Internetworking

It is the process or technique of connecting different networks by using intermediary devices such as routers or gateway devices. Internetworking ensures data communication among networks owned and operated by different entities using a common data communication and the Internet Routing Protocol

Motivation for Internetworking

It is natural that there will be very different needs.
It is also natural that people want to interconnect these different networks - no one wants to be an "island" all of the time

# The TCP/IP Internet

In the 1970s & 1980s, US govt agencies realized the importance and potential of internet technology, and funded research that made possible a global Internet. The TCP/IP Internet protocol suite commonly referred to as TCP/IP can be used to communicate across any set of interconnected networks.

Although the TCP/IP technology is noteworthy by itself, it's especially interesting viability has been demonstrated on a large scale. It forms the base technology for the global internet that connects approximately two billion individuals in homes, schools, corporations and governments in virtually all populated areas of the planet

## Internet Services

Allows use to access huge amount of information such as text, graphics, sound software over the internet

## Application Level Internet Services

The most popular and widespread Internet application services include

- World Wide Web
  - > Became the largest source of traffic on the global Internet b/w 1994 & 1995.
  - > Many popular services including Internet search (eg. Google) and social networking (eg. Facebook) use web technology.
- Cloud Access and Remote Desktop.

  Cloud computing places computation and storage facilities in cloud data centers, and arranges for users to access the services over the Internet

  Remote Desktop service allows a user to access a computer in a remote data center as if the computer is local

- File Transfer: The file transfer protocol allows user to send or receive a copy of a data file.
- Electronic Mail (email): Many users access email through a web application that allows a user to read messages in their mailbox, select a message for processing, and forward the message or send a reply

Voice and video services: Both streaming video and audio already account for a nontrivial fraction of bits transported across the global Internet, and the trend will continue.

## Network-Level Internet Services

Connectionless Packet Delivery service.
A TCP/IP internet forwards small messages from one computer to another based on address information carried in the message.

Reliable Stream Transport Service

The Internet's reliable stream service allows an application on one computer to establish a connection to an application on another computer, and allows the applications to transfer arbitrarily large amounts of data across the connection as if it were a permanent, direct hardware link.

Network Technology Independence

The global Internet includes a variety of network technologies. TCP/IP protocols define the unit of data transmission called a datagram, and specify how to transmit datagrams on a particular network.

Universal Interconnection

The Internet allows any arbitrary pair of computers to communicate

End-to-End Acknowledgement

TCP/IP Internet protocols provide acknowledgements b/w the original source and ultimate destination instead of b/w successive machines along the path.

## Application Protocol Standards

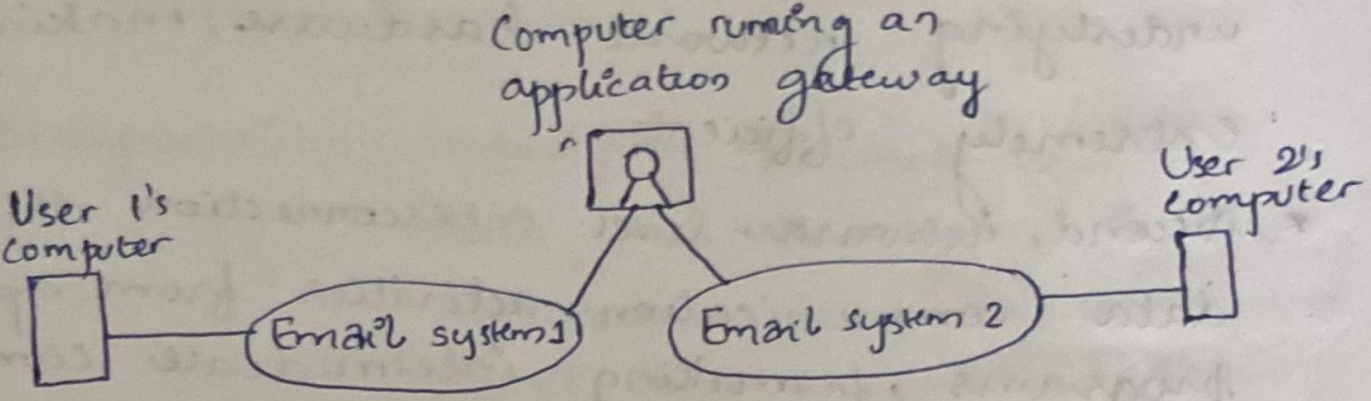
The TCP/IP protocols include standards for many common applications, including protocols that specify how to access a web page, transfer a file and send email.

