

Chapter 4

Local Area Networks

By Masud-ul-Hasan

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Why a Computer Network?

- Distribute pieces of computation among computers (called nodes)
- Coordination between processes running on different nodes
- Remote I/O Devices
- Remote Data/File Access
- Personal communications (like e-mail, chat, audio/video conferencing)
- World Wide Web
- ... and many other uses


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Local Area Network (LAN)



Metropolitan Area Network (MAN)



Wide Area Network (WAN)

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What is a Local Area Network?

- ❑ LAN is a **combination of hardware & software technology** that allows computers to share a variety of resources, e.g. printers, storage devices, data, etc.
- ❑ It allows messages/data to be sent between attached computers → Enable users to work together electronically, called as **“Collaborative computing”**.

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What is a Local Area Network?

- ❑ Generally, LANs are confined to an area no larger than a single building or a small group of buildings.
- ❑ It can be extended by connecting to other similar or dissimilar LANs, to remote users, or to mainframes computers, called as “LAN Connectivity” or “Internetworking”.
- ❑ Can be connected to other LANs of trading partners, called as “Enterprise Networking”.

Layer 2: The Datalink Layer

- ❑ The datalink layer provides point-to-point connectivity between devices over the physical connections provided by the underlying physical layer.
- ❑ The datalink layer breaks a data stream into chunks called *frames*, or *cells*.

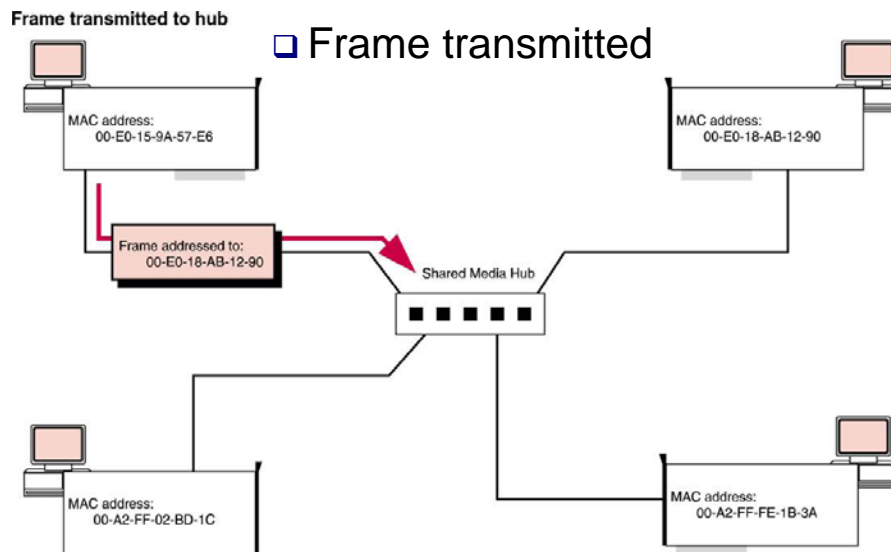
Layer 2: The Datalink Layer

- ❑ The datalink layer provides a *reliable* communications link between devices.
- ❑ Three key functions:
 - ❖ error detection
 - ❖ error correction
 - ❖ flow control
- ❑ In LANs the datalink layer can be broken down into two sublayers: media access control (MAC) and logical link control (LLC).

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Datalink Layer Addressing



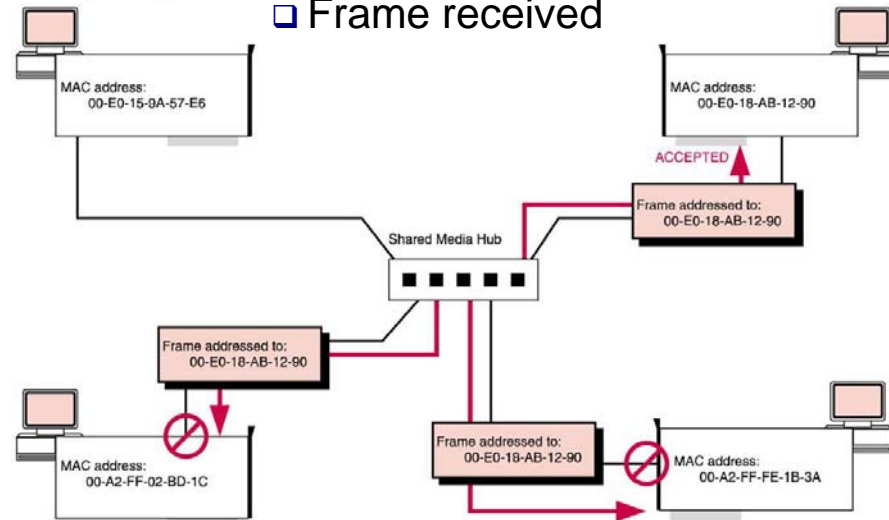
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Datalink Layer Addressing

Frame repeated by hub

□ Frame received



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How is a LAN Implemented?

1. Appropriate networking hardware & software must be added to every computer or shared peripheral device that is to communicate via the LAN.
2. Some type of network media must physically connect the various networked computers and peripheral devices to converse with each other.

