# Introduction to Computer Networks

# L2 Switching

CS640

https://pages.cs.wisc.edu/~mgliu/CS640/F22/

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# Today

## Last lecture

- How to identify a frame from bit streams?
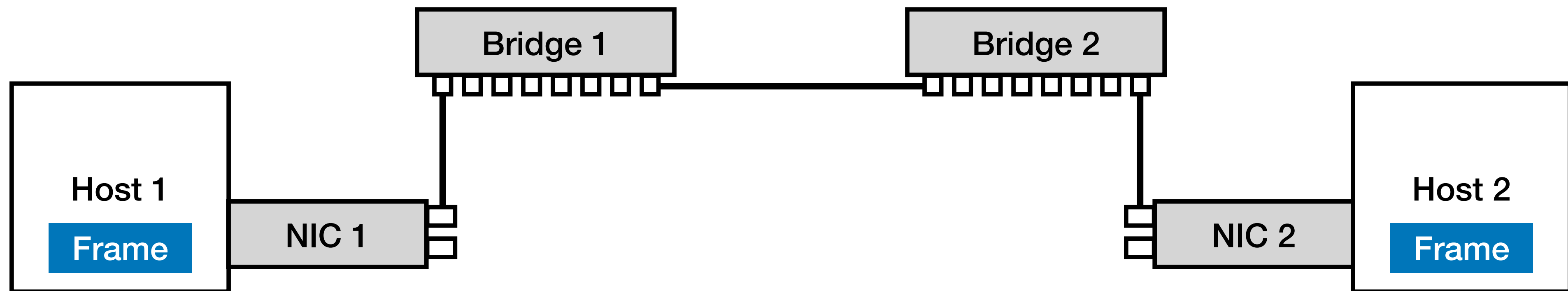
- How to handle transmission errors?

## Today

- How do frames traverse NICs/bridges?

## Announcements

- Quiz2 next Thursday

# Q: How do frames traverse NICs/bridges?

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## A: addressing + switching

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## A: addressing + switching

Q1: What is the address of each hardware entity?
Q2: How to allocate addresses for each hardware entity?
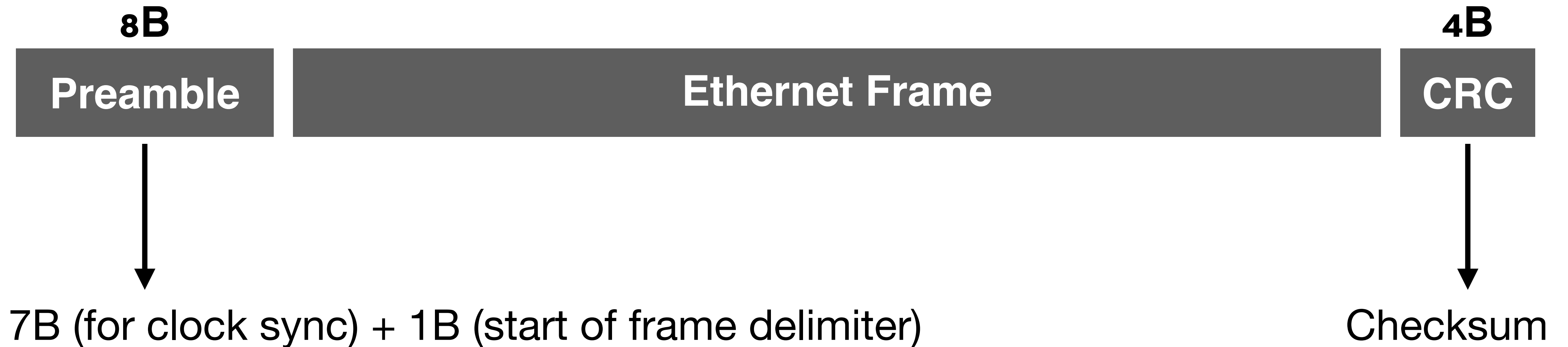Q3: How to forward a frame given a destination address?

