COMP2310/COMP6310
Systems, Networks, & Concurrency

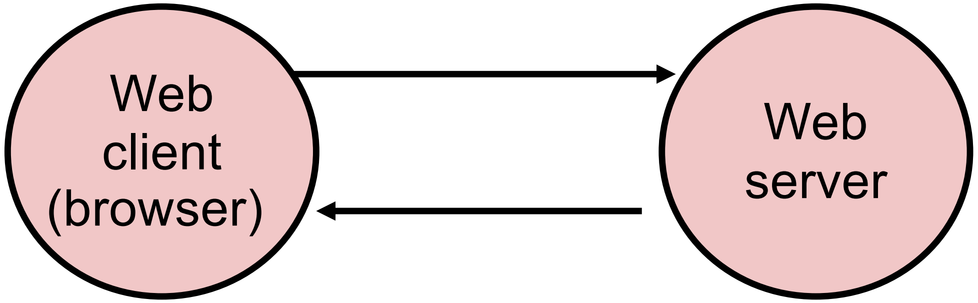
Convener: Shoaib Akram

Outline

- **Getting content on the web: Telnet/cURL Demo**
  - How the web really works
- Networking Basics
- Proxy
  - Due Tuesday, December 8th
  - Grace days allowed
- String Manipulation in C

The Web in a Textbook

- Client request page, server provides, transaction done.



- A sequential server can handle this. We just need to serve one page at a time.
- This works great for simple text pages with embedded styles.

Telnet/Curl Demo

- **Telnet**
  - Interactive remote shell – like ssh without security
  - Must build HTTP request manually
    - This can be useful if you want to test response to malformed headers

```
[rjaganna@makoshark ~]% telnet www.cmu.edu 80
Trying 128.2.42.52...
Connected to WWW-CMU-PROD-VIP.ANDREW.cmu.edu (128.2.42.52).
Escape character is '^]'.
GET http://www.cmu.edu/ HTTP/1.0

HTTP/1.1 301 Moved Permanently
Date: Sat, 11 Apr 2015 06:54:39 GMT
Server: Apache/1.3.42 (Unix) mod_gzip/1.3.26.1a mod_pubcookie/3.3.4a mod_ssl/2.8.31 OpenSSL/0.9.8e-
fips-rhel5
Location: http://www.cmu.edu/index.shtml
Connection: close
Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<HTML><HEAD>
<TITLE>301 Moved Permanently</TITLE>
</HEAD><BODY>
<H1>Moved Permanently</H1>
The document has moved <A HREF="http://www.cmu.edu/index.shtml">here</A>.<P>
<HR>
<ADDRESS>Apache/1.3.42 Server at <A HREF="mailto:webmaster@andrew.cmu.edu">www.cmu.edu</A> Port
80</ADDRESS>
</BODY></HTML>
Connection closed by foreign host.
```

Telnet/cURL Demo

- **cURL**
  - “URL transfer library” with a command line program
  - Builds valid HTTP requests for you!

```
[rjaganna@makoshark ~]% curl http://www.cmu.edu/
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<HTML><HEAD>
<TITLE>301 Moved Permanently</TITLE>
</HEAD><BODY>
<H1>Moved Permanently</H1>
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<ADDRESS>Apache/1.3.42 Server at <A HREF="mailto:webmaster@andrew.cmu.edu">www.cmu.edu</A> Port
80</ADDRESS>
</BODY></HTML>
```

  - Can also be used to generate HTTP proxy requests:

```
[rjaganna@makoshark ~]% curl --proxy lemonshark.ics.cs.cmu.edu:3092 http://www.cmu.edu/
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<HTML><HEAD>
<TITLE>301 Moved Permanently</TITLE>
</HEAD><BODY>
<H1>Moved Permanently</H1>
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<ADDRESS>Apache/1.3.42 Server at <A HREF="mailto:webmaster@andrew.cmu.edu">www.cmu.edu</A> Port
80</ADDRESS>
</BODY></HTML>
```

