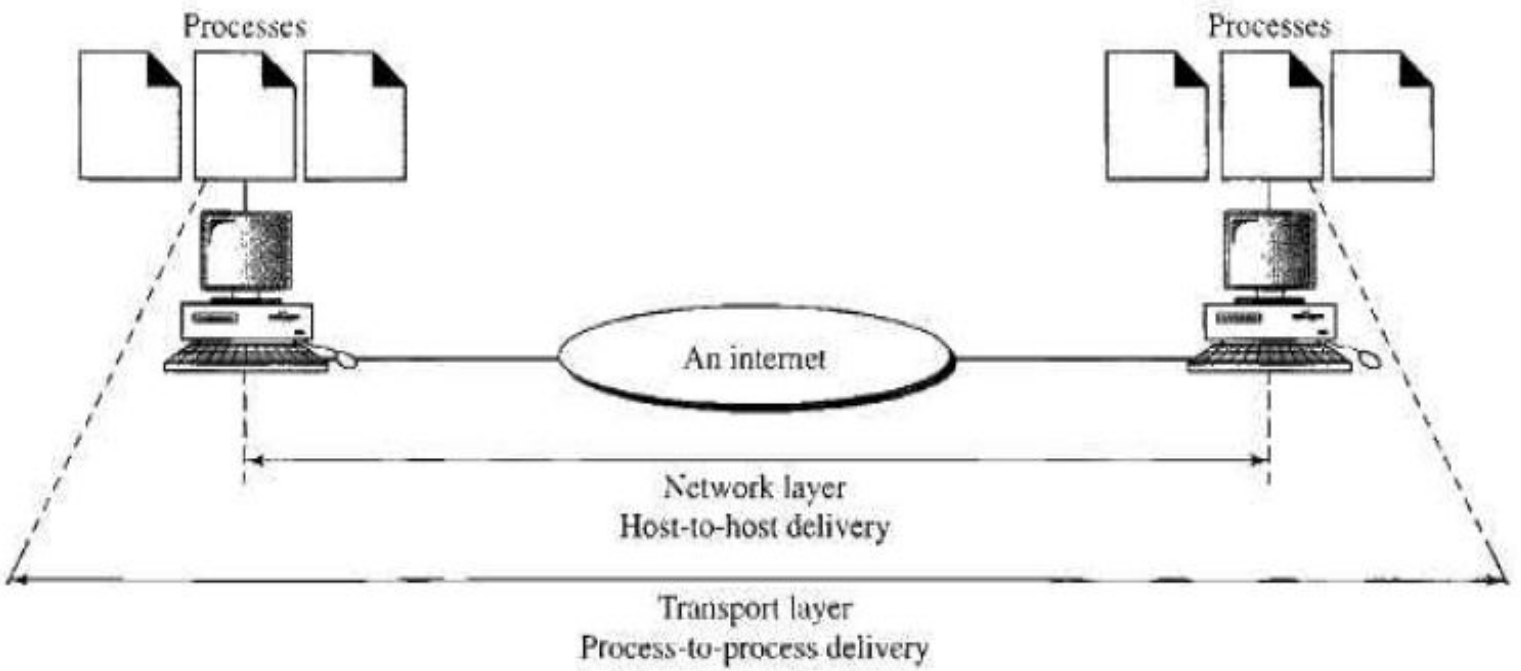
OSI: **Transport Layer**

- **Error control.**
- Like the data link layer, the transport layer is responsible for error control.
- However, error control at this layer is performed process-to-process rather than across a single link.
- The sending transport layer makes sure that the entire message arrives at the receiving transport layer without error (damage, loss, or duplication).
- Error correction is usually achieved through retransmission.

Transport Layer: process to process delivery

Figure 2.11 illustrates process-to-process delivery by the transport layer.

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



OSI: Network Layer

- The **network layer is responsible for the source-to-destination delivery of a packet**, possibly across multiple networks (links).

- Whereas the **data link layer oversees the delivery of the packet between two systems on the same network (link),** the network layer ensures that each packet gets from its point of origin to its final destination.

