CS343: Data Communication

LAN Overview

by

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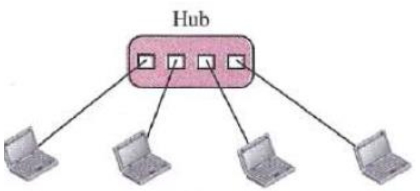
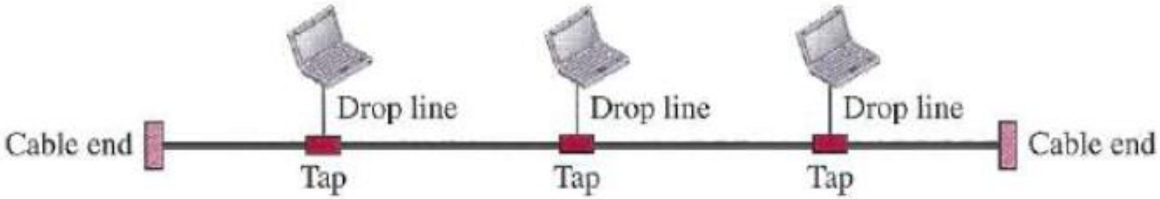
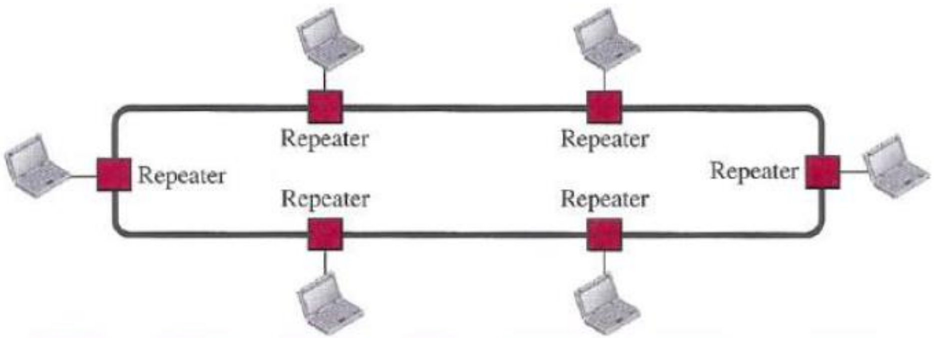
Communication Network Topology

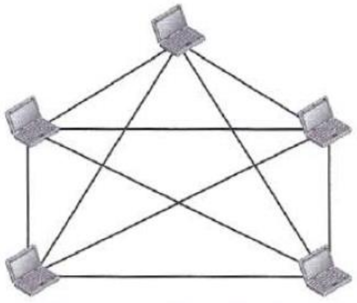
- Topology refers to the way in which the endpoints, or stations, attached to the network are interconnected.

- Common topologies for LANs
  - bus, tree/star, ring, and mesh



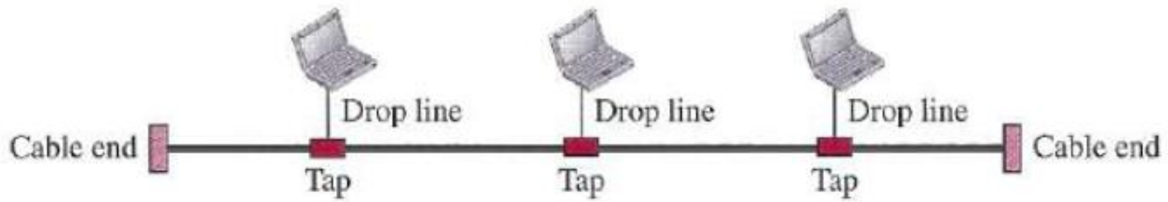






- bus topology shares many characteristics with Wireless LANs.

Bus Topology



- All stations attach, through appropriate hardware interfacing known as a tap, directly to a linear transmission medium, or bus.
- Full-duplex operation between the station and the tap allows data to be transmitted onto the bus and received from the bus.
- A transmission from any station propagates in both directions and can be received by all other stations
- Two problems:
  - needs to be some way of indicating for whom the transmission is intended
  - a mechanism is needed to regulate transmission to avoid signal overlap

Cont…

- To solve these problems, stations transmit data in small blocks, known as frames.

- Frame header contains control information - solves the first one.
- Each station on the bus is assigned a unique address, or identifier
- the destination address for a frame is included in its header.

- stations send frames in some cooperative fashion - solves the second
- It involves putting additional control information into frame header.

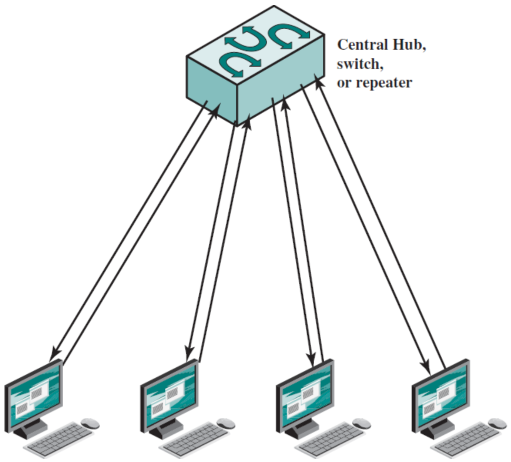
- Note: No special action needs to be taken to remove frames from the bus. When a signal reaches the end of the bus, it is absorbed by the terminator.

Star Topology

- each station is directly connected to a common central node e.g. hub

- Connected via two P2P links – uplink & downlink

- Two type of operations:
  - central node operates in a broadcast fashion
    - although the arrangement is physically a star, it is logically a bus: A transmission from any station is received by all other stations, and only one station at a time may successfully transmit
  - central node acts as a frame-switching device
    - incoming frame is buffered in the node and then retransmitted on an outgoing link to the destination station



LAN Protocol Architecture

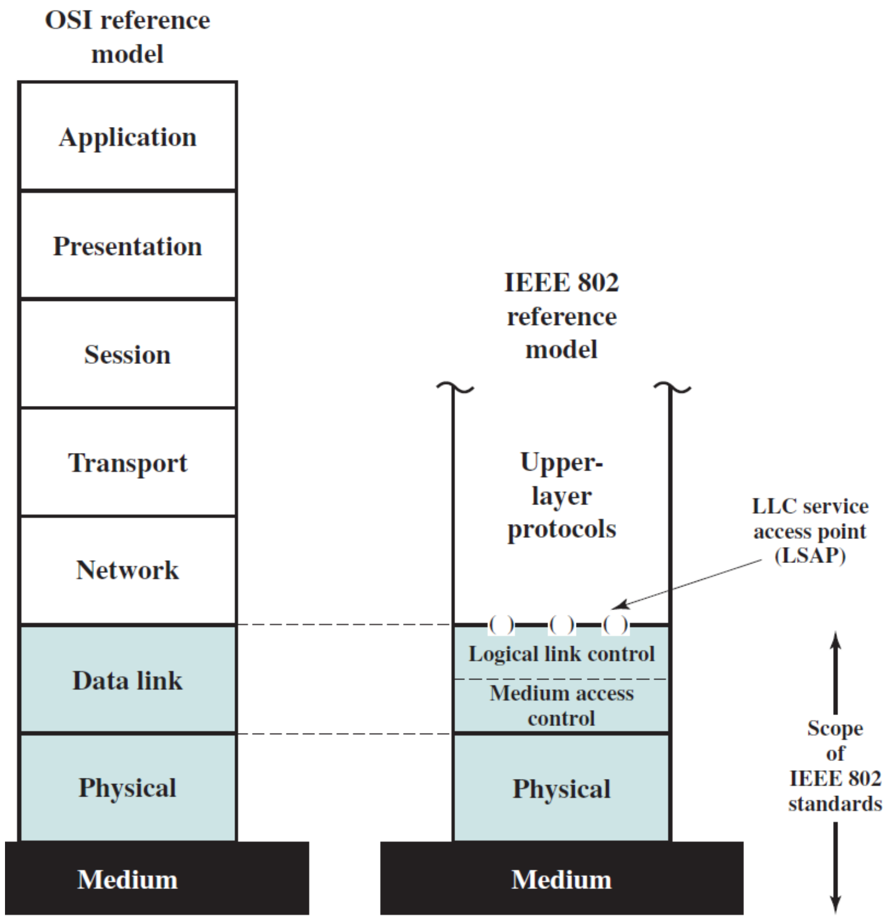
LAN Protocol Architecture

- Standardized protocol architecture for LANs, encompasses
  - Physical layer
  - Medium access control (MAC) sub-layer
  - Logical link control (LLC) sub-layer

