MONASH University
Information Technology

FIT3165 Computer Networks

PART - 1 : LOCAL AREA NETWORK OVERVIEW

Reference: Chapter 15, Data and Computer Communications, by William Stallings

PART - 2 : HIGH SPEED LANs

Reference: Chapter 16, Data and Computer Communications, by William Stallings

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Introduction

- **Range of technologies**
  - Gigabit, & 10 Gigabit Ethernet
  - Fibre Channel
  - High Speed Wireless LANs

Why High Speed LANs?

- **Office LANs used to provide basic connectivity**
  - Connecting PCs and terminals to mainframes and midrange systems that ran corporate applications
  - Providing workgroup connectivity at departmental level
  - Traffic patterns light
    - > Emphasis on file transfer and electronic mail
- **Speed and power of PCs has risen**
  - Graphics-intensive applications and GUIs
- **MIS organizations recognize LANs as essential**
  - Began with client/server computing
    - > Now dominant architecture in business environment
    - > Intranetworks
    - > Frequent transfer of large volumes of data

Applications Requiring High Speed LANs

- **Centralized server farms**
  - User needs to draw huge amounts of data from multiple centralized servers
  - E.g. Colour publishing
    - > Servers contain tens of gigabytes of image data
    - > Downloaded to imaging workstations
- **Power workgroups**
- **Small number of cooperating users**
  - Draw massive data files across network
  - E.g. Software development group testing new software version or computer-aided design (CAD) running simulations
- **High-speed local backbone**
  - Processing demand grows
  - LANs proliferate at site
  - High-speed interconnection is necessary

LAN Applications (1)

- **personal computer LANs**
  - **low cost** of attachment to the network (client/server apps etc..)
  - high-performance workstations (1 Gbps, 10 Gbps..)
- **back end networks**
  - interconnecting large systems (High performance computing systems, Server farms, Data repositories, Backup systems and Large storage devices - SAN's)
    - > high data rate
    - > high speed interface
    - > distributed access
    - > limited distance

LAN Applications (2)

- **storage area networks (SANs)**
  - backend networks
  - separate network handling storage needs
  - detaches storage tasks from specific servers
  - six data storage systems categories that include
    - > all-flash storage systems, data backup and disaster recovery software and services, backup hardware, hard disk/hybrid storage systems, SAN management tools, and server-based storage products.
  - shared storage facility
    - > eg. hard disks, BlueRay CD arrays
  - accessed using a high-speed network
    - > eg. Fibre Channel
  - improved client-server storage access
  - direct storage to storage communication for backup

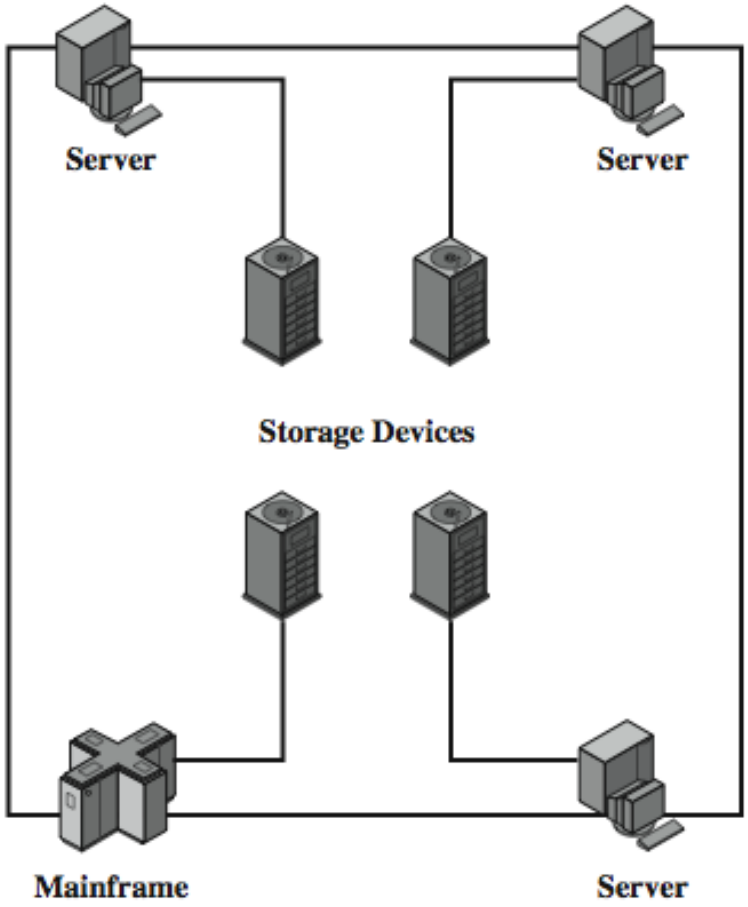
LAN Applications (3)

- **six data storage systems categories that include**
  - **backup and recovery software,** include cloud backup and recovery services, disaster recovery, snapshot and replication, electronic vaulting and archivers.
  - **Data Backup hardware** include tape libraries and drives, backup media, disk backup targets, virtual tape libraries, deduplication devices and gateway appliances for cloud backup.
  - **Storage and SAN management tools** include storage resource management and SAN management software, performance monitoring, configuration management, provisioning and data reduction.
  - **server-based storage** include hyper-converged and software-defined storage systems that include storage and servers in one chassis; software that pools data to allow storage capacity across servers to work together under common management with storage services.

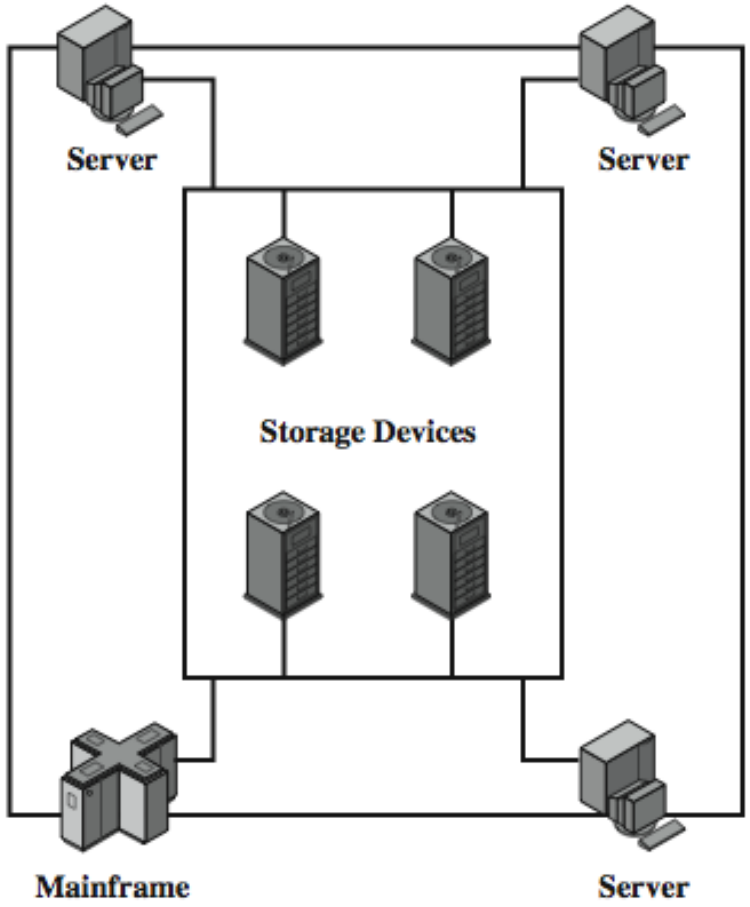
LAN Applications (4)

- **six data storage systems categories that include**
  - **All-flash systems** category include storage platforms that comes with all-flash storage and no hard disk drives; includes FC and iSCSI SAN, NAS, multi-protocol systems, converged/hyper-converged infrastructure products, Direct-attached storage (**DAS**), solid-state storage drives (**SSD's**), disk controllers, caching appliances, storage virtualization appliances and cloud-integrated storage.
  - **hybrid storage systems** include hybrid flash arrays, Fibre Channel and iSCSI SAN, NAS, multiprotocol systems, converged/hyper-converged infrastructure products, DAS, hard disk drives, disk controllers, caching appliances, storage virtualization appliances and cloud-integrated storage.