OSI: Network Layer

- **Logical addressing**
- **Routing**

OSI: Network Layer

- If two systems are connected to the same link, there is usually no need for a net-work layer.
- if the two systems are attached to different networks (links) with connecting devices between the networks (links), there is often a need for the network .

- **Logical addressing**.

  The physical addressing implemented by the data link layer handles the addressing problem locally.

  If a packet passes the network boundary, we need another addressing system to help distinguish the source and destination systems.

  The network layer adds a header to the packet coming from the upper layer that, among other things, includes the logical addresses of the sender and receiver.

OSI: Network Layer

- **Routing.**

When independent networks or links are connected together to create internetworks (network of networks) or a large network, the connecting devices (called routers or switches) route or switch the packets to their final destination.

One of the functions of the network layer is to provide this mechanism.

OSI DATA Link Layer

- **Framing**
- **Physical addressing.**
- **Flow control.**
- **Error control**.
- **Access control**

OSI: **Data Link Layer**

- **Framing.** The data link layer divides the stream of bits received from the network layer into manageable data units called frames.

- **Physical addressing.** If frames are to be distributed to different systems on the network, the data link layer adds a header to the frame to define the sender and/or receiver of the frame. If the frame is intended for a system outside the sender's network, the receiver address is the address of the connecting device that connects the network to the next one.

OSI: **Data Link Layer**

- **Flow control.** If the rate at which the data is absorbed by the receiver is less than the rate produced at the sender, the data link layer imposes a flow control mechanism to prevent overwhelming the receiver.

- **Error control**. The data link layer adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged or lost frames.
- It also uses a mechanism to recognize duplicate frames.

- Error control is normally achieved through a trailer added to the end of the frame.

- **Access control**: when two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

Physical Layer

- The physical layer coordinates the functions required to carry a bit stream over a physical medium.

OSI Physical Layer

- **Physical characteristics of interfaces and media.**
- **Representation of bits**.
- **Data rate**.
- **Synchronization of bits**.
- **Line configuration.**
- **Physical topology.**
- **Transmission mode.**

OSI :Physical Layer

The physical layer is also concerned with the following:

- **Physical characteristics of interfaces and media**. The physical layer defines the characteristics of the interface between the devices and the transmission media. It also defines the type of transmission media.

- **Representation of bits**. The physical layer data consists of a stream of bits (sequence of 0s or 1s) with no interpretation. To be transmitted, bits must be encoded into signals . The physical layer defines the type of encoding (how 0s and 1s are changed to signals).

OSI :Physical Layer

- **Data rate**. The transmission rate - the number of bits sent each second—is also defined by the physical layer. In other words, the physical layer defines the duration of a bit, which is how long it lasts.

- **Synchronization of bits**. The sender and receiver must not only use the same bit rate but must also be synchronized at the bit level. In other words, the sender and the receiver clocks must be synchronized.

