



# Computer Networks

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## Chapter 2. Direct Link Networks

- Link Service and Framing
- Error Detection and Reliable Transmission
- HDLC, PPP, and SONET
- Token Ring
- Ethernet
- Bridges and Layer-2 switch
- Wireless Networks
- Network Performance



# **Bridges and Layer-2 switch**



# Bridges and Layer-2 switch

- Ability to **expand beyond single LAN**
- Provide interconnection to other LANs/WANs

**Bridge** is used (later Layer-2 switch)

- Connects **LANs**, usually **more than two LANs**
- Identical protocols for physical and MAC layers
- Store, forward LAN frames
- **Exact bitwise copy** of frame
- Switch (route) functions needed

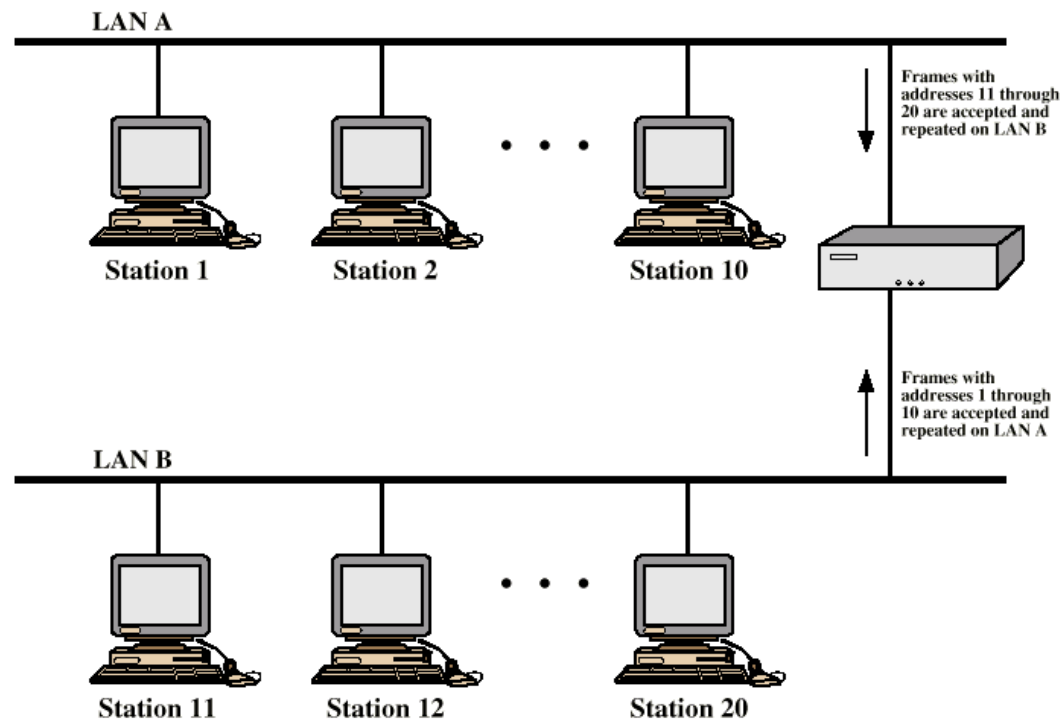


# Requirements of a Bridge

- Store and Forward
  - Read frames transmitted on one LAN, Examine frames' MAC address, **selectively store** those address to other LANs
  - Using MAC protocol of second LAN, **retransmit** each frame
- Transparent
  - Stations are unaware of presence of bridges
- Plug-and-play, self-learning
  - Bridges do not need to be configured



# Bridge Operation



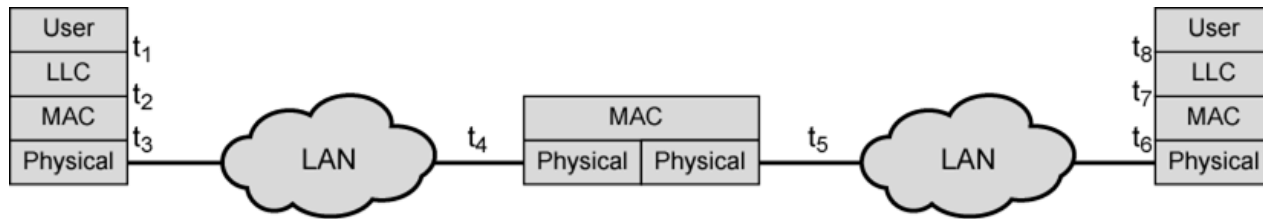


# Bridge Protocol Architecture

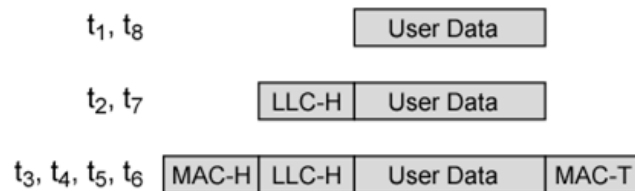
- IEEE 802.1D, MAC level
  - Use **MAC address** for switching
- Bridge does **not need LLC** layer
  - Relaying MAC frames
- Can pass frame **over external WAN or links**
  - Capture LAN frame, encapsulate it
  - Forward it across WAN (Wide Area Network) link
  - Remove encapsulation and forward over LAN link



# A Simple Connection of LANs



(a) Architecture



(b) Operation





# Routing for Bridges

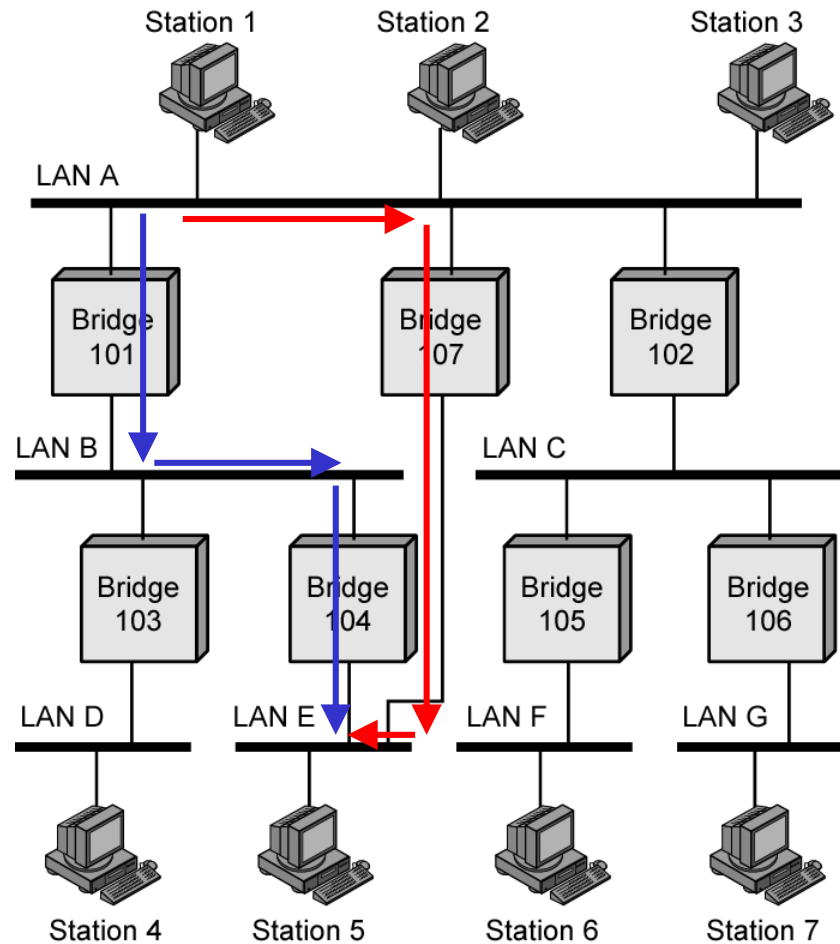
- Complex LANs configuration cause **alternative routes**
- Bridge must **decide (Switching)**
  - Whether to forward frame
  - Which LAN to forward frame on
- **Fixed routing** for each source-destination pair of LANs
  - Done in configuration
  - Station cannot be moved



