CSE4882 - Digital Communications Technologies

8 - LAN Technology

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Note: These slides contain figures from Stallings, Halsall and Forouzan, and are based on a set developed by Dr. A Pullin.

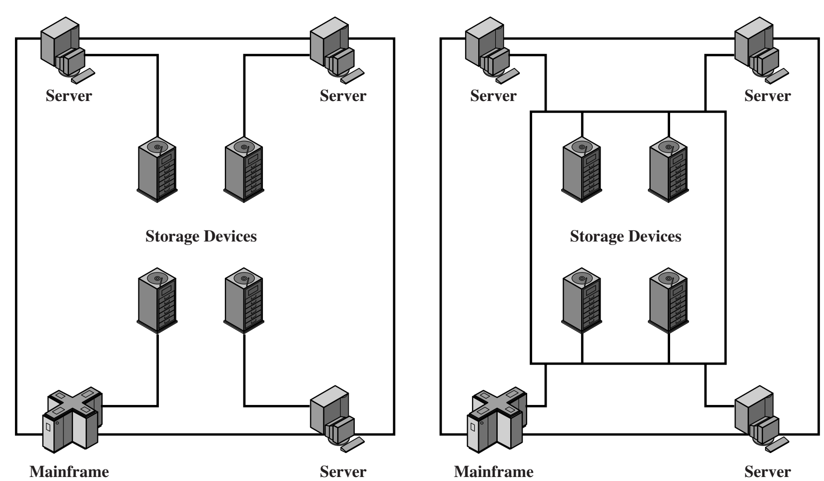
CSE4882 - Digital Communications Technologies

- LAN applications.
- LAN architecture (MAC, LLC).
- Topologies:
  - Bus,
  - Ring,
  - Star,
  - Wireless.
- Bridges.

LAN Applications

- Personal computer LANs:
  - Around offices (printers, disks, internet): Low cost and limited data rate.
- Back end networks and storage area networks:
  - Interconnecting large systems (mainframes and large storage devices):
    - High data rate (100 Mbps+) and high speed interface.
    - Distributed access: MAC needed for multiple devices.
    - Limited distance and limited number of devices.
- High speed office networks:
  - Desktop image processing (fax, document image processors, etc).
  - High capacity local storage.
- Backbone LANs:
  - Interconnect low speed local LANs with a higher speed (Backbone) LAN.
  - Improves reliability, capacity, and cost of a single LAN.

Storage Area Networks



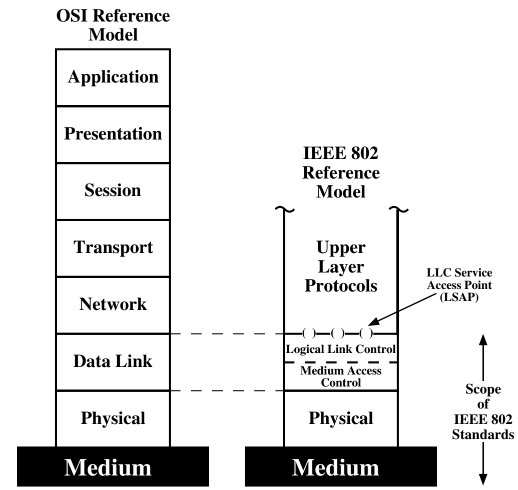
(a) Server-based storage (b) Storage area network

LAN Architecture

- Protocol architecture.
- Topologies.
- Media access control.
- Logical link control.

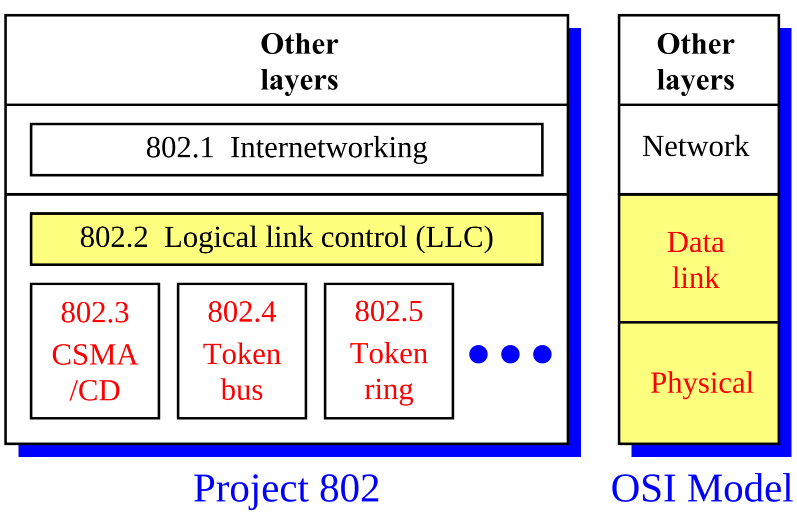
Protocol Architecture

- Only the lower layers of the OSI model are dependent on the network architecture.
- IEEE 802 reference model:
  - Physical.
  - Logical link control (LLC).
  - Media access control (MAC).



