LAN Systems

Bus topology LANs

Design problems: not only MAC algorithm, not only collision domain management, but at the Physical level the signal balancing problem (signal adjustment):

- Signal must be strong enough to meet receiver's minimum signal strength requirements
- Give adequate signal to noise ratio
- 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 amplifiers or repeaters (operate at the physical level)

Used Transmission Media

-Twisted pair

Not practical in shared bus at higher data rates

-Baseband coaxial cable

Used by ‘pure’ Ethernet

-Broadband coaxial cable

Included in 802.3 specification but no longer made (ex.: 10Broad36)

-Optical fiber

Expensive

Difficulty with availability

Not often used, eventually as link segments

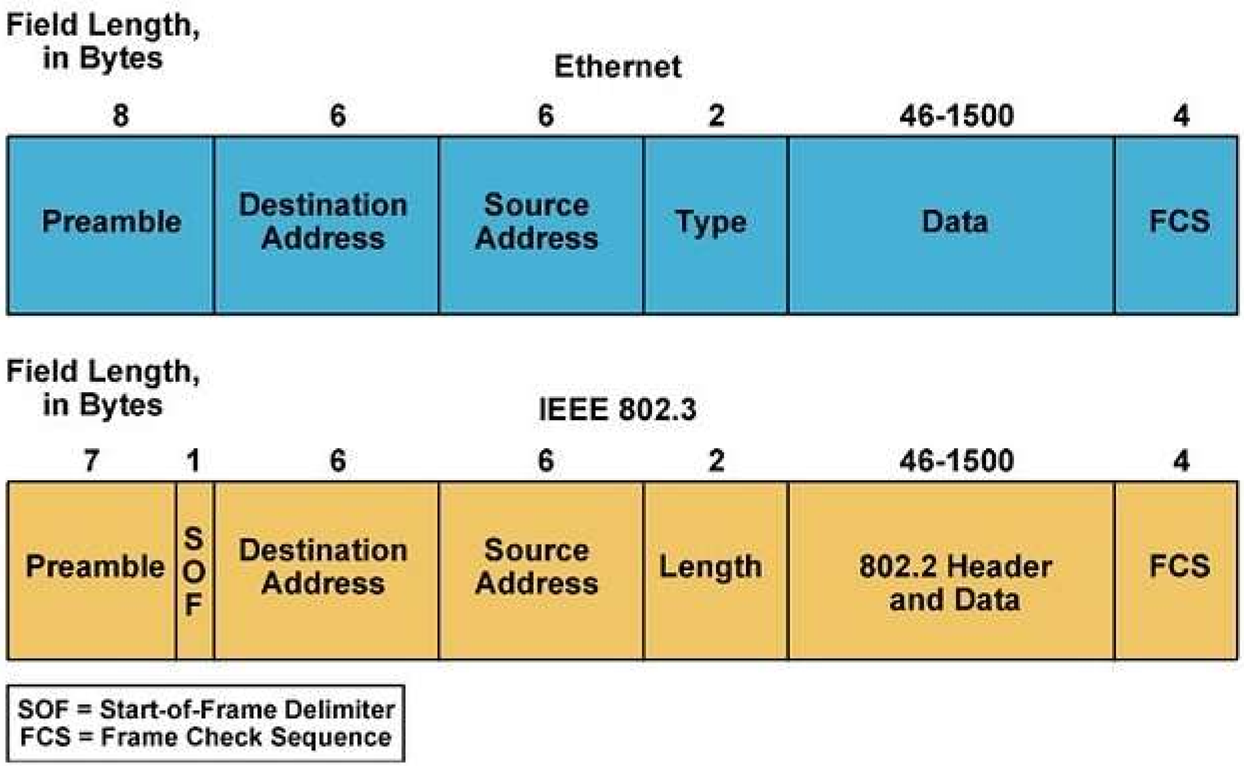
Conclusion: Few new installations, no perspectives, not allowing FD switched links

Replaced by **star based twisted pair and optical fiber**.

10Mbps CSMA/CD based LANs – IEEE 802.3 standard

MAC frame long enough to detect collision prior to transmission end
Standard 802.3 establish minimum length for the frame of 512bits, or 64bytes
Frame also upper bounded for transmission reasons
Minimum size for the Data field, if not allowed use padding (filling with *pad* char)
6 bytes for each address field: MAC address (physical address, burnt on each station network interface)

Ethernet and 802.3 frame format



10Mbps Specification (Ethernet based LANs – IEEE 802.3 standard)

Specification:

<data rate><Signaling method><Max segment length>

Example: 10Base2, 10Broad36

All implement Ethernet based CSMA/CD MAC algorithm.

Problems here: the **Round Trip Collision Delay** value, implying limitations for data format (minimum length for the frame of 512bits, or 64bytes), and maximum distance between stations (depends on link segment media).

	10BASE5	10BASE2	10BASE-T	10BASE-FP
Transmission Medium	Coaxial cable (50 Ω)	Coaxial cable (50 Ω)	Unshielded twisted pair	850-nm optical fiber pair
Signaling Technique	Baseband (Manchester)	Baseband (Manchester)	Baseband (Manchester)	Manchester/ on-off
Topology	Bus	Bus	Star	Star
Maximum Segment Length (m)	500	185	100	500
Nodes per Segment	100	30	—	33
Cable Diameter (mm)	10	5	0.4–0.6	62.5/125 μm

On baseband bus, collision produces much higher signal voltage than active signal

Collision detected if cable signal greater than single station signal; station detecting collision will generate a burst jam signal (jabber control)

Signal attenuated over distance => limits distance to 500m (10Base5) or 200m (10Base2)

Collision domain – given by the set of stations sensing collision when simultaneous transmissions; for 10Mbps standard it is allowed a number of 516 bits onto the shared medium

For higher speeds (i.e. Ethernet at 100Mbps) is kept the same minimum length, obtained by splitting the collision domain; use of hubs or switches instead of repeaters (they do not propagate the collision signal)

10BaseF (802.3 standard for fiber optic)

States use of fiber optics links (a pair of fibers, one for each direction) for CSMA/CD network at 10Mbps.

3 standard specifications:

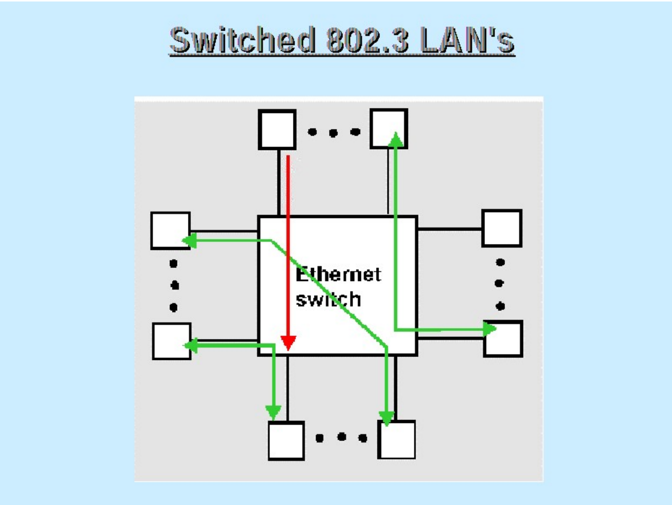
10BaseFP- passive star topology (33 stations connected to a central passive optical splitter device, up to 1km segment length between two stations)

