CS3.301 Operating Systems and Networks

Networking - Link Layer and MAC Addressing

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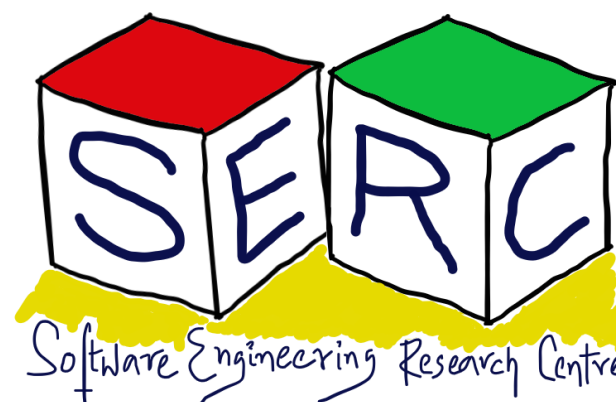
Acknowledgement

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
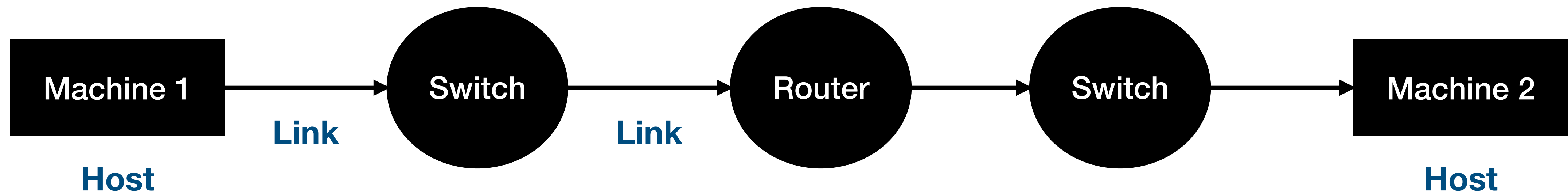
The Bigger Picture
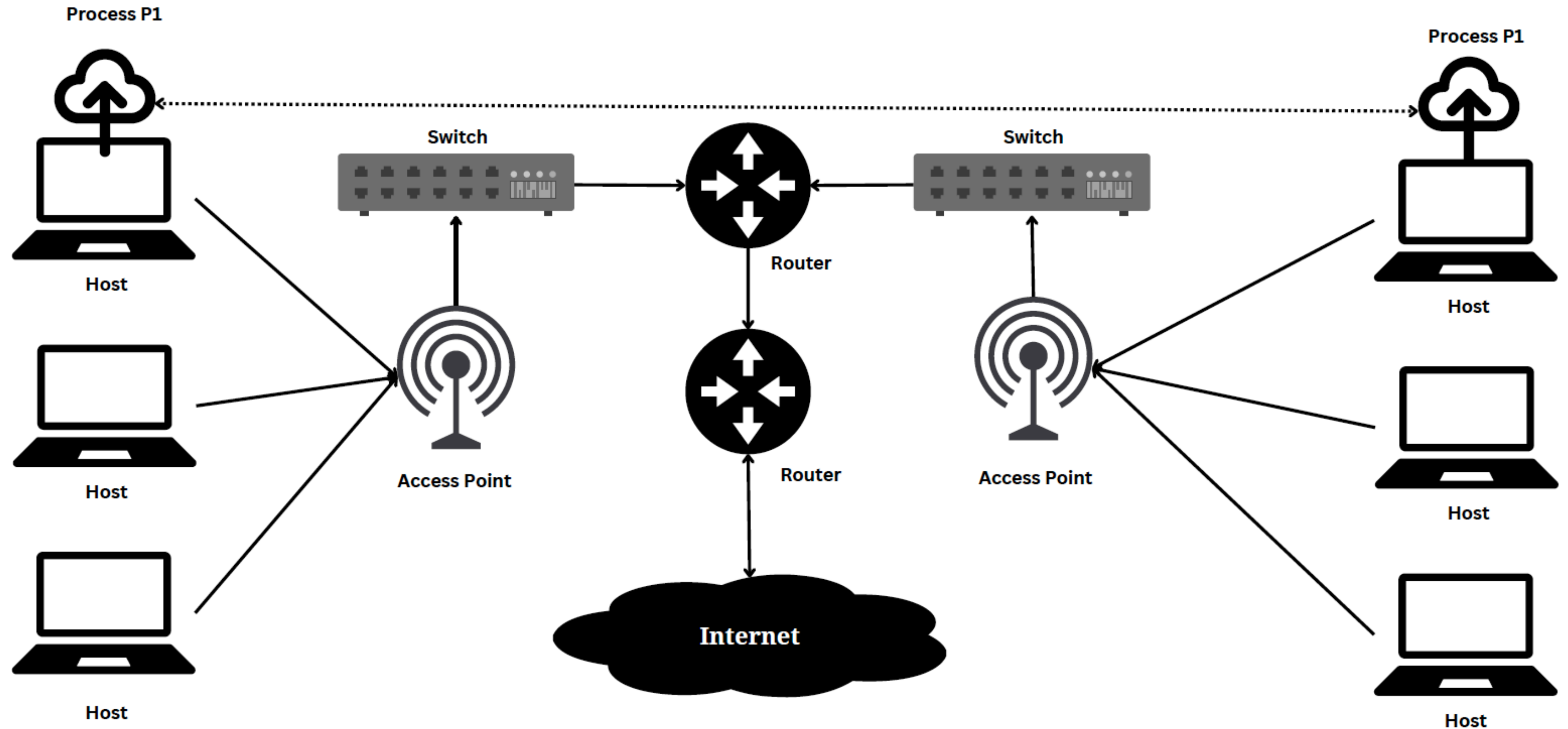
How does host to host communication work?

