# CS3.301 Operating Systems and Networks

## Networking - Link Layer and MAC Addressing

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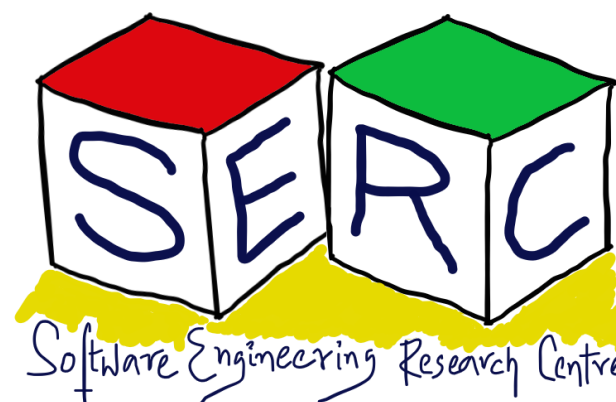
# Acknowledgement

The materials used in this presentation have been gathered/adapted/generate from various sources as well as based on my own experiences and knowledge -- Karthik Vaidhyanathan

Sources:
- Computer Networks, 6e by Tanebaum, Teamster and Wetherall
- Computer Networks: A Top Down Approach by Kurose and Ross
- Computer Networking essentials, Youtube Channel
- Other online sources which are duly cited
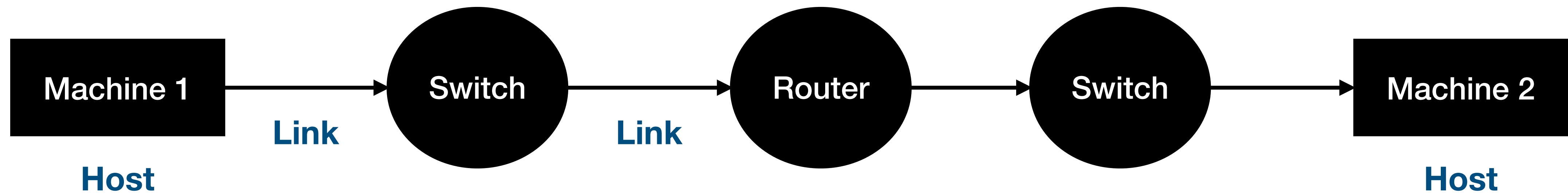
# The Bigger Picture
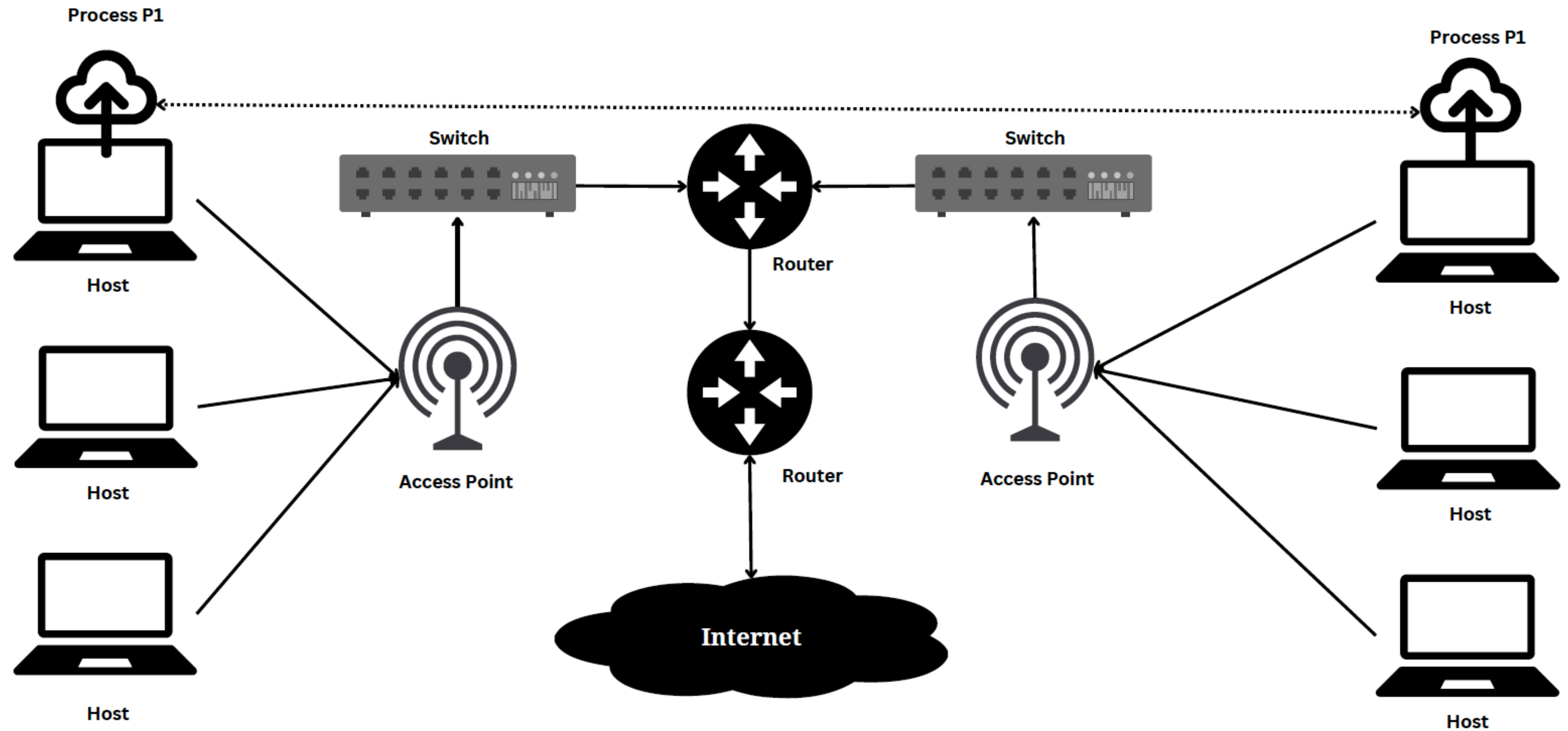
# How does host to host communication work?

