Data Communication and Computer Network

Local Area Network

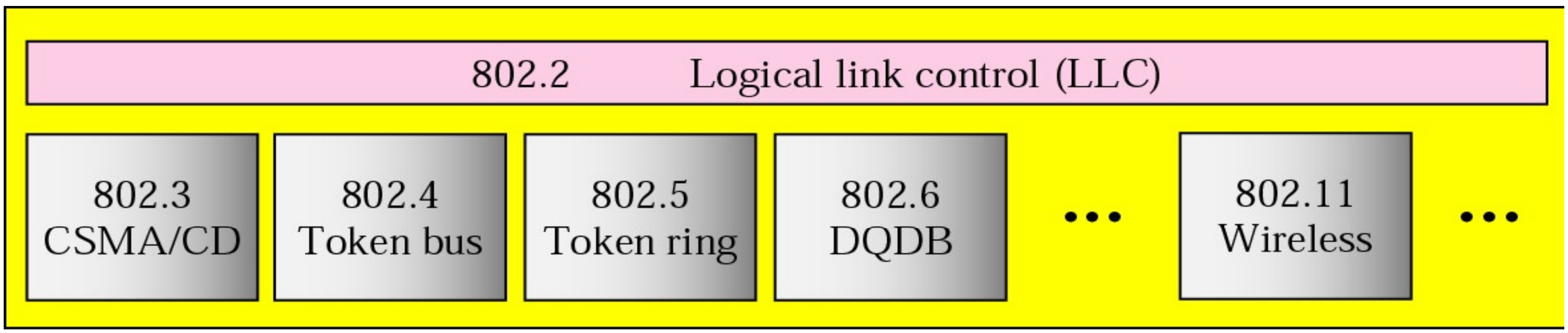
Local Area Network (LAN)

- Characteristics
  - Small geographical area, limited distance
  - Small number of directly-connected machines
  - Relatively high data rate
  - Single management
- Specifications mostly at physical layer and data link layer
- The most used example: Ethernet
- Developed in early/mid 70's in Xerox PARC

Ethernet – two standards

- DIX standard
  - **D**igital / **I**ntel / **X**erox standardized 10 Mbps Ethernet in early 80's
  - Specifies details of physical layer and MAC layer using CSMA/CD
- IEEE 802 standard (1985) split Data Link layer into two sub-layers
  - Logical Link Control: error control, flow control, etc
  - Medium Access Control: error detect (FCS), decides how to access shared medium (CSMA/CD, token ring, wireless, …)

IEEE 802 family of protocols



Project 802

IEEE 802.2 plus one of 802.3, 802.4, … specifies the complete physical & data link layers

Relation between DIX Ethernet standard and IEEE 802 standard

- Frame format for both standards almost same, except for small differences

- TCP/IP implementations use original DIX Ethernet frame format, LLC sub-layer used not used
  - Network layer directly uses Ethernet frames

- Nodes using both types can coexist on same LAN

No LLC

- In real-world *wired* networks (most use TCP/IP), the LLC sub-layer <u>almost never implemented</u>
  - Error & flow control has to be handled from source to destination (over multiple links)
  - Data can be lost within links and at intermediate nodes
  - LLC controls error & flow over a single link only

  - So, ensure error & flow control from source to destination (end nodes) at higher layers, and
  - Do away with the LLC sub-layer

IEEE 802.3 (Ethernet)

- Multiple types within this depending on speed, media type, etc
  - Standard 10 Mbps Ethernet versions
    - 10Base5 : 10 Mbps, thickwire coaxial cable
    - 10Base2 : 10 Mbps, thinwire coax or cheapernet
    - 10Base-T : 10 Mbps, twisted pair, hub-based
    - 10Base-FL : 10 Mbps, optical fiber, hub-based
  - Fast Ethernet (100 Mbps) versions
  - Gigabit Ethernet (1000 Mbps) versions
- All the above have the same frame format, same addressing format
  - differences mostly in physical layer details like medium, connector, encoding used, etc.

IEEE 802.3 (Ethernet) Cabling

Name	Cable	MAX Segment	Nodes/seg.
10Base5	Thick coaxial	500 meters	100
10Base2	Thin coaxial	200 meters	30
10Base-T	Twisted pair	100 meters	1024

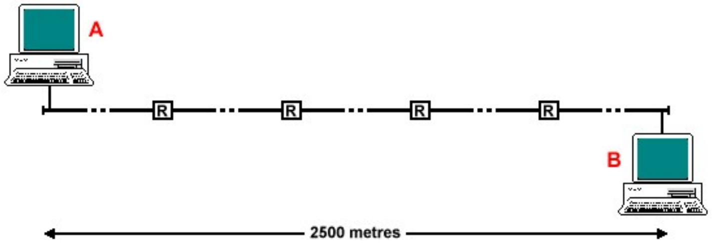
- **10Base5 cabling:** This type of cabling is popularly referred to as **thicknet**. It was one of the earliest types of cables used for LAN's. The notation 10Base5 suggests that the LAN operates at 10 Mbps, uses baseband signaling and can support segments of up to 500 meters.

- **10Base2 cabling:** 10Base2 or **thinnet,** which in contrast to thicknet, bends easily. 10Base2 cables are easier to install and are relatively inexpensive. The only drawback of using the 10Base2 cable is that it can run for only 200 meters and can handle only 30 stations per cable segment.

