# CS 524 A

## Introduction to Cloud Computing

## Module 5: Data Networking and Distributed Computation (Part 1)

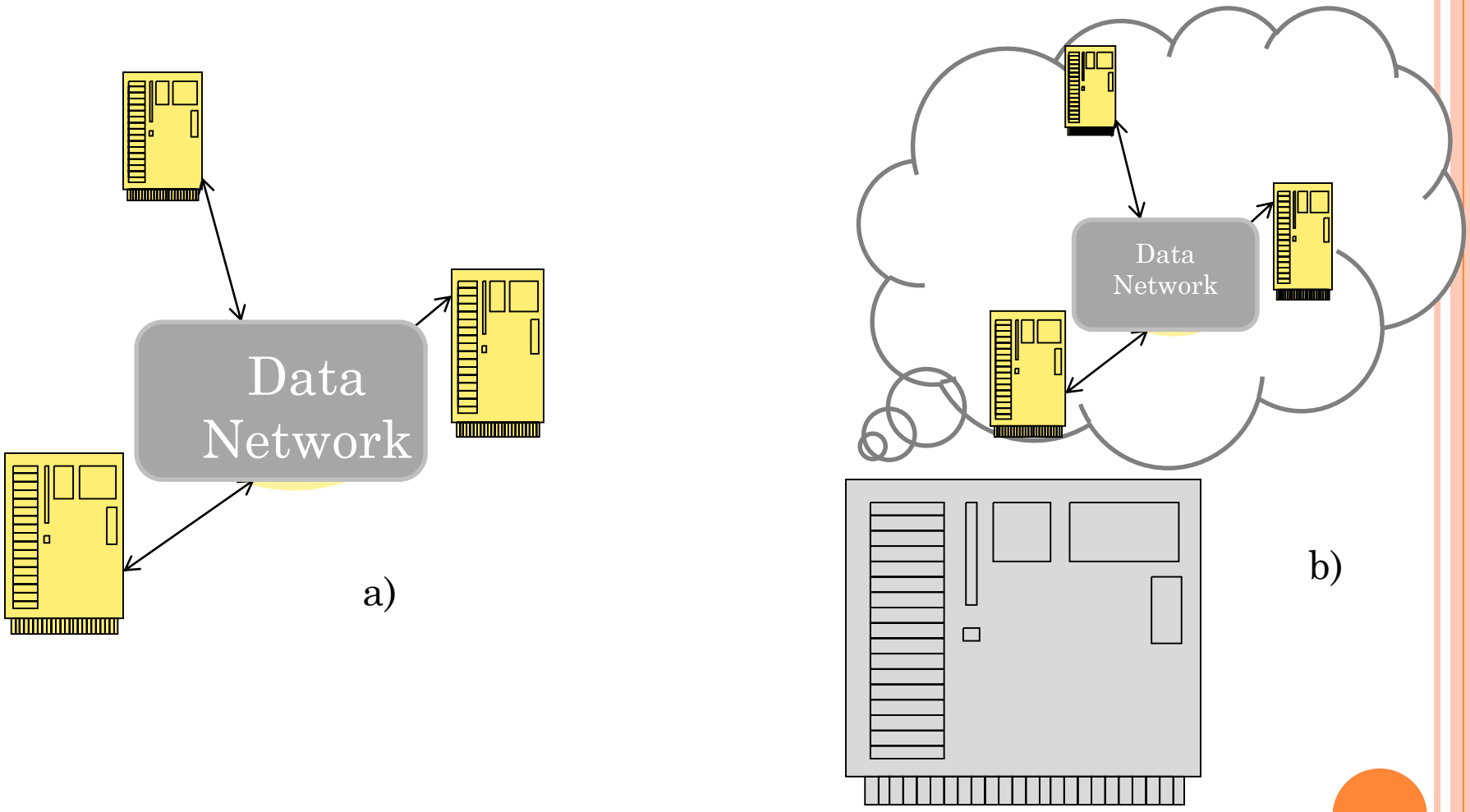
# Outline (Cloud Computing = Virtual Machines + Virtual Networks + Orchestration and Management)

- Our topic is *Networking*
- Two major topics
  - Introduction to data communications and IP networks
  - QoS in IP networks and *multiprotocol* "pipes"
  - Network organization, peering, and pricing
- Today we cover
  - History (telegraph and telephone networks, Paul Baran's work in RAND, PDN, PSDN, ISDN, Internet)
  - The OSI Reference Model
  - *Link layer in Local Area Networks ("virtual LANs"—later )*
  - An introduction to the Internet

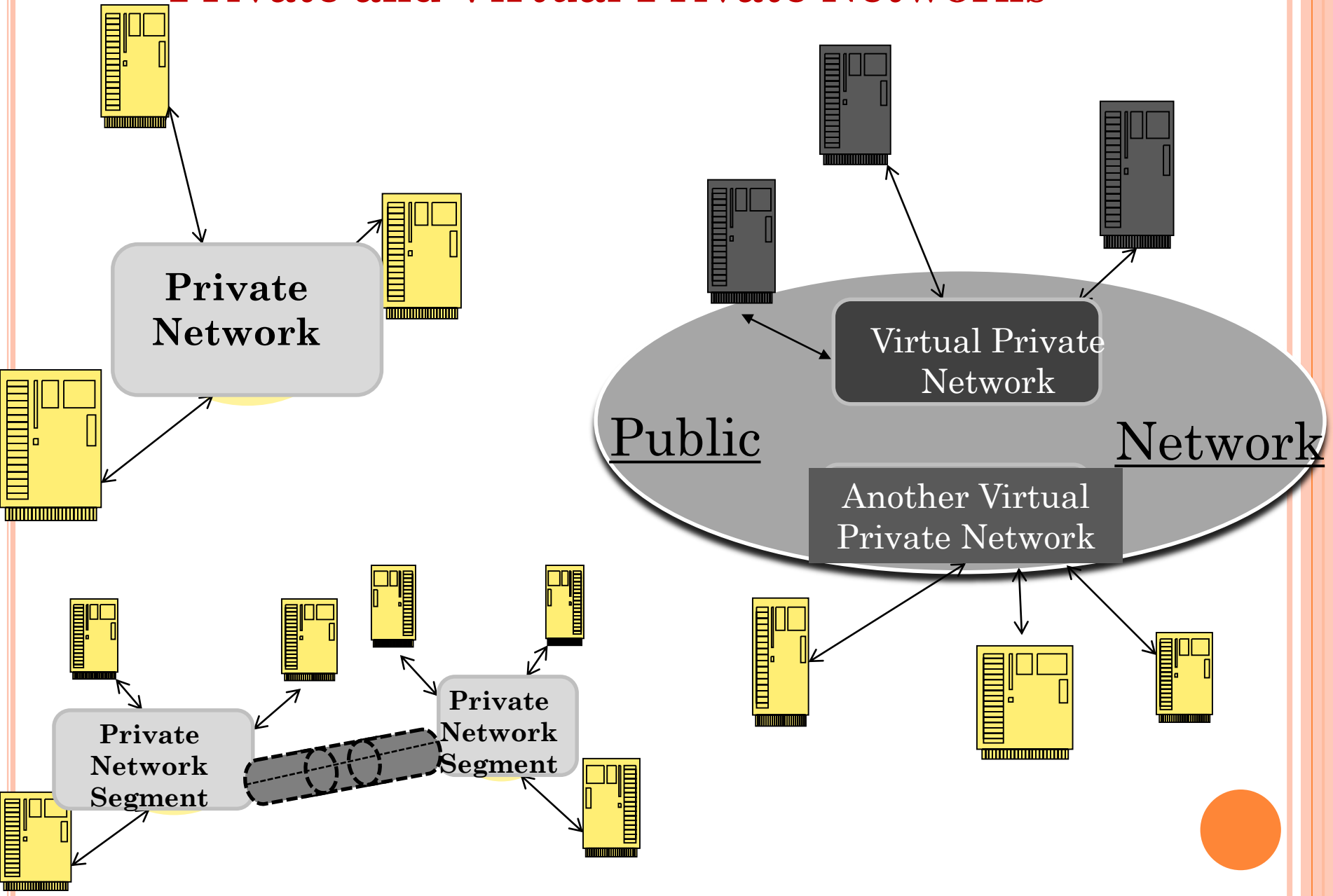
# Relation of the overall subject to Cloud Computing