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LAN Architecture Model

- All network architectures are made up of the same logical components which are:
 - ❖ Access methodology
 - ❖ Logical topology
 - ❖ Physical topology

- **Network Architecture= Access methodology + Logical topology + Physical topology**

- **Network Configuration= Network Architecture + Media choice**

Coming Up Next Network Architecture

- Access methodology
- Logical topology
- Physical topology

1. Access Methodology

- Since many users have to send requests onto the shared LAN media at the same time, there must be some way to control access by multiple users to that media. These media-sharing methods are named “**Access methodologies**”.
- Sharing the media is an important concept in LANs, which are sometimes called “**media-sharing LANs**”.
- There are two access controlling methods:
1- CSMA/CD **2-Token Passing**

CSMA/CD

- **Carrier Sense Multiple Access with Collision Detection**
- It is based on the philosophy: “*Let’s just let everyone onto the media whenever they want & if two users access the media at the same time, we’ll work it out somehow.*”
- 1. Carrier sense:** the PC wishing to put data onto the shared media listens to the network to see if any other users are “on line” by trying to sense a neutral electrical signal known as *the carrier*.
- 2. Multiple Access:** all machines on the network are free to use the network whenever they like, so long as no one else is transmitting.

CSMA/CD

3. Collision Detection: If two user PCs access the same media in the same time, a collision occurs & *collision detection* lets the user PCs to know that their data wasn't delivered. When the collision is detected, then both back off and each wait a random amount of time before retrying.

- Another factor of collisions is *propagation delaying*, which is the time it takes to a signal from a source PC to reach a destination PC.
- Because of this delay, it's possible for a workstation to sense if there is no signal on the shared media, where in fact another distant workstation has transmitted a signal that hasn't yet reached the carrier sensing PC.

CSMA/CD - Basic Ethernet Bus



- Machine 2 wants to send a message to machine 4, but first it 'listens' to make sure no one else is using the network.
- If it is all clear it starts to transmit its data on to the network (represented by the yellow flashing screen). Each packet of data contains the destination address, the senders address, and of course the data to be transmitted.
- The signal moves down the cable and is received by every machine on the network but because it is only addressed to number 4, the other machines ignore it.
- Machine 4 then sends a message back to number 2 acknowledging receipt of the data (represented by the purple flashing screen).

CSMA/CD - Collision



- ❑ Machine 2 and machine 5 both trying to transmit simultaneously. The resulting collision destroys both signals and each machine knows this has happened.
- ❑ Both machines then wait for a random period of time before re-trying. On small networks this all happens so quickly that it is virtually unnoticeable, however, as more and more machines are added to a network the number of collisions rises dramatically and eventually results in slow network response.
- ❑ The exact number of machines that a single Ethernet segment can handle depends upon the applications being used, but it is generally considered that between 40 and 70 users are the limit before network speed is compromised.

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Token Passing

- ❑ It is based on the philosophy: *“Don’t you dare access the media until it’s your turn. You must first ask permission, & only if I give you the magic token may you put your data on the shared media”*.
- ❑ It ensures that each PC user has 100% of the network channel available for data requests & transfers by insisting that no PC accesses the network without processing a specific packet of data (*Token*).
- ❑ The token is first generated by a specified PC known as *active monitor* and passed among PCs until one PC would like to access the network.

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Active Monitor

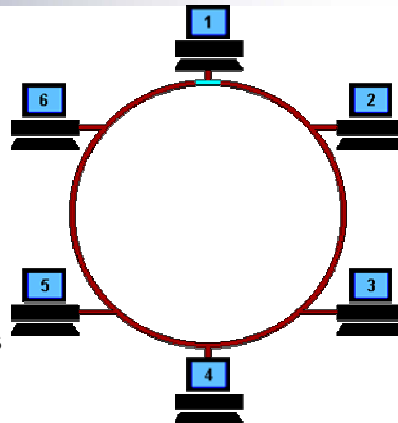
- ❑ Removes Dead frames
- ❑ Replace lost or damaged token
- ❑ Responsible for master clock
- ❑ Makes sure there is only one active monitor
- ❑ Provide buffer for token in small networks

Token Passing

- ❑ The requesting PC seizes the token, changes the token status from free to busy, puts its data frame onto the network, & doesn't release the token until it is assured that its data was delivered.
- ❑ Successful data delivery is confirmed by the destination workstation setting **frame status flags** to indicate a successful receipt of the frame.
- ❑ Upon receipt of the original frame with frame status flag set to "destination address recognized, frame copied successfully" the sending PC resets the token status from busy to free & release it.
- ❑ The token is passed along the next PC.

Token Passing

- At the start, a free Token is circulating on the ring, this is a data frame which to all intents and purposes is an empty vessel for transporting data. To use the network, a machine first has to capture the free Token and replace the data with its own message. In this example, machine 1 wants to send some data to machine 4, so it first has to capture the free Token. It then writes its data and the recipient's address onto the Token (represented by the yellow flashing screen).



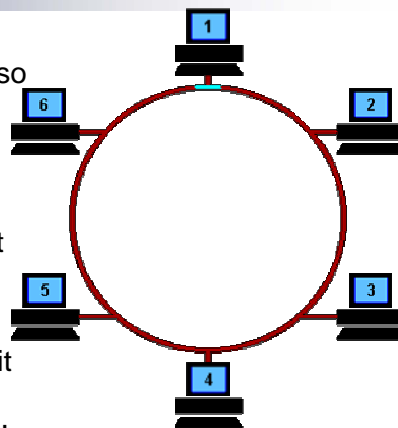
- The packet of data is then sent to machine 2 who reads the address, realizes it is not its own, so passes it on to machine 3. Machine 3 does the same and passes the Token on to machine 4.