- **10Base-T cabling**: there is no single, main cable because each station has a cable running to a central **hub** (a big repeater). Adding or removing stations is simpler in this configuration and cable breaks can be detected easily. The disadvantage of 10Base-T is that the maximum cable run from the hub is only 100 meters, sometimes 150 meters (if high quality twisted pairs are used). 10Base-T is most popular due to the ease of maintenance.

Bus topology – used in Ethernet

- Transmission propagates throughout medium, heard by all stations (bi-directional medium)
  - Each station needs unique address
- Signal balancing
  - Signal must be strong enough to meet receiver's minimum signal strength requirements
- Need to regulate transmission
  - To avoid collisions
  - To avoid hogging by a single node, break data into frames
- Multiple segments can be joined by repeaters



Repeaters

- Joins two (or more) segments of cable
- Function
  - Input signal at one of the ports
  - Extracts data from input signal (filters out noise)
  - Amplifies data: encodes data in signal and transmits along all other ports
- Does not understand frame format, does not look inside frame
- There should be only one path of segments and repeaters between any two stations

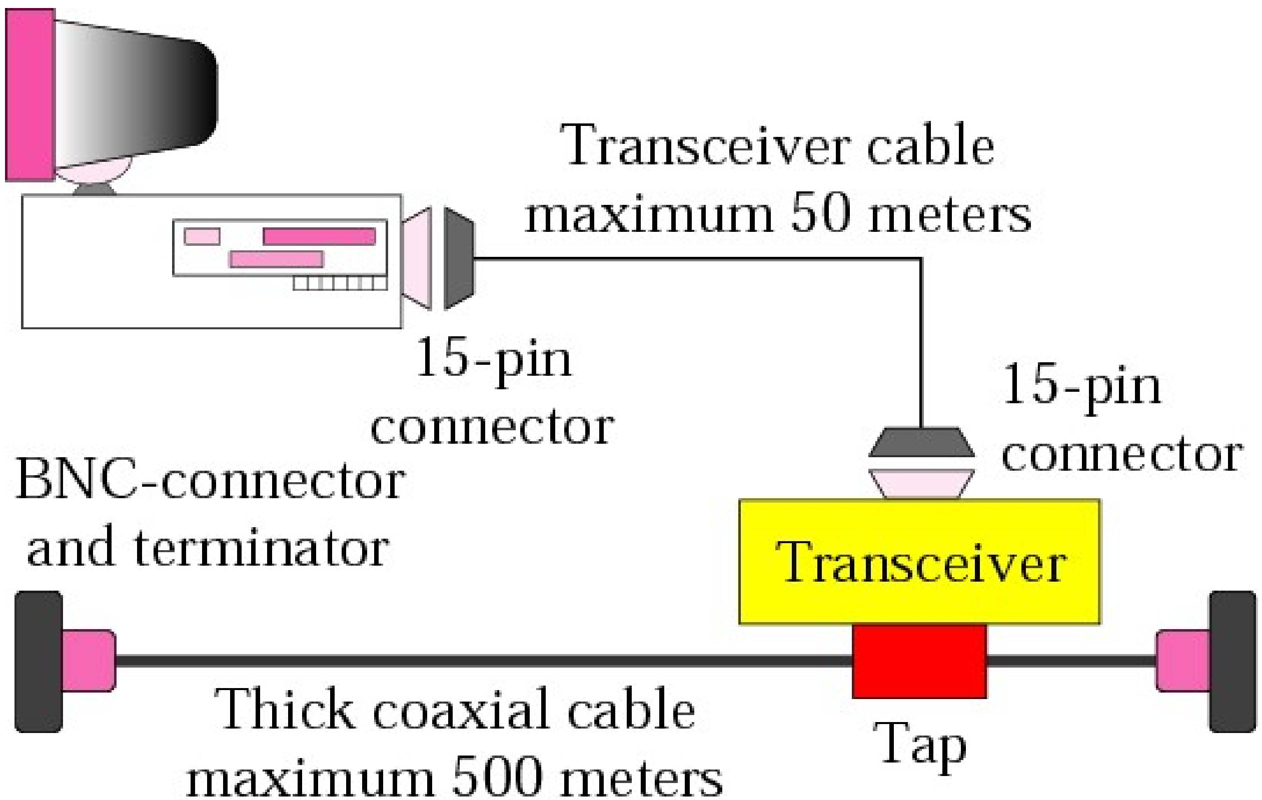
Example of a specific technology: 10Base5

- 10Base5 is the original implementation of Ethernet and 802.3
- Uses shared bus medium – thick coaxial cable (0.4 inch diameter) at 10 Mbps
  - Bus topology
  - Max cable length 500m between repeaters
  - Maximum 4 repeaters (5 segments) => maximum distance between two nodes is 2500 meters
- Distance between taps (nodes): a multiple of 2.5m
  - Hence, maximum 1000 taps
- Manchester encoding used

10Base5 technology (contd.)

