

CS3640

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# Application Layer (1): Principles & Architecture

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# Announcements

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## Updates to spot quizzes

- *Will stop displaying the answers instantaneously*
- *Balance between questions that refer directly to the lecture material vs those that need applying the concepts*

## Written assignment 1

- *Open now; submission deadline: Feb-8*
- *Part-1 requires reading a research paper on end-to-end principle*
- *Part-2 covers the overview lectures*

## End-To-End Arguments in System Design

J. H. SALTZER, D. P. REED, and D. D. CLARK  
Massachusetts Institute of Technology Laboratory for Computer Science

This paper presents a design principle that helps guide placement of functions among the modules of a distributed computer system. The principle, called the end-to-end argument, suggests that functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level. Examples discussed in the paper include bit-error recovery, security using encryption, duplicate message suppression, recovery from system crashes, and delivery acknowledgment. Low-level mechanisms to support these functions are justified only as performance enhancements.

CR Categories and Subject Descriptors: C.0 [General] Computer System Organization—*system architectures*; C.2.2 [Computer-Communication Networks]: Network Protocols—*protocol architecture*; C.2.4 [Computer-Communication Networks]: Distributed Systems; D.4.7 [Operating Systems]: Organization and Design—*distributed systems*

General Terms: Design

Additional Key Words and Phrases: Data communication, protocol design, design principles

### 1. INTRODUCTION

Choosing the proper boundaries between functions is perhaps the primary activity of the computer system designer. Design principles that provide guidance in this choice of function placement are among the most important tools of a system designer. This paper discusses one class of function placement argument that

## TL;DR:

*If a function can be **completely and correctly** implemented **only with the knowledge of** the application at the endpoints of the communication system,*

*then providing that function as a feature of the communication system is **not possible** (and could be **harmful**)*

I've never read a research paper before. How do I go about it?

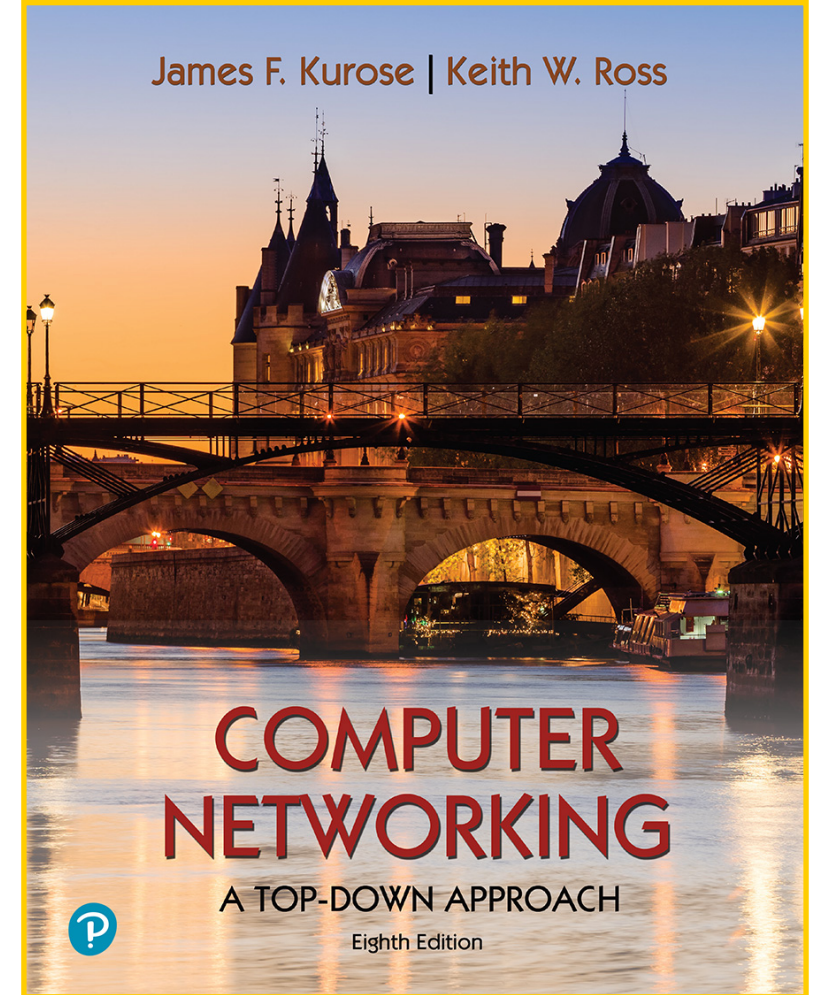
- This paper is easy to follow and fun to read (unlike most research papers)!
- Prof. Sherry has a talk on this: [https://www.youtube.com/watch?v=aR\\_UOSGEizE](https://www.youtube.com/watch?v=aR_UOSGEizE)

