COMP 3721
Introduction to Data Communications

01b. Week 1 – Part 2

Learning Outcomes

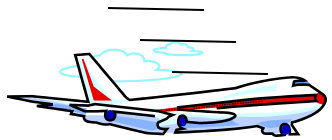
- By the end of this lecture, you will be able to:
  - Describe the concept of protocol layering in network design.
  - Describe two network models
    - TCP/IP protocol suite
    - OSI Model

Introduction

- Networks are complex, with many “pieces”:
  - hosts
  - routers
  - links of various media
  - applications
  - protocols
  - hardware, software

- Is there any hope of **organizing** structure of a network?

Analogy: Organization of Air Travel



ticket (purchase)

baggage (check)

gates (load)

runway takeoff

airplane routing

ticket (complain)

baggage (claim)

gates (unload)

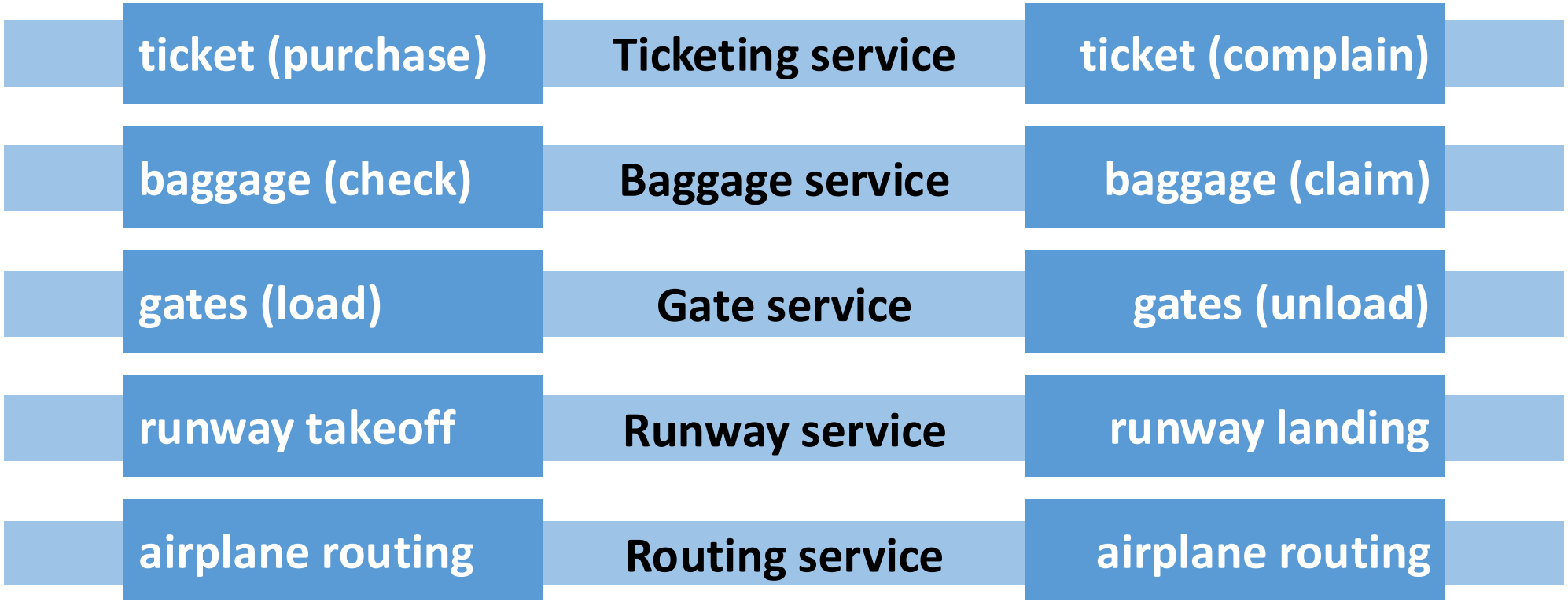
runway landing

airplane routing

airplane routing

airline travel: a series of steps, involving many services

Analogy: Organization of Air Travel



layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

What is a Protocol?

- A protocol defines **what** is communicated, **how** and **when**. This provides accurate and timely transfer of information between different devices on a network.
- In other words, a protocol defines the **format and the order of messages exchanged between two or more communicating entities** as well as **the actions** taken on the transmission and/or receipt of a message or other event.

Principles of Protocol Layering

- **First Principle**:
  - For having **bidirectional communication**, **each layer** must be able to perform **two opposite tasks**.
- **Second Principle**:
  - The two objects under each layer at both sites should be **identical**.

Protocol Layering

- **Protocol layering** enables us to divide the complex task of communication into multiple smaller and simpler tasks.
- Network designers organize protocols and the network hardware and software that implement the protocols in **layers**.
- Service model of a layer in protocol layering is the services that a layer **offers** to the layer above.
- **Each layer** provides its service by **performing certain actions** within that layer and by **using** the services of the layer directly below it.

Protocol Layering Benefits

- Advantages of protocol layering:
  1. **Separating the services from the implementation**
  2. **Simpler and less expensive intermediate systems**
  3. **Modularity** (independent layers) → black box
     - ease of maintenance and updating of the system, change in a layer's service implementation is **transparent** to rest of system.

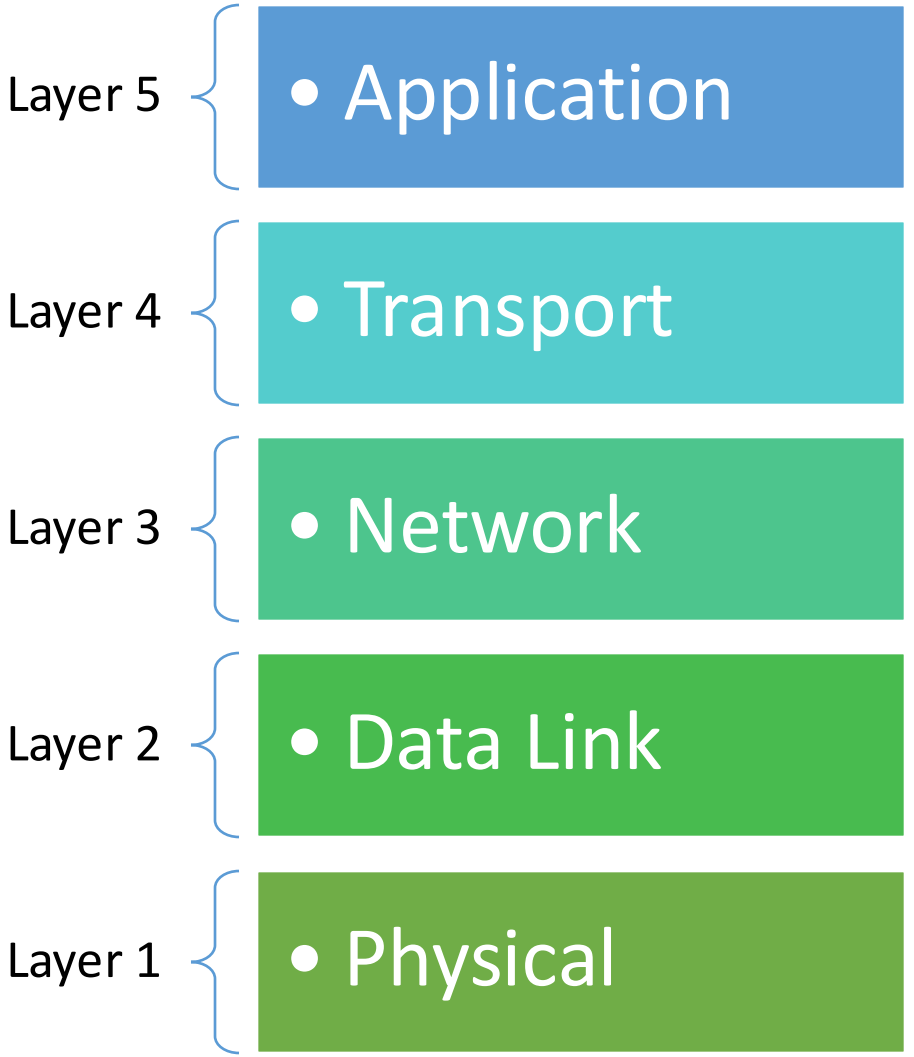
Two Models for Computer Network Operations

- **TCP/IP protocol suite**
- **OSI model**

- **Protocol Suite** (**Stack**): a set of protocols organized in different layers (designed to work together).

