EEE 432
Introduction to Data Communications

Asst. Prof. Dr. Mahmut AYKAÇ

LANS & WANS

Course Information

1. Data Communications and Networks
2. Data Transmission
3. Transmission Media
4. Signal Encoding Techniques
5. Digital Data Communication Techniques
6. Multiplexing
7. Networking and Protocol Architectures
8. Switching
9. Routing in Switched Networks
10. **LANs and WANs**
11. **Ethernet**
12. The Internet

Categorizing Network Technologies

Transmission Medium

- Wired vs Wireless

Link Configuration

- Point-to-point vs Point-to-multipoint

User Mobility

- Fixed vs mobile

Types of Users

- Access vs core (backbone)

Coverage Area

Selecting the Transmission Medium

Wired

+ No interference from others → high data rates, easy to upgrade capacity

+ Small, predictable delay

- Expensive to install in hard to access locations

- Device locations are fixed

Wireless

+ No physical connection → mobility, convenience

- Interference, varying channel conditions → Poor performance

- Licenses often required

- Hard to add more capacity

- Physical security is difficult

Selecting the Link Configuration

Point-to-point

+ Dedicated link for users → high, predictable performance

- Need many links, planning of end-points **(Topology)**

- Wired links, wireless links with directional antennas

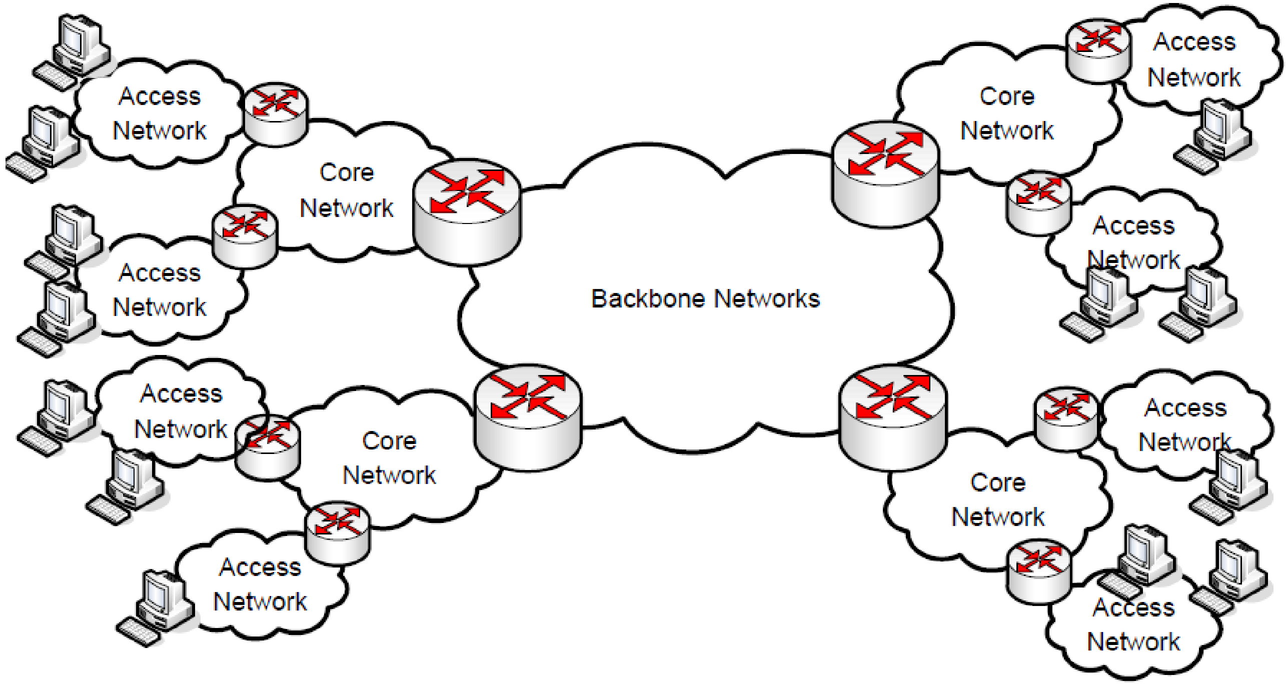
Point-to-multipoint

+ Cover multiple users with single link

- Requires sharing of medium: multiple access, **Medium Access Control** protocol

- Wireless links with omnidirectional antennas, shared wired links

Access vs Core Network



* In this figure, each cloud represent a network. So, there are totally 13 component networks, small ones, and one large one by joining them all together (network of networks, such as Internet)

