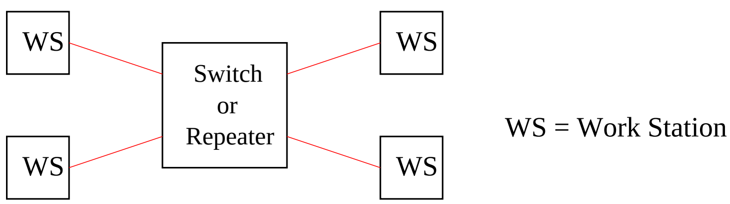
LOCAL AREA NETWORKS (LANs)

I) Topologies

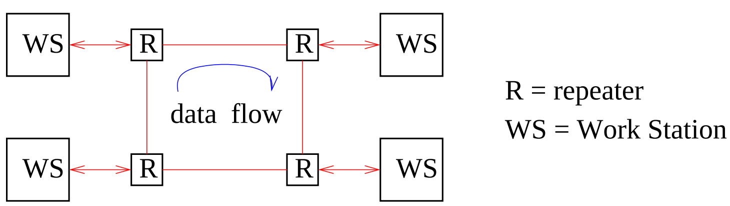
1. Star

- All communications are accomplished through the central network controller.



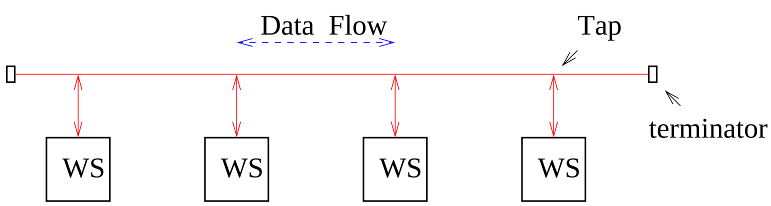
2. Ring

- The ring consists of a set of repeaters joined by point-to-point links in a closed loop.



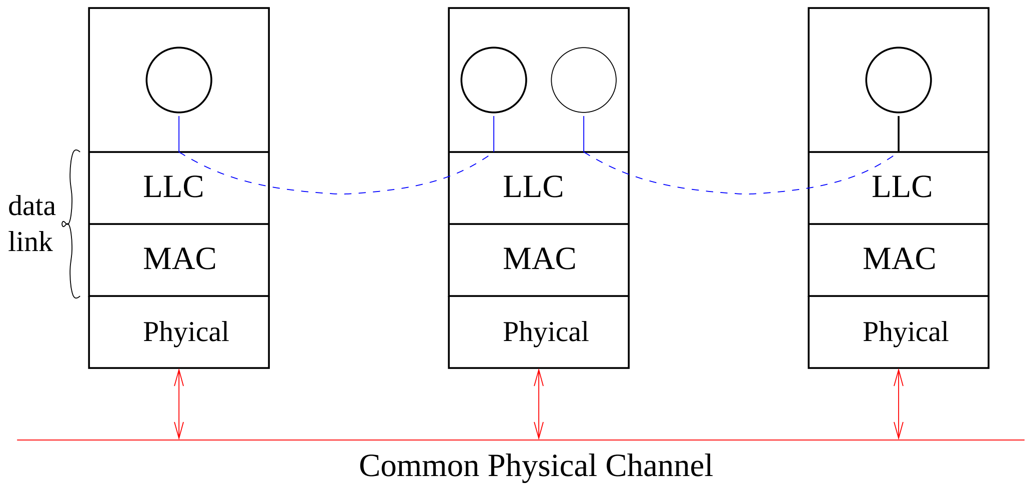
3. Bus

- The communications network is simply the transmission medium.



II) MAC and LLC sublayers

- In LAN, workstations are usually interconnected by a common channel.



- The Medium Access Control (MAC) layer deals with the access of the common channel.
- The Logical Link Control (LLC) layer deals with multiplexing, frame sequencing and retransmission.
- MAC layer provides connectionless service.
- LLC layer can provide both connection-oriented and connectionless services.

III) CSMA/CD

1. CSMA protocol

   - Carrier sense multiple access.
   - A station must first listen (sense) the channel before frame transmission.
   - If the channel is idle, it transmits.
   - If the channel is busy, it continues to listen. It transmits when the channel is found idle.
   - Collision may still occur within the first τ seconds of the transmission, where τ is the maximum signal propagation delay in the network.
   - Contention period = τ.
   - In LAN environment, $\tau \ll$ T.
   - Example:
     - LAN size = 1km.
     - average frame size = 10,000 bits.
     - channel bit rate = 10Mbps.
     - T = 10,000bits/10Mbps = 1ms.
     - τ = 1km/(2.0×10^5 km/s) = 5 μs.