## Internetworking Concept & Architecture Model

### Application - level Interconnection

When faced with heterogeneous systems, early designers relied on special application programs, called application gateways, to hide the underlying differences and provide the appearence of uniformity.

For example, when a connection b/w email systems was added, an appln gateway was used




Disadvantages

A given application gateway can only handle one specific application

Differences in functionality prevent interoperation

Frequency of Upgrades. The application gateway must be updated frequently

Network-level Interconnection

The alternative approach to application level. It provides a mechanism that delivers packets from their original source to their ultimate destination in real time. Switching packets instead of files or large messages has several advantages

* First, the scheme maps directly onto the underlying network hardware, making it extremely efficient
* Second, network-level interconnection seperates data communication activities from application programs, permitting intermediate computers to handle network traffic without understanding the applications that are sending or receiving messages
* Third, using network-level interconnection keeps the entire system flexible, making it possible to build general purpose communication facilities that are not limited to specific uses
* Fourth, the scheme allows network managers to add or change network technologies while application programs remain unchanged.

# Properties of the Internet

Encapsulation: Underlying Internet — a
Hide the underlying Internet architecture from the users and permit communication without requiring knowledge of the Internet's structure

Do not want to mandate a network interconnection topology.

Able to send data across intermediate networks even though they are not directly connected to the source or destination computers

