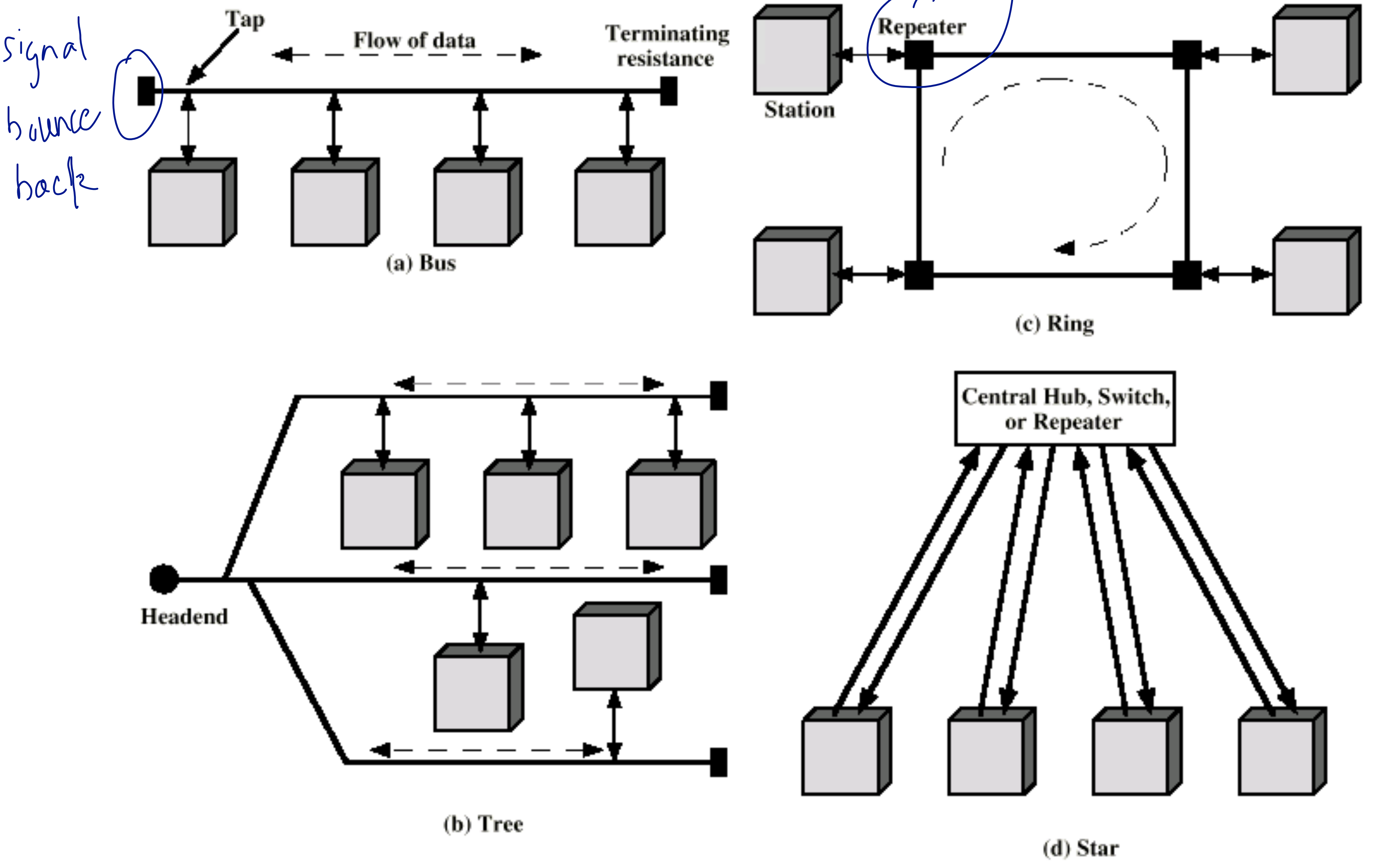
Part 3

LAN SYSTEMS (1)

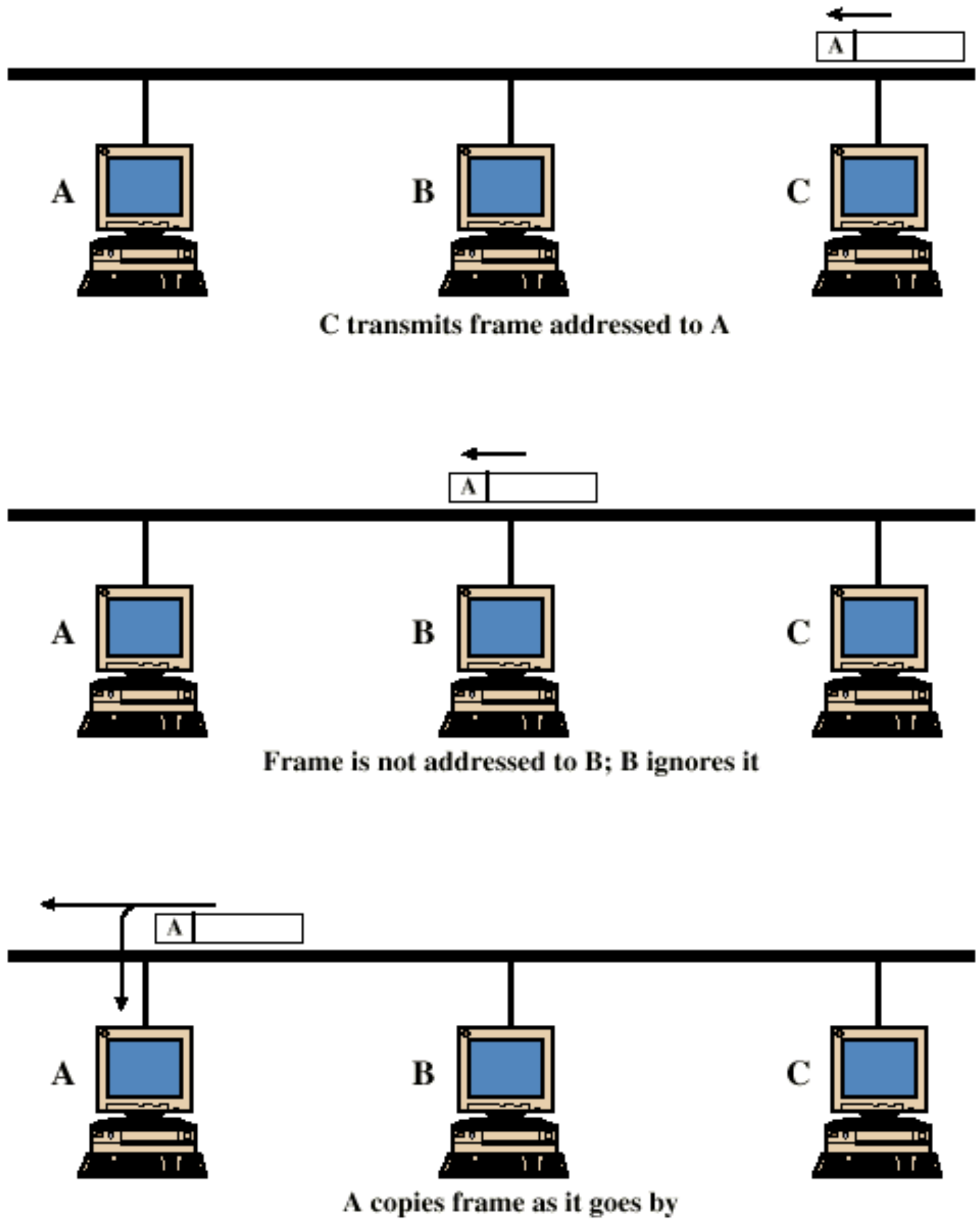
LAN Topologies



Bus and Tree

- Multipoint medium
- Transmission propagates throughout medium
- Heard by all stations
  - Need to identify target station
    - Each station has unique address
- Full duplex connection between station and tap
  - Allows for transmission and reception
- Need to regulate transmission
  - To avoid collisions
  - To avoid hogging
    - Data in small blocks - frames
- Terminator absorbs frames at end of medium

