Data Communication Network

The major criteria that a Data Communication Network must meet are:

i. 11a. Performance
ii. 11b. Consistency
iii. 11c. Reliability,
iv. 11d. Recovery and
v. 11e. Security

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a. Performance

Performance is the defined as the rate of transferring error free data. It is measured by the Response Time. Response Time is the elasped time between the end of an inquiry and the beginning of a response. Request a file transfer and start the file transfer. Factors that affect Response Time are:

a. Number of Users: More users on a network - slower the network will run
b. Transmission Speed: speed that data will be transmitted measured in bits per second (bps)
c. Media Type: Type of physical connection used to connect nodes together
d. Hardware Type: Slow computers such as XT or fast such as Pentiums
e. Software Program: How well is the network operating system (NOS) written

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b. Consistency

Consistency is the predictability of response time and accuracy of data.

a. Users prefer to have consistent response times, they develop a feel for normal operating conditions. For example: if the "normal" response time is 3 sec. for printing to a Network Printer and a response time of over 30 sec happens, we know that there is a problem in the system!
b. Accuracy of Data determines if the network is reliable! If a system loses data, then the users will not have confidence in the information and will often not use the system.

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c. Reliability

Reliability is the measure of how often a network is useable. MTBF (Mean Time Between Failures) is a measure of the average time a component is expected to operate between failures. Normally provided by the manufacturer. A network failure can be: hardware, data carrying medium and Network Operating System.

d. Recovery

Recovery is the Network's ability to return to a prescribed level of operation after a network failure. This level is where the amount of lost data is nonexistent or at a minimum. Recovery is based on having Back-up Files.

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e. Security

Security is the protection of Hardware, Software and Data from unauthorized access. Restricted physical access to computers, password protection, limiting user privileges and data encryption are common security methods. Anti-Virus monitoring programs to defend against computer viruses are a security measure.

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f. Applications

The following lists general applications of a data communication network:

i. Electronic Mail (e-mail or Email) replaces snail mail. E-mail is the forwarding of electronic files to an electronic post office for the recipient to pick up.
ii. Scheduling Programs allow people across the network to schedule appointments directly by calling up their fellow worker's schedule and selecting a time!
iii. Videotext is the capability of having a 2 way transmission of picture and sound. Games like Doom, Hearts, distance education lectures, etc..
iv. Groupware is the latest network application, it allows user groups to share documents, schedules databases, etc.. ex. Lotus Notes.
v. Teleconferencing allows people in different regions to "attend" meetings using telephone lines.
vi. Telecommuting allows employees to perform office work at home by "Remote Access" to the network.
vii. Automated Banking Machines allow banking transactions to be performed everywhere: at grocery stores, Drive-in machines etc..
viii. Information Service Providers: provide connections to the Internet and other information services. Examples are Compuserve, Genie, Prodigy, America On-Line (AOL), etc...
ix. Electronic Bulletin Boards (BBS - Bulletin Board Services) are dialup connections (use a modem and phone lines) that offer a range of services for a fee.
x. Value Added Networks are common carriers such as AGT, Bell Canada, etc.. (can be private or public companies) who provide additional leased line connections to

their customers. These can be Frame Relay, ATM (Asynchronous Transfer Mode), X.25, etc.. The leased line is the Value Added Network.

Classification of communication networks

Communication networks are usually defined by their size and complexity. We can distinguish four main types:

- Small. These networks are for the connection of computer subassemblies. They are usually contained within a single piece of equipment.
- **Local area networks (LAN).** These networks connect computer equipment and other terminals distributed in a localised area, e.g. a university campus, factory, office. The connection is usually a cable or fibre, and the extent of the cable defines the LAN.
- **Metropolitan area networks (MAN).** These networks are used to interconnect LANs that are spread around, say, a town or city. This kind of network is a high speed network using optical fibre connections.
- **Wide area networks (WAN).** These networks connect computers and other terminals over large distances. They often require multiple communication connections, including microwave radio links and satellite.

LANs may have a number of different physical configurations, i.e. the manner in which workstations on the LAN are physically connected. The physical configuration will often reflect the **media access control (MAC)** method used to allow the workstation to gain access to the connection media. Most LANs are **shared medium** networks, i.e. there is effectively one link between all the workstations on the LAN and each must wait its turn for the use of the media. There are various methods of controlling how and when a workstation gets its turn to use the media, e.g. **carrier sense multiple access with collision detect (CSMA/CD)** or the use of **token** passing.

One of the most popular configurations is the **bus** arrangement for example **Ethernet** and **token-bus** (Figure ❑).

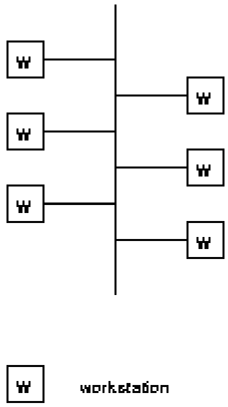

Figure: LAN bus arrangement

In this configuration, all the workstations effectively hang off from one piece of wire. Another common configuration is a **ring**, for example **token-ring** (Figure).

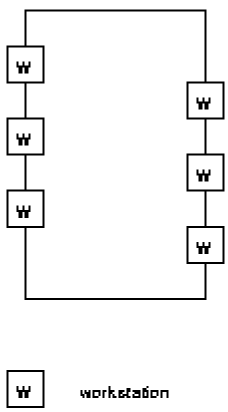

Figure: LAN ring arrangement

A **star** configuration is not seldom used to interconnect workstations on a LAN. Instead it is used to interconnect LANs via an **exchange** or **switch**, however, emerging **asynchronous transfer mode (ATM)** technology (and other high-speed networks) may make the use of star configurations a more common occurrence (Figure).

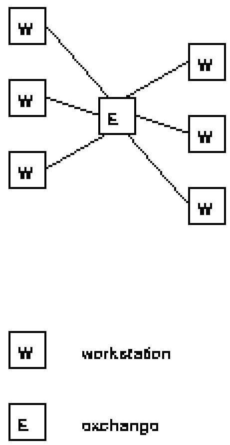

Figure: LAN star arrangement

You may hear these configurations referred to as **LAN topologies**. LAN **segments** may be interconnected by use of a **backbone** LAN that allows communication between the segments. The segments help to localise traffic, e.g. within an office or a single floor in a building. Each segment is a LAN in itself, but is connected to the backbone via a **bridge** (Figure).

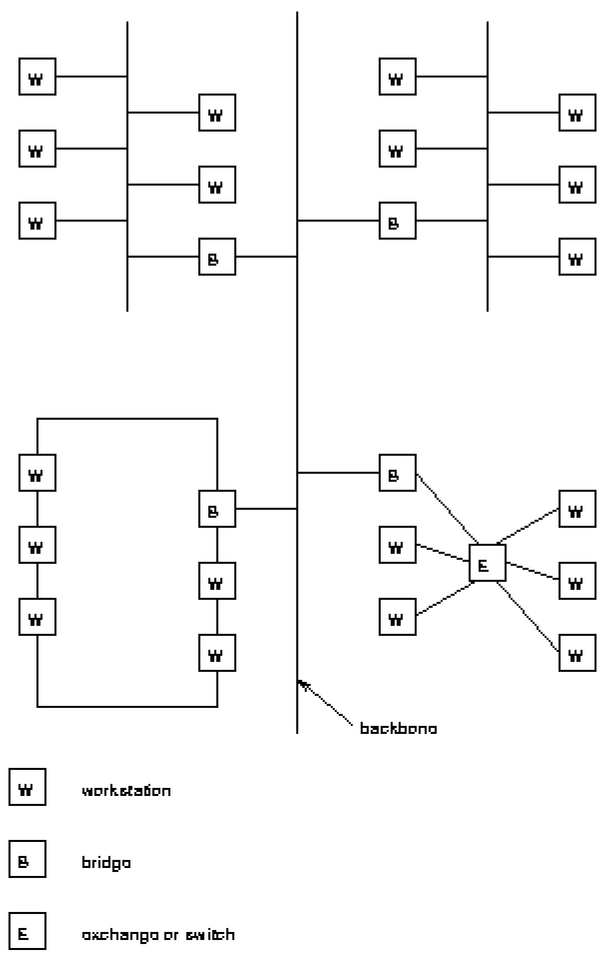

Figure: Backbone interconnecting LAN segments

WANs often exploit public networks such as the public telephone system (Figure ❑). There are two types of public network:

- **Public switched telephone network (PSTN).** This is the ordinary telephone system. This system exists in all countries of the world. It was designed specifically for the transmission of voice communication. Digital systems employing this network must produce a "voice-like" signal, and accept the low transmission rates.
- **Public switched data network (PSDN).** This is a public network designed specifically for the transmission of digital data. They arose from privately owned WANs that required higher performance than the PSTN. Many countries of the world are introducing PSDN services. They can support much higher transmission rates. An **integrated services digital network (ISDN)** is the term given to all-digital networks that can carry simultaneously voice and data communication, and offer additionally a variety of teletex services. ISDN services are being introduced all round the world and are indeed on offer in the UK.

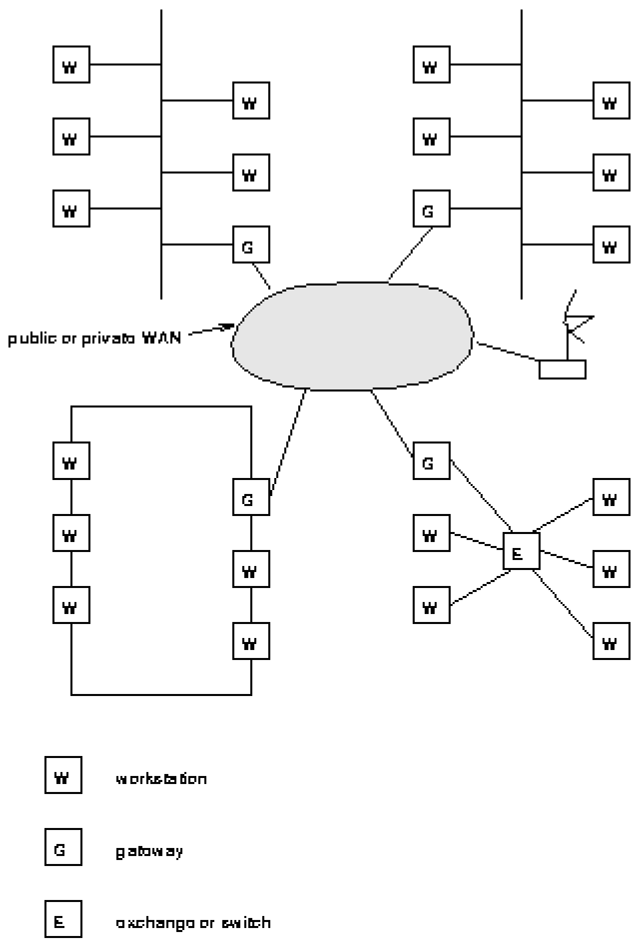

Figure: WANs to interconnect LANs

MANs are now taking some of the roles that WANs once had in particular environments for LAN ↔LAN interconnection, due to the high speeds that they offer compared to most

PSTNs and PSDNs, e.g **FDDI** and **DQDB** offer 100Mb/s, whereas a PSTN line may offer, say, 19.2Kb/s with a fast modem.

