CSCI-1680
WWW

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Based partly on lecture notes by Scott Shenker and Rodrigo Fonseca

Precursors

- **1945, Vannevar Bush, Memex:**
  - *"a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility"*
- **Precursors to hypertext**
  - "The human mind [...] operates by association. With one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts, in accordance with some intricate *web of trails* carried by the cells of the brain"
- **His essay, "As we may think", is worth reading!**

Tim Berners-Lee

- **Physicist at CERN, trying to solve real problem**
  - Distributed access to data
- **WWW: distributed database of pages linked through the Hypertext Transfer Protocol**
  - First HTTP implementation: 1990
  - HTTP/0.9 – 1991
    - Simple GET commant
  - HTTP/1.0 – 1992
    - Client/server information, simple caching
  - HTTP/1.1 – 1996
    - Extensive caching support
    - Host identification
    - Pipelined, persistent connections, …

Why so successful?

- **Ability to self publish**
  - Like youtube for video
- **But…**
  - Mechanism is *easy*
  - Independent, open
  - Free
- **Current debate**
  - Is it easy enough? Why is facebook so popular, even though it is not open?

Components

- **Content**
  - Objects (may be static or dynamically generated)
- **Clients**
  - Send requests / Receive responses
- **Servers**
  - Receive requests / Send responses
  - Store or generate content
- **Proxies**
  - Placed between clients and servers
  - Provide extra functions
    - Caching, anonymization, logging, transcoding, filtering access
  - Explicit or transparent

Ingredients

- **HTTP**
  - Hypertext Transfer Protocol
- **HTML**
  - Language for description of content
- **Names (mostly URLs)**
  - Won’t talk about URIs, URNs

URLs

protocol://[name@]hostname[:port]/directory/resource?k1=v1&k2=v2#tag

- URLs are a type of URI
- *Name* is for possible client identification
- *Hostname* is FQDN or IP address
- *Port* defaults to protocol default (e.g., 80)
- *Directory* is a path to the resource
- *Resource* is the name of the object
- ?*parameters* are passed to the server for execution
- #*tag* allows jumps to named tags within document (not even sent to server)

HTTP

- **Important properties**
  - Client-server protocol
  - Protocol (but not data) in ASCII
  - Stateless
  - Extensible (header fields)
- **Server typically listens on port 80**
- **Server sends response, may close connection (client may ask it to say open)**
- **Currently version 1.1 is most common.**
- **There is an HTTP/2 though.**

Steps in HTTP$^{(1.0)}$ Request

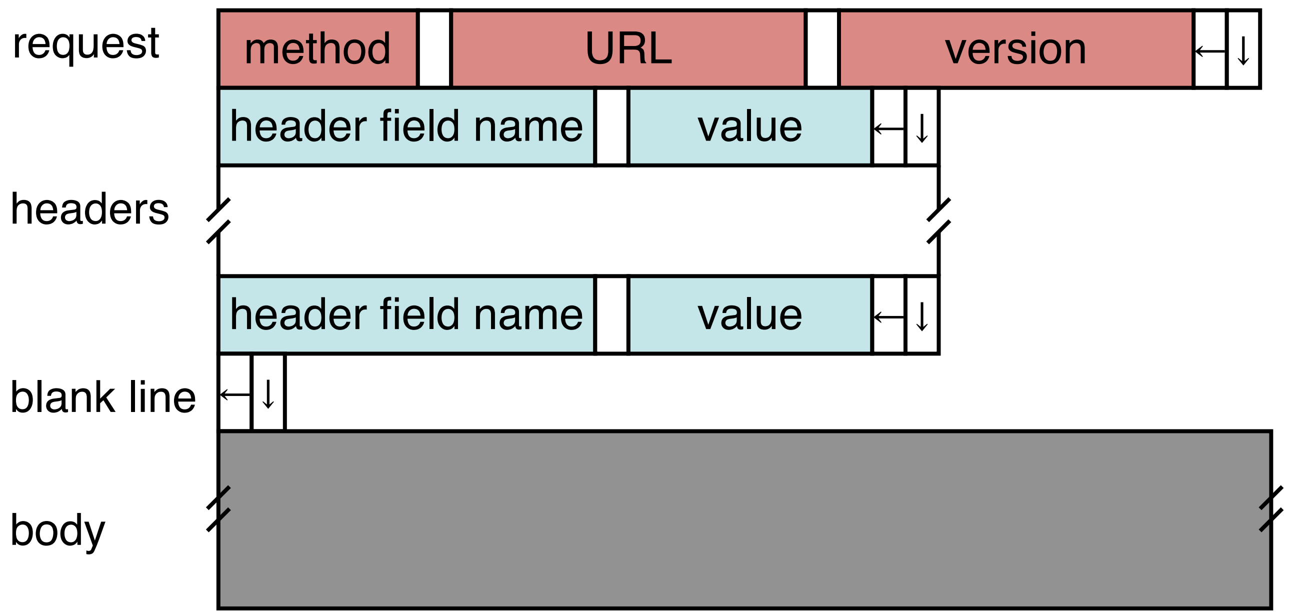
- **Open TCP connection to server**
- **Send request**
- **Receive response**
- **TCP connection terminates**
  - How many RTTs for a single request?
- **You may also need to do a DNS lookup first!**

```
> telnet www.cs.brown.edu 80
Trying 128.148.32.110...
Connected to www.cs.brown.edu.
Escape character is '^]'.
GET / HTTP/1.0

HTTP/1.1 200 OK
Date: Thu, 24 Mar 2011 12:58:46 GMT
Server: Apache/2.2.9 (Debian) mod_ssl/2.2.9 OpenSSL/0.9.8g
Last-Modified: Thu, 24 Mar 2011 12:25:27 GMT
ETag: "840a88b-236c-49f3992853bc0"
Accept-Ranges: bytes
Content-Length: 9068
Vary: Accept-Encoding
Connection: close
Content-Type: text/html

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
   "http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" xml:lang="en"
   lang="en”>
...
```

