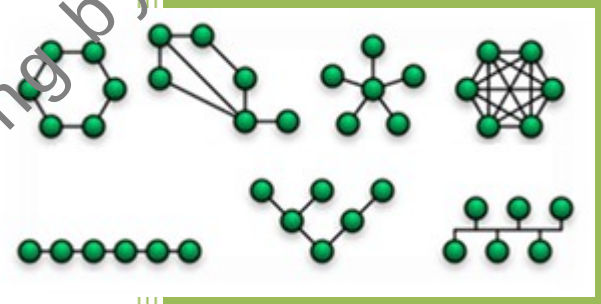
COMPUTER NETWORKING



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PREFACE

Networking, as the name suggests is an activity that takes place every day in our lives. Did you talk to someone at breakfast to review what might be on the upcoming exam? That's networking. Did you ask your professor which reference materials would be the best in preparing a term paper? That's networking. Did you ask friends if they knew of anyone driving home for the weekend? That's networking. Networking is already far more than active in our life than we might have originally thought.

A computer network, often simply referred to as a network, is a collection of computers and devices interconnected by communications channels that facilitate communications among users and allows users to share resources.

The obvious resources are sharing data and sharing tasks. Information stored in one computer is potentially available to anyone on the network. In task sharing systems, computers can send pieces of big tasks to other computers on the network that are not too busy. Those computers send the results back to the computer that sent the request so all the tasks can get done faster. Information sharing also allows things like e- mail to work. In this project, we shall explore the need of networking, types of networks, OSI model of networking, network architecture and components required for setting up a successful network.

A **computer network**, often simply referred to as a network, is a collection of computers and devices interconnected by communications channels that facilitate communications among users and allows users to share resources. Networks may be classified according to a wide variety of characteristics.

Introduction

A computer network allows sharing of resources and information among interconnected devices. In the 1960s, the Advanced Research Projects Agency (ARPA) started funding the design of the Advanced Research Projects Agency Network (ARPANET) for the United States Department of Defense. It was the first computer network in the world. Development of the network began in 1969, based on designs developed during the 1960s.

Purpose

Computer networks can be used for a variety of purposes:

- *Facilitating communications.* Using a network, people can communicate efficiently and easily via email, instant messaging, chat rooms, telephone, video telephone calls, and video conferencing.
- *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.
- *Information preservation and security*
- *Remote computing and distributed processing(GRID Computing)*

NETWORK CLASSIFICATION

The following list presents categories used for classifying networks:

v On the basis of Connection

- Wired technologies
- Wireless technologies

Computer networks can be classified according to the hardware and software technology that is used to interconnect the individual devices in the network, such as optical fiber, Ethernet, wireless LAN, Home PNA, power line communication or G.hn.

Ethernet utilizes various standards and mediums that enable communication between devices. Frequently deployed devices include hubs, switches, bridges, or routers. Wireless LAN technology is designed to connect devices without wiring. These devices use radio waves or infrared signals as a transmission medium. ITU-T G.hn technology uses existing home wiring (coaxial cable, phone lines and power lines) to create a high-speed (up to 1 Gigabit/s) local area network.

v On the basis of scale

Networks are often classified as local area network (LAN), wide area network (WAN), metropolitan area network (MAN), personal area network (PAN), virtual private network (VPN), campus area network (CAN), storage area network (SAN), and others, depending on their scale, scope and purpose, e.g., controller area network (CAN) usage, trust level, and access right often differ between these types of networks. LANs tend to be designed for internal use by an organization's internal systems and employees in individual physical locations, such as a building, while WANs may connect physically separate parts of an organization and may include connections to third parties.

v On the basis of network architecture

Computer networks may be classified according to the functional relationships which exist among the elements of the network, e.g., active networking, client–server and peer-to-peer (workgroup) architecture.

v On the basis of topology

Computer networks may be classified according to the network topology upon which the network is based, such as bus network, star network, ring network, mesh network. Network topology is the coordination by which devices in the network are arranged in their logical relations to one another, independent of physical arrangement. Even if networked computers are physically placed in a linear arrangement and are connected to a hub, the network has a star topology, rather than a bus topology. In this regard the visual and operational characteristics of a network are distinct.

v On the basis of type of data carried

Networks may be classified based on the method used to convey the data, these include digital and analog networks.

Now we will be discussing each of these separately.

OSI MODEL OF NETWORKING:

The **Open Systems Interconnection model (OSI model)** is a product of the Open Systems Interconnection effort at the International Organization for Standardization. It is a way of sub-dividing a communications system into smaller parts called layers. A layer is a collection of conceptually similar functions that provide services to the layer above it and receives services from the layer below it. On each layer an *instance* provides services to the instances at the layer above and requests service from the layer below.

For example, a layer that provides error-free communications across a network provides the path needed by applications above it, while it calls the next lower layer to send and receive packets that make up the contents of the path. Conceptually two instances at one layer are connected by a horizontal protocol connection on that layer.

Most network protocols used in the market today are based on TCP/IP stacks.

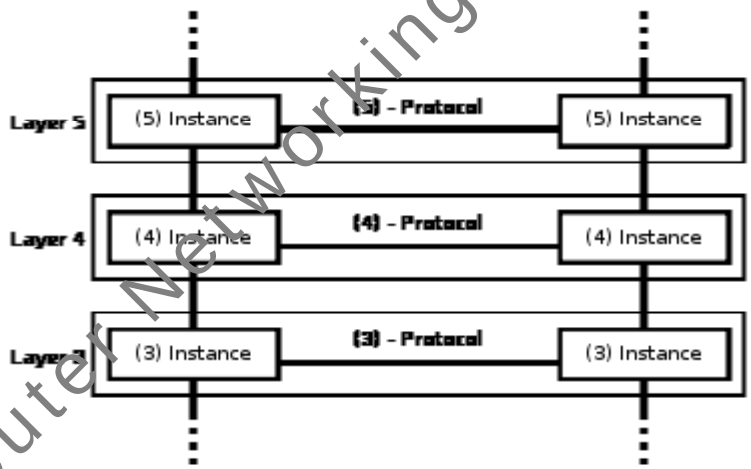

Fig. 1: Communication in the OSI-Model (Example with layers 3 to 5)

Description of osi layers:

There are seven layers, each generically known as an N layer. An N+1 entity requests services from the N entity.