At the present time the world's communication systems are in a state of flux. Historically, digital computing equipment conformed to the requirements of the PSTN. Now, increasingly, analogue traffic such as voice and video is conforming to the requirements of the PSDN.

Public networks employ two types of switching. Switching describes the method by which the corresponders are connected. A **circuit switched network (CSN)** establishes a connection through the network that is then used exclusively by the two correspondents. (Of course, only in 19th century telephone exchanges is the switching actually current driven.) The PSTN is a circuit switched network. A **packet switched network (PSN)** divides the message into packets, that are addressed to the recipient. The packets are then forwarded through the network, together with many other packets. These are locally distributed on arrival. The Post Office is a packet switched network. More relevantly, LAN communication is exclusively via a PSN. The outstanding advantage of the PSN is that the two correspondents can communicate at different rates, permitting much more efficient use of the communication channel.

The Communications Channel

A communication channel can be *simplex*, in which only one party can transmit, *full-duplex*, in which both correspondents can transmit and receive simultaneously, or *half-duplex*, in which the correspondents alternate between transmitting and receiving states (such as conversing adults). Even though the channel might be capable of supporting full-duplex communication, if the corresponding entities are not capable of transmitting and receiving simultaneously, the communications system will be half-duplex (as in the example of the conversing adults).

Communication between two entities can be considered either in-band or out-of-band, depending on context. *In-band* communication is communication which occurs via the primary channel between the communicating entities. *Out-of-band* communication occurs via an alternative channel, which is not considered to be the primary channel between the entities.

Which channel is primary and which is an alternate depends on context and the existence of an alternative channel. In the case of a conversation between two people, the primary channel could consist of verbal communication while the alternate channel consists of visual body language. Of course, if emotions rise, these two channels might reverse roles, with body language becoming the primary channel!

Simplex communication

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Simplex communication is a name for a type of communication circuit. There are two (contradictory) definitions that have been used for the term. In both cases, the other definition is referred to as half duplex.

Contents

[hide]

One way at a time

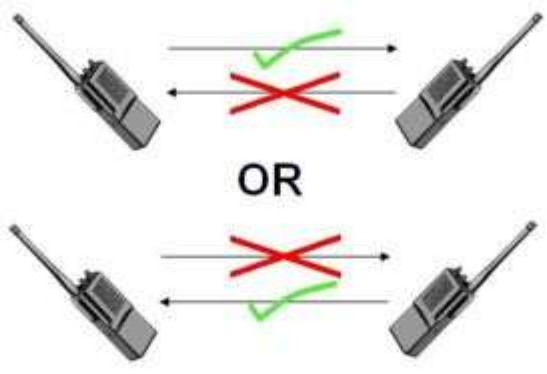
According to the ITU-T definition, a simplex circuit is one where all signals can flow in only one direction *at a time*. This was also the way Western Union used the term when describing the duplex and simplex capacity of their new transatlantic telegraph cable completed between Newfoundland and the Azores in 1928[1]. The same definition for a simplex radio channel was used by the National Fire Protection Association in 2002[2].

One way only

According to the ANSI definition, a simplex circuit is one where all signals can flow in only one direction. These systems are often employed in broadcast networks, where the receivers do not need to send any data back to the transmitter/broadcaster.

To put it simply, you won't find your radio receiver actually sending out any information; all it does is receive, so information moves *one way only* from the radio broadcasting station to your radio receiver.

Half-Duplex



A simple illustration of a half-duplex communication system.

A *half-duplex* system provides for communication in both directions, but only one direction at a time (not simultaneously). Typically, once a party begins receiving a signal, it must wait for the transmitter to stop transmitting, before replying.

An example of a half-duplex system is a two-party system such as a "walkie-talkie" style two-way radio, wherein one must use "Over" or another previously designated command to indicate the end of transmission, and ensure that only one party transmits at a time, because both parties transmit on the same frequency. A good analogy for a half-duplex system would be a one lane road with traffic controllers at each end. Traffic can flow in both directions, but only one direction at a time with this being regulated by the traffic controllers.

> *Note that this is one of two contradictory definitions for* half-duplex. *This definition matches the ANSI standard. For more detail, see Simplex communication.*

Full-Duplex

A simple illustration of a full-duplex communication system.

A *full-duplex* system allows communication in both directions, and unlike half-duplex, allows this to happen simultaneously. Land-line telephone networks are full-duplex since they allow both callers to speak and be heard at the same time. A good analogy for a *full-duplex* system would be a two lane road with one lane for each direction.

Examples: Telephone, Mobile Phone, etc.

Two way radios can be, for instance, designed as full-duplex systems, which transmit on one frequency and receive on a different frequency. This is also called *frequency-division duplex.* Frequency-division-duplex systems can be extended to farther distances using pairs of simple repeater stations, owing to the fact the communications transmitted on any one frequency always travels in the same direction.

Full-duplex Ethernet connections work by making simultaneous use of all four physical pair of twisted cable (which are inside the insulation), where two pair are used for receiving packets and two pair are using for sending packets to a directly connected device. This effectively makes the cable itself a collision-free environment, and theoretically doubles the maximum bandwidth that can be supported by the connection.

Channel Characteristics

A communications channel may be described in terms of its characteristic properties. These *channel characteristics* include*bandwidth* (how much information can be conveyed across the channel in a unit of time, commonly expressed in bits per second or *bps*[7] *), quality* (how reliably can the information be correctly conveyed across the channel, commonly in terms of bit error rate or *BER*[8] *) and whether the channel is dedicated* (to a single source) or *shared* (by multiple sources).

Obviously a higher bandwidth is usually a good thing in a channel because it allows more information to be conveyed per unit of time. High bandwidths mean that more users can share the channel, depending on their means of accessing it. High bandwidths also allow more demanding applications (such as graphics) to be supported for each user of the channel.

The capability of a channel to be shared depends of course on the medium used. A shared channel could be likened to a school classroom, where multiple students might attempt to simultaneously catch the teacher's attention by raising their hand; the teacher must then arbitrate between these conflicting requests, allowing only one student to speak at a time.

Reliability of communication is obviously important. A low quality channel is prone to distorting the messages it conveys; a high quality channel preserves the integrity of the messages it conveys. Depending on the quality of the channel in use between communicating entities, the probability of the destination correctly receiving the message from the source might be either very high or very low. If the message is received incorrectly it needs to be retransmitted.

If the probability of receiving a message correctly across a channel is too low, the system (source, channel, message, destination) must include mechanisms which overcome the errors introduced by the low quality channel. Otherwise no useful communication is possible over that channel. These mechanisms are embodied in the communication protocols employed by the corresponding entities.

The *effective bandwidth* describes what an application experiences and depends on the *quality of service (QOS)* provided by the channel. For example, modems scale back their transmission speed based largely on their perception of channel quality in order to optimally use the transmission medium.

In general, shared and reliable channels are more resource efficient than those which enjoy neither of these characteristics. Shared channels enjoy greater efficiency than dedicated ones because most data communication is bursty in nature, with long idle periods punctuated by brief message transmissions. Reliable channels are more efficient than unreliable ones because retransmissions are not required as often (because there are fewer transmission-induced errors).

The OSI Reference Model

The *Open Systems Interconnect (OSI) reference model* is commonly used to describe in an abstract manner the functions involved in data communication. This model, originally conceived in the International Organization for Standardization (ISO), defines data communications functions in terms of layers.

In the OSI reference model, each *layer* is responsible for certain basic functions, such as getting data from one device to another or from one application on a computer to another. The functions at each layer both depend and build on the functions-called *services*-provided by the layers below it. Communication between peer entities at a given layer is done via one or more protocols; this communication is invoked via the *interface* with the layer below.

The OSI reference model is depicted in Table 0.1. Successful communication between two applications depends on successful functions at all seven layers. In terms of implementation, it is possible for some layers to be trivial; in the end what is required depends on the needs of the applications (and people) engaged in communication.

Table 0.1: OSI Reference Model

	Layer	**Title**
	7	Application
Higher Layers	6	Presentation
	5	Session
	4	Transport

	3	Network
Lower Layers	2	Data Link
	1	Physical

We must emphasize that the definition of a layered data communication architecture is only an abstraction. The intent of this definition is to unambiguously describe the functions involved in data communication in a way which allows different systems to be compared. The OSI reference model definition is intended to neither imply nor constrain the implementation of any communication system.

Although various companies and standards bodies have created different layered communications models, the OSI reference model remains the universally-accepted common denominator for abstract definition. Other models define the layer functions somewhat differently and often have fewer than seven layers. In some cases constituent protocols were specified before the abstract models defining the end-to-end communication.

We will now review the functions of the OSI layers and some of the primary protocols at each layer.[9]

Layer 1 - The Physical Layer

The *physical layer* functions include all physical aspects of communicating between two directly-connected physical entities. Typically these physical properties include electromechanical characteristics of the medium or link between the communicating physical entities such as connectors, voltages, transmission frequencies, etc. This layer summarizes the physics which underlie the communication path.

The essential service provided by the physical layer consists of an unstructured *bit stream*, which can be used by higher layers to provide the basis for higher layer communication services. An example of a physical layer is the ink on paper used by this book to convey information. Another example is the radio frequencies used in a wireless communications system.

Layer 2 - The Data Link Layer

The *data link layer* accepts the unstructured bit stream provided by the physical layer and provides reliable transfer of data between two directly-connected Layer 2 entities. "Directly-connected" means that the Layer 2 entities' communication path does not require another Layer 2 entity. However, this does not imply a dedicated path; in the case of Ethernet, many Layer 2 entities can be sharing a common (physical) medium such as a coaxial cable or a 10BASE-T hub.

Layer 2 functionality is limited in scope-delivery of messages over a local area. It could be likened to an intra-office correspondence between co-workers; there is a need for reliability but addressing is relatively simple. *Local area networks (LANs)* operate at Layer 2.

The data link layer is itself conceptually subdivided into two sublayers-medium access control and logical link control-which more specifically define the primary aspects of data link layer functionality. However, this conceptual partitioning by the IEEE 802 committee is somewhat arbitrary and subject to debate.

The MAC Sublayer

The *medium access control (MAC) sublayer* is closely associated with the physical layer and defines the means by which the physical channel (medium) may be accessed. It coordinates the attempts to seize a shared channel by multiple MAC entities, much as a school teacher must arbitrate between pupils' conflicting desires to speak. The MAC layer commonly provides a limited form of error control, especially for any header information which defines the MAC-level destination and higher-layer access mechanism.

Ethernet (IEEE 802.3) is a prime example of a shared medium with a defined MAC sublayer functionality. The shared medium in Ethernet has traditionally consisted of a coaxial cable into which multiple entities were "tapped," as depicted in Figure 0.5. Although this topology still applies conceptually, a hub and spoke medium is now typically used, in which the earlier coaxial cable has been physically collapsed into a *hub* device.

