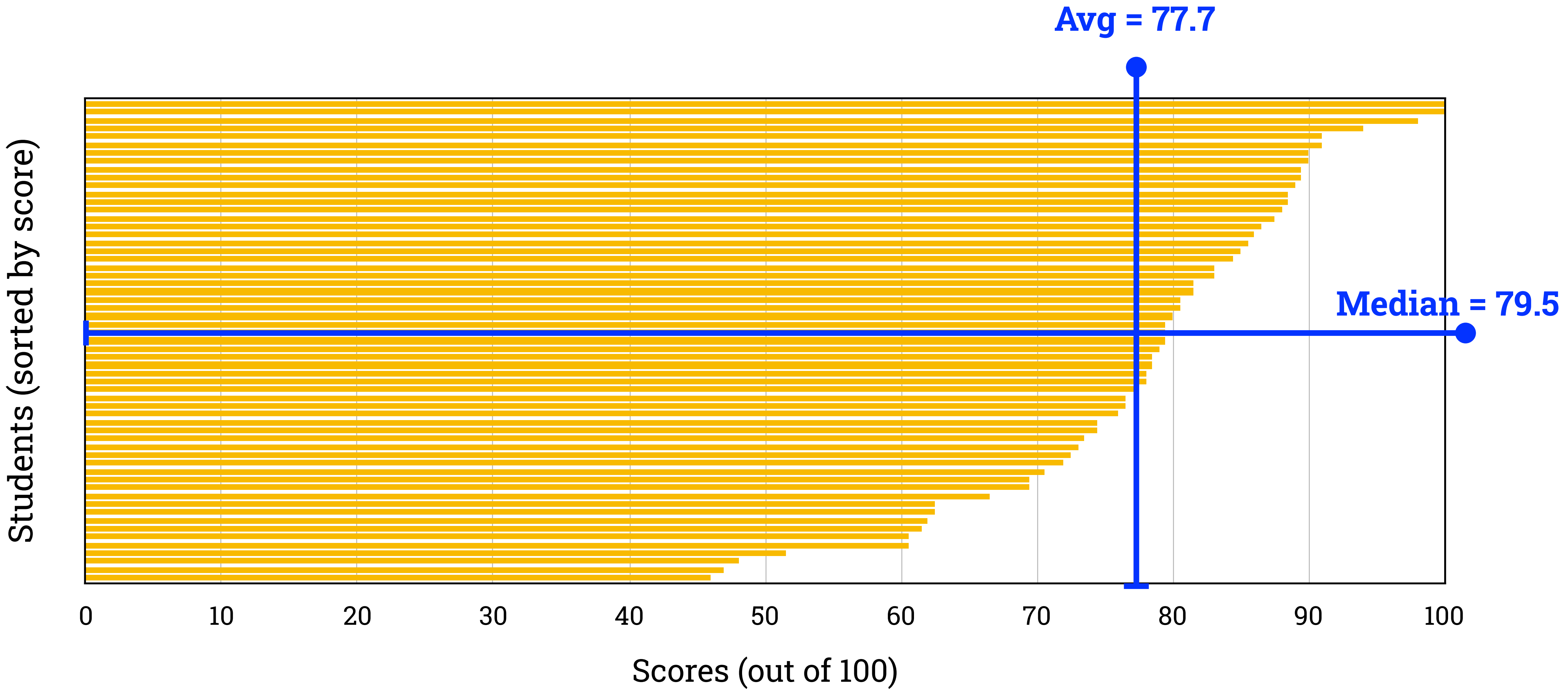
Written-1 Distribution



Std dev = 12.3

CS3640

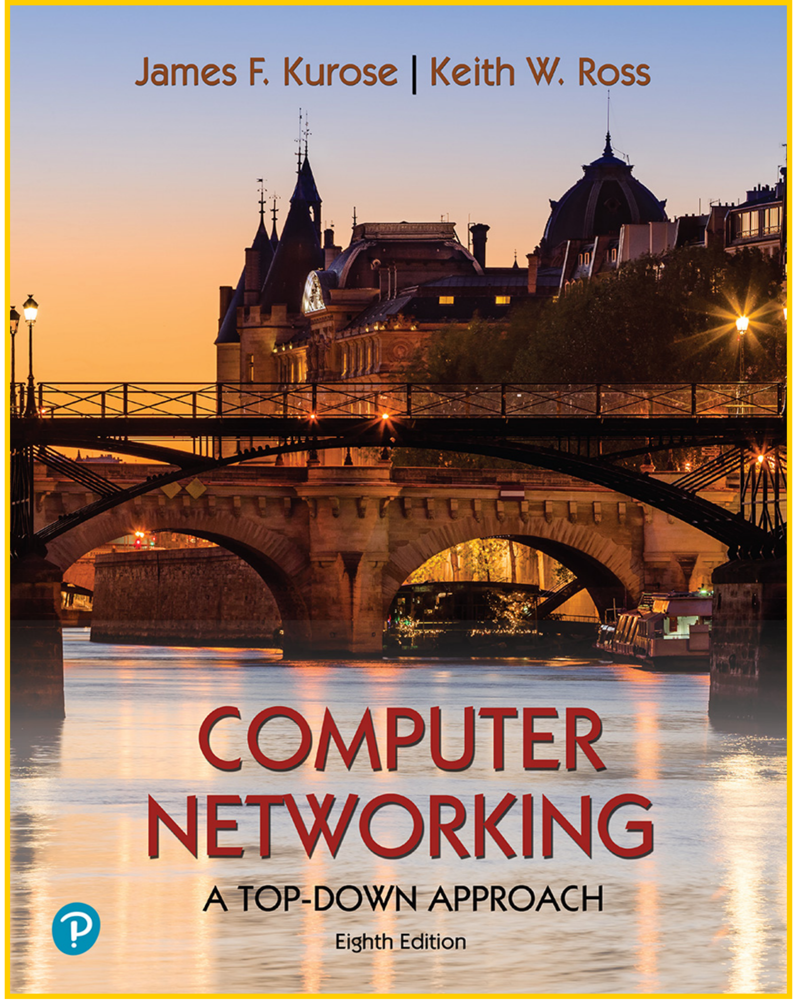
Application Layer (3): The Web & HTTP

Prof. Supreeth Shastri
Computer Science
The University of Iowa

Lecture goals

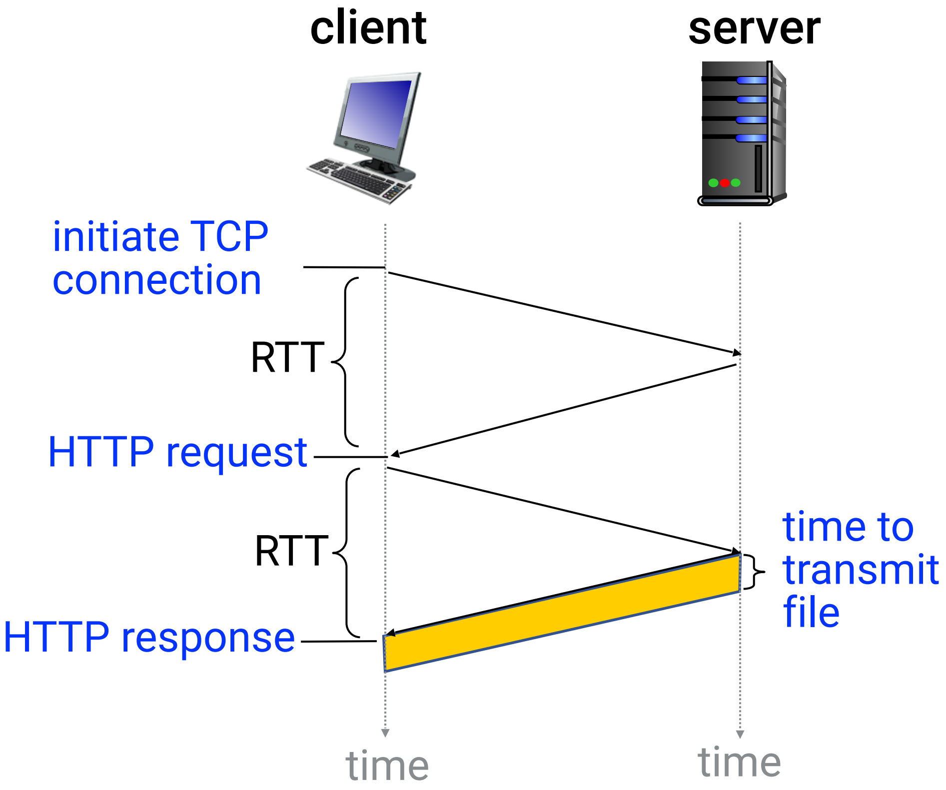
Deep dive into the design and operation of the world wide web

- *HTTP*
- *Web cookies*
- *Four Optimizations*



Chapter 2.2

Recap: HTTP



Protocol specs

- Human readable ASCII format
- Client-server model
- Uses TCP for reliable transmission

HTTP messages

- **Two** messages: request and response
- **Structure**: request/status line, then a set of headers, and finally, a body
- Five modes of request, and five categories of responses

Connection persistence

- HTTP/1.0 takes 2 RTTs per object
- HTTP/1.1 allows keeping the TCP connection open, reducing the response time to 1 RTT (on average)