- How to sense carrier (to see if line is idle)
  - Is there a transition in the middle of bit-time?
- How to detect collision
  - If two signals overlap, the average DC voltage increases above a threshold value
- Jamming signal
  - 32 or 48 bits of 01010101…
- How to understand end of frame
  - Is there a transition in the middle of bit-time?
- MAC layer specification
  - 1-persistent CSMA/CD for transmission
  - binary exponential backoff for retransmission

Connection of a station to the medium using 10Base5

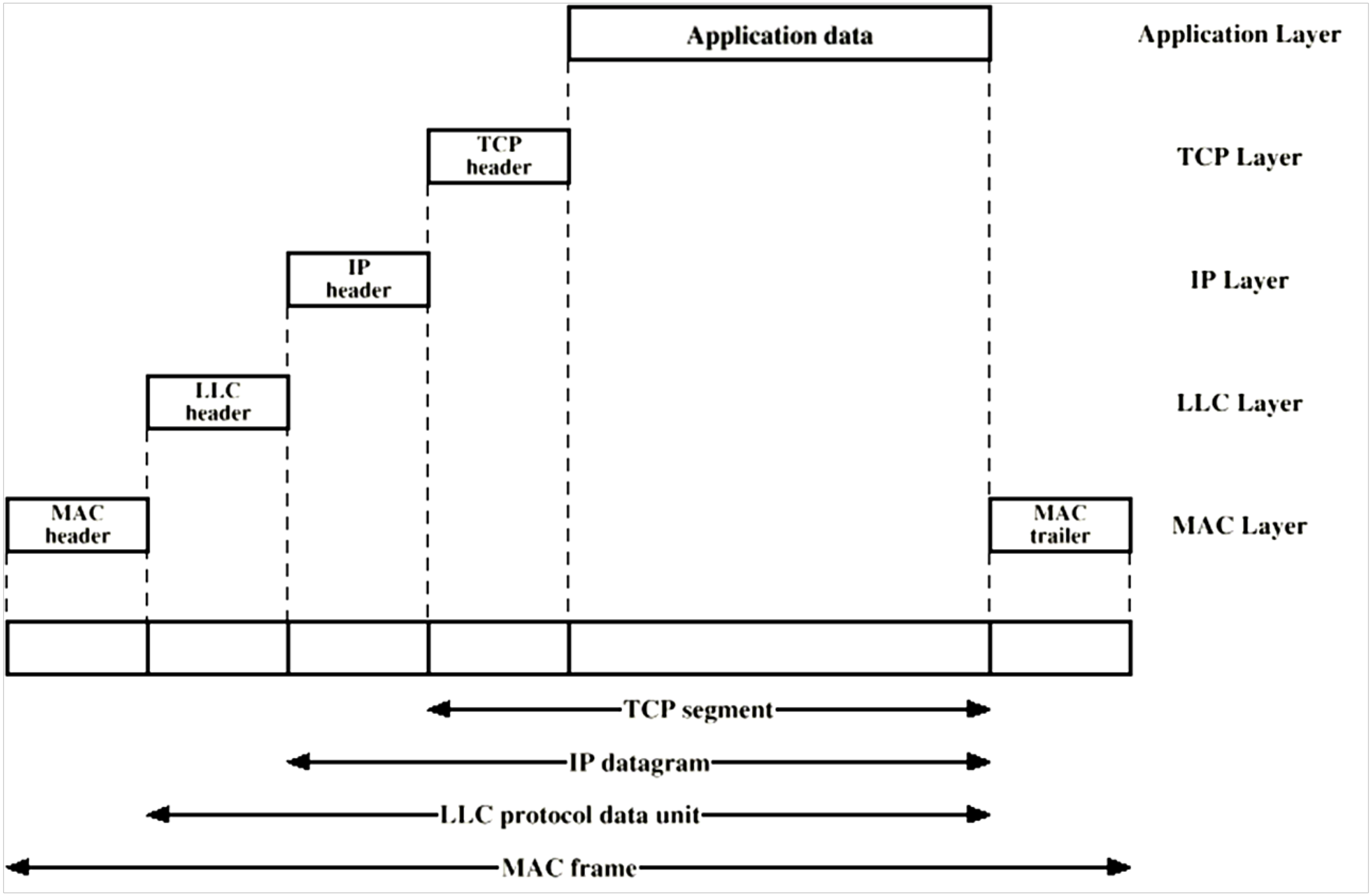


a. 10BASE5

MAC address

- A unique hardware address for each LAN interface
- Hard-coded into Network Interface Card (NIC)
- 48-bit address, expressed as 12 hex digits
  - 24-bit vendor code, 24-bit serial number
  - Different NIC vendors given different vendor codes
- ff.ff.ff.ff.ff.ff is broadcast address: this is Layer 2 broadcast