Storage Area Networks

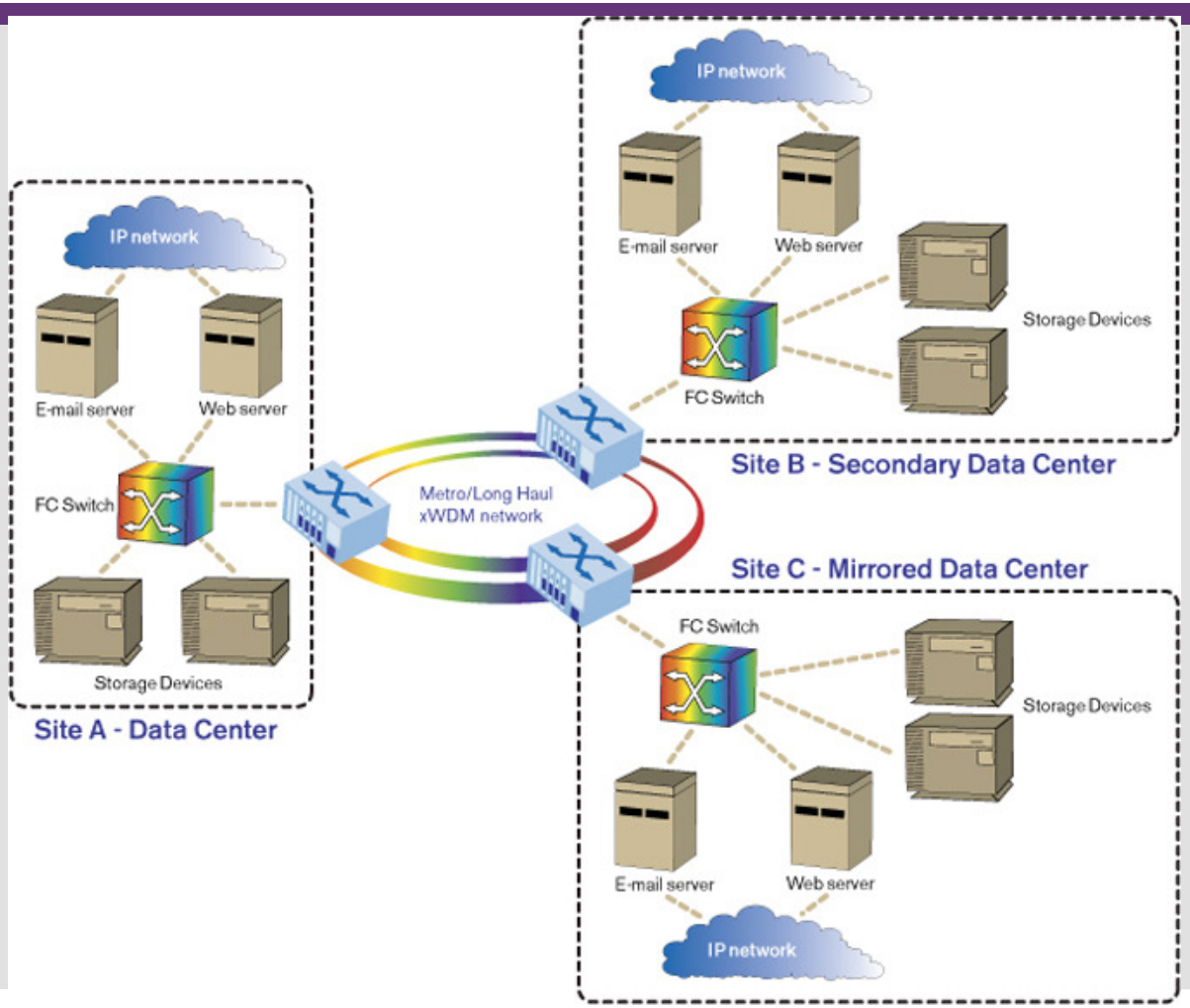


(a) Server-based storage

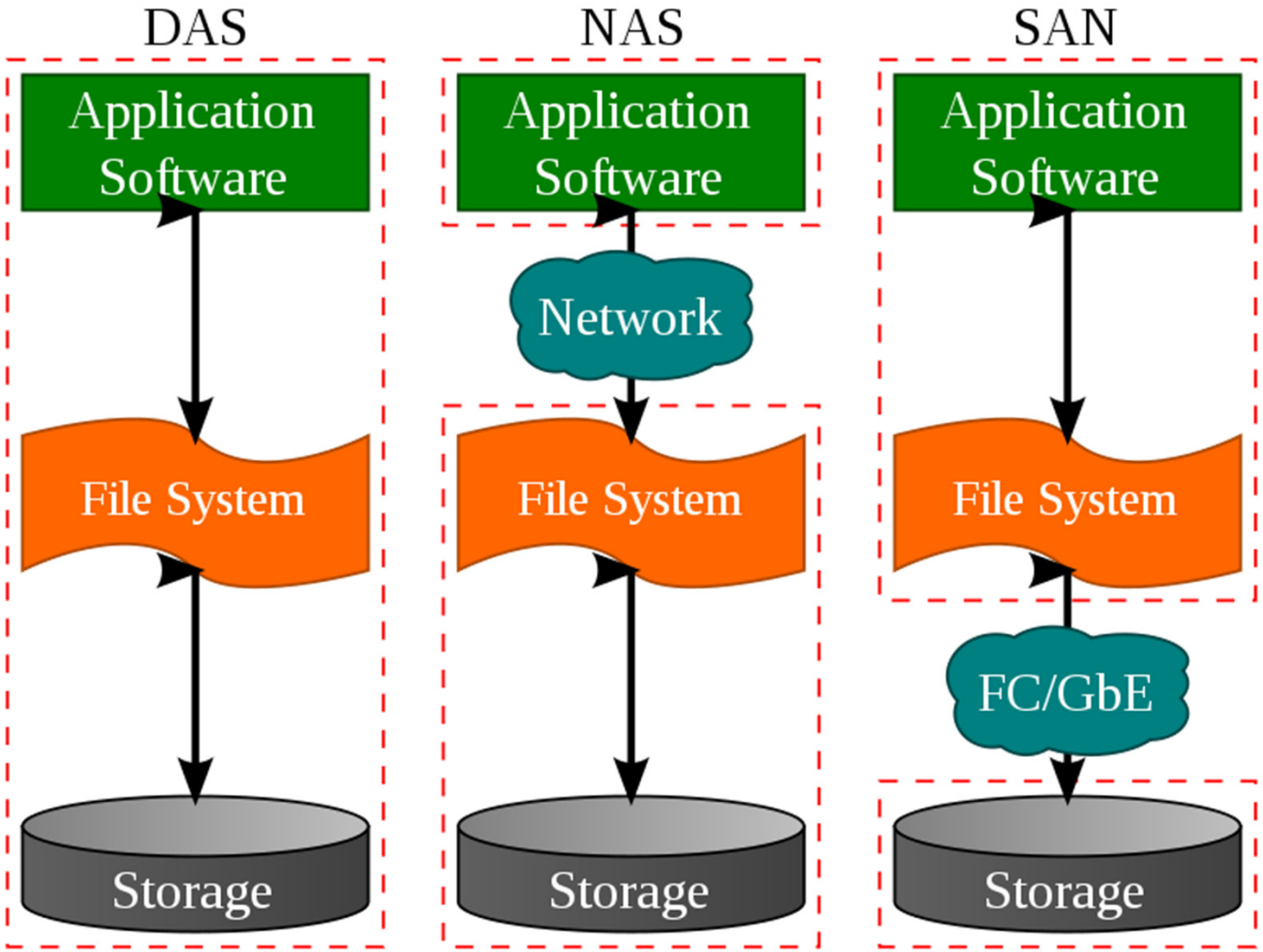


(b) Storage area network

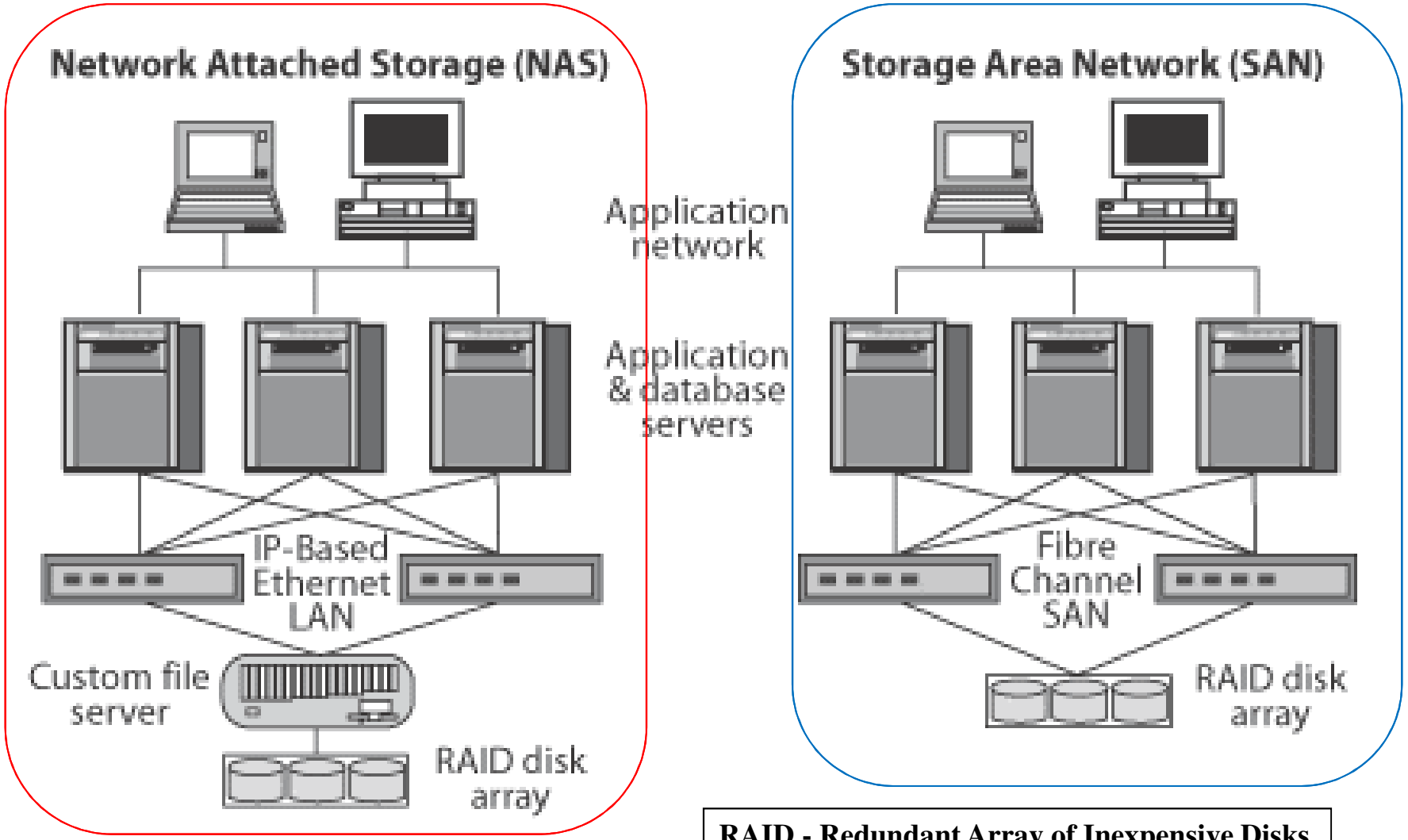
storage area networks (SANs)



Direct Attached Storage (DAS)
Network Attached Storage (NAS)
Storage Area Network (SAN)



Network Attached Storage (NAS) Vs Storage Area Networks (SANs)



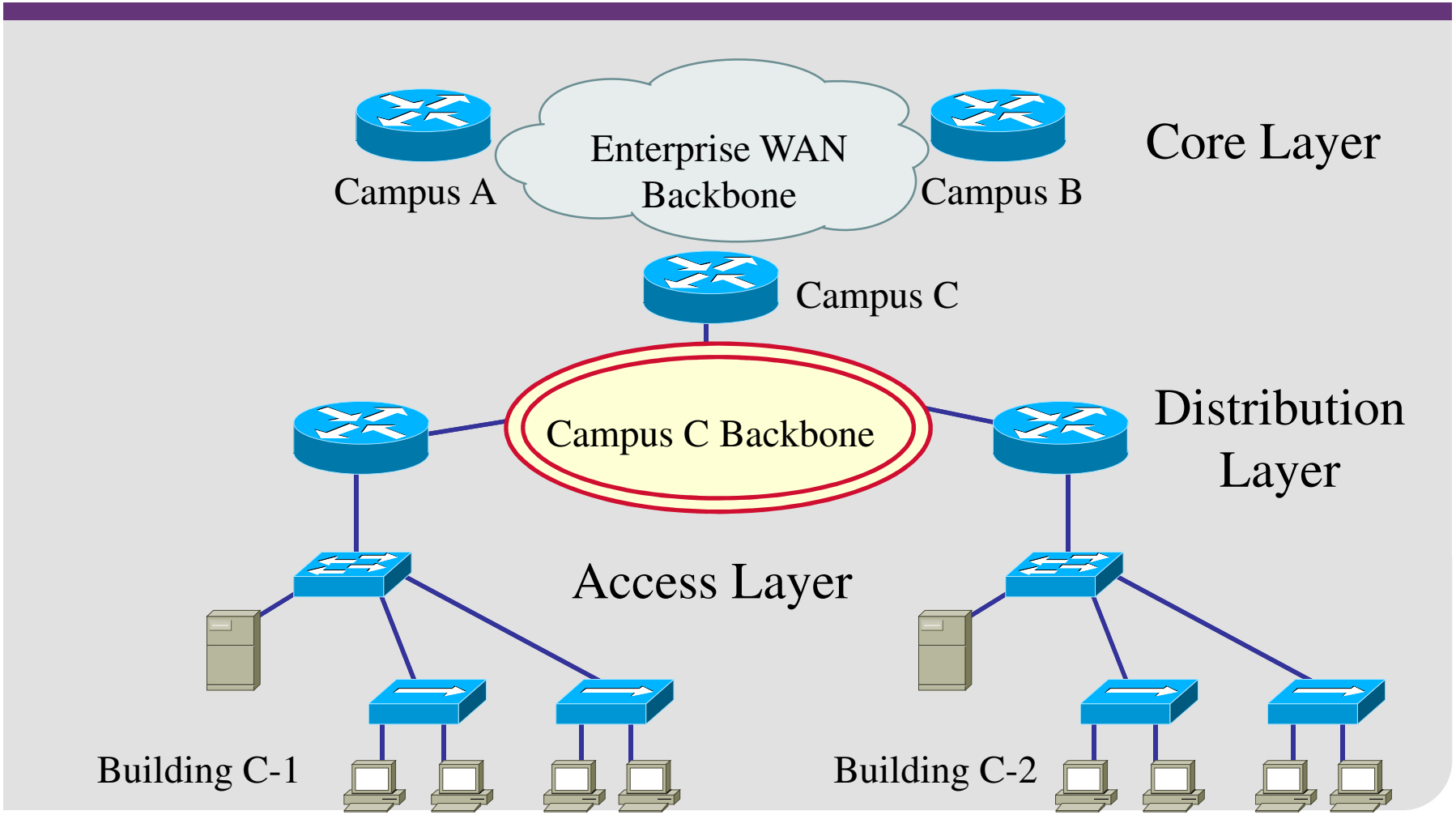
RAID - Redundant Array of Inexpensive Disks

LAN Applications (5)

- **high speed office networks**
  - desktop image processing
  - high capacity local storage
- **backbone LANs**
  - interconnect low speed local LANs
  - reliability
  - capacity
  - cost

Hierarchical Network Design

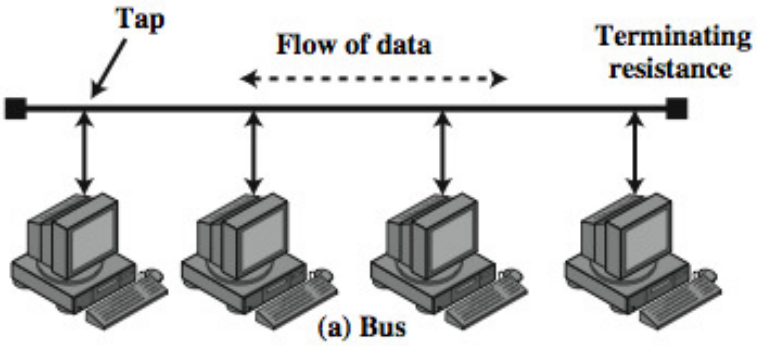
High-speed WAN routers can carry traffic across the enterprise WAN backbone, medium-speed routers can connect buildings at each campus, and switches can connect user devices and servers within buildings

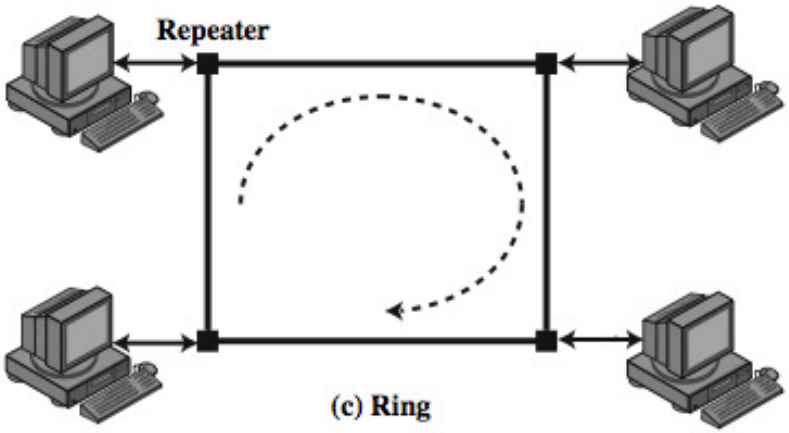


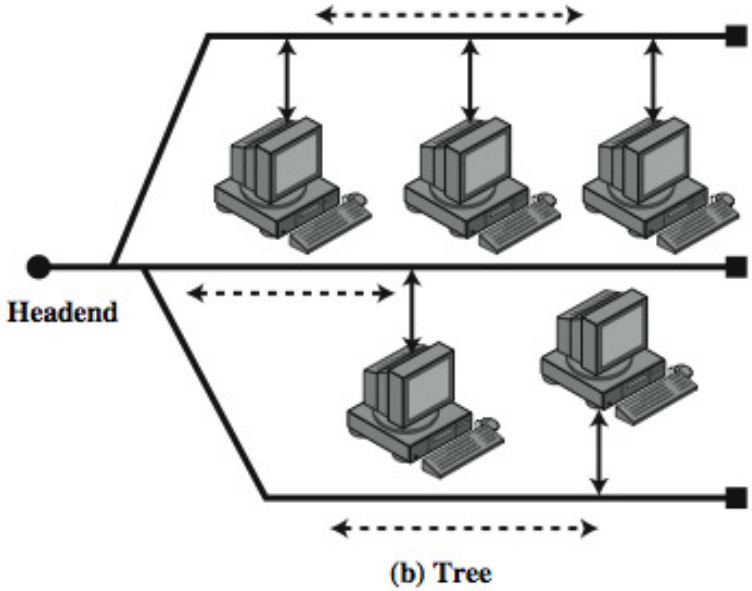
LAN Architecture evolution

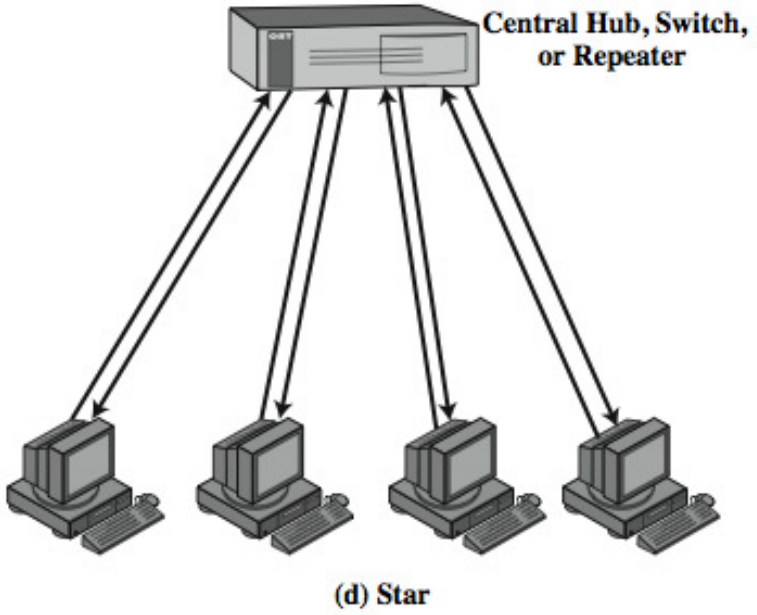
- Topologies
- Transmission medium
- Network Layout
- Medium access control