IEEE 802 Layers Compared to OSI Model

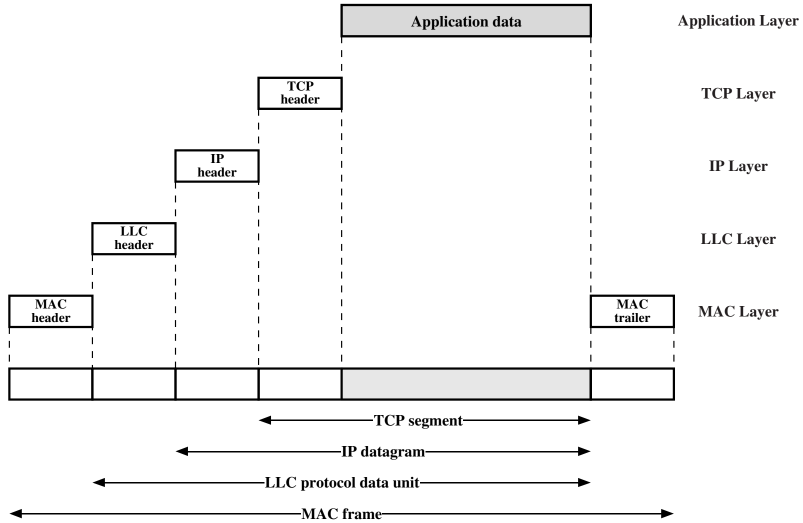
IEEE 802 Protocols



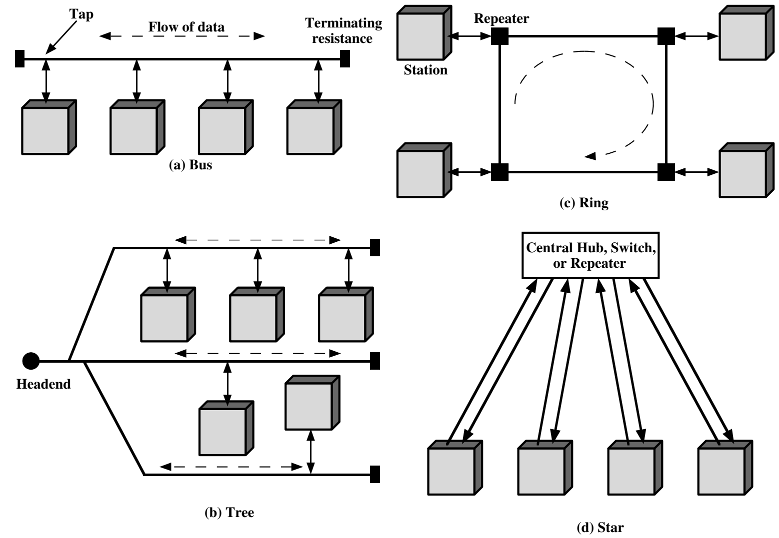
IEEE 802 Layers

- Physical:
  - Encoding/decoding of signals.
  - Preamble generation/removal (synchronisation).
  - Bit transmission/reception.
  - Transmission medium and topology (usually below OSI model).
- Media Access Control:
  - Assembly of data into a frame with address and error detection fields.
  - Disassembly of frame and perform address recognition and error detection.
  - Govern access to the transmission medium.
    - Not found in traditional layer 2 data link control.
  - For the same LLC, several MAC options may be available.
- Logical Link Control:
  - Provide an interface to the higher levels and perform flow and error control.

LAN Protocols in Context



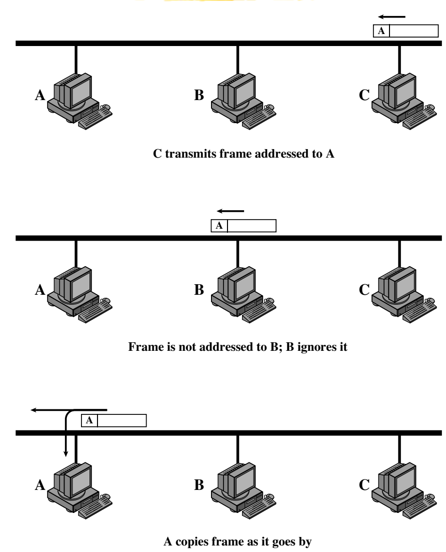
LAN Topologies



Bus and Tree Topologies

- Bus is a special case of tree - one trunk and no branches.
- Multipoint medium.
- Transmission propagates throughout the medium.
- Terminator absorbs frames at end of the medium.
- Heard by all the stations.
  - Need to identify target station: Each station has unique address.
- Full duplex connection between a station and its tap:
  - Allows for transmission and reception.
- Need to regulate transmission:
  - To avoid collisions.
  - To avoid hogging.
- Data transmitted in small blocks - frames.

