# Web Services

15-213/18-243: Introduction to Computer Systems

23rd Lecture, 20 April 2010

Instructors:

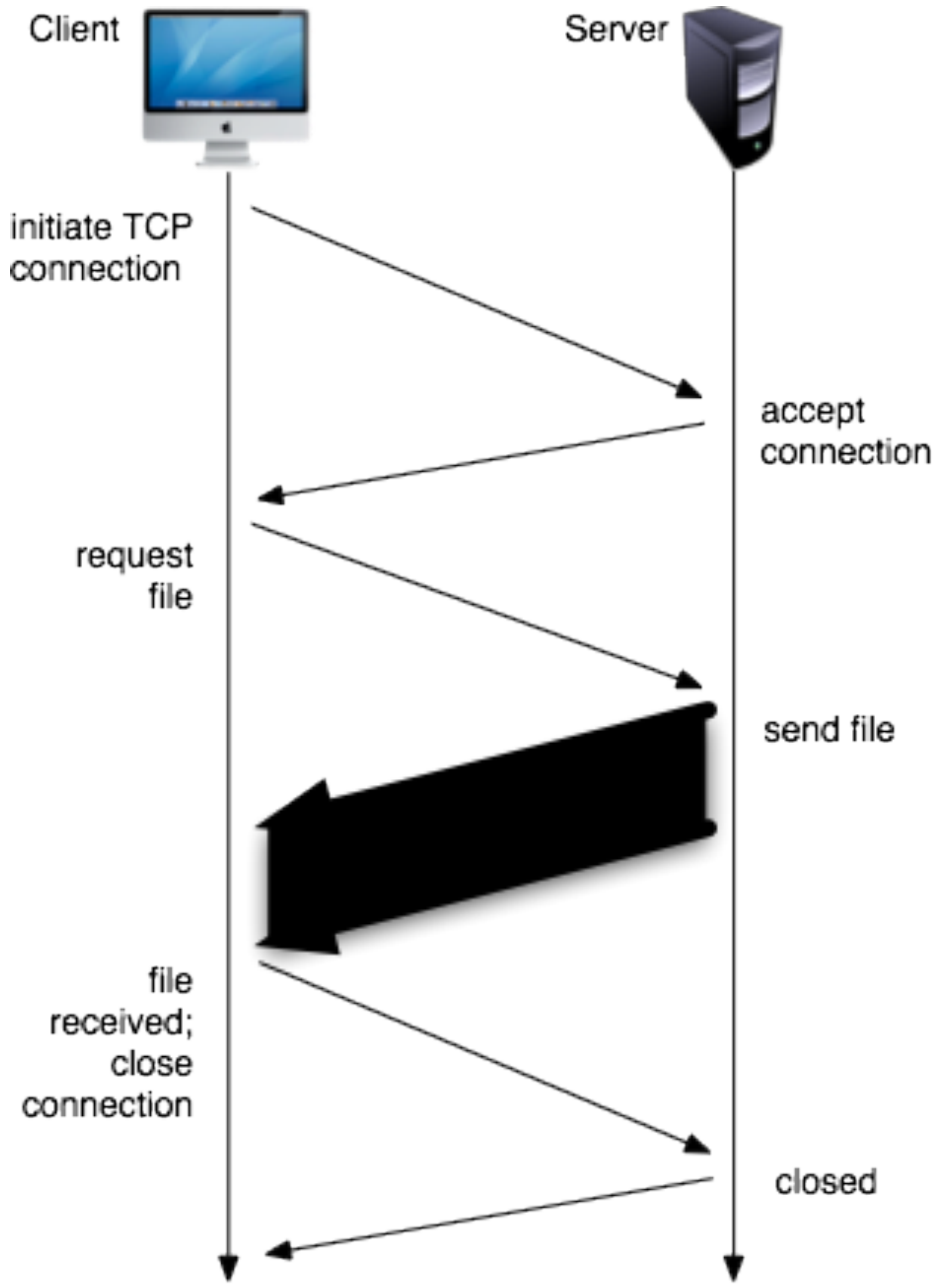
Anthony Rowe and Gregory Kesden

## Today

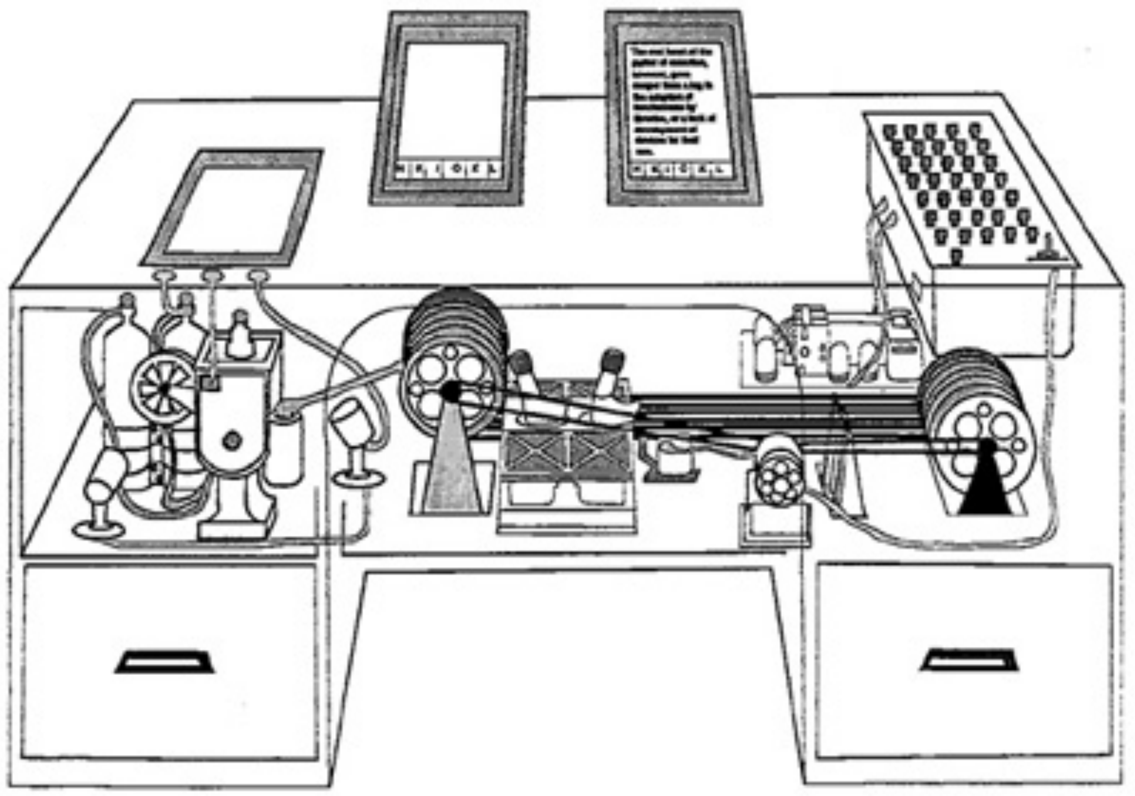
- HTTP
- Web Servers
- Proxies

# Client-server web communication

- Clients and servers communicate using the HyperText Transfer Protocol (HTTP)
  - Client and server establish TCP connection
  - Client requests content
  - Server responds with requested content
  - Client and server close connection (usually)
- Current version is HTTP/1.1
  - RFC 2616, June, 1999
  - http://www.ietf.org/rfc/rfc2616.txt



