Ch. 8 - Communication Models

Sec 2 – TCP/IP Model

COMPSCI 147

Internet-of-Things; Software and Systems

OSI: THE INTERNET THAT WASN'T

- 1960s: packet switching invented independently by Paul Baran (US) and Donald Davies (UK)
- 1969: US DARPA sponsored researchers created ARPANET, the first packet switching network, is created in the United States.
- Early 1970s: IBM+Europe telephonic monopolies hatched their own plans.
- 1972: Standardization is required: International Network Working Group (INWG) was formed.
- Researchers faced lots of battles with telecom engineers (dominating INWG).
- 1975: Researchers (e.g., Cerf) took offense (proposals got rejected), started joining ARPA.
- 1977: UK proposed new organization within ISO (not dominated by telecom companies).
- 1984: IBM still kept influencing. The uneasy alliance of computer and telecom engineers published the OSI reference model as an international standard in 1984.
- 1989: OSI advocate Brian Carpenter's talk "Is OSI too late?"
- Meanwhile, Internet flourished

A. L. Russell, "The internet that wasn't," in IEEE Spectrum, vol. 50, no. 8, pp. 39-43, August 2013.

1990s: Internet became the de-facto standard

- "On one side you have something that's free, available, you just have to load it.
- And on the other side, you have something which is much more architectured, much more complete, much more elaborate, but it is expensive.
- If you are a director of computation in a company, what do you choose?"

--Marc Levilion, an engineer for IBM France.

"**Internet**": a term adopted to refer to a network of networks that utilized ARPA's TCP/IP.

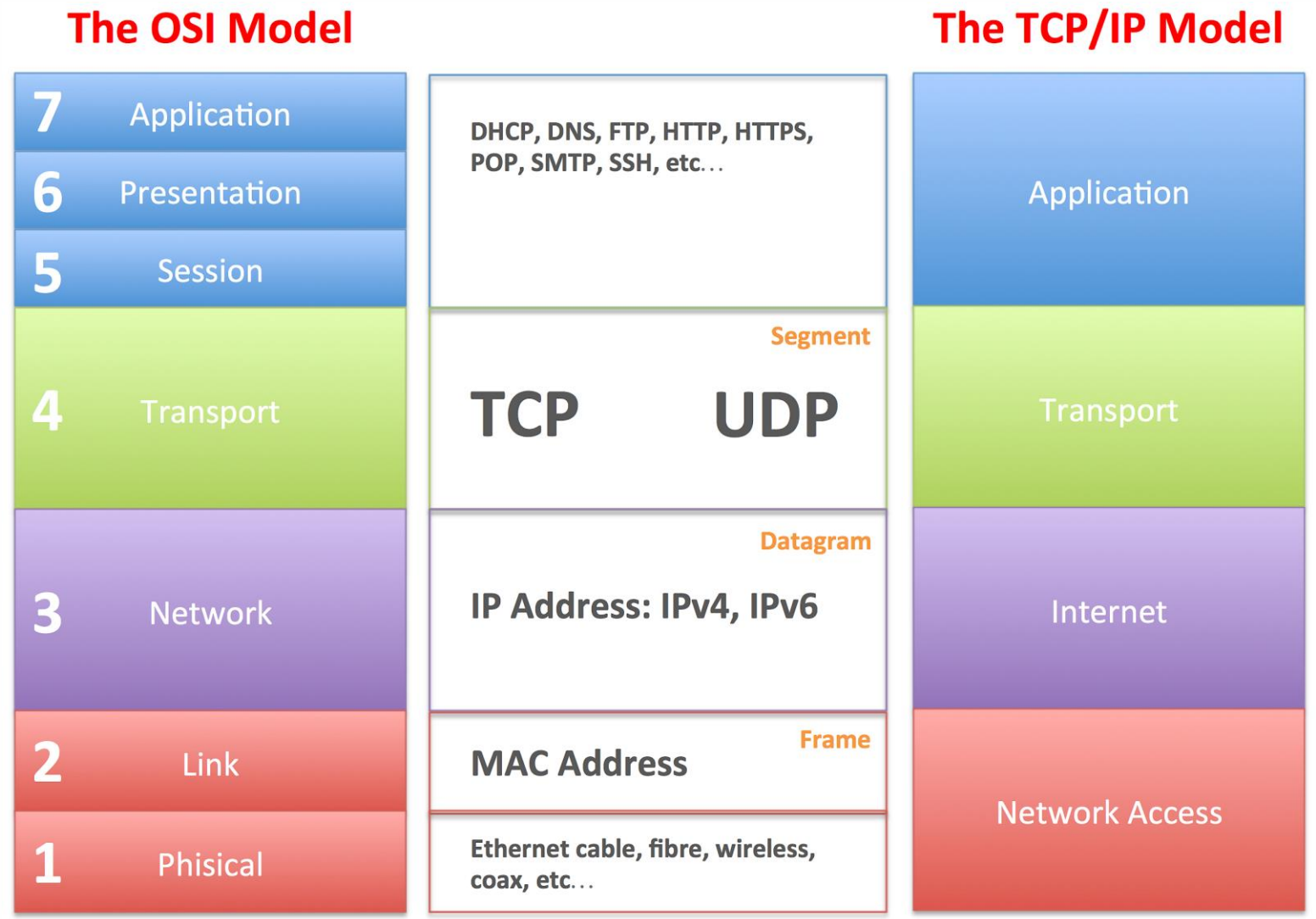
INTRODUCTION TO TCP/IP

- Evolved from the 4-layer DoD model

- The Internet protocol (IP) stack is another reference model with a set of communications protocols used in computer networks. It is based on the Transmission Control Protocol (TCP).

- Additional resources:
  - TCP / IP Protocol: The 4 Layer Model
    - https://www.youtube.com/watch?v=KEWe-5Bk3Q0
  - TCP vs. UDP
    - https://www.youtube.com/watch?v=uwoD5YsGACg
  - IPv4 and IPv6
    - https://www.youtube.com/watch?v=aor29pGhlFE
    - https://www.youtube.com/watch?v=k6nrH8JiTTU

TCP/IP VS OSI MODEL



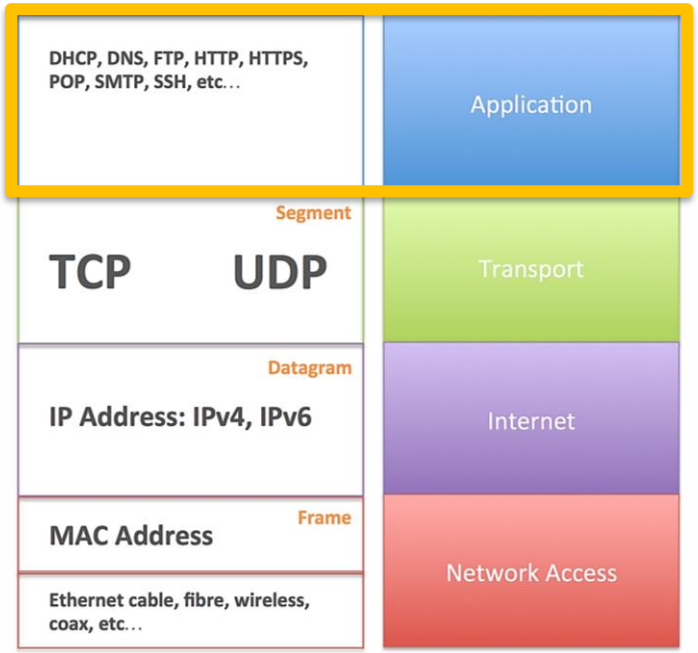
What about the missing application layers ?

- Are the services provided by these layers unimportant?
- What if an application need some of these services?

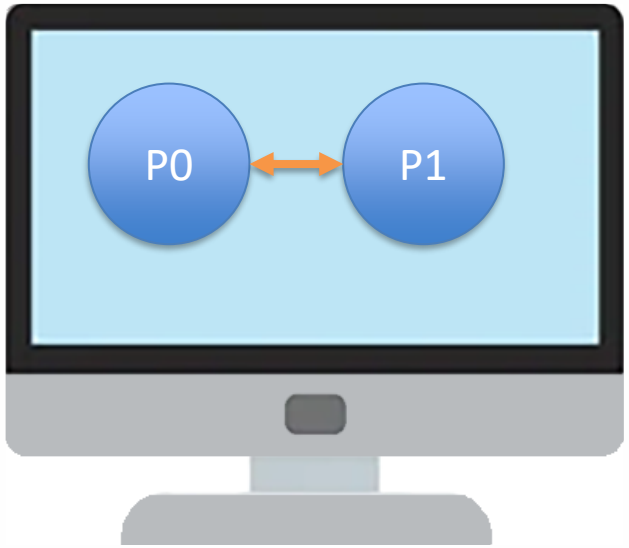
- it's up to the application developer.
  - decide if a service is important, and if it is, it's up to the application developer to build that functionality into the application.

TCP/IP LAYER 1: APPLICATION LAYER

- Applications that send data over a network
  - Web browsers and internet services
- Specific protocols by application type
  - FTP, HTTP, IMAP,..
- May include functionalities of session and presentation layers in OSI.
- Data gets sent to the transport layer.



Goal 1: Transfer data between two applications running on the same PC



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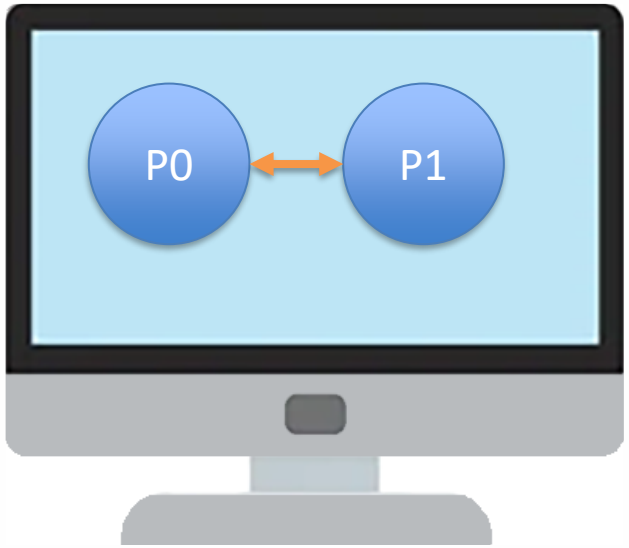
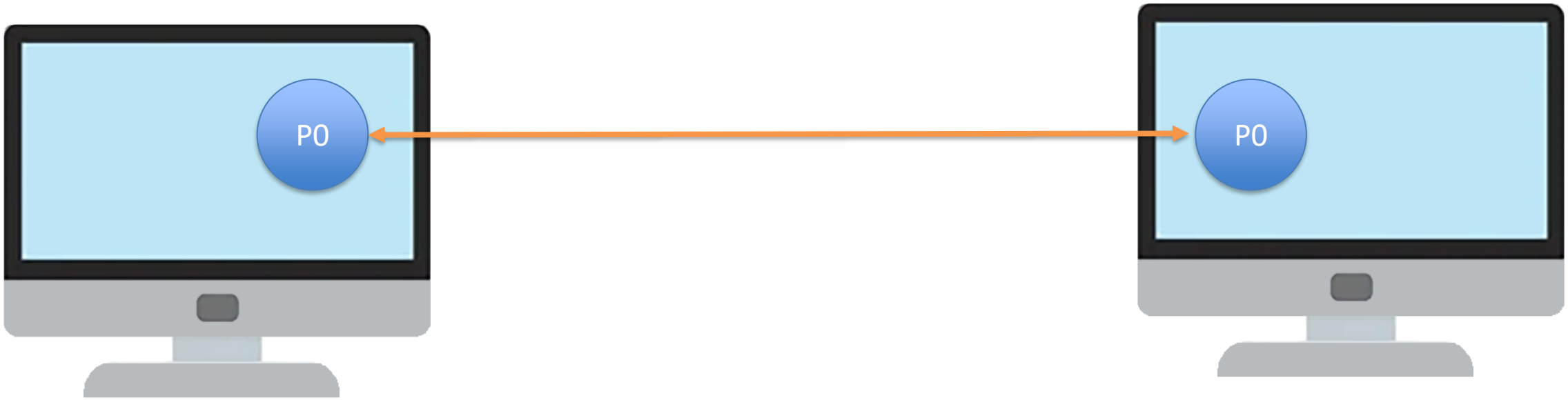
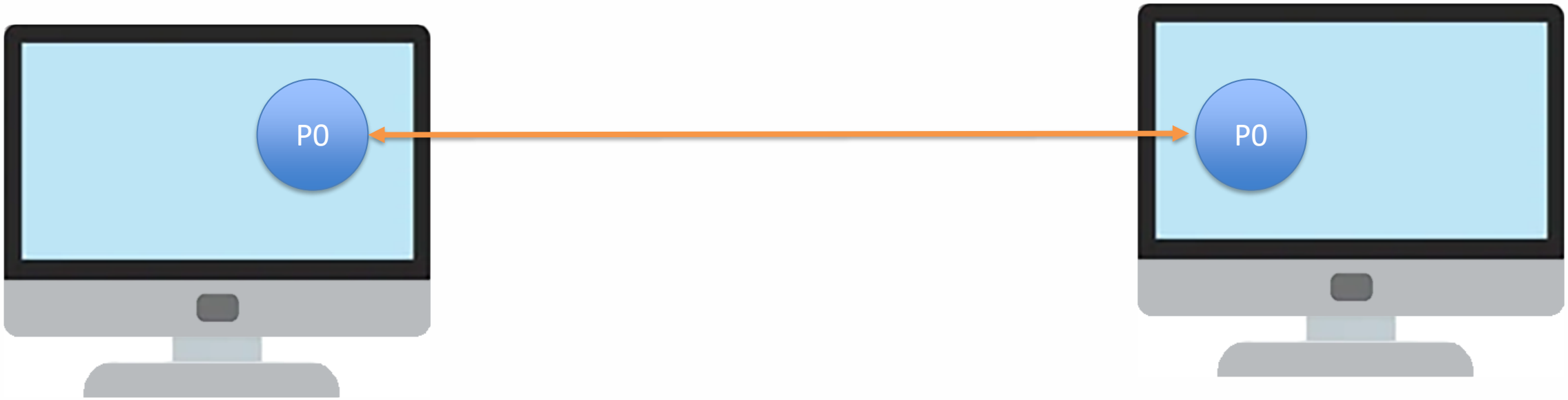


- Solution: Inter-process communication
  - Identify the other process by PID (Process ID)
  - Use OS provided mechanisms:
    - Shared Memory
    - Message passing
- **Next Challenge**: How do I transfer some data between two processes running on two different computers but in the same network ?