# What's the contribution of the link layer?

# Remember the Components?



| Machine 1 | → | Switch | → | Router | → | Switch | → | Machine 2 |

**Host**     **Link**     **Link**     **Host**

# What we have seen so far

- **Application layer**

  - Provides support for end applications to format and manage data

  - HTTP, DNS, SMTP, etc.

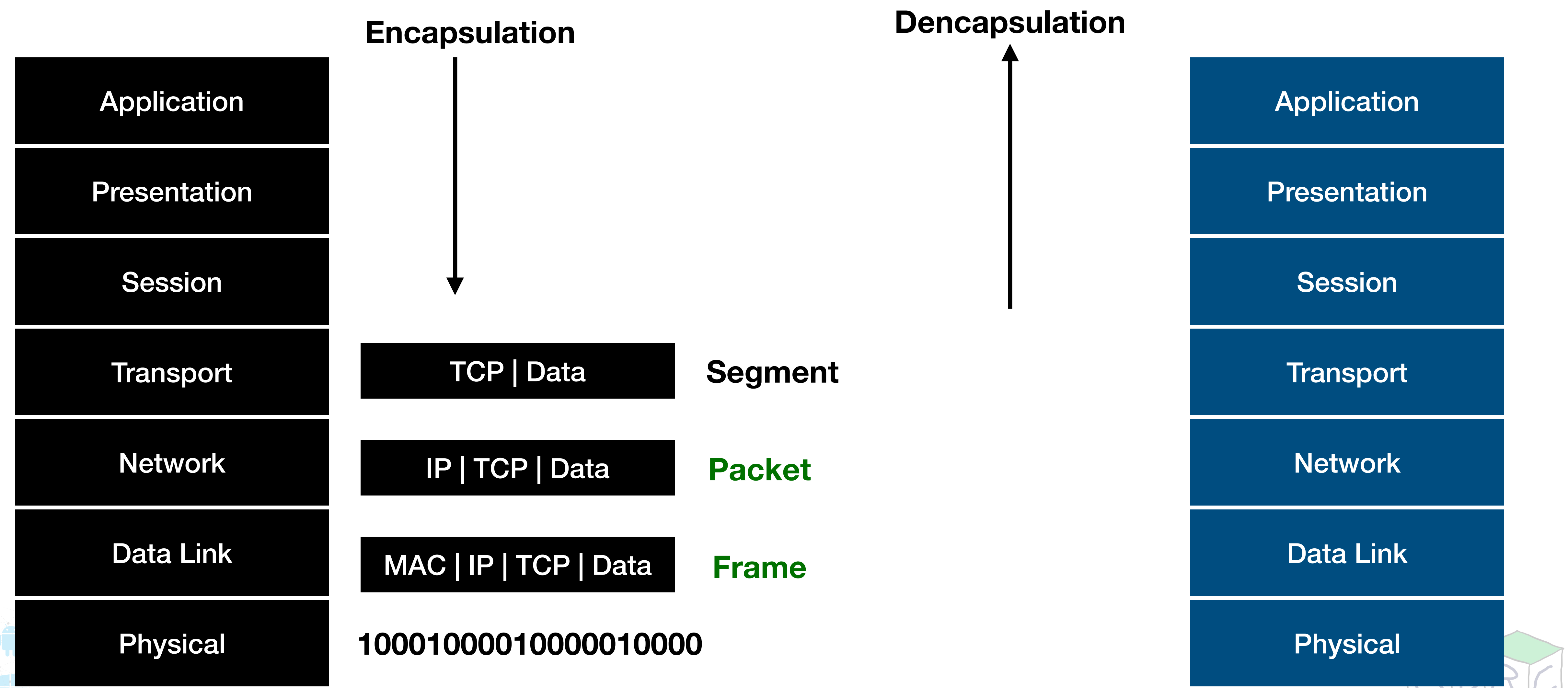  - In turn they make use of transport layer protocols

- **Transport layer**

  - Provides support for communication between services

  - TCP, UDP

  - Ports helps in identifying the right services/process

  - But transport layer by itself is not enough! - **Requires underlying support - Why?**

# Putting It Together

**Encapsulation**

**Dencapsulation**

| Application |
| :---: |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |

| TCP \| Data | Segment |
| :---: | :--- |

| IP \| TCP \| Data | **Packet** |
| :---: | :--- |

| MAC \| IP \| TCP \| Data | **Frame** |
| :---: | :--- |

**10001000010000010000**

| Application |
| :---: |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |

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# Link Layer

- Responsibility of transferring datagram from one node to a **physically adjacent node** over a link (no intermediate L3 routers)

- Supports **hop-to-hop** communication

- Ensures reliable connection link between two directly connected nodes (flow control, error correction and detection, etc.)