OSI :Physical Layer

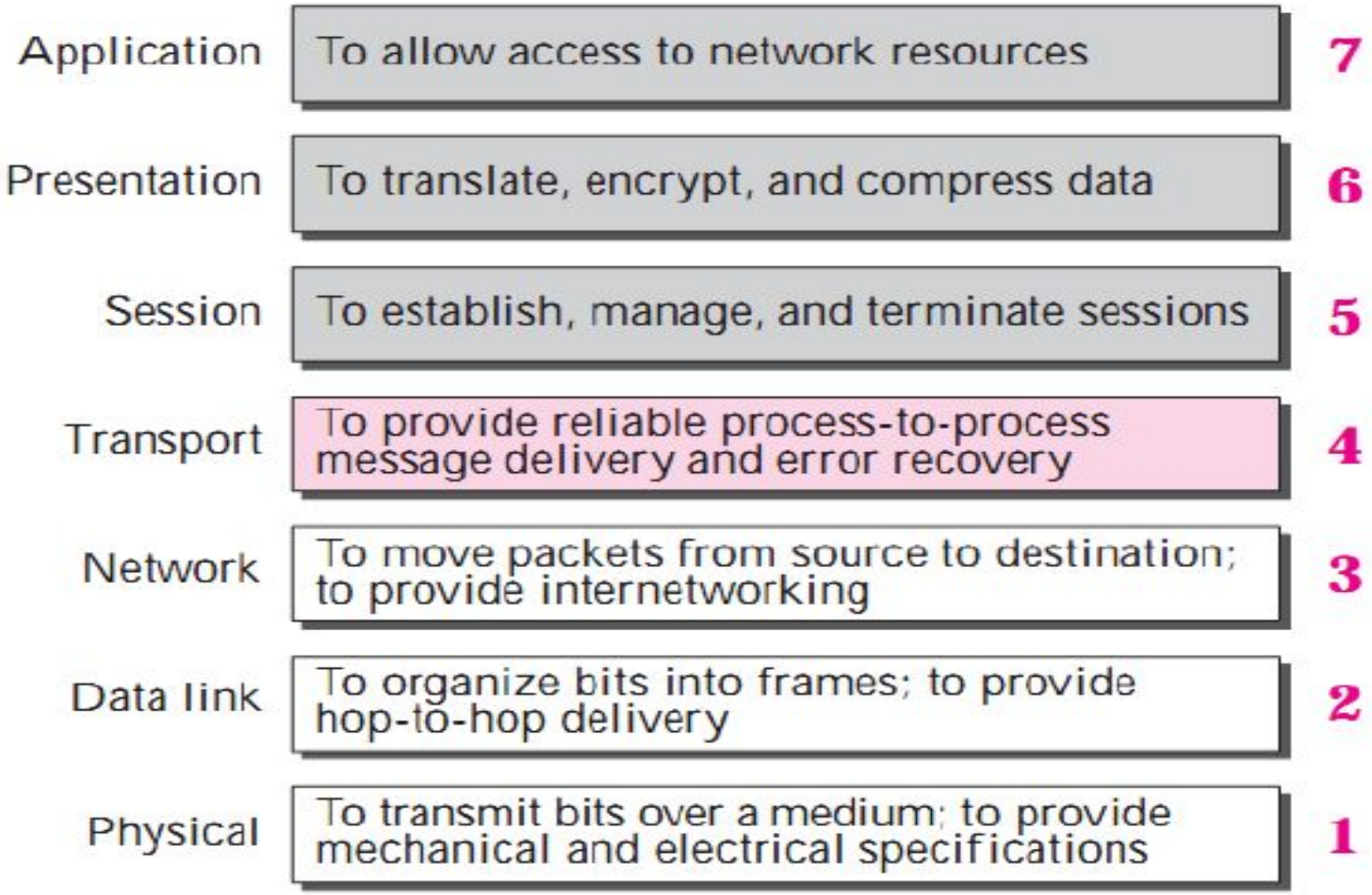
- **Line configuration.** The physical layer is concerned with the connection of devices to the media. In a **point-to-point configuration**, two devices are connected together through a dedicated link. In a **multipoint configuration**, a link is shared between several devices.

- **Physical topology.** The physical topology defines how devices are connected to make a network. Devices can be connected using a mesh topology (every device connected to every other device), a star topology (devices are connected through a central device), a ring topology (each device is connected to the next, forming a ring), or a bus topology (every device on a common link).

OSI :Physical Layer

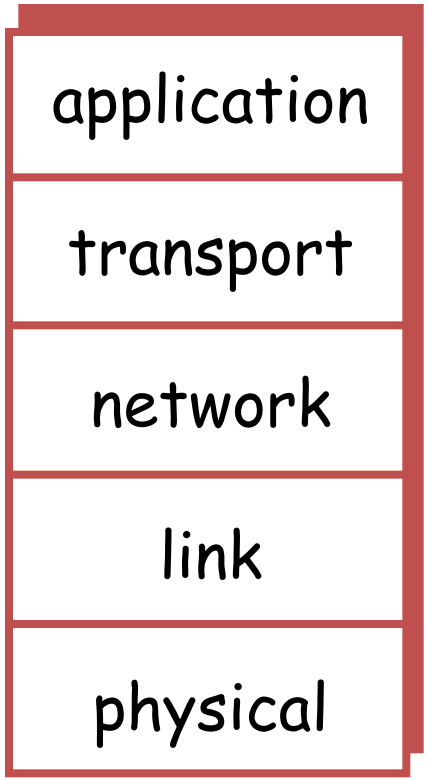
- **Transmission mode.** The physical layer also defines the direction of transmission between two devices: simplex, half-duplex, or full-duplex.