- IEEE 802 Reference Model
  - Defines protocols specifically for LAN, MAN
  - Higher Layer protocols (layer 3 and above) in OSI Reference Model are independent of network architecture and thus applicable to LANs, MANs, WANs

- Physical layer services
  - Encoding/decoding signals
  - Synchronization using Preamble
  - Bit Transmission/Reception

  - 802 Model also includes:
    - Topology
    - Transmission Medium



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- Above the PHY layer
  - Service related to LAN users
    - On transmission:
      - Assemble data into Frame
      - Addressing
      - Error detection coding
    - On reception:
      - Disassemble Frame
      - Perform address recognition
      - Perform error detection
    - Govern access to the transmission medium (multiple access rules)

Functions of Medium Access Control (MAC) sub-layer

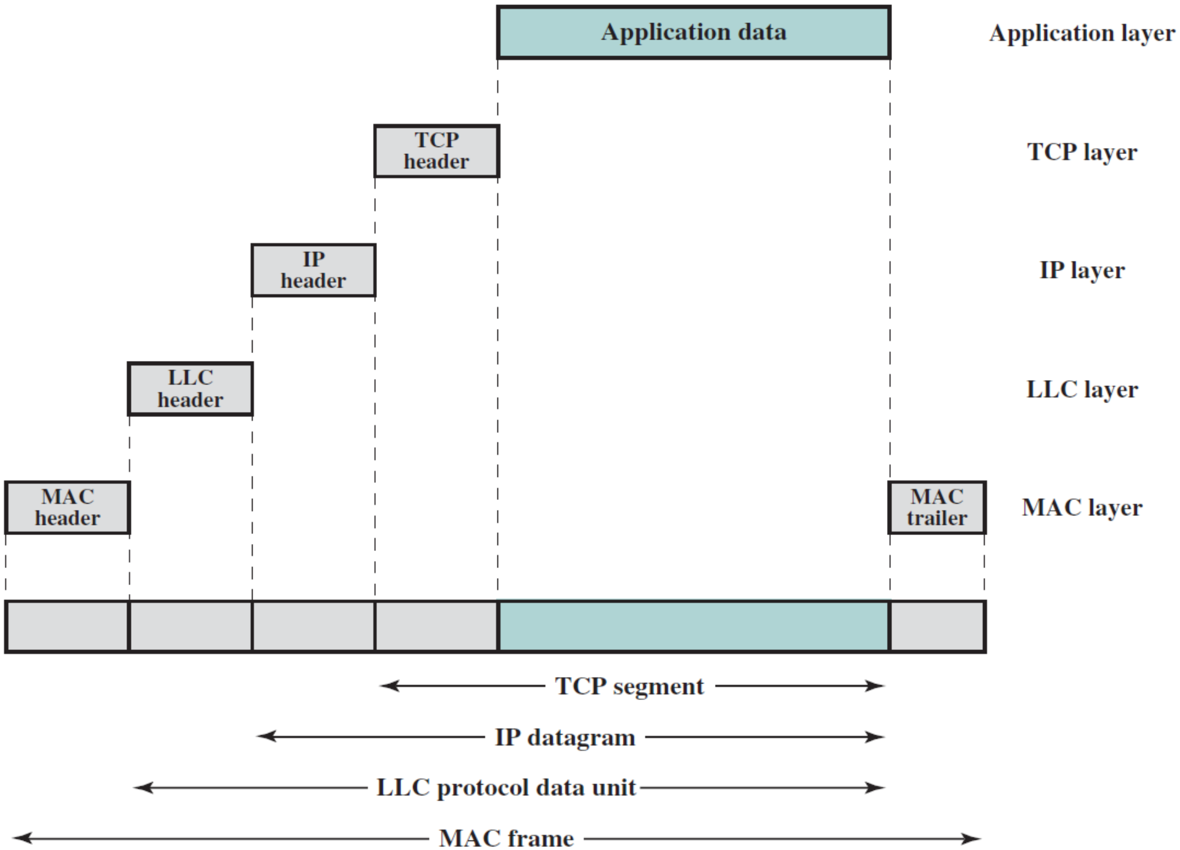
- Provide an interface to higher layer and perform flow and error control

Functions of Logical Link Control (LLC) sub-layer

Relationship of Levels

- LLC is concerned with the transmission of a link-level protocol data unit (PDU) between two stations;
- and mechanisms for addressing stations across the medium

- MAC protocol controls access to shared transmission medium



Note:

- In most data link control (DLC) protocols (e.g. HDLC), the DLC entity is responsible for detecting errors using the CRC and recovering from those errors by retransmitting damaged frames.

- In the LAN protocol architecture, these two functions are split between the MAC and LLC layers.
- The MAC layer is responsible for first one, and the LLC layer performs the second one.

LLC Services

- **Three services** are provided for attached devices using LLC:
  - Unacknowledged connection-less service
    - This service is a datagram-style service.
    - very simple service
    - does not involve any of the flow- and error-control mechanisms.
    - Thus, the delivery of data is not guaranteed.
  - Connection-mode service
    - A logical connection is set up between two users exchanging data,
    - Flow control and error control are provided.
    - This service is similar to that offered by HDLC.
  - Acknowledged connection-less service
    - It provides that datagrams are to be acknowledged,
    - but, no prior logical connection is set up.
- Typically, a vendor will provide these services as options that the customer can select when purchasing the equipment.

LLC's Application

- The unacknowledged connectionless service requires minimum logic
- It is useful in two contexts:
  - First, higher layers of software will provide the necessary reliability and flow-control mechanism (e.g. TCP in Internet)
  - Second, there are instances in which the overhead of connection establishment and maintenance is unjustified (e.g. Monitoring applications)

- The connection-mode service could be used in very simple devices, such as terminal controllers, that have little software operating above this level.
  - the LLC software must maintain some sort of table for each active connection, to keep track of the status of that connection.

- The acknowledged connectionless service is useful in several contexts.
  - a process control or automated factory environment where a central site may need to communicate with a large number of processors and programmable controllers
  - Another use is the handling of important and time-critical alarm or emergency control signals in a factory.

LLC Protocol

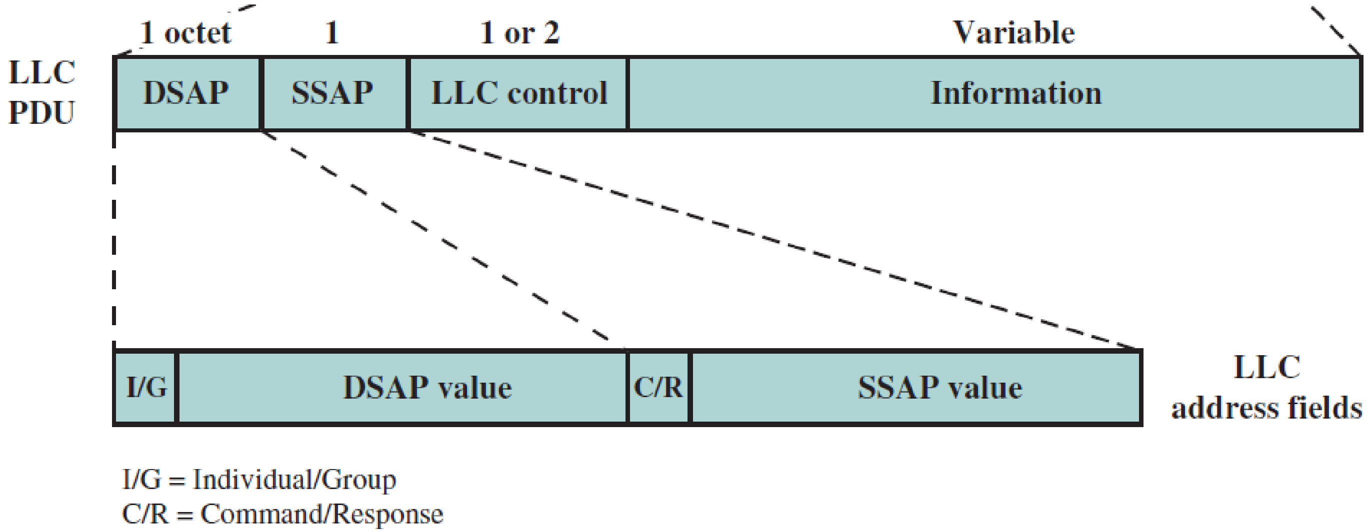


Figure 11.5 LLC PDU in a Generic MAC Frame Format

- Basic of LLC protocol is modeled from HDLC.

