COMPUTER NETWORKS NOTES

UNIT 1

1. **Define Computer Network.**
   - A computer network is an interconnected collection of autonomous computers.
   - Two computers are said to be interconnected, if they are able to exchange the information.
   - The connection may be a physical one made through copper wires or other medium such as fiber optics, microwaves & communication satellites.

2. **What are the benefits of Computer Network?**
Important benefits of computer networks are:

   - Resource sharing
   - Powerful communication medium
   - Higher reliability
   - Higher flexibility
   - Lower cost
   - Incremental expansion

3. **What are the applications of Computer Networks?**
   - **Facilitating communications**
     Using a network, people can communicate efficiently and easily via email, instant messaging, chat rooms, telephone, video telephone calls, and video conferencing.
   - **Voice over IP**: Computer networks are also used to provide voice communication. This kind of voice communication is pretty cheap as compared to the normal telephonic conversation.
   - **Video on demand**: Future services provided by the cable television networks may include video on request where a person can request for a particular movie or any clip at anytime he wish to see.
   - **Sharing hardware**
     In a networked environment, each computer on a network may access and use hardware resources on the network, such as printing a document on a shared network printer.
   - **Sharing files, data, and information**
     In a network environment, authorized user may access data and information stored on other computers on the network. The capability of providing access to data and information on shared storage devices is an important feature of many networks.
   - **Sharing software**
     Users connected to a network may run application programs on remote computers through remote login (TELNET Protocol, Secure Shell (SSH) another UNIX based remote login protocol.)
   - **Marketing and sales:** Computer networks are used extensively in both marketing and sales organizations. Marketing professionals use them to collect, exchange, and analyze data related to customer needs and product development cycles. Sales application

includes teleshopping, which uses order-entry computers or telephones connected to order processing network, and online-reservation services for hotels, airlines and so on.

- **Financial services**: Today's financial services are totally depended on computer networks. Application includes credit history searches, foreign exchange and investment services, and electronic fund transfer, which allow user to transfer money without going into a bank (an automated teller machine is an example of electronic fund transfer, automatic pay-check is another).
- **Directory services**: Directory services allow list of files to be stored in central location to speed worldwide search operations. **Information services**: A Network information service includes bulletin boards and data banks. A World Wide Web site offering technical specification for a new product is an information service.
- **Electronic data interchange (EDI)**: EDI allows business information, including documents such as purchase orders and invoices, to be transferred without using paper.

4. What are the requirements of network design?

The following are the requirements for building a network: *Connectivity & Address*.

1) Connectivity
- A network must provide connectivity among a set of computers.
- Connectivity in networks is provided by Links, Nodes, and Clouds.

2) Address
- ➢ The final requirement is that each node must be assigned an address to communicate with other nodes.
- ➢ When a source node wants the network to deliver a message to a certain destination node, it specifies the address of the destination node.
- ➢ If the sending and receiving nodes are not directly connected, then the switches and routers of the network use this address to decide how to forward the message toward the destination.
- ➢ The process of determining systematically how to forward messages toward the destination node based on its address is called *routing*.
- ➢ When the source node wants to send a message to a single destination node. It is called *unicast*.
- ➢ The source node might want to *broadcast* a message to all the nodes on the network.
- ➢ Or a source node might want to send a message to some subset of the other nodes, but not all of them, a situation called *multicast*.

5. Define the following.
- **Links:** The physical medium which connects 2 or more computers directly. Ex. Coaxial cable, optical fiber etc.,
- **Nodes:** The computers which is connected to the links.
- **Clouds:** A set of computers can be indirectly connected and these set of independent networks are called clouds.
- **Gateway:** A node that is connected to 2 or more networks. It acts as a switch which stores and forward messages from one network to another.
- **Routing:** It is a process of determining systematically how to forward message towards the destination node based on its address.

- **Multiplexing:** Multiplexing is a method by which multiple data streams are combined into one signal over a single shared physical medium.

6. What are the different types of Physical Links?

- A network can consist of two or more computers directly connected by some physical medium, such as a coaxial cable or an optical fiber. Such a physical medium is called **a *link.***
- The computers it connects are referred as *nodes.*

Point to point: The physical links which connects a pairs of nodes called point-to-point

Multiple accesses: A single physical link which connects more than 2 nodes is said to be multiple access. It covers more geographical areas.
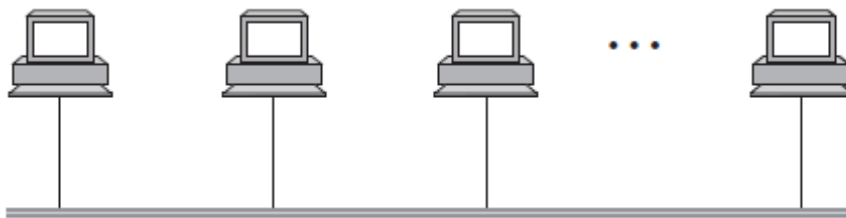
7. Define Switched Network. Explain its types.