What's the contribution of the link layer?

Remember the Components?

Machine 1 — **Host** — **Link** — Switch — **Link** — Router — Switch — Machine 2 — **Host**

What we have seen so far

- **Application layer**

  - Provides support for end applications to format and manage data

  - HTTP, DNS, SMTP, etc.

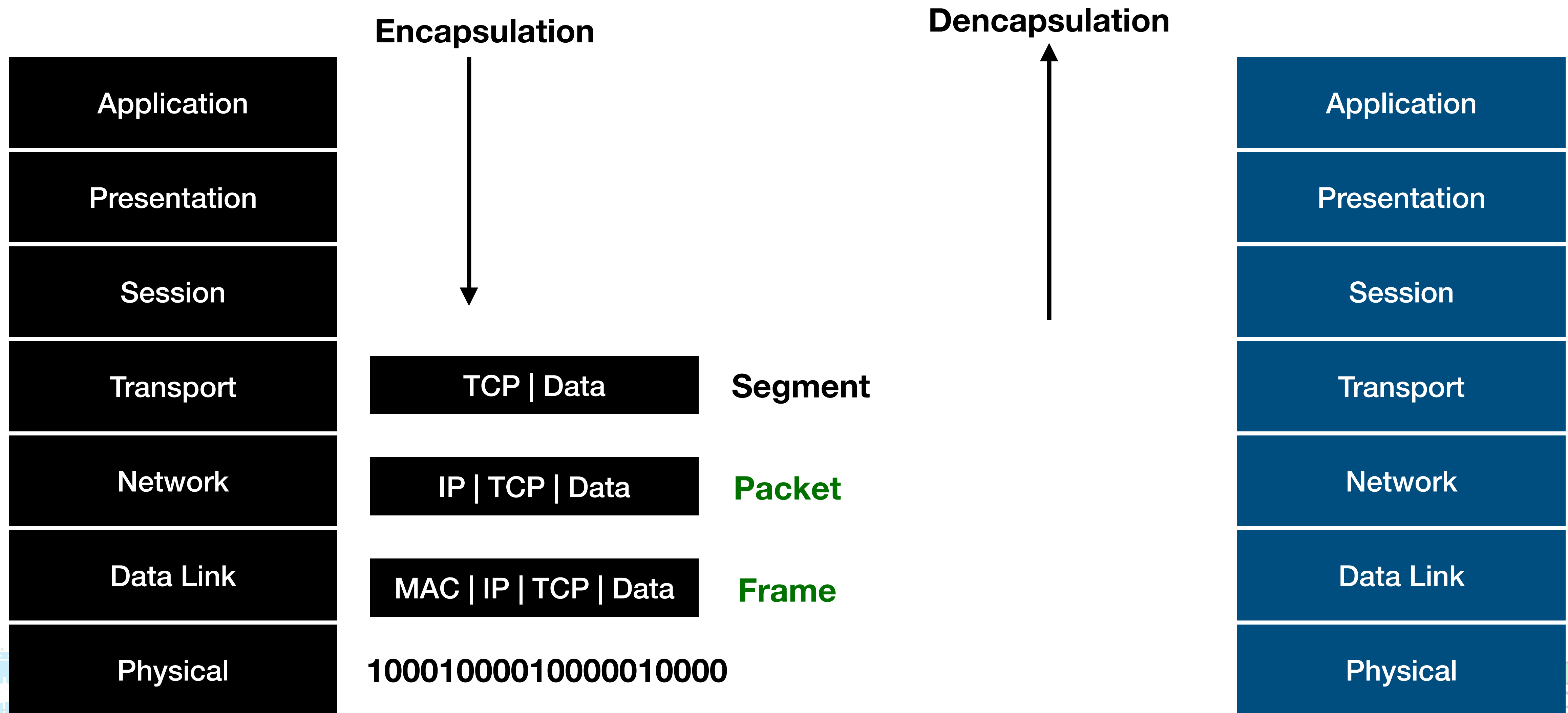 - In turn they make use of transport layer protocols