- Addressing in LLC involves specifying the source and destination LLC users.
- LLC user is a higher-layer protocol OR a network management function in a station.

- LLC user addresses are referred to as service access points (SAPs)
- DSAP: Destination service access points
- SSAP: Source service access points

Medium Access Control (MAC)

- All LANs and MANs consist of collections of devices that must share the network's transmission capacity.

- Key parameters of MAC:
  - Where: centralized or distributed control
  - Who & When: access control techniques
    - constrained by the topology and is a trade-off among competing factors, including cost, performance, and complexity

- Advantages of centralized scheme
  - relatively simple access logic
  - afford greater control over access for providing priorities, overrides, and guaranteed capacity
  - avoids problems of distributed coordination

- Disadvantages of centralized scheme
  - single point of failure
  - may act as a bottleneck, reducing performance

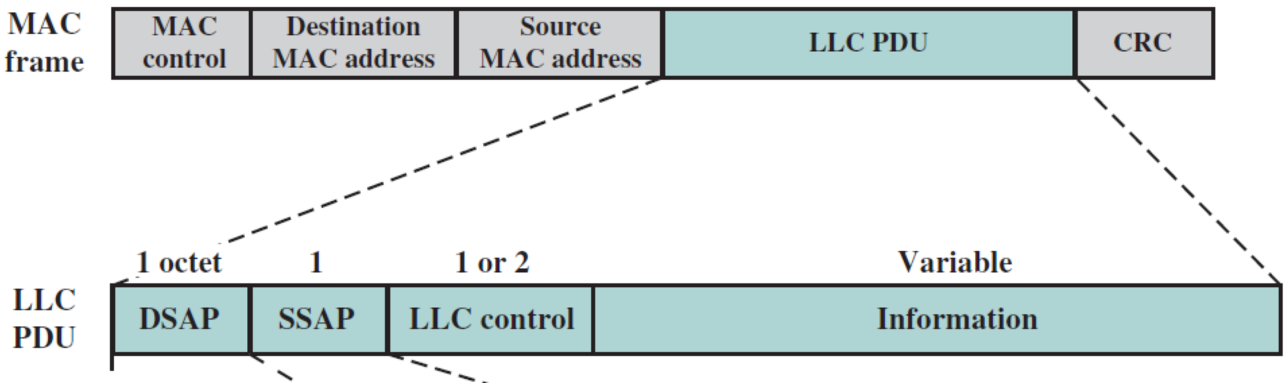
- **Access control techniques** are either synchronous or asynchronous

- Synchronous: a specific capacity is dedicated to a connection
  - Likewise TDM, FDM in switching

Cont…

- Asynchronous/dynamic: allocate capacity more or less w.r.t immediate demand
  - Round Robin / Channelization
    - each station in turn is given the opportunity to transmit
    - Control of sequence may be centralized or distributed
    - Polling is an example of a centralized round robin technique
    - When many stations have data to transmit over an extended period of time, it is very efficient
  - Reservation
    - time on the medium is divided into slots
    - A station wishing to transmit reserves future slots
    - For stream traffic (voice commun., bulk file transfer, telemetry/monitoring), it is well suited
    - reservations may be made in a centralized or distributed fashion
  - Contention / Random-access
    - appropriate for bursty traffic (short, sporadic transmissions)
    - no control is exercised to determine whose turn it is
    - all stations contend for time in a way that rough and tumble
    - These techniques are of necessity distributed in nature
    - they are simple to implement and, under light-to-moderate load, efficient
    - performance tends to collapse under heavy load

MAC Frame Format



- **MAC Control**: it contains any protocol control information needed for the functioning of the MAC protocol.
- **Destination MAC Address**: The destination physical attachment point on the LAN for this frame.
- **Source MAC Address**: The source physical attachment point on the LAN for this frame.
- **LLC PDU**: The LLC data from the next higher layer.
- **CRC**: The Cyclic Redundancy Check field (also known as the Frame Check Sequence, FCS, field). This is an error-detecting code.

We will discuss more about MAC Protocol during the discussion of Wireless LAN.

Networking Devices

Bridge

- to expand beyond the confines of a single LAN,
- to provide interconnection to other LANs and WANs
  - Two general approaches for this: using bridges and routers

- bridge is used between LANs that use identical protocols for the physical and link layers

- More sophisticated bridges are capable of mapping from one MAC format to another (e.g., to interconnect an Ethernet and a token ring LAN).

- Why not simply have one large LAN?

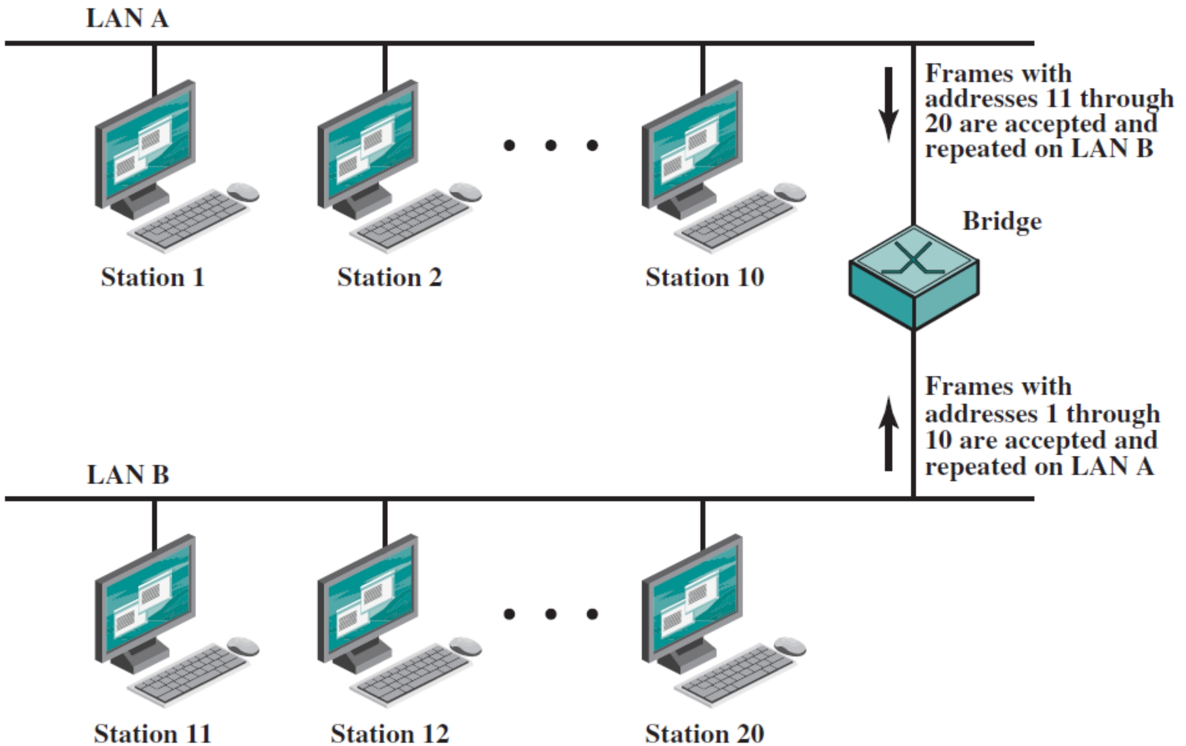
  - Reliability: a fault on the network may disable communication for all devices. By using bridges, the network can be partitioned into self-contained units.

  - Performance: performance on a LAN declines with an increase in the number of devices or the length of the wire.

  - Security: to support different types of traffic (e.g., accounting, personnel, strategic planning) that have different security needs

  - Geography: two separate LANs are needed to support devices clustered in two geographically distant locations.

Functions of a Bridge



- The bridge makes no modification to the content or format of the frames it receives,
- It doesn't encapsulate the frames with an additional header

- The bridge should contain enough buffer space to meet peak demands
- The bridge must contain addressing and routing intelligence
- A bridge may connect more than two LANs.

Bridge Protocol Architecture

- IEEE 802.1D defines the protocol architecture for MAC bridge
- The bridge can function at the MAC level
- The bridge does not strip off the MAC fields; its function is to relay the MAC frame intact to the destination LAN.
- The concept of MAC relay bridge is not limited to the use of a single bridge to connect two nearby LANs.