Set of nodes, each of which is attached to one or more point-to-point links and those nodes are attached to at least 2 links that forward data to received on the one link out an another & thus the forward nodes from a switched network
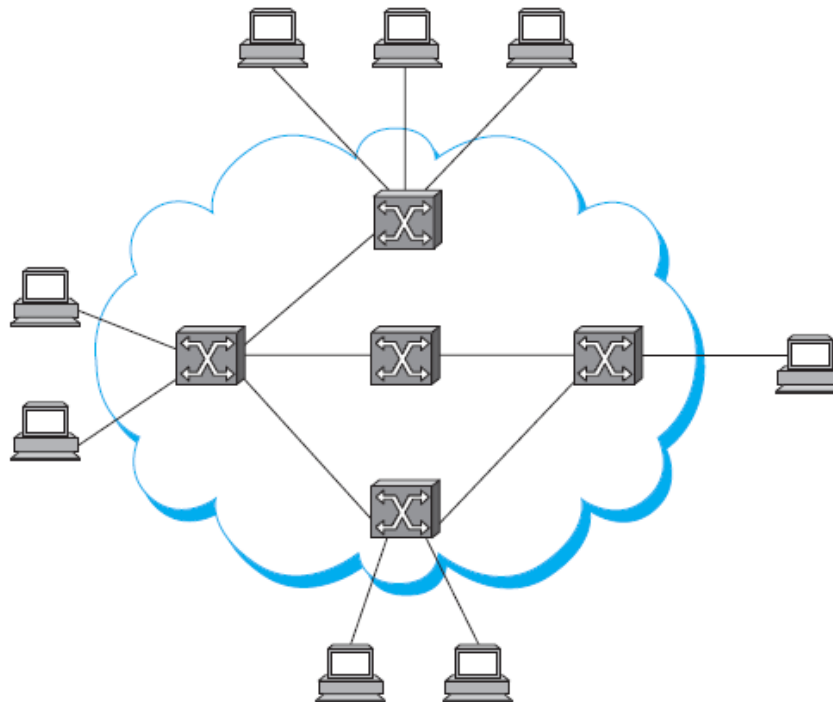
- **Switches:** The nodes present inside the cloud which implement the network are called switches. It stores and forward packets.

- Switched Networks are divided into 2 types such as: *circuit switched* **and** *packet switched*.

Circuit Switched Network	Packet Switched Network
In this network connection is established	In this,connection is not established
No Storage only Forward	Storage and Forward
It establishes a dedicated circuit across a sequence of links allows the source node to send a stream of bits across circuits to destination node	Each node in a store and forward first receives a complete packet over same links and stores in its internal memory and forward complete packet to next node
Example: Telephone System	Example: a piece of email, image file.

8. **Explain Indirect Communication or Internetwork.**
   - A set of computers can be indirectly connected.
   - A set of independent networks (clouds) are interconnected to form an *internetwork or internet.*
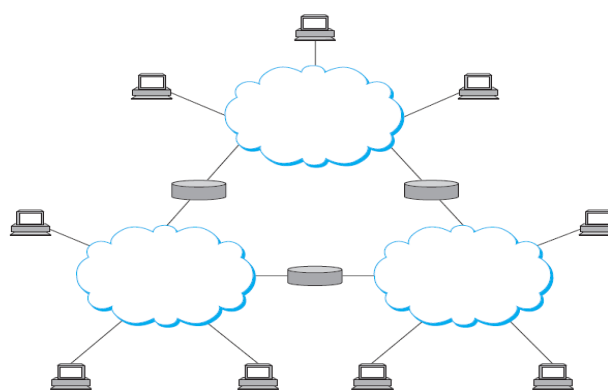
Interconnection of networks.

- **Router:** A node that is connected to 2 or more networks is called router. It acts as a switch which stores and forwards the messages from one network to another.
- **Address:** It is a byte string that identifies a node that is the network can use a node address to distinguish it from the other nodes connected to another network.

9. **What is Routing? What are the different types of Routing?**
   Routing is a process of determining systematically how to forward messages towards the destination node based on its address is called routing.
- **Uncast:** The source node wants to send in message to a single destination node is called unicast.
- **Broad Cast:** The source node wants to send a message to all nodes on network is called broad cast.
- **Multi cast:** Source node wants to send a message to some subset of the particular node but not all of them are called Multi Cast.

10. What is Multiplexing? Explain working of STDM, FDM & Statistical Multiplexing.

Multiplexing is a method by which multiple data streams are combined into one signal. The multiplexed signal is transmitted over a physical transmission medium. A reverse process, known as *demultiplexing*, can extract the combined channels on the receiver side. A device that performs the multiplexing is called a multiplexer, and a device that performs the reverse process is called a demultiplexer.

Synchronous Time Division Multiplexing (STDM):
- The idea of STDM is to divide time into equal-sized quanta and, in a round-robin fashion, give each flow a chance to send its data over the physical link.
- In other words, during time quantum 1, data from the first flow is transmitted; during time quantum 2, data from the second flow is transmitted; and so on. This process continues until all the flows have had a turn, at which time the first flow gets to go again, and the process repeats.
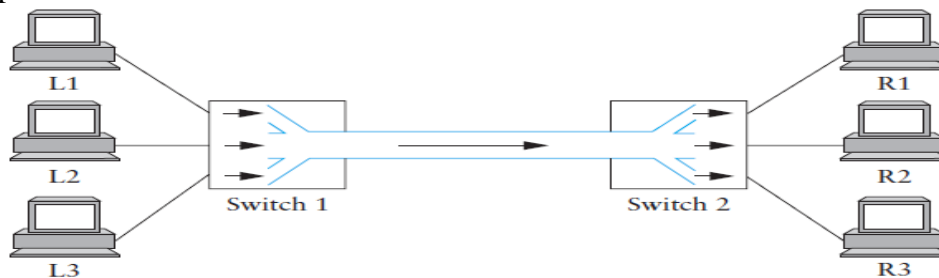

Figure 1.5   Multiplexing multiple logical flows over a single physical link.

