

Data link layer

Goals:

- ❑ Principles behind data link layer services:
 - Error detection, correction
 - Sharing a broadcast channel: Multiple access
 - Link layer addressing
 - Reliable data transfer, flow control
- ❑ Example link layer technology
 - Ethernet
- ❑ Bridges vs. routers

Link layer services

Framing and link access

- Encapsulate datagram: frame adds header, trailer
- Channel access if shared medium
- Frame headers use 'physical addresses' = "MAC" to identify source and destination
 - Different from IP address!

Reliable delivery (between adjacent nodes)

- Seldom used on low bit error links (fiber optic, co-axial cable and some twisted pairs)
- Sometimes used on high error rate links (e.g., wireless links)

Link layer services (more)

Flow Control

- Pacing between sending and receiving nodes

Error Detection

- Errors are caused by signal attenuation and noise.
- Receiver detects presence of errors
signals sender for retrans. or drops frame

Error Correction

- Receiver identifies and **corrects** bit error(s) without resorting to retransmission

Half-duplex and full-duplex

- With half duplex, nodes at both ends of link can transmit, but not at same time

MAC protocols: Three categories

❑ Channel partitioning

- Divide channel into smaller “pieces” (time slots, frequency)
- Allocate piece to node for exclusive use

❑ Random access

- Allow collisions
- “Recover” from collisions

❑ “Taking turns”

- Tightly coordinate shared access to avoid collisions

Goal: efficient, fair, simple, decentralized

Addresses

IP address (32-bit):

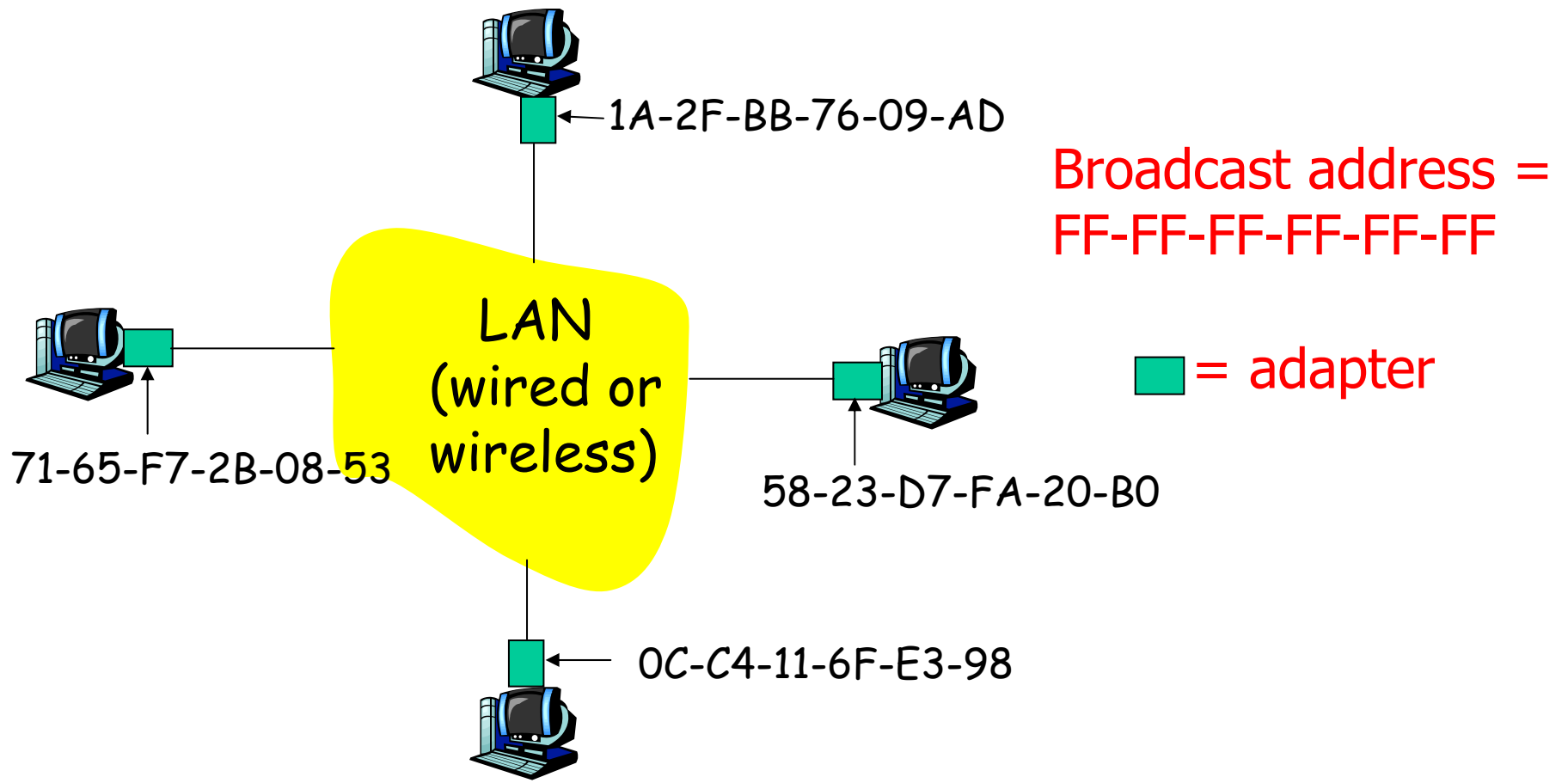
- ❑ Network-layer address
- ❑ Used to get datagram to destination network (recall IP network definition)

