NETWORK PROGRAMMING

Lecture 1

Network

- A network is a collection of computers and other devices that can send/receive data between each other.
- Each machine on a network is called a node.
- Nodes that are fully functional computers are also called hosts.
- Every network node has an address which is a series of bytes that uniquely identify it.
- Addresses are assigned differently on different kinds of networks.

Network Performance Parameters

- **Latency**: the time it takes for data(e.g. a packet) to travelfrom one point(source) to another(destination). Measured in seconds, milliseconds.
- **Bandwidth**: the amount of data that can be transmitted in a fixed period of time. Measured in kbps, Mbps, Gbps.
- **Throughput**: the actualamount of data that is successfully sent/received over a link. Presented as kbps, Mbps, Gbps.

Network Types

	Range	*Bandwidth(bps*	*Latency (ms)*
LAN	1-2 kms	10M-100G	1-10
WAN	worldwide	64K-600M	100-500
MAN	2-50 kms	1M-150M	10
Wireless LAN	0.15-1.5 km	2M-600M	5-20
Wireless WAN	worldwide	28K-1G	50-500
		10G	
5G	worldwide		1

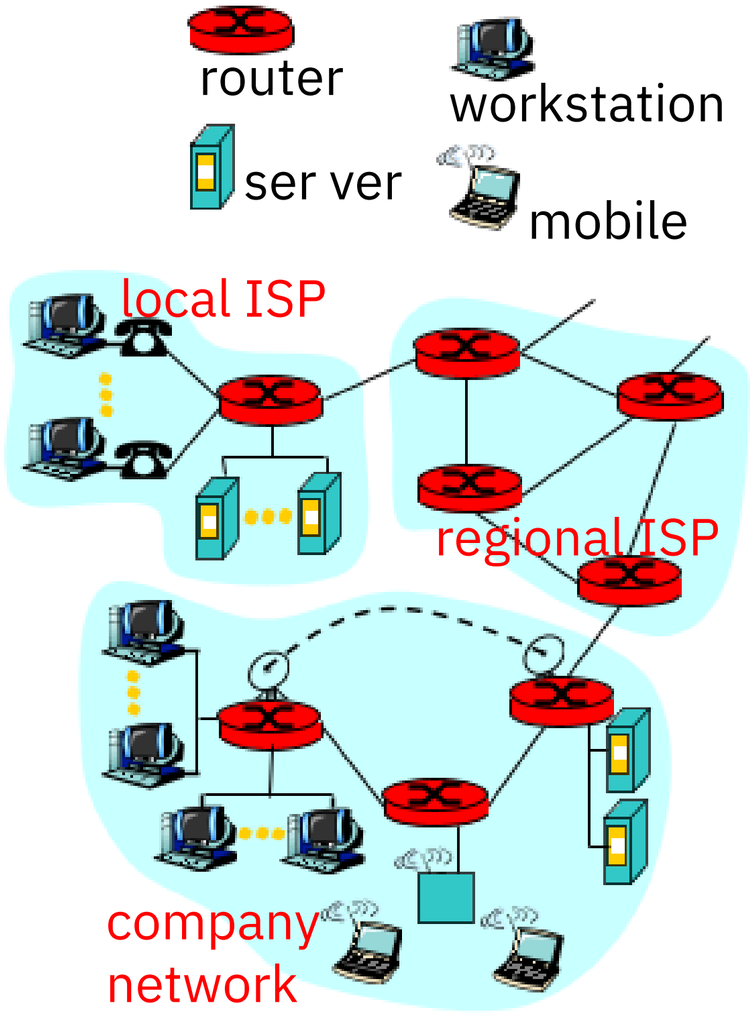
The Internet

- The first computer-to-computer message was sent in 1969.
- Today the Internetconsists of:
  - over 1.01 billion hosts over
  - 4.4 billion Internet users
- The World Wide Webis the most popular component of the Internet.

What's the Internet: "nuts and bolts"view

- Millions of connected computing devices: hosts, end-systems
  - pc's, workstations, servers
  - phones, toasters, watches

  running **network apps**
- Communication links
  - fiber, copper, radio, satellite
- Routers : forward packets (chunks) of data thru network



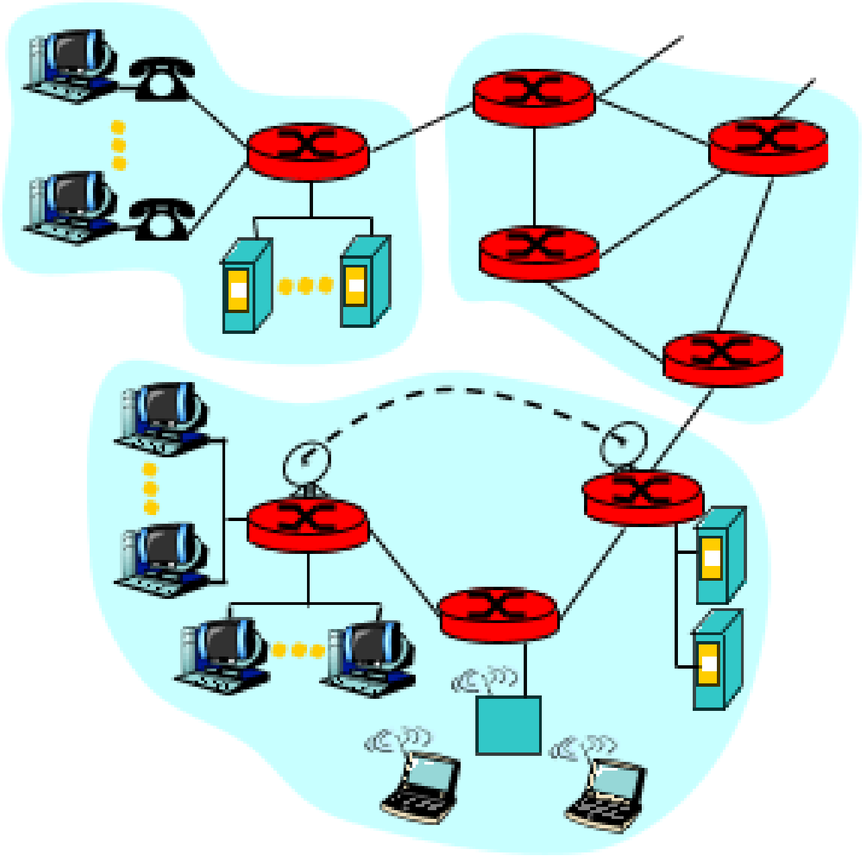
What's the Internet: "nuts and bolts"view

- Protocols: control sending, receiving of message
  - TCP, IP, HTTP, FTP, …
- Internet : "network of networks"
  - loosely hierarchical
  - public **Internet** versus private **intranet**
- Internet standards
  - RFC: Request for comments

    IETF: Internet Engineering Task Force

What’s the Internet: a service view

- Communication infrastructure enables distributed applications:
  - WWW, email, games, EC, database, voting, …
  - more?
- Communication services:
  - connectionless
  - connection-oriented
- Cyberspace [Gibson]:
  - “a consensual hallucination experienced daily by billions of operators, in every nation, ….”



Usage of Internet

- Web-browsing (World Wide Web) E-mail
- Telnet (remote login to another computer)
- FTP (transfer files between computers)
- Newsgroups / Chat rooms
- ECommerce
- Multimedia and games
- Scientific applications
- ...

World Wide Web

- The World Wide Web(WWW) is an information sharing system based on
  - inter-linked documents (web-pages)
  - that can be accessed over the Internet and
  - viewed graphically (using a web-browser)
- Located via a URL(Uniform Resource Locator):
  - <protocol>://<internet address>/page
    - http://web.csie.ndhu.edu.tw/showyang/index.html
    - ftp://www.ndhu.edu.tw

Network Communication

- Nodes may also have names. Names are not locked to addresses.
- Almost all modern networks are packet-switched networks.
- A protocol is a precise set of rules and data format defining how computers communicate.
- Network communication is layered.
- Each layer represents a different level of abstraction.