- **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

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 |
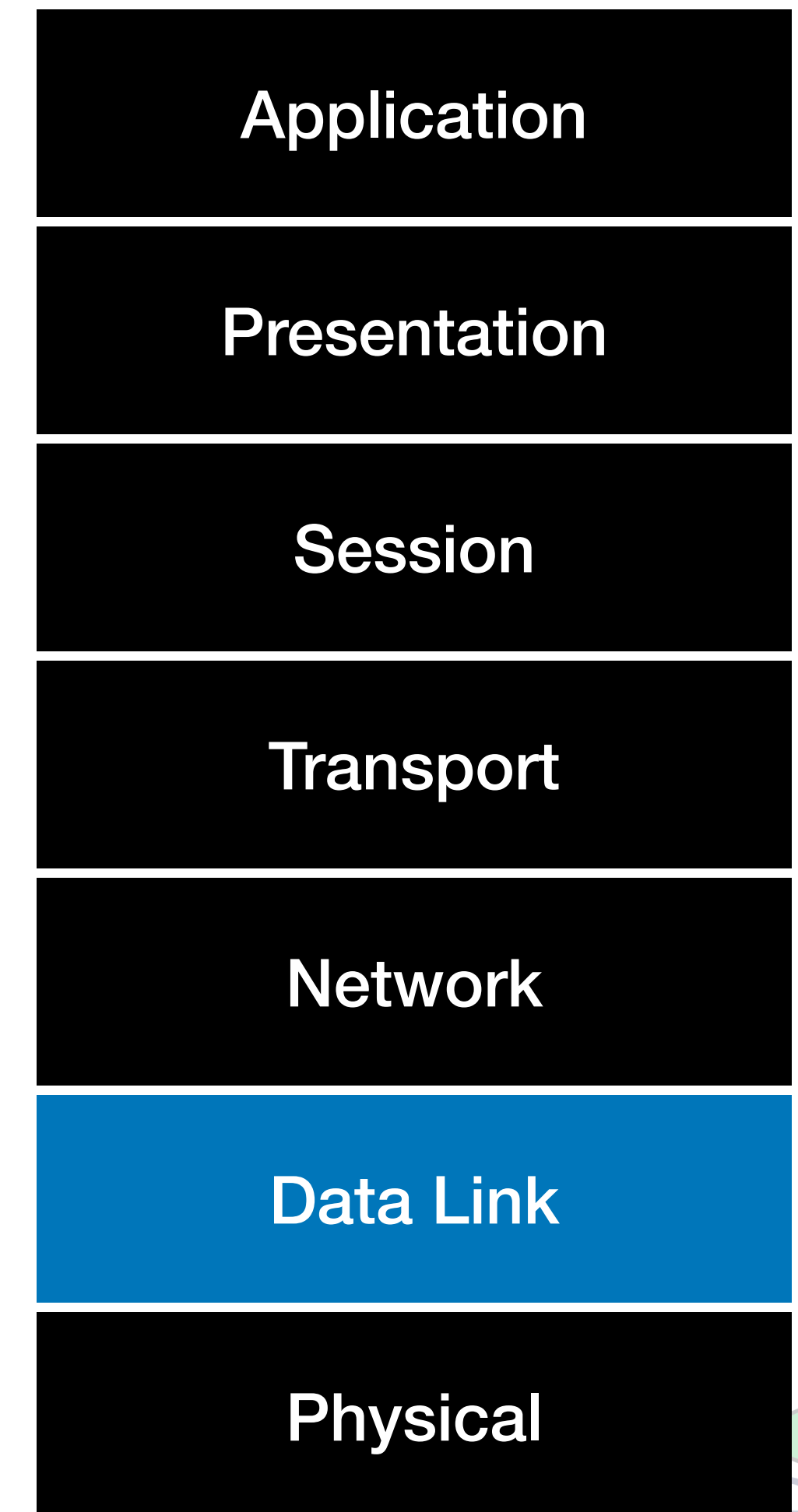
Two process want to communicate with each other

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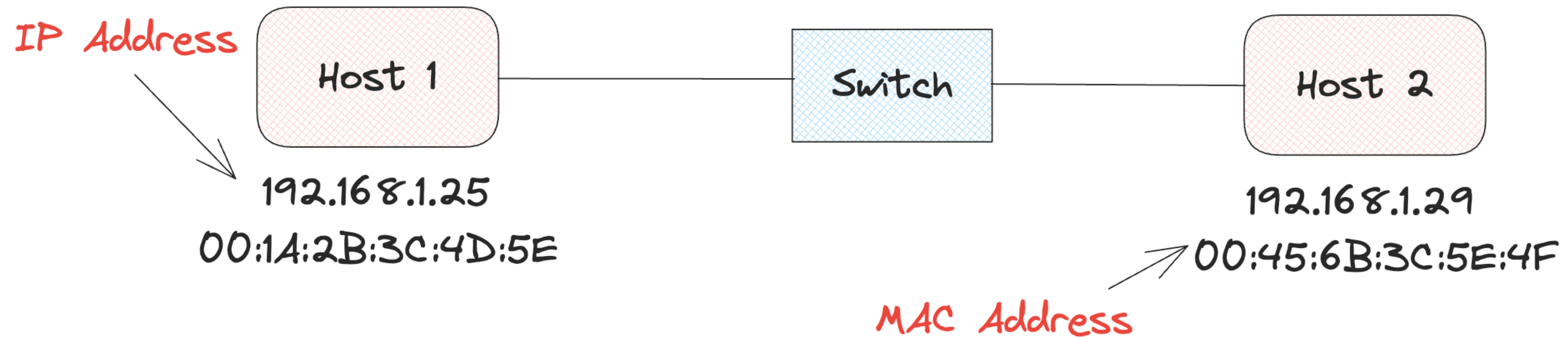
- Assume Host 1 wants to communicate to Host 2 known by domain host2.com