At each level, two entities (N-entity peers) interact by means of the N protocol by transmitting protocol data units (PDU).

A Service Data Unit (SDU) is a specific unit of data that has been passed down from an OSI layer to a lower layer, and which the lower layer has not yet encapsulated into a protocol data unit (PDU). An SDU is a set of data that is sent by a user of the services of a given layer, and is transmitted semantically unchanged to a peer service user.

The PDU at any given layer, layer 'n', is the SDU of the layer below, layer 'n-1'. In effect the SDU is the 'payload' of a given PDU. That is, the process of changing a SDU to a PDU consists of an encapsulation process, performed by the lower layer. All the data contained in the SDU becomes encapsulated within the PDU. The layer n-1 adds headers or footers, or both, to the SDU, transforming it into a PDU of layer n-1. The added headers or footers are part of the process used to make it possible to get data from a source to a destination.

OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Inter host communication
	Segments	4. Transport	End-to-end connections and reliability, flow control
Media layers	Packet	3. Network	Path determination and logical addressing
	Frame	2. Data Link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

Layer 1: Physical Layer

The Physical Layer defines the electrical and physical specifications for devices. In particular, it defines the relationship between a device and a transmission medium, such as a copper or optical cable. This includes the layout of pins, voltages, specifications, hubs, repeaters, network adapters, host bus adapters (HBA used in storage area networks) and more.

To understand the function of the Physical Layer, contrast it with the functions of the Data Link Layer. Think of the Physical Layer as concerned primarily with the interaction of a single device with a medium, whereas the Data Link Layer is concerned more with the interactions of multiple devices (i.e., at least two) with a shared medium.

The major functions and services performed by the Physical Layer are:

- Establishment and termination of a connection to a communications medium.
- Participation in the process whereby the communication resources are effectively shared among multiple users. For example, contention resolution and flow control.
- Modulation or conversion between the representation of digital data in user equipment and the corresponding signals transmitted over a communications channel. These are signals operating over the physical cabling (such as copper and optical fiber) or over a radio link.

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Layer 2: Data Link Layer

The Data Link Layer provides the functional and procedural means to transfer data between network entities and to detect and possibly correct errors that may occur in the Physical Layer. Originally, this layer was intended for point-to-point and point-to-multipoint media, characteristic of wide area media in the telephone system. Local area network architecture includes broadcast-capable multi access media. In modern practice, only error detection is present in data link protocols such as Point-to-Point Protocol (PPP).

Layer 3: Network Layer

The Network Layer provides the functional and procedural means of transferring variable length data sequences from a source to a destination via one or more networks, while maintaining the quality of service requested by the Transport Layer. The Network Layer performs network routing functions, and might also perform fragmentation and reassembly, and report delivery errors. Routers operate at this layer—sending data throughout the extended network and

making the Internet possible. This is a logical addressing scheme – values are chosen by the network engineer. The addressing scheme is not hierarchical.

Careful analysis of the Network Layer indicated that the Network Layer could have at least three sub layers:

1. Sub network Access - that considers protocols that deal with the interface to networks, such as X.25;
2. Sub network Dependent Convergence - when it is necessary to bring the level of a transit network up to the level of networks on either side;
3. Sub network Independent Convergence - which handles transfer across multiple networks.

Layer 4: Transport Layer

The Transport Layer provides transparent transfer of data between end users, providing reliable data transfer services to the upper layers. The Transport Layer controls the reliability of a given link through flow control, segmentation/ de segmentation, and error control. Some protocols are state and connection oriented. This means that the Transport Layer can keep track of the segments and retransmit those that fail. The Transport layer also provides the acknowledgement of the successful data transmission and sends the next data if no errors occurred.

Layer 5: Session Layer

The Session Layer controls the dialogues (connections) between computers. It establishes, manages and terminates the connections between the local and remote application. It provides for full-duplex, half-duplex, or simplex operation, and establishes check pointing, adjournment, termination, and restart procedures. The OSI model made this layer responsible for graceful close of sessions, which is a property of the Transmission Control Protocol, and also for session check pointing and recovery, which is not usually used in the Internet Protocol Suite. The Session Layer is commonly implemented explicitly in application environments that use remote procedure calls.

Layer 6: Presentation Layer

The Presentation Layer establishes context between Application Layer entities, in which the higher-layer entities may use different syntax and semantics if the presentation service provides a mapping between them. If a mapping is available, presentation service data units are encapsulated into session protocol data units, and passed down the stack.

This layer provides independence from data representation (e.g., encryption) by translating between application and network formats. The presentation layer transforms data into the form that the application accepts. This layer formats and encrypts data to be sent across a network. It is sometimes called the syntax layer.

Layer 7: Application Layer

The Application Layer is the OSI layer closest to the end user, which means that both the OSI application layer and the user interact directly with the software application. This layer interacts with software applications that implement a communicating component. Such application programs fall outside the scope of the OSI model. Application layer functions typically include identifying communication partners, determining resource availability, and synchronizing communication. When identifying communication partners, the application layer determines the identity and availability of communication partners for an application with data to transmit. When determining resource availability, the application layer must decide whether sufficient network or the requested communication exists. In synchronizing communication, all communication between applications requires cooperation that is managed by the application layer.

NETWORK CONNECTIONS

Wired technologies

- ***Twisted pair** wire* is the most widely used medium for telecommunication. Twisted-pair cabling consist of copper wires that are twisted into pairs. Ordinary telephone wires consist of two insulated copper wires twisted into pairs. Computer networking cabling consist of 4 pairs of copper cabling that can be utilized for both voice and data transmission. The use of two wires twisted together helps to reduce crosstalk and electromagnetic induction. The transmission speed ranges from 2 million bits per second to 100 million bits per second. Twisted pair cabling comes in two forms which are Unshielded Twisted Pair (UTP) and Shielded twisted-pair (STP) which are rated in categories which are manufactured in different increments for various scenarios.

- ***Coaxial cable*** is widely used for cable television systems, office buildings, and other worksites for local area networks. The cables consist of copper or aluminum wire wrapped with insulating layer typically of a flexible material with a high dielectric constant, all of which are surrounded by a conductive layer. The layers of insulation help minimize interference and distortion. Transmission speed range from 200 million to more than 500 million bits per second.