2. <u>Collision Detection (CD)</u>

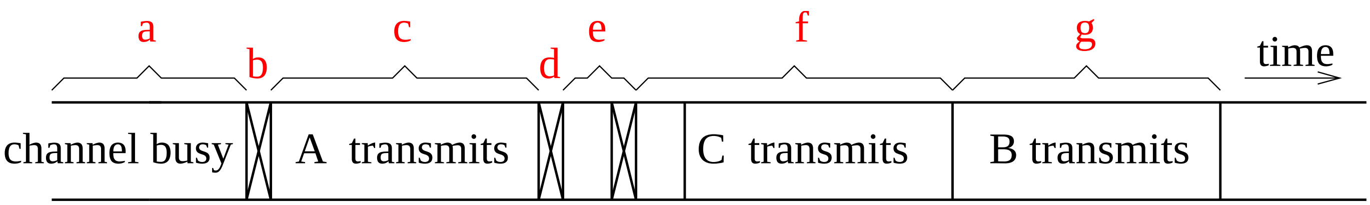
- The transmitting station continues to monitor the channel.
- If a collision is detected, it ceases transmitting and transmits a brief jamming signal.
- It then schedules a retransmission time using the binary exponential backoff algorithm.
  - Without collision detection, the channel remains unusable for T seconds after collision.
  - With collision detection, the wasted time is reduced to 2τ, which is the maximum time needed to detect collision.
- Binary exponential backoff
  - After the n^{th} consecutive collision, retransmission time is delayed by D second, where D is chosen randomly from the set:
$$\{0, 2\tau, 4\tau, ..., (2^k - 1)2\tau\}, k = \min[n, 10]$$
  - After 16 consecutive collisions, the MAC layer gives up and reports system error to the higher layer.
  - example:

$$\text{after the 1st collision, D} \in \{0, 2\tau\}.$$

after the 9th consecutive collision, D $\in \{0, 2\tau, 4\tau, ..., (2^9-1)2\tau\}$.

after the 13th consecutive collision, D $\in \{0, 2\tau, 4\tau, ..., (2^{10}-1)2\tau\}$.

3. Example



(a) Stations A, B and C are waiting for transmission.

(b) All three stations sense an idle channel and transmit. Collision results.

(c) Each station runs a binary exponential backoff algorithm:

- Station A chooses 0, stations B and C choose 2τ.

A transmits successfully.

(d) Stations B and C transmit after station A has finished transmitting. Collision results.

(e) Binary exponential backoff: B chooses 2τ and C chooses 2τ. Another collision.

(f) Binary exponential backoff: B chooses 6τ, C chooses 2τ. C transmits successfully.

(g) B transmits after C has finished.

4. Frame Format

- Basic frame format:

1	6	6	2	<1500	optional	4	(octets)
SFD	destination address	source address	length (type)	data	pad	FCS	

- IEEE 802.3 frame contains LLC header to provide the type field.

  – IEEE 802.2 (SAP)

  SAP=0x06 $\rightarrow$ IP;   SAP=0xE0 $\rightarrow$ IPX.

1	1	1		(octets)
Destination SAP	Source SAP	Control	Information	

  – IEEE 802.2 (SNAP)

  OUI = 0x000000 $\rightarrow$ Ethernet

$$\text{Type} = \begin{cases} \text{0x0800} & \rightarrow \quad \text{IP} \\ \text{0x8035} & \rightarrow \quad \text{RARP} \\ \text{0x8137-0x8138} & \rightarrow \quad \text{IPX} \\ \quad\quad\quad\quad . & \\ \quad\quad\quad\quad . & \\ \quad\quad\quad\quad . & \end{cases}$$

1	1	1	3	2		(octets)
AA	AA	03	OUI ID	Type	Information	

5. Maximum Throughput and Minimum Frame Length

- Maximum normalized throughput
  - $\rho = \frac{T}{T+\bar{N}\cdot 2\tau}$,
    $\bar{N}$ == mean number of collisions for one successful transmission.
    For optimal case, $\bar{N} \approx e$:
    $$\rho \approx \frac{1}{1+2ea}.$$
  - Increase the size of the network –> ρ decreases.
  - Increase the bit rate (R_b) –> ρ decreases.
- Minimum frame size
  - To guarantee that a collision can be detected by the sending station.
  - Frame size $\geq\ 2\tau R_b$.

6. 10-Mbps Ethernets

- 10BASE-T, star configuration;
- 10BASE-5, thick coaxial cable, maximum length = 2.5 km;
- 10BASE-2, thin coaxial cable, maximum length = 1 km.
- minimum frame size = 64 bytes.

7. 100-Mbps Ethernet (Fast Ethernet)

- Star configuration.
- Twisted pair: Maximum cable length = 100 m.
- Optical fiber: 2 km.
- $\tau = 5.12\mu s \rightarrow$ minimum frame size = 64 bytes.

