

CSCI 491-01

Topics: Internet Programming

Fall 2008

Data-link Layer

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Link Layer

5.1 Introduction and services

5.2 Error detection and correction

5.3 Multiple access protocols

5.4 Link-Layer Addressing

5.5 Ethernet

5.6 Hubs and switches

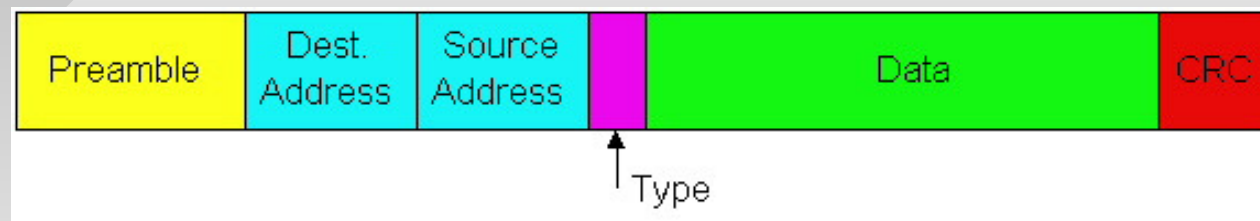
Ethernet

“Dominant” wired LAN technology:

- Designed in the 1970s
- Cheap \$20 for 100 mb/s NIC, \$40 for GE switch
- First widely used LAN technology
- Simpler, cheaper than token LANs and ATM
- Kept up with speed race: 10 mb/s – 10 gb/s

Ethernet Frame Structure

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

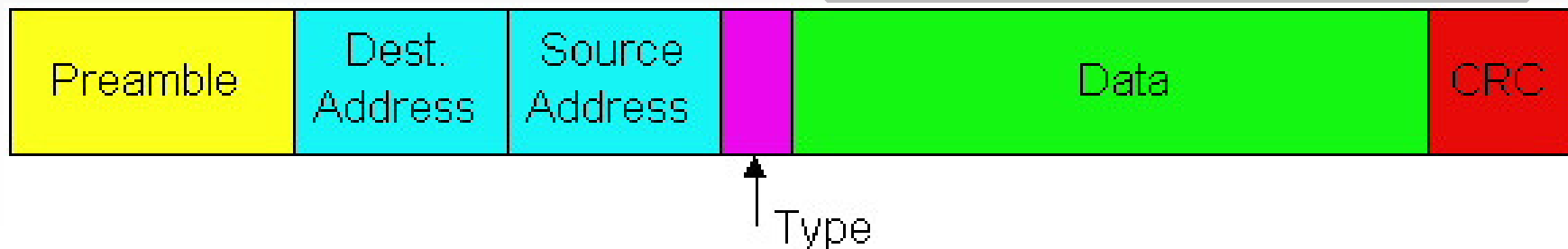


8-byte preamble:

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

Ethernet Frame Structure (More)

- **Addresses:** 6 bytes each
 - If adapter receives frame with matching destination address, or with broadcast address (e.g. ARP query packet), it passes data in frame to the network-layer protocol
 - Otherwise, adapter discards frame
- **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



Unreliable, Connectionless Service

- **Connectionless:** no handshaking between sending and receiving adapter
- **Unreliable:** receiving adapter doesn't send acks or nacks to sending adapter
 - Stream of datagrams passed to network layer can have gaps
 - Gaps will be filled (using retx) if transport layer is TCP
 - Otherwise, application will see the gaps

Ethernet CSMA/CD

- No slots
- Adapter doesn't transmit if it senses that some other adapter is transmitting, that is, **carrier sense (CS)**
- Transmitting adapter aborts when it senses that another adapter is transmitting, that is, **collision detection (CD)**
- Before attempting a retransmission, adapter waits a random time, that is, **random access**