- Supported by **Media Access Control (MAC)** addressing

- Addressing scheme: MAC addressing (48 bit address, 12 hex digits, 6 bytes)

  - Eg: **00:1A:2B:3C:4D:5E**

  - First three identify manufacturer (IEEE)

  - Next three are assigned by manufacturer and should be unique

| Application |
| --- |
| Presentation |
| Session |
| Transport |
| Network |
| Data Link |
| Physical |
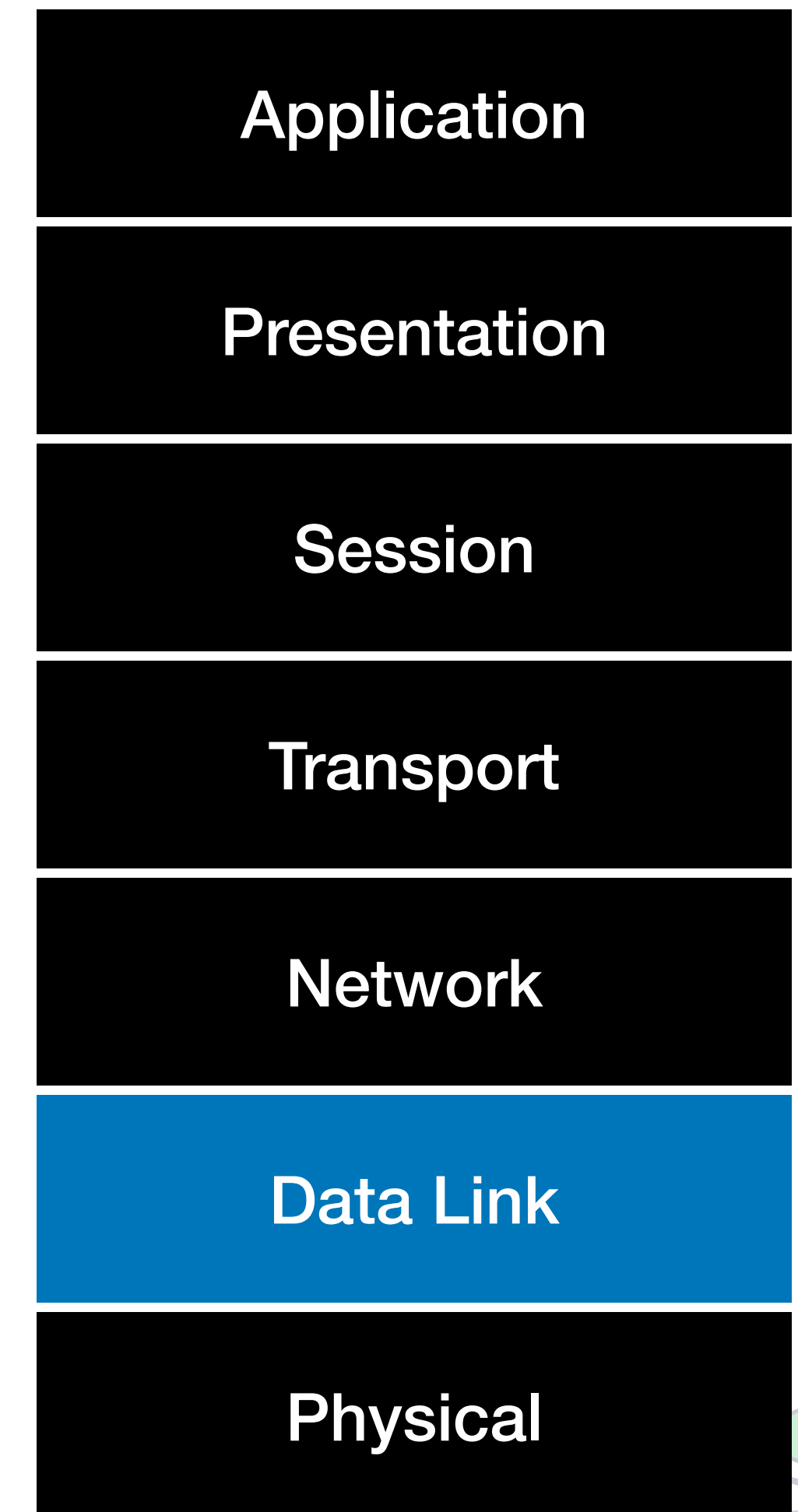
# Two process want to communicate with each other