8. Full Duplex Operation

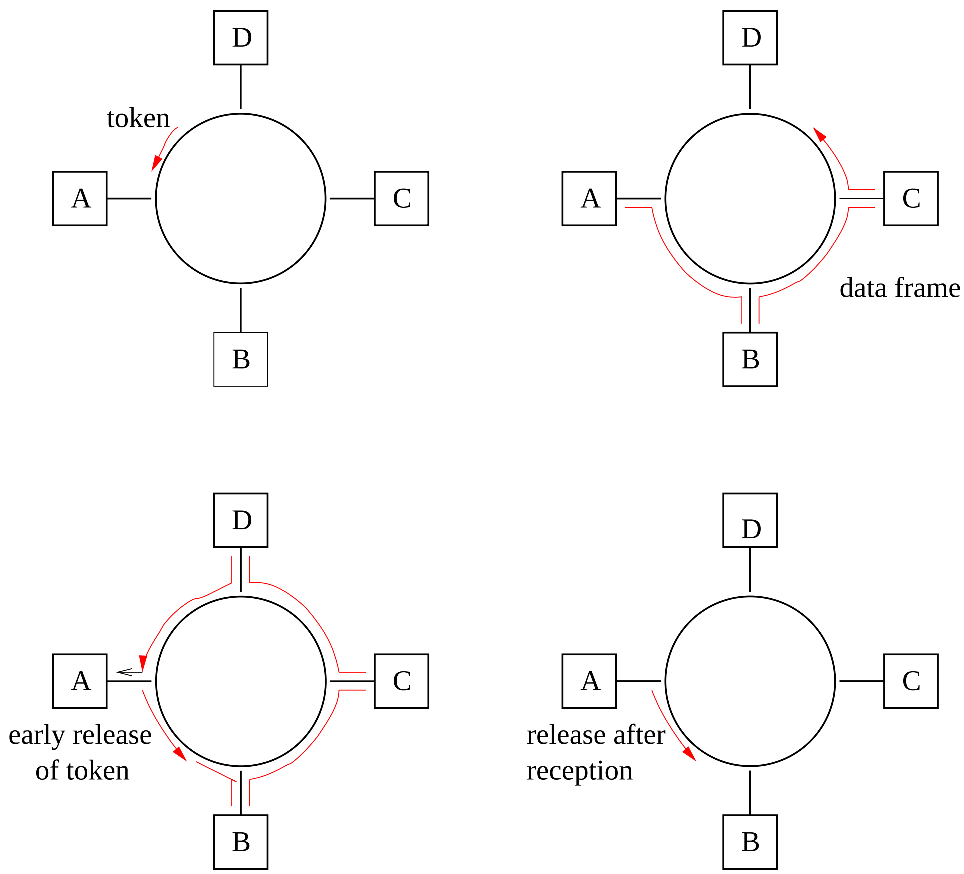
- CSMA/CD algorithm is disabled.
- Devices at each end of a full duplex link can send and receive data simultaneously over the link.
- Star topology: the central hub is a switch.
- Pause protocol is used for flow control over the link.
- Autonegotiation: automatically negotiate the best speed and duplex mode of opera tion.

9. High-speed Ethernet

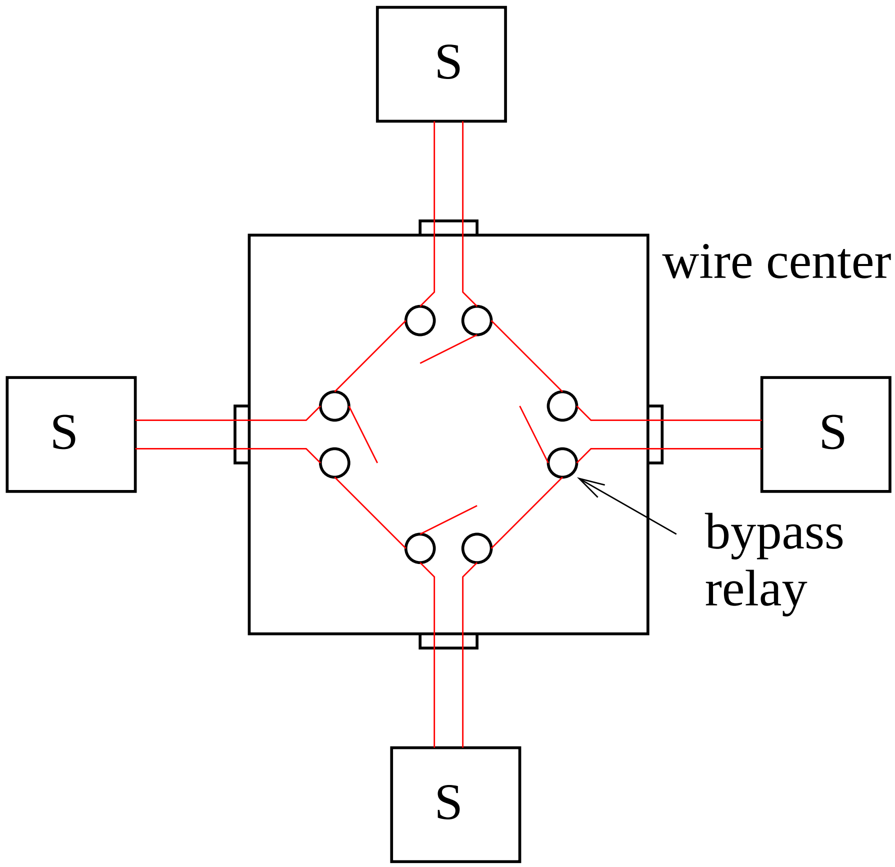
- Full Duplex Operation.
- Gigabit Ethernet: maximum distance = 5 km.
- 10-Gigabit Ethernet: maximum distance = 40 km.

IV) Token Ring

1. Basic protocol



2. Actual configuration



- Loss of the drive current due to the ring break or the crash of a station will release the relay and bypass the trouble area.

