Key Features Of A LAN

- High throughput
- Relatively low cost
- Limited to short distance
- Often rely on *shared media*
- No separate cable or Modem

Point to point connection vs. Shared media LAN in the TEXT.

Scientific Justification For Local Area Networks

- *A computer is more likely to communicate with computers that are nearby than with computers that are distant.*

Known as the *locality principle*
→ *Temporal locality of ref. (the same set of computer in time) + physical locality of reference (nearby computer)*

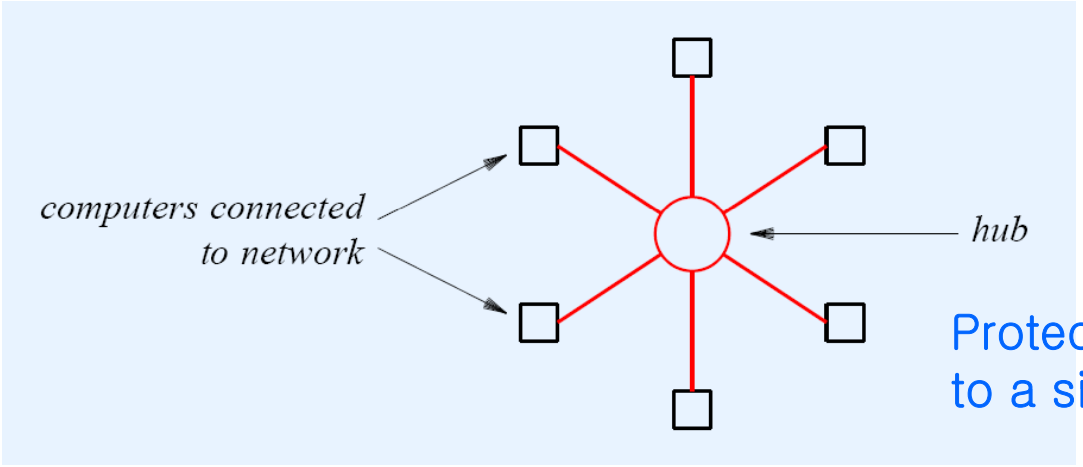
Topology

- Mathematical term
- Roughly interpreted as “geometry for curved surfaces”

Network Topology

- Specifies general “shape” of a network
- Handful of broad categories
- Often applied to LAN
- Primarily refers to interconnections
- Hides details of actual devices

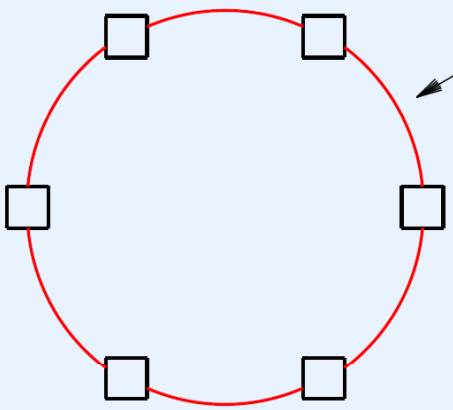
Star Topology



Protection from the damage to a single network

- Central component of network known as *hub*
- Each computer has separate connection to hub

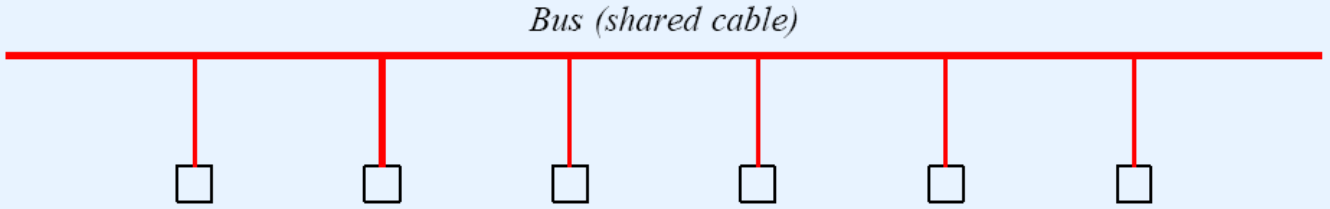
Ring Topology



Can detect whether the network
is operating easily
but entire network fails
if one fails.

- No central facility
- Connections go directly from one computer to another → Logical (not physical) concept

Bus Topology



Fewer wires than star
but entire network crashes if one fails as ring topology

- Shared medium forms main interconnect
- Each computer has a connection to the medium
- Only one computer can send signals

Example Bus Network: Ethernet

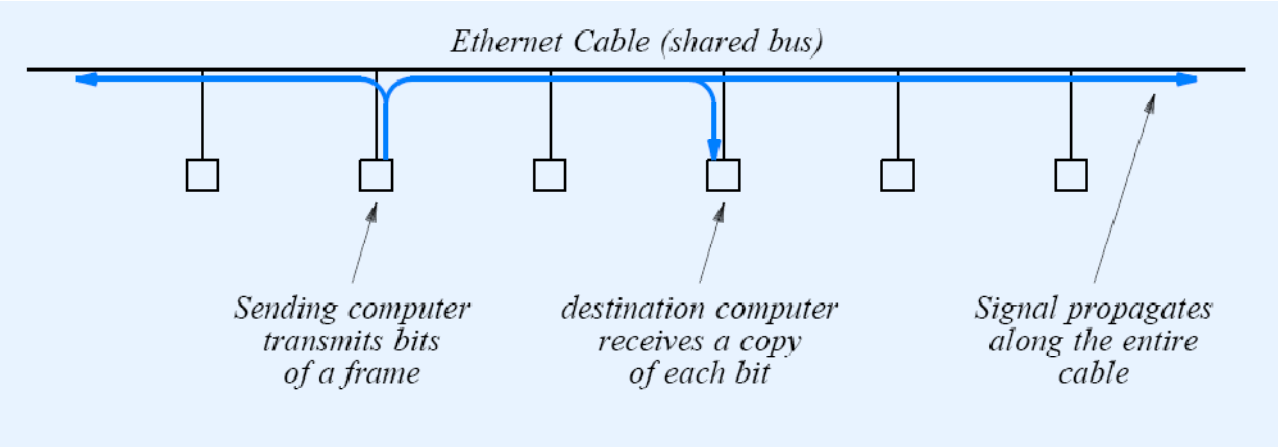
- Most popular LAN
- Widely used
- IEEE standard *802.3*
- Several generations
  - Same frame format
  - Different data rates
  - Different wiring schemes