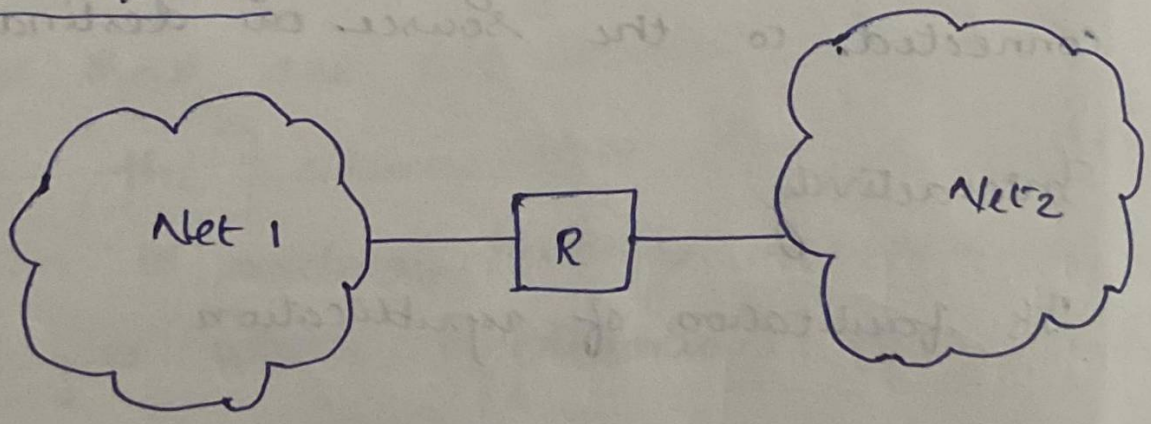
Interactivity

Its facilitation of republication

Its global nature

# Internet Architecture

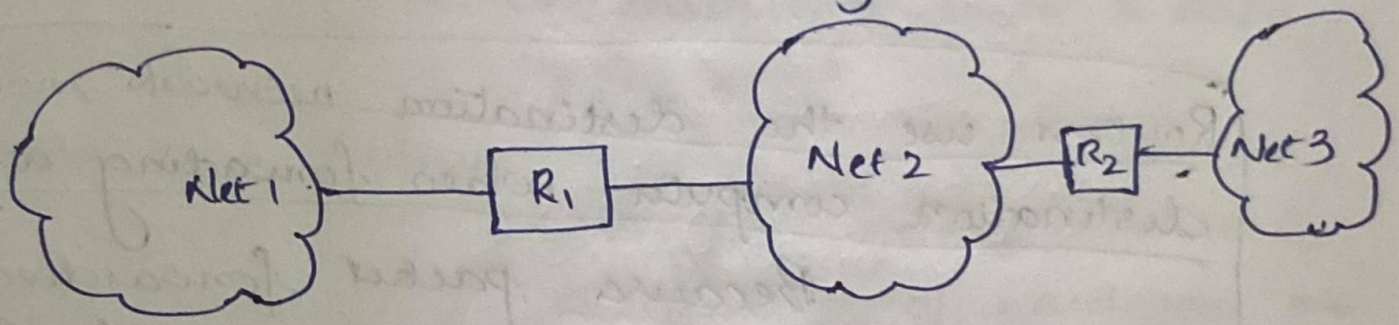
Physically, two networks cannot be plugged together directly. Instead, they can only be connected by a computer system that has the hardware needed to connect to each network. To have a viable internet, computers willing to transfer packets from one network to another are needed. Computers that interconnect two networks and pass packets from one to the other are called Internet routers or IP routers




Router R connects to both network 1 and network 2. For R to act as a router, it must capture packets on network 1 that are bound for machines on network 2 and transfer them and R must capture network 2 that are destined for machines on network 1 and transfer them

## Interconnection of Multiple Networks with IP routers

In realistic internet each router needs to know about networks beyond networks to which it connects directly




Three networks interconnected by two routers

$R_1$ must transfer from network 1 to network 2 all packets destined for computers on either network 2 or network 3. Similarly router $R_2$ must transfer packets from network 3 that are destined for either network 2 or network 1.

A Router must handle packets for networks to which the router does not attach

In a TCP/IP internet, special computer systems called IP routers provide interconnections among physical networks

Routers use the destination networks, not the destination computer, when forwading a packet

- Because packet forwarding is based on networks, the amount of information that a router needs to keep is proportional to the number of networks in the ~~computer~~ internet, not the number of computers

## Protocol Layering

It presents the general principle of layering, shows how layering makes protocol software easier to understand and build, and traces the path that packets take through the protocol software when they traverse a TCP/IP internet.

## The Need for Multiple Protocols

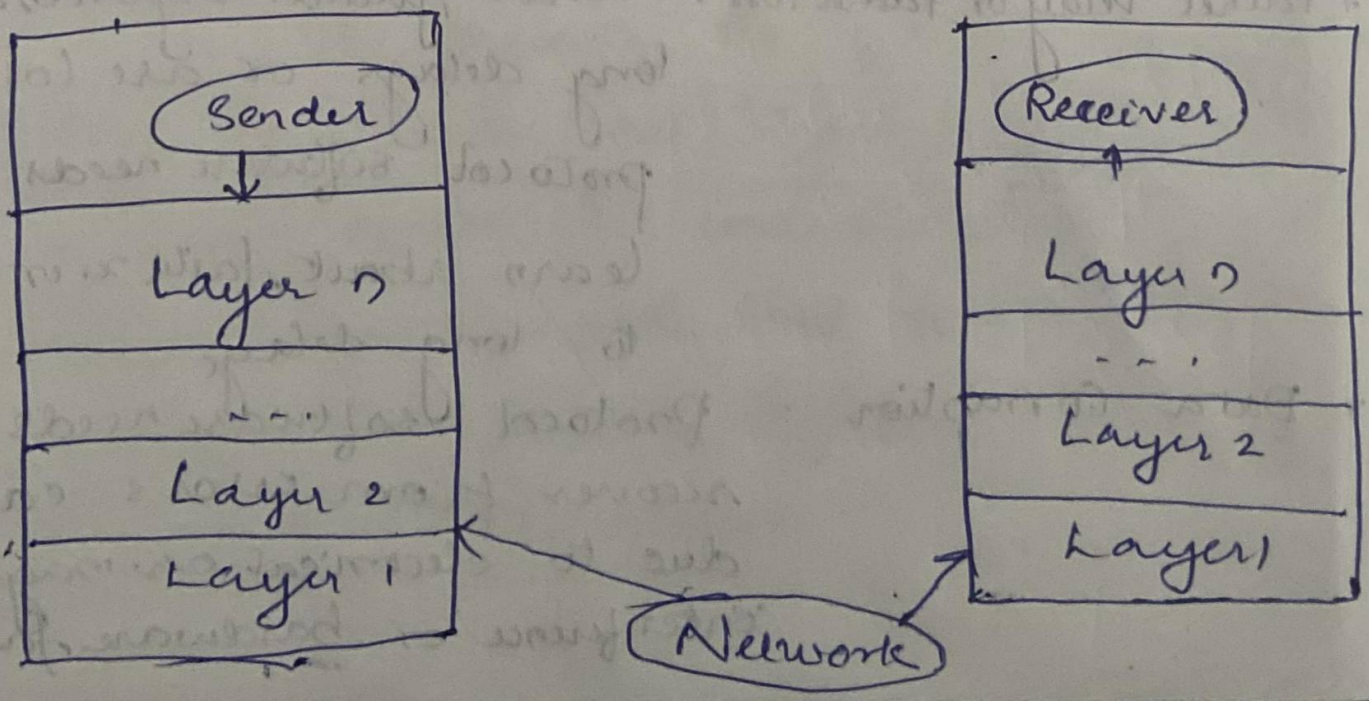
Network communication is a complex problem with many aspects. The problems arise when computers communicate over a data network.