What is a protocol?

human protocols:

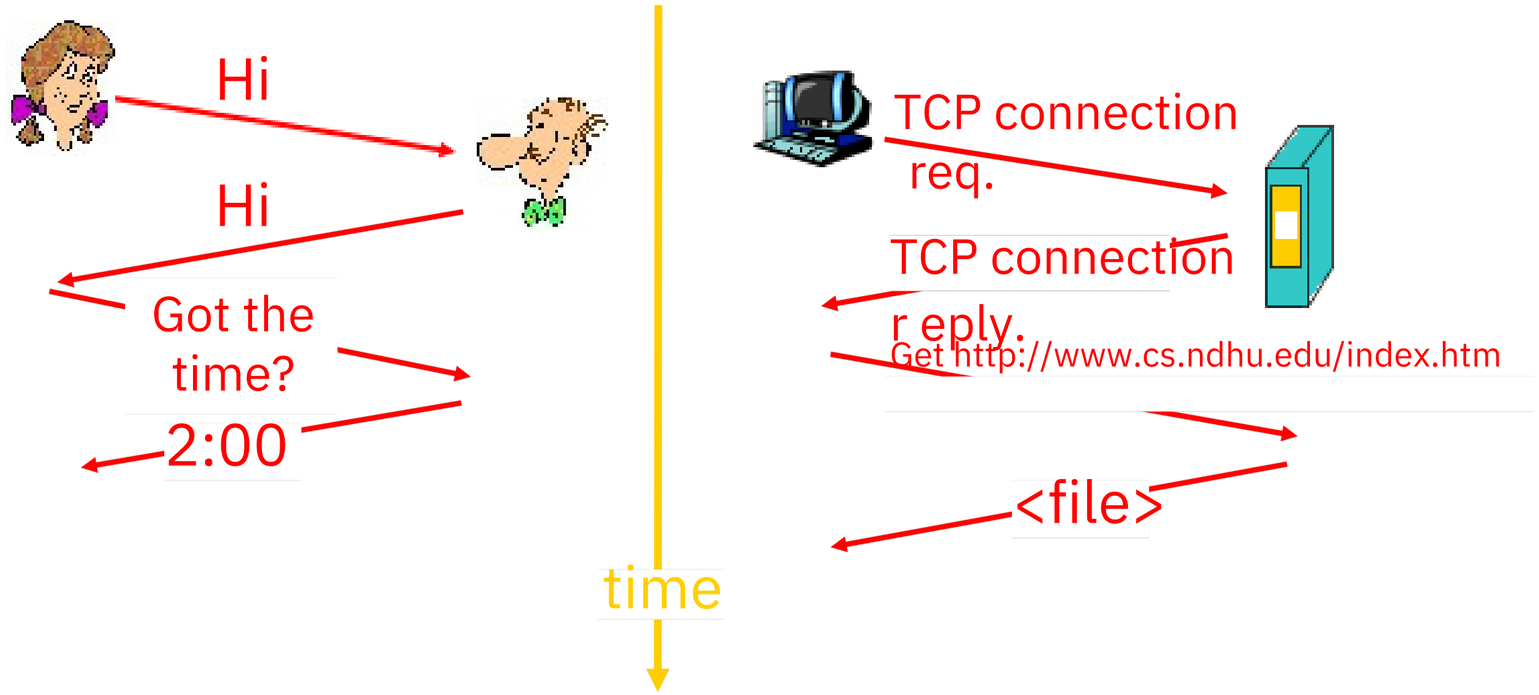
- “what’s the time?” “I have a question” introductions
- specific msgs sent
- specific actions taken when msgs received, or other events

network protocols:

- machines rather than humans.
- all communication activity in Internet governed by protocols.
- protocols define format, order of msgs sent and received among network entities, and actionstaken on msg transmission, receipt.

What is a protocol?

a human protocol and a computer network protocol



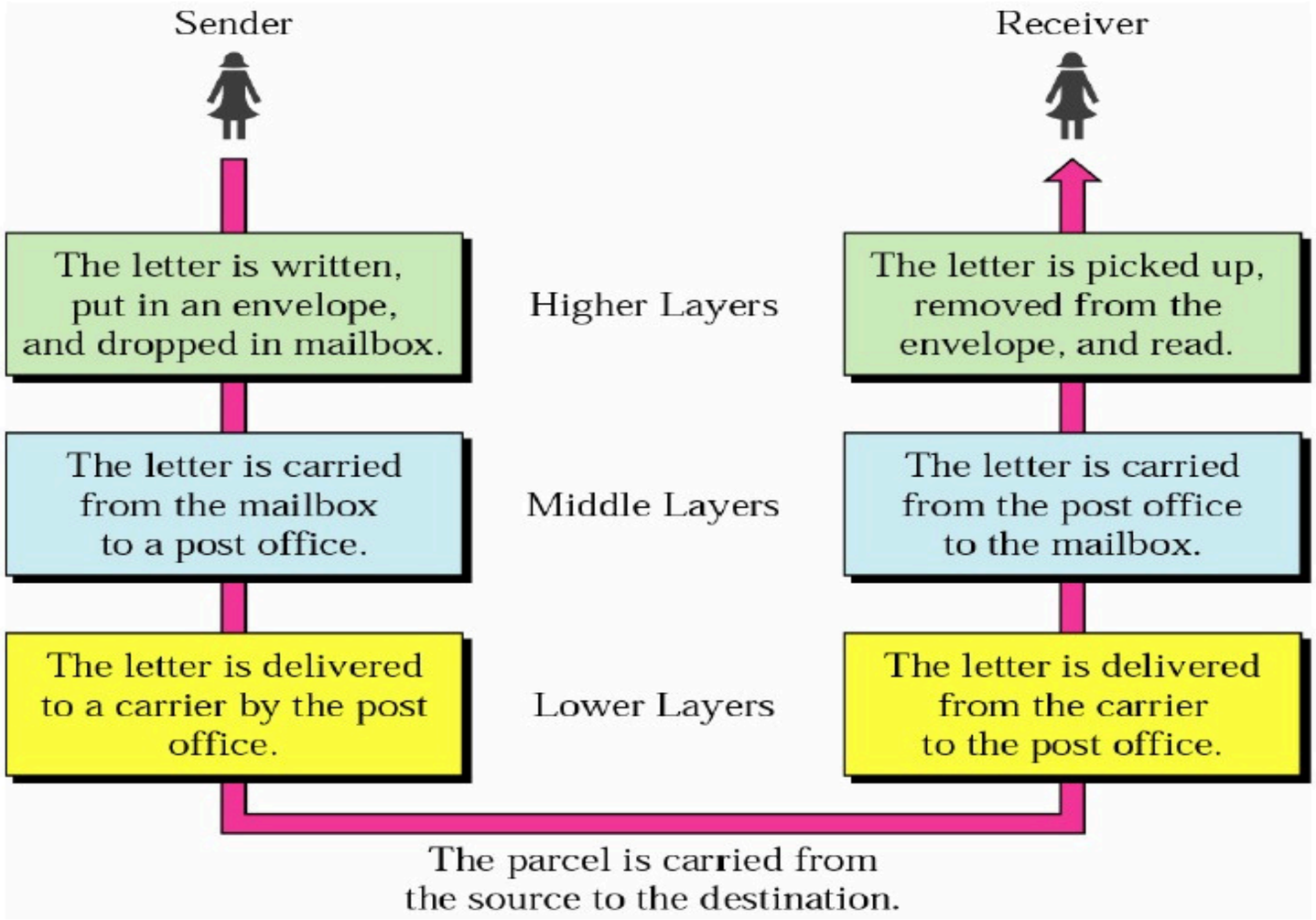
Network Models

- Using a formal model allows us to deal with various aspects of networks abstractly.
- We will look at a popular model (OSI reference model).
- The OSI reference model is a layered model.

