

# *Network Architecture and the OSI Reference Model*



**Computer Networks  
A15**

# Architecture Outline

- The Internet and IP
- Network Architecture
  - Protocols and Layers
  - Encapsulation
- The OSI Reference Model
  - The Seven OSI Layers
- The TCP/IP Internet Stack
- Layering Example
- Tiered Internet Architecture

# The Internet versus an internet

**An internet ::** involves the **interconnection** of multiple networks into a single large network. [LG&W]

**The Internet ::** refers to the successor to ARPANET. The modern **Internet** is **multi-tiered** and includes commercial participation.

**IP (the Internet Protocol) ::** provides **connectionless** transfer of packets across an internet.

# The Internet

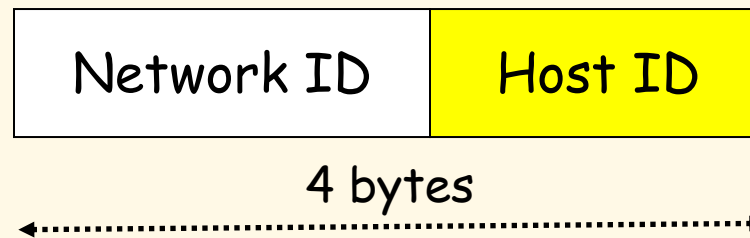
- Provides a *name space* to refer to machines connected to the Internet (*e.g. chablis.cs.wpi.edu*).
- The name space is hierarchical, but it is only administrative and not used in network routing operations.
- **DNS (Domain Name Service)** provides automatic translation of names to addresses.

# IP

- Currently IP provides **best-effort service**.
  - packets may be lost (i.e., IP is unreliable).
- General IP design philosophy
  - Keep internal operations simple by relegating complex functions to the edge of the subnet.
  - IP can operate over **any** network.
  - This design allows IP to scale!!!
  - **The end-to-end mechanisms are responsible for recovery of packet losses and congestion control.**

# IPv4

- Uses 32 bit *hierarchical address space* with location information embedded in the structure.



- IPv4 address is usually expressed in *dotted-decimal notation*

e.g.,

128.100.11.56

# IPv6

- IPv6 addresses are 128 bits long.
- 16 bytes of IPv6 address are represented as a group of hexadecimal digits, separated by colons. e.g.

[D&C]

2000:fdb8:0000:0000:0001:00ab:853c:39a1

- Shorthand - leave out groups of zeros and leading zeros.

2000:fdb8:::1:ab:853c:39a1

# Layering and Abstraction

- Layering accommodates incremental changes.
- It is possible to have alternative abstractions at each layer.

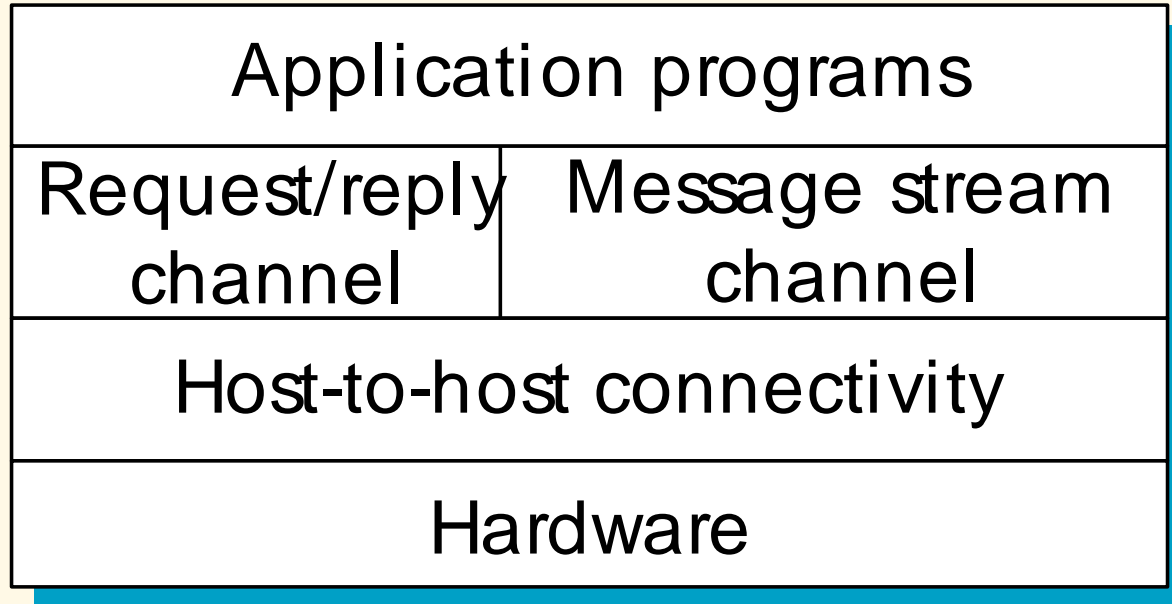


Figure 1.9 Layered system with alternate abstractions available at a given layer.

P&D

# Applications and Layered Architectures

- In the 1970's vendor companies (IBM and DEC) developed **proprietary networks** with the common feature of grouping communication functions into related and manageable sets called **layers**.

**network architecture** :: a set of **protocols** that specify how every **layer** is to function and the defined **interfaces** between the **layers**. [LG&W]

# Protocols

- Protocols are the building blocks of a network architecture.
- Each protocol object has two different interfaces:
  - *service interface* :: operations on this protocol
  - *peer-to-peer interface* :: messages exchanged with peer

# Interfaces

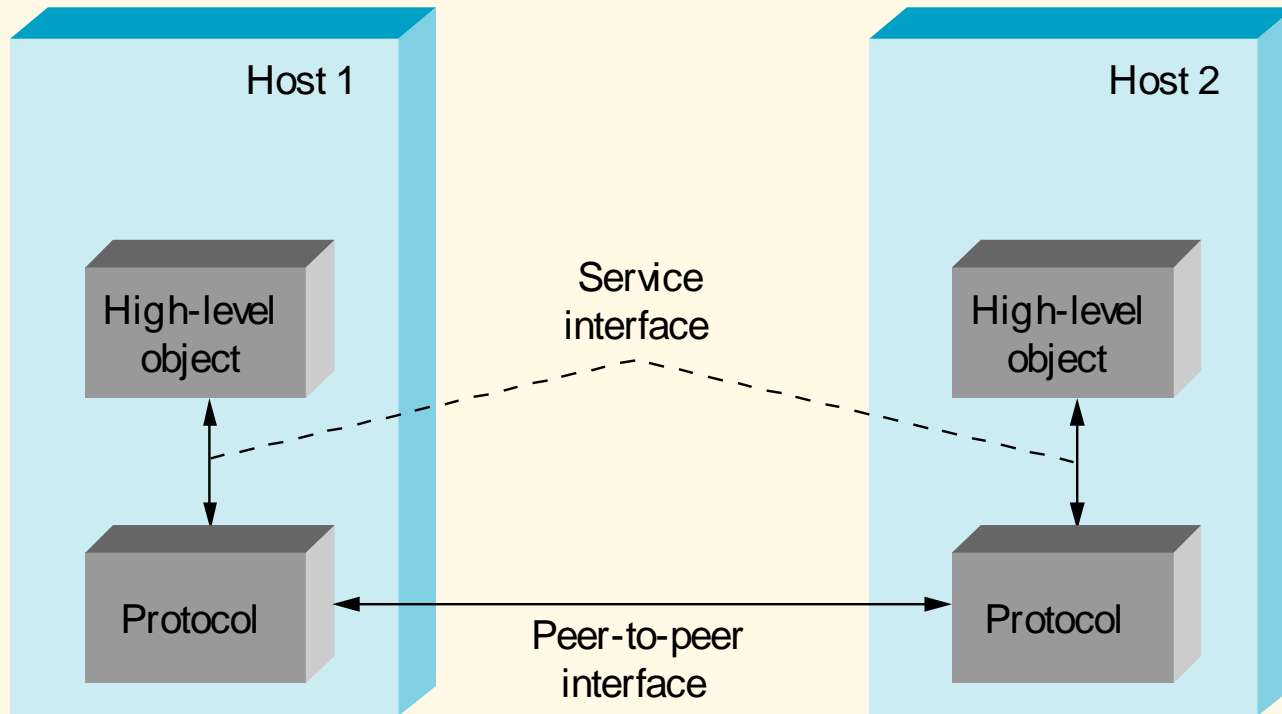


Figure 1.10 Service interfaces and peer interfaces

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# What's a protocol?

## human protocols:

- “what’s the time?”
- “I have a question”
- introductions

... specific msgs sent

... specific actions  
taken when msgs  
received, or other  
events

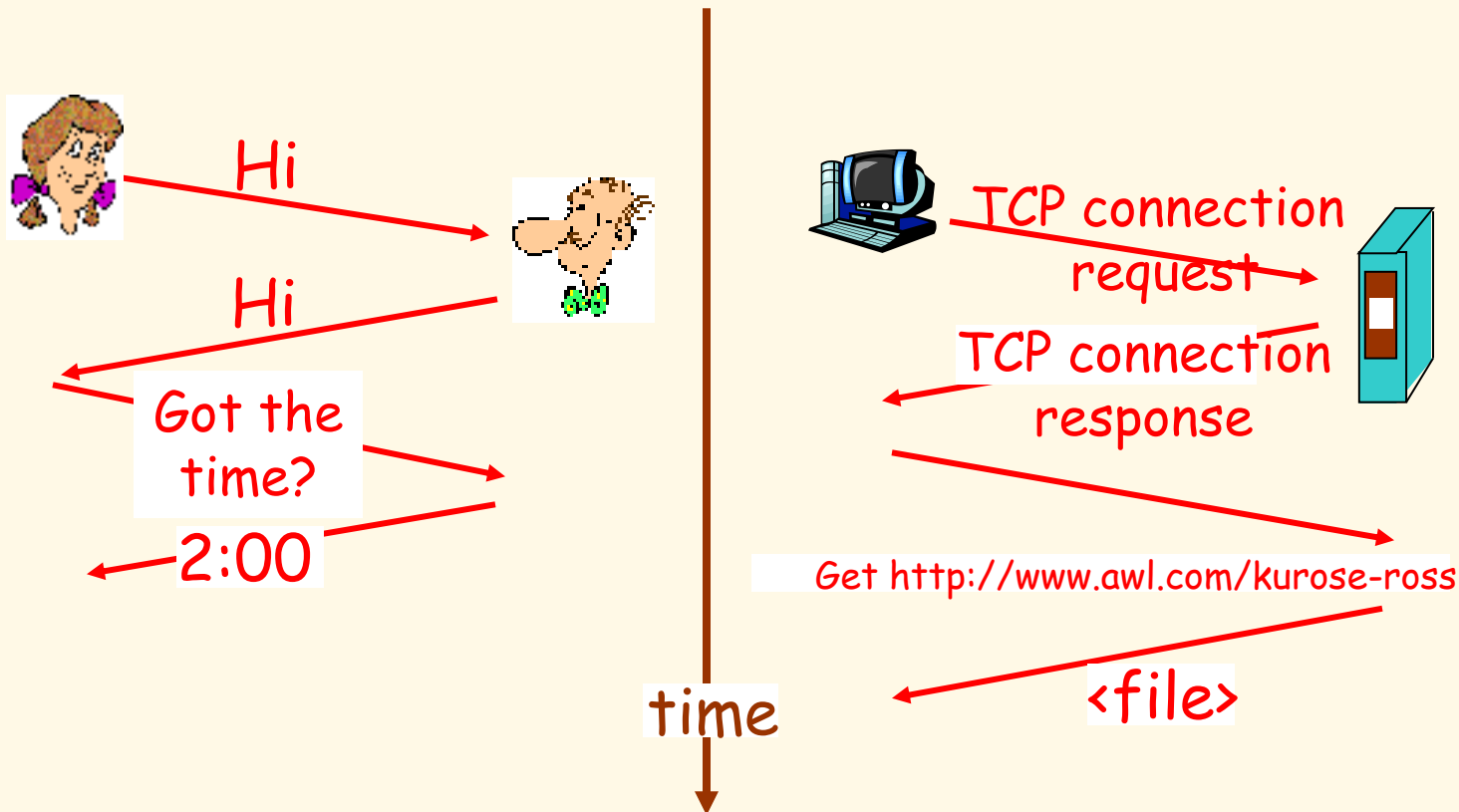
## network protocols:

- machines rather than humans
- All communication activity in the Internet is governed by protocols.