MAC (or LAN or physical or Ethernet) address:

- ❑ Data link-layer 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

Addresses (2.)

Each adapter on LAN has unique LAN address



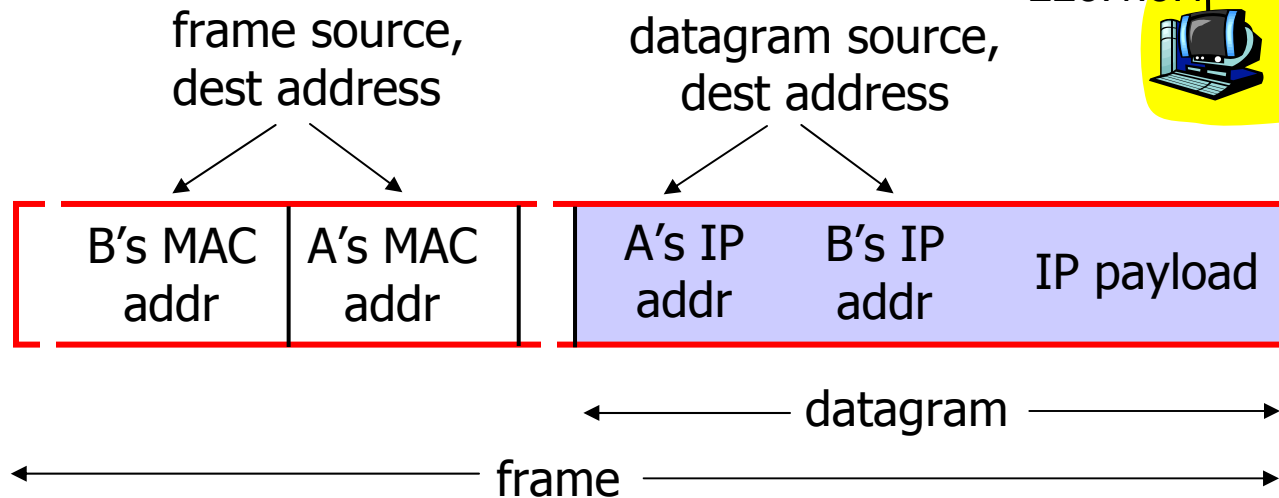
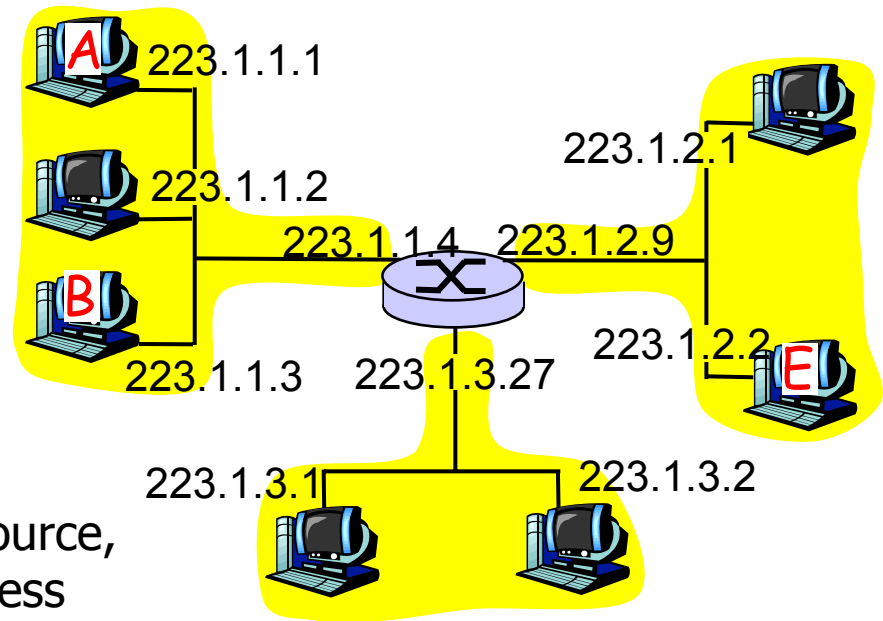
Addresses (3.)