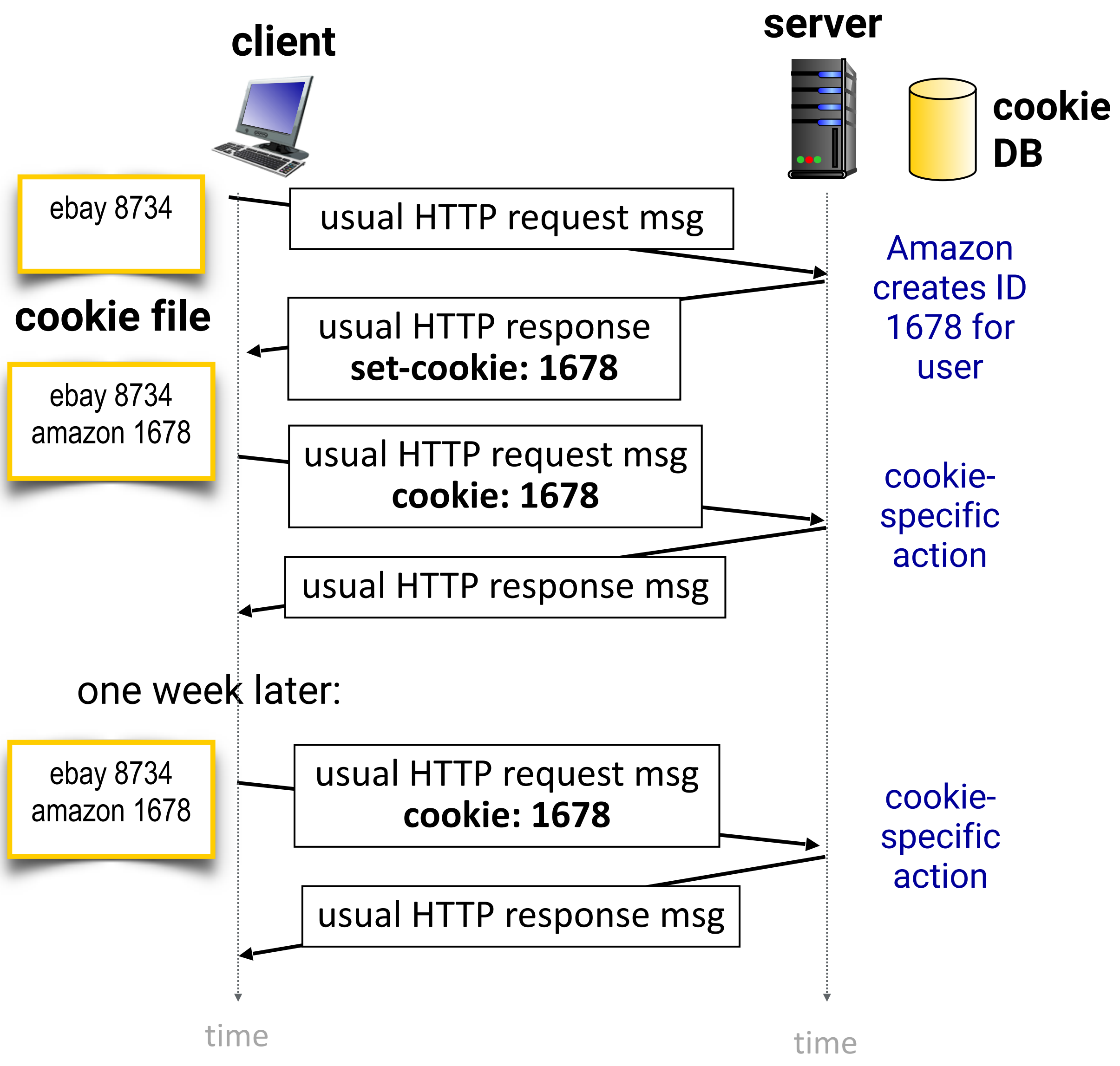
Recap: HTTP Cookies

HTTP is stateless

- no notion of multiple HTTP msg completing a “transaction”
- yet, many use cases of the web required maintaining the state

Solution: web cookies

- **RFC 6265** proposes a standard mechanism for state management
- **key components**: cookie headers, client cache file, server cache db
- **side effects**: third-party tracking, need for privacy regulations



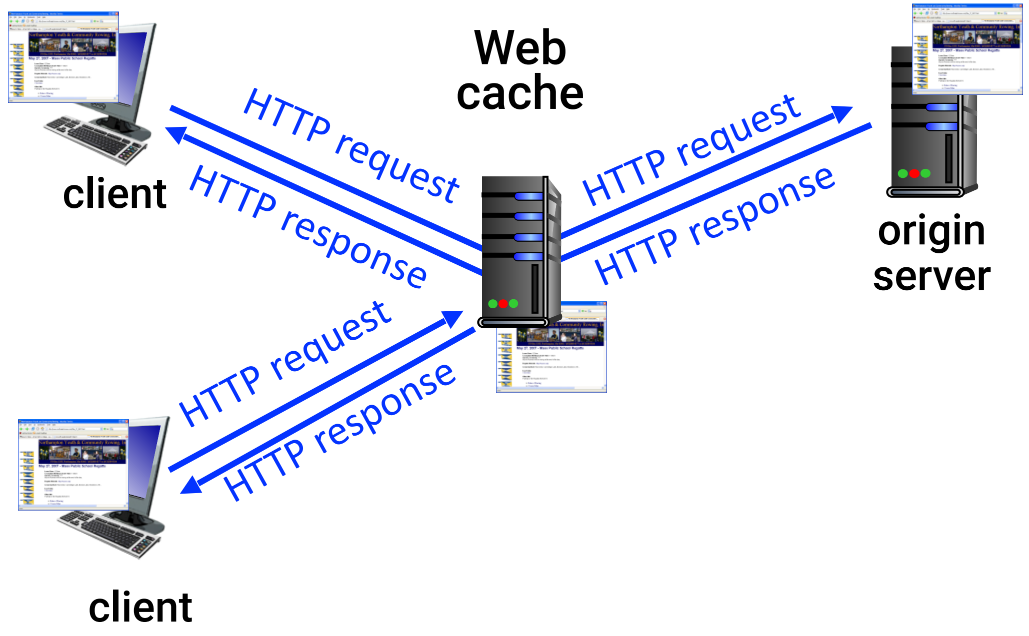
1

Web **Caches**

Web caches

Goal: *satisfy client requests without involving origin server*

- web users configure their browser to point to a (local) web cache/proxy
- browser sends all HTTP requests to the cache (instead of the web server)
- if object in cache: cache simply returns the object. Otherwise, it requests object from origin server, caches received object, then returns object to client



Cache mechanics

- web cache acts both as server (*to the requesting client*) and as client (*to the origin server*)
- origin server informs the cache about a given object's ability to be cached (via response header)

```
Cache-Control: max-age=<seconds>
```

```
Cache-Control: no-cache
```

Why cache?

