Network Architecture and Protocol Stacks

Internet of Things

Fall 2015

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 networks. [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

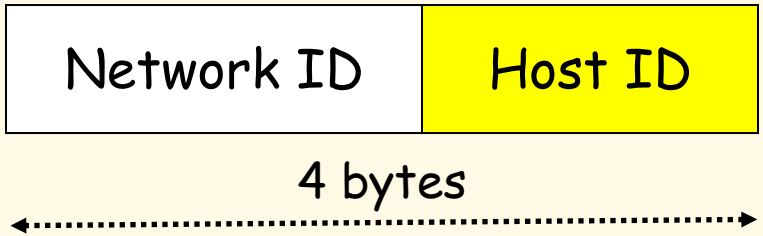
- Provides a *name space* to refer to machines connected to the Internet (e.g. chablis.cs.wpi.edu).
- The name space is hierarchical, but it is only administrative and not used in network routing operations.
- DNS (Domain Name Service) provides automatic translation of names to addresses.

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.

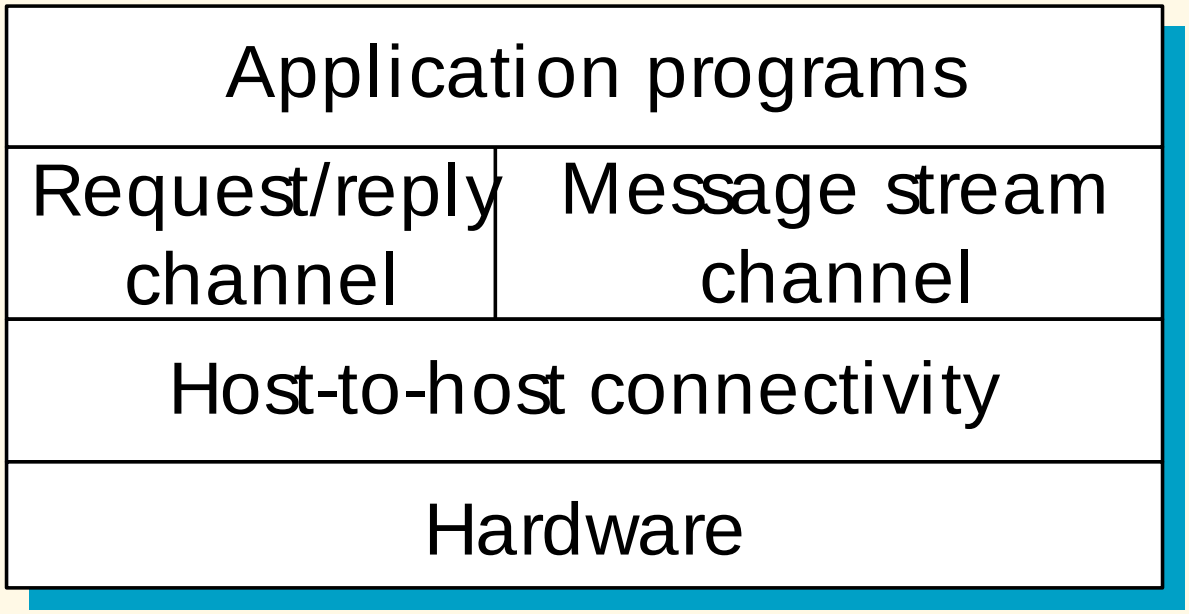


Figure 1.9 Layered system with alternate abstractions available at a given layer.

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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

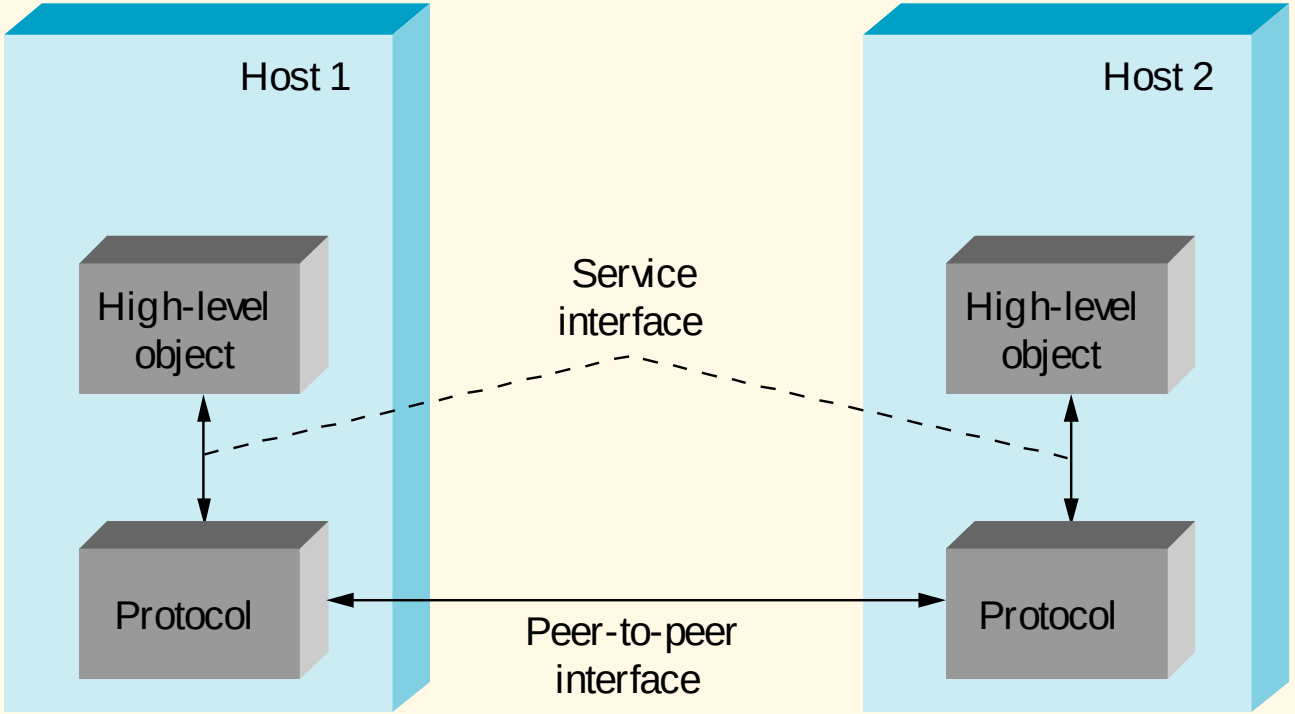

Figure 1.10 Service interfaces and peer interfaces

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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.*

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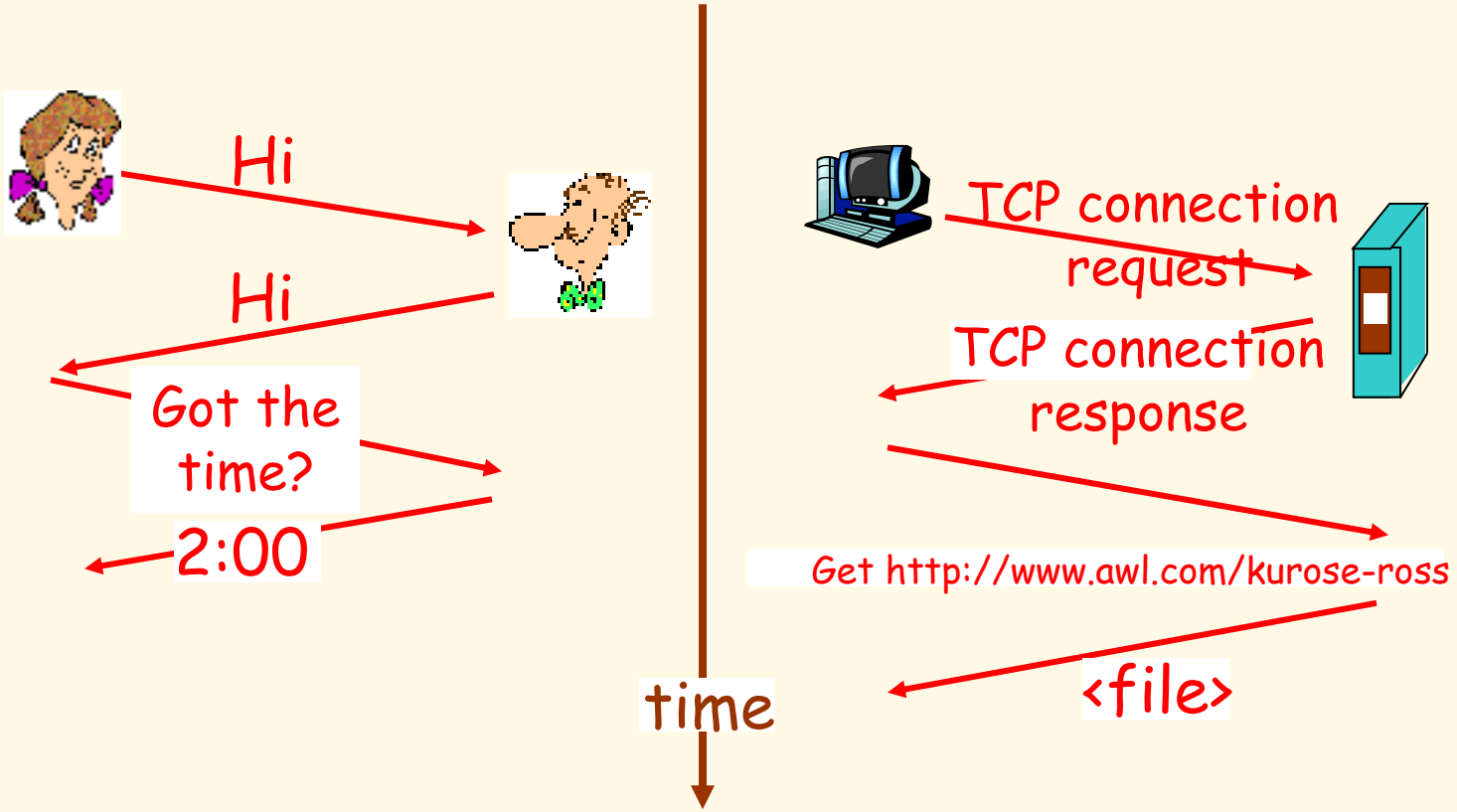
What's a protocol?

a human protocol and a computer network protocol:



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International Standards Organization Open Systems Interconnect (OSI) Reference Model