Figure 0.5: Ethernet MAC System

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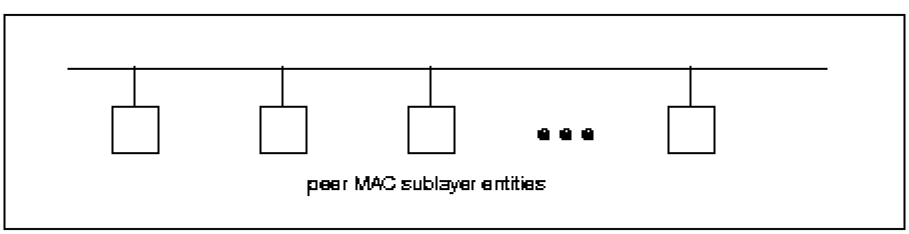
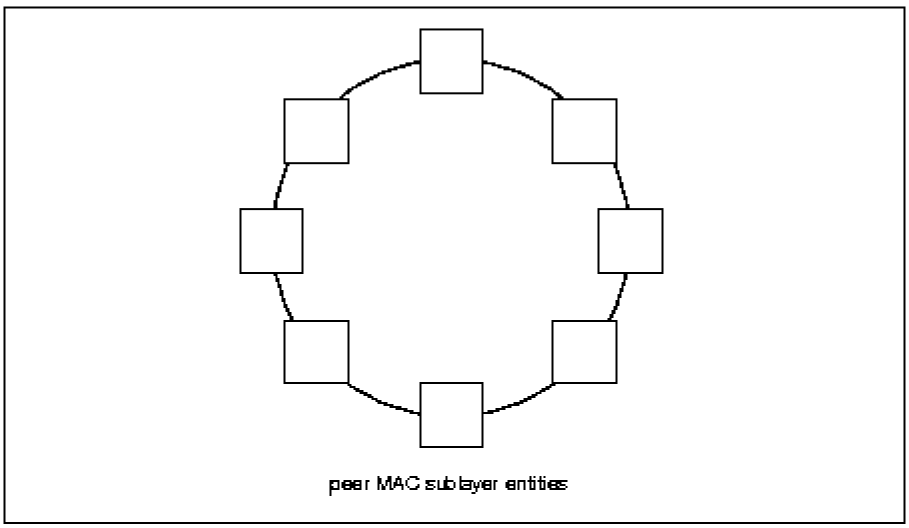


As a *contention* medium, Ethernet defines how devices *sense* a channel for its availability, wait when it is busy, *seize* the channel when it becomes available and *back-off* for a random length of time following a *collision* with another simultaneously transmitting device. On a shared channel, such as Ethernet, only a single entity can transmit at a time or messages will be garbled.

Not all shared channels involve contention. A prime example of a *contentionless* shared medium is *token ring (IEEE 802.5),* in which control of the channel is rotated between the devices sharing the channel in a deterministic round-robin manner. Conceptually, control of the channel is given to the entity currently possessing a "token." If the device has nothing to transmit, it passes the token to the next device attached to the topological "ring," depicted in Figure 0.6.

Figure 0.6: Token Ring MAC System
1#1



IEEE-defined MAC sublayer addresses are six bytes long and permanently assigned to each device, typically called a *network interface card* or*NIC. The* IEEE administers the assignment of these addresses in blocks to manufacturers to assure the global uniqueness that the MAC sublayer protocols rely on for "plug Ôn play" network setup. Each manufacturer must assure individual device identifier uniqueness within their assigned block.

The LLC Sublayer

The *logical link control (LLC) sublayer* is responsible for reliable transfer of messages-called *frames* or, more formally, *link protocol data units (LPDUs)*-between two directly-connected Layer 2 entities. Functions needed to support this reliable transfer include *framing* (indicating where a Layer 2 message begins and ends), sequence control, error control and flow control.

The degree to which sequence, error and flow control are provided by the LLC sublayer is determined by whether the link protocol is connection-oriented or connectionless. A connectionless link protocol provides little if any support for these functions. A connection-oriented link might use a windowing technique for these functions, in which frames are individually numbered and acknowledged by their sequence number, with only a few such frames outstanding at any time.

The connection-oriented functions of sequencing, error and flow control provide a foundation for services provided by higher layers. As mentioned earlier, not all layer or sublayer functions are explicitly designed or implemented in any given system. Provision of these functions depends on the services required by higher layers.

If the connection-oriented functions of the LLC sublayer are not implemented, they must be performed by higher layers for reliable end-to-end communication. If these functions are provided by several layers, they might be somewhat redundant and add unnecessary overhead (inefficiency) to the system. In the worst case, redundant provision of these functions at multiple layers could serve cross purposes and actually degrade overall system performance.

An example of a connectionless LLC protocol is *frame relay (T1.617, 618),* which defines point-to-point links with *switches* connecting individual links in a mesh topology. In a frame relay network, endpoints are connected by a series of links and switches. Because frame relay is defined in terms of the links between frame relay access devices (FRADs) and switches, and between switches themselves, it is an LLC protocol.

Connectionless Layer 2 protocols are best suited for high quality transmission media. With high quality transmission media, errors are rarely introduced in the transmission between network layer entities and discovery of and recovery from errors is most efficiently handled by the communicating hosts. In this case, it is better to move the packets quickly across the traversed subnetworks from source to destination rather than checking for errors at Layer 2.

Frame relay is derived from the *X.25 (ISO 8208)* protocol which spans Layers 2 and 3. X.25 is a connection-oriented packet-switching technology which defines how neighboring *packet switches* exchange data with one another in a reliable manner from end-to-end. Frame relay simply removes the connection-oriented functions of error and sequence control; however, *congestion control* functions are provided in frame relay, to prevent the total traffic seen at any point in the network from overwhelming it.

Connection-oriented Layer 2 protocols are best suited for low quality transmission media where it is more efficient and cost-effective to discover and recover from errors as they occur on each hop than to rely on the communicating hosts to perform error recovery functions. With ever-increasing quality of transmission facilities and decreasing costs of computation capability at hosts, the need for connection-oriented network layer protocols is diminishing. However, X.25 remains popular outside of North America, where it has been tariffed at levels which encourage its use.

End-to-end communications may be via shared or dedicated facilities or *circuits*. Shared facilities involve the use of *packet switching* technology to carry messages from end-to-end; messages are subdivided as necessary into packets, which share physical and logical channels with packets from various sources to various destinations. Packet switching is almost universally used in data communications because it is more efficient for the bursty nature of data traffic.

On the other hand, some applications require dedicated facilities from end-to-end because they are isochronous (e.g., voice) or bandwidth-intensive (e.g., large file transfer). This mode of end-to-end circuit dedication is called *circuit switched* communication. Because the facilities are dedicated to a single user, this tends to be much more expensive than the packet switched mode of communication. But some applications need it-it is an economic trade-off.

Dedicated circuits are a rather extreme form of connection-oriented protocol, requiring the same setup and tear-down phases prior to and following communication. If the circuit setup and tear-down is statically arranged (i.e., out-of-band), it is referred to as a *permanent virtual circuit* or *PVC*. If the circuit is dynamically setup and torn-down in-band, it is referred to as a *switched virtual circuit* or *SVC*.

Layer 3 - The Network Layer

The *network layer* defines the functions necessary to support data communication between indirectly-connected entities. It provides the capability of forwarding messages from one Layer 3 entity to another until the final destination is reached.

The network layer introduces another layer of abstraction to the data communications model. It moves messages-called *packets* or, more formally, *network protocol data units* (*NPDUs*)-between communicating Layer 3 entities-called *end systems*, *nodes* or *hosts*. Network layer functions include route determination or *routing* and *forwarding* of packets to their final destinations.

In order to forward a packet to its destination host, routing information must be provided to the*intermediate systems (ISs)* or *routers* responsible for forwarding packets to their respective destinations. This routing information includes the *address* of the destination, which is contained in each packet. The next *hop* to be traversed by the packet is determined primarily by this destination address. We will talk more about addressing and routing in Chapter 1.

This packet forwarding and routing is accomplished independent of both the media and transmission types used at any step along the way. The unimportance of local topology to the network layer is demonstrated by the common use of "cloud diagrams" to depict networks, as in Figure 0.7. Since the network layer is concerned with getting packets across many local networks, called *subnetworks*, its title would be more accurate if it were the "Internetwork Layer."

Figure 0.7: Network Layer ``Cloud'' Diagram
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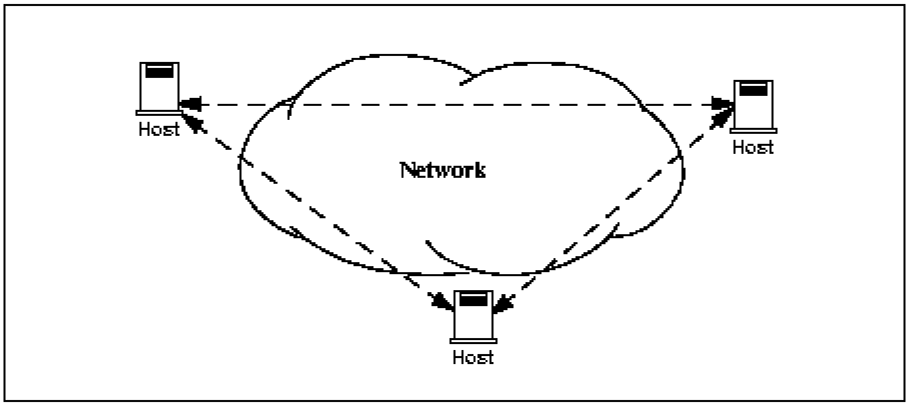


The network layer functionality is global in scope-delivery of messages over a wide area. It could be likened to the postal system, in which correspondence is passed from location to location until it eventually reaches the destination address on the envelope.[10] The network layer is the domain of *wide area networks* (*WANs*).

In order for routers to know how (i.e., on which link) to forward packets, they must have some knowledge of network topology. This knowledge may be complete or partial, and is dynamically created and maintained via *routing protocols*, used by routers to share their knowledge of network topology with each other. Routing is essentially the reduction of global internetwork topology to local "hop-by-hop" routing decisions made independently by each router.

As with Layer 2, Layer 3 protocols may be connection-oriented or connectionless. A connection-oriented Layer 3 protocol, such as *X.25 (ISO 8208)*, operates more statically. The basic idea is that an end-to-end route (X.25 virtual connection) is established from the originating *data terminal equipment (DTE)* to *data communications equipment (DCE)*, from DCE to DCE through the network, then from the last DCE to the terminating DTE; this is the call setup. Packets are then transmitted via this prearranged route, with all packets following the same path through the network. Finally the route is torn down (release) and packets cease flowing.

X.25 operation is like a phone call because it *is* a phone call. X.25 Layer 3 operation assumes that a reliable connection-oriented service is provided by Layer 2 (also defined by the X.25 standard), although it does provide flow control via sequence numbers.

Connectionless Layer 3 protocols, such as the ever popular *internet protocol (IP)(RFC*[11] *791 and 792) and its ISO counterpart connectionless network protocol (CLNP) (ISO*

8473), route packets dynamically. There is no prearranged path which is followed by subsequent packets flowing from one host to another. Instead each packet is individually routed through a routing mesh; there is no reason to believe that sequential packets flowing between hosts will follow the same path. So sequence errors may be introduced at Layer 3, which must be corrected by a higher layer entity.