- ***Optical fiber** cable* consists of one or more filaments of glass fiber wrapped in protective layers. It transmits light which can travel over extended distances. Fiber-optic cables are not affected by electromagnetic radiation. Transmission speed may reach trillions of bits per second. The transmission speed of fiber optics is hundreds of times faster than for coaxial cables and thousands of times faster than a twisted-pair wire.

Wireless technologies

- ***Terrestrial microwave*** – Terrestrial microwaves use Earth-based transmitter and receiver. The equipments look similar to satellite dishes. Terrestrial microwaves use low-gigahertz range, which limits all communications to line-of-sight. Path between relay stations is spaced approximately 30 miles apart. Microwave antennas are usually placed on top of buildings, towers, hills and mountain peaks.
- ***Communications satellites*** – The satellites use microwave radio as their telecommunications medium which are not deflected by the Earth's atmosphere. The satellites are stationed in space, typically 22,000 miles (for geosynchronous satellites) above the equator. These Earth-orbiting systems are capable of receiving and relaying voice, data and TV signals.
- ***Cellular and PCS systems*** – Use several radio communications technologies. The systems are divided into different geographic areas. Each area has a low-power transmitter or radio relay antenna device to relay calls from one area to the next area.
- ***Wireless LANs*** – Wireless local area networks use a high-frequency radio technology similar to digital cellular and a low-frequency radio technology. Wireless LANs use spread spectrum technology to enable communication between multiple devices in a limited area. An example of open-standards wireless radio-wave technology is IEEE.
- **Infrared communication ,** which can transmit signals between devices within small distances not more than 10 meters peer to peer or (face to face) without anybody in the line of transmitting.
- **Bluetooth-** Bluetooth is a proprietary open wireless technology standard for exchanging data over short distances (using short wavelength radio transmissions) from fixed and mobile devices, creating personal area networks (PANs) with high levels of security. Created by telecoms vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization. Today Bluetooth is managed by the Bluetooth Special Interest.

Fig. 2: Bluetooth Logo

Network scale

Local area network (LAN)

A local area network (LAN) is a network that connects computers and devices in a limited geographical area such as home, school, computer laboratory, office building, or closely positioned group of buildings. Each computer or device on the network is a node. Current wired LANs are most likely to be based on Ethernet technology, although new standards like ITU-T G.hn also provide a way to create a wired LAN using existing home wires (coaxial cables, phone lines and power lines).

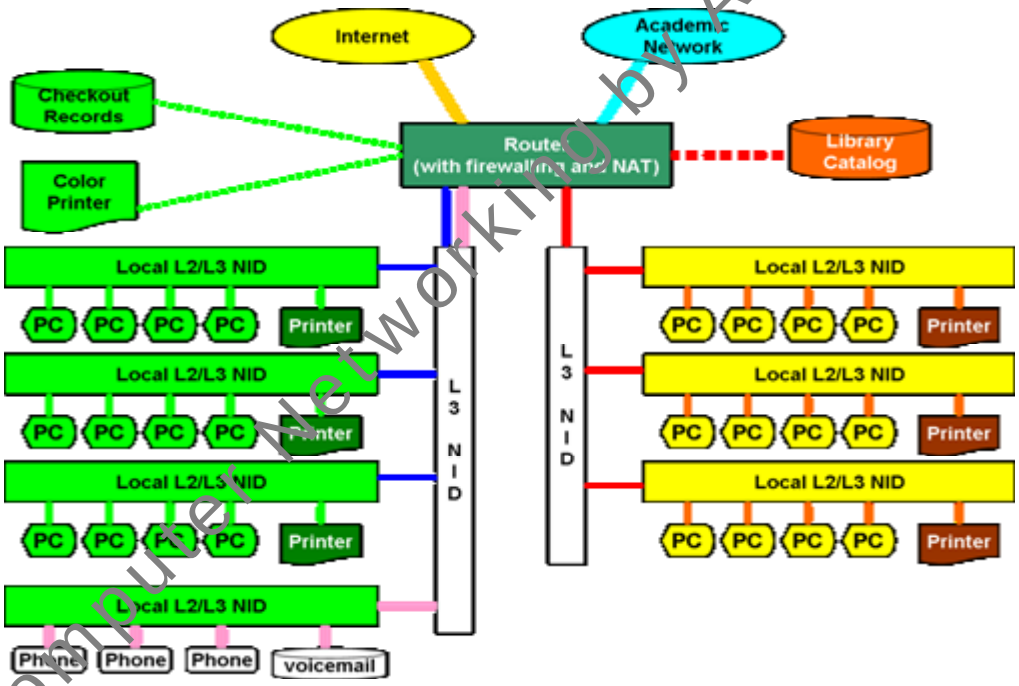

Fig. 3: Typical library network in a branching tree topology

All interconnected devices must understand the network layer (layer 3), because they are handling multiple subnets (the different colors). Those inside the library, which have only 10/100 Mbit/s Ethernet connections to the user device and a Gigabit Ethernet connection to the central router, could be called "layer 3 switches" because they only have Ethernet interfaces and must understand IP. It would be more correct to call them access routers, where the router at the top is a distribution router that connects to the Internet and academic networks' customer access routers.

Personal area network (pan)

A personal area network (PAN) is a computer network used for communication among computer and different information technological devices close to one person. Some examples of devices that are used in a PAN are personal computers, printers, fax machines, telephones, PDAs, scanners, and even video game consoles. A PAN may include wired and wireless devices. The reach of a PAN typically extends to 10 meters. A wired PAN is usually constructed with USB and Firewire connections while technologies such as Bluetooth and infrared communication typically form a wireless PAN.

Home area network (han)

A home area network (HAN) is a residential LAN which is used for communication between digital devices typically deployed in the home, usually a small number of personal computers and accessories, such as printers and mobile computing devices. An important function is the sharing of Internet access, often a broadband service through a CATV or Digital Subscriber Line (DSL) provider. It can also be referred to as an office area network (OAN).

Wide area network (wan)

A wide area network (WAN) is a computer network that covers a large geographic area such as a city, country, or spans even intercontinental distances, using a communications channel that combines many types of media such as telephone lines, cables, and air waves. A WAN often uses transmission facilities provided by common carriers, such as telephone companies. WAN technologies generally function at the lower three layers of the OSI reference model: the physical layer, the data link layer, and the network layer.

