CS 3640: Introduction to Networks and Their Applications

Fall 2023, Lecture 8: Addressing and Forwarding in the Link Layer

Instructor: Rishab Nithyanand
Teaching Assistant: Manisha Keim

Announcements

- Assignment 2 due 9/28.

Today's class

1. Recap: MAC protocols

2. Addressing and forwarding protocols

Medium Access Control protocols

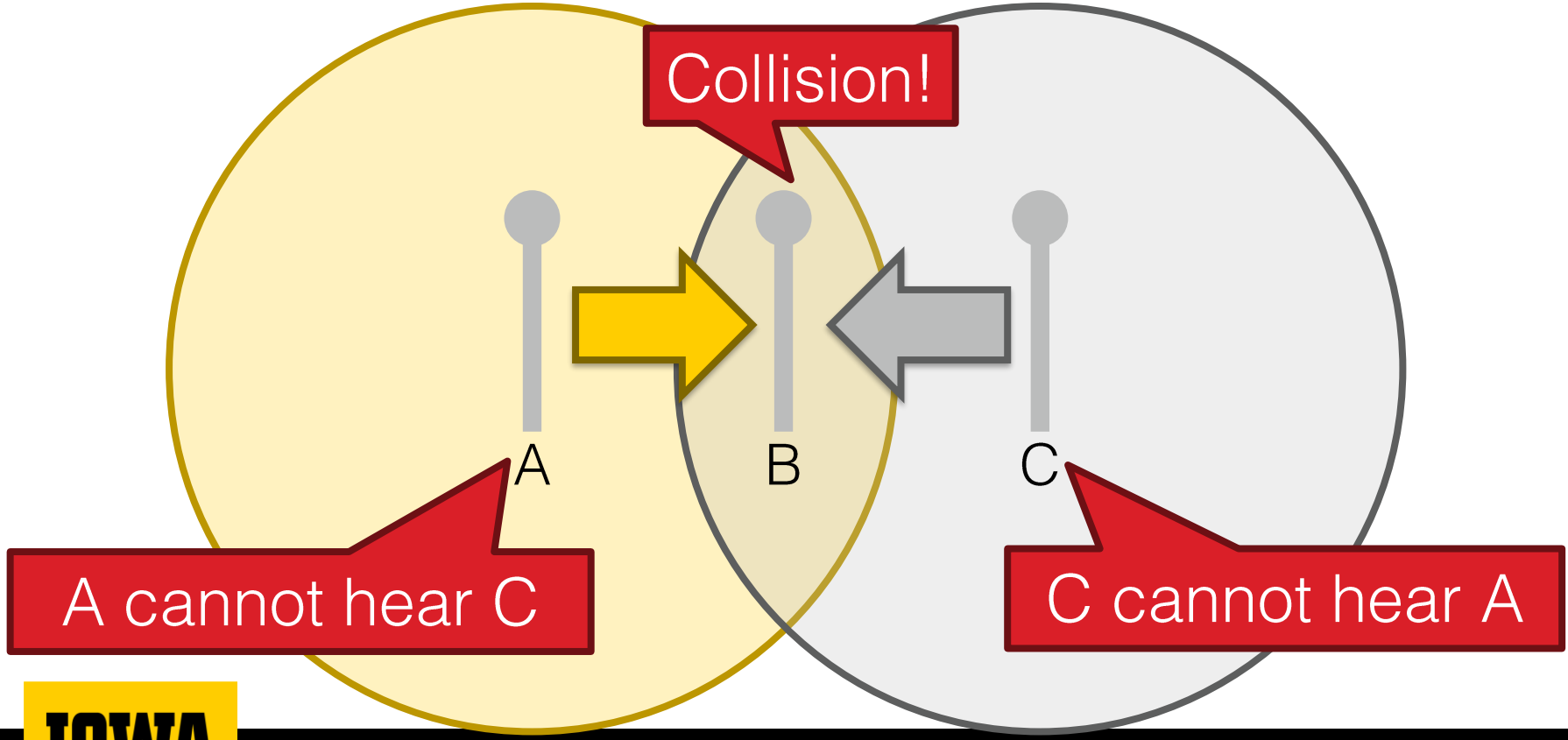
- **What is the general idea behind CSMA protocols?**
  - Sense the medium before transmitting.
  - Use randomized exponential back-off algorithms before retries.

- **Why are wireless media more challenging?**
  - Collisions can only be detected at the receiver and carrier sensing is not always accurate.

- **Why do we need a CSMA/CD and CSMA/CA protocol? What is the RTS/CTS variant?**
  - CSMA/CD: Sense the medium. Send frames. When the sender detects a collision, they send a jam signal and abort transmissions.
  - CSMA/CA: Sense the medium. Send frames only if the medium isn't being used. If you don't get an ACK back, retransmit. Used for wireless media.
  - CSMA/CA with RTS/CTS: Sense the medium. Ask for permission to send frames. Send frames if permission is granted. If you don't get an ACK back, retransmit.