- Two main possibilities

  - Two processes are running in machines in the same network

  - Two processes are running in machines in two different networks

- Same network

  - Two machines are connected through switches

  - It can be a large intranet but the machines are still in same network

# When machines are in same network

IP Address

Host 1 —— Switch —— Host 2

192.168.1.25
00:1A:2B:3C:4D:5E

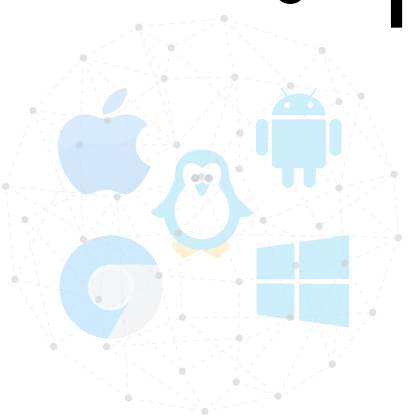192.168.1.29
00:45:6B:3C:5E:4F
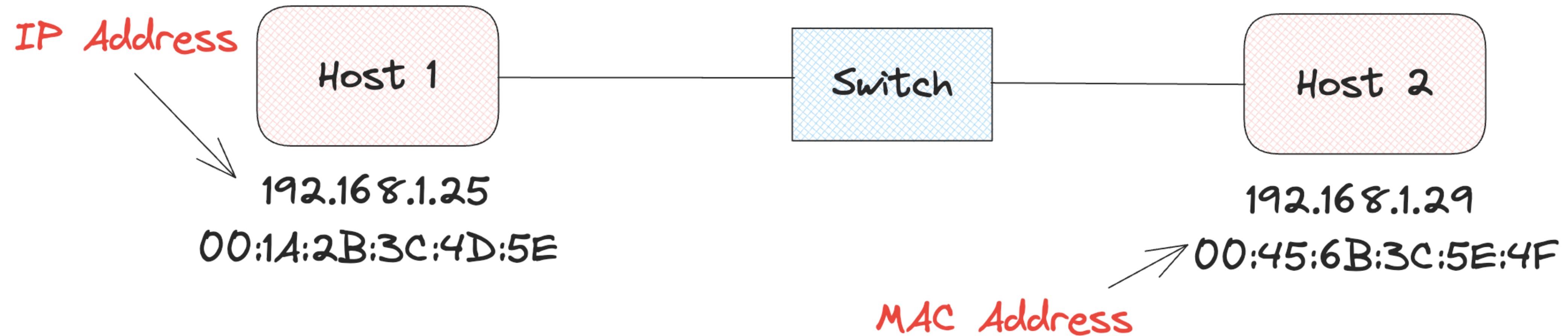
MAC Address

- Assume Host 1 wants to communicate to Host 2 known by domain host2.com

- Host 1 will know the IP address of Host 2 - **How?**

- IP address will help with L3 communication

- Will just the IP address suffice? What about L2? How to get the MAC address?
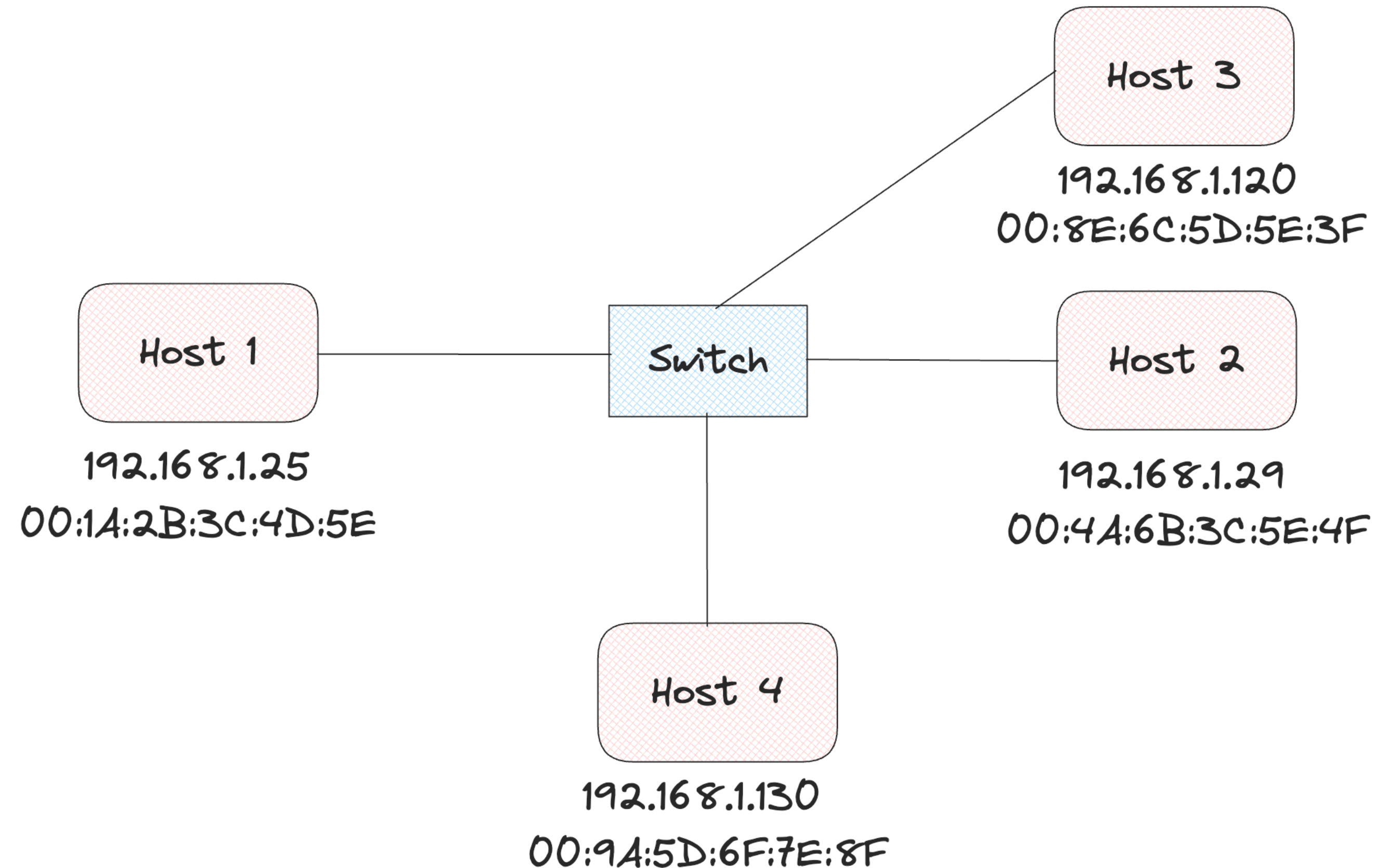
# Why MAC and not just IP