# Ethernet

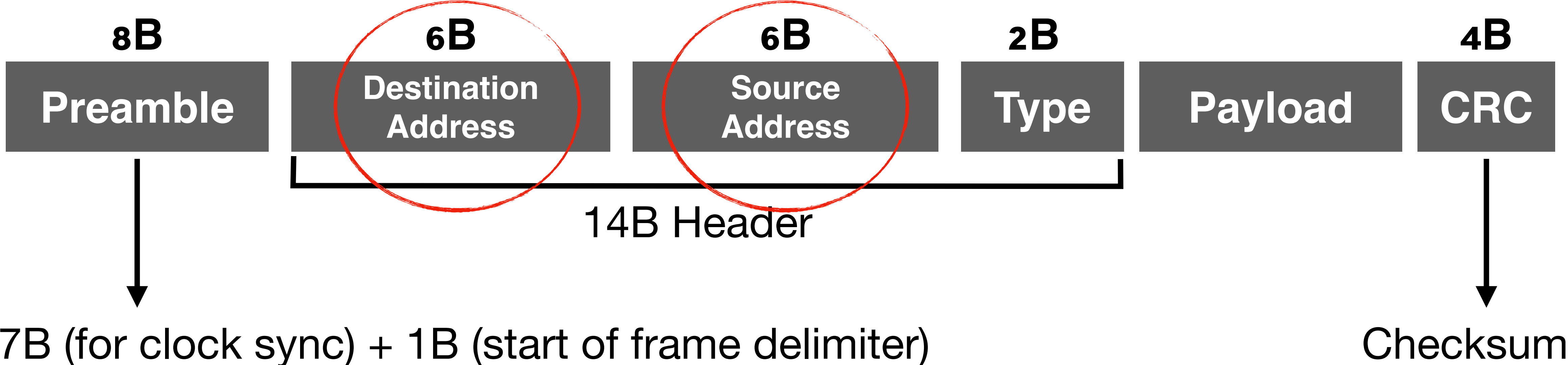## One of the most popular wired computer networking technologies

- Used in local area network (LAN) and wide area network (WAN)

# Ethernet

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8B

4B

| Preamble | Ethernet Frame | CRC |

7B (for clock sync) + 1B (start of frame delimiter)    Checksum

# Ethernet

## One of the most popular wired computer networking technologies

- Used in local area network (LAN) and wide area network (WAN)



| **8B** | **6B** | **6B** | **2B** | | **4B** |
|---|---|---|---|---|---|
| Preamble | Destination Address | Source Address | Type | Payload | CRC |

14B Header

7B (for clock sync) + 1B (start of frame delimiter)

Checksum

# Q1: What is the address of each hardware entity **in an Ethernet**?

# Q1: What is the address of each hardware entity in an Ethernet?

# A: MAC (media access control) address, a unique identifier for a NIC/switch port.

- Originally come from Xerox Network System Ethernet addressing scheme
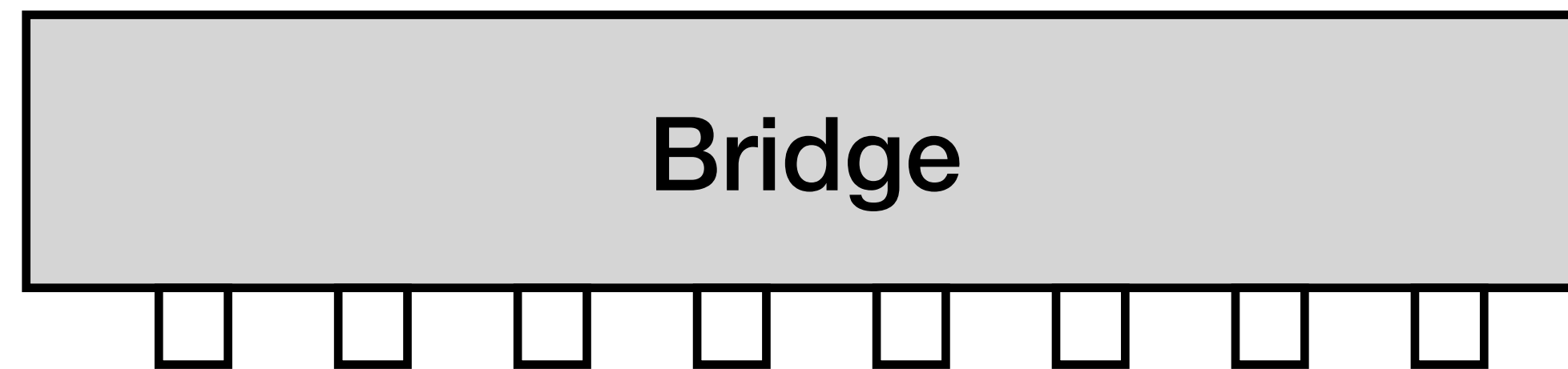- 48-bit, e.g., bc:97:e1:13:82:d4