HTTP Request



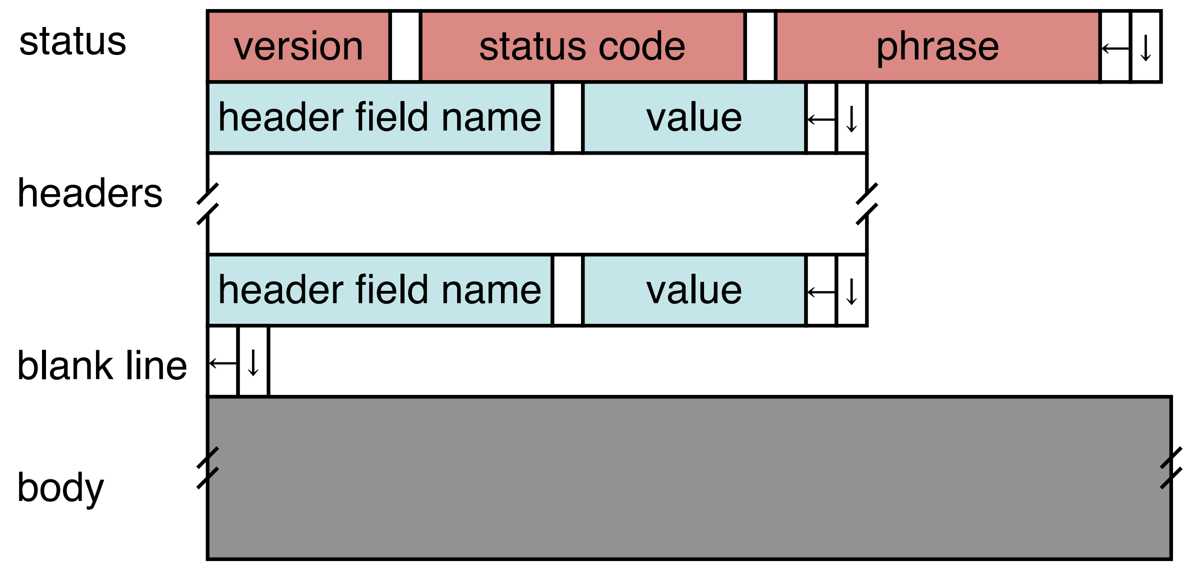
- **Method:**
  - GET: current value of resource, run program
  - HEAD: return metadata associated with a resource
  - POST: update a resource, provide input for a program
- **Headers: useful info for proxies or the server**
  - E.g., desired language, compression

Sample Browser Request

```
GET / HTTP/1.1
Host: localhost:8000
User-Agent: Mozilla/5.0 (Macinto ...
Accept: text/xml,application/xm ...
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
(empty line)
```