Campus area network (can)

A campus network is a computer network made up of an interconnection of local area networks (LAN's) within a limited geographical area. The networking equipments (switches, routers) and transmission media (optical fiber, copper plant, Cat5 cabling etc.) are almost entirely owned (by the campus tenant / owner: an enterprise, university, government etc.).

In the case of a university campus-based campus network, the network is likely to link a variety of campus buildings including; academic departments, the university library and student residence halls.

Metropolitan area network (man)

A Metropolitan area network is a large computer network that usually spans a city or a large campus. The network size falls intermediate between LANs and WANs. A MAN typically covers an area of between 5 and 50 km diameter. Many MANs cover an area the size of a city, although in some cases MANs may be as small as a group of buildings or as large as the North of Scotland. A MAN is not generally owned by a single organization. The MAN, its communications links and equipment are generally owned by either a consortium of users or by a single network provider who sells the service to the users. This level of service provided to each user must therefore be negotiated with the MAN operator, and some performance guarantees are normally specified. A MAN often acts as a high speed network to allow sharing of regional resources (similar to a large LAN). It is also frequently used to provide a shared connection to other networks using a link to a WAN.

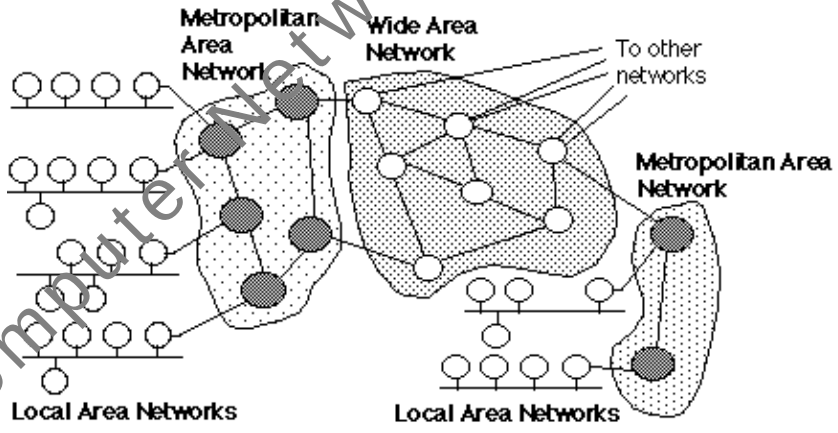

Fig. 4: Use of MANs to provide regional networks

Enterprise private network (epn)

An enterprise private network is a network build by an enterprise to interconnect various company sites, e.g., production sites, head offices, remote offices, shops, in order to share computer resources.

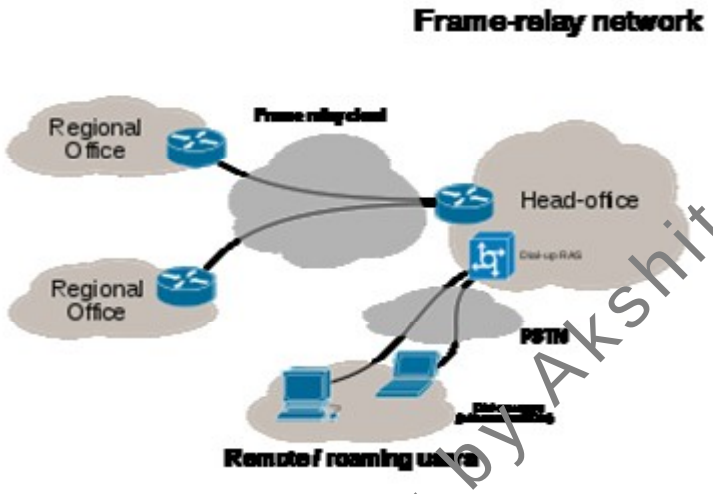

Fig. 5: Sample EPN

Virtual private network (vpn)

A virtual private network (VPN) is a computer network in which some of the links between nodes are carried by open connections or virtual circuits in some larger network (e.g., the Internet) instead of by physical wires. The data link layer protocols of the virtual network are said to be tunneled through the larger network when this is the case. One common application is secure communications through the public Internet, but a VPN need not have explicit security features, such as authentication or content encryption. VPNs, for example, can be used to separate the traffic of different user communities over an underlying network with strong security features.

VPN may have best-effort performance, or may have a defined service level agreement (SLA) between the VPN customer and the VPN service provider. Generally, a VPN has a topology more complex than point-to-point.

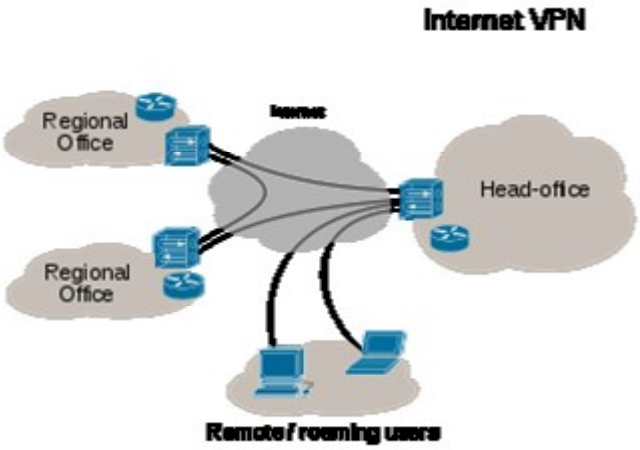

Fig. 6: A VPN used to interconnect 3 offices and remote users

Internetwork

An internetwork is the connection of two or more private computer networks via a common routing technology using routers. The Internet is an aggregation of many internet works, hence its name was shortened to Internet.

Backbone network

A backbone network or network backbone is part of a computer network infrastructure that interconnects various pieces of network, providing a path for the exchange of information between different LANs or sub networks. A backbone can tie together diverse networks in the same building, in different buildings in a campus environment, or over wide areas. Normally, the backbone's capacity is greater than the networks connected to it.

A large corporation that has many locations may have a backbone network that ties all of the locations together, for example, if a server cluster needs to be accessed by different departments of a company that are located at different geographical locations. The pieces of the network connections (for example: Ethernet, wireless) that bring these departments together is often mentioned as network backbone. Network congestion is often taken into consideration while designing backbones.

Backbone networks should not be confused with the Internet backbone.

Global Area Network (gan)

A Global Area Network (GAN) is a network used for supporting mobile communications across an arbitrary number of wireless LANs, satellite coverage areas, etc. The key challenge in mobile communications is handing off the user communications from one local coverage area to the next.