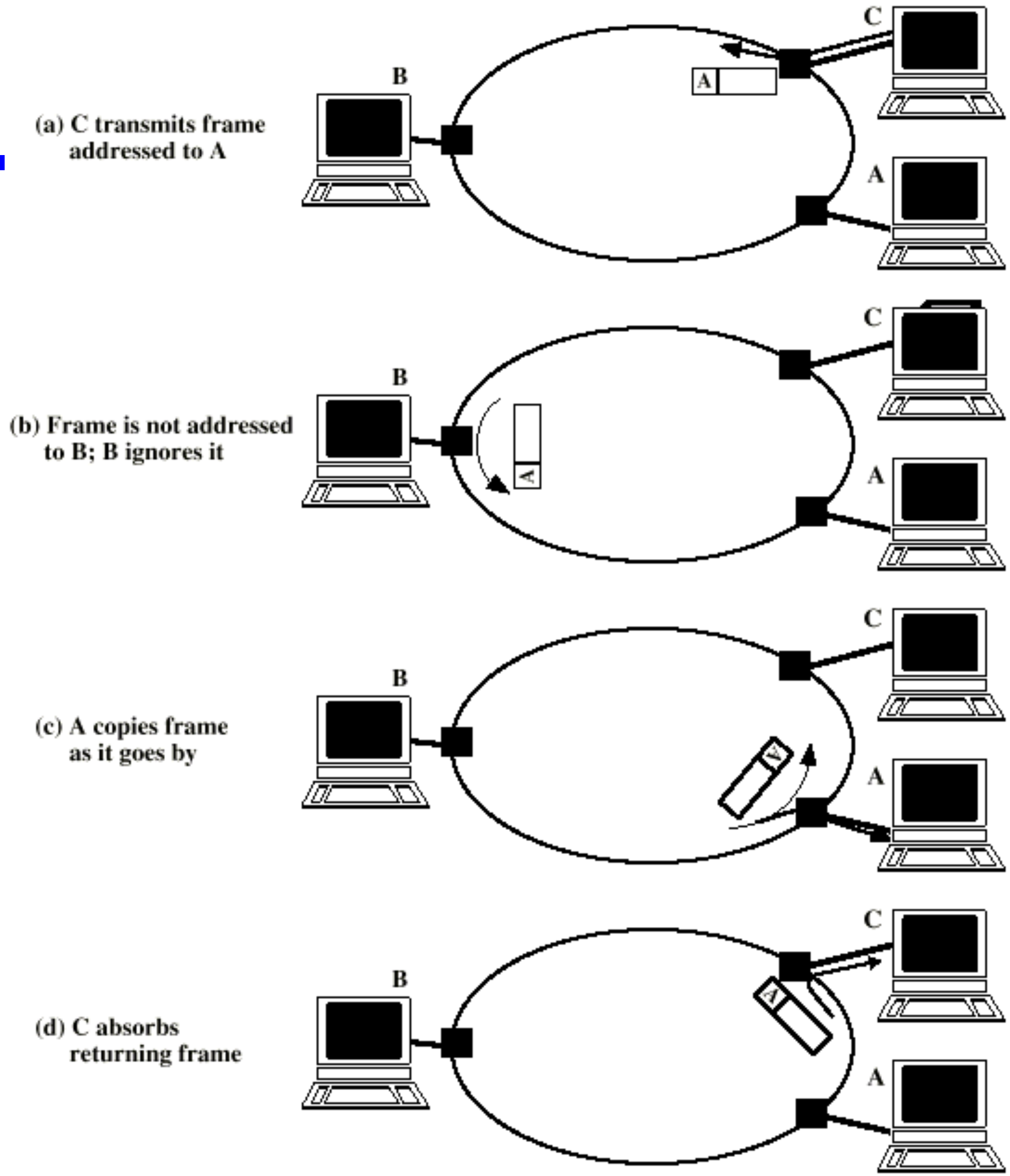
Frame Transmission - Bus LAN



Ring Topology

- Repeaters joined by point to point links in closed loop
  - Receive data on one link and retransmit on another
  - Links unidirectional
  - Stations attach to repeaters
- Data in frames
  - Circulate past all stations
  - Destination recognizes address and copies frame
  - Frame circulates back to source where it is removed
- Media access control determines when station can insert frame

Frame Transmission Ring LAN



Star Topology

- Each station connected directly to central node
  - Usually via two point to point links
- Central node can broadcast
  - Physical star, logical bus
  - Only one station can transmit at a time
- Central node can act as frame switch

Media Access Control

- Where
  - Central
    - Greater control
    - Simple access logic at station
    - Avoids problems of co-ordination
    - Single point of failure
    - Potential bottleneck
  - Distributed
- How
  - Synchronous
    - Specific capacity dedicated to connection
  - Asynchronous
    - In response to demand

Asynchronous Systems

- Round robin 小组循环
  - Good if many stations have data to transmit over extended period
- Reservation
  - Good for stream traffic
- Contention
  - Good for bursty traffic 突发
  - All stations contend for time 竞争
  - Distributed
  - Simple to implement
  - Efficient under moderate load
  - Tend to collapse under heavy load

MAC Frame Format

- MAC layer receives data from LLC layer
- MAC control
- Destination MAC address
- Source MAC address
- LLS
- CRC
- MAC layer detects errors and discards frames
- LLC optionally retransmits unsuccessful frames

Logical Link Control

- Transmission of link level PDUs between two stations
- Must support multiaccess, shared medium
- Relieved of some link access details by MAC layer
- Addressing involves specifying source and destination LLC users
  - Referred to as service access points (SAP)
  - Typically higher level protocol