# Bridges and LANs with Alternative Routes



1 → 5





# Mechanisms of a Bridge

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



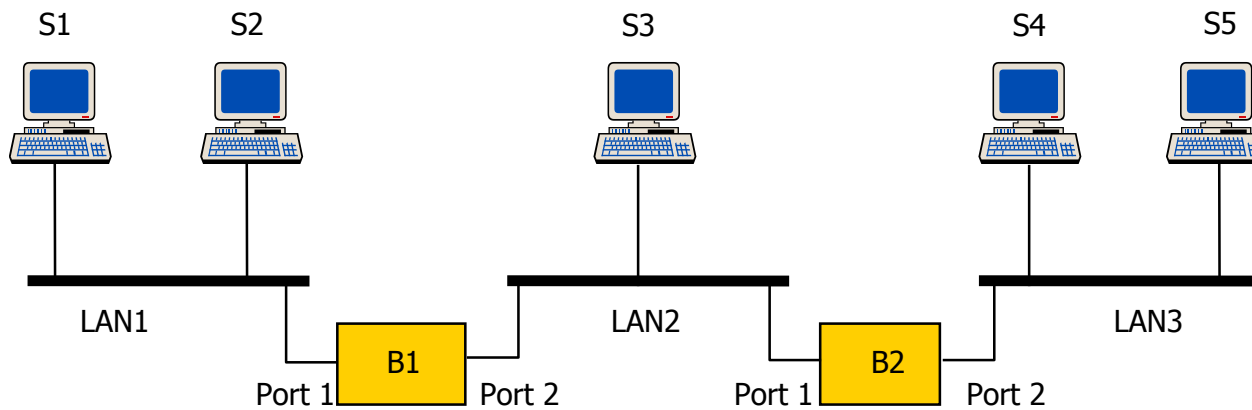
# Frame forwarding

- Maintain **forwarding database for each port**
  - <Mac Address, Port, Timestamp>: station addresses reached through each port
- For a frame arriving on **port X**
  - Search forwarding database to see if dest MAC address is listed for any port:
  - If address not found, **forward to all ports** (flooding) except X
  - If address listed for port X, drop it
  - If address listed for port Y, check port Y for **Blocking or Forwarding** state, transmit if **Forwarding state**
  - **Blocking** used to form a tree



# Address Learning

- 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, Entry deleted when timer is off
- Each time frame arrives, **source address checked** against forwarding database

