



Gayatri Vidya Parishad College of Engineering for Women

Approved by AICTE, New Delhi and Affiliated to JNTU, Kakinada, Andhra Pradesh, India.

COMPUTER NETWORKS

UNIT - I :

COURSE OBJECTIVES

1. To introduce key concepts and principles of computer networks
2. To study the Internet and its protocol stack.
3. Understanding Architecture, protocol, application-examples will include email, web and media- streaming
4. The implementation and deployment of communications services in practical networks: including wired and wireless LAN environments, will be followed by a discussion of issues of network-security and network- management

INTRODUCTION

During the 20th century, the key technology was information gathering, processing, and distribution. The merging of computers and communications had a profound influence on the way computer systems are organized. The concept of the "computer center" as a room with a large computer to which users bring their work for processing is now totally obsolete.

The old model of a single computer serving all of the organization's computational needs has been replaced by one in which a large number of separate but interconnected computers do the job. These systems are called **computer networks**.

Definition:

The term "**computer network**" to mean a collection of autonomous computers interconnected by a single technology. Two computers are said to be interconnected if they are able to exchange information.

The connection need not be via a copper wire; fiber optics, microwaves, infrared, and communication satellites can also be used. Networks come in many sizes, shapes and forms.

Examples: LAN, MAN, WAN.

There is considerable confusion in the literature between a computer network and a **distributed system**.

Definition:

The key distinction is that in a distributed system, a collection of independent computers appears to its users as a single coherent system. Each system has its own resource.

Example: WWW.

1.1 Uses of Computer Networks

1.1.1 Business Applications

The issue here is **resource sharing**, and the goal is to make all programs, equipment, and especially data available to anyone on the network without regard to the physical location of the resource and the user. In the simplest of terms, one can imagine a company's information system as consisting of one or more databases and some number of

employees who need to access them remotely. In this model, the data are stored on powerful computers called **servers**.

Often these are centrally housed and maintained by a system administrator. In contrast, the employees have simpler machines, called **clients**, on their desks, with which they access remote data, for example, to include in spreadsheets they are constructing. The client and server machines are connected by a network, as illustrated in Fig. 1-1.

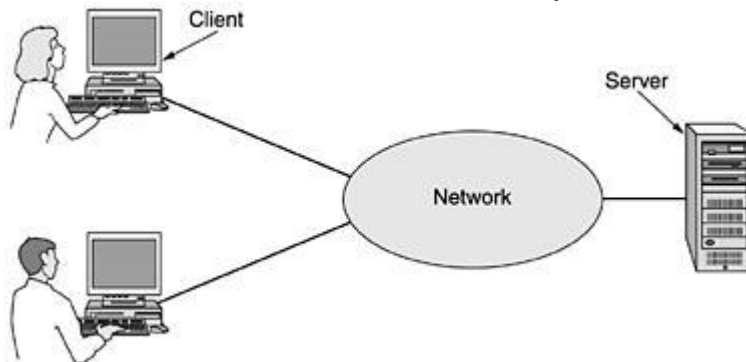


Figure 1-1. A network with two clients and one server

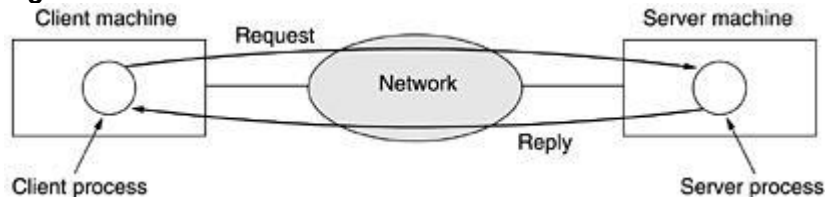


Figure 1-2. The client-server model involves requests and replies.

In client-server model Communication takes the form of the client process sending a message over the network to the server process. The client process then waits for a reply message. When the server process gets the request, it performs the requested work or looks up the requested data and sends back a reply. These messages are shown in Fig. 1-2. A second goal of setting up a computer network has to do with people rather than information or even computers. A computer network can provide a powerful **communication medium** among employees. Virtually every company that has two or more computers now has **e-mail (electronic mail)**, which employees generally use for a great deal of daily communication. But e-mail is not the only form of improved communication made possible by computer networks. With a network, it is easy for two or more people who work far apart to write a report together. When one worker makes a change to an online document, the others can see the change immediately, instead of waiting several days for a letter. Such a speedup makes cooperation among far-flung groups of people easy where it previously had been impossible. another form of computer-assisted communication is videoconferencing. Using this technology, employees at distant locations can hold a meeting, seeing and hearing each other and even writing on a shared virtual blackboard. Videoconferencing is a powerful tool for eliminating the cost and time previously devoted to travel.

A third goal for increasingly many companies is doing business electronically with other companies, especially suppliers and customers. For example, manufacturers of automobiles, aircraft, and computers, among others, buy subsystems from a variety of suppliers and then assemble the parts. Using computer networks, manufacturers can place orders electronically as needed. Being able to place orders in real time (i.e., as needed)

reduces the need for large inventories and enhances efficiency. A fourth goal that is starting to become more important is doing business with consumers over the Internet. Airlines, bookstores, and music vendors have discovered that many customers like the convenience of shopping from home.

1.1.2 Home Applications

Uses of the Internet for home users are :

1. Access to remote information.
2. Person-to-person communication.
3. Interactive entertainment.
4. Electronic commerce.

Person-to-person communication often goes by the name of **peer-to-peer** communication, to distinguish it from the client-server model. In this form, individuals who form a loose group can communicate with others in the group, as shown in Fig. 1-3. Every person can, in principle, communicate with one or more other people; there is no fixed division into clients and servers.