# Q2: How to allocate addresses for each hardware entity in the Ethernet?

**Q2: How to allocate addresses for each hardware entity <span style="color:red">in the Ethernet</span>?**

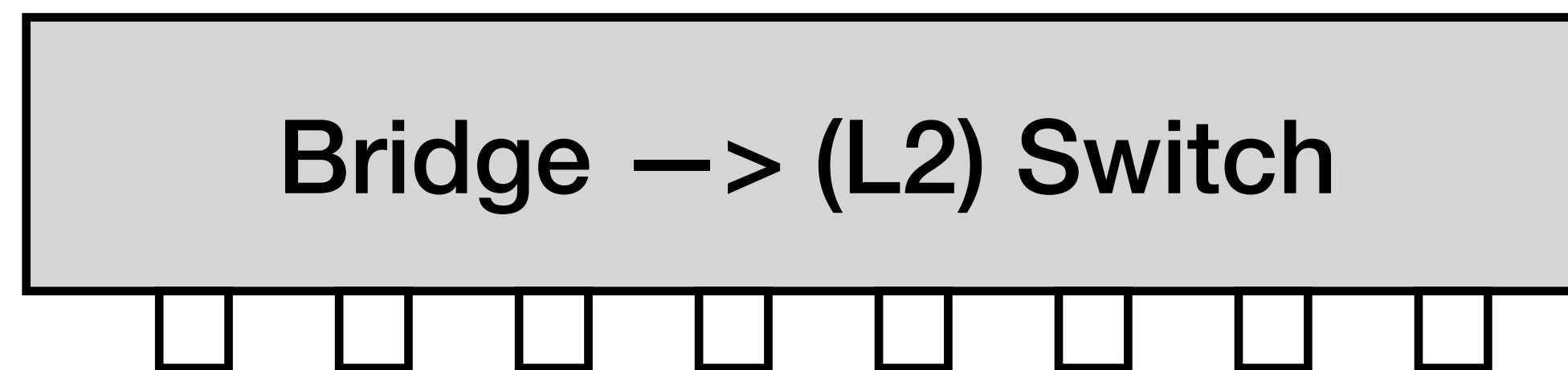**A: By vendor. The first three bytes identify the organization.**

- Also known as the organizational unique identifier (OUI)
- https://ouilookup.com/

# Q3: How to forward a frame given a destination address in the Ethernet?

# Q3: How to forward a frame given a destination address in the Ethernet?

# A: Use a forwarding/switching table

Bridge —> (L2) Switch

# Forwarding Table

## Each switch maintains a forwarding table:

- <MAC address, port, age>
- MAC address: the destination MAC address
- Port: the forwarding port number of the switch
- Age: the valid period of the entry

| MAC address | Port | Age (s) |
|:---:|:---:|:---:|
| 11:22:33:44:55:66 | 1 | 2 |
| 77:88:99:aa:bb:cc | 2 | 4 |
| dd:ee:ff:11:22:33 | 3 | 6 |

# Forwarding Logic

For every frame, the switch "looks up" the entry for the frame's destination MAC address and forwards the frame to that port

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- No entry –> Drop or broadcast

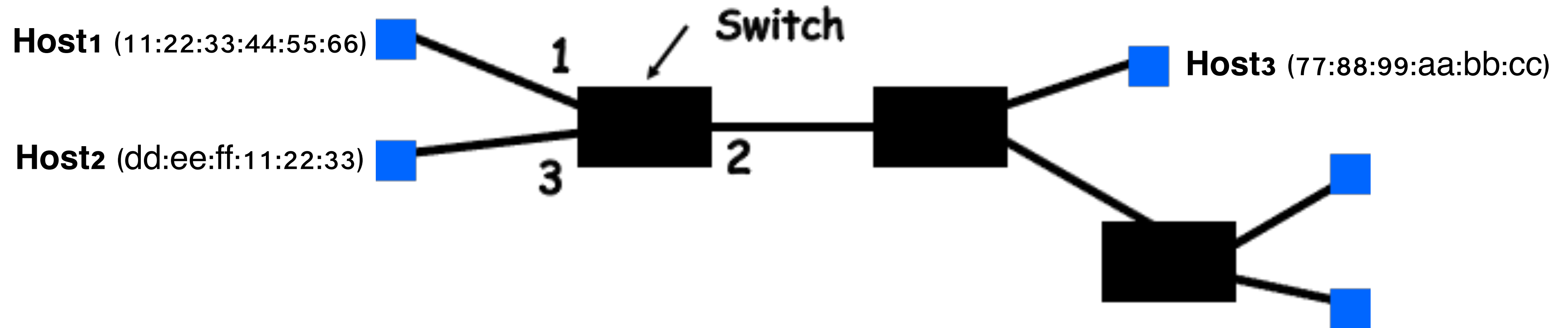**What is the size of the forwarding table?**

# Forwarding Logic

For every frame, the switch "looks up" the entry for the frame's destination MAC address and forwards the frame to that port

- No entry –> Drop or broadcast

What is the size of the forwarding table?

- >= The number of NIC ports in the network

# An Example



| MAC address | Port | Age (s) |
|:---:|:---:|:---:|
| **11:22:33:44:55:66** | 1 | 2 |
| **77:88:99:aa:bb:cc** | 2 | 4 |
| **dd:ee:ff:11:22:33** | 3 | 6 |

# An Example

Where is this table coming from?

| MAC address | Port | Age (s) |
|---|---|---|
| 11:22:33:44:55:66 | 1 | 2 |
| 77:88:99:aa:bb:cc | 2 | 4 |
| dd:ee:ff:11:22:33 | 3 | 6 |