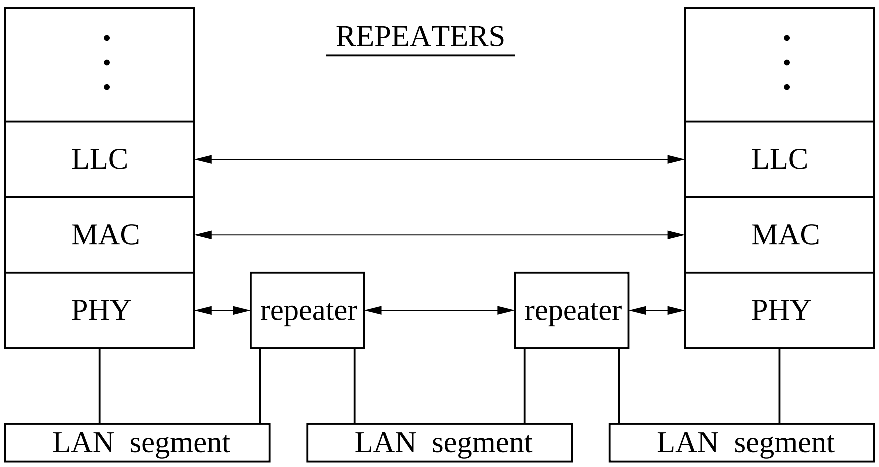
3. Frame Format

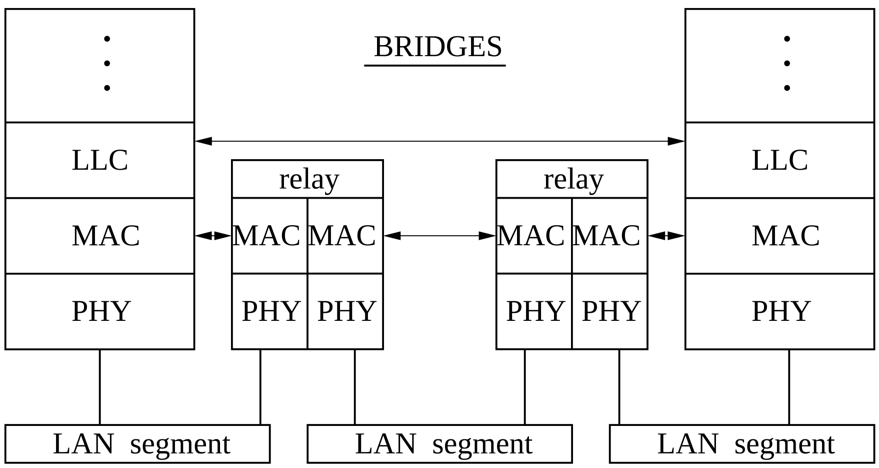
1	1	1	2/6	2/6	< 5000	4	1	1	(octets)
SD	AC	FC	DA	SA	information	FCS	ED	FS	

V) Bridges

1. Basic Operations

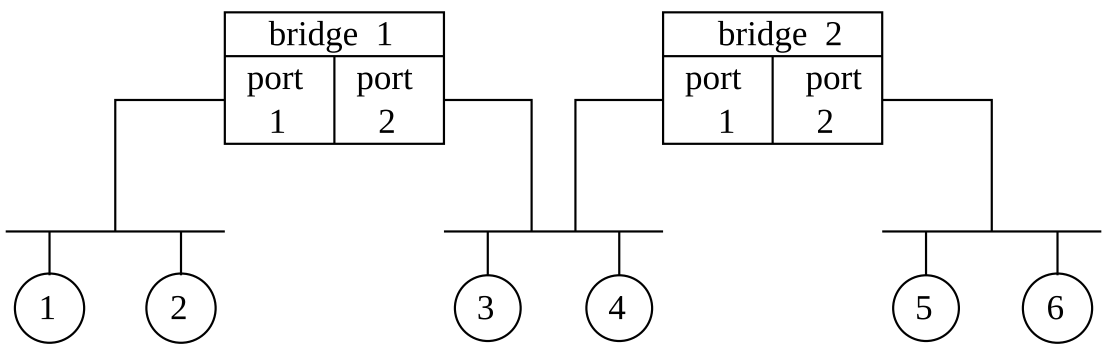
- Store and forward frames between LANs.
- Protocol conversion at the MAC layer.
- Create separate collision domains.