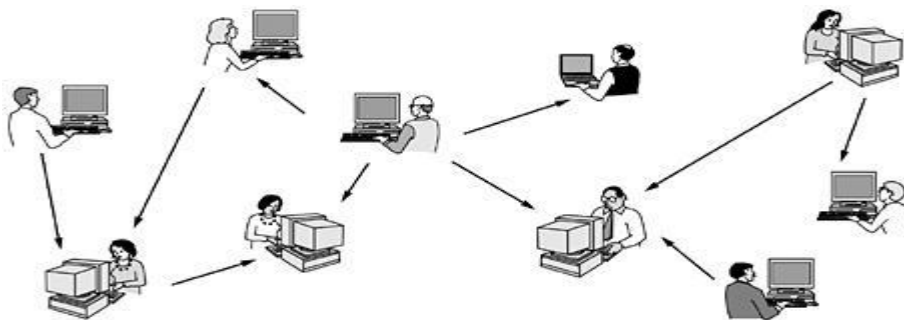


Figure 1-3. In a peer-to-peer system there are no fixed clients and servers.

On-line auctions are more of a peer-to-peer system, sort of consumer-to-consumer. Some of these forms of e-commerce have acquired cute little tags.

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books on-line
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products on line
P2P	Peer-to-peer	File sharing

Figure 1-4. Some forms of e-commerce.

1.1.3 Mobile Users

Mobile computers, such as notebook computers and personal digital assistants (PDAs), are one of the fastest-growing segments of the computer industry. Many owners of these computers have desktop machines back at the office and want to be connected to their home base even when away from home or en route. People on the road often want to use their portable electronic equipment to send and receive telephone calls, faxes, and electronic mail, surf the Web, access remote files, and log on to remote machines. And they want to do this from anywhere on land, sea, or air. Wireless networks are also important to the military. wireless networking and mobile computing are often related, they are not identical, as

Wireless	Mobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired buildings
Yes	Yes	Portable office; PDA for store inventory

Figure 1-5. Combinations of wireless networks and mobile computing.

1.1.4 Social Issues

The widespread introduction of networking has introduced new social, ethical, and political problems.

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	Metropolitan area network
10 km	City	
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Figure 1-6. Classification of interconnected processors by scale.

1.2.1 Local Area Networks (LAN)

Local area networks, generally called **LANs**, are privately-owned networks within a single building or campus of up to a few kilometers in size. They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information. LANs are distinguished from other kinds of networks by three characteristics: (1) their size, (2) their transmission technology, and (3) their topology.

LANs are restricted in size, which means that the worst-case transmission time is bounded and known in advance. Knowing this bound makes it possible to use certain kinds of designs that would not otherwise be possible. It also simplifies network management. LANs may use a transmission technology consisting of a cable to which all the machines are attached, like the telephone company party lines once used in rural areas. Traditional LANs run at speeds of 10 Mbps to 100 Mbps, have low delay (microseconds or nanoseconds), and make very few errors. Newer LANs operate at up to 10 Gbps. In this book, we will adhere to tradition and measure line speeds in megabits/sec (1 Mbps is 1,000,000 bits/sec) and gigabits/sec (1Gbps is 1,000,000,000 bits/sec). Various **topologies** are possible for broadcast LANs. [Figure 1-7](#)

In a bus (i.e., a linear cable) network, at any instant at most one machine is the master and is allowed to transmit. All other machines are required to refrain from sending. An arbitration mechanism is needed to resolve conflicts when two or more machines want to transmit simultaneously. The arbitration mechanism may be centralized or distributed. IEEE 802.3, popularly called **Ethernet**, for example, is a bus-based broadcast network with decentralized control, usually operating at 10 Mbps to 10 Gbps. Computers on an

Ethernet can transmit whenever they want to; if two or more packets collide, each computer just waits a random time and tries again later.

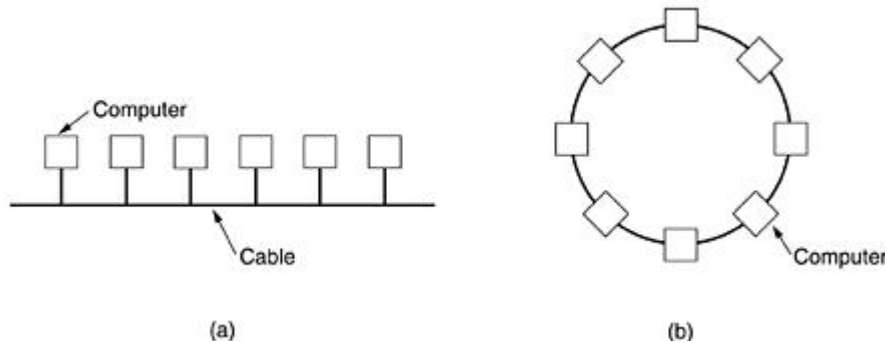


Figure 1-7. Two broadcast networks. (a) Bus. (b) Ring.

A second type of broadcast system is the ring. In a ring, each bit propagates around on its own, not waiting for the rest of the packet to which it belongs. Typically, each bit circumnavigates the entire ring in the time it takes to transmit a few bits, often before the complete packet has even been transmitted. As with all other broadcast systems, some rule is needed for arbitrating simultaneous accesses to the ring. Various methods, such as having the machines take turns, are in use. IEEE 802.5 (the IBM token ring), is a ring-based LAN operating at 4 and 16 Mbps. FDDI is another example of a ring network. Broadcast networks can be further divided into static and dynamic, depending on how the channel is allocated. A typical static allocation would be to divide time into discrete intervals and use a round-robin algorithm, allowing each machine to broadcast only when its time slot comes up. Static allocation wastes channel capacity when a machine has nothing to say during its allocated slot, so most systems attempt to allocate the channel dynamically (i.e., on demand).

Dynamic allocation methods for a common channel are either centralized or decentralized. In the centralized channel allocation method, there is a single entity, for example, a bus arbitration unit, which determines who goes next. It might do this by accepting requests and making a decision according to some internal algorithm. In the decentralized channel allocation method, there is no central entity; each machine must decide for itself whether to transmit. You might think that this always leads to chaos, but it does not.

1.2.2 Metropolitan Area Networks (MAN)

A **metropolitan area network**, or **MAN**, covers a city. The best-known example of a MAN is the cable television network available in many cities. This system grew from earlier community antenna systems used in areas with poor over-the-air television reception. MAN might look like the system shown in Fig. 1-8. In this figure we see both television signals and Internet being fed into the centralized **head end** for subsequent distribution to people's homes. Cable television is not the only MAN. Recent developments in high-speed wireless Internet access resulted in another MAN, which has been standardized as IEEE 802.16.