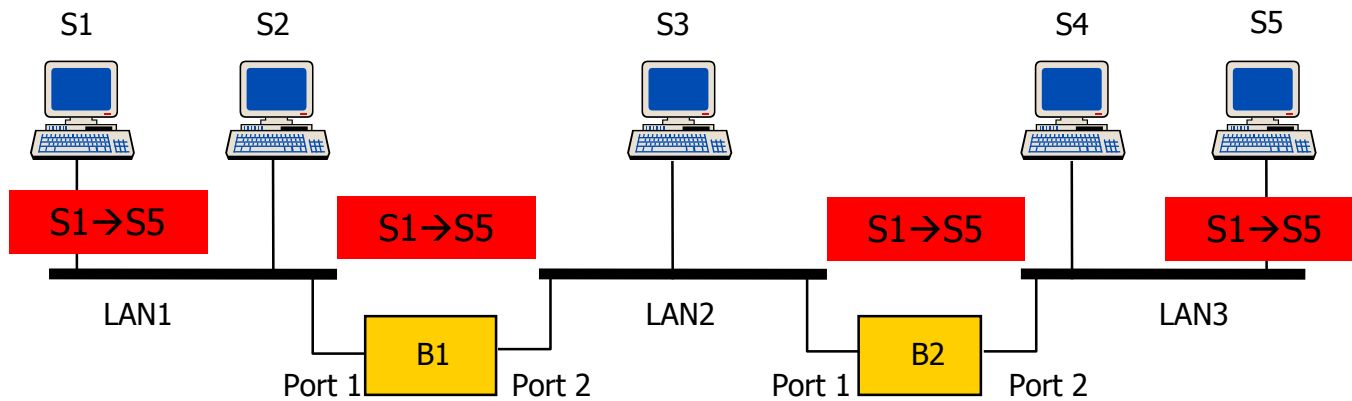


Address	Port

Address	Port



# S1→S5

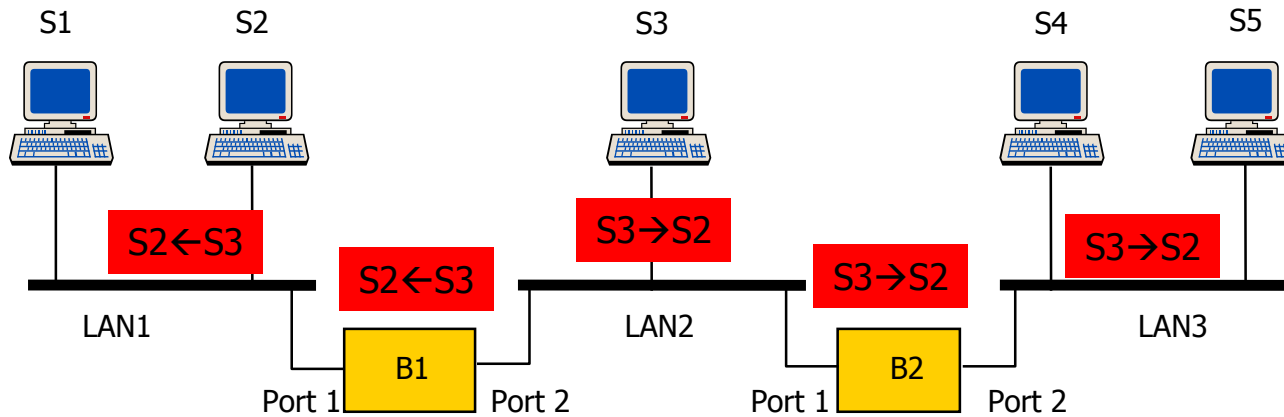


Address	Port
S1	1

Address	Port
S1	1



# S3→S2



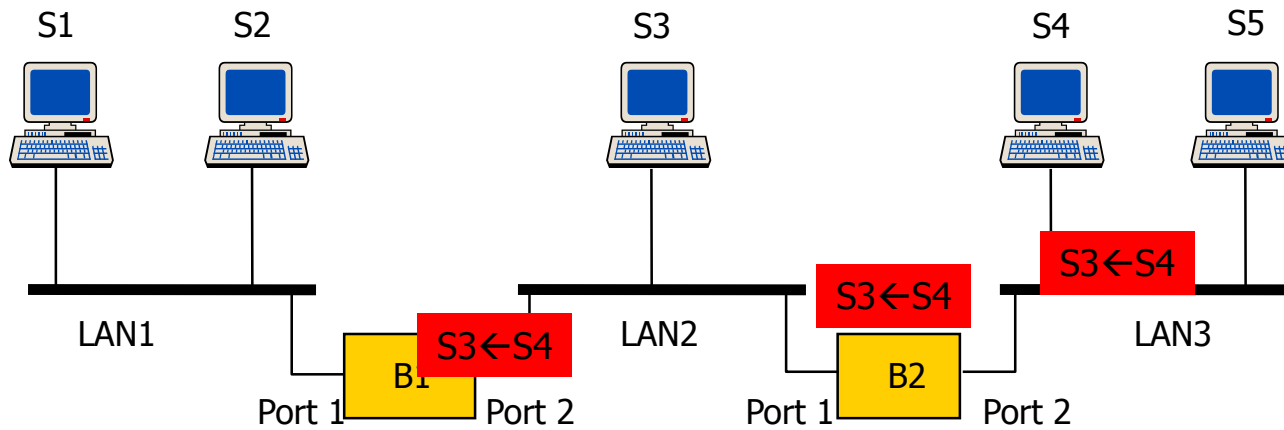
Address	Port
S1	1
S3	2

Address	Port
S1	1
S3	1





# S4→S3

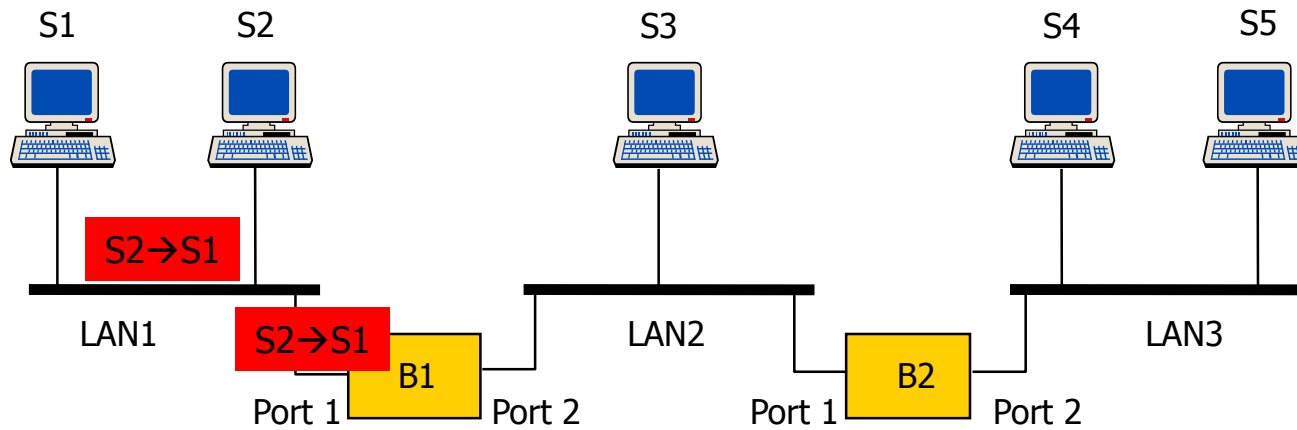


Address	Port
S1	1
S3	2
S4	2

Address	Port
S1	1
S3	1
S4	2



# S2→S1



Address	Port
S1	1
S3	2
S4	2
S2	1

Address	Port
S1	1
S3	1
S4	2

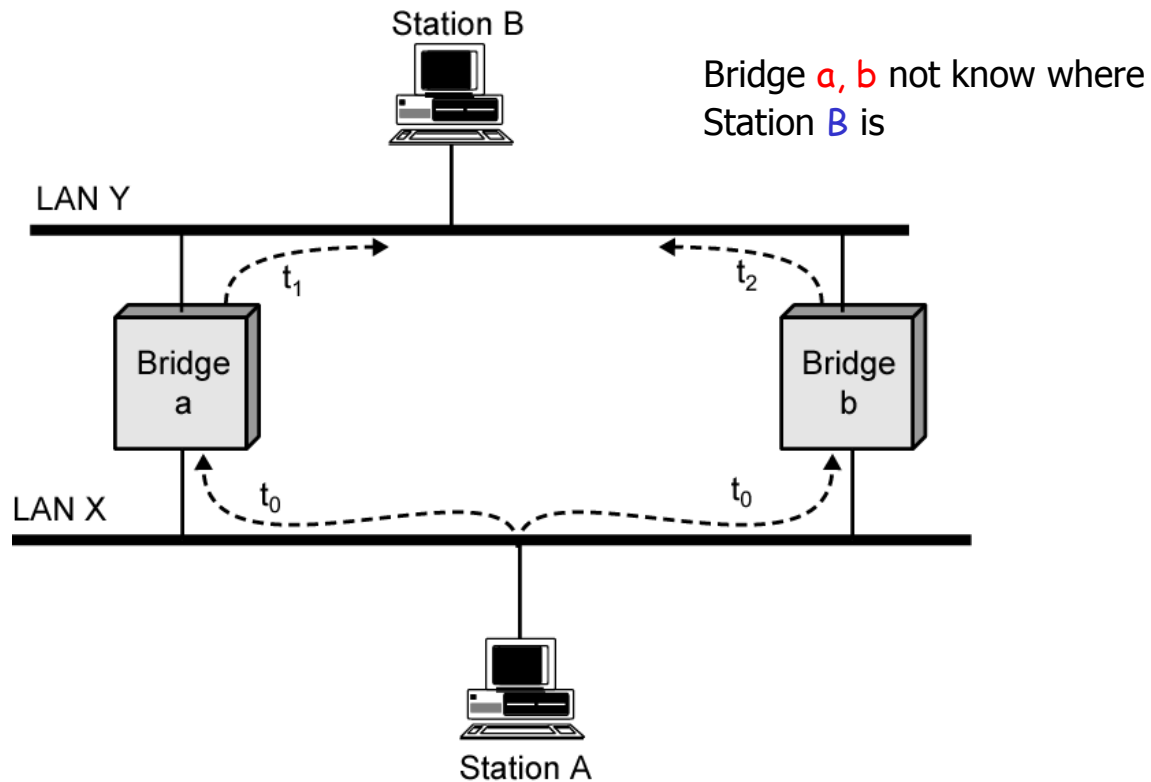


# Spanning Tree

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



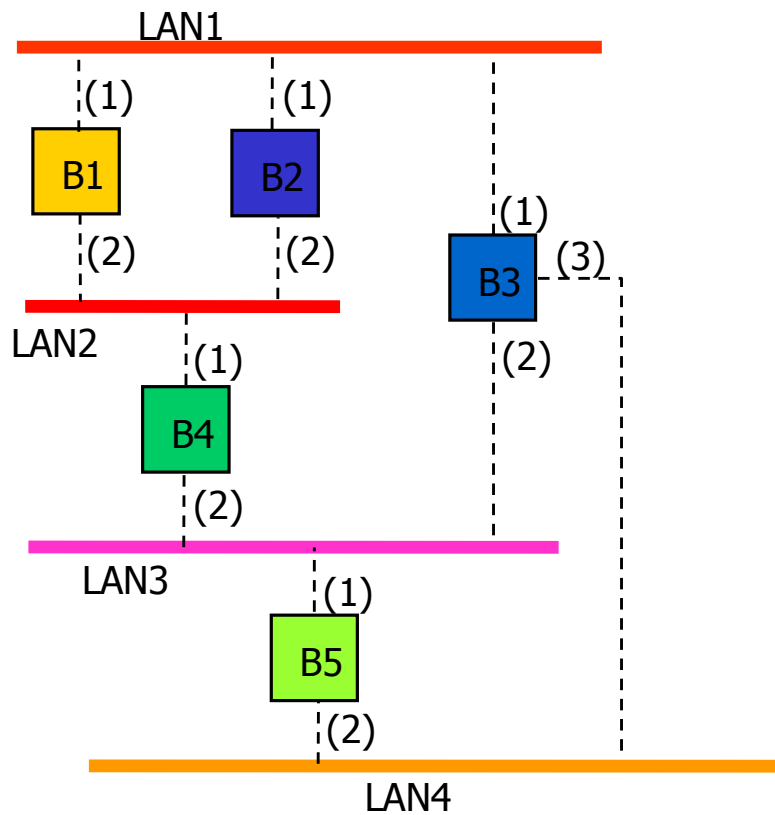
# Loop of Bridges

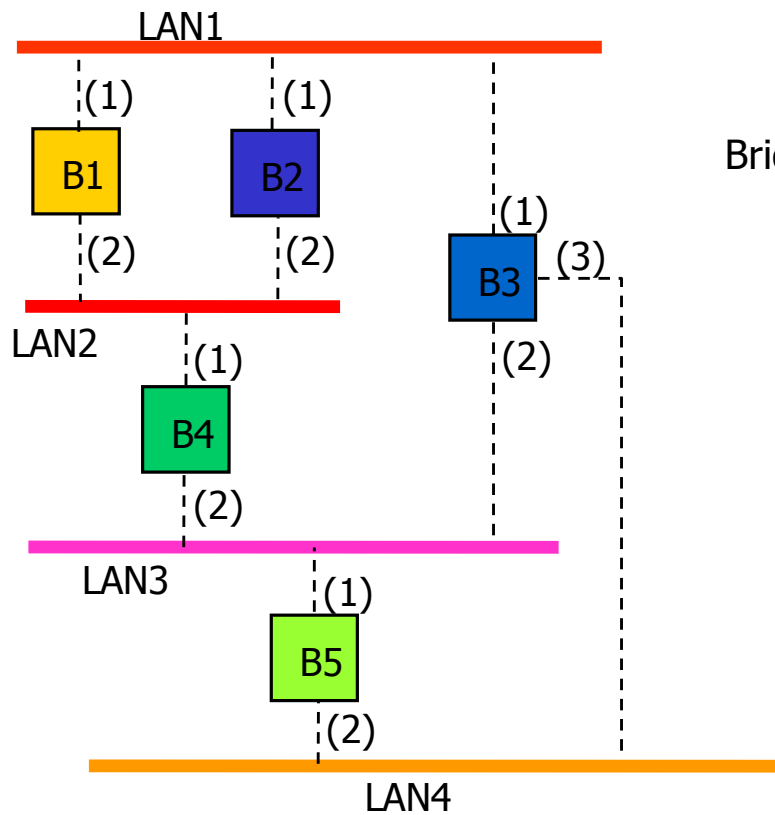