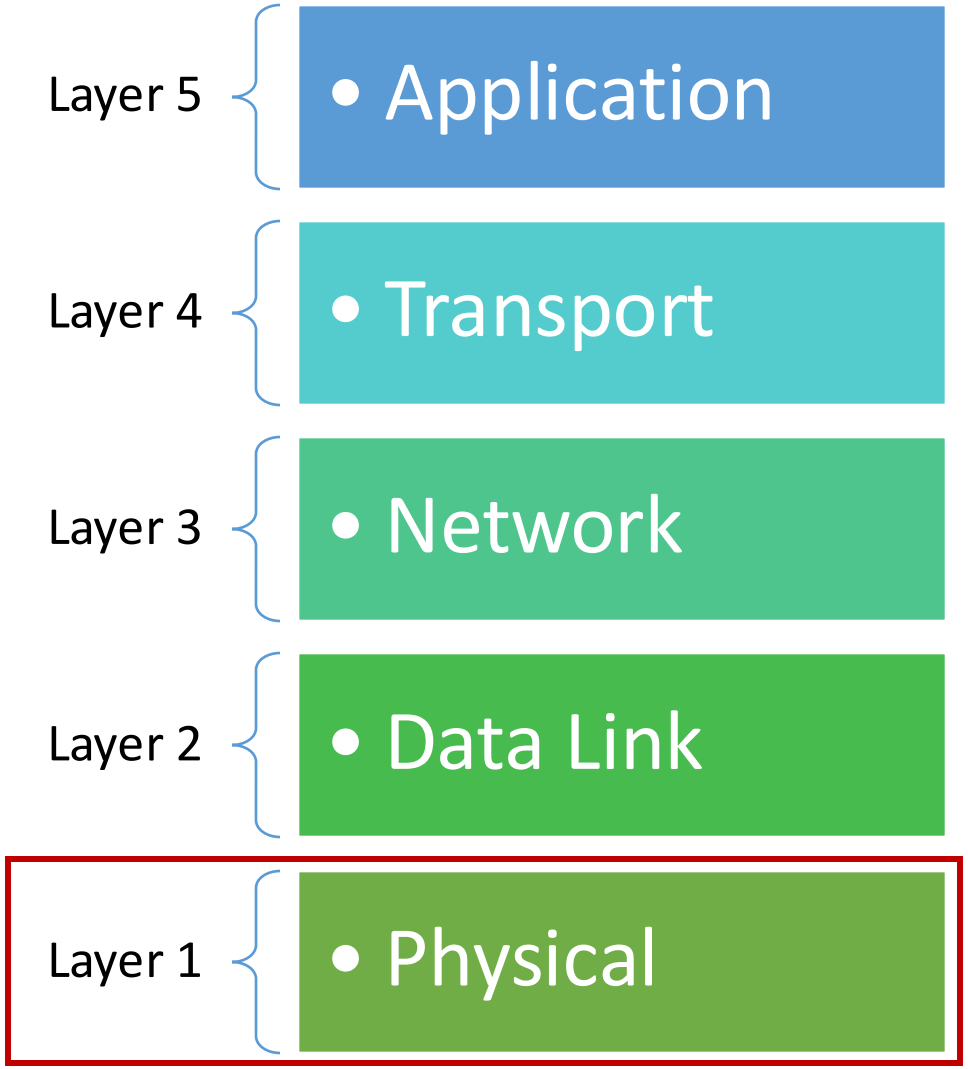
TCP/IP Protocol Suite

- **TCP/IP** (Transmission Control Protocol/Internet Protocol) **Protocol Suite**
  - used in the Internet today (**the Internet protocol stack**)
  - a **five-layer hierarchical** model



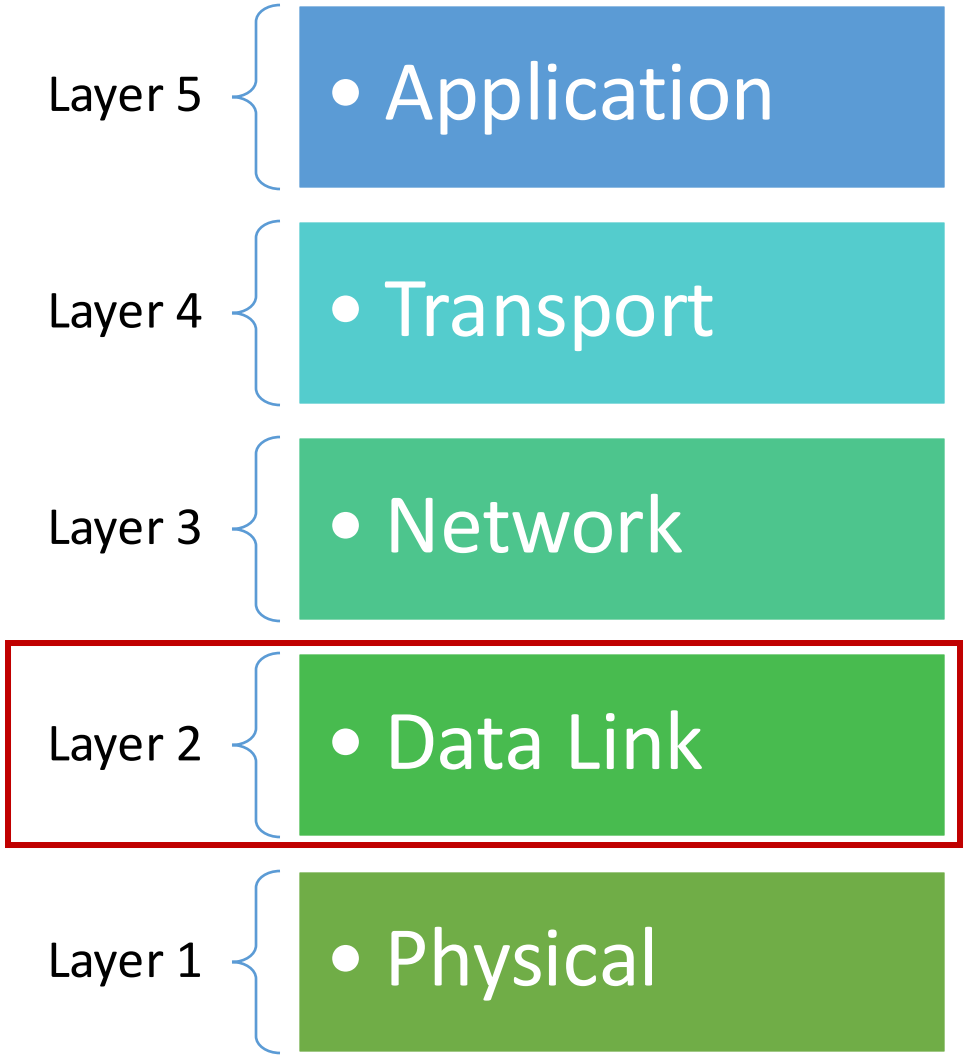
TCP/IP Protocol Suite – Physical Layer

- Carries individual **bits** across the link (from one node to the next)
- Actually, the bits received in a frame from the data-link layer are **transformed to signals** and sent through the transmission medium.
  - **physical layer protocols** are **link dependent** and they rely on the actual transmission medium of the link.