Frequency Division Multiplexing (FDM):
- The idea of FDM is to transmit each flow over physical link at different frequencies.
- Example: signals for different TV stations transmitted at different frequency on physical cable TV link.

Limitations of STDM & FDM
- If one of the flows (host pairs) does not have any data to send, its time quantum or its frequency—remains idle.
- The max number of flows is fixed known ahead of time.
- It is not practical to resize the quantum / add additional quanta(STDM) & add new frequency to FDM.

Statistical Multiplexing:
- In the SM, the physical link is shared overtime and first data from one flow is transmitted over physical link, then data from another flow is transmitted.
- The data is transmitted from each flow on demand rather than during predetermined time short.
- The statistical method as no mechanism to ensure that all the flows get there done to transmit over physical link.
- To overcome this problem the stastical multiplexing defines an upper bound on the size of the block data that each flow is permitted to transmit at a given time.
- The limited size block of data is called as packet.
- The sequence of packets flows over the physical link with a decision made on a packet by packet basis to which flows the data packet to send next.

- Each switch in a packet switch network makes the decision independently on a packet by packet basis. Example: FIFO, RR Fashion.
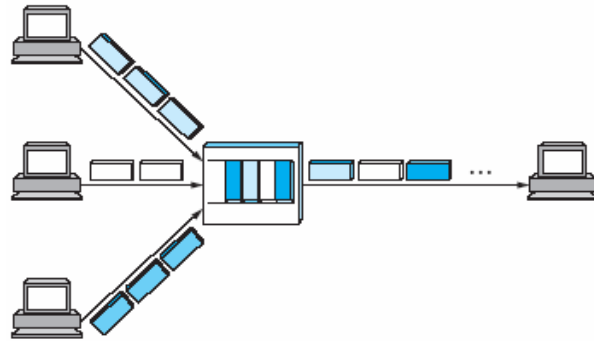

Figure 1.6   A switch multiplexing packets from multiple sources onto one shared link.

11. Define the following:
- **Packet:** The limited size block of data is called as packet.
- **Server:** The process that supports access to a file is called server.
- **Client:** The process that requests access to the data is called client.
- **Bit Error:** A type of error in which only 1 Bit of given data unit is changed from 1 to 0 or 0 to 1.
- **Byte Error:** 2 or more bits in a data unit have been changed from 1400 & 0 to 1.
- **Semantic Gap:** The challenge is to fill in the gap between what the application expects and what the underlying technology can provide.

12. Explain three classes of failures over networks.
There are three general classes of failure:
- The first, as a packet is transmitted over a physical link, bit errors may be introduced into the data. i.e., a 1 is turned into a 0 or vice versa. Sometimes, single bits are corrupted, but more often than not, a burst error occurs several consecutive bits are corrupted.
- The second class of failure is at the packets rather than the bit, level. i.e., a complete packet is lost by the network. One reason this can happen is that the packet contains an uncorrectable bit error and therefore has to be discarded.
- The third class of failure is at the nodes link level. i.e., a physical link is cut or the computer it is connected is crashed. This can be caused by software that crashes a power failure or a reckless backhoe operator.

13. With a suitable diagram, explain a layered network system.
- It gives the design simplification of networks.
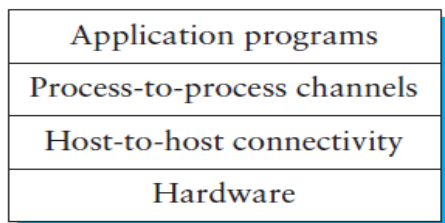
Example of a layered network system.

- We might imagine a simple network as having two layered of abstraction sandwiched between the application programs and the underlying hardware, as illustrated below
- It decomposes the problem of building a network into more manageable components rather than implementing a monolithic piece of software that does everything you will ever want, you can implement several layers, each of which solves one part of the problem.
- It provides more modular design, if you decide that you want to add some new service. You may only need to modify the functionality at one layer requesting the functions provided at all the other layers.
- The layer immediately above the hardware might provide host to host connectivity. Abstracting away the fact that there may be an arbitrarily complex network topology between any two hosts.
- The next layer up builds on the available host to host communication service and provides support for process to process channels, abstracting away the fact that the network occasionally loses messages.
- **Layering provides 2 features.**
  - o It provides a more modular design i.e., if you has some new services you may only need to modify the functionality at one layer itself
  - o It decomposes the problem of building a network into more manageable components.

14. Define Protocol and Interfaces.

Protocol: A *protocol* is a series of rules by which computing devices are able to communicate. The computers must be guided, instructed on how to share the data appropriately to ensure it is done so accurately. It is the job of the assigned protocol to provide this instruction. A protocol provides a communication service that higher-level objects (such as application processes, or perhaps higher-level protocols) use to exchange messages.
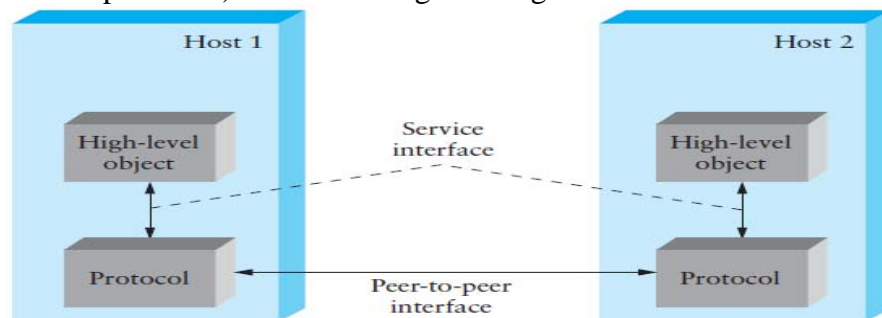

Figure 1.10   Service and peer interfaces.