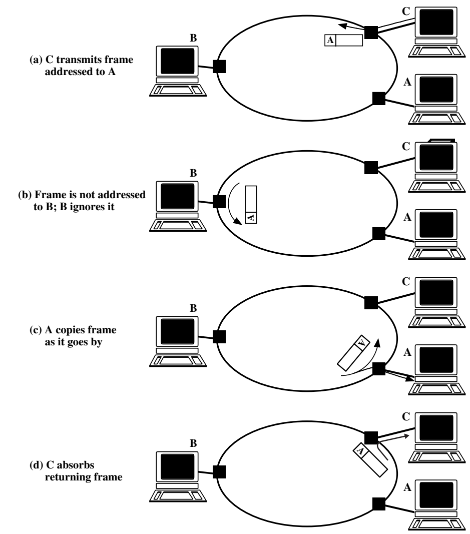
Frame Transmission on a Bus LAN



Ring Topology

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

Frame Transmission on a Ring LAN



Star Topology

- Each station is connected directly to a common central node:
  - Usually via two point-to-point links.
- Two alternatives for operation:
  - Central node can broadcast to all stations:
    - Physically a star, but logically a bus.
    - Only one station can transmit at a time.
  - Central node can act as a frame switch.

Media Access Control

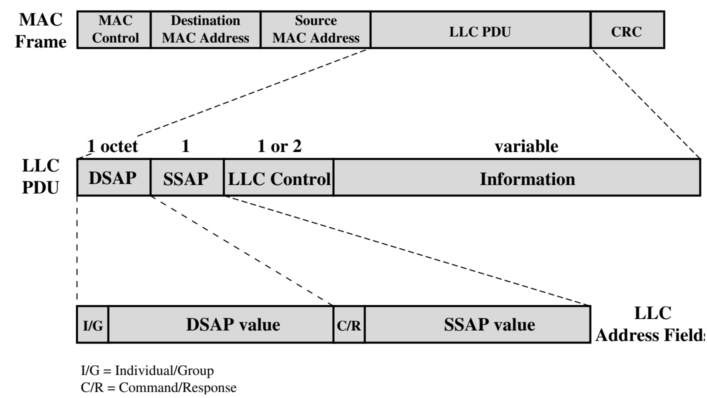
- Where:
  - Central - a controller grants access to the network.
    - Greater control (e.g. priority, overrides, guaranteed capacity).
    - Simple access logic at each station.
    - Avoids problems of co-ordination among peer stations.
    - Creates a single point of network failure.
    - Potential bottleneck.
  - Distributed - stations collectively control access.
- How:
  - Synchronous:
    - Specific capacity dedicated to a connection (like FDM, Sync. TDM).
  - Asynchronous:
    - In response to demand (the needs of the stations is unpredictable).

Asynchronous Systems

- Round Robin:
  - Each station is given the opportunity to transmit.
  - Station may decline to transmit.
  - Good if many stations have data to transmit over an extended period.
- Reservation:
  - A station reserves future time slots for transmission.
  - Good for stream traffic (e.g. voice, telemetry, bulk file transfer).
- Contention:
  - Good for bursty traffic (short, sporadic transmissions).
  - No turn based control used, all stations contend for time.
  - Distributed.
  - Simple to implement and efficient under moderate load.
  - Tends to collapse under heavy load.

MAC Frame Format

- MAC layer receives data from the LLC layer (LLC PDU).
- MAC layer detects errors and discards corrupt 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 the MAC layer.
- Addressing involves specifying source and destination LLC users:
  - Referred to as service access points (SAP).
  - Typically higher level protocol or network management function.

LLC Services and Protocol

- Operation and format is based on HDLC.
- Unacknowledged connectionless service (type 1 operation):
  - Datagram-style with no error- or flow- control (may be left to higher layer).
  - Unnumbered information (UI) PDUs with error detection and discard.
- Connection mode service (type 2 operation):
  - Similar to HDLC: logical connection with flow and error control.
  - Asynchronous balanced mode extended (SABME: only mode available).
- Acknowledged connectionless service (type 3 operation):
  - Cross between the previous two: acknowledged datagrams (stop-and-wait).
  - Two new unnumbered information PDUs: Acknowledged Connectionless (AC).
- Permits multiplexing using LSAPs.