Ethernet CSMA/CD Algorithm

1. Adaptor receives datagram from network layer & creates frame
2. If adapter senses channel idle, it starts to transmit frame. If it senses channel busy, waits until channel is idle and then transmits
3. If adapter transmits entire frame without detecting another transmission, the adapter is done with frame!
4. If adapter detects another transmission while transmitting, aborts and sends jam signal
5. After aborting, adapter enters **exponential backoff**: after the m -th collision **in a row**, adapter chooses a number K at random from the set $\{0, 1, 2, \dots, 2^m - 1\}$ and waits $K * 512$ bit times
6. Adapter returns to Step 2

Ethernet's CSMA/CD (More)

Jam Signal: make sure all other transmitters are aware of collision; 48 bits

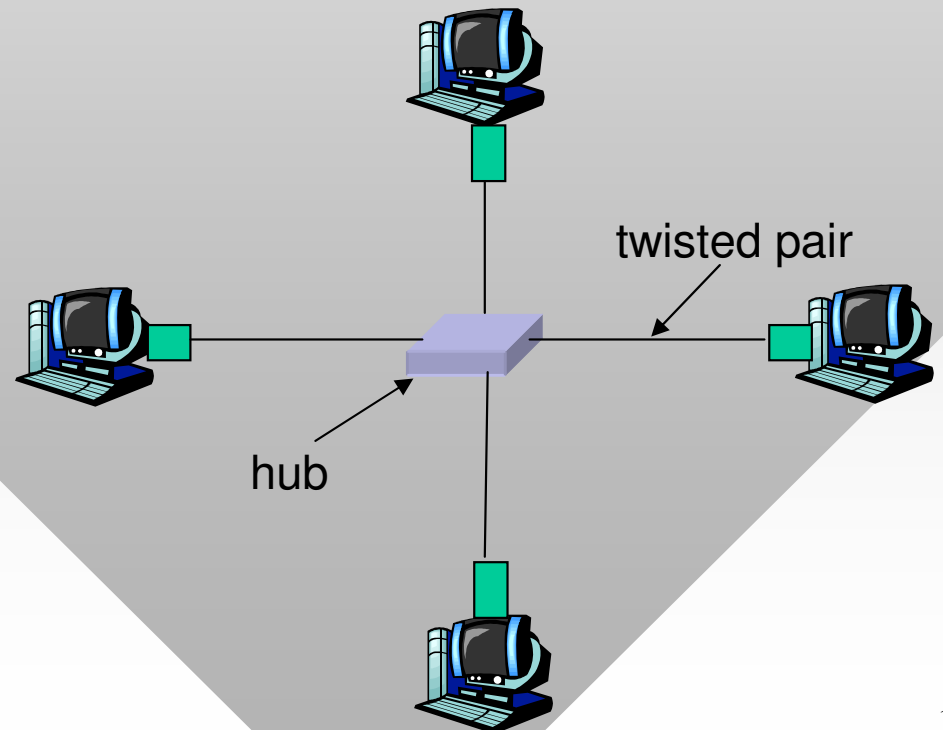
Bit time = 1/link speed: 0.1 microsec for 10 mb/s Ethernet;
for $K = 1023$, wait time is about 52 msec

Exponential Backoff:

- *Goal:* adapt retransmission attempts to estimated current load
 - Heavy load: random wait will be longer
- First collision: choose K from $\{0,1\}$; delay is $K \cdot 512$ bit transmission times
- After second collision: choose K from $\{0,1,2,3\} \dots$
- After ten collisions, choose K from $\{0,1,2,3,4, \dots, 1023\}$

10BaseT/100BaseT/1000BaseT

- 10/100/1000 Mbps rate -- called “Ethernet”, “Fast Ethernet” and “Gigabit Ethernet” respectively
 - T stands for Twisted Pair (4 pairs = 8 wires, RJ45 connector)
 - Not compatible with RJ11 phone jacks (4 or 6 wires)
- Fiber-based ethernet: 1000BaseSX, 1000BaseLX
- Nodes connect to a hub:
“star topology”: 100 m max distance between nodes and hub