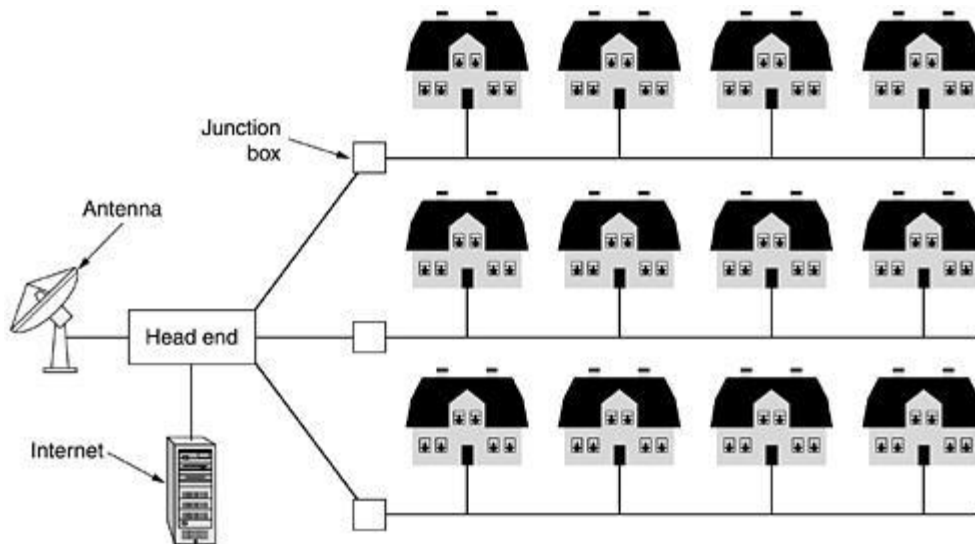


Figure 1-8. A metropolitan area network based on cable TV.

1.2.3 Wide Area Networks

A **wide area network**, or **WAN**, spans a large geographical area, often a country or continent. It contains a collection of machines intended for running user (i.e., application) programs. We will follow traditional usage and call these machines **hosts**. The hosts are connected by a **communication subnet**, or just **subnet** for short. The hosts are owned by the customers (e.g., people's personal computers), whereas the communication subnet is typically owned and operated by a telephone company or Internet service provider. The job of the subnet is to carry messages from host to host, just as the telephone system carries words from speaker to listener. subnet consists of two distinct components: transmission lines and switching elements. **Transmission lines** move bits between machines. They can be made of copper wire, optical fiber, or even radio links. **Switching elements** are specialized computers that connect three or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them. In this model, shown in Fig. 1-9, each host is frequently connected to a LAN on which a router is present, although in some cases a host can be connected directly to a router. The collection of communication lines and routers (but not the hosts) form the subnet.

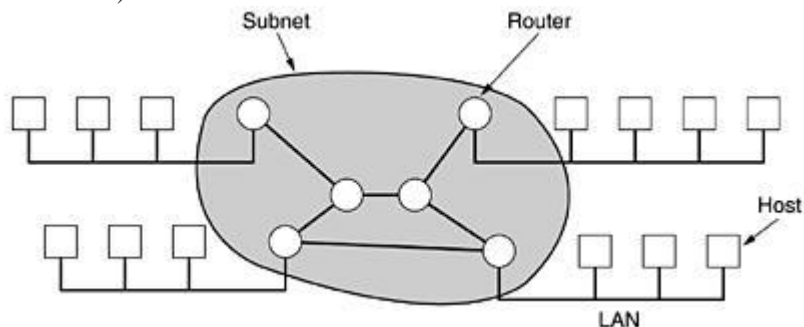


Figure 1-9. Relation between hosts on LANs and the subnet.

1.2.4 Wireless Area Networks (WAN)

wireless networks can be divided into three main categories:

1. System interconnection. 2. Wireless LANs. 3. Wireless WANs.

System interconnection is all about interconnecting the components of a computer using shortrange radio. Almost every computer has a monitor, keyboard, mouse, and printer connected to the main unit by cables. system interconnection networks use the master-slave paradigm of Fig. 1- 10(a). The system unit is normally the master, talking to the mouse, keyboard, etc., as slaves. The master tells the slaves what addresses to use, when they can broadcast, how long they can transmit, what frequencies they can use, and so on.

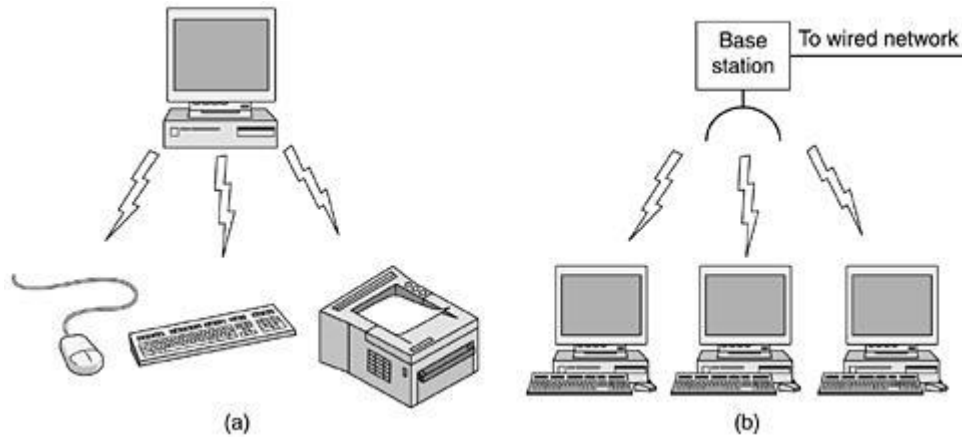


Figure 1-10. (a) Bluetooth configuration. (b) Wireless LAN.