- ❑ 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
- ❑ IP hierarchical address NOT portable
 - depends on network to which one attaches

Example

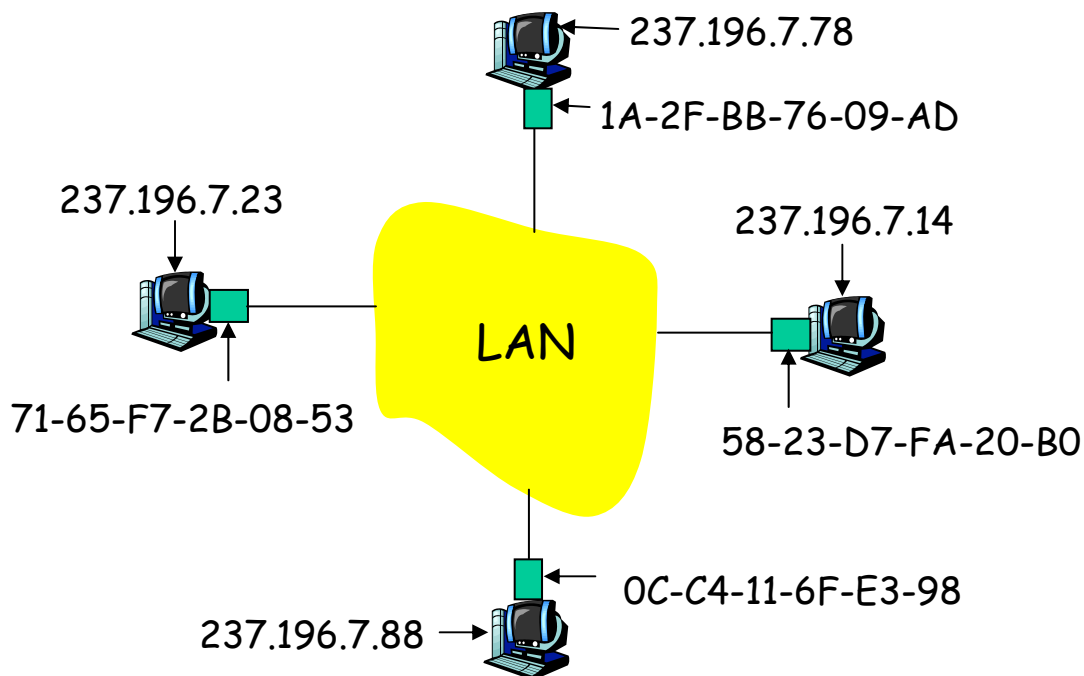
Starting at A, given IP datagram addressed to B:

- 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 MAC address of B knowing B's IP address?