How the Web Really Works

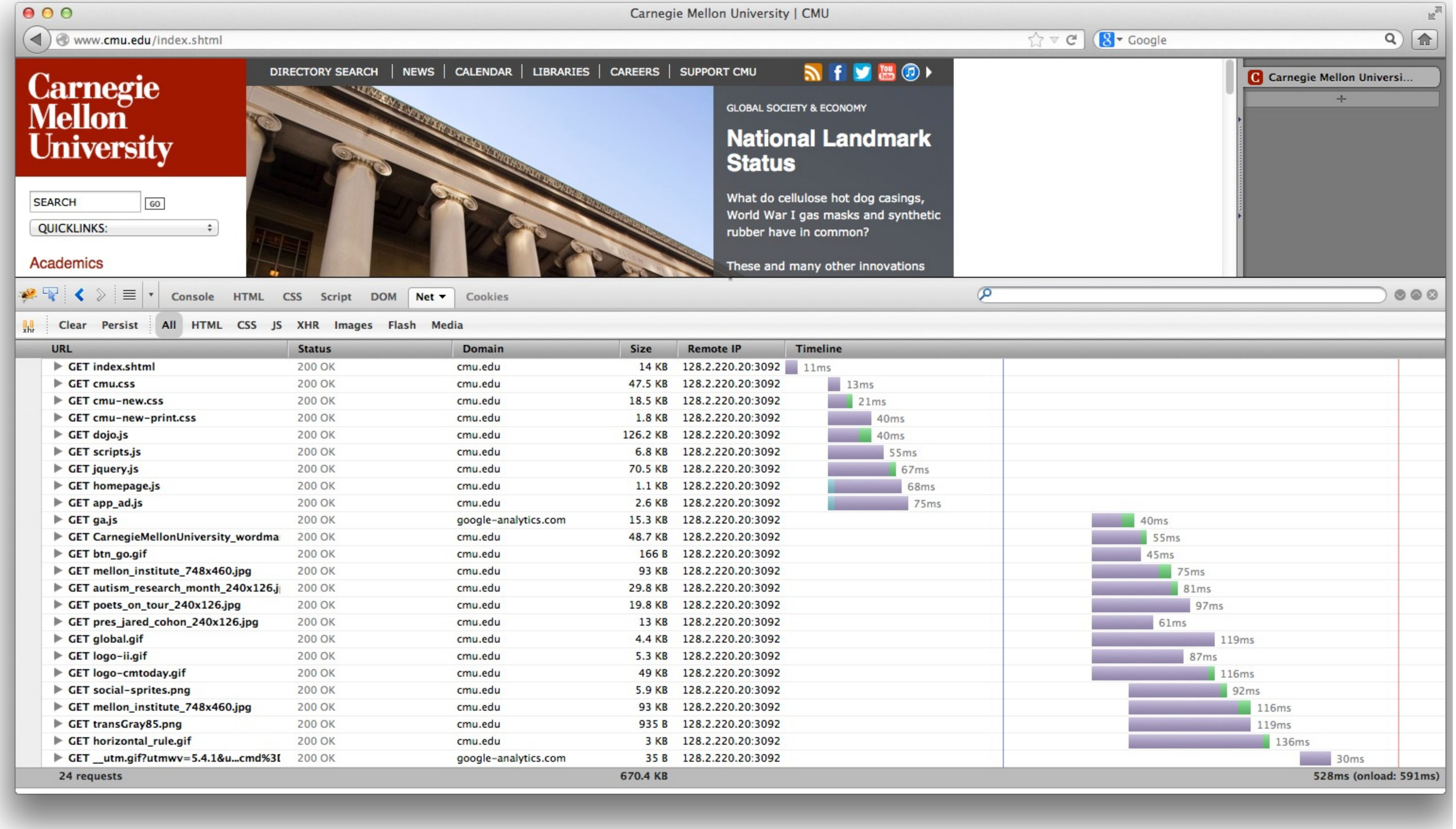
- **In reality, a single HTML page today may depend on 10s or 100s of support files (images, stylesheets, scripts, etc.)**
- **Builds a good argument for concurrent servers**
  - Just to load a single modern webpage, the client would have to wait for 10s of back-to-back request
  - I/O is likely slower than processing, so back
- **Caching is simpler if done in pieces rather than whole page**
  - If only part of the page changes, no need to fetch old parts again
  - Each object (image, stylesheet, script) already has a unique URL that can be used as a key

How the Web Really Works

- **Excerpt from www.cmu.edu/index.html:**

```
<html lang="en" xml:lang="en" xmlns="http://www.w3.org/1999/xhtml">
<head>
  ...
  <link href="homecss/cmu.css" rel="stylesheet" type="text/css"/>
  <link href="homecss/cmu-new.css" rel="stylesheet" type="text/css"/>
  <link href="homecss/cmu-new-print.css" media="print" rel="stylesheet"
type="text/css"/>
  <link href="http://www.cmu.edu/RSS/stories.rss" rel="alternate" title="Carnegie
Mellon Homepage Stories" type="application/rss+xml"/>
  ...
  <script language="JavaScript" src="js/dojo.js" type="text/javascript"></script>
  <script language="JavaScript" src="js/scripts.js"
type="text/javascript"></script>
  <script language="javascript" src="js/jquery.js" type="text/javascript"></script>
  <script language="javascript" src="js/homepage.js"
type="text/javascript"></script>
  <script language="javascript" src="js/app_ad.js" type="text/javascript"></script>
  ...
  <title>Carnegie Mellon University | CMU</title>
</head>
<body> ...
```

Sequential Proxy



GLOBAL SOCIETY & ECONOMY

National Landmark Status

What do cellulose hot dog casings, World War I gas masks and synthetic rubber have in common?