Goal 2: Transfer data between two applications running on different machines but on the same network



Goal 2: Transfer data between two applications running on different machines but on the same network

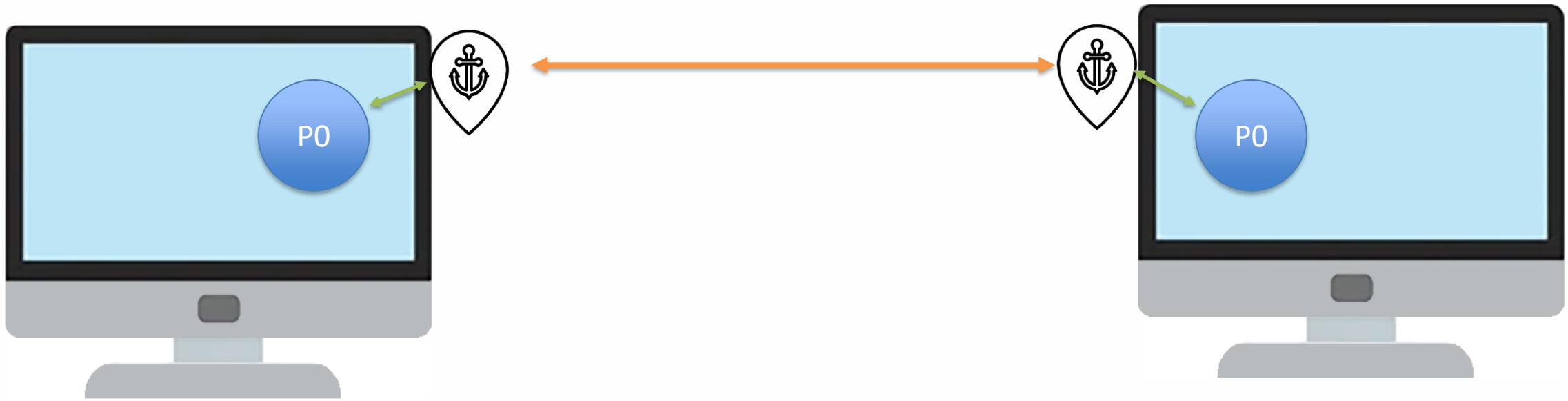


Q: Can you identify the other process by PID (Process ID)?

Q: Will existing OS provided mechanisms work?

- Shared Memory
- Message passing

Goal 2: Transfer data between two applications running on different machines but on the same network

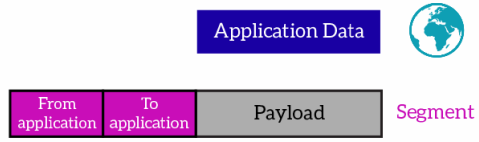


PID may be same.

- Add one more level of indirection: **Ports**
- 16-bit unsigned integer (0 to 65535)

TCP/IP LAYER 2: TRANSPORT (TCP) LAYER

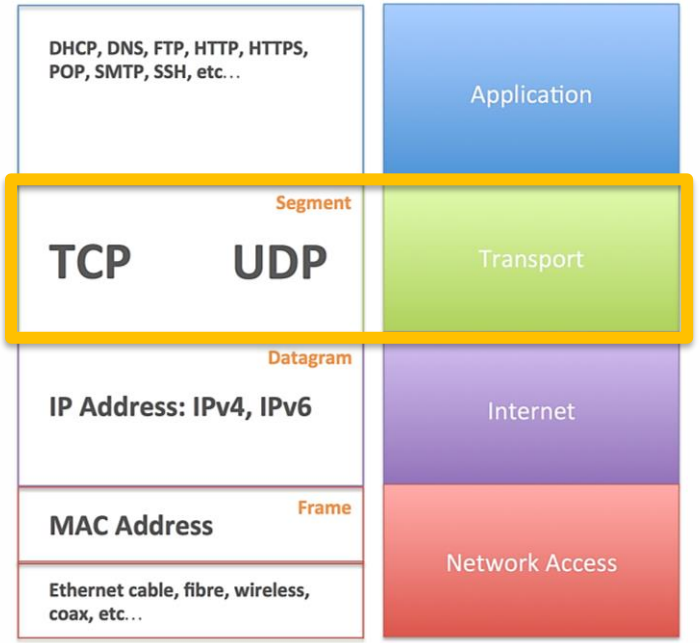
- Breaks down messages into segments.
- In the header, add port information and more bits depending on protocol.



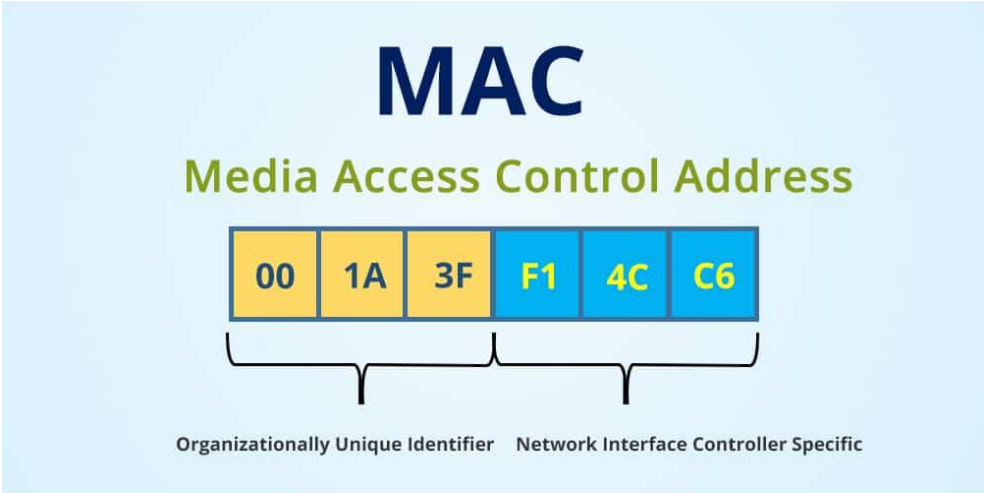
- Most popular protocols:
  - User Datagram Protocol (UDP)
    - Connectionless, unreliable
  - Transmission Control Protocol (TCP)
    - Connection-oriented, reliable (ACK)
  - Stream Control Transmission Protocol (SCTP)
    - For supporting multimedia and VOIP

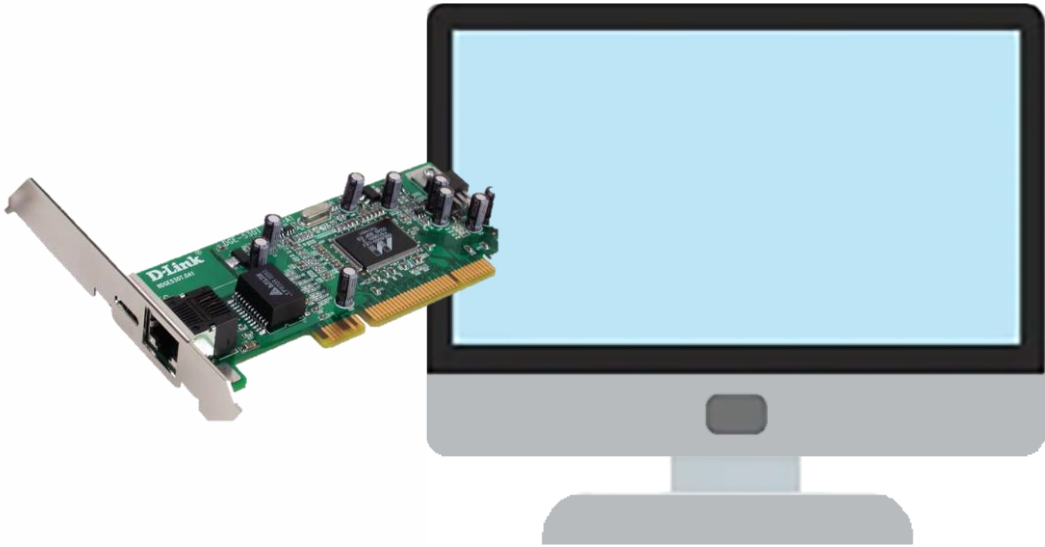
- Ensures process-to-process delivery across hosts

- Sends segments to the internet layer



Q: How to uniquely identify the other machine ?

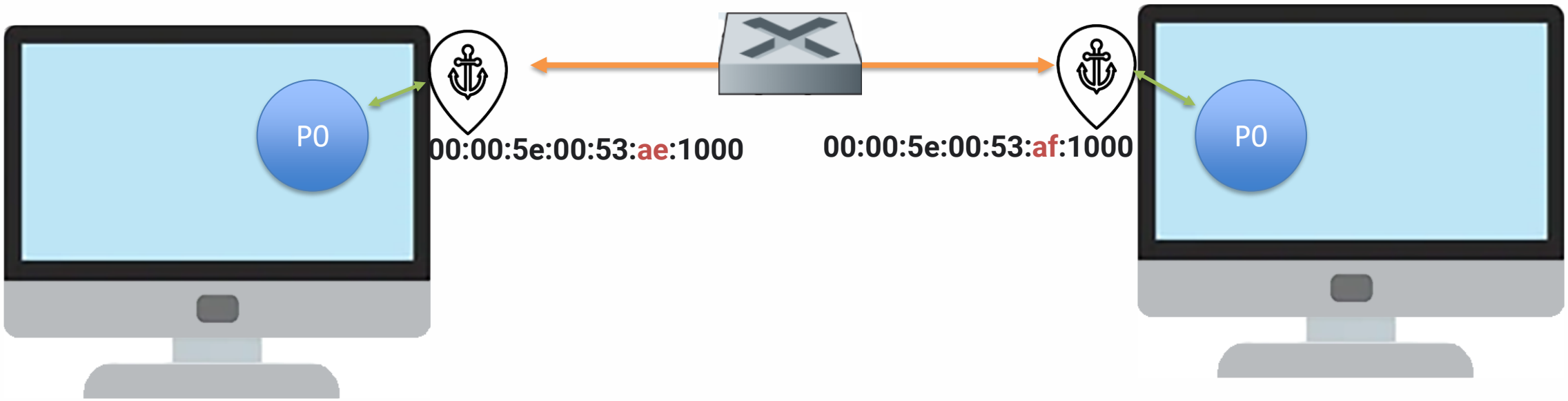




There is still a problem:

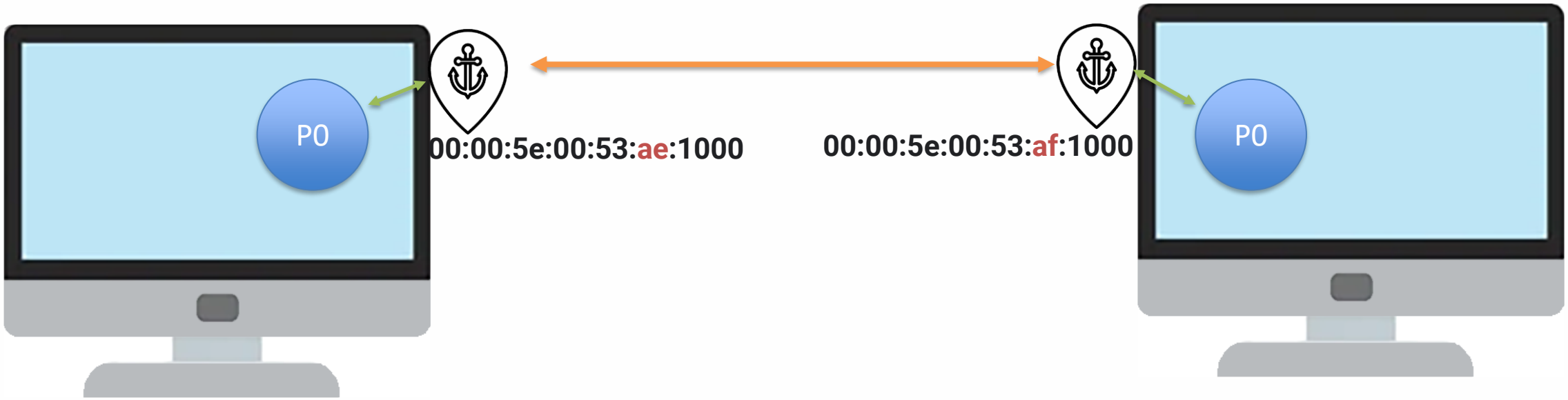
- Possibility: Should we use NIC (Network Interface Card's MAC address) that is unique to each machine ?

