Proxy Recitation

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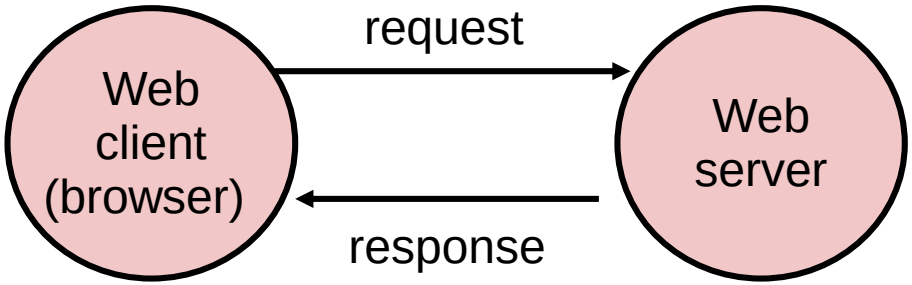
Recitation 7: May 22, 2019

Outline

- **Getting content on the web: Telnet/cURL Demo**
  - How the web really works
- **Networking Basics**
- **Proxy**
  - Due Wednesday, June 5th
- **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!

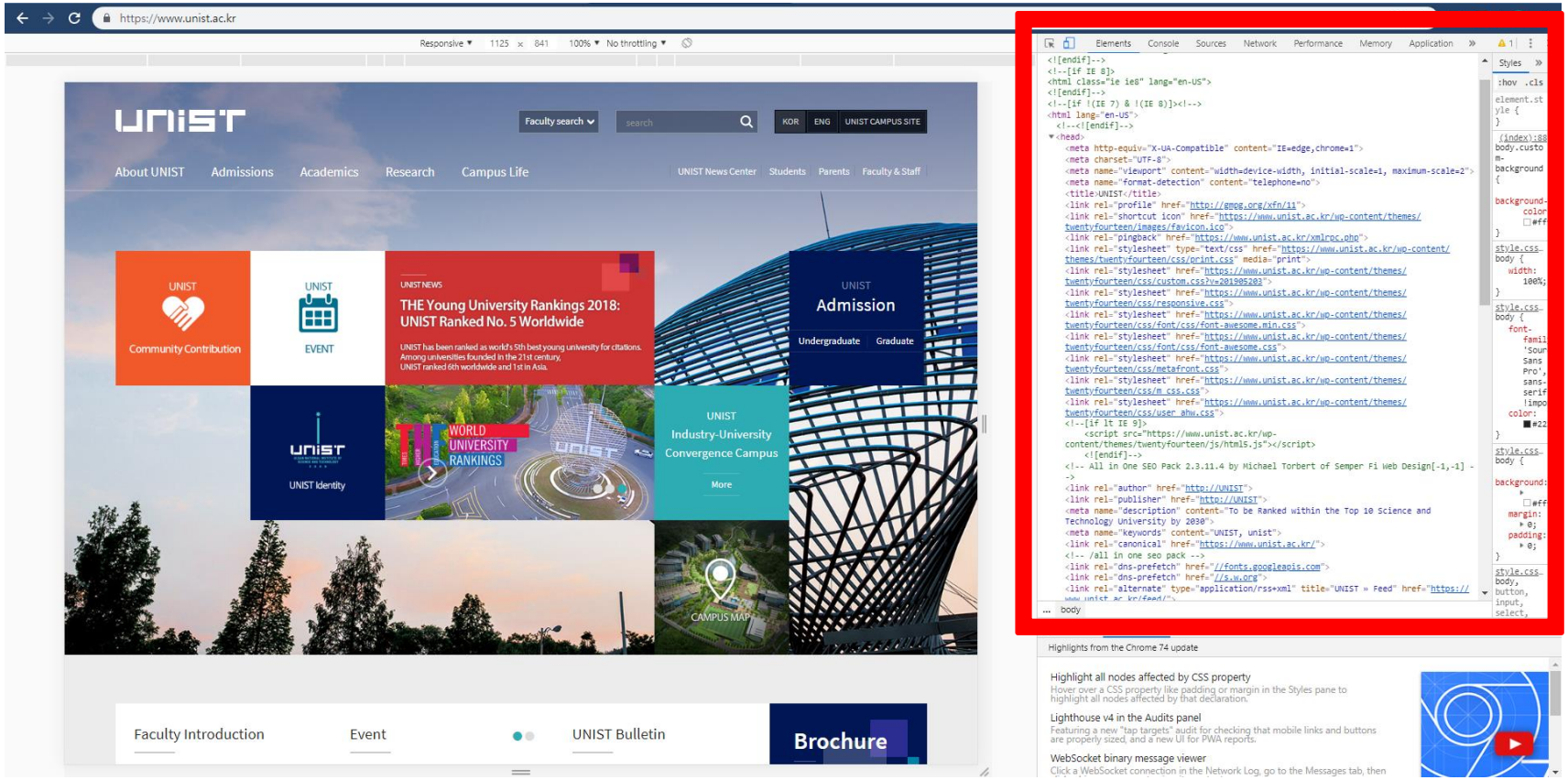
```
[rjaganna@makoshark ~]% curl http://www.cmu.edu/
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<HTML><HEAD>
<TITLE>301 Moved Permanently</TITLE>
</HEAD><BODY>
<H1>Moved Permanently</H1>
The document has moved <A HREF="http://www.cmu.edu/index.shtml">here</A>.<P>
<HR>
<ADDRESS>Apache/1.3.42 Server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

  - 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>
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>
```