**Q3: How to forward a frame given a destination address in the Ethernet?**
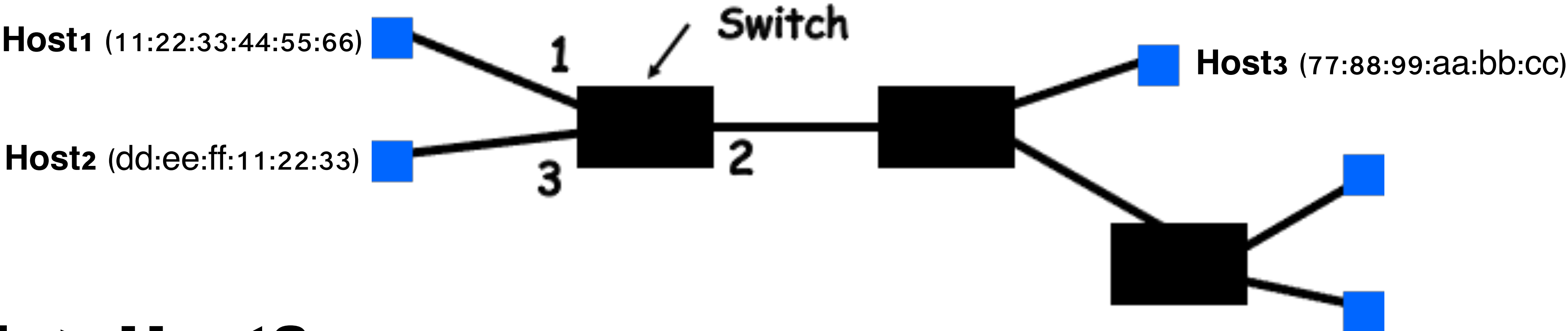
**A: Use a forwarding/switching table**
**+ Table establishment**

# MAC Learning

## Keep track of the source address of a frame and the arriving interface

- Fill in the forwarding table with the learned source address and incoming port
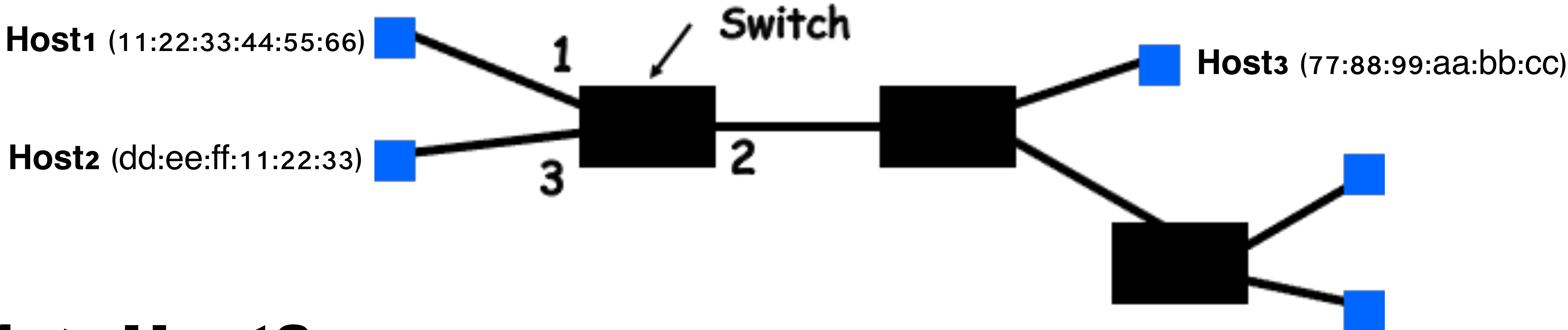
# MAC Learning Example



**Host1** (11:22:33:44:55:66)

**Host2** (dd:ee:ff:11:22:33)

**Host3** (77:88:99:aa:bb:cc)

Switch

1

3

2

## Host1 -> Host3

| MAC address | Port | Age (s) |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

# MAC Learning Example



Host1 (11:22:33:44:55:66)

Host2 (dd:ee:ff:11:22:33)

Switch

Host3 (77:88:99:aa:bb:cc)

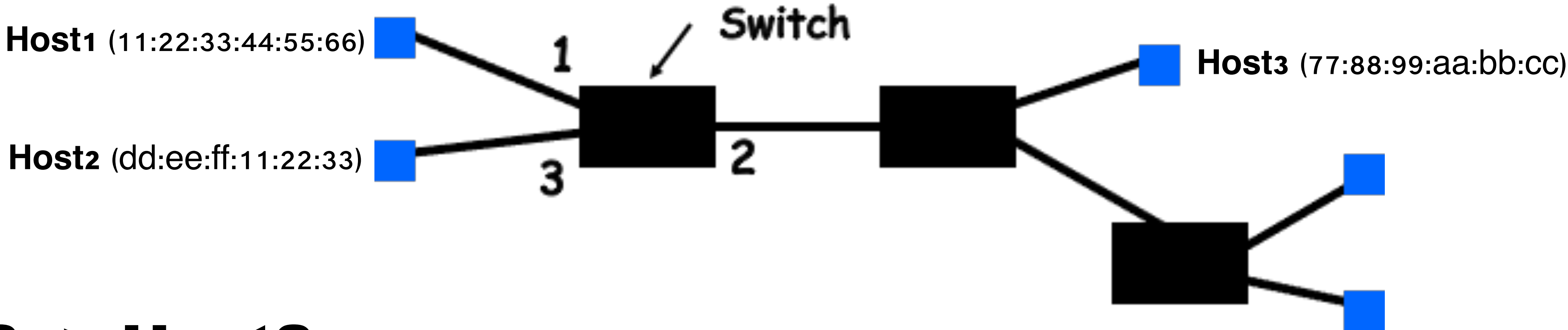## Host1 -> Host3

- The frame comes to port 1 and then broadcast
- The default aging time is 10s

| MAC address | Port | Age (s) |
|---|---|---|
| 11:22:33:44:55:66 | 1 | 10 |
| | | |
| | | |
| | | |