MAC Layer PDU



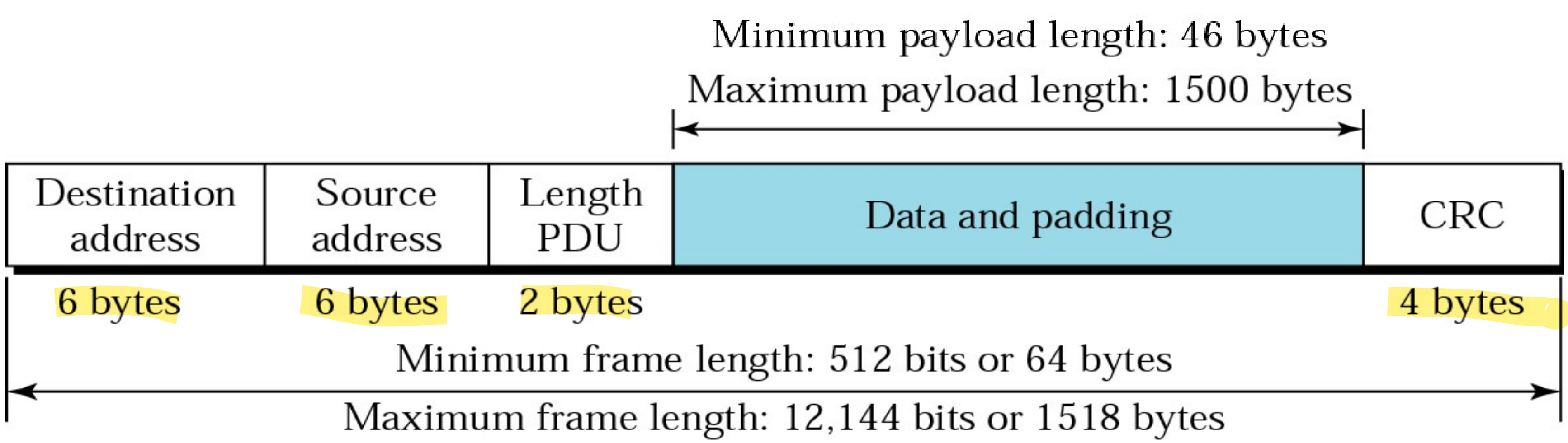
Ethernet Frame Format

PA	SFD	DA	SA	LEN	LLC PDU	PAD	FCS	IEEE 802.3
PA		DA	SA	Type	DATA	PAD	FCS	DIX Ethernet
7	1	6	6	2	46-1500		4	

- PA: Preamble --- 7 bytes 10101010s for synchronization
- SFD: Start of frame delimiter --- 10101011 to start frame
- DA, SA: Destination & source MAC address
- LEN: Length --- number of data bytes
- Type: Identify the higher-level protocol
- LLC PDU + Pad: minimum 46 bytes, maximum 1500
- FCS: Frame Check Sequence, using CRC

Minimum frame size in Ethernet

- A frame must take at least 2t time to send (t = maximum one-way propagation delay)
- For Ethernet, 2t = 51.2 microseconds
  - This includes delay introduced by four repeaters



Why must the IEEE 802.3 (Ethernet) frame be at least 64 bytes long?

Calculations:

- LAN Length (L) = 500 m (per segment) x 5 segments = 2500 meters
- Velocity of propagation on the cable (V) = $2 * 10^8$ meters/sec
- Delay added by repeater (D) = ~3μsec x 2 (Bi-Direction) x 4 Repeaters = 24 μsec
- Round Trip Delay (RTD) = (Total Distance/V) + Repeater Delays (D)
- Total Distance/V = $(2*2500/2 * 10^8)$ = $25 * 10^{-6}$ sec or 25μsec
- Hence RTD = 25 + 24 = 49 μsec

- In 10mbps Ethernet, time to transmit 64 bytes = 512 bits / $10 * 10^6$ = 51.2 10^{-6} sec or 51.2 μsec (referred to as slot time in the 802.3) which is greater than the RTD of 49 μsec.

- Hence the minimum frame size for the IEEE 802.3 (Ethernet) is 64 bytes.

* μsec → microsecond

Fast Ethernet (100Mbps)

- Fast Ethernet operates at 100Mbps. For the most part, the scheme/protocol remains the same as the 10Mbps case, except now the maximum length of the network is shortened.

- Minimum frame size is still kept at 64 bytes (for backward compatibility), which now arrive 10 times faster than they do in 10Mbps Ethernet.

- Hence the maximum length of the network must be 10 times smaller or about around 250 meters.

Gigabit Ethernet

Carrier extension for 1 Gbps Ethernet

- In Gig Ethernet, it would be necessary to reduce the LAN size to 25m in order to retain the min frame size of 64 bytes.
- Instead, Gigabit Ethernet uses a bigger slot size of 512 bytes. To maintain compatibility with Ethernet, the minimum frame size is not increased, but the "carrier event" is extended.
- If the frame is shorter than 512 bytes, then it is padded with extension symbols. These are special symbols, which cannot occur in the payload. This process is called *Carrier Extension* (performed by the NIC card in hardware and is stripped away before the FCS is calculated on the receiving side).

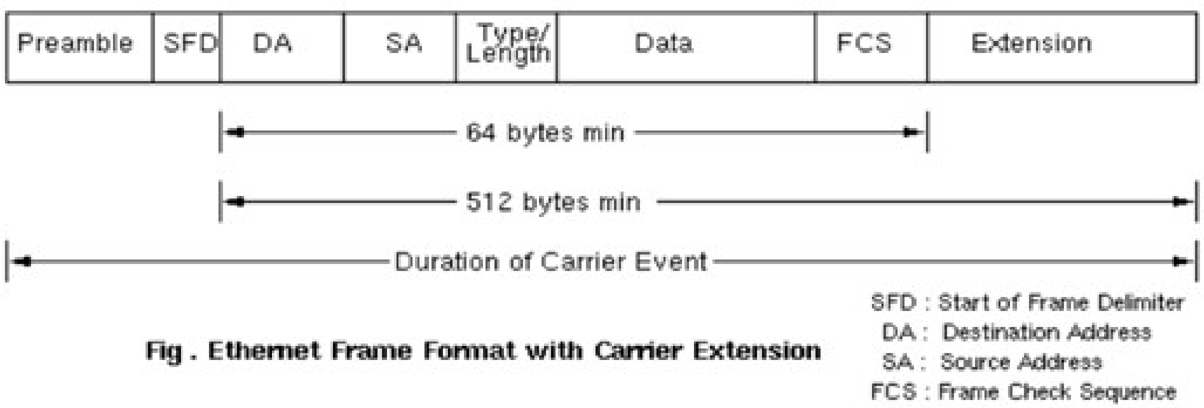


Fig . Ethernet Frame Format with Carrier Extension

IEEE 802.3 (Ethernet) Performance

- Efficiency (line utilization) decreases as the number of stations trying to transmit (under heavy load) increases due to the increased probability of collisions. 30% line utilization (or 3 Mbps throughput) is considered heavy load.