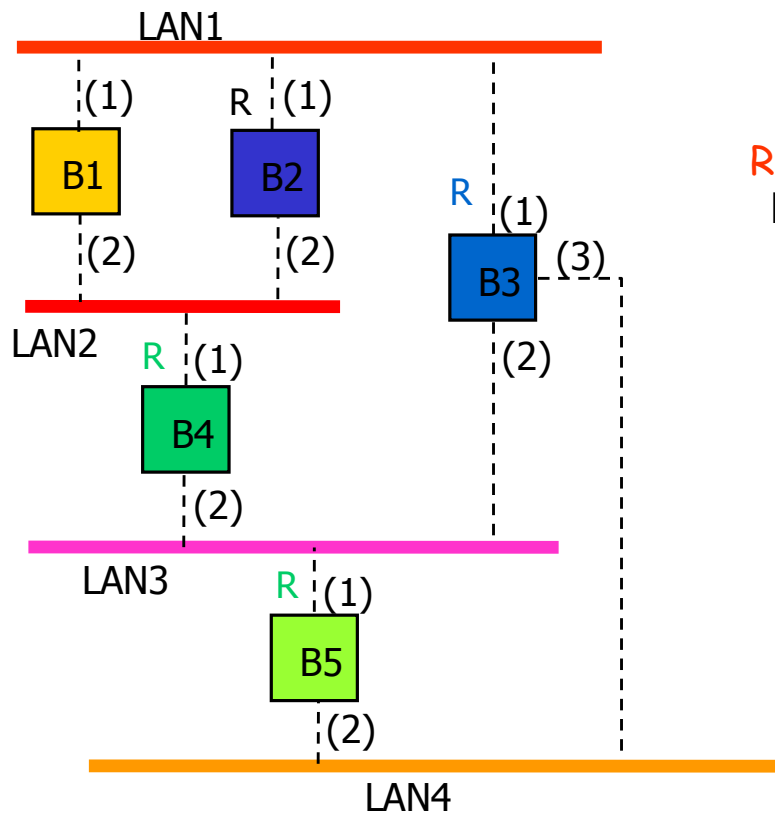
# The Algorithm

- Select a **root bridge** among all the bridges
  - Root bridge = the lowest bridge ID
- Determine the **root port** for each bridge except the root bridge
  - Root port = port with the least-cost path to the root bridge
- Select a **designated bridge** for each LAN
  - Designated bridge = bridge with the least-cost path from the LAN to the root bridge
- **Designated port** connects the LAN with the designated bridge
- All root ports and all designated ports are placed into a **forwarding** state
- The other ports are placed into a **blocking** state