- IaaS provides both virtual machines and "pipes"
- The Cloud *is* built on data networking
- All cloud services are accessed via Internet *Application Layer* protocols (at run-time) and API (by the programmer)
- We need data communications and distributed computing to understand
  - how the Cloud is built
  - what services the Cloud can provide
  - how to access Cloud services

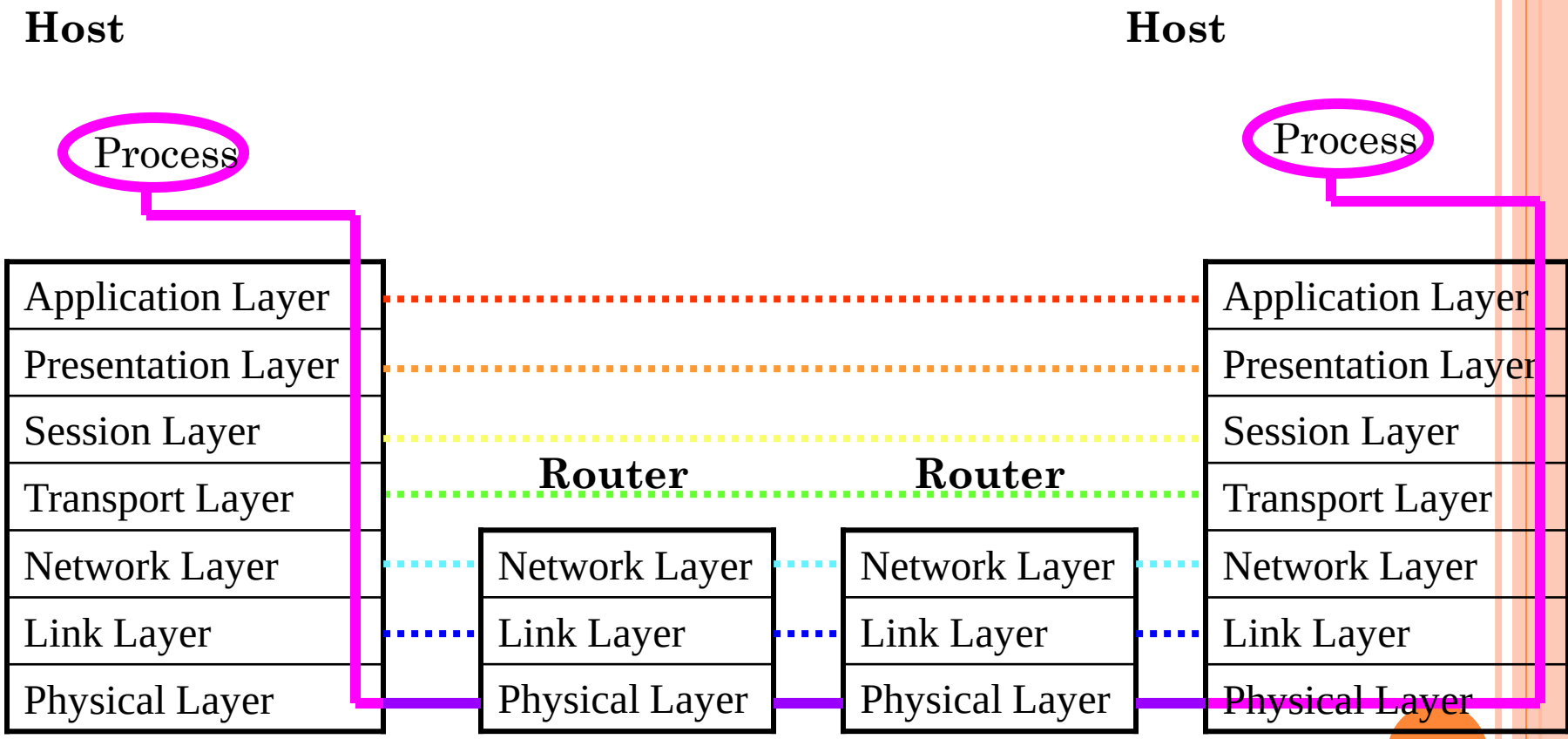
# Dual aspects of networking in Cloud Computing



# Private and Virtual Private Networks

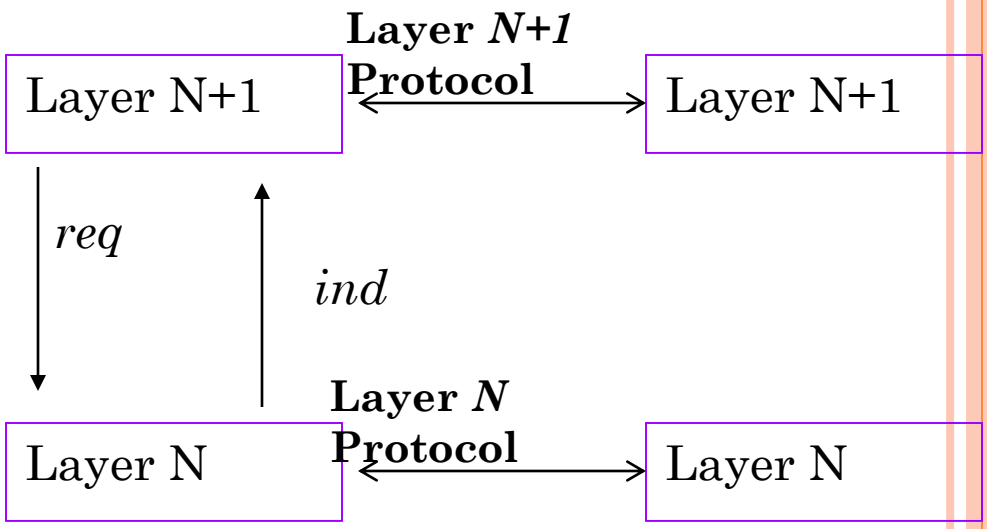


# How Do Machines Talk?
## *The OSI Reference Model*



# Requests, Indications, and Protocols

| Application Layer |
| --- |
| Presentation Layer |
| Session Layer |
| Transport Layer |
| Network Layer |
| Link Layer |
| Physical Layer |