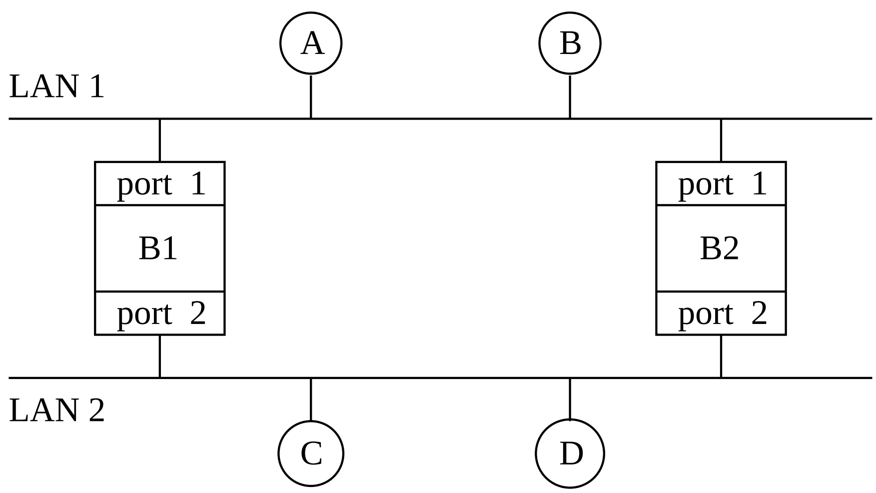


2. Transparent Bridges

- The presence of one (or more) bridge(s) in a route between two end stations is (are) transparent to the two stations.
- All the switching decisions are made by the bridge(s).
- Basic operation:
  - Promiscuous mode - all the passing frames are inspected.
  - If the destination and the source of a frame are located at the same side of the bridge, the frame is quietly discarded.
  - If the destination is at the other side of the bridge, the frame will be delivered to that side of the bridge.
- Example:

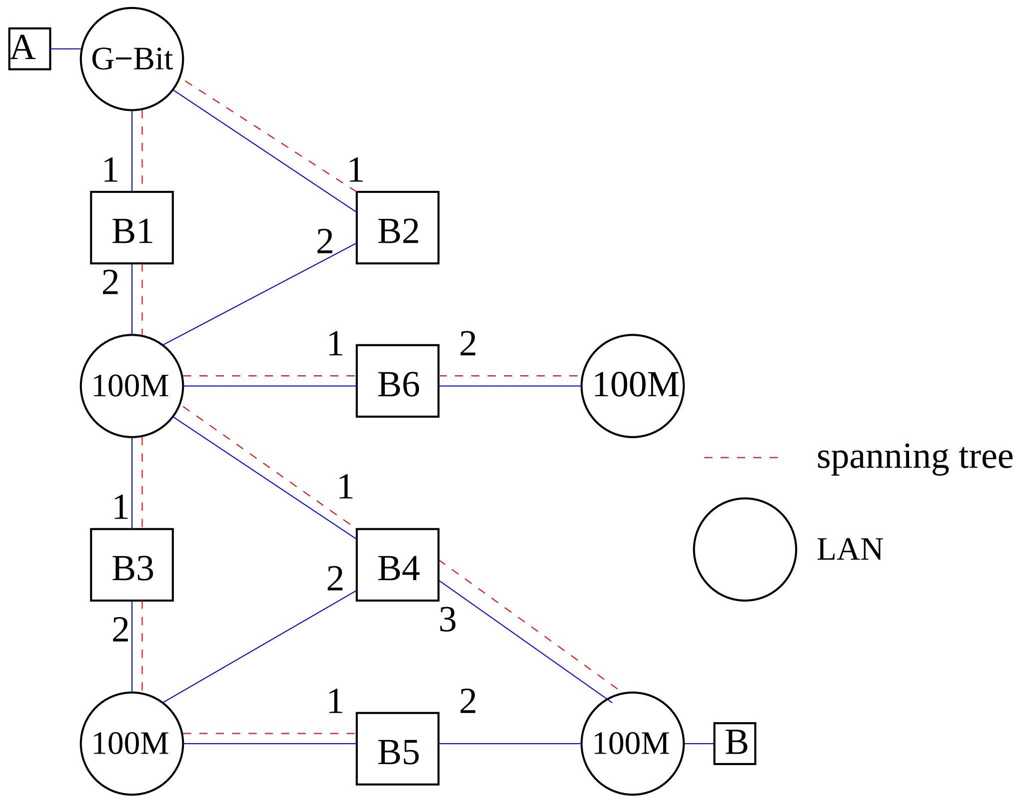


- Bridge Learning
  - The MAC table is setup dynamically. When a bridge is first powered up, its MAC table is empty.
  - Whenever a frame is received from a station that does not have an entry in the MAC table, the frame's address and the incoming port number on which the frame is received are entered into the MAC table.
- If the destination of the frame is not known, the bridge will retransmit the frame to the other LANs that are attached to the bridge – flooding.
  - The flooding procedure creates looping if there are more than one path between two LANs:



  - Solution: overlays the actual topology with a spanning tree. Once the bridges have agreed on the spanning tree, all forwarding between LANs follows the spanning tree.