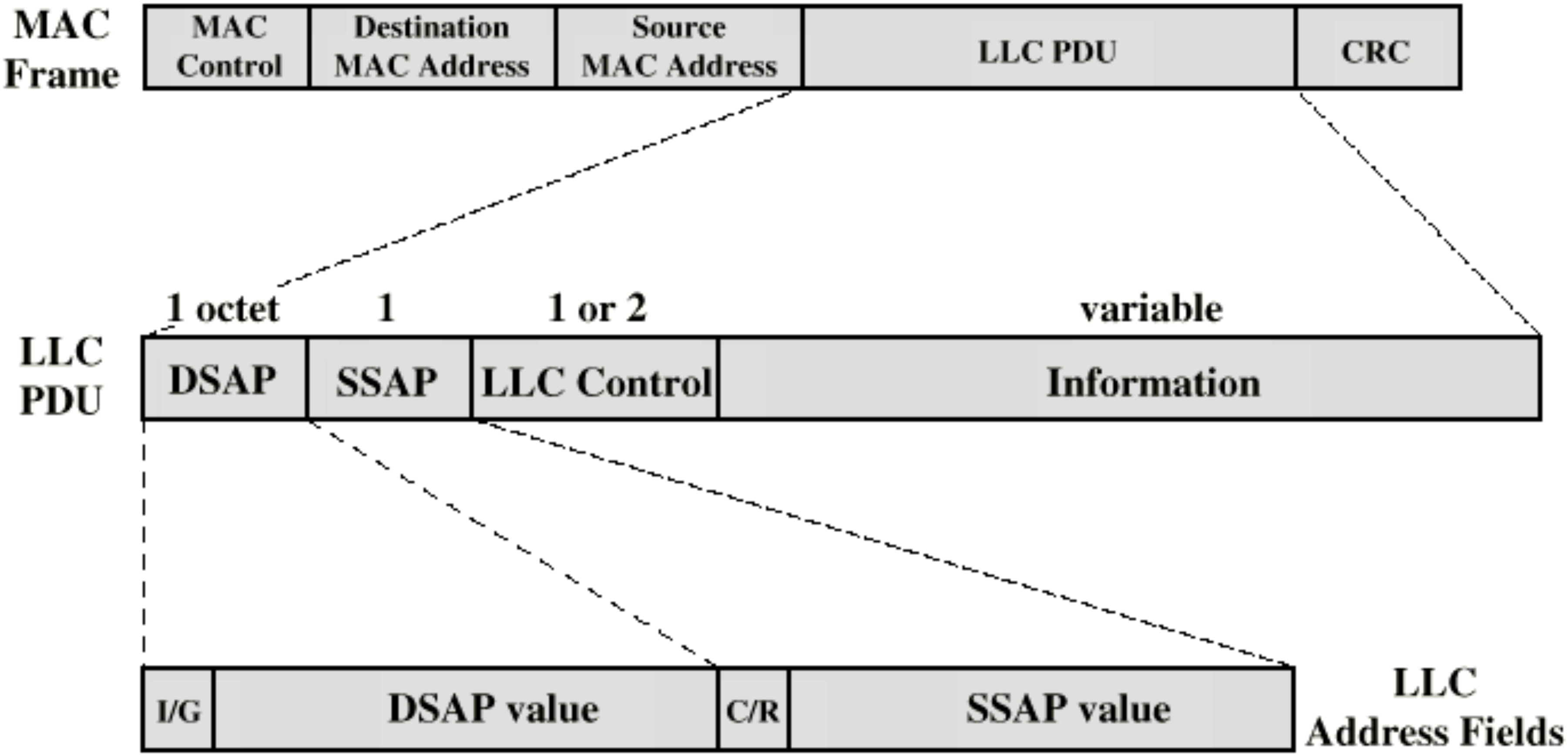
LLC Services

- Based on HDLC
- Unacknowledged connectionless service
- Connection mode service
- Acknowledged connectionless service

LLC Protocol

- Modeled after HDLC
- Asynchronous balanced mode to support connection mode LLC service (type 2 operation)
- Unnumbered information PDUs to support Acknowledged connectionless service (type 1)
- Multiplexing using LSAPs

Typical Frame Format



I/G = Individual/Group
C/R = Command/Response

Bus LANs

- Signal balancing
  - Signal must be strong enough to meet receiver's minimum signal strength requirements
  - Give adequate signal to noise ration
  - Not so strong that it overloads transmitter
  - Must satisfy these for all combinations of sending and receiving station on bus
  - Usual to divide network into small segments
  - Link segments with amplifies or repeaters

Transmission Media

- Twisted pair
  - Not practical in shared bus at higher data rates
- Baseband coaxial cable
  - Used by Ethernet
- Broadband coaxial cable
  - Included in 802.3 specification but no longer made
- Optical fiber
  - Used to be expensive, but cheaper now
  - Going to be deployed anywhere
- Few new installations
  - Replaced by star based twisted pair and optical fiber

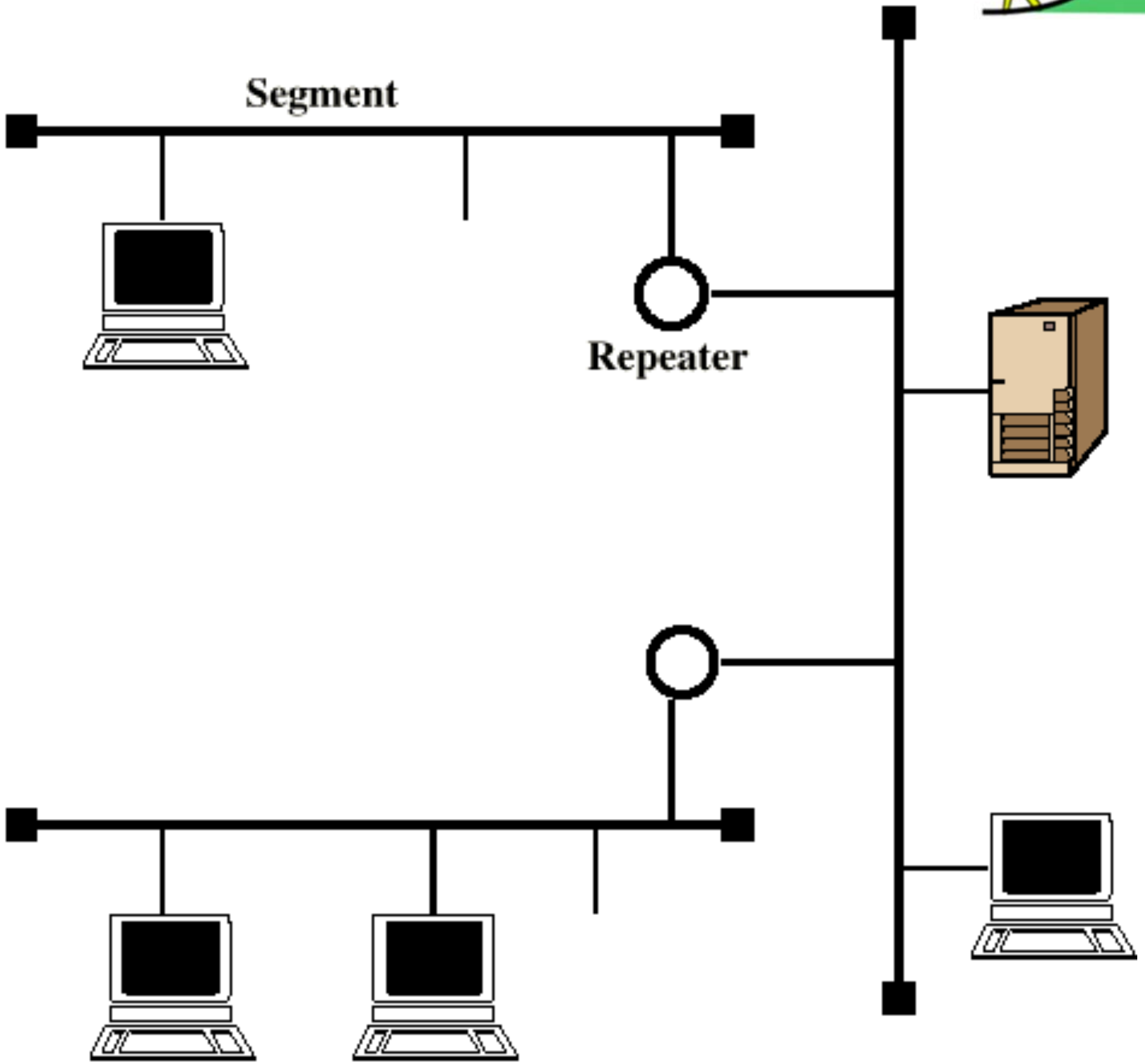
Baseband Coaxial Cable

- Uses digital signaling
- Manchester or Differential Manchester encoding
- Entire frequency spectrum of cable used
- Single channel on cable
- Bi-directional
- Few kilometer range
- Ethernet (basis for 802.3) at 10Mbps
- 50 ohm cable

Repeaters

- Transmits in both directions
- Joins two segments of cable
- No buffering
- No logical isolation of segments
- If two stations on different segments send at the same time, packets will collide
- Only one path of segments and repeaters between any two stations