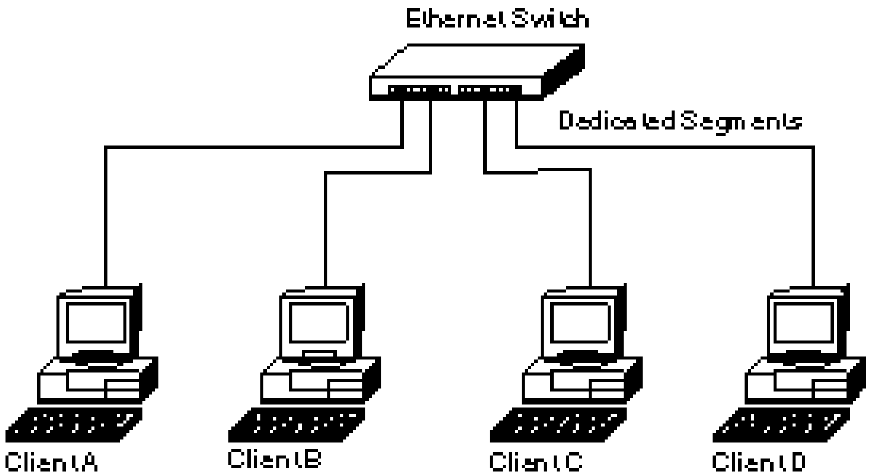
10BaseFL- point-to-point link, connecting stations & repeaters up to 2km

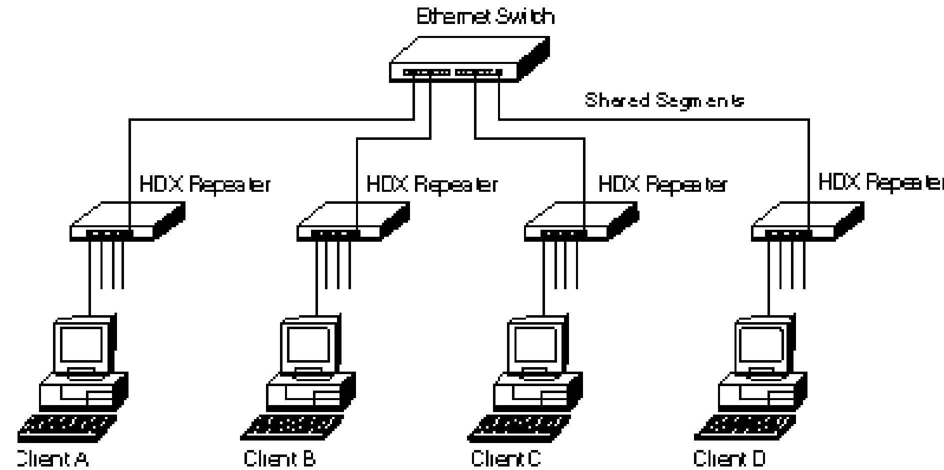
10BaseFB- backbone connecting repeaters up to 2km, using synchronous transmission (allows more repeaters cascading)

Switched Ethernet

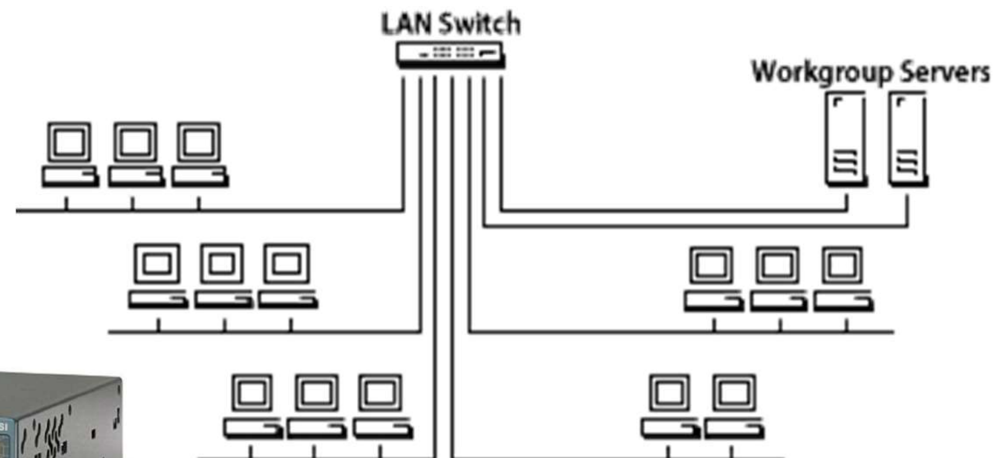
Use of *switches instead of hubs*, to join smaller LAN segments together; the switch filters and forwards the packets, in accordance with any packet protocol.
Fully Star topology.







May have dedicated segments (one per station) or shared segments (use of repeaters)



Switch device: ideal for implementing virtual LANs (for workgroup purposes)

Hubs vs. Switches

Hub: multi-port repeater, acts at Physical level

Switch: multi-port bridge, acts at Data Link level

Shared medium hub

Central hub retransmitting incoming signal to all outgoing lines

Only one station can transmit at a time

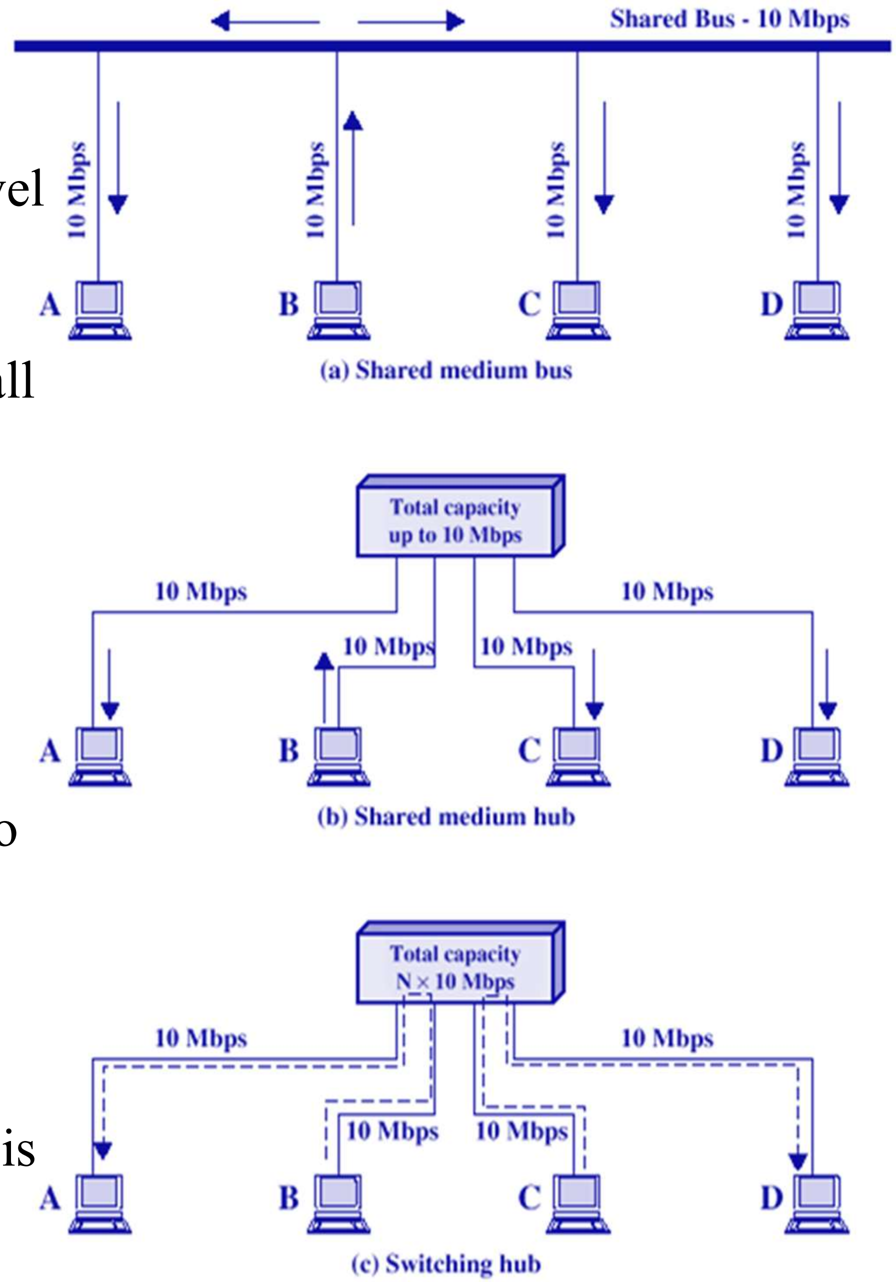
With a 10Mbps LAN, total capacity is 10Mbps

Switched LAN hub

Hub acts as switch, incoming frame switched 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 multiple of line speed (20Mbps)



Switched Hubs

No change to software or hardware of devices

Each device has dedicated capacity

Scales well

Two major categories:

-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

Switch General Problem: simultaneous transmissions to same destination:

Let first one through

Use of buffers associated with switch's ports

100Mbps specification (Fast Ethernet)

Providing low-cost Ethernet compatible LAN @ 100Mbps. Using 10Mbps legacy, development of 10/100Mbps NIC cards and devices. General specification in 100BaseX standard.