ISO Architecture

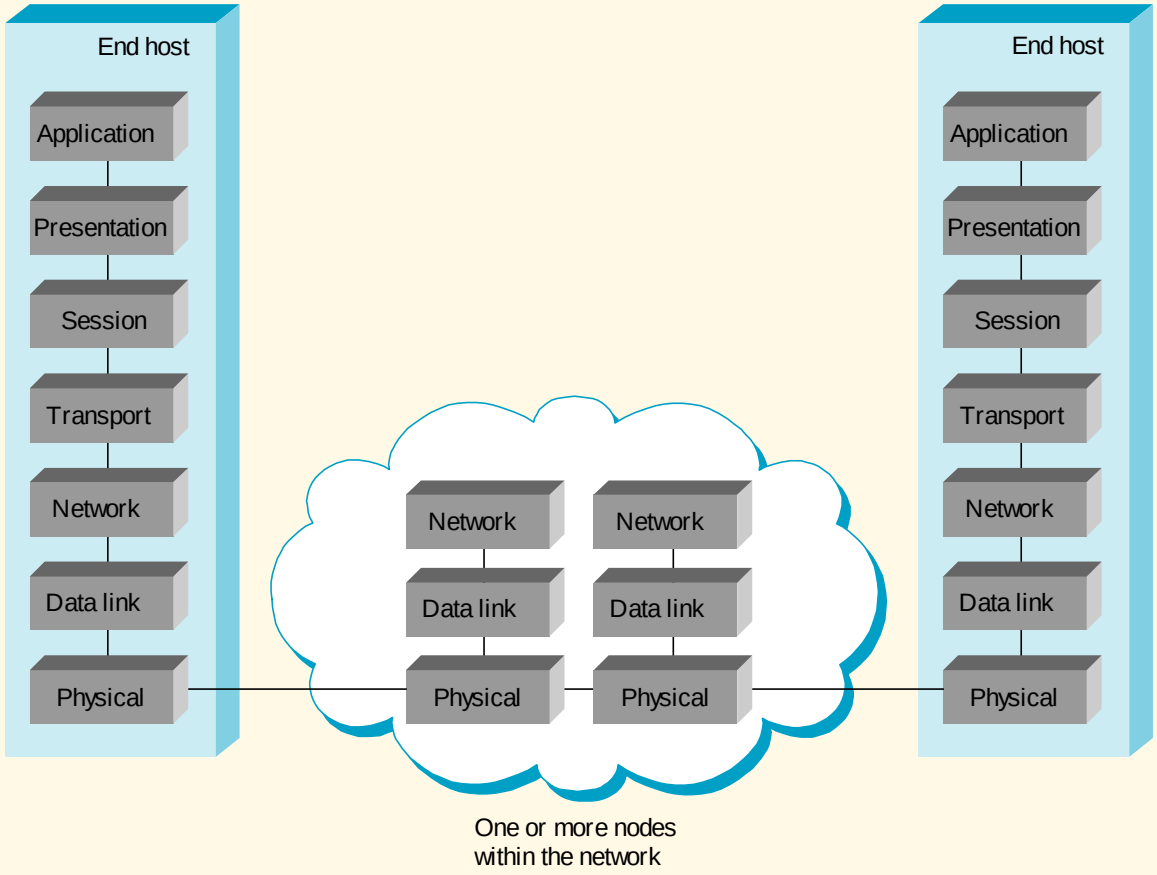

Figure 1.13 The OSI seven-layer model

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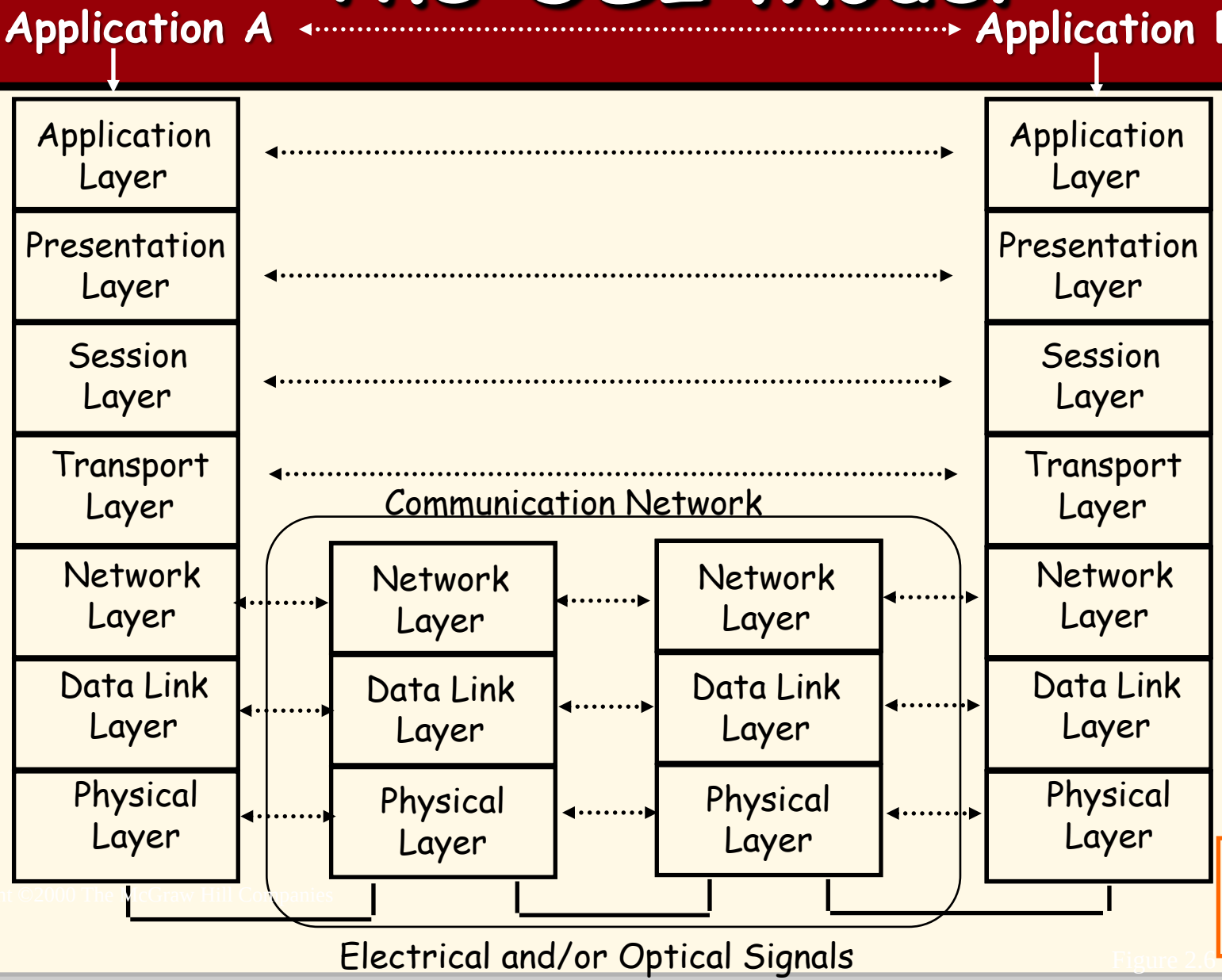
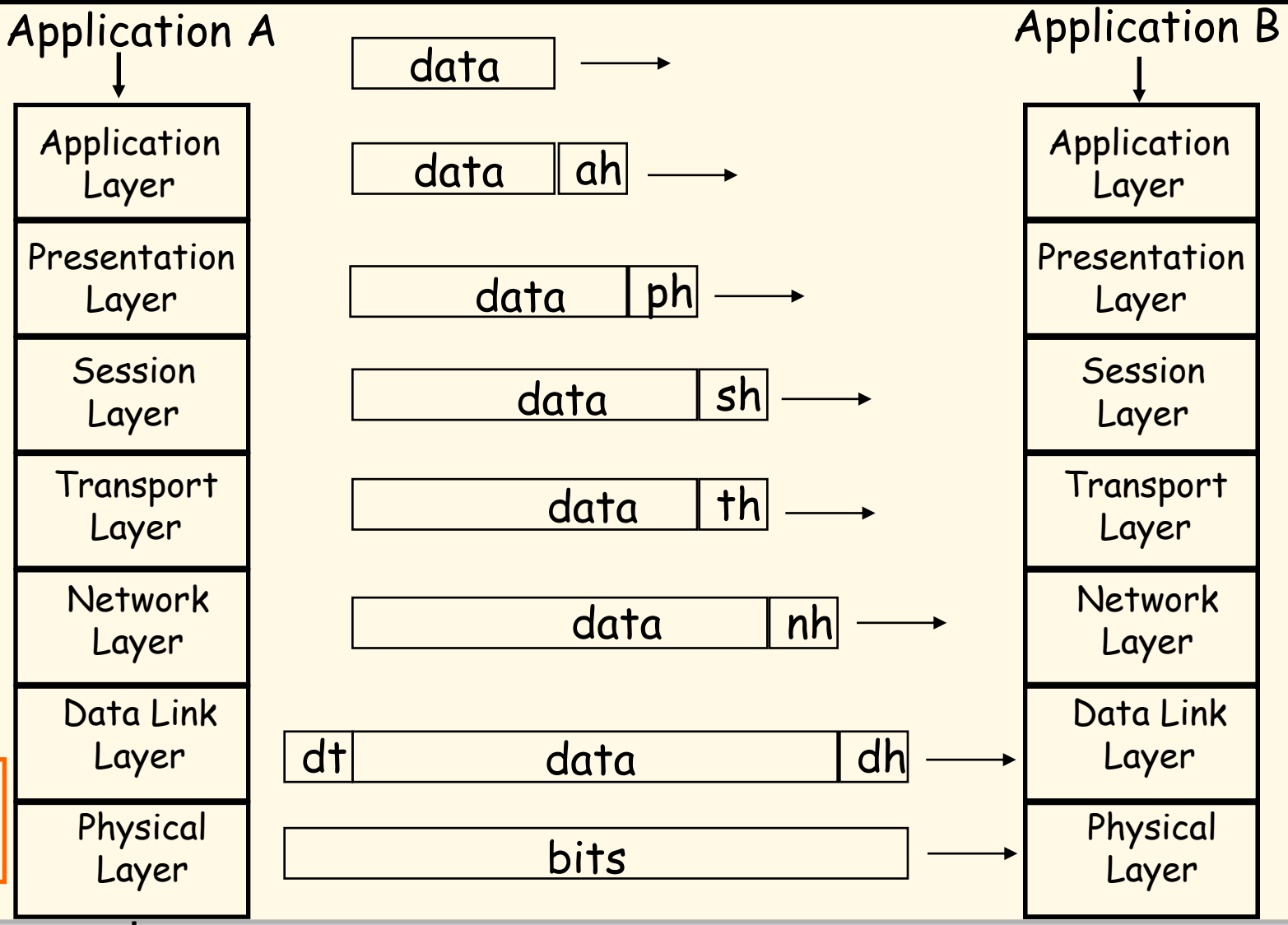
The OSI Model