**Protocols** define: *the format, the order of msgs sent and received among network entities, and the actions taken on message transmission and receipt.*

# What's a protocol?

a human protocol and a computer network protocol:



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# International Standards Organization Open Systems Interconnect (OSI) Reference Model



**Network Architecture**

# ISO Architecture

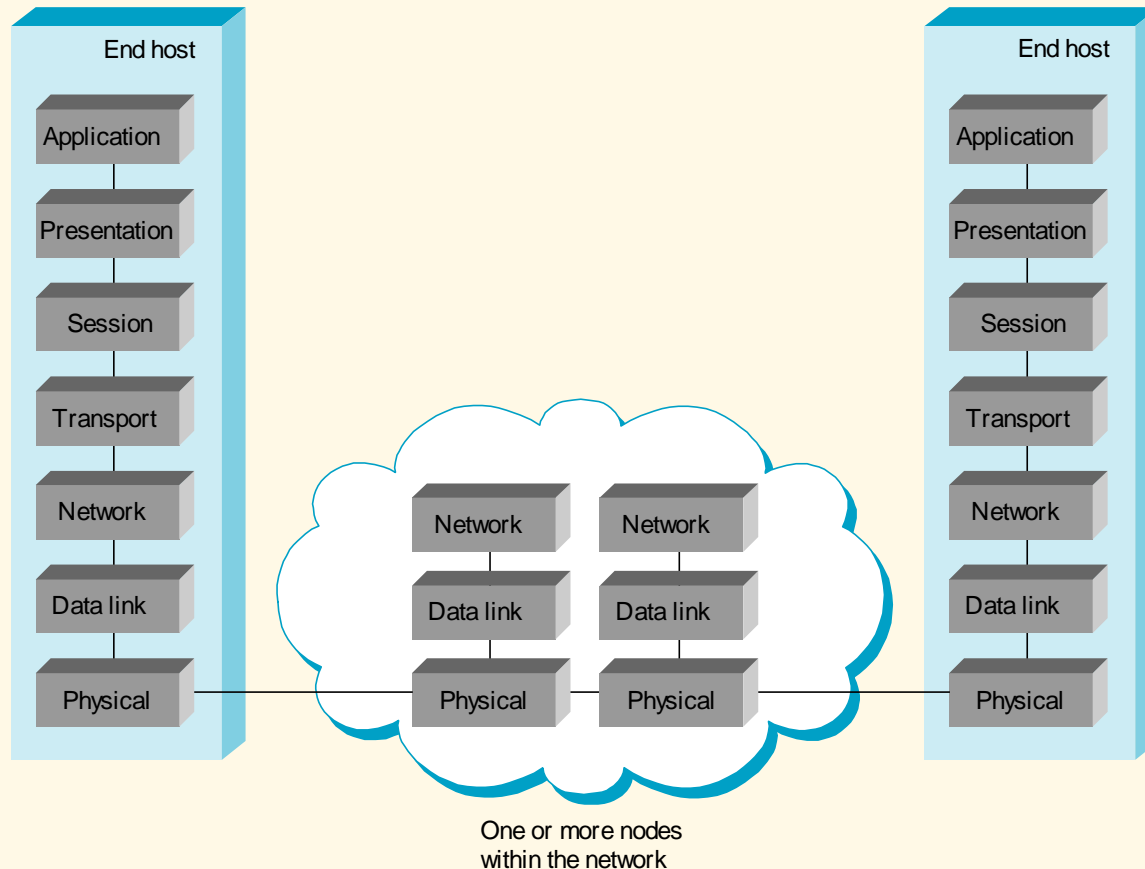
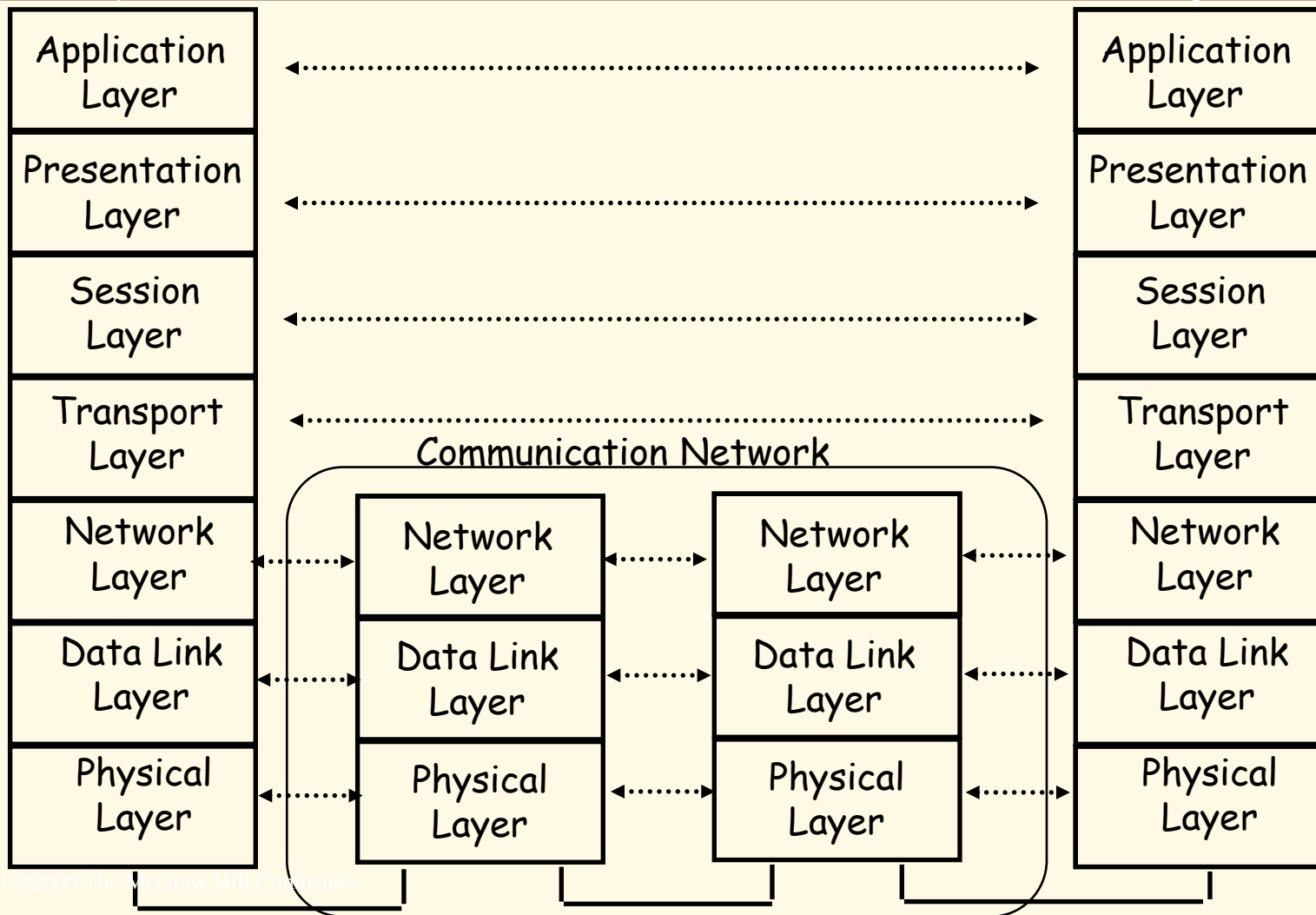


Figure 1.13 The OSI seven-layer model

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# The OSI Model

Application A ← ..... → Application B



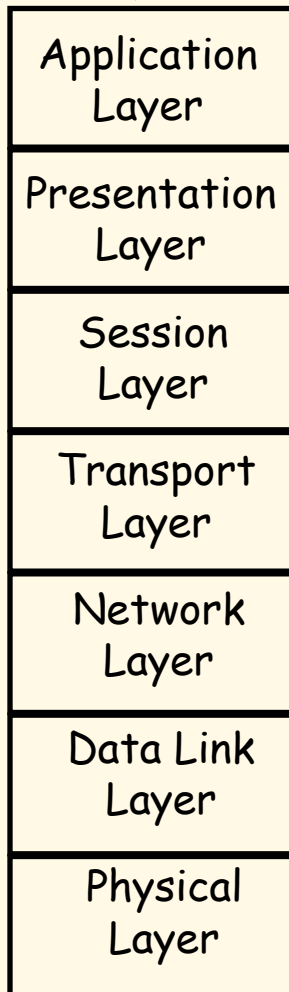
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Leon-Garcia  
& Widjaja:  
*Communication  
Networks*

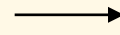
Figure 2.1

# OSI Layer Encapsulation

Application A

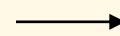


data



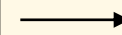
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ah



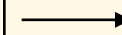
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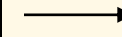
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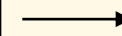
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dt

data

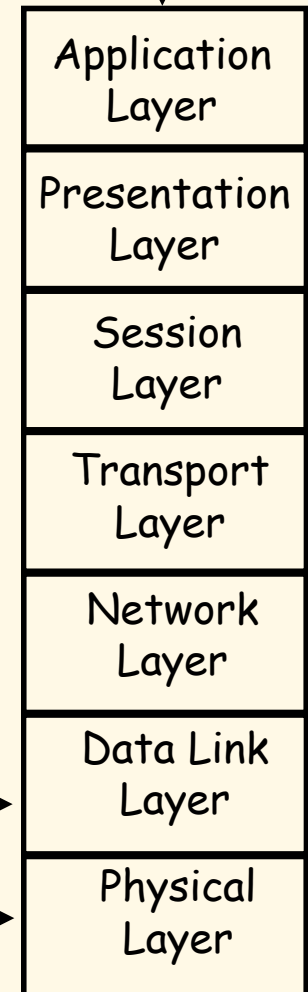
dh



bits



Application B



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Networks*

# Seven Layer OSI Model

## Application Layer

Provides users access to the OSI environment and distributed information services.