- Each entry of the MAC table will be removed if it is not used in a specified time interval
  - to allow the stations move around the network;
  - to reduce the size of the MAC table, thus improving the processing time.
- Example:



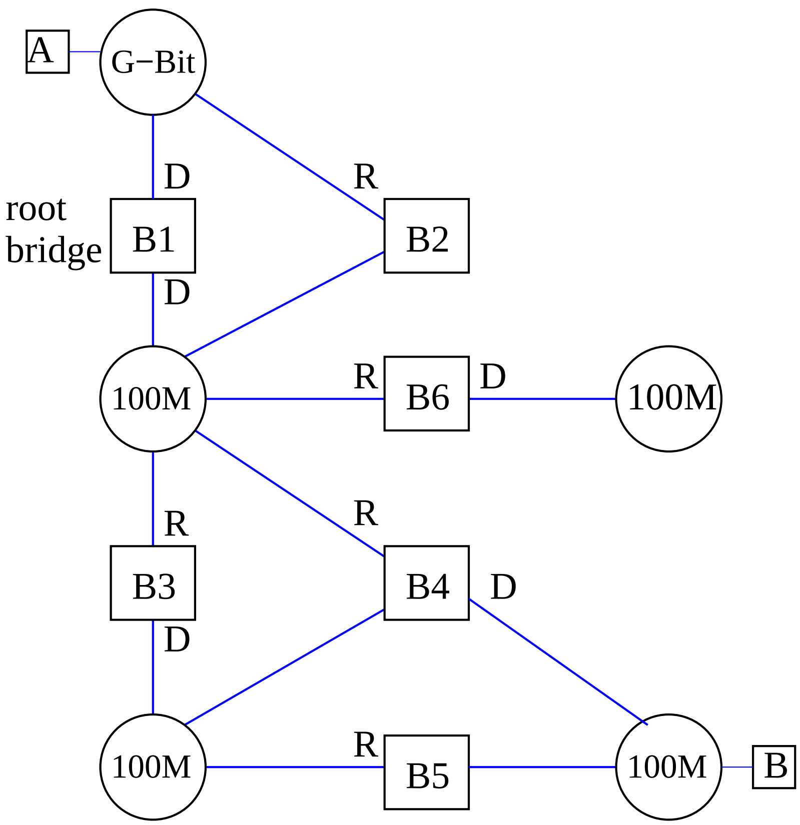
After first frame sent by A

	B1	B2	B3	B4	B5	B6
A	1	1	1	1	1	1

After first frame sent by B

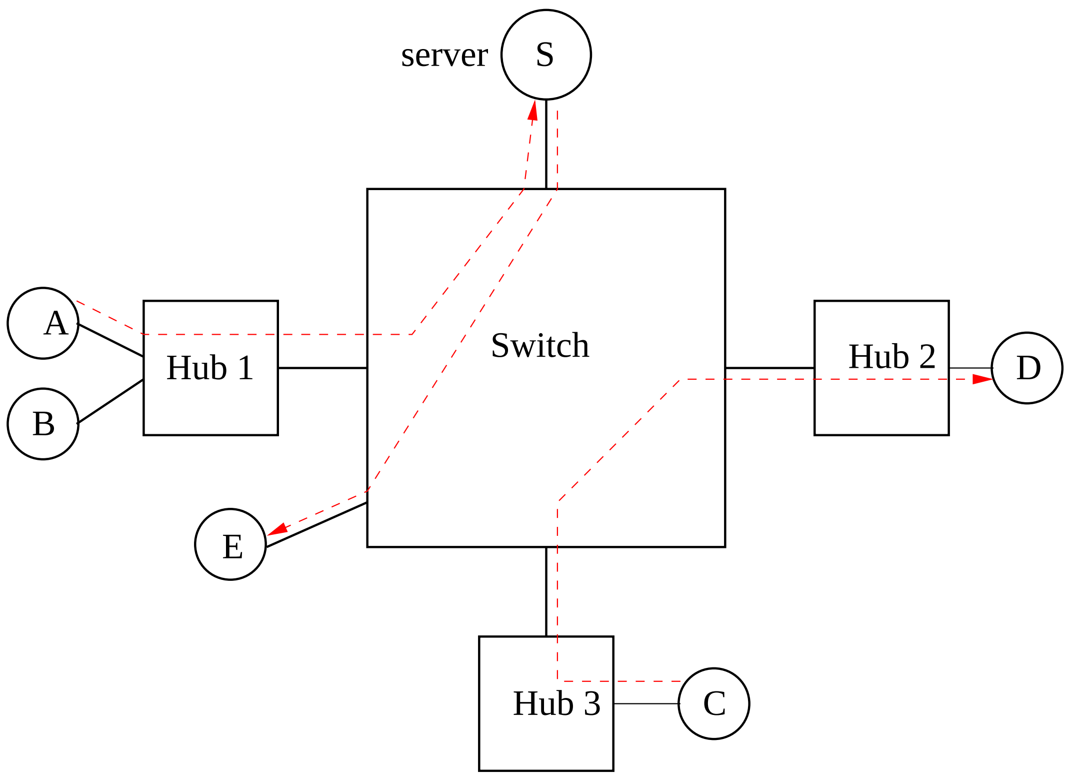
	B1	B2	B3	B4	B5	B6
A	1	1	1	1	1	1
B	2	1	1	3		1

- Spanning-Tree Algorithm:
  - Bridges exchange BPDUs.
  - Elect a root bridge.
  - Elect a root port for each nonroot bridge.
  - Elect a designated port per LAN.
  - Only the root ports and the designated port can forward data, other ports are in blocking state.