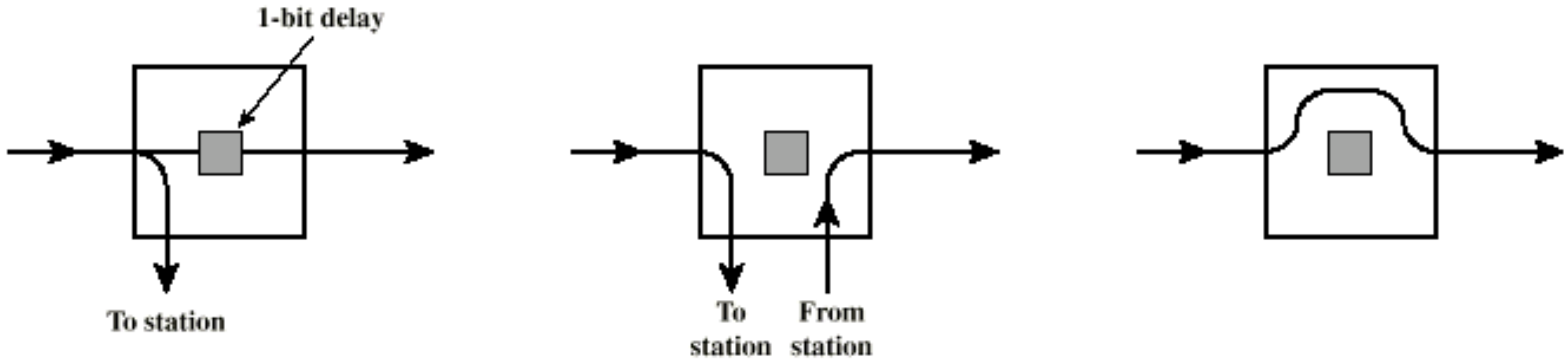
Baseband Configuration



Ring LANs

- Each repeater connects to two others via unidirectional transmission links
- Single closed path
- Data transferred bit by bit from one repeater to the next
- Repeater regenerates and retransmits each bit
- Repeater performs data insertion, data reception, data removal
- Repeater acts as attachment point
- Packet removed by transmitter after one trip round ring

Ring Repeater States



(a) Listen state (b) Transmit state (c) Bypass state

Listen State Functions

- Scan passing bit stream for patterns
  - Address of attached station
  - Token permission to transmit
- Copy incoming bit and send to attached station
  - Whilst forwarding each bit
- Modify bit as it passes
  - e.g. to indicate a packet has been copied (ACK)

Transmit State Functions

- Station has data
- Repeater has permission
- May receive incoming bits
  - If ring bit length shorter than packet
    - Pass back to station for checking (ACK)
  - May be more than one packet on ring
    - Buffer for retransmission later

Bypass State

- Signals propagate past repeater with no delay (other than propagation delay)
- Partial solution to reliability problem
- Improved performance

Ring Media

- Twisted pair
- Baseband coaxial
- Fiber optic
- Not broadband coaxial
  - Would have to receive and transmit on multiple channels, asynchronously

Timing Jitter

- Clocking included with signal
  - e.g. differential Manchester encoding
  - Clock recovered by repeaters
    - To know when to sample signal and recover bits
    - Use clocking for retransmission
  - Clock recovery deviates from midbit transmission randomly
    - Noise
    - Imperfections in circuitry
- Retransmission without distortion but with timing error
- Cumulative effect is that bit length varies
- Limits number of repeaters on ring

Solving Timing Jitter Limitations

- Repeater uses phase locked loop
  - Minimize deviation from one bit to the next
- Use buffer at one or more repeaters
  - Hold a certain number of bits
  - Expand and contract to keep bit length of ring constant
- Significant increase in maximum ring size

Potential Ring Problems

- Break in any link disables network
- Repeater failure disables network
- Installation of new repeater to attach new station requires identification of two topologically adjacent repeaters
- Timing jitter
- Method of removing circulating packets required
  - With backup in case of errors
- Mostly solved with star-ring architecture

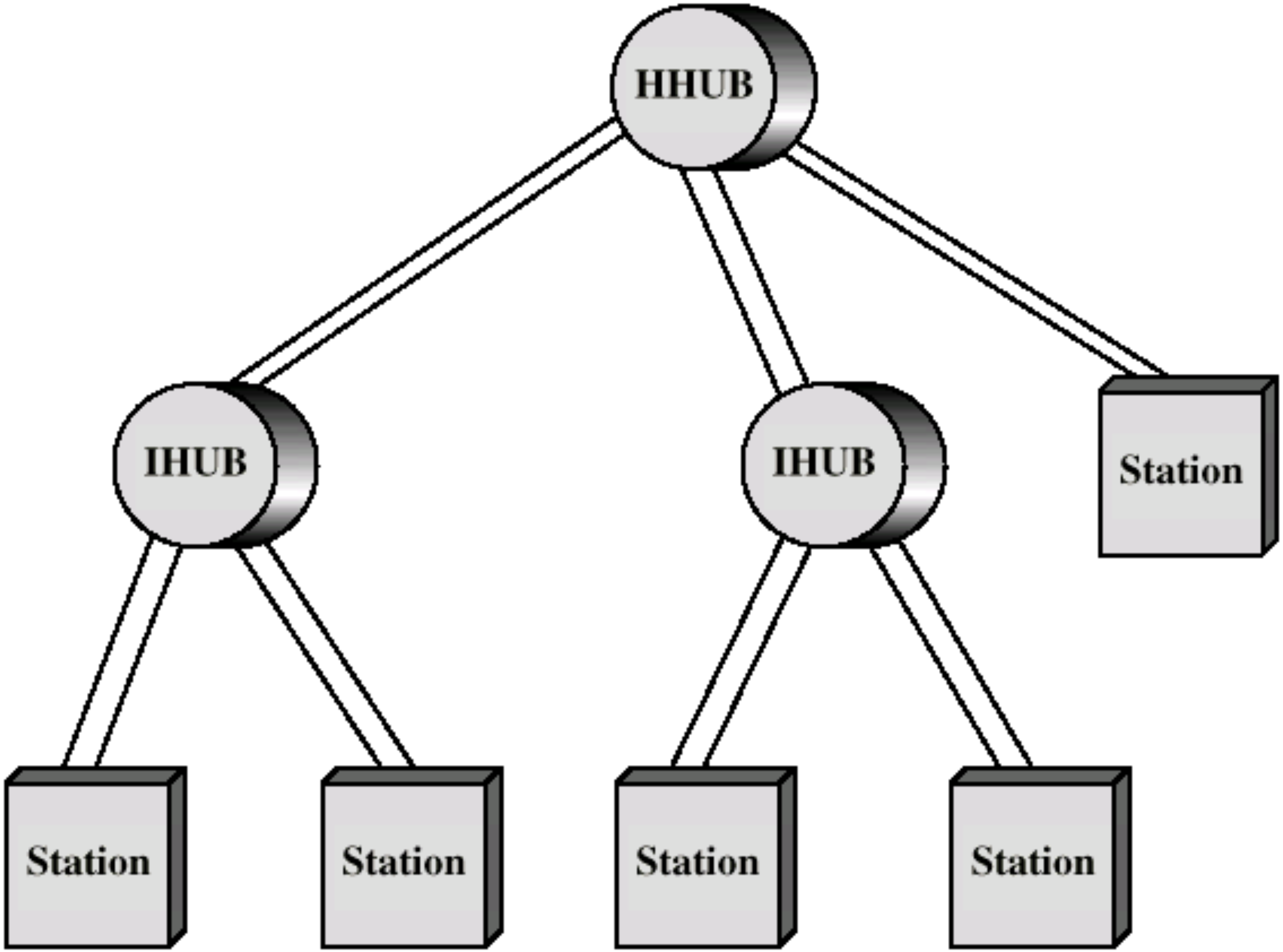
Star Ring Architecture

- Feed all inter-repeater links to single site
  - Concentrator
  - Provides central access to signal on every link
  - Easier to find faults
  - Can launch message into ring and see how far it gets
  - Faulty segment can be disconnected and repaired later
  - New repeater can be added easily
  - Bypass relay can be moved to concentrator
  - Can lead to long cable runs
- Can connect multiple rings using bridges