Leon-Garcia & Widjaja: *Communication Networks*

Figure 2.6

OSI Layer Encapsulation



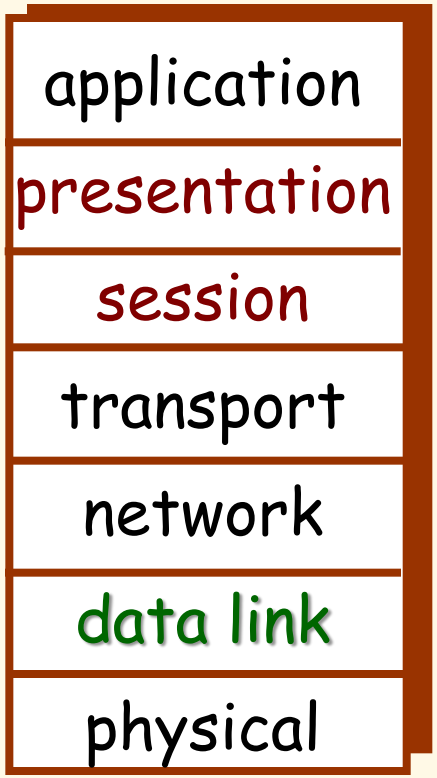
Leon-Garcia & Widjaja: *Communication Networks*

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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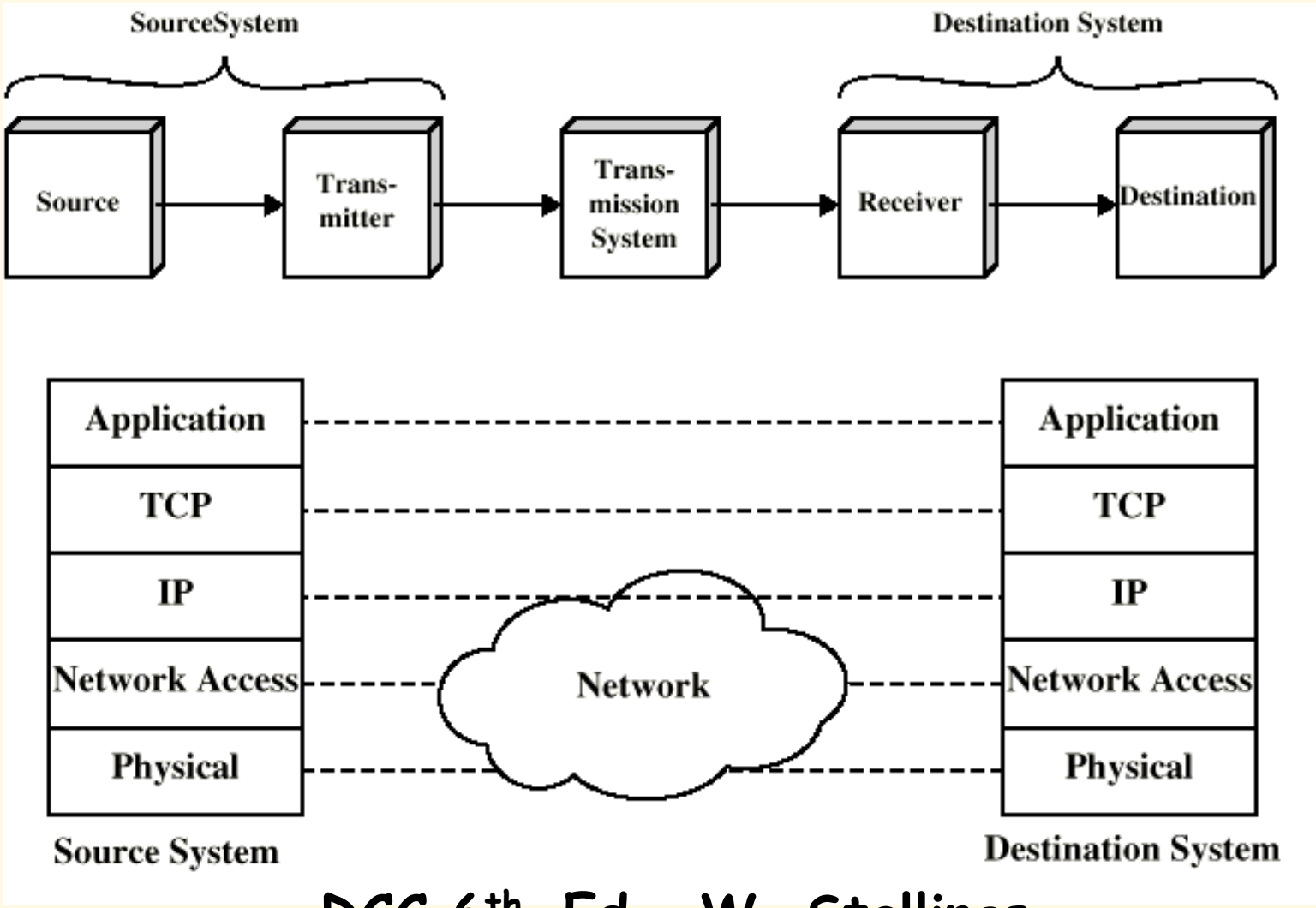
Advantages of Layering Design

- 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 6th Ed., W. Stallings

OSI versus TCP/IP

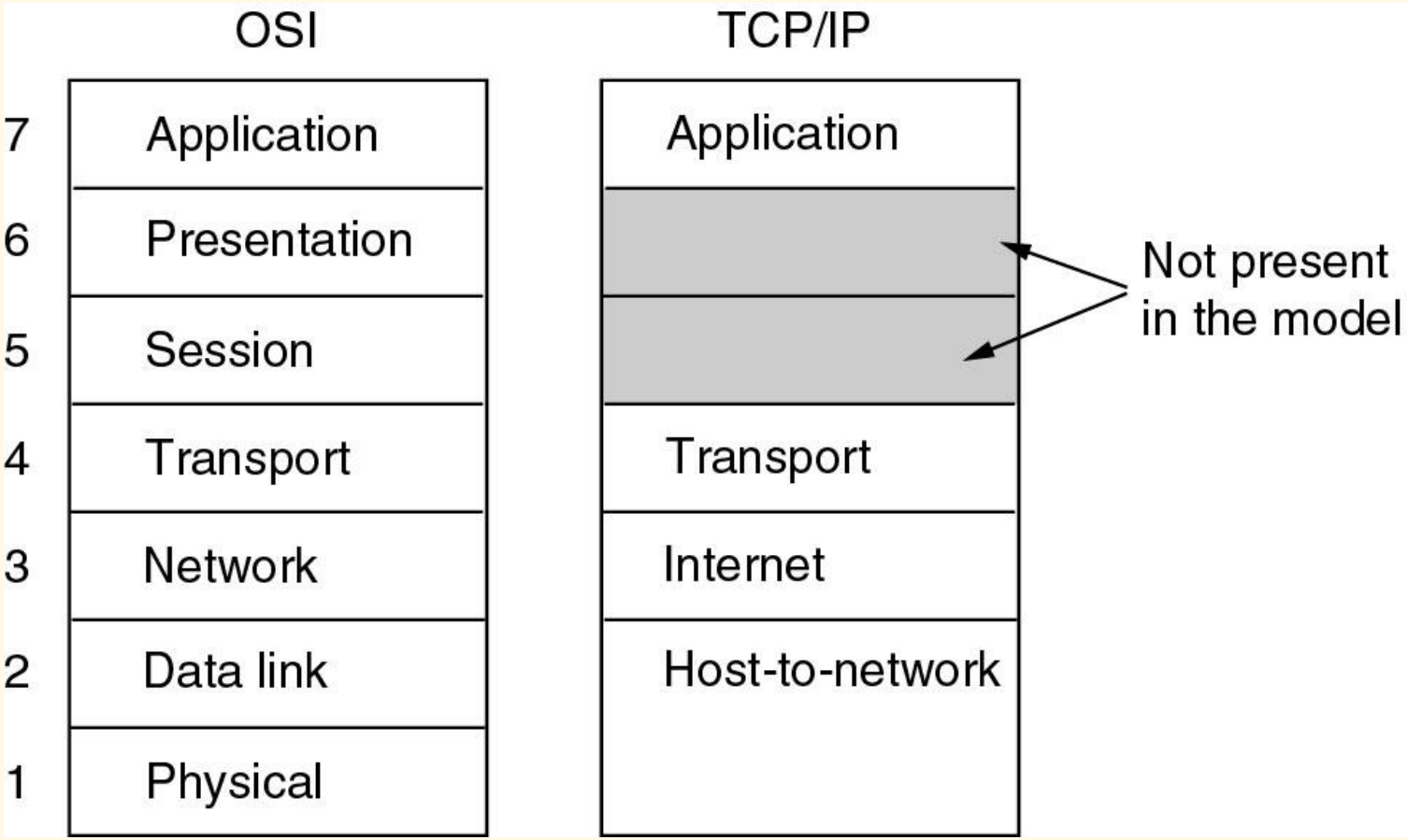
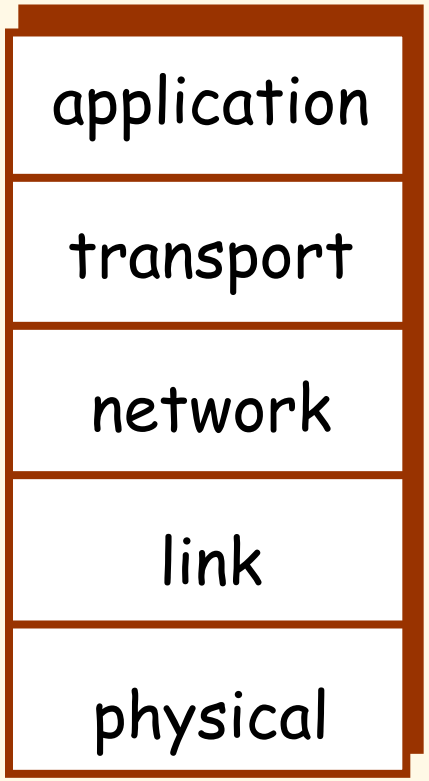


Figure 1-21. [old] The TCP/IP reference model.