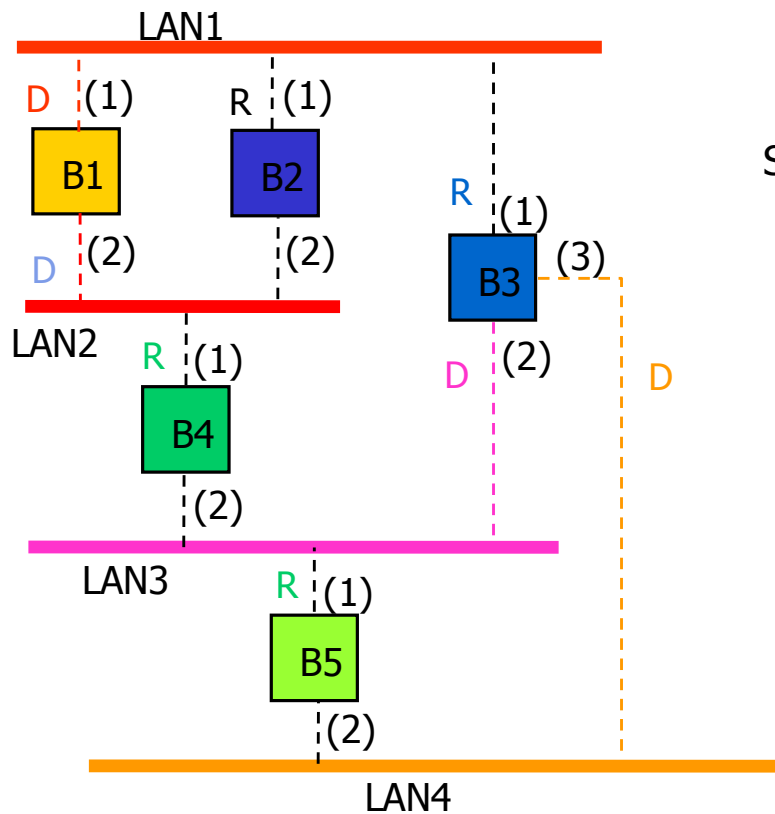


Bridge 1 selected as **root bridge**

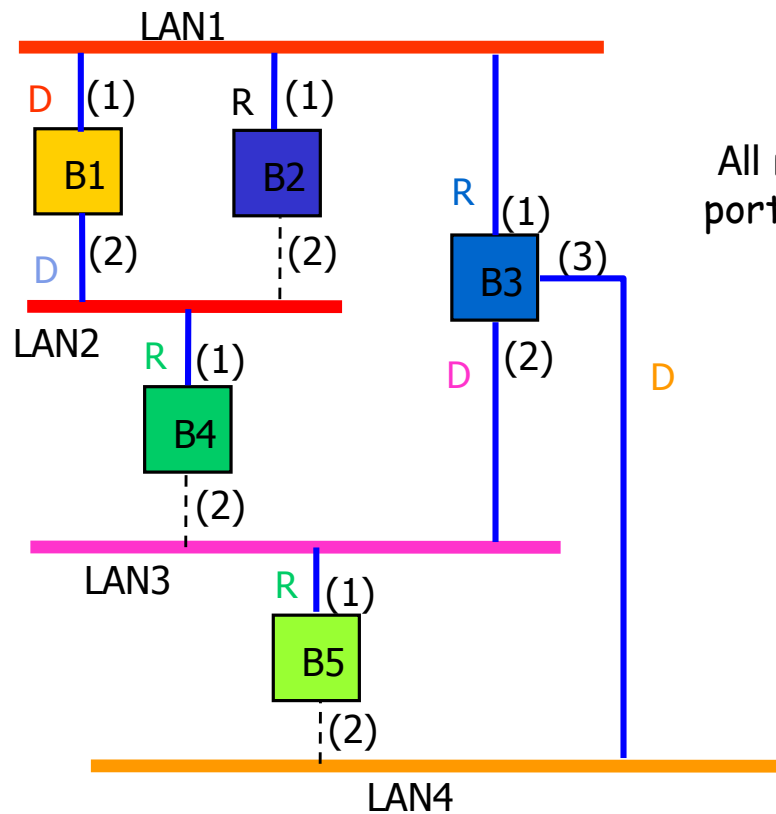


Root port selected for every bridge except root bridge





Select **designated bridge**  
for each LAN

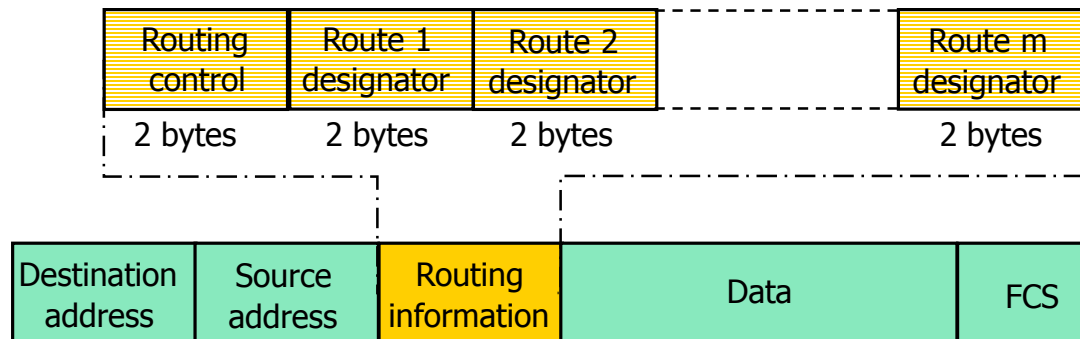


All root ports & designated ports put in **forwarding** state



# Source Routing Bridges

- To interconnect IEEE 802.5 token rings
- **The source station determines route** to destination
- Routing information inserted in frame





# Route Discovery

- For a **destination** each station broadcasts a **single-route broadcast frame**
- The frame visits every LAN once & eventually reaches **destination**
- Destination sends **all-routes broadcast frame** which generates all routes back to **source**
- **Source** collects routes & picks best



## Detailed Route Discovery (Source)

- Bridges must be configured to form a **spanning tree**
- Source sends **single-route frame** without route designator field
- Bridges in first LAN add **<incoming LAN #, bridge #, outgoing LAN #>** into frame & forwards
- Each subsequent bridge attaches **<bridge #, outgoing LAN #>**
- Eventually, **one single-route frame** arrives at destination