Layering

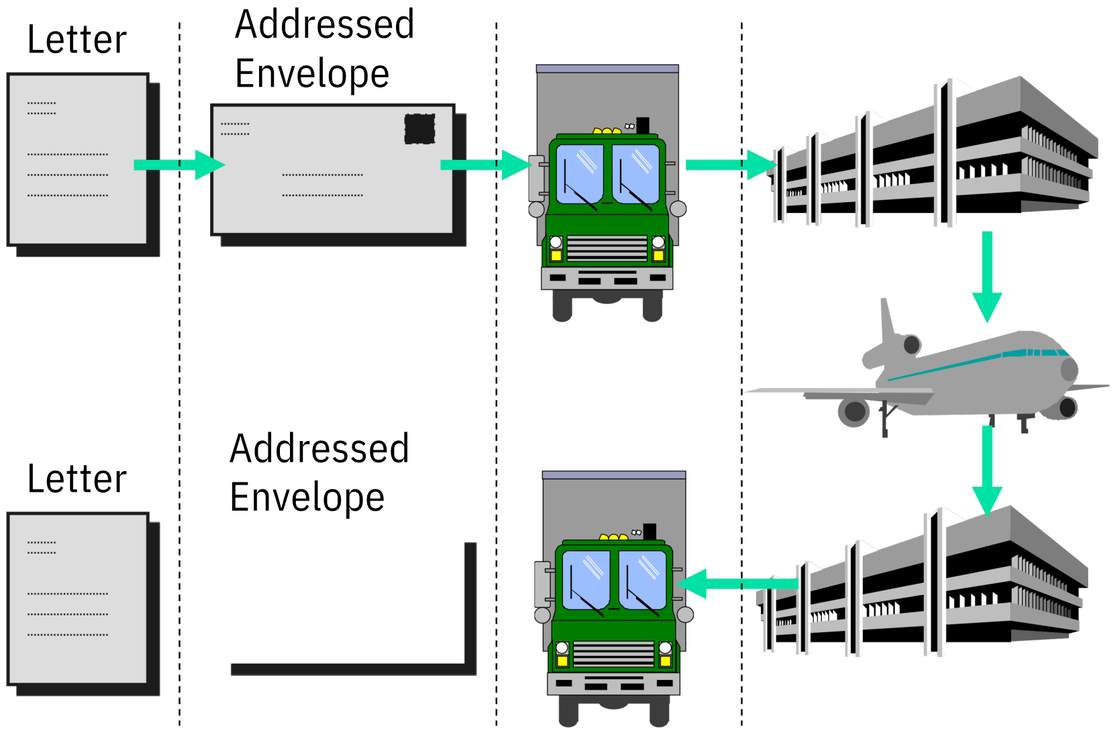
- Dividea task into pieces and then solve each piece independently (or nearly so).
- Establishing a well defined interface between layers makes porting easier.
- Major Advantages:
  - Abstraction
  - Modularity
  - Code Reuse
  - Extensibility

Layers in Sending a Letter



Layering Example: FedX Layers

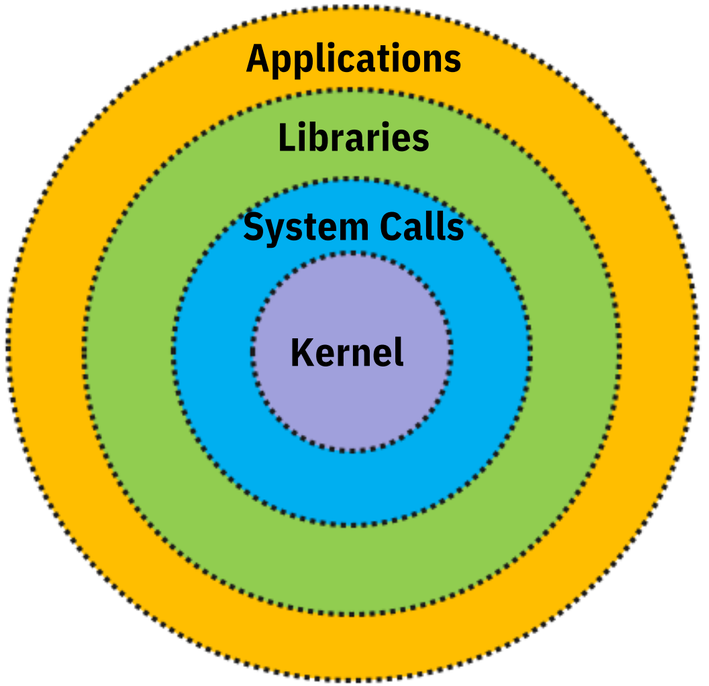
- Letter in envelope, address on outside FedX
- guy adds addressing information, barcode.
- Local office drives to airport and delivers to hub.
- Sent via airplane to nearest city.
- Delivered to right office.
- Delivered to right person



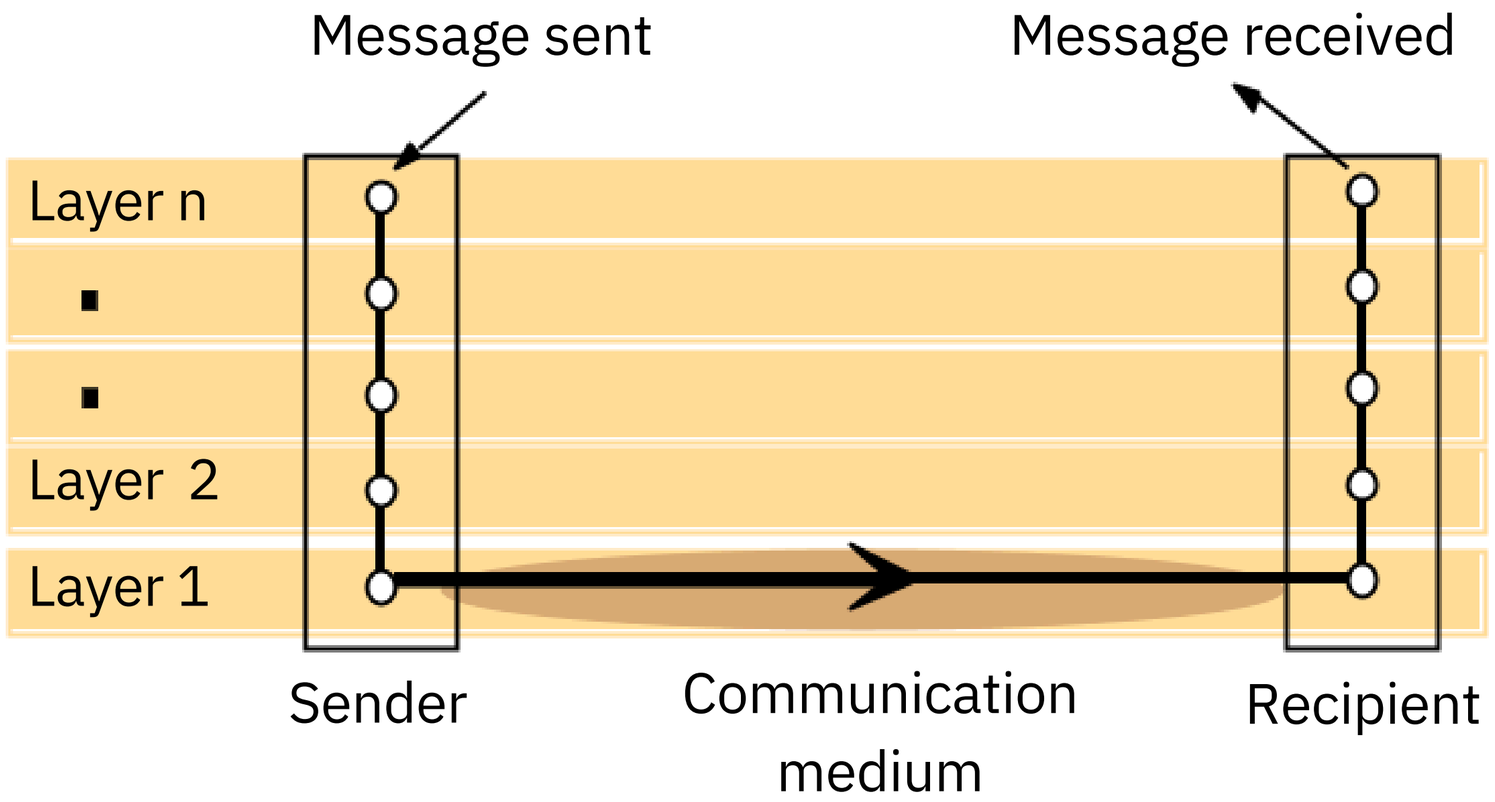
Layered Software Systems

- Network software
- Operating systems
- Windowing systems

Unix is a Layered System



Layering of Protocols



OSI Reference Model

- The International Standards Organization (ISO) proposal for the standardization of the various protocols used in computer networks (specifically those networks used to connect open systems) is called the Open Systems Interconnection Reference Model (1984), or simply the OSI model.