# MAC Learning Example



Host1 (11:22:33:44:55:66)

Host2 (dd:ee:ff:11:22:33)

Switch

Host3 (77:88:99:aa:bb:cc)

## Host3 -> Host2

- The frame comes to port 2 and then broadcast

| MAC address | Port | Age (s) |
|---|---|---|
| 11:22:33:44:55:66 | 1 | 8 |
| 77:88:99:aa:bb:cc | 2 | 10 |
| | | |
| | | |

# MAC Learning Example



Host1 (11:22:33:44:55:66)

Host2 (dd:ee:ff:11:22:33)

Host3 (77:88:99:aa:bb:cc)
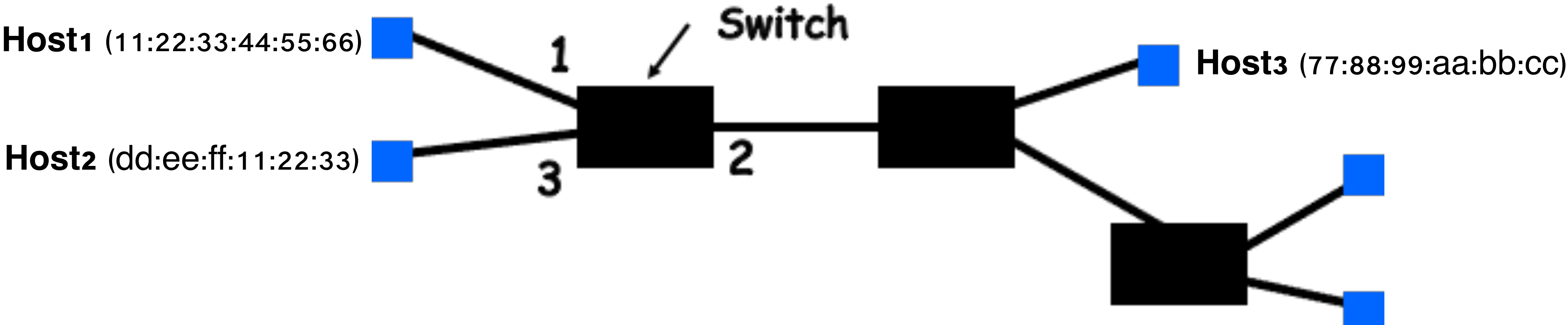
Switch

## Host3 -> Host1

- Frames come to port 2 and then forward

| MAC address | Port | Age (s) |
|---|---|---|
| 11:22:33:44:55:66 | 1 | 6 |
| 77:88:99:aa:bb:cc | 2 | 8 |
| | | |
| | | |