- ❑ Each IP node (Host, Router) on LAN has **ARP** table
- ❑ ARP 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)

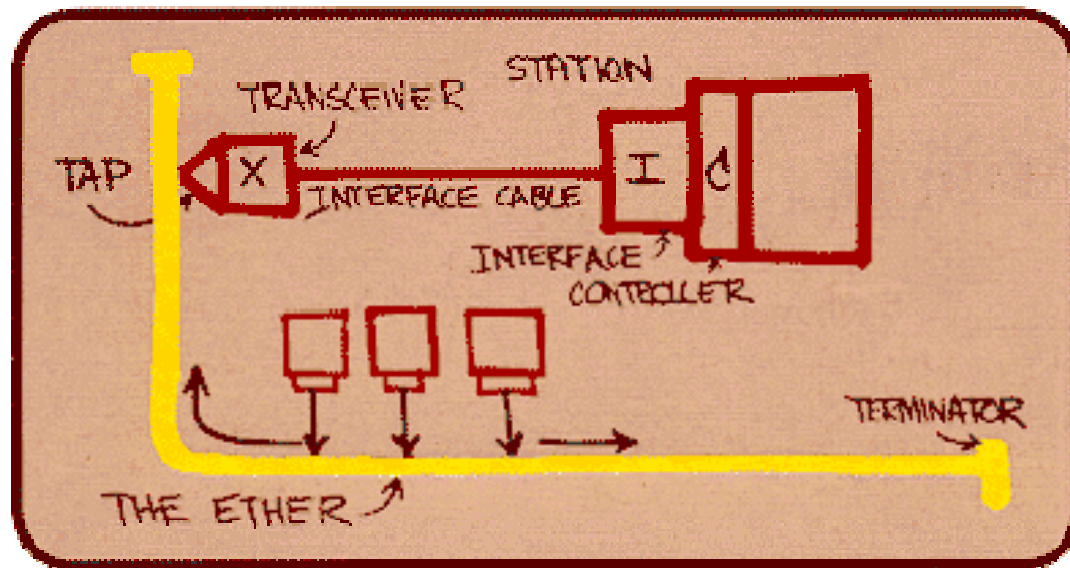
ARP protocol: Same LAN (Network)

- ❑ A wants to send datagram to B, and B's MAC address not in A's ARP table.
- ❑ A **broadcasts** ARP query packet, containing B's IP address
 - Dest MAC address = FF-FF-FF-FF-FF-FF
 - All machines on LAN receive ARP query
- ❑ B receives ARP packet, replies to A with its (B's) MAC address
 - Frame sent to A's MAC address (unicast)
- ❑ A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
 - Soft state: information that times out (goes away) unless refreshed
- ❑ ARP is "plug-and-play":
 - Nodes create their ARP tables without intervention from net administrator

Ethernet

“Dominant” LAN technology:

- ❑ Cheap \$20 for 100Mbps!
- ❑ First widely used LAN technology
- ❑ Simpler, cheaper than token LANs and ATM
- ❑ Kept up with speed race: 10 Mbps – 10 Gbps
- ❑ Shared medium



Metcalfe's Ethernet sketch

Unreliable, connectionless service

□ Connectionless:

No handshaking between sending and receiving adapter.

□ Unreliable:

Receiving adapter does not send ACKs or NACKs to sending adapter

- Stream of datagrams passed to network layer can have gaps
- Gaps will be filled if app is using TCP
- Otherwise, app will see the gaps

Ethernet uses CSMA/CD

- ❑ No slots
- ❑ Adapter does not transmit if it senses that some other adapter is transmitting, that is, **carrier sense**
- ❑ Transmitting adapter aborts when it senses that another adapter is transmitting, that is, **collision detection**
- ❑ Before attempting a retransmission, adapter waits a random time, that is, **random access**