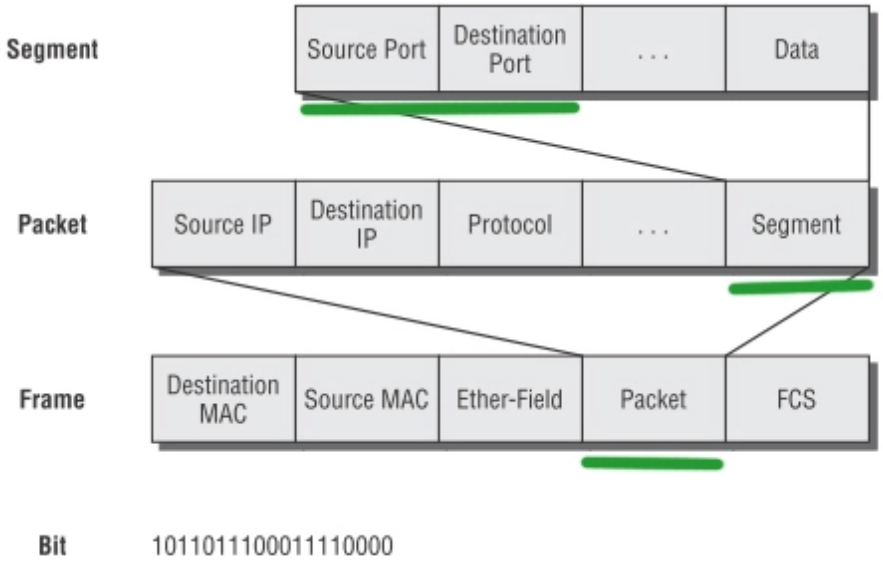
TCP/IP Protocol Suite – Data Link Layer

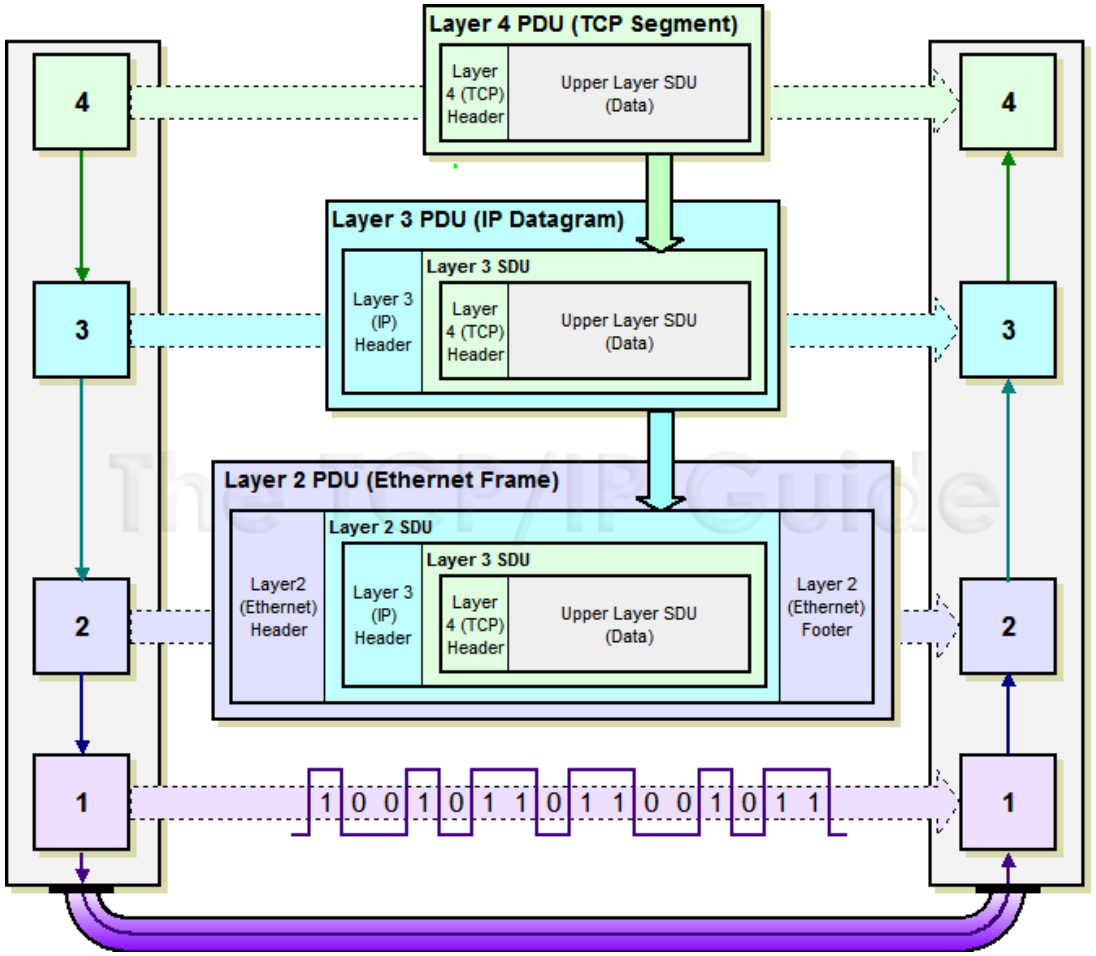
- Data transfer between **neighboring network elements/devices** (without errors)
  - PDU name: **frame**
  - protocols: Ethernet, 802.11 (WiFi), …



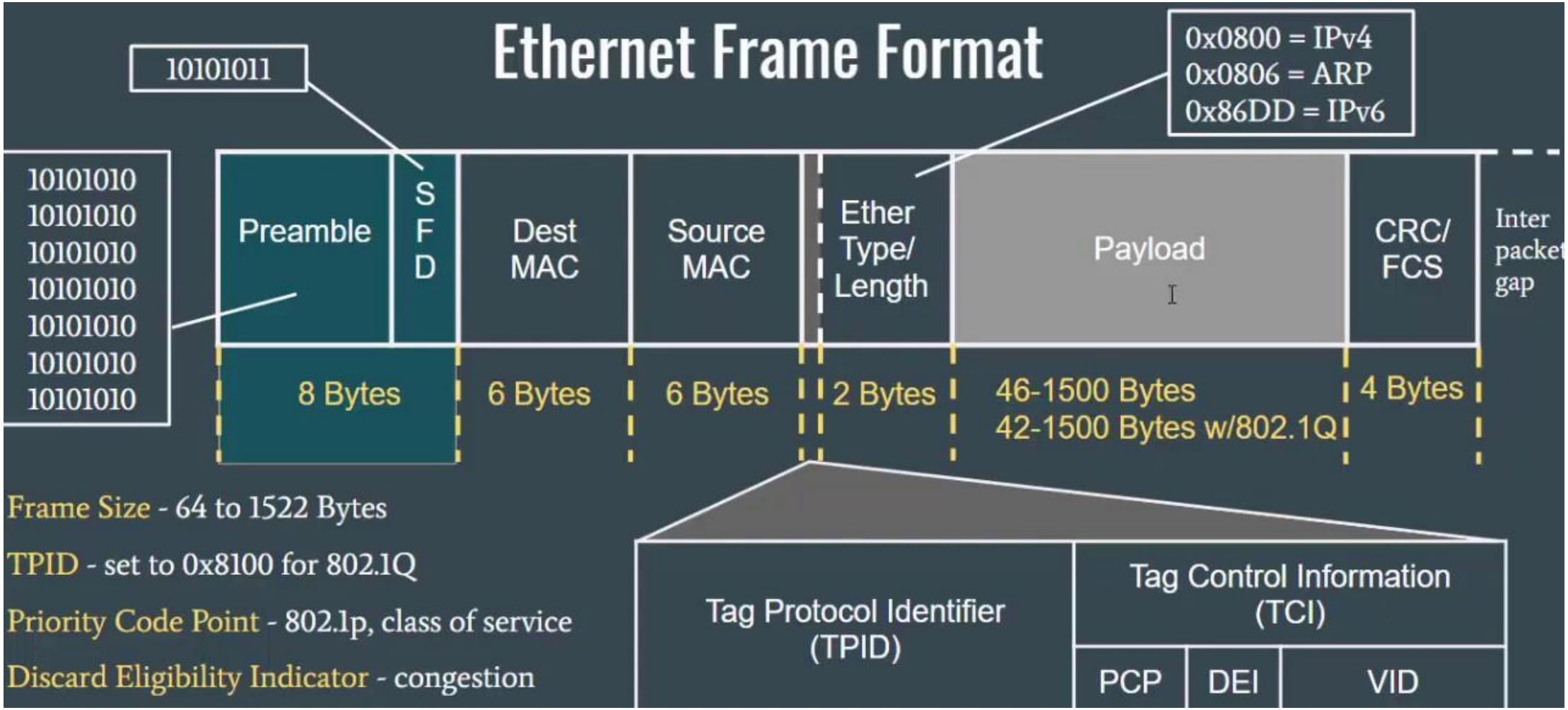
PDU

- **Protocol Data Unit**
  - a **unit of data** that is passed between different layers of a protocol stack