Ethernet segment (Coax cable) < 500m
Connection distance min. 3m

Shared Medium in a LAN

- Shared medium used for all transmissions
- Only one station transmits at any time
- Stations “take turns” using medium
- Media Access Control *(MAC)* policy ensures fairness

Illustration Of Ethernet Transmission



- Only one station transmits at any time
  (Time shared exclusive use of network)
- Signal propagates across entire cable
- All stations receive transmission
- CSMA/CD media access scheme
  Carrier Sense Multiple Access/Collision Detection

CSMA/CD Paradigm (not centralized)

- Multiple Access *(MA)*
  - Multiple computers attach to shared media
  - Each uses same access algorithm
- Carrier Sense *(CS)*
  - Wait until medium idle
  - Begin to transmit frame
- Simultaneous transmission possible

- CSMA

→ The presence of a signal to determine when to transmit signals

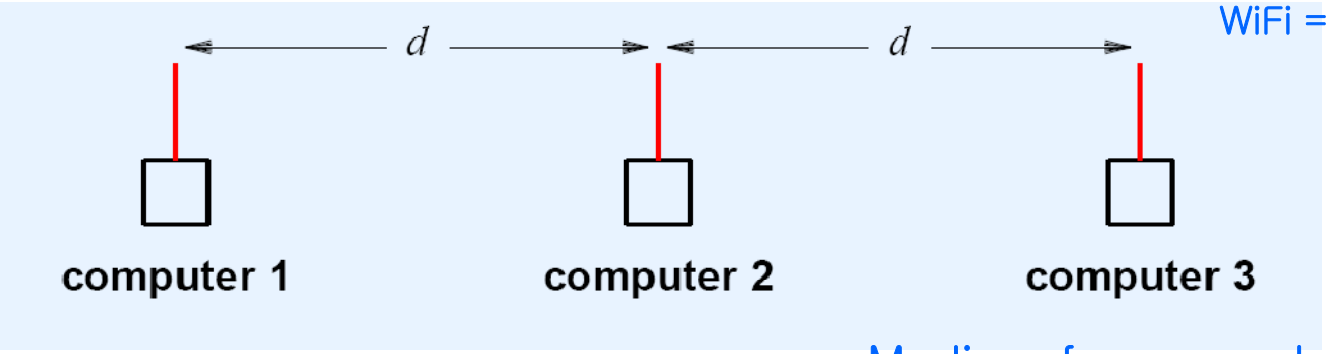
CSMA/CD Paradigm (continued)

- Two simultaneous transmissions
  - Interfere with one another
  - Called *collision*
- CSMA plus *Collision Detection (CD)*
  - Listen to medium during transmission
  - Detect whether another station's signal interferes
  - Back off from interference and try again

Back off After Collision

- When collision occurs
  - Wait random time *t1, 0 <= t1 <= d*
  - Use CSMA and try again
- If second collision occurs
  - Wait random time *t2, 0 <= t2 <= 2d*
- Double range for each successive collision
- Called *exponential back off*

Media Access On A Wireless Net



- Limited range
  - Not all stations receive all transmissions
  - Cannot use CSMA/CD
- Example in diagram
  - Maximum transmission distance is *d*
  - Stations *1* and *3* do not receive each other's transmissions

CSMA/CA (Carrier Avoidance)

- Used on wireless LANs
- Both sides send small message followed by data transmission
  - "*X* is about to send to *Y*"
  - "*Y* is about to receive from *X*"
  - Data frame sent from *X* to *Y*
- Purpose: inform all stations in range of *X* or *Y* before transmission
- Known as *Collision Avoidance* (*CA*)

If collision occurs in the procedure, back off solves the situation.

This informs farthest computer.

Wi-Fi Wireless LAN Technology

- Popular
- Uses CSMA/CA for media access
- Standards set by IEEE
  - 802.11b (11 Mbps, shared channel)
  - 802.11a (54 Mbps, shared channel)
- Named *Wi-Fi* by consortium of vendors (to enhance popular appeal)

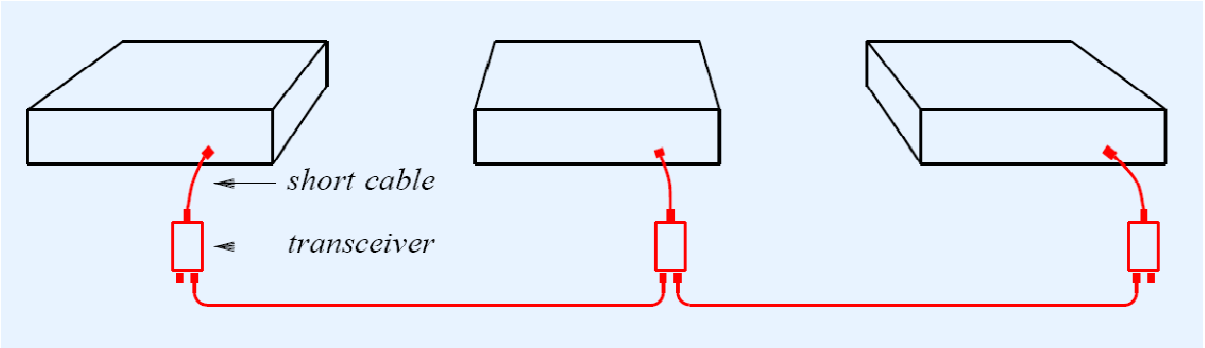
Another LAN Using Bus Topology

(Example)