# Forwarding Inside a Switch
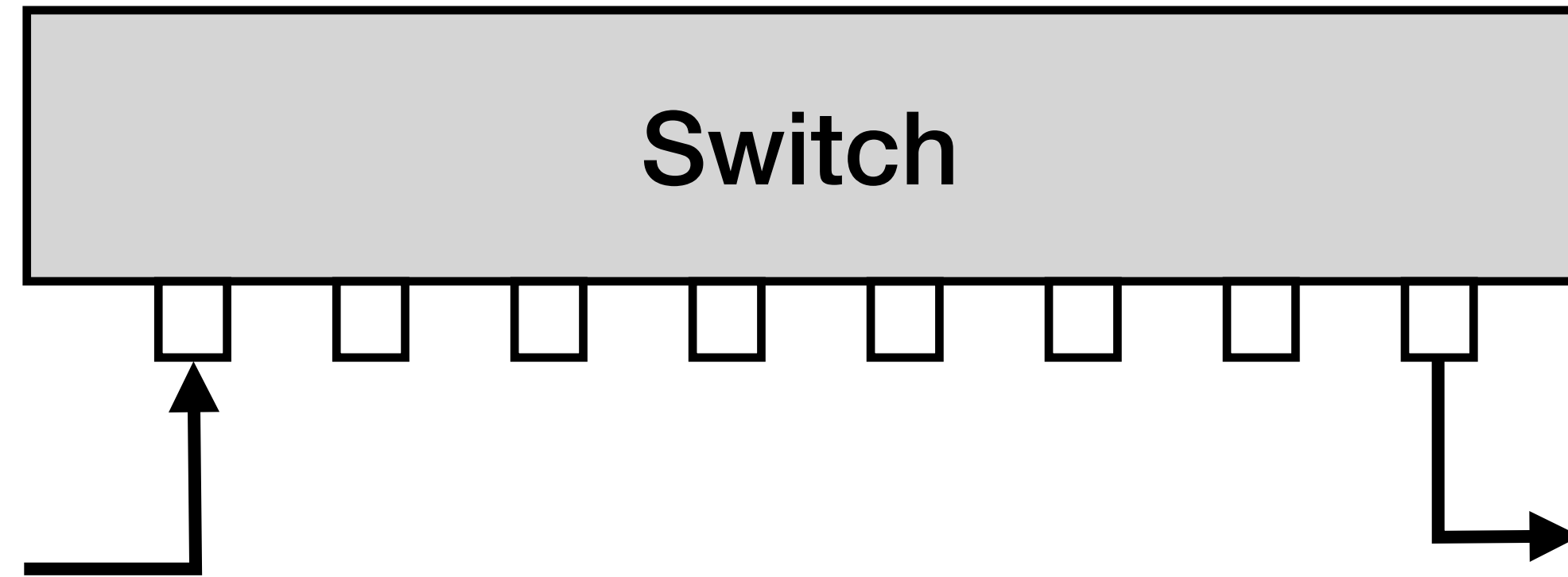
# Forwarding Inside a Switch

**Switches have different forwarding techniques**

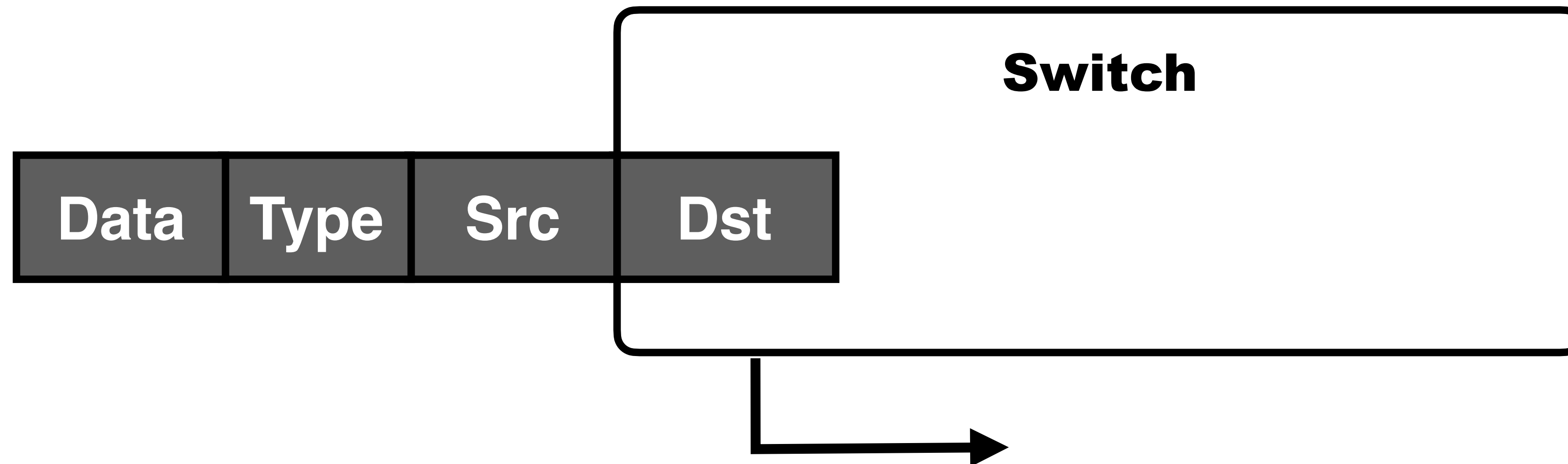| Data | Type | Src | Dst |
|------|------|-----|-----|
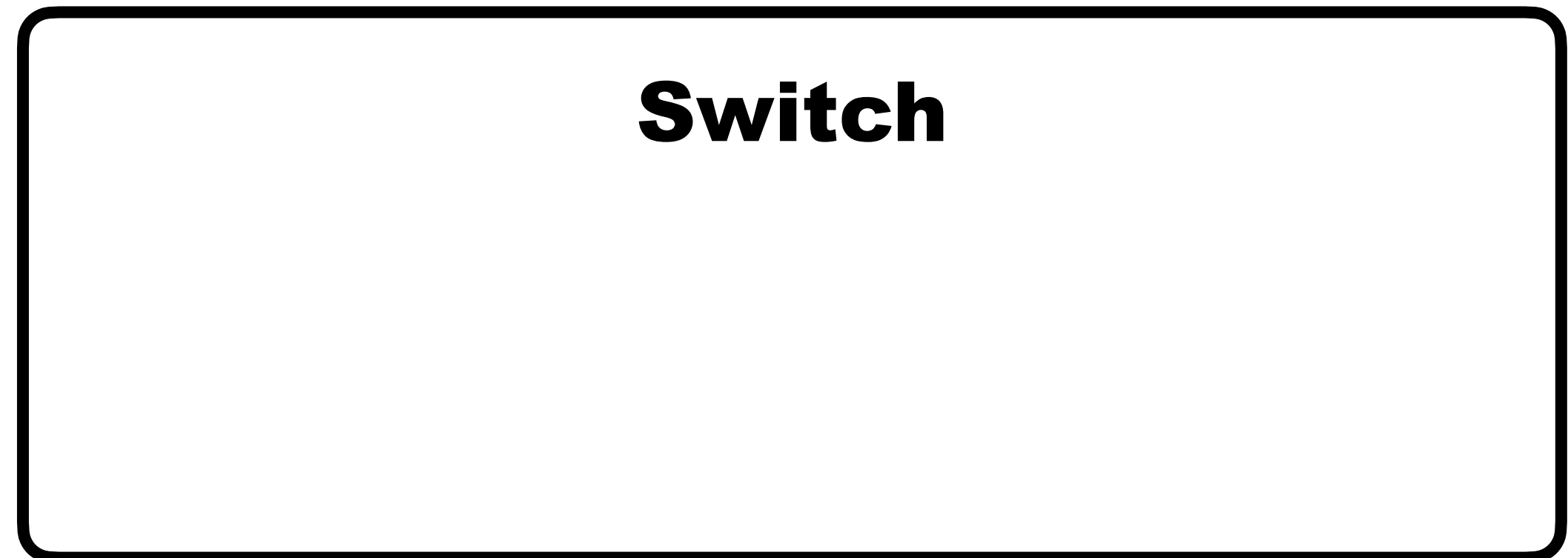
**Switch**