Different approaches:

100BaseT4

use of existing UTP Cat.3 networks (possible due to the signaling frequency of 25MHz), or Cat.5

achieve full-duplex 100Mbps transmissions using 4 UTP pairs, three used for data transmissions at 33,3Mbps and one for collision control

use of a ternary signaling scheme (8B6T- use of 27 symbols), allowing to transmit on three wires of a number of 4bits during a clock period

100BaseX (IEEE 802.13 standard)

Use of 100Mbps unidirectional data rate, so need for 2 pairs (Tx and Rx)

Two approaches, for different physical media:

100BaseTX for TP Cat.5 (UTP or STP)

100BaseFX for multi-mode fiber

Use of MLT-3 encoding scheme for 100BaseTX and of 4B/5B-NRZI for fiber based (as FDDI)

	100BASE-TX		100BASE-FX	100BASE-T4
Transmission Medium	2 pair, STP	2 pair, Category 5 UTP	2 optical fibers	4 pair, Category 3, 4, or 5 UTP
Signaling Technique	MLT-3	MLT-3	4B5B, NRZI	8B6T, NRZ
Data Rate	100 Mbps	100 Mbps	100 Mbps	100 Mbps
Maximum Segment Length	100 m	100 m	100 m	100 m
Network Span	200 m	200 m	400 m	200 m

Gigabit Ethernet (1000BaseX)

Developed by IEEE High-Speed Study Group

How to convey Ethernet packets @ Giga

Keeping backward compatibility

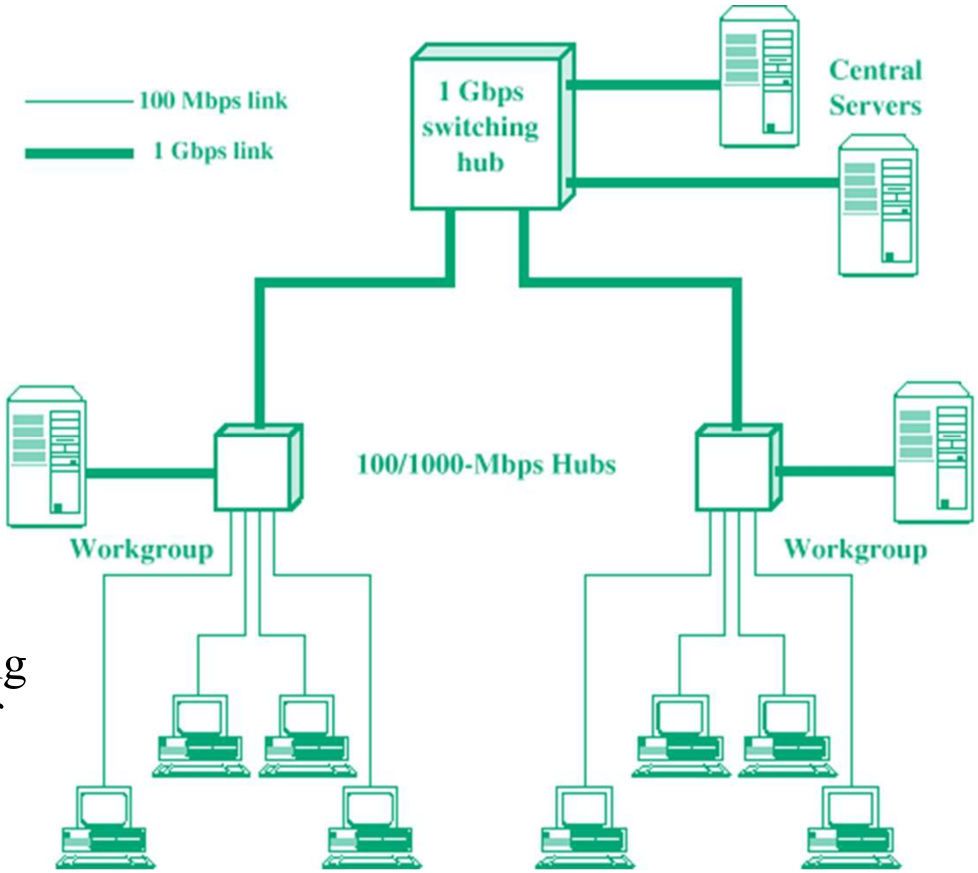
Differences vs 100Mbps at MAC level:

-Carrier extension, so the frame length of a transmission being longer than the propagation time at 1Gbps (principle of CSMA/CD)

Now transmission at least 4096 bit-times long (512 bit-times for 10/100, min. frame length of 64octets)

-Frame bursting

Multiple short frames transmitted consecutively, without CSMA/CD control; avoids the overhead of carrier extension when a single station has a number of small frames ready to send.



Gigabit Ethernet - Physical specifications: Signaling - 8B/10B

Different approaches:

1000BaseSX

Short wavelength light, multimode fiber; duplex links @ 200-400m length

1000BaseLX

Long wavelength light, Multi or single mode fiber; duplex links @ 500 – 5000m length

1000BaseCX

Use of copper jumpers < 25m made from shielded twisted pair; cluster of stations, close situated

1000BaseT

4 pairs, cat 5 UTP

10Gigabit Ethernet (10GBaseX)

Why?