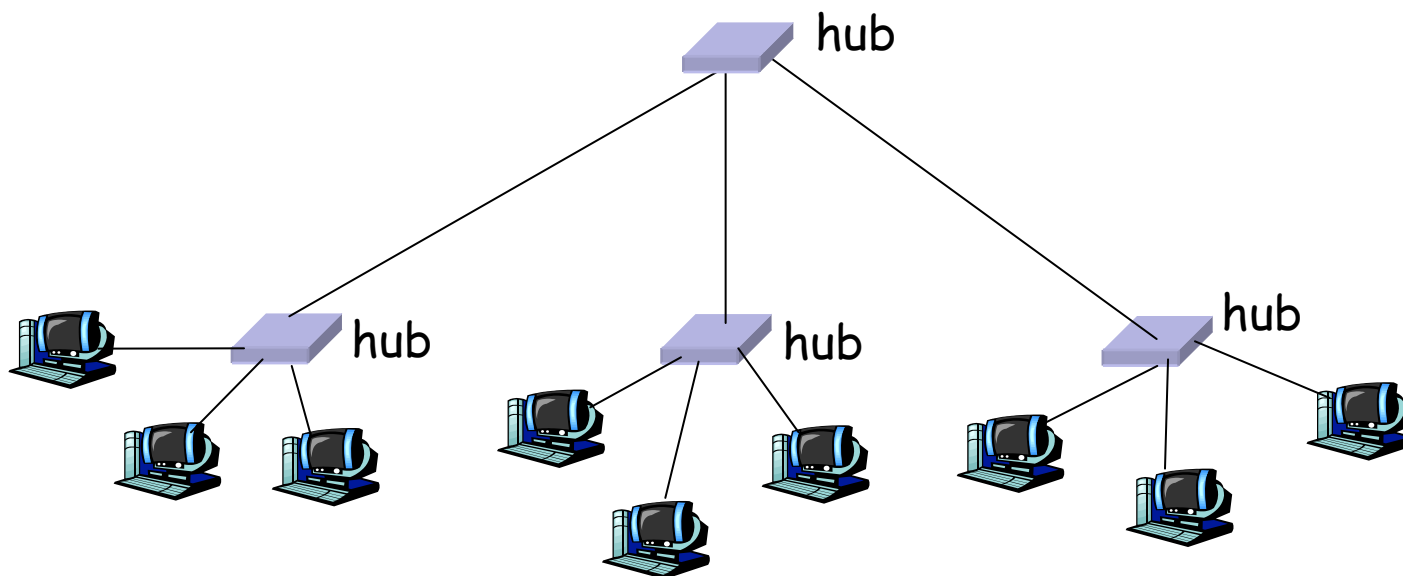
Interconnecting LANs

Q: Why not just one big LAN?

- ❑ All stations must share bandwidth
- ❑ Limited cable length
- ❑ Large “collision domain” (can collide with many stations)
- ❑ Limited number of stations

Interconnecting With Hubs

- ❑ Physical Layer devices: essentially repeaters operating at bit levels: repeat received bits on one interface to all other interfaces
- ❑ Hubs can be arranged in a **hierarchy** (or multi-tier design), with **backbone** hub at its top



Hubs (more)

- ❑ Each connected LAN referred to as LAN **segment**
- ❑ Hubs **do not isolate** collision domains: node may collide with any node residing at any segment in LAN
- ❑ Hub Advantages:
 - Simple, inexpensive device
 - Multi-tier provides graceful degradation: portions of the LAN continue to operate if one hub malfunctions
 - Extends maximum distance between node pairs (100m per Hub)

Bridges (Switches)

□ Link layer devices:

- Stores and forwards Ethernet frames
 - Examines frame header and **selectively** forwards frame based on MAC dest address
 - When frame is to be forwarded on segment, uses CSMA/CD to access segment
- ⇒ Bridge **isolates collision** domains: it buffers frames