- Larger the frame size the higher the efficiency or utilization (due to higher payload since the header size of the frame is fixed). E.g. for 1024 byte frame, efficiency is about 85% and for a 64-byte frame, efficiency is about 30%.

Switched Ethernet

(Formerly Bridge Ethernet)

Two terms

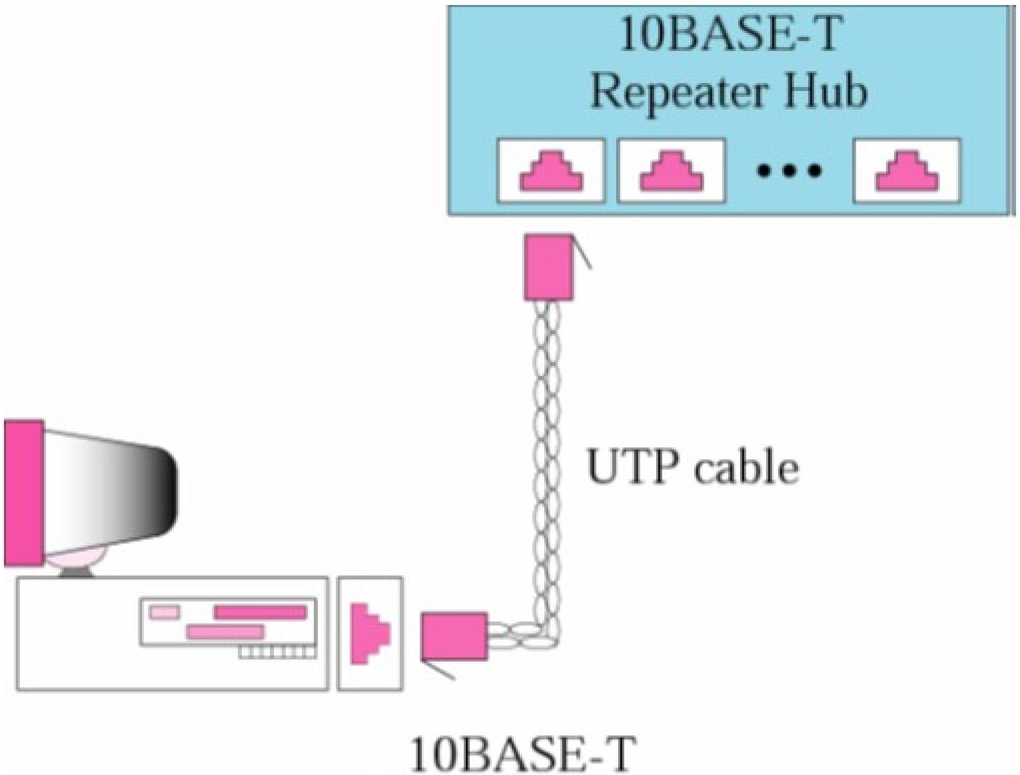
- Segment
  - Part of medium without any repeater
  - One or more stations can connect to a segment
  - Segments can be connected using repeaters
- Collision domain
  - Set of machines such that two machines transmitting can cause collision
  - One or more segments
- Repeaters (physical layer devices) do NOT guard against collision
  - Several segments connected by repeaters are within the same collision domain

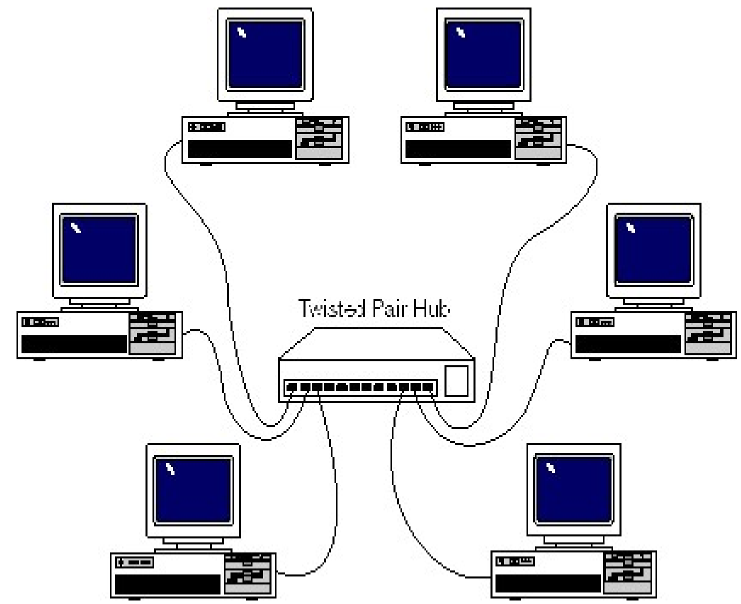
Hubs

- Hub: a multi-port repeater
  - all nodes in a LAN may be connected to a central Hub (physically a star topology)
  - inside hub is a simple medium connecting all nodes, messages sent by each node reach all other nodes (logically a bus topology)