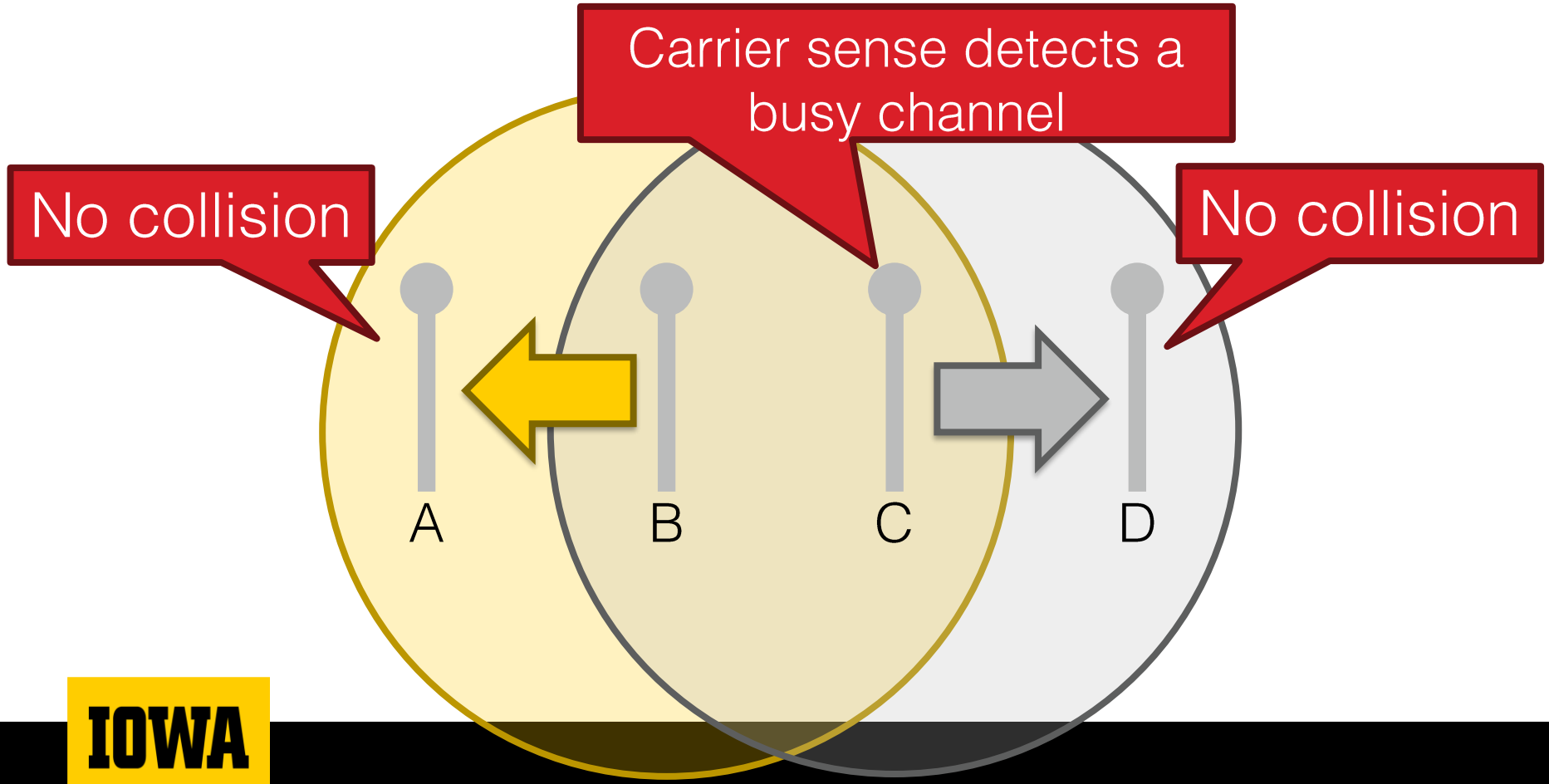
Hidden terminal problem

- Increases the false-negative rate during carrier sensing.
- Solved by the RTS/CTS variant.



Exposed terminal problem

- Increases the false-positive rate during carrier sensing.



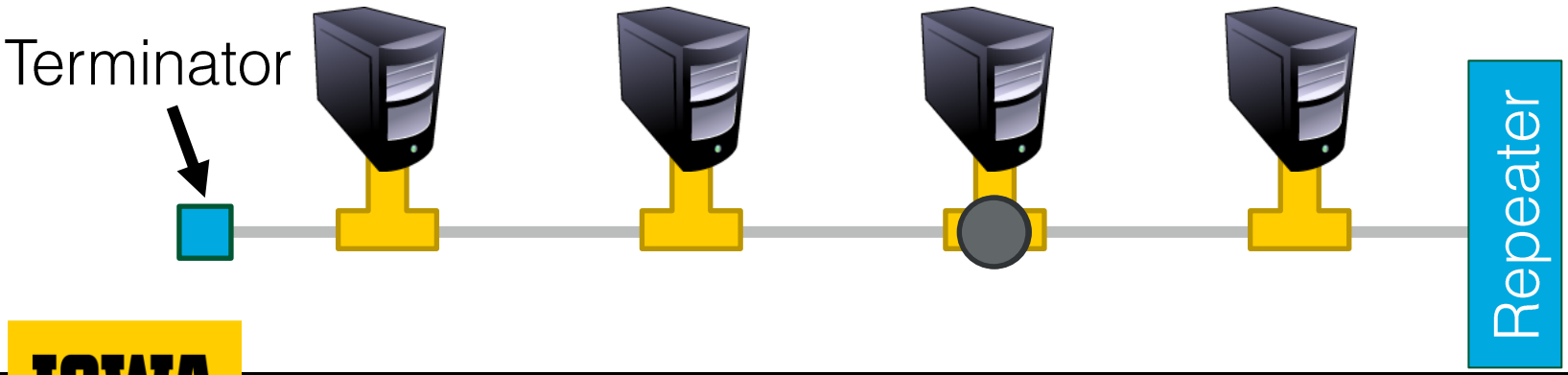
Today's class

1. Recap: MAC protocols

2. Addressing and forwarding protocols

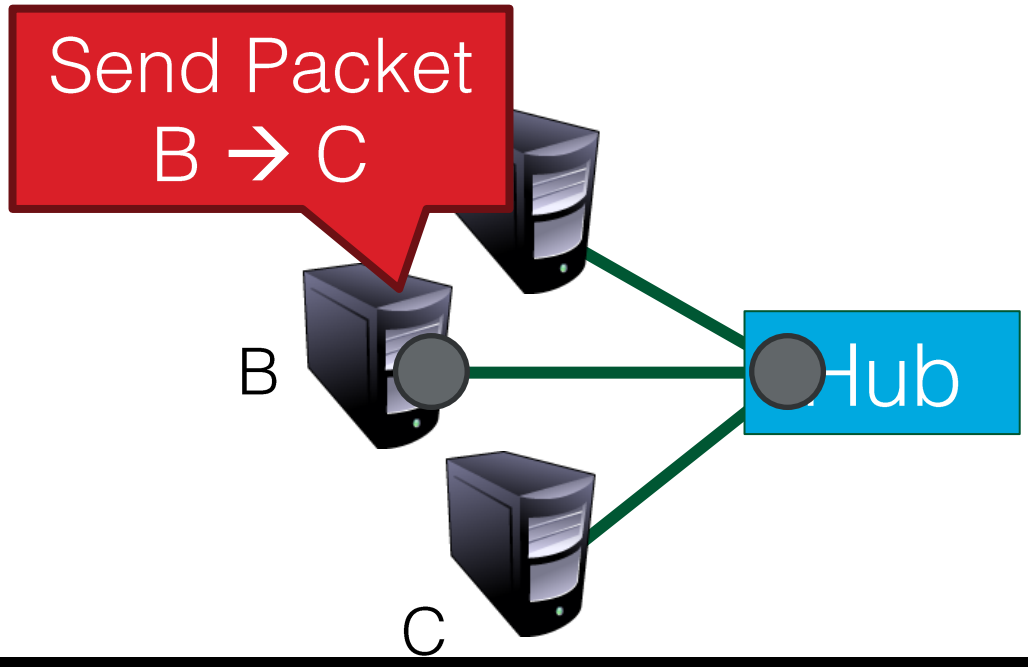
Addressing in the link layer

- **When we studied MAC protocols, we assumed that packets went on every wire (i.e., they were broadcasted).**
  - This is why collisions occurred, but there was no need for any logic in the link-layer hardware.
  - Originally, Ethernet was a broadcast-only medium and that's how things worked. Today, with new types of hardware we have new opportunities for efficiency-gain.