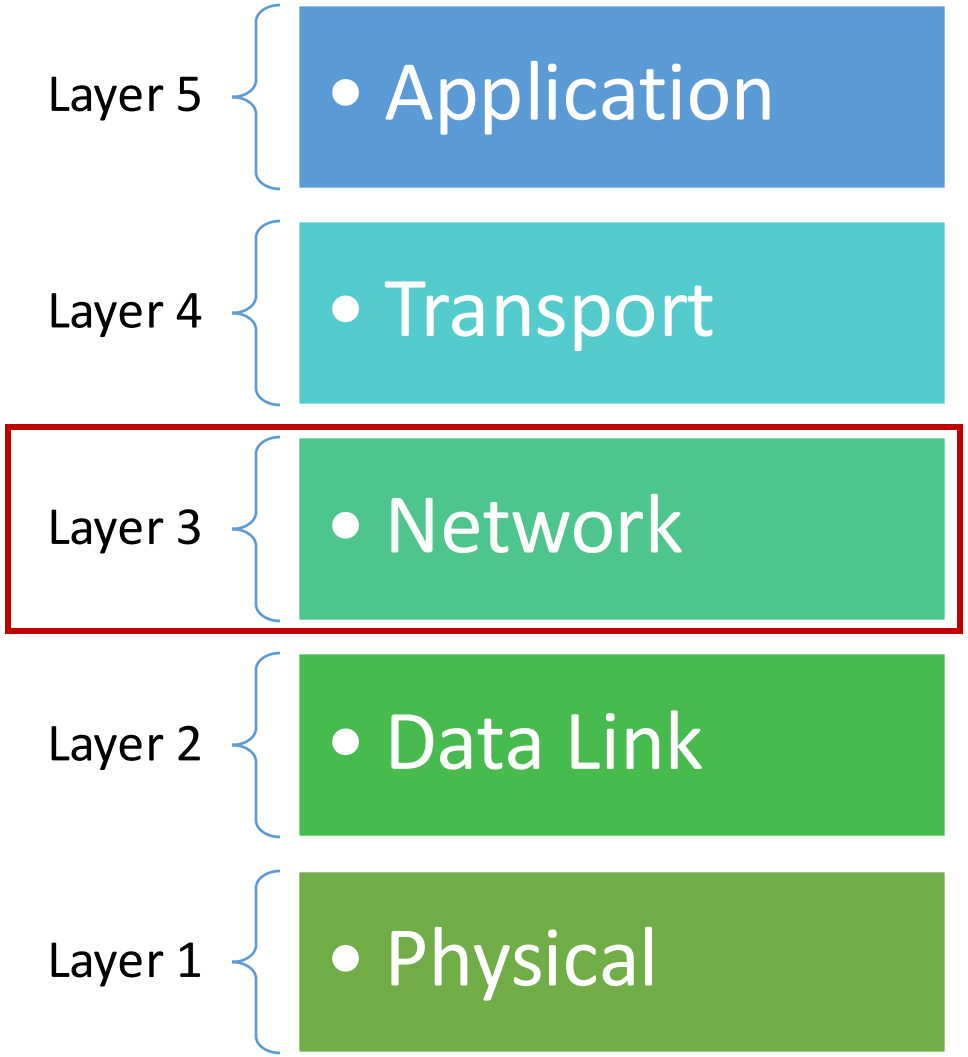


An Example – Frame



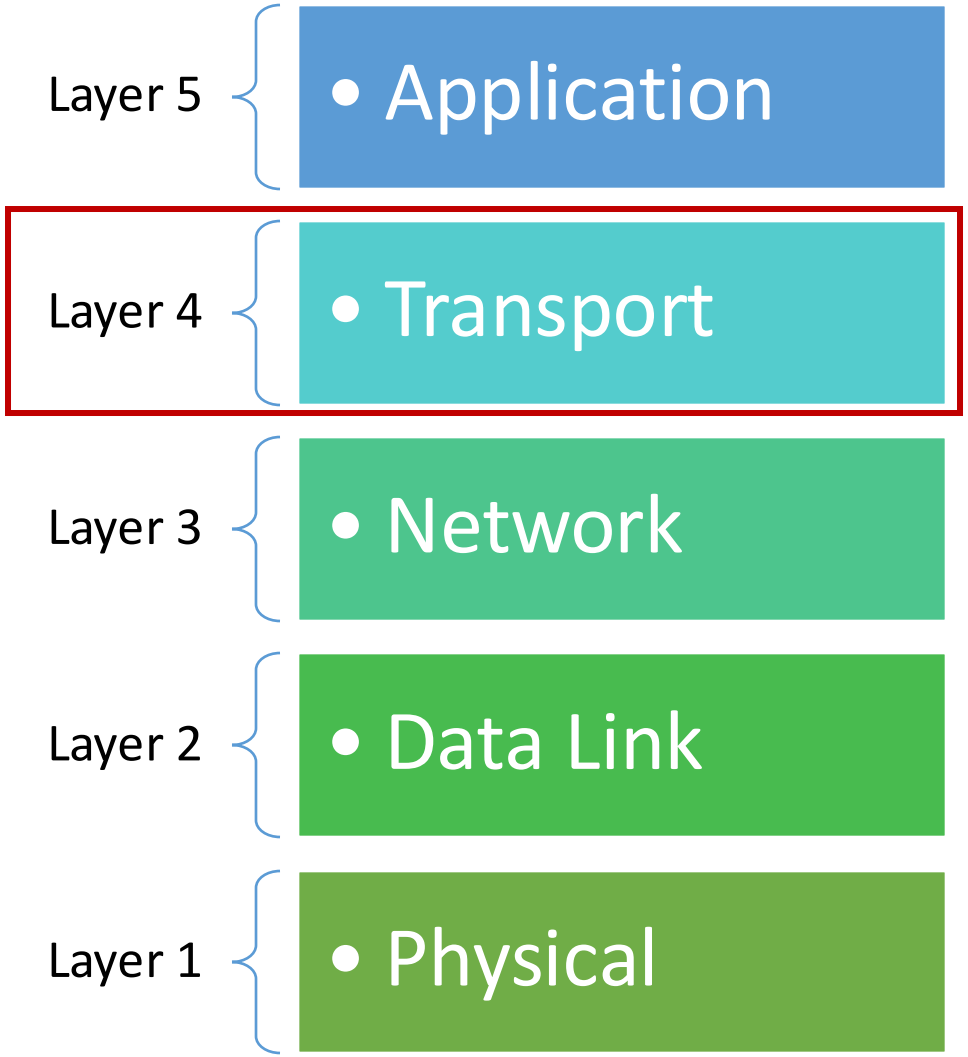
TCP/IP Protocol Suite – Network Layer

- Routing of datagrams from source to destination (**host-to-host** communication)
  - PDU name: **datagram**/**packet**
  - also called **IP layer**
  - protocols: IP (Internet Protocol), ICMP, DHCP, ARP, routing protocols,…