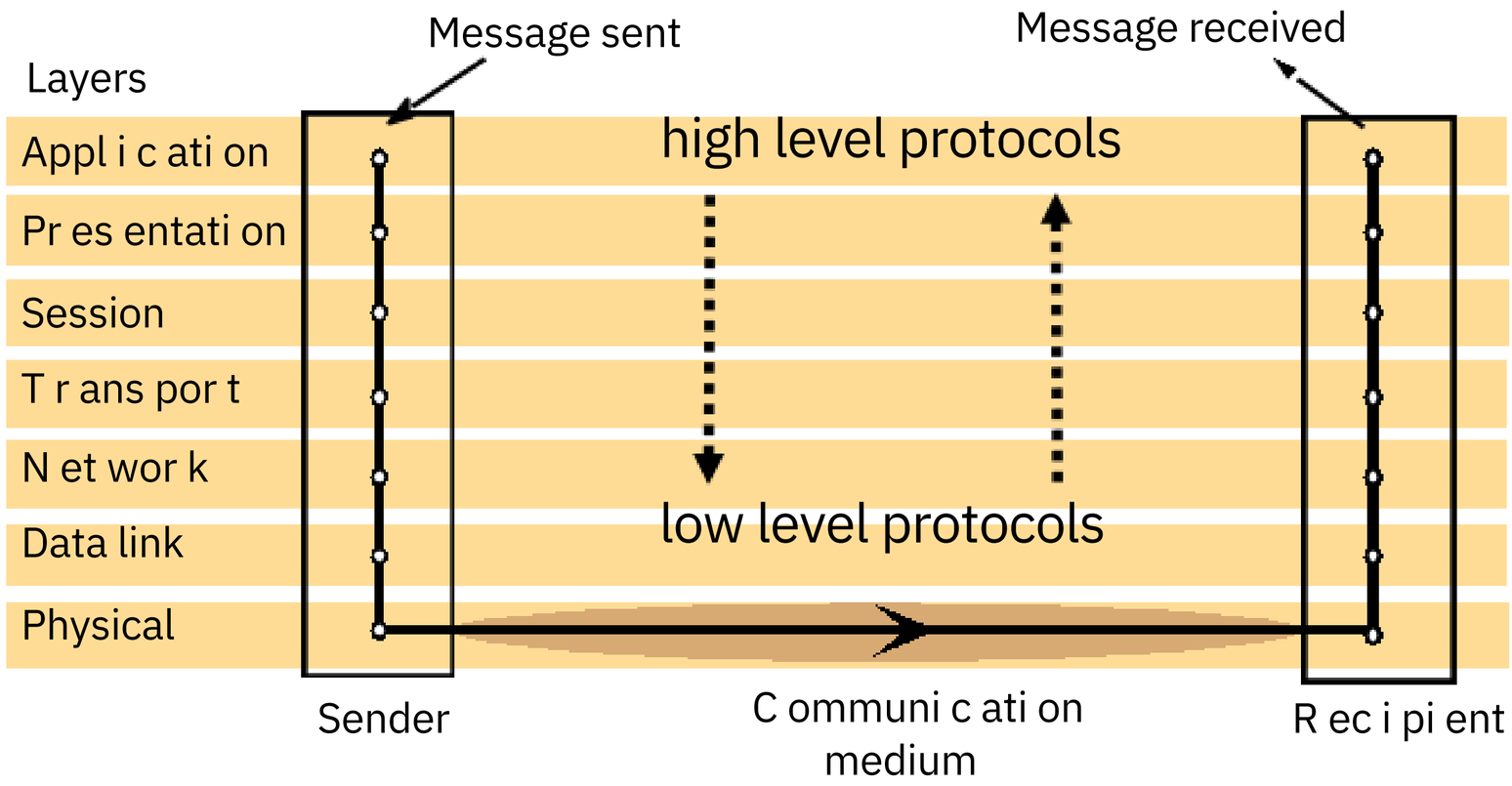
- Although the OSI model is a just a model (not a specification), it is generally regarded as the most complete model (as well it should be -nearly all of the popular network protocol suites in use today were developed before the OSI model was defined).

OSI Network Software

- Although this course is about network programming (and not about networking in general), an understanding of a complete network model is essential.
- We will give a concise introduction of the OSI Reference Model.
- Detail study of the model should be in Computer Network courses.

OSI Protocol Layers

- The ISO Open Systems Interconnection(OSI) model



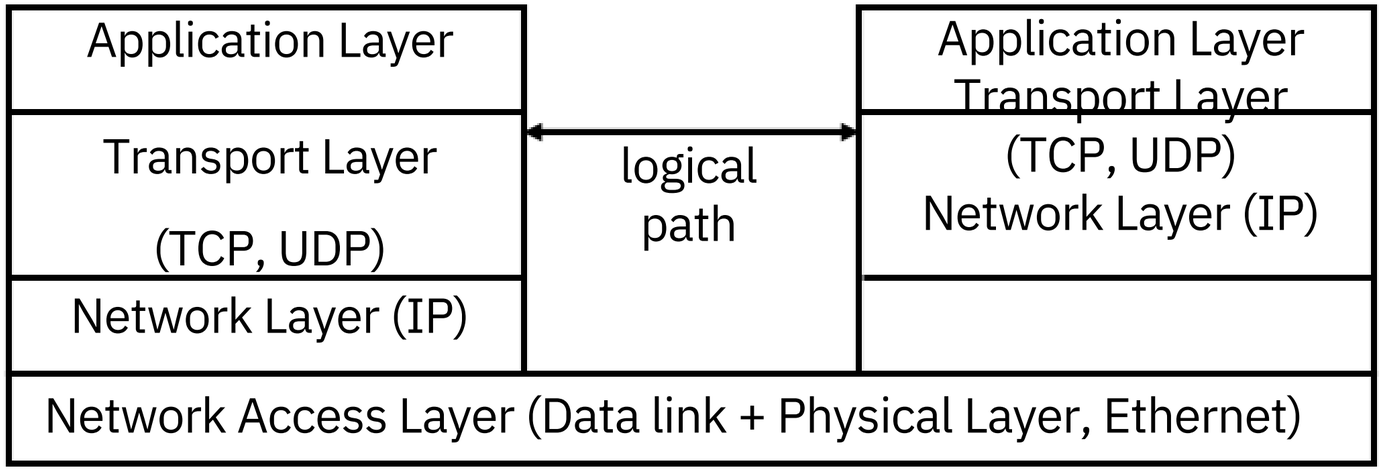
OSI Protocol Summary

- Physical: defines the cable or physical medium used to link nodes
- Data Link: defines the network packet format
- Network: routing packets across network
- Transport: divides messages into packets, ensures ordered delivery
- Session: establishes, maintains and ends sessions
- Presentation: transmits data in network representation(conversion, encryption,
- Application: application services