- 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**

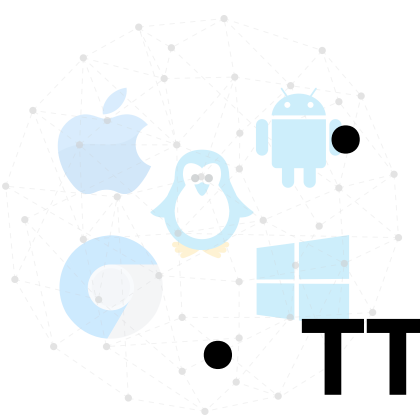- How to determine interface's MAC address knowing its IP address?

ARP - Address Resolution Protocol
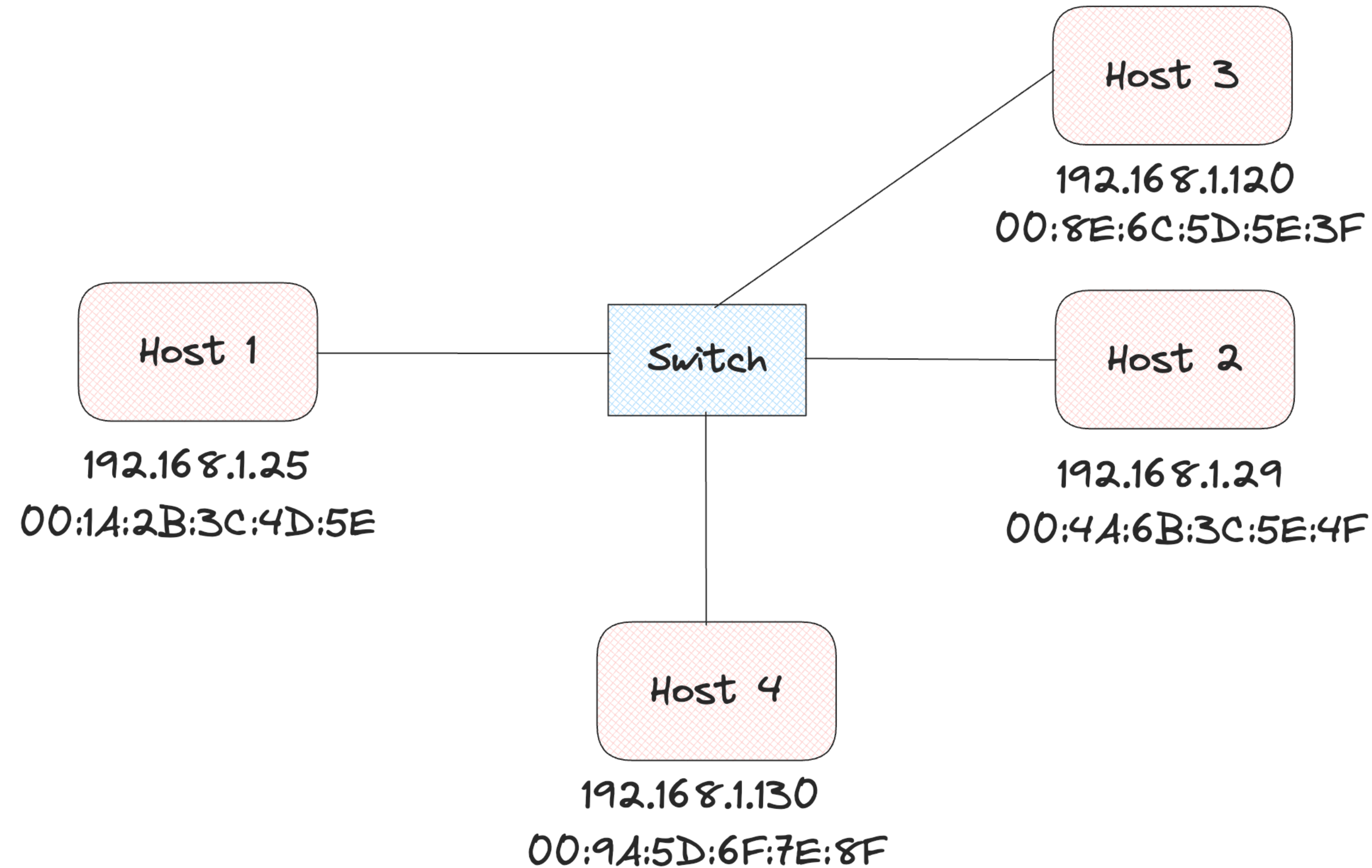
- Each IP node (router, host) on the LAN has a table - **ARP Table**