-increase in Internet and intranet traffic

-increase in the connection speed of each end-station

-increase of bandwidth-intensive applications

Allows the construction of MANs and WAN

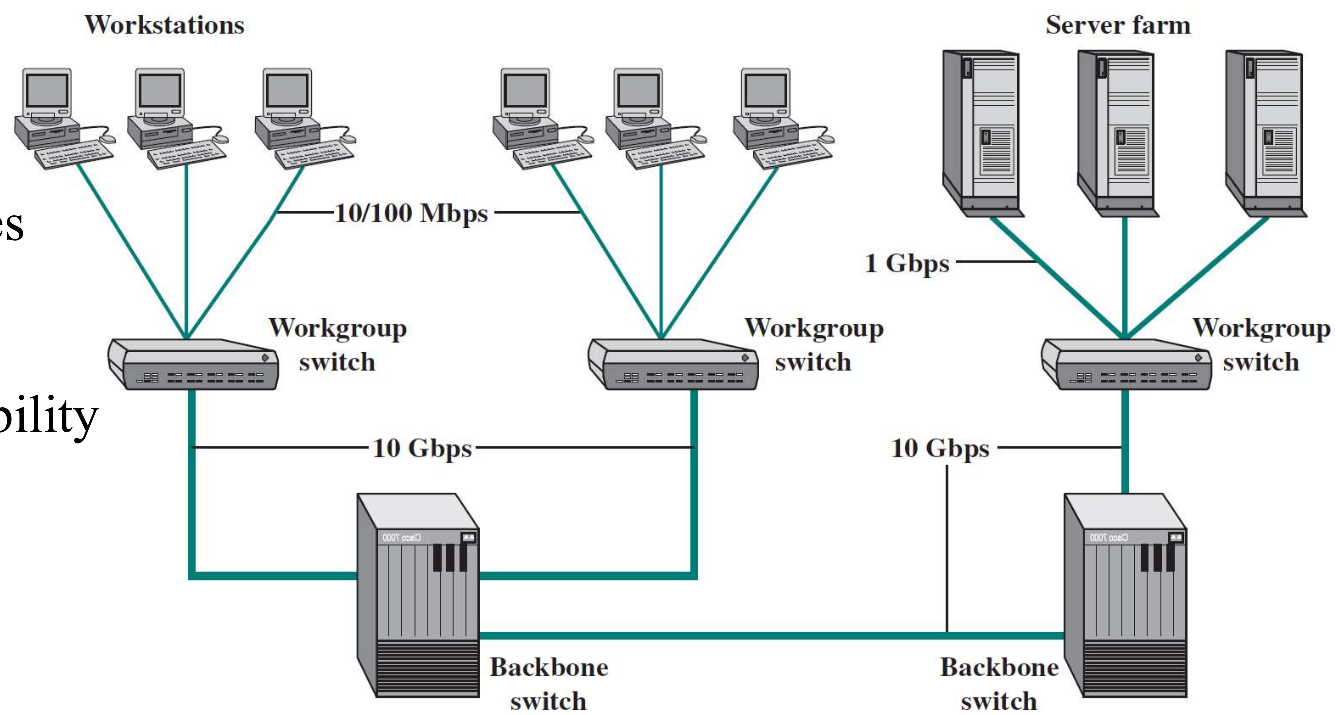
Combining IP and Ethernet offers quality of service and traffic-policing capabilities

Range:

-from 300m to 40 km

-standard optical interfaces

Keeps backward compatibility



10Gigabit Ethernet

Different approaches:

10GBASE-S (short)

multimode fiber with distances up to 300 m
10GBASE-SR and10GBASE-SW versions

10GBASE-L (long)

single-mode fiber with distances up to 10 km
10GBASE-LR and 10GBASE-LW versions

10GBASE-E (extended):

single-mode fiber with distances up to 40 km
10GBASE-ER and 10GBASE-EW versions

10GBASE-LX4:

single-mode or multimode with distances up to 10 km
uses wavelength division multiplexing (WDM) to multiplex the bit stream across four light waves.

100Gigabit Ethernet (100GBaseX)

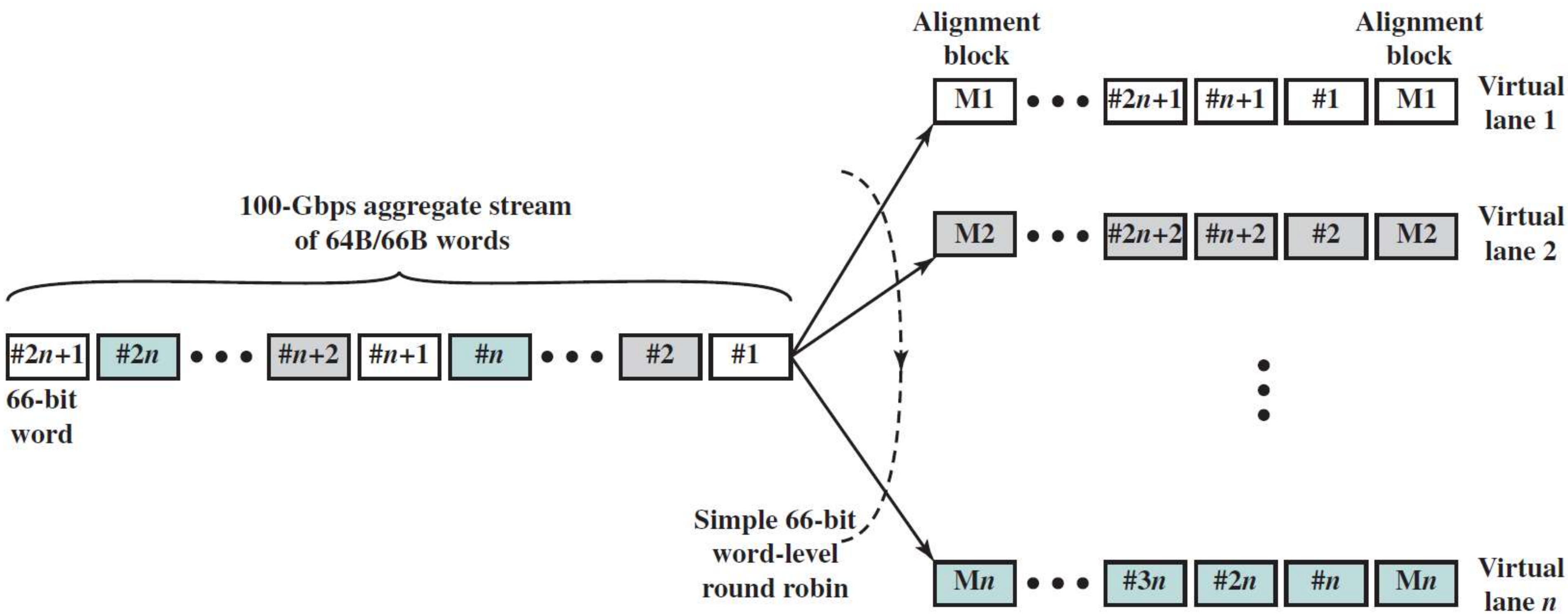
Ethernet is the preferred carrier for bridging wireless technologies, such as Wi-Fi and WiMAX, into local networks.

Where?
Data center/Internet media providers
-to support the growth of Internet multimedia content and Web applications
Metro-video/service providers
-video on demand services
• **Enterprise LANs**
-converge networks (voice/video/data) and unified communications
-most enterprises still rely on 1-Gbps or a mix of 1-Gbps and 10-Gbps Ethernet,
-adoption of 100-Gbps Ethernet - slow.
•**Internet exchanges/ISP core routing:**
-massive amount of traffic

IEEE 802.3 working group: IEEE P802.3ba 40Gb/s and 100Gb/s Ethernet Task Force
-Keeps backward compatibility

New concepts: multilane distribution and virtual lanes

- **multilane distribution**:
  - -physical links implemented as multiple parallel channels
  - -separate physical wires **or** wavelength division multiplexing over a single optical fiber link



Virtual lane concept

Media Options for 40-Gbps and 100-Gbps Ethernet

	40 Gbps	100 Gbps
1m backplane	40GBASE-KR4	
10 m copper	40GBASE-CR4	1000GBASE-CR10
100 m multimode fiber	40GBASE-SR4	1000GBASE-SR10
10 km single-mode fiber	40GBASE-LR4	1000GBASE-LR4
40 km single-mode fiber		1000GBASE-ER4

Naming nomenclature:

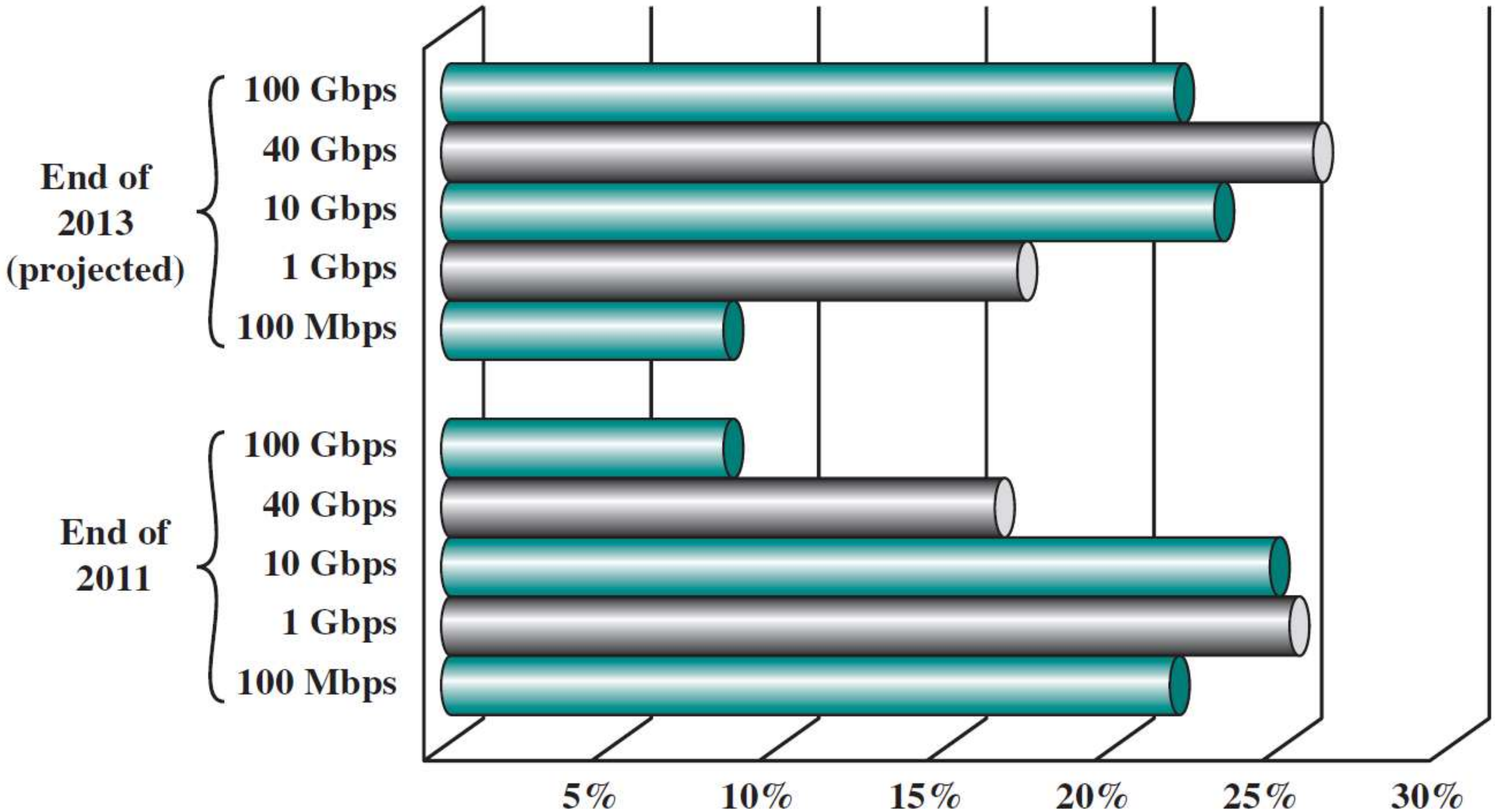
Copper: K = backplane; C = cable assembly

Optical: S = short reach (100 m); L = long reach (10 km); E = extended long reach (40 km)

Coding scheme: R = 64B/66B block coding

Final number: number of lanes (copper wires or fiber wavelengths)

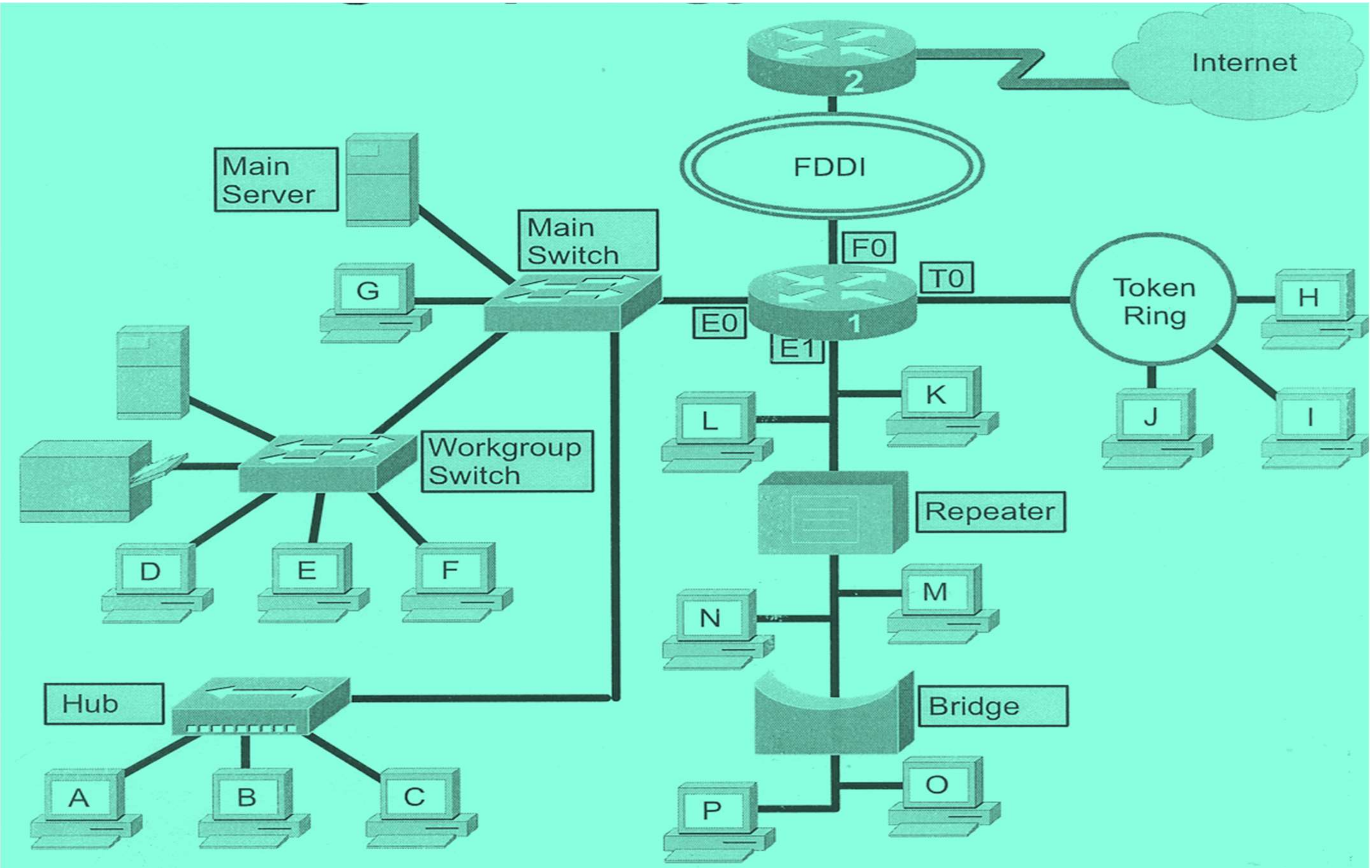
From 100Mbps to 100Gbps Ethernet usage



Data Center Study—Percentage of Ethernet Links by Speed

LAN Interconnection

– different interconnecting devices, many approaches



Need for ability to expand beyond single LAN; appears concept of **Extended LAN**, extending the number of attached stations and maximum allowed distance between them

Provide interconnection to other LANs/WANs

Remember:

Repeater: regenerate and retime network signals at the bit level to allow them to travel a longer distance on the media

Hub: regenerate and retime network signals; process known as concentration; known as a multi-port repeater; use of a central connection point for the wiring media will increase the reliability of the network.