- Hub functions at the physical layer, similar to a repeater
  - Does not guard against collision (logically bus)

Connection of stations to the medium using 10Base-T and Hub





LAN using Hub: 10BaseT

- 10 Mbps, baseband, Unshielded Twisted Pair (two pairs) Cat 3 or better used
- Logical topology bus, physical topology star using hub
- Maximum distance from station to hub = 100 m
- Collision domain: all machines connected to a hub
- Manchester encoding
- 1-persistent CSMA/CD for transmission, binary exponential backoff for retransmission
- Base wait period (Ethernet Slot Time) of 51.2μsec, Inter-frame gap of 9.6 μsec

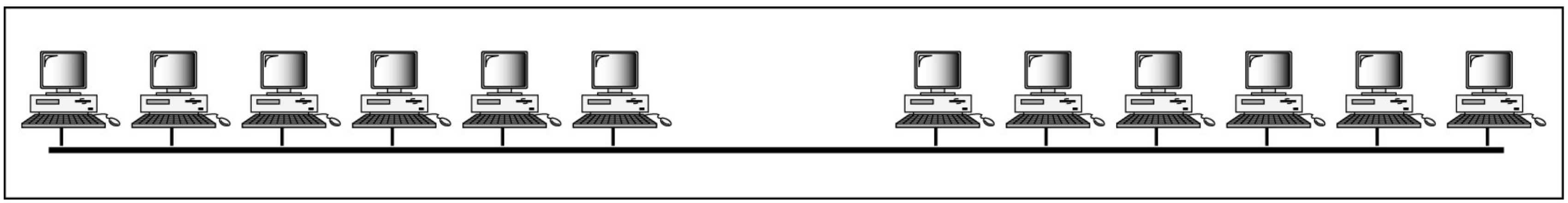
Switches in place of Hubs

- Switch (also called Layer 2 switch)
  - Hubs are nowadays replaced by switches
  - Frames NOT always broadcast, sent to only that port to which destination node is connected

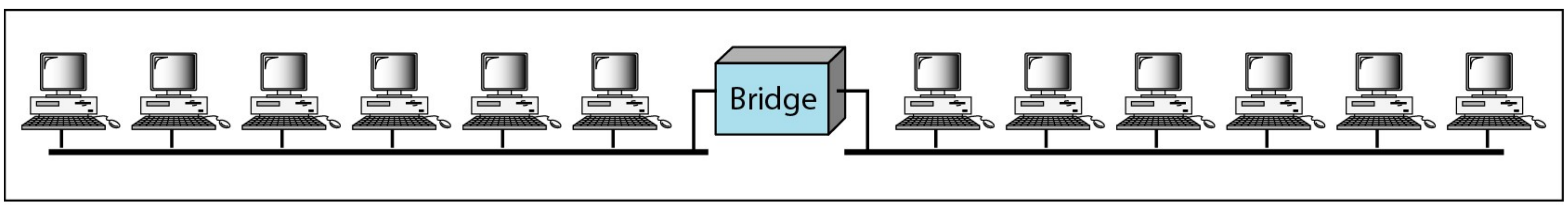
- Advantages of switch over hubs
  - Separates the single collision domain of to multiple collision domains
  - Allows more than one pair of nodes to communicate parallely

A network with and without a Bridge

- ❑ The first step in the Ethernet evolution was the division of a LAN by bridges.
- ❑ Bridges have two effects on an Ethernet LAN:
  - ➢ They raise the bandwidth and they separate collision domains.