* Hardware Failure : A computer or router may fail either because of the failure of hardware or failure of transmission link. Protocol software needs to detect such failures & recovers them if possible
* Network Congestion : Protocol software needs to arrange a way to detect congestion and suppress traffic
* Packet Delay or Packet loss : When packets experience long delays or are lost, protocol software needs to learn about failure or adapt to long delay.
* Data Corruption : Protocol software needs to recover from errors caused due to electrical or magnetic interference or hardware failures

Data Duplication or Inverted Arrivals: Networks that offer multiple routes may deliver packets out of sequence or may deliver duplicates of packets. Protocol software needs to reorder packets and remove any duplicates.

Taken together, the problems seem overwhelming. Programs translation has been partitioned into four conceptual subproblems identified with the software that handles each subproblem: compiler, assembler, link editor and loader.

## The Conceptual Layers of Protocol Software



Conceptually, sending a message from an application on one computer to an application on another means transferring the message down through successive layers of protocol software on the sender's machine, forwarding the message across the network, and transferring the message up through successive layers of protocol software on the receiver's machine

## ISO - 7 Layer Reference Model

ISO Model contains 7 conceptual layers

| Layer | Functionality |
|---|---|
| 7 | Application |
| 6 | Presentation |
| 5 | Session |
| 4 | Transport |
| 3 | Network |
| 2 | Data Link |
| 1 | Physical |

Physical Layer: Responsible for movements of individual bits from one hop(node) to the next

Data Link Layer: Responsible for moving frames one hop to the next

Network Layer: Responsible for delivery of individual packets from source host to destination host

Transport Layer: Responsible for delivery of a message from one process to another