Tanenbaum

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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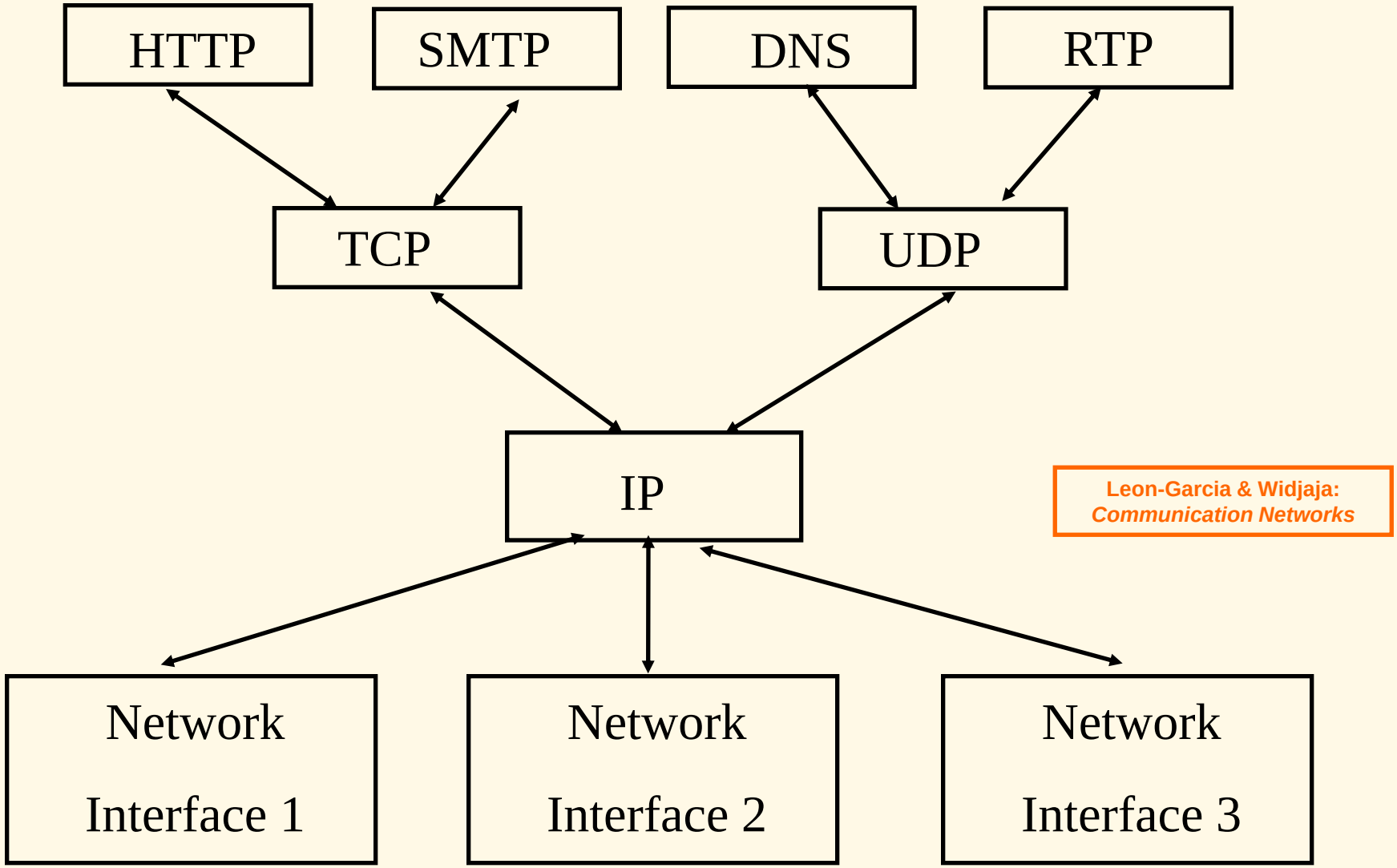
TCP/IP Protocols



Leon-Garcia & Widjaja:
Communication Networks

Alternate View

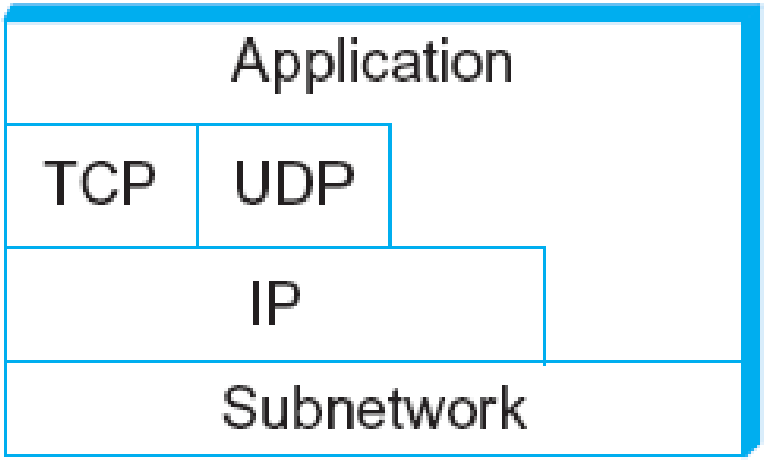


Figure 1.15 Alternate view of the Internet architecture

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Layering Example

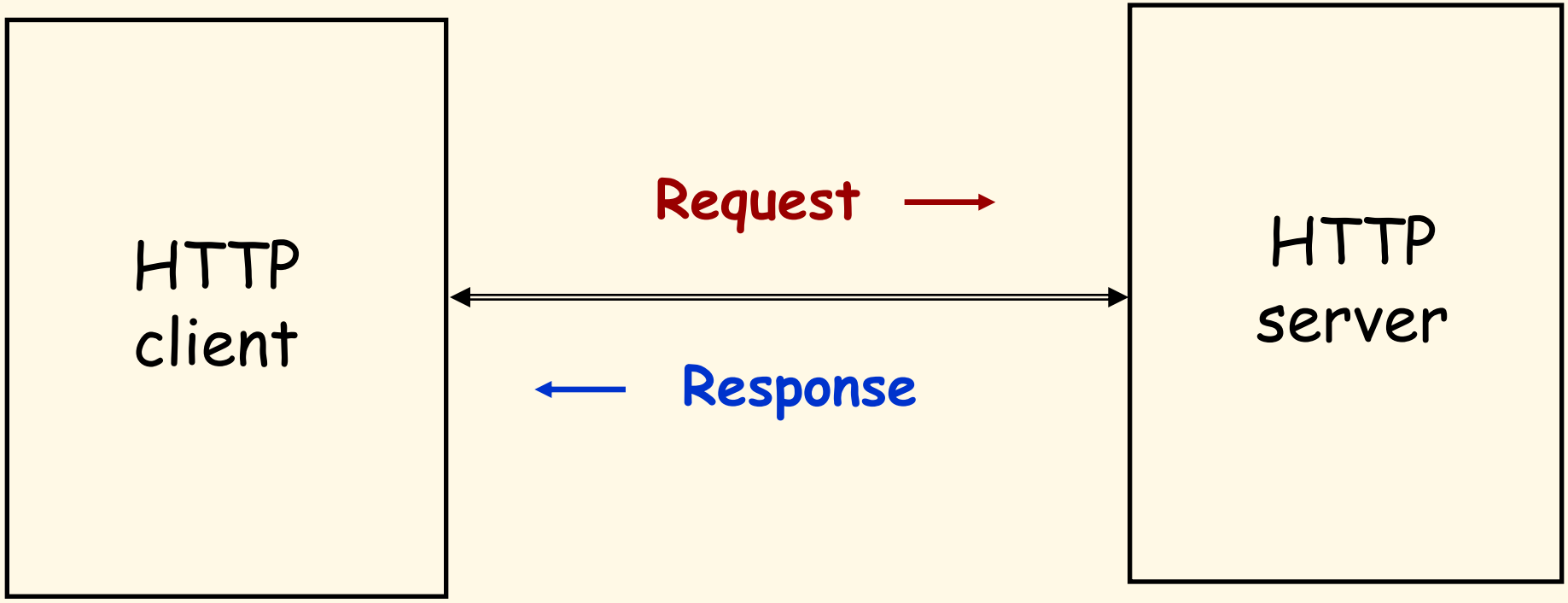
Client/server relationship

- 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).