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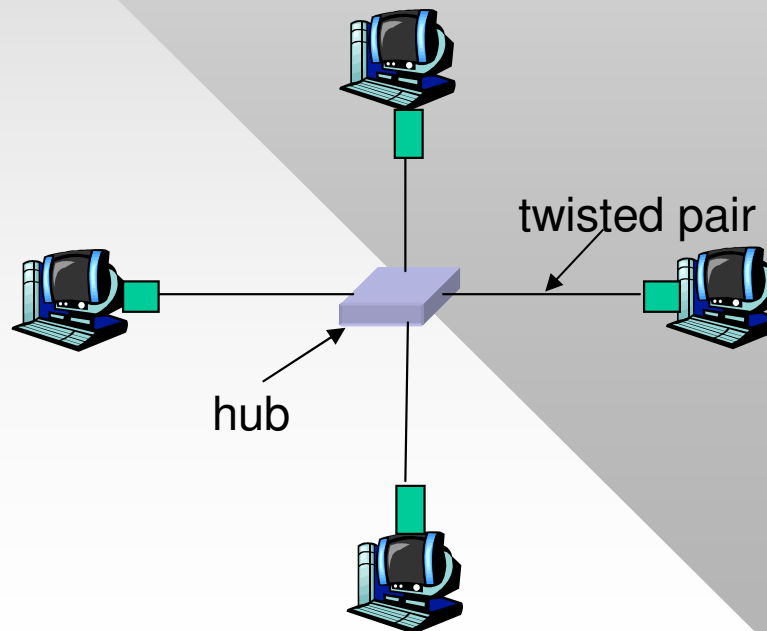
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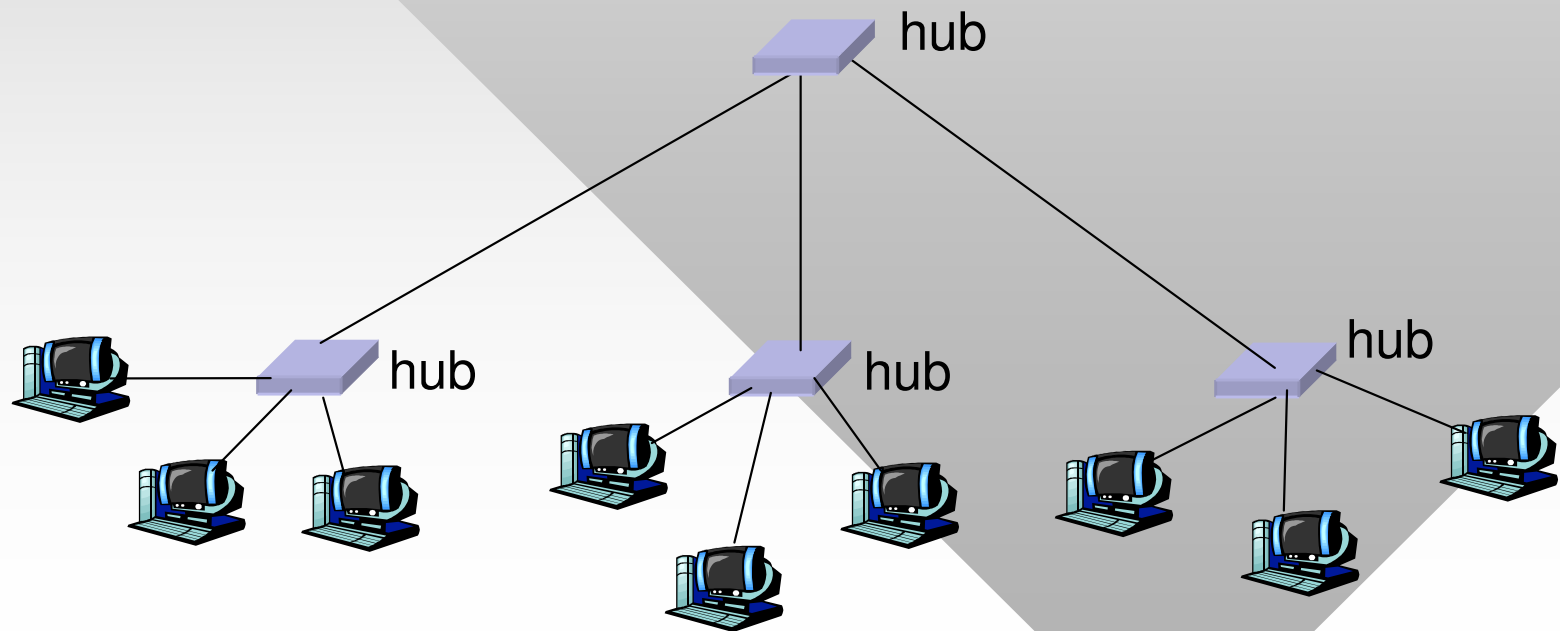
Hubs