Firefox extension LiveHTTPHeaders is a cool way to see this

HTTP Response



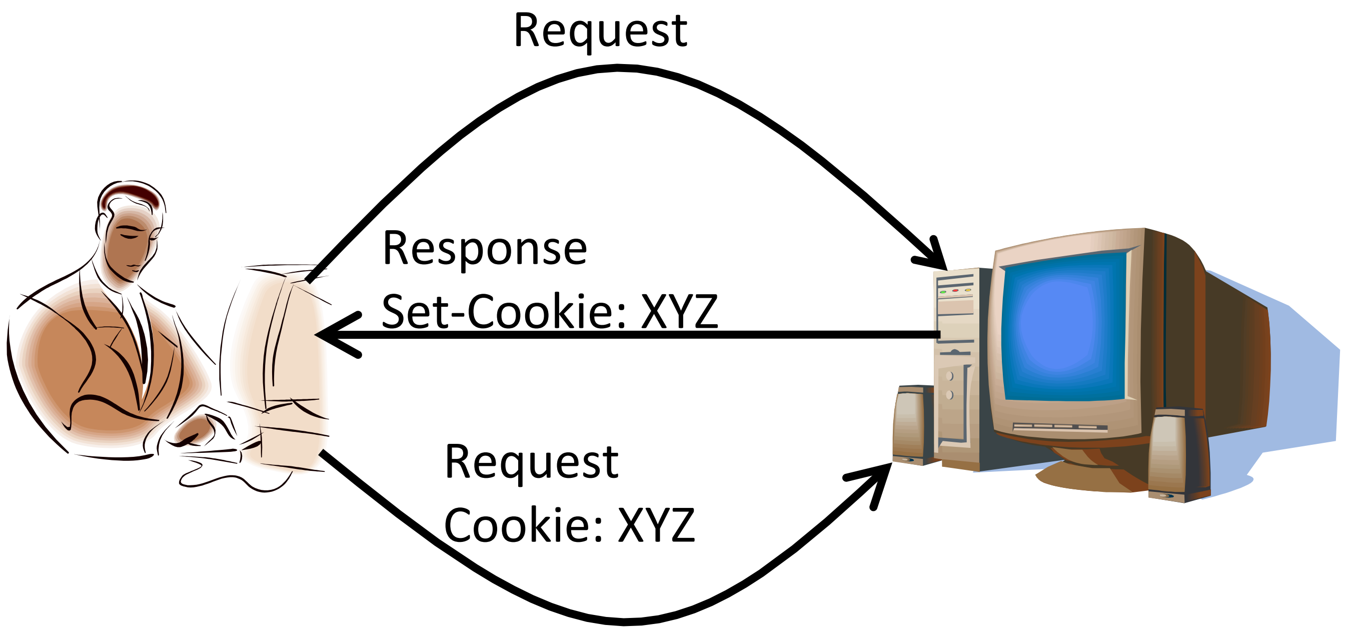
- **Status Codes:**
  - 1xx: Informatione.g, 100 Continue
  - 2xx: Success e.g., 200 OK
  - 3xx: Redirection e.g., 302 Found (elsewhere)
  - 4xx: Client Error e.g., 404 Not Found
  - 5xx: Server Error e.g, 503 Service Unavailable

HTTP is Stateless

- **Each request/response treated independently**
- **Servers not required to maintain state**
- **This is good!**
  - Improves server scalability
- **This is also bad…**
  - Some applications need persistent state
  - Need to uniquely identify user to customize content
  - E.g., shopping cart, web-mail, usage tracking, (most sites today!)

HTTP Cookies

- **Client-side state maintenance**
  - Client stores small state on behalf of server
  - Sends request in future requests to the server
  - Cookie value is meaningful to the server (e.g., session id)
- **Can provide authentication**