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Token Passing

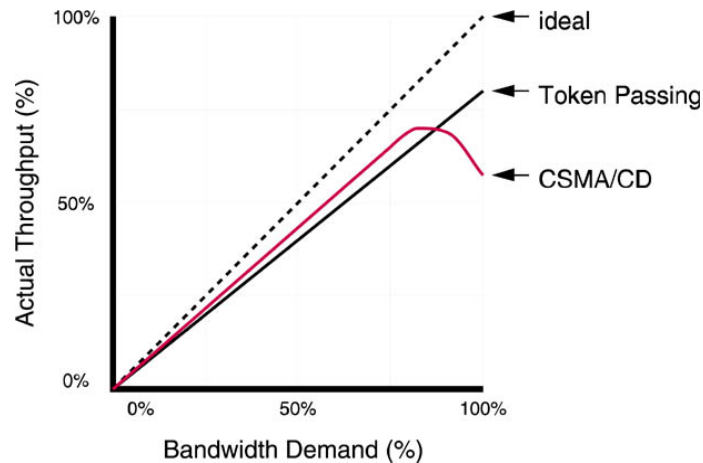
- This time it is the correct address and so number 4 reads the message (represented by the yellow flashing screen). It cannot, however, release a free Token on to the ring, it must first send the message back to number 1 with an acknowledgement to say that it has received the data (represented by the purple flashing screen).
- The receipt is then sent to machine 5 who checks the address, realizes that it is not its own and so forwards it on to the next machine in the ring, number 6.
- Machine 6 does the same and forwards the data to number 1, who sent the original message.
- Machine 1 recognizes the address, reads the acknowledgement from number 4 (represented by the purple flashing screen) and then releases the free Token back on to the ring ready for the next machine to use.



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CSMA/CD vs. Token Passing



- ❑ CSMA/CD becomes less efficient at high bandwidth demand.

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2. Logical Topology

- ❑ After the data message has reached the shared-media LAN, the next step is to determine how that message will be passed from workstation to workstation until the message reaches its intended destination.
- ❑ This passing technology is known as “**Logical Topology**”.
- ❑ A logical topology is how devices appear connected to the user. A physical topology is how they are actually interconnected with wires and cables.
- ❑ Logical topologies are bound to network protocols and describe how data are moved across the network.
- ❑ There are two known logical topologies:
 - i- **Sequential**
 - ii- **Broadcast**

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(i) Sequential Topology

- ❑ Also known as “ring logical topology”.
- ❑ The data is passed from one PC (or node) to another.
- ❑ Each node examines the destination address of the data packet to determine if this packet is meant for it.
- ❑ If the data was not meant to be delivered at this node, the data packet is passed along to another node in the logical ring.

(ii) Broadcast Topology

- ❑ Also known as “bus logical topology”.
- ❑ A data message is sent simultaneously to all nodes on the network.
- ❑ Each node decides individually if the data message was directed toward it. If not, the message is ignored.
- ❑ No need to pass the message to a neighboring node.

3. Physical Topology

- ❑ The clients & servers must be physically connected to each other according to some configuration & be linked by the shared media of choice.
- ❑ The physical layout configuration can have a significant impact on LAN performance & reliability.
- ❑ There are three main physical topologies:

1- Bus

2- Ring

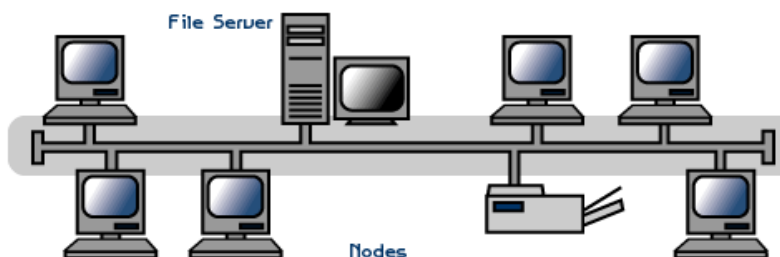
3-Star

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Bus Topology

- ❑ A linear bus topology consists of a main run of cable with a terminator at each end. All nodes (file server, workstations, and peripherals) are connected to the linear cable. The purpose of the terminator (a resistor connected to a signal wire) is to absorb signals so that they do not reflect back down the line.
- ❑ A break or loose connection anywhere along the entire bus will bring the whole network down.



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Bus Topology – Pros and Cons

□ 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.

Ring Topology

- Each PC connected via a ring topology is actually an active part of the ring, passing data packets in a sequential pattern around the ring.
- If one of the PCs dies or a network adapter card malfunctions, the “sequence” is broken, the token is lost, & the network is down!

Star Topology

- ❑ It avoids the drawbacks of both Bus & Ring topologies by employing some type of central management device. This central device may be called a **Hub**, a **wiring center**, a **concentrator**, a **MAU** (Multi-station Access Unit), a **repeater**, or a **switching hub**.
- ❑ By isolating each PC or node on its own leg or segment of the network, any node failure only affects that leg.
- ❑ If this central device goes down, the whole network goes down too.

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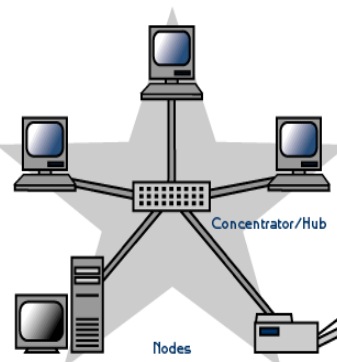
Star Topology – Pros and Cons

❑ 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.