- IP/MAC address mappings for some LAN nodes
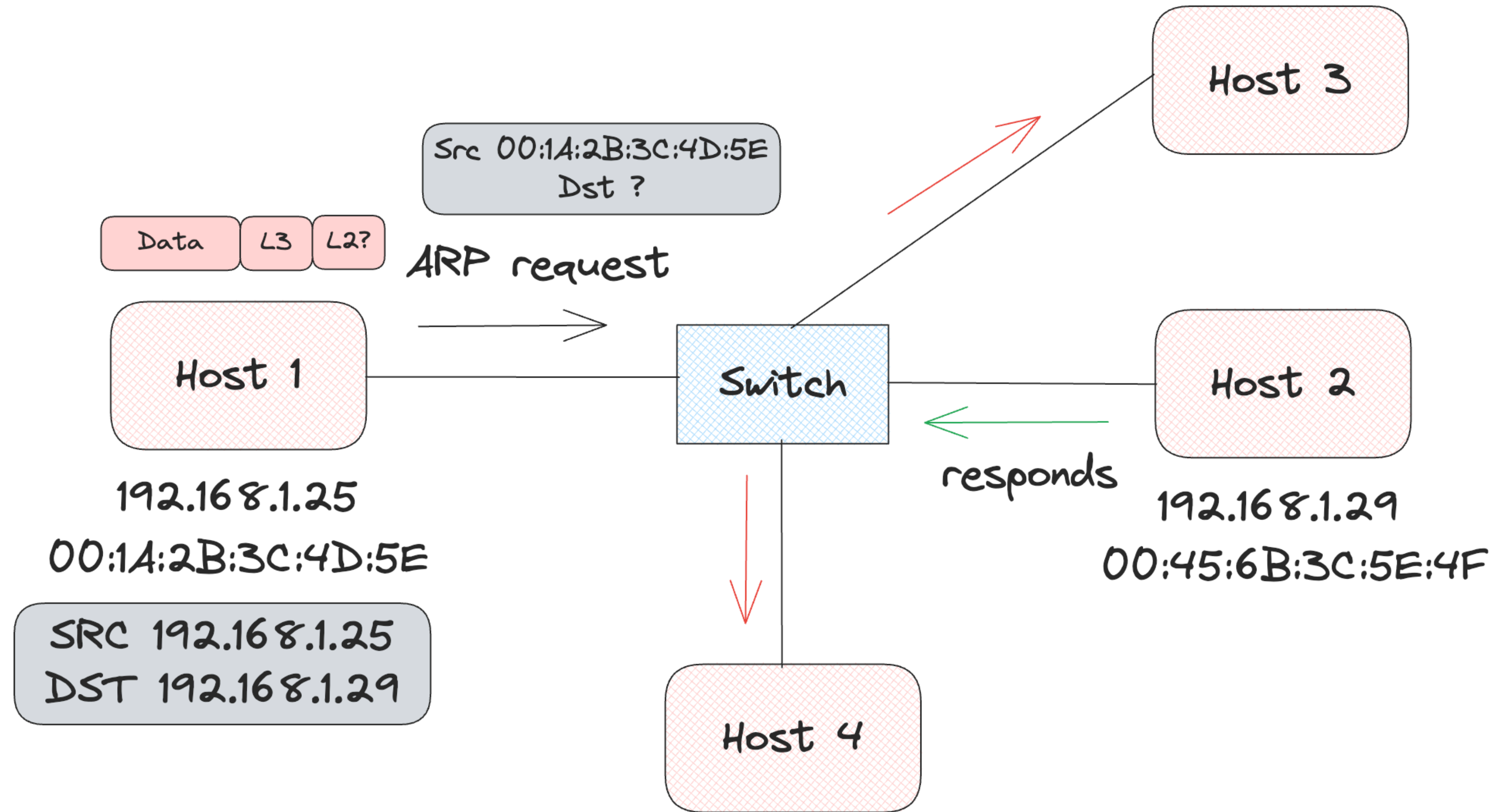
  - **<ip address, MAC address, TTL>**