The next step up in wireless networking is the wireless LANs. These are systems in which every computer has a radio modem and antenna with which it can communicate with other systems. Often there is an antenna on the ceiling that the machines talk to, as shown in Fig. 1-10(b). However, if the systems are close enough, they can communicate directly with one another in a peer-to-peer configuration. Wireless LANs are becoming increasingly common in small offices and homes, where installing Ethernet is considered too much trouble, as well as in older office buildings, company cafeterias, conference rooms, and other places. There is a standard for wireless LANs, called **IEEE 802.11**, which most systems implement and which is becoming very widespread. The third kind of wireless network is used in wide area systems. The radio network used for cellular telephones is an example of a low-bandwidth wireless system. This system has already gone through three generations. The first generation was analog and for voice only. The second generation was digital and for voice only. The third generation is digital and is for both voice and data.

1.2.6 Internetworks

A collection of interconnected networks is called an **internetwork** or **internet**. A common form of internet is a collection of LANs connected by a WAN Subnets, networks, and internetworks are often confused. Subnet makes the most sense in the context of a wide area network, where it refers to the collection of routers and communication lines owned by the network operator. An internetwork is formed when distinct networks are interconnected. In our view, connecting a LAN and a WAN or connecting two LANs forms an internetwork.

1.3 Network Software

1.3.1 Protocol Hierarchies

Networks are organized as a stack of **layers** or **levels**, each one built upon the one below it. The number of layers, the name of each layer, the contents of each layer, and the function of each layer differ from network to network. The purpose of each layer is to offer certain services to the higher layers, shielding those layers from the details of how the offered services are actually implemented. In a sense, each layer is a kind of virtual machine, offering certain services to the layer above it. Layer n on one machine carries on a conversation with layer n on another machine. The rules and conventions used in this conversation are collectively known as the layer n protocol.

Basically, a **protocol** is an agreement between the communicating parties on how Communication is to proceed. A five-layer network is illustrated in Fig. 1-11. The entities comprising the corresponding layers on different machines are called **peers**. The peers may be processes, hardware devices, or even human beings. In other words, it is the peers that communicate by using the protocol.

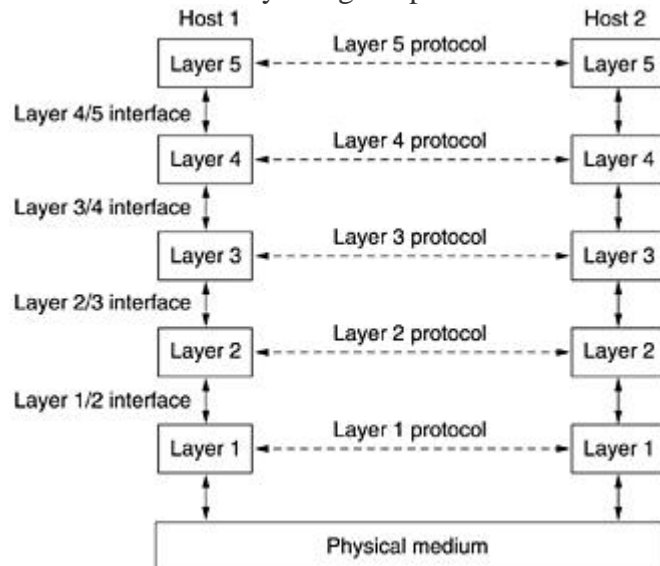


Figure 1-11. Layers, protocols, and interfaces.

In reality, no data are directly transferred from layer n on one machine to layer n on another machine. Instead, each layer passes data and control information to the layer immediately below it, until the lowest layer is reached. Below layer 1 is the **physical medium** through which actual communication occurs. In Fig. 1-11, virtual communication is shown by dotted lines and physical communication by solid lines.

Between each pair of adjacent layers is an **interface**. The interface defines which primitive operations and services the lower layer makes available to the upper one.

A set of layers and protocols is called a **network architecture**. The specification of an architecture must contain enough information to allow an implementer to write the program or build the hardware for each layer so that it will correctly obey the appropriate protocol. A list of protocols used by a certain system, one protocol per layer, is called a **protocol stack**.

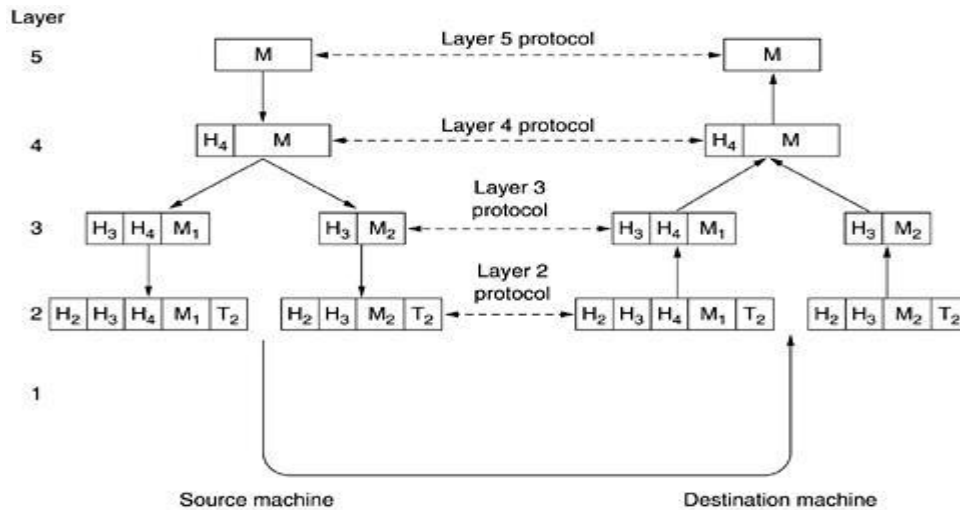


Figure 1-12. Example information flow supporting virtual communication in layer 5.

A message, M , is produced by an application process running in layer 5 and given to layer 4 for transmission. Layer 4 puts a **header** in front of the message to identify the message and passes the result to layer 3. The header includes control information, such as sequence numbers, to allow layer 4 on the destination machine to deliver messages in the right order if the lower layers do not maintain sequence. In some layers, headers can also contain sizes, times, and other control fields.