Connectionless data packets are commonly referred to as *datagrams* and the service provided by connectionless Layer 3 protocols is referred to as *datagram service*. Stateless datagram service is simpler for Layer 3 entities than connection-oriented network layer services. Because there is no state information to maintain, dynamic routing protocols can be used. If a router fails during the dialogue between two communicating hosts, neighboring routers will discover this via the routing protocols and find alternate routes which bypass the failed router.

There seems to be a fair amount of ambiguity between the network layer and the LLC sublayer. Both can provide connection-oriented or connectionless services to higher layers. To a large extent, if Layer 3 is explicitly implemented, there is no need for an LLC sublayer. The primary difference is in scope-LLC addresses and protocols are oriented toward a more local environment whereas network layer addresses and protocols are global in scope.

Excellent references to routing and forwarding of data packets can be found in [PERL92] and [STEN95].

Layer 4 - The Transport Layer

The *transport layer* is concerned with getting Layer 4 messages-called *segments* or, more formally, *transport protocol data units (TPDUs)* -from source to destination in a reliable manner. The perspective of Layer 4 is of end-to-end communications rather than the hop-by-hop perspective of Layer 3. Layer 4 assumes that packets can be moved from network entity to network entity, eventually getting to the final destination host. How this is accomplished is of no concern to Layer 4 functionality.

Like other layers, transport layer protocols can be either connection-oriented or connectionless, depending on the services required by higher layers. A common implementation of Layers 3 and 4 involves a connection-oriented transport layer protocol running over a connectionless network layer protocol, such as the ubiquitous TCP/IP protocol suite. In this instance, the communicating hosts maintain state information on communications with each other to determine when and what to send. This state information defines the connection between the communicating Layer 4 entities.

The general idea here is that two communicating hosts need not be concerned with the topology of the internetwork which lies between them. They only need to know the state of their pairwise communication. If part of the intervening internetwork "cloud" suffers a failure, the Layer 3 entities (routers) will deal with it and recover dynamically. Aside from potential retransmission of any lost segments, the hosts' Layer 4 entries do not have to be at all concerned with routing and recovery activities at Layer 3.

In the IP protocol suite, the primary connectionless Layer 4 protocol is the User Datagram Protocol (UDP)(RFC 768), which is carried by IP; the primary connection-oriented protocol is the Transmission Control Protocol (TCP)(RFC 793). The ISO world defines five classes of transport layer protocol, beginning with Class 0 (TP-0) for connectionless operation and range up to Class 4 (TP-4)(ISO 8073) for connection-oriented operation.

Layer 5 - The Session Layer

The *session layer* provides a control structure for communication between applications on hosts. The communication at layer 5 is called a *session*, which defines the relative timing of communications between the hosts' applications. Synchronization of communicating applications comes into play when coordinated timing of corresponding events at the endpoints is imperative, such as in financial transactions.

Remember, layers define communication functions, not implementations. It is unlikely that a session layer would be explicitly implemented as a stand-alone program, although its functions would be implemented somewhere. Session layer functions depend on the reliability of communications between the endpoints, and session layer functions must therefore be implemented above Layer 4.

Layer 6 - The Presentation Layer

The *presentation layer* performs any necessary data transformations or formatting required by the end applications. Functions provided by the presentation layer include data compression, file formatting and encryption. Common data formatting is important because it allows the same application file to be accessed by the application running on different computer platforms. This book is itself the product of an application running on different platforms, with common files being modified via these different platforms.

Abstract Syntax Notation (ASN.1) is commonly used to specify data values in a way which allows processors to communicate independent of their varying native integer sizes, bit orderings (big or little endian), character sets, etc. ASN.1 is a transfer syntax, a presentation layer formatting, which appears frequently in the CDPD specification for unambiguous definition of network management, accounting, limited size messaging and other functions.

An example of ASN.1 encoding from an accounting Traffic Matrix Segment in the CDPD specification is the following:

TrafficType ::= INTEGER {

registration (0),
deregistration (1),
ip(2),
clnp(3)
}

Layer 7 - The Application Layer

The *application layer* provides the services which directly support an application running on a host. These services are directly accessible by an application via common well-known *application program interfaces (APIs)*, which can actually occur at many layers. Examples of layer 7 services include *FTP (file transfer protocol)*, Telnet and *SNMP (simple network management protocol)*. Most network management activities are based on the services provided by layer 7 application entities, which in turn rely on lower layer services to be able to perform their functions.

7	**Application**	ECHO, ENRP, FTP, Gopher, HTTP, NFS, RTSP, SIP, SMTP, SNMP, SSH, Telnet, Whois, XMPP
6	**Presentation**	XDR, ASN.1, SMB, AFP, NCP
5	**Session**	ASAP, TLS, SSL, ISO 8327 / CCITT X.225, RPC, NetBIOS, ASP
4	**Transport**	TCP, UDP, RTP, SCTP, SPX, ATP, IL
3	**Network**	IP, ICMP, IGMP, IPX, OSPF, RIP, IGRP, EIGRP, ARP, RARP, X.25
2	**Data Link**	Ethernet, Token ring, HDLC, Frame relay, ISDN, ATM, 802.11 WiFi, FDDI, PPP
1	**Physical**	10BASE-T, 100BASE-T, 1000BASE-T, SONET/SDH, G.709, T-carrier/E-carrier, various 802.11 physical layers

The TCP/IP Reference Model

The TCP/IP reference model is the network model used in the current Internet architecture [19]. It has its origins back in the 1960's with the grandfather of the Internet, the ARPANET. This was a research network sponsored by the Department of Defense in the United States. The following were seen as major design goals:

- ability to connect multiple networks together seamlessly
- ability for connections to remain intact as long as the source and destination machines were functioning

- to be built on flexible architecture

The reference model was named after two of its main protocols, TCP (Transmission Control Protocol) [12] and IP (Internet Protocol).

They choose to build a packet-switched network based on a connectionless internetwork layer.

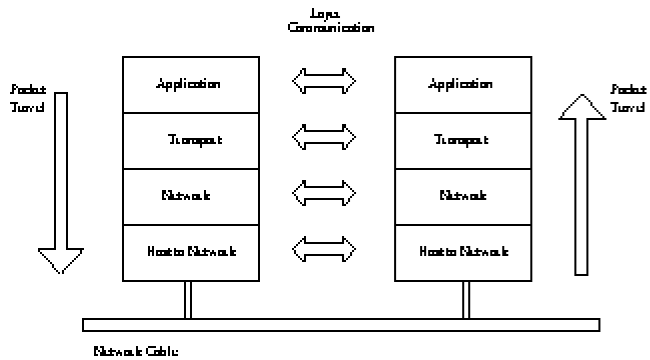


Figure 2.1: TCP/IP Network Protocol

A detailed description of the reference model is beyond the scope of this document and project. The basic idea of the networking system is to allow one application on a host computer to talk to another application on a different host computer.

The application forms its request, then passes the packet down to the lower layers, which add their own control information, either a header or a footer, onto the packet. Finally the packet reaches the physical layer and is transmitted through the cable onto the destination host. The packet then travels up through the different layers, with each layer reading, deciphering, and removing the header or footer that was attached by its counterpart on the originating computer. Finally the packet arrives at the application it was destined for. Even though technically each layer communicates with the layer above or below it, the process can be viewed as one layer talking to its partner on the host, as figure 2.1 shows.

The Host-to-Network Layer

The Host-to-Network layer interfaces the TCP/IP protocol stack to the physical network. The TCP/IP reference model does not specify in any great detail the operation of this layer, except that the host has to connect to the network using some protocol so it can send IP packets over it.

As it is not officially defined, it varies from implementation to implementation, with vendors supplying their own version.

The Network Layer

The job of the network layer is to inject packets into any network and have them travel independently to the destination. The layer defines IP (Internet Protocol) for its official packet format and protocol. Packet routing is a major job of this protocol.

The Transport Layer

The transport layer is the interface between the application layer and the complex hardware of the network. It is designed to allow peer entities on the source and destination hosts to carry on conversations.

Data may be user data or control data. Two modes are available, full-duplex and half duplex. In full-duplex operation, both sides can transmit and receive data simultaneously, whereas in half duplex, a side can only send or receive at one time.

Interaction between the transport layer and the layers immediately above and below are shown in figure 2.2. Any program running in the application layer has the ability to send a message using TCP or UDP, which are the two protocols defined for the transport layer. The application can communicate with the TCP or the UDP service, whichever it requires. Both the TCP and UDP communicate with the Internet Protocol in the internet layer. In all cases communication is a two way process. The applications can read and write to the transport layer. The diagram only shows two protocols in the transport layer. T/TCP will also reside in this layer between the other two protocols and function in the same manner.

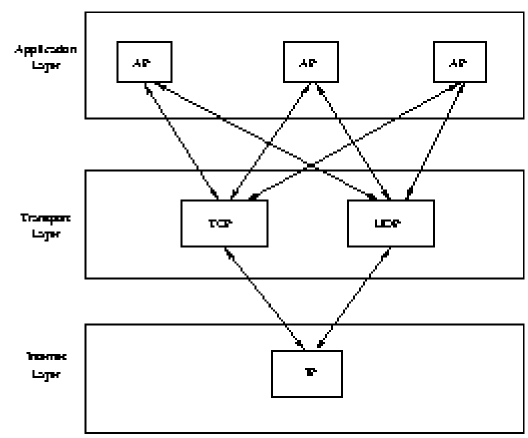


Figure 2.2: Interaction with Application, Transport and Internet Layers

A message to be sent originates in the application layer. This is then passed down onto the appropriate protocol in the transport layer. These protocols add a header to the message for the corresponding transport layer in the destination machine for purposes of reassembling the message. The segment is then passed onto the internet layer where the Internet Protocol adds a further header. Finally the segment is passed onto the physical layer, a header and a trailer are added at this stage. Figure 2.3 shows the structure of the final segment being sent.

Figure 2.3: Transmitted Segment from TCP/IP Network

The Application Layer

The original TCP/IP specification described a number of different applications that fit into the top layer of the protocol stack. These applications include Telnet, FTP, SMTP and DNS.

Telnet is a program that supports the TELNET [13] protocol over TCP. TELNET is a general two-way communication protocol that can be used to connect to another host and run applications on that host remotely.

FTP (File Transfer Protocol) [14] is a protocol that was originally designed to promote the sharing of files among computer users. It shields the user from the variations of file storage on different architectures and allows for a reliable and efficient transfer of data.

SMTP (Simple Mail Transport Protocol) [15] is the protocol used to transport electronic mail from one computer to another through a series of other computers along the route.

DNS [10] (Domain Name System) resolves the numerical address of a network node into its textual name or vice-versa. It would translate www.yahoo.com to 204.71.177.71 to allow the routing protocols to find the host that the packet is destined for.

What is a Topology?

The physical topology of a network refers to the configuration of cables, computers, and other peripherals. Physical topology should not be confused with logical topology which is the method used to pass information between workstations. Logical topology was discussed in the Protocol chapter .

Main Types of Physical Topologies

The following sections discuss the physical topologies used in networks and other related topics.