- Hubs are essentially physical-layer repeaters:
 - Bits coming from one link go out all other links
 - All ports must have the same speed
- No frame buffering
 - No CSMA/CD at hub: adapters detect collisions
 - Provides no management functionality



Interconnecting With Hubs

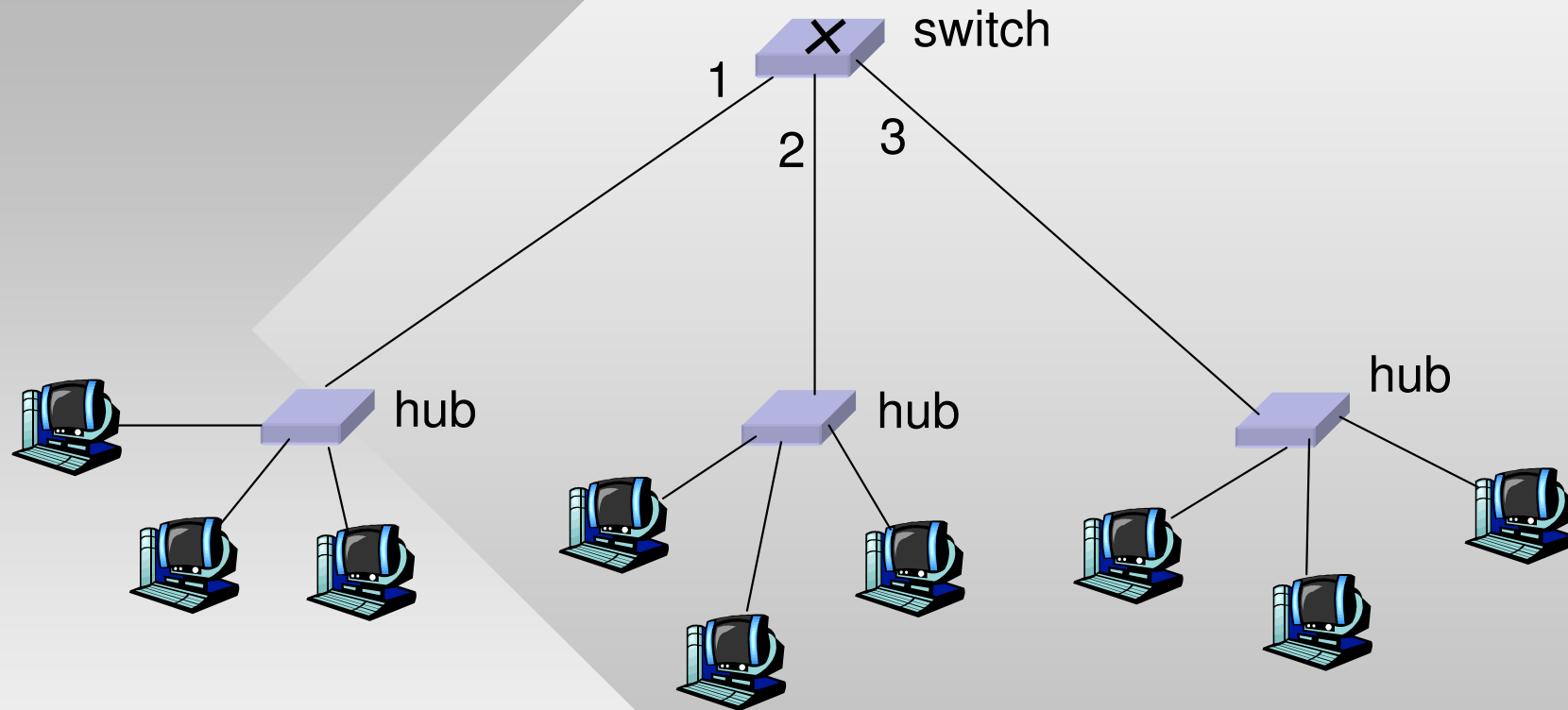
- Backbone hub interconnects LAN segments
 - Extends max distance between nodes
- But:
 - Individual segment collision domains become one large collision domain
 - Can't interconnect 10BaseT & 100BaseT