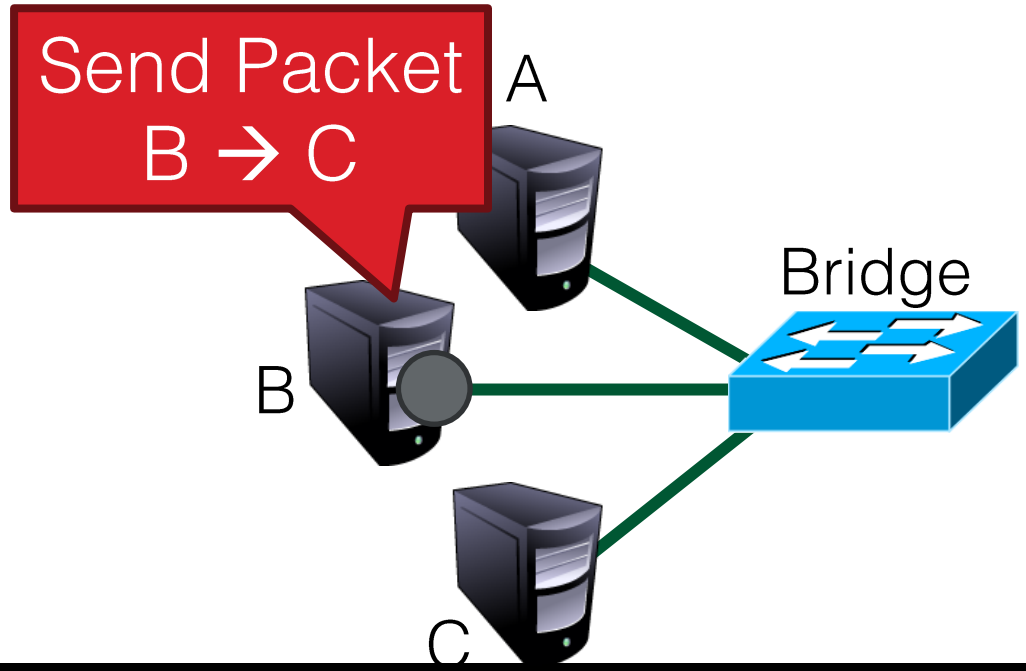
Link layer and network interface technologies: Hubs

- **Discuss: What are the pros and cons of using Hubs for your LAN?**
  - **Pros:** Dirt cheap hardware with no logic.
  - **Cons:** Poor efficiency and scalability. Good enough for small LANs.



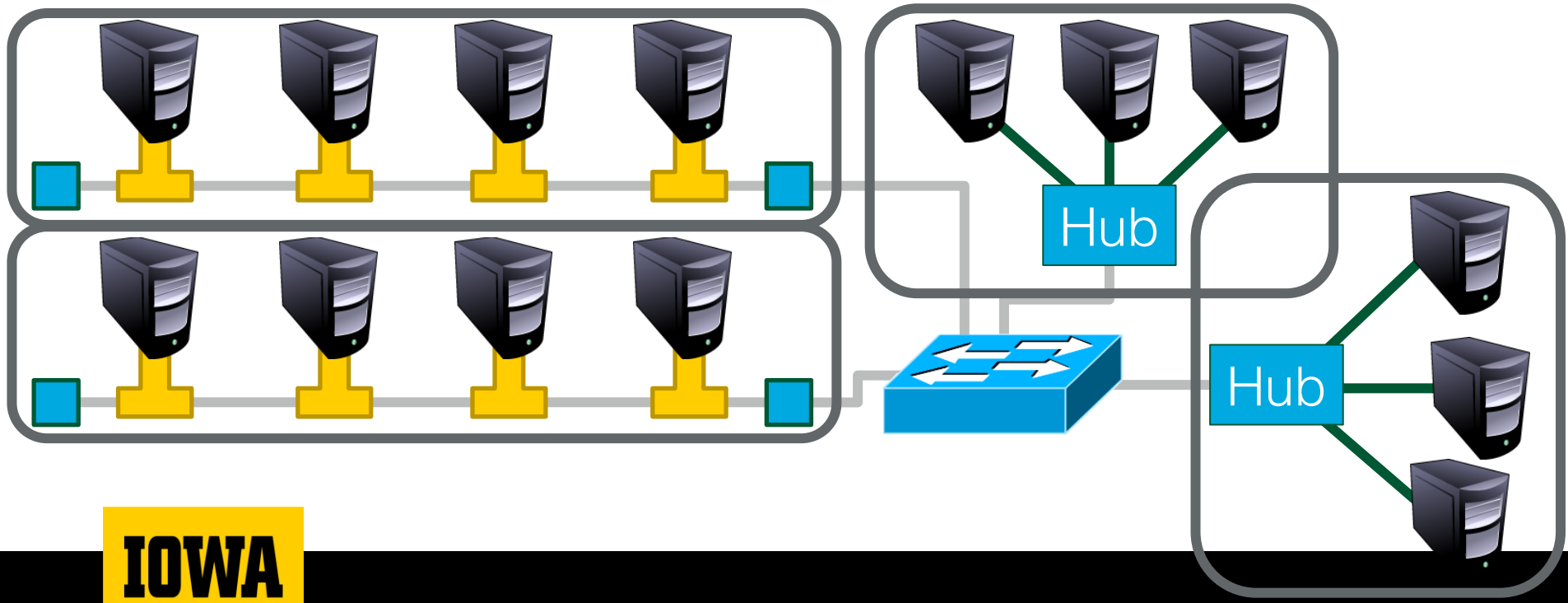
Link layer and network interface technologies: Bridges and switches

- **Discuss: What could we do to improve efficiency and scalability?**
  - Stop using broadcast! Only send packets to their intended recipients.
  - This is what bridges and switches do. They contain logic to figure out which wire to put packets on.



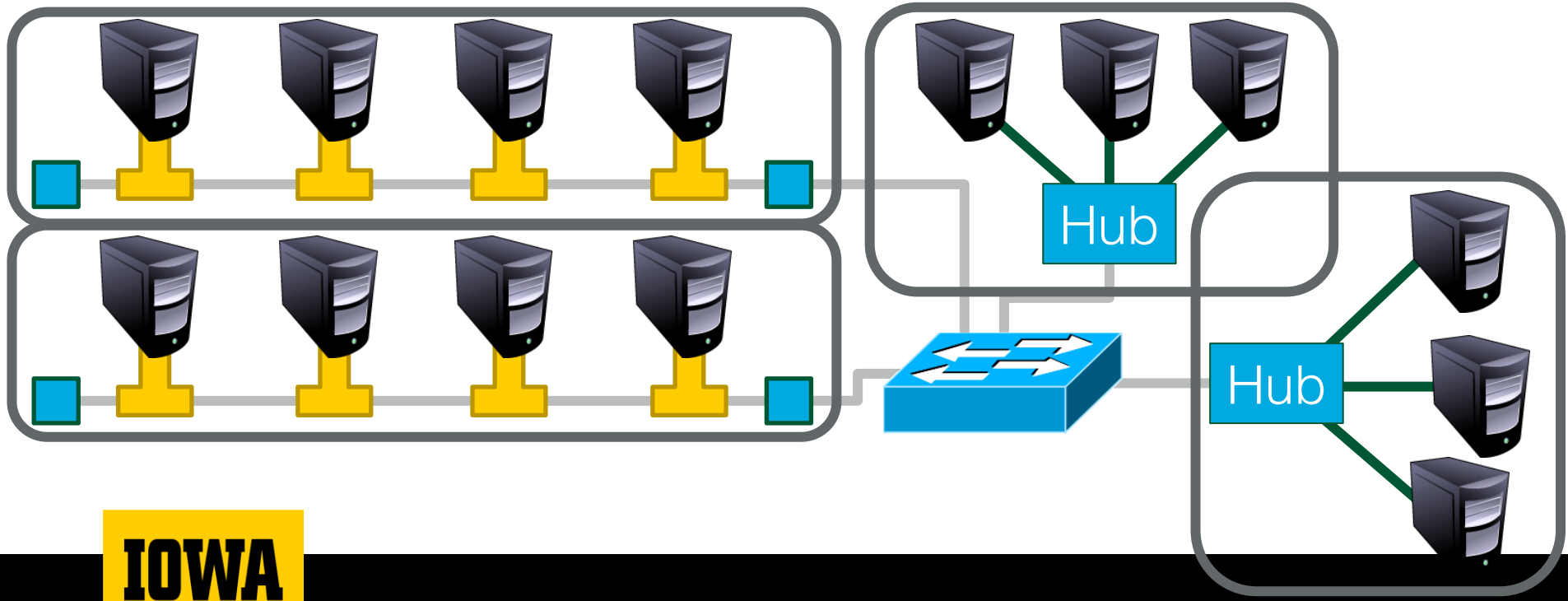
Link layer and network interface technologies: Bridges and hubs in the real world

- In the real world, we use a combination of old ethernet broadcast nets, hubs, and bridges.
- Bridges are usually used to create a "bridge" between two small LANs.



