ECCS-3631
Networks and Data Communications

Module 1-5
Network Devices:
Switches, Switching Table,
Routing, Routing Table

Dr. Ajmal Khan

MAC Address

IP address consists of 32 bits (6 bytes separated by period)

- *network-layer* address for interface
- IP address is used for layer 3 (network layer) forwarding, from one network to another network

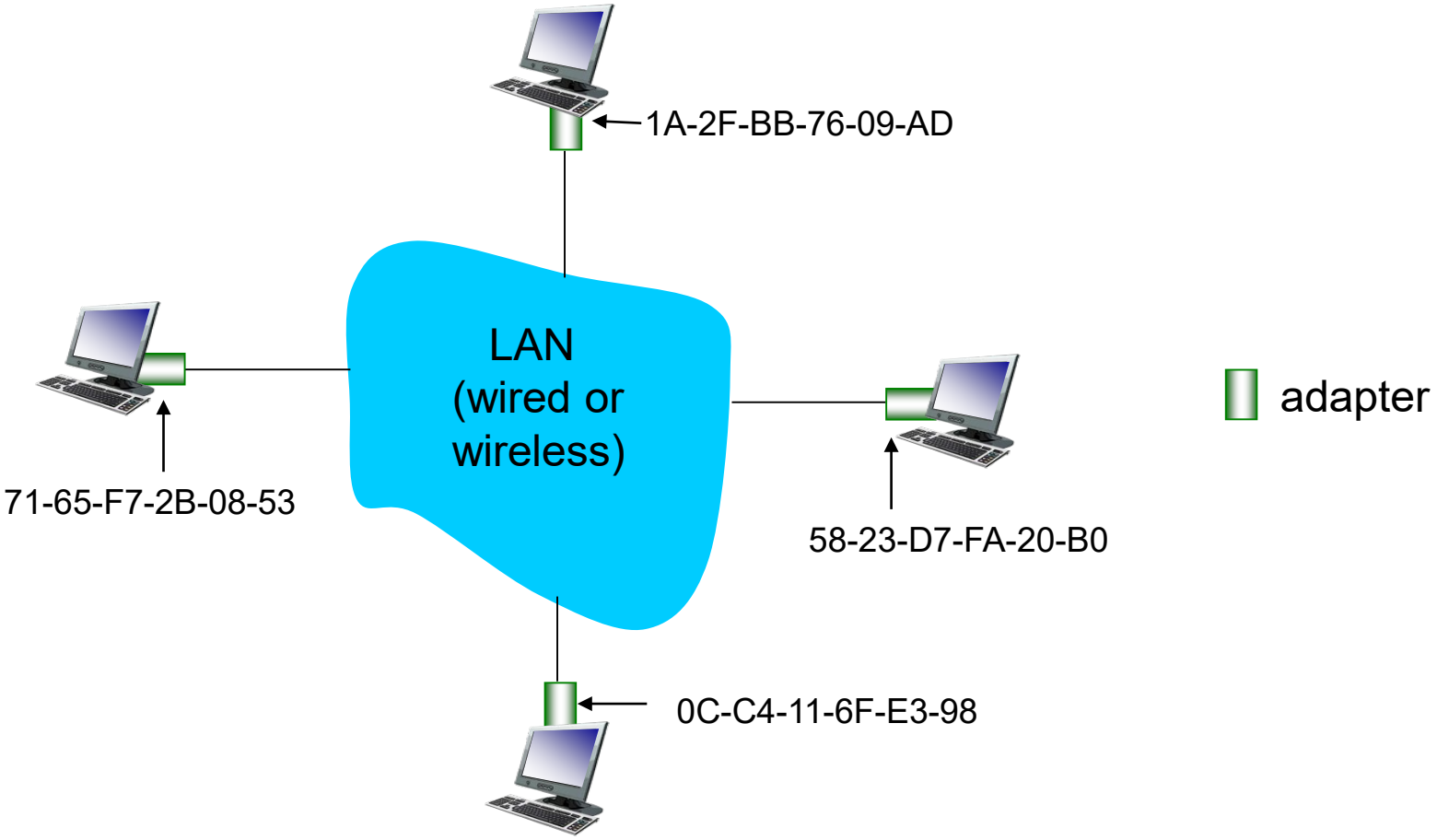
MAC (or LAN or physical or Ethernet) address:

- function: *used 'locally" to get frame from one interface to another physically-connected interface (same network, in IP-addressing sense)*
- 48 bit MAC address (for most LANs) burned in Network Interface Card (NIC) ROM, e.g.: 1A-2F-BB-76-09-AD

hexadecimal (base 16) notation
(each "number" represents 4 bits)

MAC Address

each adapter on LAN has unique MAC address



MAC Address

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- analogy:
  - MAC address: like Social Security Number
  - IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
  - MAC address of computer remains the same, where you move
- IP hierarchical address *not* portable
  - address depends on IP subnet to which node is attached.
  - Once network is changed, IP address is also changed

Ethernet Switch

link-layer device (Switch): takes an *active* role

- store, forward Ethernet frames
- examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment,

transparent

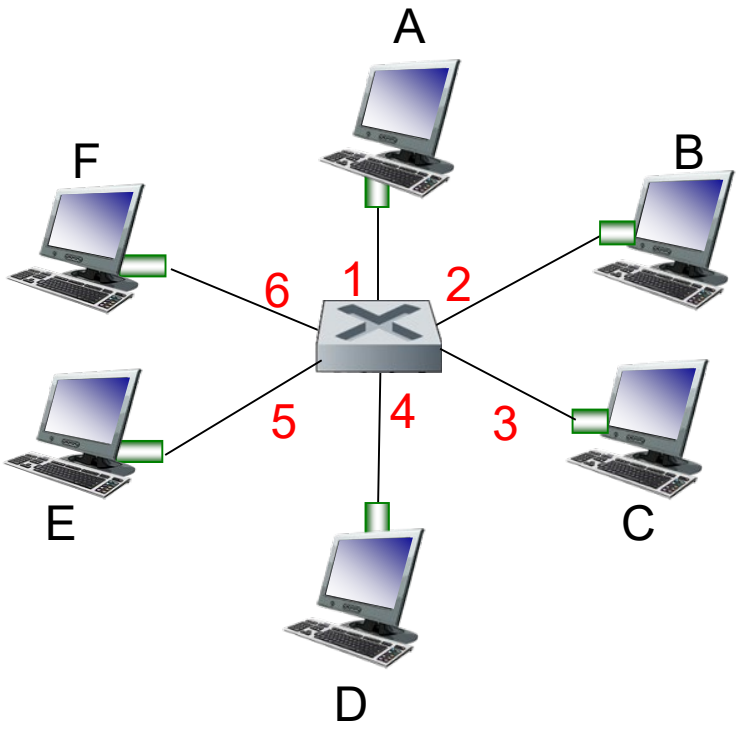
- hosts are unaware of presence of switches

plug-and-play, self-learning

- switches do not need to be configured

Switch: *multiple* simultaneous transmissions

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *switching:* A-to-D and B-to-E can transmit simultaneously, without collisions

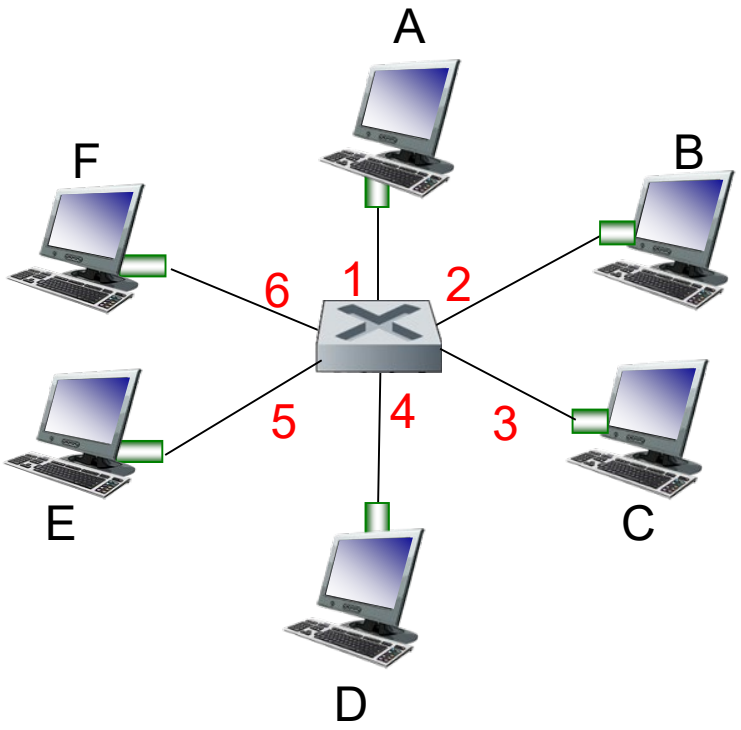


switch with six interfaces (1,2,3,4,5,6)

Switch Forwarding Table

Q: how does switch know D reachable via interface 4, E reachable via interface 5?

- A: each switch has a switch table, each entry:
  - (MAC address of host, interface to reach host, time stamp)
  - It is called Switching Table

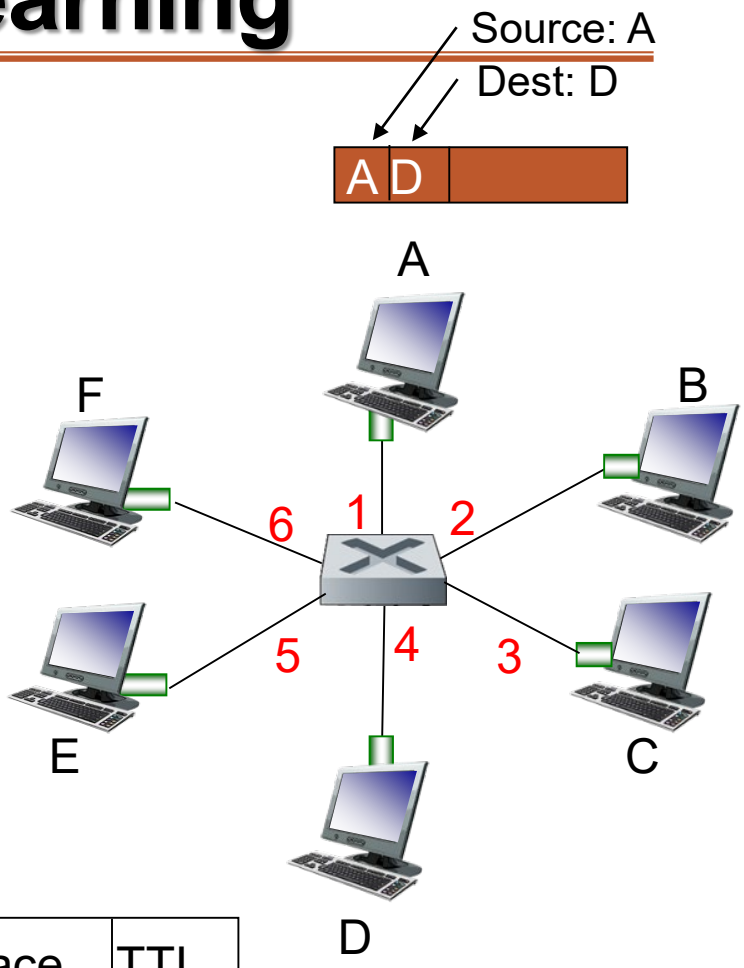


switch with six interfaces (1,2,3,4,5,6)

Switch: Self-Learning

switch *learns* which hosts can be reached through which interfaces

- when frame received, switch "learns" location of sender: incoming LAN segment
- records sender/location pair in switch table

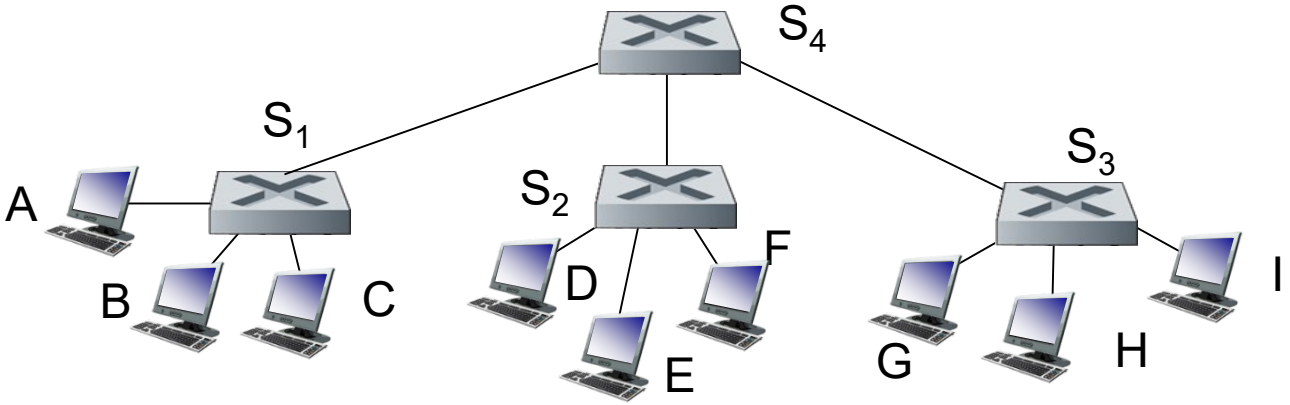


MAC addr	interface	TTL
A	1	60

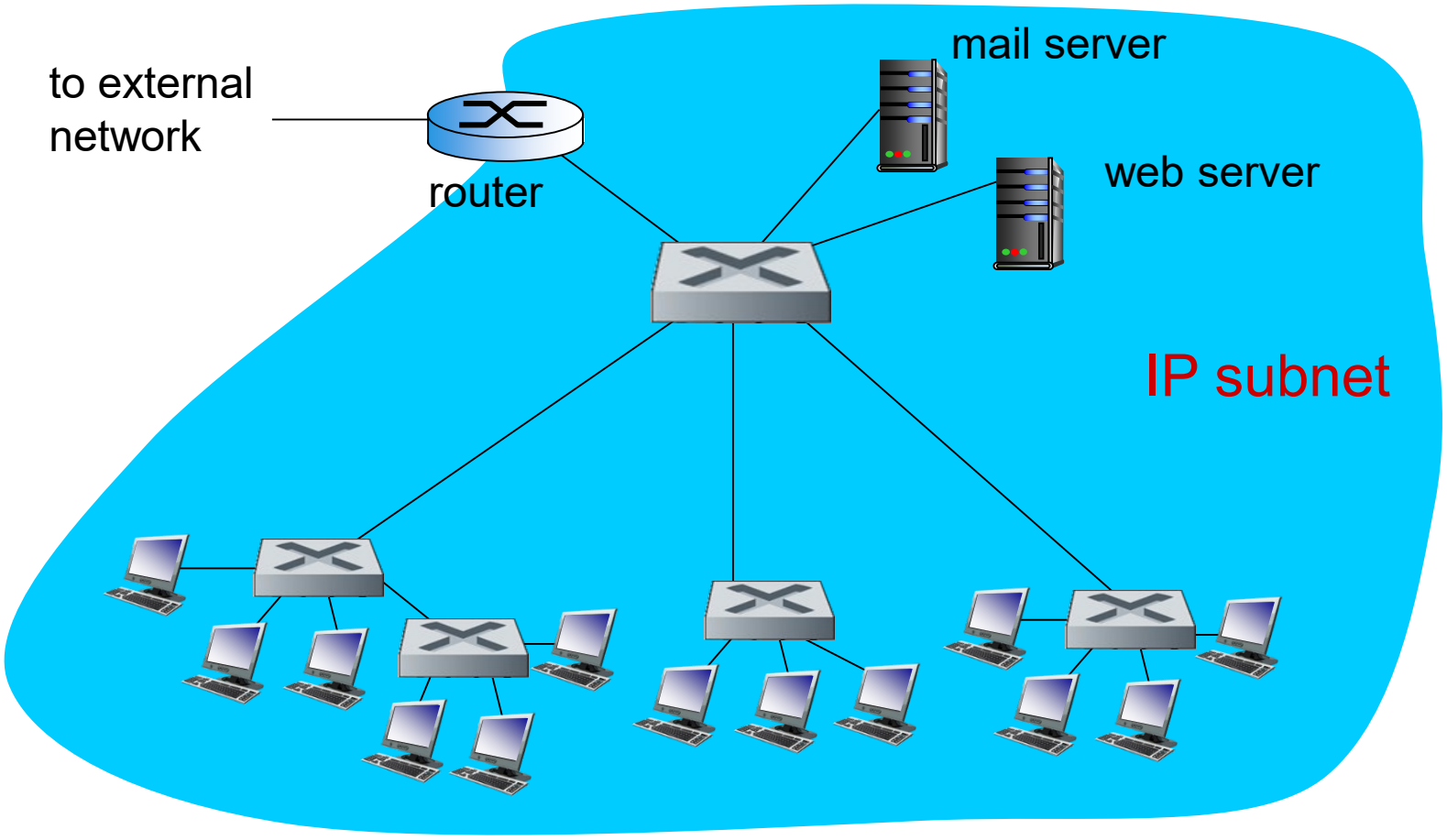
Switch table
(initially empty)

Interconnecting Switches

- switches can be connected together

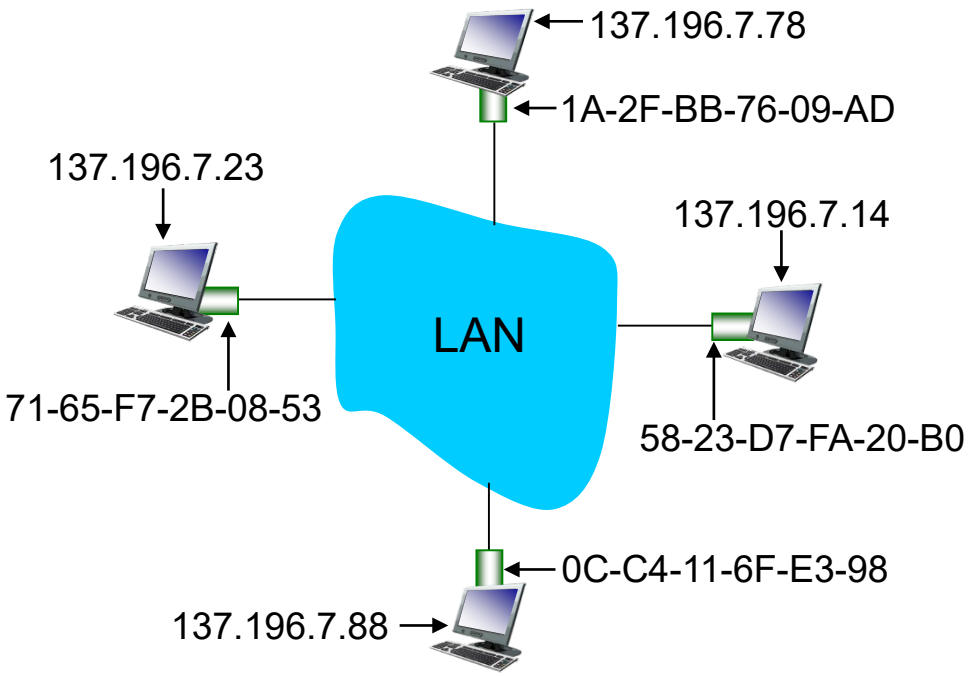


Institutional network



ARP: Address Resolution Protocol

Question: how to determine interface's MAC address, knowing its IP address?



ARP table: each IP node (host, router) on LAN has table

- IP/MAC address mappings for some LAN nodes:

< IP address; MAC address; TTL>

- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP

Let's consider, A and D are in the same LAN, and A wants to send a packet to D. A knows D's IP address. First A uses a cached ARP table to look up existing record of D's MAC address. If found, A sends an Ethernet frame with destination address to D's MAC address, otherwise A has to send a broadcast ARP message (destination FF:FF:FF:FF:FF:FF MAC address), which is accepted by all computers on the LAN, requesting an answer for D's MAC address. D responds with its MAC and IP addresses. D may insert an entry for A into its ARP table for future use. A caches the response information in its ARP table and can now send the packet

Network Layer

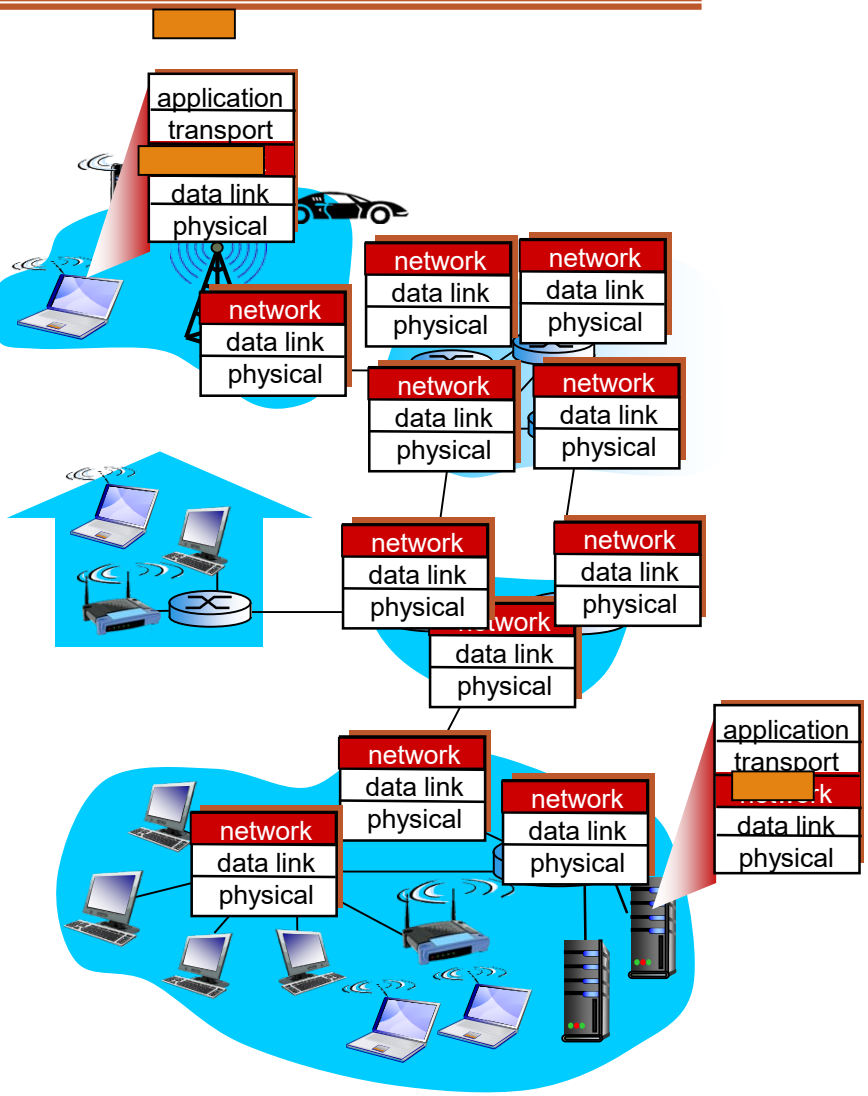
Network Layer transport segment from sending to receiving host

on sending side encapsulates segments into datagrams

on receiving side, delivers segments to transport layer

network layer protocols in *every* host, router

router examines header fields in all IP datagrams passing through it



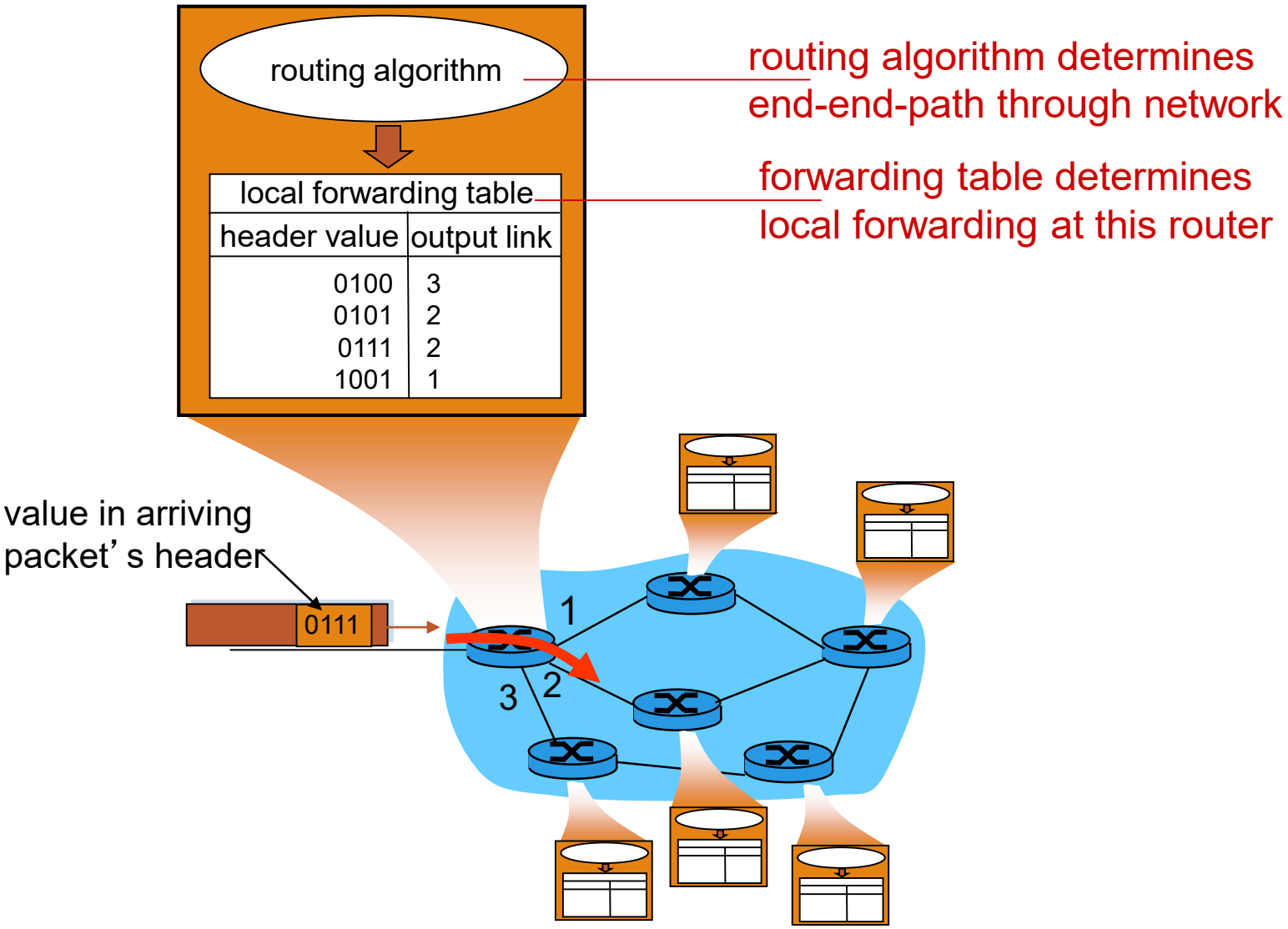
Two key Network-Layer Functions

forwarding: move packets from router's input to appropriate router output within a single router.

routing: determine route taken by packets from source to destination, involves all of a network's routers.

- *routing algorithms*

Interplay between routing and forwarding



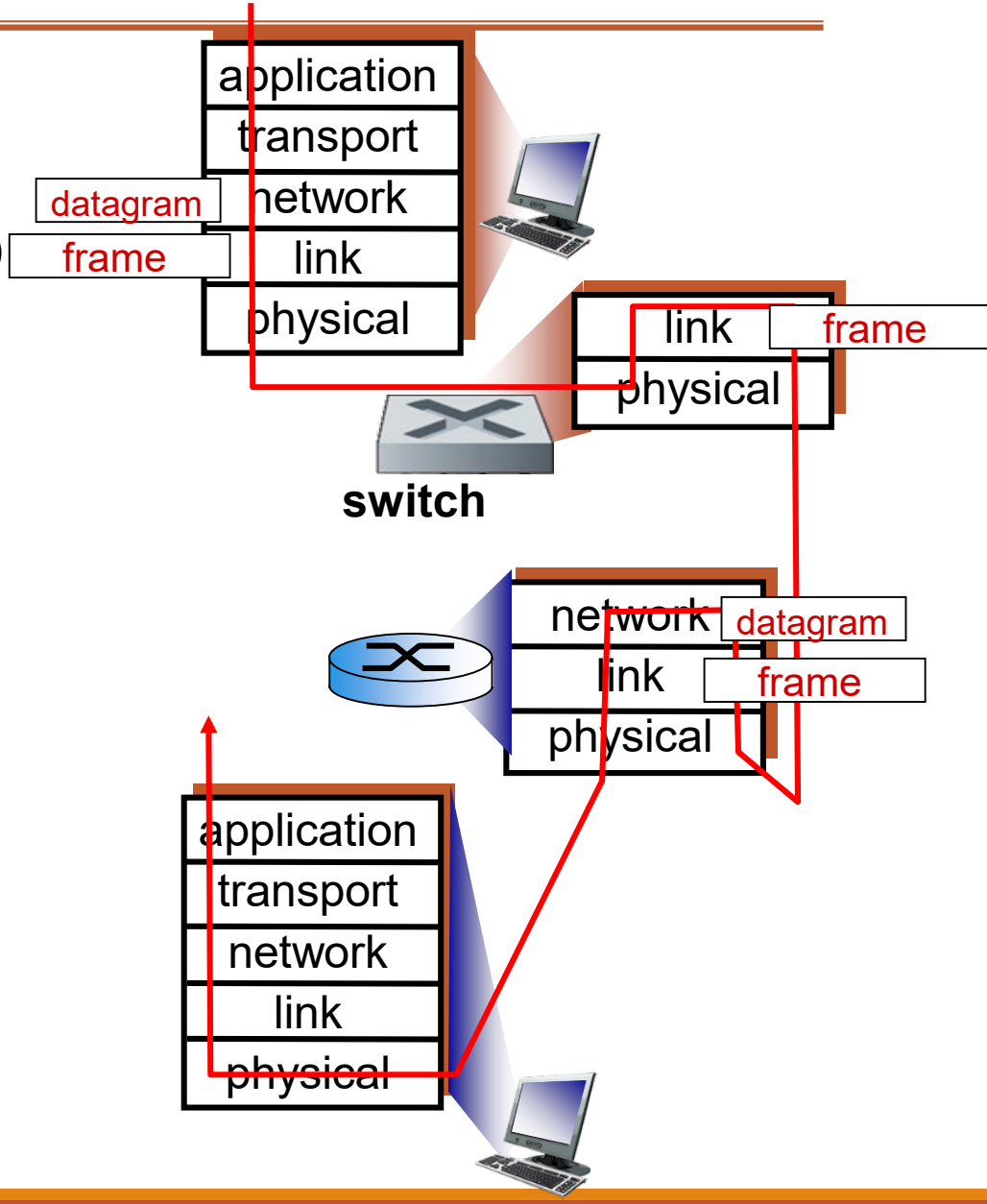
Switches vs. Routers

both are store-and-forward:

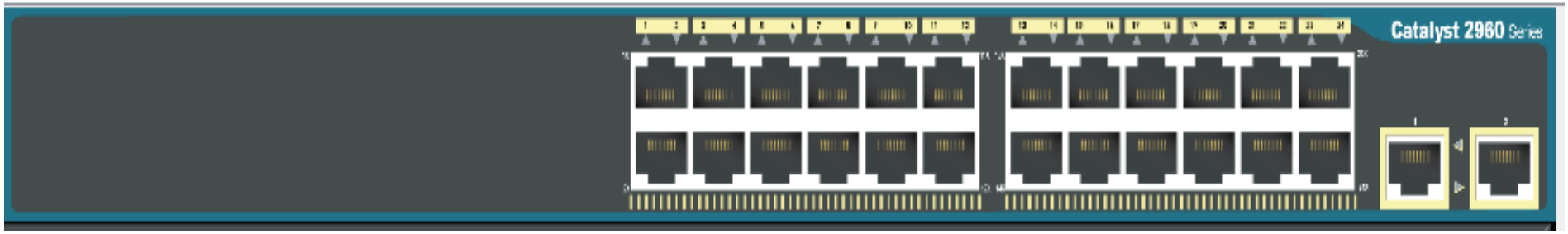
- *routers:* network-layer devices (examine network-layer headers)
- *switches:* link-layer devices (examine link-layer headers)

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



Link Layer Switch in our Lab



Router in our Lab

ping utility

- test the reachability of a host on an IP network
- measures the round-trip time for messages sent from the originating host to a destination computer
- ping replies are echoed back to the source
- ping operates by means of Internet Control Message Protocol (ICMP) packets
- ping sends ICMP echo request to the target and then receives an ICMP echo reply from the target

> ping <IP_Address>

> ping <IP_Address> -10 [sends 10 times ping request

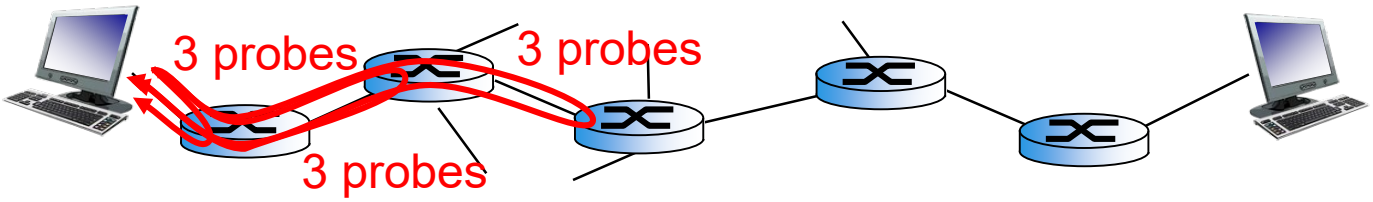
> ping <IP_Address> -t [sends request until stopped]

“Real” Internet delays and routes

what do “real” Internet delay & loss look like?

`traceroute` program: provides delay measurement from source to router along end-end Internet path towards destination. For all *i:*

- sends three packets that will reach router *i* on path towards destination
- router *i* will return packets to sender
- sender times interval between transmission and reply.
- In Microsoft Windows, traceroute utility is used with command “tracert”.
- Example: tracert 8.8.8.8 will trace route to google.com



“Real” Internet delays, routes

>tracert 8.8.8.8

Tracing route to google-public-dns-a.google.com [8.8.8.8]
over a maximum of 30 hops:

1	33 ms	1 ms	1 ms	192.168.21.1
2	2 ms	1 ms	1 ms	192.168.0.1
3	16 ms	21 ms	26 ms	cblmdm72-241-48-2.buckeyecom.net [72.241.48.2]
4	26 ms	18 ms	28 ms	24.53.168.73
5	*	*	*	Request timed out.
6	22 ms	18 ms	18 ms	24.53.168.1
7	39 ms	43 ms	34 ms	10ge14-14.core1.chi1.he.net [184.105.63.89]
8	29 ms	31 ms	28 ms	100ge14-1.core2.chi1.he.net [184.105.81.97]
9	*	*	*	Request timed out.
10	61 ms	48 ms	29 ms	108.170.243.225
11	35 ms	29 ms	34 ms	209.85.251.31
12	29 ms	46 ms	28 ms	google-public-dns-a.google.com [8.8.8.8]

* means no response (probe lost, router not replying)

Review Question

- What is the fundamental difference between a router and a link-layer switch?

A network-layer packet is a datagram. A router forwards a packet based on the packet's IP (layer 3) address. A link-layer switch forwards a packet based on the packet's MAC (layer 2) address.

Review Question

- What is the difference between routing and forwarding?

Forwarding is about moving a packet from a router's input port to the appropriate output port. Routing is about determining the end-to-routes between sources and destinations.

Review Question

- Do routers have IP addresses? If so, how many?

Yes. They have one address for each interface.

Practice Problem #1

There are 8 hosts and 3 routers with the following IP addresses. You can use any number of switches. Connect all devices as per their IP addresses and draw the network diagram. Also, label the diagram.

Device Name	IP Address
Host A	192.168.1.1/24
Host B	192.168.4.10/24
Host C	192.168.6.10/24
Host D	192.168.6.20/24
Host E	192.168.4.1/24
Host F	192.168.6.200/24
Host G	192.168.4.100/24
Host H	192.168.1.10/24
R1, fa0/0	192.168.6.1/24
R1, fa0/1	192.168.3.20/24
R1, fa0/2	192.168.5.100/24
R2, fa0/0	192.168.3.1/24
R2, fa0/1	192.168.1.2/24
R2, fa0/2	192.168.2.1/24
R3, fa0/0	192.168.5.10/24
R3, fa0/1	192.168.2.10/24
R3, fa0/2	192.168.4.20/24

Practice Problem #2

There are three hosts and three routers in a network. Find below the IP addresses of all the devices, the subnet mask is 255.255.255.224 throughout the network.

Draw the network and label the ports of routers. Connect all devices with proper cables. Label and specify the correct types of cables. Write the default gateway of all three hosts.

Host A	10.10.10.10	Default Gateway:
Host B	10.10.10.60	Default Gateway:
Host C	10.10.10.35	Default Gateway:
Router 1	FastEthernet 0/0: 10.10.10.90 FastEthernet 0/1: 10.10.10.110	
Router 2	FastEthernet 0/0: 10.10.10.50 FastEthernet 0/1: 10.10.10.65	
Router 3	FastEthernet 0/0: 10.10.10.100 FastEthernet 0/1: 10.10.10.30	