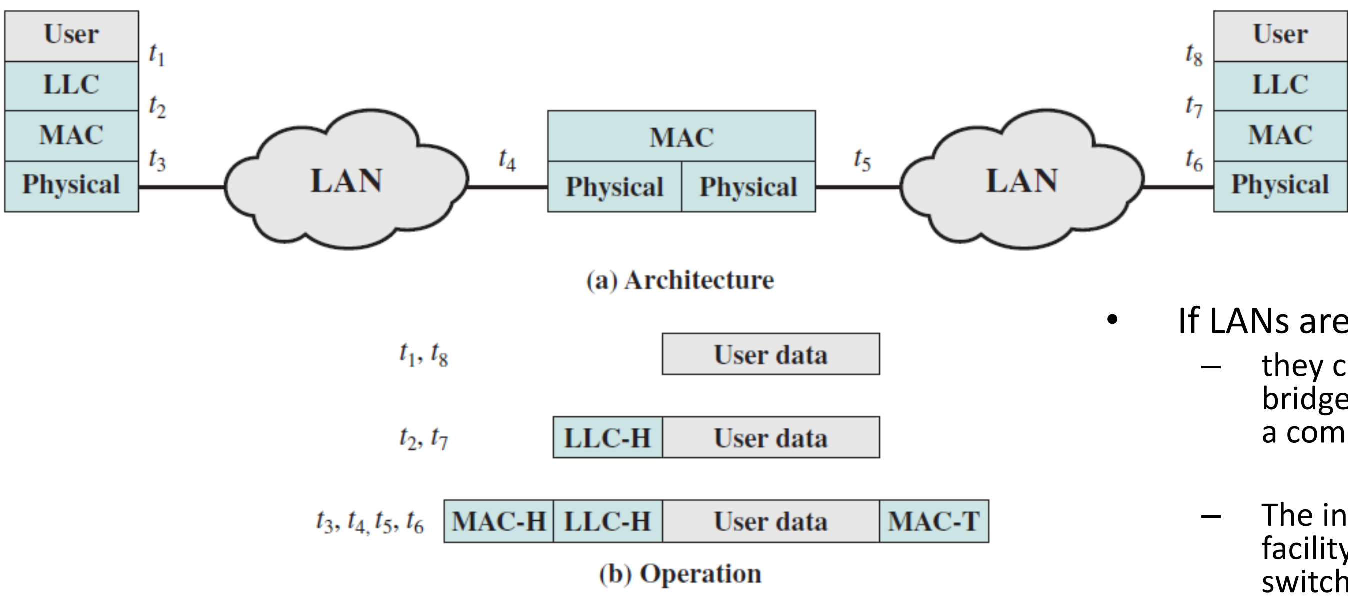


Figure 11.7 Connection of Two LANs by a Bridge

- If LANs are some distance apart, then
  - they can be connected by two bridges that are in turn connected by a communications facility.
  - The intervening communications facility can be a network (e.g. packet-switched network)

Frame Routing in Bridge

- Important to provide alternate paths between LANs via bridges
  - for load balancing
  - for reconfiguration in response to failure
- So, bridge must be equipped with routing capability (note: not like Layer 3 routing)
- When a bridge receives a frame
  - it must decide whether or not to forward the frame and,
  - if so, on which LAN the frame should be transmitted.
- Routing decision always not simple
- Routing Strategy:
  - Fixed Routing (most commonly used)
  - Spanning Tree (used in IEEE 802.1)
  - Source Routing (used in IEEE 802.5)

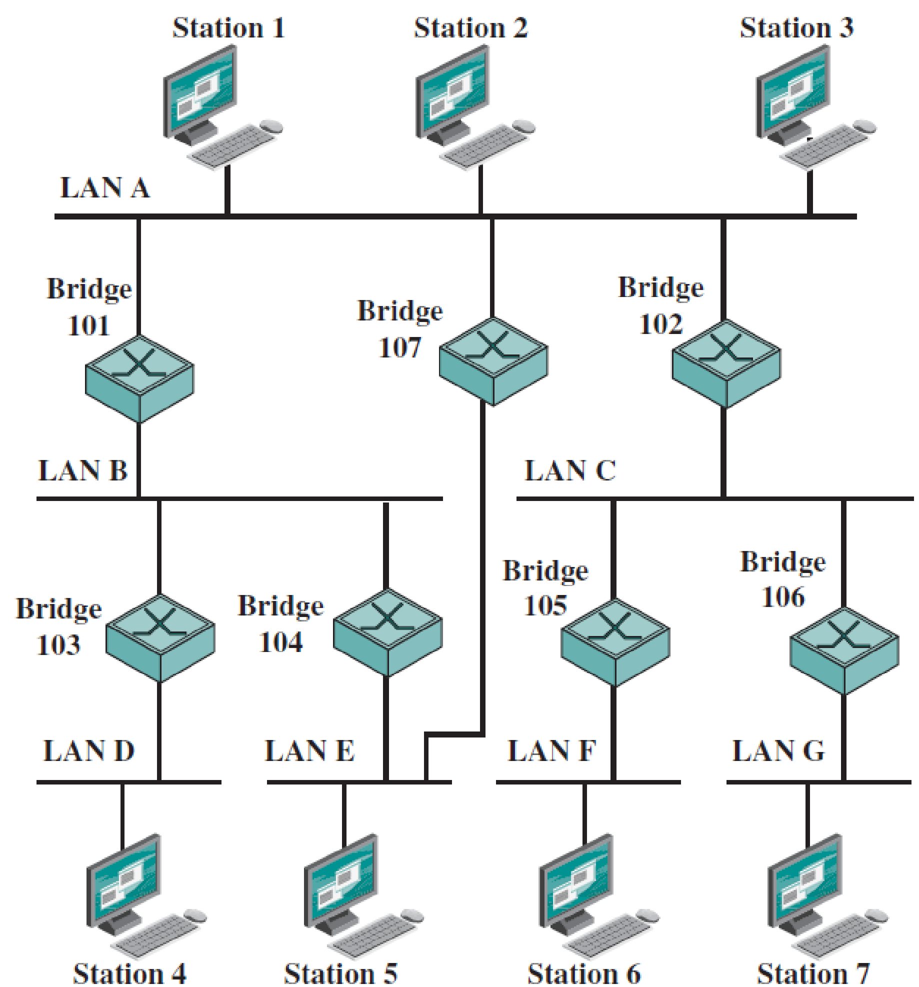


Figure 11.8 Configuration of Bridges and LANs, with Alternate Routes

Fixed Routing

- suitable for small internets and for internets that are relatively stable.
- widely used in commercially available products.

- A route is selected for each source–destination pair of LANs
- If alternate routes are available, then the route with least number of hops is selected.
- The routes are fixed, or at least only change when there is a change in the topology

- A central routing matrix is created, to be stored perhaps at a network control centre.
- Network manager manually load the data into the routing tables in fixed routing
- In a complex internet, it is an overhead to maintain the routing table.

Hub

- The hub is the active central element of the star topology layout.
- Each station is connected to the hub by two lines (transmit and receive).
- The hub acts as a repeater

- Ordinarily, the line consists of two unshielded twisted pairs. the length of a line is limited to about 100 m.
- An optical fiber link may be used. The maximum length is about 500 m.

- Note that although this scheme is physically a star, it is logically a bus

- Multiple levels of hubs can be cascaded in a hierarchical configuration

- HHUB : header hub
- IHUB: intermediate hubs

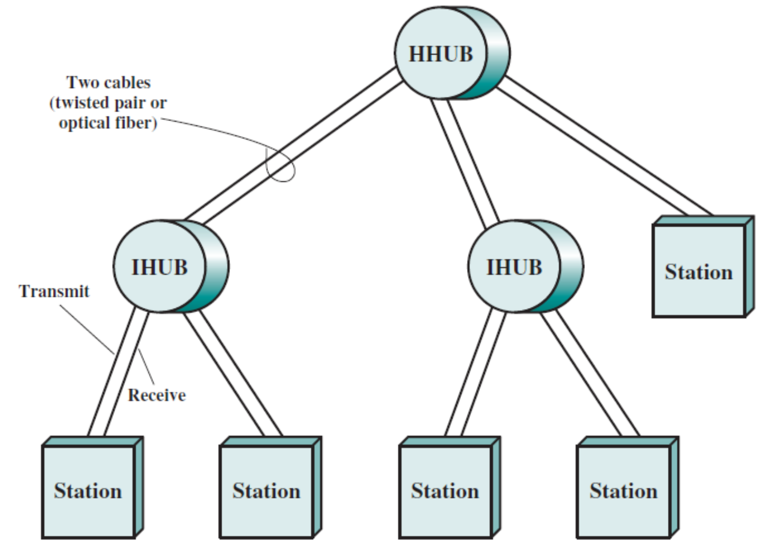


Figure 11.10 Two-Level Star Topology

Switch (up to Layer 2)

- (a) it shows a typical **bus** layout of a traditional 10-Mbps LAN
- all the stations must share the total capacity of the bus, which is 10 Mbps

- (b) **hub** uses a star wiring arrangement to attach stations to the hub.
- the total capacity of the LAN is 10 Mbps.