Q: How to uniquely identify the other machine ?
Hypothetical situation of using MAC and a switch



Q: What is the problem of using MAC address:port directly for communication?

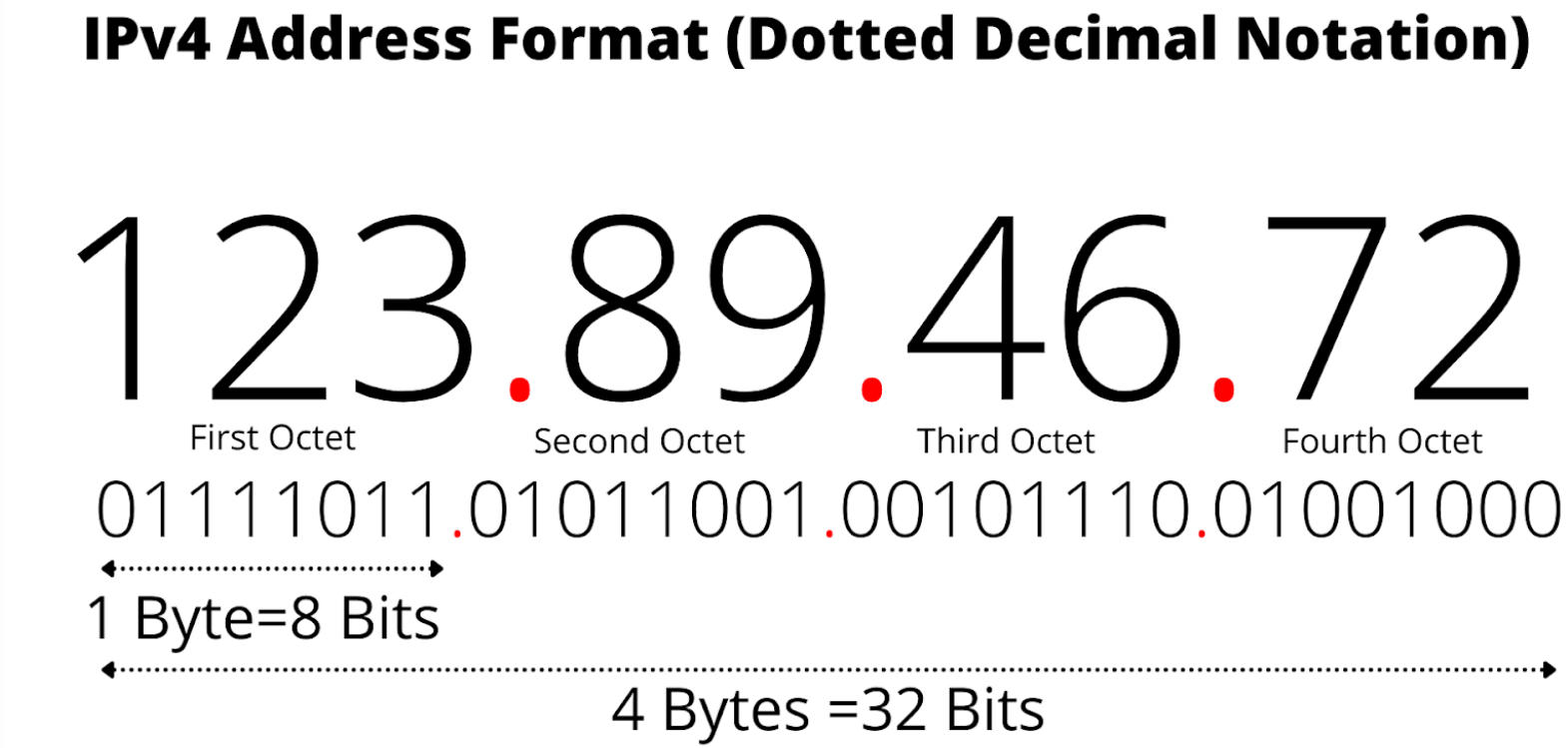
Q: How to uniquely identify the other machine ?
Hypothetical situation of using MAC directly



Q: What is the problem of using MAC address:port directly for communication?

Solution: A layer of abstraction: logical addresses!

TCP/IP LAYER 3: INTERNET (IP) LAYER



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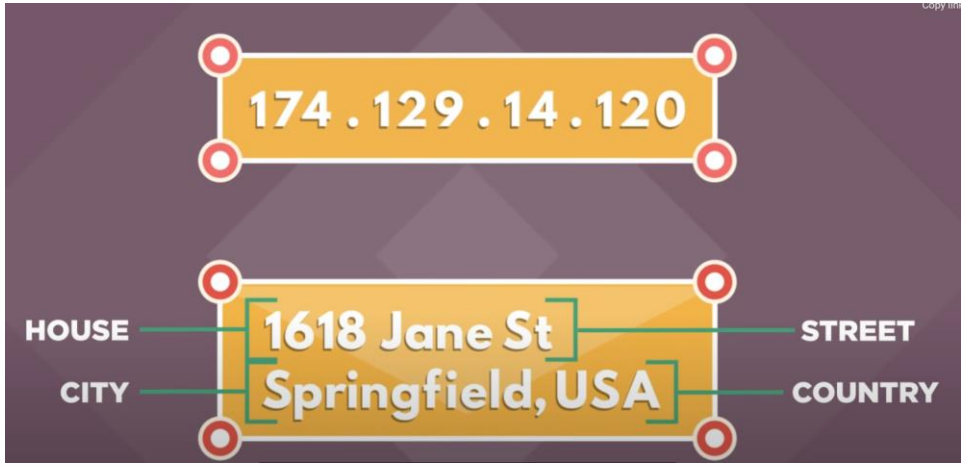

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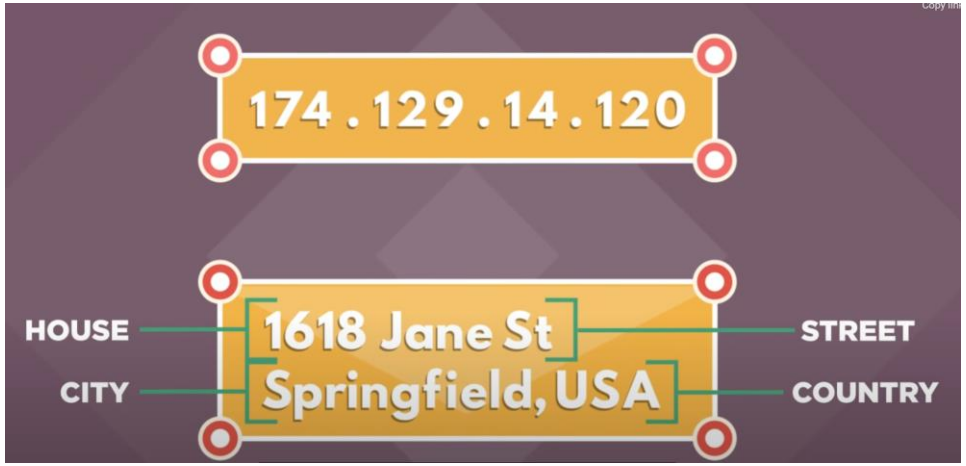
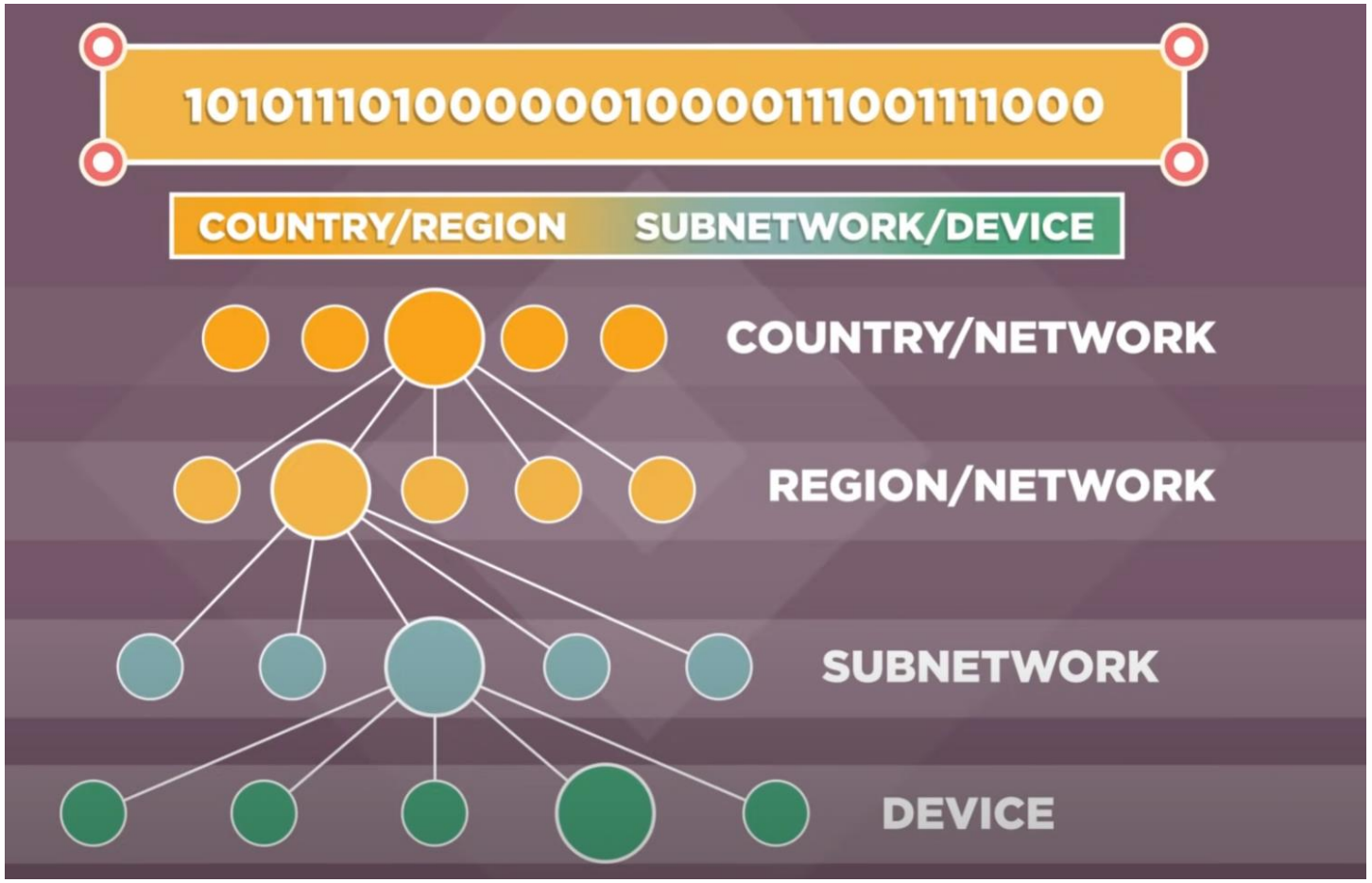
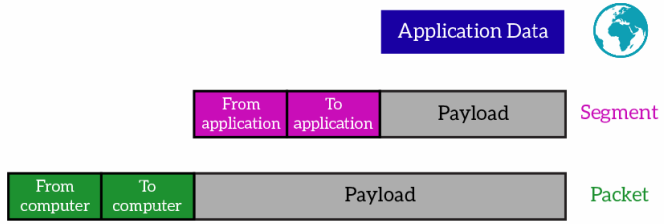


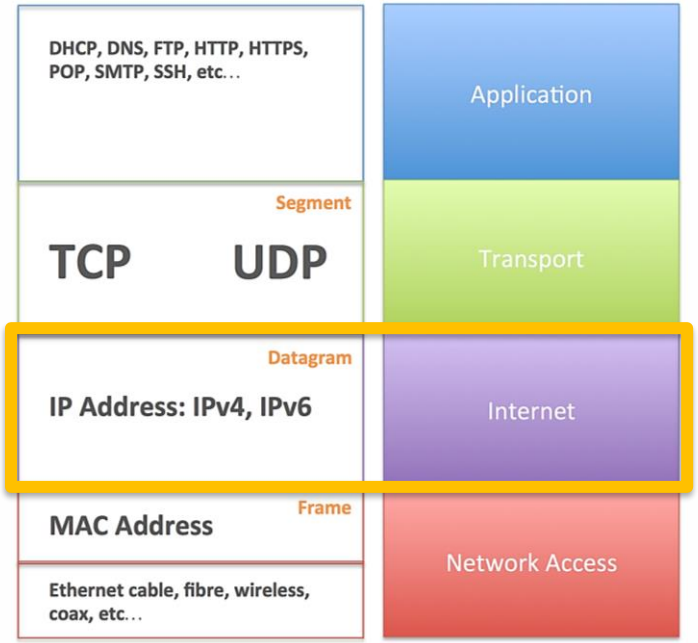


TCP/IP LAYER 3: INTERNET (IP) LAYER

- Deals with incoming and outgoing packets via IP addresses.
- Most popular internet layer protocols are IPv4 and IPv6.

- The main TCP/IP Internet Layer (or Networking Layer in OSI) devices are routers.