In many networks, there is no limit to the size of messages transmitted in the layer 4 protocol, but there is nearly always a limit imposed by the layer 3 protocol. Consequently, layer 3 must break up the incoming messages into smaller units, packets, prepending a layer 3 header to each packet. In this example, M is split into two parts, M_1 and M_2 .

Layer 3 decides which of the outgoing lines to use and passes the packets to layer 2. Layer 2 adds not only a header to each piece, but also a trailer, and gives the resulting unit to layer 1 for physical transmission. At the receiving machine the message moves upward, from layer to layer, with headers being stripped off as it progresses. None of the headers for layers below n are passed up to layer n . The important thing to understand about Fig. 1-12 is the relation between the virtual and actual communication and the difference between protocols and interfaces. The peer processes in layer 4, for example, conceptually think of their communication as being "horizontal," using the layer 4 protocol. Each one is likely to have a procedure called something like *SendToOtherSide* and *GetFromOtherSide*, even though these procedures actually communicate with lower layers across the 3/4 interface, not with the other side.

1.3.5 The Relationship of Services to Protocols

Services and protocols are distinct concepts.

A *service* is a set of primitives (operations) that a layer provides to the layer above it. The service defines what operations the layer is prepared to perform on behalf of its users, but it says nothing at all about how these operations are implemented. A service relates to an interface between two layers, with the lower layer being the service provider and the upper layer being the service user.

A *protocol*, in contrast, is a set of rules governing the format and meaning of the packets, or messages that are exchanged by the peer entities within a layer. Entities use protocols

to implement their service definitions. They are free to change their protocols at will, provided they do not change the service visible to their users.

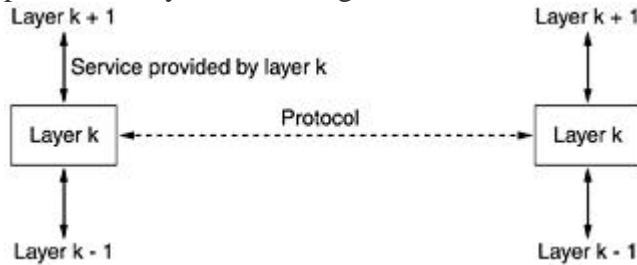


Figure 1-16. The relationship between a service and a protocol.

A service is like an abstract data type or an object in an object-oriented language. It defines operations that can be performed on an object but does not specify how these operations are implemented. A protocol relates to the *implementation* of the service and as such is not visible to the user of the service.

1.4 Reference Models

1.4.1 The OSI Reference Model

The model is called the **ISO OSI (Open Systems Interconnection) Reference Model** because it deals with connecting open systems—that is, systems that are open for communication with other systems.

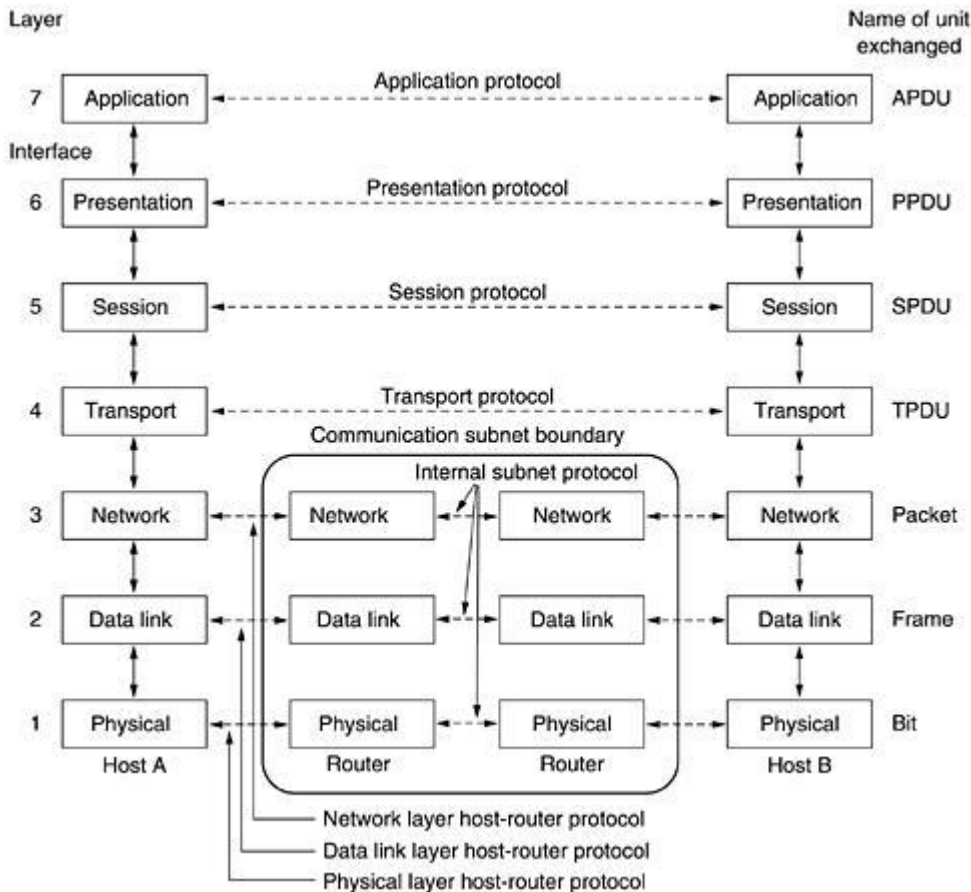


Figure 1-17. The OSI reference model.

The OSI model has seven layers.

1. A layer should be created where a different abstraction is needed.
2. Each layer should perform a well-defined function.
3. The function of each layer should be chosen with an eye toward defining internationally standardized protocols.
4. The layer boundaries should be chosen to minimize the information flow across the interfaces.
5. The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.

The Physical Layer

The **physical layer** is concerned with transmitting raw bits over a communication channel. The design issues have to do with making sure that when one side sends a 1 bit, it is received by the other side as a 1 bit, not as a 0 bit. The design issues here largely deal with mechanical, electrical, and timing interfaces, and the physical transmission medium, which lies below the physical layer.