LAN Topologies



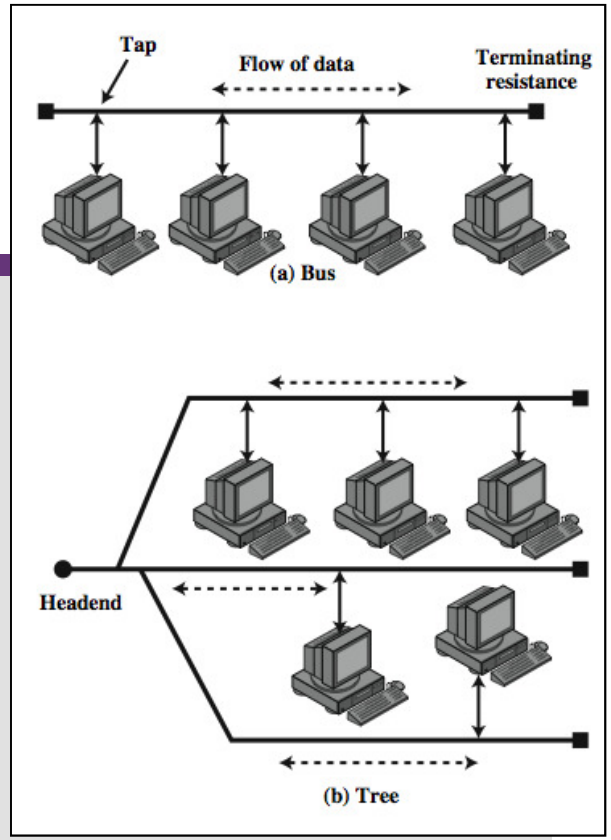


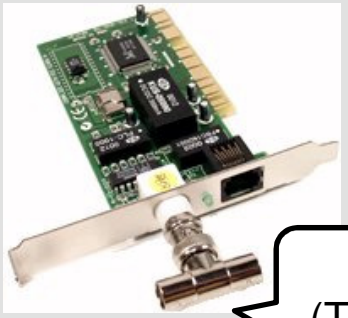




Bus and Tree

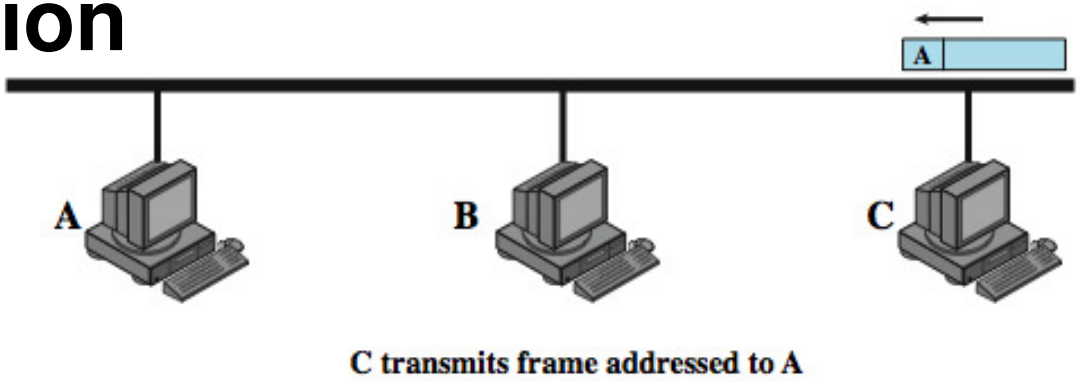
- **Characterized by the use of multipoint medium**
- **transmission propagates throughout medium**
- **heard by all stations**
- **full duplex connection between station and tap**
  - allows for transmission and reception
- **need to regulate transmission**
  - to avoid collisions and channel hogging
- **terminator absorbs frames at end of medium**
- **tree a generalization of bus**
- **head-end connected to branching cables**



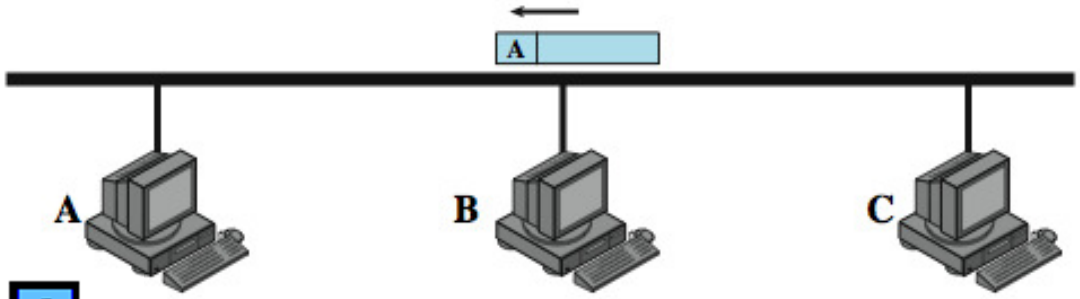


tap
(T-connector)

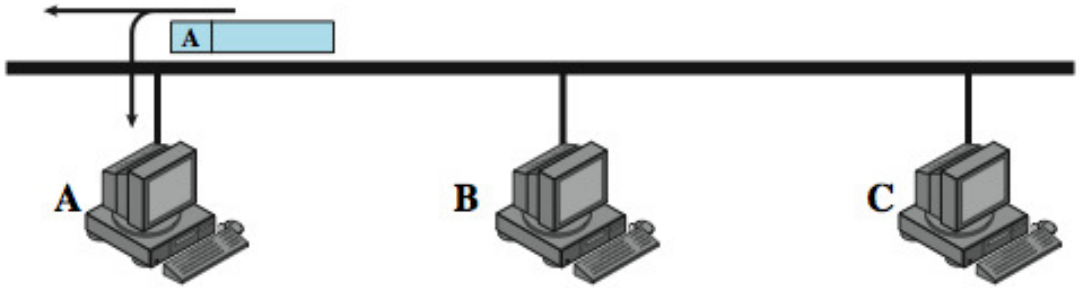
Frame Transmission on Bus LAN



C transmits frame addressed to A



Frame is not addressed to B; B ignores it



A copies frame as it goes by

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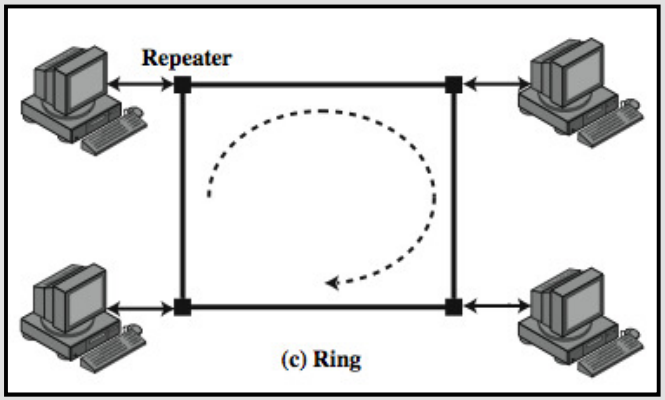
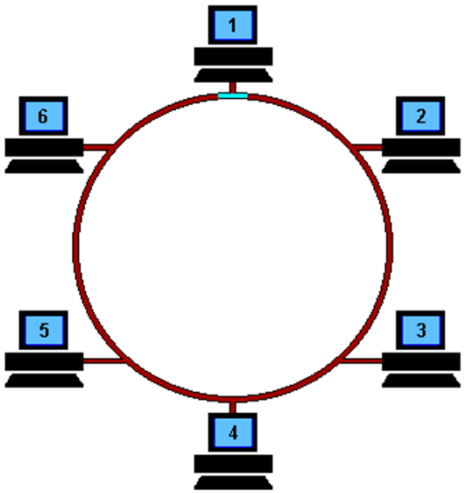
Ring Topology

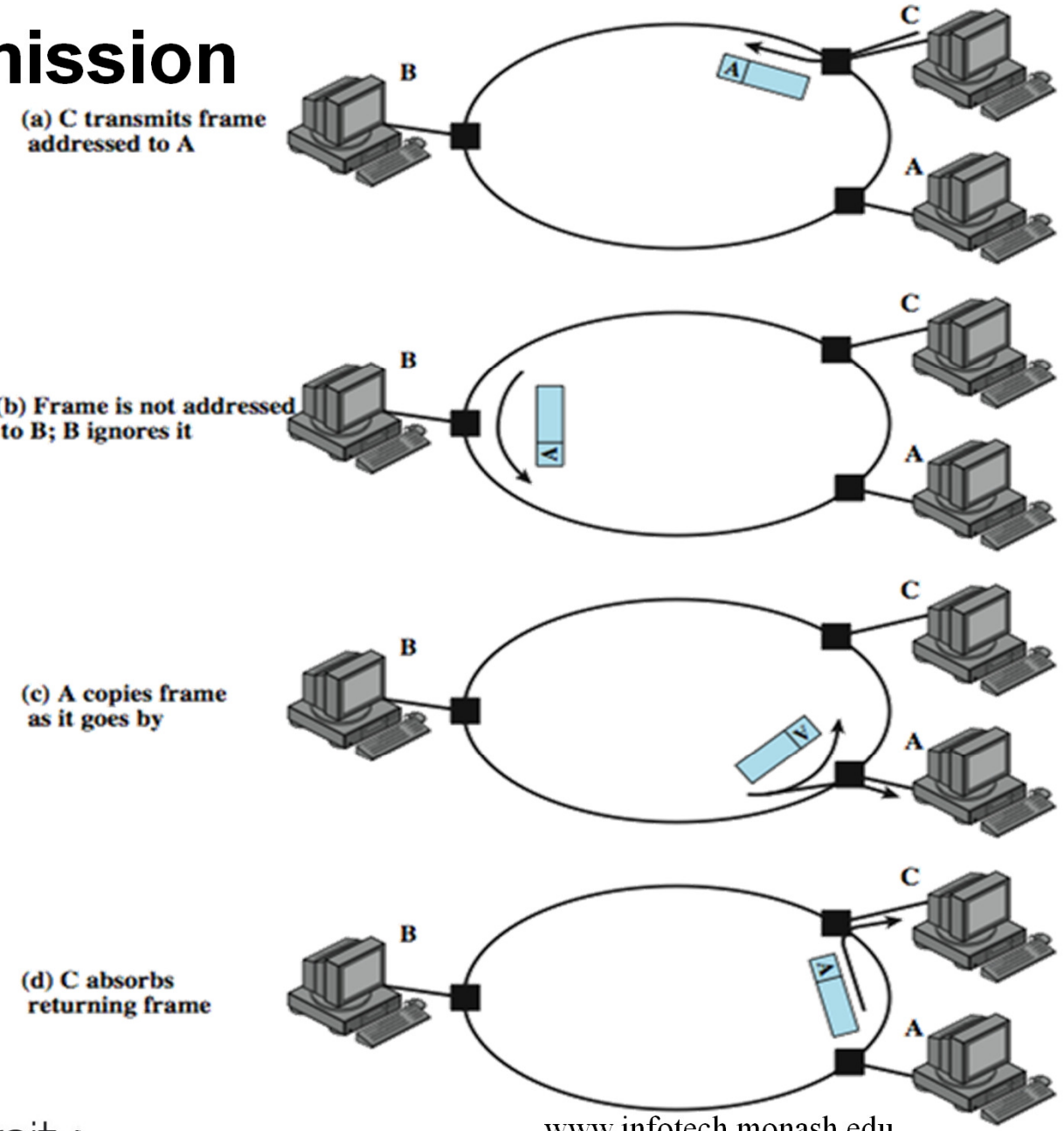
- **a closed loop of repeaters joined by point to point links**
- **receive data on one link & retransmit on another**
  - links are unidirectional
  - stations attach to repeaters
- **data transmitted as frames**
  - circulate past all stations
  - destination recognizes address and copies frame
  - frame circulates back to source where it is removed
- **medium access control determines when a station can insert frame**



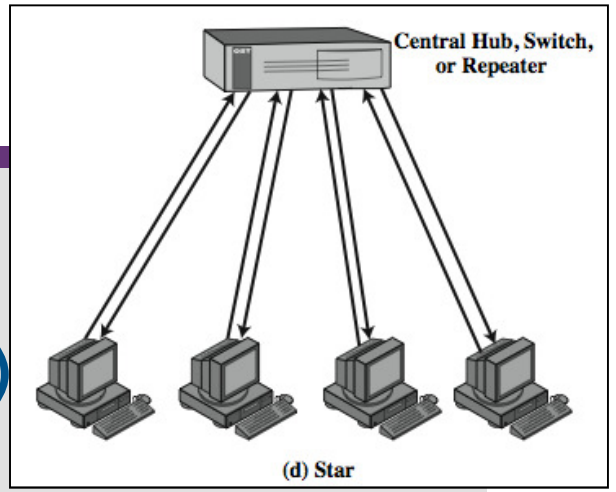
Frame Transmission Ring LAN

This figure illustrates how a frame continues to circulate until it returns to the source station, where the frame is removed





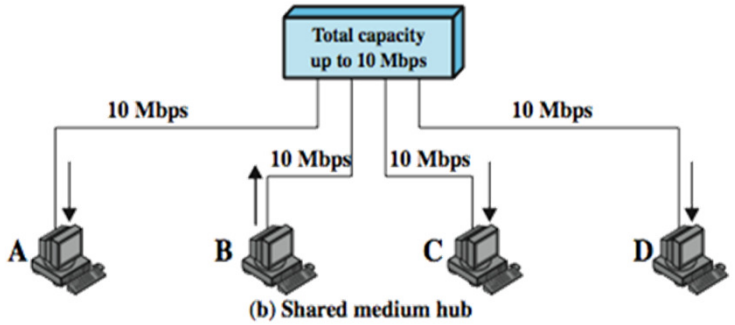
Star Topology



- **each station connects to central node**
  - usually via two point to point links (UTP)
- **either central node will broadcast (Hub)**
  - physical star, logical bus: frame broadcasting
  - transmission from a station is seen by all others
  - only one station can transmit at a time
  - if two stations transmit at the same time we have a collision
- **or central node can act as frame switch**
  - frame switching
  - non-broadcast transmission is private between peers only
  - switch, using full-duplex cables, allows simultaneous transmissions, with no collisions (from Fast Ethernet up)

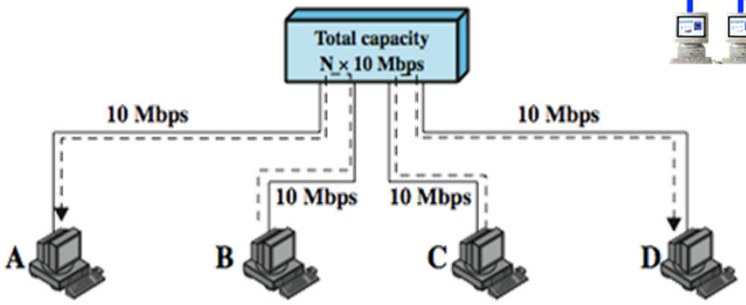
Star Topology with Hubs or Switches

- **Frame Broadcast (hub)**
  - frame retransmitted on all outgoing links
  - received by all
  - central node is then referred to as a hub.