Switch

- **Link layer device**
 - 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
- Transparent
 - Hosts are unaware of presence of switches
- Plug-and-play, self-learning
 - Switches do not need to be configured

Forwarding



- How to determine onto which LAN segment to forward frame?
 - Looks like a routing problem...
- Most LAN networks are trees, which makes the problem much simpler!

Self Learning

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

Filtering/Forwarding

When switch receives a frame:

index switch table using destination MAC 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

}

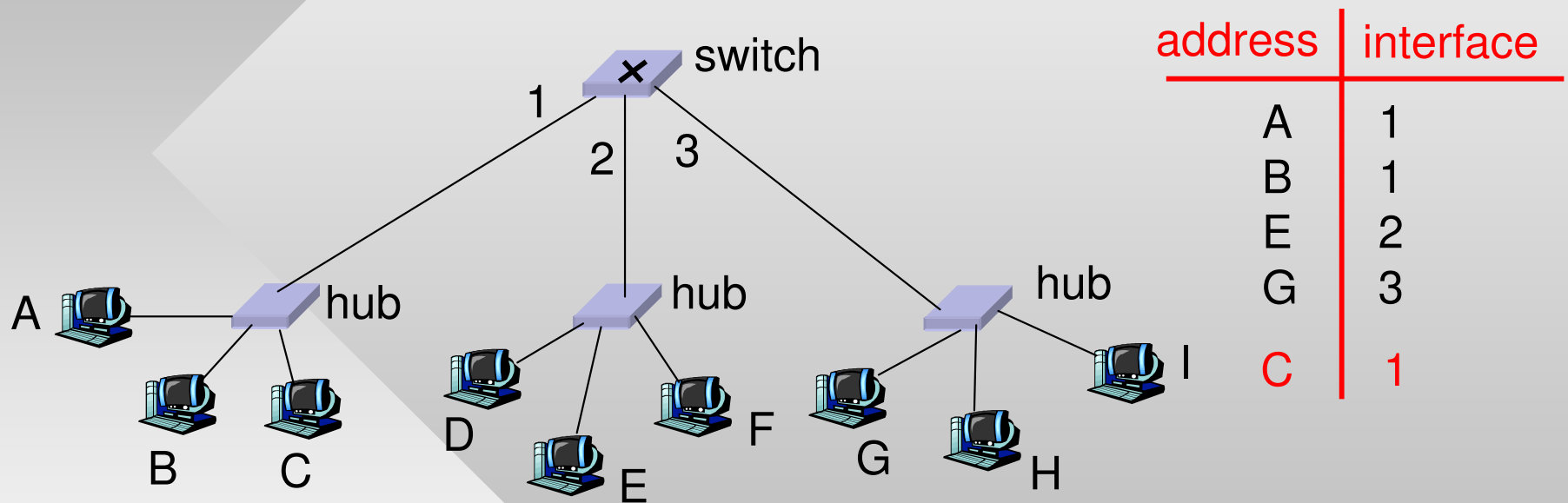
else flood



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

Switch Example

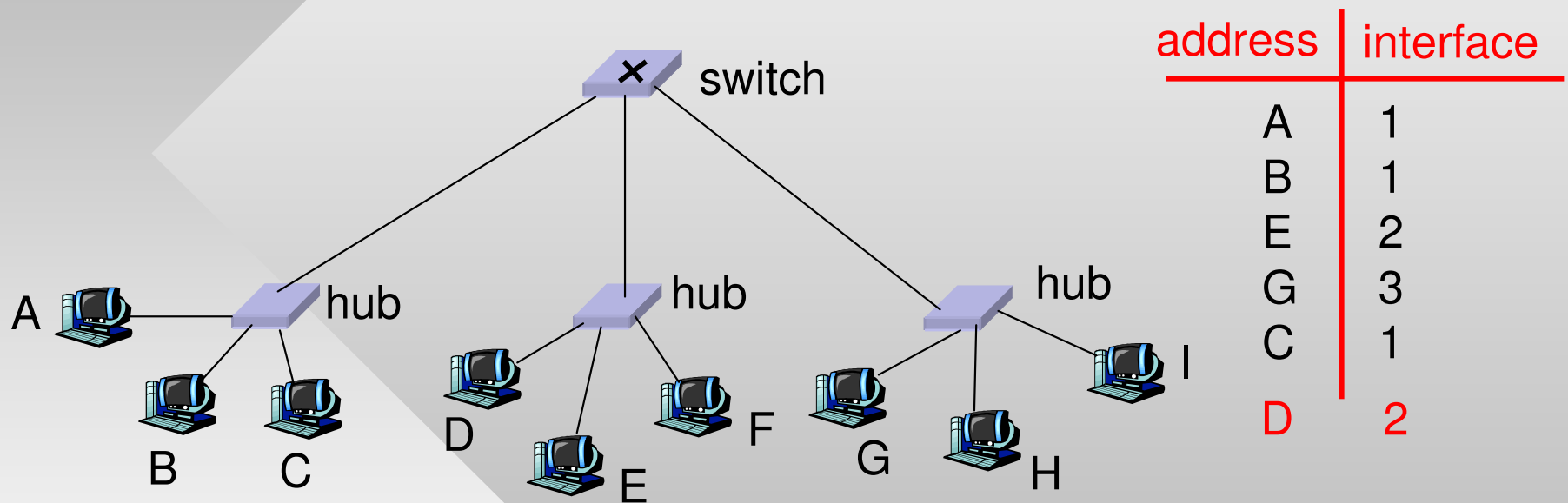
Suppose C sends a frame to D



- Switch receives frame from C
 - Notes in its table that C is on interface 1
 - Because D is not in table, switch forwards frame into interfaces 2 and 3
- Frame received by D