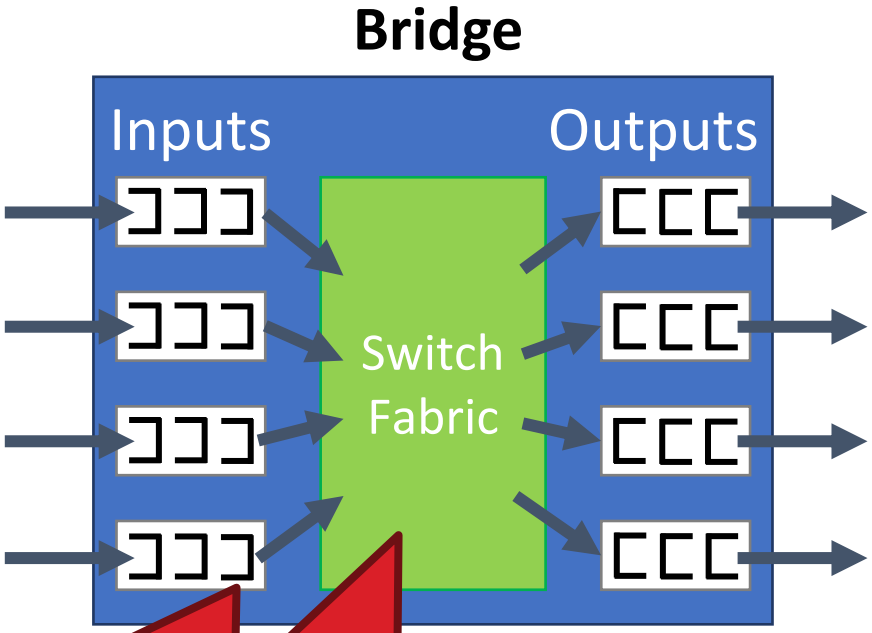
Link layer and network interface technologies: Bridges and hubs in the real world

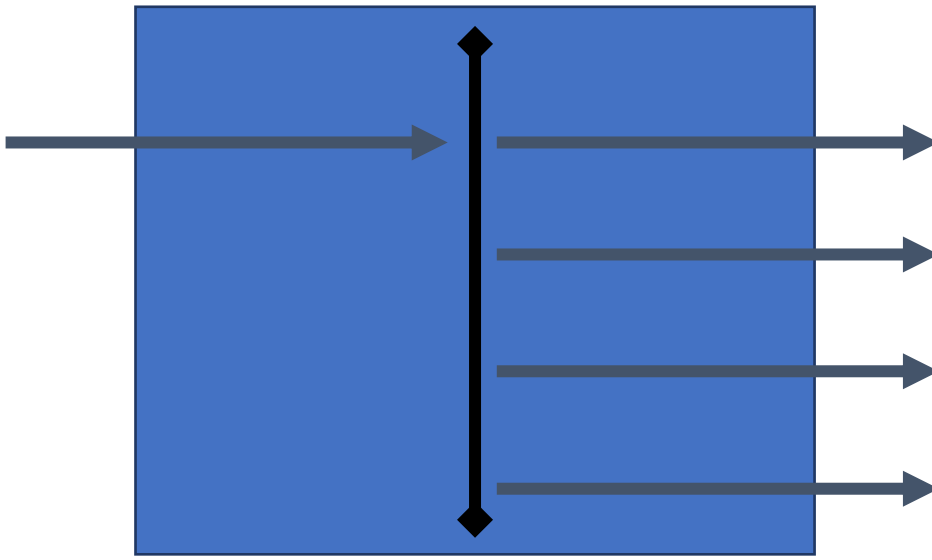
- **Why aren't bridges used within all LANs?**
  - This is the real world. You cannot force deployment – even when it is better (Windows XP in many state & federal agency computers).
  - Bridges are more expensive and complex than hubs.



Link layer and network interface technologies: Bridges vs. Hubs (the internals)

- **Why are bridges more expensive and complicated?**
  - They have memory for packets to be queued.
  - They have internal logic to forward packets to the correct wires (interfaces/ports).





Memory buffer ing
decisions

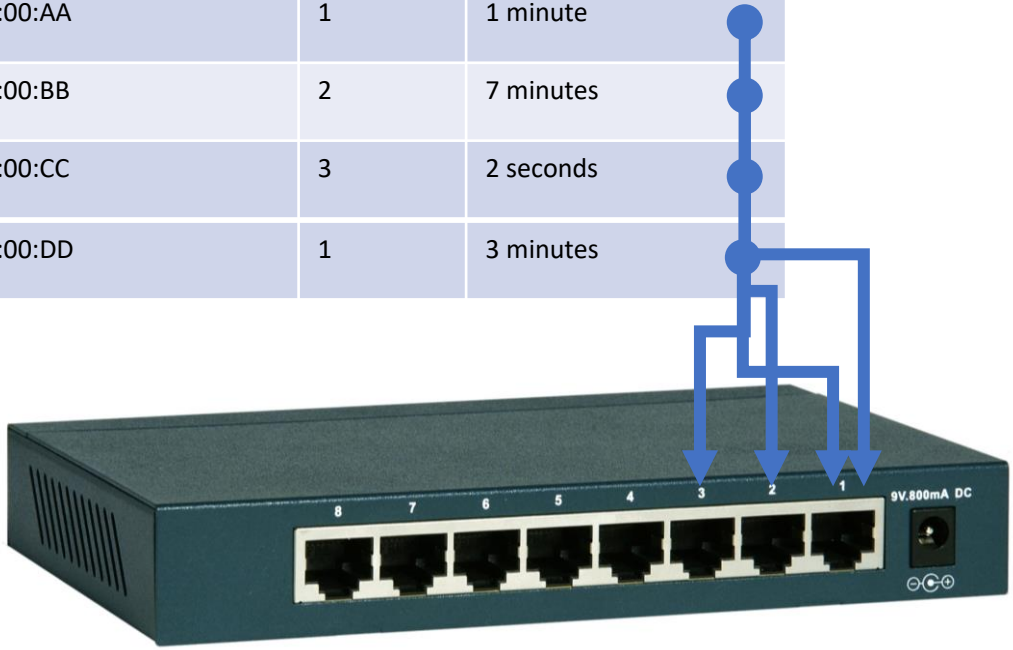
How do switches/bridges know what packet goes on which wire (interface)?