- *Requests* are typically implemented as procedure calls;
- *Indications* are technically interrupts

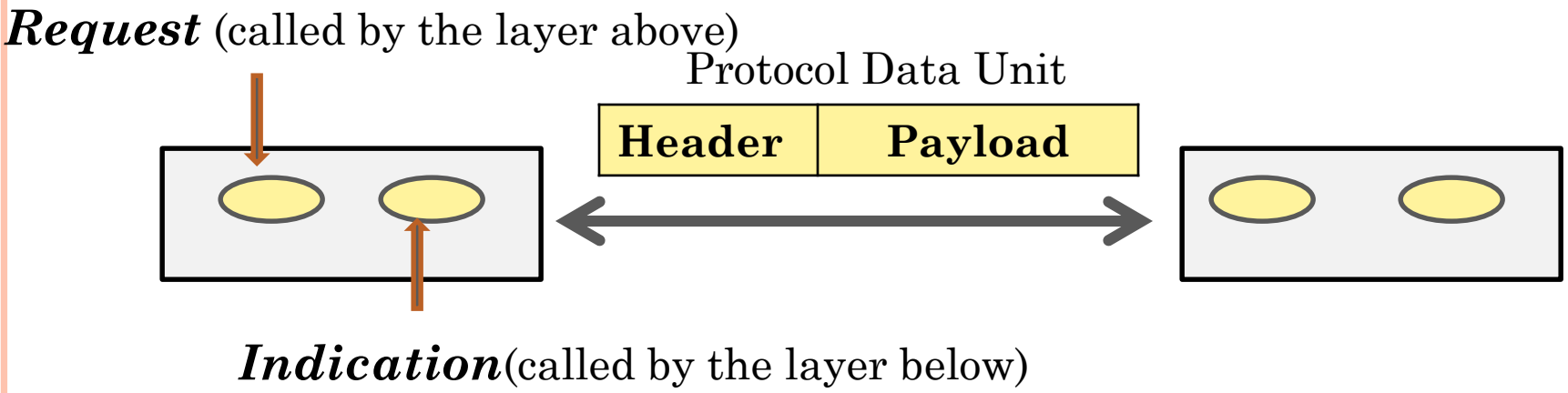



**Figure 4.4: *Requests* and *Indications* as methods in the Layer Class**

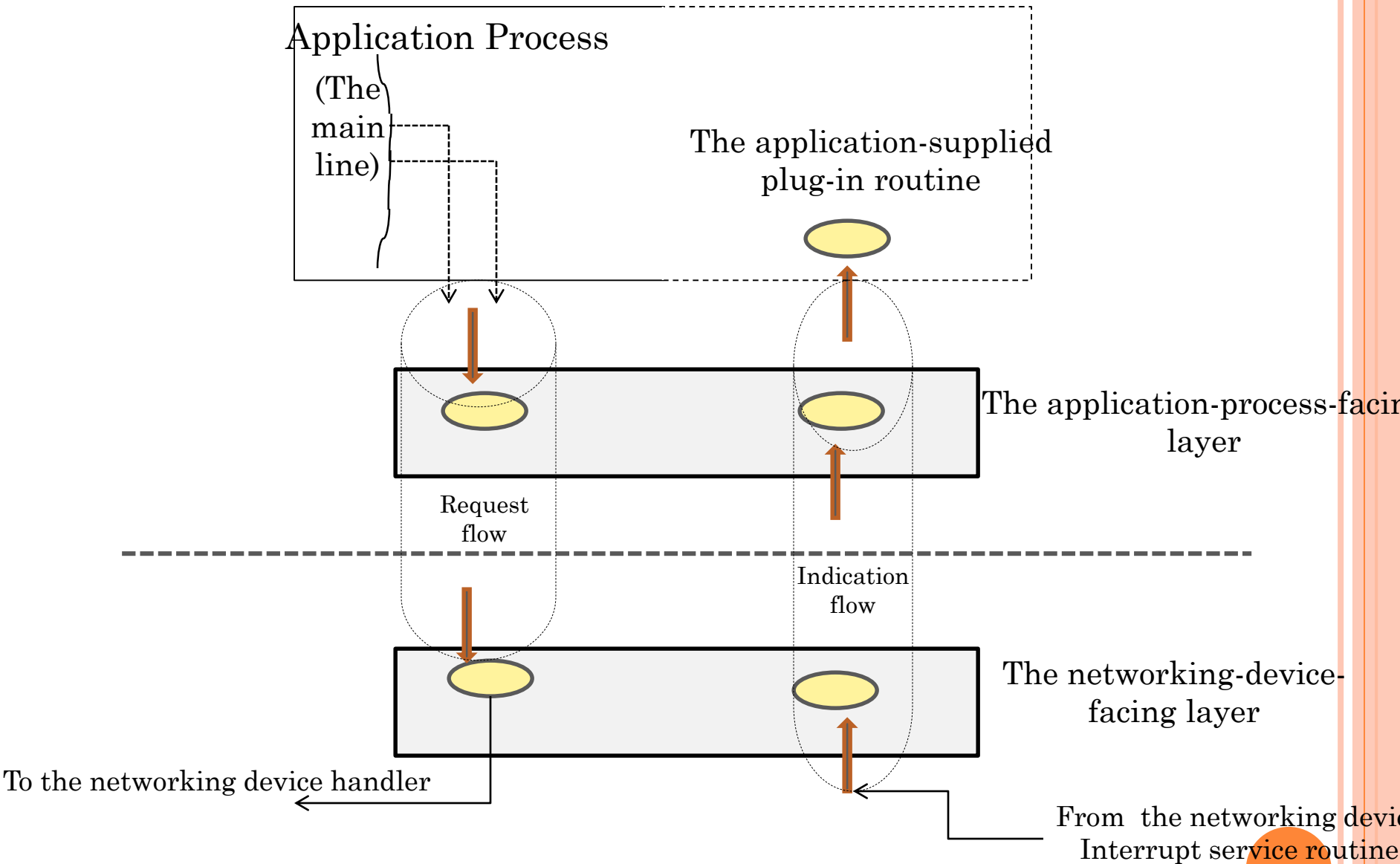
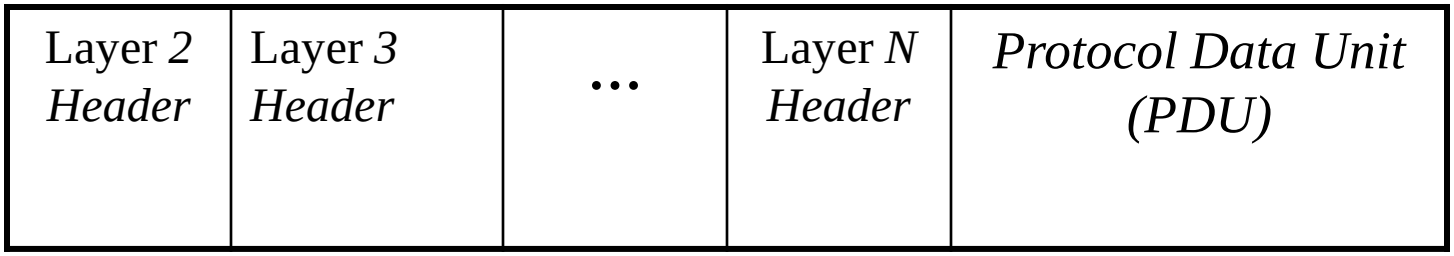