Summary of OSI Layers



Internet protocol stack

- application: supporting network applications
  - FTP, SMTP, HTTP
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet
- physical: bits “on the wire”



Internet protocol stack

Application Layer

- The application layer is where network applications and their application-layer protocols reside.

- The Internet's application layer includes many protocols, such as the HTTP protocol (which provides for Web document request and transfer), SMTP (which provides for the transfer of e-mail messages), and FTP (which provides for the transfer of files between two end systems).

Internet protocol stack

Application Layer

- Certain network functions, such as the translation of human-friendly names for Internet end systems like www.ietf.org to a 32-bit network address, are also done with the help of a specific application-layer protocol, namely, the domain name system (DNS)

Internet protocol stack

Transport Layer

- The Internet's transport layer transports application-layer messages between application endpoints.

- In the Internet there are two transport protocols, TCP and UDP, either of which can transport application-layer messages.

Internet protocol stack

Transport Layer

- TCP provides a connection-oriented service to its applications.
- This service includes guaranteed delivery of application-layer messages to the destination and flow control (that is, sender/receiver speed matching).
- Transport-layer packet as a **segment.**

Internet protocol stack

- TCP also breaks long messages into shorter segments and provides a **congestion-control mechanism**, so that a source throttles its transmission rate when the network is congested.
- The UDP protocol provides a **connectionless service** to its applications.
- This is a no-frills service that provides no reliability, no flow control, and no congestion control.

Internet protocol stack

Network Layer

- The Internet's network layer is responsible for moving network-layer packets known as **datagrams from one host to another.**

- The Internet transport-layer protocol (TCP or UDP) in a source host passes a transport-layer segment and a destination address to the network layer.

Internet protocol stack

Network Layer

- The network layer then provides the service of delivering the segment to the transport layer in the destination host.

- The Internet's network layer includes the IP Protocol, which defines the fields in the datagram as well as how the end systems and routers act on these fields.

Internet protocol stack

Network Layer

- There is only one IP protocol, and all Internet components that have a network layer must run the IP protocol.
- The Internet's network layer also contains routing protocols that determine the routes that datagrams take between sources and destinations.
- The Internet has many routing protocols

Internet protocol stack

Link Layer

- Data transfer between neighboring network elements

Physical Layer

- While the job of the link layer is to move entire frames from one network element to an adjacent network element, the job of the physical layer is to move the *individual bits within the frame from one node to the next.*

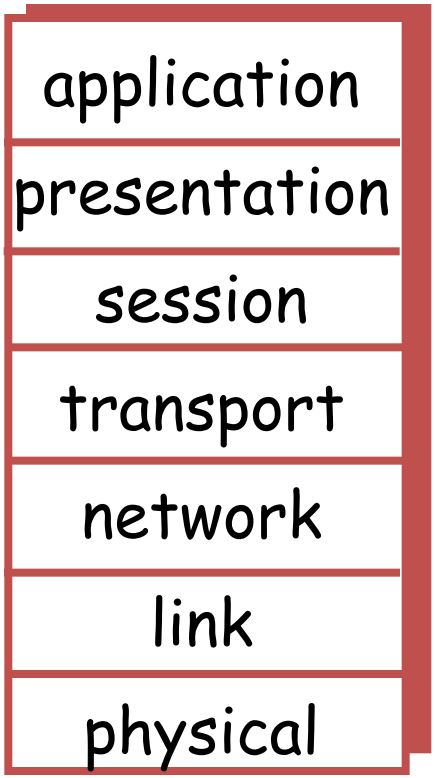
Internet protocol stack

- The protocols in this layer are again link dependent and further depend on the actual transmission medium of the link (for example, twisted-pair copper wire, single-mode fiber optics).

- For example, Ethernet has many physical-layer protocols:
- one for twisted-pair copper wire, another for coaxial cable, another for fiber, and so on.
- In each case, a bit is moved across the link in a different way.

ISO/OSI reference model

- presentation: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing
- Internet stack "missing" these layers!
  - these services, *if needed,* must be implemented in application layer



Encapsulation