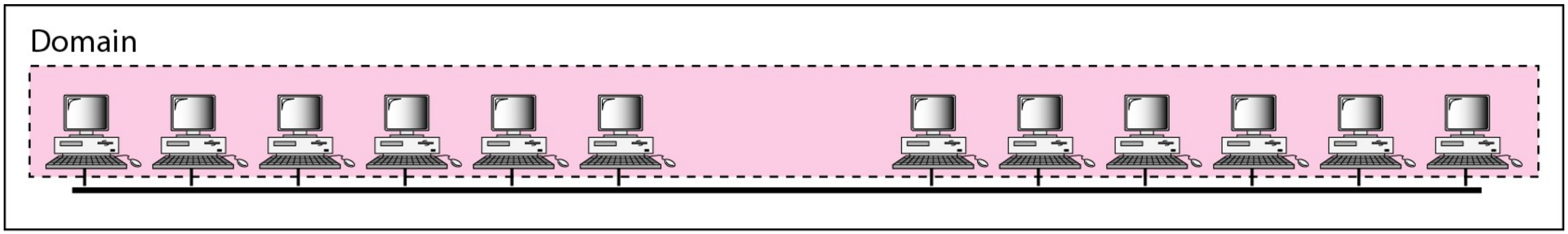


a. Without bridging

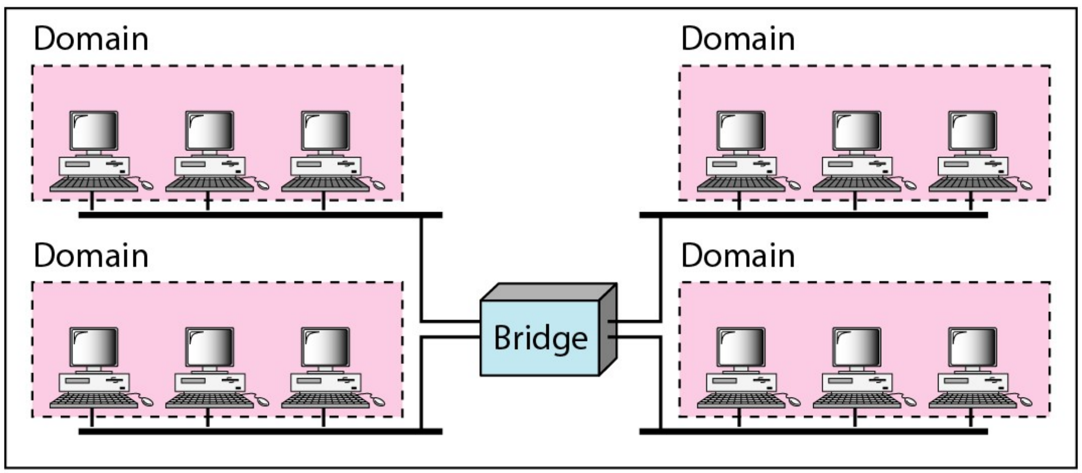


b. With bridging

Collision domains in an unbridged network and a bridged network



a. Without bridging



b. With bridging

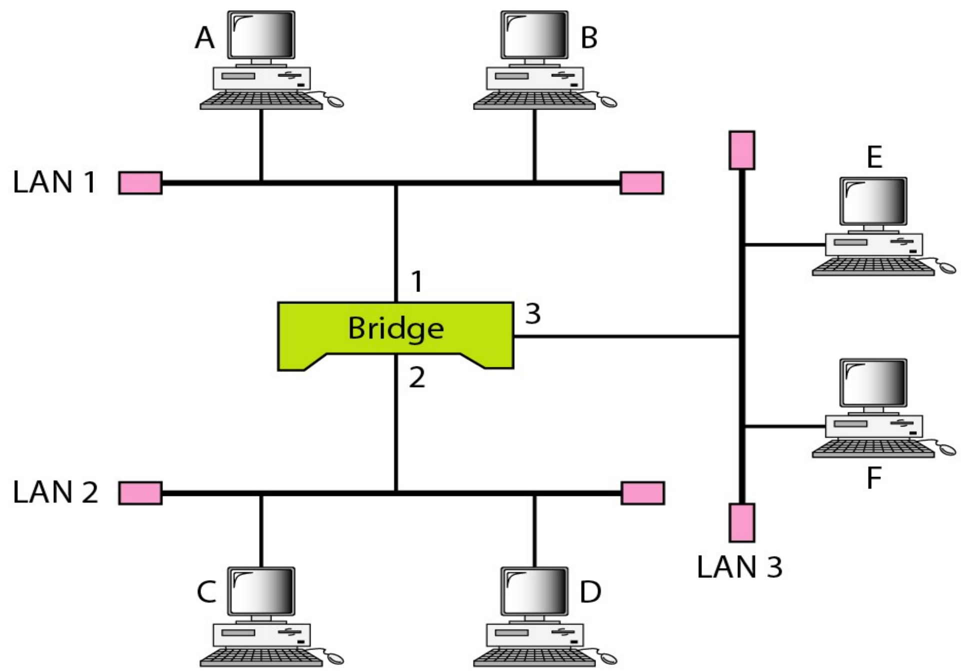
L2 Switches

- As traffic increases (due to increased number of stations) the LAN will eventually saturate. The solution is a switched 802.3 LAN.
- A layer 2 switch is an N-port bridge with additional sophistication
- For selective send of frames, switch needs to know which node is connected to which port
- Switch learns – switch builds up a table of MAC address of nodes and port numbers

L2 Switches

- Suppose m/c A sends frame to m/c B
  - Switch knows nothing initially, so broadcasts to all ports
  - But switch now knows which port A is connected to!
  - Hereafter, if a frame comes for A, it will be forwarded to only A's port
  - Internal table completely built up when every m/c has sent at least one frame