## Web History



**"Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, "memex" will do. A memex is 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. It is an enlarged intimate supplement to his memory."**

- 1945:
  - Vannevar Bush, "As we may think", Atlantic Monthly, July, 1945.
    - Describes the idea of a distributed hypertext system.
    - A "memex" that mimics the "web of trails" in our minds.

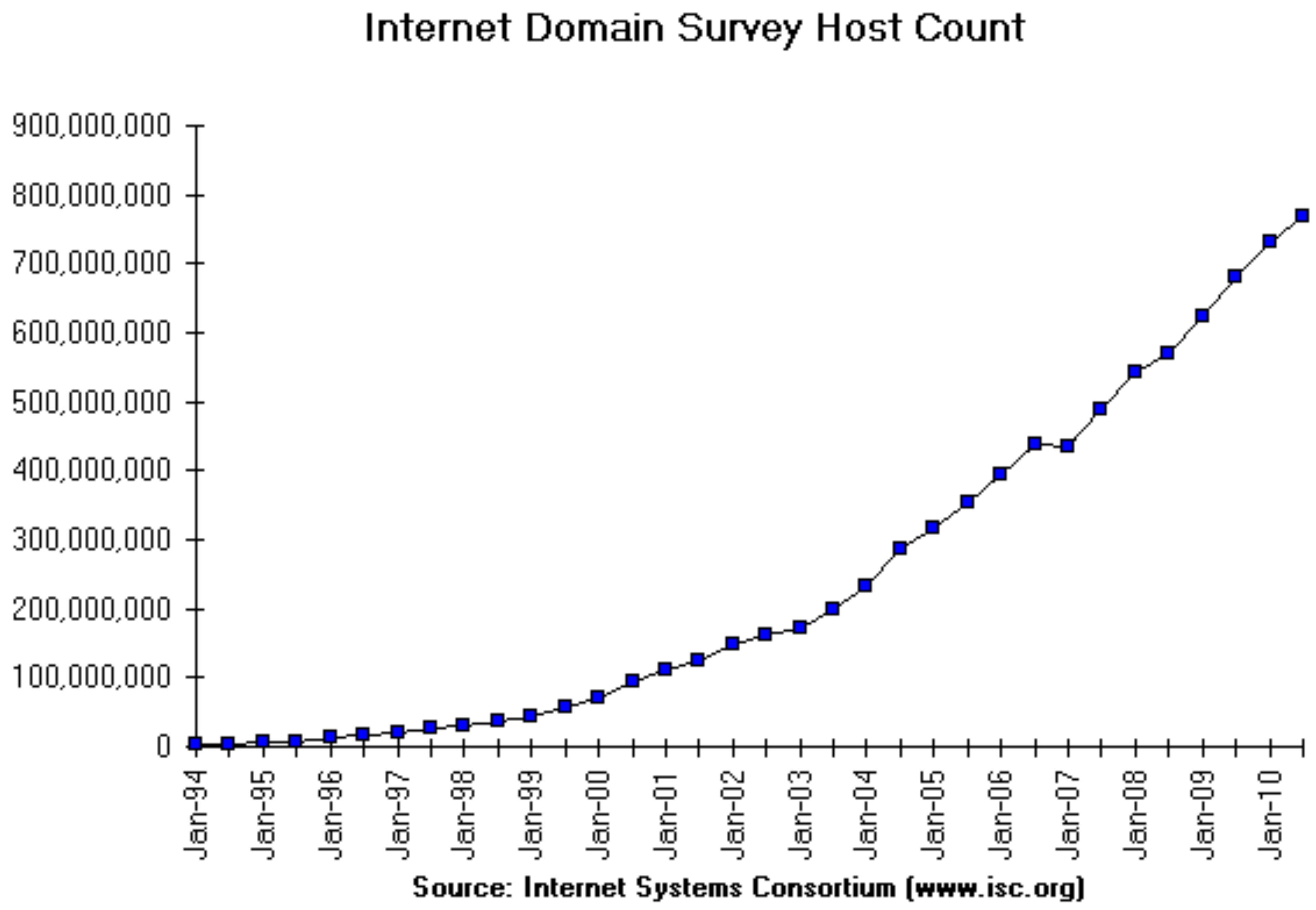
## Web History

- 1989:
  - Tim Berners-Lee (CERN) writes internal proposal to develop a distributed hypertext system.
    - Connects “a web of notes with links.”
    - Intended to help CERN physicists in large projects share and manage information
- 1990:
  - Tim BL writes a graphical browser for Next machines.