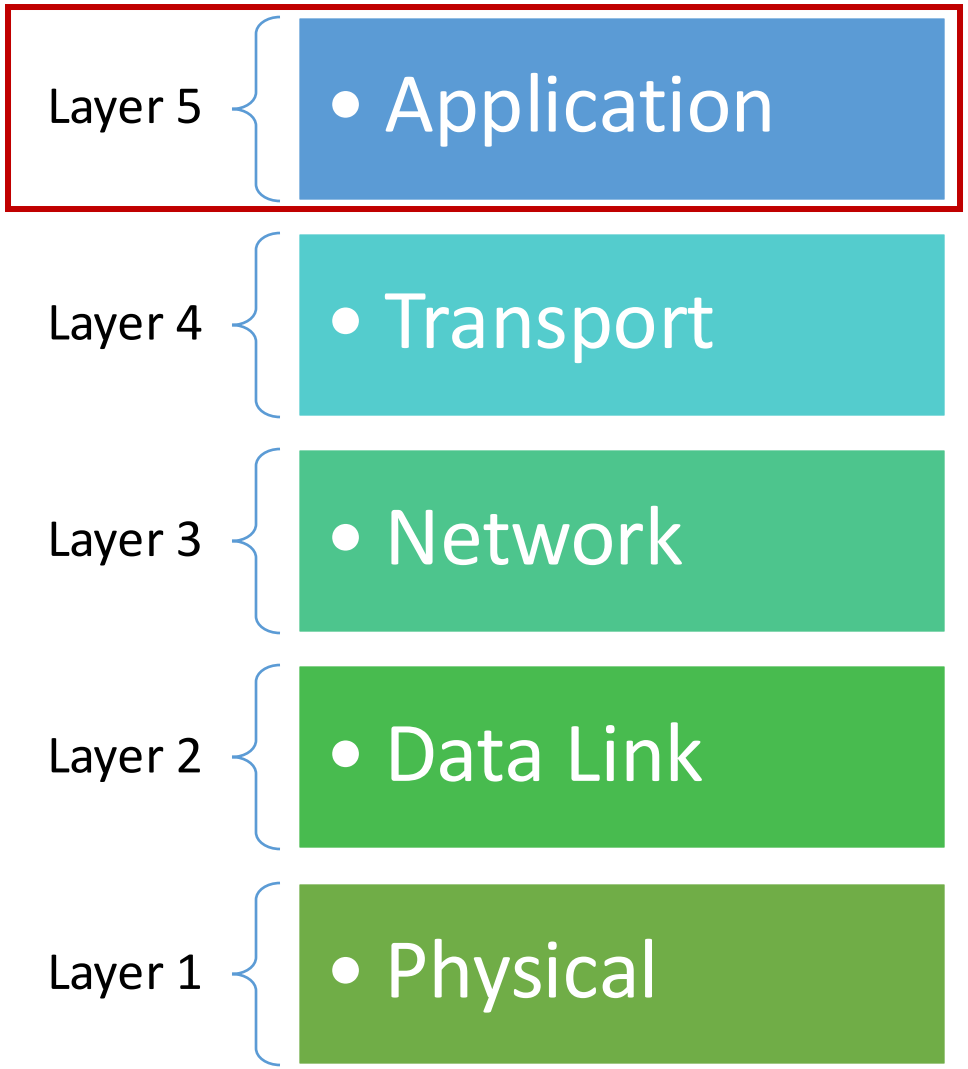
TCP/IP Protocol Suite – Transport Layer

- Logical communication between application processes running on different hosts (**process-to-process delivery** of the entire message)
  - PDU name: **segment/user datagram**
  - protocols: TCP, UDP, SCTP
  - transport layer protocols almost always implemented in **software** in the end systems.

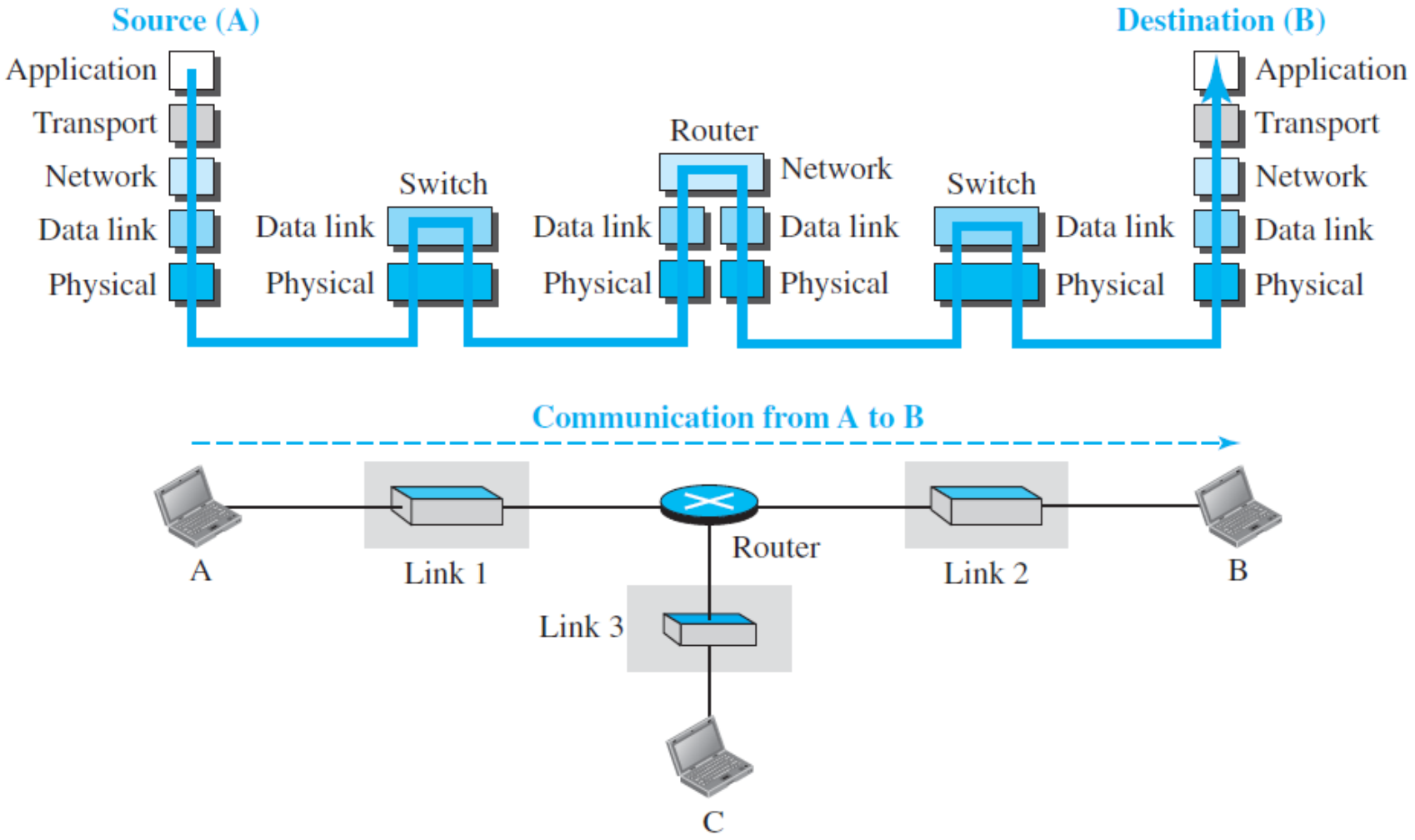


TCP/IP Protocol Suite – Application Layer

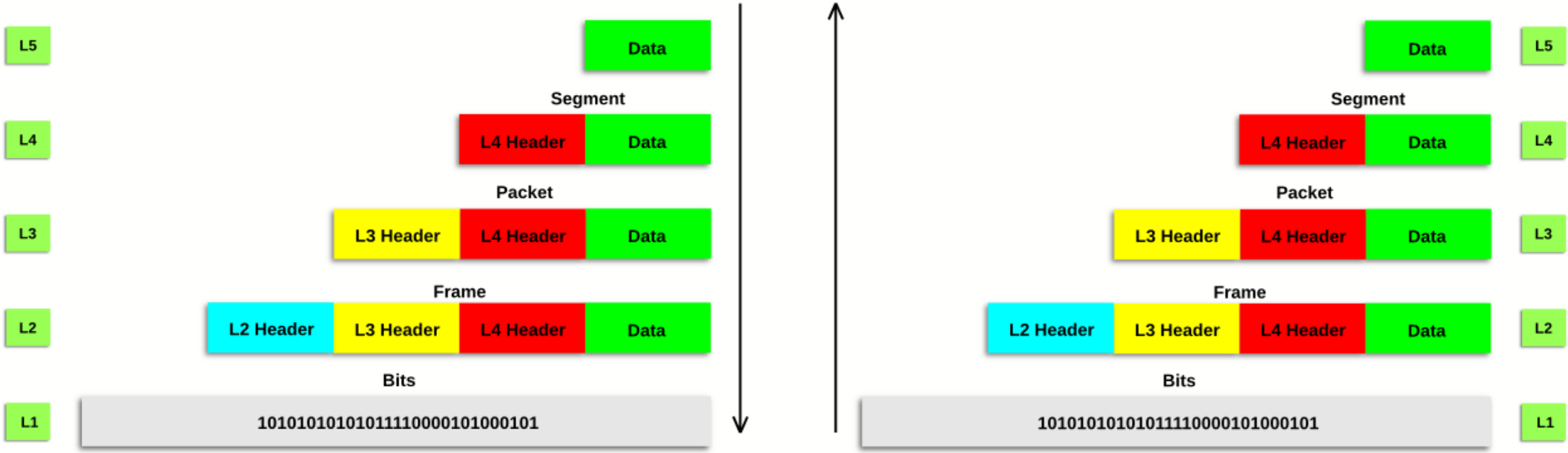
- Communication for a network application takes place between end systems at the application layer.
  - PDU name: **message**
  - protocols: IMAP, SMTP, HTTP, FTP, Telnet, DNS, …
  - application layer protocols are implemented in **software** in the end systems.