Network architecture

Client–server model

The **client–server model** of computing is a distributed application structure that partitions tasks or workloads between the providers of a resource or service, called servers, and service requesters, called clients. Often clients and servers communicate over a computer network on separate hardware, but both client and server may reside in the same system. A server machine is a host that is running one or more server programs which share their resources with clients. A client does not share any of its resources, but requests a server's content or service function. Clients therefore initiate communication sessions with servers which await incoming requests.

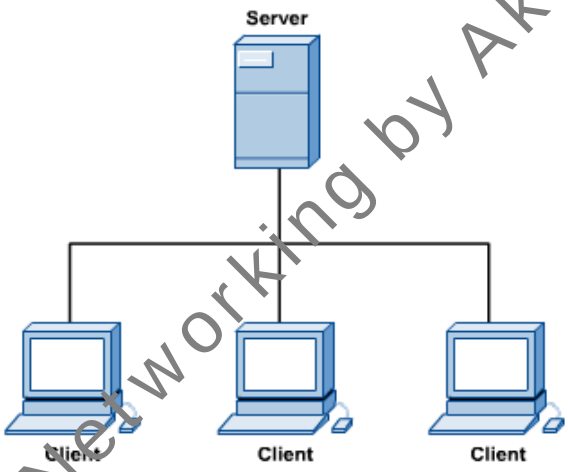

Fig. 7: Client – Server Architecture- Basic Structure

Description

The *client–server* characteristic describes the relationship of cooperating programs in an application. The server component provides a function or service to one or many clients, which initiate requests for such services.

Functions such as email exchange, web access and database access, are built on the client–server model. Users accessing banking services from their computer use a web browser client to send a request to a web server at a bank. That program may in turn forward the request to its own database client program that sends a request to a database server at another bank computer to retrieve the account information. The balance is returned to the bank database

client, which in turn serves it back to the web browser client displaying the results to the user. The client–server model has become one of the central ideas of network computing. Many business applications being written today use the client–server model. So do the Internet's main application protocols, such as HTTP, SMTP, Telnet, and DNS.

The interaction between client and server is often described using sequence diagrams. Sequence diagrams are standardized in the Unified Modeling Language.

Specific types of clients include web browsers, email clients, and online chat clients.

Specific types of servers include web servers, ftp servers, application servers, database servers , name servers, mail servers, file servers, print servers, and terminal servers. Most web services are also types of servers.

Comparison with peer-to-peer architecture

In peer-to-peer architectures, each host or instance of the program can simultaneously act as both a client and a server, and each has equivalent responsibilities and status.

Both client–server and peer-to-peer architectures are in wide usage today. Details may be found in Comparison of Centralized (Client-Server) and Decentralized (Peer-to-Peer) Networking.

Advantages

- In most cases, client–server architecture enables the roles and responsibilities of a computing system to be distributed among several independent computers that are known to each other only through a network. This creates an additional advantage to this architecture: greater ease of maintenance. For example, it is possible to replace, repair, upgrade, or even relocate a server while its clients remain both unaware and unaffected by that change.

- All data is stored on the servers, which generally have far greater security controls than most clients. Servers can better control access and resources, to guarantee that only those clients with the appropriate permissions may access and change data.

- Since data storage is centralized, updates to that data are far easier to administer in comparison to a P2P paradigm. In the latter, data updates may need to be distributed and applied to each peer in the network, which is both time-consuming and error-prone, as there can be thousands or even millions of peers.
- Many mature client–server technologies are already available which were designed to ensure security, friendliness of the user interface, and ease of use.

Disadvantages

- As the number of simultaneous client requests to a given server increases, the server can become overloaded. Contrast that to a P2P network, where its aggregated bandwidth actually increases as nodes are added, since the P2P network's overall bandwidth can be roughly computed as the sum of the bandwidths of every node in that network.
- The client–server paradigm lacks the robustness of a good P2P network. Under client–server, should a critical server fail, clients' requests cannot be fulfilled. In P2P networks, resources are usually distributed among many nodes. Even if one or more nodes depart and abandon a downloading file, the remaining nodes should still have the data needed to complete the download.

Network topology

Network topology is the layout pattern of interconnections of the various elements (links, nodes, etc.) of a computer network. Network topologies may be physical or logical. Physical topology means the physical design of a network including the devices, location and cable installation. Logical topology refers to how data is actually transferred in a network as opposed to its physical design.

Topology can be considered as a virtual shape or structure of a network. This shape does not correspond to the actual physical design of the devices on the computer network. The computers on a home network can be arranged in a circle but it does not necessarily mean that it represents a ring topology.

Any particular network topology is determined only by the graphical mapping of the configuration of physical and/or logical connections between nodes. The study of network topology uses graph theory. Distances between nodes, physical interconnections, transmission rates, and/or signal types may differ in two networks and yet their topologies may be identical.

A local area network (LAN) is one example of a network that exhibits both a physical topology and a logical topology. Any given node in the LAN has one or more links to one or more nodes in the network and the mapping of these links and nodes in a graph results in a geometric shape that may be used to describe the physical topology of the network. Likewise, the mapping of the data flow between the nodes in the network determines the logical topology of the network. The physical and logical topologies may or may not be identical in any particular network.

Basic Topology Types

The study of network topology recognizes seven basic topologies:

- Point-to-point topology
- Bus (point-to-multipoint) topology
- Star topology
- Ring topology
- Tree topology
- Mesh topology

- Hybrid topology

This classification is based on the interconnection between computers — be it physical or logical.

The physical topology of a network is determined by the capabilities of the network access devices and media, the level of control or fault tolerance desired, and the cost associated with cabling or telecommunications circuits.