- **Analogy:**

  - MAC address is like Aadhar card number

  - IP address is like Postal address

- **MAC address is unique to each interface**

  - Each interface on a LAN has globally unique MAC address

  - Each interface has a **locally unique IP address**

- How to determine interface's MAC address knowing its IP address?

# ARP - Address Resolution Protocol (RFC 826)

Host 3
192.168.1.120
00:8E:6C:5D:5E:3F

Host 1
192.168.1.25
00:14:2B:3C:4D:5E

Switch

Host 2
192.168.1.29
00:4A:6B:3C:5E:4F

Host 4
192.168.1.130
00:9A:5D:6F:7E:8F

- Each IP node (router, host) on the LAN has a table - **ARP Cache/ARP Table**

- IP/MAC address mappings for some LAN nodes

  - **<ip address, MAC address, TTL>**

- **TTL:** Time to live, time after which the mapping will be forgotten (20 mins)
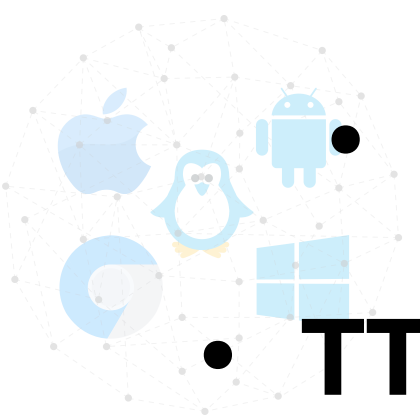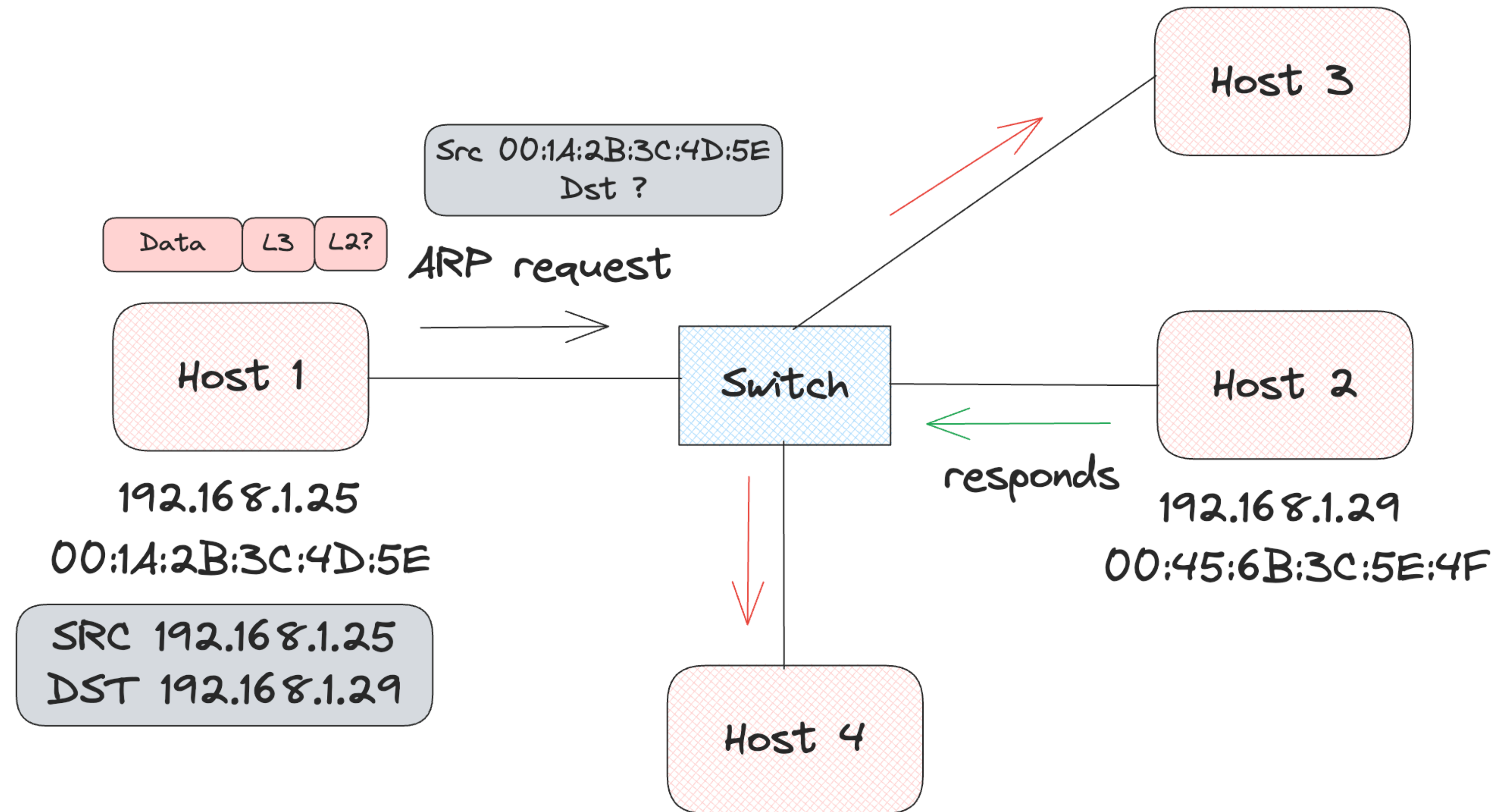
# ARP - Address Resolution Protocol

**ARP Table in Host 1**

| IP | MAC | TTL |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

Src 00:1A:2B:3C:4D:5E
Dst ?