**Figure 4.5: Summary of the overall computational model**

# Protocol Frame Format




11100100110001001000010010010010001000100010001001111100100111 0

Layer 1 (*Physical layer)* just produces a bit stream

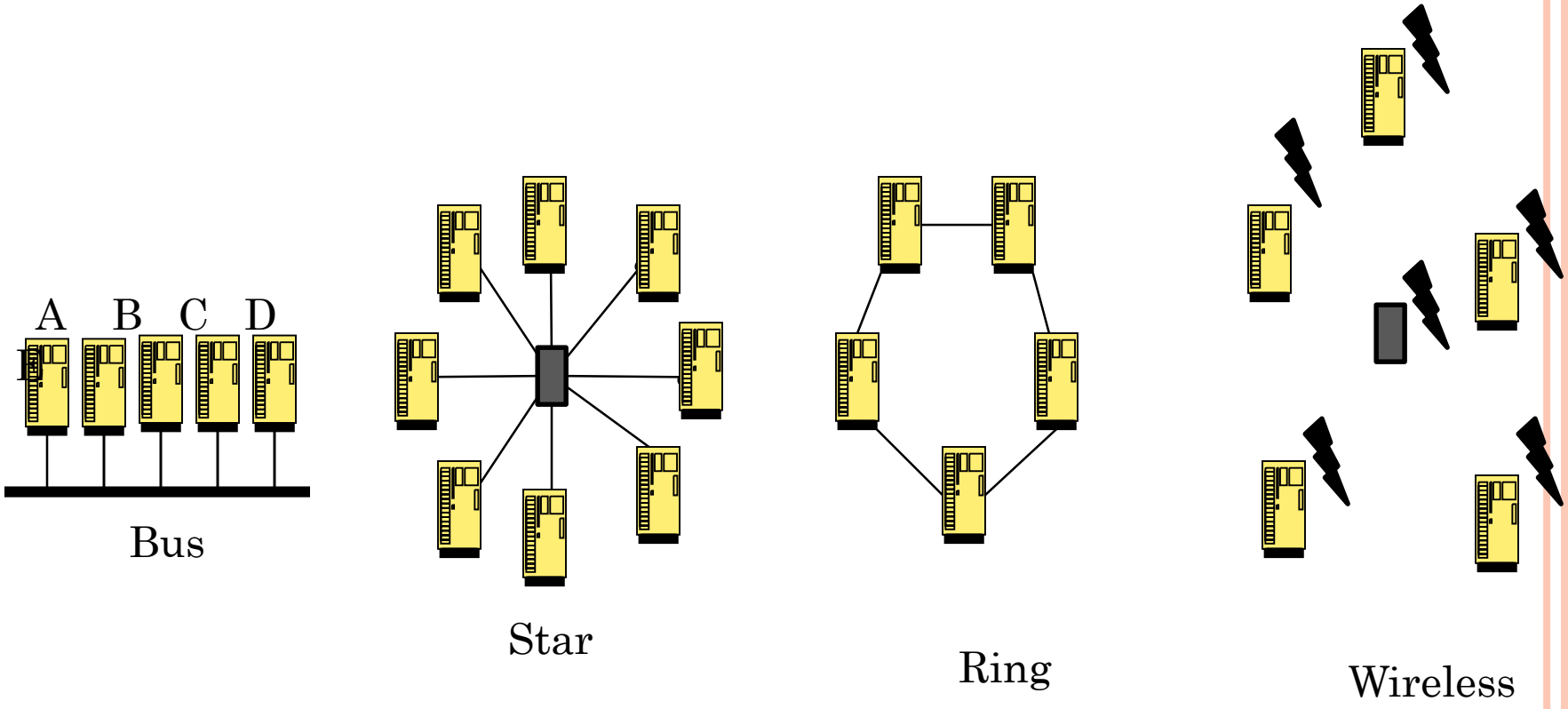
# The Physical Layer

- The Physical layer is concerned with transmitting "*0*"*s* and "*1*"s
- It  knows how to establish the connection (in case of modems and telephone lines) or avoid collisions (in case of *Ethernet*-like networks)
- It has to know how voltages or light bursts are mapped into binary digits

0 0 0 1 0…

1 0 1 1 1 0 0…

# Broadcast media configurations




NB: The dangers of the *promiscuous* mode

# The Data Link Layer

- The data link layer is responsible for *framing* the *1*s and *0*s of the Physical Layer
- In some cases it is also responsible for guaranteeing delivery (so it needs checksums and other error detection [or error correction] mechanisms as well as retransmission of the garbled packets)
- Thus the data link *protocol* often involves the mechanisms for requesting retransmission

# Network Layer

- The network layer may establish a *circuit* (in the case of *connection-oriented* protocols), or it may simply send its datagrams—probably repeating them—in the directions determined by the *forwarding* mechanisms
- The network layer elements have to know the *topology* of the network, which is determined through the *routing* protocol
- The network layer may also break larger messages into smaller ones
- The network layer entities (routers) have *routing* and *forwarding* as their two major functions

# Local Area Networks (LANs)

- LANs are privately owned (within a building or campus)
- LANs are characterized by
  - size (up to five kilometers)
  - transmission technology (e.g., bus, wireless, star, or ring)
  - speed (10 to 100 megabits per second [mbps])
  - physical and link-layer protocols standardized in the *IEEE 802.** series of standards
- LANs can be connected by *Layer 2 switches*