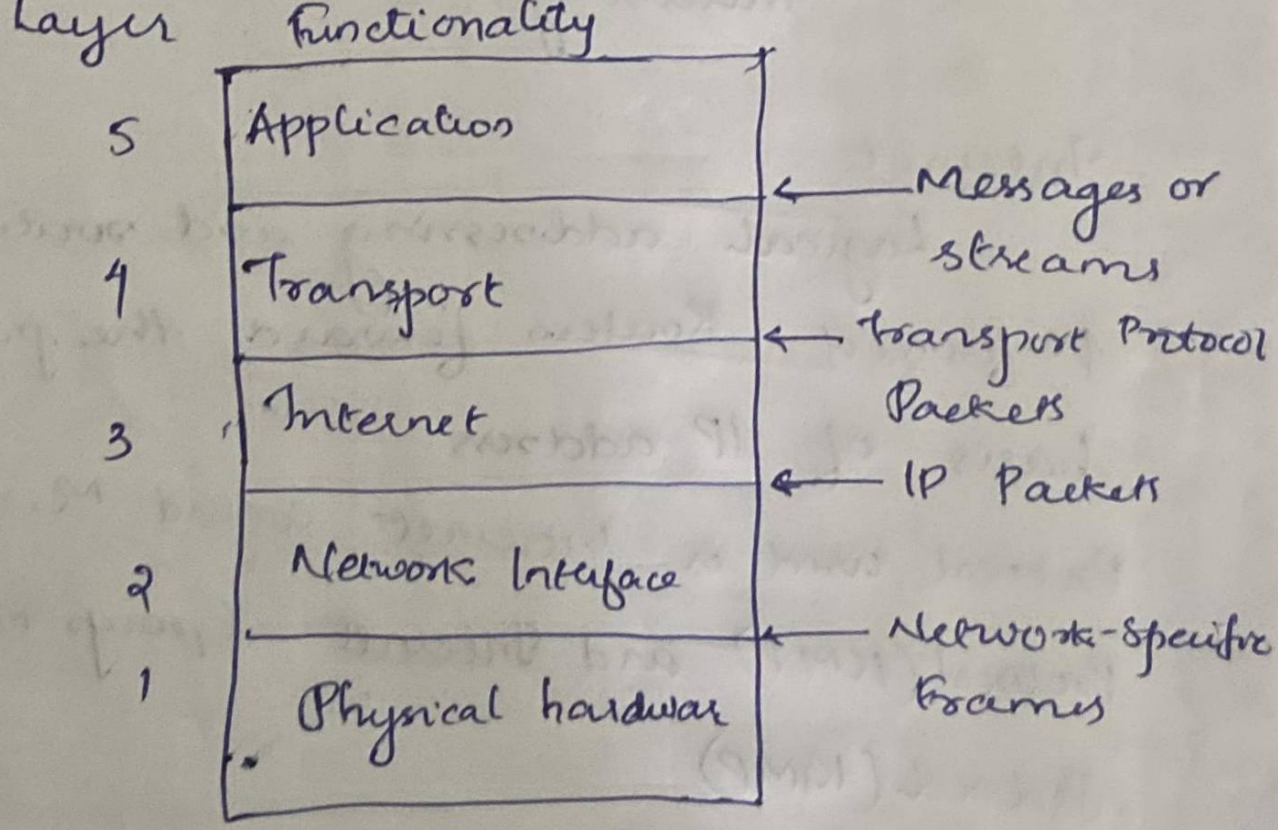
Session Layer: Responsible for dialog control and synchronization

Presentation Layer: Responsible for translation, compression & encryption

Application Layer: Responsible for providing services to user

# TCP/IP 5-Layer Reference Model

Unlike the ISO Model, which was defined by committees before protocols were implemented, the Internet 5-layer reference model was formalized after protocols had been designed and tested




## Application Layer

Acts as an interface between the application programs and uses protocols like SMTP, HTTP, FTP... Data acts as a Protocol Data Unit (PDU)

## Host-to-Host Layer (Transport Layer)

Responsible for delivery of data

TCP - Reliable delivery of data is needed, TCP will be used.