- **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 3

Host 1

Switch

Host 2

responds

192.168.1.25

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

192.168.1.29

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

SRC 192.168.1.25
DST 192.168.1.29

Host 4

- Host 1 wants to send data to Host 2

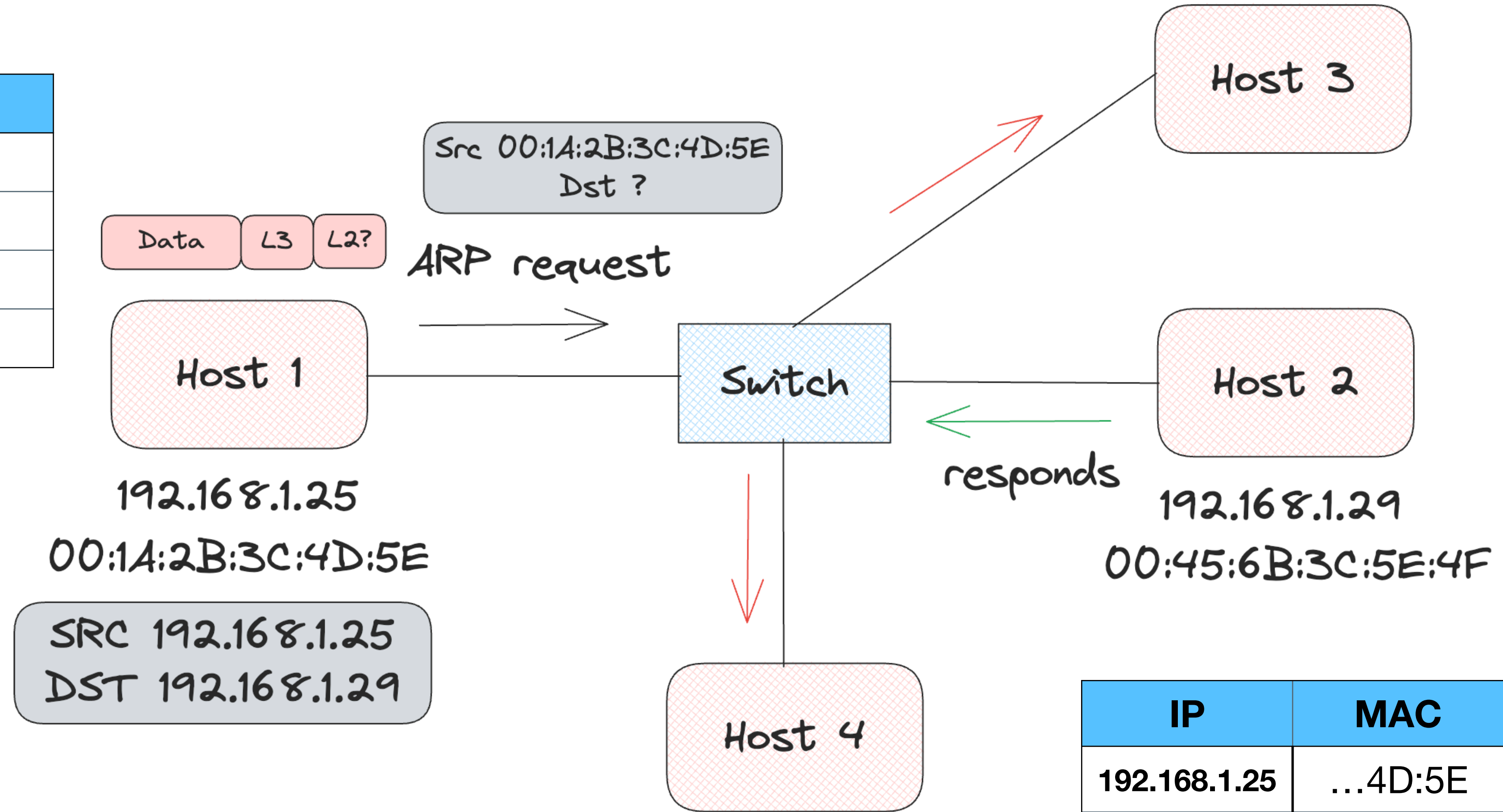- Sends ARP request to all the hosts in the network and updates table

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
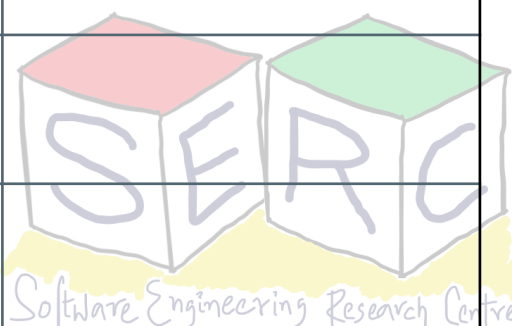
ARP Table

IP	MAC	TTL
192.168.1.29	…:5E:4F	20

ARP Table at Host 1

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

Data   L3   L2?