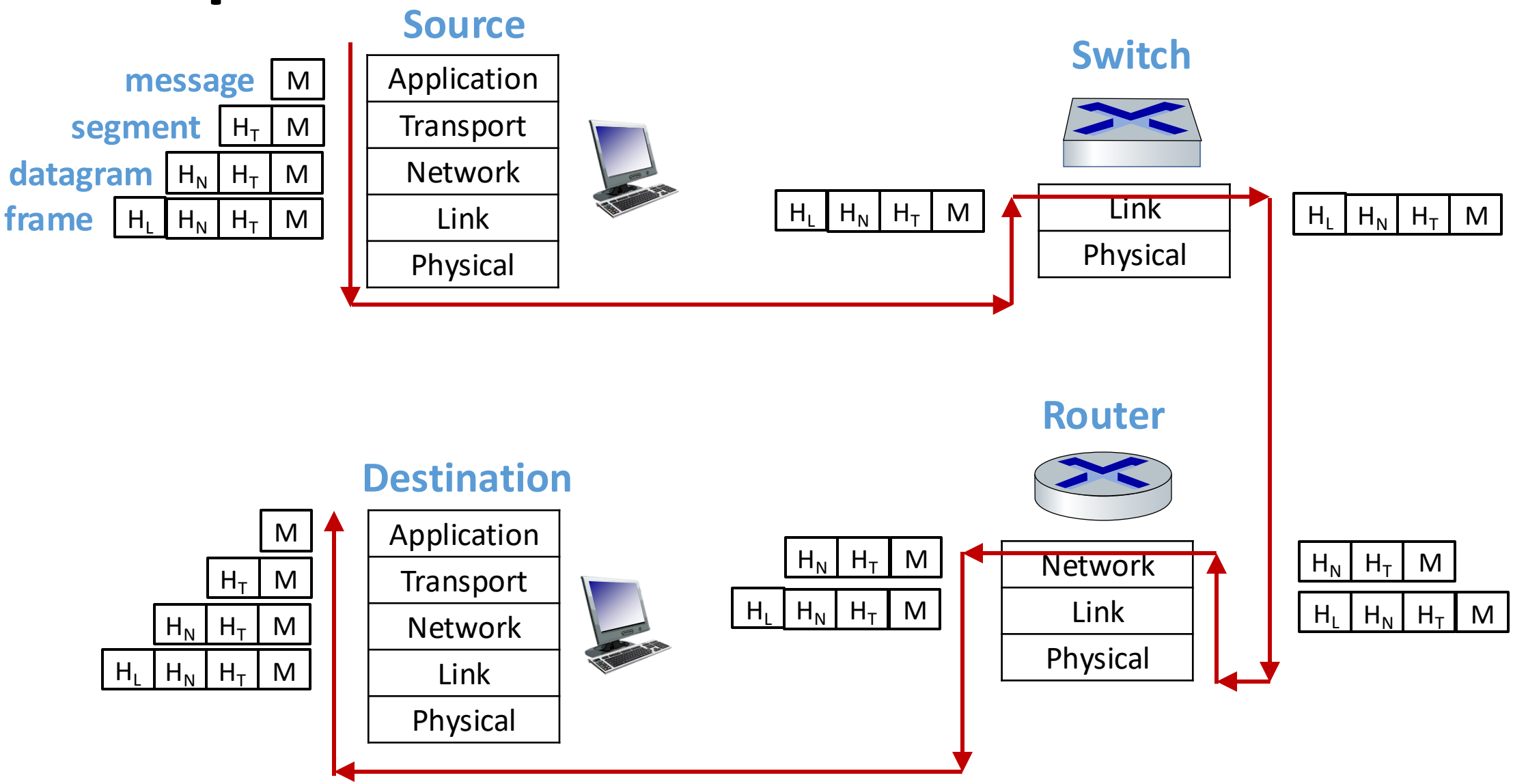
Communication through an internet



Encapsulation and Decapsulation

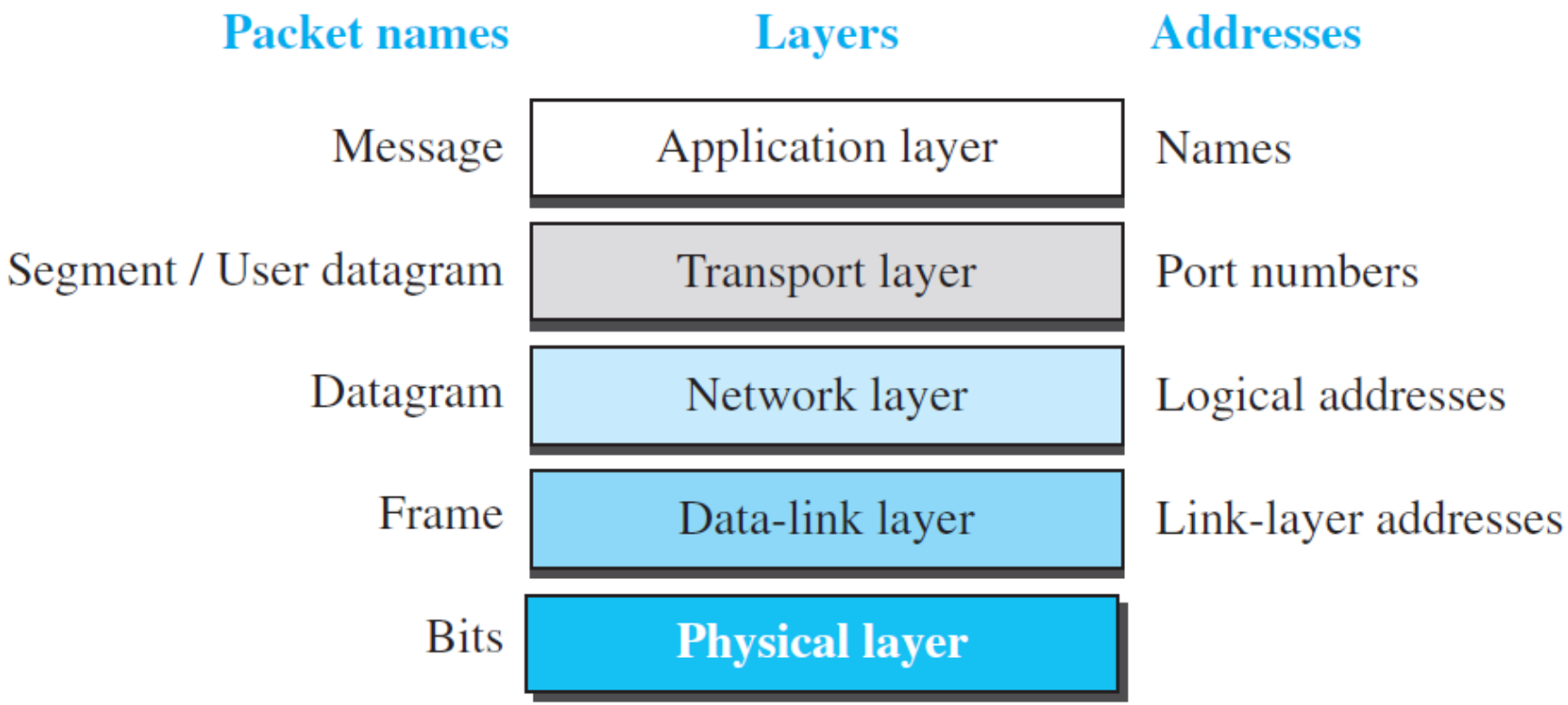


Example


Source
message
segment
datagram
frame
M
H_T M
H_N H_T M
H_L H_N H_T M
Application
Transport
Network
Link
Physical
Switch
H_L H_N H_T M
Link
Physical
H_L H_N H_T M
Router
H_N H_T M
H_L H_N H_T M
Network
Link
Physical
H_N H_T M
H_L H_N H_T M
Destination
M
H_T M
H_N H_T M
H_L H_N H_T M
Application
Transport
Network
Link
Physical