(Relocated Compared to Original Slide)

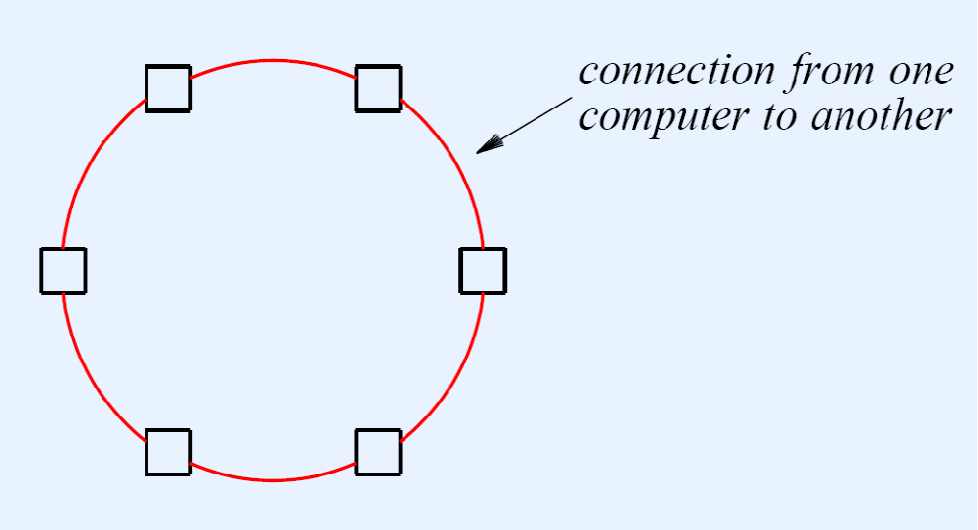
- LocalTalk
  - Developed by Apple Corp.
  - Simple to use
  - Slow by current standards

Illustration Of Local Talk



- Transceiver required per station
- Transceiver terminates cable

Ring Topology



- Once a popular topology for LANs
- Bits flow in single direction

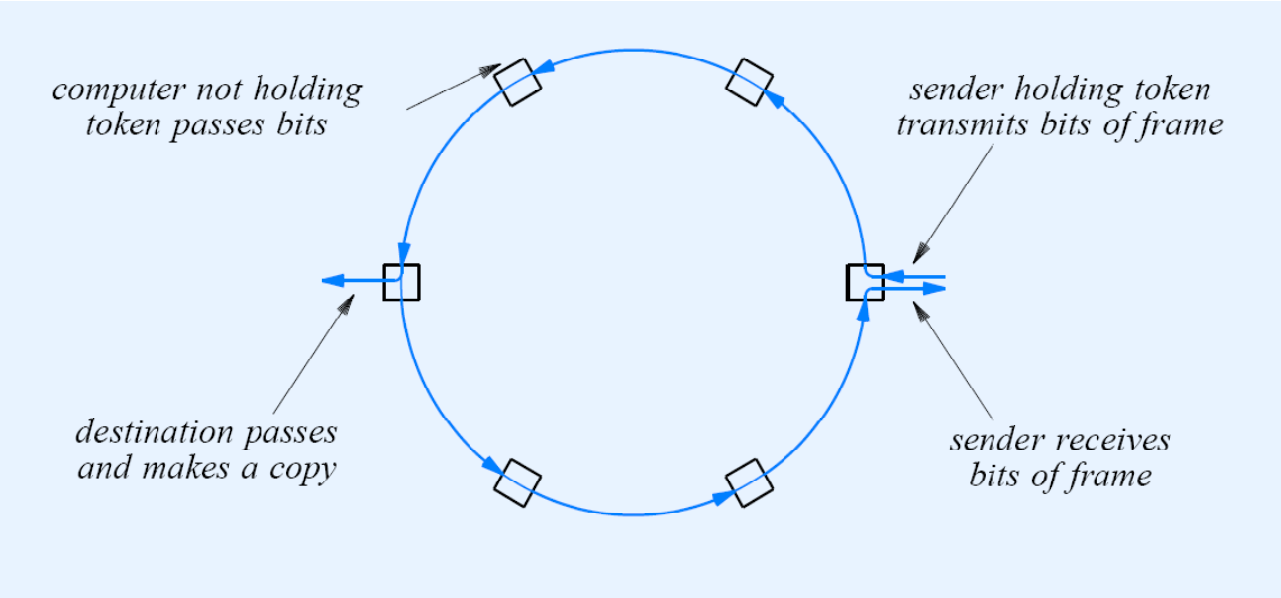
Token Passing

- Designed for ring topology
- Guarantees fair access
- *Token*
  - Special (reserved) message
  - Small (a few bits)

Token Passing Paradigm

- Station
  - Waits for token to arrive
  - Transmits one packet around ring
  - Transmits token around ring
- When no station has data to send
  - Token circulates continuously

Token Passing Ring Transmission



- Station waits for token before sending
- Signal travels around entire ring
- Sender receives its own transmission