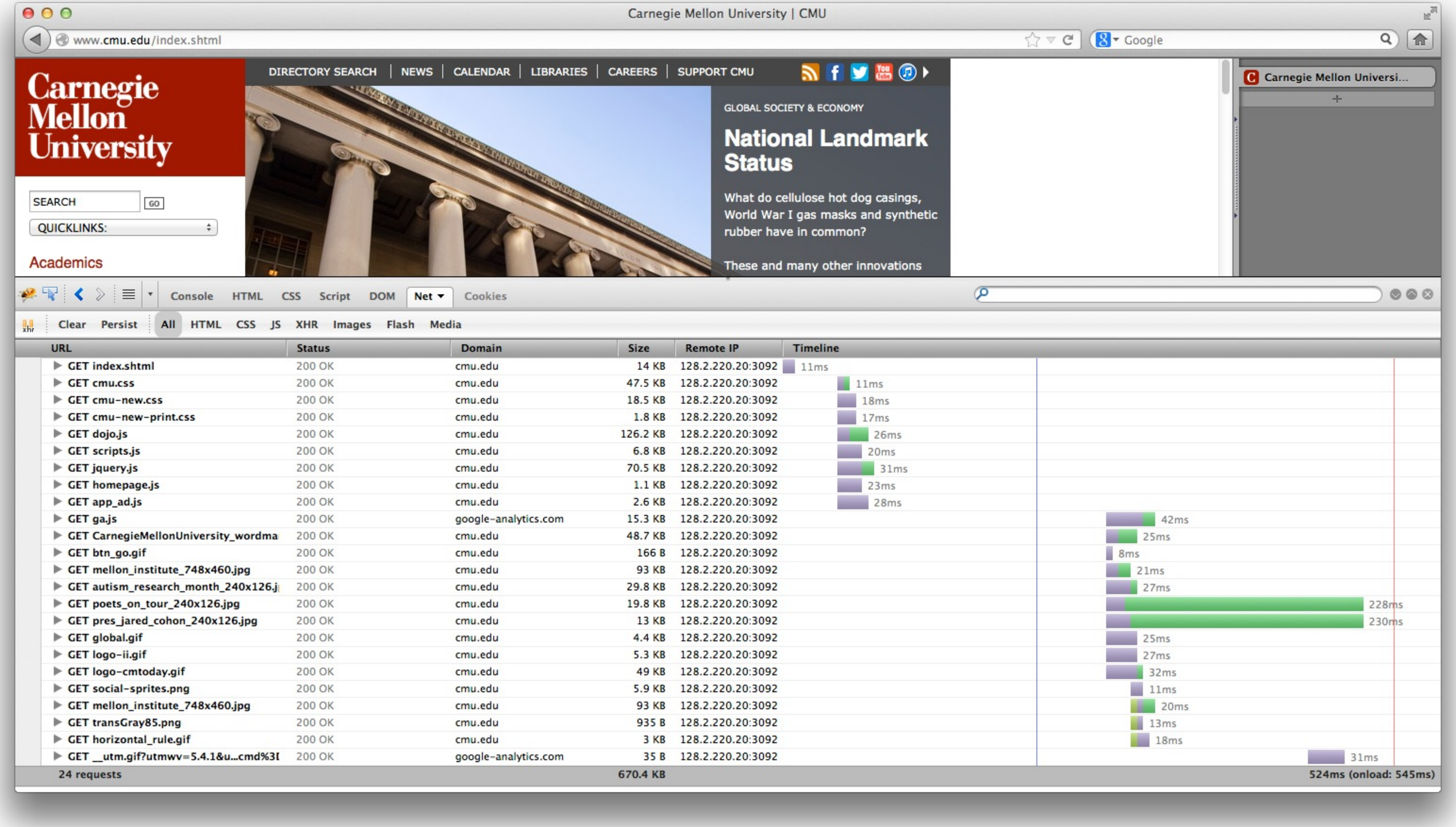
These and many other innovations

URL	Status	Domain	Size	Remote IP	Timeline
GET index.shtml	200 OK	cmu.edu	14 KB	128.2.220.20:3092	11ms
GET cmu.css	200 OK	cmu.edu	47.5 KB	128.2.220.20:3092	13ms
GET cmu-new.css	200 OK	cmu.edu	18.5 KB	128.2.220.20:3092	21ms
GET cmu-new-print.css	200 OK	cmu.edu	1.8 KB	128.2.220.20:3092	40ms
GET dojo.js	200 OK	cmu.edu	126.2 KB	128.2.220.20:3092	40ms
GET scripts.js	200 OK	cmu.edu	6.8 KB	128.2.220.20:3092	55ms
GET jquery.js	200 OK	cmu.edu	70.5 KB	128.2.220.20:3092	67ms
GET homepage.js	200 OK	cmu.edu	1.1 KB	128.2.220.20:3092	68ms
GET app_ad.js	200 OK	cmu.edu	2.6 KB	128.2.220.20:3092	75ms
GET ga.js	200 OK	google-analytics.com	15.3 KB	128.2.220.20:3092	40ms
GET CarnegieMellonUniversity_wordma	200 OK	cmu.edu	48.7 KB	128.2.220.20:3092	55ms
GET btn_go.gif	200 OK	cmu.edu	166 B	128.2.220.20:3092	45ms
GET mellon_institute_748x460.jpg	200 OK	cmu.edu	93 KB	128.2.220.20:3092	75ms
GET autism_research_month_240x126.j	200 OK	cmu.edu	29.8 KB	128.2.220.20:3092	81ms
GET poets_on_tour_240x126.jpg	200 OK	cmu.edu	19.8 KB	128.2.220.20:3092	97ms
GET pres_jared_cohon_240x126.jpg	200 OK	cmu.edu	13 KB	128.2.220.20:3092	61ms
GET global.gif	200 OK	cmu.edu	4.4 KB	128.2.220.20:3092	119ms
GET logo-ii.gif	200 OK	cmu.edu	5.3 KB	128.2.220.20:3092	87ms
GET logo-cmtoday.gif	200 OK	cmu.edu	49 KB	128.2.220.20:3092	116ms
GET social-sprites.png	200 OK	cmu.edu	5.9 KB	128.2.220.20:3092	92ms
GET mellon_institute_748x460.jpg	200 OK	cmu.edu	93 KB	128.2.220.20:3092	116ms
GET transGray85.png	200 OK	cmu.edu	935 B	128.2.220.20:3092	119ms
GET horizontal_rule.gif	200 OK	cmu.edu	3 KB	128.2.220.20:3092	136ms
GET __utm.gif?utmwv=5.4.1&u...cmd%3I	200 OK	google-analytics.com	35 B	128.2.220.20:3092	30ms
24 requests			670.4 KB		528ms (onload: 591ms)

Sequential Proxy

- **Note the sloped shape of when requests finish**