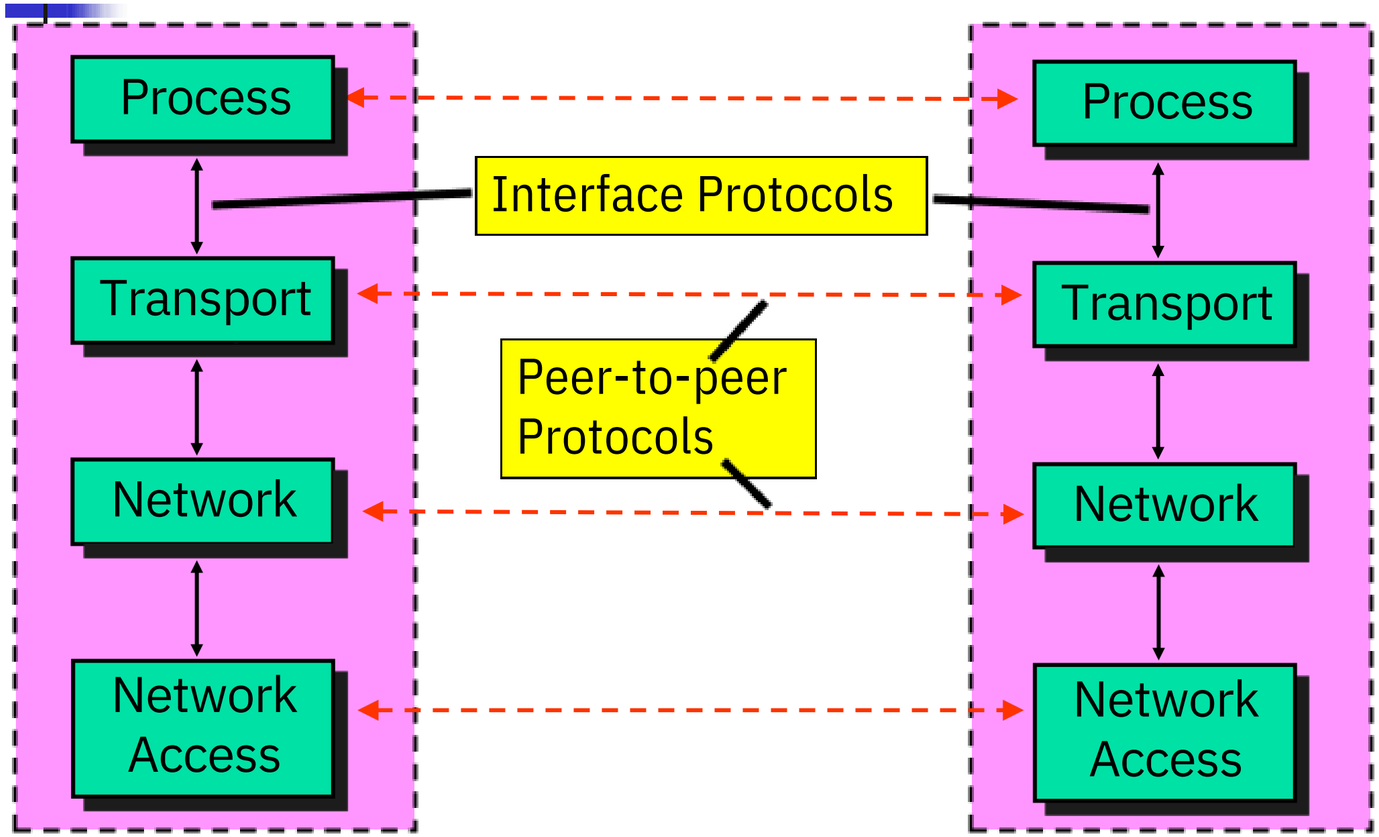
Layer	*Description*	*Examples*
Application	To meet the communication requirements of specific applications, often defining the interface to a service.	HTTP, FTP, SMTP, CORBA IIOP
Presentation	Transmit data in a network representation that is independent of the representations used in individual computers, which may differ. Encryption is also performed in this layer, if required.	Secure Sockets (SSL),CORBA Data Rep.
Session	At this level reliability and adaptation are performed, such as detection of failures and automatic recovery.	
Transport	This is the lowest level at which messages (rather than packets) are handled. Messages are addressed to communication ports attached to processes, Protocols in this layer may be connection-oriented or connectionless.	TCP, UDP
Network	Transfers data packets between computers in a specific network. In a WAN or an internetwork this involves the generation of a route passing through routers. In a single LAN no routing is required. Responsible for transmission of packets between nodes that are directly connected by a physical link. In a WAN transmission is between pairs of	IP, ATM virtual circuits
Data link	Responsible for transmission of packets between nodes that are directly connected by a physical link. In a WAN transmission is between pairs of routers or between routers and hosts. In a LAN it is between any pair of hosts.	Ethernet MAC, ATM cell transfer, PPP
Physical	The circuits and hardware that drive the network. It transmits sequences of binary data by analogue signalling, using amplitude or frequency modulation of electrical signals (on cable circuits), light signals (on fibre optic circuits) or other electromagnetic signals (on radio and microwave circuits).	Ethernet base-band signalling, ISDN

Internet Protocol Layers

- The Internet connection can be simplified into a four(five)-layermodel. Each layer only talks to the layers immediately above and below it.
- Layers model reduces complexity and increase modularity.