Switch Example

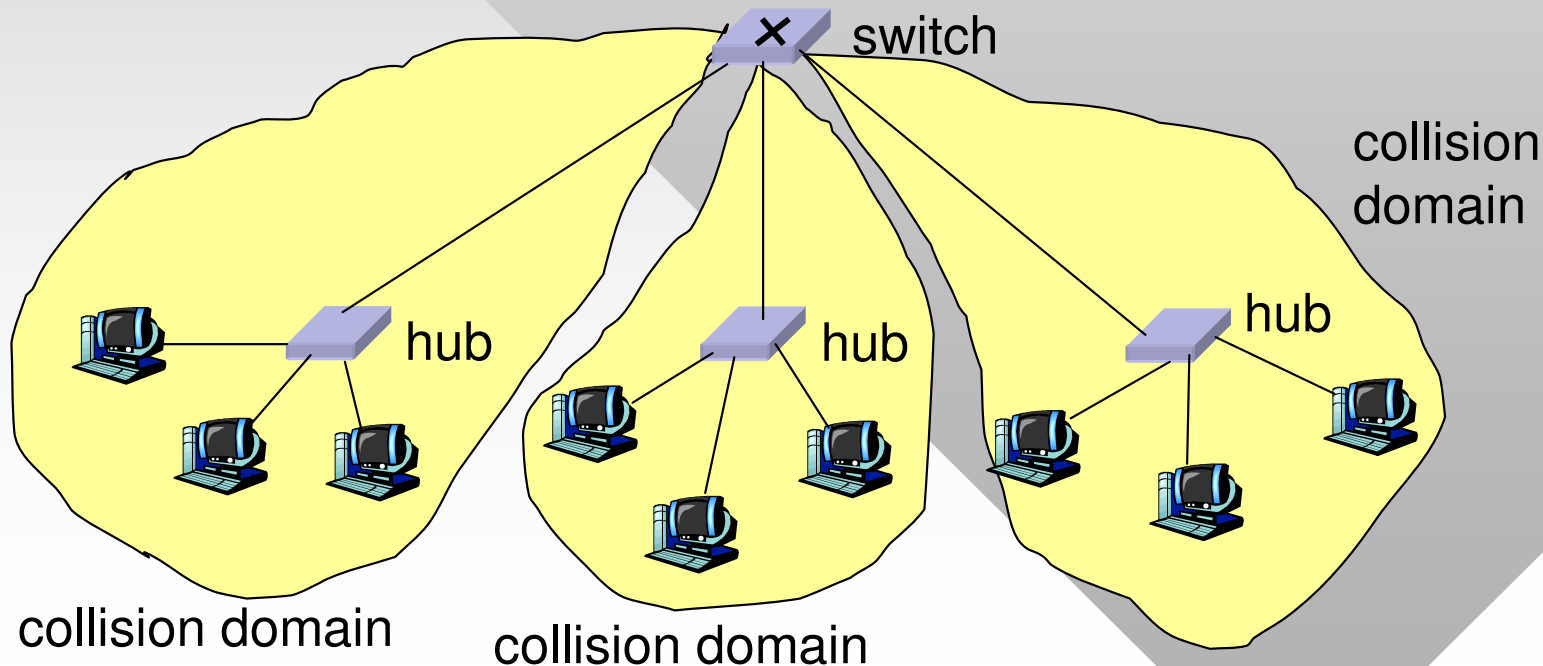
Suppose D replies back with frame to C



- Switch receives frame from from D
 - Notes in the table that D is on interface 2
 - Because C is in table, switch forwards frame only to interface 1
- Frame received by C