  - Although many requests are made at once, the proxy does not accept a new job until it finishes the current one
  - Requests are made in batches. This results from how HTML is structured as files that reference other files.
- **Compared to the concurrent example (next), this page takes a long time to load with just static content**

Concurrent Proxy



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GET cmu-new-print.css	200 OK	cmu.edu	1.8 KB	128.2.220.20:3092	17ms
GET dojo.js	200 OK	cmu.edu	126.2 KB	128.2.220.20:3092	26ms
GET scripts.js	200 OK	cmu.edu	6.8 KB	128.2.220.20:3092	20ms
GET jquery.js	200 OK	cmu.edu	70.5 KB	128.2.220.20:3092	31ms
GET homepage.js	200 OK	cmu.edu	1.1 KB	128.2.220.20:3092	23ms
GET app_ad.js	200 OK	cmu.edu	2.6 KB	128.2.220.20:3092	28ms
GET ga.js	200 OK	google-analytics.com	15.3 KB	128.2.220.20:3092	42ms
GET CarnegieMellonUniversity_wordma	200 OK	cmu.edu	48.7 KB	128.2.220.20:3092	25ms
GET btn_go.gif	200 OK	cmu.edu	166 B	128.2.220.20:3092	8ms
GET mellon_institute_748x460.jpg	200 OK	cmu.edu	93 KB	128.2.220.20:3092	21ms
GET autism_research_month_240x126.j	200 OK	cmu.edu	29.8 KB	128.2.220.20:3092	27ms
GET poets_on_tour_240x126.jpg	200 OK	cmu.edu	19.8 KB	128.2.220.20:3092	228ms
GET pres_jared_cohon_240x126.jpg	200 OK	cmu.edu	13 KB	128.2.220.20:3092	230ms
GET global.gif	200 OK	cmu.edu	4.4 KB	128.2.220.20:3092	25ms
GET logo-ii.gif	200 OK	cmu.edu	5.3 KB	128.2.220.20:3092	27ms
GET logo-cmtoday.gif	200 OK	cmu.edu	49 KB	128.2.220.20:3092	32ms
GET social-sprites.png	200 OK	cmu.edu	5.9 KB	128.2.220.20:3092	11ms
GET mellon_institute_748x460.jpg	200 OK	cmu.edu	93 KB	128.2.220.20:3092	20ms
GET transGray85.png	200 OK	cmu.edu	935 B	128.2.220.20:3092	13ms
GET horizontal_rule.gif	200 OK	cmu.edu	3 KB	128.2.220.20:3092	18ms
GET __utm.gif?utmwv=5.4.1&u...cmd%3I	200 OK	google-analytics.com	35 B	128.2.220.20:3092	31ms
24 requests			670.4 KB		524ms (onload: 545ms)