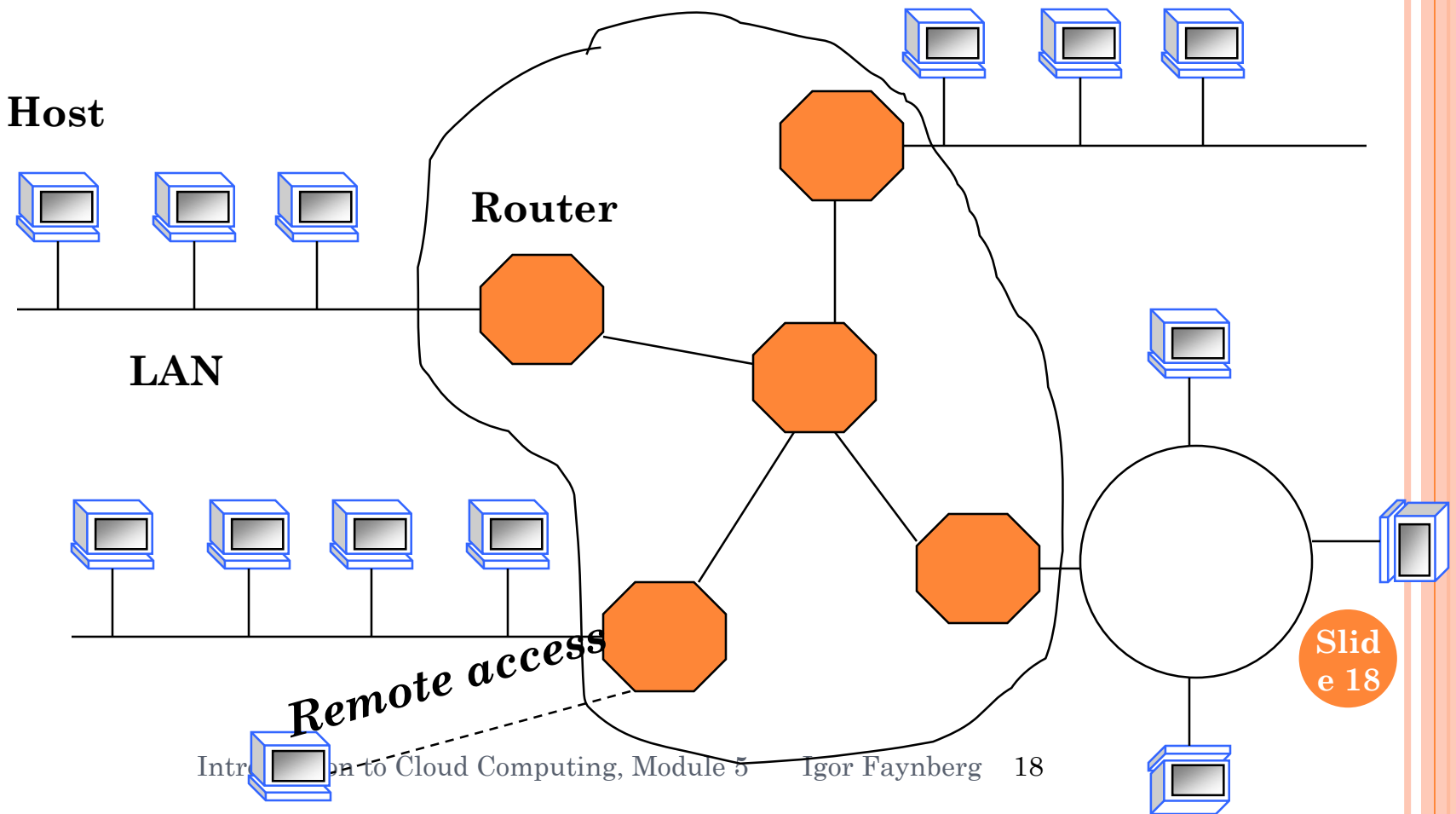
# Metropolitan Area Networks (MANs)

- MANs are simply bigger LANs (covering a group of offices in the campus)
- MANs characteristics are similar to those of LANs
- MANs may contain *Layer 2 switching elements* (in addition to media transmission elements!

# Wide Area Networks (WANs)

- WANs span large geographic areas
- WANs consist of user computers (hosts or endpoints) attached to subnets
- Subnets are interconnected by means of routers and transmission lines
- It is possible—we will talk about it in the next lecture—to provide WANs as *virtual LANs*, and this is something the Cloud can do!

# Wide Area Networks (WANs)



# Transport Layer

- The transport layer is concerned with delivering messages from one host to another
- The transport layer service can be *reliable* (in which cases *both* the delivery as well as delivery in sequence are guaranteed) or *unreliable*
- In the Internet, the *Transmission Control Protocol (TCP)* provides a reliable service, while the *User Datagram Protocol (UDP)* provides unreliable service

# Session Layer

- The session layer is an enhanced (process-to-process) version of the connection-oriented transport layer
- It provides dialog control and synchronization facilities
- It has been implemented in SNA and a varieties of old ISO-based architectures, but it is not named absent in the Internet suite, where TCP is actually doing the job of *both* the transport and session layers

# Presentation Layer

- The presentation layer is concerned with the semantics of the message
- The presentation layer ensures, for example, that the byte layout of the sending machine is properly translated into that of the receiving machine
- Earlier applications of the presentation layer involved translating from one set of character representations into another (like *ASCII* into *EBCDIC* and vice versa)
- The transmission of the integers, sets, and other data structures can also be taken care of by the presentation layer

# The Application Layer

- Early application layer protocols in the Internet were the *File Transfer Protocol (FTP)*, *Simple Mail Transfer Protocol (SMTP)*, and *Directory Services Protocol (DSP)*
- But the HyperText Transfer Protocol (HTTP) has become the protocol of choice for almost everything on the Web (we will talk more and more… and more about that)!
- And now the Internet hourglass:

# Introduction to the Internet (outline)

- Definition and basic principles
- Routing in the Internet
- The Internet protocol stack

# The Internet

In general,

- An *internet* is a collection of **interconnected networks** (typically, Local Area Networks [LANs], Metropolitan Area Networks [MANs], and Wide Area Networks [WANs] governed by the **Internet Standards**