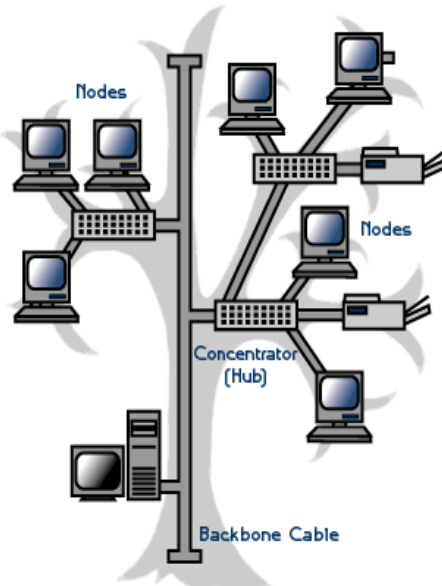


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Tree (Extended Star) Topology

- ❑ 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.
- ❑ Tree topologies allow for the expansion of an existing network.



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Tree Topology – Pros and Cons

- ❑ Advantages of a Tree Topology
 - ❖ Point-to-point wiring for individual segments.
 - ❖ Supported by several hardware and software vendors.
- ❑ 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.

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Summary - LAN Components

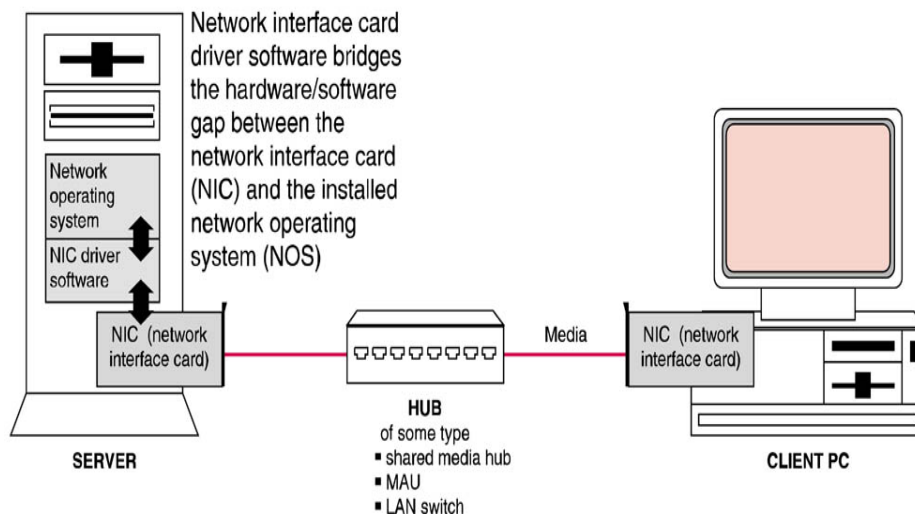
- A local area network, regardless of network architecture, requires the following components:
 - ❖ *A central wiring concentrator*
 - ❖ *Media*
 - ❖ *Network Interface Cards*
 - ❖ *Network interface card drivers.*

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LAN Technology Architecture

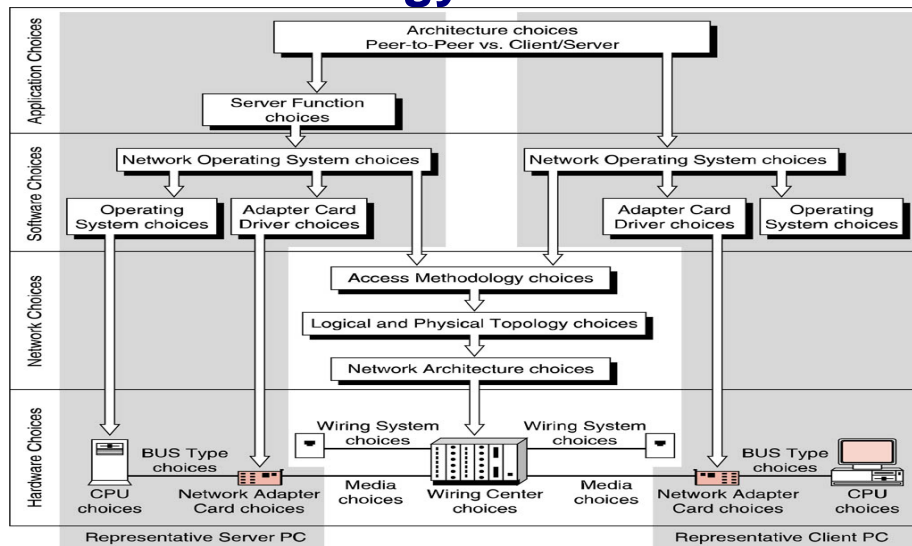
Logical Diagram



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LAN Technology Choices



Implications of LAN choices

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IEEE Standards

Data Packet (Frame) Standards:

- ❑ **IEEE 802.5** A physical layer standard that defines the token-passing access method on a ring topology.
- ❑ **IEEE 802.4** A physical layer standard that defines the token-passing access method on a bus topology.
- ❑ **IEEE 802.3** A physical layer standard that defines the CSMA/CD access method on a bus topology.
- ❑ **IEEE 802.2** A data link layer standard used with 802.3, 802.4, and 802.5

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Network Architectures: 1. Ethernet

Origins:

- ❖ Invented by Robert Metcalfe (founder of 3COM Corporation) in early 80s.
- ❖ Ethernet II developed in 1982 followed by IEEE 802.3
- ❖ Although Ethernet & IEEE 802.3 are slightly different standards. Ethernet is commonly used to refer to any IEEE 802.3 compliant network.

Functionality:

- ❖ Access methodology: CSMA/CD.
- ❖ Logical topology: broadcast.
- ❖ Physical topology: before → bus; now → star.