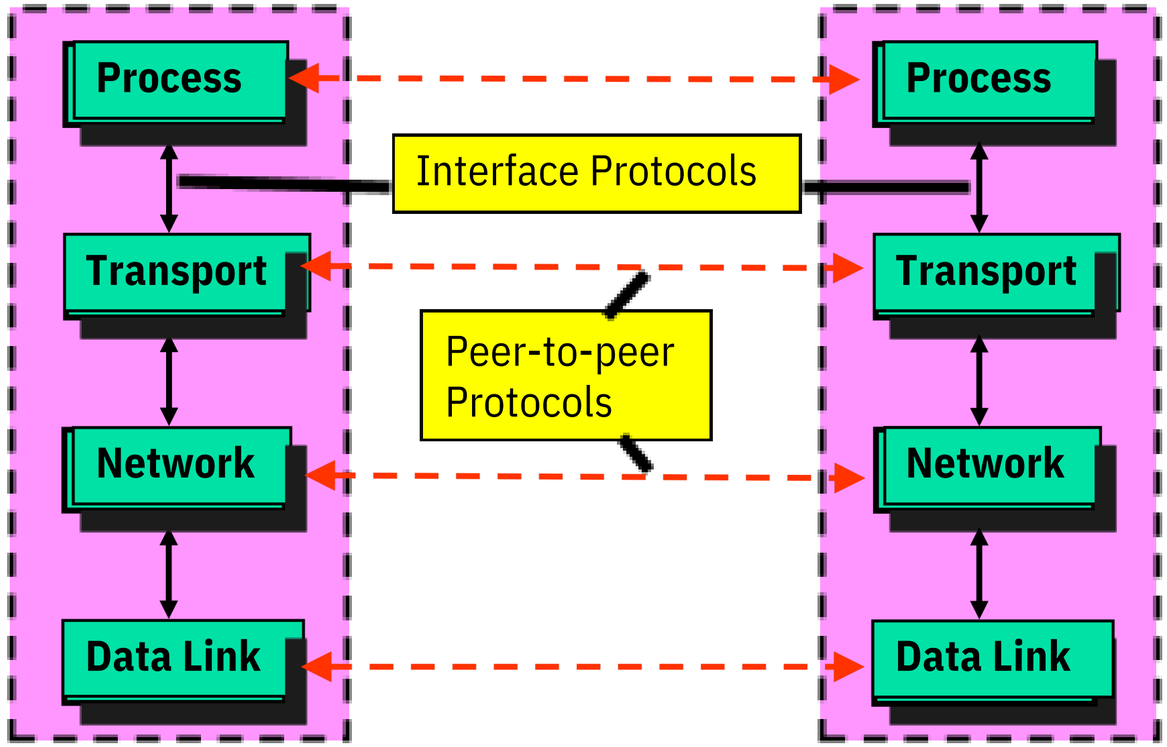


Simplified Network Model

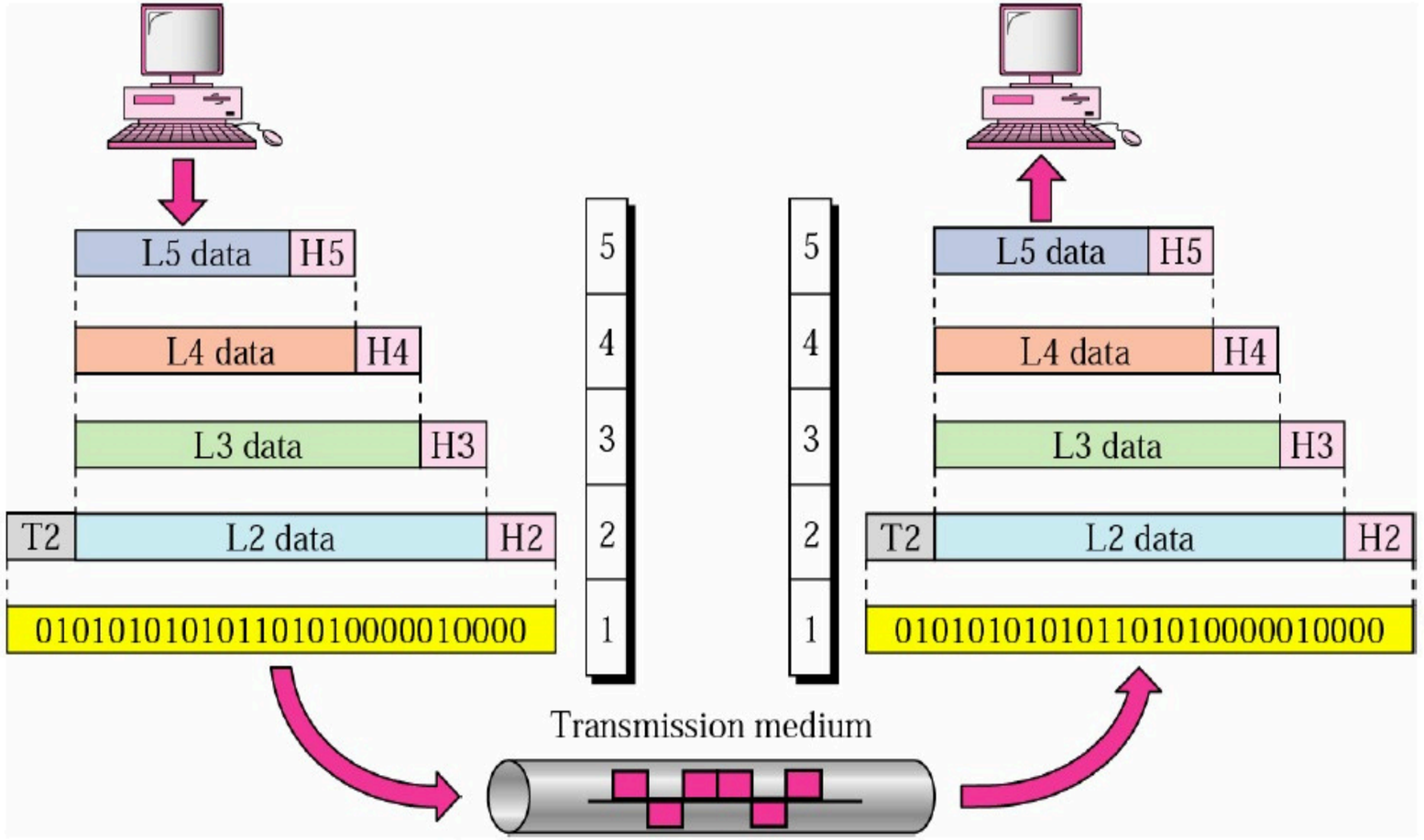


Interface and Peer-to-peer Protocols

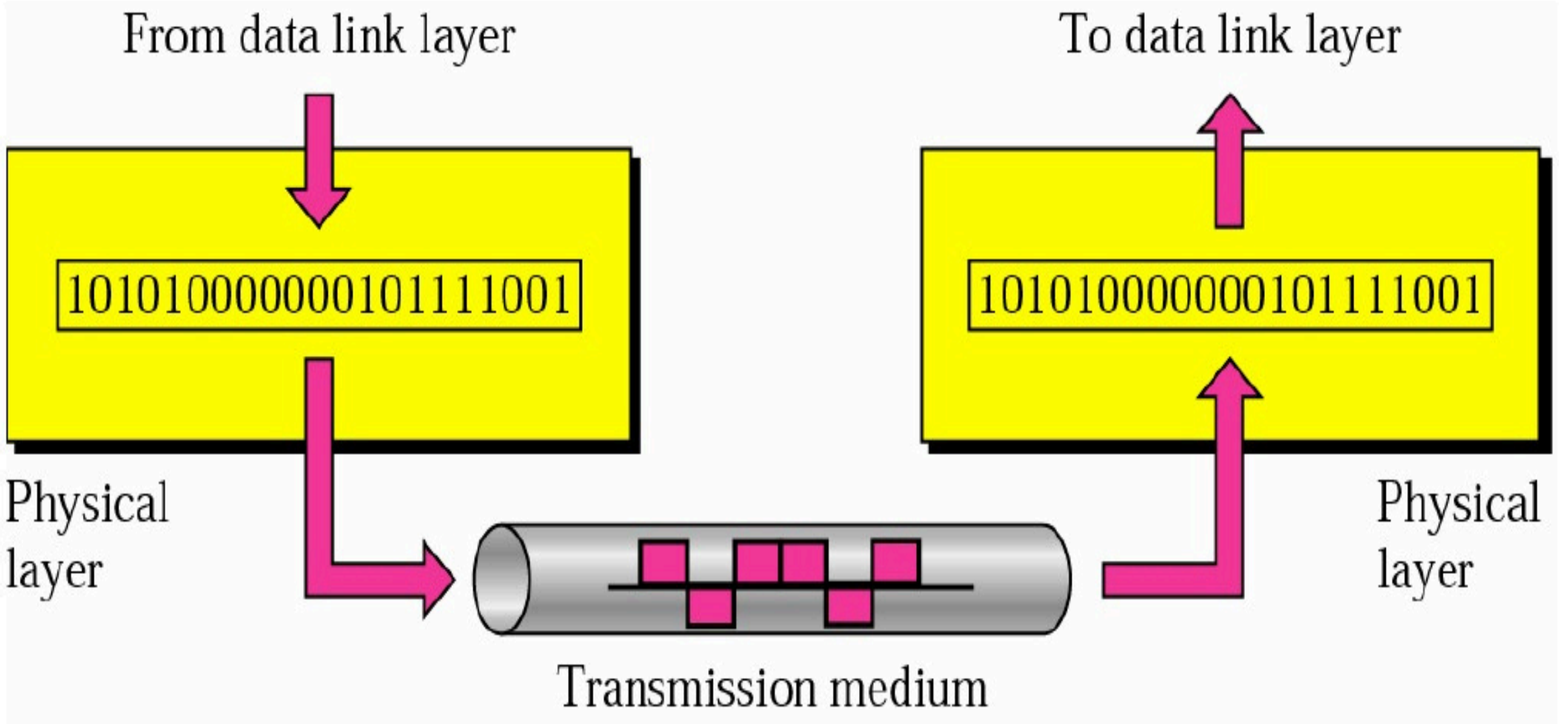
- Interface protocols describe the communication between layers on the same endpoint.
- Peer-to-peer protocols describe communication between peers at the same layer.