Strengths Of Token Ring Approach

- Easy detection of
  - Broken ring
  - Hardware failures
  - Interference

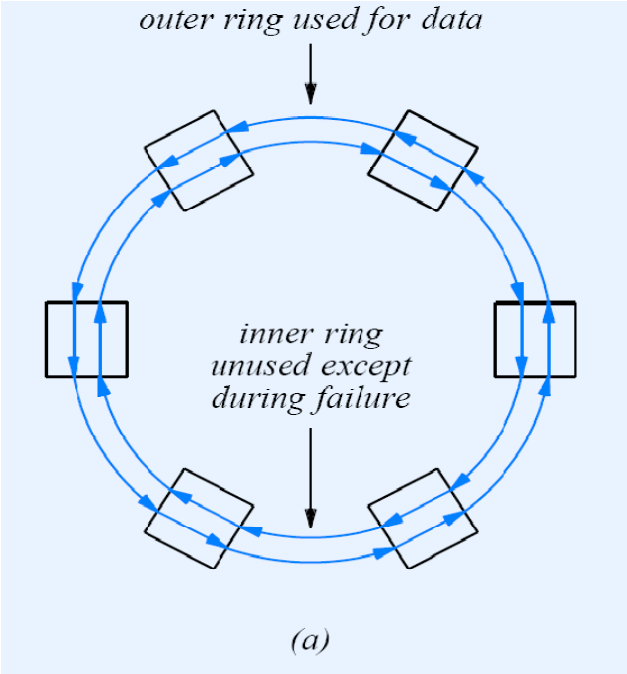
Weaknesses Of Token Ring Approach

- Broken wire disables entire ring
- Point-to-point wiring
  - Awkward in office environment
  - Difficult to add/move stations

Failure Recovery In Ring Networks

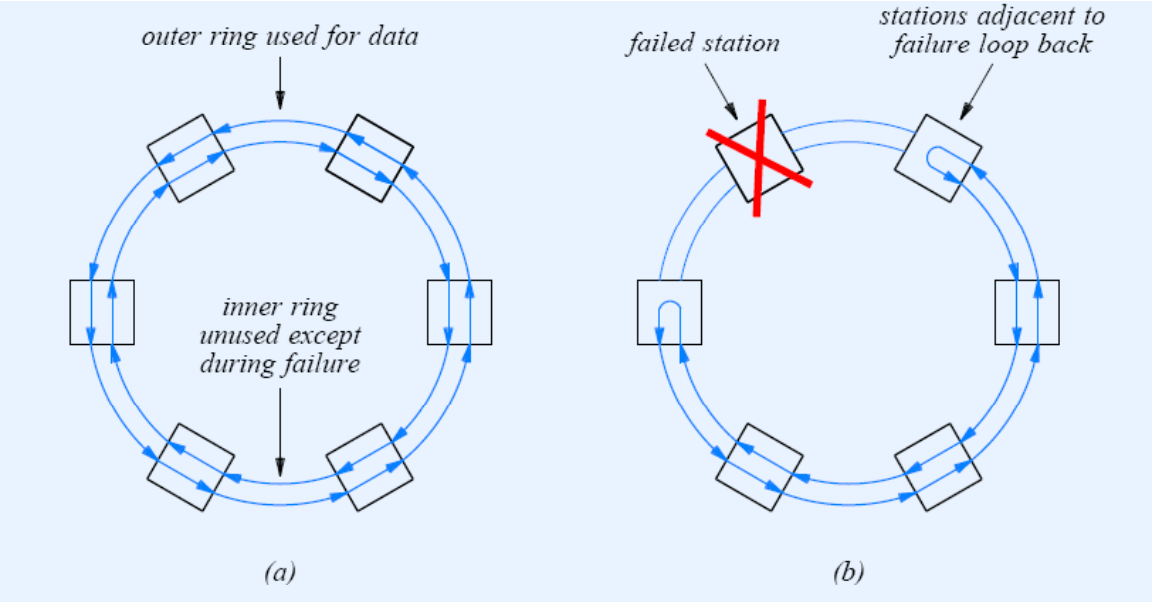
- Automatic failure recovery
- Introduced by FDDI (Fiber Distributed Data Interconnect)
- Uses two rings
- Terminology
  - *Dual-attached*
  - *Counter rotating*
  - *Self healing*

Illustration Of Failure Recovery



- Normal operation uses one of two rings

Illustration Of Failure Recovery



Self Healing

- Normal operation uses one of two rings
- Second ring used for loopback during failure

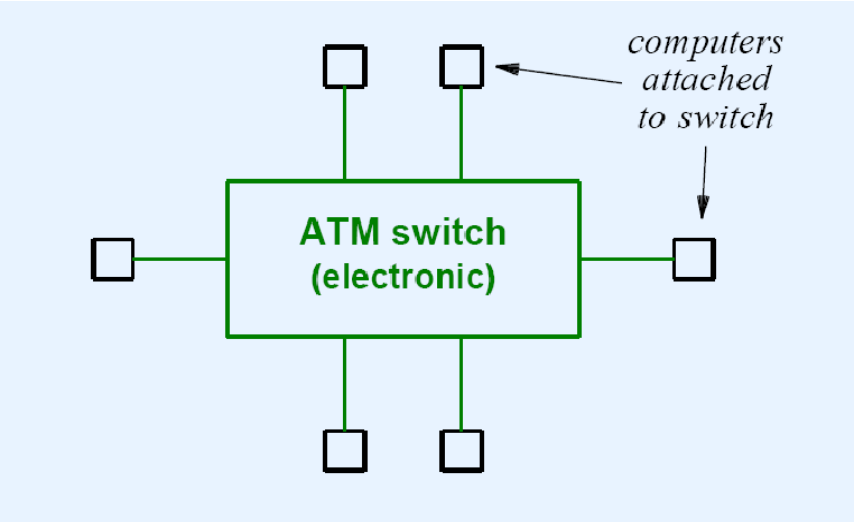
Token Passing Ring Technologies

- *ProNet-10*
  - Operated at 10 Mbps
- *IBM Token Ring*
  - Originally operated at 4 Mbps
  - Later version operated at 16 Mbps
- *Fiber Distributed Data Interconnect (FDDI)*
  - Operates at 100 Mbps
- All are now virtually obsolete