ARP request

Host 3

Host 1

Switch

Host 2

responds

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

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

SRC 192.168.1.25
DST 192.168.1.29

Host 4

IP	MAC	TTL
192.168.1.25	…4D:5E	20

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

15

When Machines are in Different Network

Host 1 — 192.168.1.25 — 7E:8F — /24

subnet mask 255.255.255.0

Switch

Host 4 — 192.168.1.32 — 9F:6D — /24

Router — 172.18.12.92 — 1A:2D — /24

Switch

Host 3 — 10.8.17.81 — 9C:5A — /24

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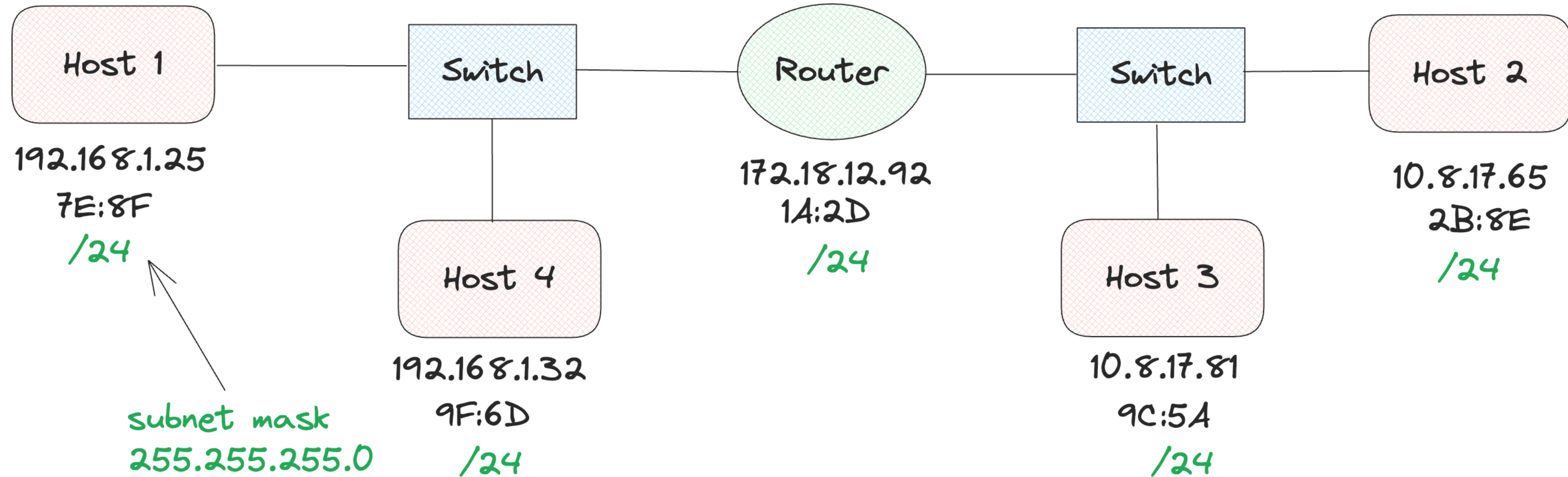
- Host 1 wants to communicate to Host 2 - Knows the IP address

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

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

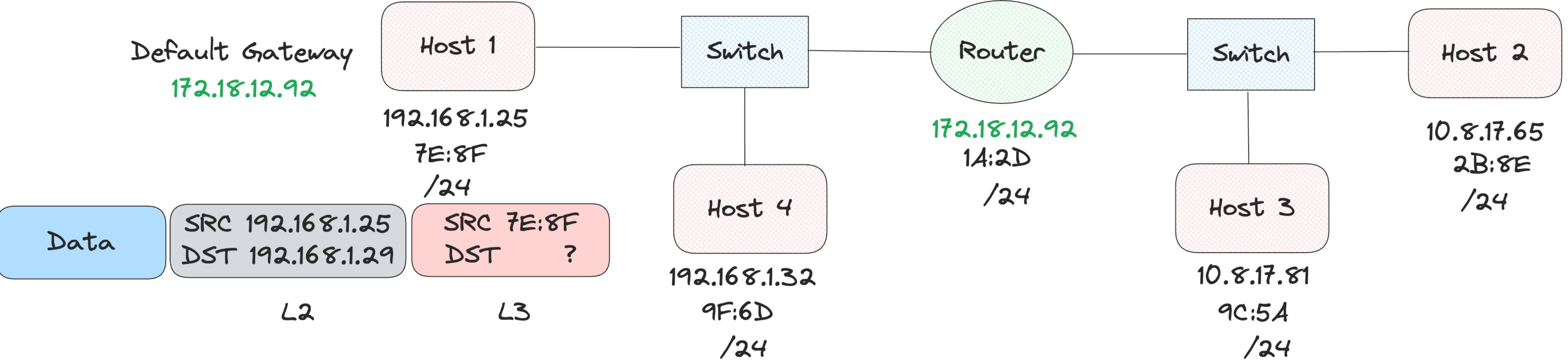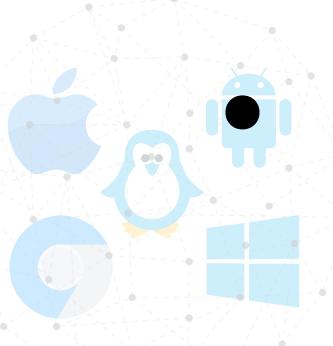 - Router **bridges** the two different networks
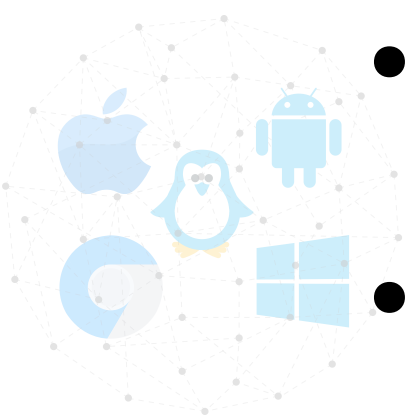
Subnets