Bus LANs

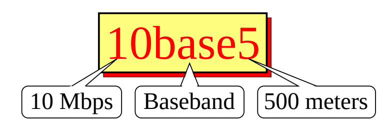
- Multipoint configuration: more than two devices connected to the medium.
- Signal balancing:
  - Signal must be strong enough to meet the receiver's minimum signal strength requirements.
  - Strong enough to provide adequate signal-to-noise ratio.
  - Not so strong that it overloads the transmitter.
  - 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

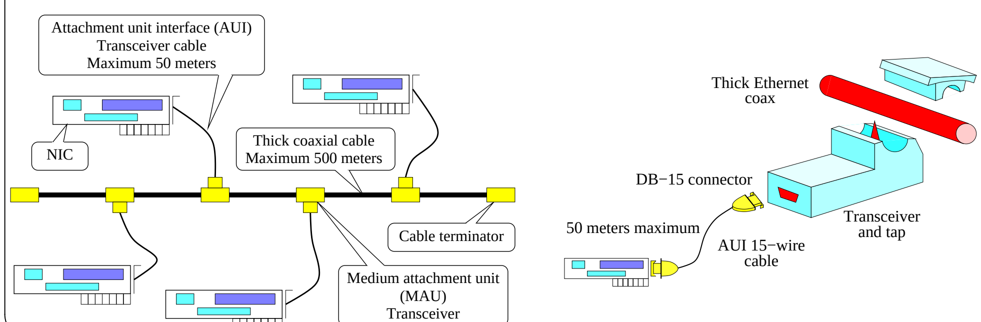
- Twisted-pair:
  - Not practical in shared bus at higher data rates.
- Baseband coaxial cable:
  - Used by the original Ethernet and IEEE 802.3 systems.
  - Only medium to achieve widespread use.
- Broadband coaxial cable:
  - Included in 802.3 specification but no longer made.
- Optical fibre:
  - Expensive, difficulty with availability, not commonly used.
- Few new bus LAN installations:
  - Replaced by star based twisted-pair and optical fibre.

Baseband Coaxial Cable

- Uses digital signalling:
  - Manchester or Differential Manchester encoding.
- Entire frequency spectrum of the cable used (baseband):
  - A single channel on the cable.
- Bi-directional transmission over a few kilometer range.
- Original used for Ethernet (basis for 802.3) at 10Mbps.
- 50-ohm cable - less reflections and noise than CATV 75-ohm cable.



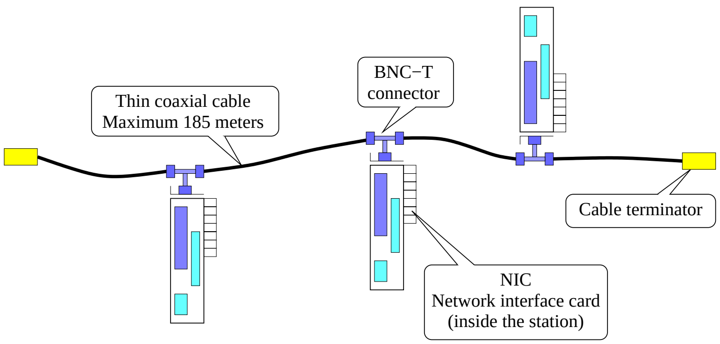
- Ethernet and 802.3 originally used 0.4 inch diameter cable at 10 Mbps.
- Max cable length 500m, and the distance between taps a multiple of 2.5m:
  - Ensures that reflections from taps do not add in phase.
- Maximum of 100 taps.



10base2

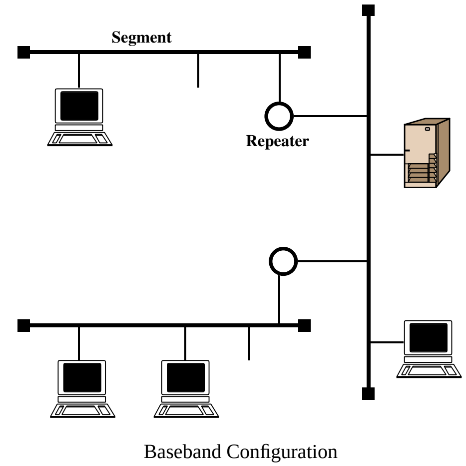
10 Mbps | Baseband | 185 meters

- Cheapernet using a thinner 0.25 inch cable.
- More flexible; Easier to bring to workstation; Cheaper electronics.
- Greater attenuation; Lower noise resistance; Fewer taps (30); Shorter distance (185m).



Repeaters

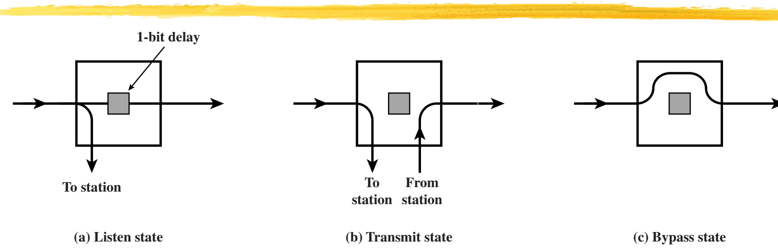
- Transmits in both directions.
- Joins two segments of cable.
- No buffering.
- No logical isolation of segments.
- If two stations on different segments send at the same time, packets will collide.
- Only one path of segments and repeaters between any two stations.