Star LANs

- Use unshielded twisted pair wire (telephone)
  - Minimal installation cost
    - May already be an installed base
    - All locations in building covered by existing installation
- Attach to a central active hub
- Two links
  - Transmit and receive
- Hub repeats incoming signal on all outgoing lines
- Link lengths limited to about 100m
  - Fiber optic - up to 500m
- Logical bus - with collisions

Two Level Star Topology



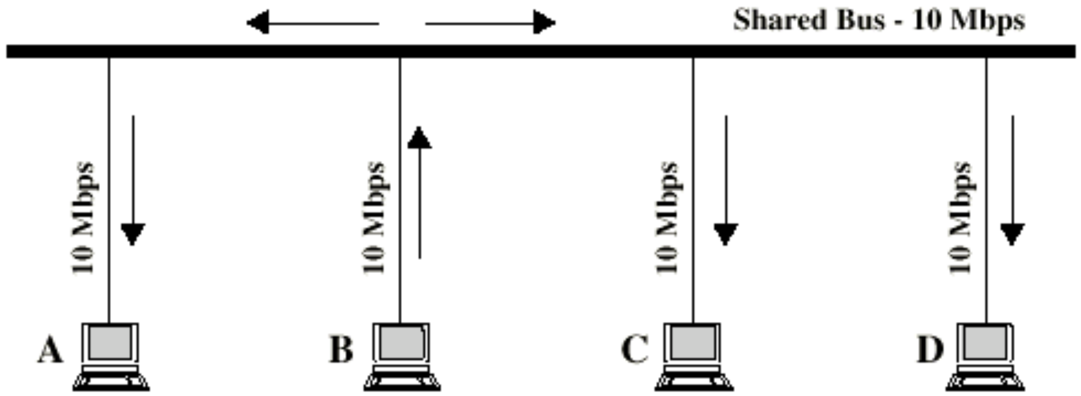
Hubs and Switches

- Shared medium hub
  - Central hub
  - Hub retransmits incoming signal to all outgoing lines
  - Only one station can transmit at a time
  - With a 10Mbps LAN, total capacity is 10Mbps
- Switched LAN hub
  - Hub acts as switch
  - Incoming frame switches to appropriate outgoing line
  - Unused lines can also be used to switch other traffic
  - With two pairs of lines in use, overall capacity is now 20Mbps

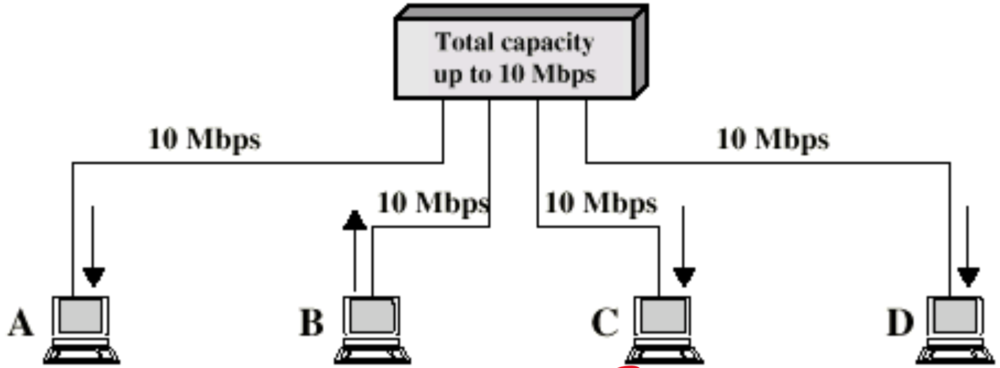
Switched Hubs

- No change to software or hardware of devices
- Each device has dedicated capacity
- Scales well
- Store and forward switch
  - Accept input, buffer it briefly, then output
- Cut through switch
  - Take advantage of the destination address being at the start of the frame
  - Begin repeating incoming frame onto output line as soon as address recognized
  - May propagate some bad frames

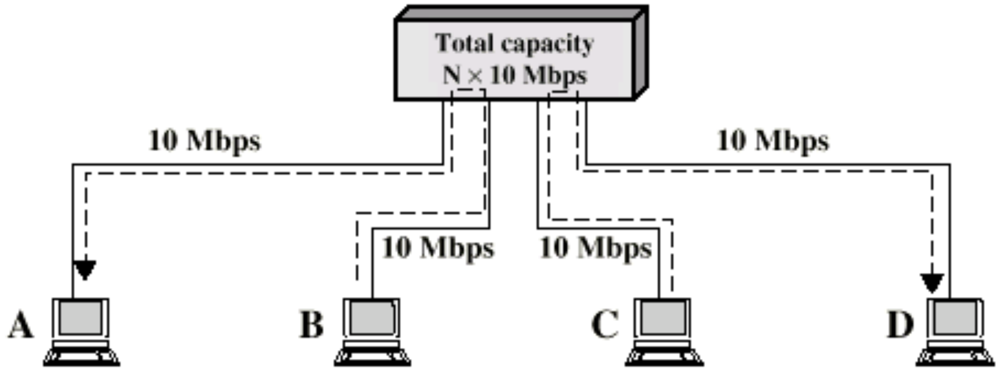
Hubs and Switches



(a) Shared medium bus



(b) Shared medium hub



(c) Switching hub

Wireless LANs

- Mobility
- Flexibility
- Hard to wire areas
- Reduced cost of wireless systems
- Improved performance of wireless systems