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Ethernet II and IEEE 802.3 Standards

Ethernet II Frame Layout

Preamble	Destination Address	Source Address	Type	Data Unit	Frame Check Sequence
8 Octets	6 Octets	6 Octets	2 Octets	46 to 1,500 bytes	4 Octets

The overall frame length varies from 64 to 1,518 Octets

IEEE 802.3 Frame Layout

Preamble	Start Frame Delimiter	Destination Address	Source Address	Length	Logical Link Control IEEE 802.2 Data	Frame Check Sequence
7 Octets	1 Octet	2 or 6 Octets	2 or 6 Octets	2 Octets	46 to 1,500 bytes	4 Octets

The overall frame length varies from 64 to 1,518 Octets

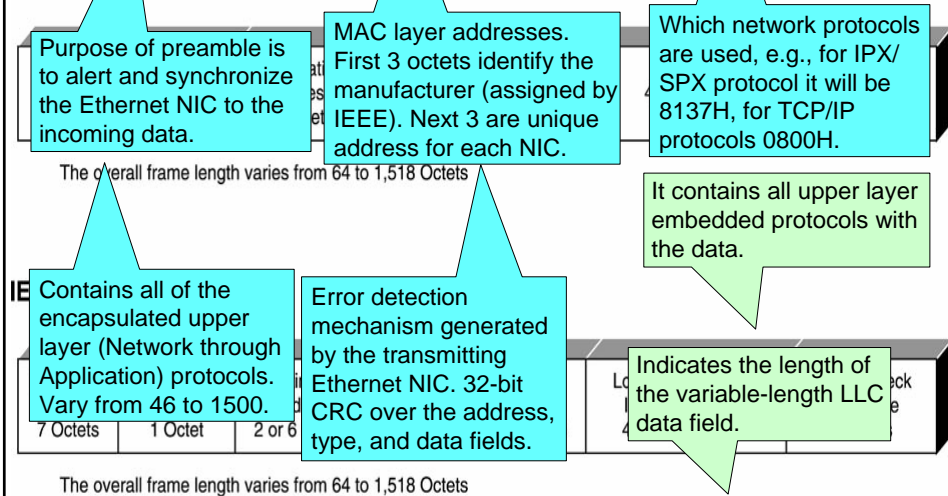
NOTE: 1 Octet = 8 bits

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Ethernet II and IEEE 802.3 Standards

Ethernet II Frame Layout

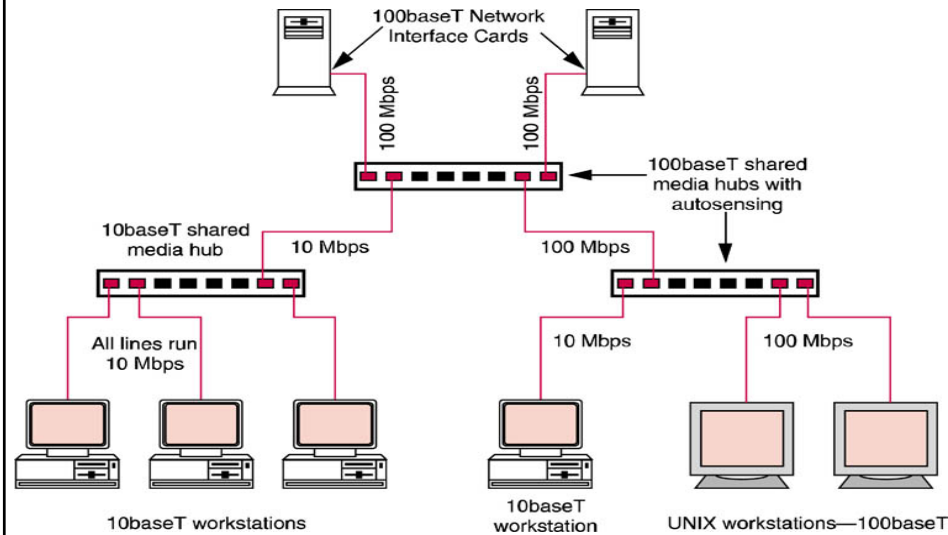


NOTE: 1 Octet = 8 bits

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LAN Architecture



Typical Fast Ethernet Implementation

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100BaseT - Technology

- ❑ Most of the 100BaseT NICs are called 10/100 NICs which means that they are able to support either 10BaseT or 100BaseT but not simultaneously.
- ❑ 10BaseT & 100BaseT networks can only interoperate with the help of internetworking devices such as 10/100 bridges & routers.
- ❑ Some Ethernet switches can support 100BaseT connection & can auto-sense, or distinguish between 10BaseT & 100BaseT traffic.

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Gigabit Ethernet

- ❑ From the family of Fast Ethernet, IEEE 802.3z standard, known as (1000BaseX).
 - ❖ **1000BaseSX**: Uses **short wavelength** (850nm) laser multimode fiber optic, horizontal floor planning.
 - ❖ **1000BaseLX**: Uses **long wavelength** (1300nm) laser single mode fiber optic, high speed backbone
 - ❖ **1000BaseCX**: Copper Wire (Dead) by 1000BaseTX
 - ❖ **1000BaseTX**: Four pairs of Cat 5 UTP, max. 100m.
- ❑ The final standard retains Ethernet's CSMA/CD access methodology.
- ❑ Same 100m cable length, so no need for new cabling.

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Gigabit Ethernet

- Gigabit Ethernet combined Speed with Maximum Transmission distance by using single mode fibers that can run up to 5Km. This reflects on its applications:
 - ❖ Resolving Server bandwidth constraints
 - ❖ Removing bottlenecks from backbone.
 - ❖ Both can be solved by simply adding a Gigabit capable switch and Gigabit NICs.