- (c) central hub acts as a **switch**, much as a packet switch or circuit switch
- an incoming frame from a particular station is switched to the appropriate output line to be delivered to the intended destination
- At the same time, other unused lines can be used for switching other traffic
- In this example, the current throughput on the LAN is 20 Mbps!

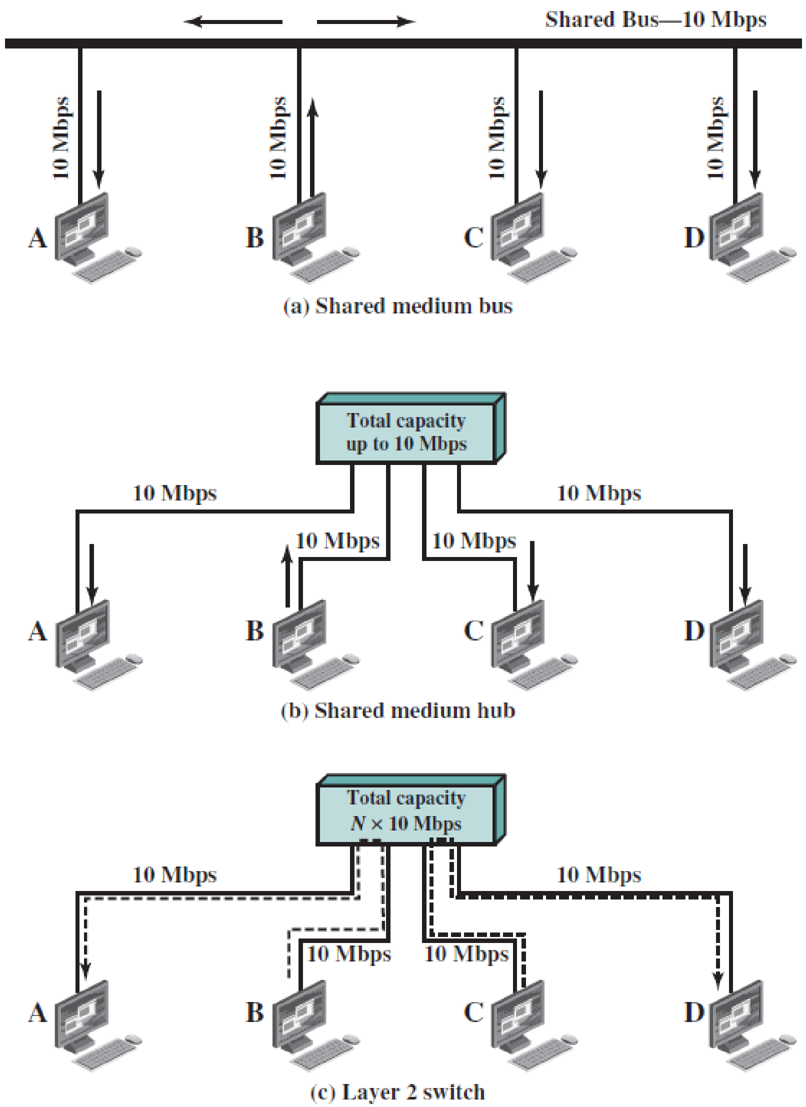
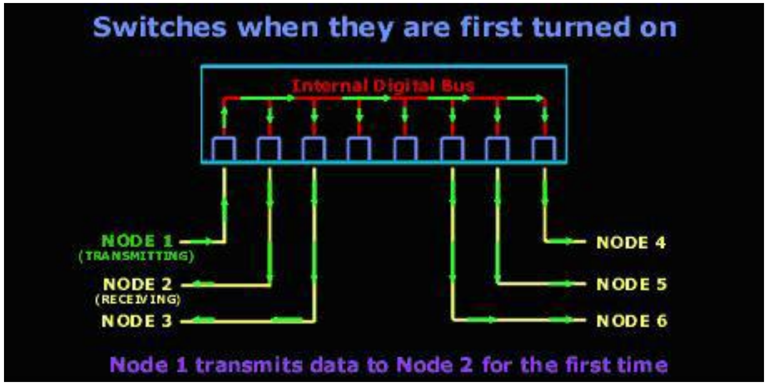
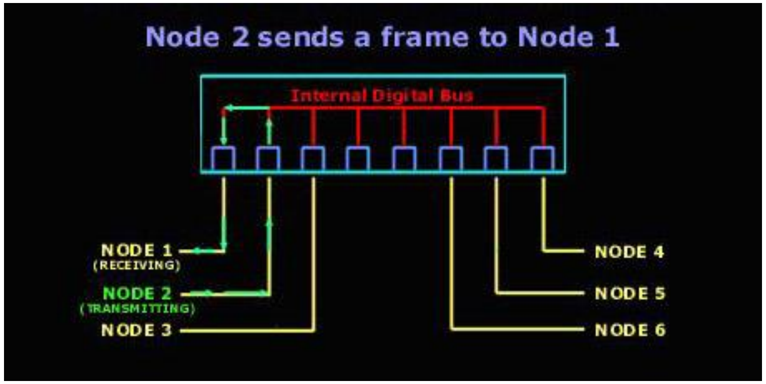


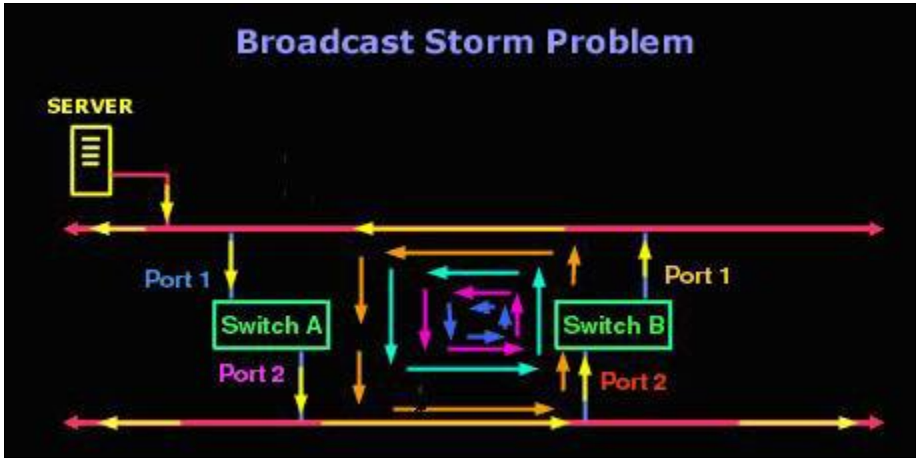
Figure 11.11 LAN Hubs and Switches

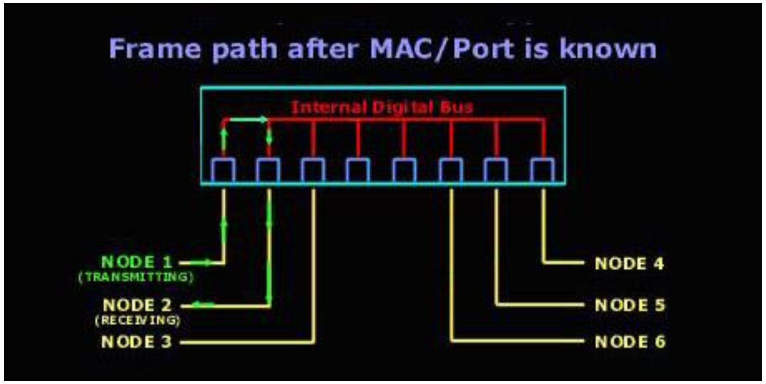
Switch Operations

- All switch go through the three stages (sometimes two stages) when powered up and during operation
  - Address Learning
  - Forward/Filter decisions
  - Loop Avoidance (Optional)









Switch v/s Bridge

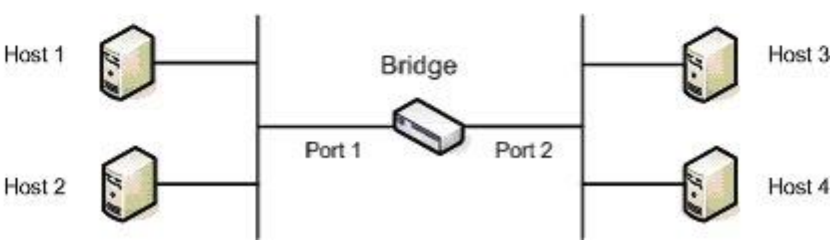
- Every port of **bridge** is connected to a shared common memory. Frame handling is done in software.
- **Switch** performs the address recognition and frame forwarding functions in hardware as it uses Application Specific Integrated Circuits (ASIC's) chip to build and maintain filter tables.