- Linear Bus

- Star
- Star-Wired Ring
- Tree
- Considerations When Choosing a Topology
- Summary Chart

Linear Bus

A linear bus topology consists of a main run of cable with a terminator at each end (See fig. 1). All nodes (file server, workstations, and peripherals) are connected to the linear cable. Ethernet and LocalTalk networks use a linear bus topology.

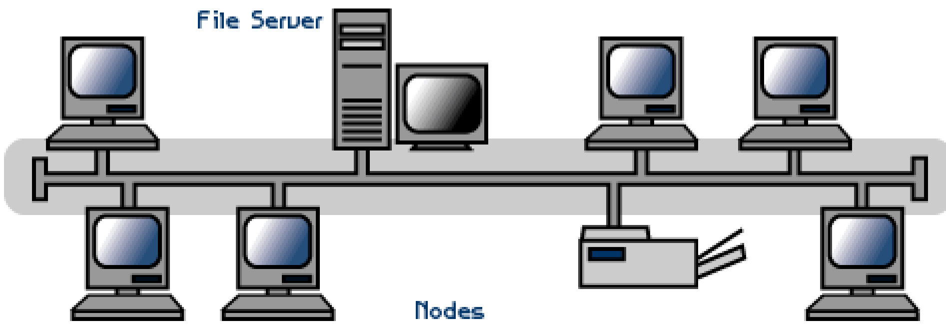


Fig. 1. Linear Bus topology

Advantages of a Linear Bus Topology

- Easy to connect a computer or peripheral to a linear bus.
- Requires less cable length than a star topology.

Disadvantages of a Linear Bus Topology

- Entire network shuts down if there is a break in the main cable.
- Terminators are required at both ends of the backbone cable.
- Difficult to identify the problem if the entire network shuts down.
- Not meant to be used as a stand-alone solution in a large building.

Star

A star topology is designed with each node (file server, workstations, and peripherals) connected directly to a central network hub or concentrator (See fig. 2).

Data on a star network passes through the hub or concentrator before continuing to its destination. The hub or concentrator manages and controls all functions of the network. It also acts as a repeater for the data flow. This configuration is common with twisted pair cable; however, it can also be used with coaxial cable or fiber optic cable.

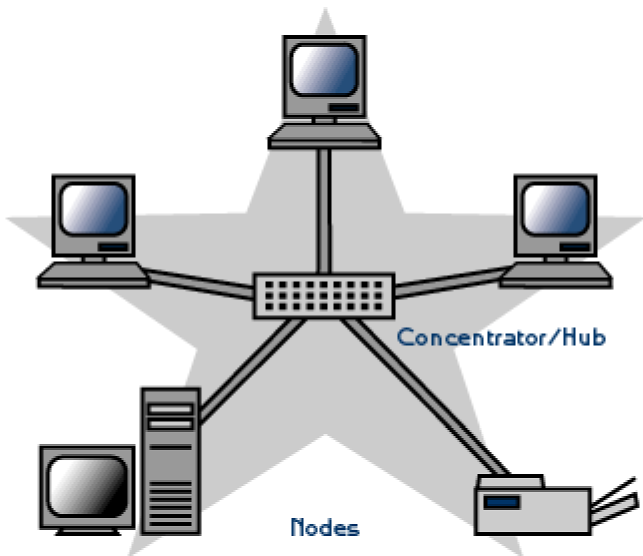


Fig. 2. Star topology

Advantages of a Star Topology

- Easy to install and wire.
- No disruptions to the network then connecting or removing devices.
- Easy to detect faults and to remove parts.

Disadvantages of a Star Topology

- Requires more cable length than a linear topology.
- If the hub or concentrator fails, nodes attached are disabled.
- More expensive than linear bus topologies because of the cost of the concentrators.

The protocols used with star configurations are usually Ethernet or LocalTalk. Token Ring uses a similar topology, called the star-wired ring.

Star-Wired Ring

A star-wired ring topology may appear (externally) to be the same as a star topology. Internally, the MAU (multistation access unit) of a star-wired ring contains wiring that allows information to pass from one device to another in a circle or ring (See fig. 3). The Token Ring protocol uses a star-wired ring topology.

Tree

A tree topology combines characteristics of linear bus and star topologies. It consists of groups of star-configured workstations connected to a linear bus backbone cable (See fig.

4). Tree topologies allow for the expansion of an existing network, and enable schools to configure a network to meet their needs.

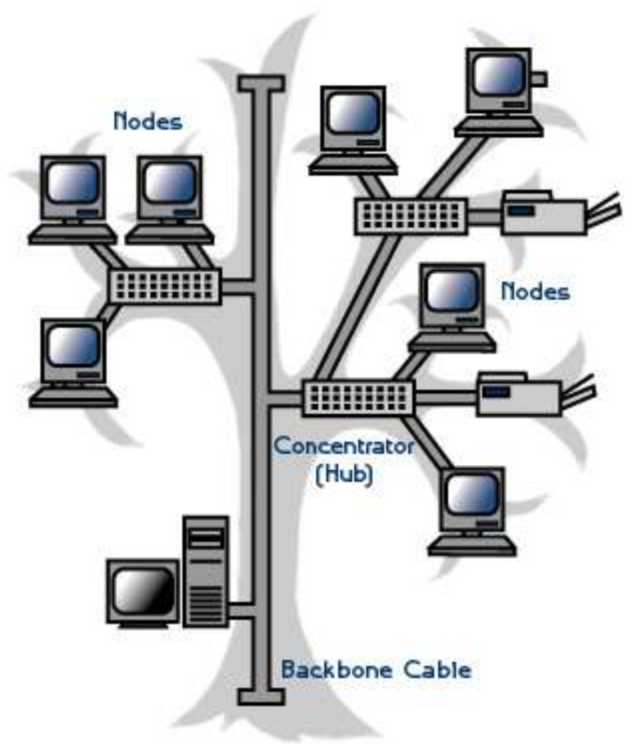


Fig. 4. Tree topology

Advantages of a Tree Topology

- Point-to-point wiring for individual segments.
- Supported by several hardware and software venders.

Disadvantages of a Tree Topology

- Overall length of each segment is limited by the type of cabling used.
- If the backbone line breaks, the entire segment goes down.
- More difficult to configure and wire than other topologies.

5-4-3 Rule

A consideration in setting up a tree topology using Ethernet protocol is the 5-4-3 rule. One aspect of the Ethernet protocol requires that a signal sent out on the network cable reach every part of the network within a specified length of time. Each concentrator or repeater that a signal goes through adds a small amount of time. This leads to the rule that between any two nodes on the network there can only be a maximum of 5 segments, connected through 4 repeaters/concentrators. In addition, only 3 of the segments may be populated (trunk) segments if they are made of coaxial cable. A populated segment is one which has one or more nodes attached to it . In Figure 4, the 5-4-3 rule is adhered to. The furthest two nodes on the network have 4 segments and 3 repeaters/concentrators between them.

This rule does not apply to other network protocols or Ethernet networks where all fiber optic cabling or a combination of a fiber backbone with UTP cabling is used. If there is a combination of fiber optic backbone and UTP cabling, the rule is simply translated to 7-6-5 rule.

] Mesh:

Full:

Fully Connected:

The type of network topology in which each of the nodes of the network is connected to each of the other nodes in the network with a point-to-point link – this makes it possible for data to be simultaneously transmitted from any single node to all of the other nodes.

Note: 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[3].

Partial:

Partially Connected:

The type of network topology in which some of the nodes of the network are connected to more than one other node in the network with a point-to-point link – 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.

Note: In most practical networks that are based upon the physical partially connected mesh topology, all of the data that is transmitted between nodes in the network takes the shortest path between nodes, except in the case of a failure or break in one of the links, in which case the data takes an alternate path to the destination – this implies that the nodes of the network possess some type of logical 'routing' algorithm to determine the correct path to use at any particular time.

[edit] Hybrid Network Topologies

The hybrid topology is a type of network topology that is composed of one or more interconnections of two or more networks that are based upon different physical topologies or a type of network topology that is composed of one or more interconnections of two or more networks that are based upon the same physical topology, but where the physical topology of the network resulting from such an interconnection does not meet the definition of the original physical topology of the interconnected networks (e.g., the physical topology of a network that would result from an interconnection of two or more networks that are based upon the physical star topology might create a hybrid topology which resembles a mixture of the physical star and physical bus topologies or a mixture of the physical star and the physical tree topologies, depending upon how the individual networks are interconnected, while the physical topology of a network that would result from an interconnection of two or more networks that are based upon the physical distributed bus network retains the topology of a physical distributed bus network).

Star-Bus:
A type of network topology in which the central nodes of one or more individual networks that are based upon the physical star topology are connected together using a common 'bus' network whose physical topology is based upon the physical linear bus topology, the endpoints of the common 'bus' being terminated with the characteristic impedance of the transmission medium where required – e.g., two or more hubs connected to a common backbone with drop cables through the port on the hub that is provided for that purpose (e.g., a properly configured 'uplink' port) would comprise the physical bus portion of the physical star-bus topology, while each of the individual hubs, combined with the individual nodes which are connected to them, would comprise the physical star portion of the physical star-bus topology.

Star-of-Stars:

Hierarchical Star:
A type of network topology that is composed of an interconnection of individual networks that are based upon the physical star topology connected together in a hierarchical fashion to form a more complex network – e.g., a top level central node which is the 'hub' of the top level physical star topology and to which other second level central nodes are attached as the 'spoke' nodes, each of which, in turn, may also become the central nodes of a third level physical star topology.

Notes:
1.) The physical hierarchical star topology is not a combination of the physical linear bus and the physical star topologies, as cited in some texts, as there is no common linear bus within the topology, although the top level 'hub' which is the beginning of the physical hierarchical star topology may be connected to the backbone of another network, such as a common carrier, which is, topologically, not considered to be a part of the local network – if the top level central node is connected to a backbone that is considered to be a part of the local network, then the resulting network topology would be considered to be a hybrid topology that is a mixture of the topology of the backbone network and the physical hierarchical star topology.
2.) The physical hierarchical star topology is also sometimes incorrectly referred to as a physical tree topology, since its physical topology is hierarchical, however, the physical hierarchical star topology does not have a structure that is determined by a branching factor, as is the case with the physical tree topology and, therefore, nodes may be added to, or removed from, any node that is the 'hub' of one of the individual physical star topology networks within a network that is based upon the physical hierarchical star topology.
3.) The physical hierarchical star topology is commonly used in 'outside plant' (OSP) cabling to connect various buildings to a central connection facility, which

may also house the 'demarcation point' for the connection to the data transmission facilities of a common carrier, and in 'inside plant' (ISP) cabling to connect multiple wiring closets within a building to a common wiring closet within the same building, which is also generally where the main backbone or trunk that connects to a larger network, if any, enters the building.

Star-wired Ring:

A type of hybrid physical network topology that is a combination of the physical star topology and the physical ring topology, the physical star portion of the topology consisting of a network in which each of the nodes of which the network is composed are connected to a central node with a point-to-point link in a 'hub' and 'spoke' fashion, the central node being the 'hub' and the nodes that are attached to the central node being the 'spokes' (e.g., a collection of point-to-point links from the peripheral nodes that converge at a central node) in a fashion that is identical to the physical star topology, while the physical ring portion of the topology consists of circuitry within the central node which routes the signals on the network to each of the connected nodes sequentially, in a circular fashion.