# Store-and-Forward Switching

A switch perform store-and-forward will wait to forward a frame until it receives the entire frame
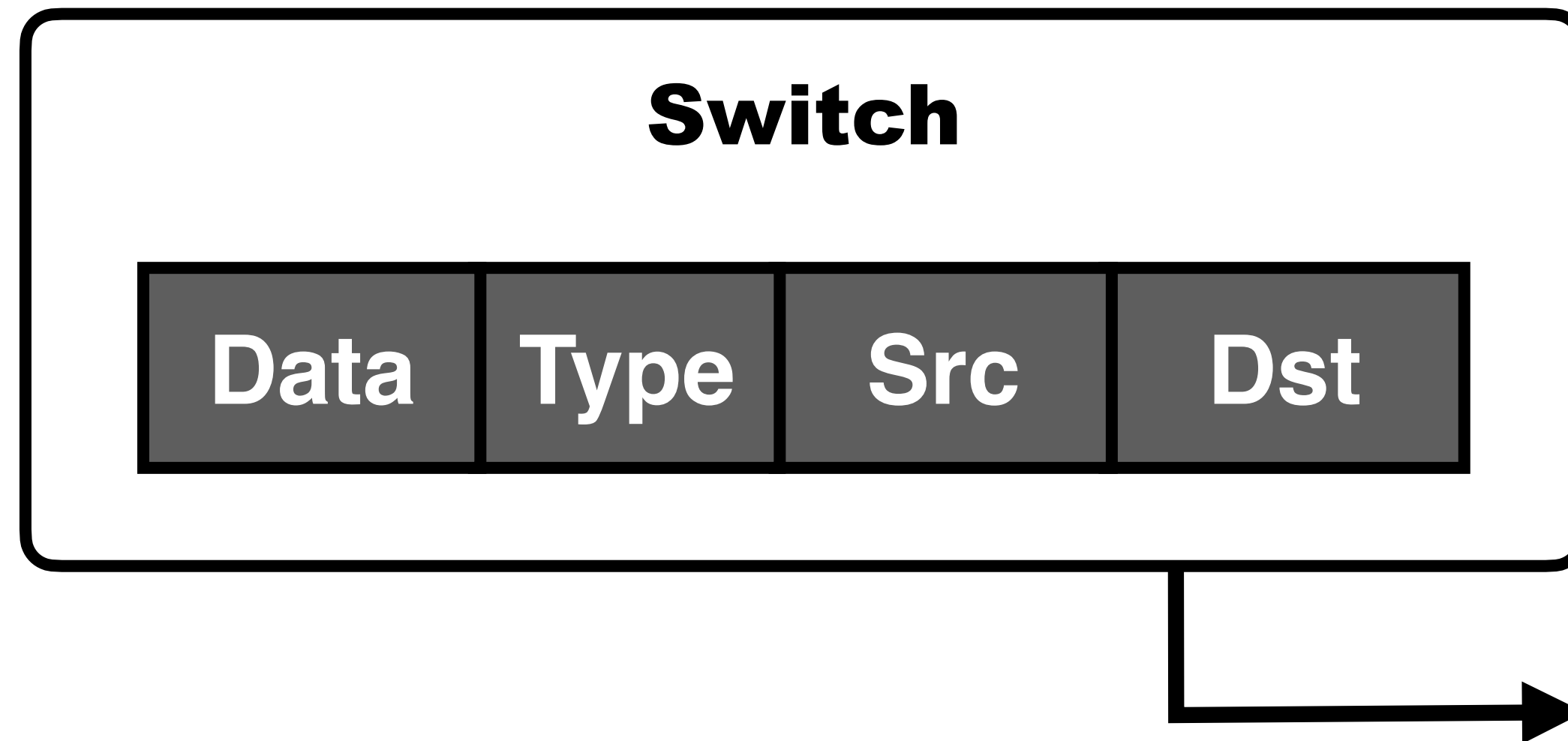
# Cut-Through Switching