* We connect many small networks to form one large network

Coverage Area

- *centimetres*; people, objects
  - **B**ody **A**rea **N**etwork
  - **P**ersonal **A**rea **N**etwork
  - Infrared, Bluetooth, ZigBee, IEEE 802.15.4, . . .
- *metres*; homes, offices, buildings
  - **L**ocal **A**rea **N**etwork
  - **H**ome **A**rea **N**etwork
  - **S**torage **A**rea **N**etwork
  - IEEE 802.3 (Ethernet), IEEE 802.11 (WiFi), Fibre Channel . . .
- *kilometres*; cities, countries, between countries
  - **M**etropolitan **A**rea **N**etwork
  - **W**ide **A**rea **N**etwork
  - PDH, SDH, ATM, Frame-Relay, WiMax, satellite, . . .
- *megametres*; globe, between planets
  - **G**lobal **A**rea **N**etwork
  - the Internet, interplanetary networks

WANs and LANs

Wide Area Networks (WANs)

- Connect devices/networks over large geographical area
- Between campuses, office buildings, cities, countries
- Owned and operated by organisations on behalf of users, e.g. TOT, CAT, TT&T
- Leased to users, e.g. unis, companies, smaller ISPs

Local Area Networks (LANs)

- Connect end-user devices over small area
- Within campuses, buildings, homes
- Owned and operated by organisation using the network
- Typically support higher data rates than WANs (internal communications, multiplexing)

Network Topologies

- **Topology:** arrangement of nodes (devices) and links
- Devices with data to communicate to others: stations, hosts, end nodes
- Devices that support communications: switches, repeaters, hubs
- Links: point-to-point, point-to-multipoint

Mesh, every station has point-to-point link to every other station

Bus, every station connected via a multipoint link

Ring, point-to-point links between pairs of stations, or via special link, to form ring

Star, every station has point-to-point link to central device

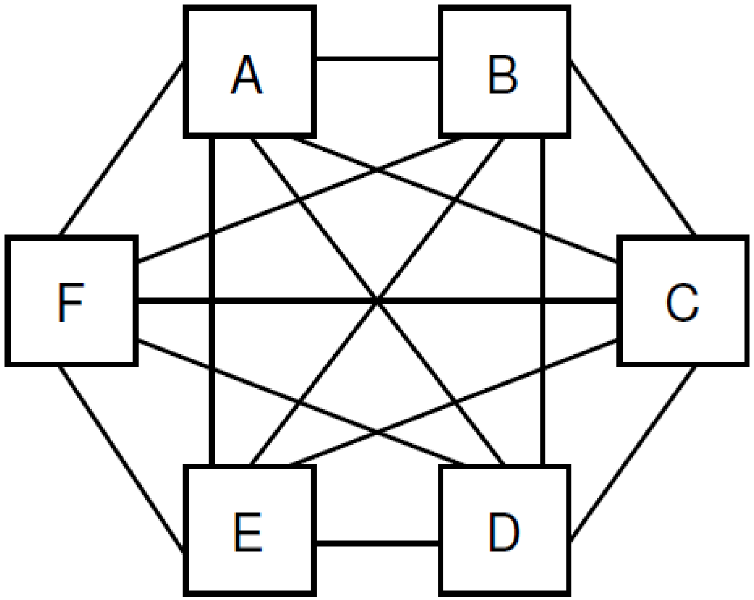
Hybrid, combination of 2 or more of above, e.g. tree is combination of star and bus topologies

Topology Design Requirements

- Station should be able to communicate with any other station
- Dedicated point-to-point links are better than shared multipoint links
- Use as few links as possible
- Scales well: adding a new node requires little effort
- Fault-tolerant: failure of a link still allows other nodes to communicate; failure of a device doesn't prevent other nodes from communicating
- Fault-detection: a fault can be automatically detected by network

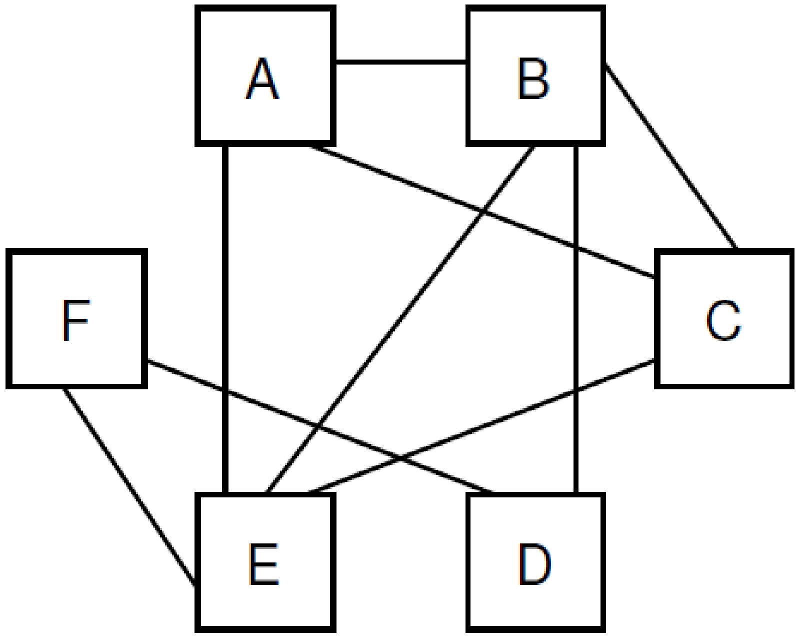
Mesh Topology

- Used in small WANs; becomes too complex as number of nodes increase
- Each pair of nodes have dedicated point-to-point link
- Addresses not needed in frames