Data | L3 | L2?

ARP request

Host 1

Host 3

Switch

Host 2

responds

Host 4

192.168.1.25

00:1A:2B:3C:4D:5E

SRC 192.168.1.25
DST 192.168.1.29

192.168.1.29

00:45:6B:3C:5E:4F

- Host 1 wants to send data to Host 2

- Sends ARP request to all the hosts in the network and updates table

# ARP Query

- When ARP query is sent initially, it is broadcast to all the nodes in the network

- The request includes senders IP address and MAC address

- It also includes the target IP address

  - Destination MAC is set as **FF:FF:FF:FF:FF:FF** (Reserved to send packet to all in the network)

- All the nodes will have an ARP cache or ARP table

  - It stores the mapping, when the initial request is send from one host, all other hosts stores the incoming mapping as well
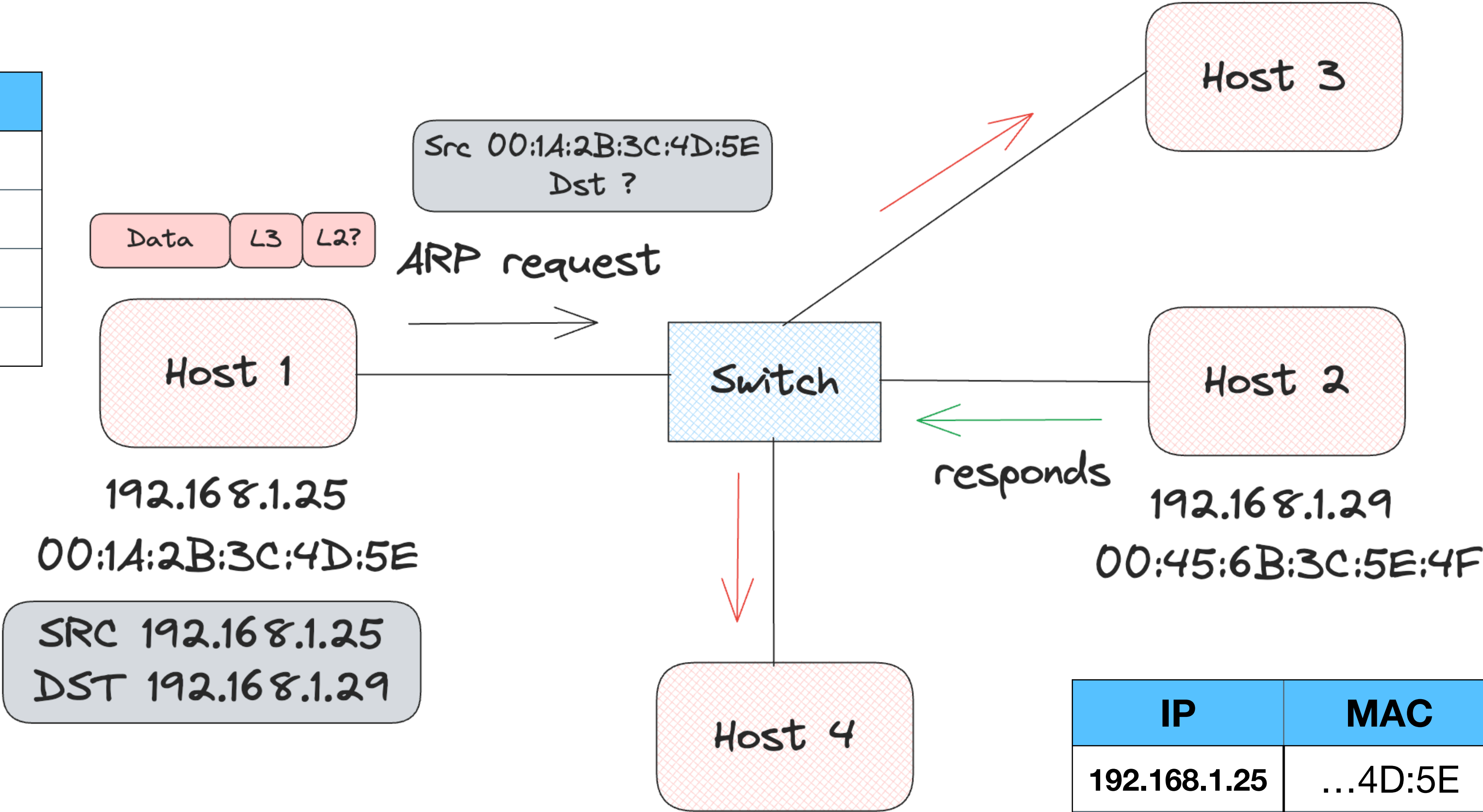
# ARP Table

| IP | MAC | TTL |
|---|---|---|
| 192.168.1.29 | …:5E:4F | 20 |
| | | |
| | | |
| | | |

**ARP Table at Host 1**

Data | L3 | L2?