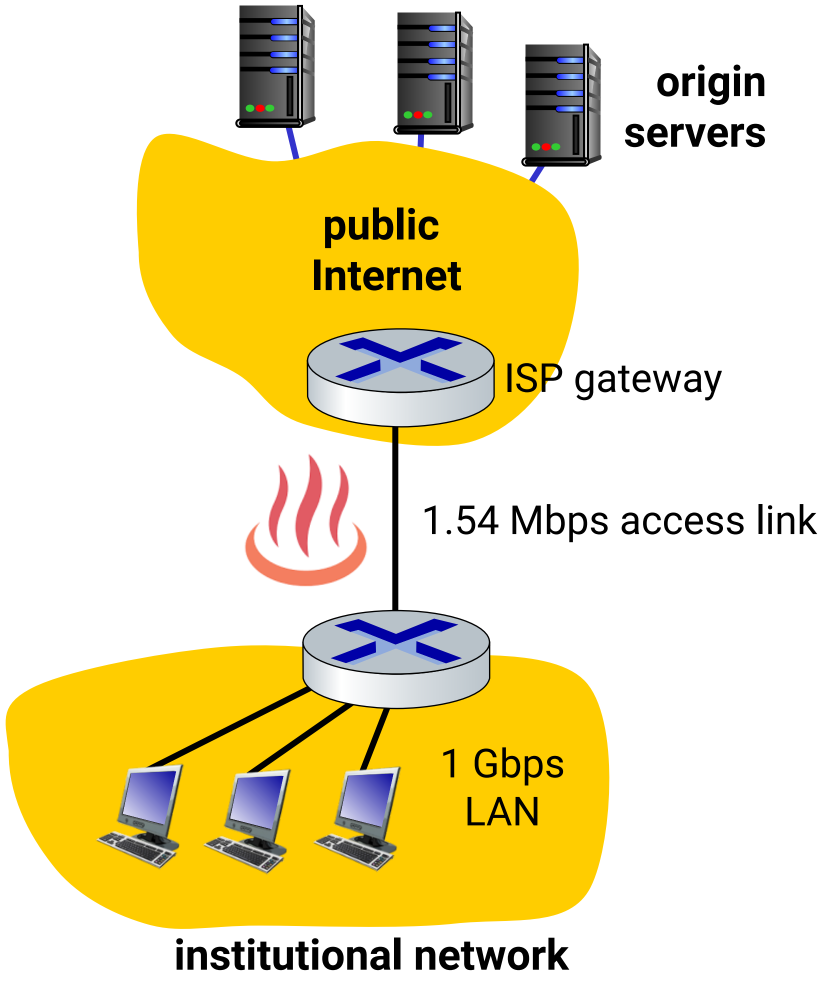
- reduces response time for client requests *(since cache is closer to client)*
- reduces traffic on an institution's access link
- allows resource-starved content providers and administrators to deliver content more effectively

Internet is **dense** with web caches

Do web caches violate end-to-end principle?

A web access scenario

- access link rate: 1.54 Mbps
- RTT from institutional router to server: 2 sec
- size of web objects: 100Kb
- users make 15 request/sec (avg) for web objects
- avg data rate to institutional router = 1.5 Mbps



End to end delay

access link utilization = 1.5Mbps / 1.54Mbps = **97%**

end-to-end delay

= Internet delay + access link delay + LAN delay

= 2 sec + several minutes + µsec

Option-1: buy a faster access link

- access link rate: ~~1.54 Mbps~~ **154 Mbps**
- RTT from institutional router to server: 2 sec
- size of web objects: 100Kb
- users make 15 request/sec (avg) for web objects
- avg data rate to institutional router = 1.5 Mbps

End to end delay

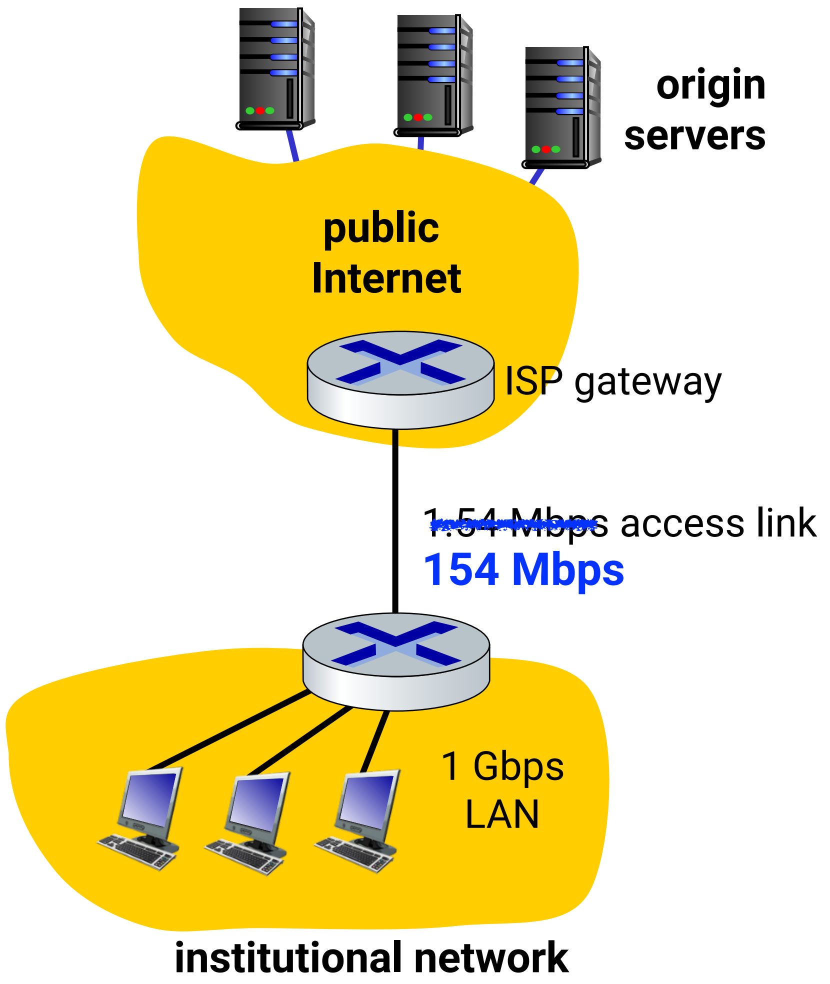
access link utilization = 1.5Mbps / **154 Mbps = 0.97%**