(b) Shared medium hub

- **Frame Switching (switch)**
  - incoming frame is buffered in the switch and retransmitted only on an outgoing link to the destination station.
  - central node is referred to as a switch.



(c) Layer 2 switch

Choice of Topology

The choice of topology depends on a variety of factors

- **reliability**
- **expandability**
- **performance**
- **needs considering in context of:**
  - medium
  - wiring layout
  - access control

Bus LAN
Transmission Media (1)

- **twisted pair**
  - early LANs used voice grade cable
  - didn't scale for fast LANs
  - not used in bus LANs now

- **baseband coaxial cable**
  - uses digital signalling
  - original Ethernet

  baseband coaxial cabling is still used in old existing Ethernet but not often in new installations

  (also known as thin ***ethernet, thinnet*** or thick ***ethernet thicknet***)

Bus LAN
Transmission Media (2)

- **broadband coaxial cable**
  - as in cable TV systems
  - analog signals at radio frequencies
  - expensive, hard to install and maintain
  - no longer used in LANs
- **optical fiber**
  - expensive taps
  - better alternatives available
  - not used in bus LANs
- **less convenient than star topology twisted pair**

broadband coaxial still used in old existing Ethernet but not often in new installations (also known as thin ***ethernet, thinnet*** or thick ***ethernet thicknet***)

Ring and Star Usage

- **ring**
  - very high speed links over long distances
  - single link or repeater failure disables network
- **star**
  - uses natural layout of wiring in building
  - best for short distances
  - high data rates for small number of devices
  - The star topology currently dominates the market.

Choice of Medium

choice of transmission medium is determined by a number of factors and constrained by LAN topology

- **capacity**
- **reliability**
- **types of data supported**
- **environmental scope**

Media Available

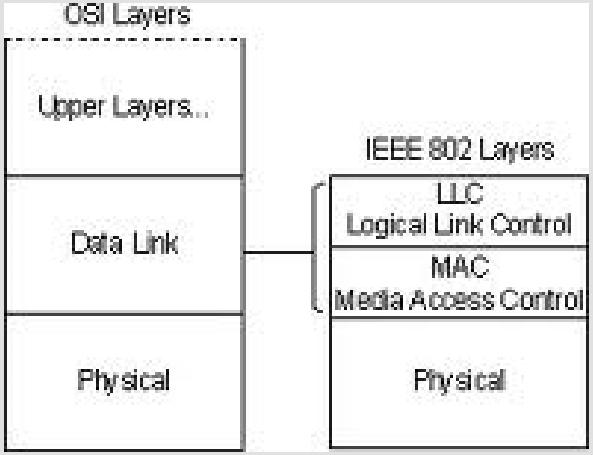
- **Voice grade unshielded twisted pair (UTP)**
  - Cat 3 UTP cable for phones
  - cheap but low data rates
- **Shielded twisted pair / baseband coaxial**
  - more expensive, higher data rates
- **Broadband coaxial cable**
  - even more expensive, higher data rate
- **High performance UTP**
  - Cat 5, 5e, 6, 7 & 8 very high data rates, switched star topology
- **Optical fibre**
  - security, high capacity, small size, highest cost

IEEE 802 Layers (1)

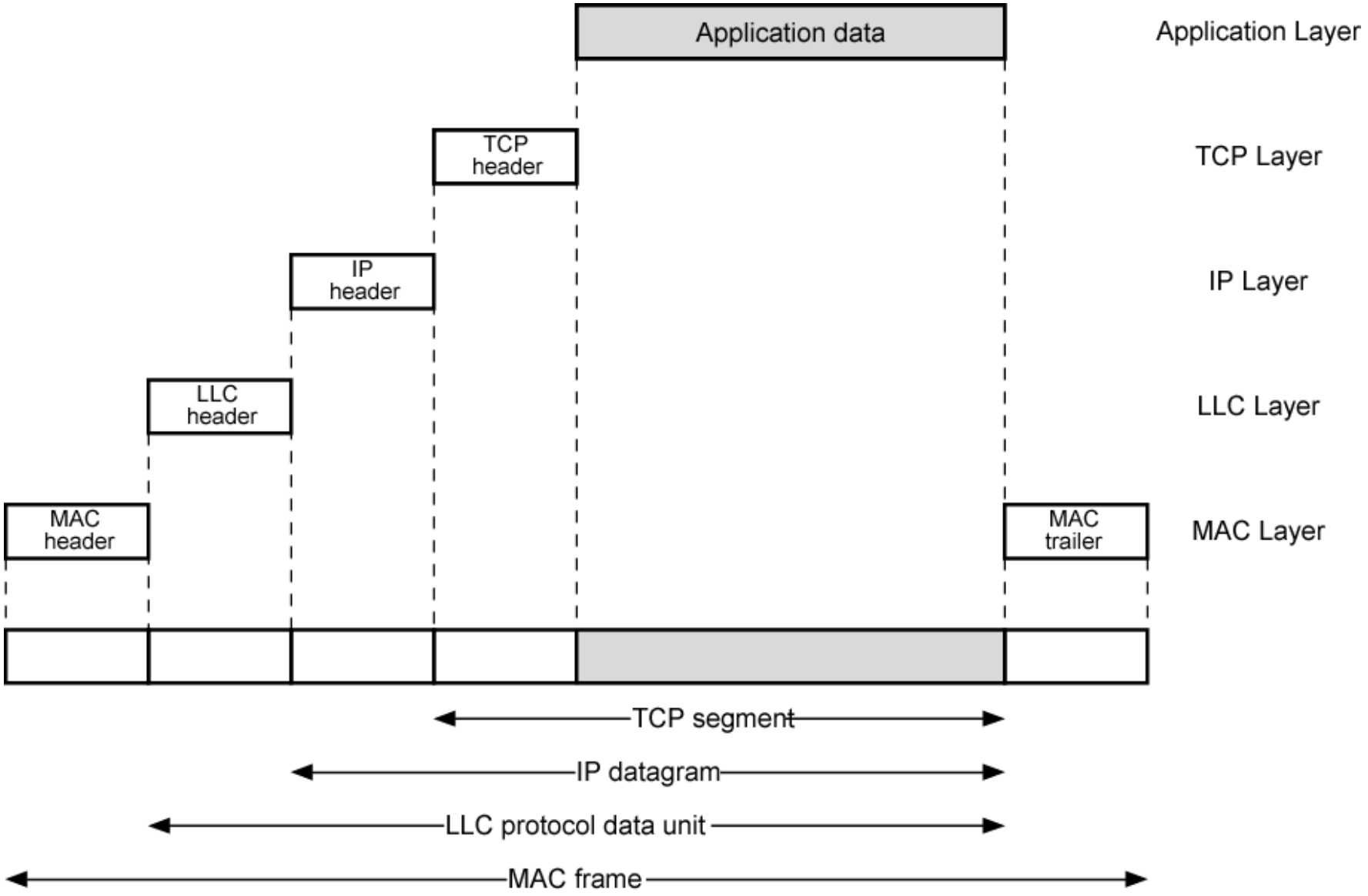
- **Physical**
  - encoding/decoding of signals
  - preamble generation/removal (synchronization)
  - bit transmission/reception
  - transmission medium and topology

IEEE 802 Layers (2)

- **Logical Link Control**
  - interface to higher levels
  - flow and error control
- **Medium Access Control**
  - on transmit, assemble data into frame
  - on receive, disassemble frame
  - govern access to transmission medium
  - for the same LLC, there may be several MAC options



LAN Protocols in Context



LLC Services

- mechanisms for addressing stations across the medium and controlling data exchange
- format and operations are based on HDLC

1. unacknowledged connectionless service
2. connection-mode service
3. acknowledged connectionless service

The IEEE 802 Reference Model

This architecture was developed by the IEEE 802 committee and has since then been adopted in the definition of LAN standards:

- **IEEE 802.3 Ethernet MAC**
- IEEE 802.5 Token Ring MAC
- IEEE 802.6 Metropolitan Area Networks – obsoleted
- **IEEE 802.11 Wireless LAN - "Wi-Fi" - MAC**
- IEEE 802.14 Cable modems - obsoleted
- IEEE 802.15 Wireless PAN
  - > IEEE 802.15.1 Bluetooth
  - > IEEE 802.15.4 ZigBee
- IEEE 802.16 Broadband Wireless Access – "WiMAX"
- IEEE 802.16e (Mobile) Broadband Wireless Access

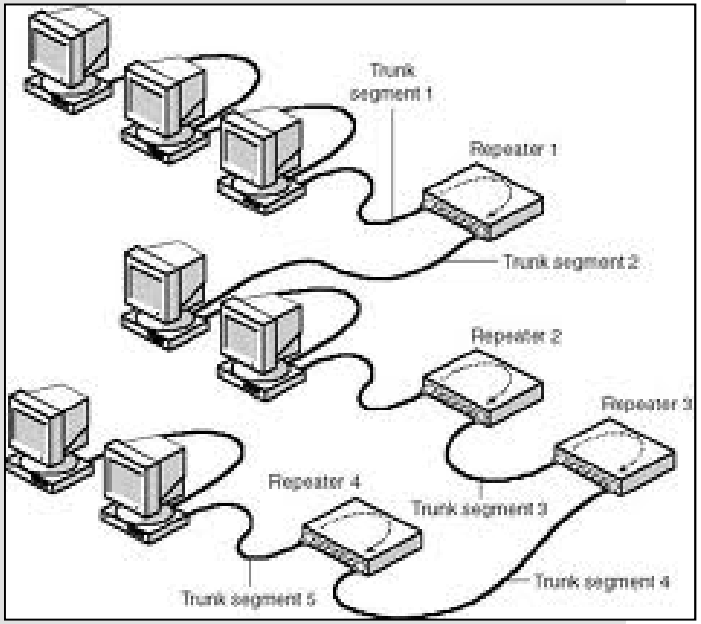
MAC Frame Handling

- **MAC layer receives data from LLC layer**
- **fields**
  - MAC control
  - destination MAC address
  - source MAC address
  - LLC
  - CRC
- **MAC layer detects errors and discards frames**
- **LLC optionally retransmits unsuccessful frames**

Expanding Networks: Using Repeaters

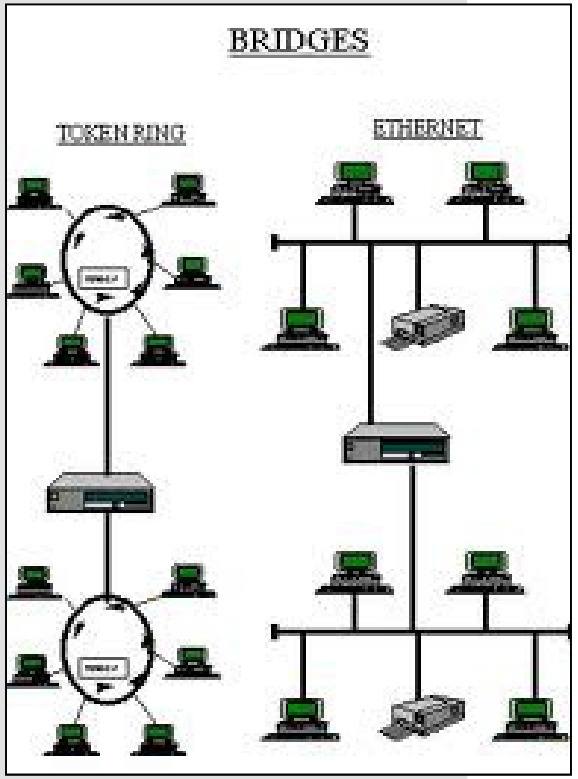
- Repeaters can address signal attenuation.
- Operates purely at the physical layer.
- Any type of LAN segment has a defined maximum limit to the physical length of the segment and the number of stations that may be attached to it.

- Repeaters are used to connect segments of a LAN.
- Repeaters may use optical isolation to protect segments from power surge transients.
- Signals are simply digitally regenerated.
- But no error checking is performed.