- 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

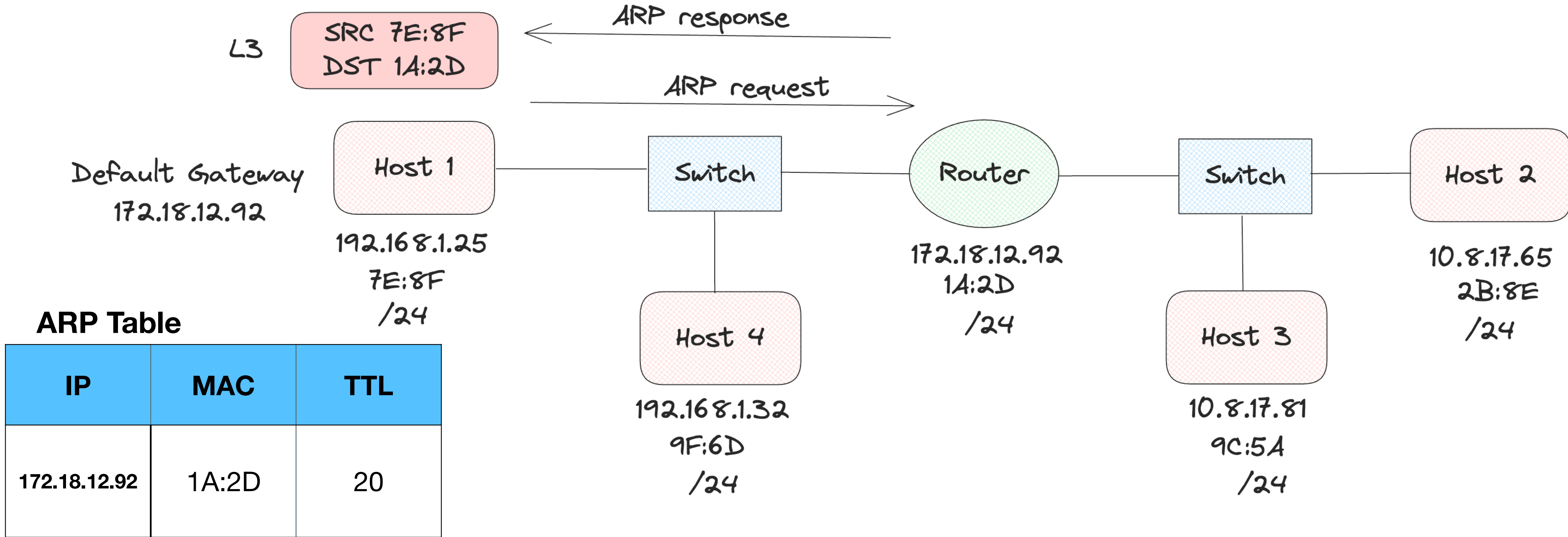 - **What about subnet mask 255.255.0.0? Or /16?**

When Machines are in Different Network

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

Data

SRC 192.168.1.25
DST 192.168.1.29

L2

SRC 7E:8F
DST   ?

L3

Host 4
192.168.1.32
9F:6D
/24

Host 3
10.8.17.81
9C:5A
/24

- 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

Host 4

192.168.1.32
9F:6D
/24

Router

172.18.12.92
14:2D
/24

Switch

Host 3

10.8.17.81
9C:5A
/24

Host 2

10.8.17.65
2B:8E
/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)
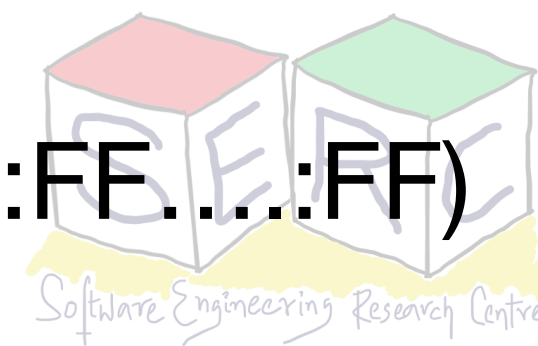
How does end-to-end communication work?

What is the role of the network layer?

Thank you

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