- **Each interface has a "MAC address".**
  - This is a 48-bit string that is allocated by the device manufacturer.
  - MAC addresses are unique to a device and usually cannot be changed.
  - Regulated by the IEEE.
  - Every link layer frame needs to have a source and destination MAC address to ensure forwarding is done correctly.

How do switches/bridges know what packet goes on which wire (interface)?

- **Each interface has a "MAC address".**
- **Each bridge/switch maintains a "forwarding table".**
  - Basically a collection of records of which MAC addresses are accessible through which ports. Records expire after a "timeout".

MAC address	port	age
00:00:00:00:00:AA	1	1 minute
00:00:00:00:00:BB	2	7 minutes
00:00:00:00:00:CC	3	2 seconds
00:00:00:00:00:DD	1	3 minutes



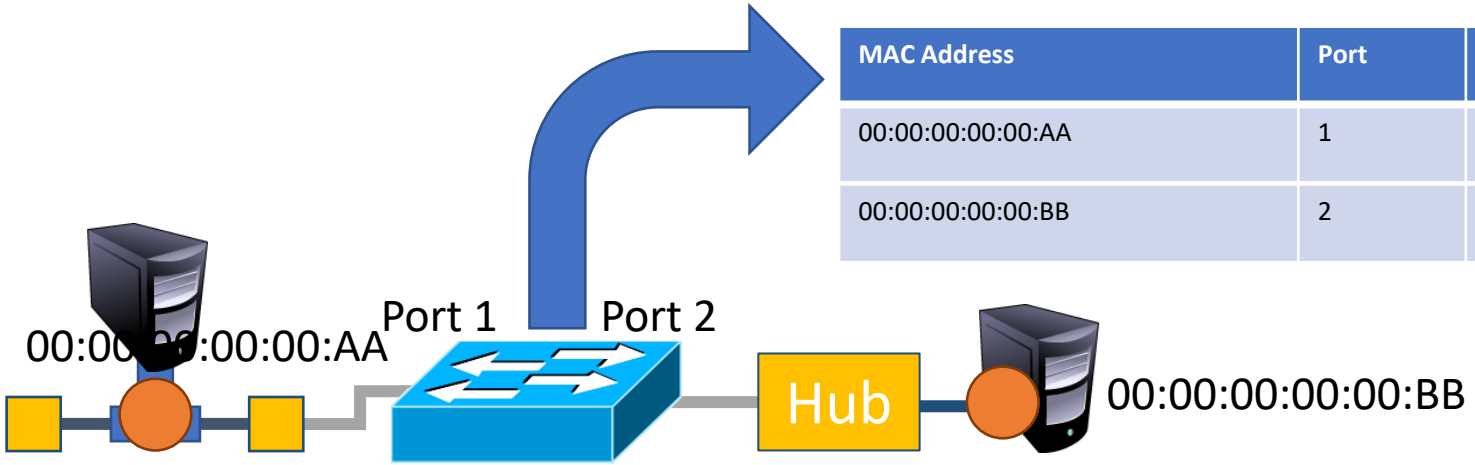
IOWA

How do switches/bridges know what packet goes on which wire (interface)?

- **How is the forwarding table built?**
  - Look at the source of each arriving frame.
    - Which MAC address sent the frame?
    - Which port did it reach the bridge on?