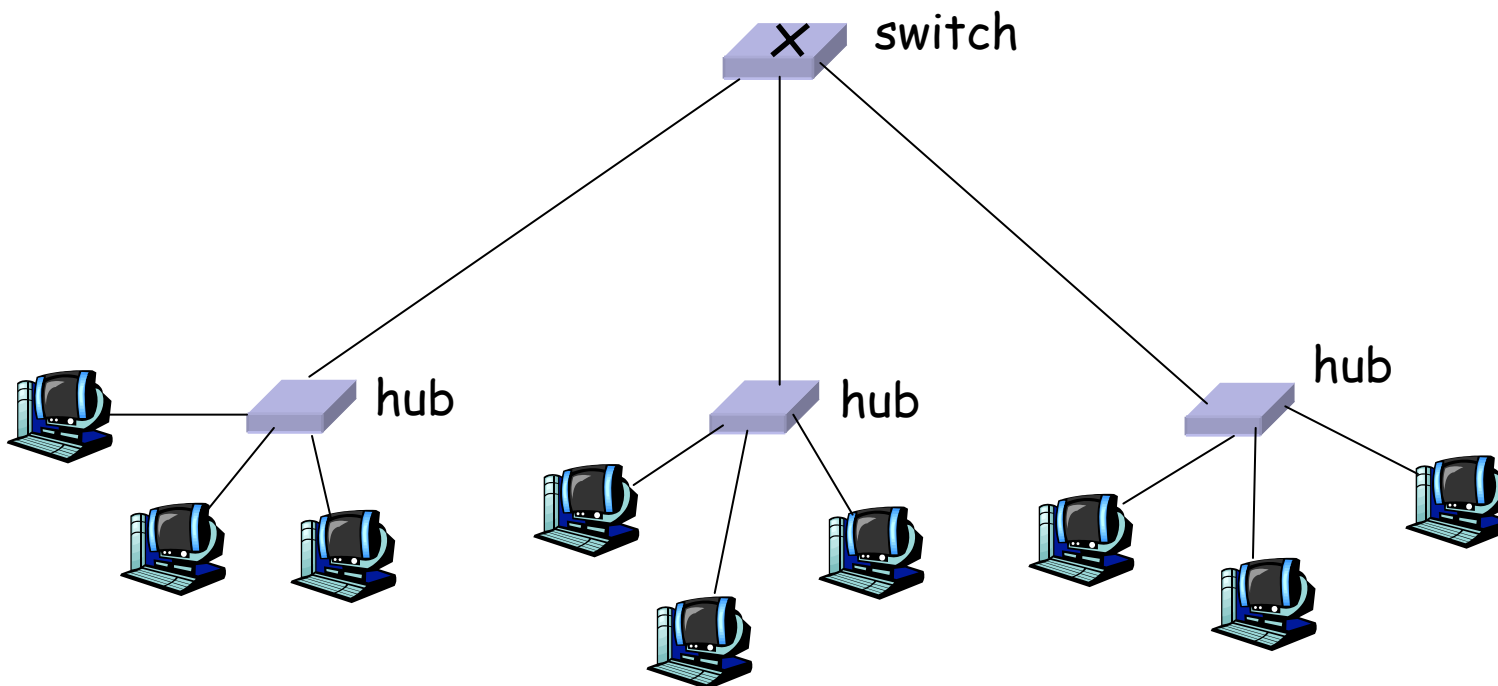
Bridges/Switch: Advantages

- ❑ Higher total max throughput
- ❑ No limit on number of nodes
- ❑ No limit on geographical coverage
- ❑ Can connect different Ethernet types (store and forward)
- ❑ Transparent: hosts do not need to change LAN adapters
- ❑ Plug-and-play, self-learning
 - Switches do not need to be configured

Bridges/Switch: Forwarding

□ Forwarding:

- To which LAN segment should a frame be forwarded?
- Looks like a routing problem



Bridges/Switch: Self Learning

- ❑ A bridge/switch has a **bridge/switch table**
- ❑ Entry in table:
 - (MAC Address, Interface, Time Stamp)
 - Stale entries in table dropped (TTL can be 60 min)
- ❑ Bridge *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 bridge table