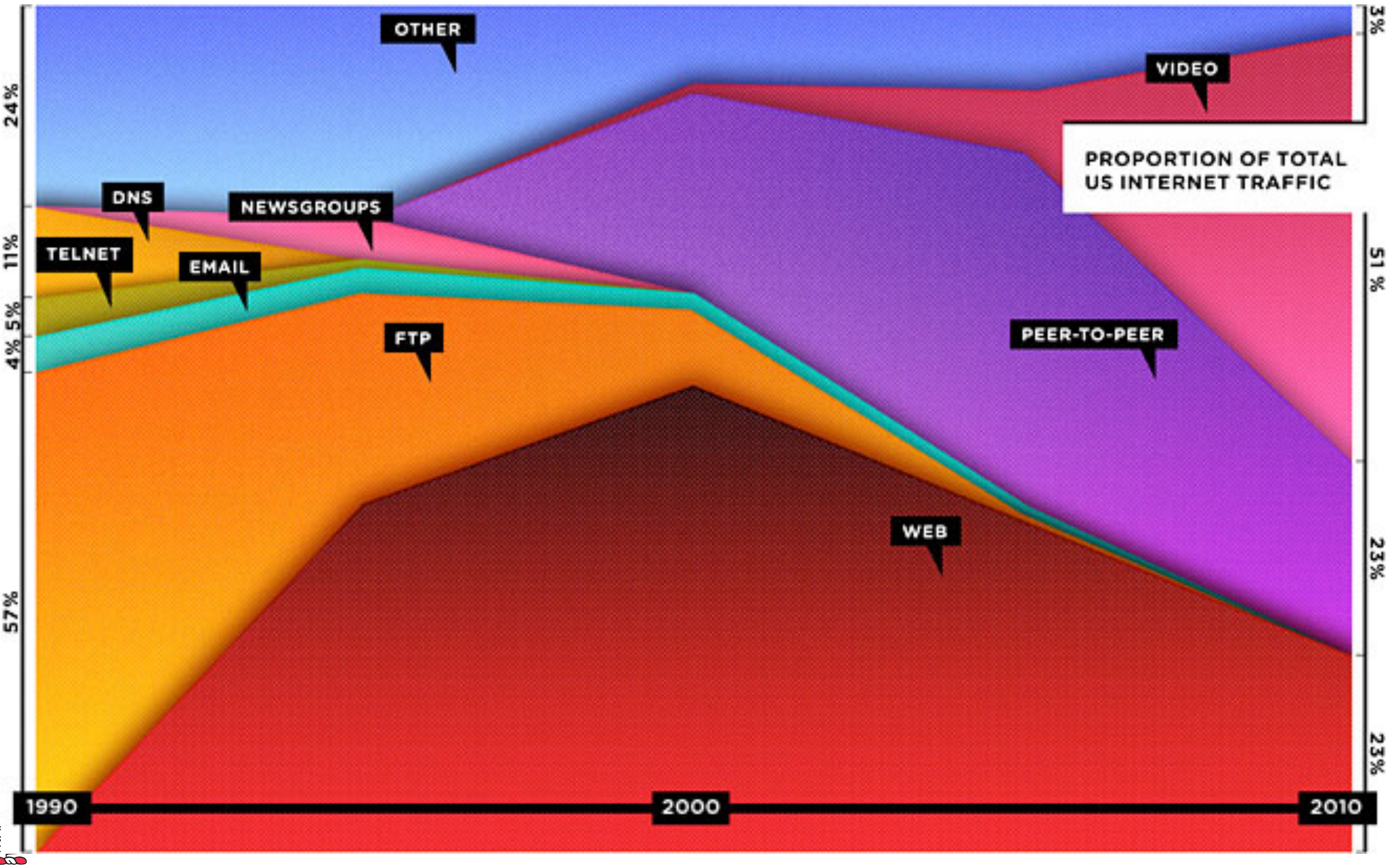
Anatomy of a Web Page

- **HTML content**
- **A number of additional resources**
  - Images
  - Scripts
  - Frames
- **Browser makes one HTTP request for each object**
  - Course web page: 14 objects
  - My facebook page this morning: 100 objects

What about AJAX?

- ***Asynchronous Javascript and XML***
- **Based on XMLHttpRequest object in browsers, which allow code in the page to:**
  - Issue a new, non-blocking request to the server, without leaving the current page
  - Receive the content
  - Process the content
- **Used to add interactivity to web pages**
  - XML not always used, HTML fragments, JSON, and plain text also popular

The Web is Dead? (Wired, Aug 2010)



http://www.wired.com/magazine/2010/08/ff_webrip/all/1

Consumer Internet Traffic, 2013–2018

	2013	2014	2015	2016	2017	2018	CAGR 2013–2018
By Network (PB per Month)							
Fixed	27,882	33,782	40,640	48,861	58,703	70,070	20%
Mobile	1,189	2,102	3,563	5,774	8,968	13,228	62%
By Subsegment (PB per Month)							
Internet video	17,455	22,600	29,210	37,783	48,900	62,972	29%
Web, email, and data	5,505	6,706	8,150	9,913	11,827	13,430	20%
File sharing	6,085	6,548	6,803	6,875	6,856	6,784	2%
Online gaming	26	30	41	64	88	113	34%