Beyond Gigabit Ethernet: *10 Gigabit Ethernet*

10 Gigabit Ethernet

- IEEE 802.3ae standard, 10Gbps over fiber.
 - ❖ **10GbaseSR/SW**: Uses **short wavelength** (850nm) laser multimode fiber optic, horizontal floor planning (26 to 100m).
 - ❖ **10GbaseLR/LW**: Uses **long wavelength** (1310nm) laser single mode fiber optic, metro area backbone (Up to 10km).
 - ❖ **10GbaseER/EW**: Uses **extra long wavelength** (1550nm) laser single mode fiber optic, long haul carrier backbone applications (Up to 40km).
 - ❖ **10GbaseLX4**: Uses **wave division multiplexed** (1310nm) laser multimode (MMF) or single mode fiber (SMF) optic media (Up to 300m MMF & 10km SMF).
- The difference between xR's & xW's is their use. The xR's are used with dedicated fiber like in MAN, while XW's are used for WAN.

10 Gigabit Ethernet Applications

- ❑ Data Centers, backbones, campus networks, MANs, WANs.
- ❑ Web hosting and application hosting sites like high quality video.
- ❑ Storage area networks (SANs). Used to connect high-performance storage devices and RAID (Redundant Arrays of Independence/ Inexpensive Disks) subsystems to computers.

Token Ring (IEEE 802.5)

- ❑ IBM was the driving force behind the standardization and adoption of token ring.
- ❑ **Access methodology:** Token passing
- ❑ **Logical Topology:** Sequential
- ❑ **Physical Topology:** Star
- ❑ New installations are uncommon

Wireless LANs

- ❑ IEEE 802.11 standard.
- ❑ CSMA/CD at MAC layer.
- ❑ 802.11 frames are similar to Ethernet frames.

Wireless LANs – 802.11b

- ❑ 11 Mbps theoretical, 4 Mbps practical.
- ❑ 2.4 Ghz band – subject to interference from common electronic equipment.
- ❑ Shared access – sensitive to number of simultaneous users.
- ❑ Commonly available, inexpensive.
- ❑ Range is measured in 100's of feet, lower indoors.

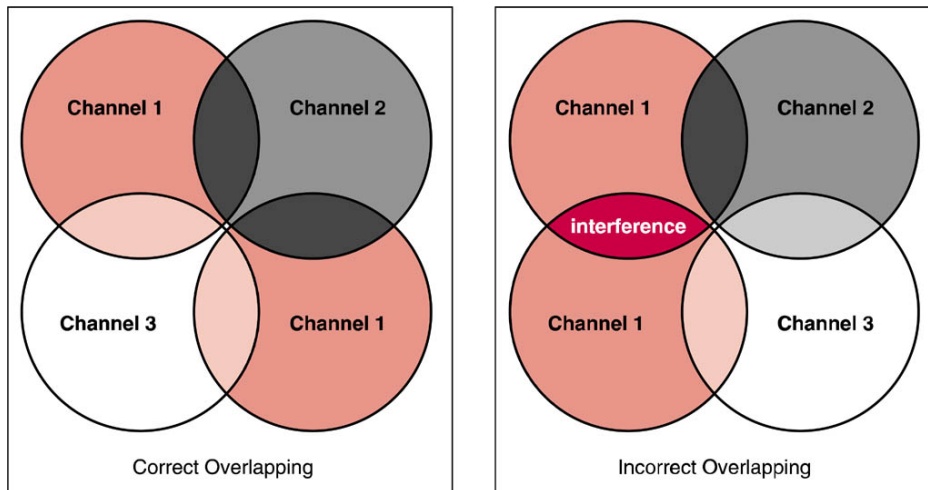
Wireless LANs – 802.11g

- ❑ Interoperates with, similar to 802.11b
- ❑ 54 Mbps theoretical
- ❑ Same band
- ❑ Similar range
- ❑ Also very common, inexpensive

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Wireless LANs

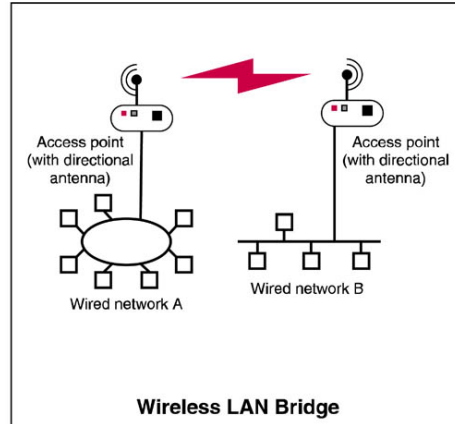
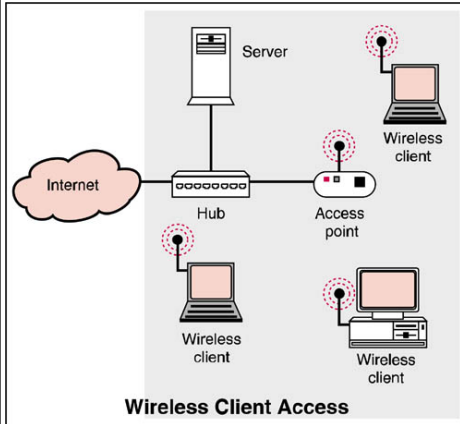