Bridges/switch: filtering/forwarding

When switch receives a frame:

index switch table using MAC dest address

if entry found for destination

then{

if dest on segment from which frame arrived

then drop the frame

else forward the frame on interface indicated

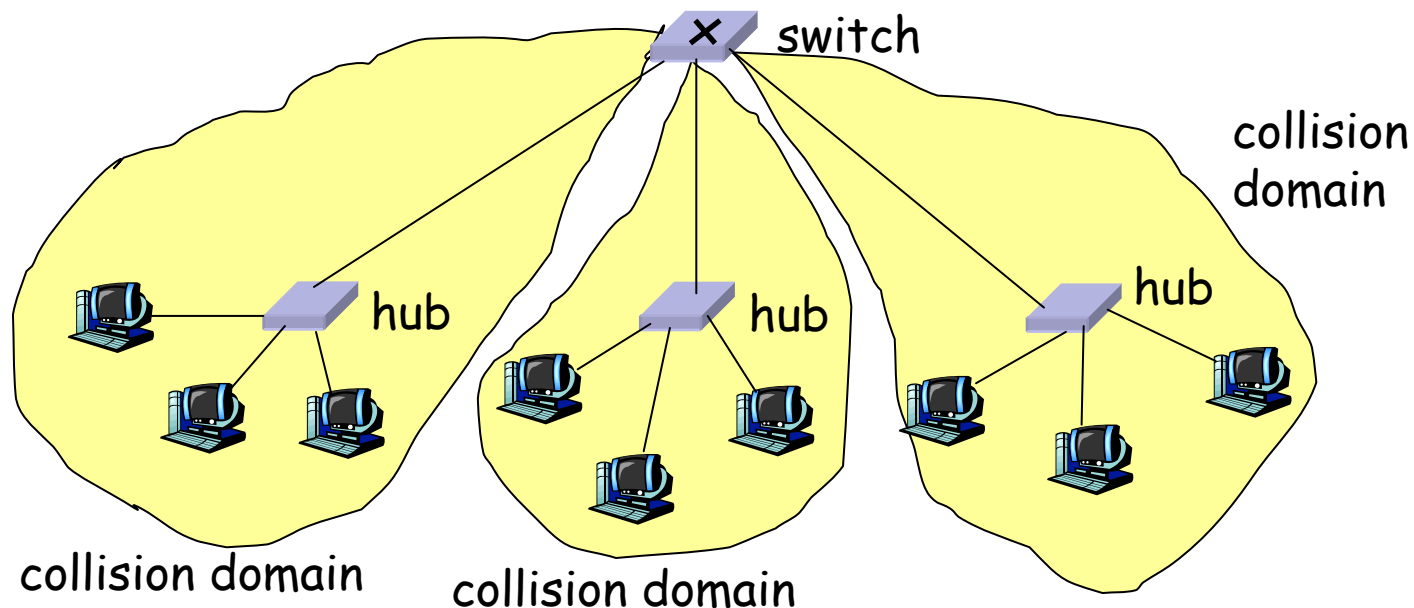
}

else flood

*forward on all but the interface
on which the frame arrived*

Switch: Traffic Isolation

- ❑ Switch installation breaks subnet into LAN segments
- ❑ Switch **filters** packets:
 - Same-LAN-segment frames not usually forwarded onto other LAN segments
 - Segments become separate **collision domains**