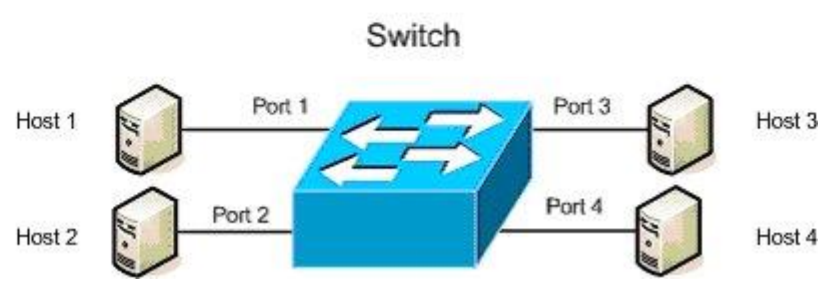
- A **bridge** can typically only analyze and forward one frame at a time.
- A **switch** has multiple parallel data paths and can handle multiple frames at a time.

- A **bridge** uses store-and-forward operation.
- A **switch** provides both, store-and-forward and cut-through operations.

- **Bridges** can only have one spanning-tree instance per bridge
- **Switches** can have many.

- **Bridges** can only have up to 16 ports
- a **switch** can have hundreds!

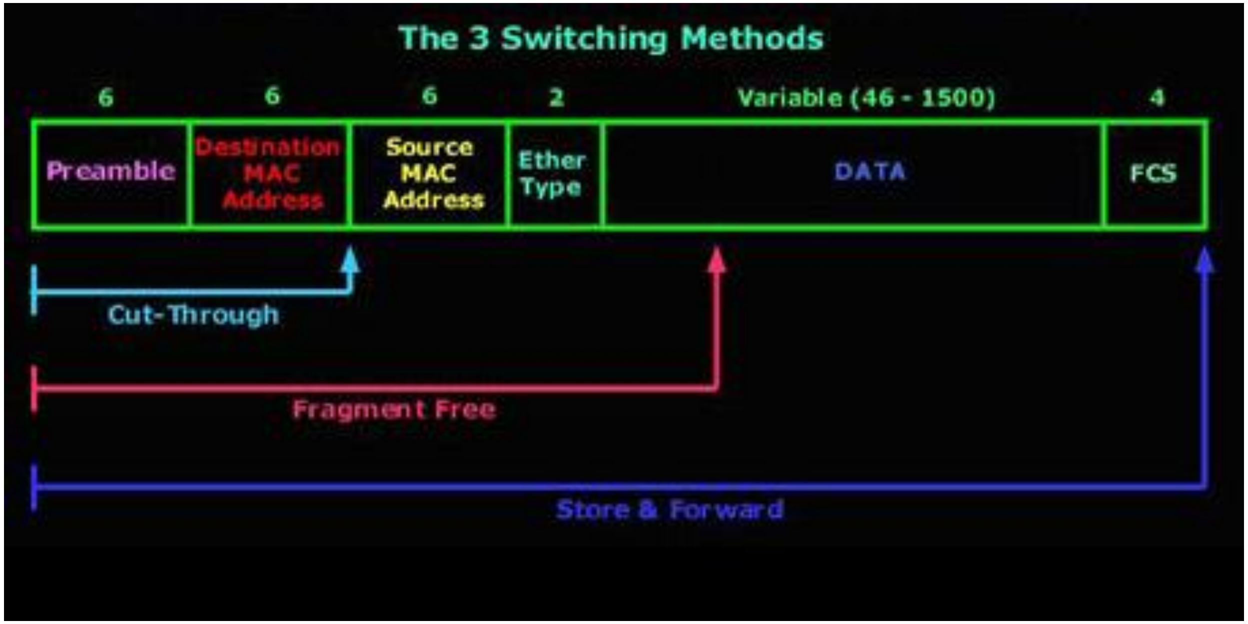




Switch Types

- **Store-and-forward switch:** The layer 2 switch accepts a frame on an input line, buffers it briefly, check error, and then routes it to the appropriate output line.

- **Cut-through (real-time) switch:** The layer 2 switch takes advantage of the fact that the destination address appears at the beginning of the MAC frame. The layer 2 switch begins repeating the incoming frame onto the appropriate output line as soon as the layer 2 switch recognizes the destination address.



- **Fragment free**: This method is a hybrid of the two other switching methods. The frame's first 64 bytes are only checked before forwarding the frame out the designated port.

Virtual LAN

Multiple Groups of LAN Devices

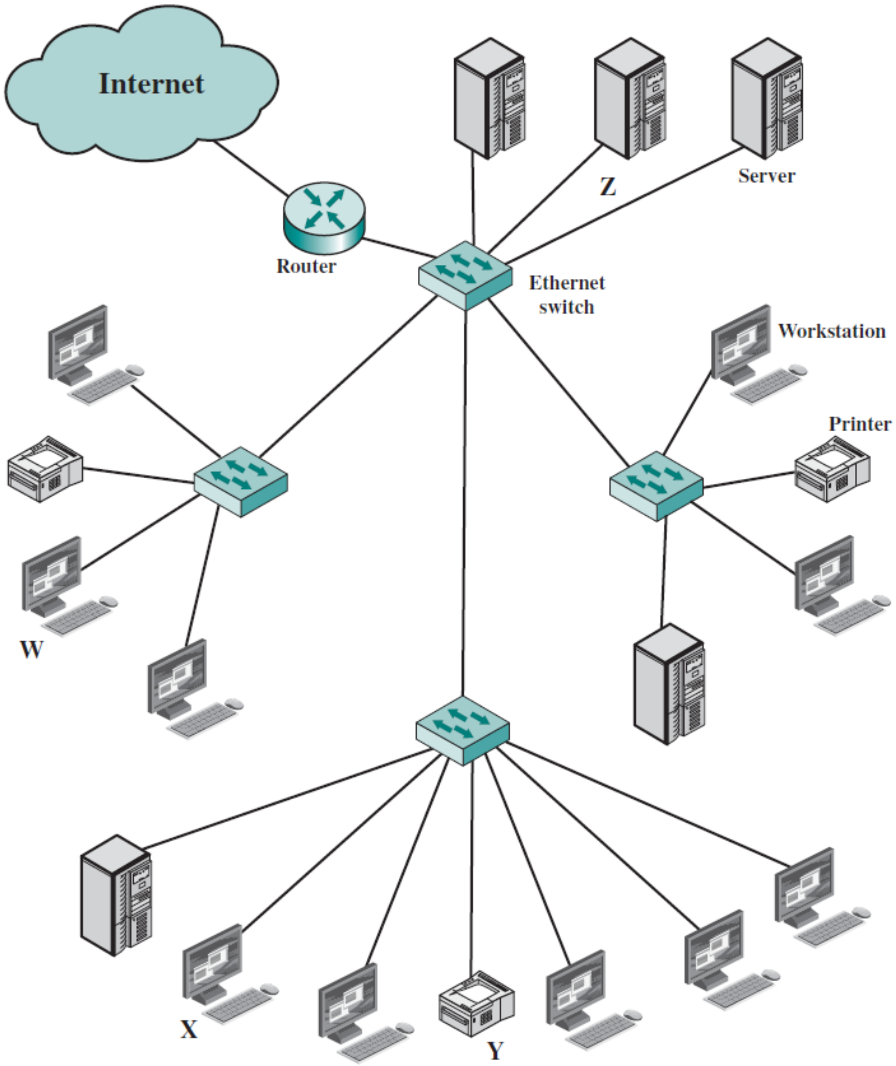


Figure 11.12 A LAN Configuration

- Let the devices on the LAN are organized into four groups, each served by a LAN switch.
- Let a transmission from workstation X.
- Suppose the destination MAC address is Z
- the local switch routes the MAC frame through appropriate switches to the intended destination.
- It follows unicast addressing
- A MAC frame may also contain a broadcast address in which case all devices on the LAN should receive a copy of the frame.
- In many situations, broadcast frame has information that is only useful to a particular department,
- then transmission and computation **capacity is wasted** on the other portions of LAN and on the other switches

How to avoid this wastage?