Ring LANs

- Each repeater connects to two others via unidirectional transmission links.
- Creates a 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



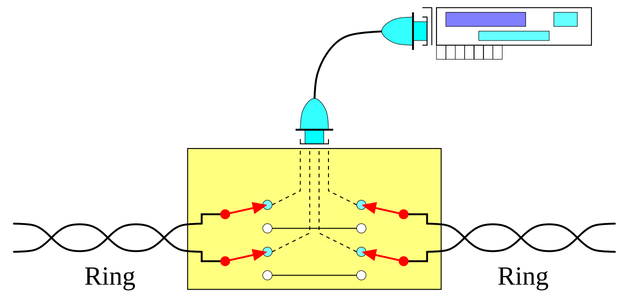
- Listen State Functions:
  - Scan passing bit stream for pertinent patterns:
    - Address of the attached station.
    - Token for permission to transmit.
  - Copy each incoming bit and send it to the attached station whilst forwarding each bit.
  - Modify a bit as it passes by:
    - e.g. to indicate a packet has been copied (acknowledgement).

Ring Repeater States

- Transmit State Functions:
  - Station has data to send.
  - Repeater has permission to transmit.
  - May receive incoming bits during transmission:
    - If the ring bit length is shorter than a packet:
      - Pass bits back to the station for checking (ACK).
    - May be more than one packet on the ring:
      - Buffer for retransmission later.
- Bypass State:
  - Signals propagate past repeater with no delay (other than propagation delay).
  - Partial solution to the reliability problem (see later).
  - Improved performance for inactive stations.

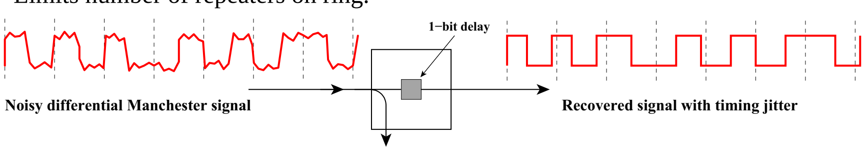
Ring Media

- Twisted-pair.
- Baseband coaxial.
- Fibre 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 each repeater:
    - To know when to sample signal and recover bits.
    - Use the clocking for retransmission to the next repeater.
  - Clock recovery deviates from the midbit transmission randomly:
    - Noise during transmission.
    - Imperfections in the receiver circuitry.
    - Known as timing jitter.
- Retransmission without distortion but with timing error.
- Cumulative effect is that bit length varies.
- Limits number of repeaters on ring.



Solving Timing Jitter Limitations

- Two solutions used in combination.
- Repeater uses phase locked loop:
  - Minimise 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

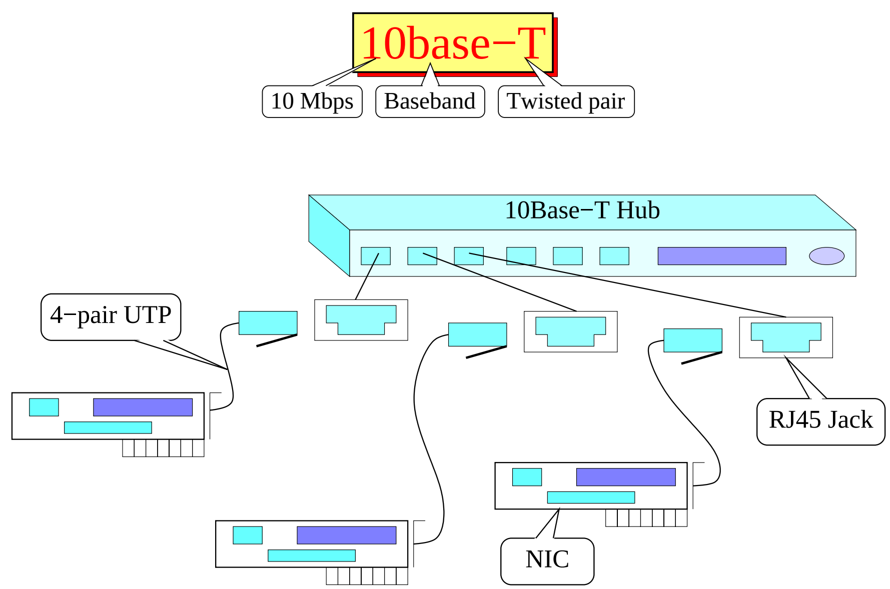
- Break in any link disables the network.
- Repeater failure disables the network.
- Installation of a new repeater to attach a new station requires the identification of two topologically adjacent repeaters.
- Timing jitter must be dealt with.
- Method of removing circulating packets required:
  - With 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.