Networks can be classified according to their physical span as follows:

- LANs (Local Area Networks)
- Building or campus internetworks
- Wide area internetworks

Classification of network topologies

There are also two basic categories of network topologies:

- Physical topologies
- Logical topologies

Physical topologies

The shape of the cabling layout used to link devices is called the physical topology of the network. This refers to how the cables are laid out to connect many computers to one network. The physical topology you choose for your network influences and is influenced by several factors:

- Office Layout
- Troubleshooting Techniques
- Cost of Installation
- Type of cable used

Classification of physical topologies

Bus topology:

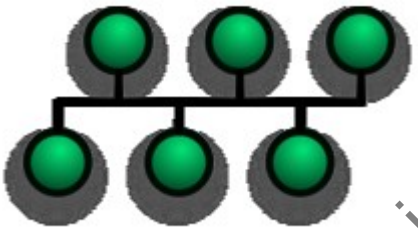

Fig. 8: Bus topology

In local area networks where bus topology is used, each machine is connected to a single cable. Each computer or server is connected to the single bus cable through some kind of connector. A terminator is required at each end of the bus cable to prevent the signal from bouncing back and forth on the bus cable. A signal from the source travels in both directions to all machines connected on the bus cable until it finds the MAC address or IP address on the network that is the intended recipient. If the machine address does not match the intended address for the data, the machine ignores the data. Alternatively, if the data does match the machine address, the data is accepted. Since the bus topology consists of only one wire, it is rather inexpensive to implement when compared to other topologies. However, the low cost of implementing the technology is offset by the high cost of managing the network. Additionally, since only one cable is utilized, it can be the single point of failure. If the network cable breaks, the entire network will be down.

Linear bus

The type of network topology in which all of the nodes of the network are connected to a common transmission medium which has exactly two endpoints (this is the 'bus', which is also commonly referred to as the backbone, or trunk) – all data that is transmitted between nodes in the network is transmitted over this common transmission medium and is able to be received by all nodes in the network virtually simultaneously (disregarding propagation delays).

Distributed bus

The type of network topology in which all of the nodes of the network are connected to a common transmission medium which has more than two endpoints that are created by adding branches to the main section of the transmission medium – the physical distributed bus topology functions in exactly the same fashion as the physical linear bus topology (i.e., all nodes share a common transmission medium).

Star Topology

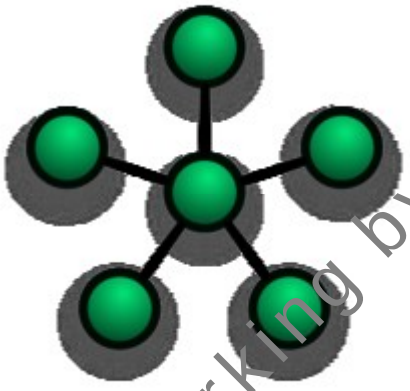

Fig. 9: Star Topology

In local area networks with a star topology, each network host is connected to a central hub. In contrast to the bus topology, the star topology connects each node to the hub with a point-to-point connection. All traffic that traverses the network passes through the central hub. The hub acts as a signal booster or repeater. The star topology is considered the easiest topology to design and implement. An advantage of the star topology is the simplicity of adding additional nodes. The primary disadvantage of the star topology is that the hub represents a single point of failure.

- A point-to-point link is sometimes categorized as a special instance of the physical star topology – therefore, the simplest type of network that is based upon the physical star topology would consist of one node with a single point-to-point link to a second node, the choice of which node is the 'hub' and which node is the 'spoke' being arbitrary.
- After the special case of the point-to-point link, as above, the next simplest type of network that is based upon the physical star topology would consist of one

central node – the 'hub' – with two separate point-to-point links to two peripheral nodes – the 'spokes'.

- Although most networks that are based upon the physical star topology are commonly implemented using a special device such as a hub or switch as the central node (i.e., the 'hub' of the star), it is also possible to implement a network that is based upon the physical star topology using a computer or even a simple common connection point as the 'hub' or central node – however, since many illustrations of the physical star network topology depict the central node as one of these special devices, some confusion is possible, since this practice may lead to the misconception that a physical star network requires the central node to be one of these special devices, which is not true because a simple network consisting of three computers connected as above also has the topology of the physical star.
- Star networks may also be described as either broadcast multi-access or non broadcast multi-access (NBMA), depending on whether the technology of the network either automatically propagates a signal at the hub to all spokes, or only addresses individual spokes with each communication.

Extended star

A type of network topology in which a network that is based upon the physical star topology has one or more repeaters between the central node (the 'hub' of the star) and the peripheral or 'spoke' nodes, the repeaters being used to extend the maximum transmission distance of the point-to-point links between the central node and the peripheral nodes beyond that which is supported by the transmitter power of the central node or beyond that which is supported by the standard upon which the physical layer of the physical star network is based.

If the repeaters in a network that is based upon the physical extended star topology are replaced with hubs or switches, then a hybrid network topology is created that is referred to as a physical hierarchical star topology, although some texts make no distinction between the two topologies.

Distributed Star

A type of network topology that is composed of individual networks that are based upon the physical star topology connected together in a linear fashion – i.e., 'daisy-chained' – with no central or top level connection point (e.g., two or more 'stacked' hubs, along with their associated star connected nodes or 'spokes').

Ring Topology

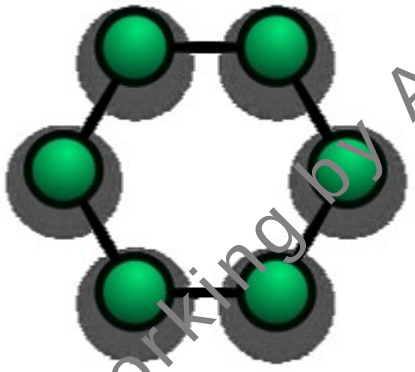

Fig. 10: Ring Network Topology

A network topology that is set up in a circular fashion in which data travels around the ring in one direction and each device on the right acts as a repeater to keep the signal strong as it travels. Each device incorporates a receiver for the incoming signal and a transmitter to send the data on to the next device in the ring. The network is dependent on the ability of the signal to travel around the ring.

Mesh Topology

The value of fully meshed networks is proportional to the exponent of the number of subscribers, assuming that communicating groups of any two endpoints, up to and including all the endpoints, is approximated by Reed's Law.

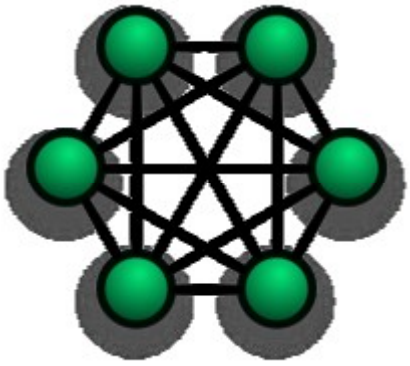

Fig. 11: Fully connected mesh topology

The number of connections in a full mesh = n(n - 1) / 2

Fully connected

The physical fully connected mesh topology is generally too costly and complex for practical networks, although the topology is used when there are only a small number of nodes to be interconnected.