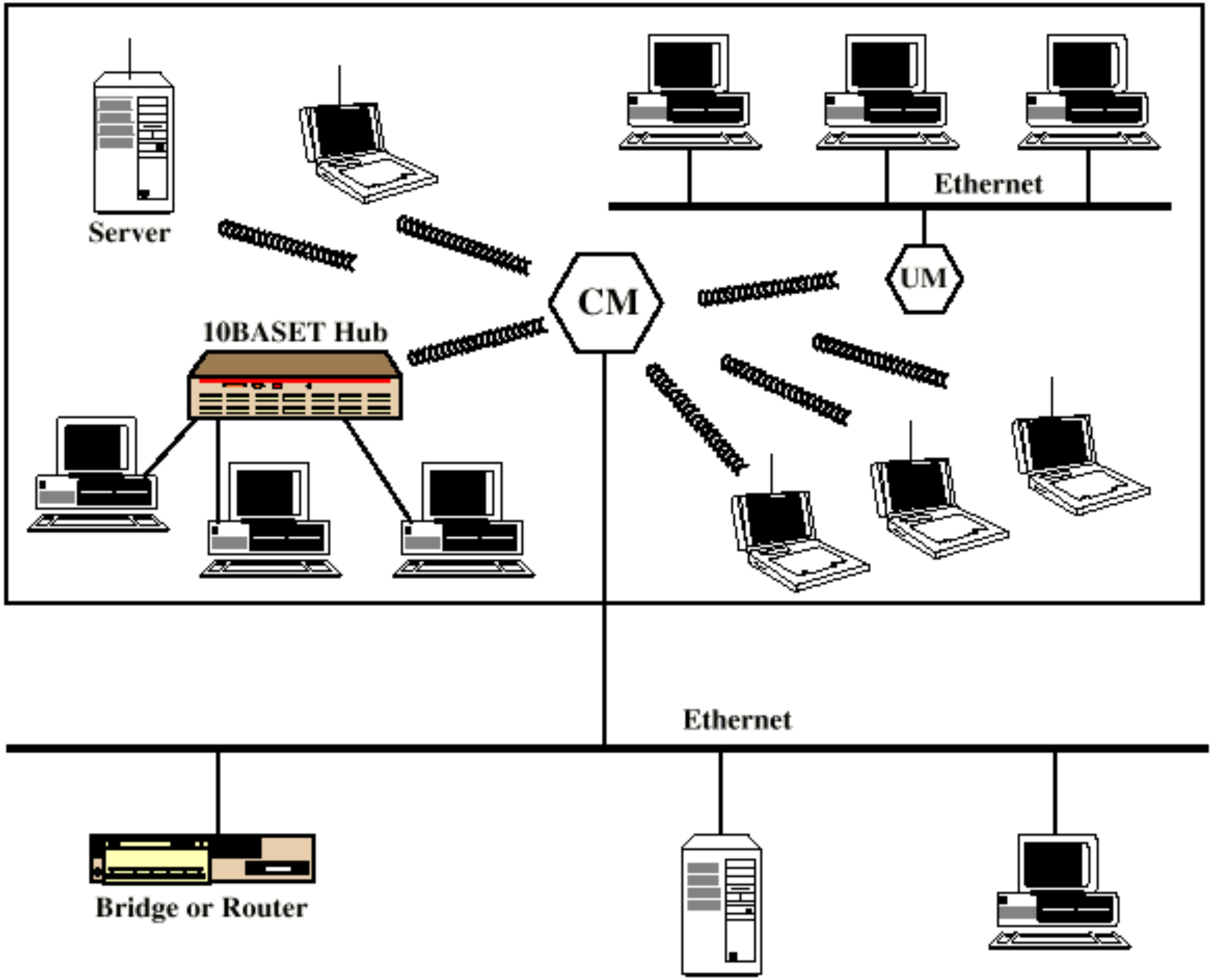
Wireless LAN Applications

- LAN Extension
- Cross building interconnection
- Nomadic access
- Ad hoc networks

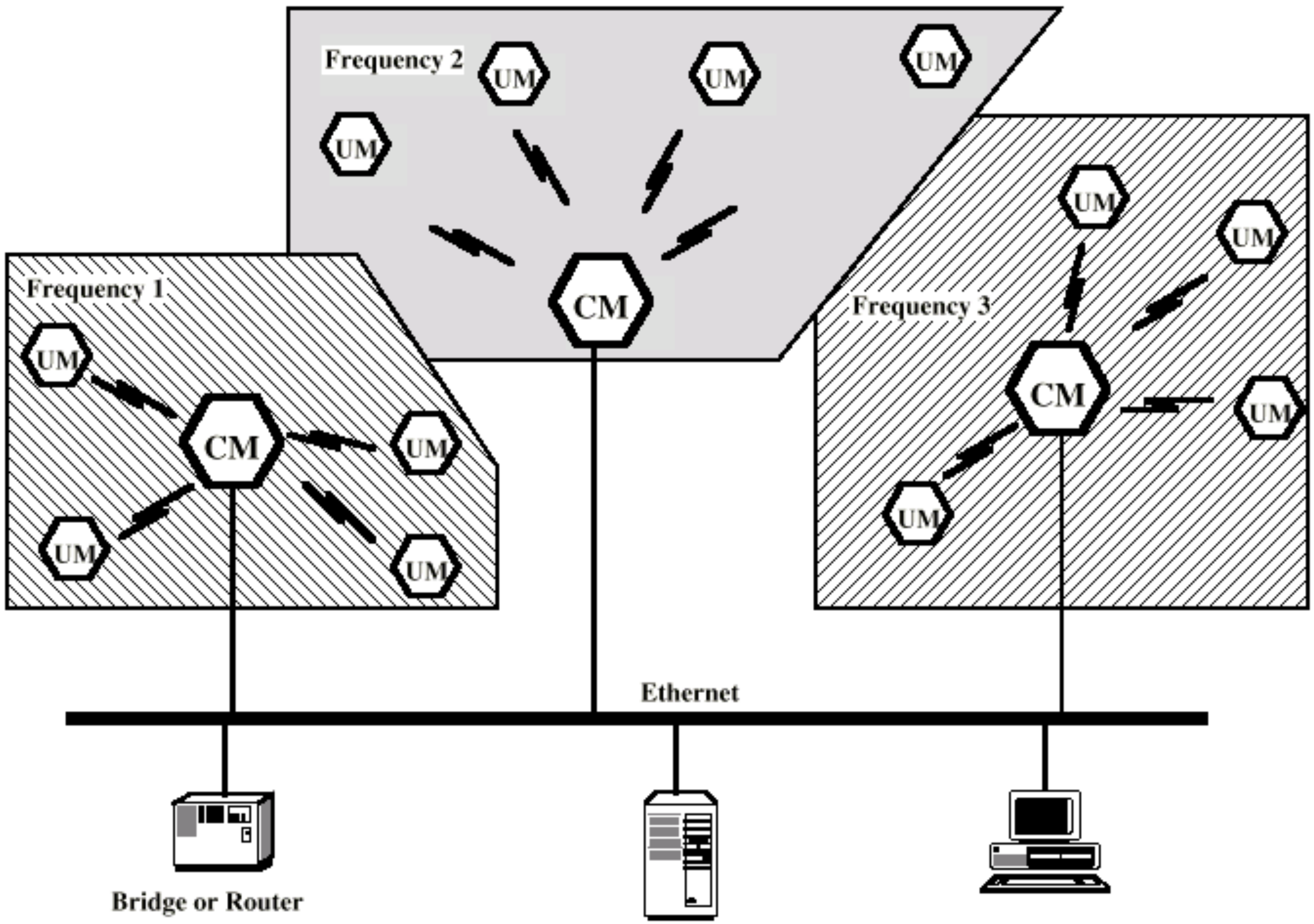
LAN Extension

- Buildings with large open areas
  - Manufacturing plants
  - Warehouses
- Historical buildings
- Small offices
- May be mixed with fixed wiring system

Single Cell Wireless LAN



Multi Cell Wireless LAN



Cross Building Interconnection

- Point to point wireless link between buildings
- Typically connecting bridges or routers
- Used where cable connection not possible
  - e.g. across a street