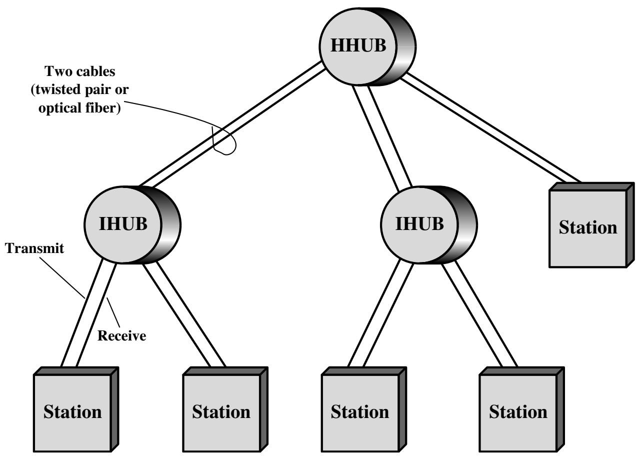
Star LANs

- Use unshielded twisted-pair wire (telephone):
  - Minimal installation cost:
    - May already be an installed base.
    - All locations in the building covered by an 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 (or fibre optic - up to 500m).
- Logical bus - with collisions.



Two Level Star Topology

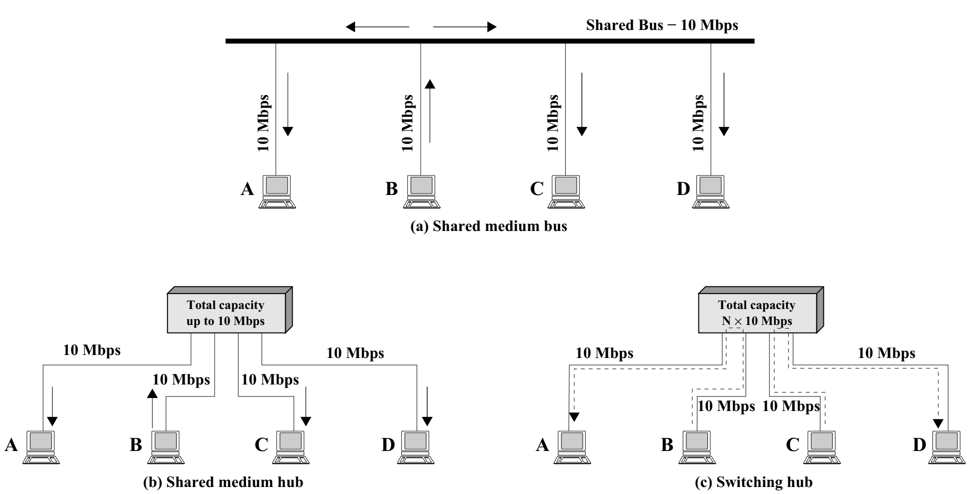
- One header hub (HHUB), and one or more intermediate hubs (IHUB).



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 LAN capacity is now 20Mbps.

Hubs and Switches Diagram



Switched Hubs

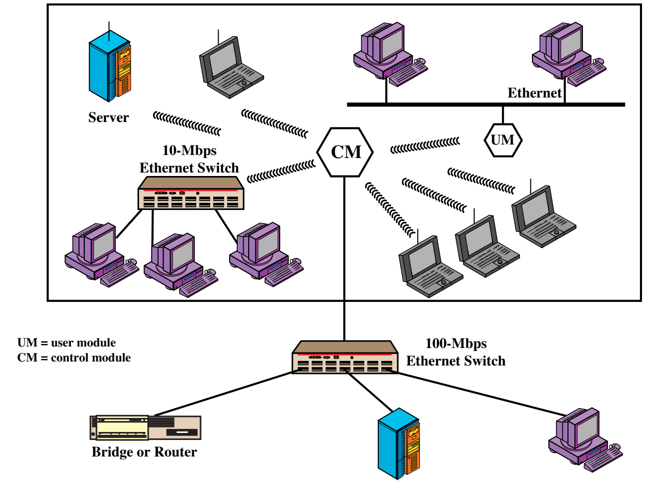
- No change to software or hardware of devices to change from shared to switched.
- Each device has dedicated capacity.
- Scales well.
- Two types of switching used:
  - Store and forward switch:
    - Accept input, buffer it briefly, then output.
  - Cut through switch:
    - Take advantage of the destination address being at the start of the frame.
    - Begin repeating incoming frame onto output line as soon as address recognised.
    - Highest possible throughput.
    - May propagate some bad frames (no CRC check performed).