Note: In an 802.5 Token Ring network the central node is called a Multistation Access Unit (MAU).

Hybrid Mesh:

A type of hybrid physical network topology that is a combination of the physical partially connected topology and one or more other physical topologies the mesh portion of the topology consisting of redundant or alternate connections between some of the nodes in the network – the physical hybrid mesh topology is commonly used in networks which require a high degree of availability.

Considerations When Choosing a Topology:

- **Money**. A linear bus network may be the least expensive way to install a network; you do not have to purchase concentrators.
- **Length of cable needed**. The linear bus network uses shorter lengths of cable.
- **Future growth**. With a star topology, expanding a network is easily done by adding another concentrator.
- **Cable type**. The most common cable in schools is unshielded twisted pair, which is most often used with star topologies.

Summary Chart:

	Common Cable	**Common Protocol**
Linear Bus	Twisted Pair	Ethernet

	Fiber	
Star	Twisted Pair Fiber	Ethernet LocalTalk
Star-Wired Ring	Twisted Pair	Token Ring
Tree	Twisted Pair Coaxial Fiber	Ethernet

Internet vs. Web

The Internet and the World Wide Web are not synonymous: the Internet is a collection of interconnected *computer networks*, linked by copper wires, fiber-optic cables, wireless connections, etc.; the Web is a collection of interconnected documents and other *resources*, linked by hyperlinks and URLs. The World Wide Web is accessible via the Internet, as are many other services including e-mail, file sharing, and others described below.

The best way to define and distinguish between these terms is to understand the Internet protocol suite. This collection of protocols is organized into layers such that each layer provides the foundation and the services required by the layer above. In this conception, the term Internet refers to computer networks that all communicate with IP (Internet protocol) and TCP (transfer control protocol). Once this networking structure is established, then other protocols can run “on top.” These other protocols are sometimes called services or applications. Hypertext transfer protocol, or HTTP, is an application layer protocol that links billions of files together into the World Wide Web.

Common uses of the Internet

The World Wide Web

. Through keyword-driven Internet research using search engines, like Google, millions worldwide have easy, instant access to a vast and diverse amount of online information. Compared to encyclopedias and traditional libraries, the World Wide Web has enabled a sudden and extreme decentralization of information and data.

Many individuals and some companies and groups have adopted the use of "Web logs" or blogs, which are largely used as easily-updatable online diaries. Some commercial organizations encourage staff to fill them with advice on their areas of specialization in the hope that visitors will be impressed by the expert knowledge and free information, and be attracted to the corporation as a result. One example of this practice is Microsoft, whose product developers publish their personal blogs in order to pique the public's interest in their work.

For more information on the distinction between the World Wide Web and the Internet itself — as in everyday use the two are sometimes confused — see Dark internet where this is discussed in more detail.

Remote access

The Internet allows computer users to connect to other computers and information stores easily, wherever they may be across the world. They may do this with or without the use of security, authentication and encryption technologies, depending on the requirements.

This is encouraging new ways of working from home, collaboration and information sharing in many industries. An accountant sitting at home can audit the books of a company based in another country, on a server situated in a third country that is remotely maintained by IT specialists in a fourth. These accounts could have been created by home-working book-keepers, in other remote locations, based on information e-mailed to them from offices all over the world. Some of these things were possible before the widespread use of the Internet, but the cost of private, leased lines would have made many of them infeasible in practice.

An office worker away from his desk, perhaps the other side of the world on a business trip or a holiday, can open a remote desktop session into his normal office PC using a secure Virtual Private Network (VPN) connection via the Internet. This gives him complete access to all his normal files and data, including e-mail and other applications, while he is away.

This concept is also referred to by some network security people as the Virtual Private Nightmare, because it extends the secure perimeter of a corporate network into its employees' homes; this has been the source of some notable security breaches, but also provides security for the workers.

Functions

- E-mail
- File-sharing
- Instant messaging
- Internet fax
- Search engine
- World Wide Web

Intranets

What are Intranets?

- Intranet is Intra+ Net so an Intranet is an internal or private Internet used strictly within the confines of a company, university, or organization. "Inter" means "between or among," hence the difference between the Internet and an Intranet.

Some formal definitions of Intranets

- Brown & Duguid: “Intranets help present and

  circulate boundary objects”

- Choo, Detlor, & Turnbull: “Intranets… support the creation, sharing, and use of knowledge”
- Stenmark: “Intranets are organizationally

  restricted”

A technical definition

- An Intranet is a network based on the internet TCP/IP open standard. An intranet belongs to an organization, and is designed to be accessible only by the organization's members, employees, or others with authorization. An intranet's Web site looks and act just like other Web sites, but has a firewall surrounding it to fend off unauthorized users.

Design Of Intranets

Steps

- Analyze the organization’s information ecology
- Identify the typical problems experienced by users
- Analyze the information behaviors of these set of users
- Create value added processes to resolve the problems of users and to improve the Information Ecology.

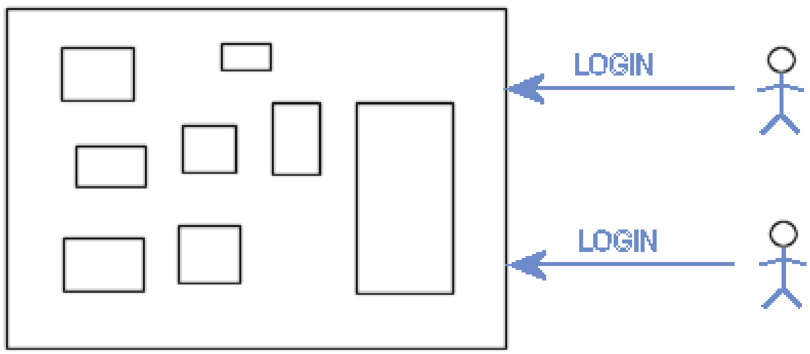
Value Added Processes

- Intranets may be designed to improve the organizational information ecology.

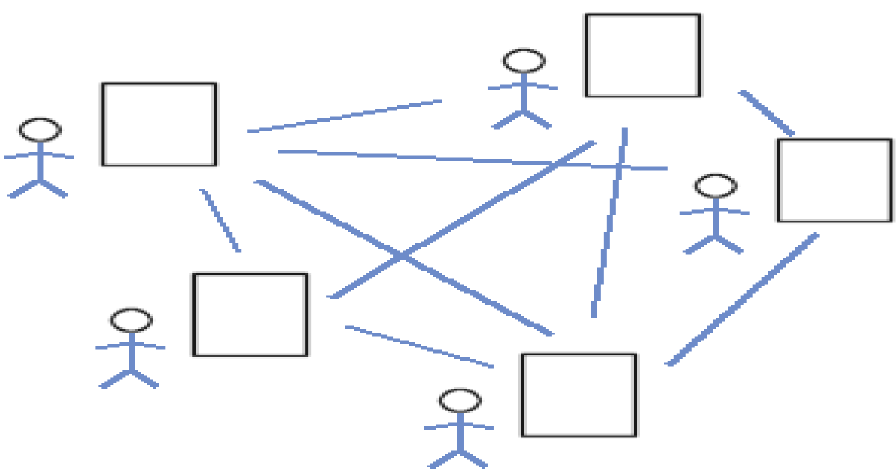
- Intranets provide a unified information space in which users can communicate and collaborate with others.
- intranet applications and services may add value by supporting the organization's knowledge creating and decision making process

Two Models of Online Environments

Centralized



Distributed



Centralized Environments

- **Before the web, the centralized model was all we had (examples include CompuServe, Prodigy)**
- **On the web, centralized models include site-based services such as Yahoo!**
- **Most (all?) college and university services are offered using the centralized model**

- **But centralized environments are static, inflexible, expensive**

Distributed Environments

- **The World Wide Web is an example of a distributed environment**
- **Resources, access are *not* centralized, but scattered around the world:**
  - Resources, in the form of a network of connected (via DNS) web servers
  - Access, in the form of a network of connected (via DNS) internet service providers
  - Users, in the form of individualized and connected (via HTTP) web browsers
- **The big issue – integration – that is, making different systems work together**

Design Principles

Network Design Principles

- Specifies how networks differ from traditional learning
- The idea is that each principle confers an *advantage* over non-network systems
- Can be used as a means of evaluating new technology

1. Decentralize

- Centralized networks have a characteristic ‘star’ shape
  - Some entities have many connections
  - The vast majority have few
  - Eg., broadcast network, teacher in a classroom
- Decentralized networks form a mesh
  - The weight of connections, flow is distributed
  - Balanced load = more stable
  - Foster connections between entities, ‘fill out’ the star

. Distribute

- Network entities reside in different physical locations
  - Reduces risk of network failure
  - Reduces need for major infrastructure, such as powerful servers, large bandwidth, massive storage
- Examples:
  - Peer-to-peer networks, such as Kazaa, Gnutella
  - Content syndication networks, such as RSS
- Emphasis is on *sharing*, not copying
  - ‘Local’ copies are temporary

Computer Graphics

Computer Graphics is about animation (films)

Games are very important in Computer Graphics

Medical Imaging is another driving force

Computer Aided Design too

Graphics Definitions

- Point
  - a location in space, 2D or 3D
  - sometimes denotes one pixel
- Line
  - straight path connecting two points
  - infinitesimal width, consistent density
  - beginning and end on points
- Vertex
  - point in 3D
- Edge
  - line in 3D connecting two vertices
- Polygon/Face/Facet
  - arbitrary shape formed by connected vertices
  - fundamental unit of 3D computer graphics

- Raster
  - derived from TV systems for a row of pixels
  - commonly referred to as a *scanline*
  - does influence algorithms – reducing memory requirements, parallelism, etc.
  - is the derivation of *rasterization, scan-line algorithms*

Displays

- Most desktop displays use a cathode ray tube (CRT), while portable computing devices such as laptops incorporate liquid crystal display (LCD)
- Because of their slimmer design and smaller energy consumption, monitors using LCD technologies are beginning to replace the venerable CRT on many desktops

Cathode-Ray Tubes

- Classical output device is a monitor.
- Cathode-Ray Tube (CRT)
  - Invented by Karl Ferdinand Braun (1897)
  - Beam of electrons directed from cathode (-)to phosphor-coated (fluorescent) screen (anode (+))
  - Directed by magnetic focusing and deflection coils (anodes) in vacuum filled tube
  - Phosphor emits photon of light, when hit by an electron, of varied persistence (long 15-20 ms for texts / short < 1ms for animation)
  - Refresh rate (50-60 Hz / 72-76 Hz) to avoid flicker / trail
  - Phosphors are organic compounds characterized by their persistence and their color (blue, red, green).

Cathode-Ray Tubes

- Cathode-Ray Tube (CRT)
  - Horizontal deflection and vertical deflection direct the electron beam to any point on the screen
  - Intensity knob: regulates the flow of electrons by controlling the voltage at the control grid (high voltage reduces the electron density and thus brightness)
  - Accelerating voltage from positive coating inside screen (anode screen) or an accelerating anode
- Image maintenance
  - Charge distribution to store picture information OR
  - Refresh CRT: refreshes the display constantly to maintain phosphor glow.