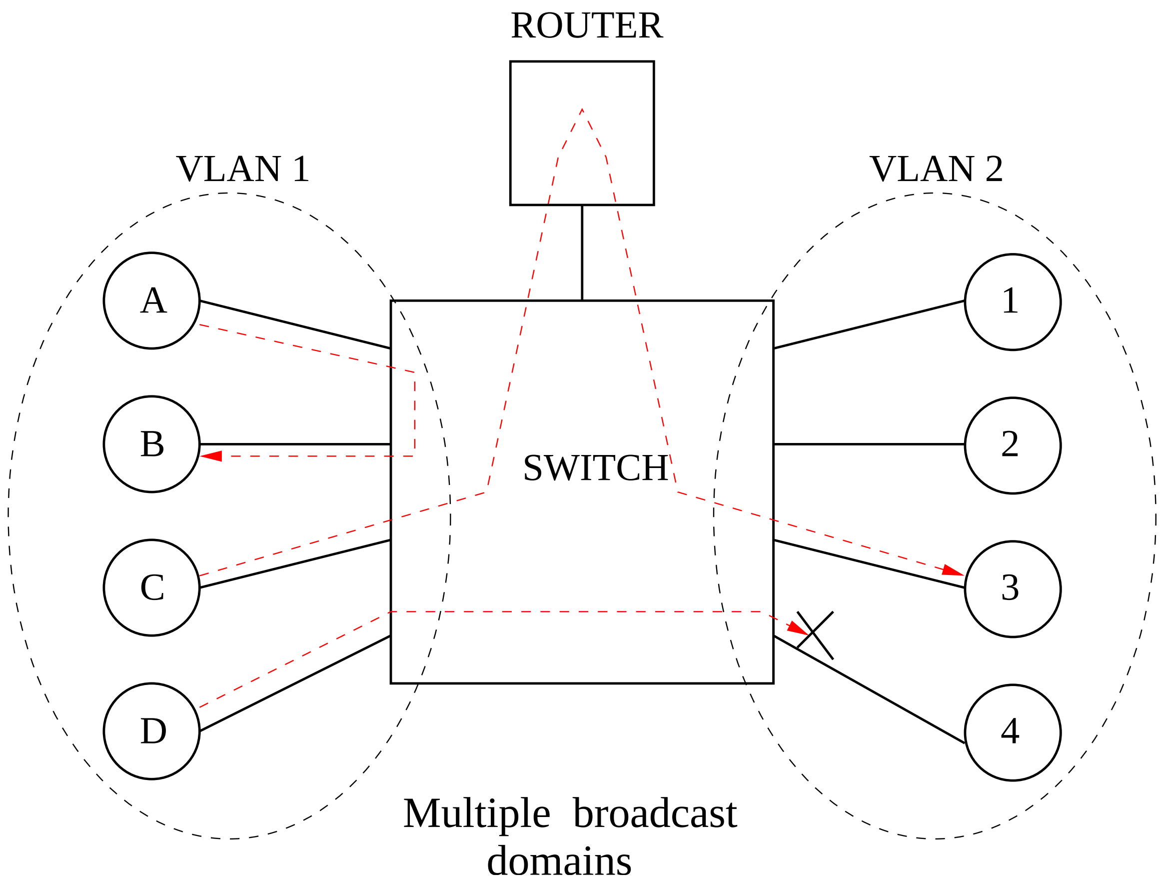
3. <u>Ethernet switch</u>

- Switch – high-speed multiport bridge.



- Full Duplex Operation.
- Partition a LAN into multiple collision domains.

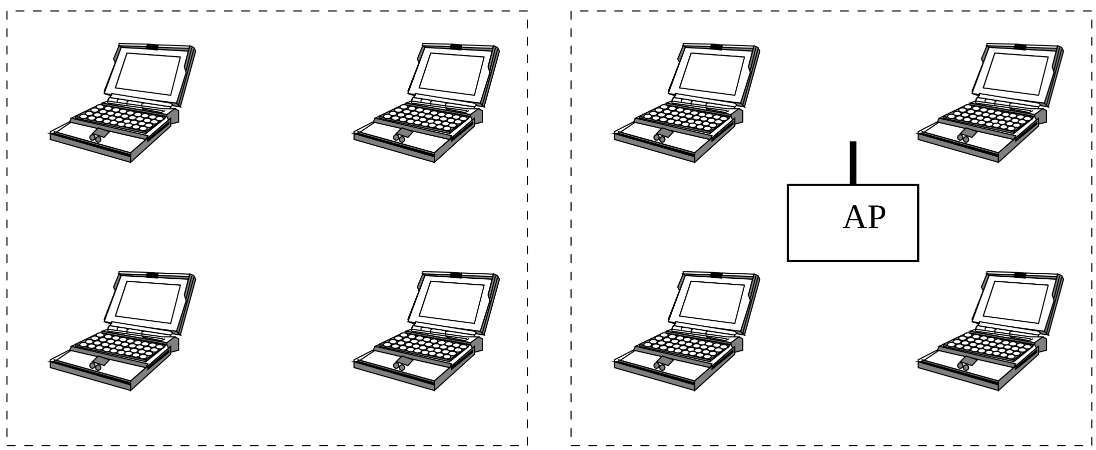
- Virtual LAN (VLAN)
  - Each VLAN is a logical broadcast domain.
  - Routers are required for the communication among VLANs.