A cut-through switch will forward the frame before it has completed receiving the frame

**Switch**

| Data | Type | Src | Dst |

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**Question 2. [5 points] Hardware infrastructure**

(a). [**1.5 points**] Suppose a NIC has 2 ports, where it can forward traffic between these two ports. A host only has 1 NIC. Can we build a 10 hosts network where all hosts are fully connected (i.e., there is a connection between any two hosts)? If so, please give an example.

(b). [**1.5 points**] The fat tree topology has been widely used to construct data center networks. Below is an example. How many communication paths are between NIC1 and NIC4?
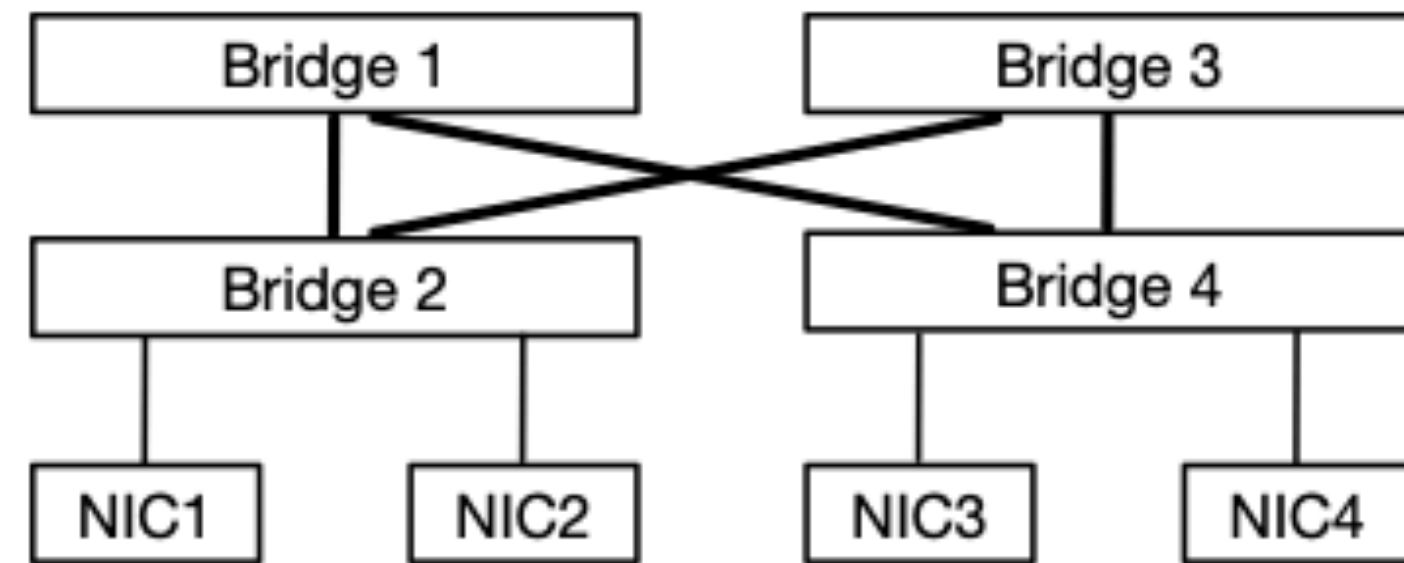


(c). [**2 points**] Given the above network topology, how many communication paths are between NIC1 and NIC2?

## Terminology

1. Host
2. NIC
3. Multi-port I/O bridge
4. Protocol
5. RTT
6. Packet
7. Header
8. Payload
9. BDP
10. Baud rate
11. Frame/Framing
12. Parity bit
13. Checksum
14. Ethernet
15. MAC
16. (L2) Switch
17. Broadcast

## Principle

1. Layering

## Technique

1. NRZ Encoding
2. NRZI Encoding
3. Manchester Encoding
4. 4B/5B Encoding
5. Byte Stuffing
6. Byte Counting
7. Bit Stuffing
8. 2-D Parity
9. CRC
10. MAC Learning
11. Store-and-Forward
12. Cut-through

# Summary

## Today's takeaways

#1: L2 switching uses the MAC address in the Ethernet

#2: The switch should provide MAC learning and forwarding capabilities

## Next lecture

• Spanning tree protocol

• Ethernet more