Source: Cisco VNI, 2014

The Web is Dead? **(Wired, Aug 2010)**

- You wake up and ***check your email*** on your bedside iPad — that's one app. During breakfast you browse Facebook, Twitter, and The New York Times — three more ***apps***. On the way to the office, you listen to a ***podcast*** on your smartphone. Another app. At work, you scroll through ***RSS feeds in a reader*** and have ***Skype*** and ***IM*** conversations. More apps. At the end of the day, you come home, make dinner while listening to ***Pandora***, play some games on ***Xbox Live***, and watch a movie on ***Netflix****'s* streaming service. You've spent the day on the Internet — but not on the Web. And you are not alone.

HTTP Performance

- **What matters for performance?**
- **Depends on type of request**
  - Lots of small requests (objects in a page)
  - Some big requests (large download or video)

Small Requests

- **Latency matters**
- **RTT dominates**
- **Two major causes:**
  - Opening a TCP connection
  - Actually sending the request and receiving response
  - And a third one: DNS lookup!

How can we reduce the number of connection setups?

- **Keep the connection open and request all objects serially**
  - Works for all objects coming from the same server
  - Which also means you don’t have to “open” the window each time
- **Persistent connections (HTTP/1.1)**

Browser Request

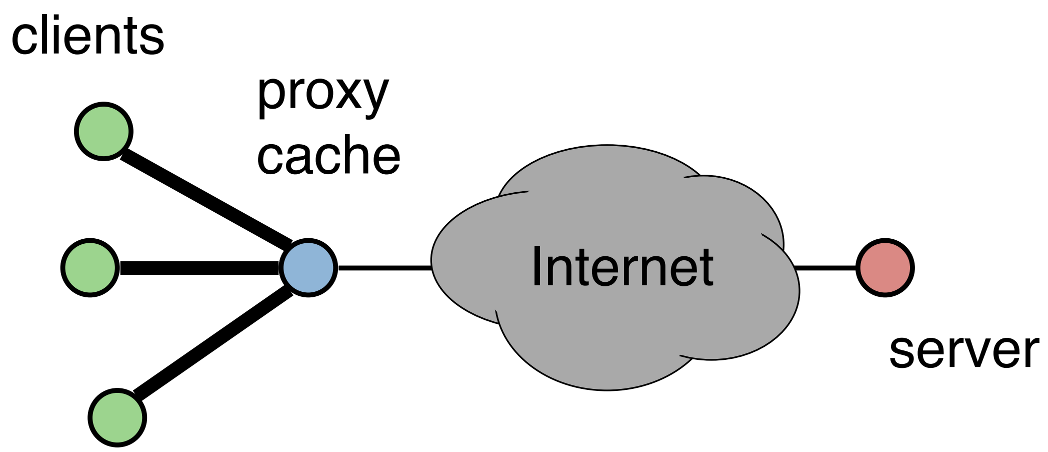
```
GET / HTTP/1.1
Host: localhost:8000
User-Agent: Mozilla/5.0 (Macinto ...
Accept: text/xml,application/xm ...
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.7
Keep-Alive: 300
Connection: keep-alive
```

Small Requests (cont)

- **Second problem is that requests are serialized**
  - Similar to stop-and-wait protocols!
- **Two solutions**
  - Pipelined requests (similar to sliding windows)
  - Parallel Connections
    - HTTP standard says no more than 2 concurrent connections per host name
    - Most browsers use more (up to 8 per host, ~35 total)
      - See http://www.browserscope.org/
  - How are these two approaches different?

Larger Objects

- **Problem is throughput in bottleneck link**
- **Solution: HTTP Proxy Caching**
  – Also improves latency, and reduces server load



How to Control Caching?

- **Server sets options**
  - **Expires** header
  - No-Cache header
- **Client can do a conditional request:**
  - Header option: if-modified-since
  - Server can reply with 304 NOT MODIFIED
- **More when we talk about Content Distribution**

Next Class

- **Global data distribution**
  - CDN and P2P
- **How to create your own application layer protocol!**
  - Data / RPC