Partially connected

The type of network topology in which some of the nodes of the network are connected to more than one node in the network with a point-to-point link is known as partially connected Mesh Topology. This makes it possible to take advantage of some of the redundancy that is provided by a physical fully connected mesh topology without the expense and complexity required for a connection between every node in the network.

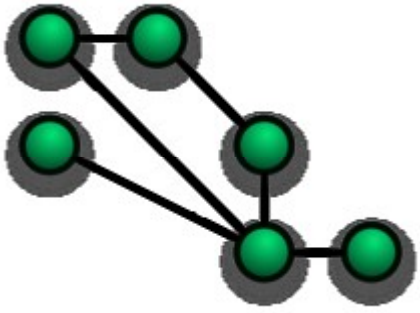

Fig. 12: Partially connected mesh topology

Tree Topology

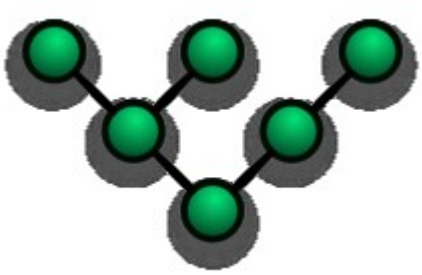

Fig. 13: Tree network topology

It is also known as a **hierarchical network**.

The type of network topology in which a central 'root' node (the top level of the hierarchy) is connected to one or more other nodes that are one level lower in the hierarchy (i.e., the second level) with a point-to-point link between each of the second level nodes and the top level central 'root' node, while each of the second level nodes that are connected to the top level central 'root' node will also have one or more other nodes that are one level lower in the hierarchy (i.e., the third level) connected to it, also with a point-to-point link, the top level central 'root' node being the only node that has no other node above it in the hierarchy (The hierarchy of the tree is symmetrical.) Each node in the network has a specific fixed number of nodes connected to it at the next lower level in the hierarchy, the number, being referred to as the 'branching factor' of the hierarchical tree. This tree has individual peripheral nodes.

- A network that is based upon the physical hierarchical topology must have at least three levels in the hierarchy of the tree, since a network with a central 'root' node and only one hierarchical level below it would exhibit the physical topology of a star.
- A network that is based upon the physical hierarchical topology and with a branching factor of 1 would be classified as a physical linear topology.
- The branching factor, f, is independent of the total number of nodes in the network and, therefore, if the nodes in the network require ports for connection to other nodes the total number of ports per node may be kept low even though the total number of nodes is large – this makes the effect of the cost of adding ports to each node totally dependent upon the branching factor and may therefore be kept as low as required without any effect upon the total number of nodes that are possible.

- The total number of point-to-point links in a network that is based upon the physical hierarchical topology will be one less than the total number of nodes in the network.
- If the nodes in a network that is based upon the physical hierarchical topology are required to perform any processing upon the data that is transmitted between nodes in the network, the nodes that are at higher levels in the hierarchy will be required to perform more processing operations on behalf of other nodes than the nodes that are lower in the hierarchy. Such a type of network topology is very useful and highly recommended.

Logical topology

Logical topology describes the way in which a network transmits information from network/computer to another and not the way the network looks or how it is laid out. The logical layout also describes the different speeds of the cables being used from one network to another.

The logical topology, in contrast to the "physical", is the way that the signals act on the network media, or the way that the data passes through the network from one device to the next without regard to the physical interconnection of the devices. A network's logical topology is not necessarily the same as its physical topology. For example, twisted pair Ethernet is a logical bus topology in a physical star topology layout. While IBM's Token Ring is a logical ring topology, it is physically set up in a star topology.

Classification of logical topologies

The logical classification of network topologies generally follows the same classifications as those in the physical classifications of network topologies, the path that the *data* takes between nodes being used to determine the topology as opposed to the actual *physical* connections being used to determine the topology

- Logical topologies are often closely associated with media access control (MAC) methods and protocols.
- The logical topologies are generally determined by network protocols as opposed to being determined by the physical layout of cables, wires, and network devices or by the

flow of the electrical signals, although in many cases the paths that the electrical signals take between nodes may closely match the logical flow of data, hence the convention of using the terms 'logical topology' and 'signal topology' interchangeably.

- Logical topologies are able to be dynamically reconfigured by special types of equipment such as routers and switches.

Basic Hardware components for networking

All networks are made up of basic hardware building blocks to interconnect network nodes, such as Network Interface Cards (NICs), Bridges, Hubs, Switches, and Routers.

Network interface cards

A network card, network adapter, or NIC (network interface card) is a piece of computer hardware designed to allow computers to communicate over a computer network. It provides physical access to a networking medium and often provides a low-level addressing system through the use of MAC addresses.

Each network interface card has its unique id. This is written on a chip which is mounted on the card.

Repeaters

A repeater is an electronic device that receives a signal, cleans it of unnecessary noise, regenerates it, and retransmits it at a higher power level, or to the other side of an obstruction, so that the signal can cover longer distances without degradation. In most twisted pair Ethernet configurations, repeaters are required for cable that runs longer than 100 meters. Repeaters work on the Physical Layer of the OSI model.

Hubs

A network hub contains multiple ports. When a packet arrives at one port, it is copied unmodified to all ports of the hub for transmission. The destination address in the frame is not changed to a broadcast address. It works on the Physical Layer of the OSI model.

Bridges

A network bridge connects multiple network segments at the data link layer (layer 2) of the OSI model. Bridges broadcast to all ports except the port on which the broadcast was received. However, bridges do not promiscuously copy traffic to all ports, as hubs do, but learn which MAC addresses are reachable through specific ports. Once the bridge associates a port and an address, it will send traffic for that address to that port only.

Bridges learn the association of ports and addresses by examining the source address of frames that it sees on various ports. Once a frame arrives through a port, its source address is stored and the bridge assumes that MAC address is associated with that port. The first time that a previously unknown destination address is seen, the bridge will forward the frame to all ports other than the one on which the frame arrived.

Bridges come in three basic types:

- Local bridges: Directly connect local area networks (LANs)
- Remote bridges: Can be used to create a wide area network (WAN) link between LANs. Remote bridges, where the connecting link is slower than the end networks, largely have been replaced with routers.
- Wireless bridges: Can be used to join LANs or connect remote stations to LANs.