Interface: Each protocol defines 2 different interfaces.
- **Service Interface:** is used to common services these service interface defines the operations that local objects can perform on the protocol.
- Ex: an implementation of HTTP protocol which supports an operation to fetch a page of hyper text from a remote server.
- **Peer interface:** This interface defines the forms & meaning of message exchanges between protocol peers.

- Ex: The protocol specification which defines how a get command is formatted, what arguments can be used with the command & how a web server should respond when it receives such a command.

15. With Suitable Diagram explain the protocol graph.
- It is a graph that represents the suits of protocols that makes a network system.
- Nodes of graph represents to protocols.
- Edges of graph represents depends on relation
- Protocols can be used in 2 different ways such as
    o Refers to abstract interfaces
    o Refers to module interfaces.
- The nodes of the graph corresponds to protocols and the edges represents a depends on relation
- The below diagram illustrate a protocol graph for the hypothetical layered system we have been shown
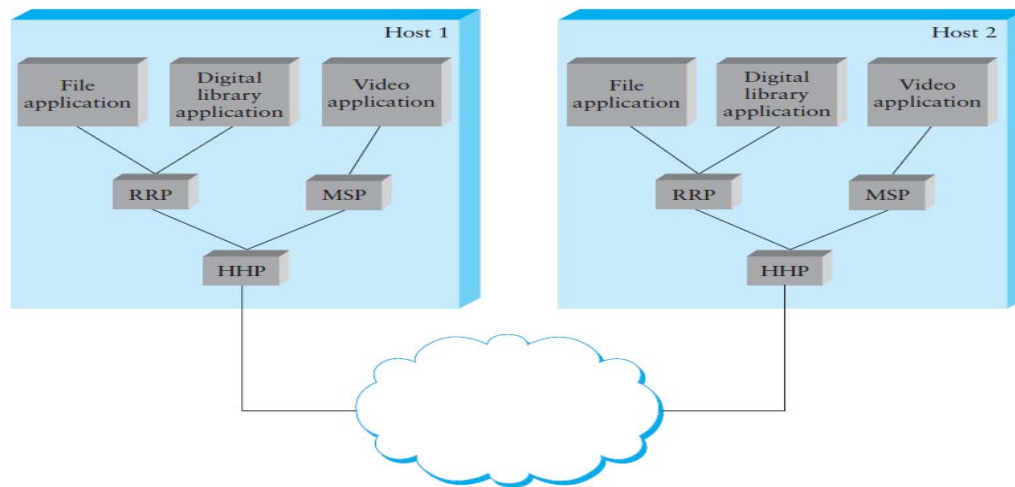

Figure 1.11   Example of a protocol graph.

- The protocols (RRP) and (MSP) implements process to process channels & both depend on host to host protocol which provides host to host connectivity service.
- Suppose that the file access program on host wants to send a message to its peer on host2 using the common service offered by protocol RRP.
- RRP invokes the services of HTTP which in turn transmits the message to its peer on the other machine.
- Once the message has arrived at protocol HTTP on host2, HTTP passes the message up to RRP, which in turn delivers the message to the file.

16. Explain OSI network architecture with neat diagram and compare it with TCP/IT.
- The OSI stands for Open System Interconnection.
- It defines a partitioning of network functionality into server layers, where one or more protocols implement the functionality assigned to a given layer.