Partial Mesh Topology

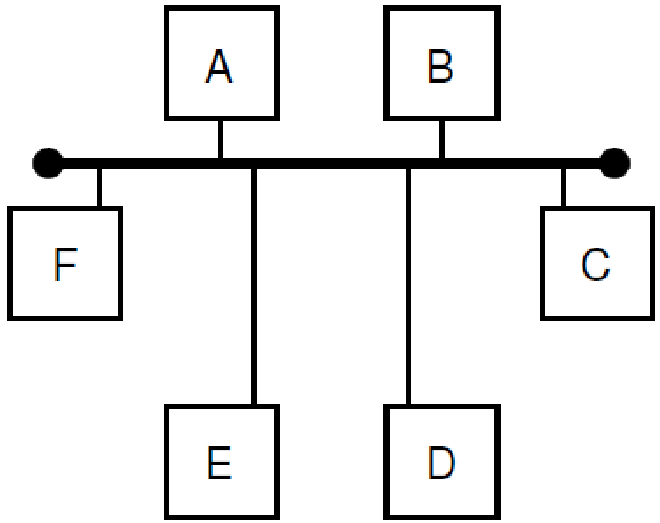
- Selection of node pairs have point-to-point link
- Some pairs cannot communicate, unless nodes can forward data (see Internet topic)
- Used in WANs



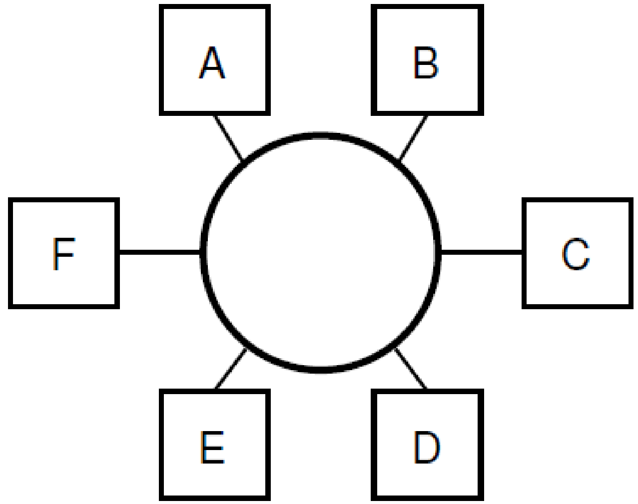
Bus Topology

- Used in early (Ethernet) LANs, but replaced by star
- Single multipoint link connects all stations
- Transmission propagates throughout medium and is heard by all stations
- Terminator absorbs frames at end of medium/cable
- Frames need addresses
- **Pros:** easy installation
- **Cons:** require protocols to share medium;

faulty link stops all communications; limited number of stations



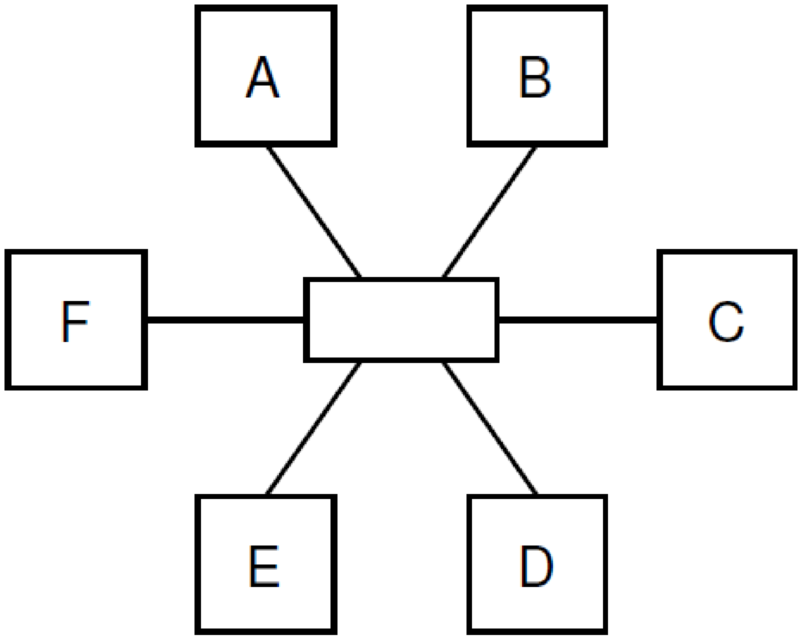
Ring Topology



- Unidirectional point-to-point links to form loop
- Stations attach to repeaters
- Frames need addresses
- **Pros:** simple to install and reconfigure; easy to identify faults
- **Cons:** require protocols to share medium; traffic flows in one direction
- **Usage:** old LANs (e.g. IBM/IEEE 802.5 Token Ring); MANs and WANs