Message Exchange

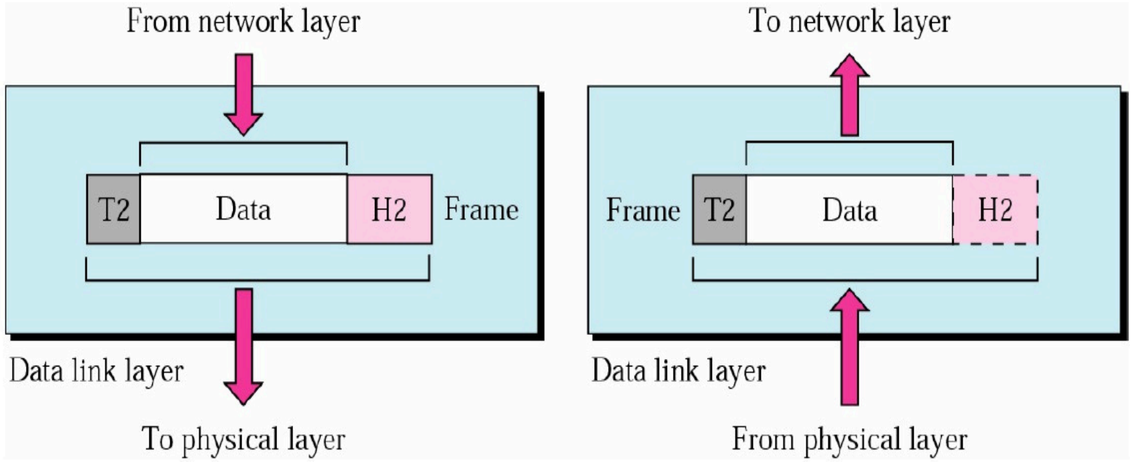


Physical Layer



- The physical layer is responsible for transmitting individual **bits**from one **node**to the next.

Data Link Layer

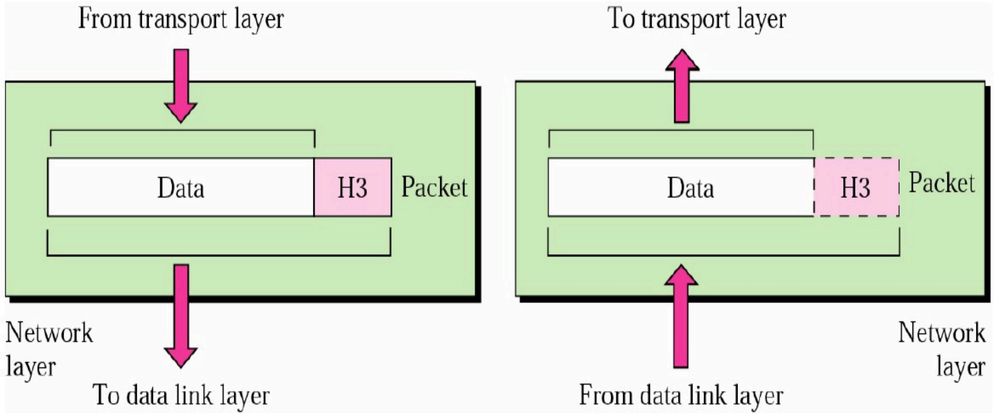


- The data link layer is responsible for transmitting network packets(frames) from one nodeto the next.

The Network Access Layer

- = physical layer+ data link layer
- The actual wires used to connect different computers make up the **physical layer**.
  - packets of electricity bits and bytes.
  - Digital-to-analog(sending), Analog-to-digital(receiving)
- Error correctionand redundancyare done in the **data link layer**. (Ethernet)
- A specific data link layer requires specialized hardware. (Bridges: convert information from one type to another.)
- For most network programming, we don't need to worry about either of the two layers.

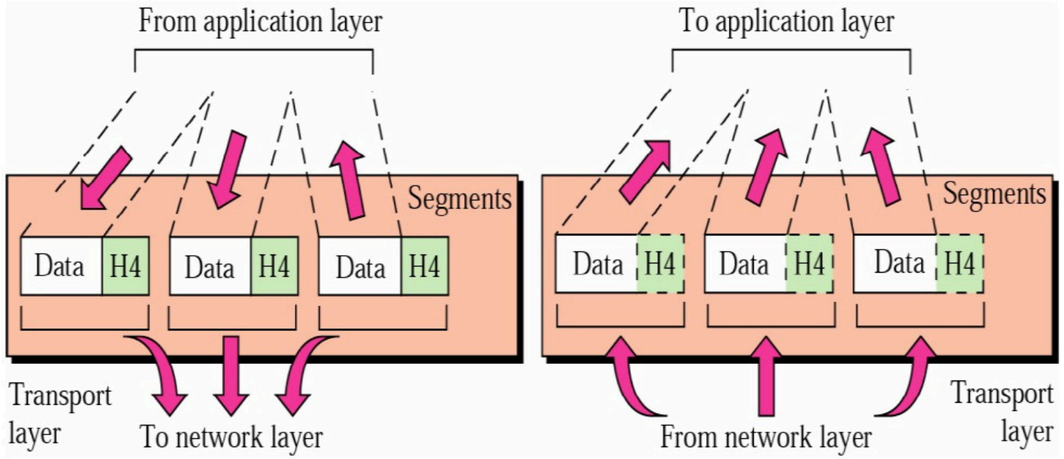
Network Layer



- The network layer is responsible for the delivery of **packets**from the original **source**to the final **destination**.

- A protocoldefines how bits and bytes are organized into packets, and the addressing schemeby which different machines find each other.
- Internet Protocol**(**IP**)**: the most popular one
- Others: IPX(Netware), AppleTalk(Apple Mac)
- Internet layer protocols are hardware-independent.
- Data is sent in packets called datagrams.
- Each IP datagram contains a header(20 ~ 60 bytes) and a payload(up to 65515 bytes).
- The header contains the protocol version no. and the addressesof the sending and receiving hosts.