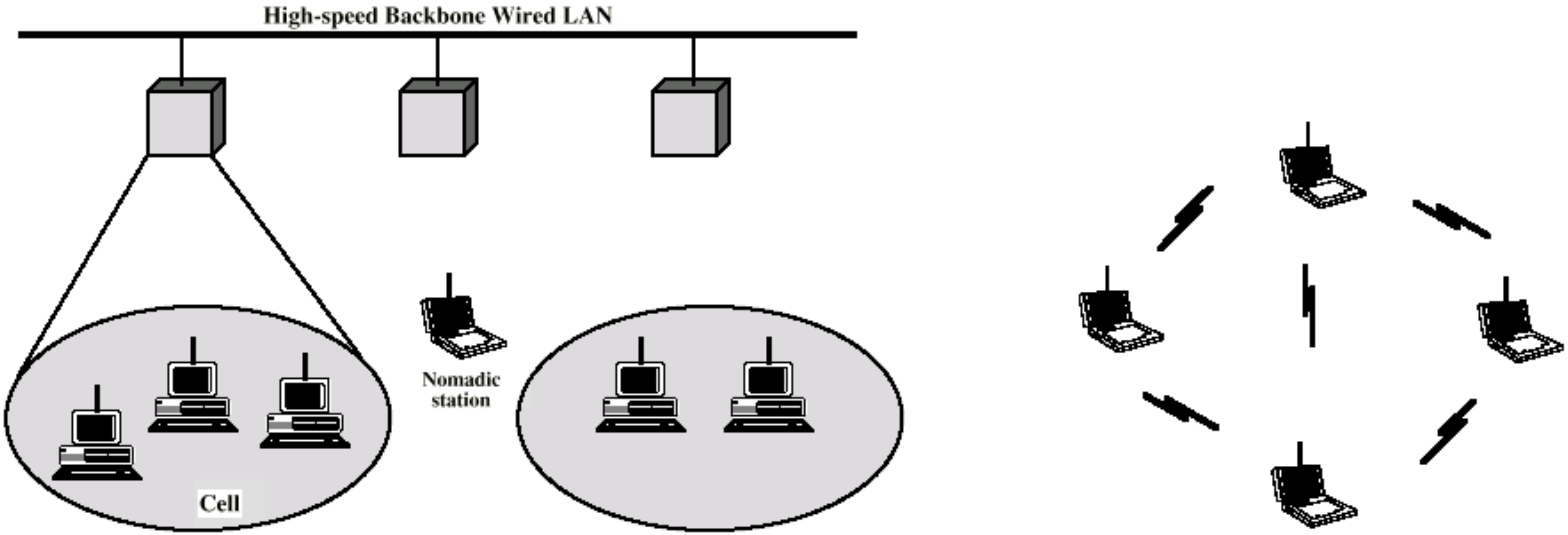
Nomadic Access

- Mobile data terminal
  - e.g. laptop
- Transfer of data from laptop to server
- Campus or cluster of buildings

Ad Hoc Networking

- Peer to peer
- Temporary
- e.g. conference

Wireless LAN Configurations



(a) Infrastructure Wireless LAN

(b) Ad hoc LAN

Wireless LAN Requirements

- Throughput
- Number of nodes
- Connection to backbone
- Service area
- Battery power consumption
- Transmission robustness and security
- Collocated network operation
- License free operation
- Handoff/roaming
- Dynamic configuration

Wireless LAN Technology

- Infrared (IR) LANs
- Spread spectrum LANs
- Narrow band microwave

Bridges

- Ability to expand beyond single LAN
- Provide interconnection to other LANs/WANs
- Use Bridge or router
- Bridge is simpler
  - Connects similar LANs
  - Identical protocols for physical and link layers
  - Minimal processing
- Router more general purpose
  - Interconnect various LANs and WANs
  - see later

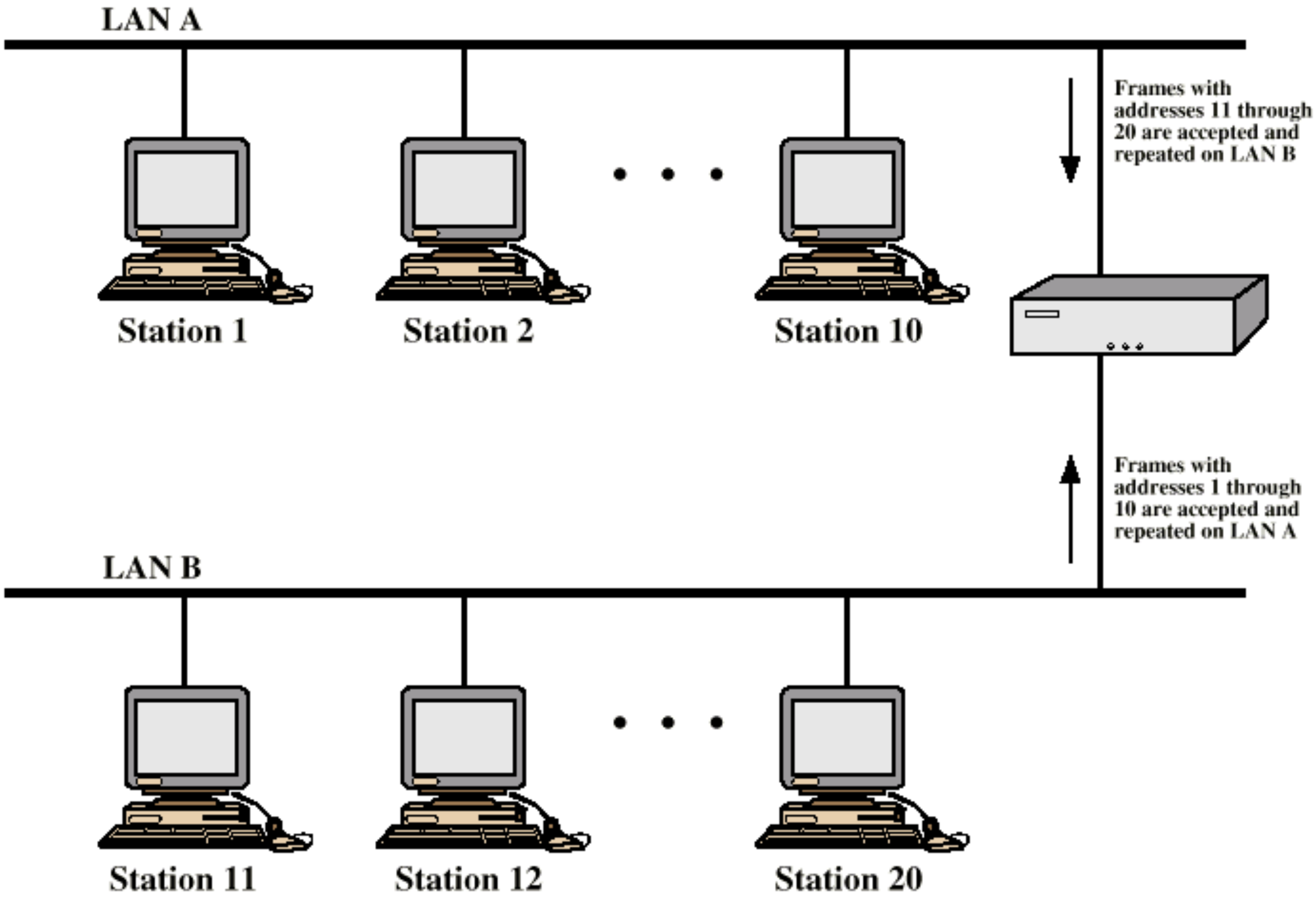
Why Bridge?

- Reliability
- Performance
- Security
- Geography

Functions of a Bridge

- Read all frames transmitted on one LAN and accept those address to any station on the other LAN
- Using MAC protocol for second LAN, retransmit each frame
- Do the same the other way round

Bridge Operation



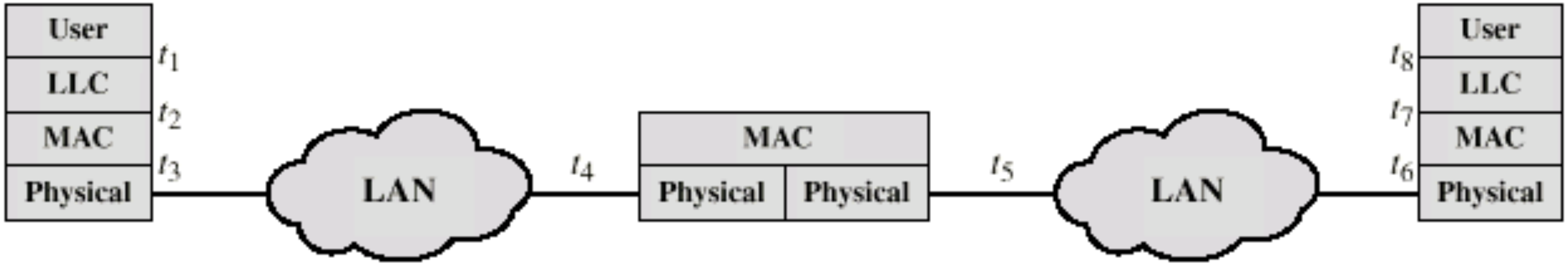
Bridge Design Aspects

- No modification to content or format of frame
- No encapsulation
- Exact bitwise copy of frame
- Minimal buffering to meet peak demand
- Contains routing and address intelligence
  - Must be able to tell which frames to pass
  - May be more than one bridge to cross
- May connect more than two LANs
- Bridging is transparent to stations
  - Appears to all stations on multiple LANs as if they are on one single LAN