Example of a physical Star Topology

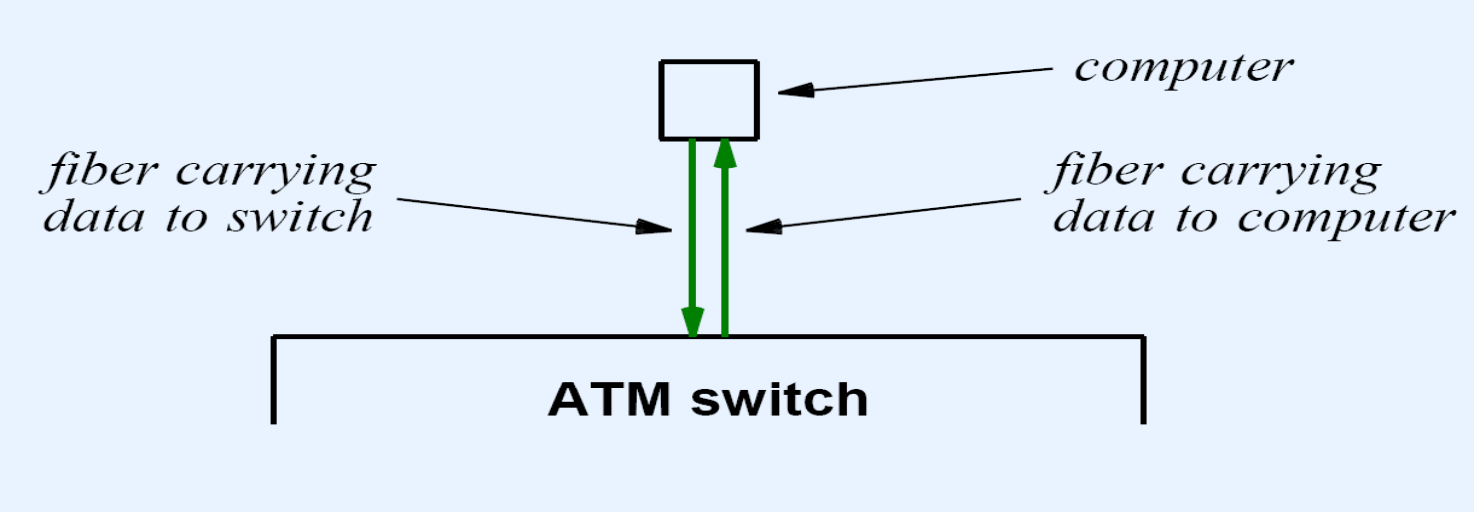
- *Asynchronous Transfer Mode (ATM)*
- Designed by telephone companies
- Intended to accommodate
  - Voice
  - Video
  - Data

ATM



- Building block known as *ATM switch*
- Each station connects to switch
- Switches can be interconnected

Details Of ATM Connection



- Full-duplex connections
- Two fibers used

ATM Characteristics

- High data rates (e.g. 155 Mbps)
- Fixed size packets
  - Called *cells*
  - Important for voice
- Cell size is 53 octets
  - 48 octets of data
  - 5 octets of header

Identifying a Destination

- All stations on shared-media LAN receive all transmissions
- To allow sender to specify destination
  - Each station assigned unique numbers

    (physical address = hardware address = MAC address)
  - Known as station's *address*
  - Each frame contains address of intended recipient

Ethernet Addressing

- Standardized by IEEE
- Each station assigned unique 48-bit address
- Address assigned when network interface card *(NIC)* manufactured

Ethernet Address Recognition

- Each frame contains destination address
  (also source address for reply)
- All stations receive a transmission
- Station discards any frame addressed to another station
- Important: interface hardware (independent from processor), not software, checks address
  → basically compares the destination address with own MAC address (+ frame length check, CRC) Discard the frames with errors)

Format of a Physical Address

Static,
Configurable (during installation),
Dynamic address (during booting)
in the Text (pp.126)

Possible Destinations

- Packet can be sent to:
  - Single destination *(unicast)*
  - All stations on network *(broadcast)*
  - Subset of stations *(multicast)*
- Address used to distinguish

Advantages Of Address Alternatives

- Unicast
  - Efficient for interaction between two computers
- Broadcast
  - Efficient for transmitting to all computers
- Multicast
  - Efficient for transmitting to a subset of computers

Broadcast On Ethernet

- All *1s* address specifies broadcast
- Sender
  - Places broadcast address in frame
  - Transmits one copy on shared network
  - All stations receive copy
- Receiver always accepts frame that contains
  - Station's unicast address
  - The broadcast (multicast) address

Multicast On Ethernet

- Half of addresses reserved for multicast
- Network interface card
  - Always accepts unicast and broadcast
  - Can accept zero or more multicast addresses
- Software (Application Program)
  - Determines multicast address to accept
    (after boot, only computer's address and broadcast address are recognized.)
  - Informs network interface card by software

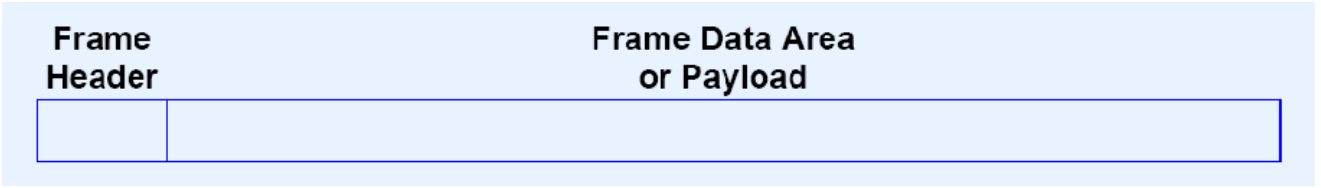
Promiscuous Mode

- Designed for testing/debugging
- Allows interface to accept *all* packets
- Available on most interface hardware