UDP - fast delivery without ~~delivery~~ reliability is needed

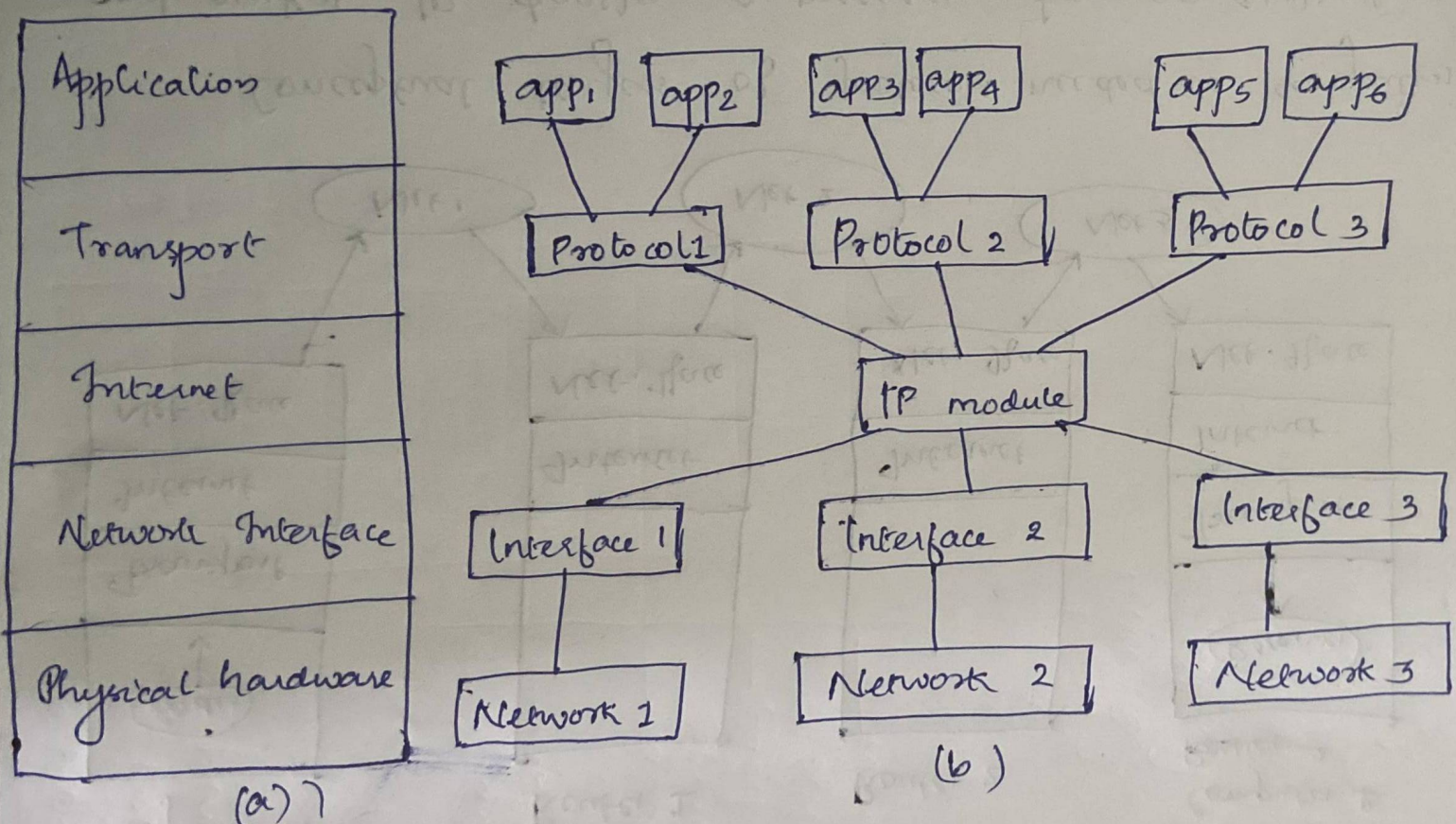
### Internet

Logical addressing and routing is performed. Routers forward the packet on the basis of IP address