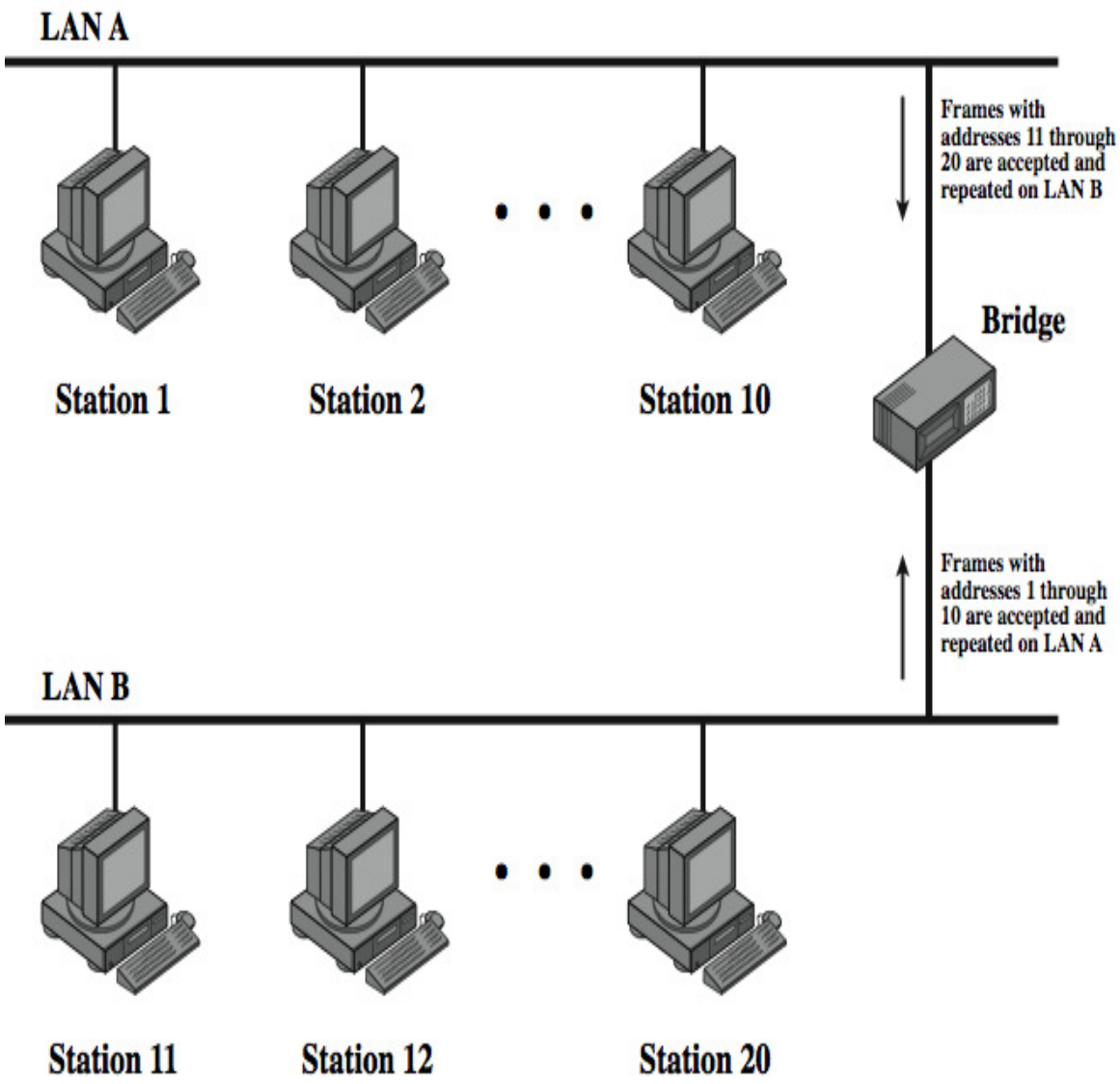
Expanding Networks: Using Bridges

- connect similar LANs
- operate at the data link layer (L2)
- identical physical / link layer protocols
- minimal processing (Fast)
- can map between MAC formats
- perform error checking
- reasons for use
  - Reliability (partition, fault isolation)
  - Performance (small broadcast domains)
  - Security (physical traffic management)
  - Geography (physical separation)

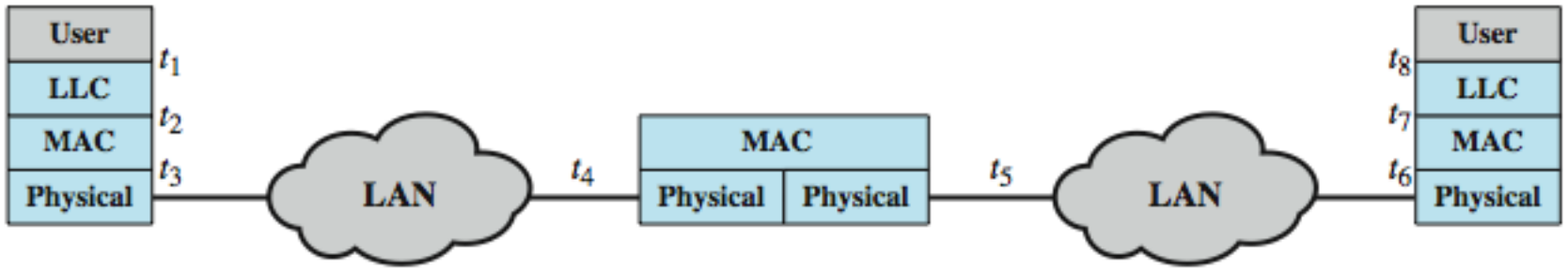


Bridge Function

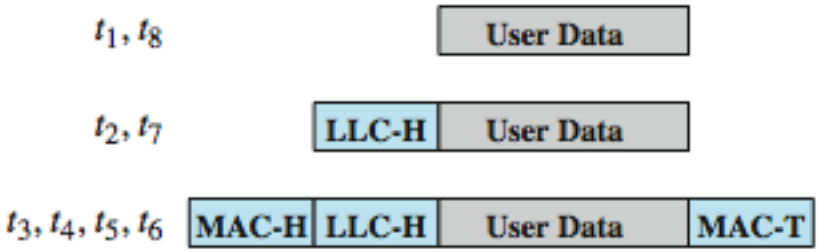
- **A bridge receives and buffers the frames from a segment.**
- **A bridge will forward frames only if**
  - they are error-free and
  - are addressed to the other segment in the LAN.



Connection of Two LANs using bridge

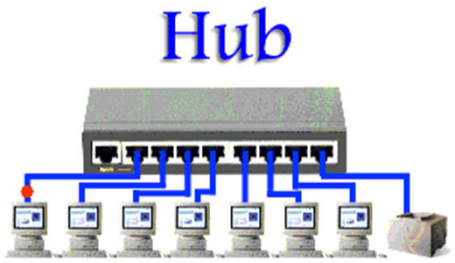


(a) Architecture

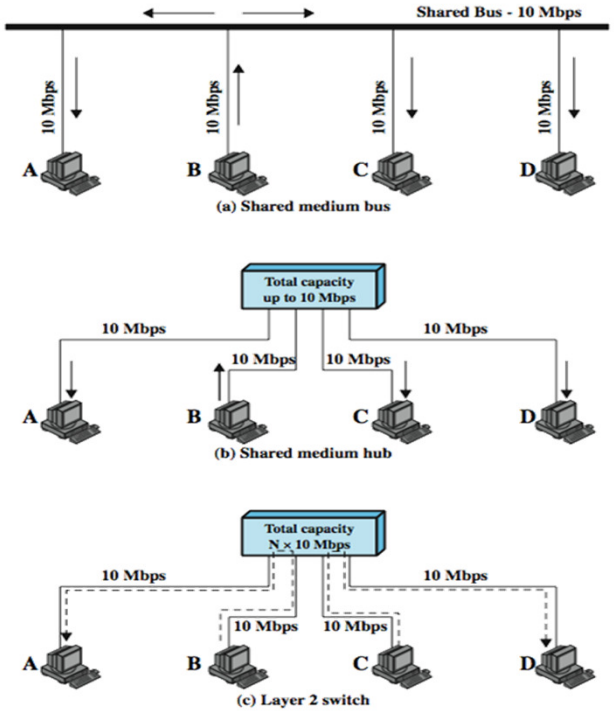


(b) Operation

Interconnecting LANs: bus, hubs and switches



- **Bus: shared medium**
- **Frame Broadcast (hub)**
  - frame retransmitted on all outgoing links
  - received by all stations
  - central node is then referred to as a hub.
- **Frame Switching (switch)**
  - incoming frame is buffered in the central node and retransmitted on an outgoing link to the destination station.
  - The central node is referred to as a (Layer 2) switch.



Types of Layer 2 Switches

- **store-and-forward switch**
  - accepts frame on input line, buffers briefly, routes to destination port
  - see delay between sender and receiver
  - better integrity
- **cut-through switch**
  - use destination address at beginning of frame
  - switch begins repeating frame onto output line as soon as destination address recognized
  - highest possible throughput
  - risk of propagating bad frames

Layer 2 Switch vs Bridge

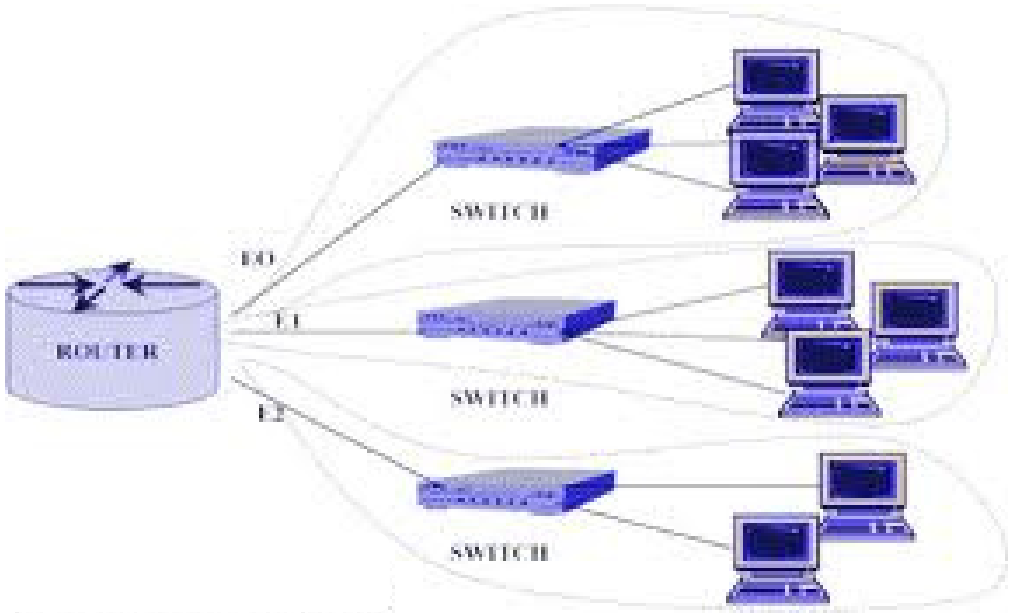
- **Layer 2 switch can be viewed as full-duplex hub**
- **incorporates logic to function as multiport bridge**
- **differences between switches & bridges:**
  - **bridge** frame handling done in **software**
  - **switch** performs frame forwarding in **hardware**
  - **bridge** analyzes and forwards one frame at a time
  - **switch** can handle multiple frames at a time
  - **bridge** uses store-and-forward operation
  - **switch** can have cut-through operation
- **hence bridge have suffered commercially**

Layer 2 Switch Problems

- **Large, flat networks will suffer from broadcast overload**
  - frames are not broadcast at all times (as in hubs), unless the MAC broadcast address (all bits are 1s) is used
  - MAC broadcasts necessary in some situations, e.g., ARP (address resolution protocol, sender knows destination's IP address but seeks unknown MAC address)
  - broadcast frames are delivered to all devices connected by layer 2 switches and/or bridges
  - broadcast frames can create big overhead
  - broadcast storm from malfunctioning devices
- **Current standards lack provision for multiple links**
  - limits performance & reliability

Expanding Networks: Routers

- **Break up flat networks into separate networks**
- **Connect two LANs that may not share common medium access control.**
- **Operates at Layer 3**
  (OSI Network Layer)
- **Hardware with embedded software:**
  1. Hardware -- can be network server/special device
  2. Software – Network Operating System (NOS) and routing protocol



- **Main functions:**
  1. determine a route that a packet will take to reach its destination.
  2. choose the best route, or balance load across routes between the networks when there are several possible routes.
  3. Filters traffic by segment.
  4. May include *firewall* functions to isolate traffic by type, destination or direction.

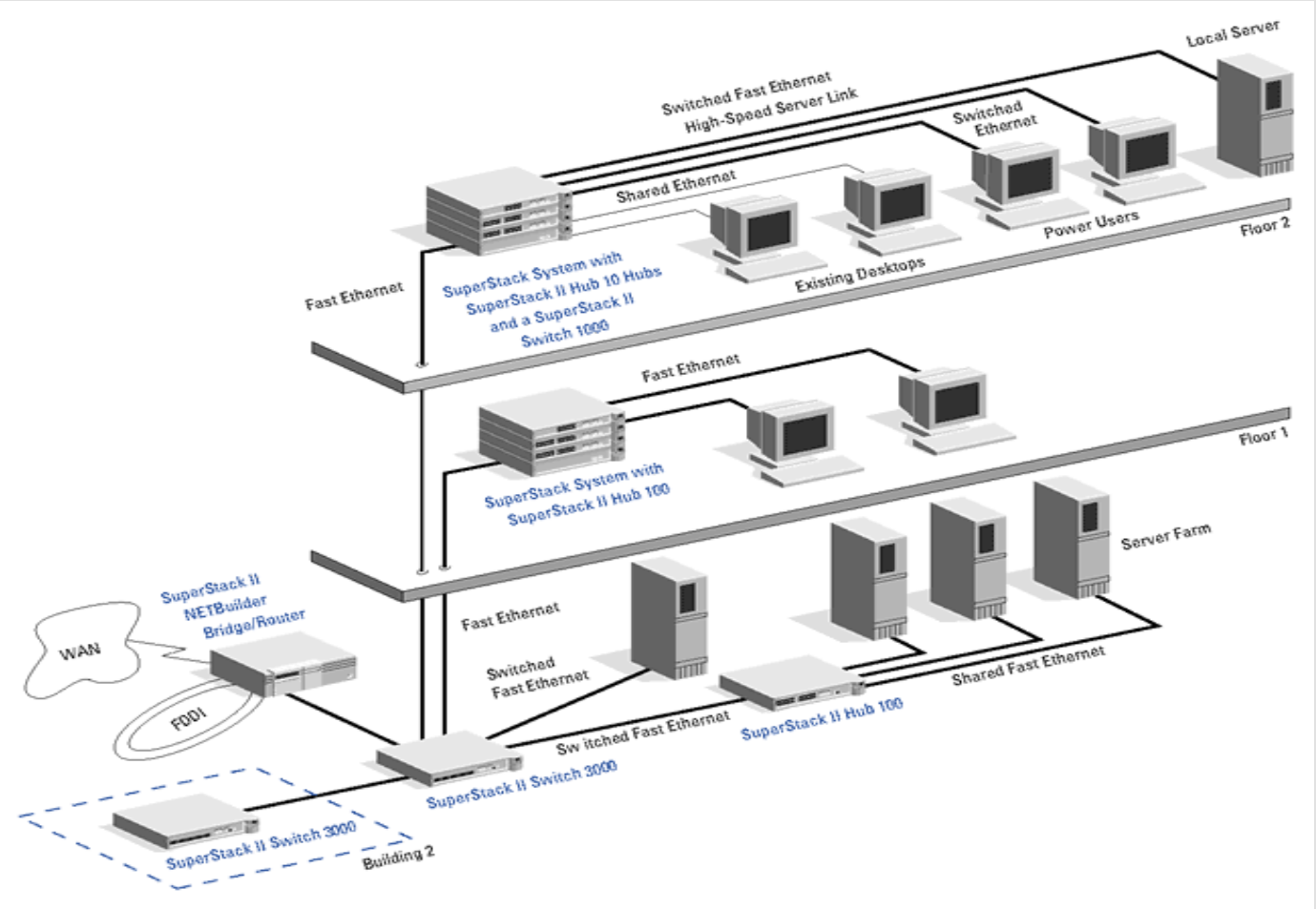
Layer 3 Switches

- **Routers do all IP-level processing in software**
  - High-speed LANs and high-performance layer 2 switches pump millions of packets per second.
  - But routers handle well over a million packets per second.
- **Solution: layer 3 switches**
  - implement packet-forwarding logic of router in hardware
- **Layer 3 switches are of two categories**
  - **Packet by Packet** (like a router does, but faster)
  - **Flow based**
    - > identifies flows of IP packets with same source and destination
    - > by observing traffic or using a flow label in packet header (IPv6)
    - > a predefined (optimized) route is used for identified flows

Gateways

- Connect two or more LANs that use completely different protocols, e.g., IP vs. AppleTalk or IPX.
- Interpret and translates one network protocol into another, translates data formats.
- May consist of software, dedicated hardware, or a combination of both.
- Example: gateways are typically used to connect IBM mainframes that use SNA (System Network Architecture) to LANs that use TCP/IP and Ethernet.
- Disambiguation: the term “default gateway” is typically used to designate an outgoing router or gateway to exit one’s network.