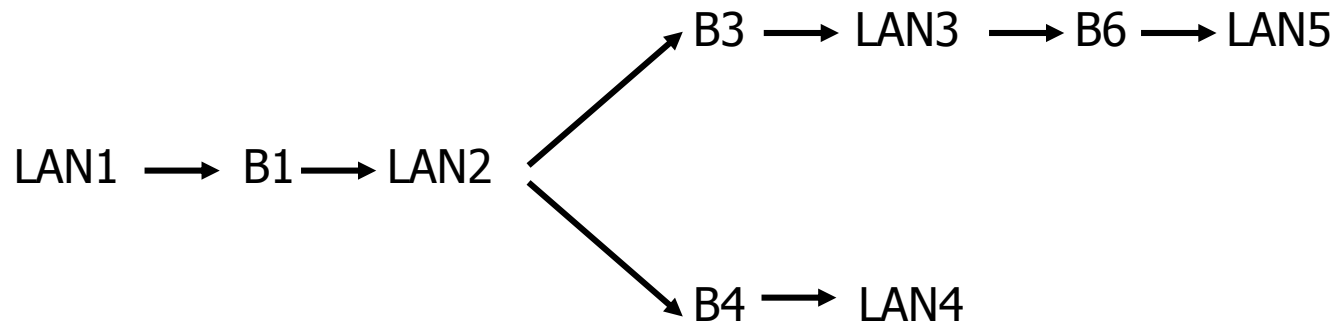
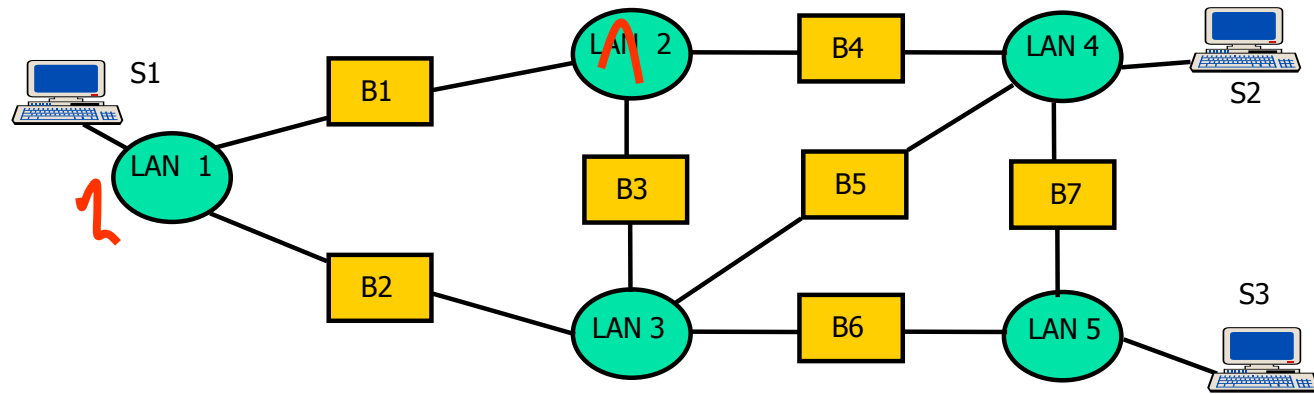


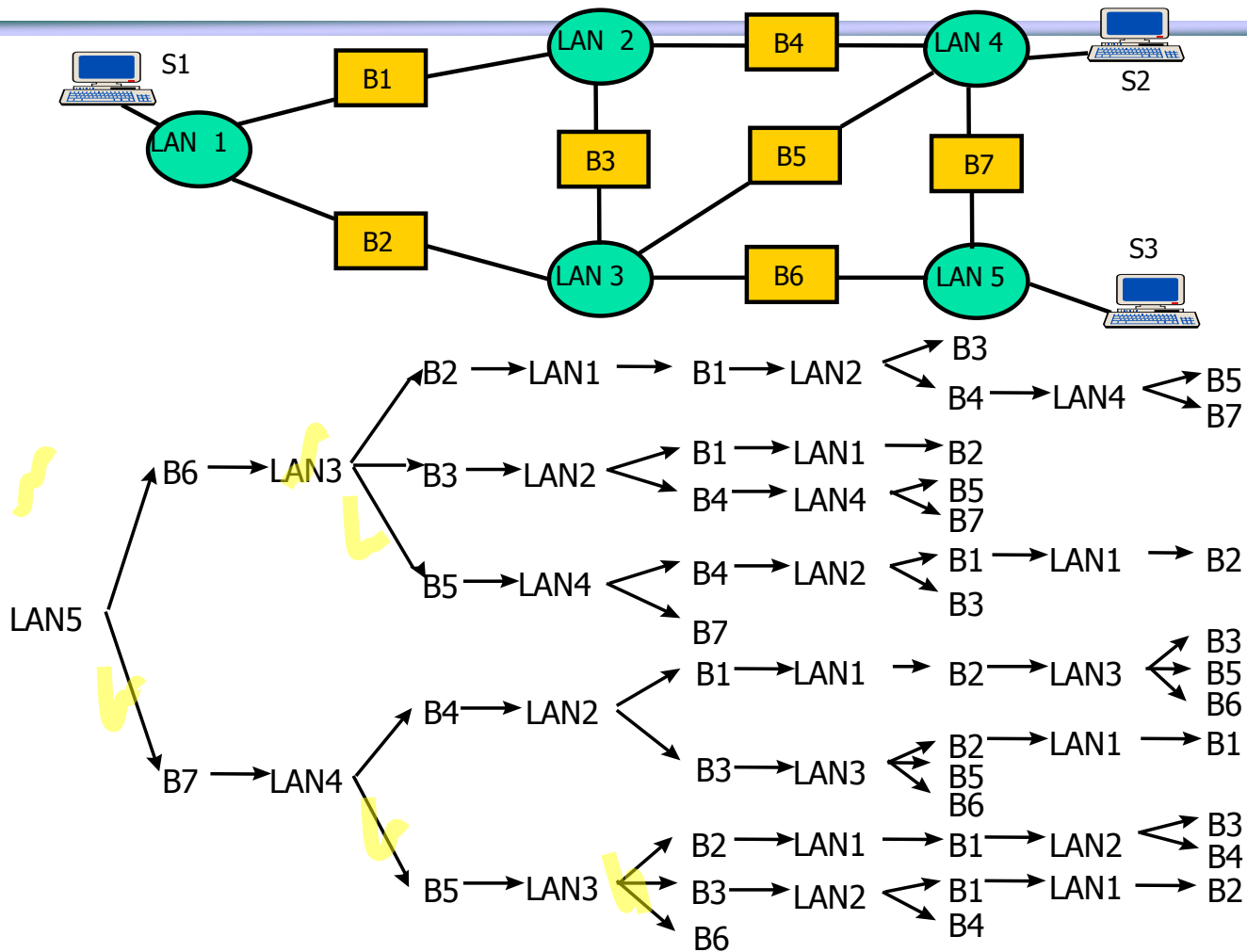
## Detailed Route Discovery (Destination)

- When destination receives **single-route broadcast frame** it responds with **all-routes broadcast frame**
- Bridge at first hop inserts **<incoming LAN #, bridge #, outgoing LAN #>** and forwards
- Subsequent bridges insert **<bridge #, outgoing LAN #>** and forward
- Before forwarding, bridge checks to see if outgoing LAN already in designator field
- Source eventually receives **all routes** to destination station



# Find Routes from S1 to S3









# Hubs and Switches

- Other types of devices for interconnecting LANs
- **Hubs**: physical repeaters
- **Layer 2 switches**: involving bridge functions
- **Layer 3 switches**: involving router functions