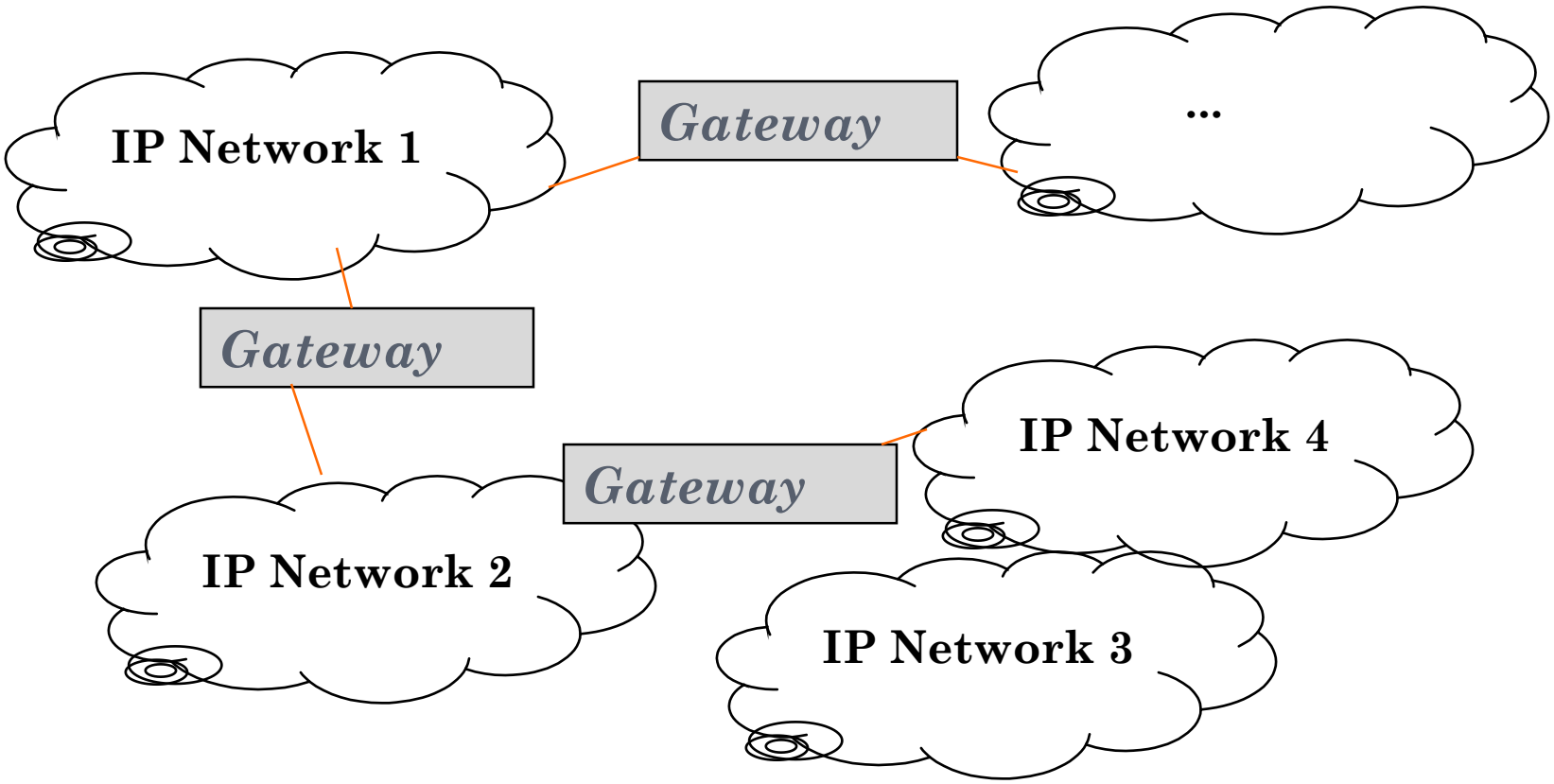
Specifically,

- ***the Internet*** is a… **world-wide internet that is widely used to connect university, government offices, companies and private individuals.** (A. S. Tanenbaum, "Computer Networks")

# Internet Standardization

- Internet standards are produced (by consensus) by the Internet Engineering Task Force (IETF)
- Anyone can participate in the IETF by joining a mailing list of a working group: there is no fee
- All IETF documents and standards are available at its web site (www.ietf.org) at no charge
- Internet Society is a *legal umbrella* of the IETF

# The Internet

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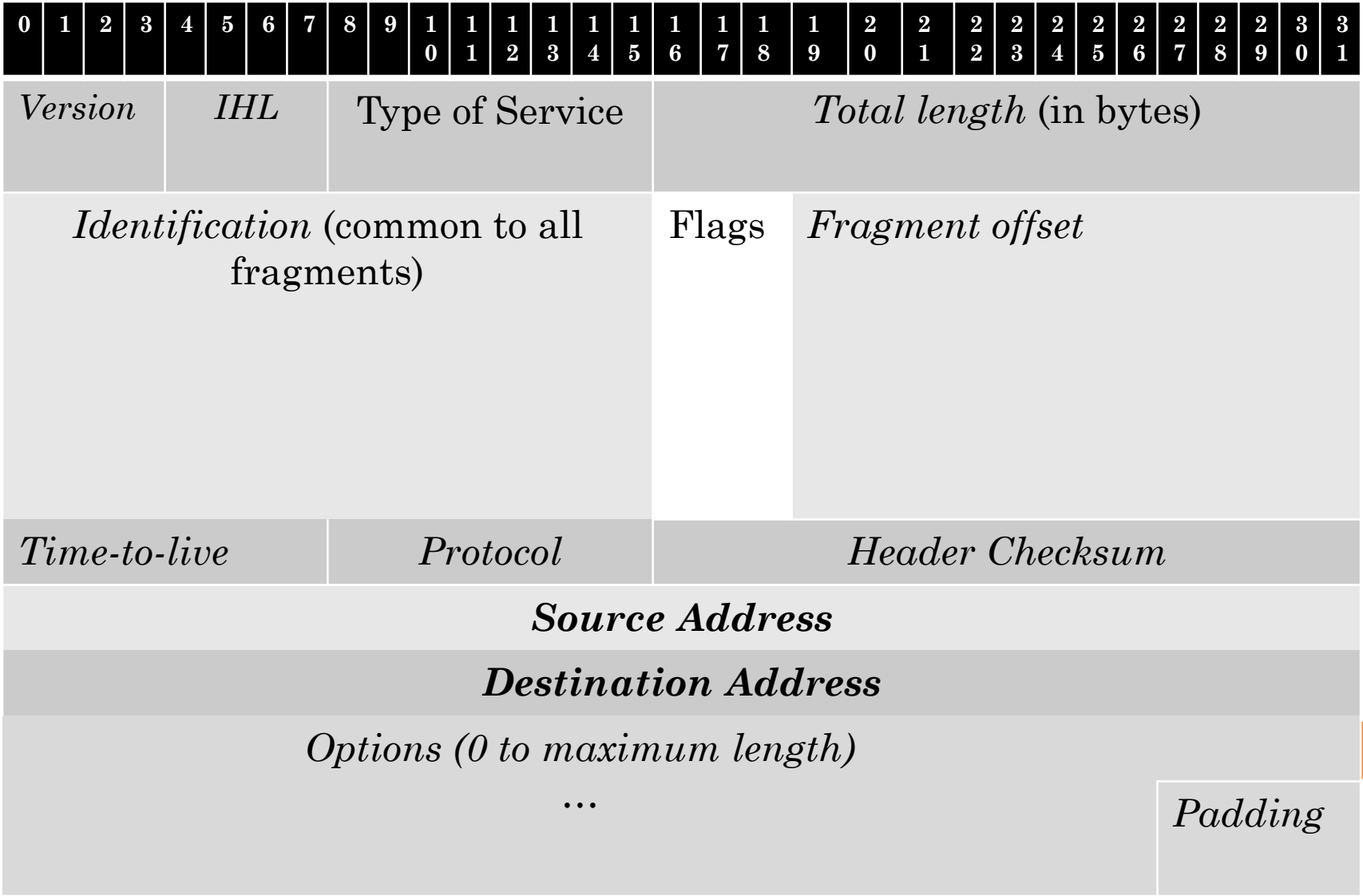
# The Internet Protocol (IP): the Glue of the Internet