Concurrent Proxy

- **Now, we see much less purple (waiting), and less time spent overall.**
- **Notice how multiple green (receiving) blocks overlap in time**
  - Our proxy has multiple connections open to the browser to handle several tasks at once

How the Web Really Works

- **A note on AJAX (and XMLHttpRequests)**
  - Normally, a browser will make the initial page request then request any supporting files
  - And XMLHttpRequest is simply a request from the page once it has been loaded & the scripts are running
  - The distinction does not matter on the server side – everything is an HTTP Request

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- **Networking Basics**
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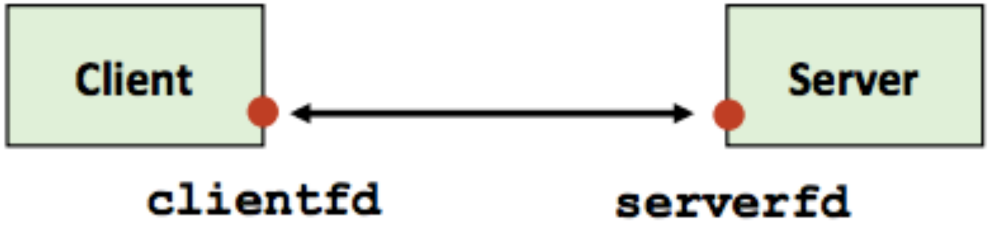
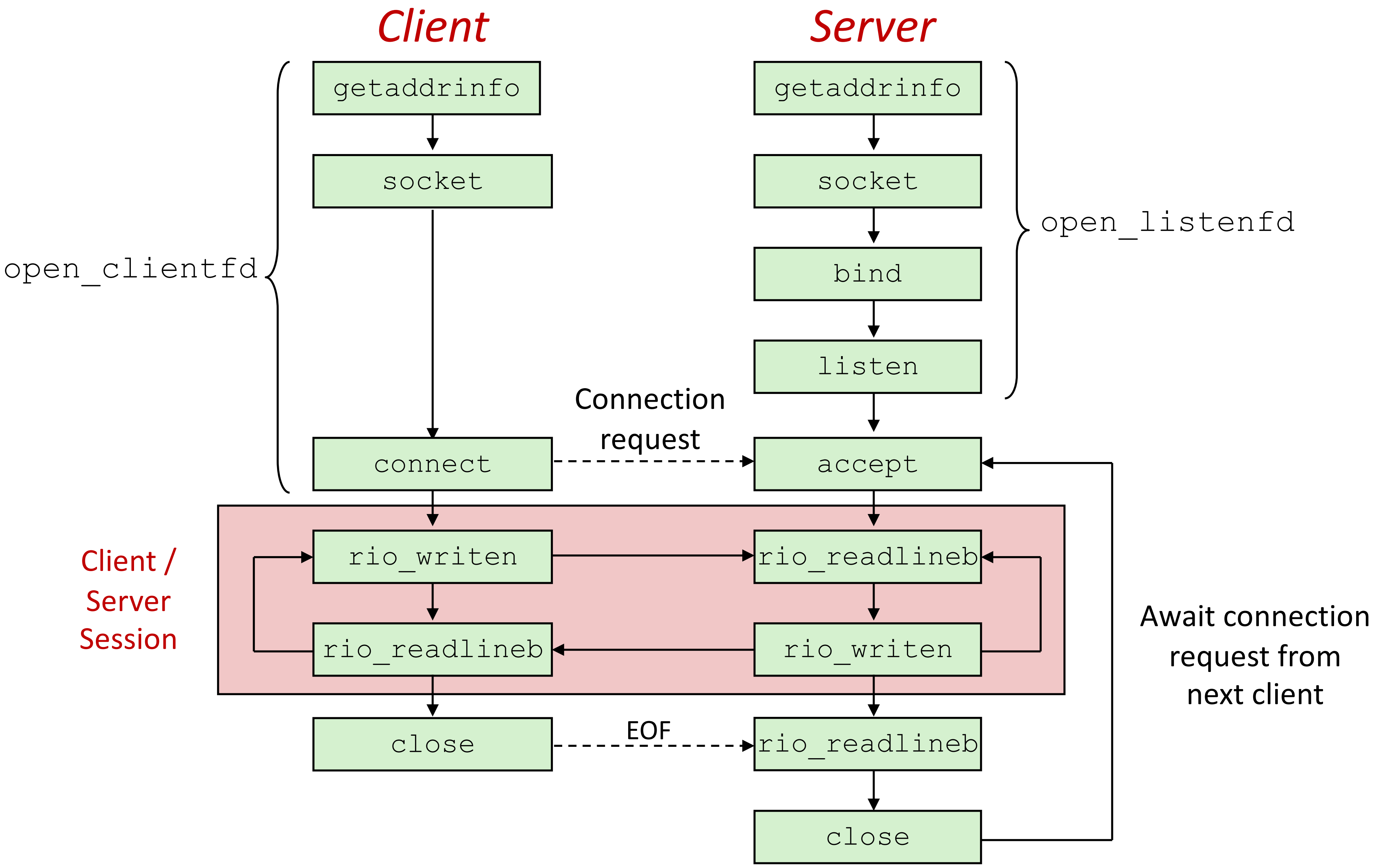
Sockets