One or more nodes
within the network
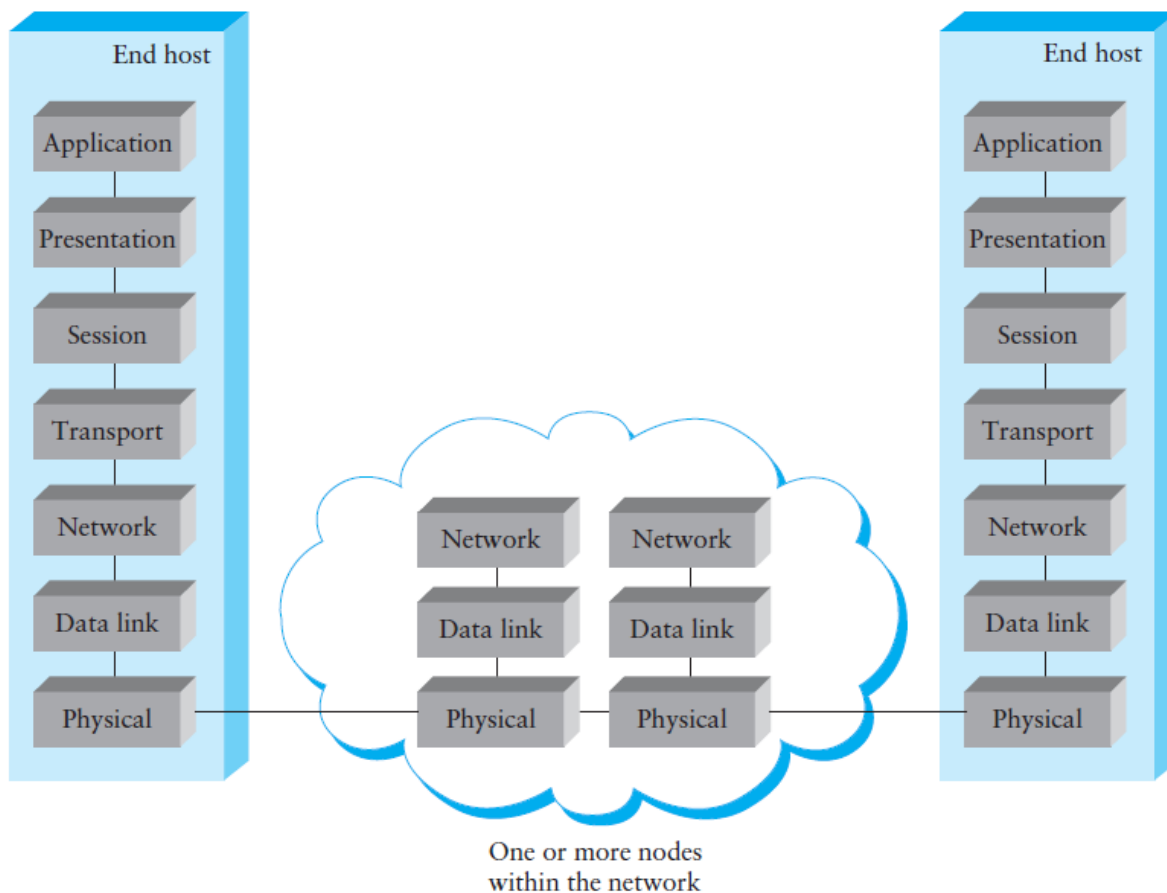
- **Physical Link:** This layer handles the transmission of raw bits of information over a communication link.
- **Data Link:** This layer collects a stream of bits into a layer aggregate called Frame. Network adapters along with device drivers running in the node implement the data link layer
- **Network Layer:** This layer handles the routing node with in a packet switch networks. The unit of data extend among nodes is called a 'packet'. The lower three layer i.e., network, data link, physical layers are implemented on all the network nodes including switches within the network and host connected along the exterior of the network.
- **Transport Layer:** This layer implements what we have to send by calling a process to process channel. The unit of data exchange is called message. The transport layers and remaining other higher layer are run only on the end host but not on the intermediate switches are routers.
- **Session Layer:** Above transport we have the session layer. The *session* layer provides a session between the hosts. It is used to hold the connection until the session is over.
- **Presentation Layer:** Above session, we have the ***presentation*** layer. It is concerned with the format of data exchanged between peers, for example, whether an integer is 16, 32, or 64 bits long and whether the most significant bit is transmitted first or last, or how a video stream is formatted.
- **Application Layer:** On top we have the ***application* layer**. Application layer protocols include things like the File Transfer Protocol (FTP), which defines a protocol by which file transfer applications can interoperate.

17. Explain Internet Architecture (TCP/IP) with a neat diagram
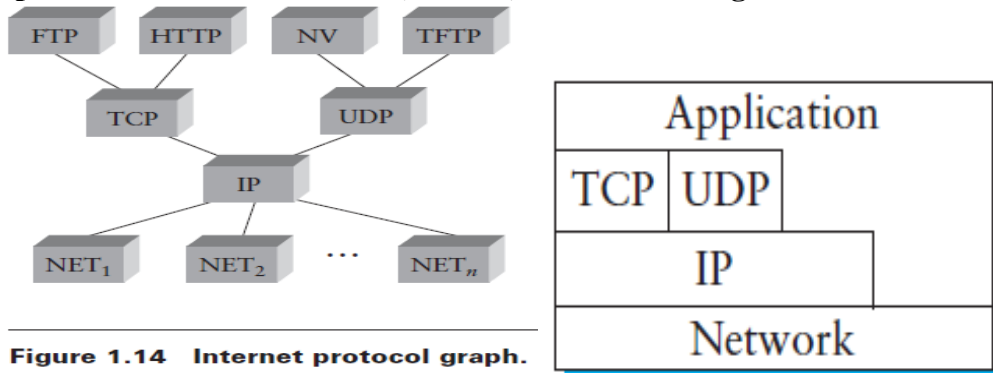
Figure 1.14   Internet protocol graph.