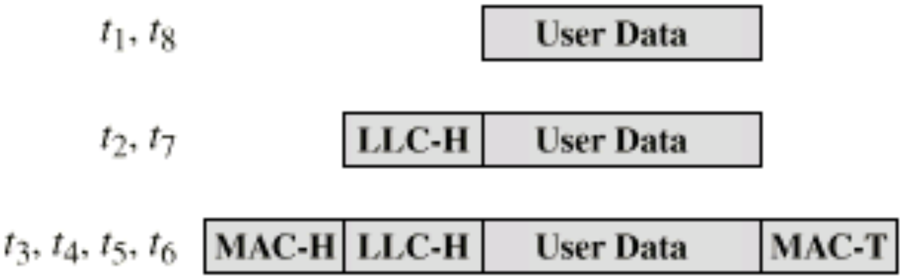
Bridge Protocol Architecture

- IEEE 802.1D
- MAC level
  - Station address is at this level
- Bridge does not need LLC layer
  - It is relaying MAC frames
- Can pass frame over external comms system
  - e.g. WAN link
  - Capture frame
  - Encapsulate it
  - Forward it across link
  - Remove encapsulation and forward over LAN link

Connection of Two LANs



(a) Architecture



(b) Operation

Fixed Routing

- Complex large LANs need alternative routes
  - Load balancing
  - Fault tolerance
- Bridge must decide whether to forward frame
- Bridge must decide which LAN to forward frame on
- Routing selected for each source-destination pair of LANs
  - Done in configuration
  - Usually least hop route
  - Only changed when topology changes

Fixed Routing Tables

CENTRAL ROUTING DIRECTORY

To Node \ From Node	1	2	3	4	5	6
1	—	1	5	2	4	5
2	2	—	5	2	4	5
3	4	3	—	5	3	5
4	4	4	5	—	4	5
5	4	4	5	5	—	5
6	4	4	5	5	6	—

Node 1 Directory

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Directory

Destination	Next Node
1	1
3	3
4	4
5	4
6	4

Node 3 Directory

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Directory

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

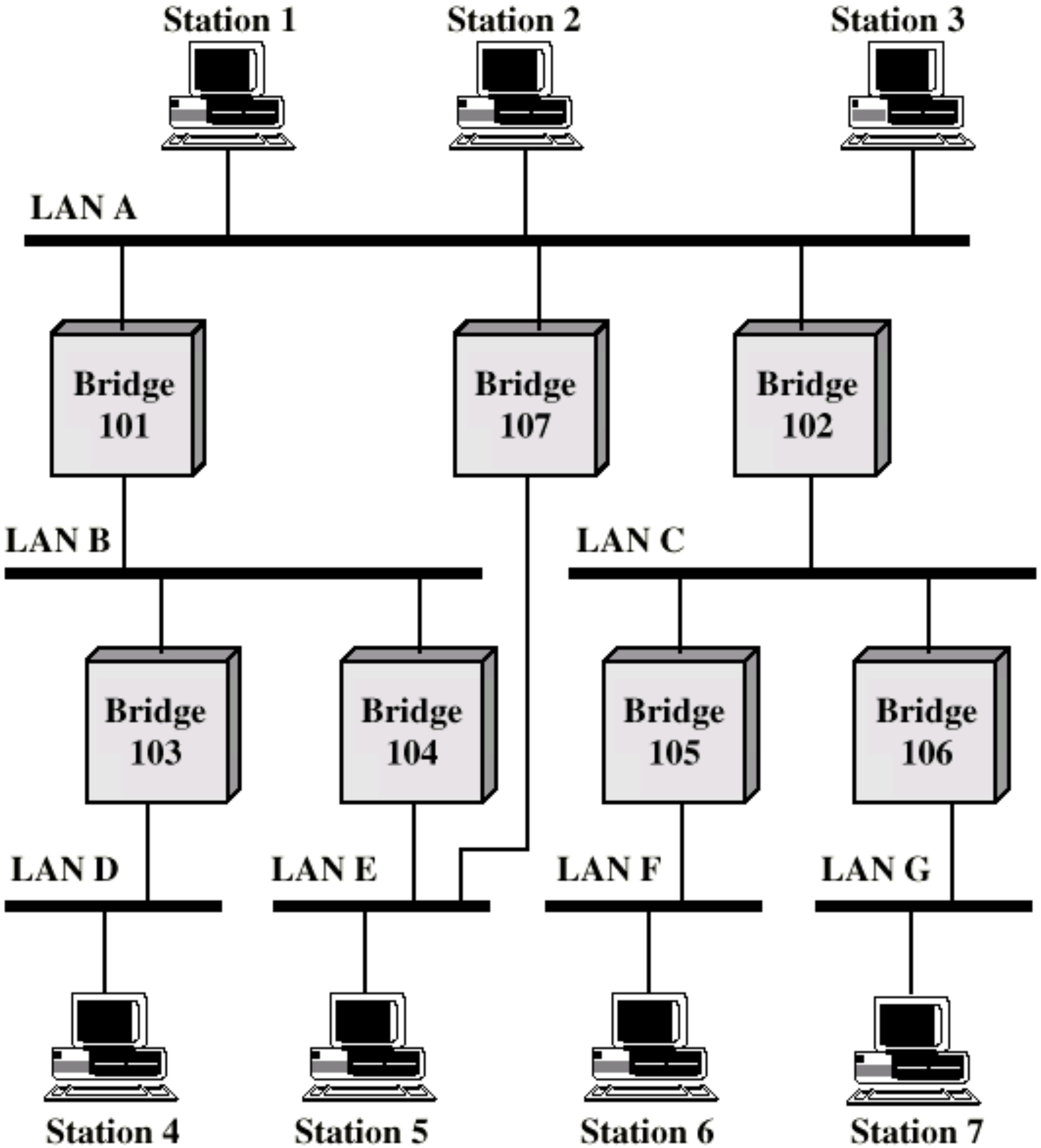
Node 5 Directory

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

Node 6 Directory

Destination	Next Node
1	5
2	5
3	5
4	5
5	5

Multiple LANs



Spanning Tree

- Bridge automatically develops routing table
- Automatically update in response to changes
- Frame forwarding
- Address learning
- Loop resolution

Frame forwarding

- Maintain forwarding database for each port
  - List station addresses reached through each port
- For a frame arriving on port X:
  - Search forwarding database to see if MAC address is listed for any port except X
  - If address not found, forward to all ports except X
  - If address listed for port Y, check port Y for blocking or forwarding state
    - Blocking prevents port from receiving or transmitting
  - If not blocked, transmit frame through port Y

Address Learning

- Can preload forwarding database
- Can be learned
- When frame arrives at port X, it has come from the LAN attached to port X
- Use the source address to update forwarding database for port X to include that address
- Timer on each entry in database
- Each time frame arrives, source address checked against forwarding database

Spanning Tree Algorithm

- Address learning works for tree layout
  - i.e. no closed loops
- For any connected graph there is a spanning tree that maintains connectivity but contains no closed loops
- Each bridge assigned unique identifier
- Exchange between bridges to establish spanning tree

Loop of Bridges