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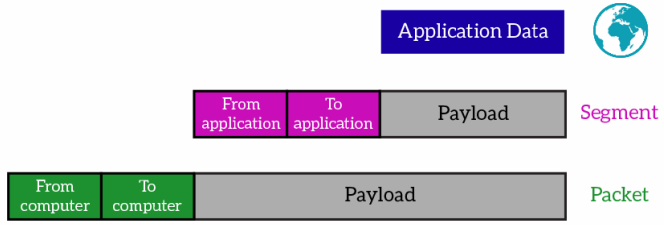

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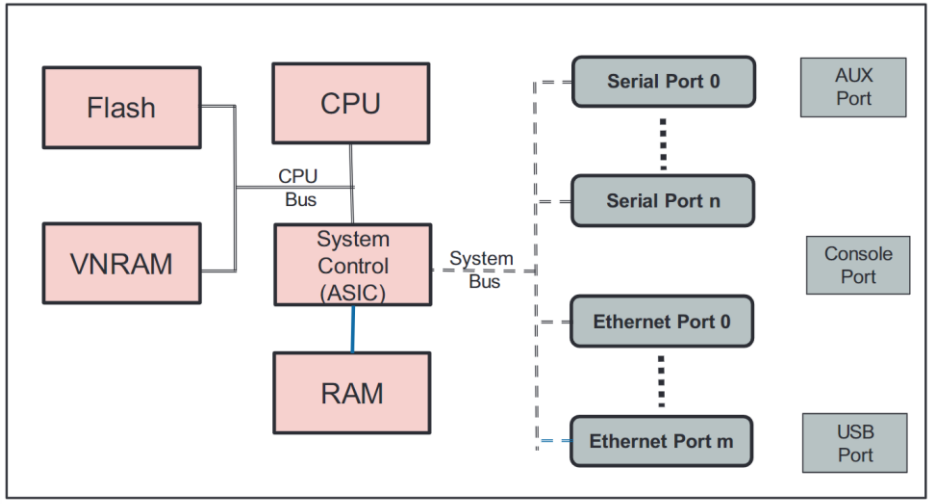
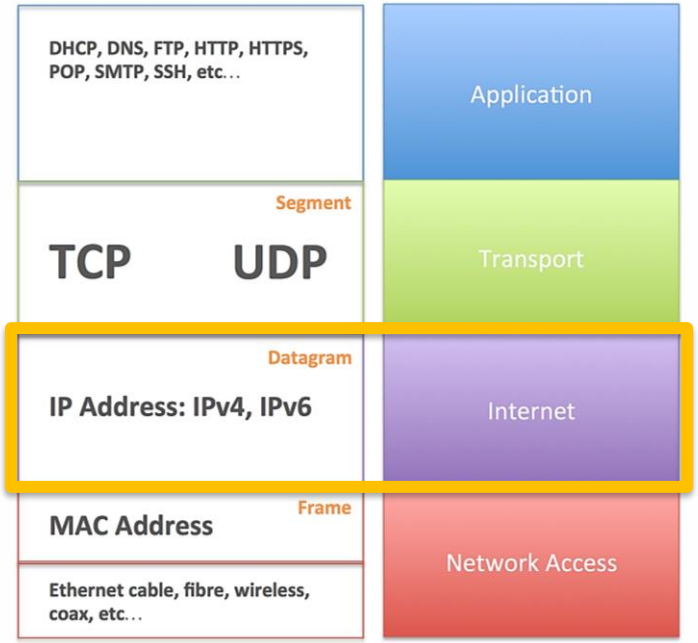
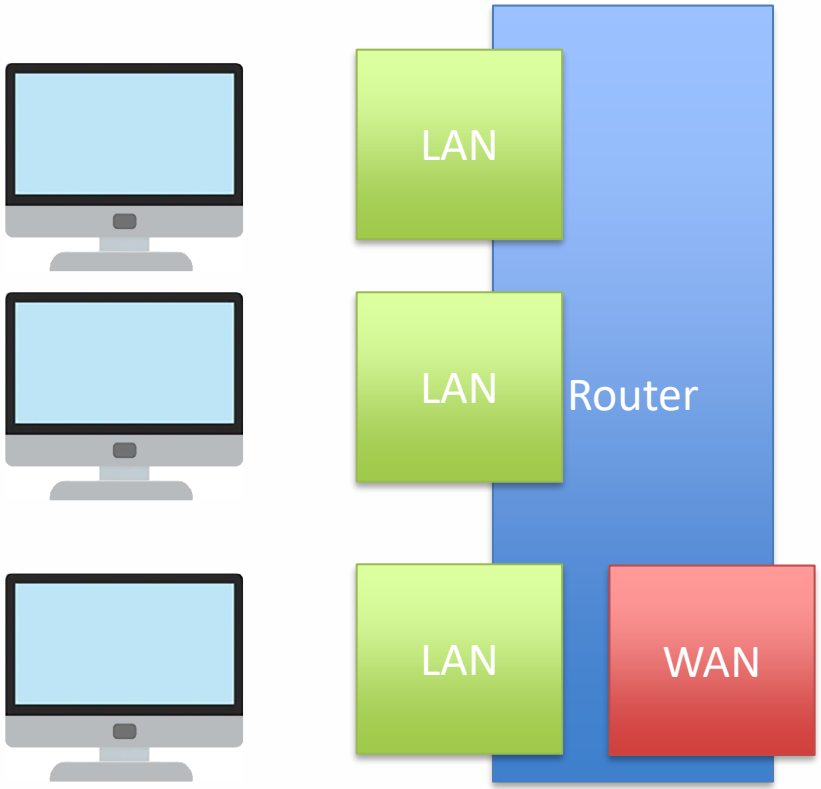


Fig. 2.4 Router main components



TCP/IP LAYER 3: INTERNET (IP) LAYER

- Understanding IP Addresses



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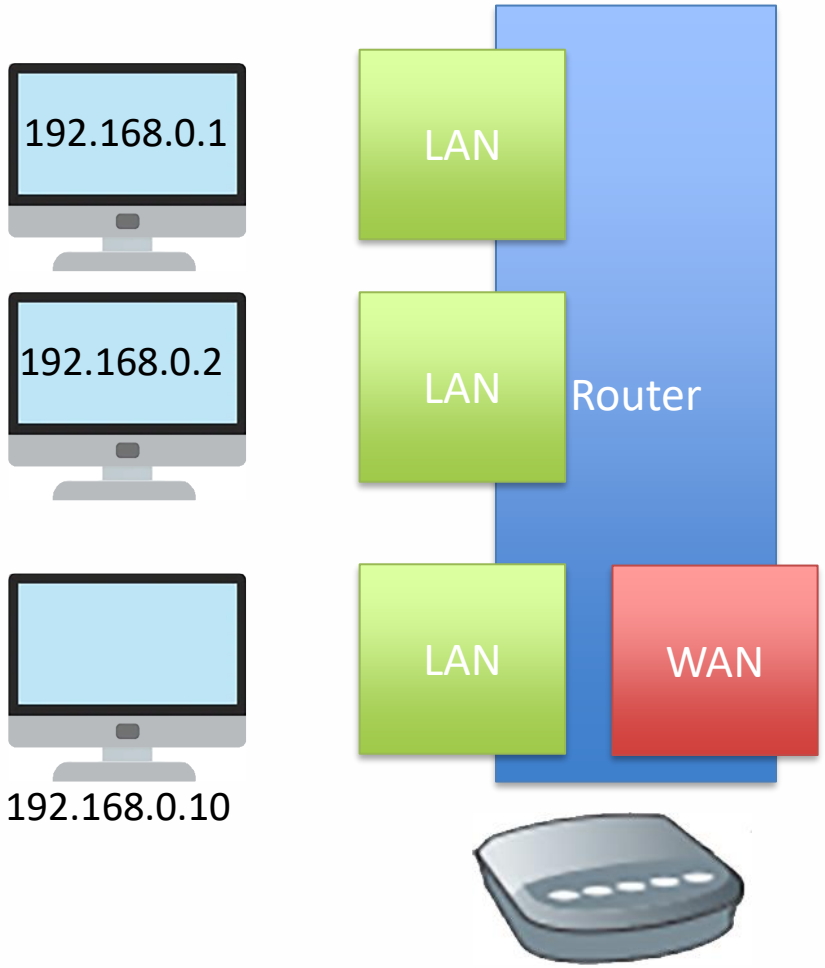

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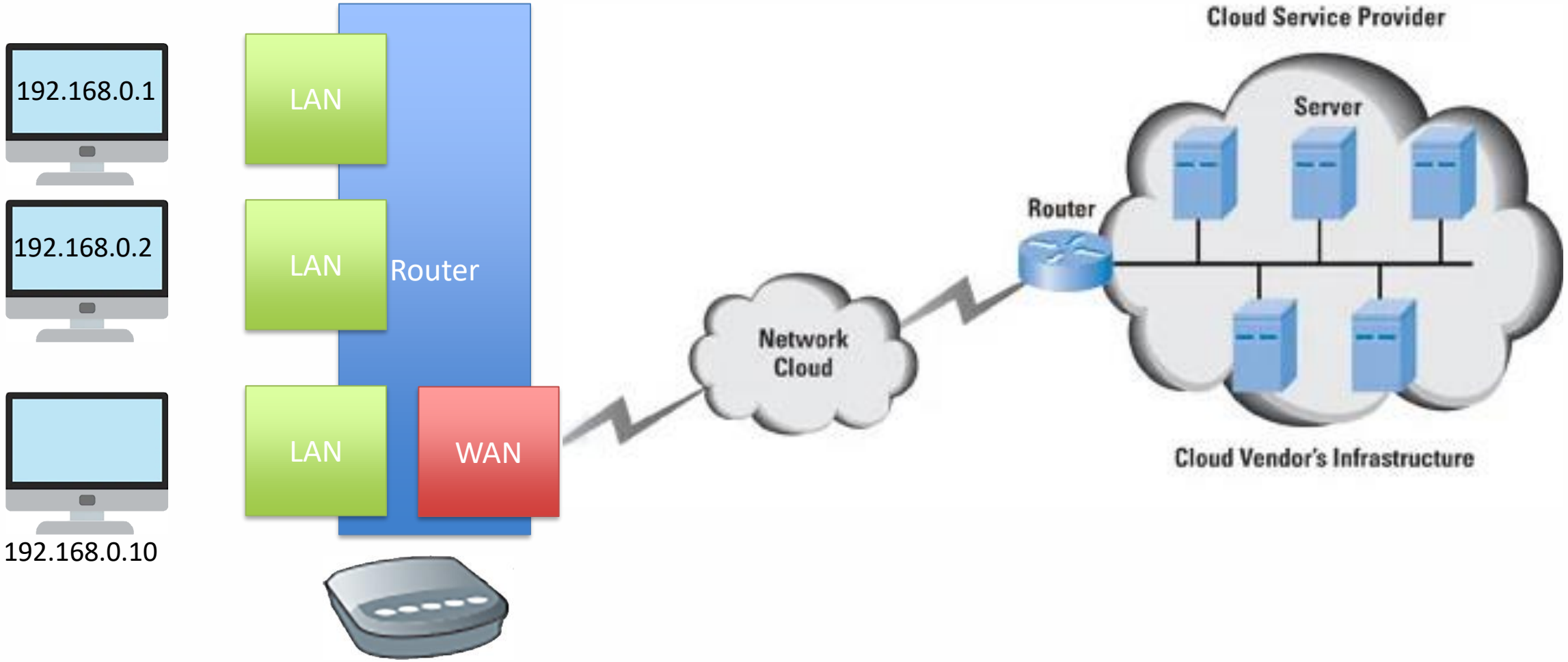