Wireless LANs

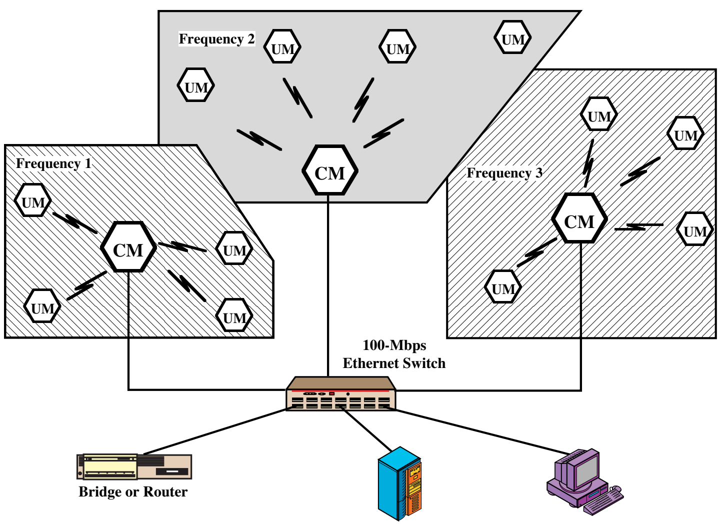
- Provide: Mobility, Flexibility, Coverage of hard to wire areas.
- Increased popularity: Reduced cost and improved performance of wireless systems.
- LAN Extension:
  - Buildings with large open areas (e.g. Manufacturing plants, Warehouses).
  - Historical buildings: may not damage building.
  - Small offices: wired less economical.
  - May be mixed with fixed wiring system (hence LAN extension).
  - Either a single-cell or multiple-cell wireless LAN.
- Cross building interconnection:
  - Point-to-point wireless link between buildings (e.g. Rural Monash Campuses).
  - Typically connecting bridges or routers.
  - Used where cable connection not possible (e.g. across a street).

Single Cell Wireless LAN

- Control module (CM) and User Module (UM).

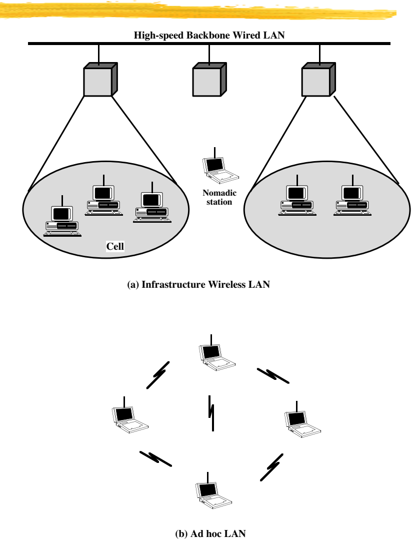


Multi Cell Wireless LAN



Wireless LAN Applications

- Nomadic access:
  - Between a LAN hub and mobile data terminal (e.g. laptop).
  - Transfer of data from laptop to server.
  - Campus or cluster of buildings.
- Ad hoc networks:
  - Peer-to-peer (no centralised server).
  - Temporary connection (e.g. conference).
  - Bluetooth standard.



Wireless LAN Configurations

Wireless LAN Requirements and Technology

- **Throughput:** MAC protocol should make efficient use of medium.
- **Number of nodes:** may need to support hundreds of nodes, multiple cells.
- **Connection to backbone:** using control modules that connect to both.
- **Service area:** typical coverage area of 100m to 300m diameter.
- **Battery power consumption:** MAC should limit monitoring and handshakes.
- **Transmission robustness and security:** permit use in noise insecure environment.
- **Collocated network operation:** avoid interference between LANs in the same area.
- **License free operation:** use wireless without paying for frequency band allocations.
- **Handoff/roaming:** be able to move from one cell to another.
- **Dynamic configuration:** automated addition, deletion and relocation of end systems.
- **Technology:** Infrared (IR), spread spectrum, narrow band microwave.

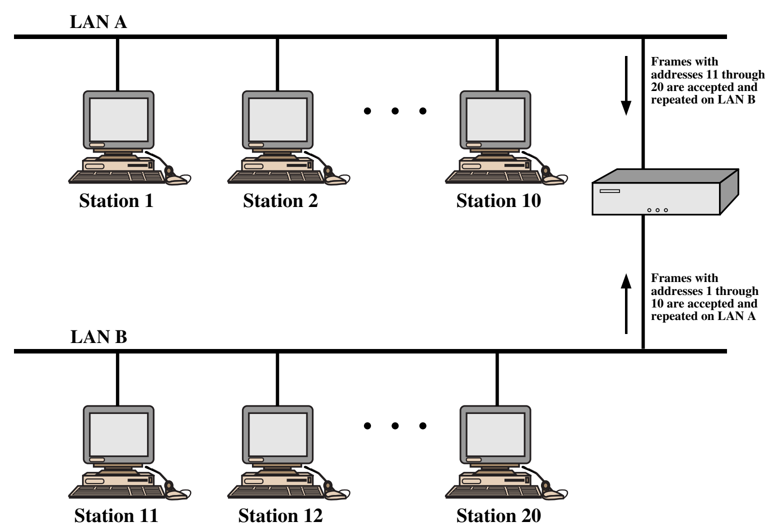
Bridges

- 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.
  - May use MAC format translation in more sophisticated bridges.
- Router more general purpose:
  - Interconnect various LANs and WANs.
  - Covered in higher layers of the protocol stack.