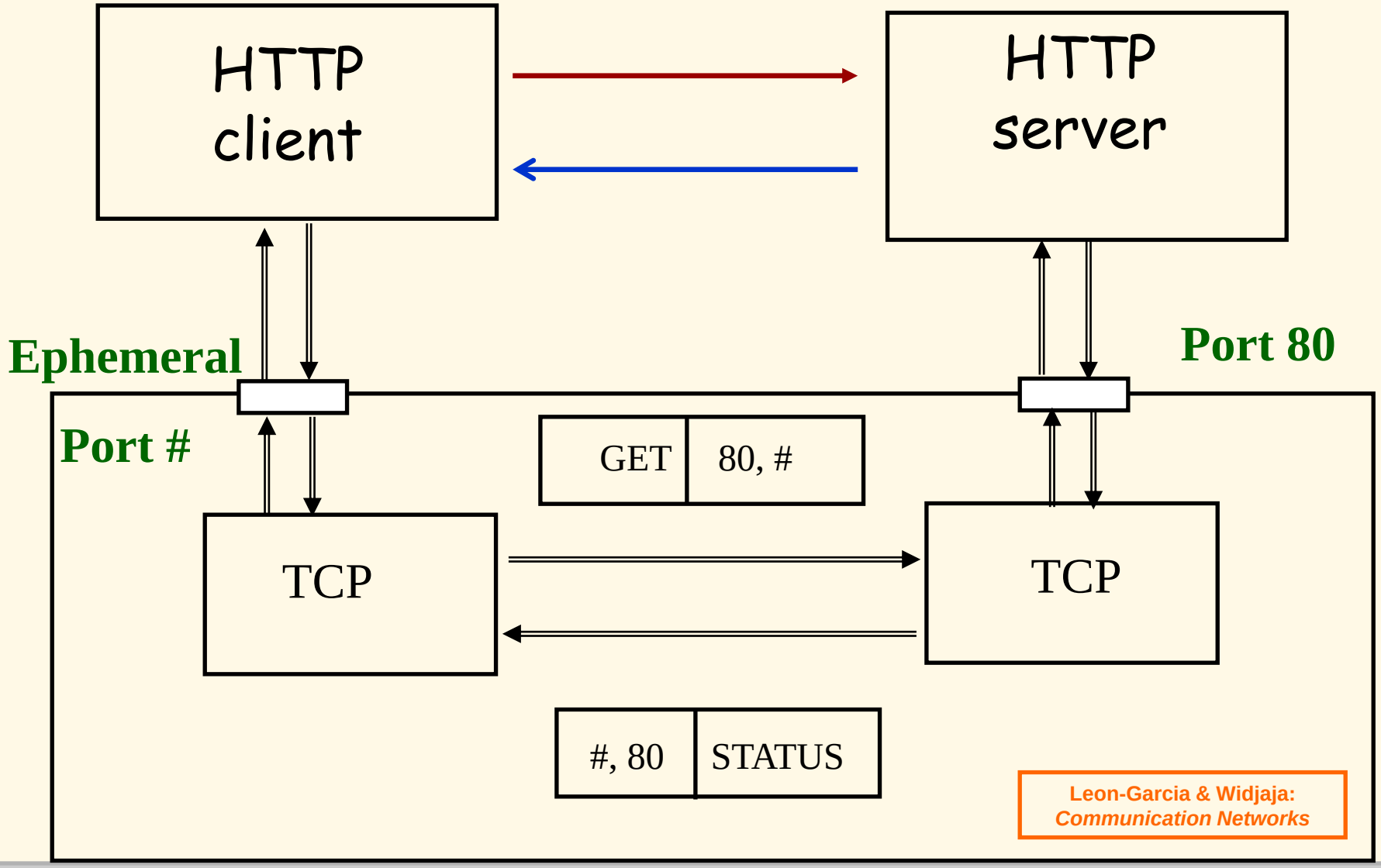
HTTP Example

- 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



HTTP/TCP Layering Interface



HTTP Encapsulation Example

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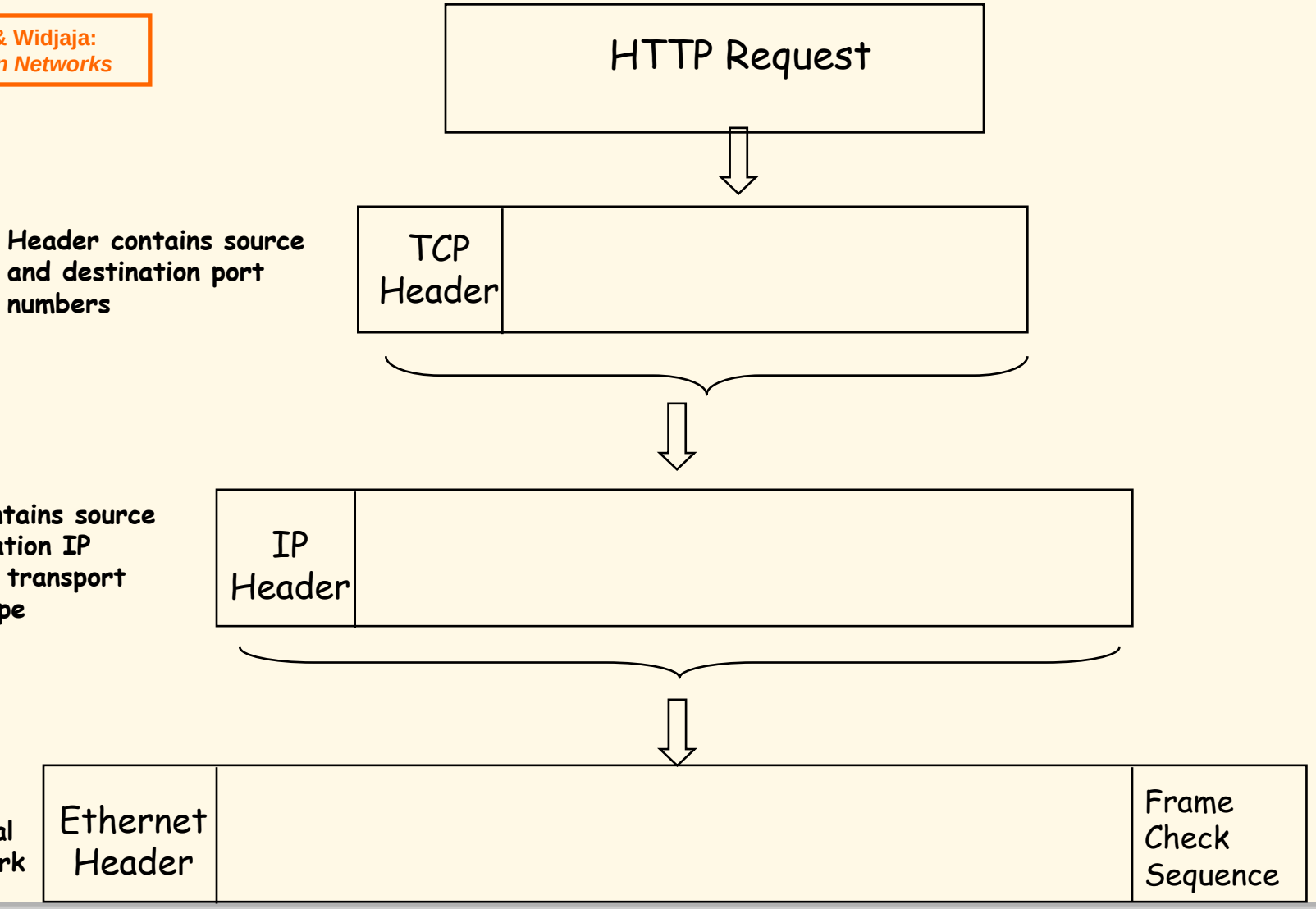
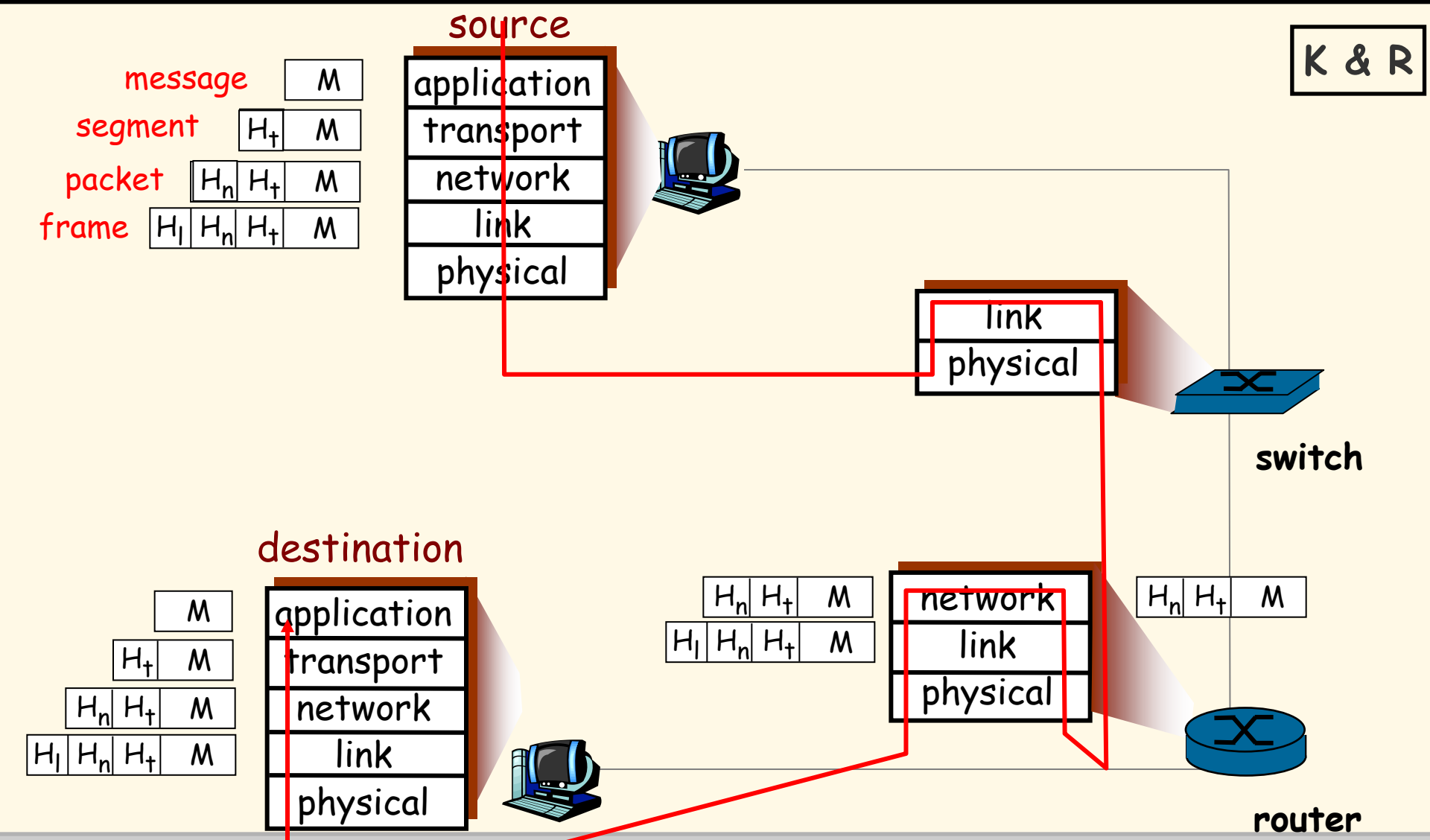
Communication Networks