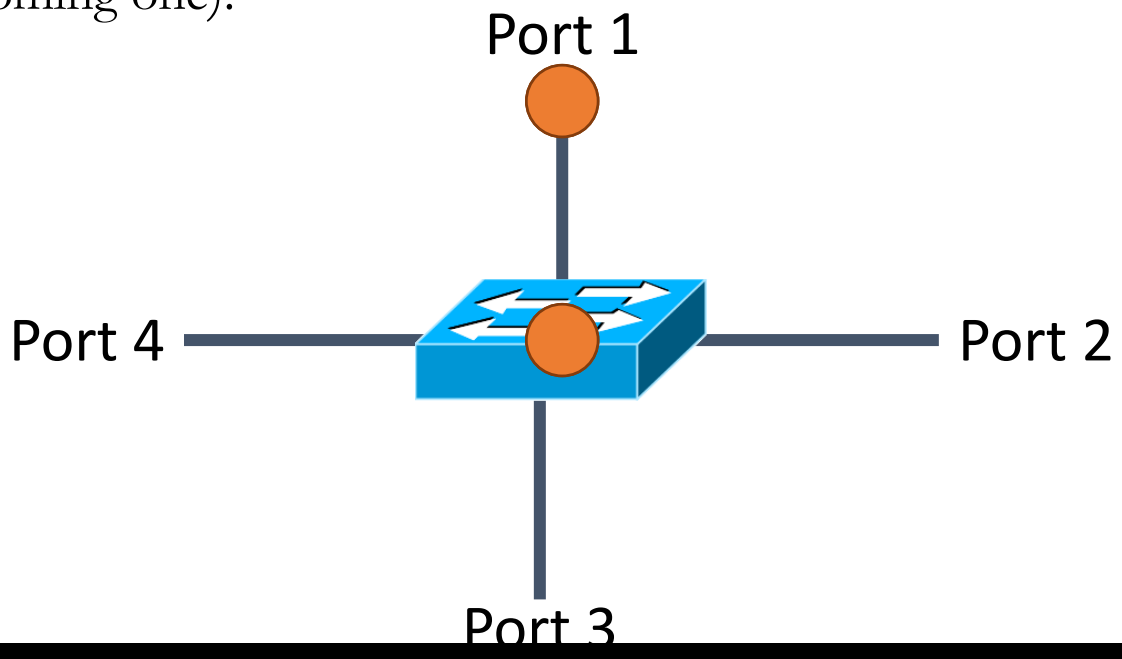
Delete old entries after a timeout

MAC Address	Port	Age
00:00:00:00:00:AA	1	0 minutes
00:00:00:00:00:BB	2	0 minutes



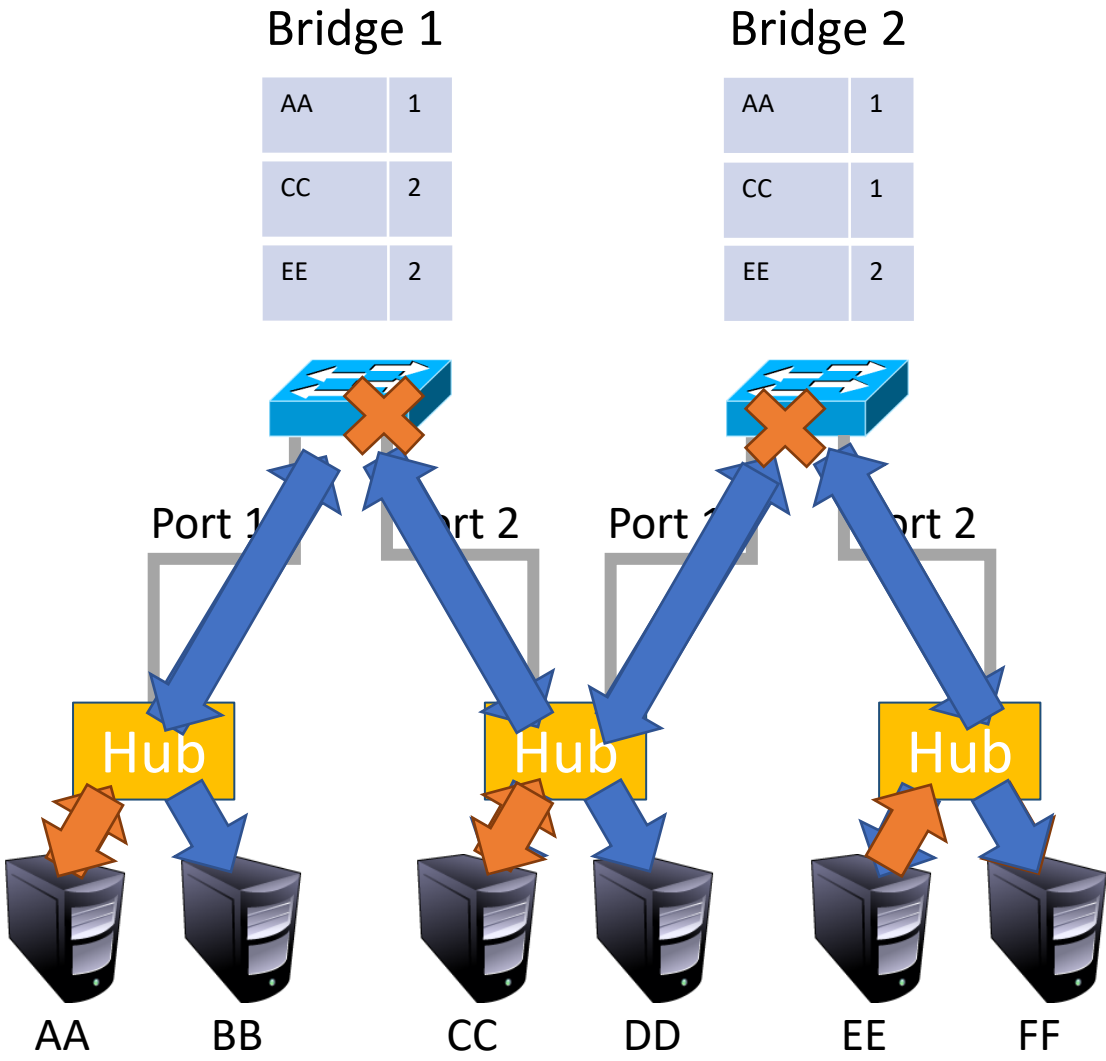
How do switches/bridges know what packet goes on which wire (interface)?

- **How is the forwarding table used?**
  - If the frame has a destination MAC address that is in the forwarding table, send the frame out the corresponding port.
  - If the frame has a destination MAC address that is not in the forwarding table, broadcast the frame through all ports (except the incoming one).