- ❑ Care must be taken in wireless LAN designs

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Wireless LANs

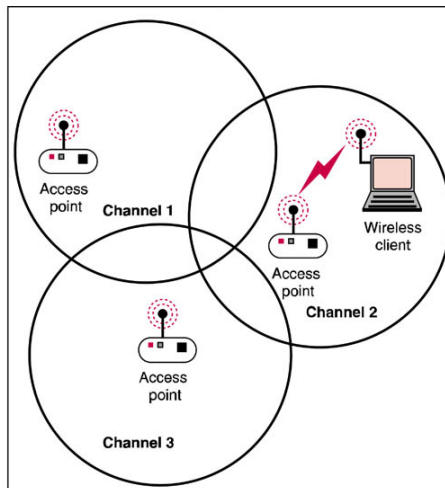
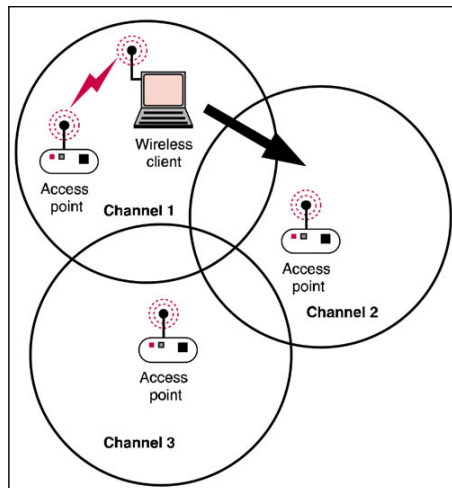


- Wireless access points can provide for client access or provide a bridge.

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Wireless LANs



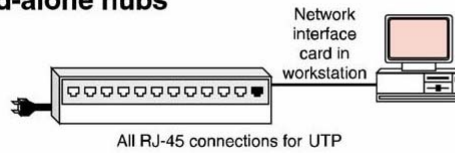
- A wireless client will access the stronger channel.

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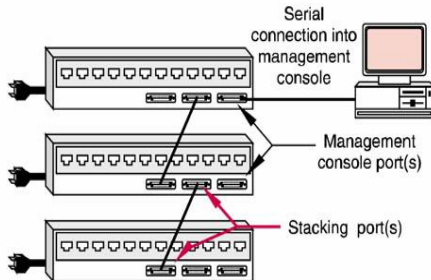
LAN Interconnection Hardware

Stand-alone hubs



- Fixed number of ports
- Single network architecture
- Hubs are cascadable
- Single media type

Stackable hubs



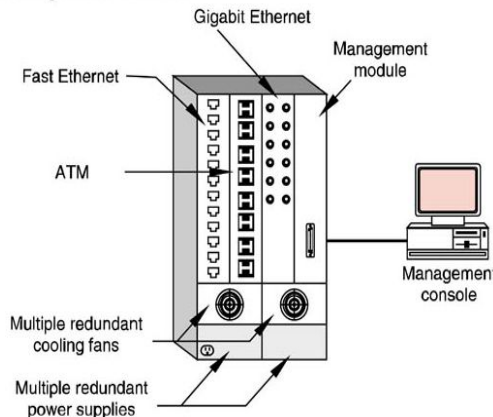
- Each hub has a fixed number of ports
- Hubs are stackable
- Single network architecture and media
- Provides management software and link to network management console
- Logically one large hub/switch

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LAN Interconnection Hardware

Enterprise hubs



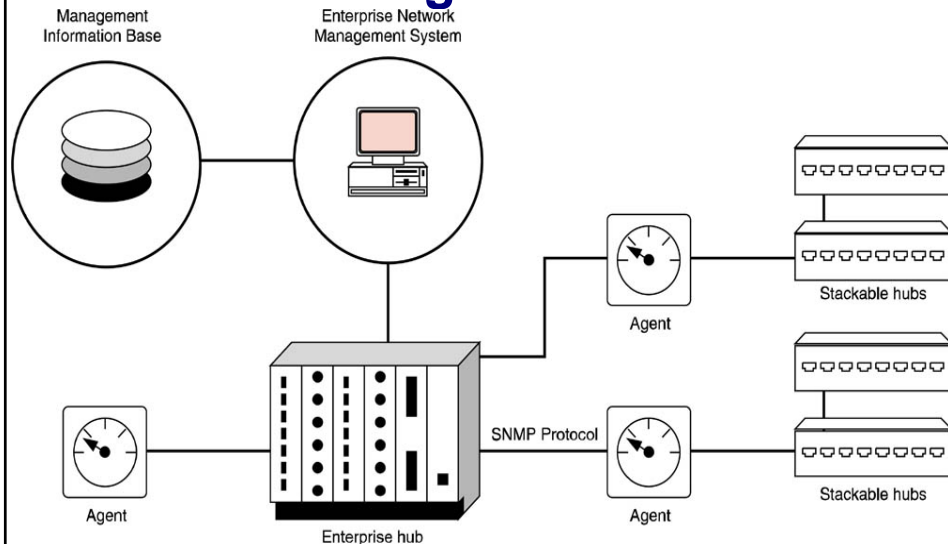
- Modular chassis-based design
- Supports multiple network architectures and media types
- Integrated management module
- May include internetworking or WAN modules

□ Enterprise hubs have modular design.

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Network Management



- SNMP is used to manage network devices

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SNMP- Simple Network Management Protocol

- SNMP is a set of rules that allows a computer to get statistics from another computer across the network.
- Computers keep track of various statistics that measure what they're doing. E.g., routers can keep track of the number of bytes, packets, and errors that were transmitted and received on each port. Web servers might keep a track of the number of hits they have received.
- Other kinds of equipment has configuration information that's available through SNMP.
- Each of these pieces of information is kept in a database described by a **Management Information Base (MIB)**.