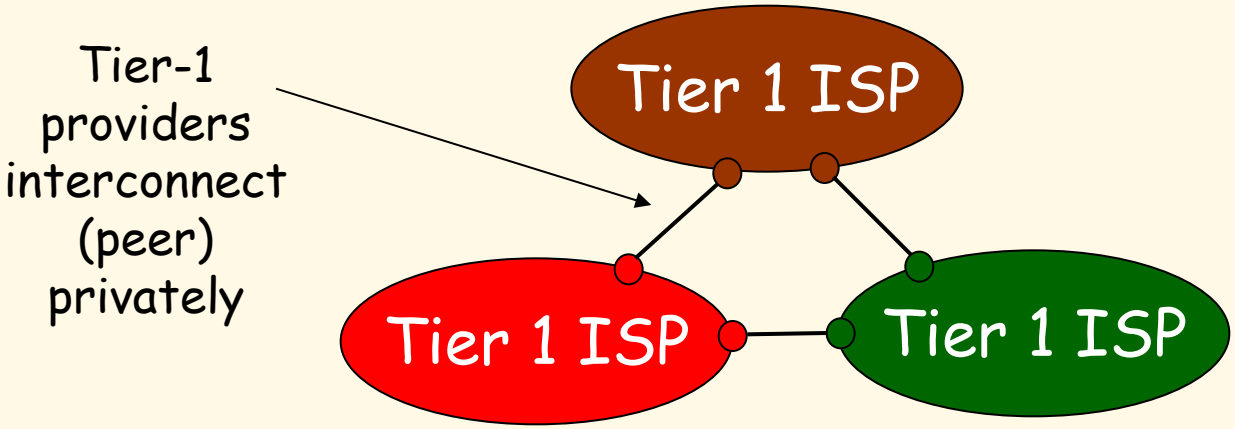


Encapsulation Animation



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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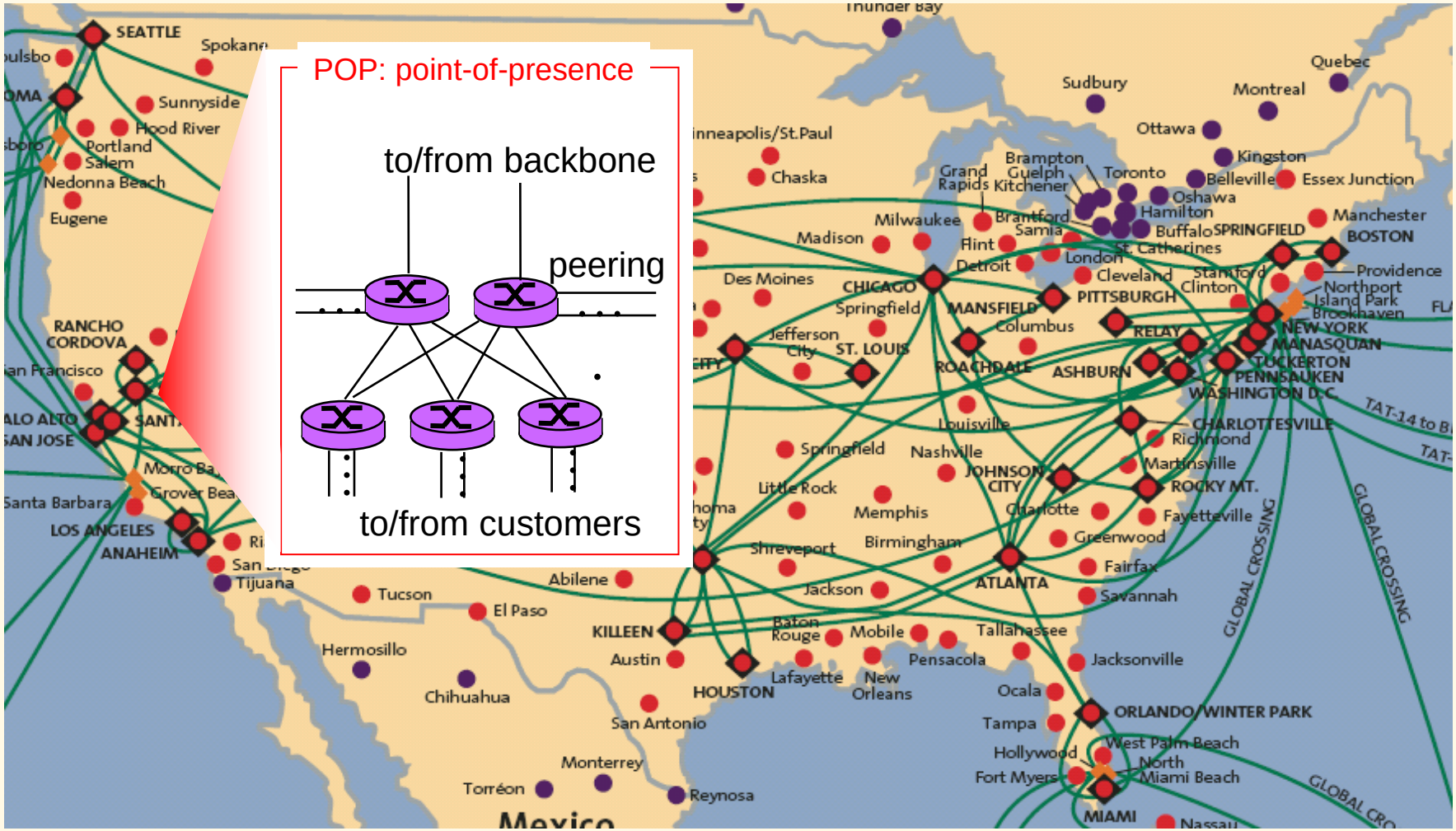
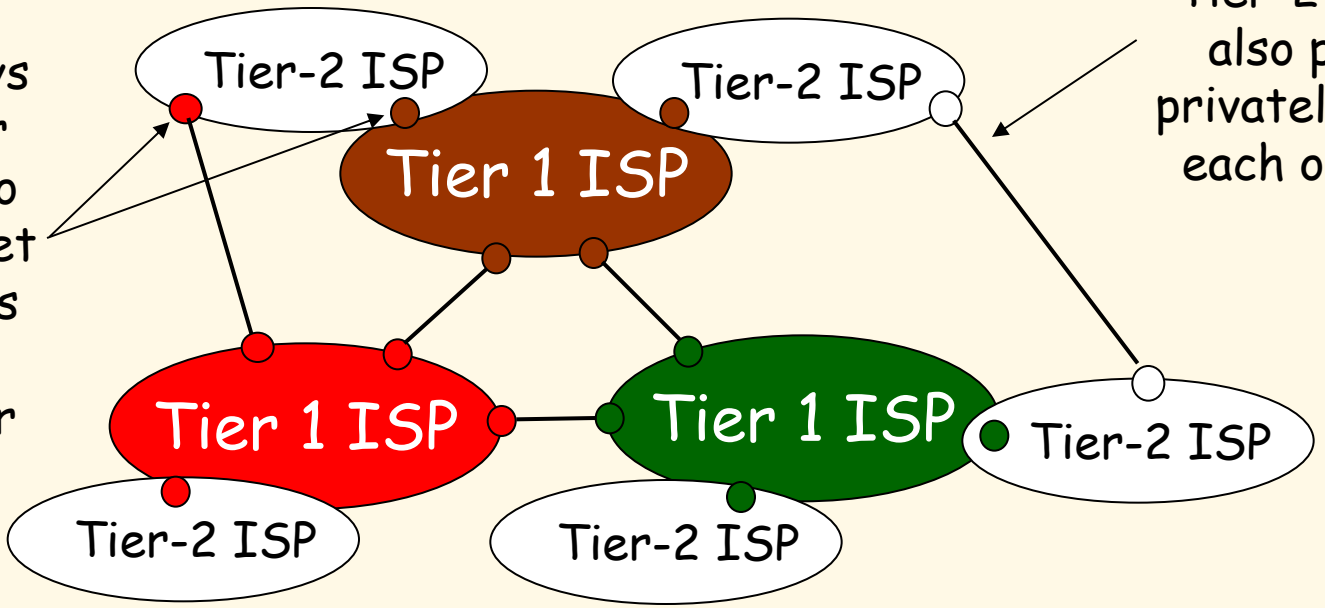
Tier-1 ISP: e.g., Sprint



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

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet
- tier-2 ISP is *customer* of tier-1 provider



Tier-2 ISPs also peer privately with each other.

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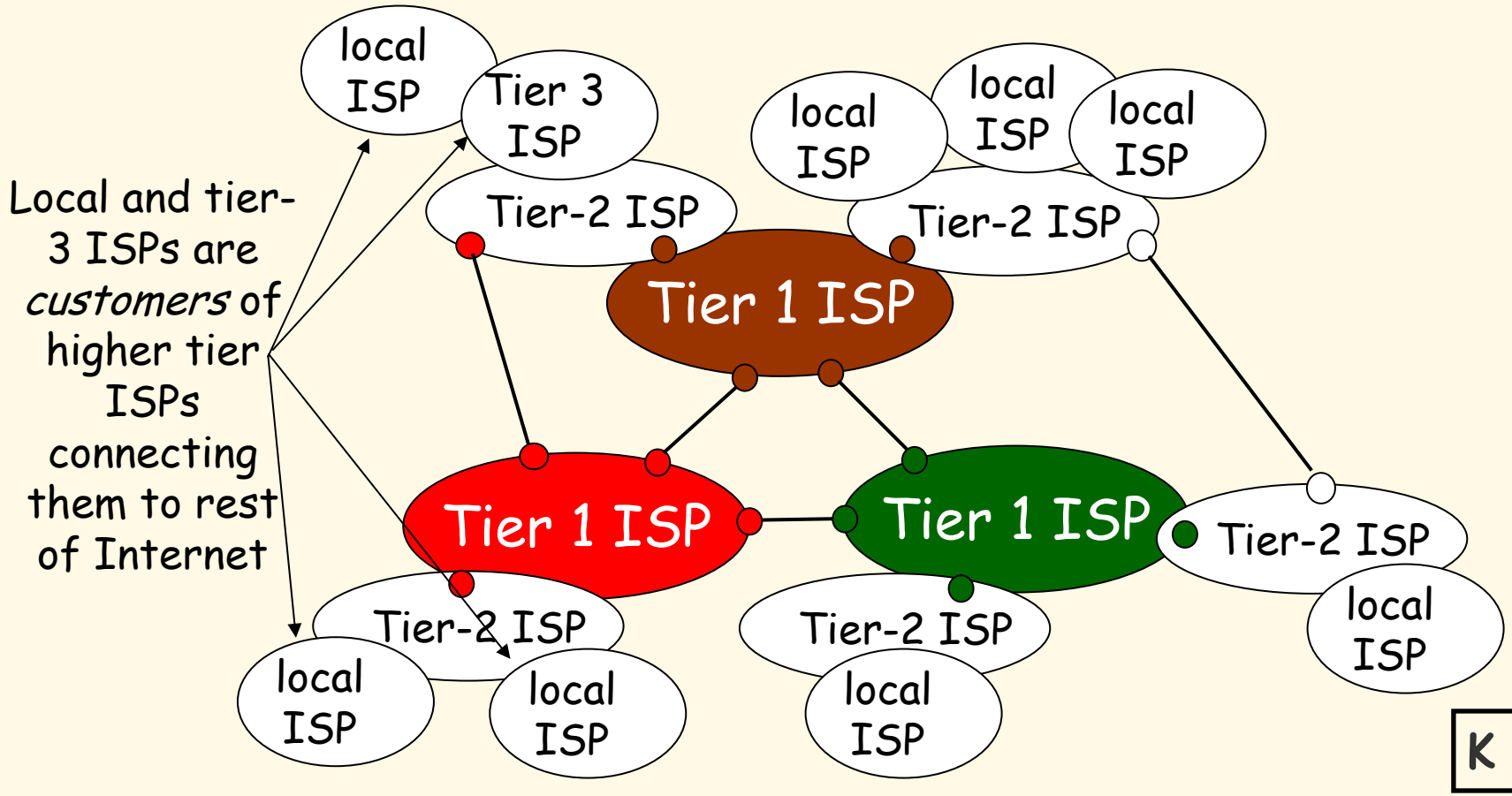
Internet Structure: Network of Networks