Partition of LAN

- Simple solution:
- physically partition the LAN into separate broadcast domains

- We now have four separate LANs connected by a router

- Drawback to this approach
  - How to put a user into two broadcast domain?
  - Complex network formation with multiple routers.

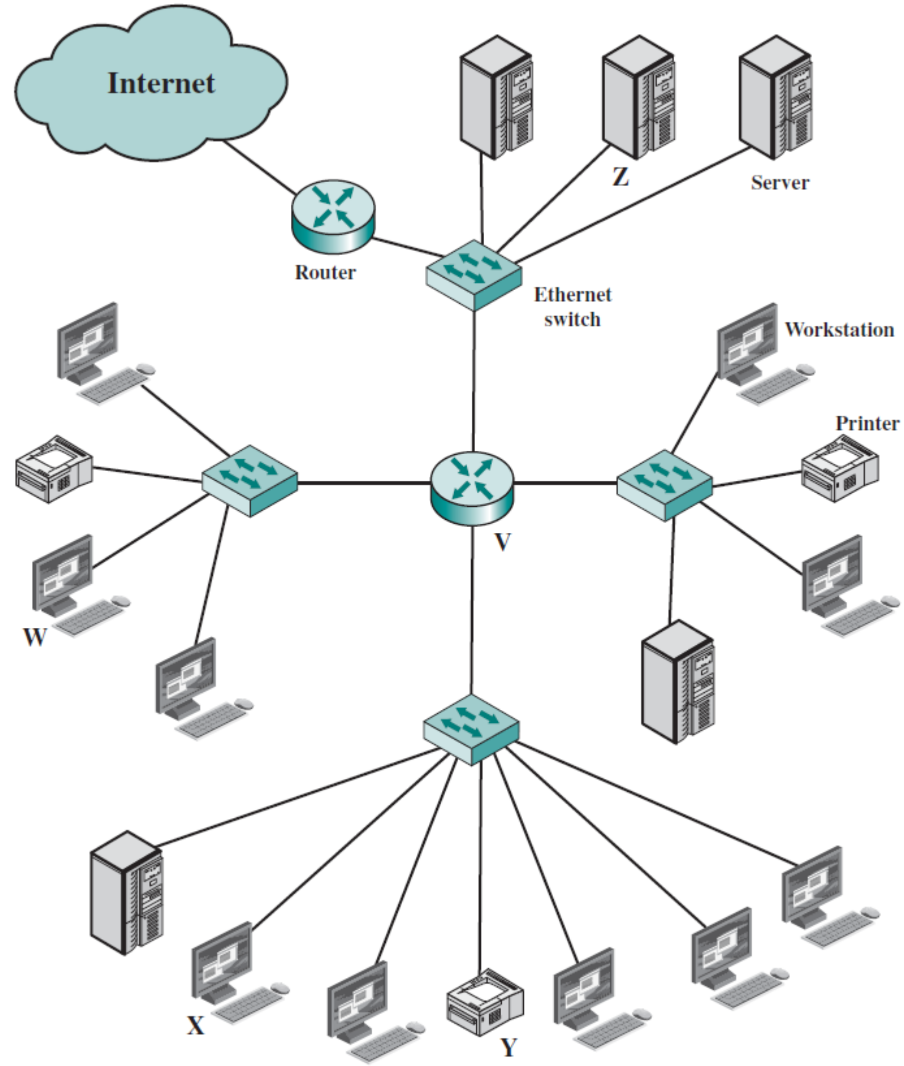


Figure 11.13 A Partitioned LAN

Virtual LAN

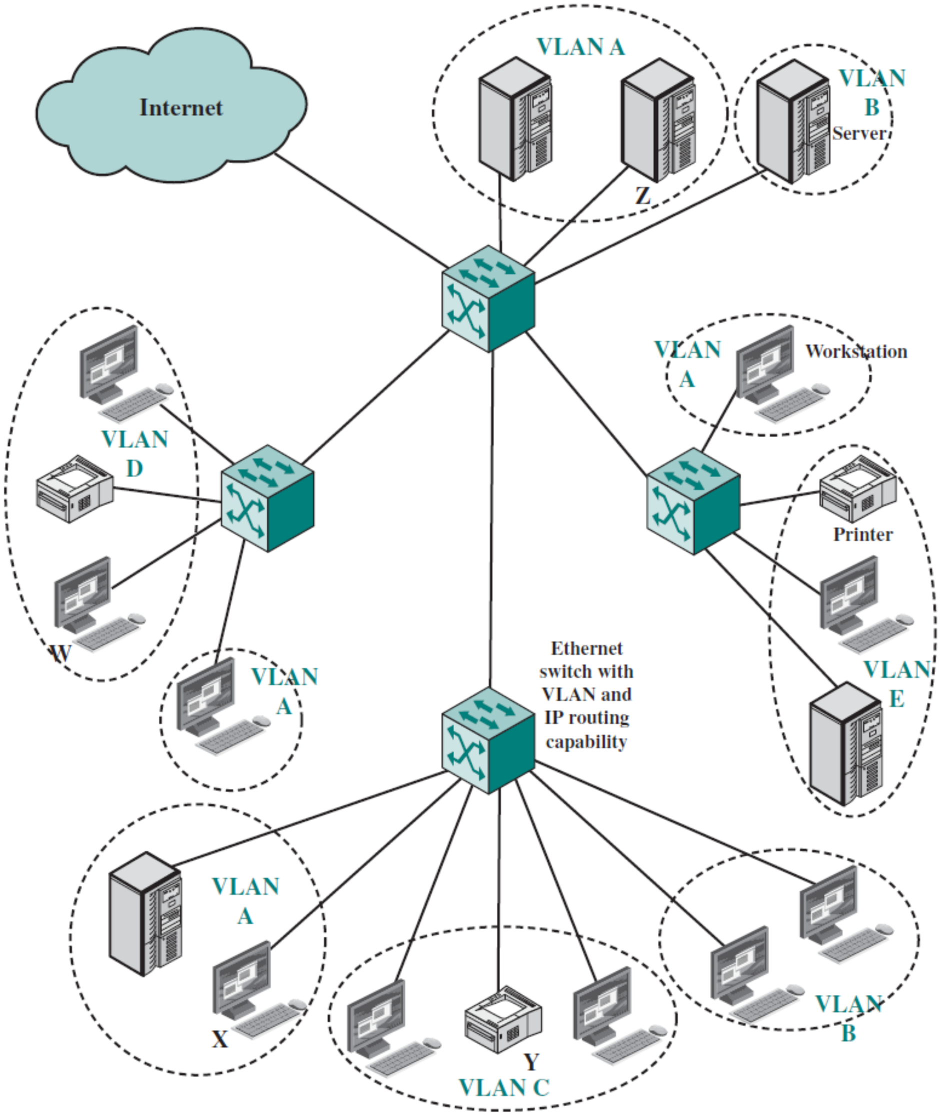


Figure 11.14 A VLAN Configuration

- More effective solution:
- creation of separate virtual LAN (VLAN) for each group.

- VLAN is a logical subgroup within a LAN
- It is created by software rather than by physically moving and separating devices

- It combines user stations and network devices into a single broadcast domain regardless of the physical LAN segment they are attached to

- The VLAN logic is implemented in LAN switches and functions at the MAC layer.