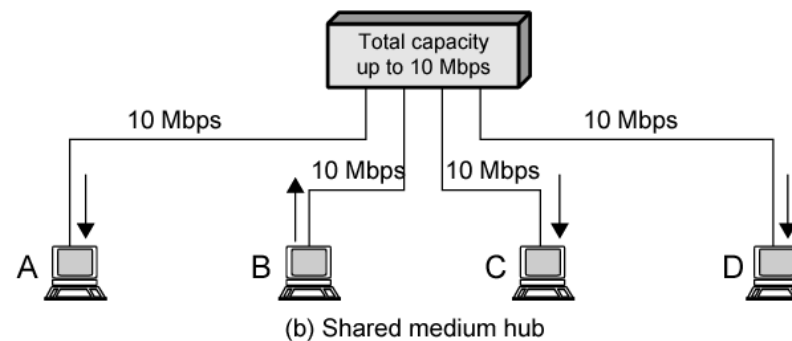
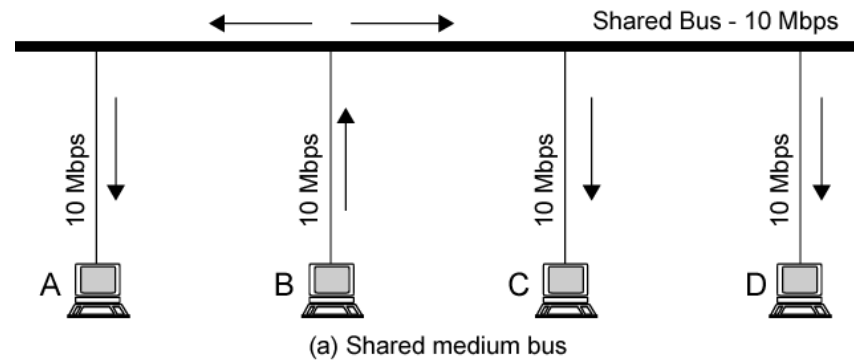


# Hubs

- Active central element of **star layout**
- Each station connected to hub by two lines
  - Transmit and receive
- Hub **acts as a repeater**
  - When a station transmits, hub repeats signal on outgoing line to all other stations
- **Physically star, logically bus**
  - Transmission from any station received by all other stations
  - If two stations transmit at the same time, collision



# Shared Medium Bus and Hub





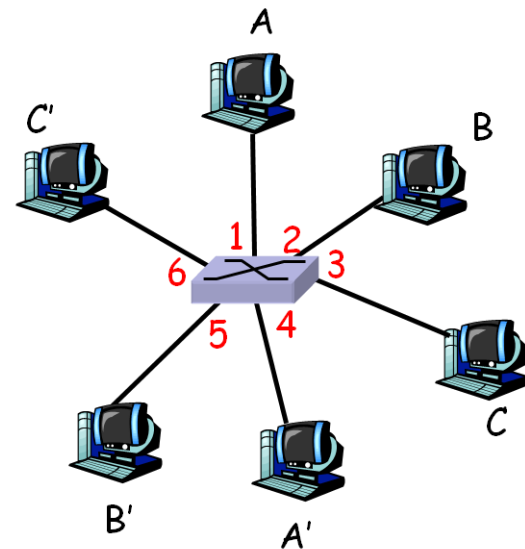
# Layer 2 Switch: Requirement

- Link-layer device: takes an active role
  - Store, forward Ethernet frames
  - Examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
- Transparent
  - Hosts are unaware of presence of switches
- Plug-and-play, self-learning
  - Switches do not need to be configured
- Switch vs. Bridge
  - Bridge: connect two subnets
  - Switch: connect multiple hosts/subnets



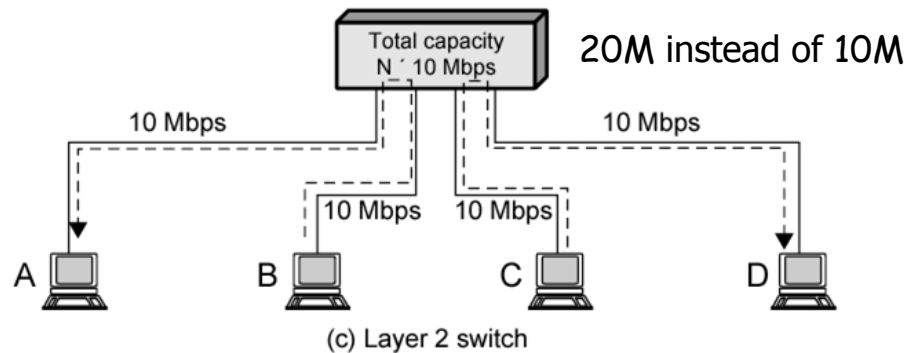
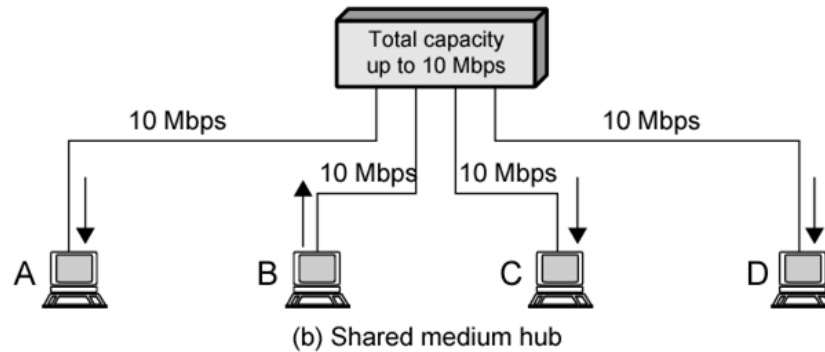
# Switch: multiple simultaneous transmissions

- Stations have dedicated, direct connection to switch
- Switches buffer and forward frames
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- **switching:** A-to-A' and B-to-B' can transmit simultaneously, without collisions
- Multiplying capacity of LANs
  - Each port/link forms a LAN segment (**no collisions**)
  - **More than one station** transmitting at a time