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



Internet Structure: Network of Networks

- a packet passes through many networks!

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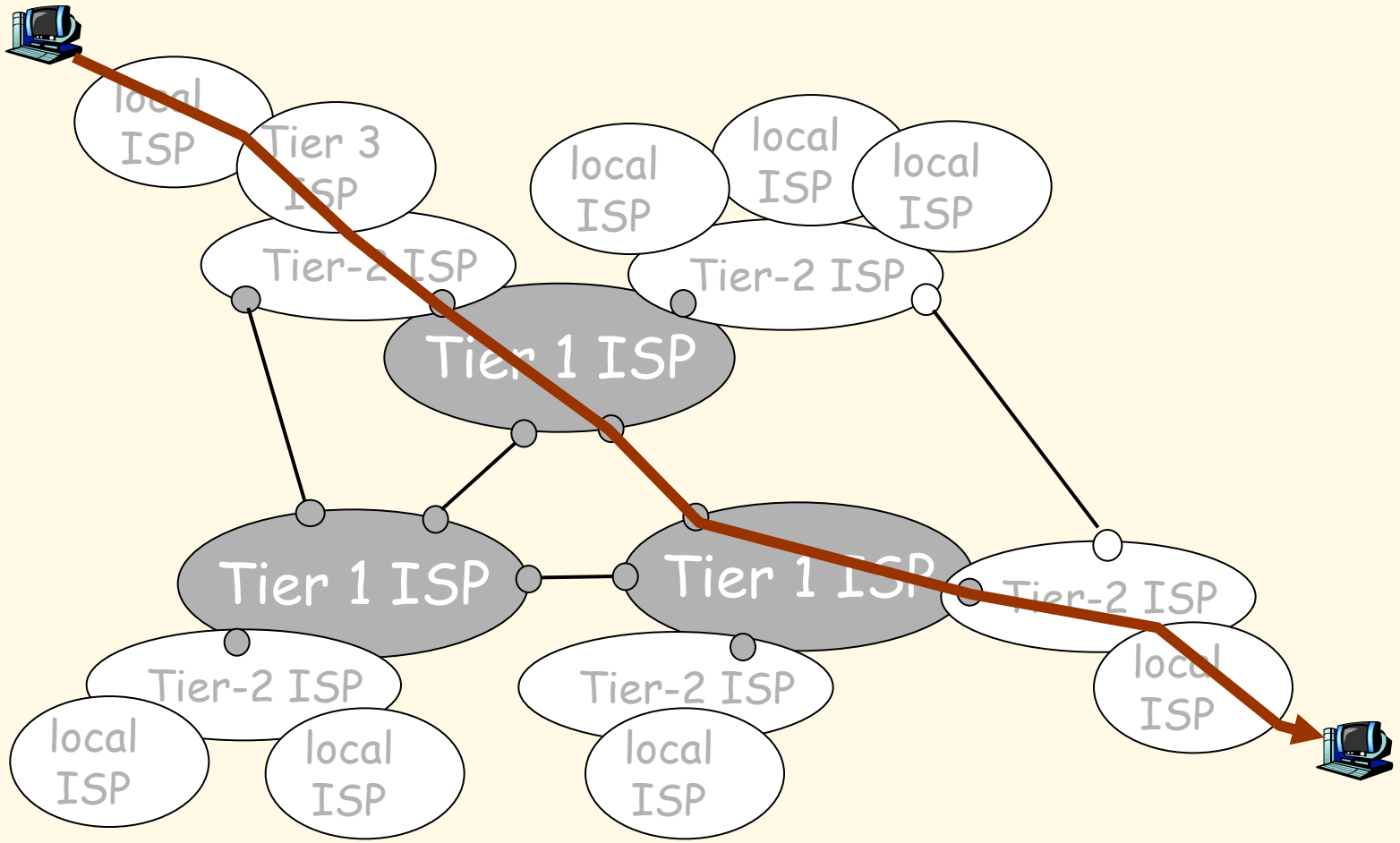
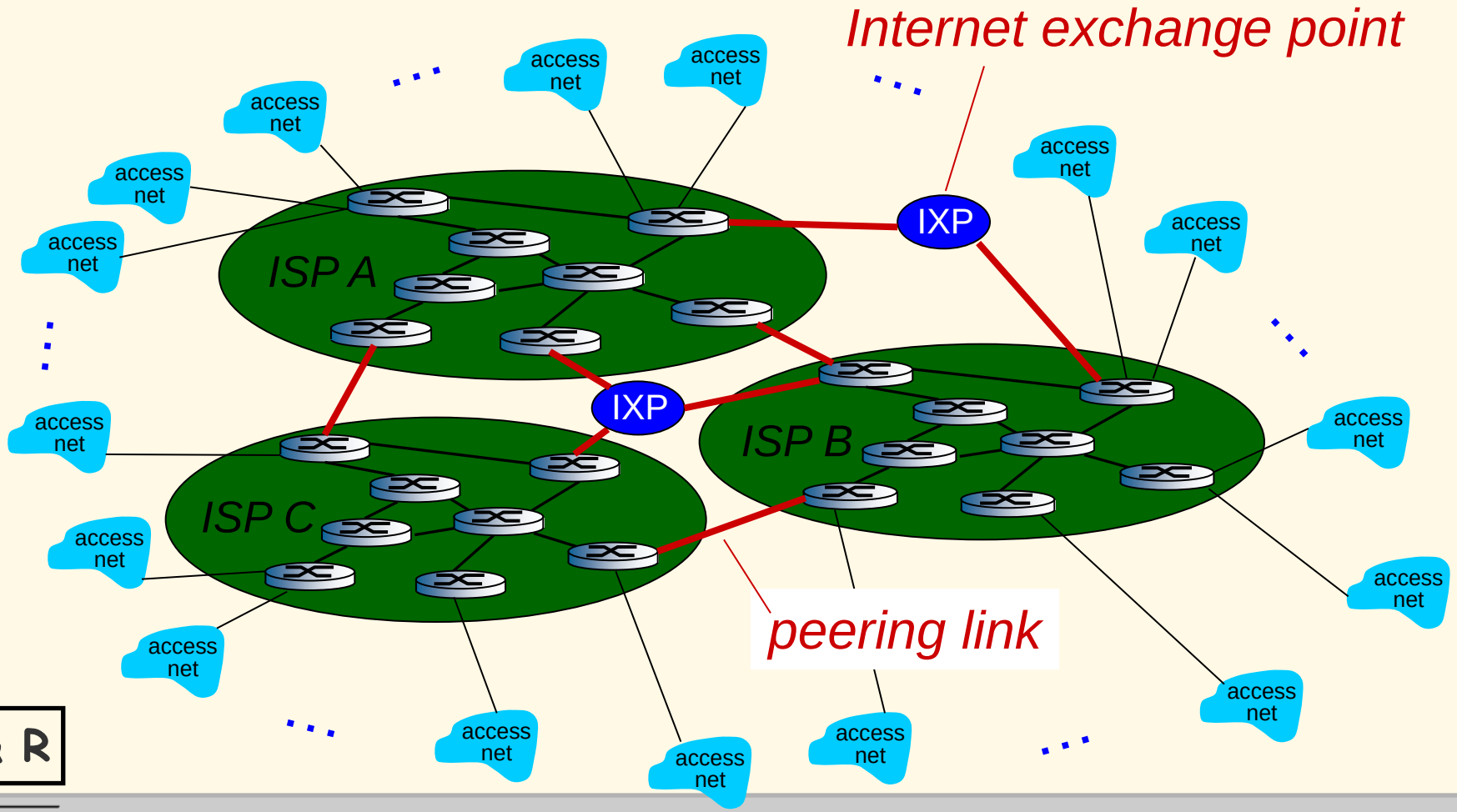