Identifying Frame Contents

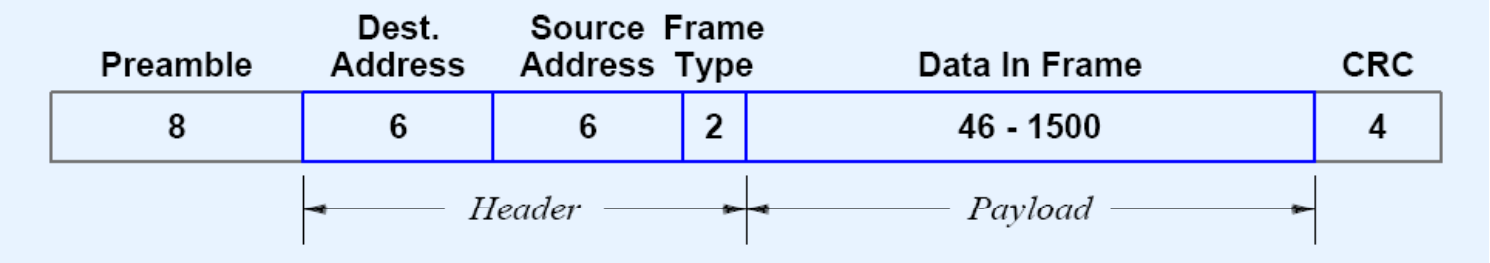
- Integer *type field* tells recipient the type of data being carried
- Two possibilities
  - *Self-identifying* or *explicit type* (hardware records frame type field in a frame)
  - *Implicit type* (application program must handle type implicitly)

Conceptual Frame Format



- *Header*
  - Contains address and type information
  - Layout fixed
- *Payload*
  - Contains data being sent

Illustration Of Ethernet Frame



Preamble: series of alternating 1's and 0's for sync.

- Sender places
  - Sender's address in *source*
  - Recipient's address in *destination*
  - Type of data in *frame type*
  - Cyclic redundancy check in *CRC*

Example Ethernet Types (Frame Type)

(2 bytes – 4 HEX number)

Value	Meaning
0000-05DC	Reserved for use with IEEE LLC/SNAP
0800	Internet IP Version 4
0805	CCITT X.25
0900	Ungermann-Bass Corporation network debugger
0BAD	Banyan Systems Corporation VINES
1000-100F	Berkeley UNIX Trailer encapsulation
6004	Digital Equipment Corporation LAT
6559	Frame Relay
8005	Hewlett Packard Corporation network probe
8008	AT&T Corporation
8014	Silicon Graphics Corporation network games
8035	Internet Reverse ARP
8038	Digital Equipment Corporation LANBridge
805C	Stanford University V Kernel
809B	Apple Computer Corporation AppleTalk
80C4-80C5	Banyan Systems Corporation
80D5	IBM Corporation SNA
80FF-8103	Wellfleet Communications
8137-8138	Novell Corporation IPX
818D	Motorola Corporation
FFFF	Reserved

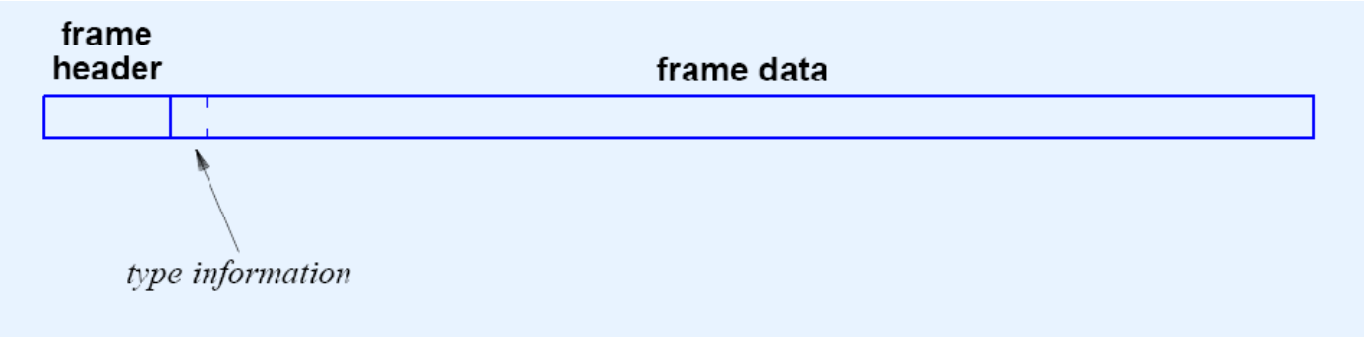
All 1's in 48 bit: Broadcast

Other addresses starting with 1: Multicast

When Network Hardware Does Not Include Types

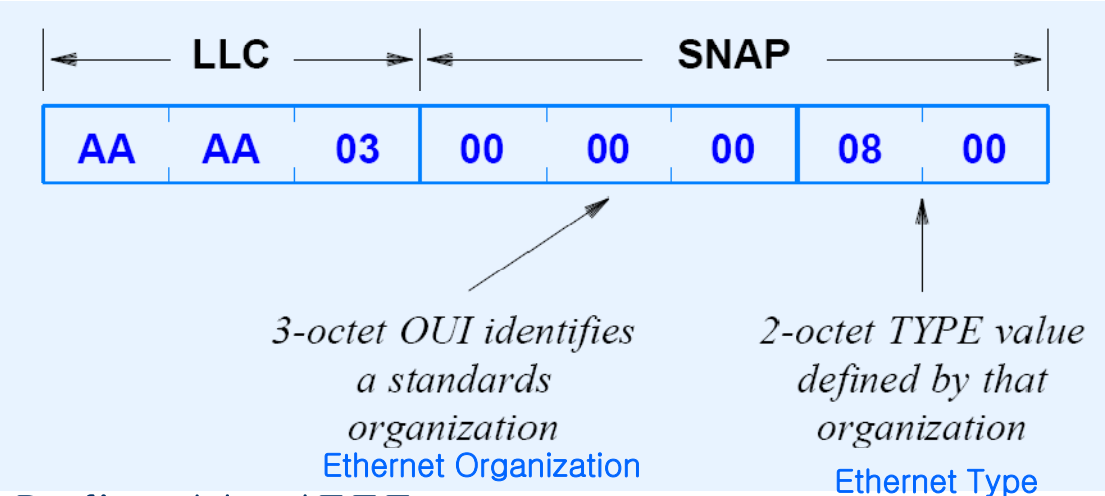
- Sending and receiving computers must agree
  - To only send one type of data
  - To put type information in first few octets of payload
- Most systems need type information