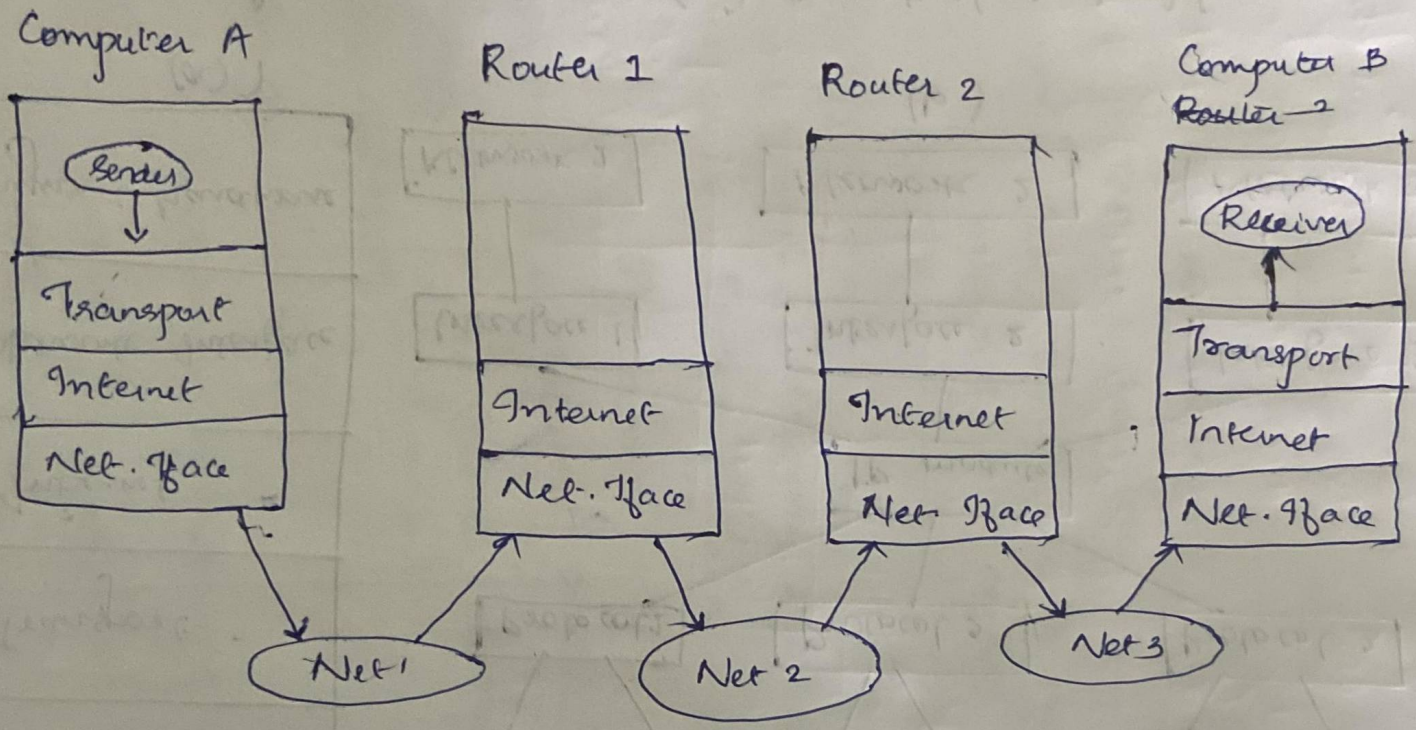
Protocol used is Internet control Message Protocol (ICMP) and Internet Group Management Protocol (IGMP)

### Network Access Layer

Hardware addressing is done. It defines protocols for physical transmission of data. Ethernet is the most important




A comparison of (a) conceptual protocol layering and (b) a more realistic view of protocol software with multiple network interfaces and multiple protocols




Conceptual layers of protocols needed by computers and routers to transfer a message from an application A to an application on computer B

## Mapping Internet Address to Physical Address

When an IP address is mapped to physical or MAC address, ARP is used to on broadcast networks such as Ethernet, token ring and ARCnet. When a node uses IP to send a packet, it must determine which physical address on the network corresponds to the destination IP address. To find the physical address, the node broadcasts an ARP packet containing the destination IP address. The node with the specified destination IP address sends its physical address back to the requesting node.

# Proxy ARP

It is a technique by which a proxy server on a given network answers the Address Resolution Protocol queries for an IP address that is not on that network. The proxy is aware of the location of the traffic's destination and offers its own MAC address as the destination