VI) Wireless LAN - IEEE 802.11

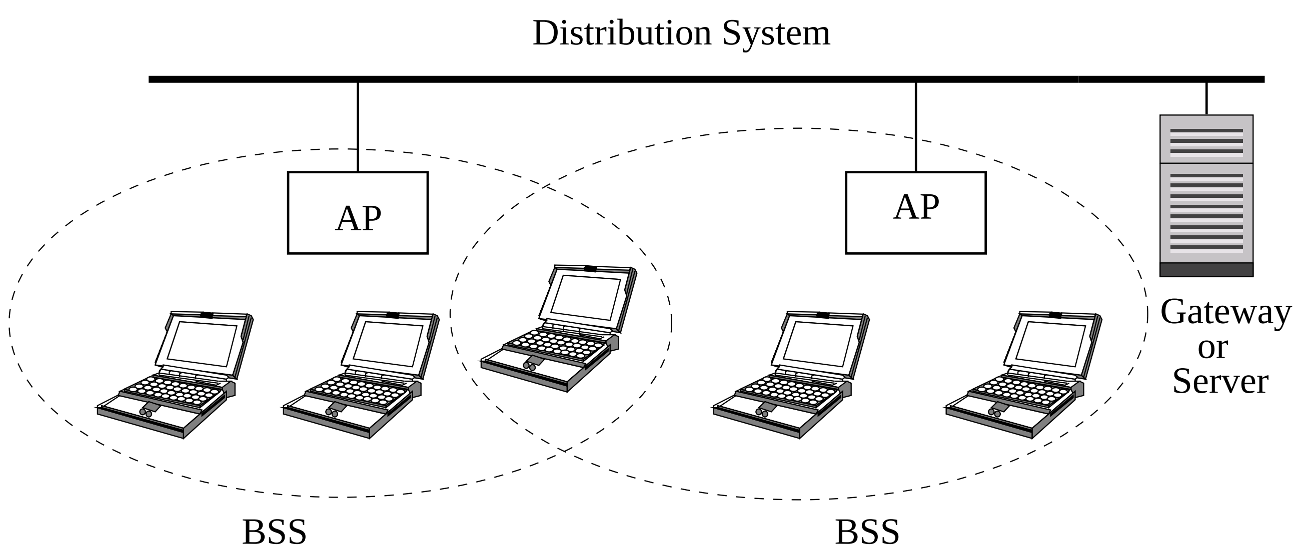
1. Wireless LAN building blocks

- Basic Service Set (BSS):



BSS without AP (ad hoc network) BSS with AP

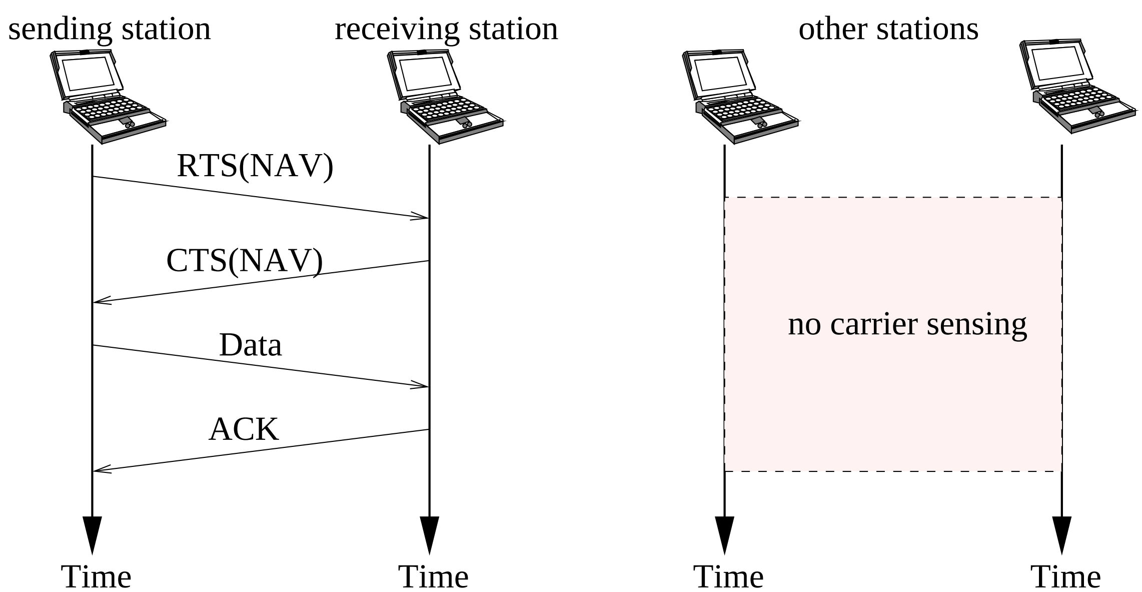
- Extended Service Set (ESS).



Extended Service Set

2. Medium Access Control

- Point Coordination function (PCF).
  - Based on polling performed by AP.
- Distributed Coordination function (DCF).
  - Based on CSMA/CA.
  - CSMA is used for medium access.
  - Acknowledgement mechanism is used to detect collision.
  - RTS/CTS mechanism is used for collision avoidance



– Protocol flow chart for the sending station: