Data Link Layer introduction

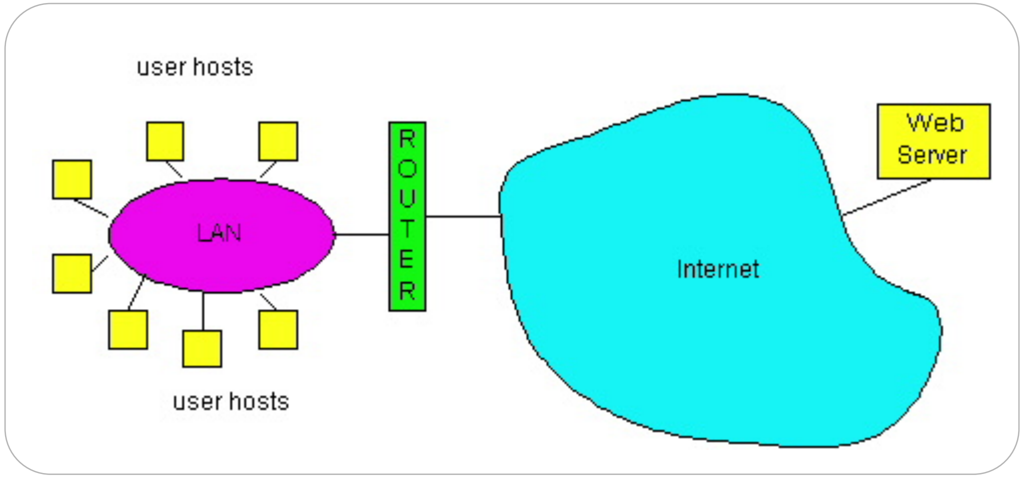
LAN technologies

Data Link Layer so far

- Services, error detection/correction, multiple access

Next: LAN technologies

- Addressing
- Ethernet
- Switches
- MPLS



Data Link Layer introduction

LAN addresses and ARP

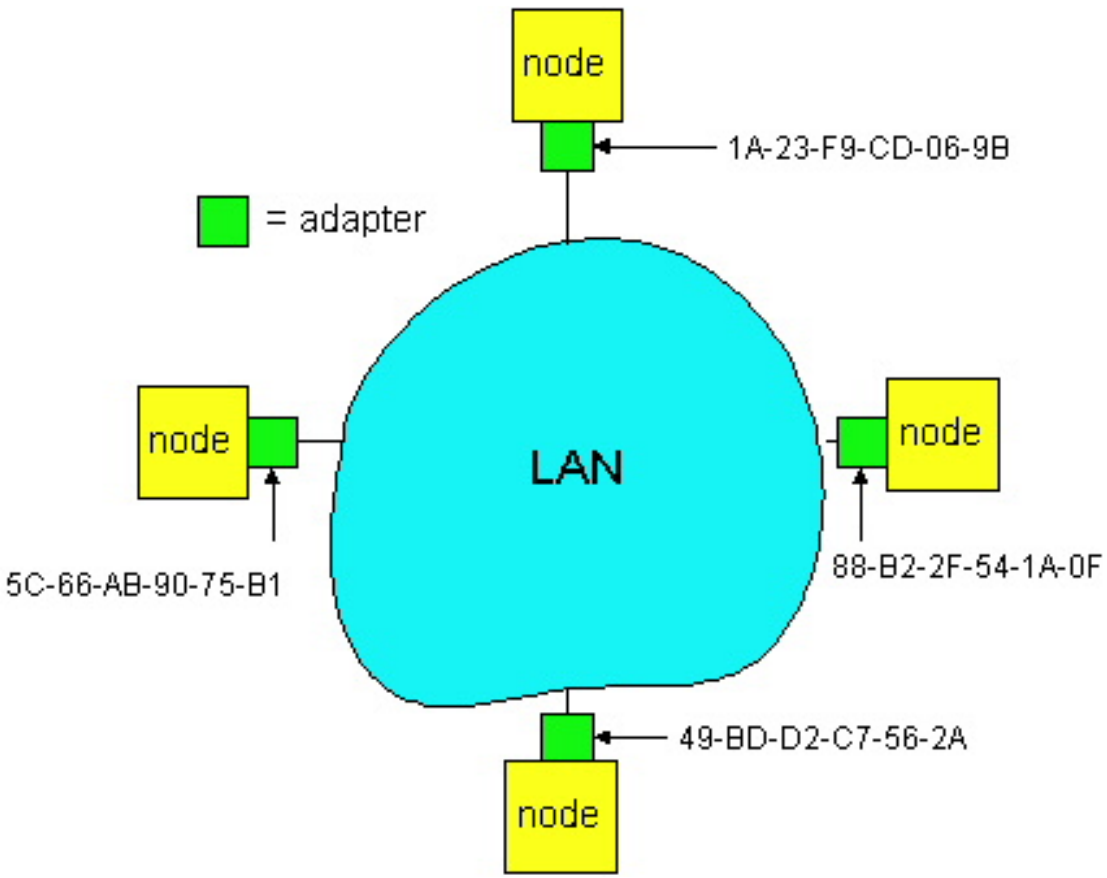
32 bit IP address

- Network Layer address
- Used to get datagram to destination network (recall IP network definition)

LAN (or MAC or physical) address

- Used to get datagram from one interface to another physically connected interface (same network)
- 48 bit MAC address (for most LANs) burned in the adapter ROM

LAN addresses and ARP (cont.)



LAN addresses

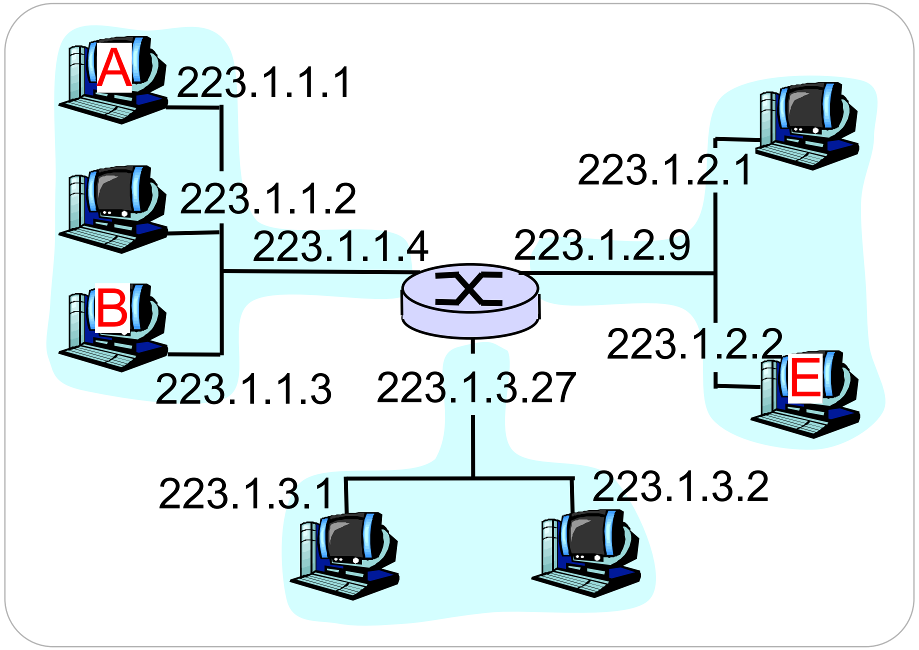
- MAC address allocation administered by IEEE
- Manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy
  - (a) MAC address - like Tax File Number
  - (b) IP address - like postal address
- MAC **flat** address > portability
  - – can move LAN card from one LAN to another
- IP hierarchical address **not** portable
  - – depends on network to which one attaches

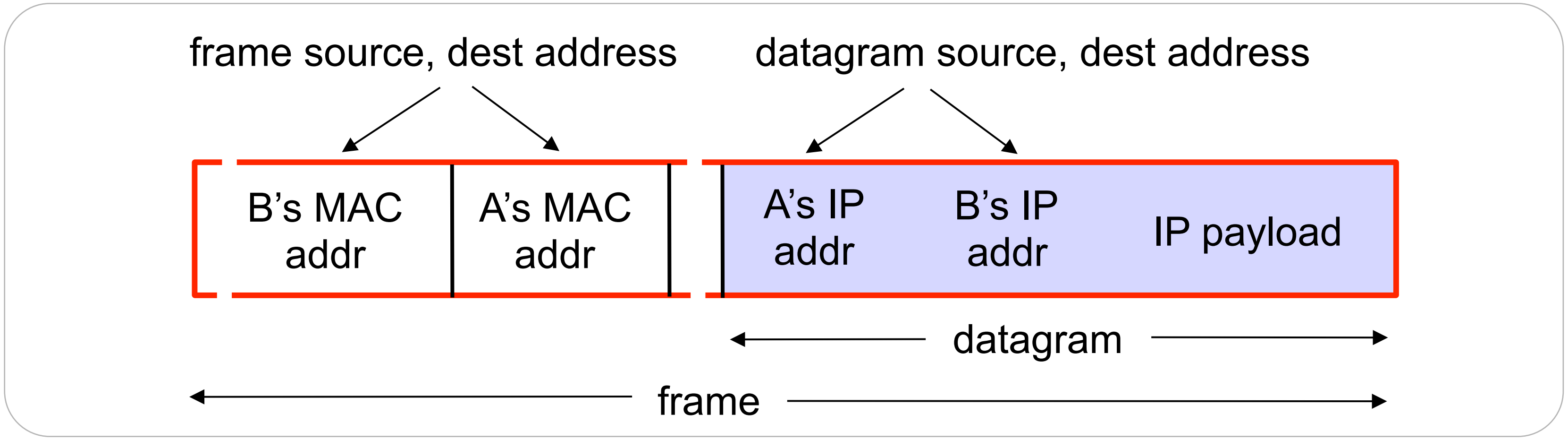
Data Link Layer introduction

Earlier routing discussion?

Starting at A, given IP datagram addressed to B:

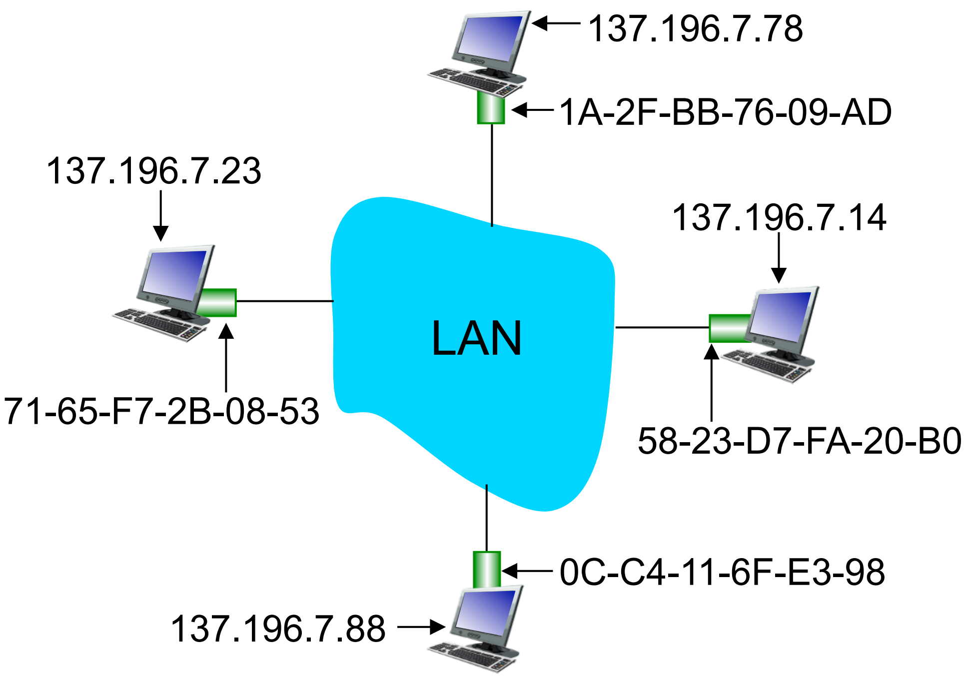
- look up net. address of B, find B on same net. as A
- **link layer send datagram to B inside link layer frame**





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:

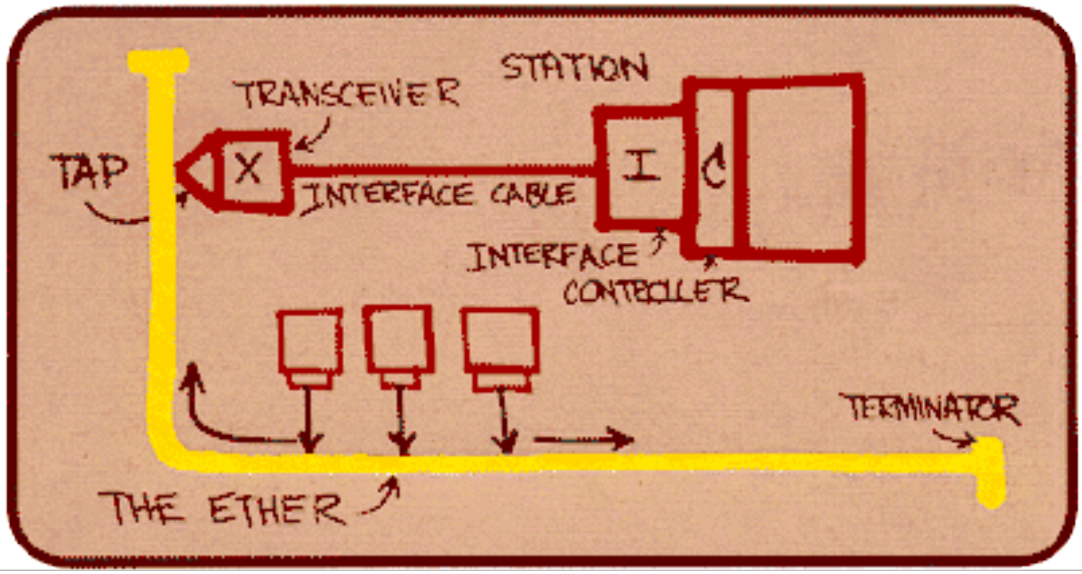
< IP address; MAC address; TTL>

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

Ethernet

'Dominant' LAN technology

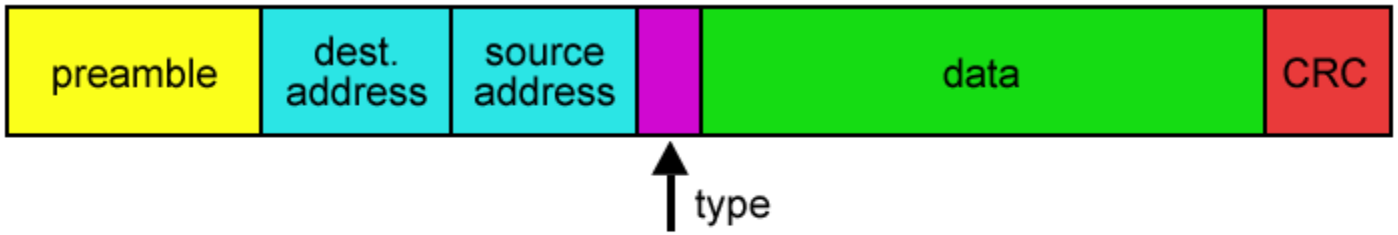
- cheap $20 for 100 Mbs!
- first widely used LAN technology
- simpler, cheaper than token LANs and ATM
- kept up with speed race: 10, 100 and 1000 Mbps



Data Link Layer introduction

Frame structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in **Ethernet frame**



Preamble

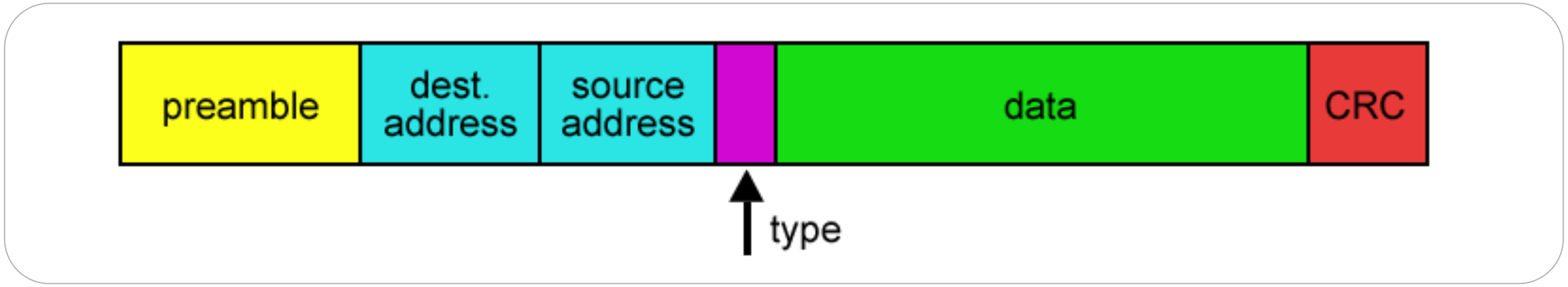
- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- Used to synchronize receiver, sender clock rates

Frame structure (cont.)

Addresses: 6 bytes, frame is received by all adapters on a LAN and dropped if address does not match

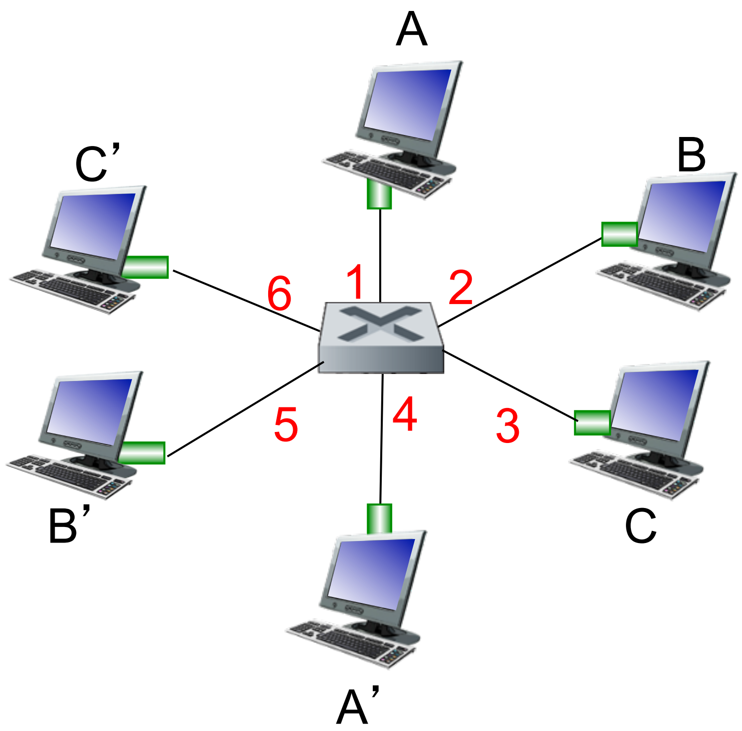
Type: indicates the higher layer protocol, mostly IP but others may be supported such as Novell IPX and AppleTalk

CRC: checked at receiver, if error is detected, the frame is simply dropped



Switch: *multiple* simultaneous transmissions

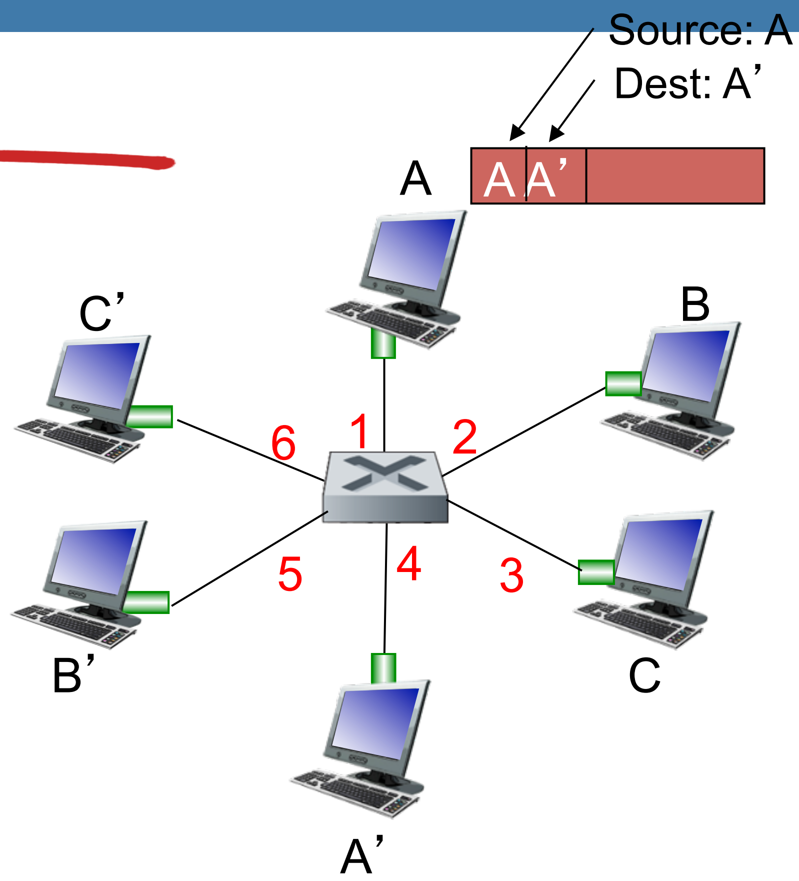
- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, but no collisions; full duplex
  - each link is its own collision domain
- *switching:* A-to-A' and B-to-B' can transmit simultaneously, without collisions



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)

Switch filtering (cont.)

Filtering procedure

if destination is on LAN on which frame was received

then drop the frame

else {

lookup filtering table

if entry found for destination

then forward the frame on interface indicated;

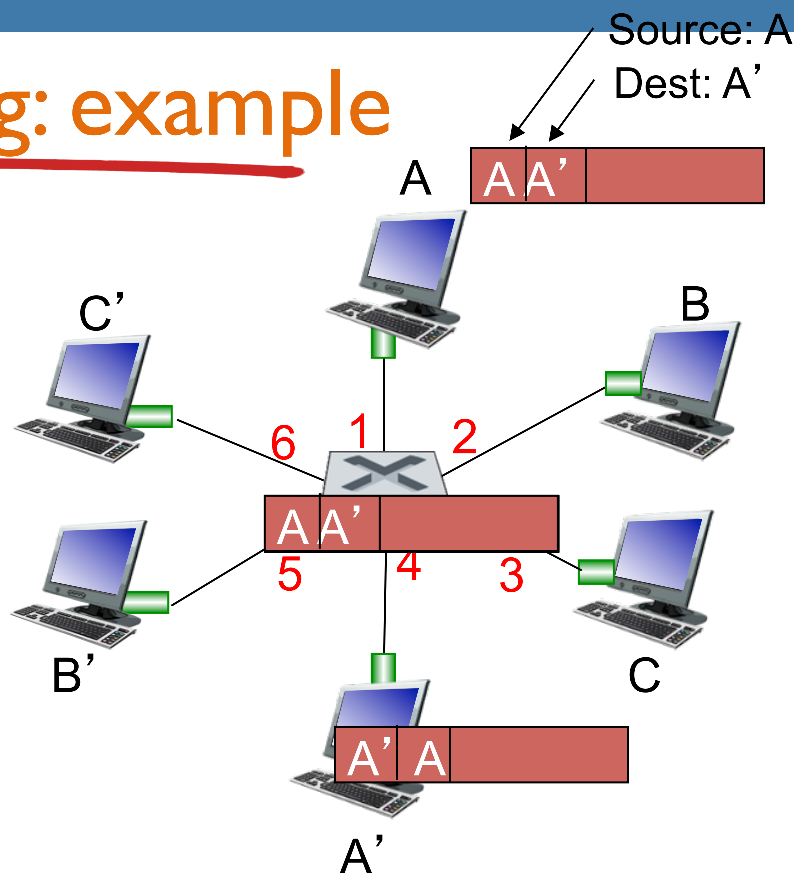
else flood; /* forward on all but the interface on which the frame arrived */

}

Self-learning, forwarding: example

- frame destination, A', location unknown: *flood*

- destination A location known: selectively send on just one link

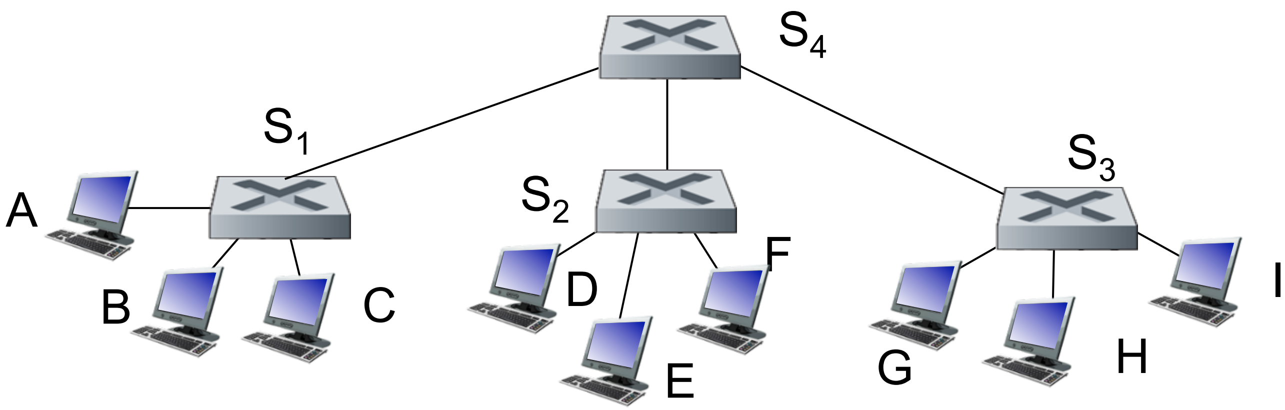


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

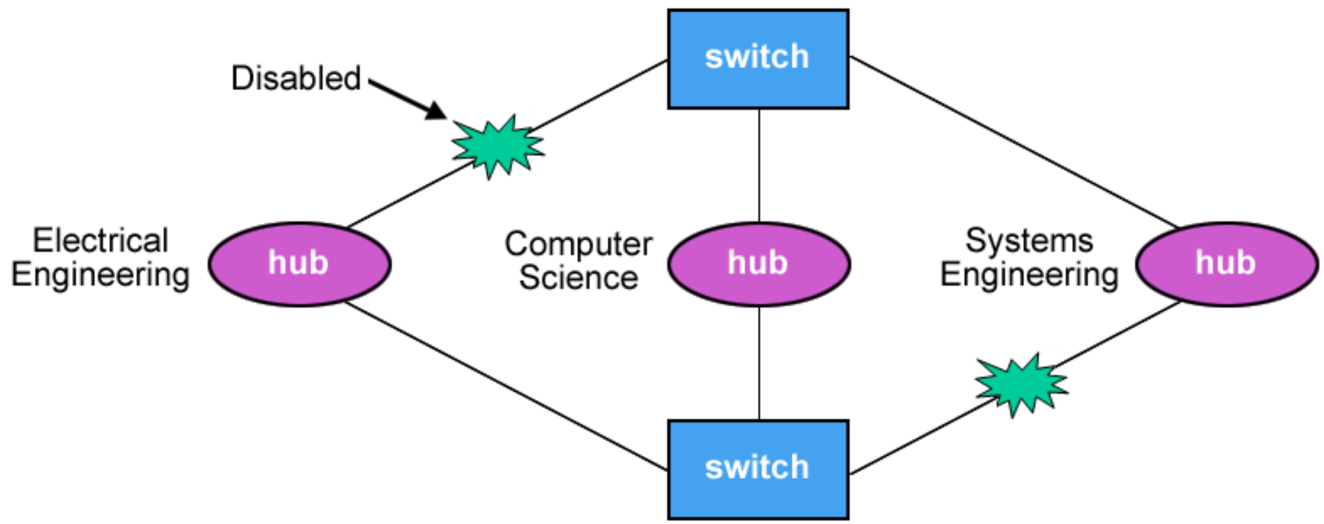
Backbone switch

self-learning switches can be connected together:



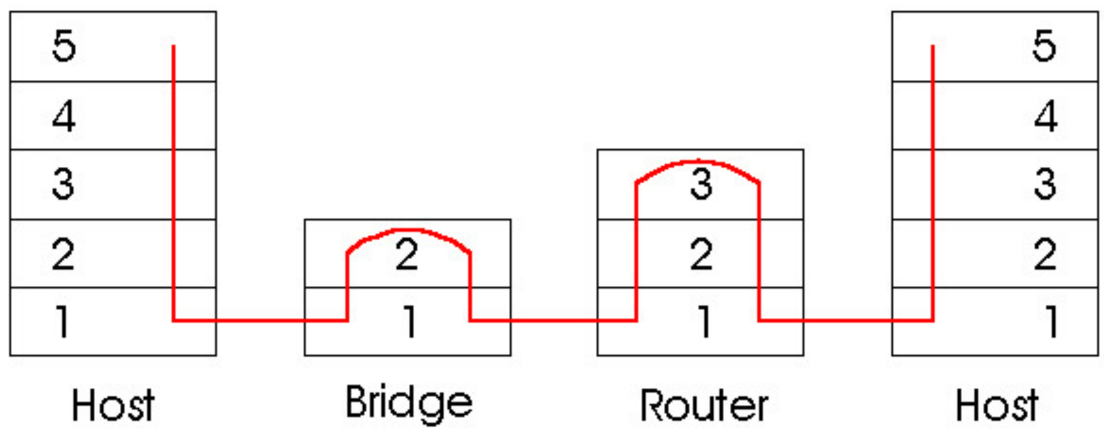
Switches - spanning trees

- Increased reliability
  - desirable to have redundant, alternate paths from source to destination
- With multiple simultaneous paths cycles result
  - switches may multiply and forward frame forever
- Solution: organize switches in a spanning tree by disabling subset of interfaces



Switches versus routers

- Both store-and-forward devices
  - routers are network layer devices (examine network layer headers)
  - switches are link layer devices
- Routers maintain routing tables, implement routing algorithms
- Switches maintain filtering tables, implement filtering, learning and spanning tree algorithms



Data Link Layer introduction

Routers versus switches

Switches + and –

- \+ Switch operation is simpler requiring less processing bandwidth
- – Topologies are restricted with switches (a spanning tree must be built to avoid cycles)
- – Switches do not offer protection from broadcast storms (endless broadcasting by a host will be forwarded by a switch)

Routers versus switches (cont.)

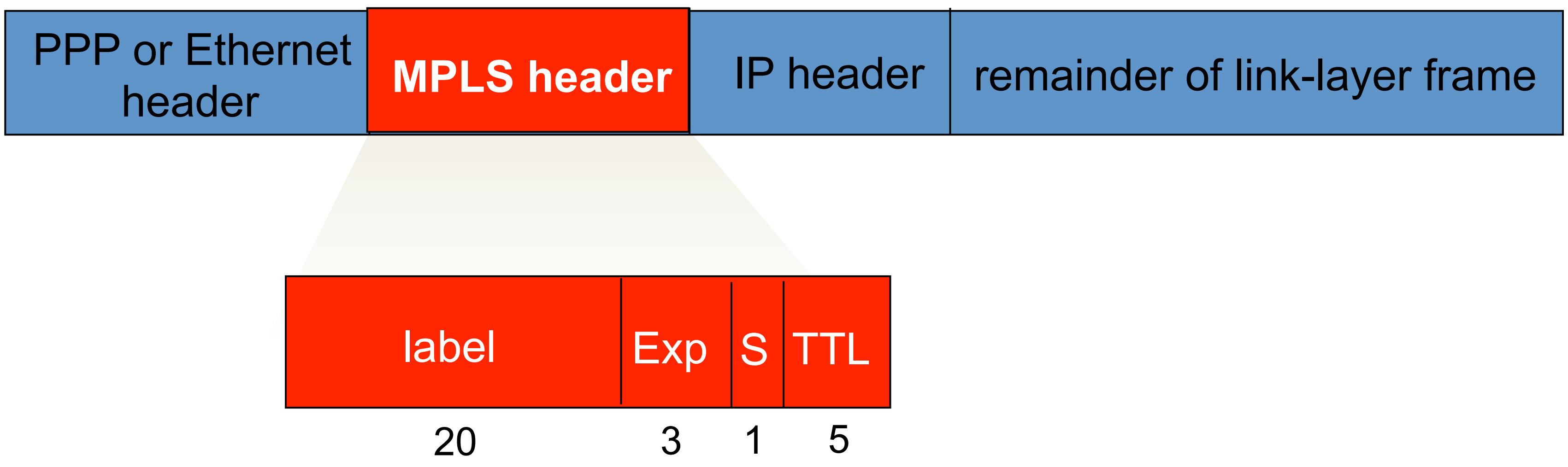
Routers **+** and **–**

- **+** **Arbitrary** topologies can be supported, cycling is limited by TTL counters (and good routing protocols)
- **+** Provide **firewall protection** against broadcast storms
- **–** Require IP address configuration (not plug and play)
- **–** Require higher processing bandwidth

Switches do well in small (few hundred hosts) while routers used in large networks (thousands of hosts)

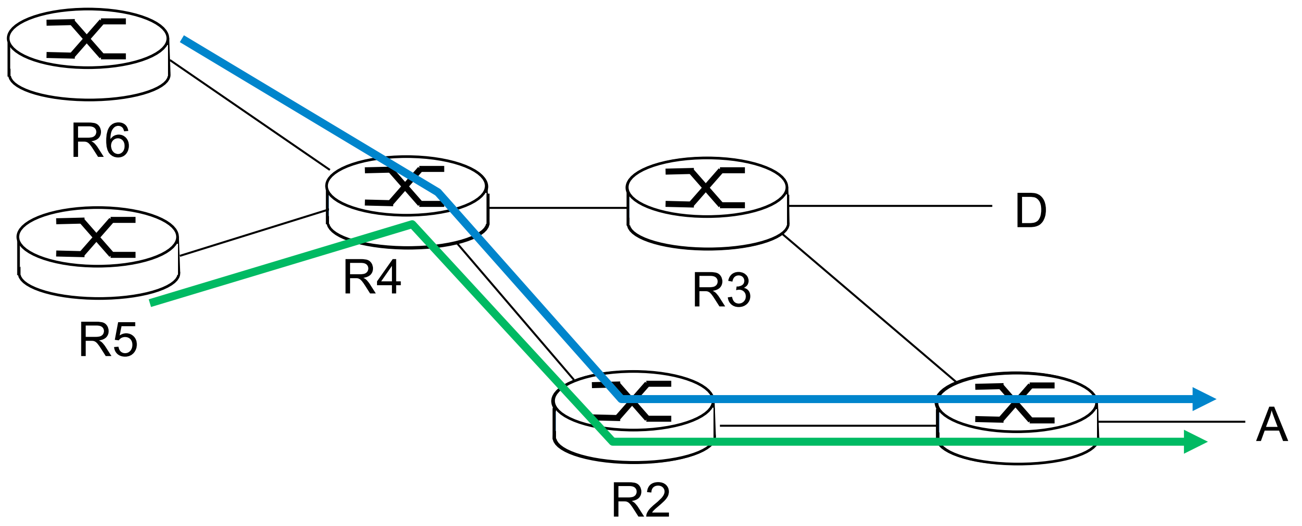
Multiprotocol label switching (MPLS)

- initial goal: high-speed IP forwarding using fixed length label (instead of IP address)
  - fast lookup using fixed length identifier (rather than shortest prefix matching)
  - borrowing ideas from Virtual Circuit (VC) approach
  - but IP datagram still keeps IP address!



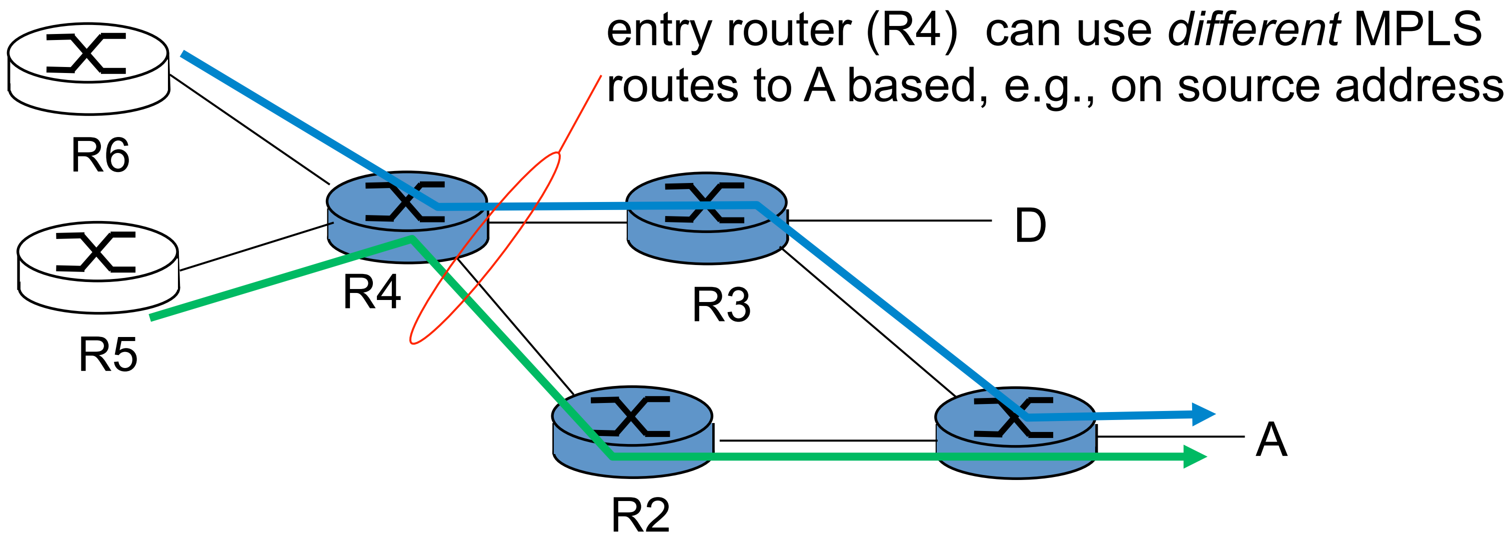
MPLS capable routers

- a.k.a. label-switched router
- forward packets to outgoing interface based only on label value (*don't inspect IP address*)
  - MPLS forwarding table distinct from IP forwarding tables
- *flexibility:* MPLS forwarding decisions can *differ* from those of IP
  - use destination *and* source addresses to route flows to same destination differently (traffic engineering)
  - re-route flows quickly if link fails: pre-computed backup paths (useful for VoIP)

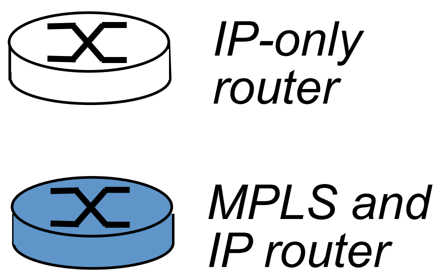


- *IP routing: path to destination determined by destination address alone*

MPLS versus IP paths



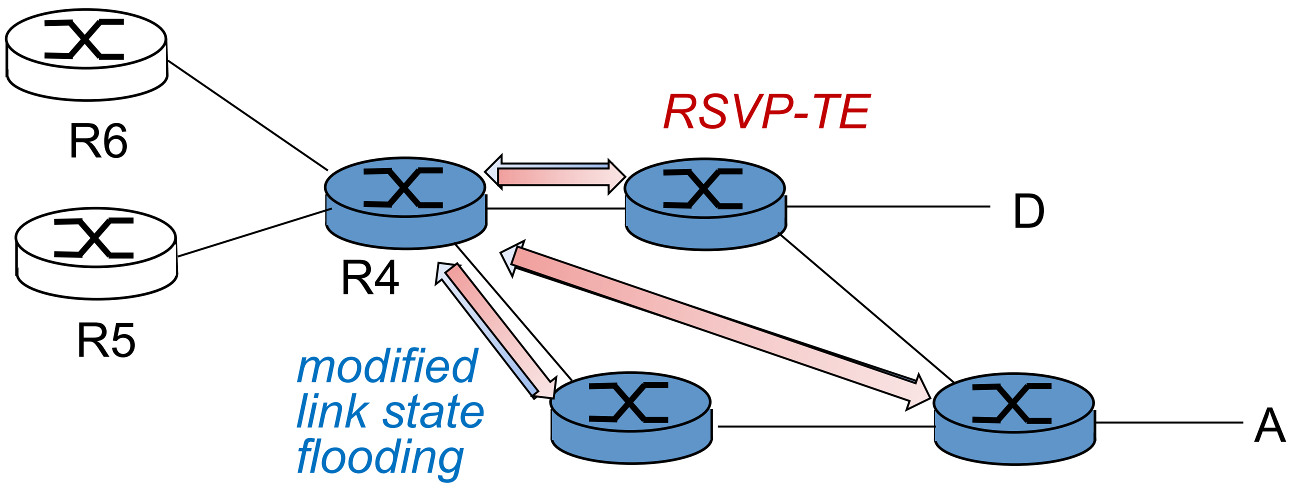
- *IP routing:* *path to destination determined by destination address alone*
- *MPLS routing:* path to destination can be based on source *and* destination address
  - *fast reroute:* precompute backup routes in case of link failure



MPLS signaling

- modify OSPF, IS-IS link-state flooding protocols to carry info used by MPLS routing,
  - e.g., link bandwidth, amount of "reserved" link bandwidth

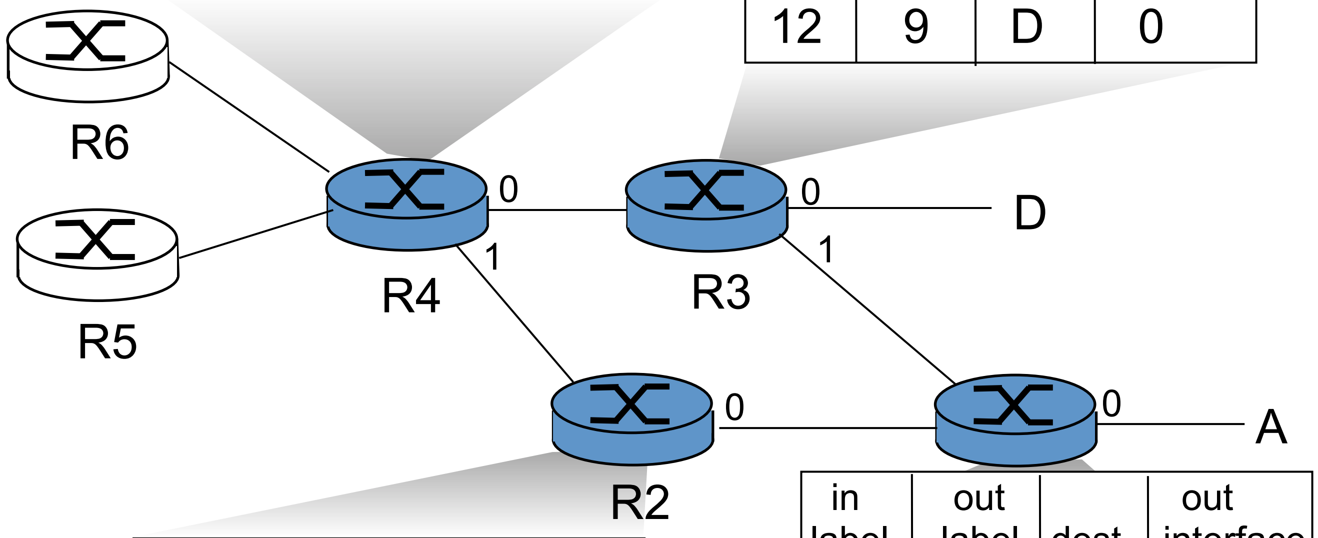
- *entry MPLS router uses RSVP-TE signaling protocol to set up MPLS forwarding at downstream routers*



MPLS forwarding tables

in label	out label	dest	out interface
	10	A	0
	12	D	0
	8	A	1

in label	out label	dest	out interface
10	6	A	1
12	9	D	0



in label	out label	dest	out interface
8	6	A	0

in label	out label	dest	out interface
6	-	A	0