## Web History (cont)

- 1992
  - NCSA server released
  - 26 WWW servers worldwide
- 1993
  - Marc Andreessen releases first version of NCSA Mosaic browser
  - Mosaic version released for (Windows, Mac, Unix).
  - Web (port 80) traffic at 1% of NSFNET backbone traffic.
  - Over 200 WWW servers worldwide.
- 1994
  - Andreessen and colleagues leave NCSA to form “Mosaic Communications Corp” (predecessor to Netscape).

## Internet Hosts



- How many of the $2^{32}$ IP addresses have registered domain names?

## Web Content

- Web servers return content to clients
  - content: a sequence of bytes with an associated MIME (Multipurpose Internet Mail Extensions) type
- Example MIME types

| | |
|---|---|
| text/html | HTML document |
| text/plain | Unformatted text |
| image/gif | Binary image encoded in GIF format |
| image/jpeg | Binary image encoded in JPEG format |
| video/mpeg | Video encoded with MPEG |

# Static and Dynamic Content

The content returned in HTTP responses can be either *static* or *dynamic*.

- *Static content*: content stored in files and retrieved in response to an HTTP request
  - Examples: HTML files, images, audio clips.
- *Dynamic content*: content produced on-the-fly in response to an HTTP request
  - Example: content produced by a program executed by the server on behalf of the client.

Bottom line: *All Web content is associated with a "file" that is managed by the server.*

## URL: Universal Resource Locator

- URL: A name to identify an object managed by a server
- URLs for static content:
  - `http://www.cs.cmu.edu:80/index.html`
  - `http://www.cs.cmu.edu/index.html`
  - `http://www.cs.cmu.edu`
    - Identifies a file called `index.html`, managed by a Web server at `www.cs.cmu.edu` that is listening on port 80
- URLs for dynamic content:
  - `http://www.imdb.com/find?s=all&q=the+net`
    - Identifies an executable file called find, managed by a Web server at www.imdb.com, that has 2 input parameters:
      - `s`, which has a value of "all"
      - `q`, which has a value of "the net" (note whitespace changed to '+' because of URL syntax rules)

# How Clients and Servers Use URLs

**Example URL:** `http://www.aol.com:80/index.html`

**Clients use *prefix* (`http://www.aol.com:80`) to infer:**

- What kind of server to contact (Web server)
- Where the server is (`www.aol.com`)
- What port it is listening on (80)

**Servers use *suffix* (`/index.html`) to:**

- Determine if request is for static or dynamic content.
  - No hard and fast rules for this.
  - Convention: executables reside in `cgi-bin` directory
- Find file on file system.
  - Initial "`/`" in suffix denotes home directory for requested content.
  - Minimal suffix is "`/`", which all servers expand to some default home page (e.g., `index.html`).

## Anatomy of an HTTP Transaction

| | |
|---|---|
| `unix> telnet www.aol.com 80` | ***Client: open connection to server*** |
| `Trying 205.188.146.23...` | ***Telnet prints 3 lines to the terminal*** |
| `Connected to aol.com.` | |
| `Escape character is '^]'.` | |
| `GET / HTTP/1.1` | ***Client: request line*** |
| `host: www.aol.com` | ***Client: required HTTP/1.1 HOST header*** |
| | ***Client: empty line terminates headers.*** |
| `HTTP/1.0 200 OK` | Server: response line |
| `MIME-Version: 1.0` | ***Server: followed by five response headers*** |
| `Date: Mon, 08 Jan 2001 04:59:42 GMT` | |
| `Server: NaviServer/2.0 AOLserver/2.3.3` | |
| `Content-Type: text/html` | ***Server: expect HTML in the response body*** |
| `Content-Length: 42092` | ***Server: expect 42,092 bytes*** |
| | ***Server: empty line ("`\r\n`") terminates hdr*** |
| `<html>` | ***Server: first HTML line in response body*** |
| `...` | ***Server: 766 lines of HTML not shown.*** |
| `</html>` | ***Server: last HTML line in response body*** |
| `Connection closed by foreign host.` | ***Server: closes connection*** |
| `unix>` | ***Client: closes connection and terminates*** |

## HTTP Requests

- HTTP request is a request line, followed by zero or more request headers, followed by a blank line (CRLF), followed by an optional message body

```
Request = Request-Line
          *(header CRLF)
          CRLF
          [message-body]
```

- Request line describes the object that is desired

```
Request-Line = Method SP Request-URI SP HTTP-Version CRLF
```

  - `Method` is a verb describing the action to be taken (details on next slide)
  - `Request-URI` is typically the URL naming the object desired
    - A URL is a type of URI (Uniform Resource Identifier)
    - See http://www.ietf.org/rfc/rfc2396.txt
  - `HTTP-Version` is the HTTP version of request (HTTP/1.0 or HTTP/1.1)

## HTTP Requests (cont)

- HTTP methods:
  - `GET`: Retrieve an object (web page, etc)
    - Workhorse method (99% of requests)
    - "Conditional GET"if header includes If-Modified-Since, If-Match, etc.
  - `POST`: Send data to the server (can also be used to retrieve dynamic content)
    - Arguments for dynamic content are in the request body
  - `HEAD`: Retrieve metadata about an object (validity, modification time, etc)
    - Like `GET` but no data in response body
  - `OPTIONS`: Get server or object attributes
  - `PUT`: Write a file to the server!
  - `DELETE`: Delete an object (file) on the server!
  - `TRACE`: Echo request in response body
    - Useful for debugging

```
Request = Request-Line
          *(header CRLF)
          CRLF
          [message-body]
```

```
Request-Line = Method SP Request-URI SP HTTP-Version CRLF
```

## HTTP Requests (cont)

- Request Headers provide additional information to the server
  - Modify the request in some form

```
header = Header-Name COLON SP Value
```

- Examples:
  - Host: www.w3.org
  - If-Modified-Since: Mon, 19 Aug 2010 19:43:31 GMT
  - User-Agent: Mozilla/5.0 (Macintosh; U; Intel Mac OS X 10_7...Safari/533.4
  - Connection: Keep-Alive
  - Transfer-Encoding: chunked

```
Request = Request-Line
          *(header CRLF)
          CRLF
          [message-body]
```