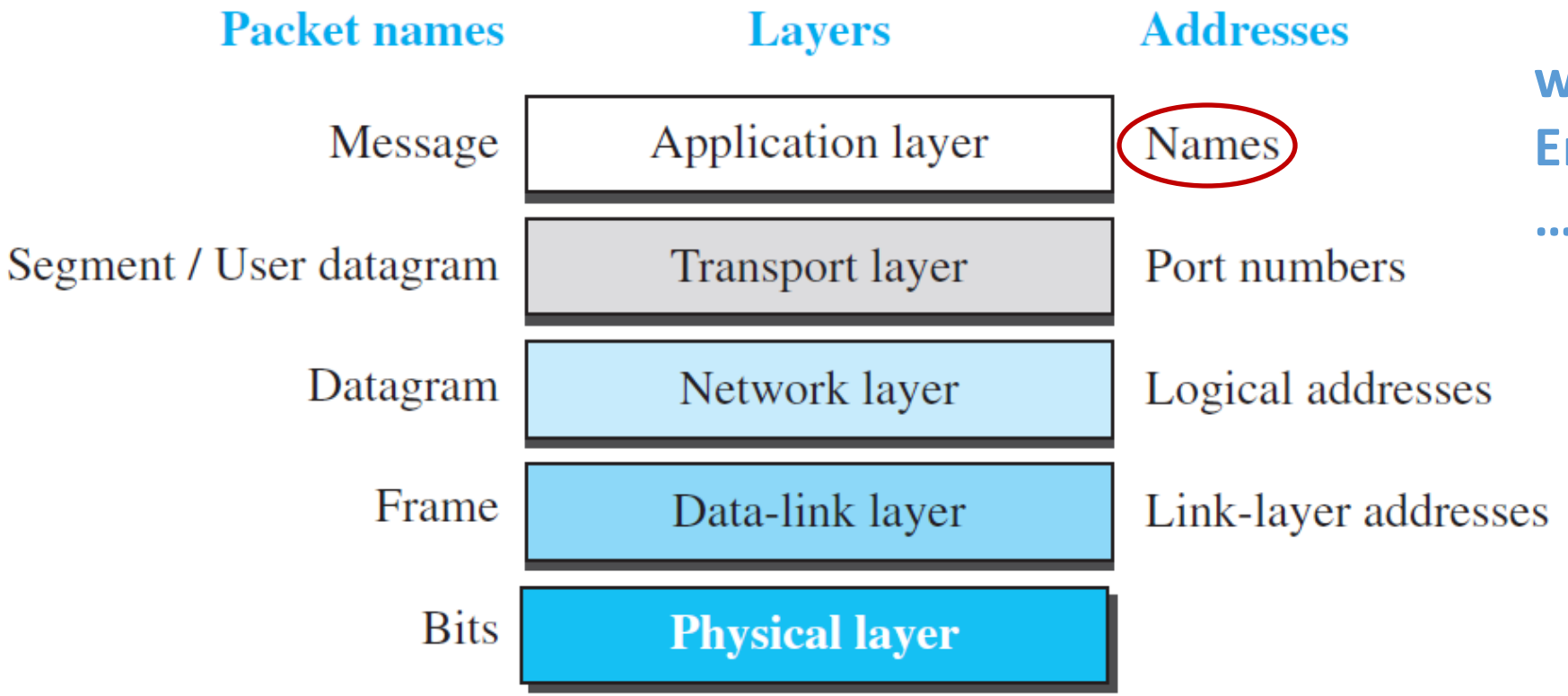
Addressing

- **Four levels of addresses** are used in an internet following the TCP/IP protocols:



Addressing

- **Four levels of addresses** are used in an internet following the TCP/IP protocols:



website URLs,
Email addresses,
…

Addressing

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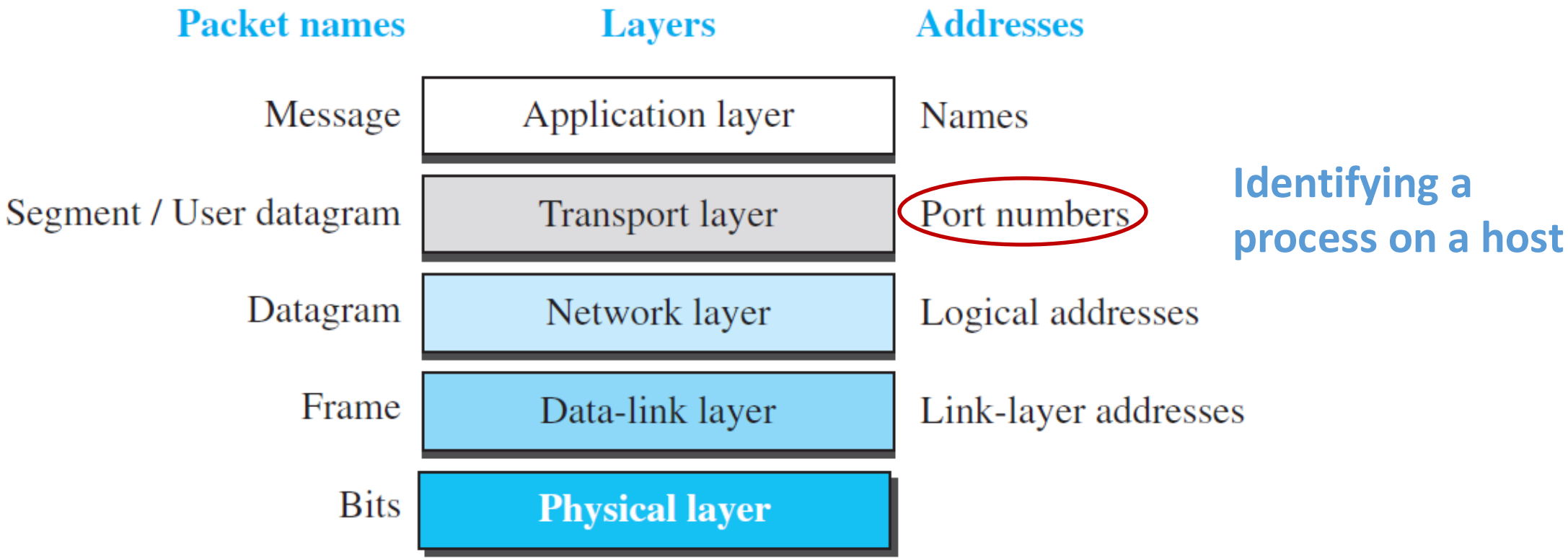

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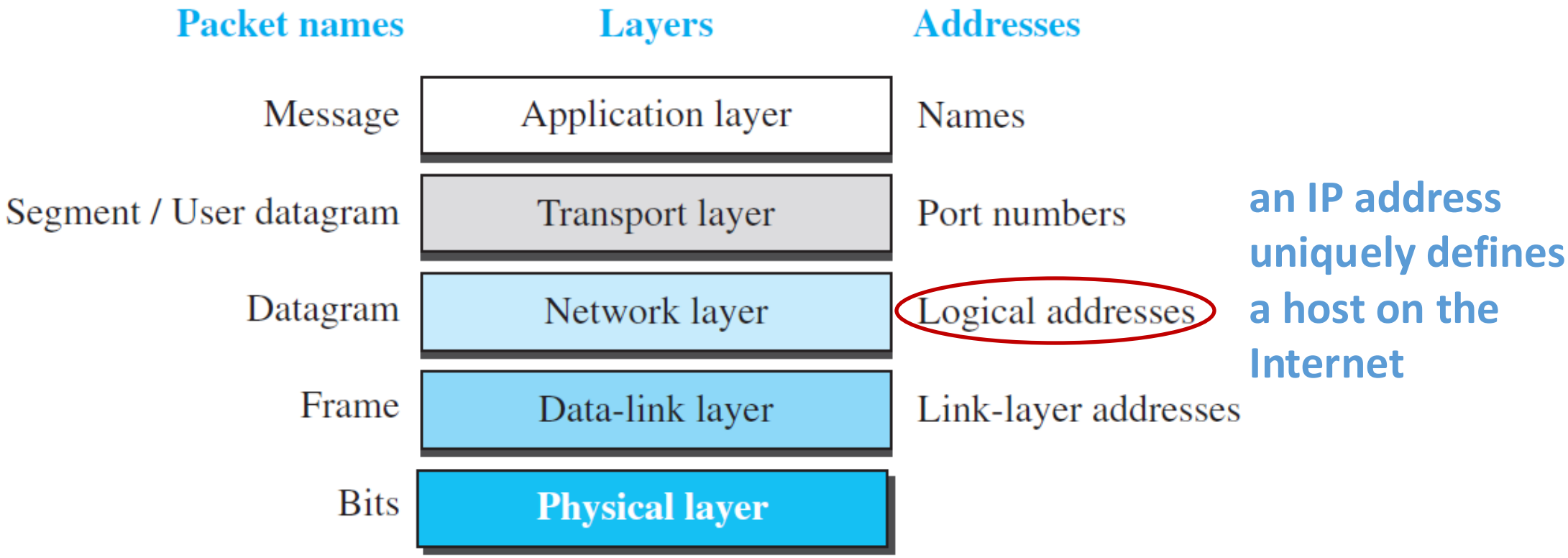