Bridge - a Layer 2 device designed to connect two LAN segments; filter traffic on a LAN, keep local traffic local, allow connectivity to other parts (segments) of the LAN for traffic that has been directed there

Switch - a Layer 2 device just as a bridge is; called a multi-port bridge

Router - work with that is at the OSI network layer; make decisions based on groups of network addresses (Classes), as opposed to individual Layer 2 MAC addresses

Hub


ETHER Series

Bridge


On - Server
Off - Client
Flash - Setup
9-12 VDC
On - LAN Valid
Flash - LAN Active
Off - No LAN
10/100

Switch

Routers

Bridges

Use Bridge or Router, but bridge is simpler (operates at Data Link level)

- Connects similar LANs
- Identical protocols for physical and data link layers
- Minimal processing

Router more general purpose: interconnect various LANs and WANs, level 3 device

Why Bridge?

Reliability – not an unique big LAN for that enterprise, but a set of small. Self contained units

Performance – avoid performance problem given by an increased number of stations

Security – may keep separately different kinds of traffic

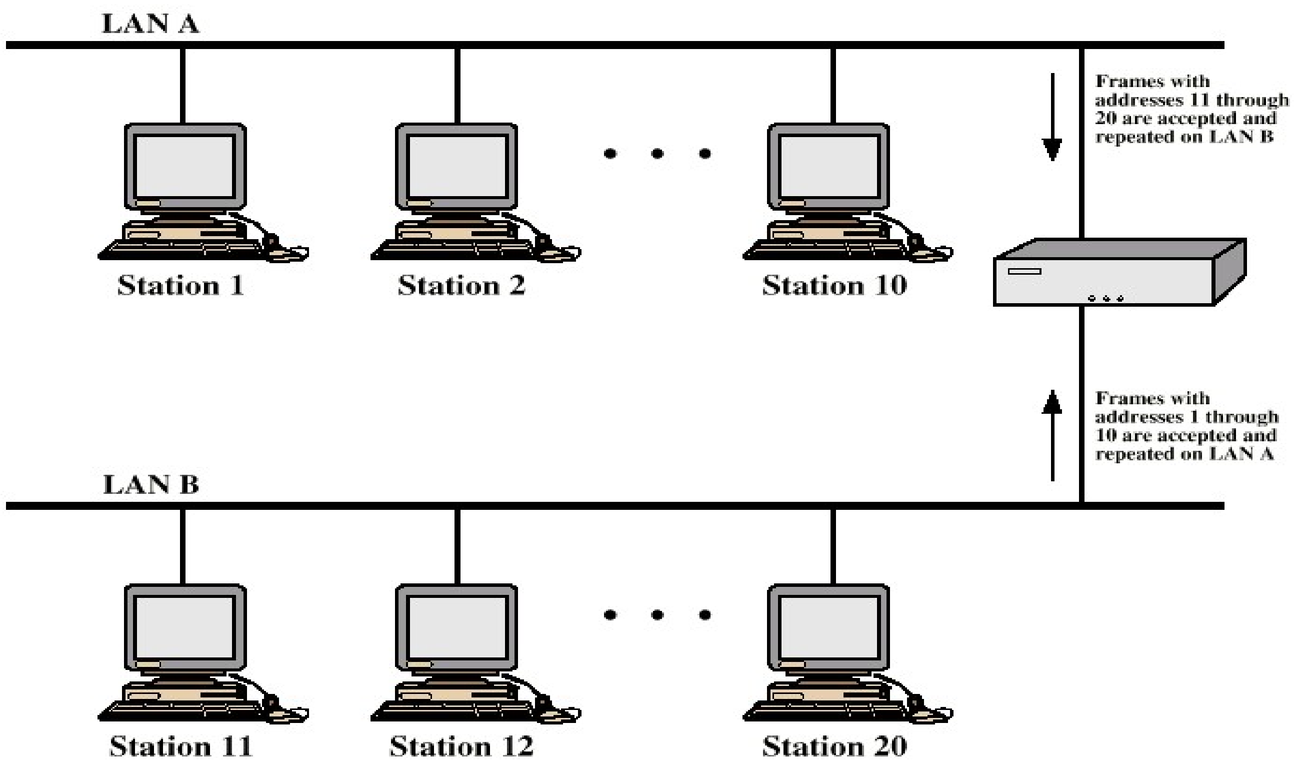
Geography – may interconnect geographically separated LANs

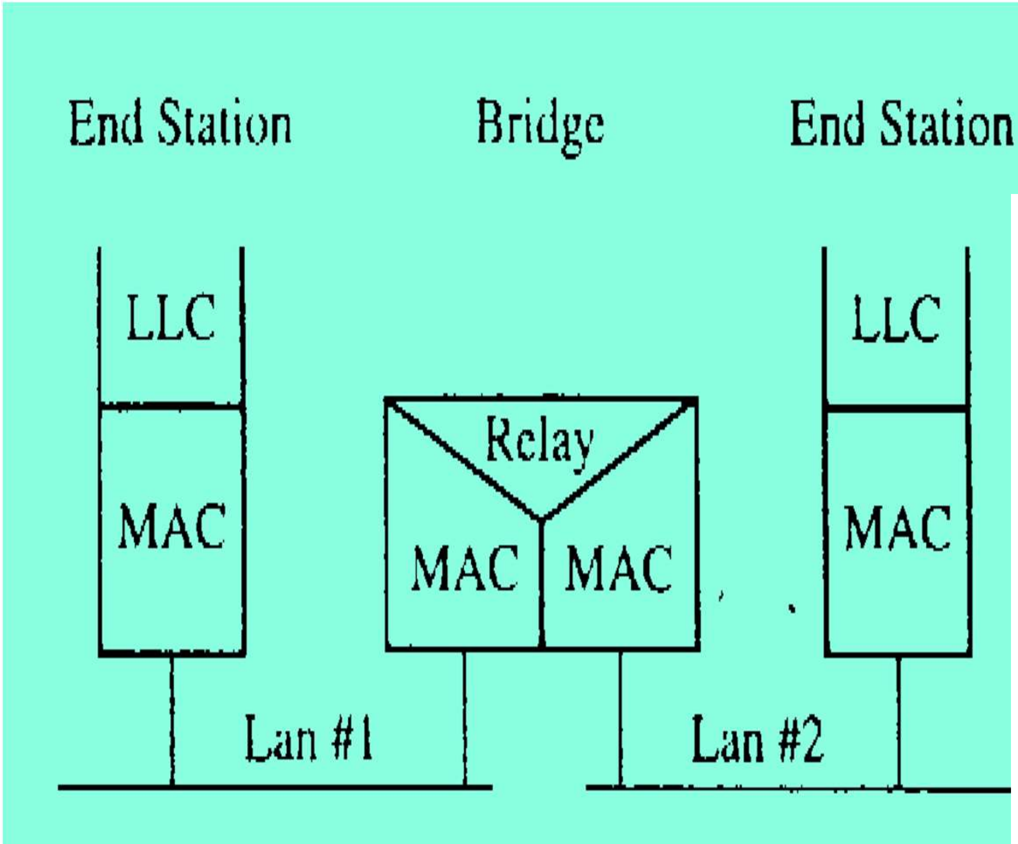
Two types of bridges:

transparent bridge – IEEE standard; operates in promiscuous mode, use of addressing tables

source-routing bridge – proposed by IBM's Token Ring, follows the route imposed by the source station

Bridge Operation





Bridge as protocol converter

Characteristics of a Transparent 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; acts as a **protocol relay**