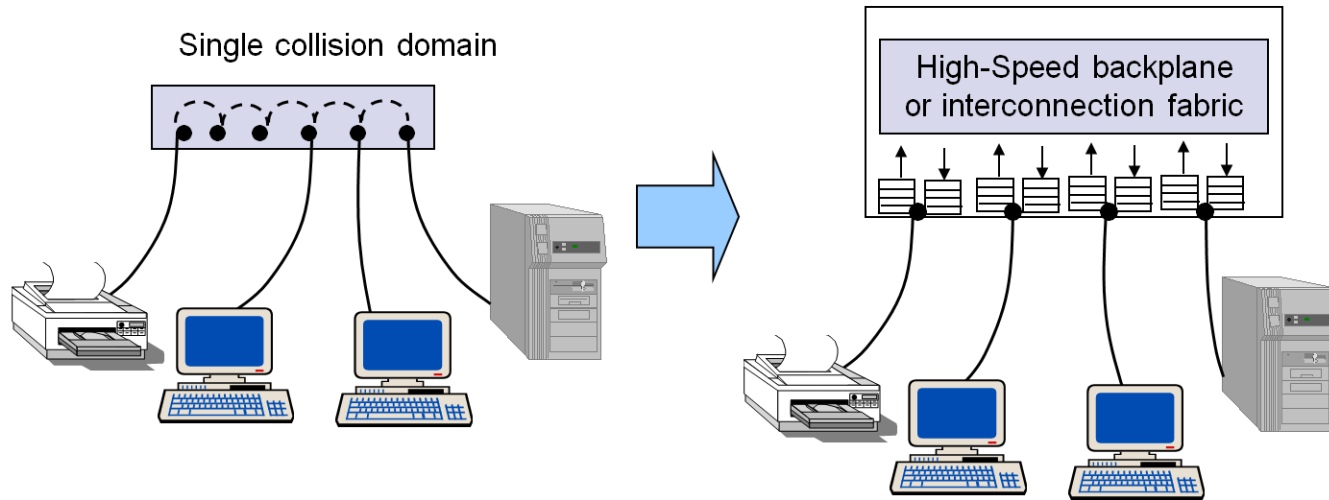


# Shared Medium Hub and Layer 2 Switch





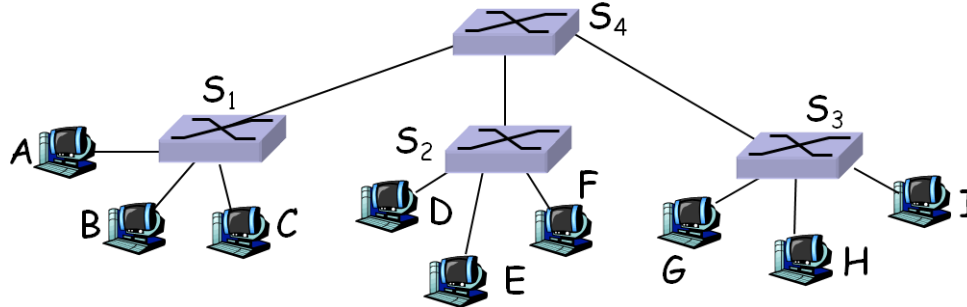
# Shared Medium Hub and Layer 2 Switch





# Layer 2 Switch Benefits

- No change to attached stations to convert bus/hub LAN to switched LAN
  - For Ethernet LAN, each station uses Ethernet MAC protocol
- Station has **dedicated capacity** equal to original LAN
  - Assuming switch has sufficient capacity to keep up with all stations
- Layer 2 switch **scales easily**
  - New layer 2 switch added to accommodate additional stations







# Types of Layer 2 Switch

## ■ Store-and-forward switch

- Accepts frame on input line
- **Buffers and** routes it to appropriate output line
- Adds delay between sender and receiver while boosts integrity of network

## ■ Cut-through switch (直通式交换)

- Takes advantage of dest address appearing at beginning of frame
- Begins **repeating frame** onto output line **as soon as it recognizes dest address**
- Highest possible throughput
- Risk of propagating bad frames: unable to check *CRC* prior to retransmission



# Layer 3 Switches

- As number of stations grows, layer 2 switches reveal inadequacies
  - Broadcast overload
  - Lack of multiple paths
- Layer 3 switch
  - Implement packet-forwarding (IP) logic of a router in hardware
  - Interconnecting similar LANs, as in layer 2 switches



# Broadcast Overload

- Set of stations and LANs connected by layer 2 switches builds singular physical net
- All nodes share **common MAC broadcast address**
- **Broadcast frame** delivered to all stations attached to LANs connected by layer 2 switches
- Under broadcast, layer 2 switches become hubs
- IP causes many broadcasts under daily work, e.g. ARP, DHCP, IGMP



# Lack of Multiple Paths

- Layer 2 switches uses spanning tree for routing (switching)
- **Dictate no closed loops:** only one path between any two stations
- Limits both performance and reliability

## Solution:

- Break up LANs into **sub-networks** connected by **switches using router functions (layer 3 switch)**
- MAC broadcast frames limited to single sub-network
- Allow use of multiple paths between sub-networks



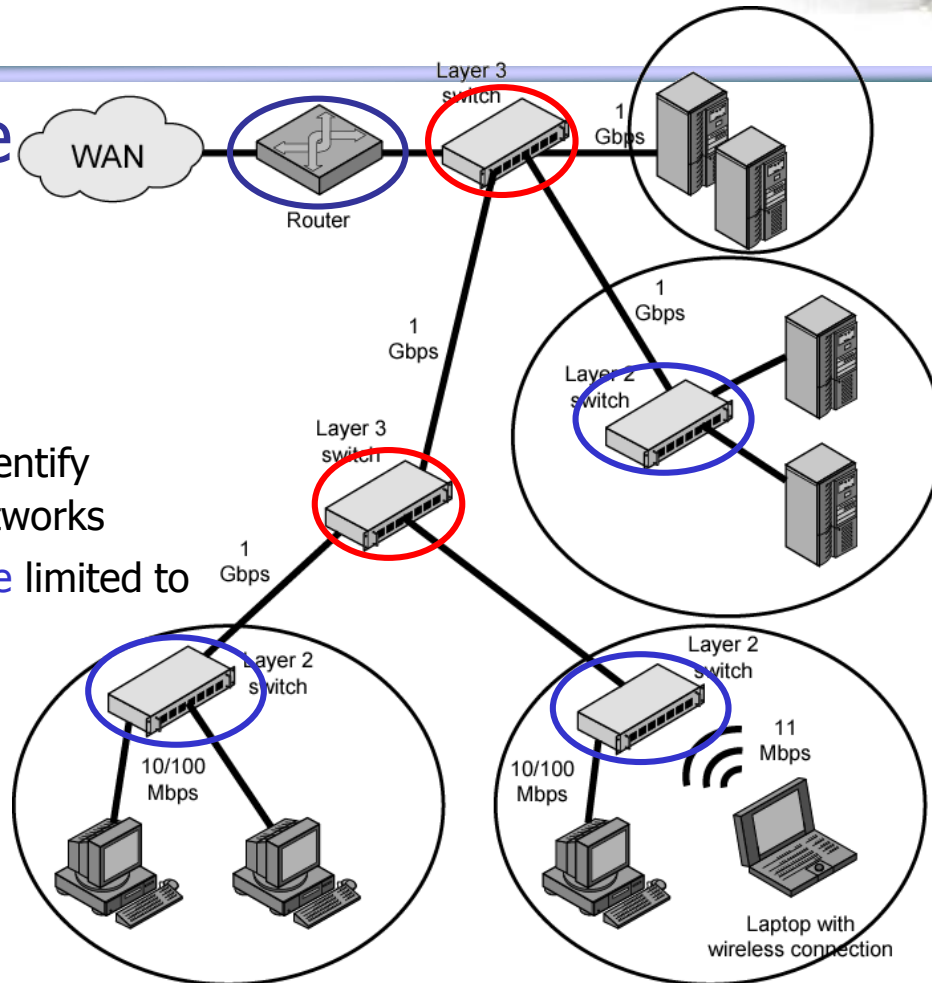
# Two Categories of Layer 3 Switches

- **Packet by packet**
  - Operates in same way as traditional router
  - Order of magnitude increase in performance compared to software-based router
- **Flow-based switch** tries to enhance performance by identifying **flows of IP packets**
  - Same source and destination
  - Done by using a special flow label in packet header
  - Once flow is identified, predefined route can be established



# Typical Large LANs in an Organization

- **Circles** in diagram identify separate LAN subnetworks
- **MAC broadcast frame** limited to its subnetwork





# Summary

- Bridge and Layer 2 Switch
  - 概念
  - 转发表
  - 地址学习
  - 生成树算法
  - 路由发现机制
- 比较: Bridge, hub, Layer 2 Switch, Layer 3 Switch, Router



# Homework

- 书第15章习题: 15.3, 15.4, 15.6, 15.8, 15.9, 15.10