## Presentation Layer

Provides application processes independence from differences in data representations.

## Session Layer

Provides the control structure for communicating between applications.  
Establishes, manages and terminates session connections between cooperating applications.

## Transport Layer

Provides reliable transparent transfer of data between end points.  
Provides end-to-end flow control and error recovery.

## Network Layer

Provides independence from the data transmission, routing/switching technologies used to connect systems. Responsible for establishing, managing and terminating connections.

## Data Link Layer

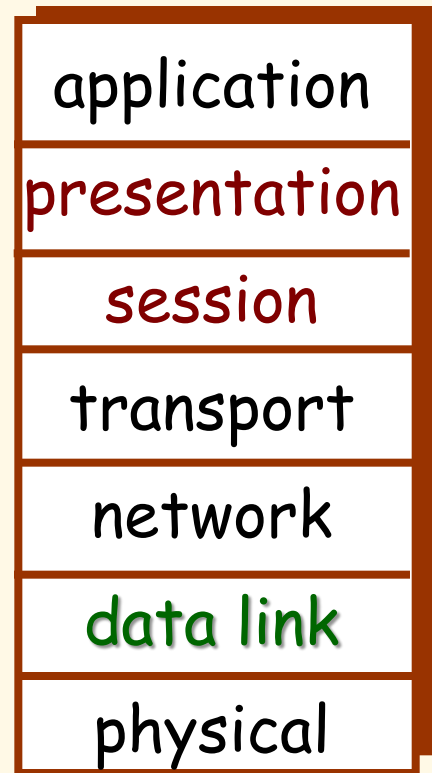
Provides for reliable transfer of information across the physical layer. Sends and receives frames with the necessary synchronization, flow control and error control.

## Physical Layer

Concerned with transmission of unstructured bit stream over a physical medium. Deals with mechanical, electrical, functional and procedural characteristics to access the physical medium.

# ISO/OSI Reference Model

- **Presentation layer:** allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- **Session layer:** synchronization, check-pointing, recovery of data exchange
- The TCP/IP Internet stack is “missing” these two layers!
  - these services, *if needed*, must be implemented in an application.
  - needed?



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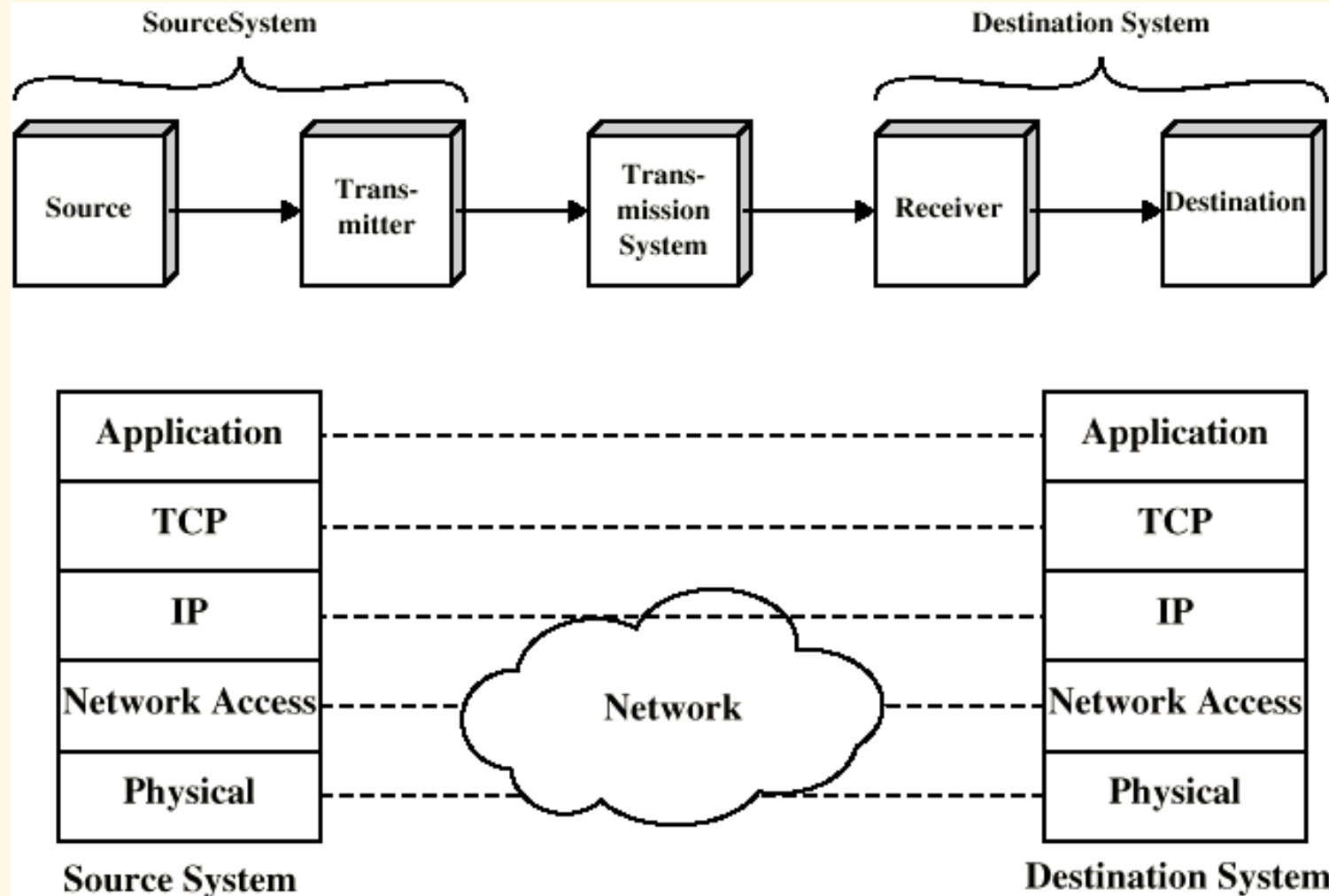
# Advantages of Layering Design

- An explicit structure for dealing with a complex system:
  - allows identification and structures the relationship of complex system's pieces.
  - layered **reference model** for discussion.
- Provides an abstraction for functional locality.
- Simplifies the design process.

# Advantages of Layering Design

- **Modularity of layers eases maintenance and updating of system components:**
  - **change in implementation of a layer's service is transparent to rest of the system.**
  - **Led to flexibility in modifying and developing network architectures.**
  - **Accommodates incremental changes.**

# TCP/IP Architectural Model



DCC 6<sup>th</sup> Ed., W. Stallings

# OSI versus TCP/IP

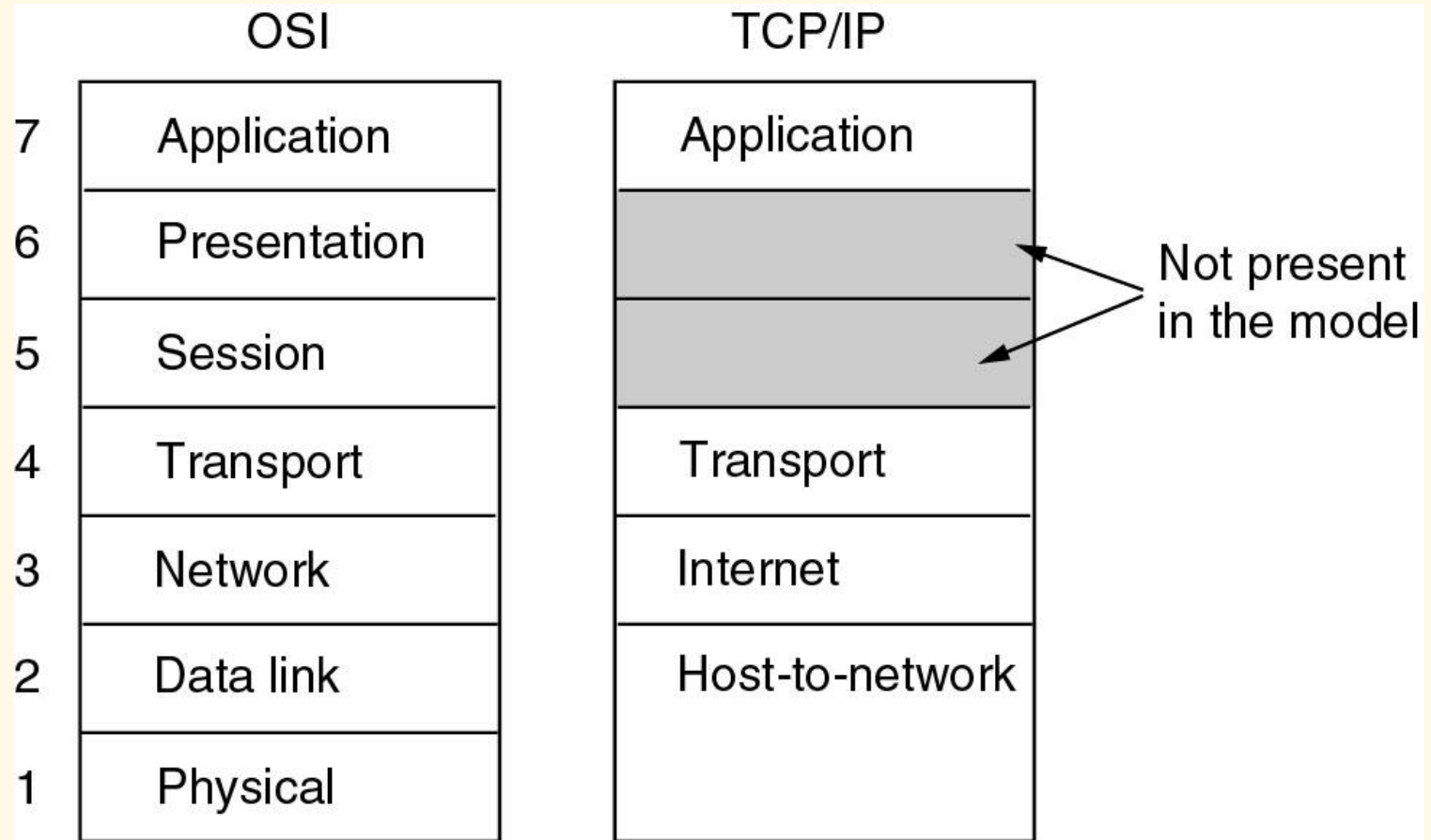
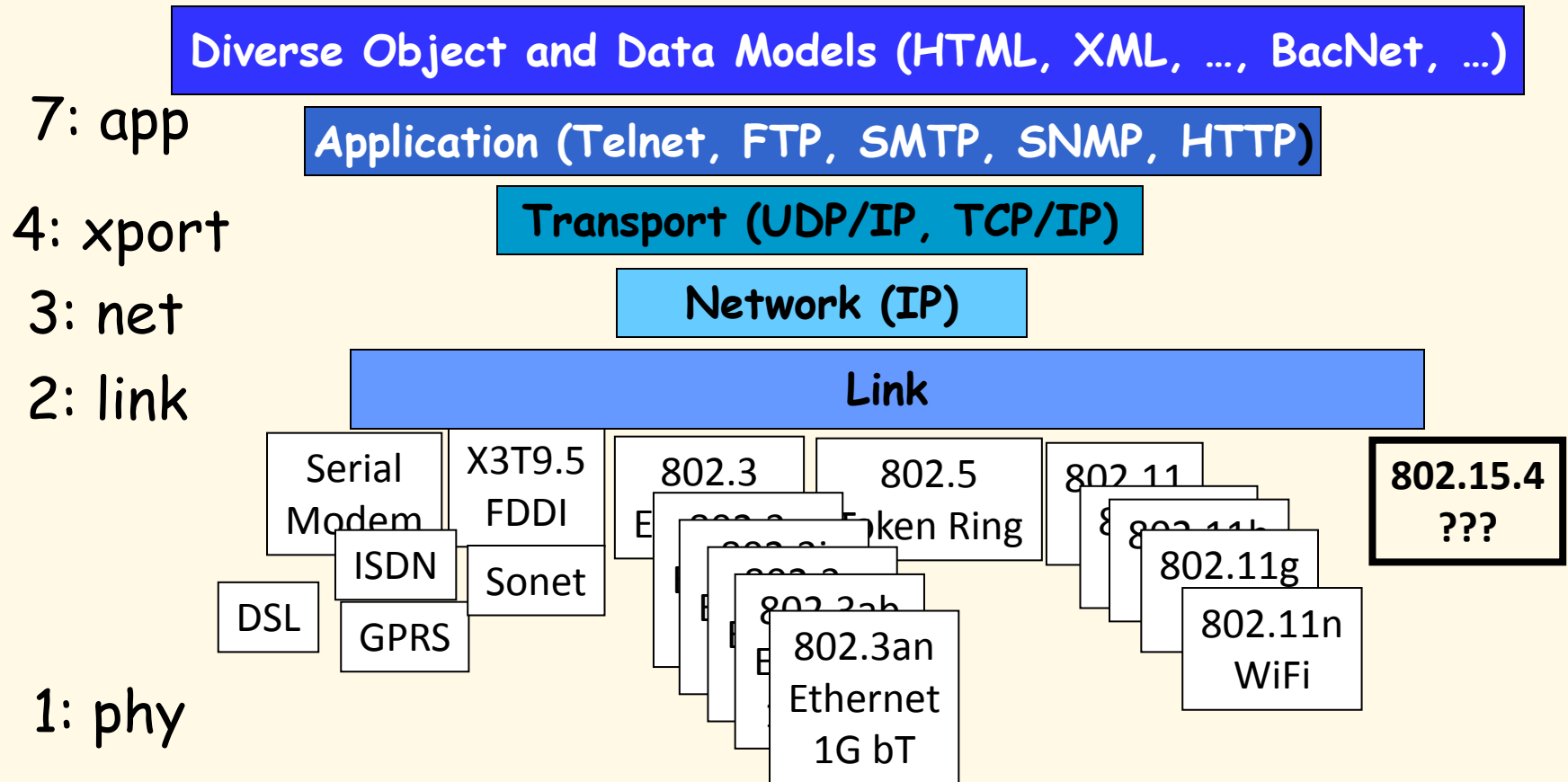


Figure 1-21. [old] The TCP/IP reference model.

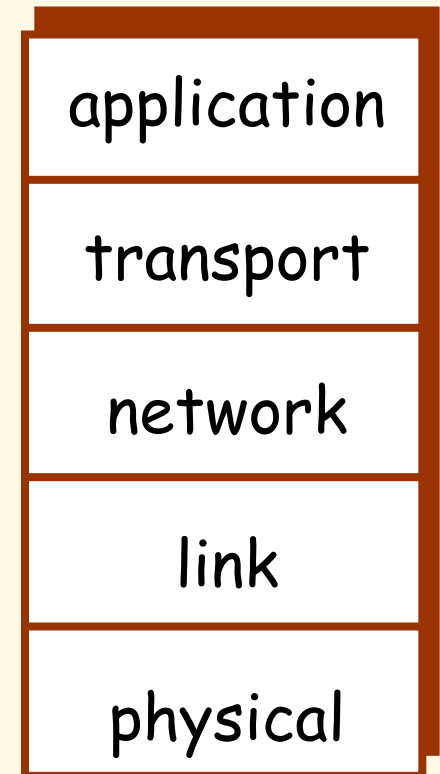
Tanenbaum

# Internet Concepts: Layering...



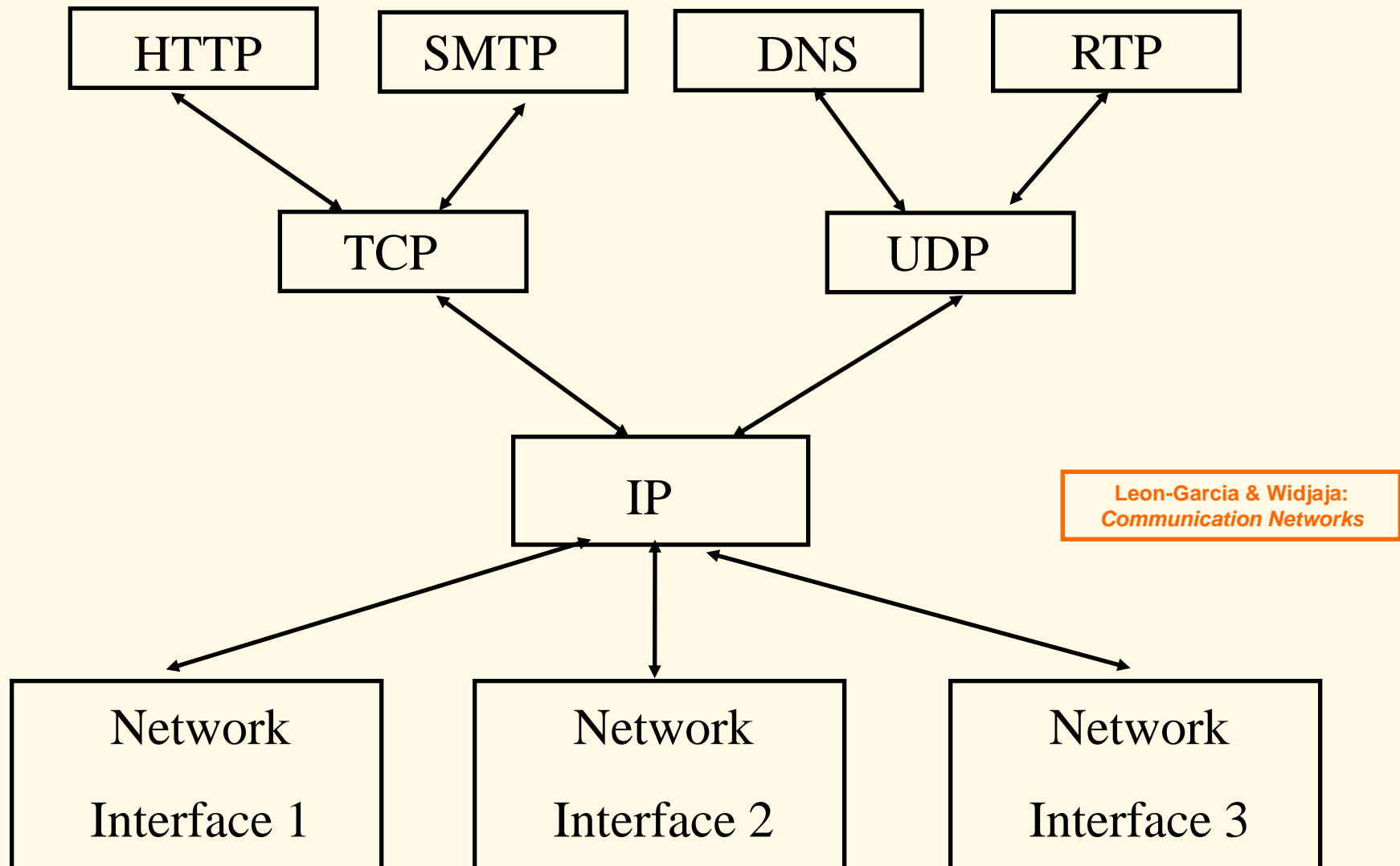
# Internet Protocol Stack

- **application:** supporting network applications
  - FTP, SMTP, HTTP
- **transport:** process-process data transfer
  - TCP, UDP
- **network:** routing of datagrams from source to destination
  - IP, routing protocols
- **link:** data transfer between neighboring network elements
  - PPP, Ethernet
- **physical:** bits “on the wire” or in the air



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# TCP/IP Protocols



# Alternate View

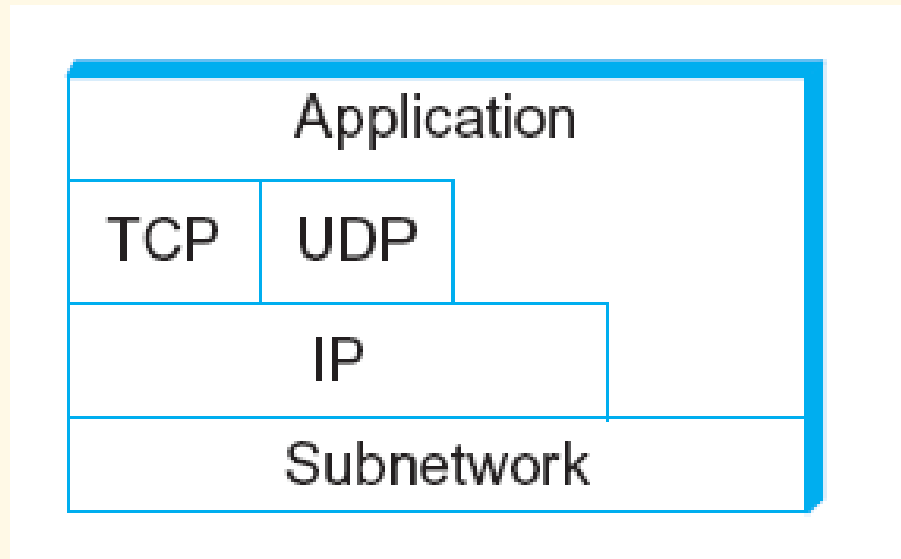


Figure 1.15 Alternate view of the Internet architecture

# Layering Example

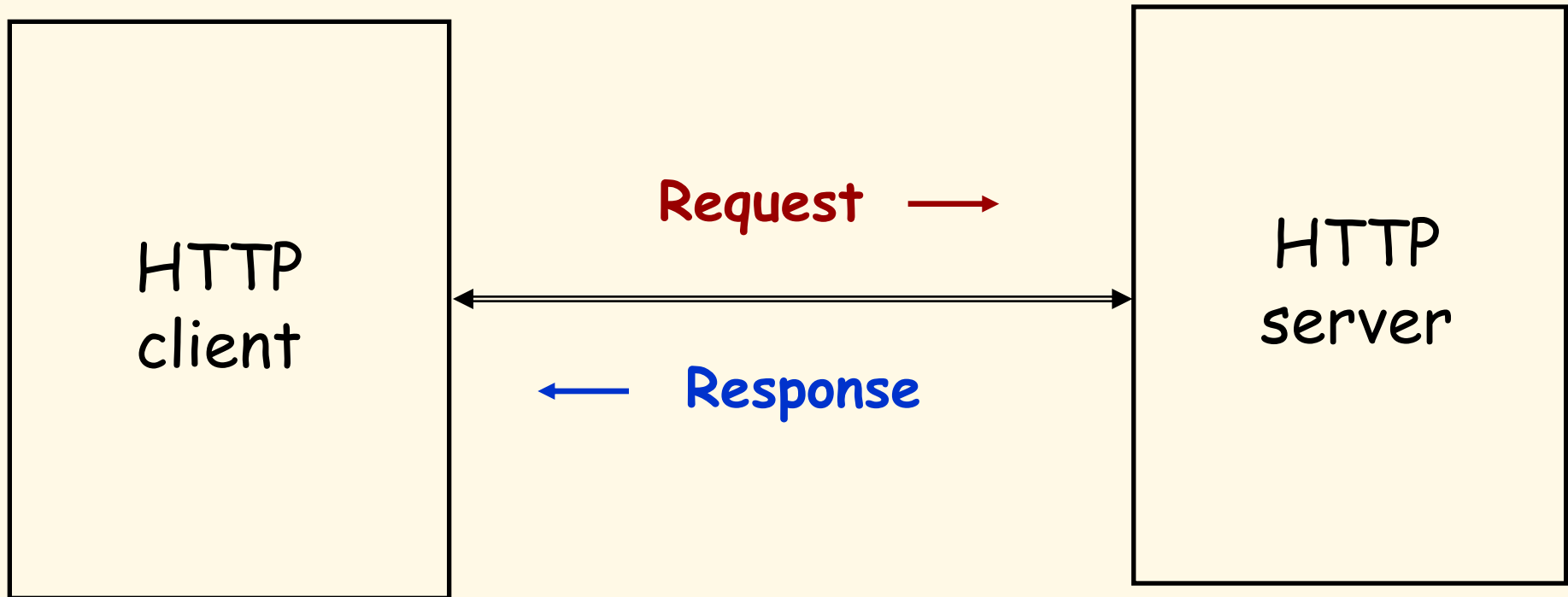
## Client/server relationship

- Server process waits for incoming requests by listening to a **port**.
- Client process makes requests as required.
- Server process provides responses to these requests.
- The server process usually runs in the background as a daemon (e.g. httpd is the server daemon). for HTTP).

# HTTP Example

- **HTTP (HyperText Transfer Protocol)** specifies rules by which the client and the server interact so as to retrieve a document.
- The protocol assumes the client and the server can exchange messages directly.
- The client software needs to set up a two-way connection prior to the HTTP request.

# HTTP Client/Server Interaction

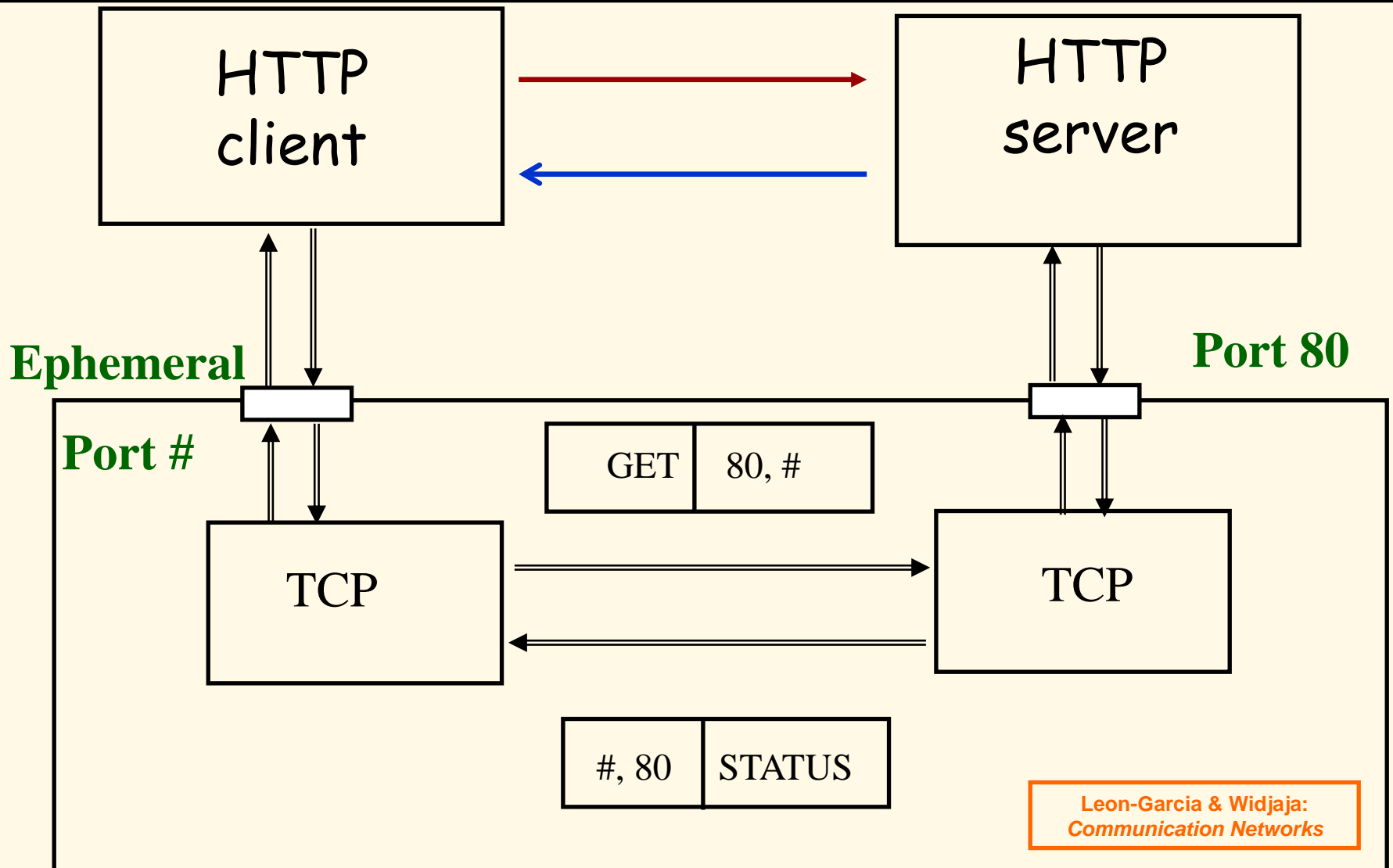


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Leon-Garcia & Widjaja: *Communication Networks*

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*Communication Networks*

# HTTP/TCP Layering Interface



# HTTP Encapsulation Example

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HTTP Request

Header contains source  
and destination port  
numbers

TCP  
Header

Header contains source  
and destination IP  
addresses; transport  
protocol type

IP  
Header

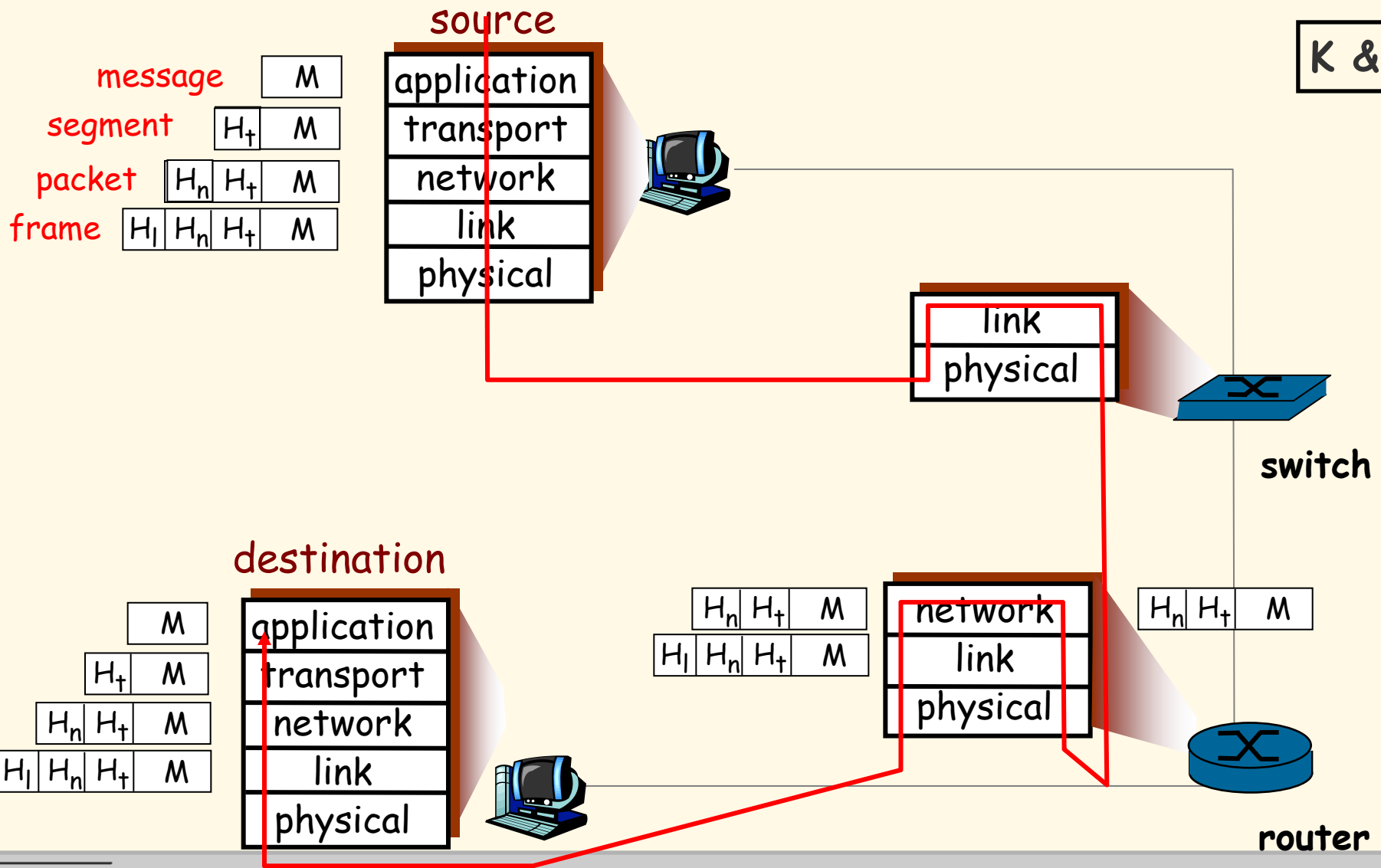
Header contains  
source and  
destination physical  
addresses; network  
protocol type

Ethernet  
Header

Frame  
Check  
Sequence

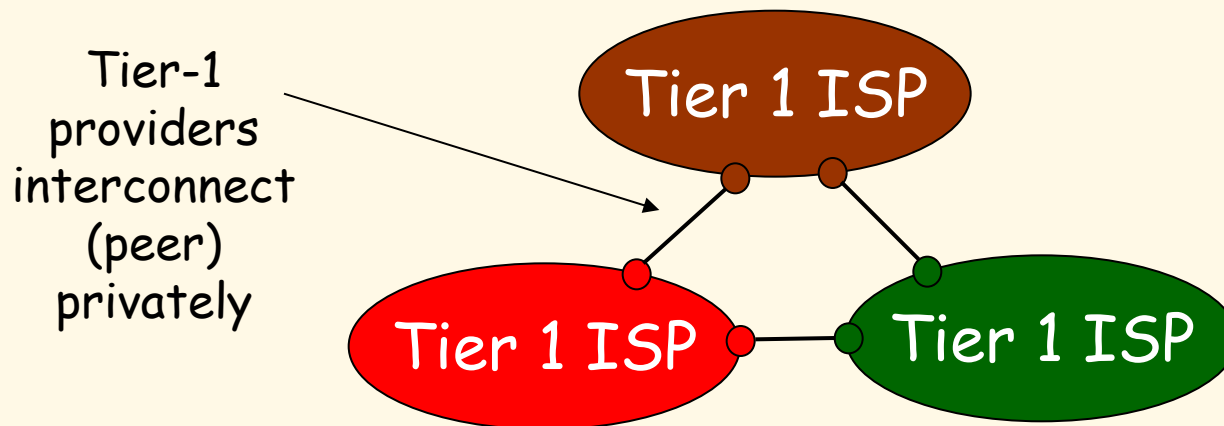
# Encapsulation Animation

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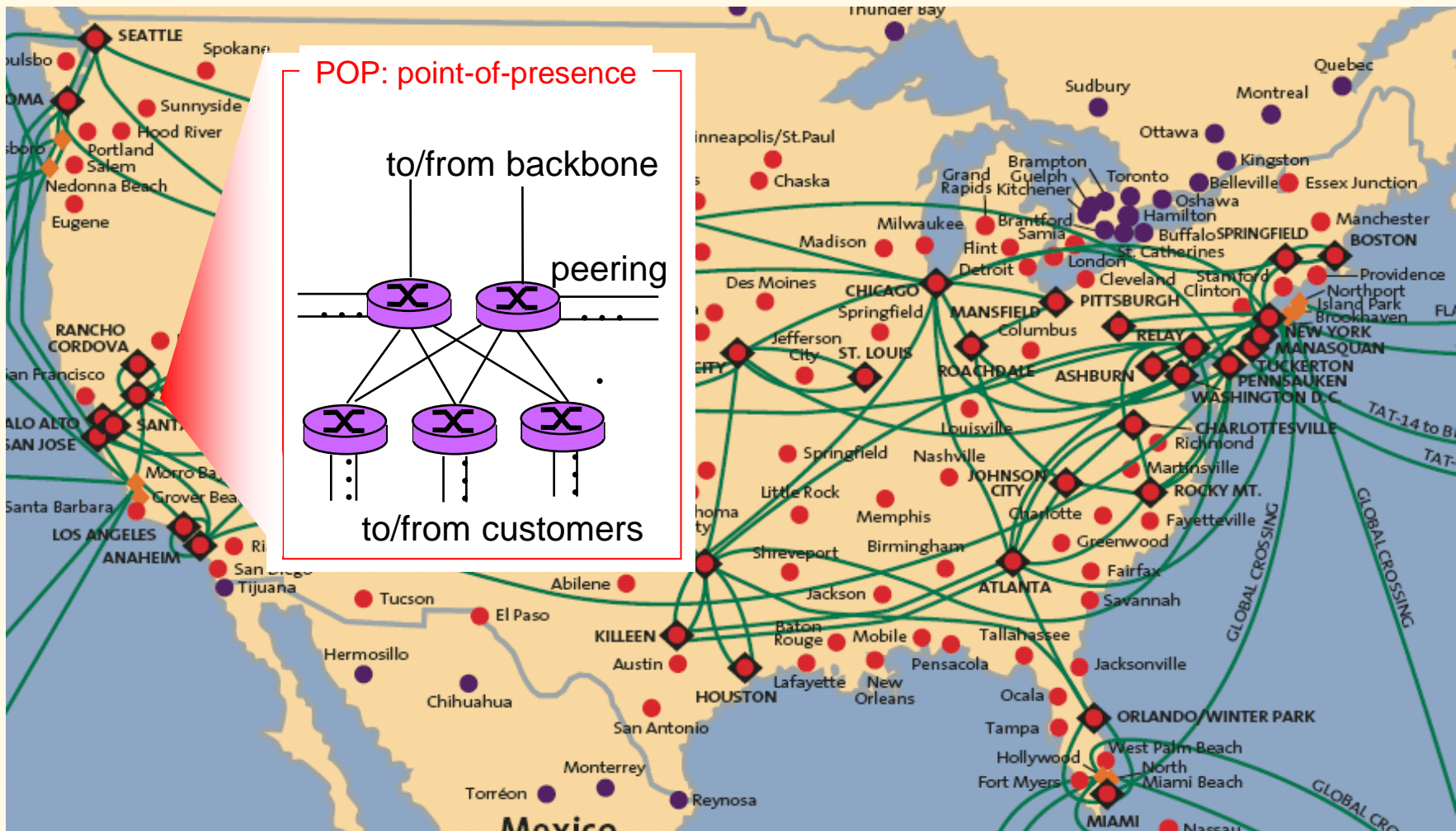
# Internet Structure: Network of Networks

- roughly hierarchical
- **at center: "tier-1" ISPs** (e.g., Verizon, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals



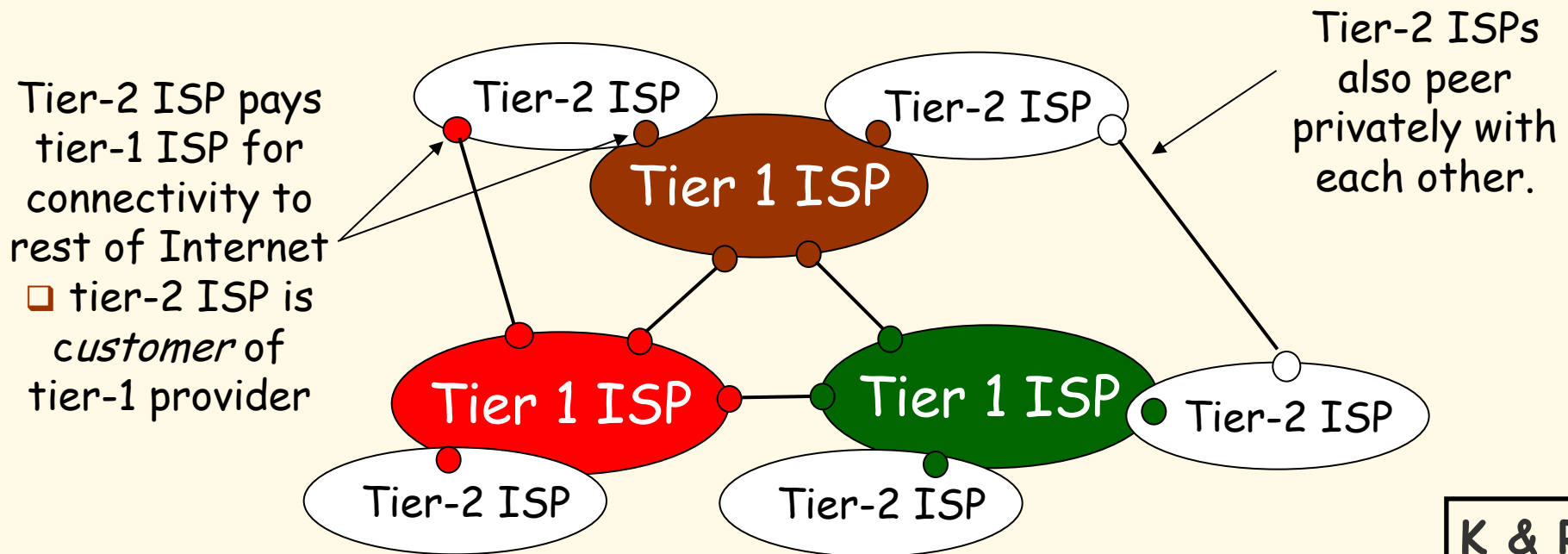
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# Tier-1 ISP: e.g., Sprint



# Internet Structure: Network of Networks

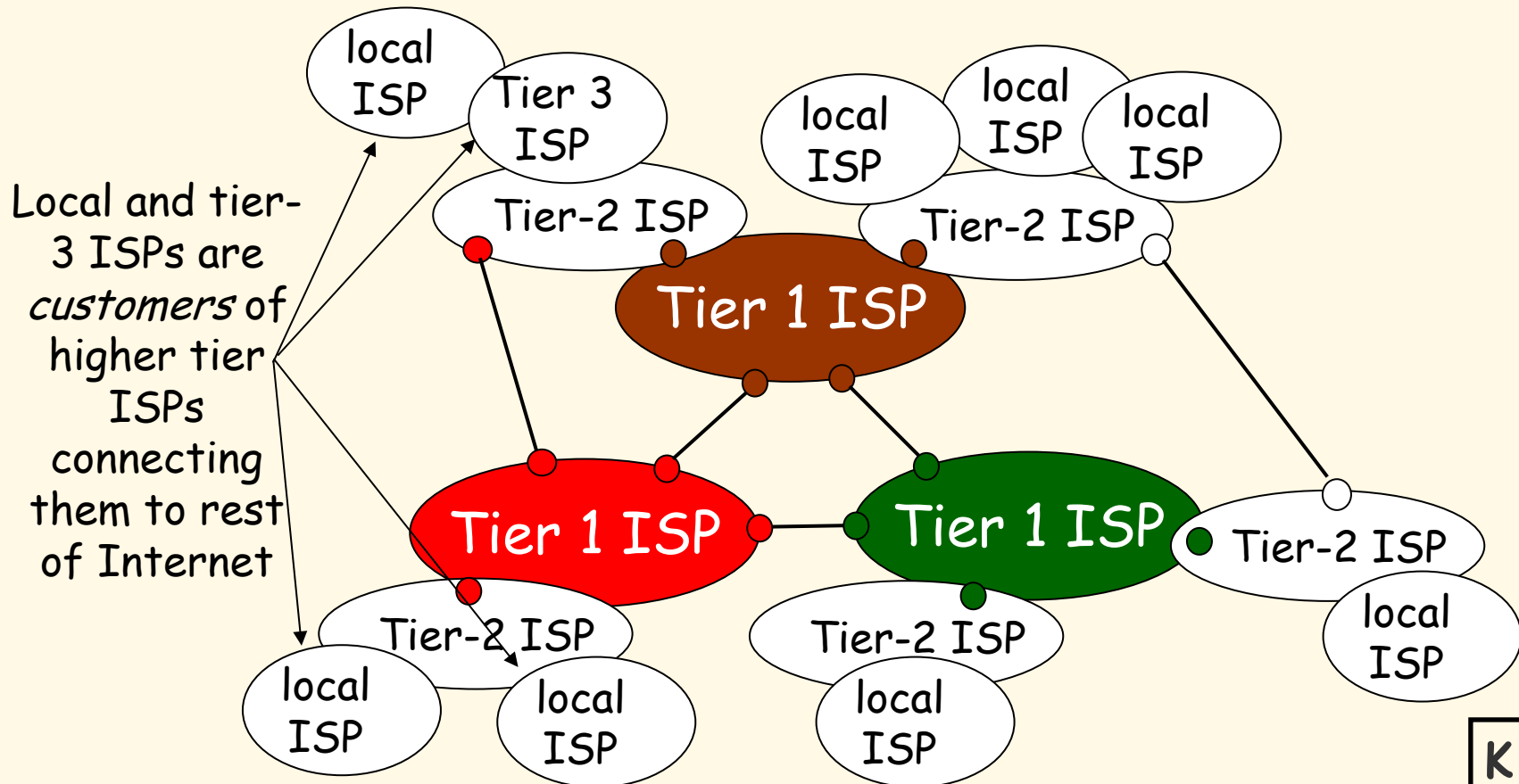
- “Tier-2” ISPs: smaller (often regional) ISPs
  - Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs



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# Internet Structure: Network of Networks

- **“Tier-3” ISPs and local ISPs**
  - last hop (“access”) network (closest to end systems)

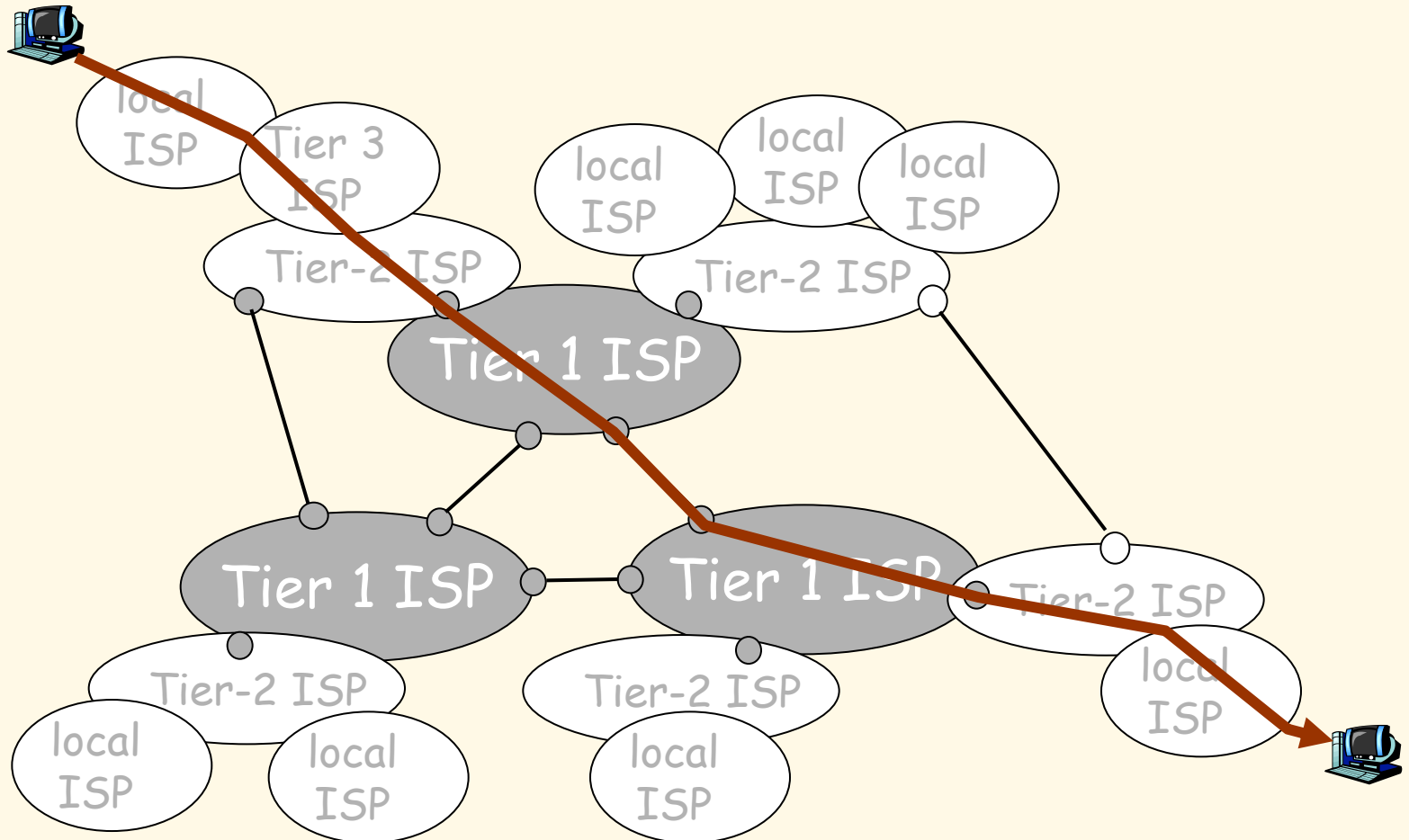


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# Internet Structure: Network of Networks

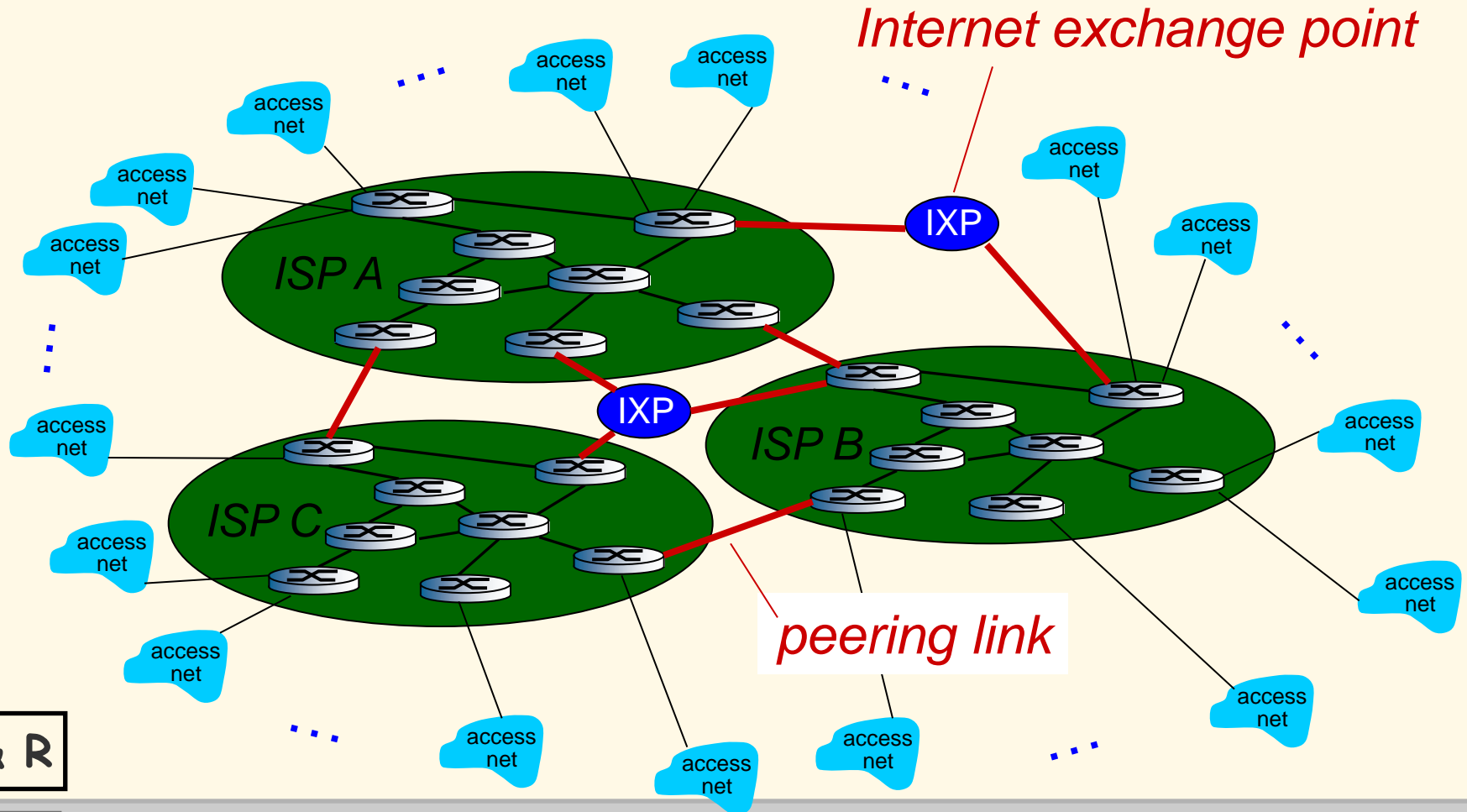
- a packet passes through many networks!

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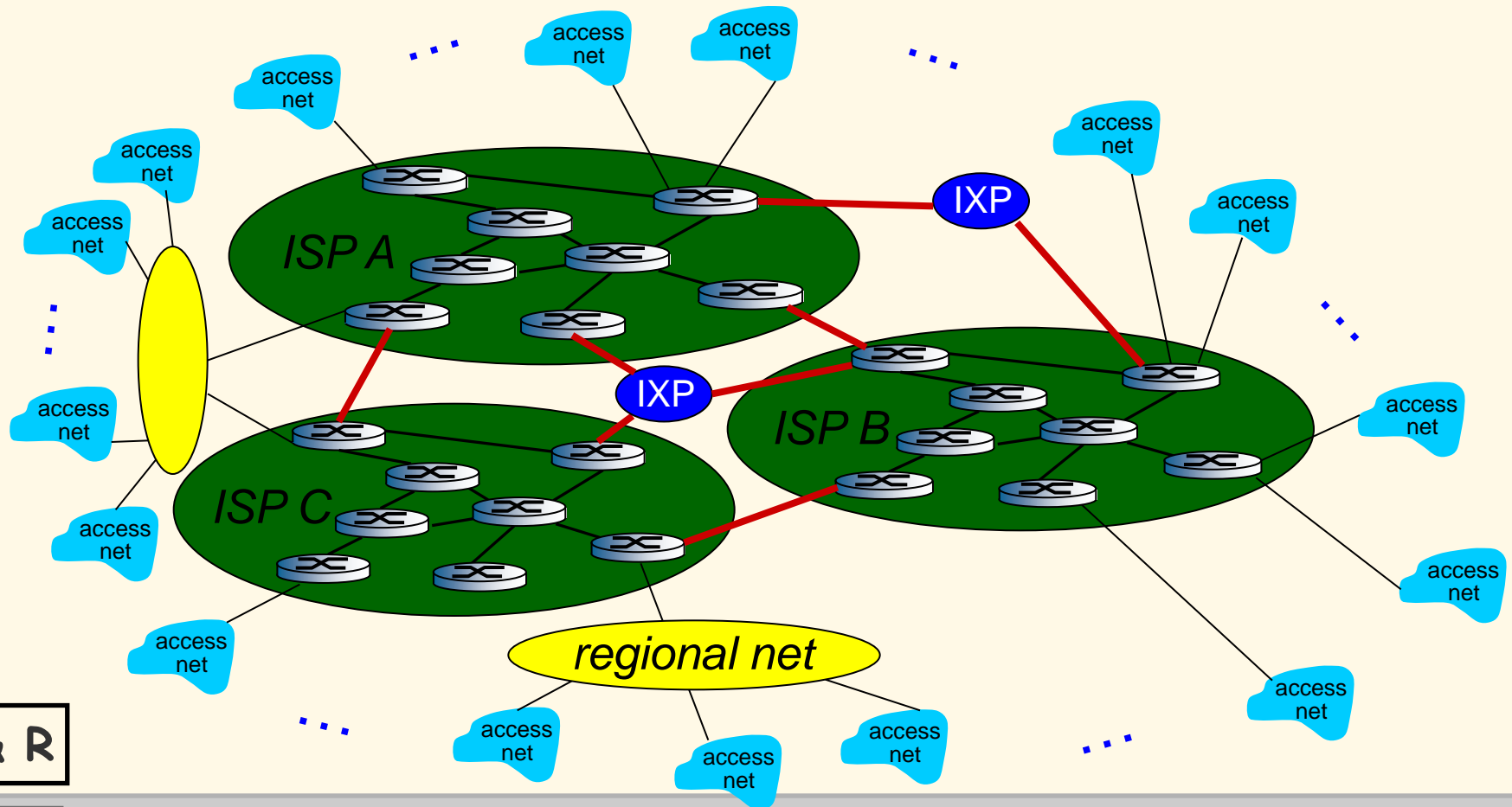
# Internet Structure: Network of Networks

But if one global ISP is viable business, there will be competitors  
.... which must be interconnected



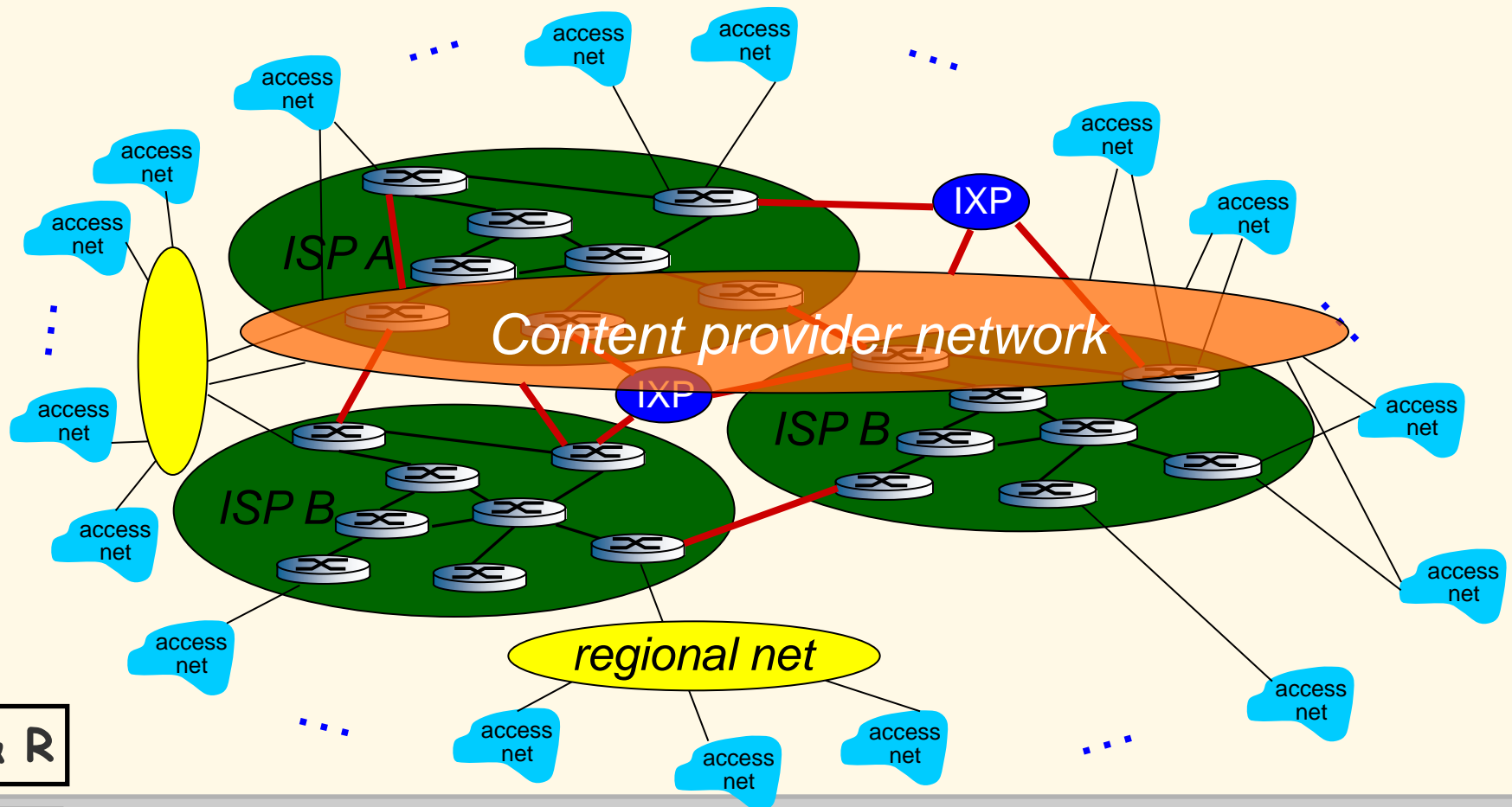
# Internet Structure: Network of Networks

... and regional networks may arise to connect access nets to ISPs

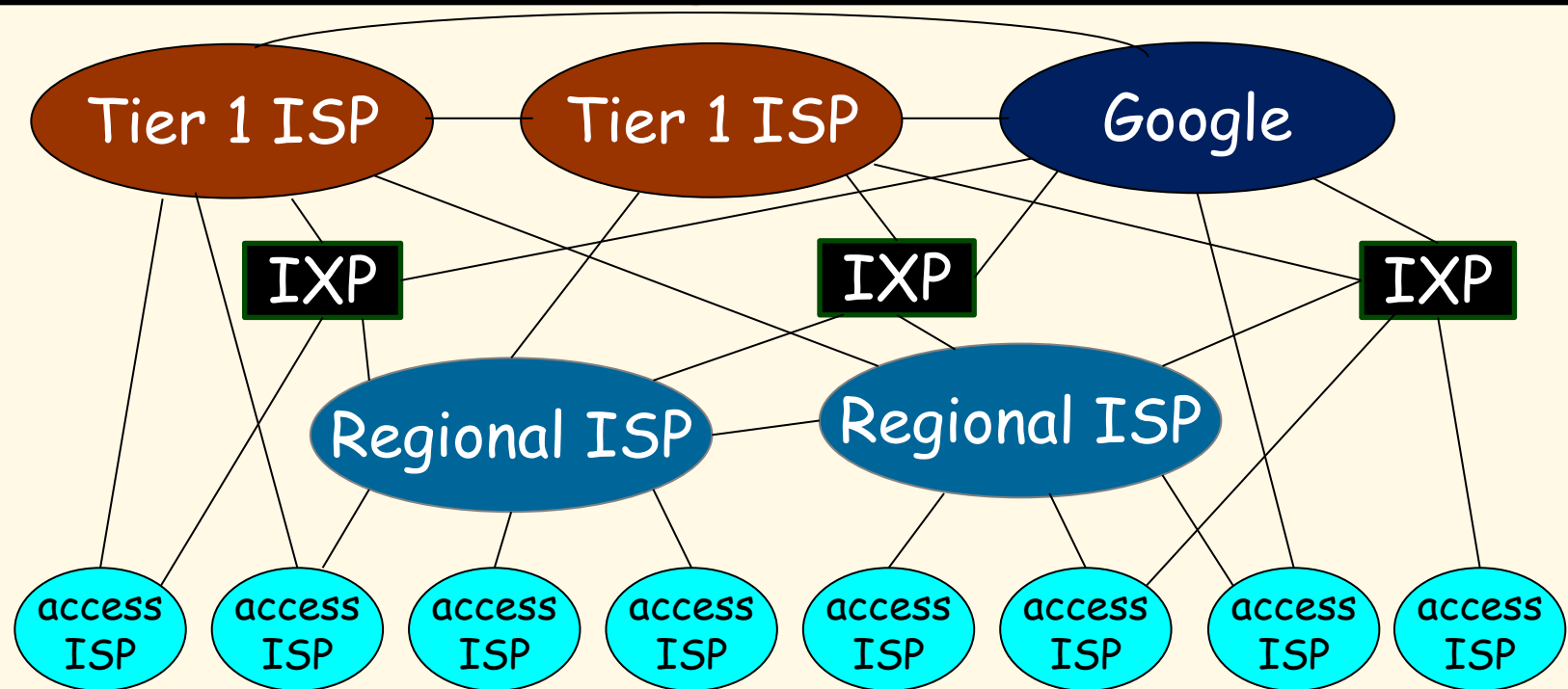


# Internet Structure: Network of Networks

... and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



# Internet Structure: Network of Networks



- at center: small # of well-connected large networks
  - **“tier-1” commercial ISPs** (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - **content provider network** (e.g, Google): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

# Architecture Summary

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