The Data Link Layer

The main task of the **data link layer** is to transform a raw transmission facility into a line that appears free of undetected transmission errors to the network layer. It accomplishes this task by having the sender break up the input data into **data frames** (typically a few hundred or a few thousand bytes) and transmit the frames sequentially. If the service is reliable, the receiver confirms correct receipt of each frame by sending back an **acknowledgement frame**. Another issue that arises in the data link layer (and most of the higher layers as well) is how to keep a fast transmitter from drowning a slow receiver in data. Some traffic regulation mechanism is often needed to let the transmitter know how much buffer space the receiver has at the moment. Frequently, this flow regulation and the error handling are integrated.

The Network Layer

The **network layer** controls the operation of the subnet. A key design issue is determining how packets are routed from source to destination.

If too many packets are present in the subnet at the same time, they will get in one another's way, forming bottlenecks. The control of such congestion also belongs to the network layer. More generally, the quality of service provided (delay, transit time, jitter, etc.) is also a network layer issue.

When a packet has to travel from one network to another to get to its destination, many problems can arise. The addressing used by the second network may be different from the first one. The second one may not accept the packet at all because it is too large. The protocols may differ, and so on. It is up to the network layer to overcome all these problems to allow heterogeneous networks to be interconnected. In broadcast networks, the routing problem is simple, so the network layer is often thin or even nonexistent.

The Transport Layer

The basic function of the **transport layer** is to accept data from above, split it up into smaller units if need be, pass these to the network layer, and ensure that the pieces all arrive correctly at the other end. Furthermore, all this must be done efficiently and in a way that isolates the upper layers from the inevitable changes in the hardware technology. The transport layer also determines what type of service to provide to the session layer,

and, ultimately, to the users of the network. The most popular type of transport connection is an error-free point-to-point channel that delivers messages or bytes in the order in which they were sent. The transport layer is a true end-to-end layer, all the way from the source to the destination. In other words, a program on the source machine carries on a conversation with a similar program on the destination machine, using the message headers and control messages. In the lower layers, the protocols are between each machine and its immediate neighbors, and not between the ultimate source and destination machines, which may be separated by many routers. The difference between layers 1 through 3, which are chained, and layers 4 through 7, which are end-to-end.

The Session Layer

The session layer allows users on different machines to establish **sessions** between them. Sessions offer various services, including **dialog control** (keeping track of whose turn it is to transmit), **token management** (preventing two parties from attempting the same critical operation at the same time), and **synchronization** (checkpointing long transmissions to allow them to continue from where they were after a crash).

The Presentation Layer

Lower layers, which are mostly concerned with moving bits around, the **presentation layer** is concerned with the syntax and semantics of the information transmitted. In order to make it possible for computers with different data representations to communicate, the data structures to be exchanged can be defined in an abstract way, along with a standard encoding to be used "on the wire." The presentation layer manages these abstract data structures and allows higher-level data structures (e.g., banking records), to be defined and exchanged.

The Application Layer

The **application layer** contains a variety of protocols that are commonly needed by users. One widely-used application protocol is **HTTP (HyperText Transfer Protocol)**, which is the basis for the World Wide Web. When a browser wants a Web page, it sends the name of the page it wants to the server using HTTP. The server then sends the page back. Other application protocols are used for file transfer, electronic mail, and network news.

1.4.2 The TCP/IP Reference Model

TCP/IP stands for Transmission Control Protocol / Internet Protocol. The TCP/IP reference model is a set of protocols that allow communication across multiple diverse networks.

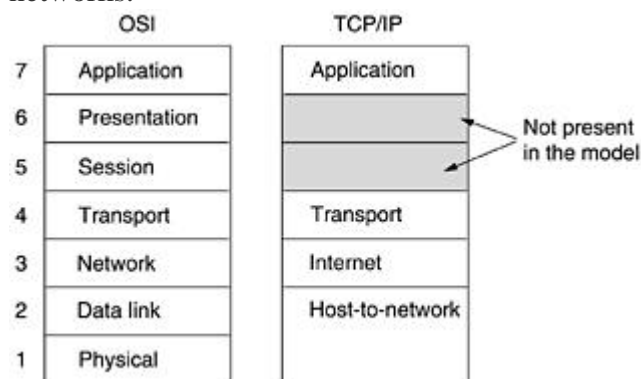


Figure 1-18. The TCP/IP reference model.

The Internet Layer

Its job is to permit hosts to inject packets into any network and have them travel independently to the destination (potentially on a different network). They may even arrive in a different order than they were sent, in which case it is the job of higher layers to rearrange them, if in-order delivery is desired. Note that "internet" is used here in a generic sense, even though this layer is present in the Internet. The internet layer defines an official packet format and protocol called **IP (Internet Protocol)**. The job of the internet layer is to deliver IP packets where they are supposed to go. Packet routing is clearly the major issue here, as is avoiding congestion. For these reasons, it is reasonable to say that the TCP/IP internet layer is similar in functionality to the OSI network layer. [Figure 1-18](#) shows this correspondence.

The Transport Layer

The layer above the internet layer in the TCP/IP model is now usually called the **transport layer**. It is designed to allow peer entities on the source and destination hosts to carry on a conversation, just as in the OSI transport layer. Two end-to-end transport protocols have been defined here. The first one, **TCP (Transmission Control Protocol)**, is a reliable connection oriented protocol that allows a byte stream originating on one machine to be delivered without error on any other machine in the internet. It fragments the incoming byte stream into discrete messages and passes each one on to the internet layer. At the destination, the receiving TCP process reassembles the received messages into the output stream. TCP also handles flow control to make sure a fast sender cannot swamp a slow receiver with more messages than it can handle. The second protocol in this layer, **UDP (User Datagram Protocol)**, is an unreliable, connectionless protocol for applications that do not want TCP's sequencing or flow control and wish to provide their own. It is also widely used for one-shot, client-server-type request-reply queries and applications in which prompt delivery is more important than accurate delivery, such as transmitting speech or video.