- Message Body contains data objects
  - Data for `POST`, `PUT`, `TRACE` methods

## HTTP Responses

- HTTP response format is similar to request, except first line is a "status line"

```
Response = status-line
           *(header CRLF)
           CRLF
           [message-body]
```

```
status-line = HTTP-Version SP Status-code SP Reason-Phrase CRLF
```

  - `HTTP-Version` is the HTTP version of request (HTTP/1.0 or HTTP/1.1)
  - `Status-code` is numeric status, Reason-Phrase is corresponding English

| | | |
|---|---|---|
| `200` | `OK` | Request was handled without error |
| `301` | `Moved Permanently` | Object is in new location |
| `404` | `Not found` | Server couldn't find the file |

- Response headers, similar to request headers
  - `Content-Type: text/html`
  - `Content-Length: 22629` (in bytes)
  - `Location: new-folder/new-object-name.html`

## HTTP Versions

- HTTP/1.0 (1990) got the web up and running
  - HTTP/1.0 uses a new TCP connection for each transaction (i.e. request-reply)
- HTTP/1.1 (1999) added performance features
  - Supports persistent connections
    - Multiple transactions over the same connection, amortizing TCP startup
    - `Connection: Keep-Alive`
  - Supports pipelined connections
    - Multiple transactions at the same time over single a TCP connection
  - Requires HOST header
    - `Host: www.chatroulette.com`
  - Supports chunked encoding (described later)
    - `Transfer-Encoding: chunked`
  - Adds additional support for caching web objects

## GET Request to www.cmu.edu from Safari

Request-URI is just the suffix, not the entire URL

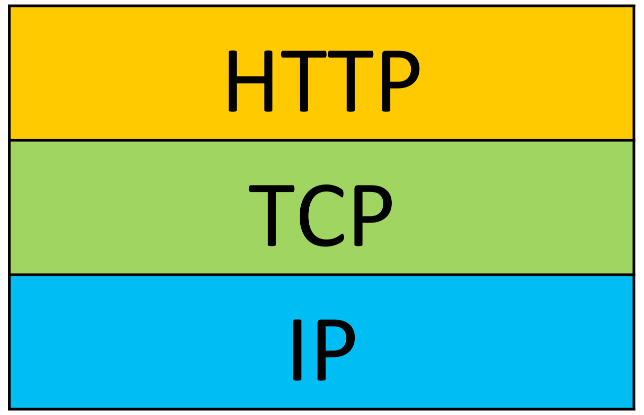
```
GET /index.shtml HTTP/1.1Host:
www.cmu.eduReferer: http://www.cmu.edu/
index.shtmlUser-Agent: Mozilla/5.0
(Macintosh...Safari...Accept: */*Accept-Language:
en-usAccept-Encoding: gzip, deflateCookie:
__unam=74ba...webstats-cmu=cmu128.2...Connection:
keep-aliveCRLF (\r\n)
```

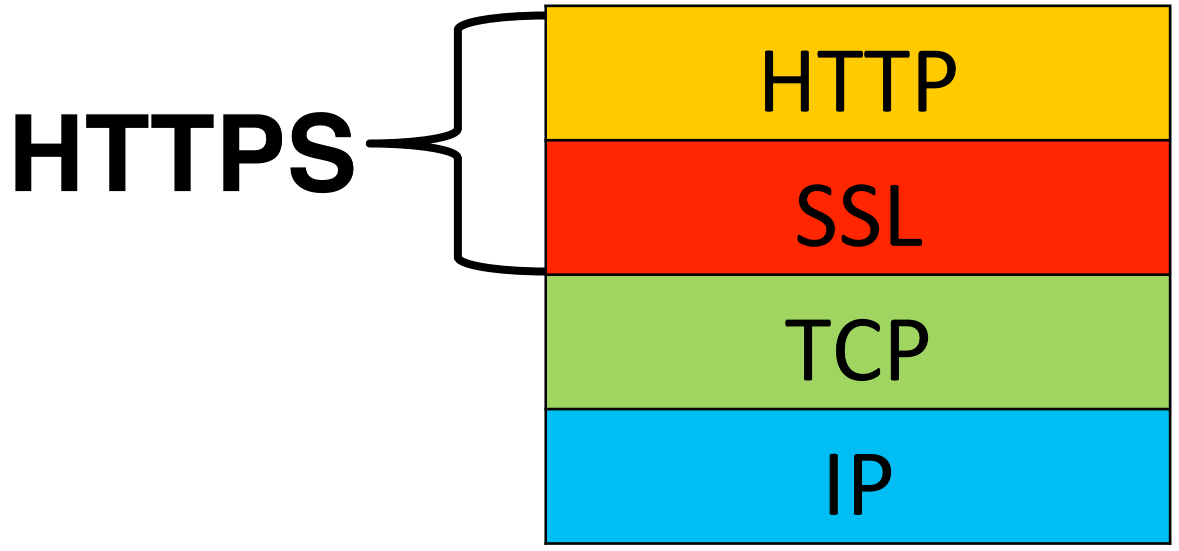
## GET Response From www.cmu.edu Server

```
HTTP/1.1 200 OKDate: Tue, 20 Apr 2010 12:50:27 GMTServer:
Apache/1.3.39 (Unix) ... mod_ssl/2.8.30 OpenSSL/0.9.6m+Keep-
Alive: timeout=5, max=99Connection: Keep-AliveTransfer-Encoding:
chunkedContent-Type: text/htmlCRLF (\r\n)<!DOCTYPE html
PUBLIC ...><html xmlns="http://www.w3.org/1999/
xhtml"><head>...<title>Carnegie Mellon University</title></
head><body><table border="0" cellpadding="0" cellspacing="0"
width="100%"><tr><td align="left" class="home_leftnav_bg"
valign="top" width="252">...</body></html>
```