Do the same the other way round

No modification to content or format of frame, no more encapsulation

Exact bitwise copy of frame

Minimal buffering to meet peak demand

Contains routing and address intelligence

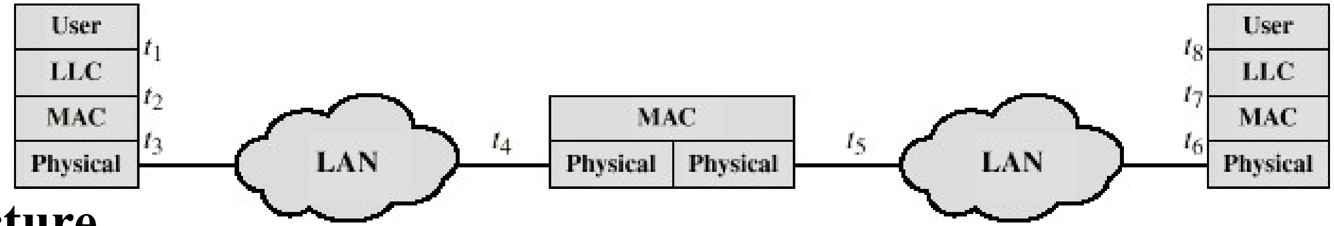
- Must be able to tell which frames to pass
- May be more than one bridge to cross

May connect more than two LANs

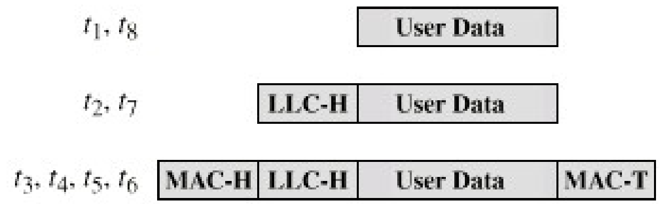
Bridging is **transparent** to stations

- Appears to all stations on multiple LANs as if they are on one single LAN

Bridge Protocol Architecture



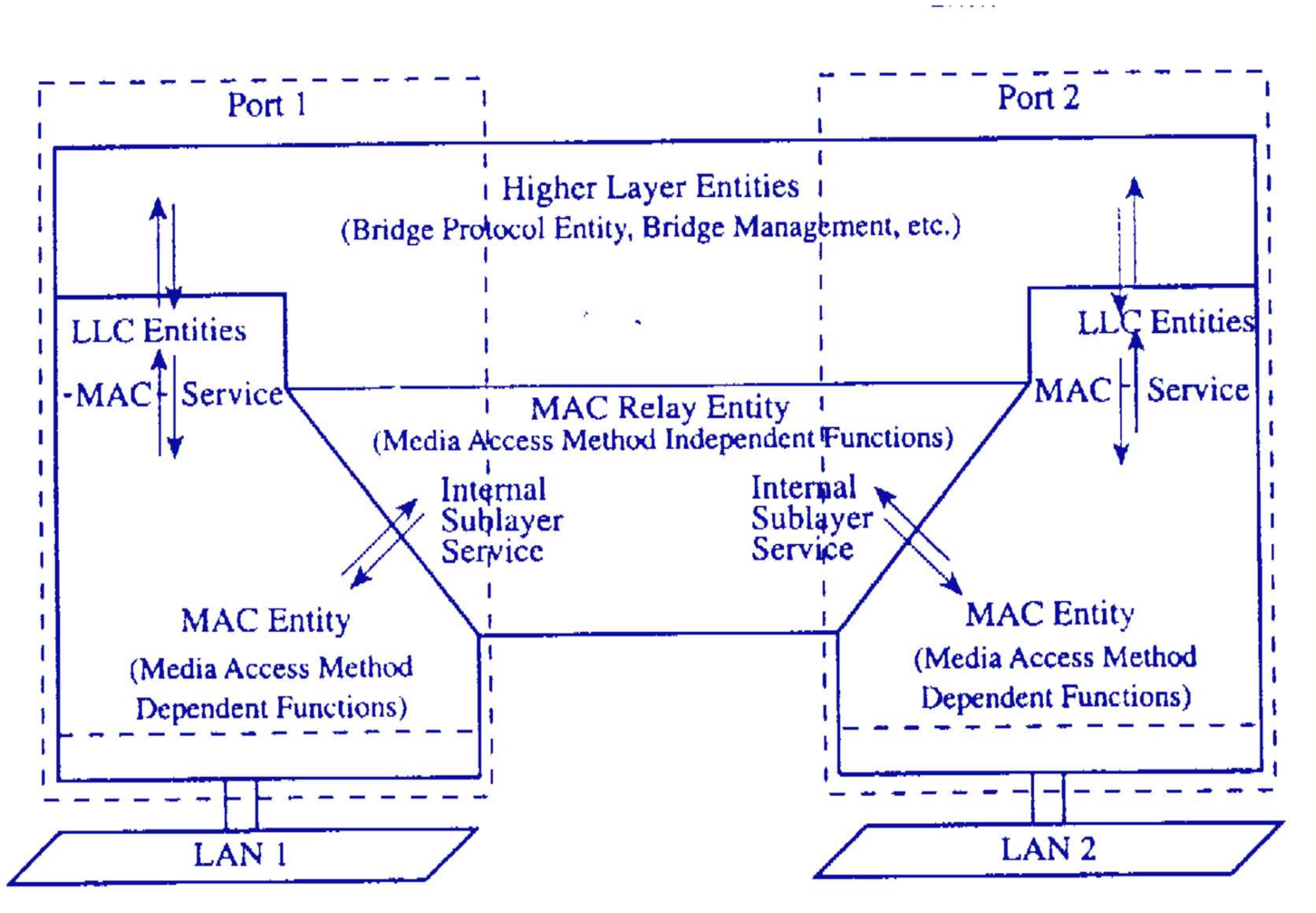
(a) Architecture



(b) Operation

IEEE 802.1D standard

- 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 (WAN link)
  - Capture frame
  - Encapsulate it
  - Forward it across link
  - Remove encapsulation and forward over LAN link



Bridge Architectural Structure

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

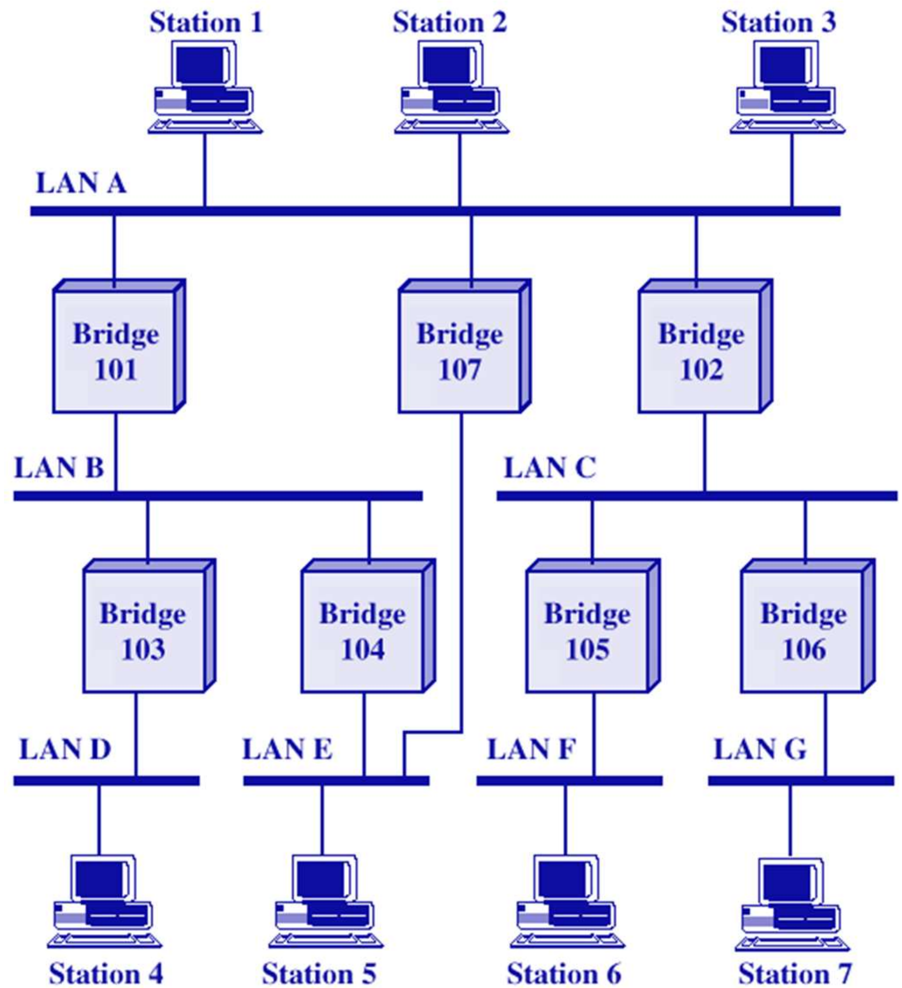
- Done in configuration
- Usually least hop route
- Only changed when topology changes