Typical Building – Floor LAN Organization Diagram

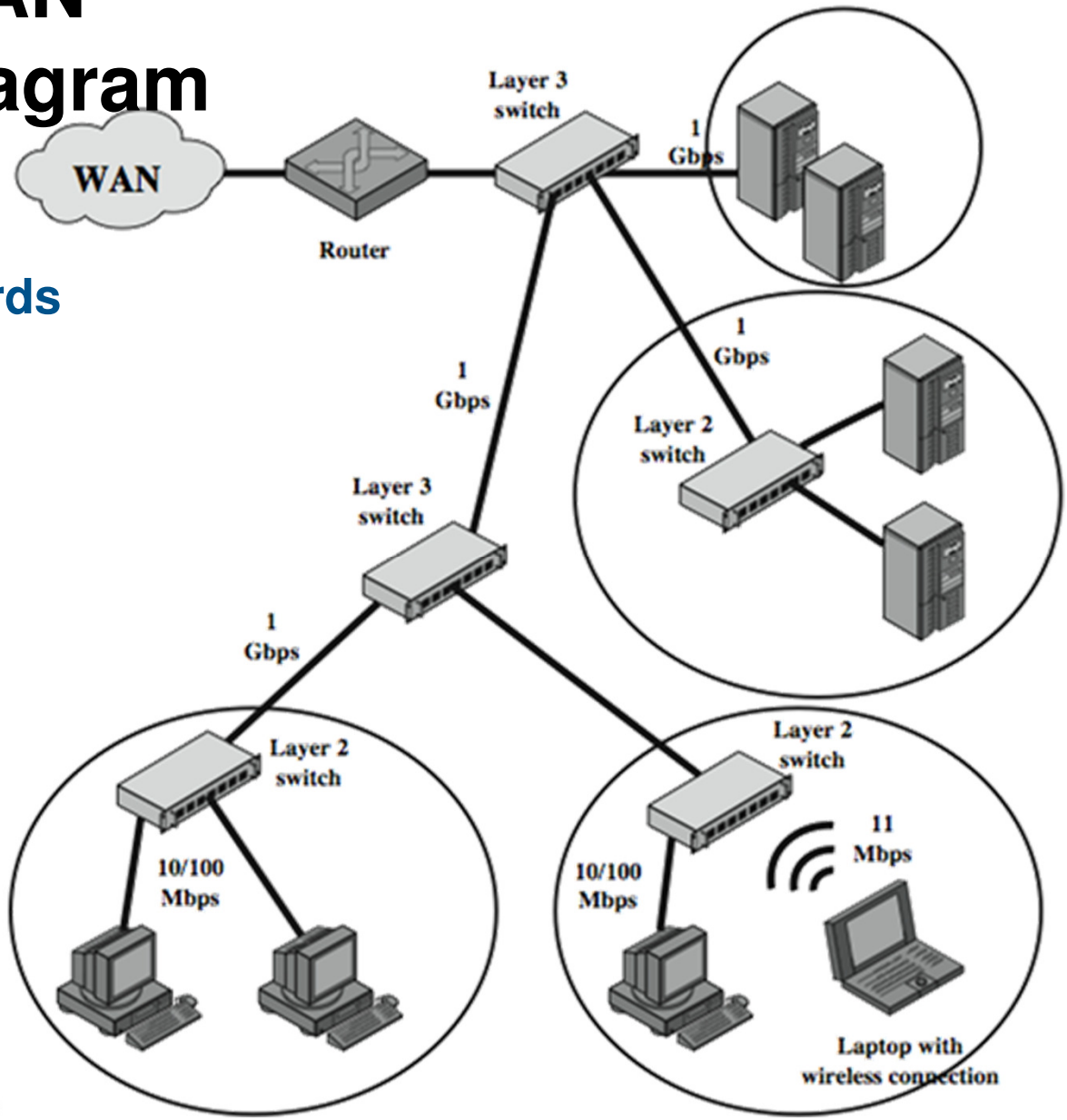


Typical Large LAN Organization Diagram

Network Components:

- **Network Interface Cards**
- **Connectors**
- **Transmission Media**
- **Server(s)**
- **Intermediary devices:**
  - Core Switches
  - Core Routers
  - Workgroup Switches

  Not in diagram:
  - Repeaters
  - Bridges
  - Gateways



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Summary

- **LAN topologies and media**
- **LAN protocol architecture**
- **Campus Backbone**
  - Core L2-Switches, Core L3-Routers
  - In addition bridges, repeaters, workgroup switches, internal L3-routers

MONASH University
Information Technology

FIT3165 Computer Networks

PART-2 : HIGH SPEED LANs

Reference: Chapter 16, Data and Computer Communications, by William Stallings

Introduction

- **range of technologies**
  - Fast and Gigabit Ethernet
  - Fibre Channel
  - High Speed Wireless LANs

Why High Speed LANs?

- **speed and power of PCs has risen**
  - graphics-intensive applications and GUIs
- **LANs are seen as essential to organizations**
  - for client/server computing
- **now have requirements for**
  - centralized server farms
  - power workgroups
  - high-speed local backbone

Ethernet Switched & Shared(CSMA/CD/CA)

- **most widely used LAN standard**
- **developed by**
  - Xerox - original Ethernet
  - IEEE 802.3
- **Carrier Sense Multiple Access with Collision Detection (CSMA/CD) - Legacy**
  - random / contention access to media
- **Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) - Wireless**

Legacy 10Mbps Specification (Ethernet)

	10BASE5	10BASE2	10BASE-T	10BASE-FP
Transmission medium	Coaxial cable (50 ohm)	Coaxial cable (50 ohm)	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 to 0.6	62.5/125 µm

Legacy 100Mbps Fast Ethernet

	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

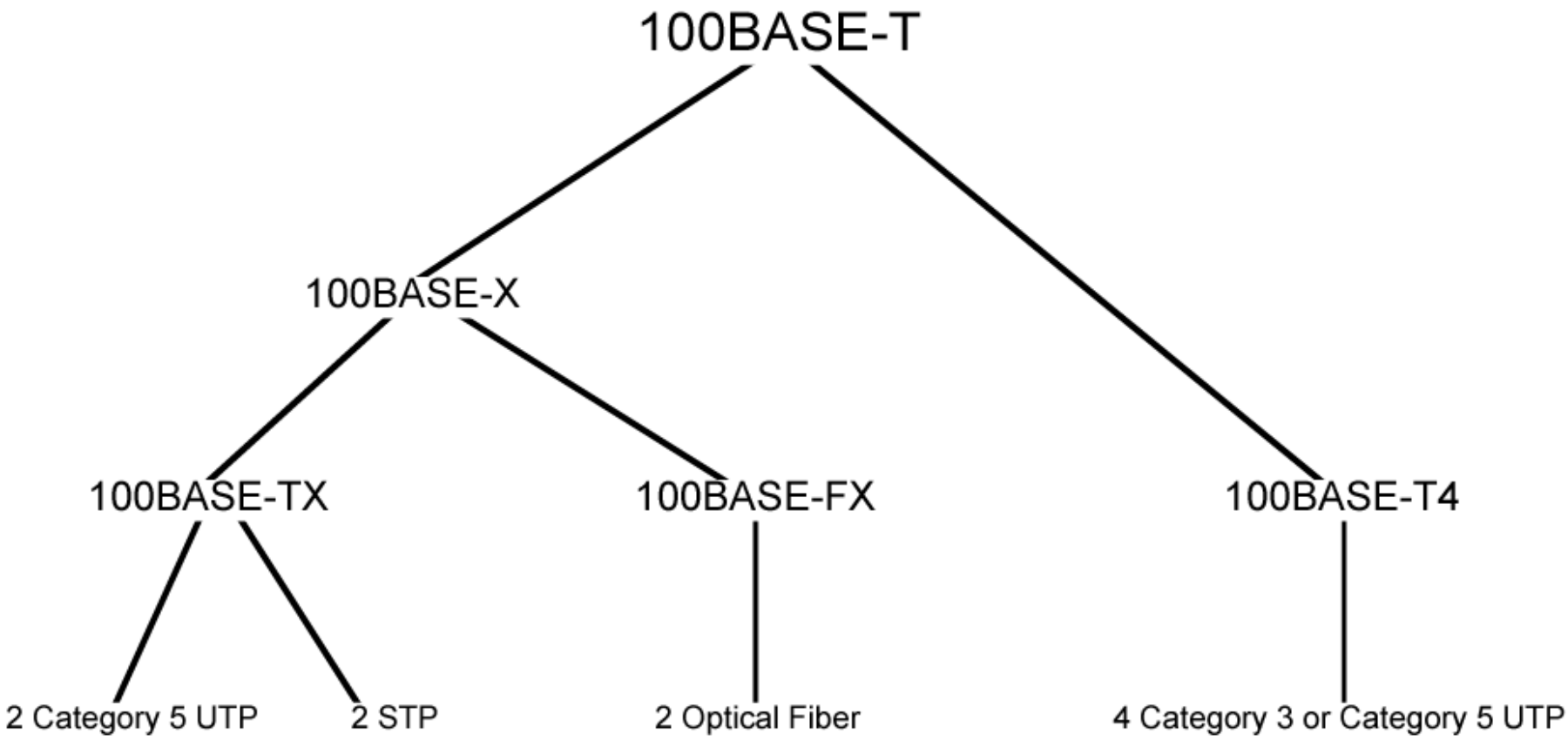
100BASE-X

- **uses a unidirectional data rate 100 Mbps over single twisted pair or optical fiber link**
- **two physical medium specifications**
  - 100BASE-TX
    - > uses two pairs of twisted-pair cable for tx & rx
    - > STP and Category 5 UTP allowed
    - > MTL-3 signaling scheme is used
  - 100BASE-FX
    - > uses two optical fiber cables for tx & rx
    - > convert 4B/5B-NRZI code group into optical signals

100BASE-T4

- **100-Mbps over lower-quality Cat 3 UTP**
  - takes advantage of large installed base of cat 3 cabling
  - does not transmit continuous signal between packets
  - useful in battery-powered applications
- **cannot get 100 Mbps on single twisted pair**
  - so data stream split into three separate streams
  - four twisted pairs used
  - data transmitted and received using three pairs
  - two pairs configured for bidirectional transmission
- **use ternary signaling scheme (8B6T)**

100BASE-T Options



Full Duplex Operation

- **traditional Ethernet was only half duplex**
- **using full-duplex, station can transmit and receive simultaneously**
- **100-Mbps Ethernet in full-duplex mode, giving a theoretical transfer rate of 200 Mbps**
- **stations must have full-duplex adapter cards**
- **and must use switching (switch)**
  - each station constitutes separate collision domain
  - **CSMA/CD algorithm no longer needed**
  - 802.3 MAC frame format used

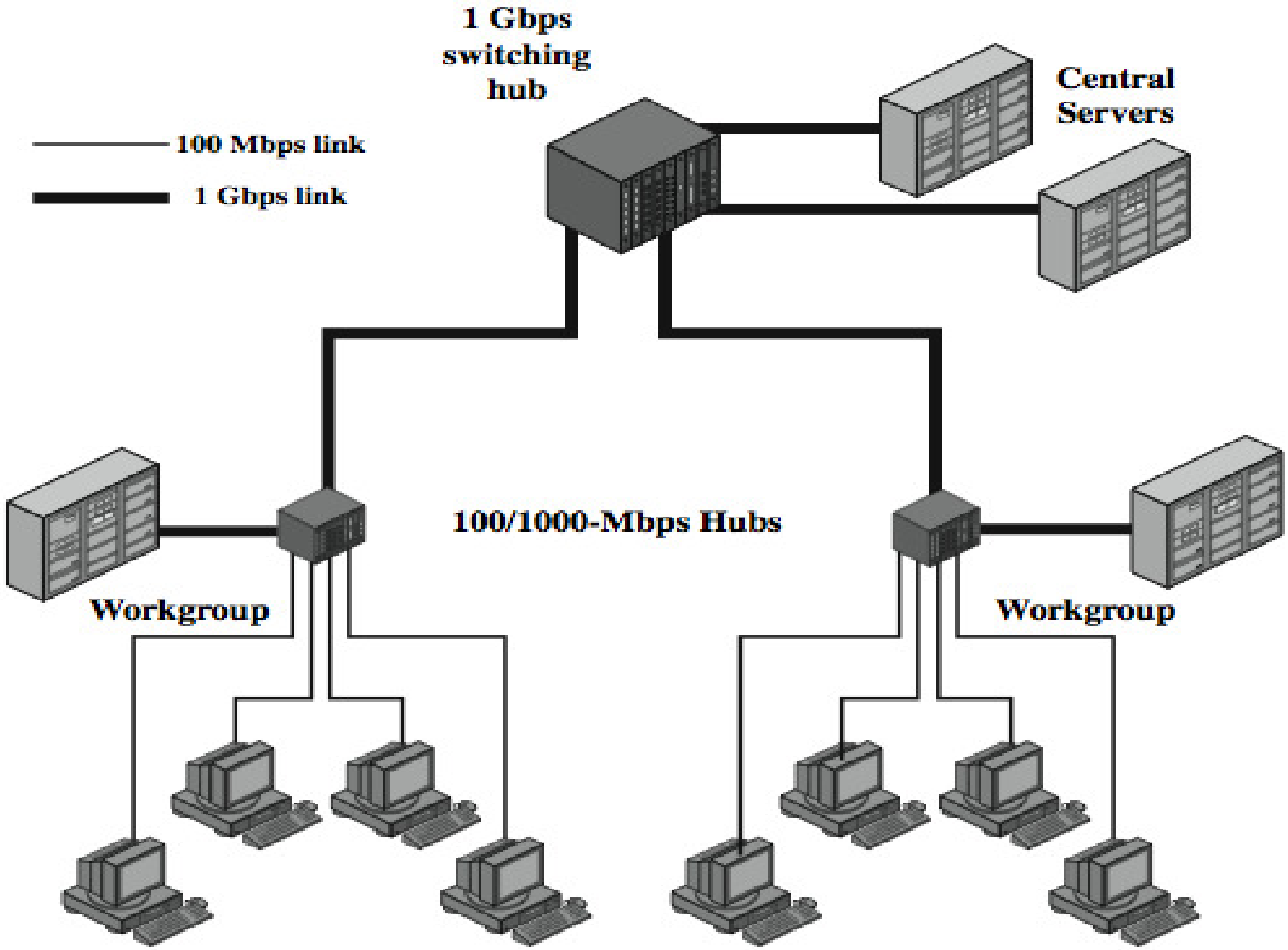
Mixed Configurations

- **Fast Ethernet LANs supports mixture of existing 10-Mbps LANs and newer 100-Mbps LANs**
- **supporting older and newer technologies**
  - e.g. 100-Mbps backbone LAN supports 10-Mbps hubs
    - > stations attach to 10-Mbps hubs using 10BASE-T
    - > hubs connected to switching hubs using 100BASE-T
    - > high-capacity workstations and servers attach directly to 10/100 switches
    - > switches connected to 100-Mbps hubs use 100-Mbps backbone links
    - > 100-Mbps hubs provide building backbone
    - > connected to router providing connection to WAN