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SNMP- Simple Network Management Protocol

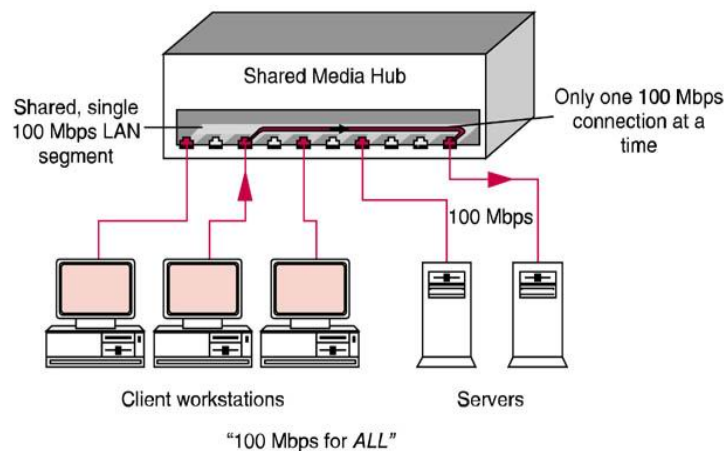
- ❑ SNMP works by sending messages, called **protocol data units (PDUs)**, to different parts of a network.
- ❑ SNMP-compliant devices, called **agents**, store data about themselves in MIBs and return this data to the SNMP requesters.
- ❑ **RMON (Remote MONitoring)** protocol that allows network information to be gathered at a single workstation.
- ❑ For RMON to work, network devices (e.g., hubs and switches) must be designed to support it.

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LAN Interconnection Hardware

Shared Media LAN Architecture



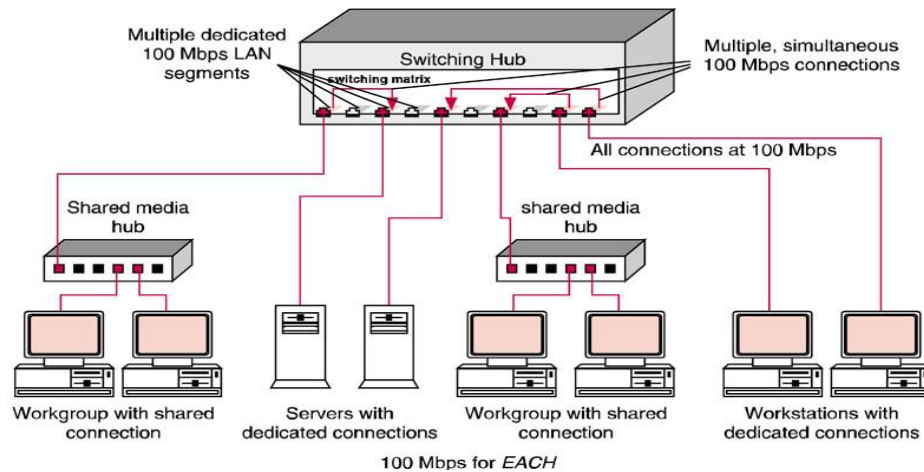
- ❑ Fixed bandwidth shared by all stations.

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LAN Interconnection Hardware

Switch-Based LAN Architecture



- ❑ Multiple, simultaneous connections at the same rate.

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Switching

- ❑ Switching is a datalink layer process, making forwarding decisions based on the contents of layer two frame addresses.
- ❑ Switches are transparent devices, receiving every frame broadcast on a port.

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Switching

- ❑ A switch checks the source address of each frame it receives and adds that source address to the **local address table** (LAT) for the port.
- ❑ The switch is learning, without having to be manually reconfigured, about new workstations that might have been added to the network.

Store and Forward Switching

- ❑ The entire frame is read into switch memory.
- ❑ The contents of frame check sequence is read and compared with the locally calculated.
- ❑ If it matches then the switch consults the address lookup table, establishes the point to point connection and forwards the frame.
- ❑ Bad frames are not forwarded.

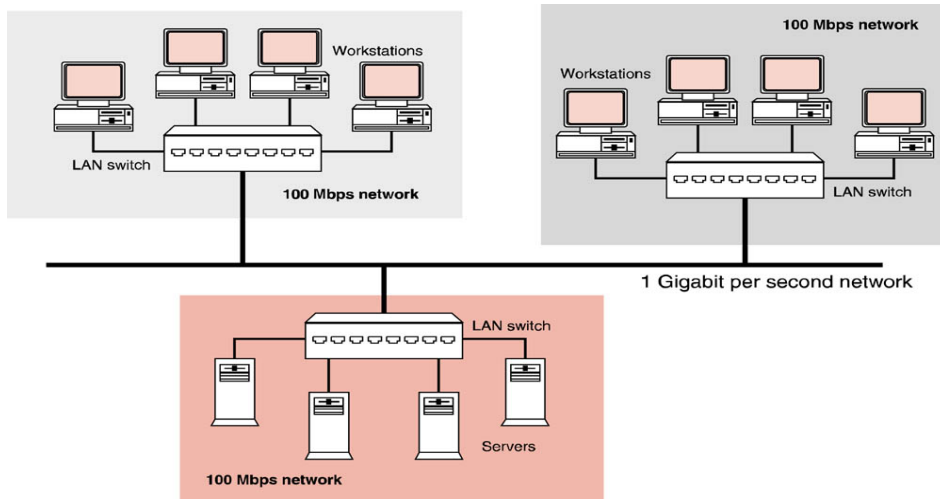
Cut-through Switching

- ❑ Only the address information in the header is read before beginning processing.
- ❑ After reading the destination address, the switch consults an address lookup table to determine which port on the switch this frame should be forwarded to.
- ❑ Then point-to-point connection is created and frame is immediately forwarded.
- ❑ Very fast
- ❑ Bad frames are forwarded.

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Switching



- ❑ Switches can transparently connect nodes or LAN segments running at different speeds.

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