# Lecture goals

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*Learn the conceptual and implementation framework of network applications*

- *Design and architecture*
- *Utilizing transport services*
- *Understanding protocols*



Chapter 2.1

# **Architecture of Networked Apps**

# Network applications are ubiquitous in modern world

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## Socializing



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## Communicating



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## Shopping



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## Entertainment

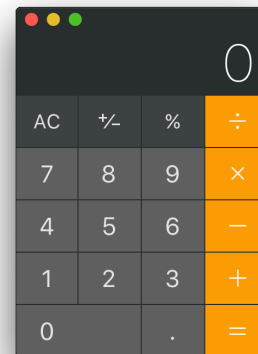


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## Traveling




**Challenge:** name three applications that are not networked



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## Convert values

- In the Calculator app  on your Mac, enter the original value, choose Convert in the menu bar, then choose a category, such as Temperature or Currency.

Note: You must be connected to the internet to get the most recent currency conversion rate.

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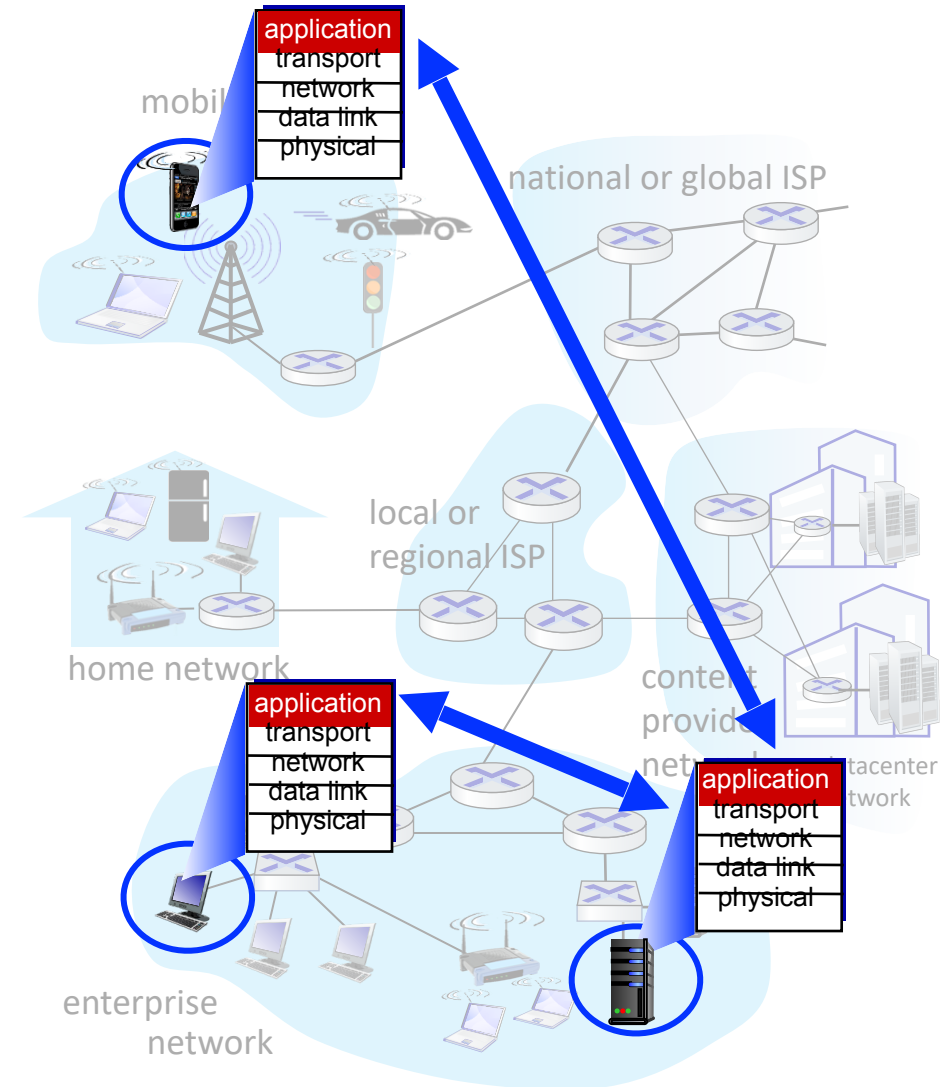
# Creating a network app