Mixed Configurations (2)

- **Gigabit Ethernet supports mixture of existing 100 Mbps and 10 Mbps**
- **supporting older and newer technologies**
  - e.g. 1000-Mbps backbone LAN supports 100-Mbps switches
    - > stations attach to 10/100-Mbps switch using 100BASE-T
    - > Standard workstations and servers attach directly to 10/100 switches
    - > high-capacity workstations and servers attach directly to 1000-Mbps switches
    - > switches connected to 10/100-Mbps switch use 1000-Mbps backbone links
    - > 1000-Mbps switches provide building blocks for backbone
    - > connected to router providing connection to WAN

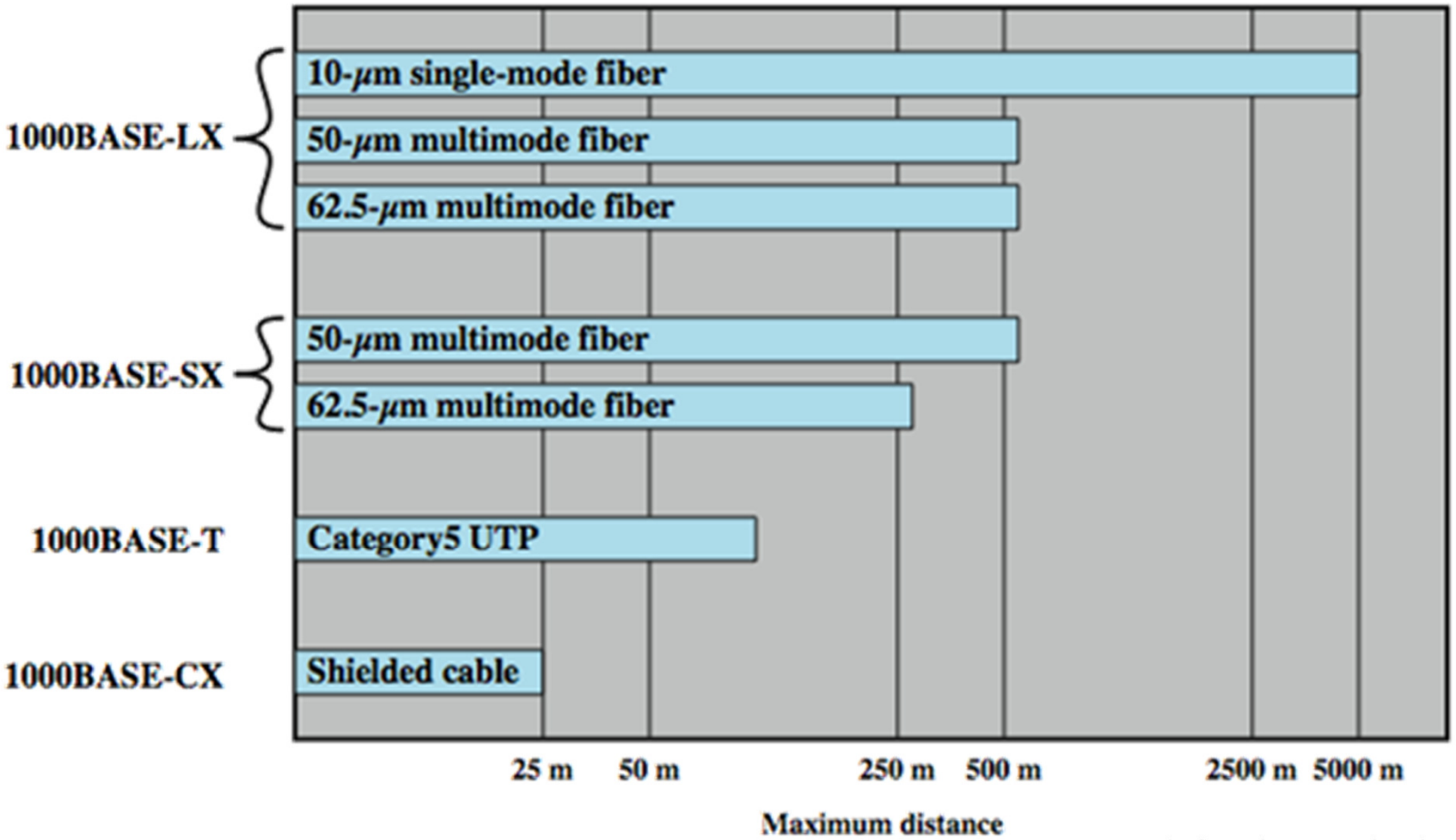
Gigabit Ethernet Configuration



Gigabit Ethernet – Physical

- **1000Base-SX**
  - Short wavelength, multimode fiber
- **1000Base-LX**
  - Long wavelength, Multi or single mode fiber
- **1000Base-CX**
  - Copper jumpers <25m, shielded twisted pair
- **1000Base-T**
  - 4 pairs, cat 5 UTP
- **Signaling - 8B/10B**

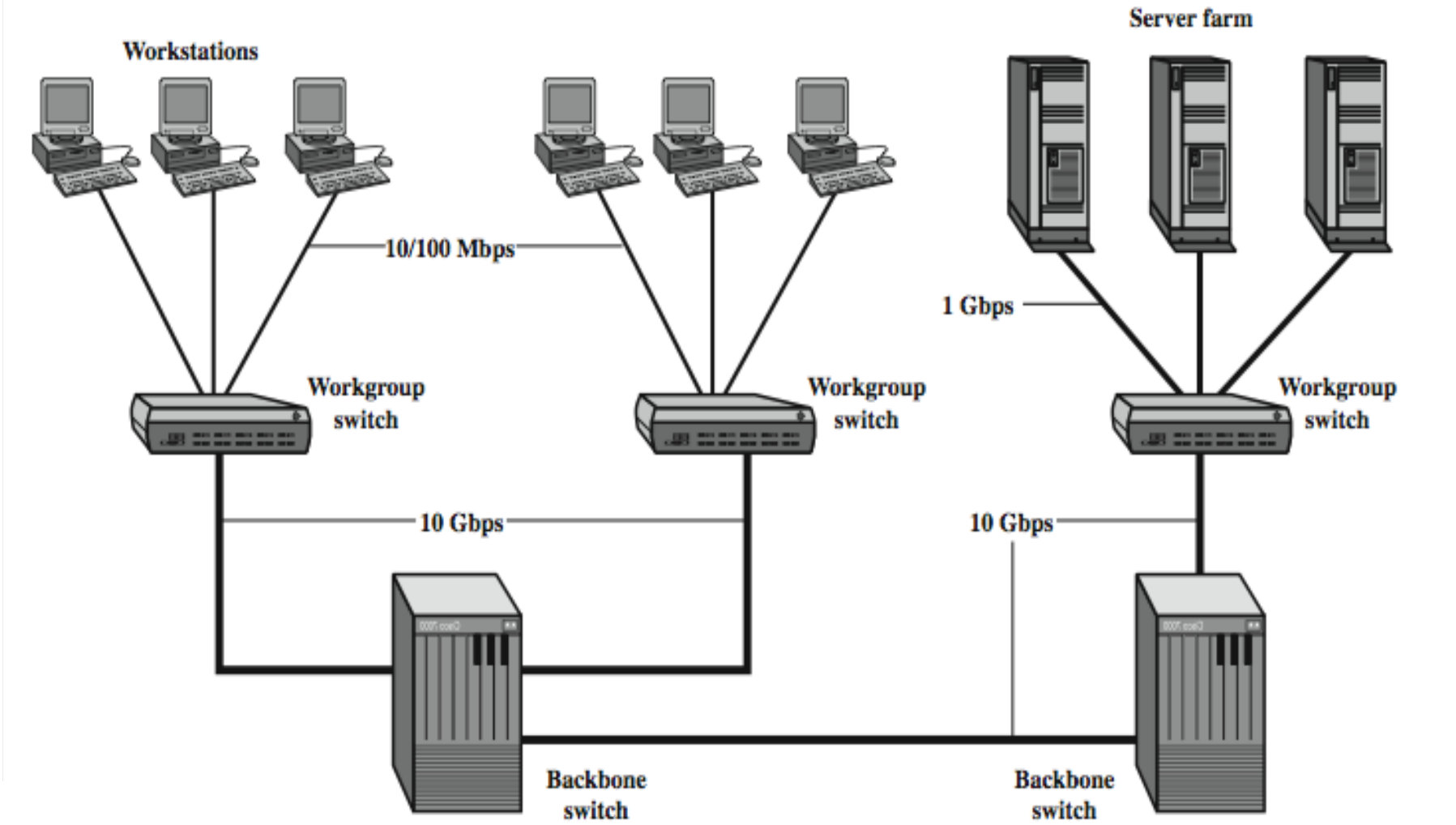
Gigabit Ethernet – Physical
Gbit Ethernet Medium Options (log scale)



10Gbps Ethernet

- **growing interest and trend in 10Gbps Ethernet**
  - for high-speed backbone use
  - with future wider deployment
- **alternative to ATM and other WAN technologies**
- **uniform technology for LAN, MAN, or WAN**
- **advantages of 10Gbps Ethernet**
  - no expensive, bandwidth-consuming conversion between Ethernet packets and ATM cells
  - *IP and Ethernet together offers QoS and traffic policing approach ATM*
  - have a variety of standard optical interfaces

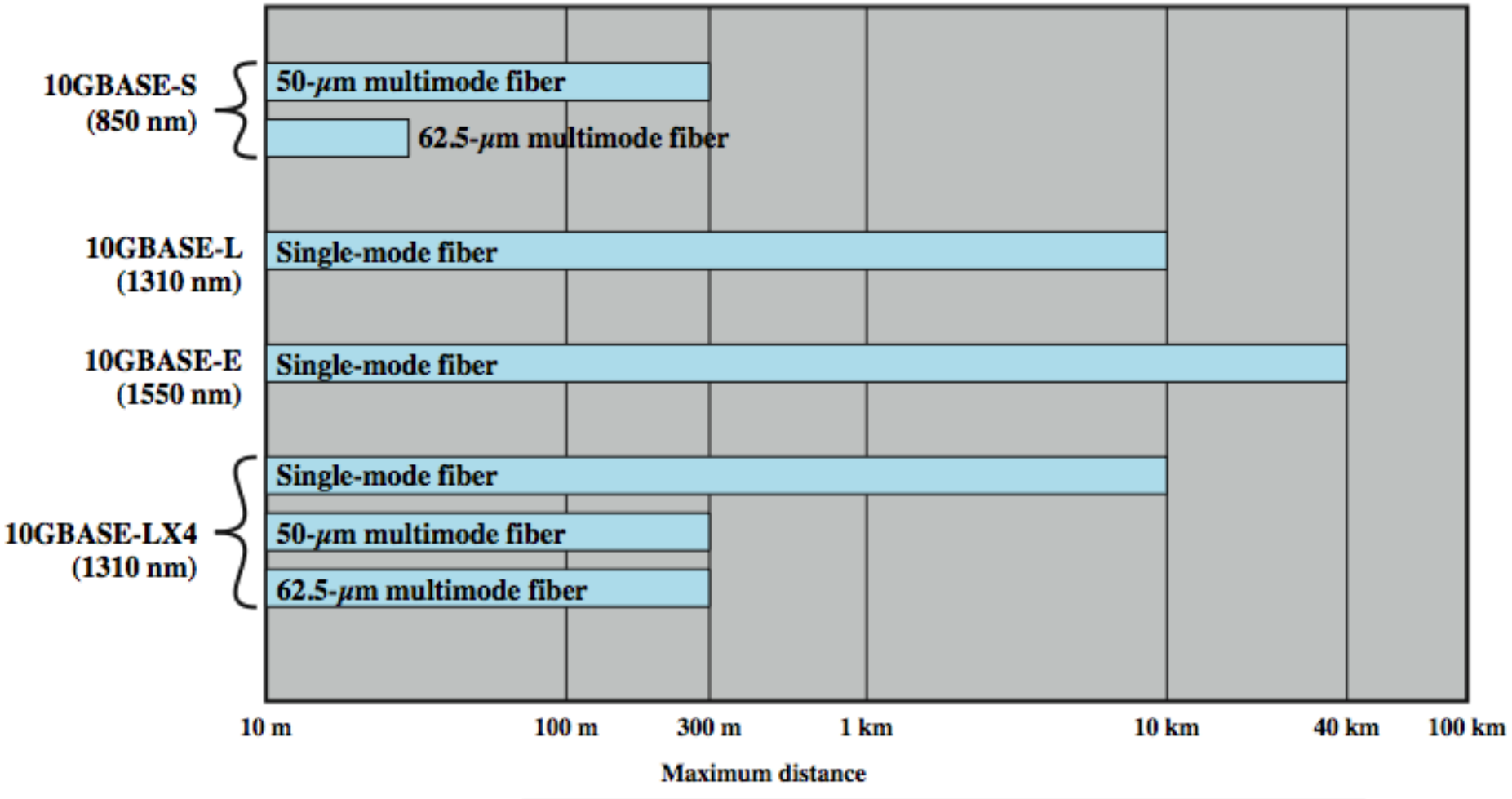
10Gbps Ethernet Configurations



10Gbps Ethernet - Advantages

- **Maximum link distances cover 300 m to 40 km**
- **Full-duplex mode only**
- **10GBASE-S (short):**
  - 850 nm on multimode fiber
  - Up to 300 m
- **10GBASE-L (long)**
  - 1310 nm on single-mode fiber
  - Up to 10 km
- **10GBASE-E (extended)**
  - 1550 nm on single-mode fiber
  - Up to 40 km
- **10GBASE-LX4:**
  - 1310 nm on single-mode or multimode fiber
  - Up to 10 km
  - Wavelength-division multiplexing (WDM) bit stream across four light waves