end-to-end delay

= Internet delay + access link delay + LAN delay

= 2 sec + ~~several minutes~~ + μsec ≃ **2 sec**

μsec



Faster access links are **expensive**!

Option-2: install a web cache

Cache hit rate

- fraction of requests fulfilled locally by the cache
- its value tends to be 20-70% in practice
- *suppose our cache has a hit rate of 40%*

For requests satisfied at origin server

access link utilization = (1.5Mbps * 60%) / 1.54Mbps = 58%
this results in low (μsec) queueing delay at access link

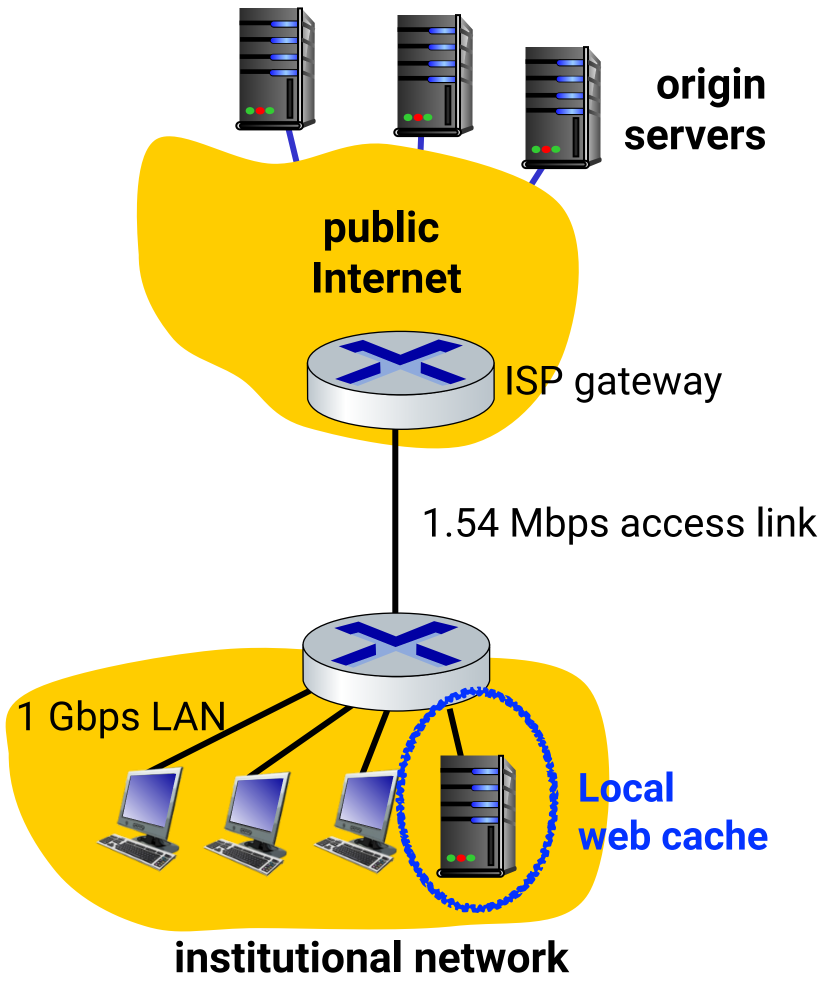
For requests satisfied at cache

delay = LAN delay = ~ μsec

Average end-end delay

*= 60% * (delay to origin servers) + 40% * (delay to cache)*

*= 60% * (2 sec) + 40% (~ μsec) = **~1.2sec***



Cache achieves **lower delay** at **cheaper** cost!