- ➢ The Internet architecture is also called the *TCP/IP architecture* after its two main protocols.
- ➢ This architecture is used in ARPANET and Internet. Both the Internet and the ARPANET were funded by the Advanced Research Projects Agency (ARPA), one of the R&D funding agencies of the U.S. Department of Defense.
- ➢ It is a four-layer model.
- ➢ At the lowest level are a wide variety of network protocols, denoted NET1, NET2, and so on.
- ➢ In practice, these protocols are implemented by a combination of hardware (e.g., a network adaptor) and software (e.g., a network device driver).
- ➢ The second layer consists of a single protocol—the *Internet Protocol* (IP). This is the protocol that supports the interconnection of multiple networking technologies into a single, logical internetwork.
- ➢ The third layer contains two main protocols—the *Transmission Control Protocol* (**TCP**) **and the** *User Datagram Protocol* (**UDP**). TCP and UDP provide alternative logical channels to application programs: TCP provides a reliable byte-stream channel, and UDP provides an unreliable datagram delivery channel (*datagram* may be thought of as a synonym for message). In the language of the Internet, TCP and UDP are sometimes called *end-to-end* protocols.
- ➢ Running above the transport layer are a range of application protocols, such as FTP, TFTP (Trivial File Transport Protocol), Telnet (remote login), and SMTP (Simple Mail Transfer Protocol, or electronic mail), that enable the interoperation of popular applications.
- ➢ The Internet architecture has three features.
  - o First, the Internet architecture does not imply strict layering. The application is free to bypass the defined transport layers and to directly use IP or one of the underlying networks. In fact, programmers are free to define new channel abstractions or applications that run on top of any of the existing protocols.
  - o Second, if we look closely at the protocol graph we will notice an hourglass shape— wide at the top, narrow in the middle, and wide at the bottom. That is, IP serves as the focal point for the architecture—it defines a common method for exchanging packets among a wide collection of networks. Above IP can be arbitrarily many transport protocols, each offering a different channel abstraction to application programs. Thus, the issue of delivering messages from host to host is completely separated from the issue of providing a useful process-to-process communication service. Below IP, the architecture allows for arbitrarily many different network technologies, ranging from Ethernet to FDDI to ATM to single point-to-point links.

    o When a new protocol is to be officially added to the architecture, it needs an implementation. Design should ensure that the protocols can be efficiently implemented.

18. Explain the difference between OSI and TCP/IP

OSI	TCP/IP
It contains 7 layers	It contain 4 layers
3 conecpts are central to OSI model i.e., Service, Interface and Protocols	In TCP/IP service interface and protocols are not distinguish properly
Protocols in OSI model are better hidden than TCP/IP and cab be replaced relatively easy as the technology changes	Protocols in the TCP/IP are not hidden and therefore the replacement of new technology is difficult
OSI supports both connection less and connection oriented communication in the network layer	TCP/IP model as connection less in the internet layer and connection less and connection oriented in transport layer
In OSI, model first and then protocols	Protocols come first and then models.

19. What are application programming interfaces and explain how API's are used with TCP.

- The interface that OS provides to its network subsystems is called network API.
- Socket Interface provided by Berkeley distribution of unix.
- Each protocol provides set of services, API provides syntax by which those services can be invoked in particular OS.
- Socket is a point where a local application process attaches to network.
- The interface defines operations for creating socket, attaching socket to network, sending/receiving message closing/sending.
- The first step is to create a socket.

Syntax:

```
int socket(int domain, int type, int protocol)
```

- Where: domain—parameter specifies the protocol family
  - o i.e., PF-INET :- Denotes the internet family
  - o PF-UNIX:- Denotes the UNIX pipe facility
  - o PF-PACKET:- Denotes direct access to the network interface
- Type: the type argument indicates the symounties of the communication
  - o SOCK-STREAM—Used to denote a byte stream.
  - o SOCK-DGRAM—denotes the message oriented services provides by UDP.
- Protocol: This argument identifies the specific protocol that is going to be used.
  - o Ex: UNSPEC—Combination of protocol family internet and socket stream which implies TCP.
- Server invokes the following 3 options

```
int bind(int socket, struct sockaddr *address, int addr_len)

int listen(int socket, int backlog)

int accept(int socket, struct sockaddr *address, int *addr_len)
```

Mrs. Reena Vimal A. G.
Dept. of MCA, TOCE.

- Where the binds operation once the newly created sockets to the specified address i.e., the network address of the local participant in the server.
- When we use it with the internet protocol, the address is a data structure that includes both the IP address of the server and a ASP port number.
- Ex: web serves commonly accept connections on port
- The listen operations define how many connections can be pending on the specified socket.
- The accept operation carries out the passive open it is a blocking operation that does not return until a remote participation as establish a connection, when it does complete, it returns a new socket that corresponds to establish connections
- The address arguments contains the remote participant address
- The Client Machine
- The client machine performs an active open which communicate with the server by the following single operation.

  int connect(int socket, struct sockaddr *address, int addr_len)

- This operation does not return until TCP as successfully establish a connection at which the time application is free to begin the sending data
- Address: contains the remote participant address
- Connection establishment
- After the connection has been establish the application network invoke 2 operations such as

  int send(int socket, char *message, int msg_len, int flags)

 int recv(int socket, char *buffer, int buf_len, int flags)

- The first operation sends the given message over the specified socket
- The second operation receives the message from the specified socket into the given buffer
- The slacks are used to control the details of operations.

20. Explain with neat diagram process model.
- An abstraction provided by an OS is called process.
- OS is responsible for using of resources, addresses spaces and CPU cycles which are collected to all current process
- When a OS stops one process from executing on CPU startup another one then the change is called a CONTEXT Switch.
- There are 2 types of model such as

Process-per protocol:
  o Here, each protocol is implemented by a separate process. i.e., the message moves up or down the protocol stack.
  o It is passed from one process to another process that implements protocol, I process the message then process it to protocol i-1 etc.
  o One process or protocol passes a message to one process or protocol depends on the support the host OS provides the inter process communication.
  o The context switch is required at each level of protocol graph.
  o Disadvantage: Time consuming operation