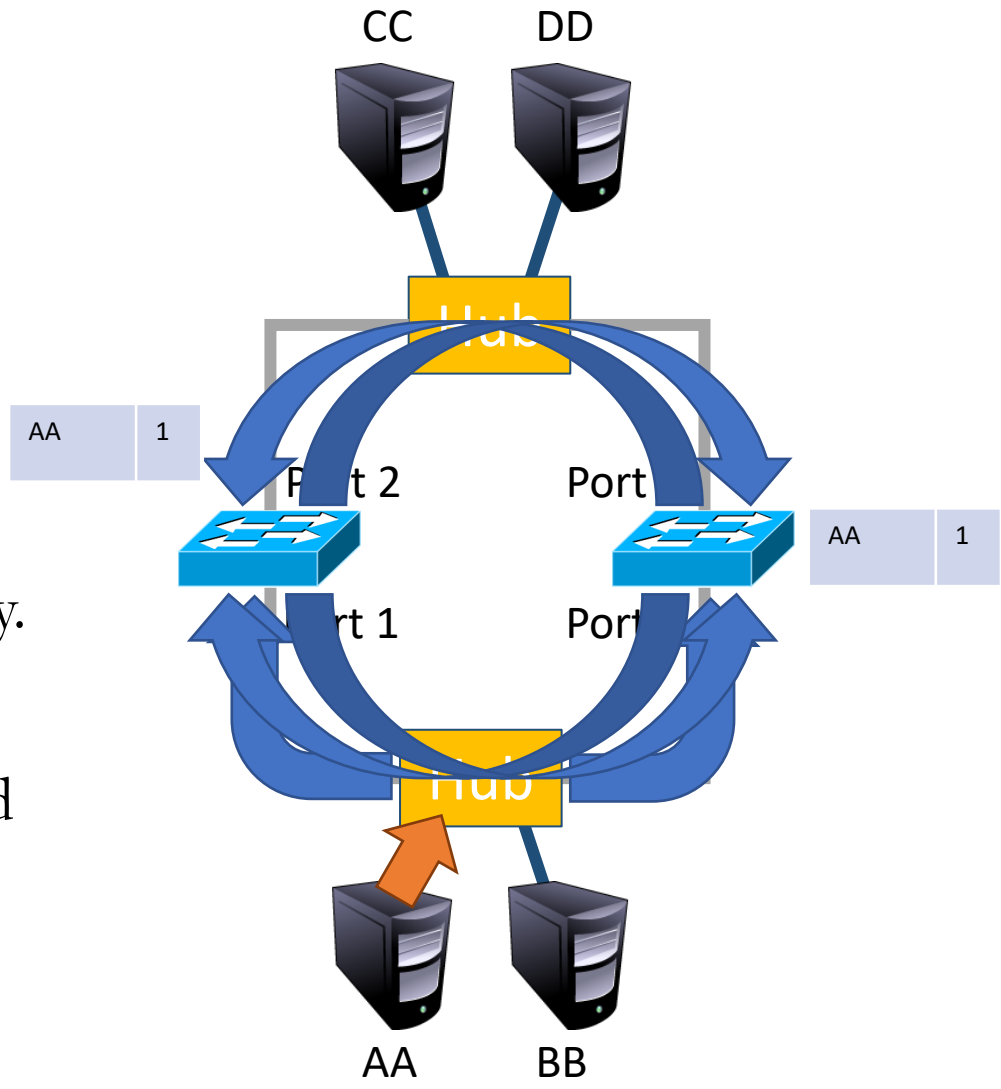
Forwarding tables in action

- <Src=AA, Dest=FF>
- <Src=CC, Dest=AA>
- <Src=EE, Dest=CC>



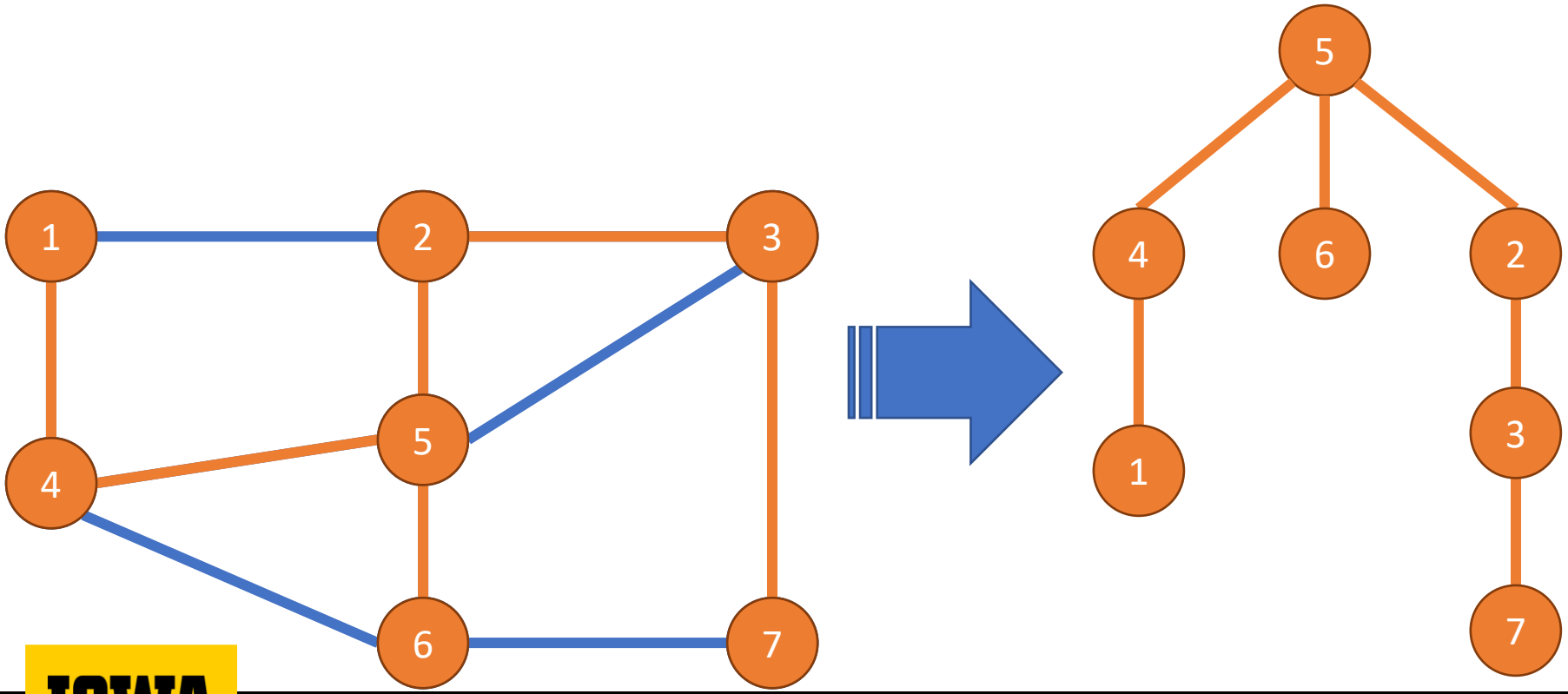
The problem with loops

- **Discuss: What happens when <Src=AA, Dest=DD>?**
- This continues to infinity.
  - **Discuss: How do we stop this?**
- Remove loops from the topology.
- We use an algorithm to build and maintain a spanning tree for link layer addressing.



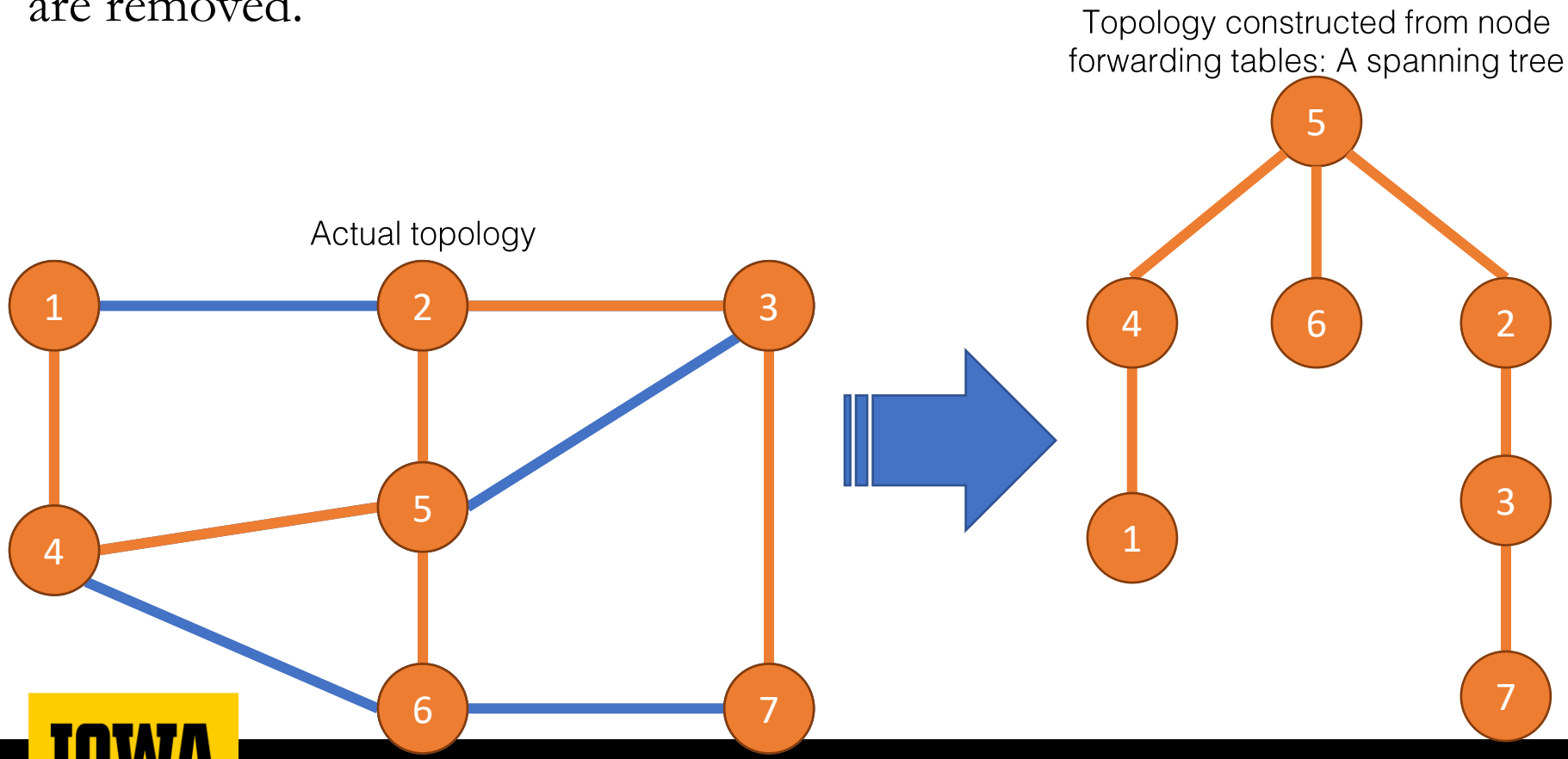
Spanning trees

- A subset of edges in a graph that:
  - Spans all nodes.
  - Does not create any cycles.



Why do spanning trees help?

- If bridges in our topology can collectively organize their forwarding tables to make the topology seem like a spanning tree, then all loops are removed.