## Write programs that

- run on (different) end systems
- communicate over network
- e.g., web server software communicates with browser software

## What do you need to write for network-core devices?

- nothing! network-core devices do not run user applications
- limiting app building to end systems allows for rapid development and deployment



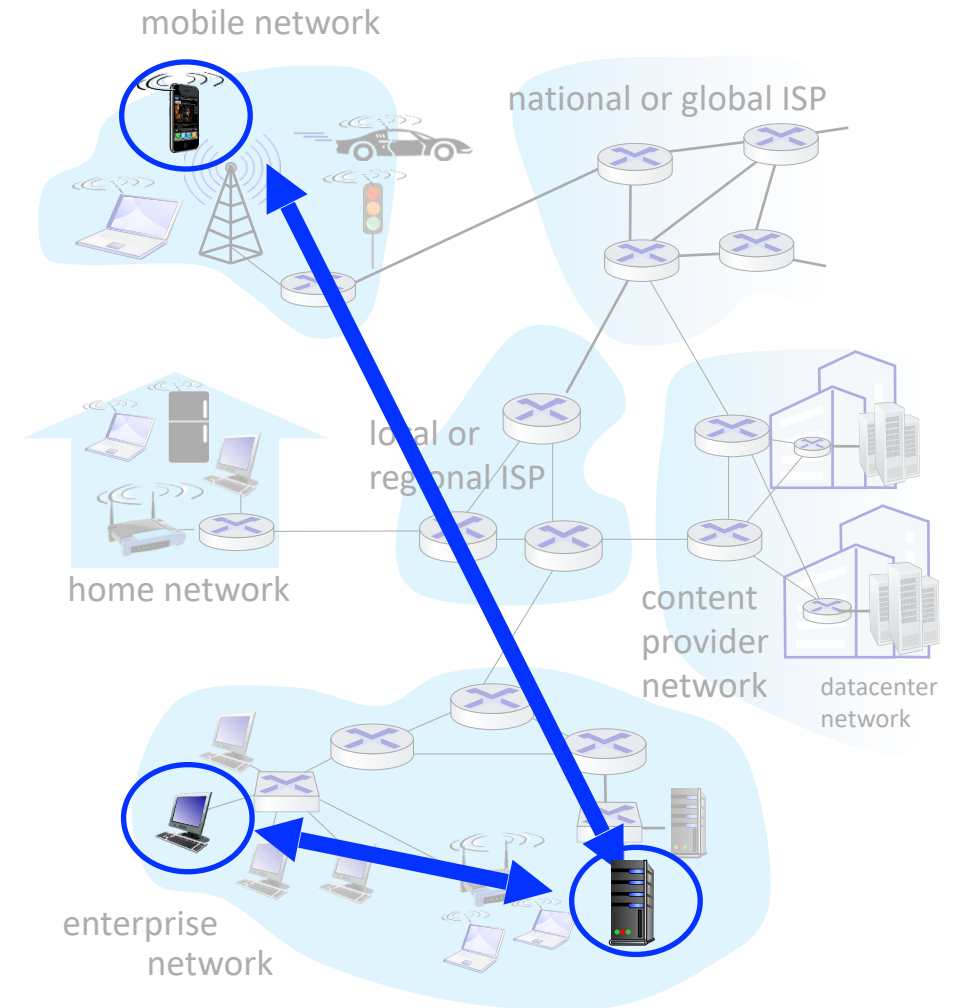
# Architecture: client-server model

## Server

- always-on host
- has a permanent IP address
- often located in data centers
- ability to scale to match the load

## Clients:

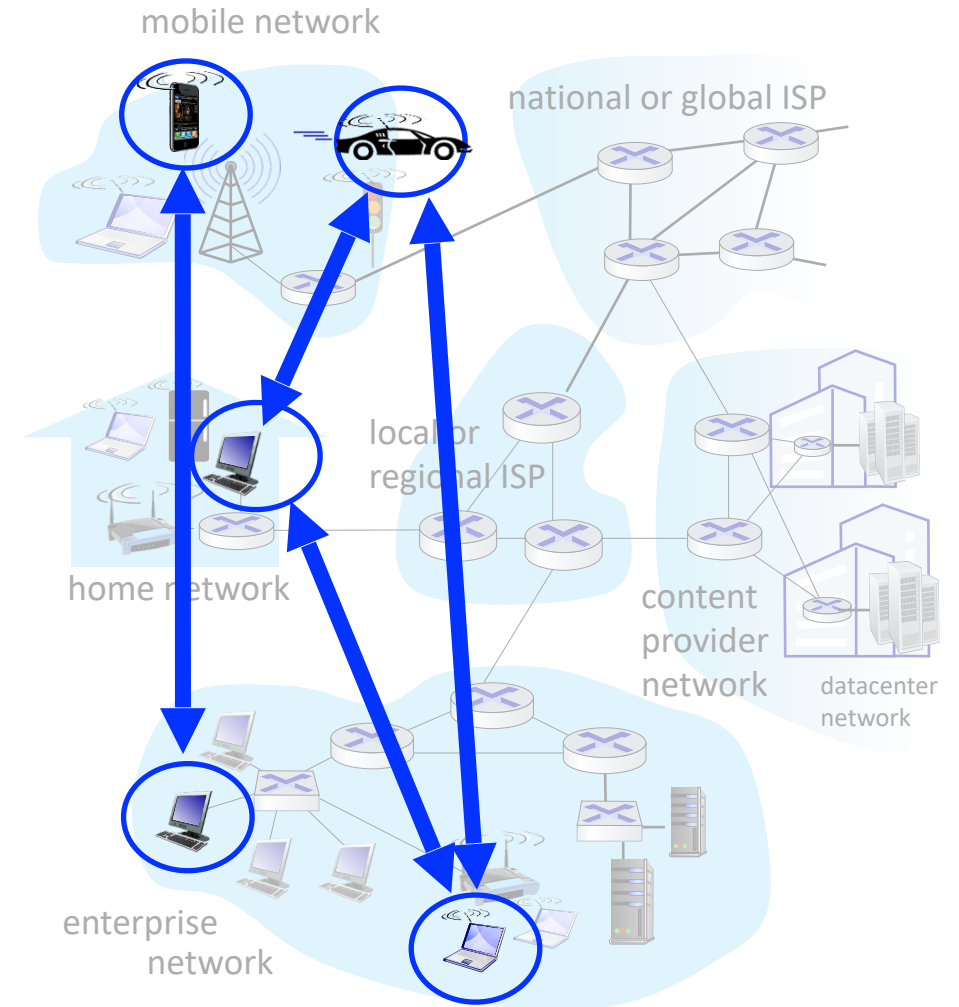
- contact and communicate with server
- do not communicate directly with each other
- may be intermittently connected
- may have dynamic IP addresses
- examples: HTTP, IMAP, FTP





# Architecture: peer-peer model

- there is no always-on server
- end systems communicate directly
- peers request service from other peers, provide service in return to other peers
- self scalability: new peers bring new service capacity, as well as new service demands
- peers are intermittently connected and can change IP addresses
- service management tends to be complex
- Examples: P2P file sharing, Skype



# Communication: between the apps

## *A primer on **process** and their **communications***

- Process is a program running on a host system
- Two processes within same host typically communicate using inter-process communication
- Processes in different hosts communicate by exchanging messages

### clients, servers

**client:** *the process that initiates communication*

**server:** *the process that waits to be contacted*

*In P2P architectures, an app can be both client and server at the same time*

# Communication: identifying an app on the network

*To exchange messages, a process must have a unique **identifier***

**How about using the IP address?**

- Every host device has a unique 32-bit IP address
- But, IP address alone cannot identify the process that intends to communicate

*IP address: **Port number***

- Ports are 16-bit numbers (0 - 65535) that identify processes running on a given host
- Categories: system ports, registered ports, and ephemeral ports
- *System ports are reserved: HTTP server runs on 80, SSH server on 22, SMTP server on 25*
- *Example: to reach the YouTube web server, send the packet to **172.217.4.78 : 80***

*more in Transport-layer*

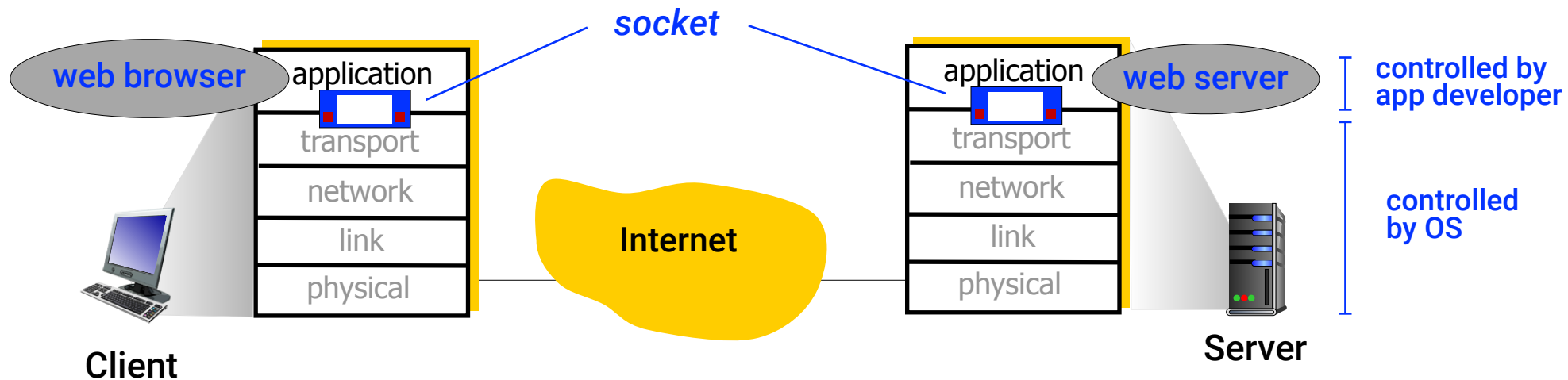
# Communication: interfacing with the network

*Host OS expose APIs for networked applications called **sockets***

- Host OS implements the network stack from transport to physical layers
- App developers implement the application layer and the app itself

*Networked applications use **sockets** to send/receive messages*

- Useful to consider the analogy of sockets as doors within a building (i.e., host systems)



# Transport-layer **Services**

# What transport services do applications need?

## Integrity

- some apps (e.g., *world wide web*) require 100% reliable data transfer
- other apps (e.g., *teleconferencing*) can tolerate some loss

## Latency

- some apps (e.g., *interactive games*) require low delay to be effective
- other apps (e.g., *emails*) can tolerate longer delays

## Throughput

- some apps (e.g., *streaming*) require a relatively stable throughput
- other apps (e.g., *file transfer*) make use of whatever throughput they get

## Other services

- privacy and security
- monitoring network conditions
- ...



# What transport services do applications need?

	Integrity	Latency	Throughput
File transfer	loss intolerant	not sensitive	elastic
Email	loss intolerant	not sensitive	elastic
WWW	loss intolerant	not sensitive	elastic
Teleconferencing	loss tolerant	< 10ms	~Kbps - Mbps
Video streaming	loss tolerant	tens of seconds	~Mbps
Text messaging	loss intolerant	usage dependent	elastic

# Services offered by transport protocols

## TCP

Transmission  
Control Protocol

**connection-oriented**  
*client and server agree  
before the flow of packets*

**reliable transport**  
*lossless and in-order  
delivery of packets*

**flow management**  
*so senders won't  
overwhelm receivers*

**congestion control**  
*throttling transfer when  
network is overloaded*

**what's not offered**

- control over latency
- throughput guarantees
- security

## UDP

User Datagram  
Protocol

**unreliable transport**  
*between sending and  
receiving processes*

**what's not offered**

- reliability
- flow management
- congestion control
- control over latency
- throughput guarantees
- security

# Applications and protocols

	Application Protocol	Transport Protocol
<b>File transfer</b>	FTP (RFC 959)	TCP
<b>Email</b>	SMTP (RFC 5321)	TCP
<b>WWW</b>	HTTP (RFC 7320)	TPC
<b>Teleconferencing</b>	SIP (RFC 3261) & RTP (RFC3550)	TCP & UDP
<b>Video streaming</b>	HLS (RFC 8216) or DASH	TCP
<b>Name resolution</b>	DNS (RFC 1034)	UDP

# **Protocols** for Network Apps

~~Network protocols~~ define  
the **format** and **order** of **messages** sent and received among  
~~network entities~~, and the **actions taken** on message transmission and receipt

if



Applications on **end hosts**

then



**Application** protocols

A vast **majority** of  
the Internet RFCs  
are application layer  
protocols

Application protocols vary significantly in their  
**size** and **complexity**.

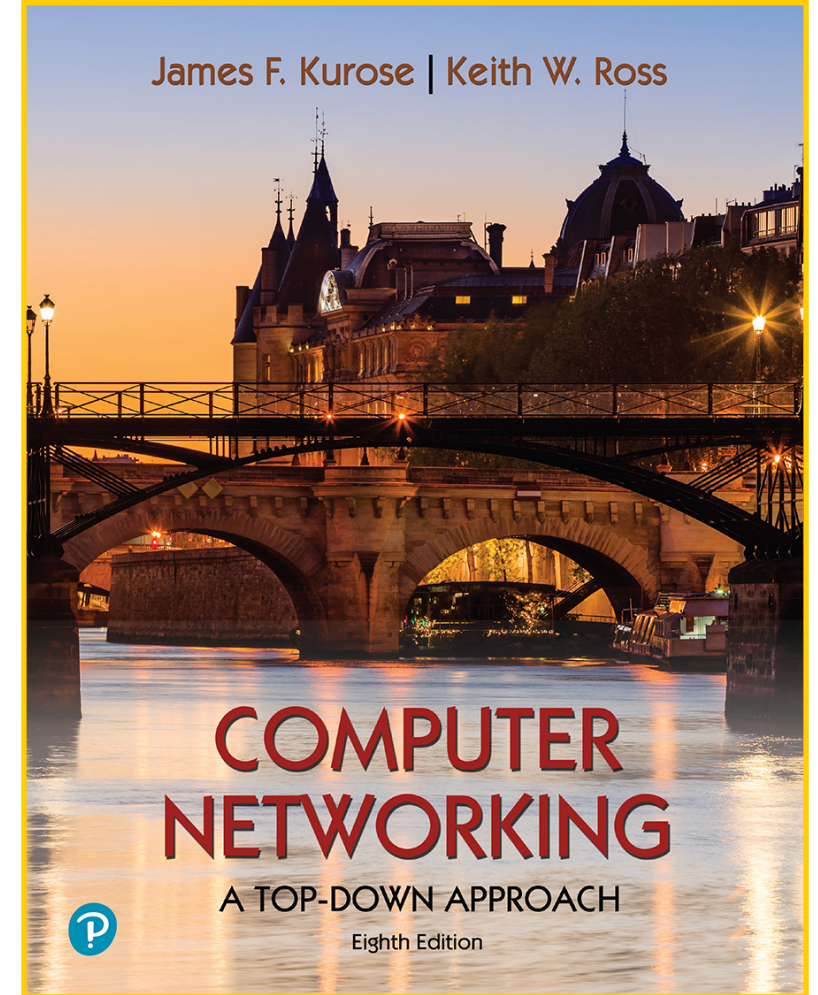
E.g., *Time Protocol* (RFC 868) is just 419 words, whereas  
*Network File System* (RFC 3530) is 79,803 words

# Next lecture

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*Deep dive into the design and operation of the world wide web*

- *HTTP*
- *Web cookies*
- *Web caches*



Chapter 2.2



# **Spot Quiz (ICON)**