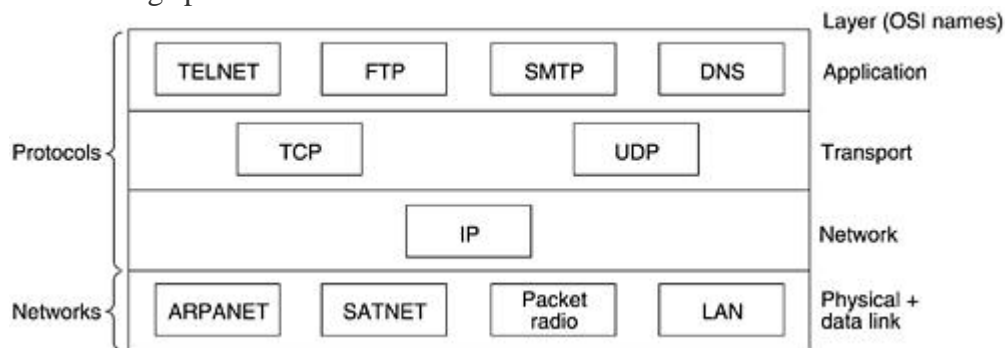


Figure 1-19. Protocols and networks in the TCP/IP model initially.

The Application Layer

The TCP/IP model does not have session or presentation layers. No need for them was perceived, so they were not included. Experience with the OSI model has proven this view correct: they are of little use to most applications. On top of the transport layer is the **application layer**. It contains all the higher-level protocols. The early ones included virtual terminal (TELNET), file transfer (FTP), and electronic mail (SMTP), as shown in [Fig. 1-19](#). The virtual terminal protocol allows a user on one machine to log onto a distant machine and work there. The file transfer protocol provides a way to move data efficiently from one machine to another. Electronic mail was originally just a kind of file

transfer, but later a specialized protocol (SMTP) was developed for it. Many other protocols have been added to these over the years: the Domain Name System (DNS) for mapping host names onto their network addresses, NNTP, the protocol for moving USENET news articles around, and HTTP, the protocol for fetching pages on the World Wide Web, and many others.

The Host-to-Network Layer

Below the internet layer is a great void. The TCP/IP reference model does not really say much about what happens here, except to point out that the host has to connect to the network using some protocol so it can send IP packets to it. This protocol is not defined and varies from host to host and network to network.

1.5 Example Networks

1.5.1 The Internet

The Internet is not a network at all, but a vast collection of different networks that use certain common protocols and provide certain common services. It is an unusual system in that it was not planned by anyone and is not controlled by anyone.

The ARPANET

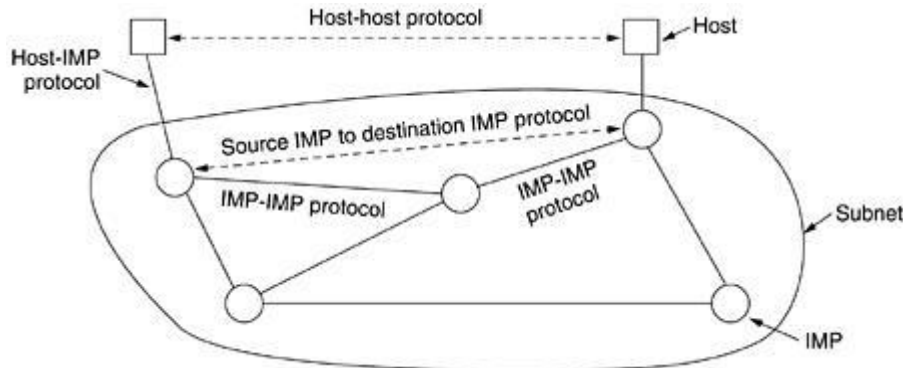


Figure 1-20. The original ARPANET design.

The ARPANET was a research network sponsored by the DoD (U.S. Department of Defense). It eventually connected hundreds of universities and government installations, using leased telephone lines. The subnet would consist of minicomputers called **IMPs** (**Interface Message Processors**) connected by 56-kbps transmission lines. For high reliability, each IMP would be connected to at least two other IMPs. The subnet was to be a datagram subnet, so if some lines and IMPs were destroyed, messages could be automatically rerouted along alternative paths. Each node of the network was to consist of an IMP and a host, in the same room, connected by a short wire. A host could send messages of up to 8063 bits to its IMP, which would then break these up into packets of at most 1008 bits and forward them independently toward the destination. Each packet was received in its entirety before being forwarded, so the subnet was the first electronic store-and-forward packet-switching network. The software was split into two parts: subnet and host. The subnet software consisted of the IMP end of the host-IMP connection, the IMP-IMP protocol, and a source IMP to destination IMP protocol designed to improve reliability. The original ARPANET design is shown in Fig. 1-20.

The Internet and its predecessors had four main applications:

1. E-mail. The ability to compose, send, and receive electronic mail has been around since the early days of the ARPANET and is enormously popular. Many people get dozens of messages a day and consider it their primary way of interacting with the outside world, far outdistancing the telephone and snail mail. E-mail programs are available on virtually every kind of computer these days.

2. News. Newsgroups are specialized forums in which users with a common interest can exchange messages. Thousands of newsgroups exist, devoted to technical and nontechnical topics, including computers, science, recreation, and politics. Each newsgroup has its own etiquette, style, and customs, and woe betide anyone violating them.

3. Remote login. Using the telnet, rlogin, or ssh programs, users anywhere on the Internet can log on to any other machine on which they have an account.

4. File transfer. Using the FTP program, users can copy files from one machine on the Internet to another. Vast numbers of articles, databases, and other information are available this way.