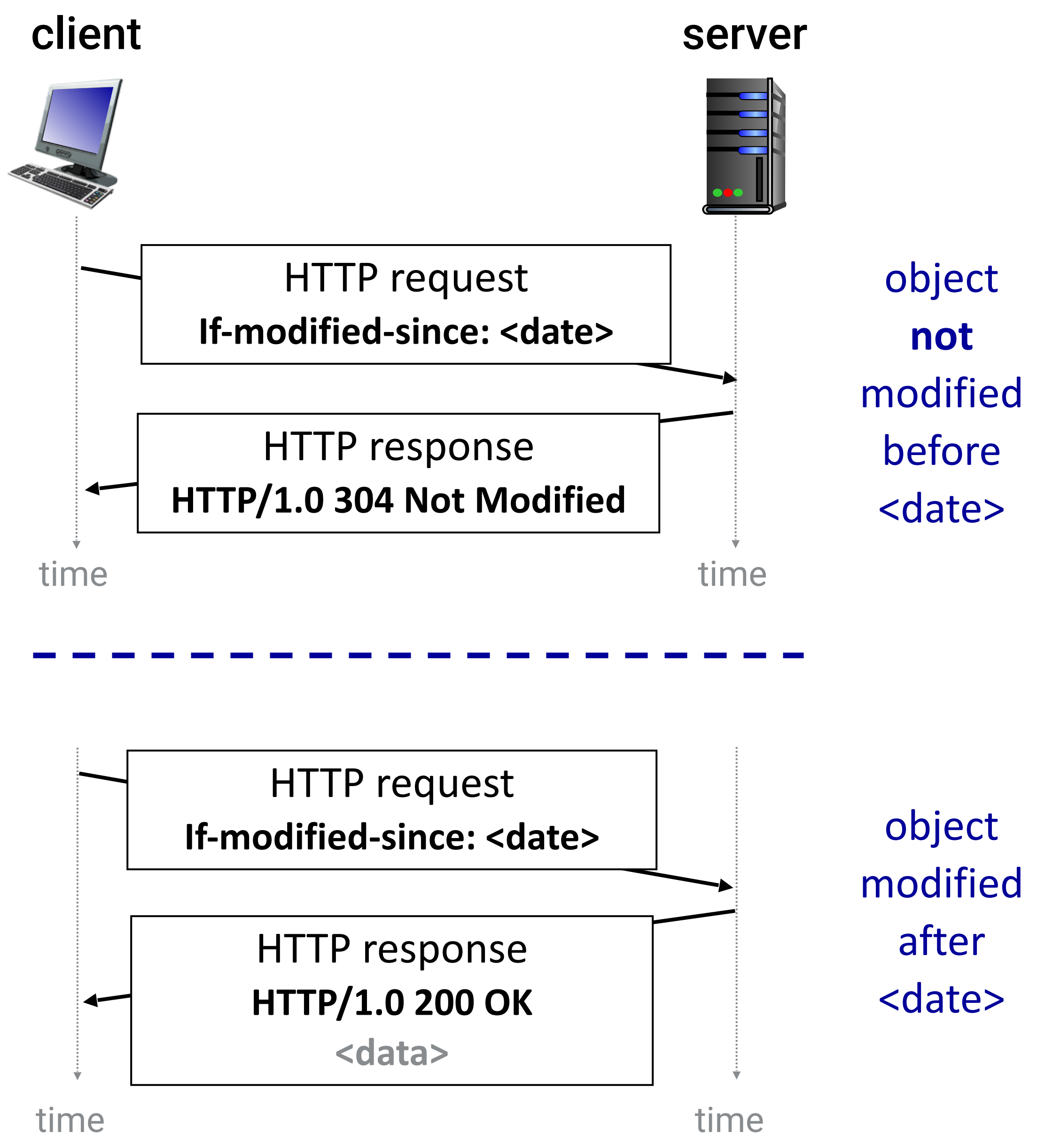
2

Conditional GET

Conditional GET

Goal: *don't send object if the client already has up-to-date version*

- no object transmission delay and no use of network resources
- **client** will specify date of cached copy using `if-modified-since` header in HTTP request
- **server** will respond with status code of `304 not modified` with an empty body if the cached copy is up to date



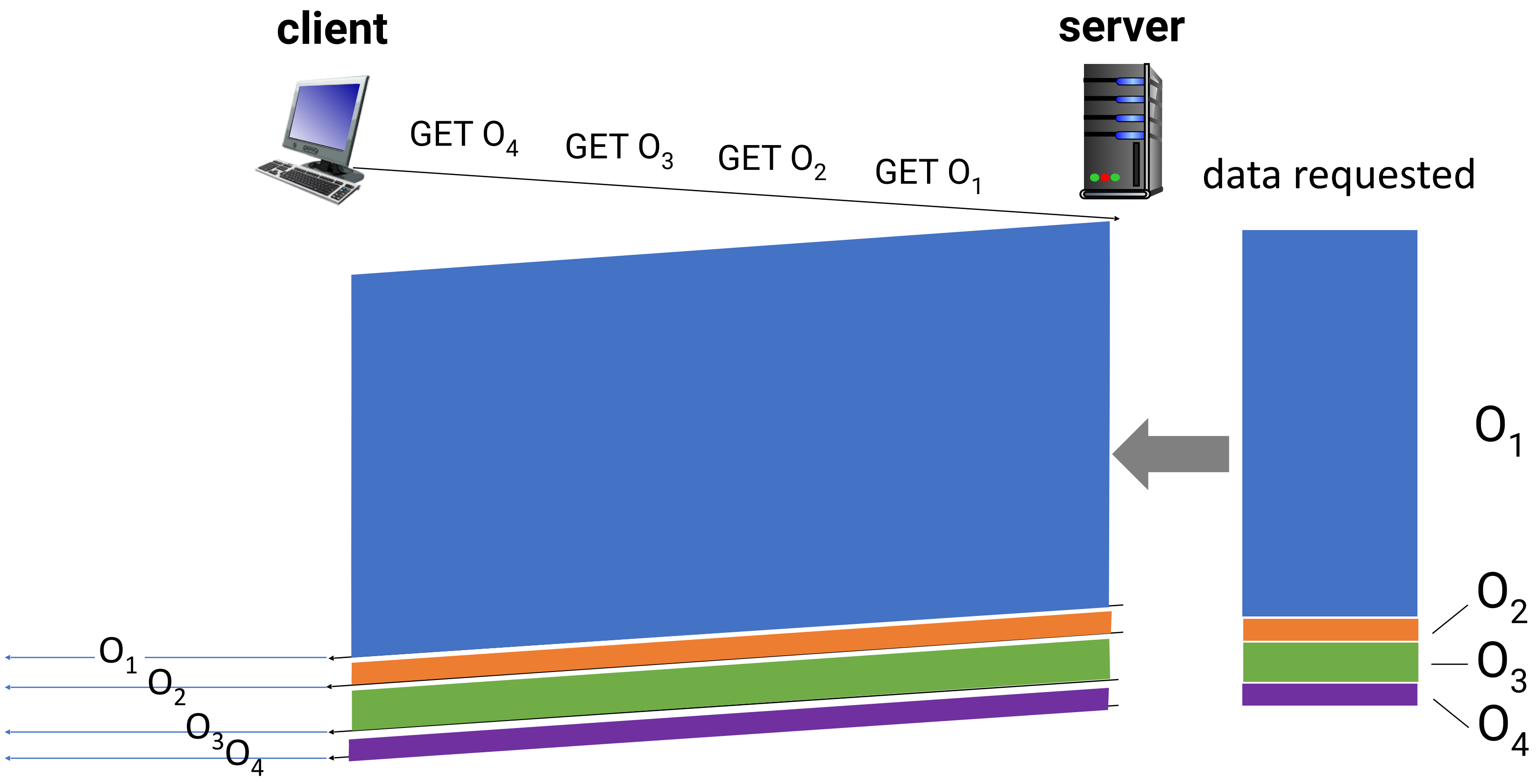
3

HOL **Blocking**

HTTP/1.1: HOL blocking

- HTTP/1.1 introduced multiple, pipelined GETs over a single TCP connection
- HTTP server responds *in-order* (FCFS: first-come-first-serve) to GET requests
- FCFS could result in small objects having to wait for transmission behind large object(s), known as head of line (HOL) blocking

***Example**: a client requests 1 large object and 3 smaller objects*



objects delivered in order requested, so O_2, O_3, O_4 wait behind O_1

HTTP/2

Key goal: decrease the delay in multi-object HTTP requests

- transmission order of objects is based on client-specified priority (not necessarily FCFS)
- divide objects into frames, and then schedule frames to mitigate HOL blocking
- push unrequested objects to client
- methods, status codes, most header fields unchanged from HTTP/1.1

Internet Engineering Task Force (IETF)
Request for Comments: 7540
Category: Standards Track
ISSN: 2070-1721

M. Belshe
BitGo
R. Peon
Google, Inc
M. Thomson, Ed.
Mozilla

May 2015

Hypertext Transfer Protocol Version 2 (HTTP/2)

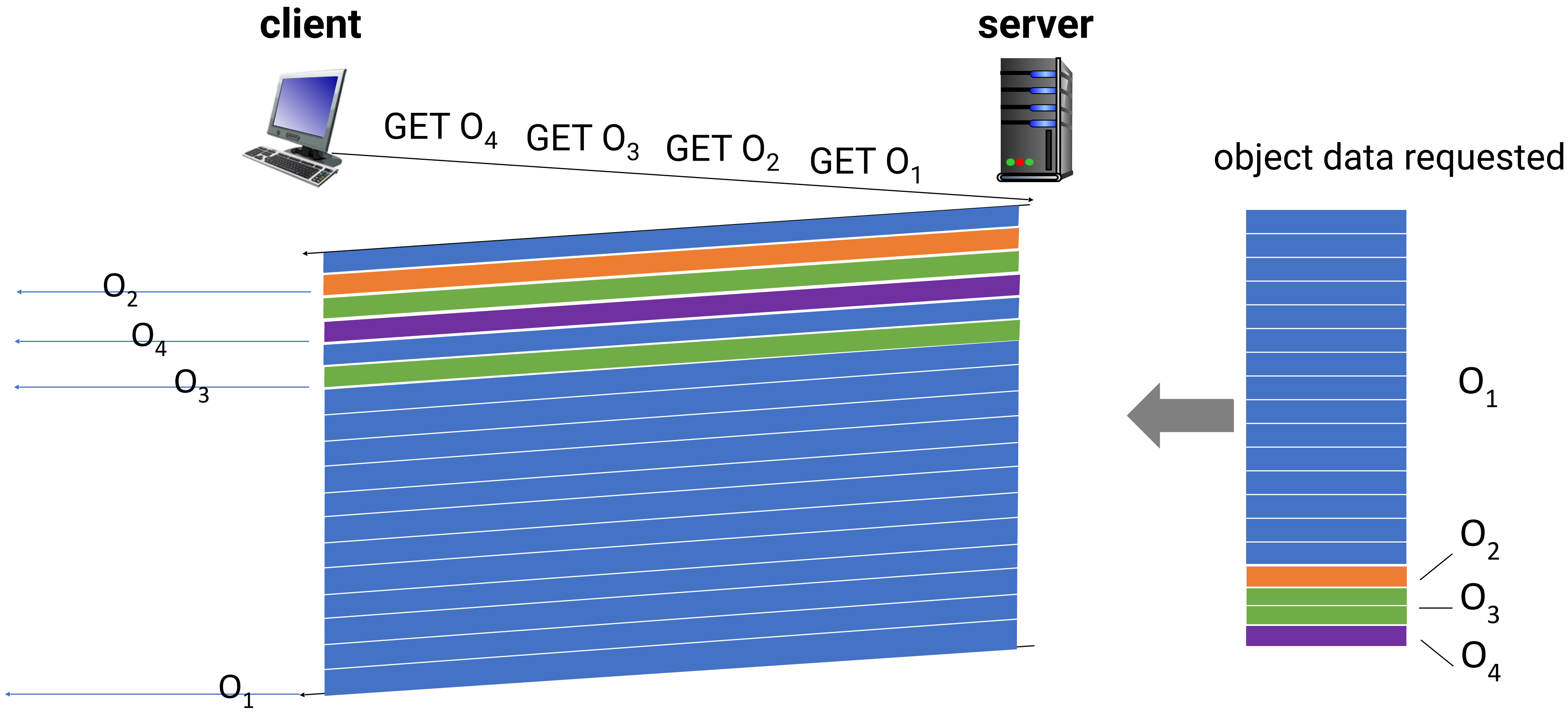
Abstract

This specification describes an optimized expression of the semantics of the Hypertext Transfer Protocol (HTTP), referred to as HTTP version 2 (HTTP/2). HTTP/2 enables a more efficient use of network resources and a reduced perception of latency by introducing header field compression and allowing multiple concurrent exchanges on the same connection. It also introduces unsolicited push of representations from servers to clients.

This specification is an alternative to, but does not obsolete, the HTTP/1.1 message syntax. HTTP's existing semantics remain unchanged.

HTTP/2: mitigating HOL blocking

Divide objects into frames, and interleave frame transmission



O_2, O_3, O_4 delivered quickly, O_1 slightly delayed

4 Moving away from **TCP**

HTTP/2 → HTTP/3

HTTP/2 shortcomings

all HTTP traffic flows over a single TCP connection

- recovery from a packet loss stalls all subsequent object transmissions
- thus, browsers are still compelled to open multiple parallel TCP connections to reduce stalling, and improve throughput

offers no built-in security

```
Internet Engineering Task Force (IETF)                 M. Bishop, Ed.
Request for Comments: 9114                                     Akamai
Category: Standards Track                                   June 2022
ISSN: 2070-1721


                              HTTP/3

Abstract

   The QUIC transport protocol has several features that are desirable
   in a transport for HTTP, such as stream multiplexing, per-stream flow
   control, and low-latency connection establishment.  This document
   describes a mapping of HTTP semantics over QUIC.  This document also
   identifies HTTP/2 features that are subsumed by QUIC and describes
   how HTTP/2 extensions can be ported to HTTP/3.
```

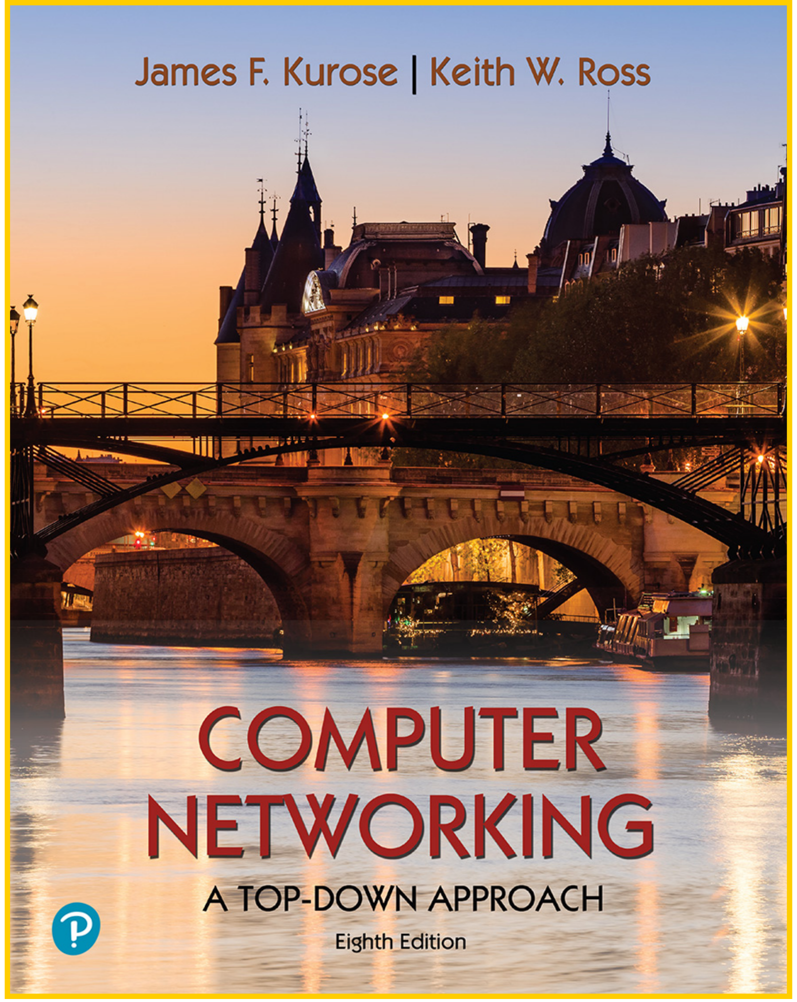
HTTP/3 *(released a short while ago)*

- replaces TCP with QUIC
- allows per object error- and congestion-control
- offers security natively

Next lecture

Understand the protocols and mechanics of the electronic mail

- *Email infrastructure*
- *SMTP*
- *IMAP*



Chapter 2.3

Spot Quiz (ICON)