Switches

A network switch is a device that forwards and filters OSI layer 2 datagrams (chunks of data communication) between ports (connected cables) based on the MAC addresses in the packets. A switch is distinct from a hub in that it only forwards the frames to the ports involved in the communication rather than all ports connected. A switch breaks the collision domain but represents itself as a broadcast domain. Switches make forwarding decisions of frames on the basis of MAC addresses. A switch normally has numerous ports, facilitating a star topology for devices, and cascading additional switches. Some switches are capable of routing based on Layer 3 addressing or additional logical levels; these are called multi-layer switches. The term *switch* is used loosely in marketing to encompass devices including routers and bridges, as well as devices that may distribute traffic on load or by application content (e.g., a Web URL identifier).

Routers

A router is an internetworking device that forwards packets between networks by processing information found in the datagram or packet (Internet protocol information from Layer 3 of the OSI Model). In many situations, this information is processed in conjunction with the routing table (also known as forwarding table). Routers use routing tables to determine what interface to forward packets (this can include the "null" also known as the "black hole" interface because data can go into it, however, no further processing is done for said data).

Firewalls

Firewalls are the most important aspect of a network with respect to security. A firewalled system does not need every interaction or data transfer monitored by a human, as automated processes can be set up to assist in rejecting access requests from unsafe sources, and allowing actions from recognized ones. The vital role firewalls play in network security grows in parallel with the constant increase in 'cyber' attacks for the purpose of stealing/corrupting data, planting viruses, etc.

Internet: A network of networks

The Internet is a global system of interconnected government, academic, corporate, public, and private computer networks. It is based on the networking technologies of the Internet Protocol Suite. It is the successor of the Advanced Research Projects Agency Network (ARPANET) developed by DARPA of the United States Department of Defense. The Internet is also the communications backbone underlying the World Wide Web (WWW).

Participants in the Internet use a diverse array of methods of several hundred documented and often standardized, protocols compatible with the Internet Protocol Suite and an addressing system (IP addresses) administered by the Internet Assigned Numbers Authority and address registries. Service providers and large enterprises exchange information about the reach ability of their address spaces through the Border Gateway Protocol (BGP), forming a redundant worldwide mesh of transmission paths.

Intranets and extranets

Intranets and extranets are parts or extensions of a computer network, usually a local area network.

An intranet is a set of networks, using the Internet Protocol and IP-based tools such as web browsers and file transfer an application, which is under the control of a single administrative entity. That administrative entity closes the intranet to all but specific, authorized users. Most commonly, an intranet is the internal network of an organization. A large intranet will typically have at least one web server to provide users with organizational information.

An extranet is a network that is limited in scope to a single organization or entity and also has limited connections to the networks of one or more other usually, but not necessarily, trusted organizations or entities—a company's customers may be given access to some part of its intranet—while at the same time the customers may not be considered *trusted* from a security standpoint. Technically, an extranet may also be categorized as a CAN, MAN, WAN, or other type of network, although an extranet cannot consist of a single LAN; it must have at least one connection with an external network.

Overlay network

An overlay network is a virtual computer network that is built on top of another network. Nodes in the overlay are connected by virtual or logical links, each of which corresponds to a path, perhaps through many physical links, in the underlying network.

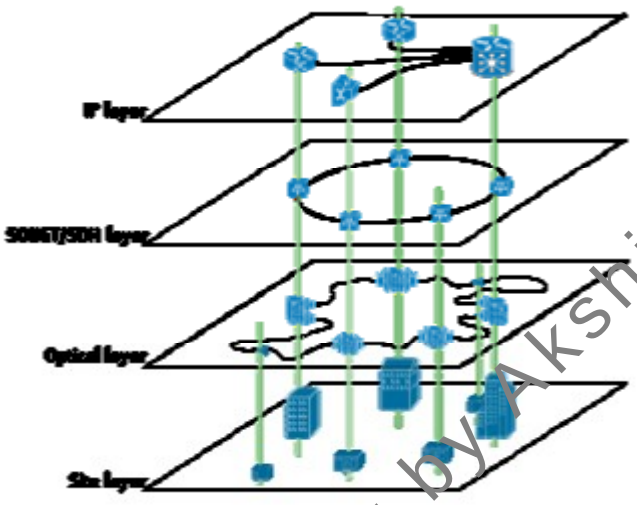

Fig. 14: A sample overlay network: IP over SONET over Optical

For example, many peer-to-peer networks are overlay networks because they are organized as nodes of a virtual system of links run on top of the Internet. The Internet was initially built as an overlay on the telephone network.

Overlay networks have been around since the invention of networking when computer systems were connected over telephone lines using modem, before any data network existed.

Nowadays the Internet is the basis for many overlaid networks that can be constructed to permit routing of messages to destinations specified by an IP address. For example, distributed hash tables can be used to route messages to a node having a specific logical address, whose IP address is known in advance.

Overlay networks have also been proposed as a way to improve Internet routing, such as through quality of service guarantees to achieve higher-quality streaming media. On the other hand, an overlay network can be incrementally deployed on end-hosts running the overlay protocol software, without cooperation from Internet service providers. The overlay has no control over how packets are routed in the underlying network between two overlay nodes, but it can control, for example, the sequence of overlay nodes a message traverses before reaching its destination.

ADVANTAGES OF NETWORKS:

- **Resource Sharing**
  - Ø Hardware (computing resources, disks, printers)
  - Ø Software (application software)
- **Information Sharing**
  - Ø Easy accessibility from anywhere (files, databases)
  - Ø Search Capability (WWW)
- **Communication**
  - Ø Email
  - Ø Message broadcasting

disADVANTAGES OF NETWORKS:

- If a network file server develops a fault, then users may not be able to run application programs
- A fault on the network can cause users to lose data (if the files being worked upon are not saved)
- If the network stops operating, then it may not be possible to access various resources
- User's work input becomes dependent upon network and the skill of the systems manager
- It is difficult to make the system secure from hackers, novices or industrial espionage
- Decisions on resource planning tend to become centralized, for example, what word processor is used, what printers are bought
- Networks that have grown with little thought can be inefficient in the long term.
- As traffic increases on a network, the performance degrades unless it is designed properly
- Resources may be located too far away from some users

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