Architecture of the Internet

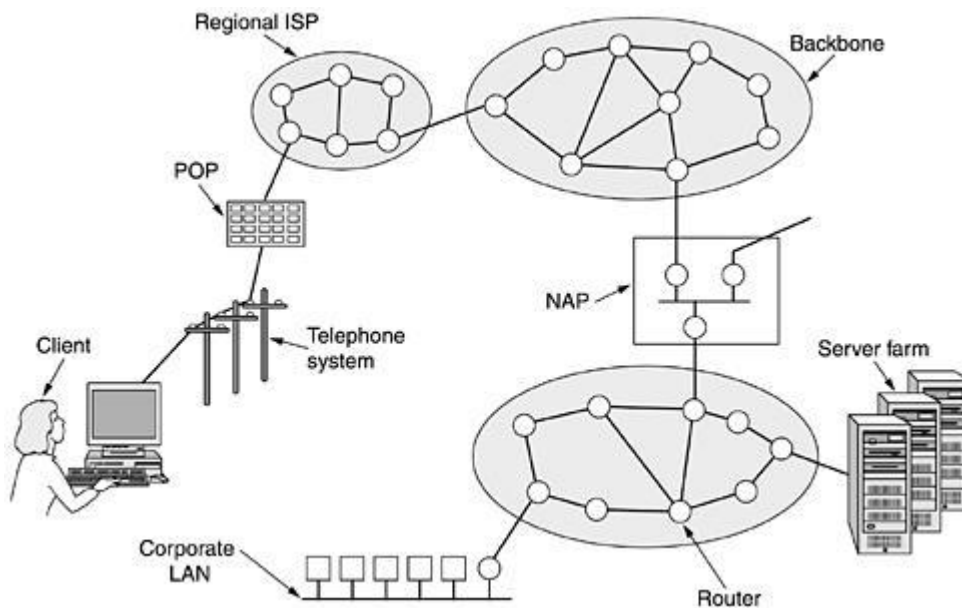


Figure 1-21. Overview of the Internet.

1.5.2 Connection-Oriented Networks: X.25, Frame Relay, and ATM

X.25, which was the first public data connection oriented network. It was deployed in the 1970s at a time when telephone service was a monopoly everywhere and the telephone company in each country expected there to be one data network per country—theirs. To use X.25, a computer first established a connection to the remote computer, that is, placed a telephone call. This connection was given a connection number to be used in data transfer packets (because multiple connections could be open at the same time). Data packets were very simple, consisting of a 3-byte header and up to 128 bytes of data. The header consisted of a 12-bit connection number, a packet sequence number, an acknowledgement number, and a few miscellaneous bits. X.25 networks operated for about a decade with mixed success.

In the 1980s, the X.25 networks were largely replaced by a new kind of network called **frame relay**. The essence of frame relay is that it is a connection-oriented network with no error control and no flow control. Because it was connection-oriented, packets were delivered in order (if they were delivered at all). The properties of in-order delivery, no error control, and no flow control make frame relay akin to a wide area LAN. Its most important application is interconnecting LANs at multiple company offices. Frame relay enjoyed a modest success and is still in use in places today.

Network Topologies :

A Network Topology is the arrangement with which computer systems or network devices are connected to each other. Topologies may define both physical and logical aspect of the network. Both logical and physical topologies could be same or different in a same network.

Point-to-Point

Point-to-point networks contains exactly two hosts such as computer, switches or routers, servers connected back to back using a single piece of cable. Often, the receiving end of one host is connected to sending end of the other and vice-versa.

If the hosts are connected point-to-point logically, then may have multiple intermediate devices. But the end hosts are unaware of underlying network and see each other as if they are connected directly.

Bus Topology

In case of Bus topology, all devices share single communication line or cable. Bus topology may have problem while multiple hosts sending data at the same time. Therefore, Bus topology either uses CSMA/CD technology or recognizes one host as Bus Master to solve the issue. It is one of the simple forms of networking where a failure of a device does not affect the other devices. But failure of the shared communication line can make all other devices stop functioning.

Both ends of the shared channel have line terminator. The data is sent in only one direction and as soon as it reaches the extreme end, the terminator removes the data from the line.

Star Topology

All hosts in Star topology are connected to a central device, known as hub device, using a point-to-point connection. That is, there exists a point to point connection between hosts and hub. The hub device can be any of the following:

- Layer-1 device such as hub or repeater
- Layer-2 device such as switch or bridge
- Layer-3 device such as router or gateway

As in Bus topology, hub acts as single point of failure. If hub fails, connectivity of all hosts to all other hosts fails. Every communication between hosts, takes place through only the hub. Star topology is not expensive as to connect one more host, only one cable is required and configuration is simple.

Ring Topology

In ring topology, each host machine connects to exactly two other machines, creating a circular network structure. When one host tries to communicate or send message to a host which is not adjacent to it, the data travels through all intermediate hosts. To connect one more host in the existing structure, the administrator may need only one more extra cable.

Failure of any host results in failure of the whole ring. Thus, every connection in the ring is a point of failure. There are methods which employ one more backup ring.

Mesh Topology

In this type of topology, a host is connected to one or multiple hosts. This topology has hosts in point-to-point connection with every other host or may also have hosts which are

Hosts in Mesh topology also work as relay for other hosts which do not have direct point-to-point links. Mesh technology comes into two types:

- **Full Mesh:** All hosts have a point-to-point connection to every other host in the network. Thus for every new host $n(n-1)/2$ connections are required. It provides the most reliable network structure among all network topologies.
- **Partially Mesh:** Not all hosts have point-to-point connection to every other host. Hosts connect to each other in some arbitrarily fashion. This topology exists where we need to provide reliability to some hosts out of all.

Tree Topology

Also known as Hierarchical Topology, this is the most common form of network topology in use presently. This topology imitates as extended Star topology and inherits properties of bus topology.

This topology divides the network in to multiple levels/layers of network. Mainly in LANs, a network is bifurcated into three types of network devices. The lowermost is access-layer where computers are attached. The middle layer is known as distribution layer, which works as mediator between upper layer and lower layer. The highest layer is

known as core layer, and is central point of the network, i.e. root of the tree from which all nodes fork.

All neighboring hosts have point-to-point connection between them. Similar to the Bus topology, if the root goes down, then the entire network suffers even though it is not the single point of failure. Every connection serves as point of failure, failing of which divides the network into unreachable segment.

Hybrid Topology

A network structure whose design contains more than one topology is said to be hybrid topology. Hybrid topology inherits merits and demerits of all the incorporating topologies.

The picture represents an arbitrarily hybrid topology. The combining topologies may contain attributes of Star, Ring, Bus, and Daisy-chain topologies. Most WANs are connected by means of Dual-Ring topology and networks connected to them are mostly Star topology networks. Internet is the best example of largest Hybrid topology