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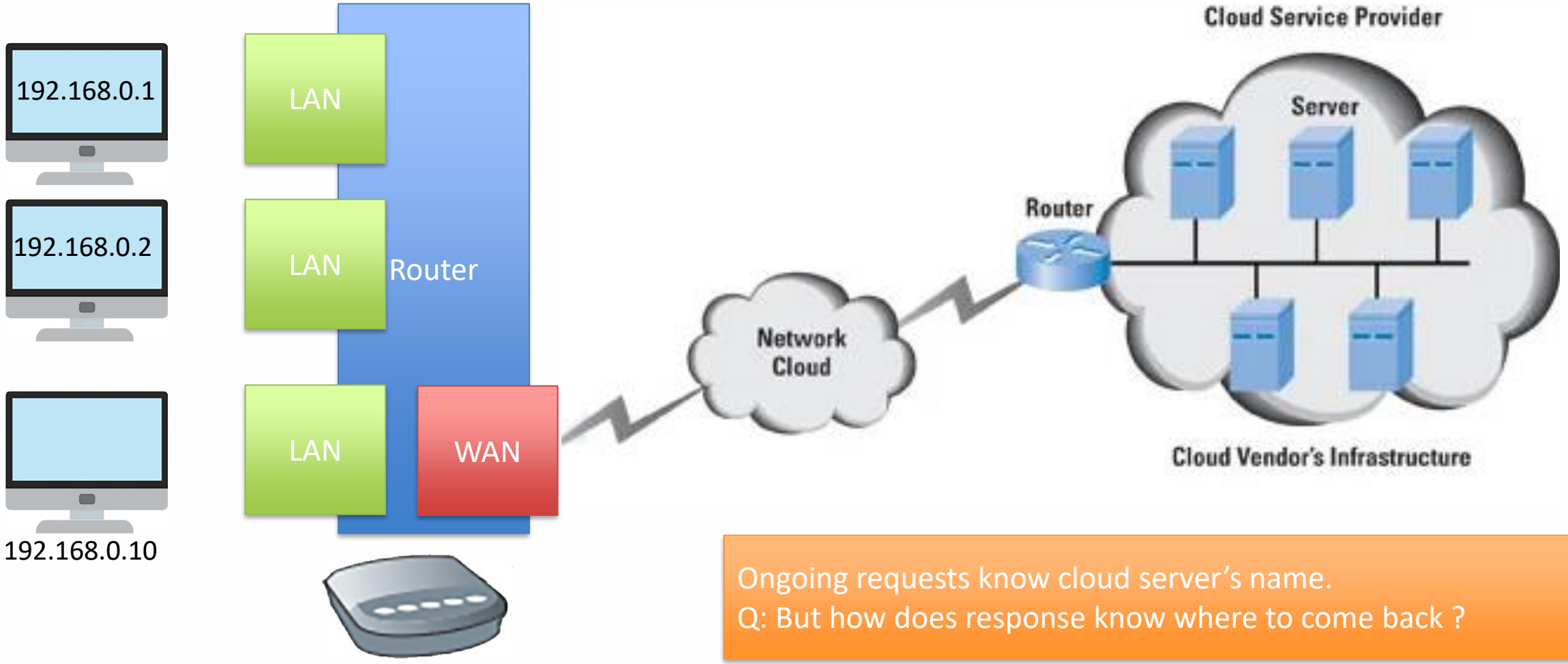
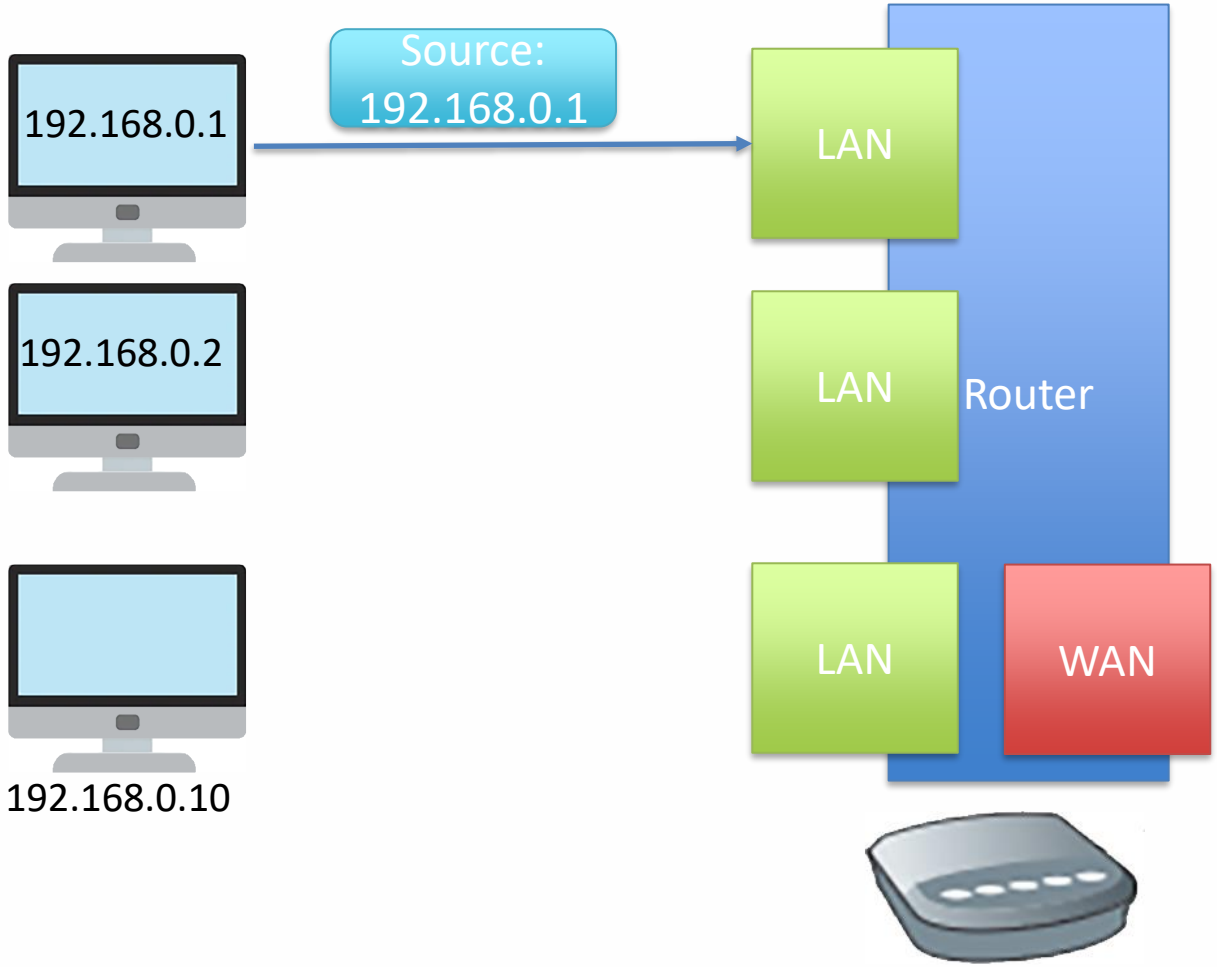


Ongoing requests know cloud server's name.
Q: But how does response know where to come back ?

TCP/IP LAYER 3: INTERNET (IP) LAYER

- Understanding IP Addresses



TCP/IP LAYER 3: INTERNET (IP) LAYER

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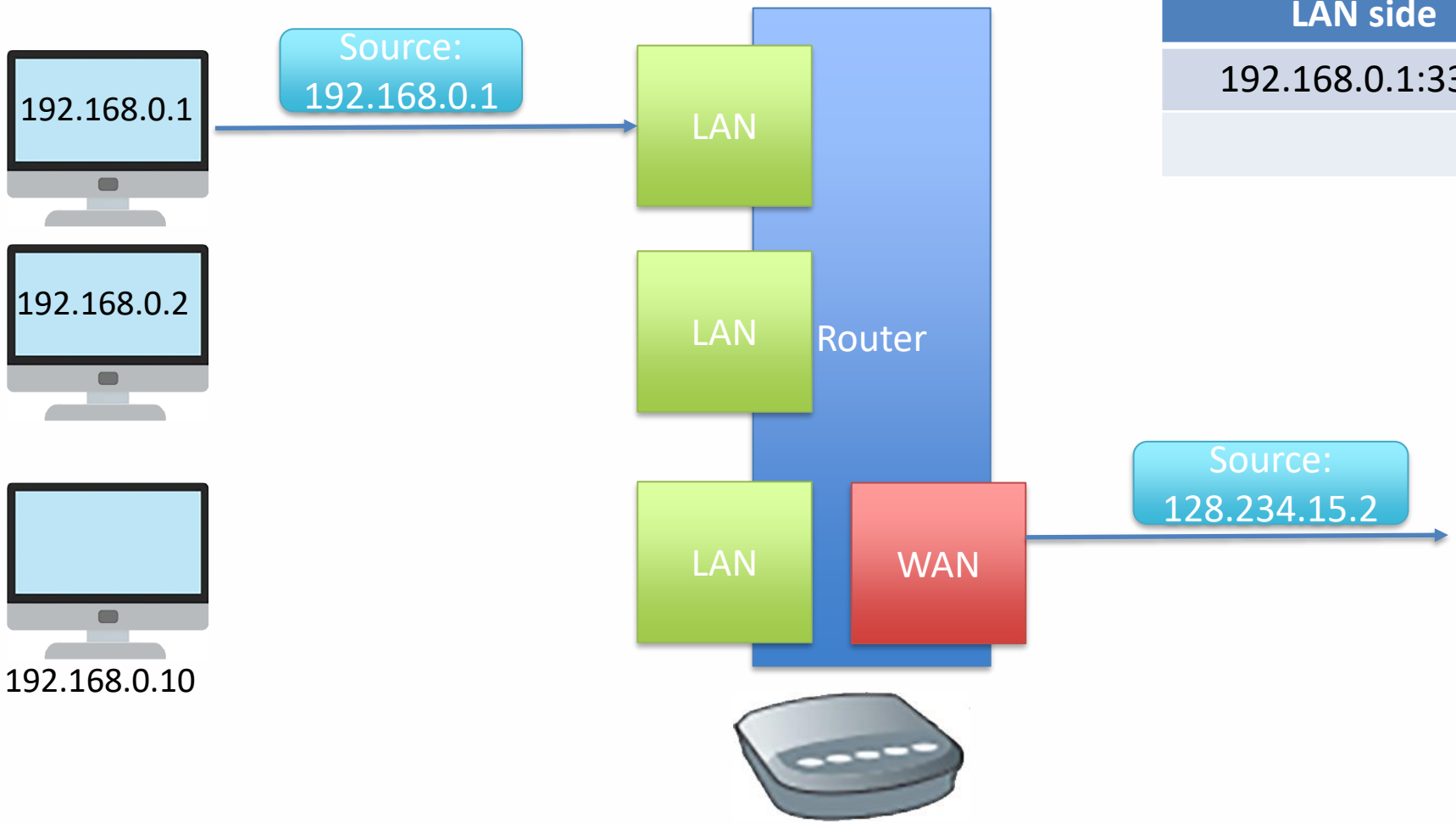
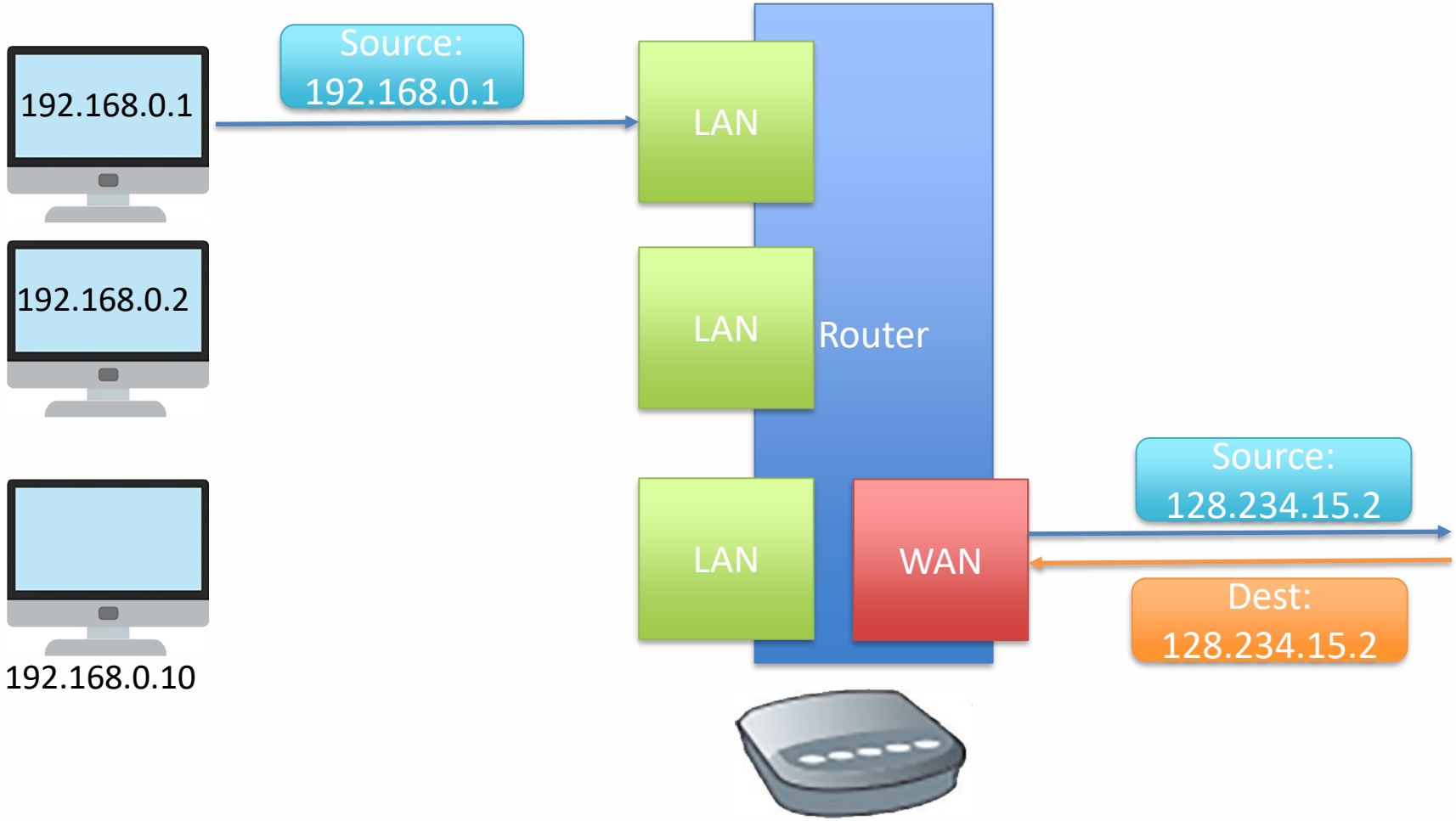