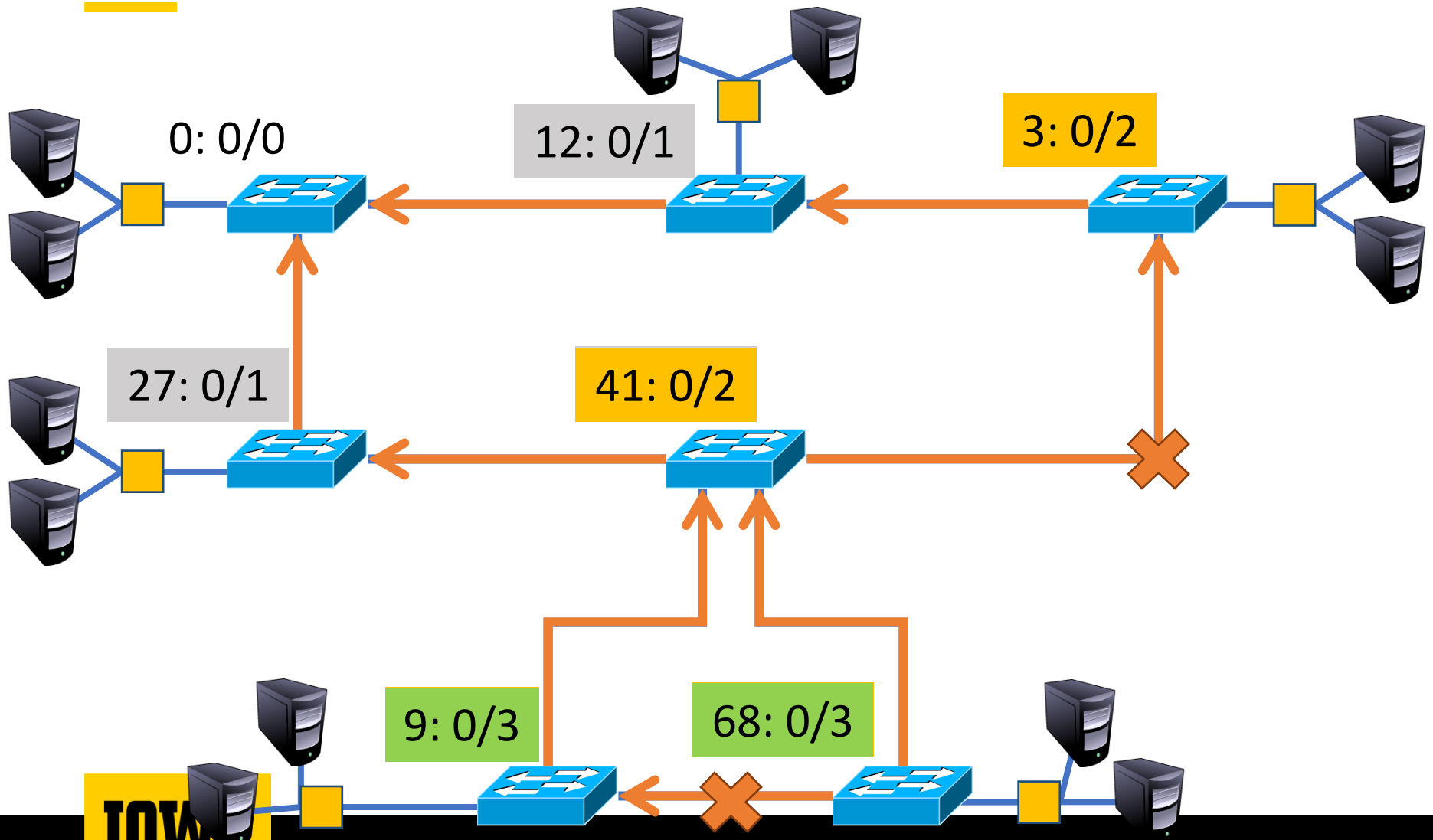
How do nodes construct a spanning tree from any network topology?

- **All bridges randomly elect a single bridge as the "root" of the spanning tree.**
  - Example (shortest straw): All bridges pick a random number. The bridge with the smallest random number is the root.

- **Each bridge finds the shortest path to this root.**
  - Problem: Need to know where the root is and the shortest way to get there.
  - Solution: Broadcast your best knowledge to all neighbors. Update your knowledge. Repeat until steady state is reached.

- **The union of all these paths is a spanning tree.**

How do nodes construct a spanning tree from any network topology?



Bridges vs. Switches

- **Both make it possible to increase LAN capacity via the same approaches.**
  - Automatically learn and maintain forwarding tables.

- **A switch is a special case of a bridge.**
  - Bridge: Each port can be connected to either another bridge, hub, or broadcast net.
  - Switch: Each port can only be connected to a single device (an end-host or another switch).
  - You don't need MAC protocols in switches! Why?

How does the link layer frame travel from source to destination within a LAN?

- **We know how frames are forwarded within the LAN.**
  - Switches and bridges. Both rely on knowing the destination MAC address.

- **But how does the sender know the MAC address of the receiver?**
  - The Address Resolution Protocol (ARP)
  - Each end-host maintains an ARP table.
    - This is a collection of <IP address, MAC address, TTL> tuples.
  - When a packet from the network layer arrives, the link layer looks at the destination IP address and fetches the corresponding record from the ARP table.
  - **Discuss:** What if there is no entry in the ARP table?
    - Broadcast an ARP request asking for a response from the end-host owning the destination IP address.
    - ARP response has MAC address.

Discussion

- **Could the whole Internet be one big switching domain? What would this look like? What issues would appear?**
  - Constant broadcasting to locate unknown hosts (billions of these!) would be a disaster!
  - Reaching a steady state with the spanning tree would be very improbable.
  - Each switch would need to know every MAC address on the Internet! Think of the memory that would require!
- **We use IP addressing and network-layer routing to avoid these problems.**
  - Topic for the next few weeks ☺


JOHN DEERE


OUR STUDENT
PROGRAMS

- **Information Technology Internship Program**

Length of Program	3 months
Class Status	Sophomores, Juniors, Seniors attending graduate school, or first-year graduate students
Functional Areas	Software Engineering, Cyber Security
Majors	Computer Science, Computer Engineering, Software Engineering, Information Systems, or related major
Minimum Required Cumulative GPA	2.8
Possible Geographic Locations	Quad Cities (Moline, IL) and Des Moines Area (Ames, Johnston, Urbandale)
Visa Sponsorship	No

https://careers.deere.com: IT – Software Engineering Summer Intern 2024a

- **Information Technology Development Program**

Length of Development Program	2 years
Class Status	Graduating Seniors and Graduate Students
Number of Rotations	Two, 12-month rotations
Rotational Areas	Software Engineering, Cyber Security
Possible Geographic Locations	Quad Cities (Moline, IL) and Des Moines Area (Ames, Johnston, Urbandale)
Minimum Required Cumulative GPA	2.8
Visa Sponsorship	No

https://careers.deere.com: IT Development Program – Software Engineering 2024a

Connect with John Deere

- **Engineering Employer of the Week**
- Tuesday, September 19th, 9a – 3p
- Seamans Center Second Floor Lobby
- **HackUIowa**
- Saturday, September 23, Xa – Yp
- Iowa Memorial Union
- **Engineering Career Fair**
- Thursday, September 28th, 11a – 4p
- Iowa Memorial Union


JOHN DEERE IS A TECH
COMPANY