an IP address uniquely defines a host on the Internet

Addressing

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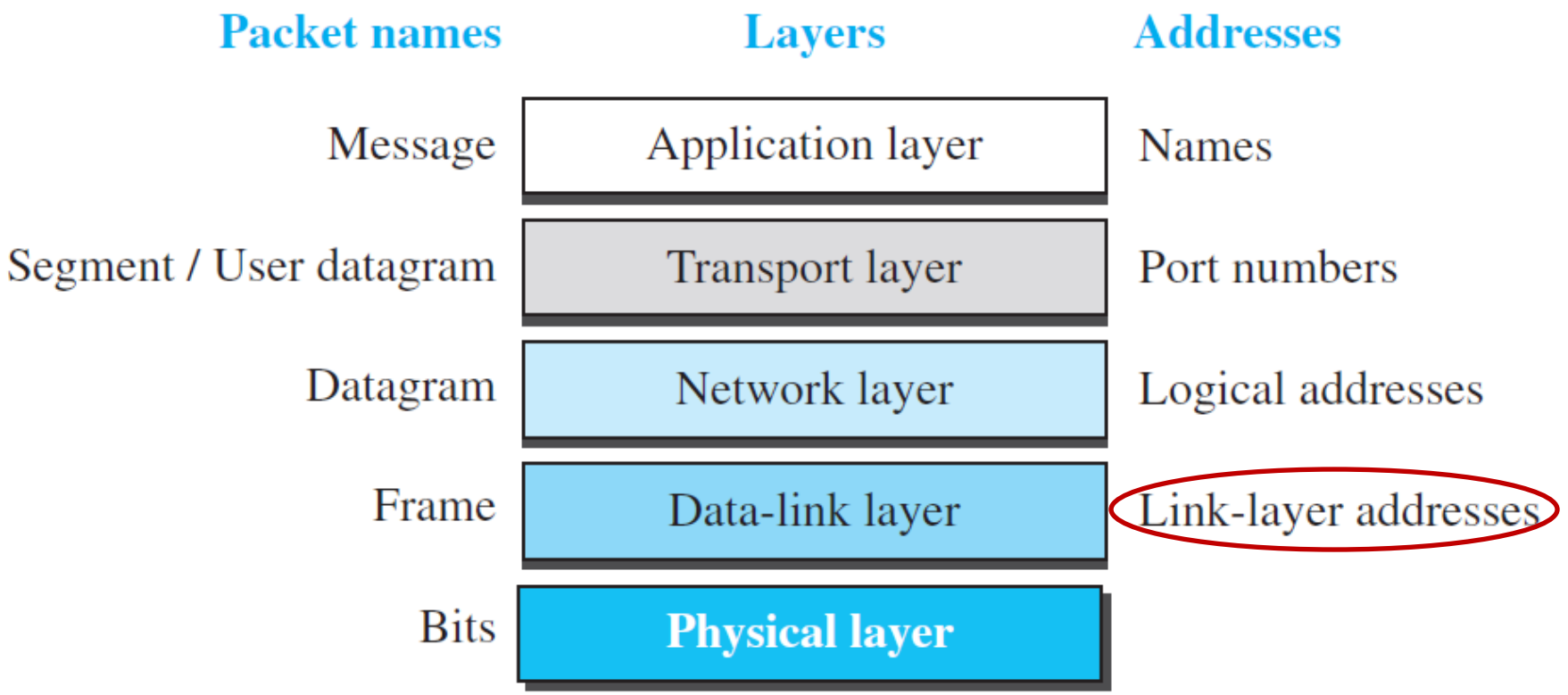


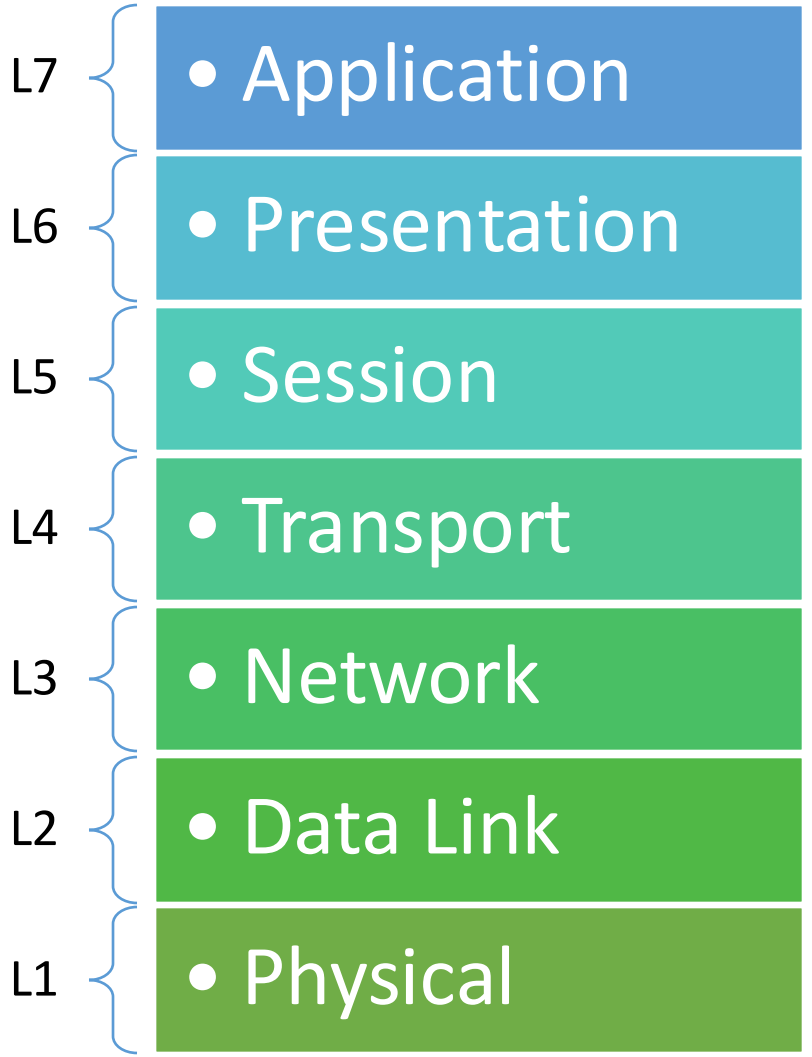
defining a specific host or router in a network (LAN or WAN)

Good to Know

- **Physical layer** and **data-link layer** typically implemented in a NIC (Network Interface Card) and they handle **communication over a specific link**.
- **Hosts** (**end systems**) implement all 5 layers of the TCP/IP protocol stack.

The OSI Model

- **Open Systems Interconnection** (**OSI**) model
  - an ISO standard for network communications
  - a layered framework (7 layers)
  - Application, Presentation, and Session layers → combined into Application layer in TCP/IP suite
  - **Presentation layer**: allows communicating applications to interpret the meaning of data exchanged
    - data compression, data encryption, …
  - **Session layer**:
    - session management, synchronization of data exchange, …



Summary

- Protocol layering and its benefits.
- Network models, including TCP/IP protocol suite and OSI model.

References

[1] Behrouz A.Forouzan, Data Communications & Networking with TCP/IP Protocol Suite, 6th Ed, 2022, McGraw-Hill companies.

[2] J.F. Kurose, K.W. Ross, Computer Networking: A Top-Down Approach, 7th Ed, 2017, Pearson Education, Inc.

Reading

- Chapter 1 of the textbook, sections 1.4 – 1.6 (inclusive)
- Chapter 1 of the textbook, section 1.8 (Practice Test)