NAT Translation Table

LAN side	WAN side
192.168.0.1:3345	128.234.15.2:5001

TCP/IP LAYER 3: INTERNET (IP) LAYER

- Understanding IP Addresses



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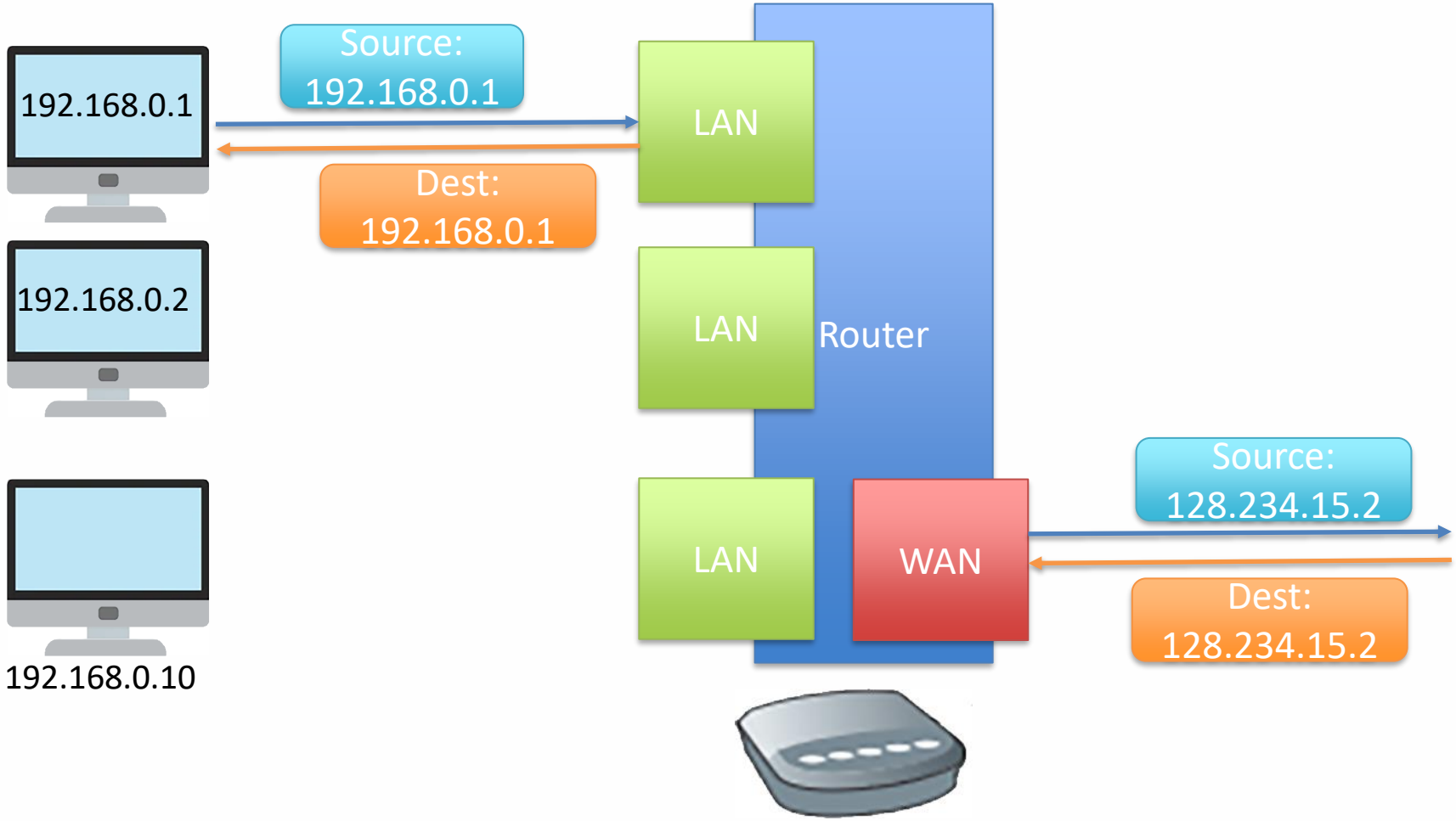
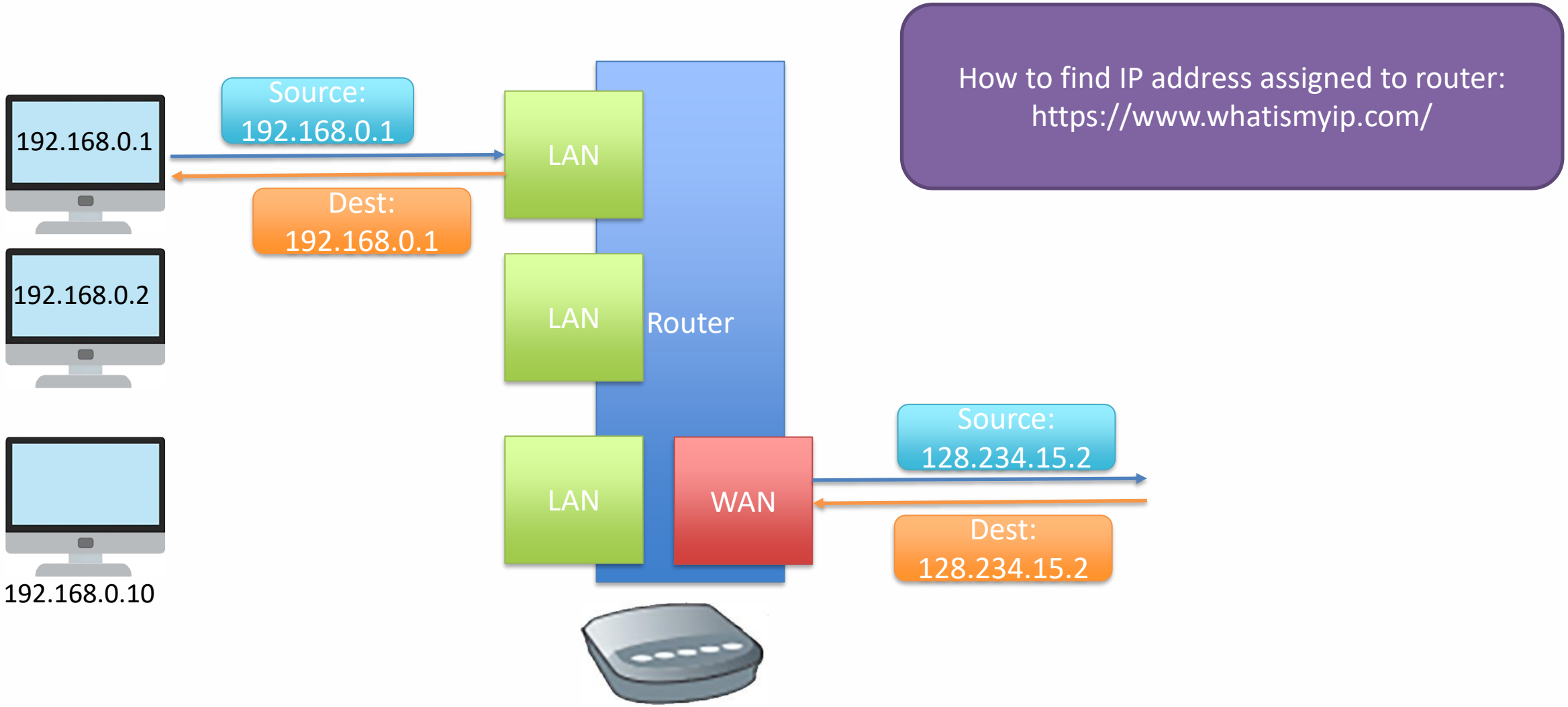


TCP/IP LAYER 3: INTERNET (IP) LAYER

- Understanding IP Addresses



TCP/IP LAYER 3: INTERNET (IP) LAYER

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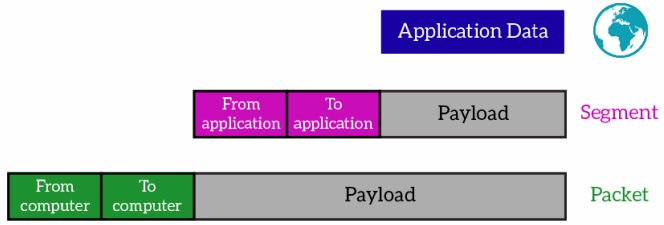
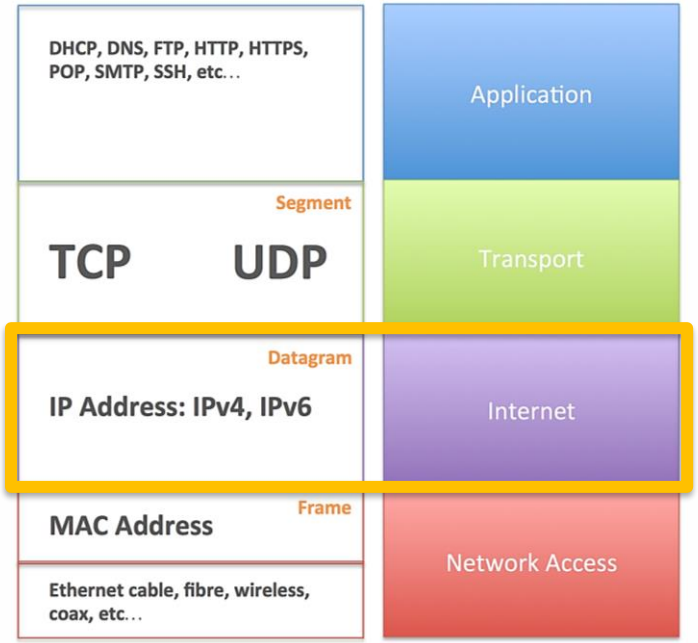


- The main TCP/IP Internet Layer (or Networking Layer in OSI) devices are routers.

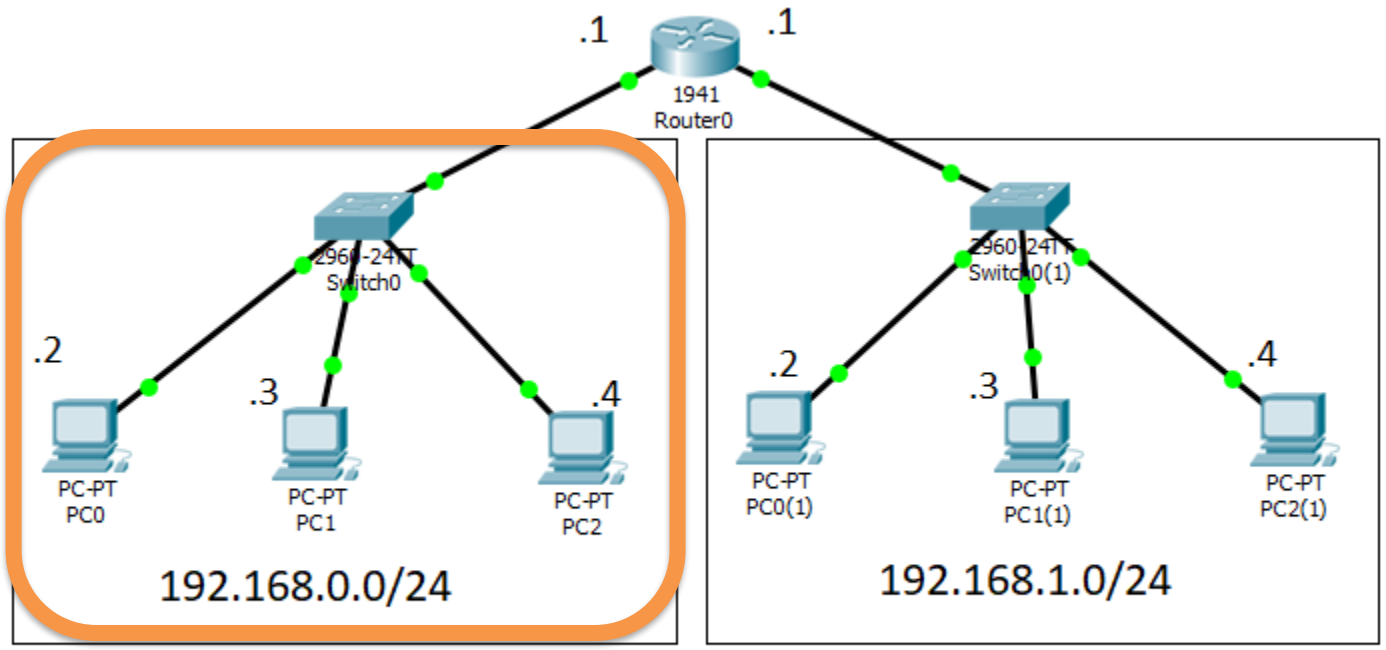
- Two main functions of routers are
- Forwarding. When a packet arrives at a router's input link, the router must move the packet to the appropriate output link (in a single router).

- Routing: Path taken by packets as they flow from a sender to a receiver.