- **What is a socket?**
  - To an application, a socket is a file descriptor that lets the application read/write from/to the network
  - (all Unix I/O devices, including networks, are modeled as files)
- **Clients and servers communicate with each other by reading from and writing to socket descriptors**



- **The main difference between regular file I/O and socket I/O is how the application "opens" the socket descriptors**

Overview of the Sockets Interface



Host and Service Conversion: `getaddrinfo`

- **`getaddrinfo`** is the modern way to convert string representations of host, ports, and service names to socket address structures.
  - Replaces obsolete `gethostbyname` - unsafe because it returns a pointer to a static variable
- **Advantages:**
  - Reentrant (can be safely used by threaded programs).
  - Allows us to write portable protocol-independent code(IPv4 and IPv6)
  - Given `host` and `service`, `getaddrinfo` returns `result` that points to a linked list of `addrinfo` structs, each pointing to socket address struct, which contains arguments for sockets APIs.

- **`getnameinfo` is the inverse of getaddrinfo, converting a socket address to the corresponding host and service.**

Sockets API

- int socket(int domain, int type, int protocol);
  - Create a file descriptor for network communication
  - used by both clients and servers
  - int sock_fd = socket(PF_INET, SOCK_STREAM, IPPROTO_TCP);
  - One socket can be used for two-way communication

- int bind(int socket, const struct sockaddr *address, socklen_t address_len);
  - Associate a socket with an IP address and port number
  - used by servers
  - struct sockaddr_in sockaddr – family, address, port

Sockets API

- int listen(int socket, int backlog);
    - socket: socket to listen on
    - used by servers
    - backlog: maximum number of waiting connections
    - err = listen(sock_fd, MAX_WAITING_CONNECTIONS);
- int accept(int socket, struct sockaddr *address, socklen_t *address_len);
    - used by servers
    - socket: socket to listen on
    - address: pointer to sockaddr struct to hold client information after accept returns
    - return: file descriptor

Sockets API

- int connect(int socket, struct sockaddr *address, socklen_t address_len);
  - attempt to connect to the specified IP address and port described in address
  - used by clients
- int close(int fd);
  - used by both clients and servers
  - (also used for file I/O)
  - fd: socket fd to close

Sockets API

- ssize_t read(int fd, void *buf, size_t nbyte);
  - used by both clients and servers
  - (also used for file I/O)
  - fd: (socket) fd to read from
  - buf: buffer to read into
  - nbytes: buf length

- ssize_t write(int fd, void *buf, size_t nbyte);
  - used by both clients and servers
  - (also used for file I/O)
  - fd: (socket) fd to write to
  - buf: buffer to write
  - nbytes: buf length

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Byte Ordering Reminder

- **So, how are the bytes within a multi-byte word ordered in memory?**
- **Conventions**
  - Big Endian: Sun, PPC Mac, Internet
    - Least significant byte has highest address
  - Little Endian: x86, ARM processors running Android, iOS, and Windows
    - Least significant byte has lowest address

Byte Ordering Reminder

- **So, how are the bytes within a multi-byte word ordered in memory?**
- **Conventions**
  - Big Endian: Sun, PPC Mac, **Internet**
    - Least significant byte has highest address
- **Make sure to use correct endianness**

Proxy - Functionality

- **Should work on vast majority of sites**
  - Twitch, CNN, NY Times, etc.
  - Some features of sites which require the POST operation (sending data to the website), will not work
    - Logging in to websites, sending Facebook message
  - HTTPS is not expected to work
    - Google, YouTube (and some other popular websites) now try to push users to HTTPs by default; watch out for that
- **Cache previous requests**
  - Use LRU eviction policy
  - Must allow for concurrent reads while maintaining consistency
  - Details in write up