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- Characteristics of Cathode-Ray Tube (CRT)

  - Intensity is proportional to the number of electrons repelled in beam per second (brightness)
  - Resolution is the maximum number of points that can be displayed without overlap; is expressed as number of horizontal points by number of vertical points; points are called pixels (picture elements); example: resolution 1024 x 768 pixels. Typical resolution is 1280 x 1024 pixels.
- High-definition systems: high resolution systems.

- Focusing
  - Focusing forces the electron beam to converge to a point on the monitor screen
  - Can be electrostatic (lens) or magnetic (field)
- Deflection
  - Deflection directs the electron beam horizontally and/or vertically to any point on the screen
  - Can be controlled by electric (deflection plates, slide 9) or magnetic fields (deflection coils, slide 5)
  - Magnetic coils: two pairs (top/bottom, left/right) of tube neck
  - Electric plates: two pairs (horizontal, vertical)

Raster-scan Displays

•Video displays can be either raster-scan or random-scan displays.

•Raster-scan display is the most common type of monitor using a CRT.

•The electron beam scans the screen from top to bottom one row at a time. Each row is called a scan line.

•The electron beam is turned on and off to produce a collection of dots painted one row at a time. These will form the image.

•A raster is a matrix of pixels covering the screen area and is composed of raster lines.

Raster-scan Displays

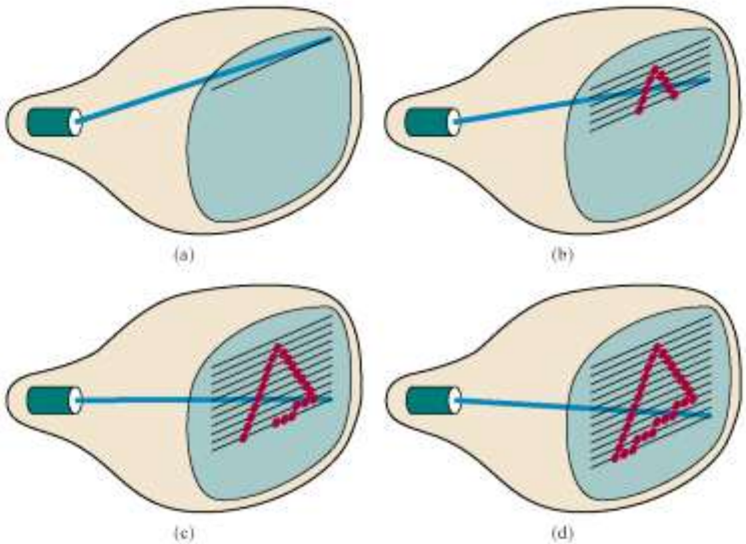


Figure 2-7
A raster-scan system displays an object as a set of discrete points across each scan line.

Raster-scan Displays
•The image is stored in a frame buffer containing the total screen area and where each memory location corresponds to a pixel.
•In a monochrome system, each bit is 1 or 0 for the corresponding pixel to be on or off (bitmap).
•The display processor scans the frame buffer to turn electron beam on/off depending if the bit is 1 or 0.
•For color monitors, the frame buffer also contains the color of each pixel (color buffer) as well as other characteristics of the image (gray scale, …). 8 bits/pixel → 0..255 (pixmap).
•Depth of the buffer area is the number of bits per pixel (bit planes), up to 24.
•Examples: television panels, printers, PC monitors (99% of raster-scan)...

Raster-scan Displays
•Refresh rate: 24 is a minimum to avoid flicker, corresponding to 24 Hz (1 Hz = 1 refresh per second)
•Current raster-scan displays have a refresh rate of at least 60 frames (60 Hz) per second, up to 120 (120 Hz).
•Uses large memory: 640x480 → 307200 bits → 38 kB
•Refresh procedure:

–Horizontal retrace – beam returns to left of screen
–Vertical retrace – bean returns to top left corner of screen
–Interlaced refresh – display first even-numbered lines, then odd-numbered lines permits to see the image in half the time
useful for slow refresh rates (30 Hz shows as 60 Hz).

Random-scan Displays
•Random scan systems are also called vector, stroke-writing, or calligraphic displays.
•The electron beam directly draws the picture in any specified order.
•A pen plotter is an example of such a system.
•Picture is stored in a display list, refresh display file, vector file, or display program as a set of line drawing commands.
•Refreshes by scanning the list 30 to 60 times per second.
•More suited for line-drawing applications such as architecture and manufacturing.

Random-scan Displays
•Advantages:
–High resolution
–Easy animation
–Requires little memory
•Disadvantages:
–Requires intelligent electron beam (processor controlled)
–Limited screen density, limited to simple, line-based images
–Limited color capability.
•Improved in the 1960's by the Direct View Storage Tube (DVST) from Tektronix.

Color CRT Monitor
Uses different phosphors, a combination of Red, Green, and Blue, to produce any color.
Two methods:
Random scan: uses beam penetration.
2 layers (Red, Green) phosphors; low speed electrons excite Red, high speed electrons excite Green, interrmediate speed excite both to get yellow and orange. Color is controlled by electron beam voltage.
Only produces a restricted set of colors.
Raster scan: uses a shadow mask with three electron guns: Red, Green, and Blue (RGB color model). Color is produced by adjusting the intensity level of each electron beam. Produces a wide range of colors, from 8 to several millions.

Raster scan

Most common, as found in televisions.

Beam scanned left to right, flicked back to rescan, from top to bottom, then repeated. Repeated at 30Hz per frame, sometimes higher to reduce flicker. Interlacing, scanning odd lines in whole screen then even lines, is also used to reduce flicker. Can also use high-persistence phosphor to reduce flicker but causes image smearing especially with significant animation.

Resolution typically 512x512, but high-quality screens are available (and becoming more common) at up to approximately 1600x1200 pixels. Sun workstations have screens of 1192x980 pixels.

Black & white screens can display grayscale by varying the intensity of the electron beam.

Colour is achieved using three electron guns which hit red, green or blue phosphors. Combining these colours can produce many others, including white (all on). Phosphor dots focused using a shadow mask - makes colour screens lower resolution than monochrome.

Alternative approach: beam penetration. Special phosphor glows a different colour depending on intensity of beam.
Colour or intensity at pixel held by computer's video card. 1 bit/pixel can store off/on information, hence only black &white. More bits/pixel give rise to more colour possibilities, e.g.. 8 bits/pixel gives rise to 2^8=256 possible colours at any one time.

Random Scan (Directed-beam refresh, vector display)

Instead of scanning the whole display sequentially and horizontally, the random scan draws the lines to be displayed directly. Screen update at >30Hz to reduce flicker. Jaggies not found, and higher resolutions possible (up to 4096x4096 pixels). Colour achieved using beam penetration, generally of poorer quality. Eye strain and fatigue still a problem, and vector displays are more expensive.

Direct view storage tube (DVST)
Used a lot in analogue storage oscilloscopes.
Similar to random scan c.r.t. but image maintained by flood guns - no flicker. Can be incrementally updated but not selectively erased; image has to be redrawn on completely erased screen. High resolution (typically 4096x3120 pixels), but low contrast, low brightness and difficulty in displaying colour.

What is a Multimedia System?

- A system that involves:
  - generation
  - representation
  - storage
  - transmission
  - search and retrieval
  - delivery

of multimedia information

- production/authoring tools
- compression and formats
- file system design
- networking issues
- database management
- server design, streaming

Multimedia System Architecture

Information management subsystem **Presentation, Query**

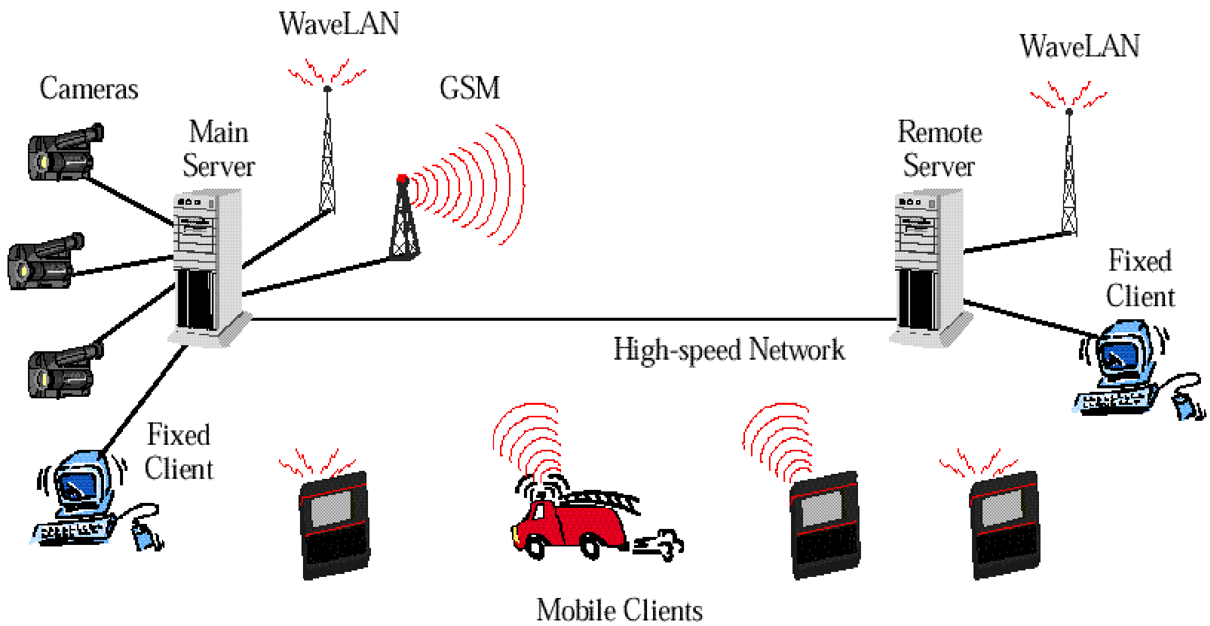
Storage subsystem **Efficiently stored & retrieved**

Network subsystem **Delivery**

Adaptation in Multimedia Systems

- Multimedia systems can profit a lot from personalization
  - User behavior
  - User properties
- Adaptation
  - Models
  - Mechanisms

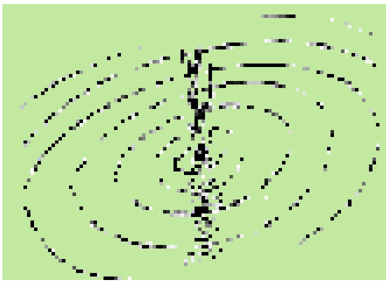
Multimedia in a mobile environment



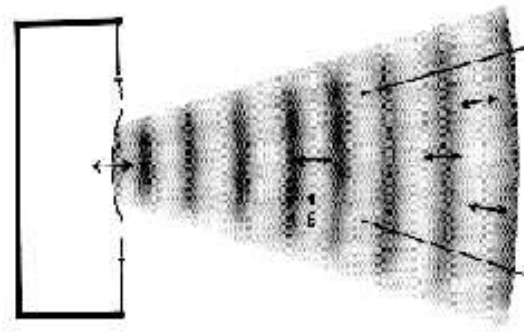
- Applications:
  - Emergency response systems, mobile commerce, phone service, entertainment, games, ...