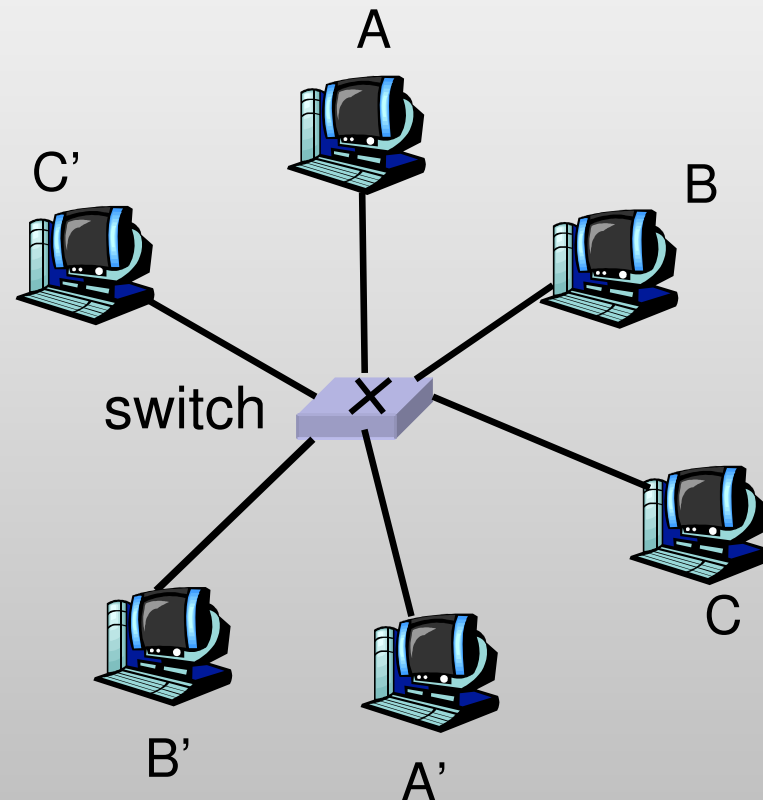
Switch: Traffic Isolation

- 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**

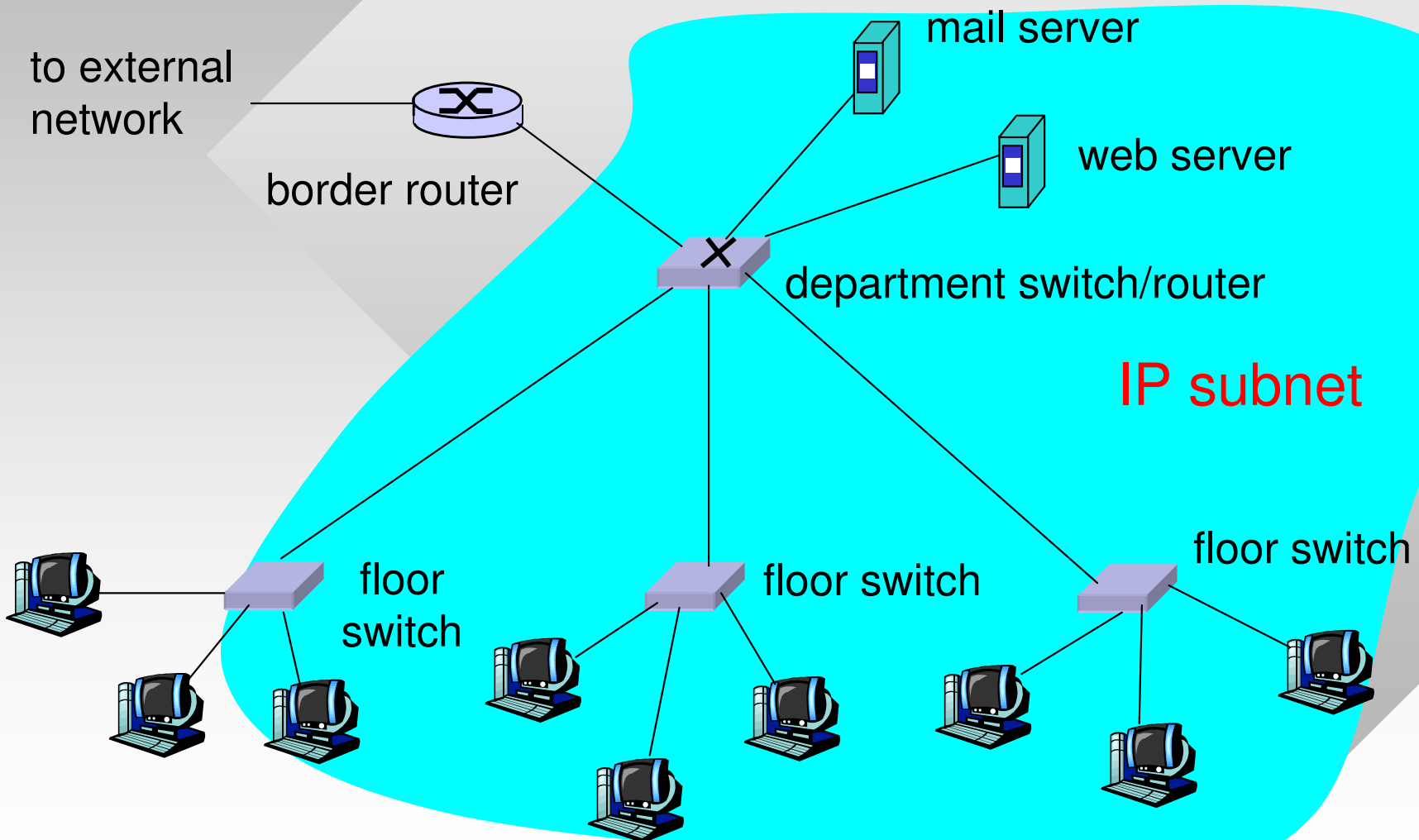


Switches: Dedicated Access

- Switch with many interfaces
- **Dedicated**: hosts have **direct** connection to switch
 - No collisions; full duplex
- **Switching**: A-to-A' and B-to-B' simultaneous, no collisions
- **Buffering**: A-to-A' and C-to-A' simultaneous, no collisions
- Combinations of shared/dedicated, or various (10/100/1000 mb/s) interfaces are possible



Campus Network



Switches vs. Routers

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