10Gbps Ethernet Options (log scale)



Fibre Channel - Background

- **I/O channel**
  - Direct point to point or multipoint comms link
  - Hardware based
  - High Speed
  - Very short distance
  - User data moved from source buffer to destiation buffer
- **Network connection**
  - Interconnected access points
  - Software based protocol
  - Flow control, error detection &recovery
  - End systems connections

Fibre Channel

- **Best of both technologies**
- **Channel oriented**
  - Data type qualifiers for routing frame payload
  - Link level constructs associated with I/O ops
  - Protocol interface specifications to support existing I/O architectures
    - > e.g. SCSI
- **Network oriented**
  - Full multiplexing between multiple destinations
  - Peer to peer connectivity
  - Internetworking to other connection technologies

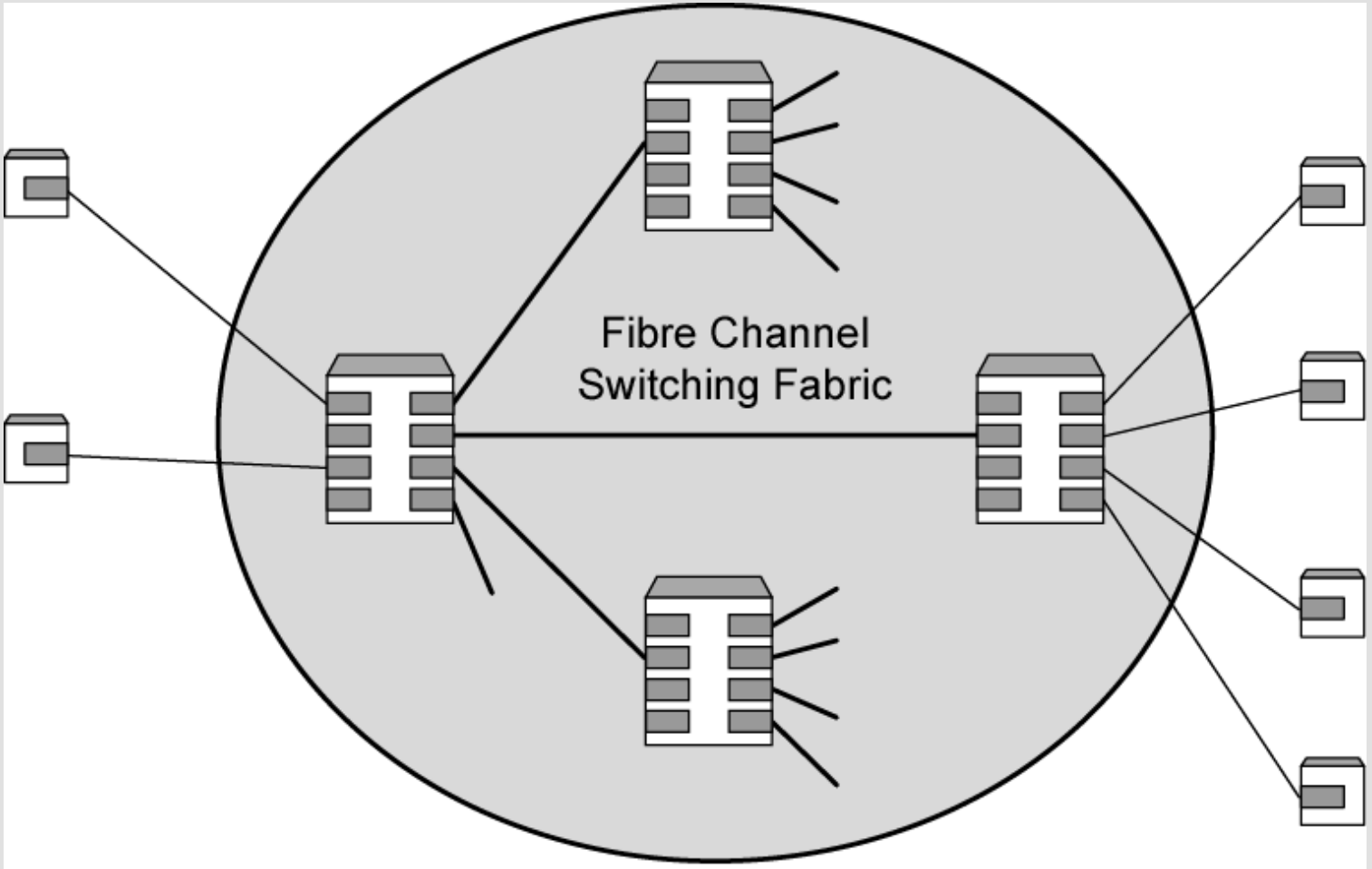
Fibre Channel Requirements

- **Full duplex links with two fibers per link**
- **1 Gbps to 10 Gbps on single line**
  - Full duplex 2 Gbps to 20 Gbps per link
  - Multiple links are supported
- **Up to 10 km**
- **Small connectors**
- **High-capacity utilization, distance insensitivity**
- **Multiple cost/performance levels**
  - Small systems to supercomputers
- **Uses generic transport mechanism based on point-to-point links and a switching network**
- **Supports simple encoding and framing scheme**
- **In turn supports a variety of channel and network protocols**

Fibre Channel Elements

- End systems - Nodes
- Switched elements - the network or fabric
- Communication across point to point links

Fibre Channel Network



Fibre Channel Protocol Architecture

- **FC-0 Physical Media**
  - Optical fiber for long distance
  - coaxial cable for high speed short distance
  - STP for lower speed short distance
- **FC-1 Transmission Protocol**
  - 8B/10B signal encoding
- **FC-2 Framing Protocol**
  - Topologies, Framing formats, Flow and error control
- **FC-3 Common Services**
  - Including multicasting
- **FC-4 Mapping**
  - Mapping of channel and network services onto fiber channel
    - > e.g. IEEE 802, ATM, IP, SCSI

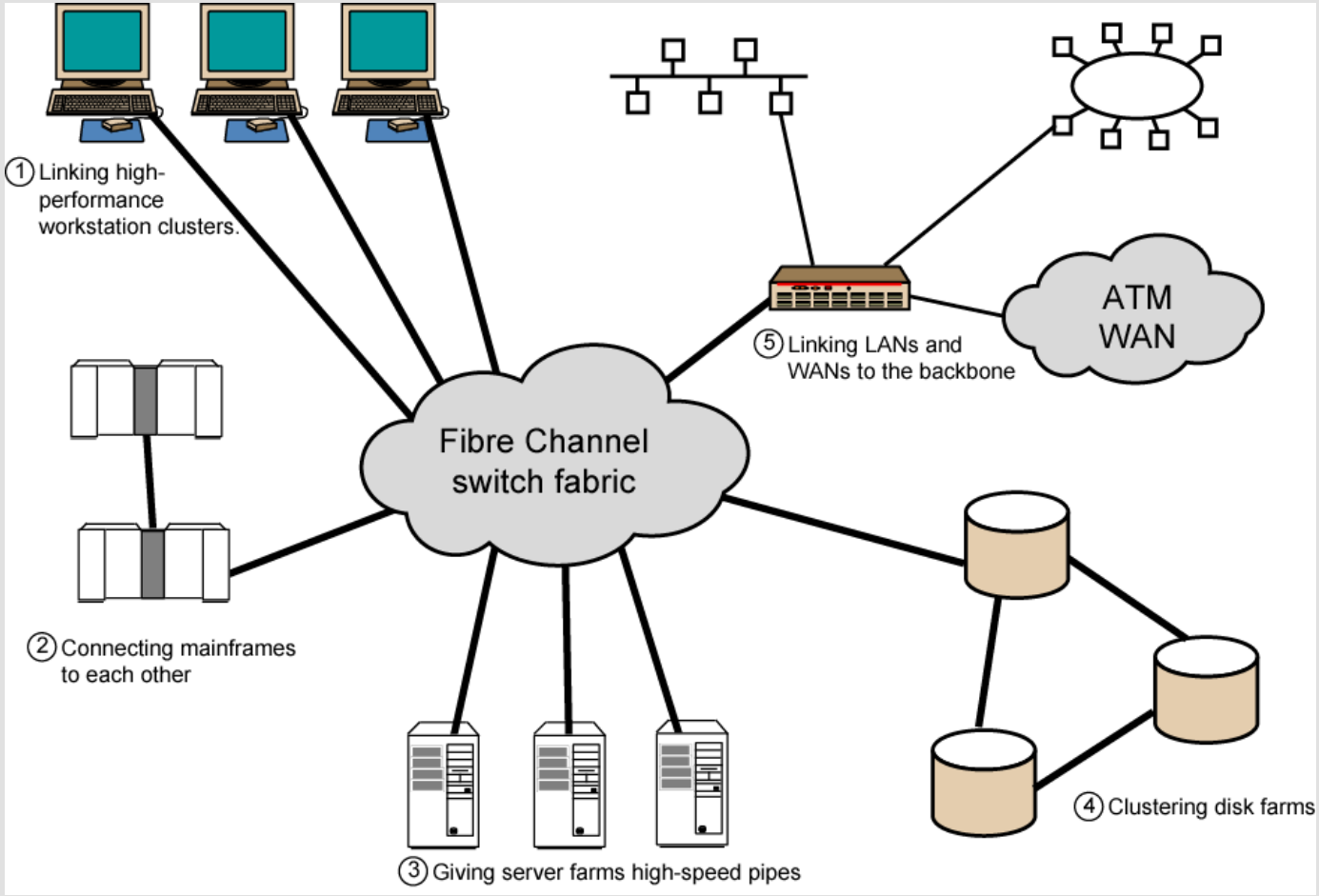
Fibre Channel Physical Media

- Provides range of options for physical medium, the data rate on medium, and topology of network
- Shielded twisted pair, video coaxial cable, and optical fiber
- Data rates exceeding 40 Gbps
- Point-to-point up to 10 km

Fabric Advantages

- **Scalability of capacity**
  - As additional ports added, aggregate capacity of network increases
  - Minimizes congestion and contention
  - Increases throughput
- **Protocol independent**
- **Distance insensitive**
- **Switch and transmission link technologies may change without affecting overall configuration**

Five Applications of Fibre Channel



Fibre Channel Prospects

- **Backed by Fibre Channel Association (FCA)**
- **Interface cards for different applications available**
- **Most widely accepted as peripheral device interconnect**
  - To replace such schemes as SCSI
- **Technically attractive to general high-speed LAN requirements**
- **Must compete with Ethernet and ATM (legacy) LANs**
- **Cost and performance issues should dominate the consideration of these competing technologies**

Summary

- **High speed LANs emergence**
- **Ethernet technologies**
  - CSMA & CSMA/CD/CA media access
  - 10Mbps Ethernet
  - 100Mbps Ethernet
  - 1Gbps Ethernet
  - 10Gbps Ethernet
- **Web sites on Ethernet, Gbit Ethernet, 10Gbit Ethernet, Fibre Channel etc.**

Ethernet Designations

Designation	Description
10Base-2	10 Mbps baseband Ethernet over coaxial cable with a maximum distance of 185 meters. Also referred to as *Thin Ethernet* or *Thinnet* or *Thinwire*.
10Base-5	10 Mbps baseband Ethernet over coaxial cable with a maximum distance of 500 meters. Also referred to as *Thick Ethernet* or *Thicknet* or *Thickwire*.
10Base-36	10 Mbps baseband Ethernet over multi-channel coaxial cable with a maximum distance of 3,600 meters.
10Base-F	10 Mbps baseband Ethernet over optical fiber.
10Base-FB	10 Mbps baseband Ethernet over two multi-mode optical fibers using a synchronous active hub.
10Base-FL	10 Mbps baseband Ethernet over two optical fibers and can include an optional asynchronous hub.
10Base-FP	10 Mbps baseband Ethernet over two optical fibers using a passive hub to connect communication devices.
10Base-T	10 Mbps baseband Ethernet over twisted pair cables with a maximum length of 100 meters.
10Broad-36	10 Mbps baseband Ethernet over three channels of a cable television system with a maximum cable length of 3,600 meters.

Fast Ethernet Designations

Designation	Description
100Base-FX	100 Mbps baseband Ethernet over two multimode optical fibers.
100Base-T	100 Mbps baseband Ethernet over twisted pair cable.
100Base-T2	100 Mbps baseband Ethernet over two pairs of Category 3 or higher unshielded twisted pair cable.
100Base-T4	100 Mbps baseband Ethernet over four pairs of Category 3 or higher unshielded twisted pair cable.
100Base-TX	100 Mbps baseband Ethernet over two pairs of shielded twisted pair or Category 4 twisted pair cable.
100Base-X	A generic name for 100 Mbps Ethernet systems.

1 Gigabit & 10 Gigabit Ethernet Designations

Designation	Description
1000Base-CX	1000 Mbps baseband Ethernet over two pairs of 150 shielded twisted pair cable.
1000Base-LX	1000 Mbps baseband Ethernet over two multimode or single-mode optical fibers using longwave laser optics.
1000Base-SX	1000 Mbps baseband Ethernet over two multimode optical fibers using shortwave laser optics.
1000Base-T	1000 Mbps baseband Ethernet over four pairs of Category 5 unshielded twisted pair cable.
1000Base-X	A generic name for 1000 Mbps Ethernet systems.

Designation	Description
10 Gigabit Ethernet	Ethernet at 10 billion bits per second over optical fiber. Multimode fiber supports distances up to 300 meters; single mode fiber supports distances up to 40 kilometers.