What is Sound?

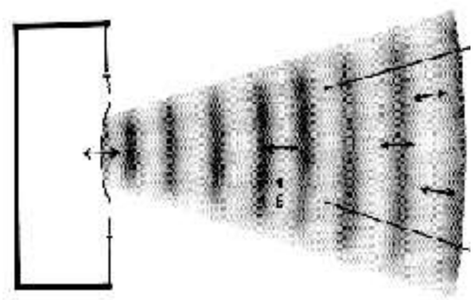
- A ripple is a pressure wave in water, created by an object striking the water.



- Sound is a pressure wave in air, created, for example, by an object such as a string or our vocal cords vibrating. Dark here represents more pressure; light represents less.

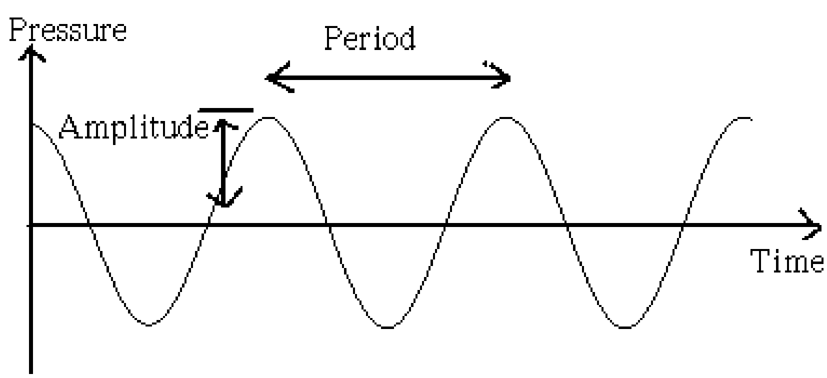


Sine Waves Form Pure Tones



This simple sound wave is a Sine Wave, a "Pure tone", produced by a simple vibration.

Sine Wave Sample Tone



This can be represented graphically as shown above.

Converting Pressure into Voltage

The pressure wave of sound moves a diaphragm in the microphone, which produces a voltage proportional to the pressure of the sound wave at each instant.

Animation

- **Animation** is the rapid display of a sequence of images of 2-D artwork or model positions in order to create an illusion of movement. It is an optical illusion of motion due to the phenomenon of persistence of vision. This could be anything from a flip book to a motion picture film. Animation deals with the generation, sequencing and display a set of images which is called frames to create an effect of visual change or motion, similar to a movie film.
- Animation is used in those instance where videography is not possible.

Hardware Requirement For Animation

- Image Generation Tools & Devices
- Computer monitors with image display Capability

Software Requirement For Animation

- Animation creating software
- Screen Capture Software
- Animation Clips
- Software support For High Resolution
- Recording & Playback Capability
- Transition effect

Early animation

There is no single person that can be considered the "creator" of the art of animation, as there were several people doing several projects which could be considered various types of animation all around the same time. (Short, hand-drawn animation scenes could be presented with the Phenakistoscope, the Zoetrope, and other optical "toys" already in the early 1800s.)

The following is a brief listing on those who are often acknowledged as significant to the development of animation. Note that this list is by no means a comprehensive list of contributors to early animation.

Georges Méliès was a creator of special effect films, such as A Trip to the Moon. He used many techniques – one of which was to stop the camera rolling, change something in the scene, and then continue rolling the film. This is a very similar idea to that of stop-motion animation. Méliès accidentally happened upon the technique when his camera broke down while shooting a bus driving by. When the camera was fixed, a horse happened to be passing by just as Méliès continued to film. The result was that the bus appeared to change into a horse.

Fantasmagorie by Emile Cohl, 1908

Émile Cohl began drawing cartoon strips and created a film in 1908 called Fantasmagorie. The film largely consisted of a stick figure moving about and encountering all manner of morphing objects, such as a wine bottle that transforms into a flower. There were also sections of live action where the animator's hands would enter the scene. The film was created by drawing each frame on paper and then shooting each frame onto negative film, which gave the picture a blackboard look.

Winsor McCay created detailed animations that required a team of artists and painstaking attention for detail. Each frame was drawn on paper, requiring backgrounds to be redrawn, as well characters to be animated. His films such as Gertie the Dinosaur (1914) and The Sinking of the Lusitania (1918) were of an impressive scale, although The Sinking of the Lusitania used cels.

In 1919 Otto Messmer created the character of Felix the cat for Pat Sullivan's animation studios. The importance of Felix lies in the character's strong personality, created largely through gesture and actions.

Animation techniques

Animation techniques are incredibly varied and difficult to categorize. Techniques are often related or combined. The following is a brief on common types of animation. Again, this list is by no means comprehensive.

Traditional animation

An example of traditional animation, a horse animated by rotoscoping from Edweard Muybridge's 19th century photos.

Main article: Traditional animation

Also called **cel animation**, the frames of a traditionally animated movie are hand-drawn. The drawings are traced or copied onto transparent acetate sheets called cels, which are then placed over a painted background and photographed one by one on a rostrum camera. Nowadays, the use of cels (and cameras) is mostly obsolete, since the drawings are scanned into computers, and digitally transferred directly to 35 mm film. The "look" of traditional cel animation is still preserved, and the character animator's work has remained essentially the same over the past 70 years. Because of the digital influence over modern cel animation, it is also known as tradigital animation. Examples: *The Lion King*, *Spirited Away*, *Les Triplettes de Belleville*

Full animation
The most common style in animation, known for its realistic and often very detailed art.
Examples: All Disney feature length animated films, *The Secret of NIMH*, *The Iron Giant*

Limited animation
A cheaper process of making animated cartoons that does not follow a "realistic" approach.
Examples: *The Flintstones*, *Yellow Submarine*

Rubber hose
The characters are usually cartoony, and the animators have a lot of artistic freedom as rubber hose animations don't have to follow the laws of physics and anatomy in the same degree as the other main styles in animation.
Examples: Early Mickey Mouse cartoons, *Ren and Stimpy*, *Popeye*

Rotoscoping
A technique where animators trace live action movement, frame by frame, for use in animated films.
Examples: *Gulliver's Travels*, *American Pop*

Stop motion

Stop-motion animation is any type of animation which requires the animator to physically alter the scene, shoot a frame, again alter the scene and shoot a frame and so on, to create the animation. There are many different types of stop-motion animation some noteable, examples are listed below.

Clay animation

A clay animation scene from a TV commercial.

Often abbreviated to *claymation*, this is a type of stop-motion animation using figures made of clay or a similar malleable material. The figures may have an armature or wire frame inside of them, similar to **puppet animation** (below). Alternatively, the figures may be made entirely of clay, such as in the films of Bruce Bickford where clay creatures morph into a variety of different shapes.

Examples: *Wallace and Gromit*; *Dimensions of Dialogue* by Jan Švankmajer; *The Amazing Mr. Bickford*; The Trap Door

Cutout animation

In this type of stop-motion animation, the animation is formed by moving 2-dimensional pieces of material such as paper or cloth.

Examples: the animated sequences of *Monty Python's Flying Circus* (often referred to as Dada animation, named after the *Dada* art movement[*citation needed*]); *Tale of Tales*; early episodes of *South Park*

Silhouette animation

A type of cutout animation where the viewer only sees black silhouettes.

Example: *The Adventures of Prince Achmed*, the world's oldest surviving animated feature film, from 1926.

Graphic animation

Model animation

In this form of animation, model animated characters interact with, and are a part of, the live-action world.

Examples: The films of Ray Harryhausen (*Jason and the Argonauts*) and Willis O'Brien (*King Kong*)

Go motion

Object animation

Pixilation

Examples: *Neighbours*

Puppet animation

Puppet animation typically involves puppet figures interacting with each other in a constructed environment, in contrast to the real-world interaction in **model**

animation (above). The puppets generally have an armature inside of them to keep them still and steady as well as constraining them to move at particular joints.
Examples: *The Nightmare Before Christmas*, *Robot Chicken*, *The Tale of the Fox*
Brickfilm
Puppetoon

Computer animation

A short gif animation

Like stop motion, computer animation encompasses a variety of techniques, the unifying idea being that the animation is created digitally on a computer.

2D animation
Figures are created and/or edited on the computer using 2D bitmap graphics or created and edited using 2D vector graphics. This includes automated computerized versions of traditional animation techniques such as of tweening, morphing, onion skinning and interpolated rotoscoping.
Examples: *A Scanner Darkly*, *Jib Jab*

- Analog computer animation
- Flash animation
- PowerPoint animation

A completely synthetic, computer-generated scene.

3D animation

Figures are created in the computer using polygons. To allow these meshes to move they are given a digital armature (sculpture). This process is called rigging. Various other techniques can be applied, such as mathematical functions (gravity), simulated fur or hair, effects such as fire and water and the use of motion capture to name but a few.
Examples *The Incredibles*, *Shrek*

- Cel-shaded animation
- Morph target animation
- Skeletal animation
- Motion capture
- Crowd simulation

Less common techniques

Drawn on film animation A technique where footage is produced by creating the images directly on film stock.

Paint-on-glass animationA technique for making animated films by manipulating slow-drying oil paints on sheets of glass.

Pinscreen animation Makes use of a screen filled with movable pins, which can be moved in or out by pressing an object onto the screen. The screen is lit from the side so that the pins cast shadows. The technique has been used to create animated films with a range of textural effects difficult to achieve with traditional cel animation.

Sand animation Sand is moved around on a backlighted or frontlighted piece of glass to create each frame for an animated film.

Multimedia

Multimedia (Lat. Multum + Medium) is media that uses multiple forms of information content and information processing (e.g. text, audio, graphics, animation, video, interactivity) to inform or entertain the (user) audience. *Multimedia* also refers to the use of (but not limited to) electronic media to store and experience multimedia content. Multimedia is similar to traditional mixed media in fine art, but with a broader scope. The term "rich media" is synonymous for interactive multimedia.

Categorization

Multimedia may be broadly divided into **linear** and **non-linear** categories. Linear active content progresses without any navigation control for the viewer such as a cinema presentation. Non-linear content offers user interactivity to control progress as used with a computer game or used in self-paced computer based training. Non-linear content is also known as hypermedia content.

Multimedia presentations can be live or recorded. A recorded presentation may allow interactivity via a navigation system. A live multimedia presentation may allow interactivity via interaction with the presenter or performer.

There are 2 basic way to represent some information

- Unimedium Presentation
- Multimedia Presentation

In case of computer system, the commonly used medioa for the purpose of storage, access and transmission of information are:

- Text
- Graphics
- Animation
- Audio
- Video

Multimedia Computer System require

- Faster CPU
- Larger Storage Devices
- Larger Main Memory
- Good Graphics Terminal
- I/O devices required to play an audio associated with the program

Transmission Mode

- Asynchronous
- Synchronous
- Isochronous