Illustration Of Type Information Added To Data

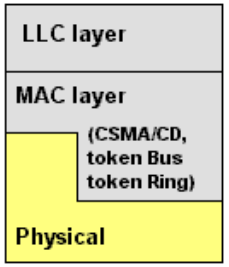


- In practice
  - Type information small compared to data carried
  - Format of type information standardized

A Standard For Type Information



(Octet: group of 8 bits)
(OUI: Organization Unique Identifier)



- Defined by IEEE
- Used when hardware does not include type field
- Called *{LLC (Logical Link Control) → Common Interface to MAC ← Data Link Layer /SNAP (Subnetwork Attachment Point) } header*

Demultiplexing On Type

- Network interface hardware
  - Receives copy of each transmitted frame
  - Examines address and either discards or accepts
  - Passes accepted frame to system software
- Network device software
  - Examines frame type
  - Passes frame to correct software module

Network Analyzer (Packet Analyzer)

- Device used for testing and maintenance
- Listens in promiscuous mode
- Produces
  - Summaries (e.g., % of broadcast frames)
  - Specific items (e.g., frames from a given address)
  - Avg. frame size, Avg. # of frames/sec., # of collisions

Ethernet Wiring

- Three schemes
  - Correspond to three generations
  - All use same frame format

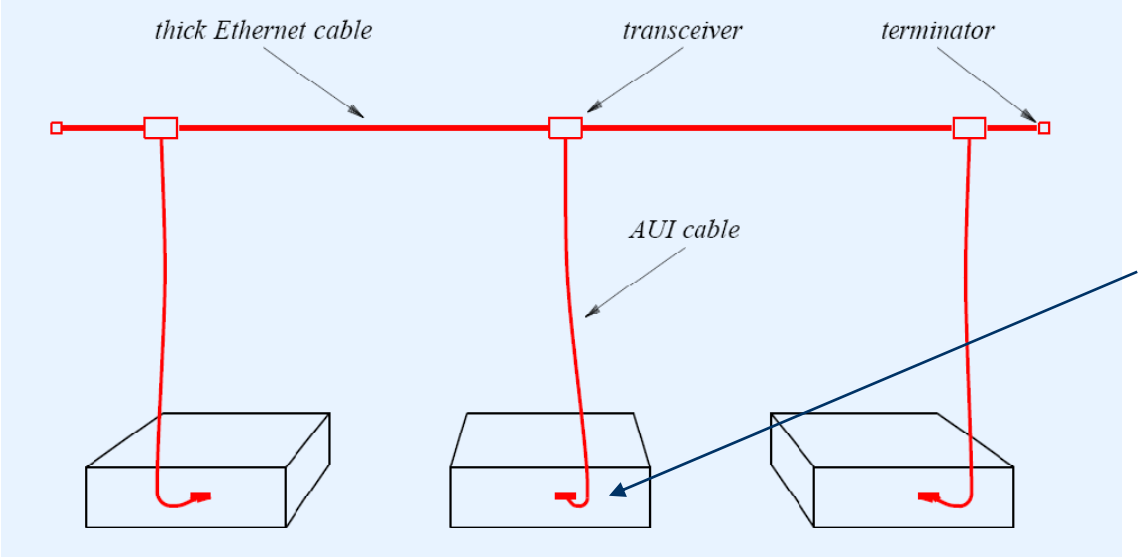
Network Interface Card (NIC)

- Handles the speed gap btw. Processor and Network (more demanding)
- DMA, Interrupt based, I/O like mechanism
- Processor allows buffer area solely for NIC
- NIC copies the frame, verify checksum and check destination address is correct (including broadcast and multicast)

  → interrupt processor

  (How to mitigate the speed gap btw. Comp. & Network)

Original Ethernet Wiring

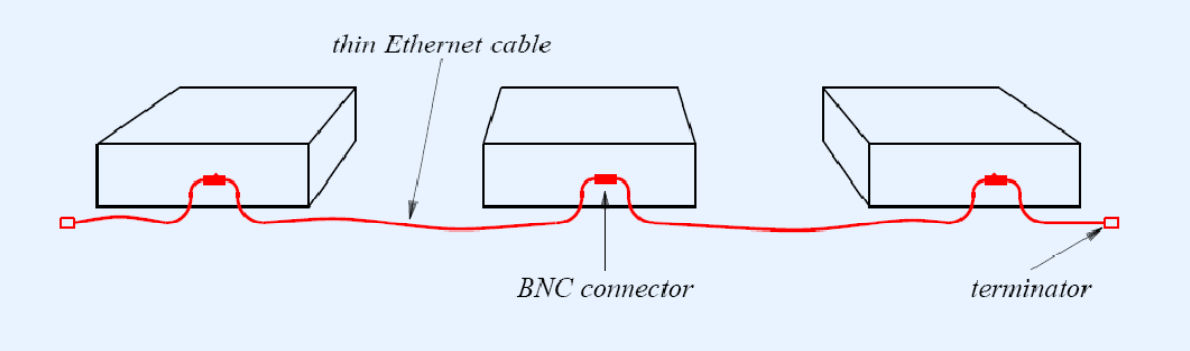


AUI: Attachment Unit Interface

NIC: (digital side)
(error detection,
address recognition,
CRC generation
and verification, bus based
processor communication,
interrupt)