Src 00:14:2B:3C:4D:5E
Dst ?

ARP request

Host 1

192.168.1.25
00:14:2B:3C:4D:5E

SRC 192.168.1.25
DST 192.168.1.29

Switch

Host 3

Host 2

responds

192.168.1.29
00:45:6B:3C:5E:4F

Host 4

**Host 2 is saving the MAC of Host 1 request in its ARP table**

| IP | MAC | TTL |
|---|---|---|
| 192.168.1.25 | …4D:5E | 20 |
| | | |
| | | |
| | | |

# When Machines are in Different Network



Host 1 — 192.168.1.25 — 7E:8F — /24
subnet mask 255.255.255.0

Host 4 — 192.168.1.32 — 9F:6D — /24

Router — 172.18.12.92 — 1A:2D — /24

Host 3 — 10.8.17.81 — 9C:5A — /24

Host 2 — 10.8.17.65 — 2B:8E — /24
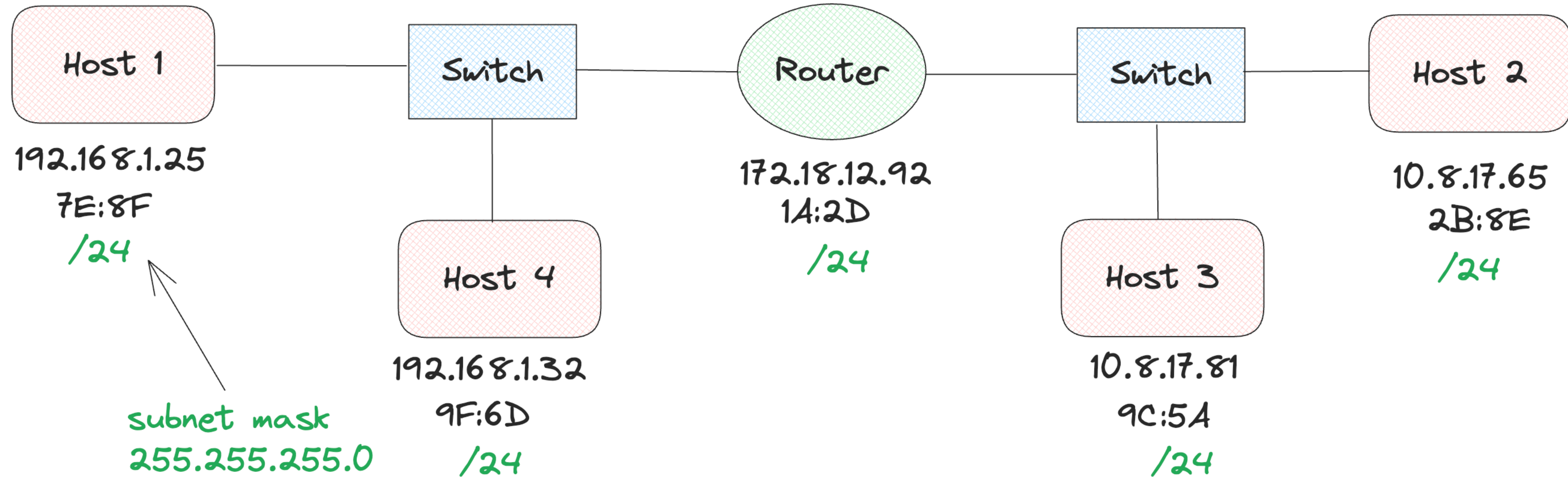
- Host 1 wants to communicate to Host 2 - Knows the IP address

- Host 1 also knows that Host 2 is not in the same network? - **How?**

  - /24 - Subnet mask, what do we mean by that?

  - Router **bridges** the two different networks

# Subnets

- Practice of dividing a network into one or more networks is subnetting

- Allows to create hierarchy within an organisation

  - Think about 172.18.21.x (country.organization.department.machine)

  - Another set of IP within organisations 172.18.y.x

- Consider an IP address 172.18.21.0 with a subnet mask of 255.255.255.0 or /24

  - Implies one network that can contain 254 host addresses (only the last one can change)

  - /24 - CIDR Notation (Classless Inter domain routing) - Number of 1s in the address