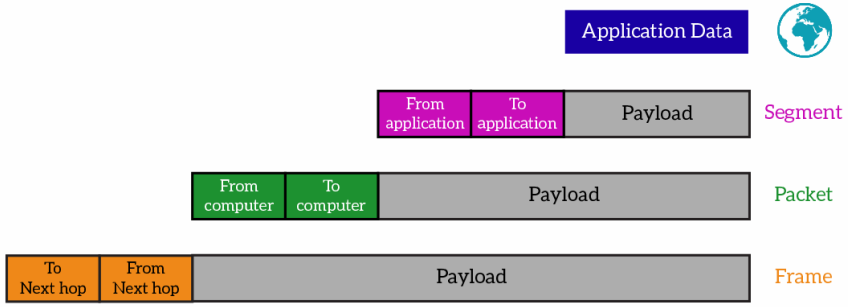
Routers as building blocks of the internet

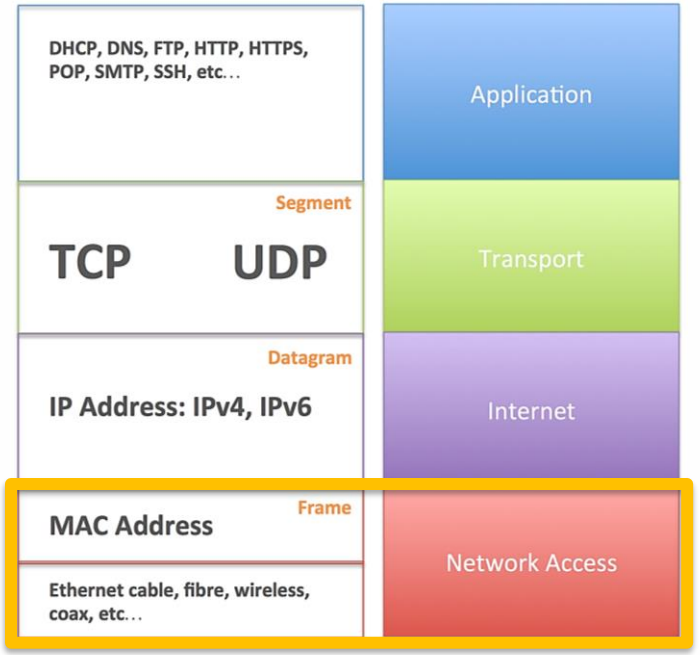
- Routers create subnetworks.
- Internet = Network of Networks connected using TCP/IP protocol stack



TCP/IP LAYER 4: NETWORK (LINK) LAYER

- Set of protocols and mediums to send packets across the individual links that make up the end-to-end communication path.
  - Framing (append headers to datagrams/packets)
  - How to access a link shared by multiple hosts
  - Reliable delivery
  - Address resolution (Translate logical to physical: IP to MAC)
  - Reverse address resolution

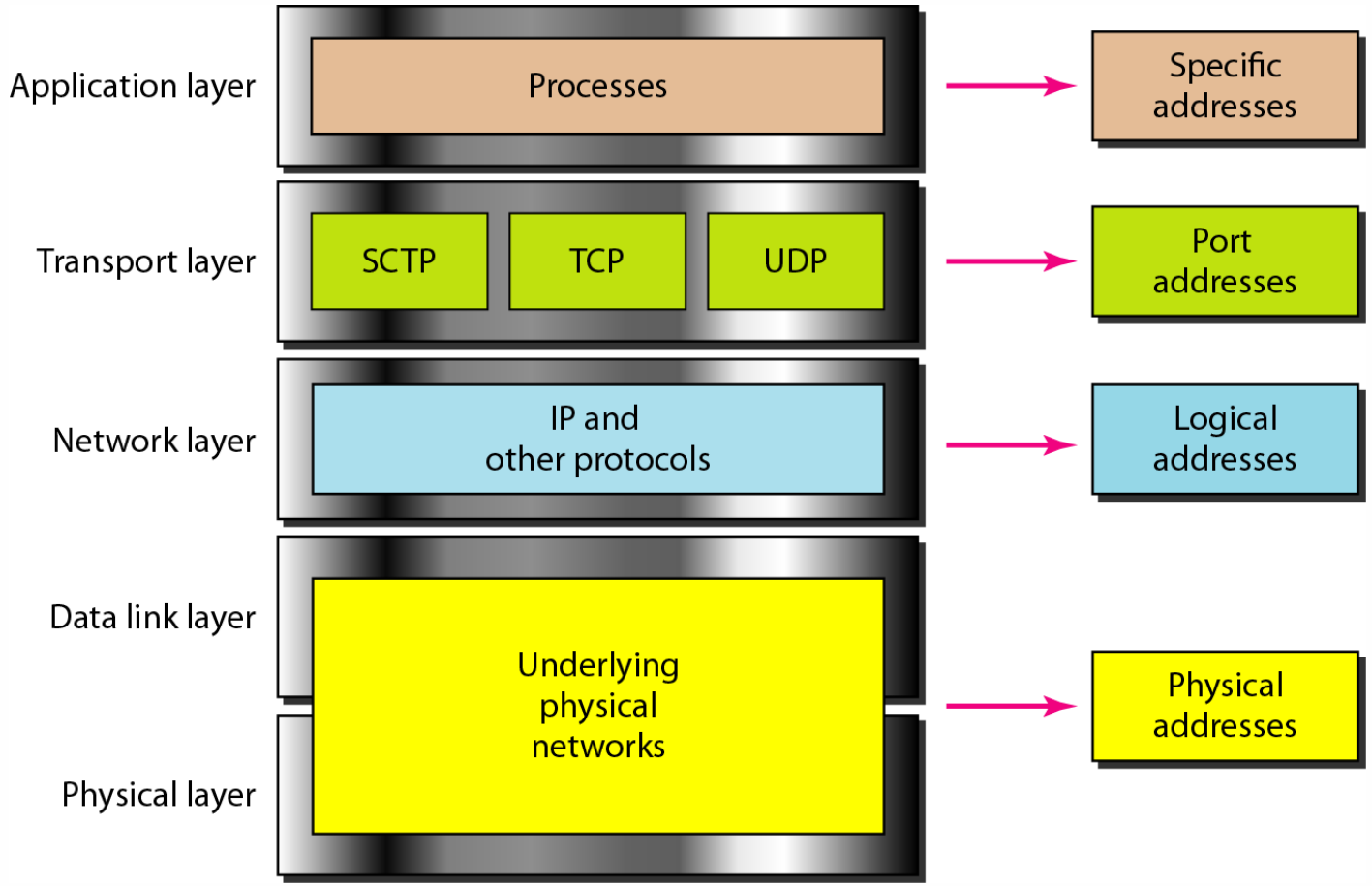




TCP/IP MODEL -- ADDRESSING

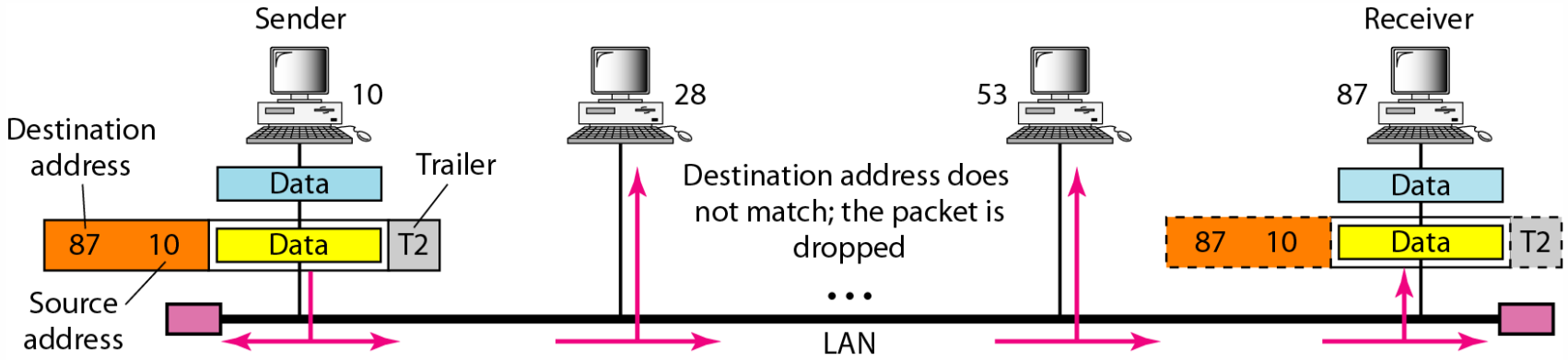
- **Four levels of addresses** are used in the TCP/IP model:
  - Physical address: Ex. Ethernet address, machine address
  - Logical address: IP address
  - Port number
  - Specific:

    URL, Email address, domain name



PHYSICAL ADDRESSES

- The physical addresses will change from hop to hop,
- but the logical addresses usually remain the same.



TCP/IP IN A NETWORK

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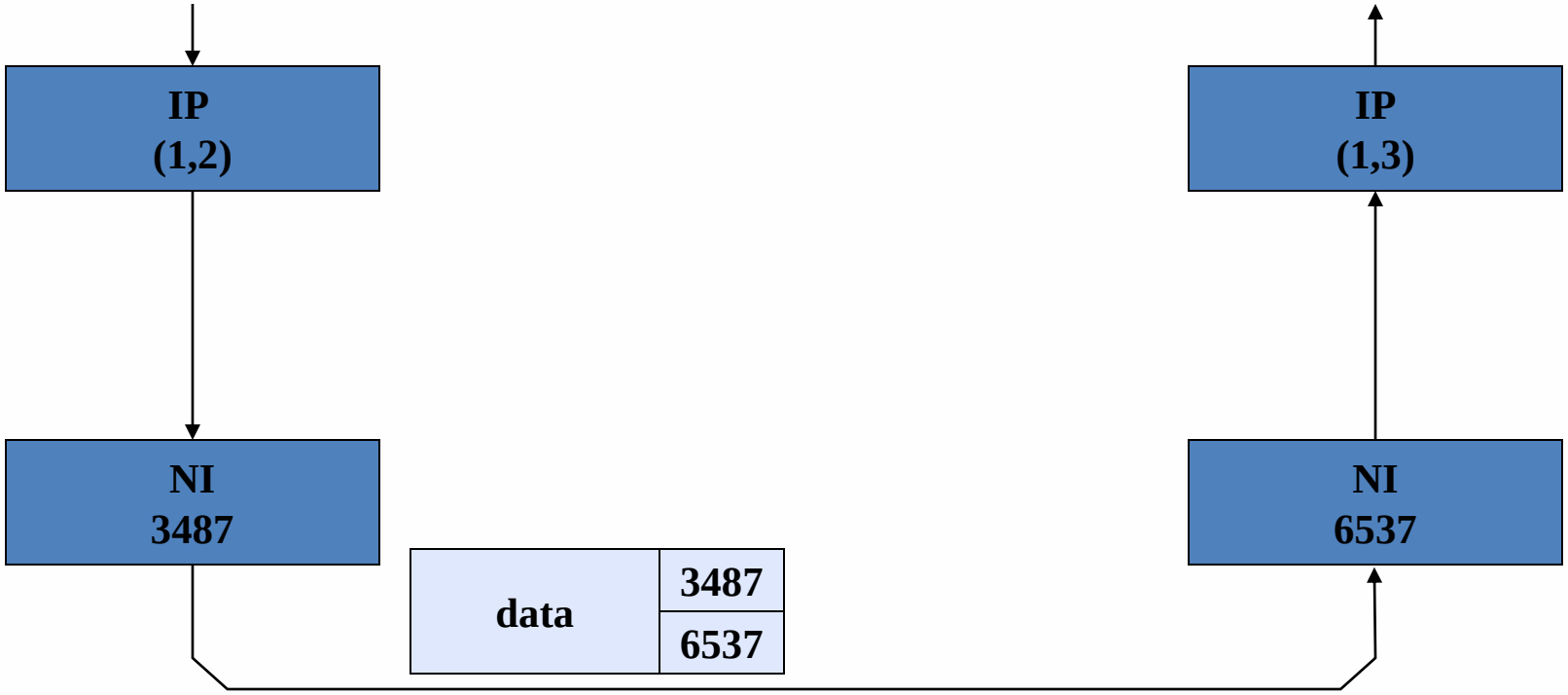
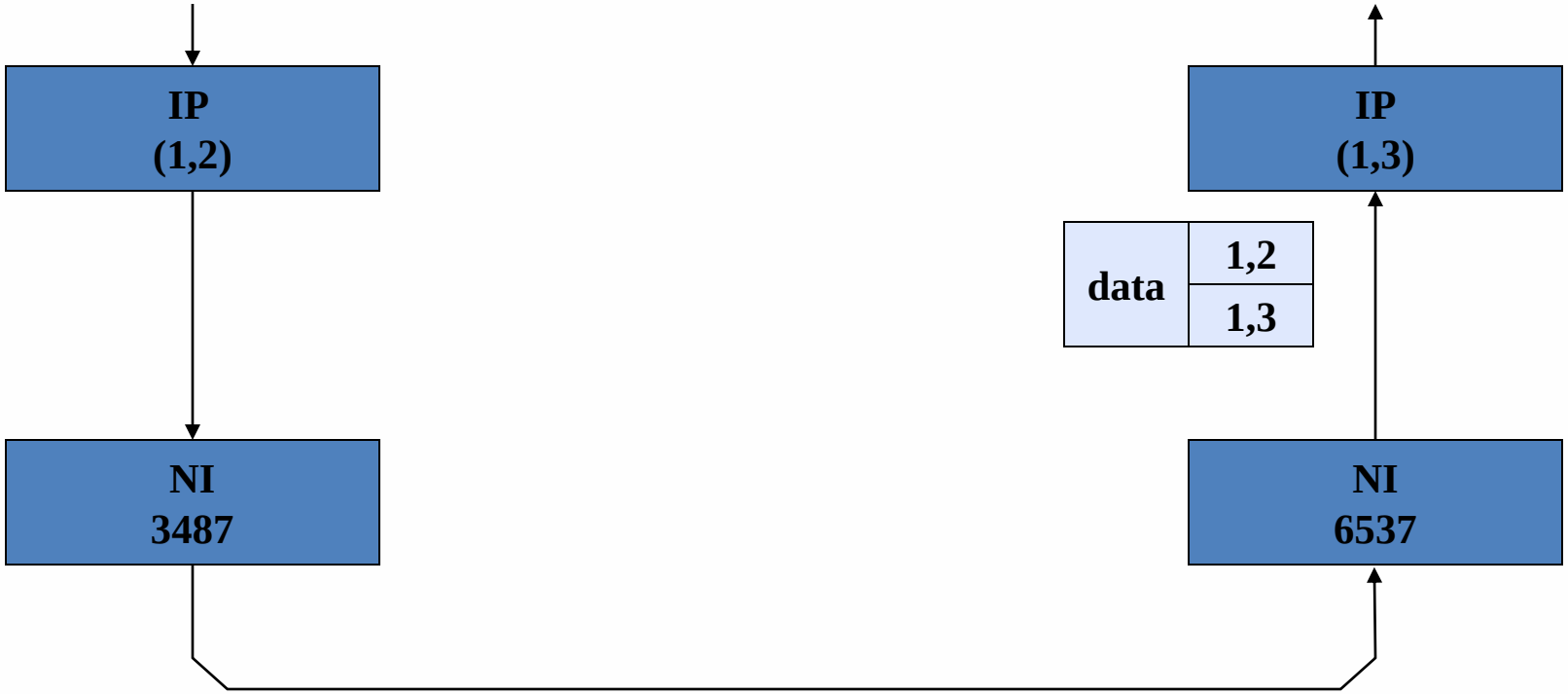
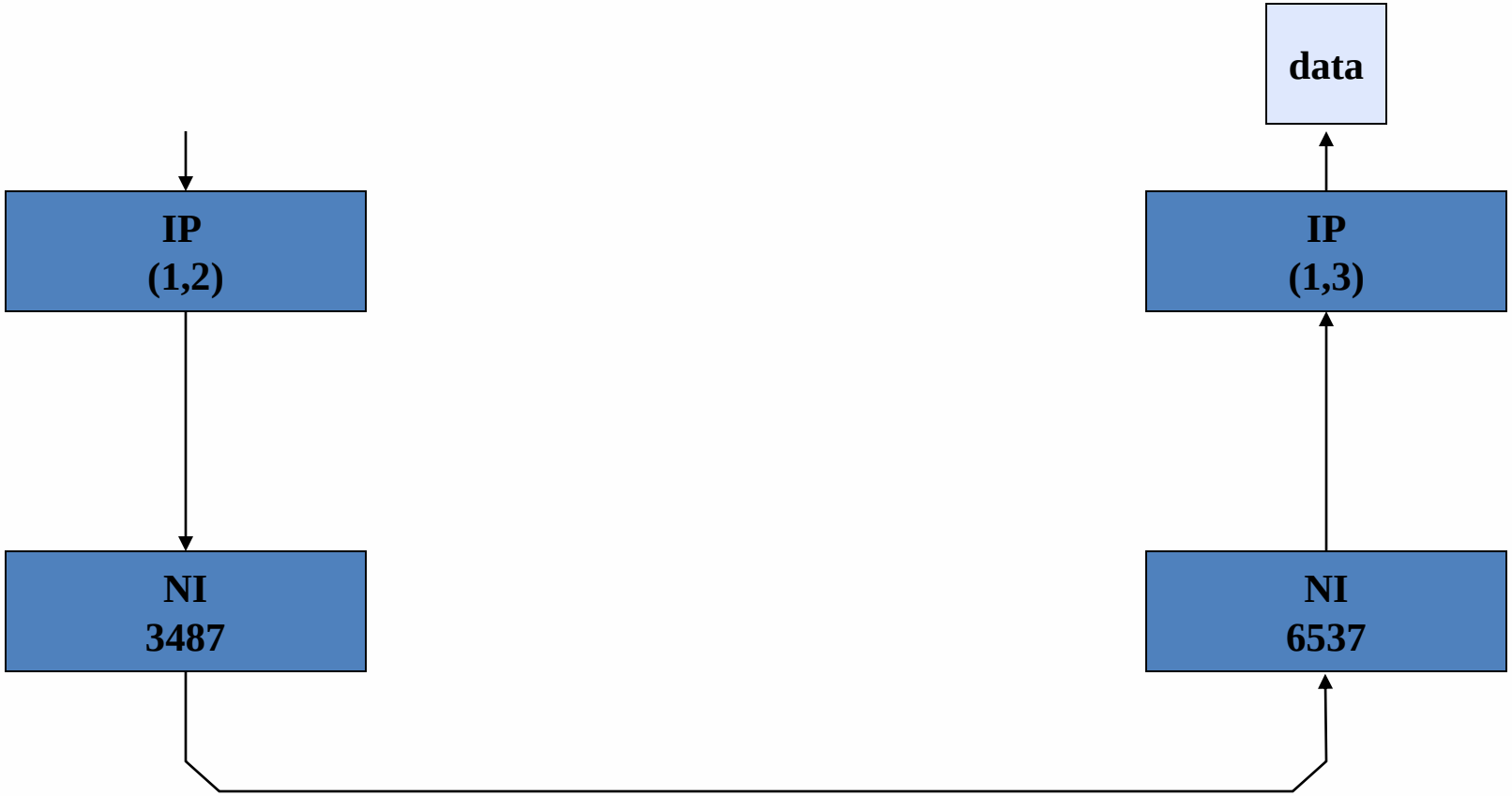