## HTTPS

- Provides encrypted channel for Web Requests/Responses
- Implemented as normal HTTP over Secure Socket Layer (SSL)
- Abstracts away security issues from Web Server Developer
  - Need to match certificate with host makes virtual hosting a challenge





## Today

- HTTP and Static Content
- Web Servers
- Proxies

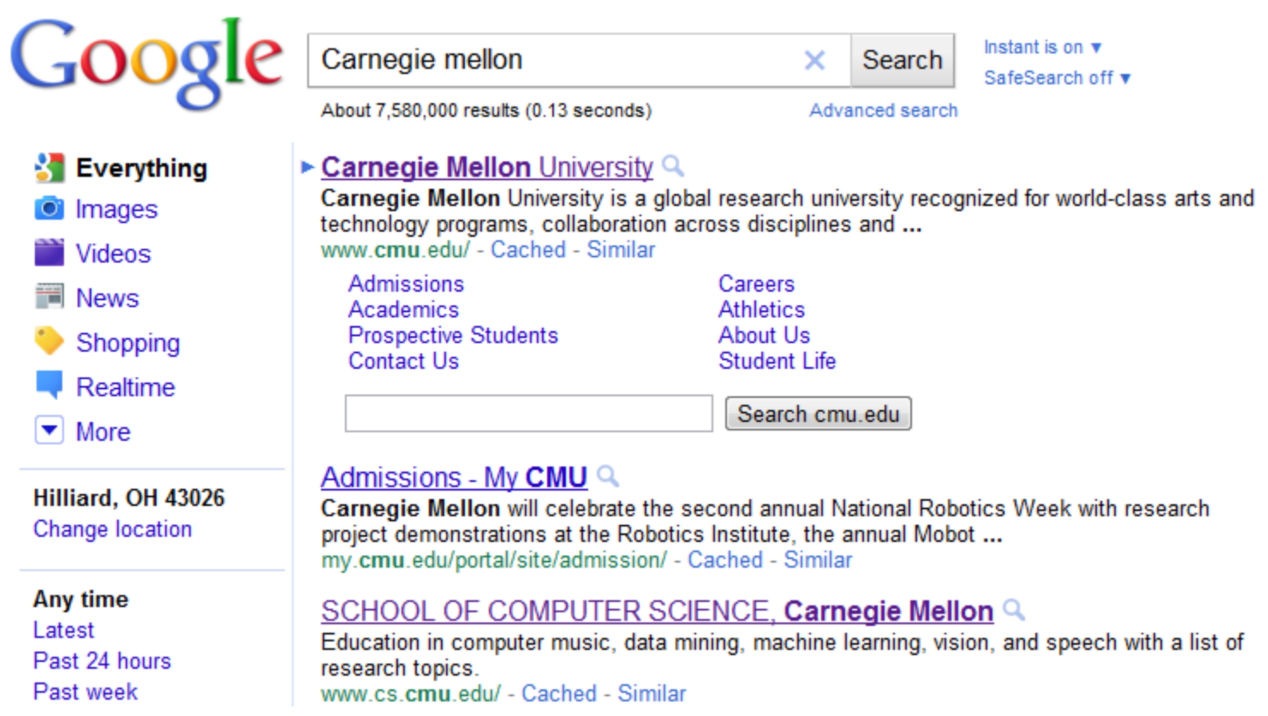
## Serving Content

- Content is either Static or Dynamic
  - Static content is generally served from a file system and rarely changes
  - Dynamic content varies from request to request and is generated per request
  - Client doesn't know the difference

**Static Content**

**/images/logos/ps_logo2.png**

**Dynamic Content**



Carnegie mellon

About 7,580,000 results (0.13 seconds)

Hilliard, OH 43026

Carnegie Mellon University
Carnegie Mellon University is a global research university recognized for world-class arts and technology programs, collaboration across disciplines and ...
www.cmu.edu/ - Cached - Similar

| | |
|---|---|
| Admissions | Careers |
| Academics | Athletics |
| Prospective Students | About Us |
| Contact Us | Student Life |

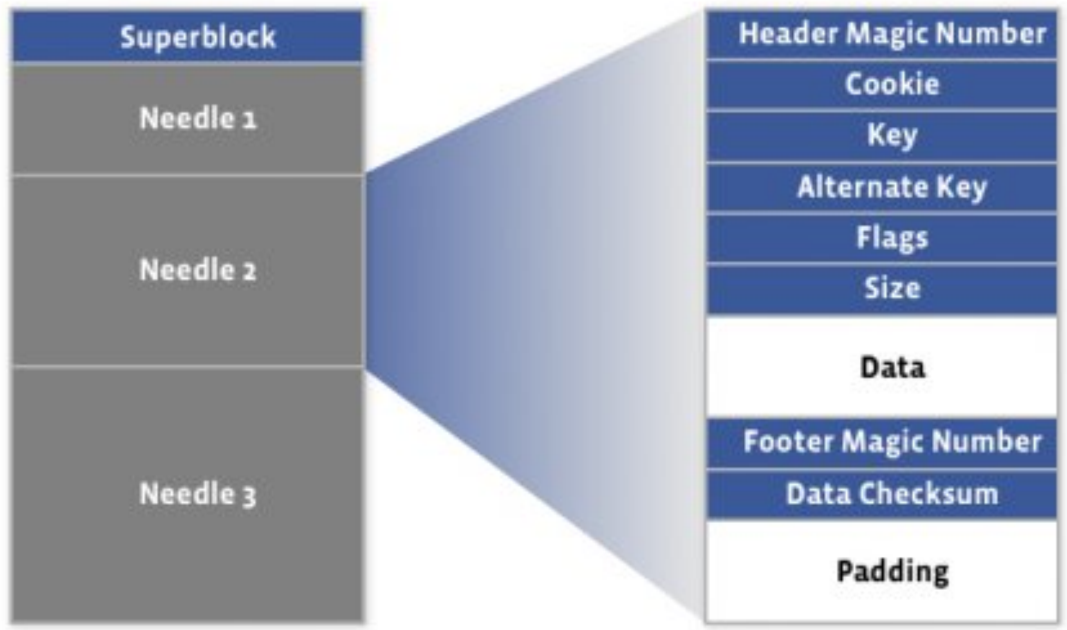
Admissions - My CMU
Carnegie Mellon will celebrate the second annual National Robotics Week with research project demonstrations at the Robotics Institute, the annual Mobot ...
my.cmu.edu/portal/site/admission/ - Cached - Similar