Proxy - Functionality

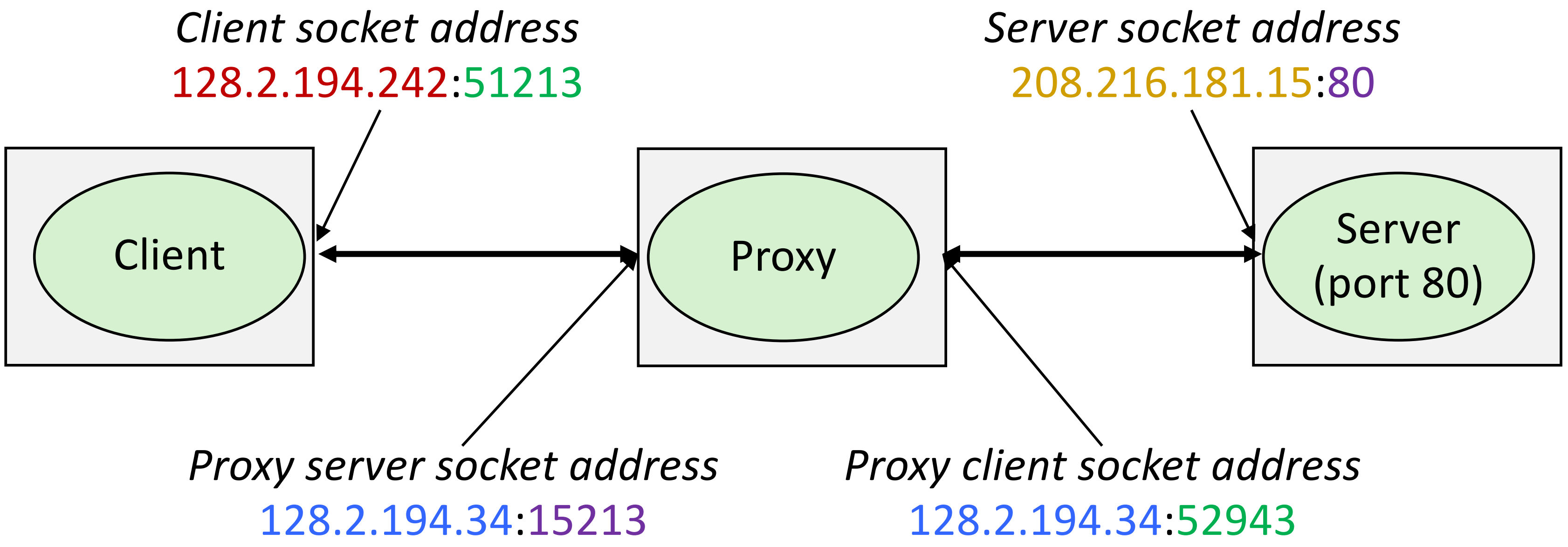
- **Why a multi-threaded cache?**
  - Sequential cache would bottleneck parallel proxy
  - Multiple threads can read cached content safely
    - Search cache for the right data and return it
    - Two threads can read from the same cache block
  - But what about writing content?
    - Overwrite block while another thread reading?
    - Two threads writing to same cache block?

Proxy - How

- Proxies are a bit special - they are a server and a client at the same time.
- They take a request from one computer (acting as the server), and make it on their behalf (as the client).
- Ultimately, the control flow of your program will look like a server, but will have to act as a client to complete the request
- **Start small**
  - Grab yourself a copy of the echo server (pg. 946) and client (pg. 947) in the book
  - Also review the tiny.c basic web server code to see how to deal with HTTP headers
    - Note that tiny.c ignores these; you may not

Proxy - How

- **What you end up with will resemble:**



Client socket address
128.2.194.242:51213

Server socket address
208.216.181.15:80

Proxy server socket address
128.2.194.34:15213

Proxy client socket address
128.2.194.34:52943

Summary

- **Step 1: Sequential Proxy**
  - Works great for simple text pages with embedded styles
- **Step 2: Concurrent Proxy**
  - multi-threading
- **Step 3 : Cache Web Objects**
  - Cache individual objects, not the whole page
  - **Use an LRU eviction policy**
  - Your caching system must allow for *concurrent reads* while maintaining consistency. Concurrency? Shared Resource?

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String manipulation in C

- **sscanf: Read input in specific format**

  *int sscanf(const char *str, const char *format, …);*

  Example:

  buf = “213 is awesome”

  // Read integer and string separated by white space from buffer ‘buf’

  // into passed variables

  ret = sscanf(buf, “%d %s %s”, &course, str1, str2);

  This results in:

  course = 213, str1 = is, str2 = awesome, ret = 3

String manipulation (cont)

- **sprintf: Write input into buffer in specific format**

  *int sprintf(char *str, const char *format, …);*

  Example:

  buf[100];

  str = “213 is awesome”

  // Build the string in double quotes (“”) using the passed arguments

  // and write to buffer ‘buf’

  sprintf(buf, “String (%s) is of length %d”, str, strlen(str));

  This results in:

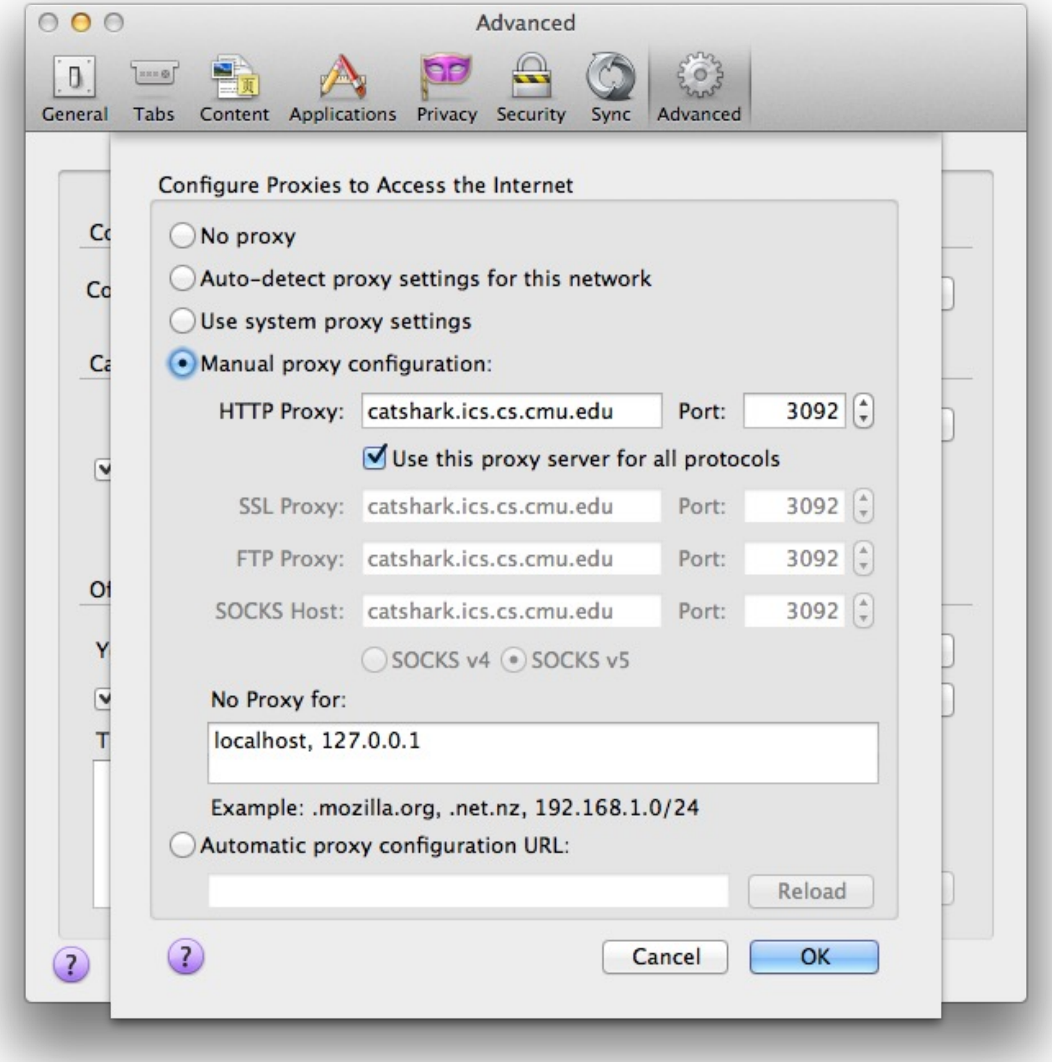
  buf = String (213 is awesome) is of length 14

String manipulation (cont)

Other useful string manipulation functions:

- strcmp, strncmp, strncasecmp
- strstr
- strlen
- strcpy, strncpy

Aside: Setting up Firefox to use a proxy



Configure Proxies to Access the Internet

○ No proxy

○ Auto-detect proxy settings for this network

○ Use system proxy settings

● Manual proxy configuration:

HTTP Proxy: catshark.ics.cs.cmu.edu Port: 3092

☑ Use this proxy server for all protocols

SSL Proxy: catshark.ics.cs.cmu.edu Port: 3092

FTP Proxy: catshark.ics.cs.cmu.edu Port: 3092

SOCKS Host: catshark.ics.cs.cmu.edu Port: 3092

○ SOCKS v4 ● SOCKS v5

No Proxy for:

localhost, 127.0.0.1

Example: .mozilla.org, .net.nz, 192.168.1.0/24

○ Automatic proxy configuration URL:

- You may use any browser, but we'll be grading with Firefox
- Preferences > Advanced > Network > Settings… (under Connection)
- Check "Use this proxy for all protocols" or your proxy will appear to work for HTTPS traffic.