(a)   (b)
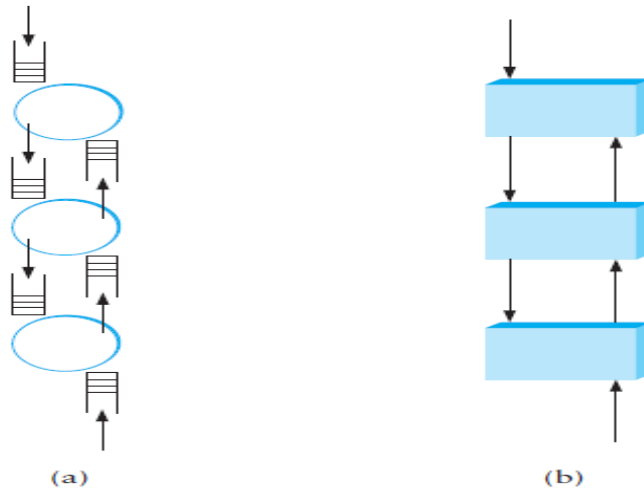
Process per message:
- o In this model each protocol has a static piece of code and associates the process with the message. i.e., when message arrives from the network. The OS dispatches a process that makes responsible for the message as it moves up the protocol.
- o At each level the procedure implements the protocol invoked, which results in the procedure for the next protocol be invoked and applications process invokes the necessary procedure calls until the message is delivered.

21. Define the following:
Bandwidth:
- It is given by the number of bits that can be transmitted over network in certain period of time. Ex: a network is having a bandwidth of 10 million bits/sec. i.e., 100 million bits every second and takes 0.1(ms) to transmit each bit.

Delay:
- It corresponds to how long it takes a message to travel from one end of a network to another.
- It is measured in terms of time.
- Ex: a transcontinental network has latency of 24 milli seconds. i.e., it takes message 24 ms to travel from one end to other end.

Latency:
- It is measured strictly in terms of time.
- **Latency = propagation + transmit + queue**
- It depends on 3 factors:
  - o **RTT:** Time taken to send a message from one end of a network to the other and back**.** It is a one-way latency.
  - o **Jitter:** In the delay one way latency of a network is 100ms or 500ms as how much the latency varies from packet to packet. The variation in latency is called jitter.
  - o **Propagation:** It is the ratio between distance and speed of light where distance is length of wire over which data will travel and speed of light is the effective speed of light over that wire.

Problems:

Conversions:

- 1 Giga bit = 10^9 or 2^{40} bits

- 1 Mega Bit = 10^6 or 2^{20} bits

- 1 Kilo Bit = 10^3 or 2^{10} bits

- 1 Mili second(1ms) = 10^{-3} sec

- 1 Micro Second (1 µs) = 10^{-6} sec

- 1 Nan Second (1ns) = 10^{-9} sec

- 1 KM = 10^3 m

1. **Consider a point to point link 2km in length at what bandwidth would propagation delay(at speed of $2X10^8$ m/sec equal transmit delay for 100 byte packet? What about 512 byte packet.**
   - Speed of light is 2X108 m/sec.
   - 100 bytes = ?
   - 512 bytes = ?
   - Distance = 2 Kms. = 2 X 103 Mts
     P = D /SL
     2 X 10^3 m/ $2X10^8$ m/sec = $1X10^{-5}$ X 10/10 = 10 X 10^{-6} sec = 10 µs.
     transmit = size / bandwidth
     Bandwidth = size/ transmit
     $\qquad$ = 100 byte/10 X 10^{-6} sec
     $\qquad$ = 100 X 8 bits / 10 X 10^{-6} sec
     $\qquad$ = 80 X 10^6 bps
     $\qquad$ = 80 Mbps
     - o for 512 byte packet
       Bandwidth = size / transmit
       = 512 byes / 10 X 10^{-6} sec
       = 8 X 512 bits/ 10 X 10^{-6} sec
       = 4096 / 10 X 10^{-6} sec
       = 409.6 X 10^6 bps
       = 409.6Mbps

2. **Consider a point to point link 50 kms in length at what bandwidth would propagation delay (at a speed of light $2X10^8$ m/sec) equal transmit delay for 100 bytes packet? What about 512 byte packet?**
   - Speed of light is $2X10^8$ m/sec.
   - 100 bytes = ?
   - 512 bytes = ?

- Distance = 50 Kms.

  P = D /SL

  50 X 10^3 m/ 2X10^8m/sec

  $= 25X10^{-5}X 10/10 = 250 X 10^{-6} = 250$ μs.

  Propagation delay = transmit

  So transmit = propagation delay

  But transmit = size / bandwidth

  Bandwidth = size/ transmit

  $= 100$ byte/250 X10^{-6}

  $= 8 X 100$ bits/250 X 10^{-6} sec

  $= 800/250X10^{-6}$ bps

  $= 3.2 X 10^6$ bps

  $= 3.2$ Mbps

  o   for 512 byte packet

  Bandwidth = size / transmit

  $= 512$ bytes/250X10^{-6} sec

  $= 8X512$ bits/250X10^{-6} sec

  $= 4096$ bits/250 X10^{-6} sec

  $= 16.4 X 10^6$ bps

  $=16.4$ Mbps

  o   100 bytes / 100 ms   = 100 bytes/250 ms = 0.4 MB/sec

  o   512 bytes / 100ms   = 512 bytes / 250ms = 2.048 MB/sec

3. **For a Dial up link of 56 Kbps bandwidth and 87 μs round trip delay find the delay X Bandwidth product.**

   Delay X Bandwidth = 86 X 10^{-6} X 56 x 10^3 b/s

   $= 4872$ x 10^{-3} bits

   $= 4872/1000$

   $= 4.873$ which is approximately 5 bits

4. **For a wireless LAN of 54 Mbps bandwidth and 0.33 μs Round trip delay find the delay x bandwidth product.**

   Delay X Bandwidth = 54 X 10^6 bps X 0.33 X 10^{-6} sec

   $= 17.82$ bits which is approximately 18 bits.