SCHOOL OF COMPUTER SCIENCE, Carnegie Mellon
Education in computer music, data mining, machine learning, vision, and speech with a list of research topics.
www.cs.cmu.edu/ - Cached - Similar

**/#q=Carnegie+Mellon**

## Static Content

- Generally very fast
  - Limited by IO speed of disk/network
- Pages are served directly from the file system
  - Or memory
  - Or one large file (Facebook's Haystack)



**Facebook's Haystack image server writes many images to one contiguous file, where they can be quickly read by the web server**
**http://www.facebook.com/note.php?note_id=76191543919**

## Dynamic Content – Single Process

- Web server generates certain pages by itself
- Pros
  - [Potentially] very fast
- Cons
  - Limited to single language
  - Upgrade path can be complicated
  - Bugs can crash the server
- Who actually does this?
  - Almost no one
  - Except Facebook
    - HipHop compiles PHP to C++ with its own server built in

## Dynamic Content – Common Gateway Interface

- First widely used approach to the problem
- Similar to executing a shell remotely
  - Server forks
  - Executes a program in cgi-bin/ directory with request as input
  - Server forwards output of program back to Client
- Pros
  - Simple interface
  - Language independent
- Cons
  - Slow
  - Resource intensive
- Who actually does this?
  - Almost no one, anymore

## Dynamic Content – Embedded Interpreter

- Language interpreter is loaded into the web server
- Pros
  - Works well for Apache ecosystem
  - Possible to support many languages
  - Allows web programming in easier, safe languages
- Cons
  - Module systems complicate web server architectures
  - Modules must be written for each web server
- Who actually does this?
  - Apache's mod_py, mod_php, etc.
  - Many others

## Dynamic Content – Out-of-Process Handlers

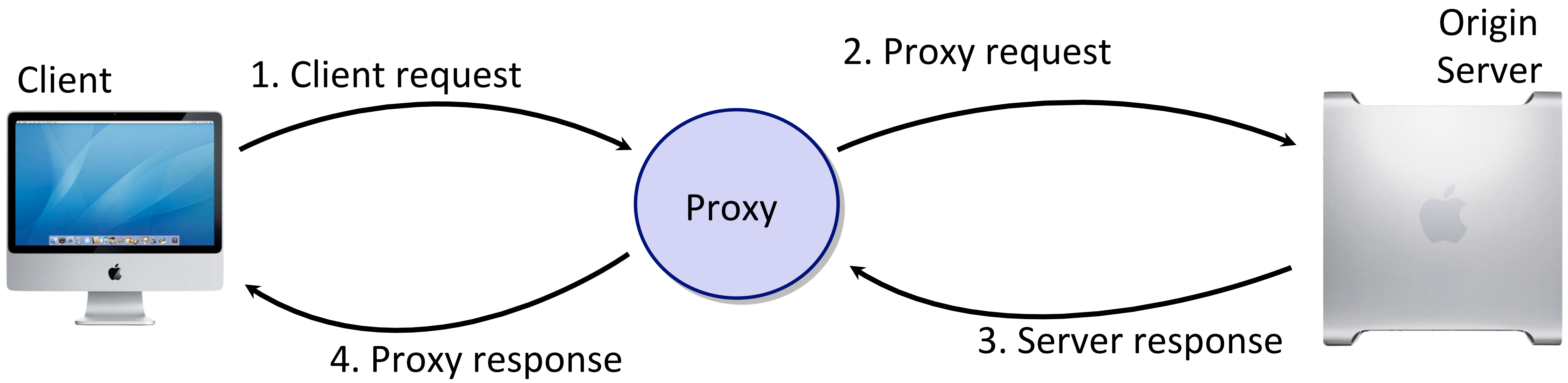
- "Handler" program stays alive
- Communication is performed over sockets
- Pros
  - Simple interface
  - Language independent
  - Far less process maintenance cost
- Cons
  - Slightly slower than Single Process
- Who actually does this?
  - FastCGI: Apache, Lighttpd, Nginx, many others
  - Other: Mongrel2