Cont…

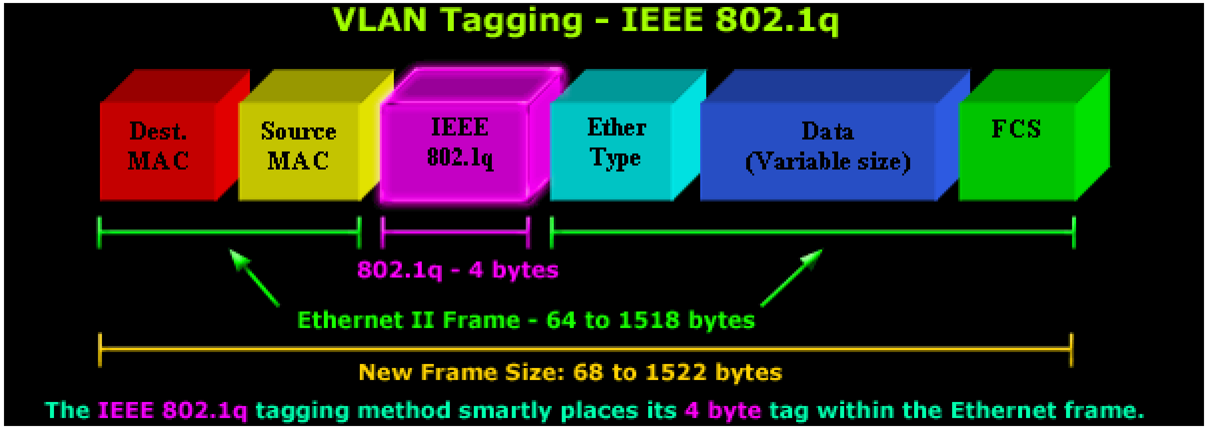
- Different approaches for defining membership for VLAN configuration
  - by MAC address
  - by port number
  - by protocol information (e.g. IP address, TCP information)

- In brief, the benefits of VLANs:
  - simplification of moves, adds, and changes;
  - controlled broadcast activity;
  - workgroup and network security

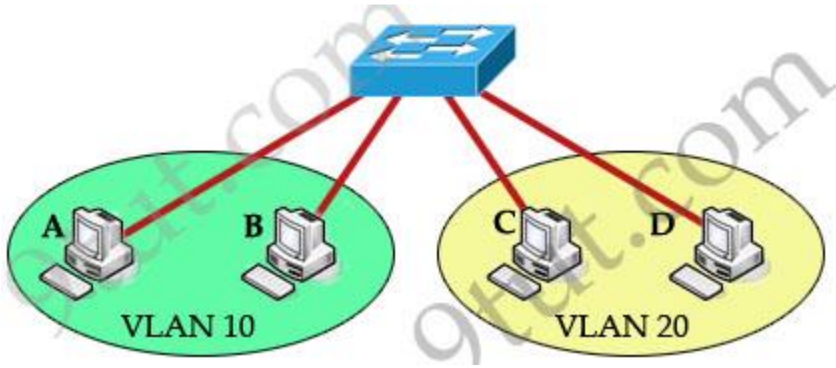
VLAN Trunks

- Large networks often contain more than one switch;
- if you want to span virtual LANs across two or more switches, a VLAN trunk can be used.

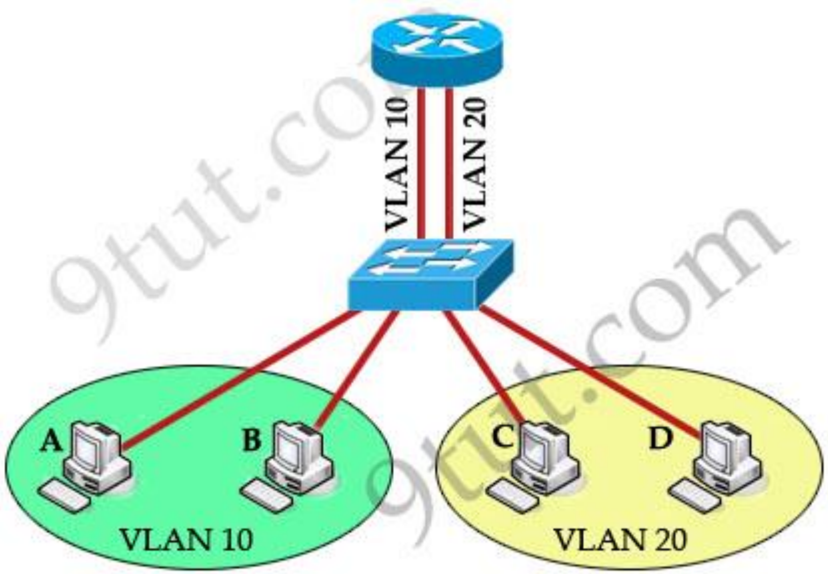
- Communicating VLAN Membership in Large network
  - Switches must have a way of understanding VLAN membership when network traffic arrives from other switches
    - A more common approach is frame tagging (IEEE 802.1q)
    - a header is inserted into each frame to uniquely identify to which VLAN a particular MAC-layer frame belongs

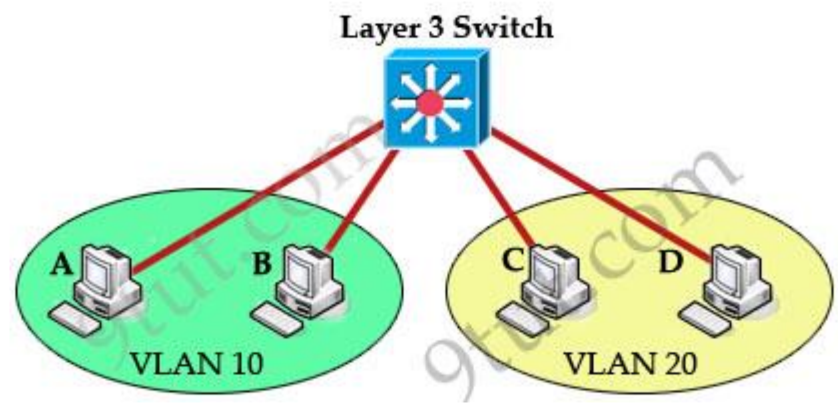


Inter-VLAN Routing



- host A and B can communicate with each other in the same VLAN 10;
- host C and D can communicate in the same VLAN 20
- But host A can’t communicate with host C or D because they are in different VLANs.
- To allow hosts in different VLANs communicate with each other, we need a Layer 3 device (like a router) for routing.
- Routers can be implemented as separate devices OR the router logic can be implemented as part of the LAN switch.





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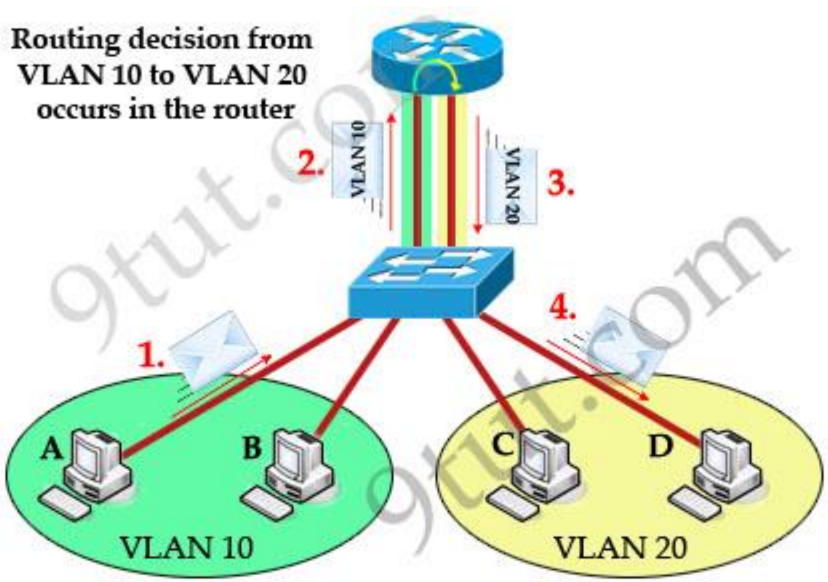
- **For example**,
- devices on VLAN 10 will be configured to use IPv4 addresses in the 10.10.10.X IP space while devices on VLAN 20 will be configured to use IPv4 addresses in the 10.10.20.x space.
- In addition to each device having its own IP address and subnet mask, a default gateway IP addresses is required.
- Every device in VLAN 10 will be configured to use the same default gateway IP address such as 10.10.10.1 and every device configured for VLAN 20 will use the gateway of 10.10.20.1. The default gateway IP address is a router interface (either physical or virtual) that is responsible for routing traffic to other IP networks.



Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2017), Data and Computer Communications, 10th Ed.
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2012), Data Communication and Networking, 5th Ed.