Spanning Tree

Algorithm used for:

Automatically develop **routing table**

Automatically update in response to changes



Bridge Operations:

- 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 learnt

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

Each time frame arrives, source address checked against forwarding database

Loop Resolution

Use of **Spanning Tree Algorithm**

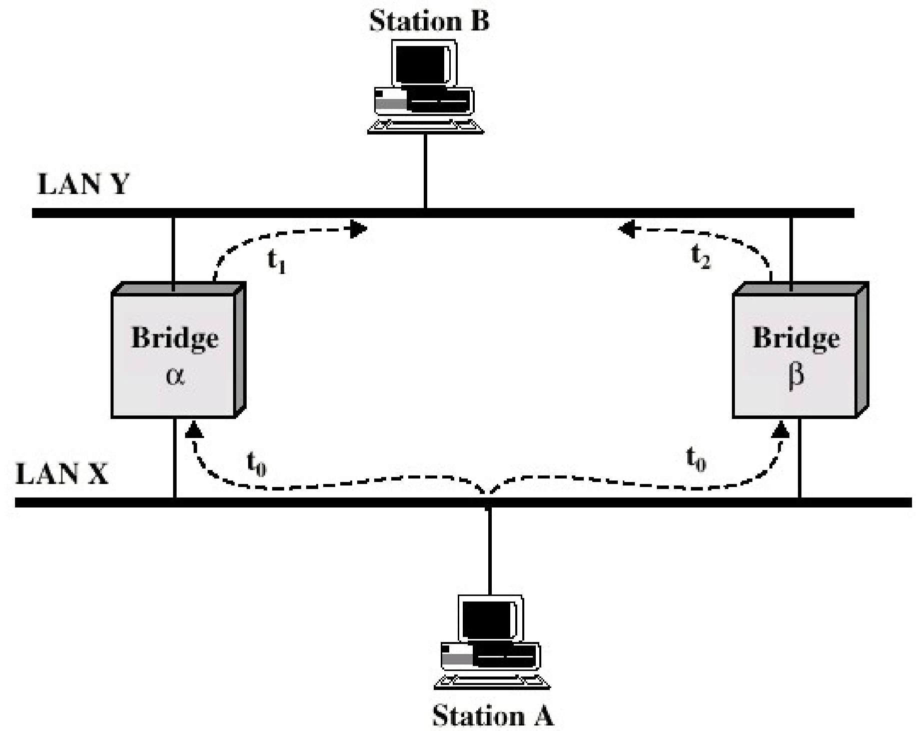
Address learning works for tree layout

i.e. no closed loops

THEORY: 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 of Configuration Bridge PDUs, to establish spanning tree (every 2 seconds).



IEEE 802.1d Spanning-Tree Protocol

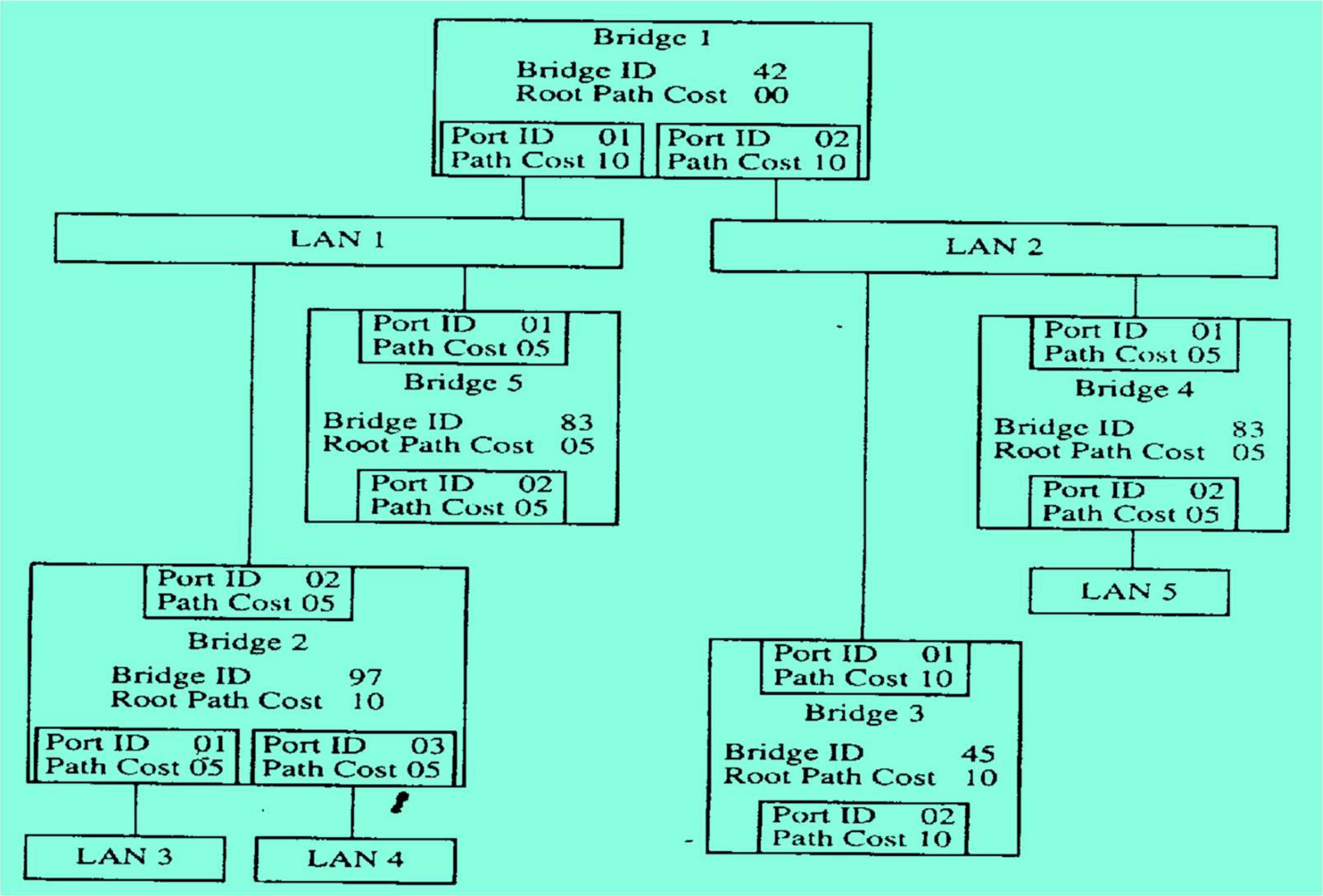
Root BID	Root Path Cost	Sender BID	Port ID

BPDU message structure

7	6	5	4	3	2	1	0
Bridge Priority		MAC address					

BID structure

Spanning-tree algorithm used to configure the extended-LAN: sample of bridge IDs and associated costs



Link Speed	**Cost**
10Mbps	2000000
100Mbps	200000
1Gbps	20000
10Gbps	2000
1Tbps	20
10Tbps	2