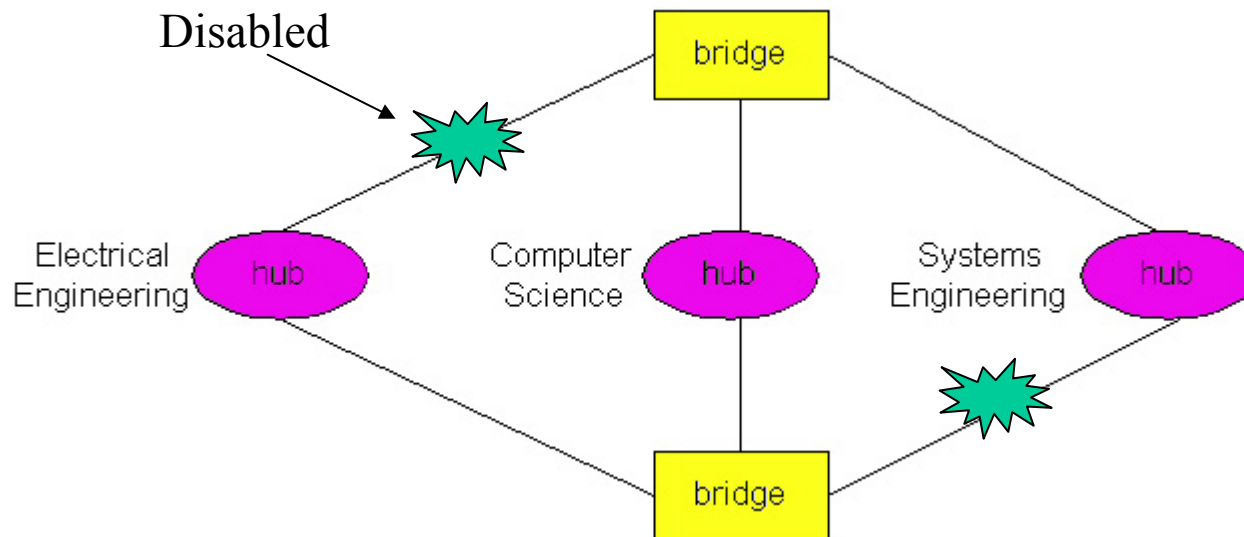


Redundant networks

- ❑ Network with multiple paths
 - Alternate path for each source, destination pair
- ❑ Advantage
 - Increased reliability
 - Single network failure OK
 - More opportunities for load distribution
- ❑ Disadvantage
 - Added complexity

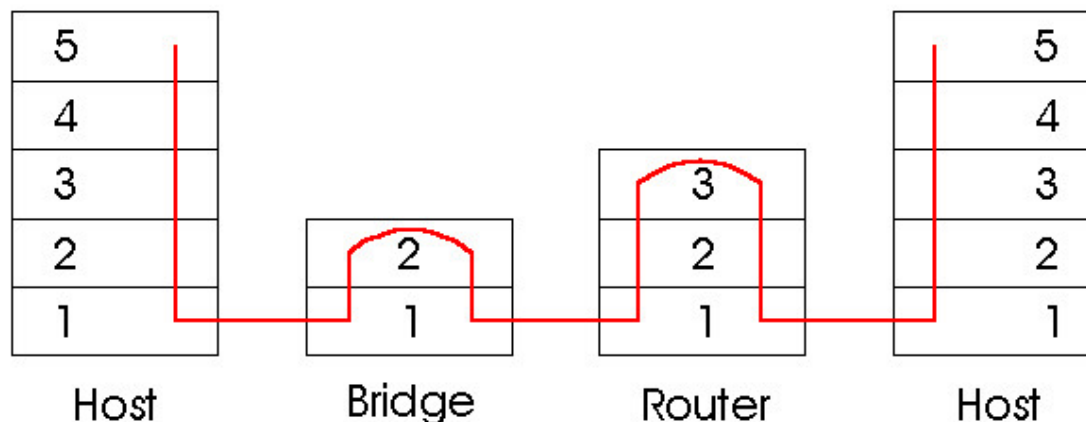
Bridges spanning tree

- ❑ Avoid cycles
 - Frames may multiply and forwarded forever
- ❑ Organize bridges into spanning tree
 - Disable a subset of interfaces



Bridges vs. Routers

- ❑ Both store-and-forward devices
 - Routers: network layer devices (examine network layer headers)
 - Bridges: link layer devices
- ❑ Use tables
 - Routers: routing tables via routing algorithms
 - Bridges: filtering tables via filtering, learning, spanning tree algorithm



Bridges + and -

- + Simple operation

 - Low processing bandwidth

- Restricted topologies:

 - Spanning tree to avoid cycles

- Single broadcast domain

 - No protection from broadcast storms
(broadcasts will be forwarded by bridge)

Routers + and -

- + Arbitrary topologies

 - Limited cycling (TTL and good routing protocols)

- + Firewalls protection

 - Against broadcast storms

- Complex operation

 - Require IP address configuration (not plug and play)

 - Require higher processing bandwidth

Routers vs. Bridges

❑ Bridges

- Good in small networks (few hundred hosts)

❑ Routers

- Good in large networks (thousands of hosts)