- Used heavy coaxial cable
- Formal name *10Base5*
- Called *thicknet*

Second Generation Ethernet Wiring



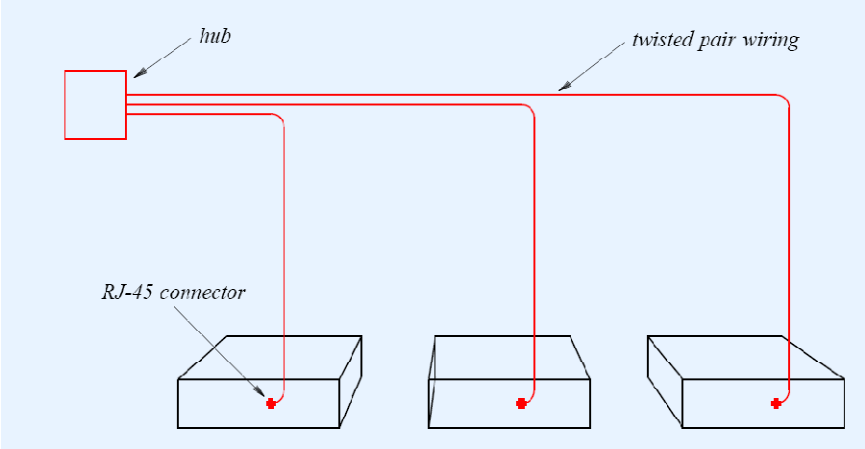
- Used thinner coaxial cable
- Formal name *10Base2*
- Called *thinnet*

Terminator:
(To get rid of reflection, affects exponential back off collision detection)

(Transceiver + NIC in 10Base5 → NIC)

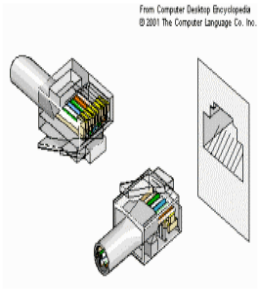
Modern Ethernet Wiring

Pin #	Ethernet 10BASE-T 100BASE-TX	EIA/TIA 568A	EIA/TIA 568B or AT&T 258A
1	Transmit +	White with green strip	White with orange stripe
2	Transmit -	Green with white stripe or solid green	Orange with white stripe or solid orange
3	Receive +	White with orange stripe	White with green stripe
4	N/A	Blue with white stripe or solid blue	Blue with white stripe or solid blue
5	N/A	White with blue stripe	White with blue stripe
6	Receive -	Orange with white stripe or solid orange	Green with white stripe or solid
7	N/A	White with brown strip or solid brown	White with brown strip or solid brown
8	N/A	Brown with white stripe or solid brown.	Brown with white stripe or solid brown



(Registered Jack-45) A telephone connector that holds up to eight wires. RJ-45 plugs and sockets are used in Ethernet and Token Ring Type 3 devices. See RJ-48.

Pinout for Ethernet

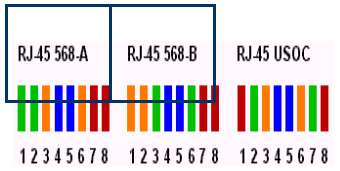


RJ-45 Connectors

Eight-wire RJ-45 connectors are used with Ethernet and Type 3 Token Ring networks.

- Uses a *hub*
- Formal name *10Base-T*
- Called *twisted pair Ethernet*

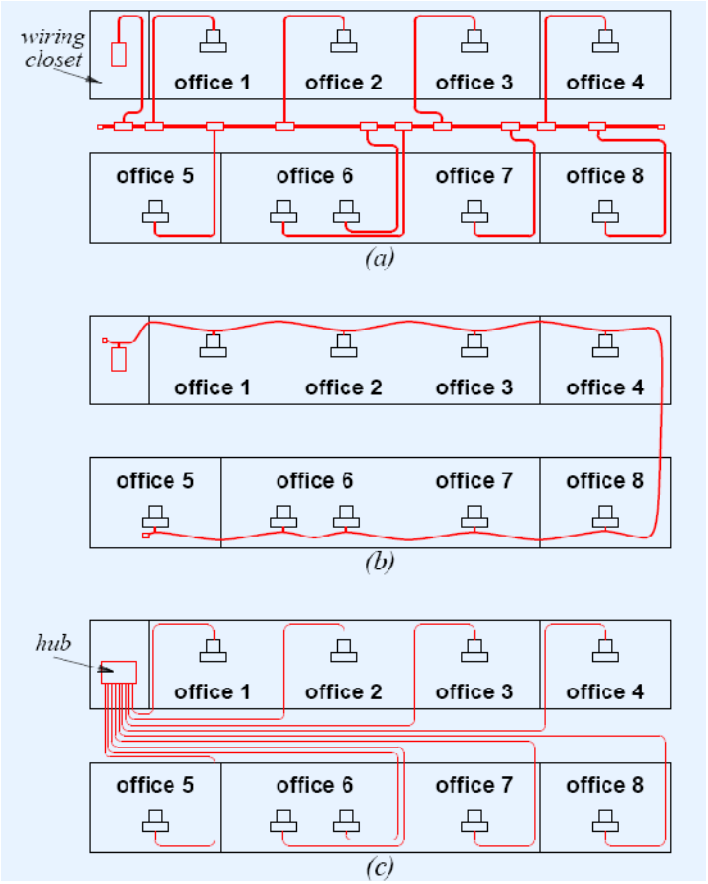
Most commonly used



Variations of RJ-45

These are the variations of RJ-45 pins and wire colors.

Ethernet Wiring In An Office



Thick Ethernet

Thin Ethernet

Twisted pair Ethernet
(Basically star topology)

A Note About Ethernet Topology

- Apparently
  - Original Ethernet used bus topology
  - Modern Ethernet uses star topology
- In fact, modern Ethernet is
  - Physical star
  - Logical bus
  - Called *star-shaped bus*

They are using star topology HUB.

Higher Speed Ethernets

- *Fast Ethernet*
  - Operates at 100 Mbps
  - Formally *100Base-T*
  - Two wiring standards
  - 10/100 Ethernet devices available
- *Gigabit Ethernet*
  - Operates at 1000 Mbps (1 Gbps)
  - Slightly more expensive

→Auto-negotiation between NIC
to check both are capable of 100Base-T