Use and Function of a Bridge

- Why use a bridge rather than one large LAN?
  - **Reliability:** A fault on the network may disable all devices. Partition network into self-contained units.
  - **Performance:** Reduce the number of devices on a single length of wire. Improved performance when intranetwork traffic exceeds internetwork traffic.
  - **Security:** Keep different levels of secure information on separate physical media.
  - **Geography:** Multiple LANs separated by geographical distances. May use a microwave bridge.
- Functions of a bridge:
  - Read all frames transmitted on one LAN and accept those address to any station on the other LAN.
  - Using the MAC protocol for the second LAN, retransmit each frame.
  - Do the same the other way round.

Bridge Operation



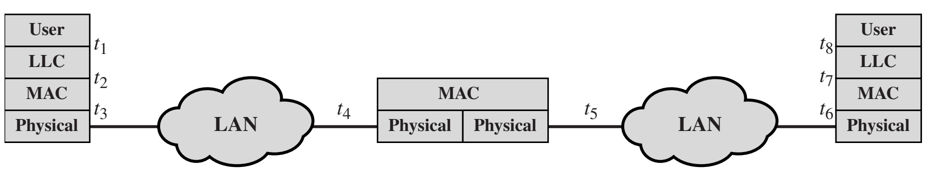
Bridge Design Aspects

- No modification to content or format of frame.
- No encapsulation.
- Exact bitwise copy of the frame from one LAN to the other.
- 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.

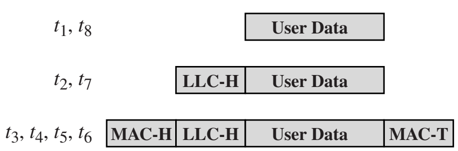
Bridge Protocol Architecture

- IEEE 802.1D defines the bridge protocol architecture.
- Function at the 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, packet-switched or point-to-point link.
  - Capture frame.
  - Encapsulate it.
  - Forward it across link.
  - Remove encapsulation and forward over LAN link.

Connection of Two LANs



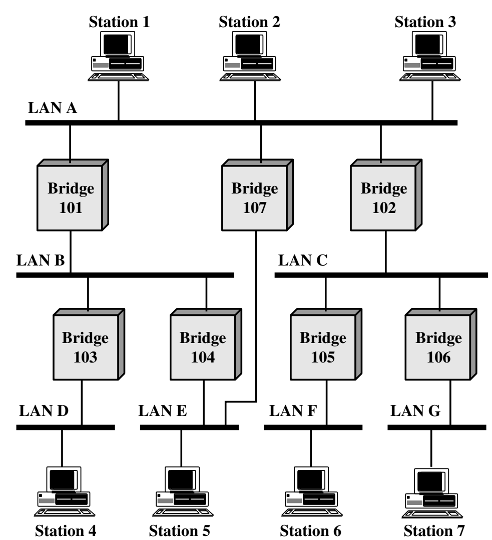
(a) Architecture



(b) Operation

Bridge Routing

- Complex large LANs need alternative routes:
  - Load balancing.
  - Fault tolerance.
- A bridge must decide:
  - Whether to forward a frame.
  - Which LAN to forward a frame on to.



Fixed Routing

- Routing selected for each source-destination pair of LANs:
  - Done in configuration (central routing matrix).
  - Usually least hop route is selected.
  - Only changed when the internet topology changes.

Spanning Tree

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

Frame Forwarding

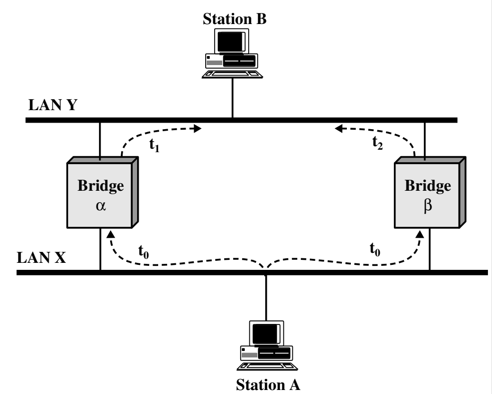
- Bridge maintains a forwarding database for each port:
  - List station addresses reached through each port.
  - E.g. Bridge 102: stations on C, F, and G on the LAN C side (6 and 7) and stations on A, B, D and E on the LAN A side (1 - 5).
- For a frame arriving on port X:
  - Search forwarding database to see if the MAC address is listed for any port except X.
  - If address not found, forward to all ports except X (learning process).
  - 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 into each bridge.
- Bridges can learn forwarding database.
- When frame arrives at port X, it has come form 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: entry removed when timer expires.
- 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 a unique identifier.
- Exchange between bridges to establish spanning tree.



Loop of Bridges

Further Reading

- **Stallings, W. Data and Computer Communications (6th Edition), Prentice Hall, 1999. Chapters 13.**
- Forouzan, B. Data Communications and Networking (2nd Edition), McGraw-Hill, 2001. Chapter 12.