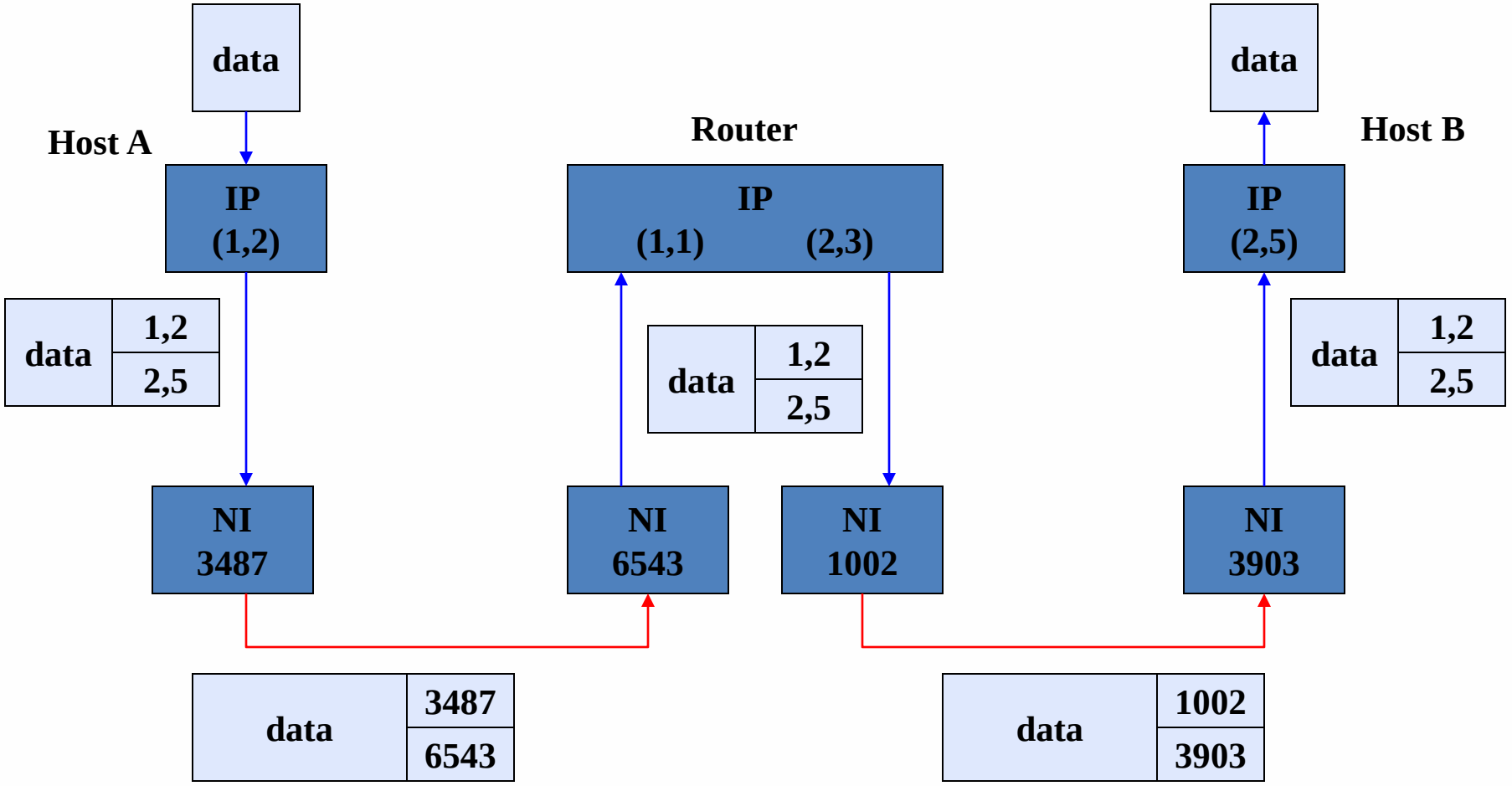
TCP/IP IN A NETWORK



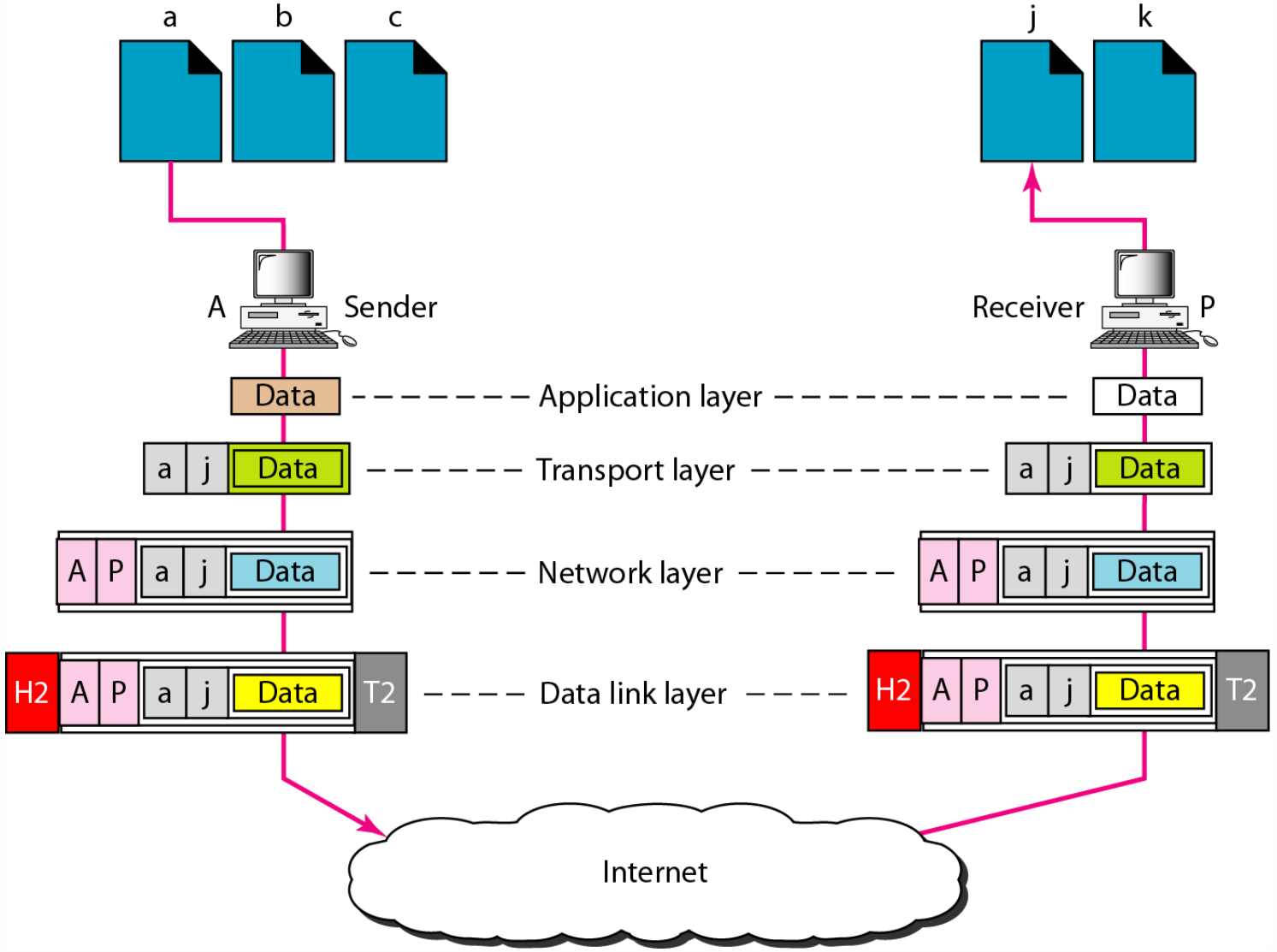
TCP/IP IN A NETWORK



TCP/IP EXAMPLE 2: THRU A ROUTER



TCP/IP WITH PORT ADDRESSES



SERVER IN TCP/IP

- Server Port Number – 0 to 1023 are reserved to well-known services (applications).

Protocol	Reserved Port #	Comments
FTP	21	File Transfer
telnet	23	remote login
SMTP	25	E-mail
DNS	53	Domain name system
HTTP	80	World Wide Web