- IP packets (datagrams) specify the version of the protocol, time-to-live, source and destination addresses, options (e.g., security), and some other header-related information
- Within the network layer packets are unacknowledged
- IP (RFC 791) is an Internet Standard

# The IPv4 Packet Header (After RFC 791)

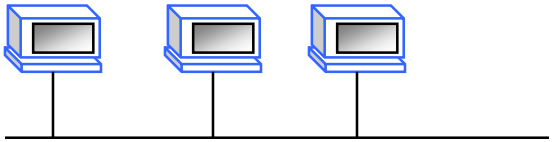


# IP Addresses (IPv4)

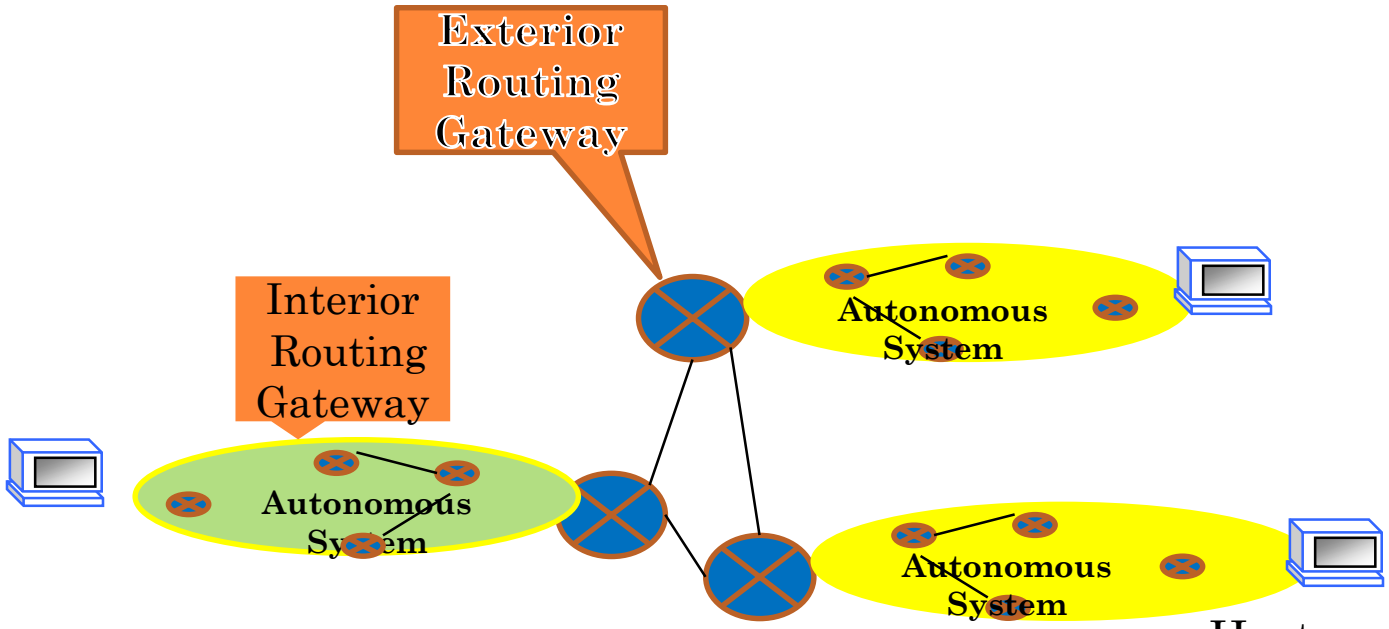
- IP addresses are assigned to all hosts and routers
- All IP addresses are 32-bit-long; they are normally written in decimal form byte-by-byte, separated by "."s (e.g., 123.100.86.35)
- Each address has a form of either
  - <class> <network> (for classes A [0], B [10], and C [110]) or
  - 1110 <Multicast Address> (for class D [1110]) or
  - 11110 <Reserved for future use>
  - And there is ***Anycast*** (please read RFC 4786 http://tools.ietf.org/html/rfc4786 and RFC 4193 for IPv6 addresses)

# Routing protocol classification

a) LAN: No routing needed



b) Routing within and among the Autonomous systems



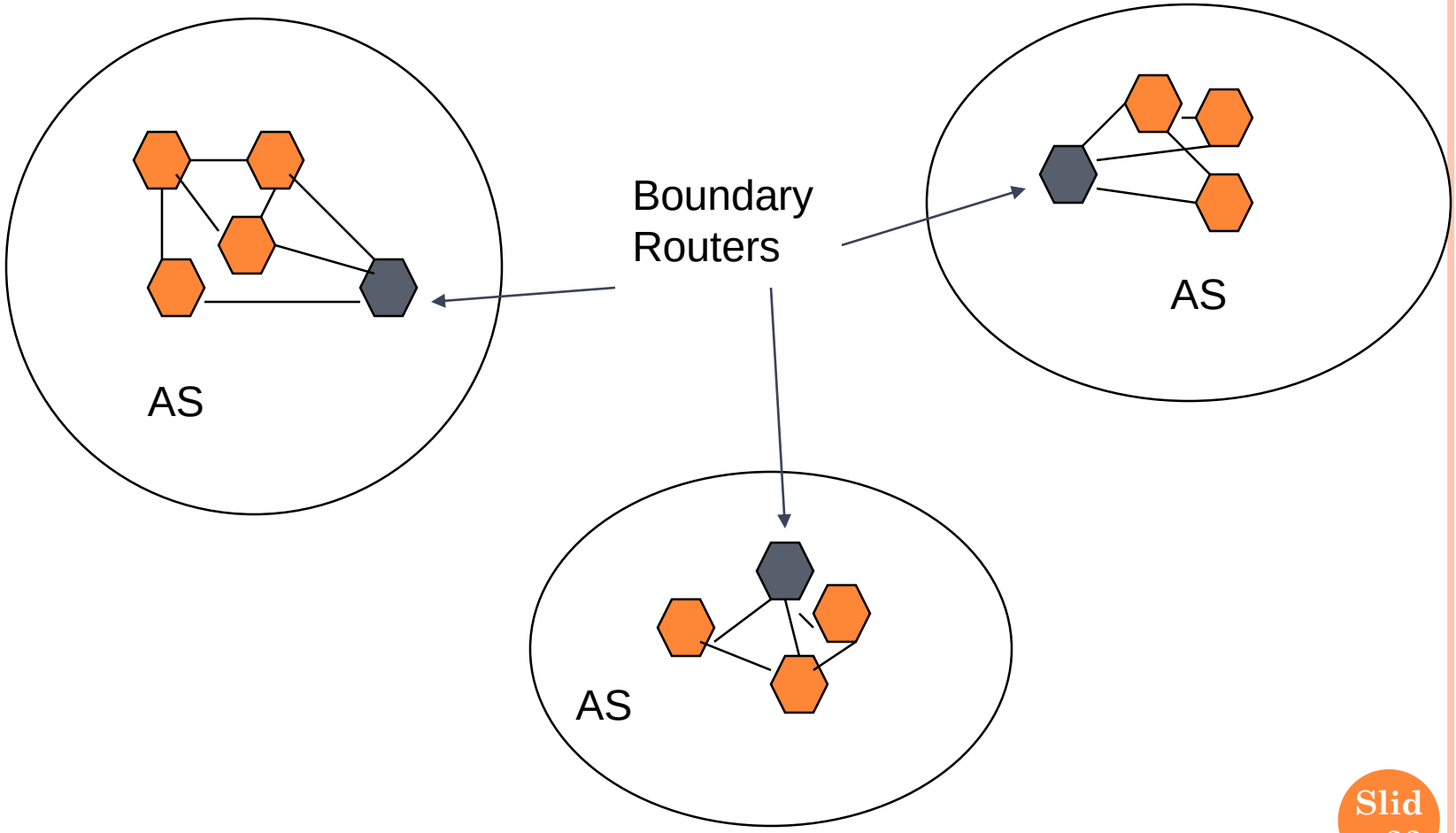
# Internet Architectural Principles (RFC1958)

- Emphasize intelligence at the edges, distributed processing, dynamic (versus static) solutions, and modularity
- Support accommodation of multiple network types
- Are not a religion (RFC 1958 is *informational*)
- Are inherently hostile to the needs of Internet-wide IP telephony or other applications not envisioned as the Internet ones

# Routing in the Internet

- Network is a graph: routers (vertices) and links connecting routers (edges)
- Links are assigned weights according to a metric
- With Open Shortest Path First (OSPF) (RFC 2328), routers exchange the information on all links, compute shortest paths and construct forwarding tables with the next hop for each destination. OSPF is typically used within an Autonomous System (AS)
- With the Border Gateway Protocol (BGP) (RFC 1772), ASs are effectively the vertices of the routing graph

# Autonomous Systems

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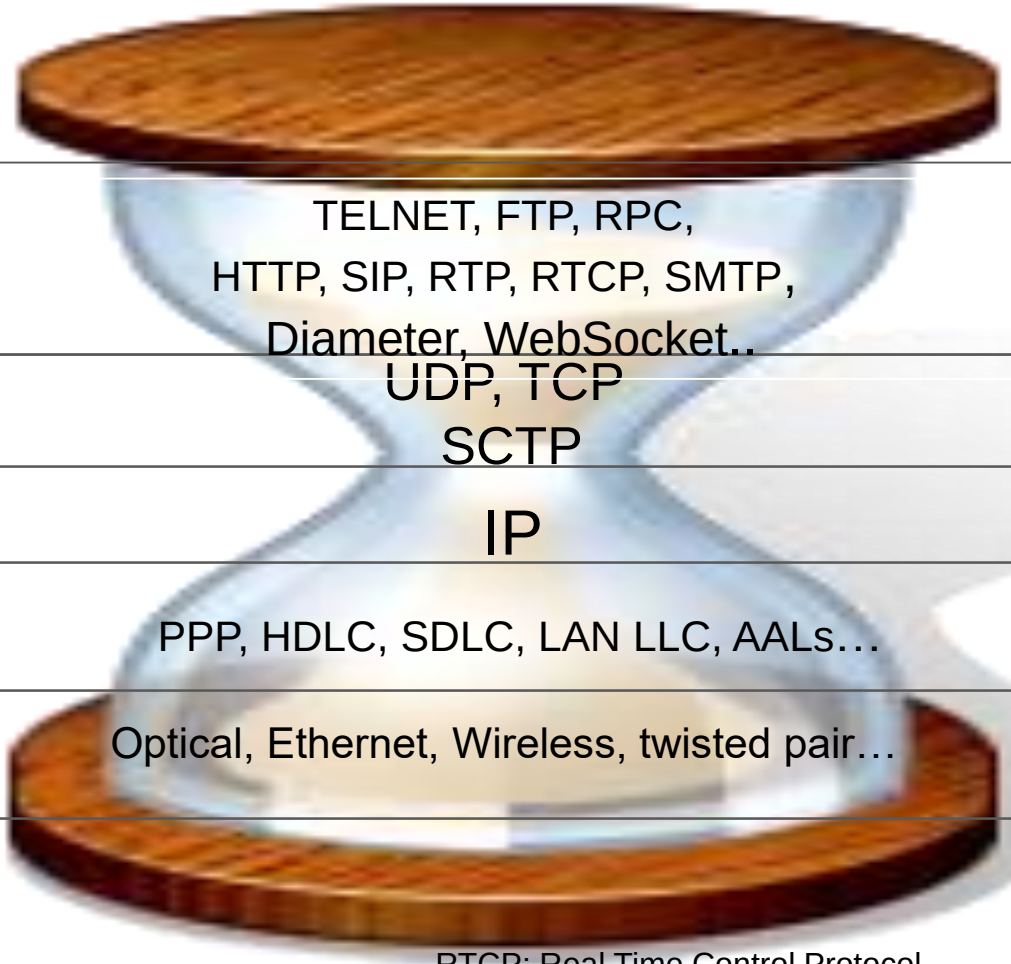
# The Internet Protocol Hourglass (after Steve Deering)



| | |
|---|---|
| Application | TELNET, FTP, RPC,<br>HTTP, SIP, RTP, RTCP, SMTP,<br>Diameter, WebSocket.. |
| Transport | UDP, TCP<br>SCTP |
| Network | IP |
| Link | PPP, HDLC, SDLC, LAN LLC, AALs… |
| Physical | Optical, Ethernet, Wireless, twisted pair… |

AAL: ATM Adaptation Layer
HTTP: Hyper Text Transfer Protocol
HDLC: High? Data Link Control
LLC: Logical Link Control
PPP: Point-to-Point Protocol
RPC: Remote Procedure Call
RTP: Real Time Protocol
RTCP: Real Time Control Protocol
SDLC: High? Data Link Control
SMTP: Simple Mail Transfer Protocol
SCTP: Stream Control Transmission Protocol
SIP: Session Initiation Protocol
TCP: Transmission Control Protocol
UDP: User Datagram Protocol