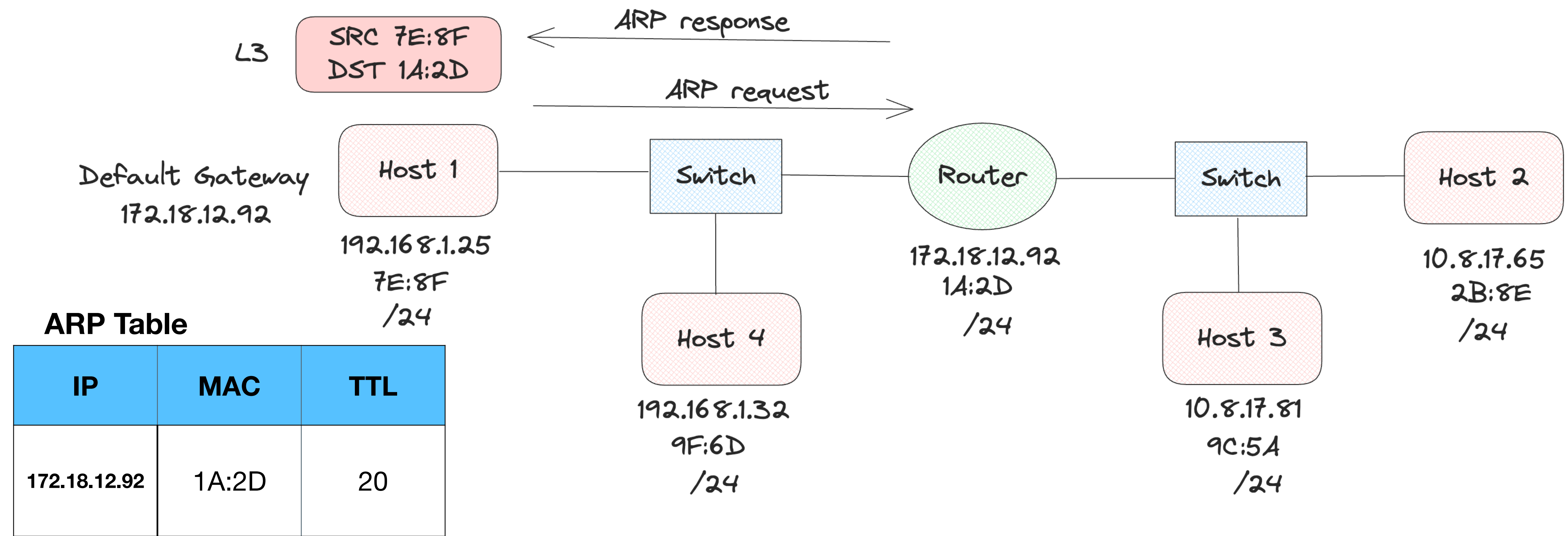  - **What about subnet mask 255.255.0.0? Or /16?**
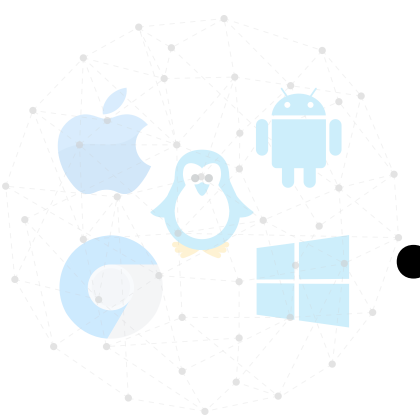
# When Machines are in Different Network
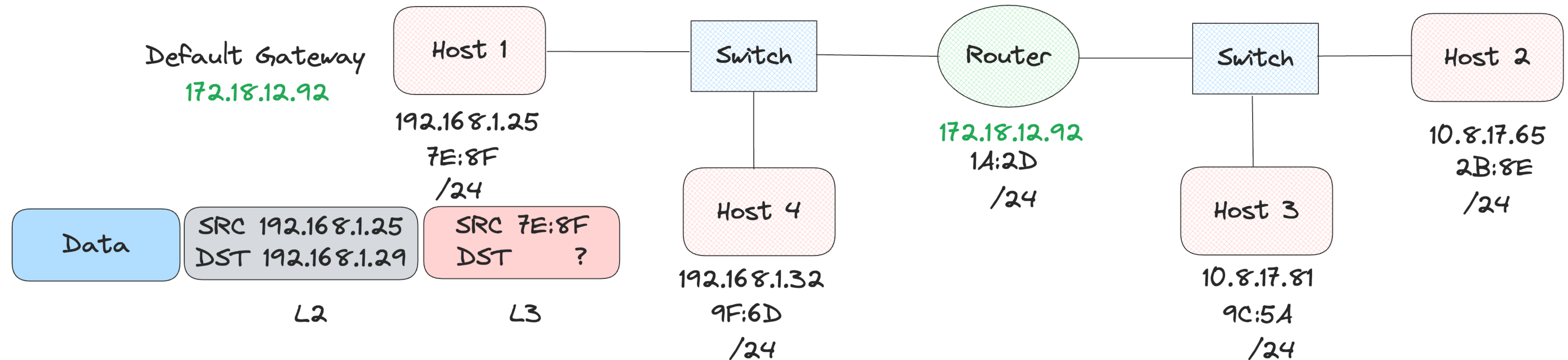


- Host 1 does not know the destination MAC address

- It need not broadcast to all MAC in the same network - **Why?**

- It can make use of the default gateway - IP address of the router

# When Machines are in Different Network

L3

SRC 7E:8F
DST 14:2D

ARP response

ARP request

Default Gateway
172.18.12.92

**Host 1**

192.168.1.25
7E:8F
/24

**Switch**

**Router**

172.18.12.92
14:2D
/24

**Switch**

**Host 2**

10.8.17.65
2B:8E
/24

**Host 4**

192.168.1.32
9F:6D
/24

**Host 3**

10.8.17.81
9C:5A
/24

**ARP Table**

| IP | MAC | TTL |
|---|---|---|
| 172.18.12.92 | 1A:2D | 20 |

- The ARP process needs to happen only once, since router is the gateway

- First step - Check if the IP of the receiver is in the same or different network

- If different network => Send ARP to gateway else, send ARP to all nodes in the network (FF:FF.....:FF)

# How does end-to-end communication work?

# What is the role of the network layer?

# Thank you

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**Twitter: @karthi_ishere**