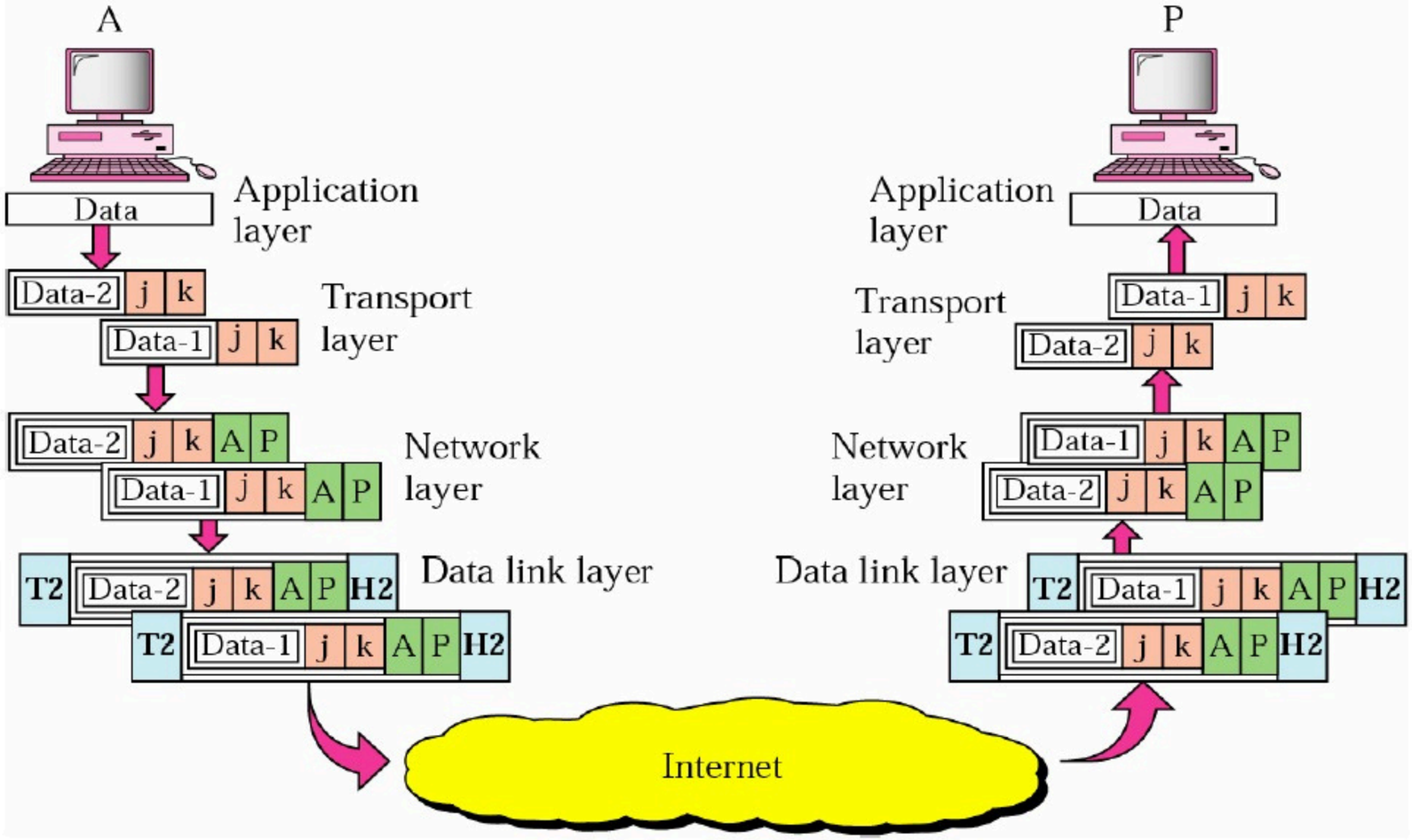
Transport Layer



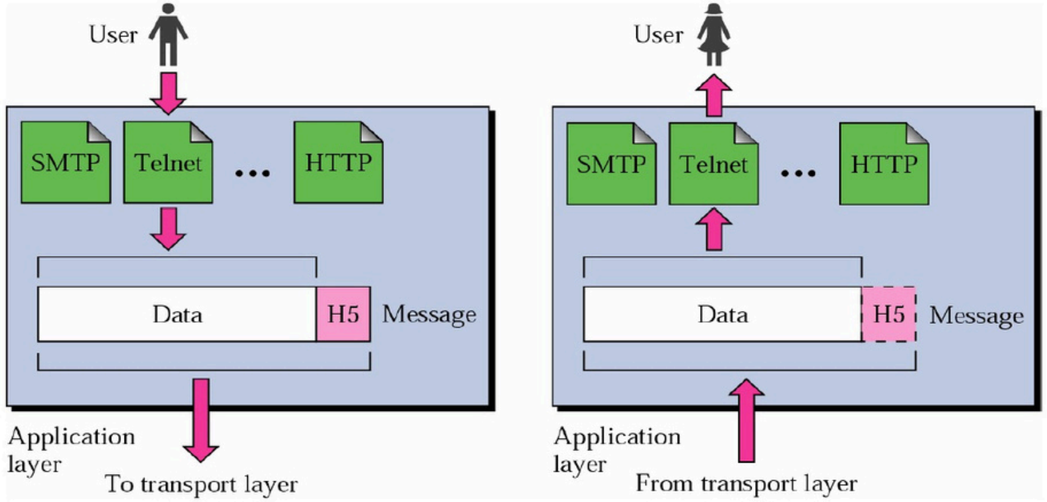
- The transport layer is responsible for delivery of a **message** from one **process** to another.

- Datagrams may not be delivered or arrived orderly.
- Responsible for ensuring that packets are received in the order sent and that no data is lost.
- Lost packets must be retransmitted.
- Two primary protocols: **TCP** and **UDP**.
- The Transmission Control Protocol (TCP) is a **reliable** protocol that guarantees the order of packets and no data lost, with higher overhead.
- The User Datagram Protocol (UDP) is an **unreliable** protocol that does not guarantee correct delivery of packets, but much faster.

Transport Layer Communication



Application Layer



- The application layer is responsible for providing **services** to the user.

- Deliver data to and from the application processes.
- Lower layers define **how** data is transferred.
- The application layer decides **what** to do with that data and **when** it's transferred.
- **Example**: HTTP makes sure that your browser knows to display an image as a picture, not a long stream of numbers.
- **Examples**: SMTP and POP for email, FTP for file transfer, NNTP for news, ...
- The way these four(five) layers work together is called **encapsulation**.

Protocol Encapsulation

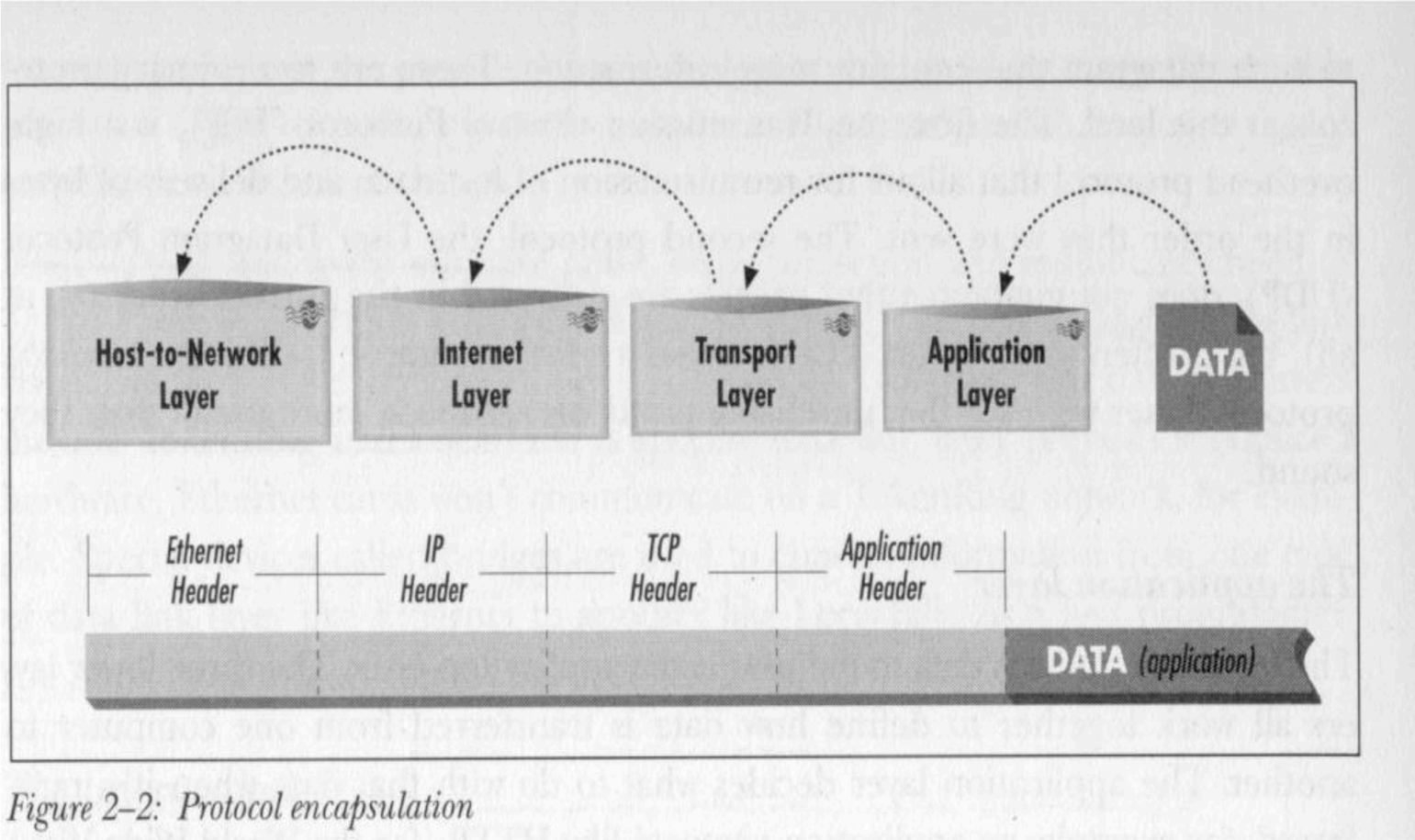


Figure 2–2: Protocol encapsulation

Summary of Duties