5. **For a satellite link of 45 Mbps and 23ms delay find the delay X bandwidth product.**

   Delay X Bandwidth = 230 XD 10^{-3} sec X 45 X 10^6 bps

   $= 10350 X 10^3$ bps

   $= 10350 X 10^3 X 10^3 / 10^{-3}$ bits

   = which is approximately 10 Mbits

6. **A cross country fiber of 10Gbps bandwidth and 40 ms delay can hold how many bits (i.e., find delay X Bandwidth)?**

   Delay X Bandwidth = 40 X 10^{-3} sec X 10 X 10^9 bps

   $= 400 X 10^6$ bits

   $= 400$ Mbits

7. **How many bits does a channel with a one way latency of 50 ms and a bandwidth of 45 Mbps is able to hold(i.e., find delay X bandwidth)?**

Delay X Bandwidth = 50 X 10-3 sec X 45 X 106 bps

$$= 2250 \times 10^3 \text{ bits}$$
$$= 2250 \times 10^3 \times 10^3 / 10^{-3}$$
$$= 2.250 \times 10^6 \text{ bits}$$

Which is approximately 2Mbits

8. **How wide is a bit on a 1 Gbps link? How long is a bit copper wire, where the speed of propagation is 2×10^8 m/s?**

Given delay X bandwidth = 1 bit

So delay = 1 bit / bandwidth

$$= 1 \text{ bit}/ 1 \times 10^9 \text{ bps}$$
$$= 1 \times 10^{-9} \text{ sec}$$
$$= 1 \text{ (ns) wide}$$

We know, propagation = distance / speed of light

i.e., delay = distance / speed of light

i.e., distance = delay X speed of light

$$= 1 \times 10^{-9} \times 2.3 \times 10^8 \text{ m/sec}$$
$$= 2.3 \times 10^{-1} \text{ m}$$
$$= 0.23 \text{ m}$$

9. **Suppose a 100 Mbps point to point link is being set up between earth and a new lunar colony. The distance from moon to earth is approximately 3,85,000 kms and data travels over the link at the speed of light 3 X 108 m/sec.**
   a. **Calculate the minimum RTT for the link.**
   b. **Using the RTT as the delay, calculate the delay X bandwidth product for the link.**
   c. **A camera on the lunar base takes pictures of earth and saves them in digital format disk. Suppose mission control on earth wishes to download most current image, which is 25MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer finished?**

   a. Minimum RTT = propagation delay X 2

   $$= \text{distance / speed of light} \times 2$$
   $$= 2 \times 3,85,000 \times 10^3 \text{m}/ 3 \times 10^8 \text{ m/sec}$$
   $$= 2 \times 385 \times 10^6 \text{ sec}/ 3 \times 10^8$$
   $$= 2 \times 385/300$$
   $$= 2 \times 1/283$$
   $$= 2.57 \text{ sec.}$$

   b. Delay X bandwidth

   $$= 1.283 \text{ sec} \times 100 \times 10^6 \text{ bps}$$
   $$= 128.3 \times 10^6 \text{ bits}$$
   $$= 128.3 \text{ Mbits}$$

   c. Min amount of time = transmit.

   So transmit = size / bandwidth.

   $$= 25 \text{ Mb}/100\text{Mbps}$$

Mrs. Reena Vimal A. G.
Dept. of MCA, TOCE.

$= 25 \times 10^8$ Mb/100 Mbps

$= 200/100$ sec

$= 2$ sec.

So total time = transmit + delay

$= 2 + 1.283$

$= 3.283$ sec.

10. Suppose a 128 Kbps point to point link is set up between earth and a river on mars. The distance from earth to mars is approximately 55Gm and data travels over the link at speed of light 3 X 10 8m/se.

    a. Calculate the minimum RTT for the link

    b. Calculate the delay X bandwidth product.

    c. A camera on the river takes a picture of its surroundings and sends those to earth. How quickly after a picture is taken can it reach mission contro; on earth? Assume that each image is 5 MB in size.

a. Minimum RTT = 2 X propagation delay.

$= 2 \times$ distance/ speed of light

$= 2 \times 55 \times 10^9$ m/ 3×10^8 m/sec

$= 2 \times 550/3$ sec

$= 2 \times 184$ sec

$= 368$ sec.

b. Delay X bandwidth

$= 184$ sec X 128×10^3 bps

$= 23552 \times 10^3$ bits

$= 23552 \times 10^3 \times 10^3/10^{-3}$

$= 23.552$ Mbits

$= 2.944$ Mbytes.

$=$ which is approximately 3 Mbytes

c. Transmit = size / bandwidth

$= 5$ MB / 128×10^3 bps

$= 5 \times 8$ bits / 128×10^3

$= 40 \times 10^6$ bits/128×10^6 bps

$= 0.3125 \times 10^3$ sec

$= 312.5$ sec

Total time   = transmit + delay

$= 312.5 + 184$

$= 496.5$ sec