A learning L2 Switch and the process of learning



Address	Port

a. Original

Address	Port
A	1

b. After A sends a frame to D

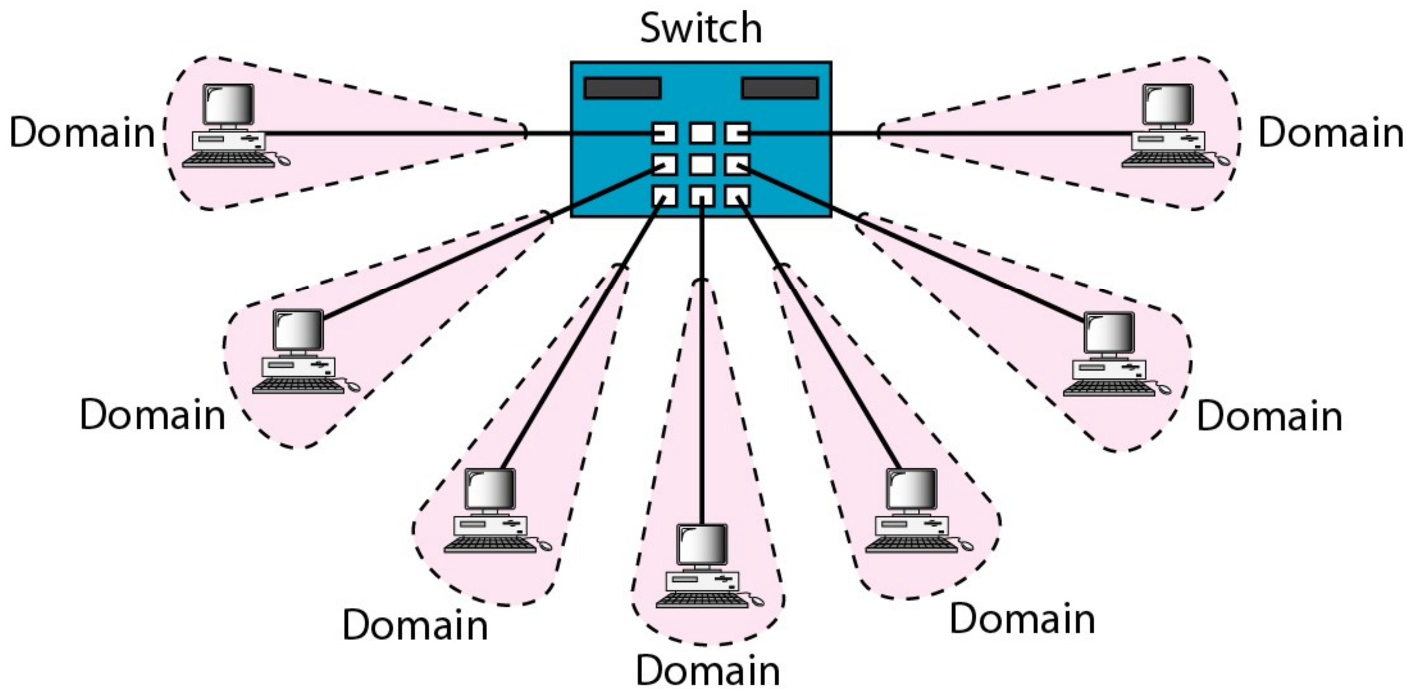
Address	Port
A	1
E	3

c. After E sends a frame to A

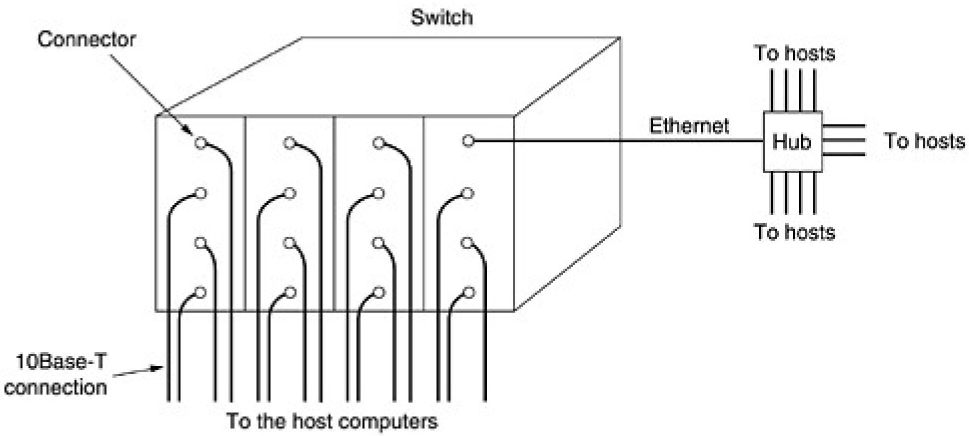
Address	Port
A	1
E	3
B	1

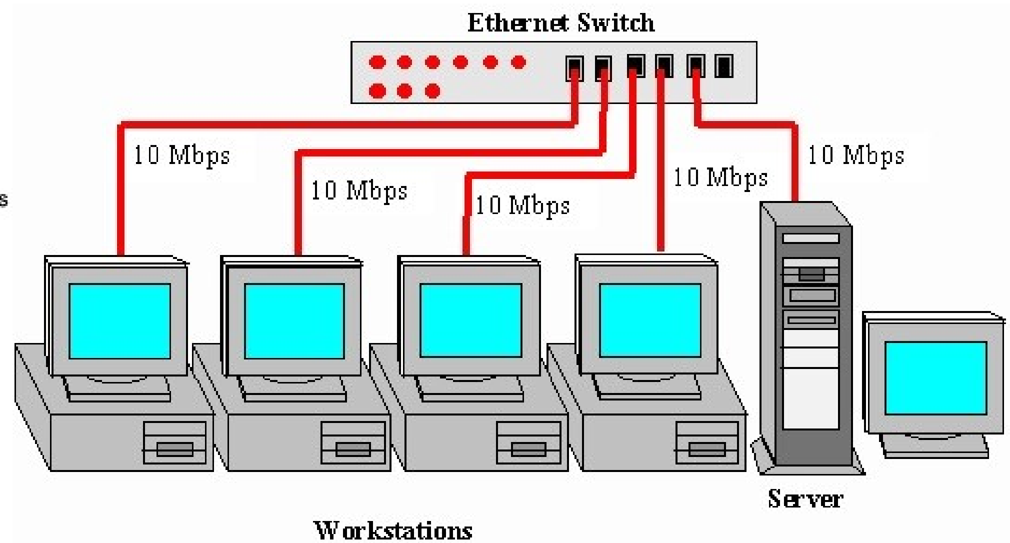
d. After B sends a frame to C

Switched Ethernet (modern days LAN)



Switched Ethernet (modern days LAN)





References

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- *Computer Networks, Andrew S. Tanenbaum and David J. Wetherall*
- *Wikipedia*