Star Topology

- Traffic between stations goes via the central node
- Usually two point-to-point links between station and central node (or duplex link)
- Frames needed addresses
- **Pros:** easy to install; fault tolerance for links
- **Cons:** depends on central node
- **Usage:** Most LANs today



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ETHERNET

Introduction

- Ethernet is a family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN).
- Ethernet has become the most popular wired local area network standard. While maintaining a low cost, it has gone through six versions, most ten times faster than the previous version (10 Mbps, 100 Mbps, 1 Gbps, 10Gbps, 40 Gbps, 100 Gbps, and in the works 400 Gbps).

Fig. Connection of Cat 5/6 cable With RJ45 connector to Ethernet socket

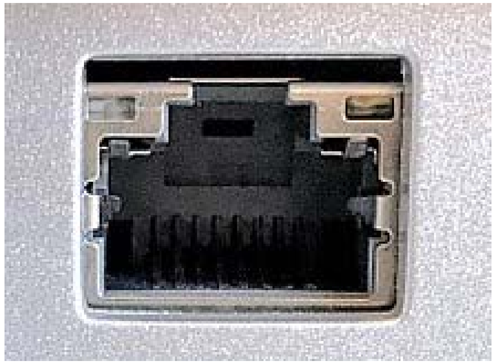


Fig. Ethernet Socket for RJ45 connector

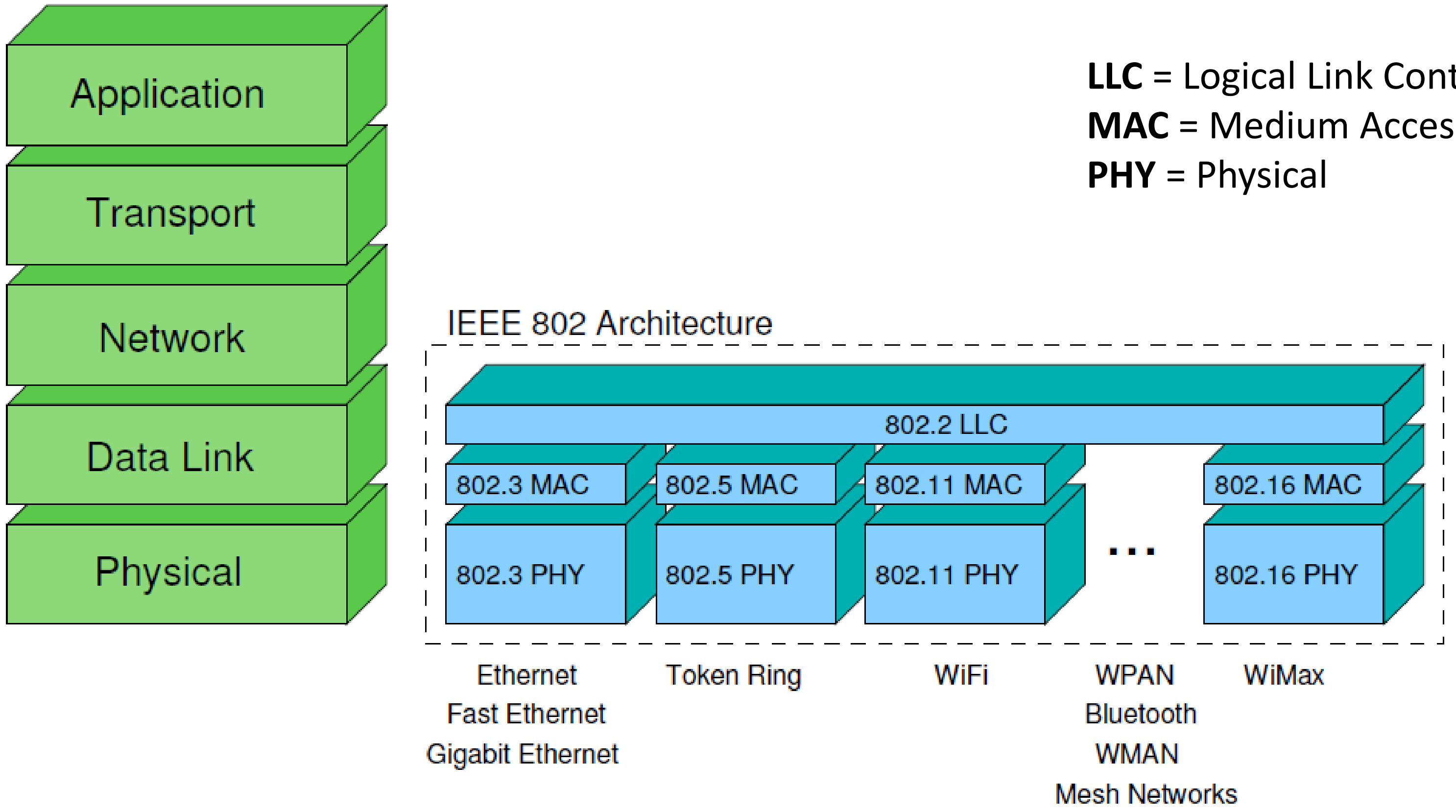
Fig. Ethernet Card for a desktop computer

IEEE 802 LANs → IEEE 802 LAN Architecture

- **I**nstitute of **E**lectrical and **E**lectronics **E**ngineers: professional and standards organisation
  - 754 (Floating Point Arithmetic), 828, 829, 830, (Software Development), 1003 (POSIX), 1076 (VHDL), 1363 (Cryptography), 1394 (Firewire), . . .
- IEEE 802: LAN/MAN standards committee
  - Developing standards for PANs, LANs, MANs, WANs
  - Divided into numbered working groups
- IEEE 802 standards focus on:
  - Physical (PHY) layer
  - Data link (DL) layer
    - Medium Access Control (MAC): efficient data transfer, sharing the medium
    - Logical Link Control (LLC): addressing, connecting to other networks
- **IEEE 802.3 (Ethernet)**, IEEE 802.5 (Token Ring), IEEE 802.11 (WiFi), IEEE 802.15.1 (Bluetooth), IEEE 802.16 (WiMax), . . .

IEEE 802 LAN Architecture

LLC = Logical Link Control
MAC = Medium Access Control
PHY = Physical



IEEE 802.3: Ethernet

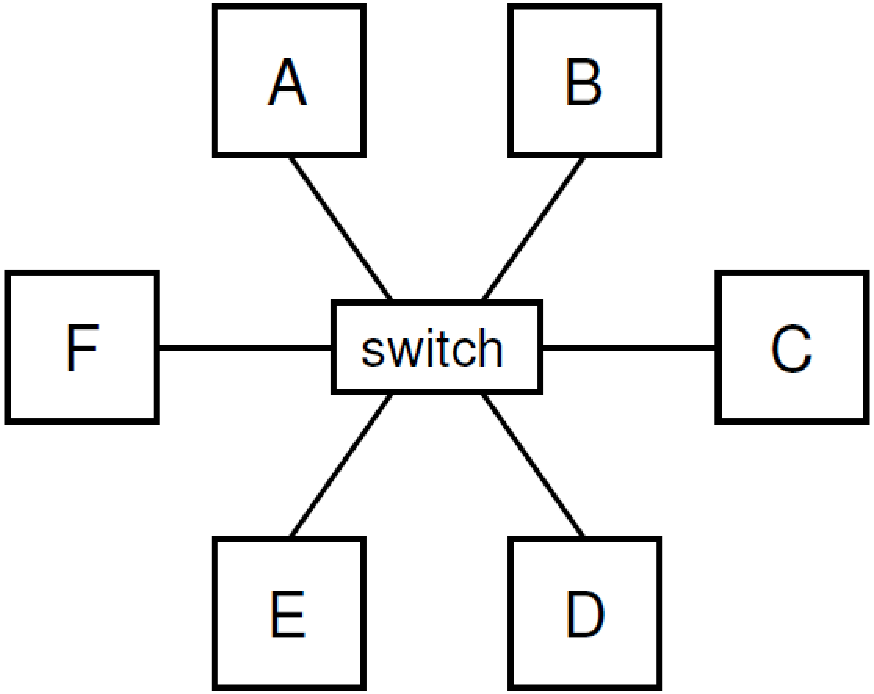
- Ethernet developed for LAN communications in 1970's; standardised as IEEE 802.3 in 1983
- Several competing technologies at the time: Token Ring, Token Bus
- Ethernet became most popular and now most common LAN standard
- Evolution of Ethernet:
  - Ethernet ('73): 3 Mb/s, coaxial cable, bus topology, half-duplex, shared medium
  - Ethernet II ('83): 10 Mb/s
  - Fast Ethernet ('87): 100 Mb/s, twisted pair, star topology with hub
  - Switched Ethernet ('90): 100 Mb/s, full duplex, star topology with switch, point-to-point links
  - Gigabit Ethernet ('99): 1 Gb/s, twisted pair or optical fibre
  - For data centres, MANs and WANs: 10 Gb/s, 40 Gb/s, 100 Gb/s, 400 Gb/s

Switched Ethernet

- Most LANs today use Ethernet in a star topology
- Centre device is called switch (different from a hub)
- Key characteristics of today's LANs:
  - Stations have full-duplex, point-to-point links to switch
  - Twisted pair cable (Category 5 or 6 UTP)
  - Data rate: 100 Mb/s or 1 Gb/s (auto-negotiation)
  - PHY standard: 802.3u (100BASE-TX) or 802.3ab (1000BASE-T)
  - Distance: 100 m
  - Random access is not used

Switched Ethernet Topology

- Stations (hosts, routers) connect via full-duplex twisted pair to switch
- Switch has multiple ports, e.g. 4, 8, 24, 48
- All frames between stations pass via the switch



Ethernet Frames and Addressing →IEEE 802 Addresses

- IEEE 802 standards use common IEEE 48-bit address format
- Commonly called MAC or hardware addresses
- Globally unique (ideally)
  - First 24-bits assigned by IEEE to manufacturer http://standards.ieee.org/regauth/oui/
  - Second 24-bits assigned by manufacturer to device
- For simplicity, represented as 6×2 digit hexadecimal numbers, e.g. 90:2b:34:60:dc:2f
- Special case broadcast address: ff:ff:ff:ff:ff:ff
- Common in other standards: Bluetooth, ATM, FDDI, FibreChannel
- IEEE 64-bit address is alternative format: Firewire, ZigBee, IPv6

IEEE 802.3 Frames

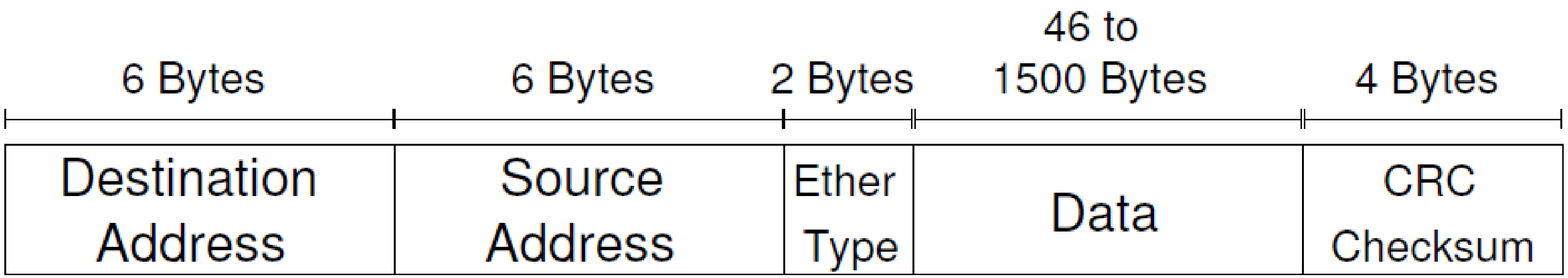
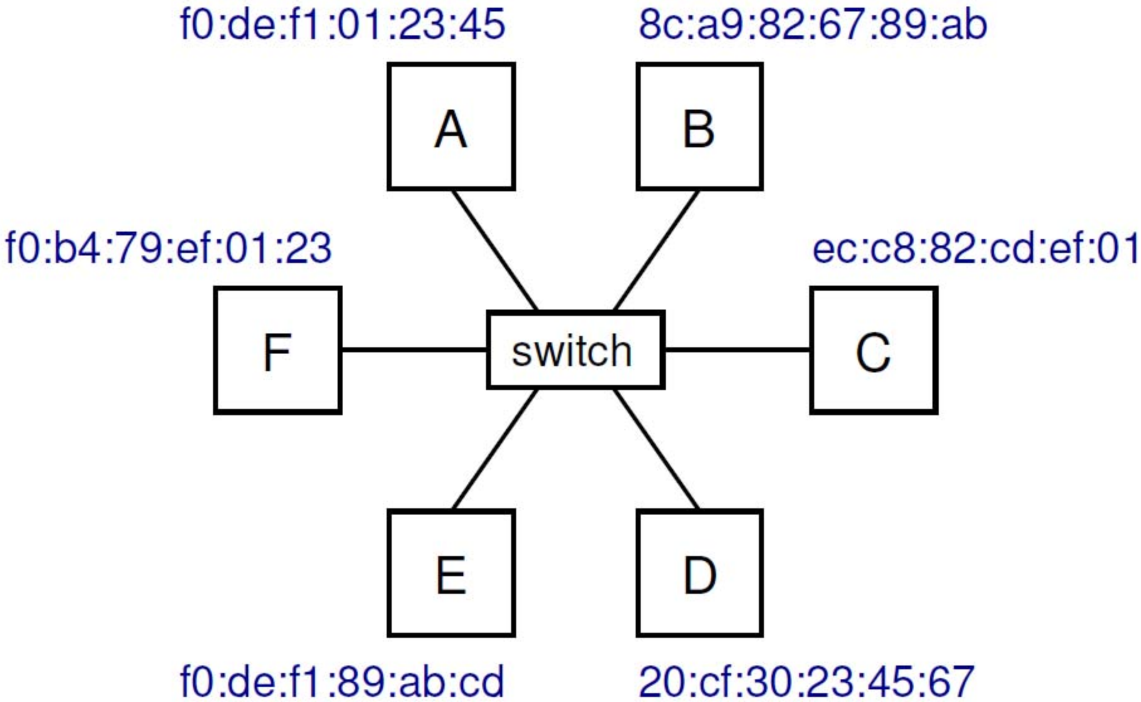


Figure. Ethernet Frame

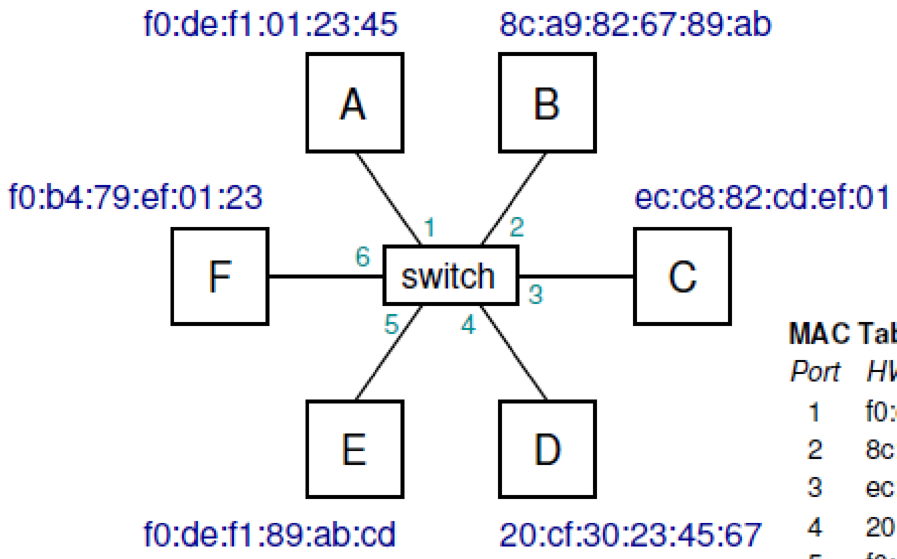
- Typical maximum frame size is 1500 Bytes of payload and 18 bytes of overhead, which makes 1518 Bytes. Minimum payload is 46B, which makes minimum frame is 64B.
- 1st 8 bytes (preamble, delimiter) sometimes considered part of Physical layer

Example Hardware Addresses



- Hardware (MAC) addresses are assigned to LAN card by manufacturer
- Each station (hosts and routers) has address for each network interface card

Example MAC Table used by Switch



MAC Table of switch

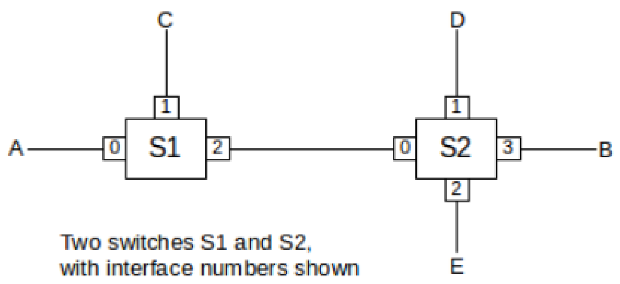
Port	*HWaddress*
1	f0:de:f1:01:23:45
2	8c:a9:82:67:89:ab
3	ec:c8:82:cd:ef:01
4	20:cf:30:23:45:67
5	f0:de:f1:89:ab:cd
6	f0:b4:79:ef:01:23

- Switch learns address of station at other end point of link
- Store address and port in memory; used for forwarding frames

Datagram Forwarding

- In the datagram-forwarding model of packet delivery, packet headers contain a destination address. It is up to the intervening switches or routers to look at this address and get the packet to the correct destination.

- In the diagram below, switch S1 has interfaces 0, 1 and 2, and S2 has interfaces 0,1,2,3. If A is to send a packet P to B, S1 must know that P must be forwarded out interface 2 and S2 must know P must be forwarded out interface 3. In datagram forwarding this is achieved by providing each switch with a forwarding table of xdestination, next_hopy pairs. When a packet arrives, the switch looks up the destination address (presumed globally unique) in this table, and finds the next_hop information: the immediate-neighbour address to which or interface by which–the packet should be forwarded in order to bring it one step closer to its final destination.



S1	
destination	next_hop
A	0
C	1
B	2
D	2
E	2

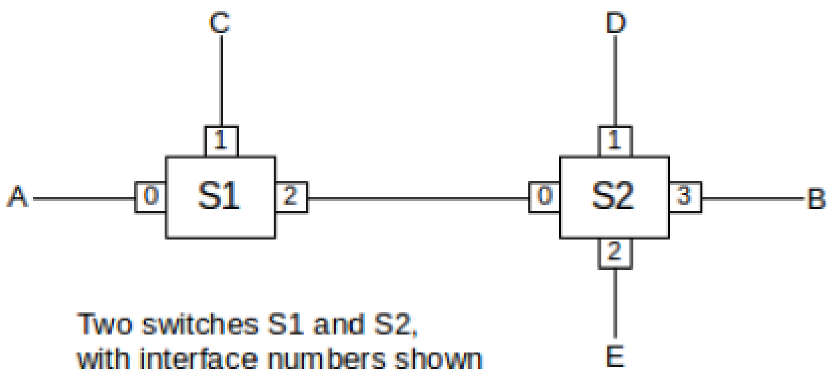
S2	
destination	next_hop
A,C	0
D	1
E	2
B	3

Datagram Forwarding tables for S1 and S2

Datagram Forwarding

- For human readers, using neighbours in the next_hop column is usually much more readable. S1's table can now be written as follows (with consolidation of the entries for B, D and E)

- By convention, switching devices acting at the LAN layer and forwarding packets based on the LAN address are called switches (or, in earlier days, bridges), while such devices acting at the IP layer and forwarding on the IP address are called routers. Datagram forwarding is used both by Ethernet switches and by IP routers, though the destinations in Ethernet forwarding tables are individual nodes while the destinations in IP routers are entire networks (that is, sets of nodes).



Two switches S1 and S2, with interface numbers shown

S1	
destination	next_hop
A	A
C	C
B,D,E	S2

Datagram Forwarding tables for S1

Ethernet Learning Algorithm

- Ethernet switches use datagram forwarding. The trick is to build their forwarding tables without any cooperation from ordinary, non-switch hosts. Switches start out with empty forwarding tables, and build them through a learning process. If a switch does not have an entry for a particular destination, it will fall back to broadcast: it will forward the packet out every interface other than the one on which the packet arrived. The availability of fallback-to-broadcast is what makes it possible for Ethernet switches to learn their forwarding tables without any switch-to-switch or switch-to-host communication or coordination.

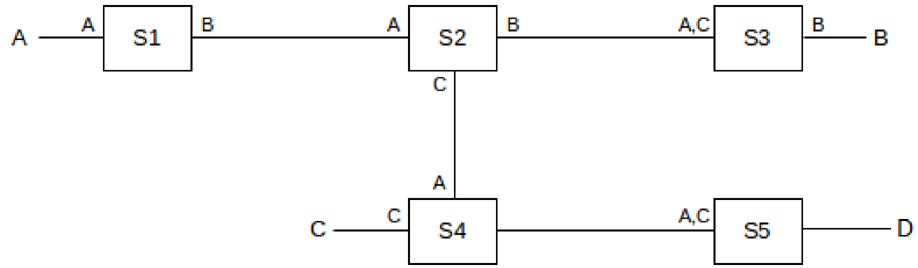
- A switch learns address locations as follows: for each interface, the switch maintains a table of physical MAC (Media Access Control) addresses that have appeared as source addresses in packets arriving via that interface. The switch thus knows that to reach these addresses, if one of them later shows up as a destination address, the packet needs to be sent only via that interface. Specifically, when a packet arrives on interface I with source address S and destination unicast address D, the switch enters <S,I> into its forwarding table.

Ethernet Learning Algorithm

To actually deliver the packet, the switch also looks up D in the forwarding table. If there is an entry <D,J> with J≠I that is, D is known to be reached via interface J – then the switch forwards the packet out interface J. If J=I, that is, the packet has arrived on the same interfaces by which the destination is reached, then the packet does not get forwarded at all; it presumably arrived at interface I only because that interface was connected to a shared Ethernet segment that also either contained D or contained another switch that would bring the packet closer to D. If there is no entry for D, the switch must forward the packet out all interfaces J with J ≠ I; this represents the fallback to broadcast. After a short while, this fallback to broadcast is needed less and less often, as switches learn where the active hosts are located. (However, in some switch implementations, forwarding tables also include timestamps, and entries are removed if they have not been used for, say, five minutes.)

Ethernet Learning Algorithm

- If the destination address D is the broadcast address, or, for many switches, a multicast address, broadcast is required. Some switches try to keep track of multicast groups, so as to forward multicast traffic only out interfaces with known subscribers;
- In the diagram above, each switch's tables are indicated by listing near each interface the destinations (identified by MAC addresses) known to be reachable by that interface. The entries shown are the result of the following packets:
- A sends to B; all switches learn where A is
- B sends to A; this packet goes directly to A; only S3, S2 and S1 learn where B is
- C sends to B; S4 does not know where B is so this packet goes to S5; S2 does know where B is so the packet does not go to S1.



Five learning bridges after three packet transmissions