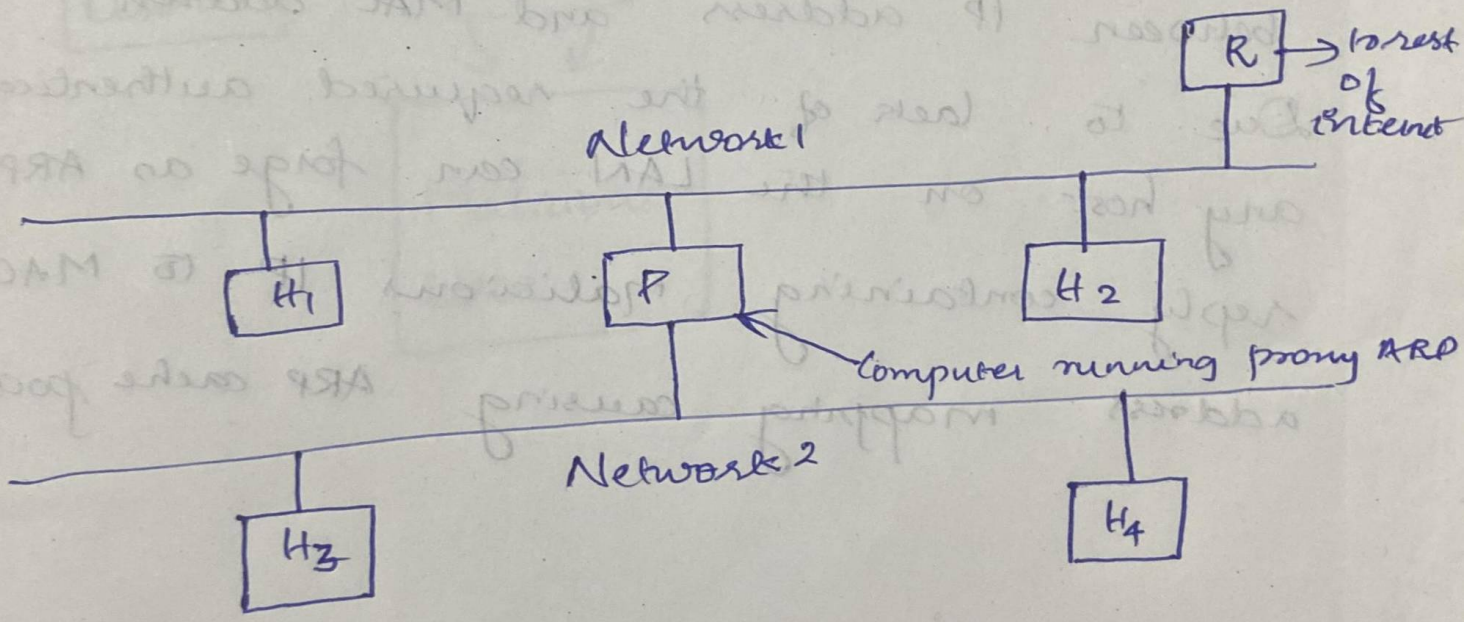


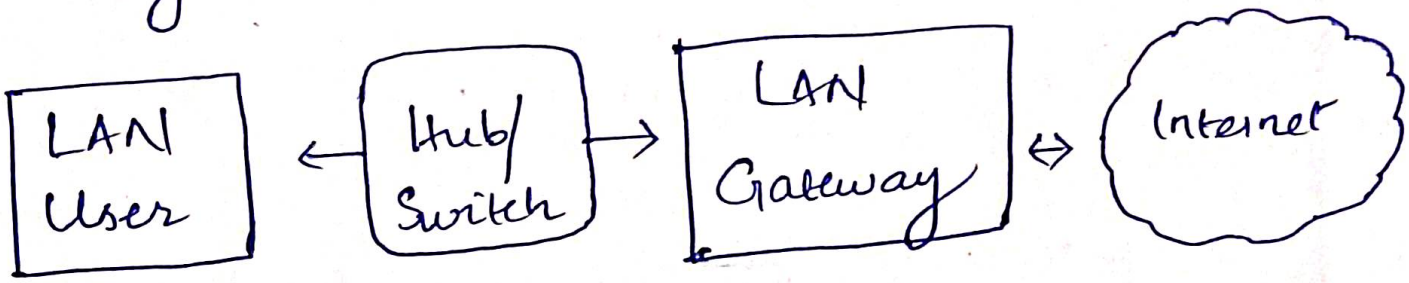

Illustration of two networks using proxy ARP

2. ARP is often cites as a security weakness. Explain why

ARP spoofing can enable malicious parties to intercept, modify or even stop data being transmitted b/w parties. ARP spoofing attacks only occur on LAN that utilizi the Address Resolution Protocol

The cause of this problem is the absense of authentication of the mapping between IP address and MAC address. Due to lack of the required authentication any host on the LAN can forge an ARP reply containing malicious IP to MAC address mapping causing ARP cache poisoning.

Routing under normal operation




Routing subject to ARP Cache Poisoning