## Today

- HTTP
- Web Servers
- Proxies

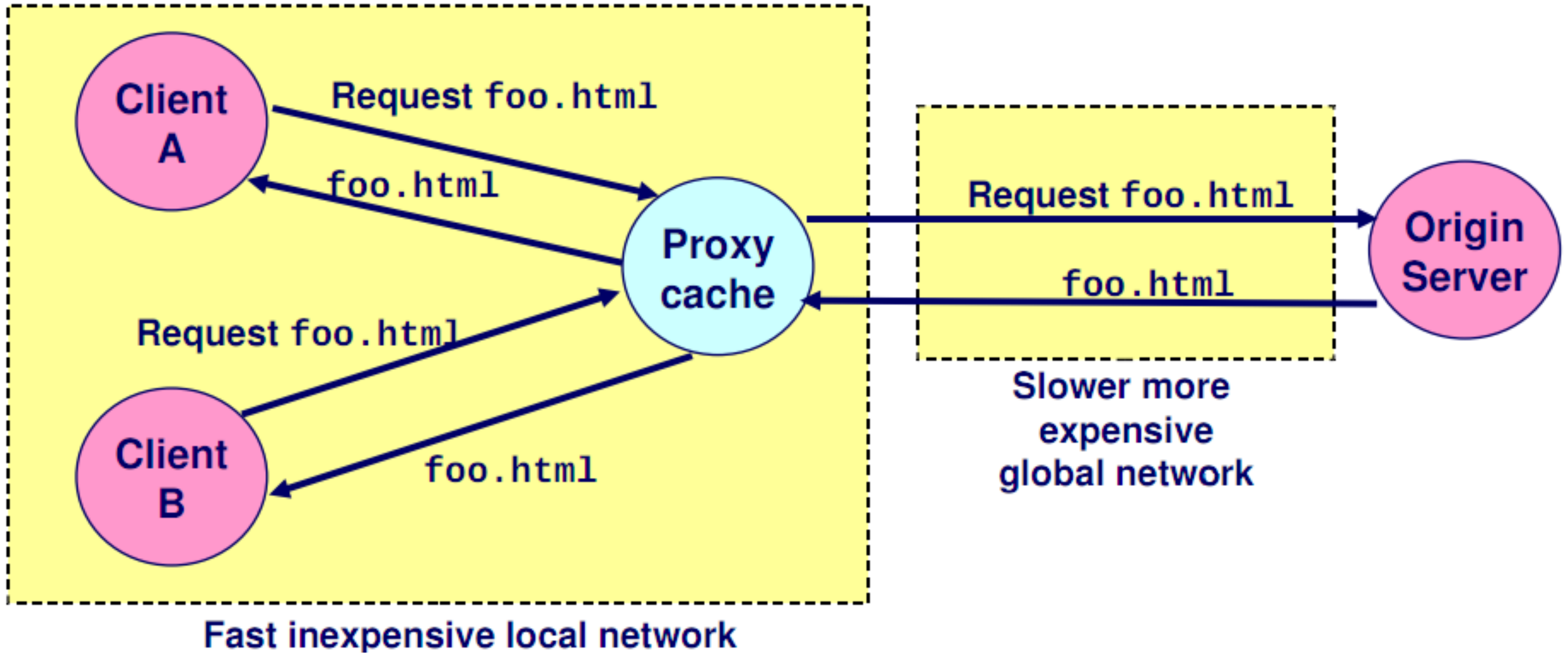
## Proxies

- A proxy is an intermediary between a client and an origin server
  - To the client, the proxy acts like a server
  - To the server, the proxy acts like a client