Internet Structure: Network of Networks

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



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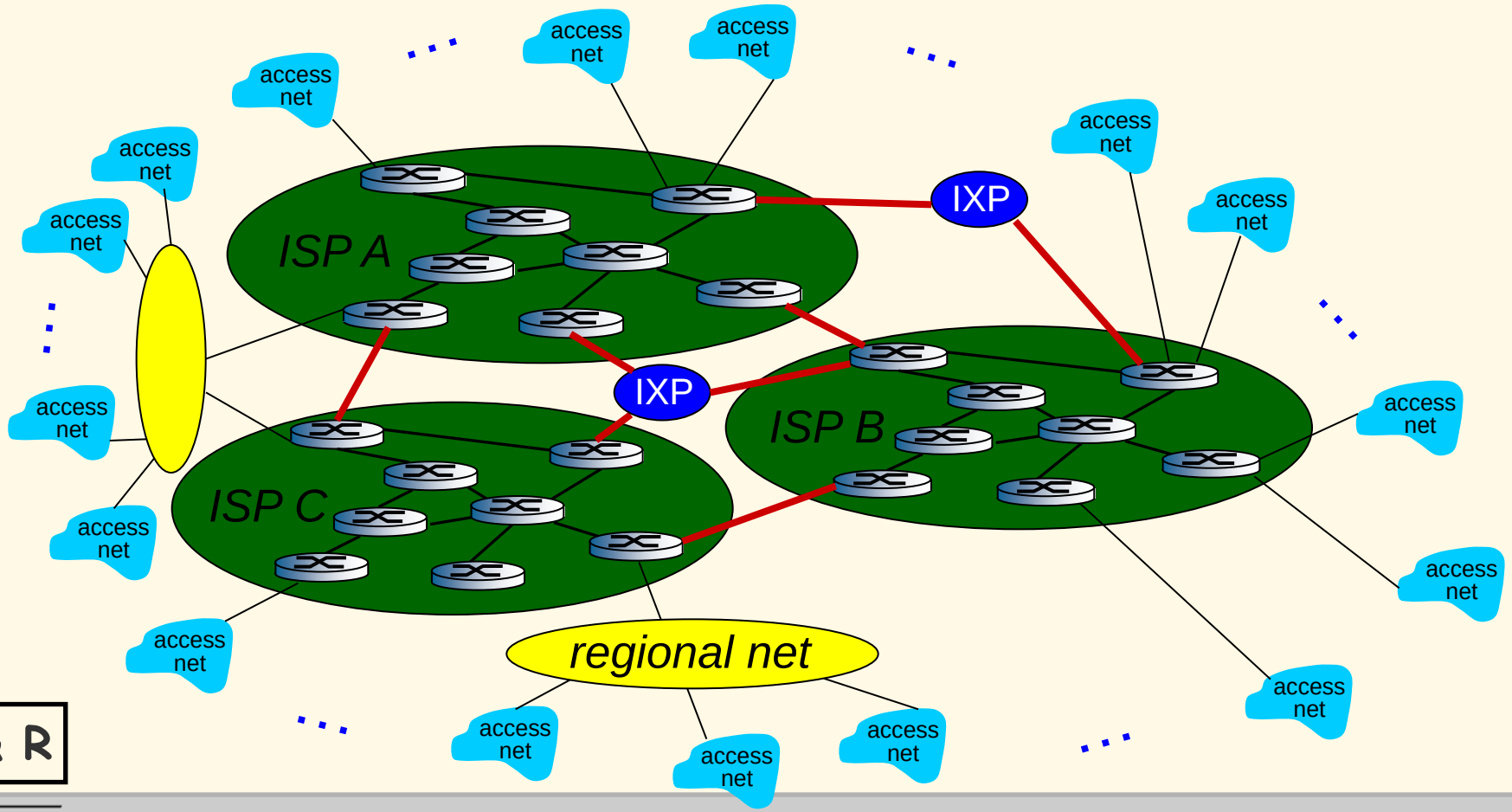
Internet Structure: Network of Networks

… and regional networks may arise to connect access nets to ISPS



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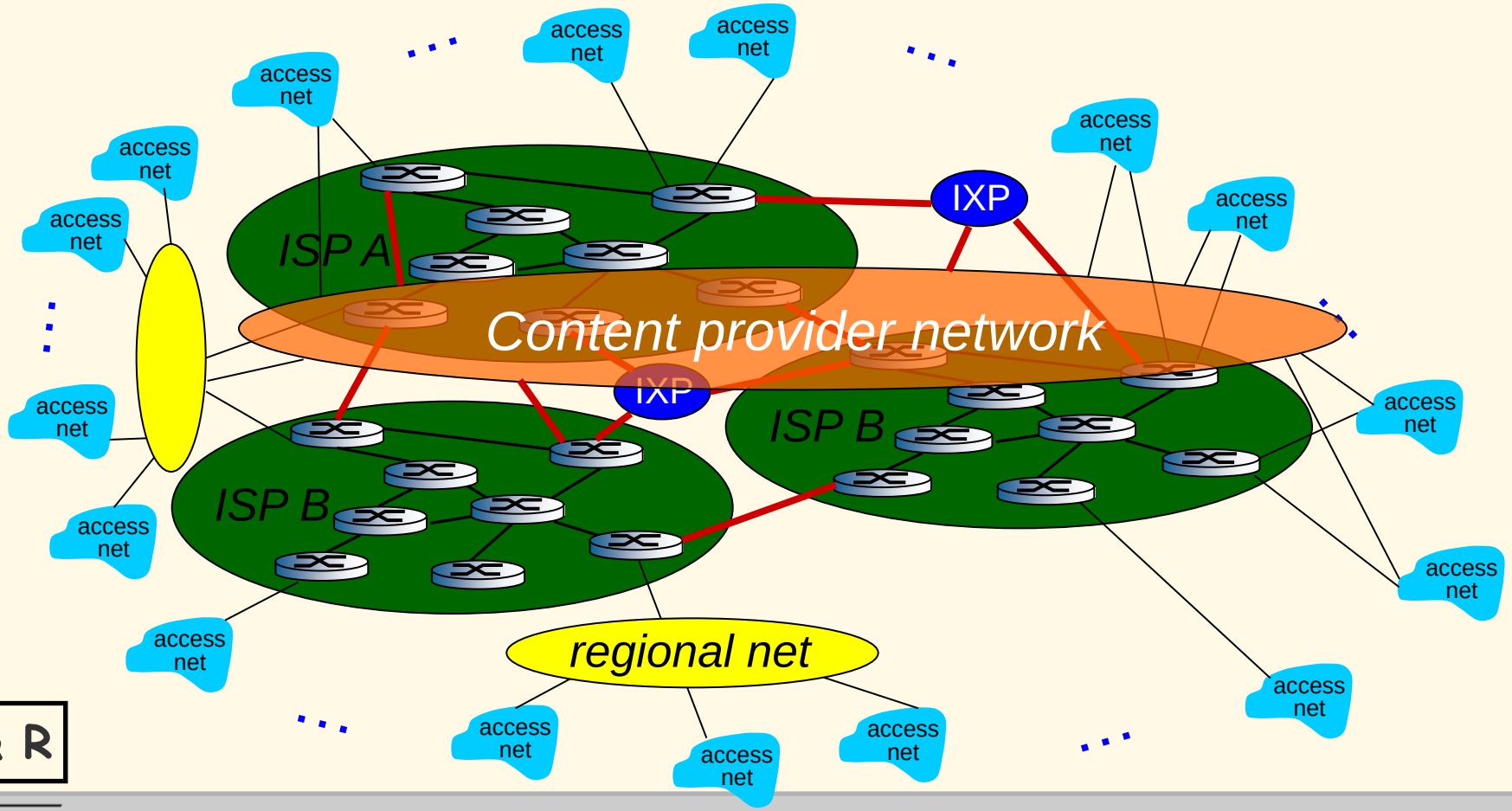
Internet Structure: Network of Networks

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



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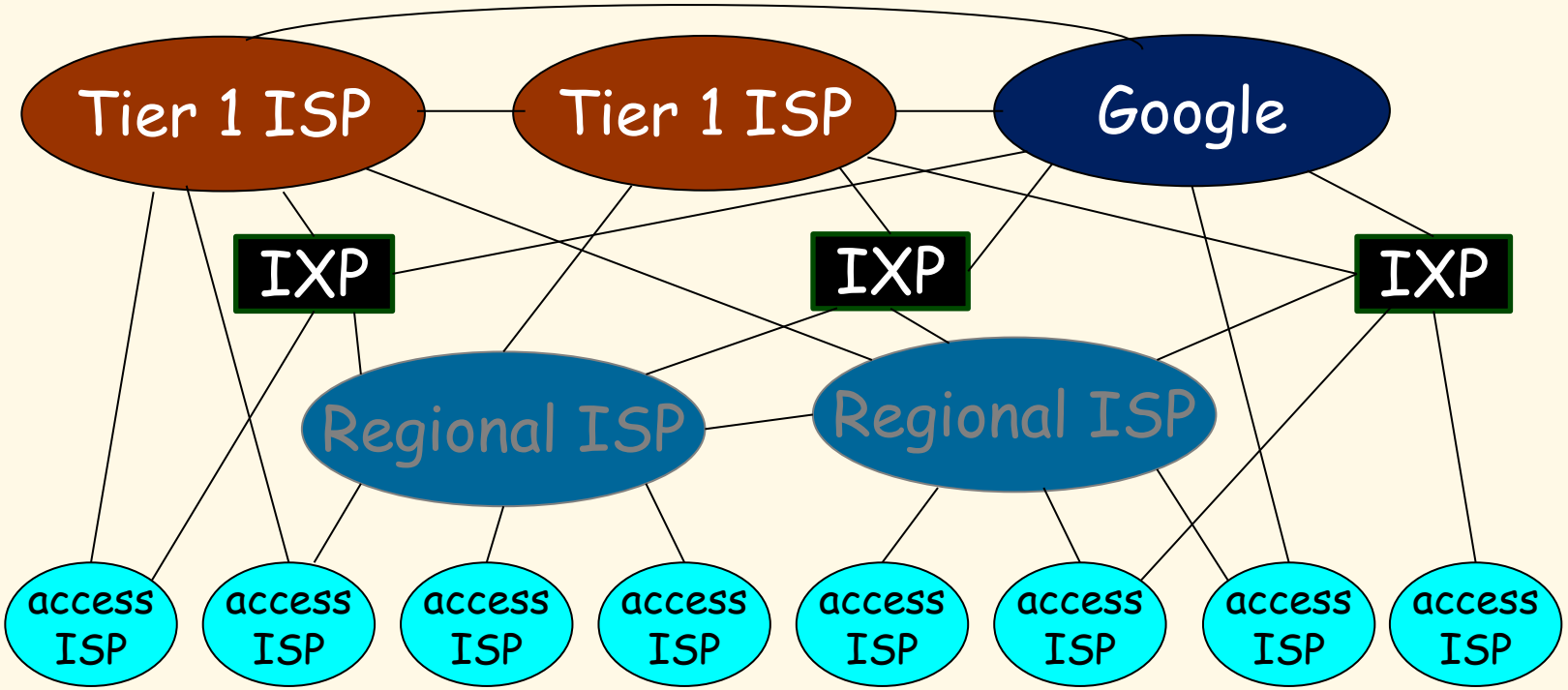
Internet Structure: Network of Networks



- 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 it data centers to Internet, often bypassing tier-1, regional ISPs

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