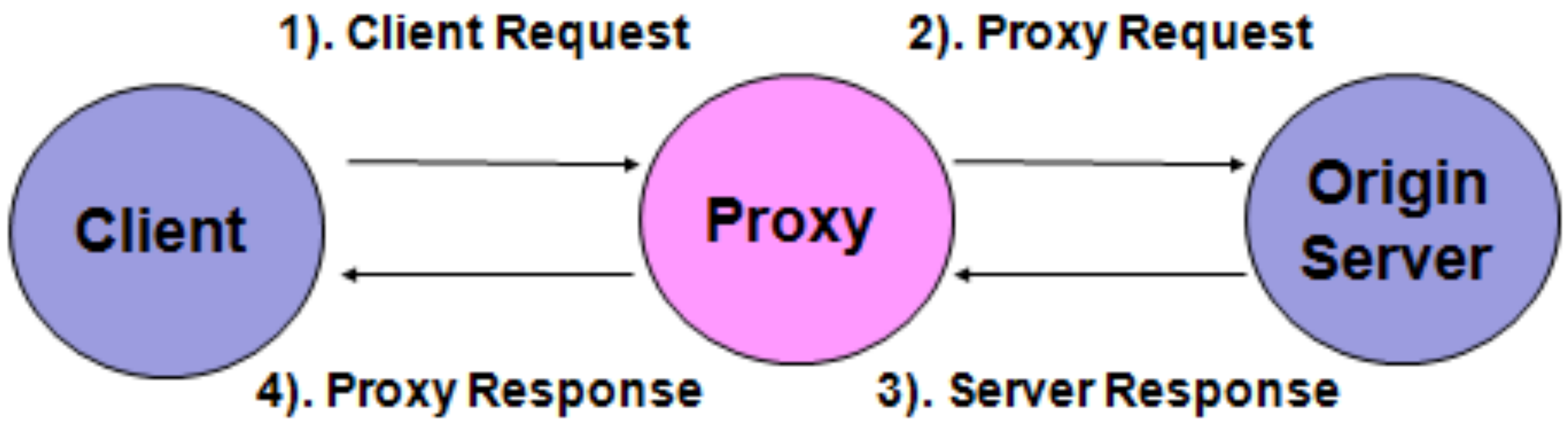


## Why Proxies?

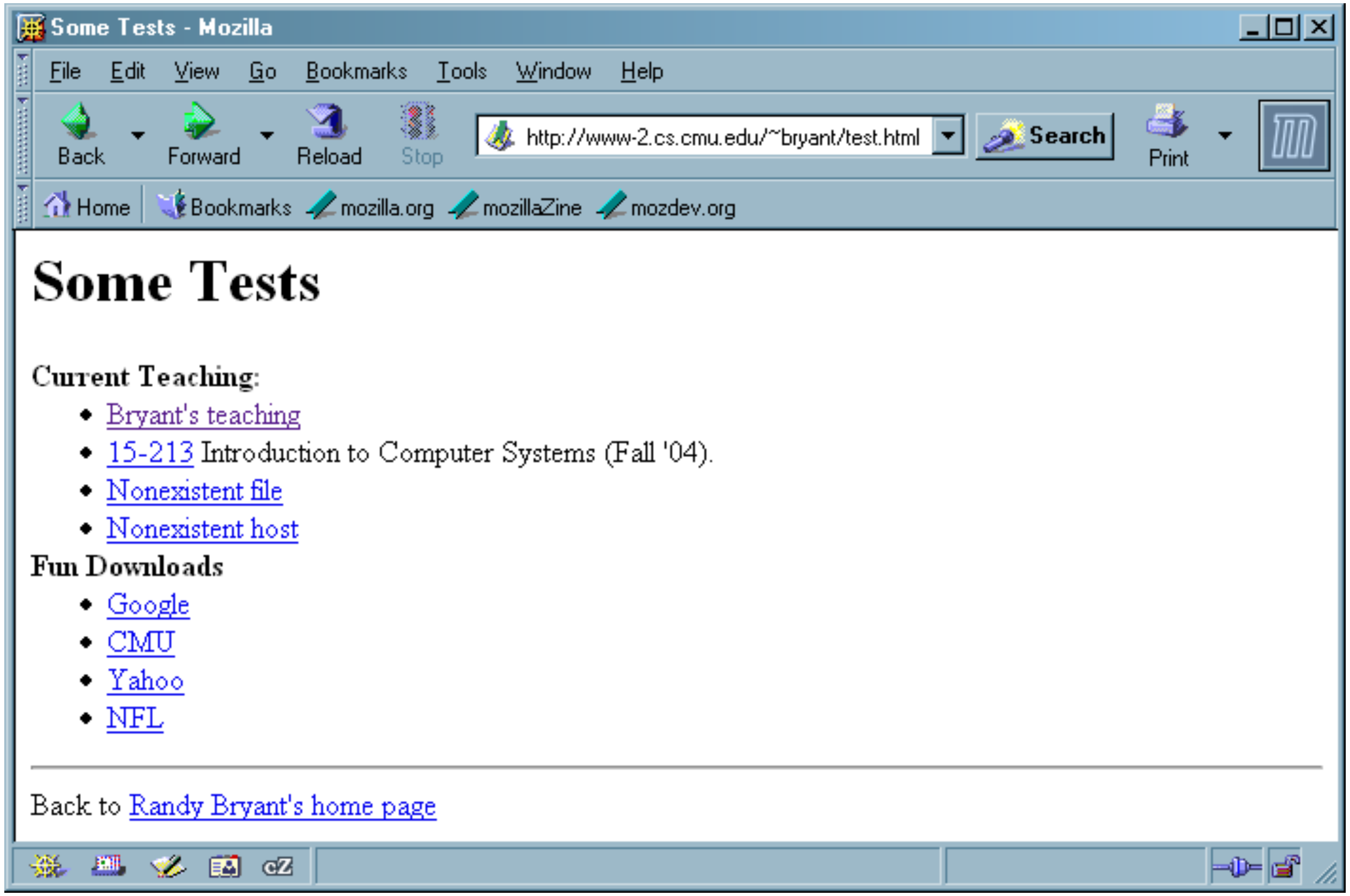
- Can perform useful functions as requests and responses pass by
  - Caching, logging, anonymization, filtering



## Putting it Together



## Servicing Web Page Request



# Some Tests

**Current Teaching:**

- Bryant's teaching
- 15-213 Introduction to Computer Systems (Fall '04).
- Nonexistent file
- Nonexistent host

**Fun Downloads**

- Google
- CMU
- Yahoo
- NFL

---

Back to Randy Bryant's home page

## Client → Proxy

The browser sends a complete URL for the Request-URI

```
GET http://www-2.cs.cmu.edu/~bryant/test.html HTTP/1.1
Host: www-2.cs.cmu.edu
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:
1.7.3) Gecko/20040910
Accept: text/xml,application/xml,application/xhtml+xml,text/
html;q=0.9,text/plain;q=0.8,image/png,*/*;q=0.5
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
Proxy-Connection: keep-alive
CRLF (\r\n)
```

## Proxy ➞ Server

The proxy sends a Request-URI that is just the object path

```
GET /~bryant/test.html HTTP/1.1
Host: www-2.cs.cmu.edu
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:
1.7.3) Gecko/20040910
Accept: text/xml,application/xml,application/xhtml+xml,text/
html;q=0.9,text/plain;q=0.8,image/png,*/*;q=0.5
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
CRLF (\r\n)
```

## Server → Proxy → Client

```
HTTP/1.1 200 OK
Date: Mon, 29 Nov 2004 01:27:15 GMT
Server: Apache/1.3.27 (Unix) mod_ssl/2.8.12 OpenSSL/0.9.6
     mod_pubcookie/a5/1.76-009
Transfer-Encoding: chunked
Content-Type: text/html
\r\n
```

- Chunked Transfer Encoding
  - Alternate way of specifying content length
  - Each "chunk" prefixed with chunk length, postfixed with CRLF
  - Used to allow the server to start sending data without knowing the final size of the entire content
    - Also, headers (like security hashes that must be calculated) can be sent after the dynamic data to which they refer has been already been sent
  - See http://www.w3.org/Protocols/rfc2616/rfc2616-sec3.html

# Server → Proxy → Client (cont)

First Chunk: 0x2ec = 748 bytes

```
2ec
<head><title>Some Tests</title></head>
<h1>Some Tests</h1>
<dl>
 <dt> <strong>Current Teaching: </strong>
 <ul>
  <li> <a href="teaching.html">Bryant's teaching</a>
  <li> <a href="/afs/cs.cmu.edu/academic/class/15213-f04/www/">
    15-213</a> Introduction to Computer Systems (Fall '04).
  <li> <a href="http://www.cs.cmu.edu/nothing.html">Nonexistent file</a>
  <li> <a href="http://nowhere.cmu.edu/nothing.html">Nonexistent host</a>
 </ul>
 <dt><strong>Fun Downloads</strong>
 <ul>
  <li> <a href="http://www.google.com">Google</a>
  <li> <a href="http://www.cmu.edu">CMU</a>
  <li> <a href="http://www.yahoo.com">Yahoo</a>
  <li> <a href="http://www.nfl.com">NFL</a>
 </ul>
</dl>
<hr>
Back to <a href="index.html">Randy Bryant's home page</a>
CRLF (\r\n)
0\r\n
\r\n
```

Second Chunk: 0 bytes (indicates last chunk)

## For More Information

- Study the Tiny Web server described in your text
  - Tiny is a sequential Web server (one request at a time)
  - Serves static and dynamic content to real browsers
    - text files, HTML files, GIF and JPEG images
  - 220 lines of commented C code
  - Also comes with an implementation of the CGI script for the addition portal

- See the HTTP/1.1 standard:
  - http://www.ietf.org/rfc/rfc2616.txt
  - RFCs are standards documents, but still remarkably readable

## Summary

- HTTP
- Web Servers
- Proxies

- Next Time:
  - Concurrency -- doing lots of stuff at the same time