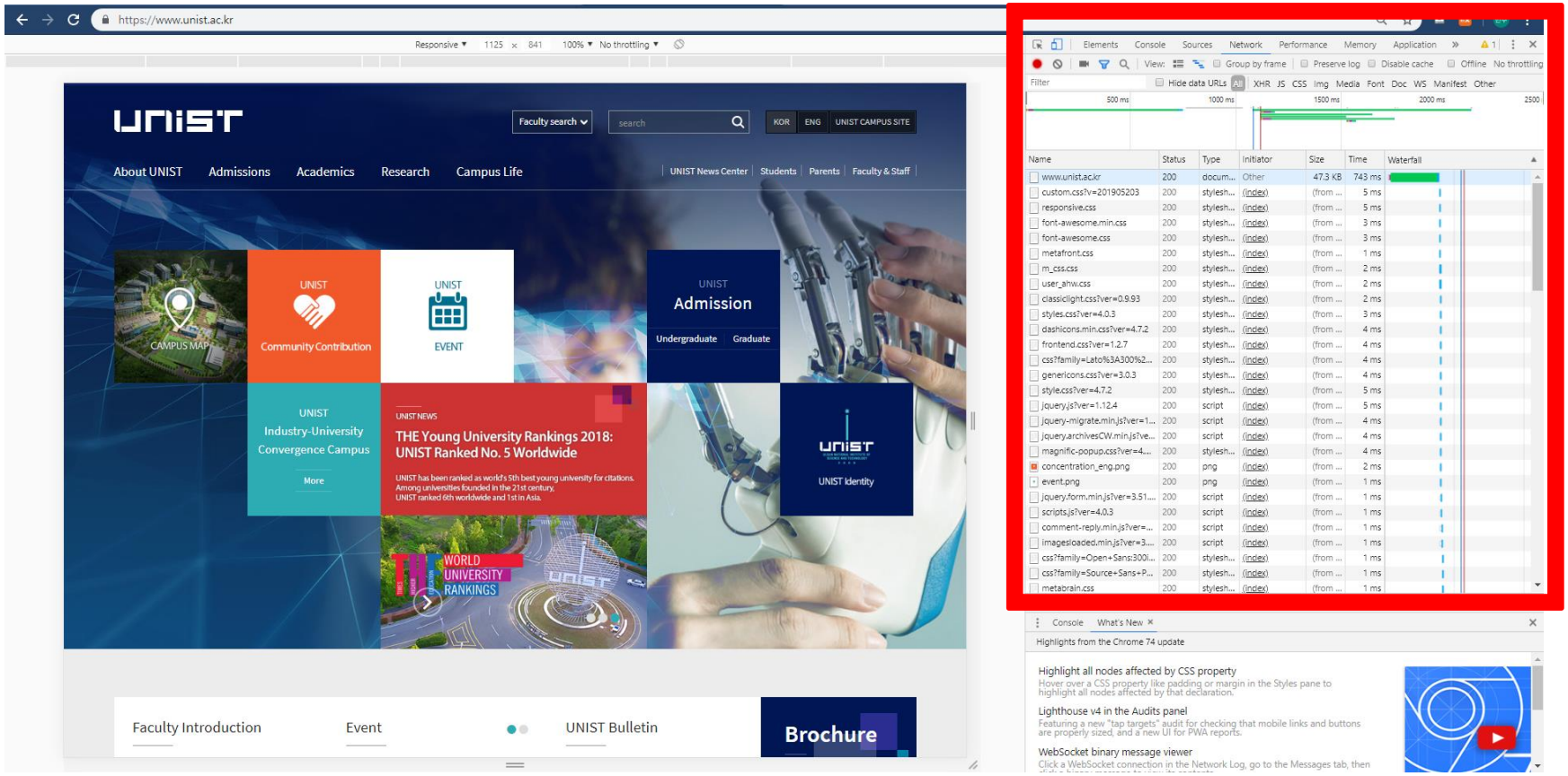
Web-browser Demo

- **Chrome Developer Console**
  - Type domain name (ip address) on search bar, press F12 key and see that what codes have been sent from web server.
  - [Elements tab]



Web-browser Demo

- **Chrome Developer Console**
  - Type domain name (ip address) on search bar, press F12 key and see that what codes have been sent from web server.
  - [Network tab]

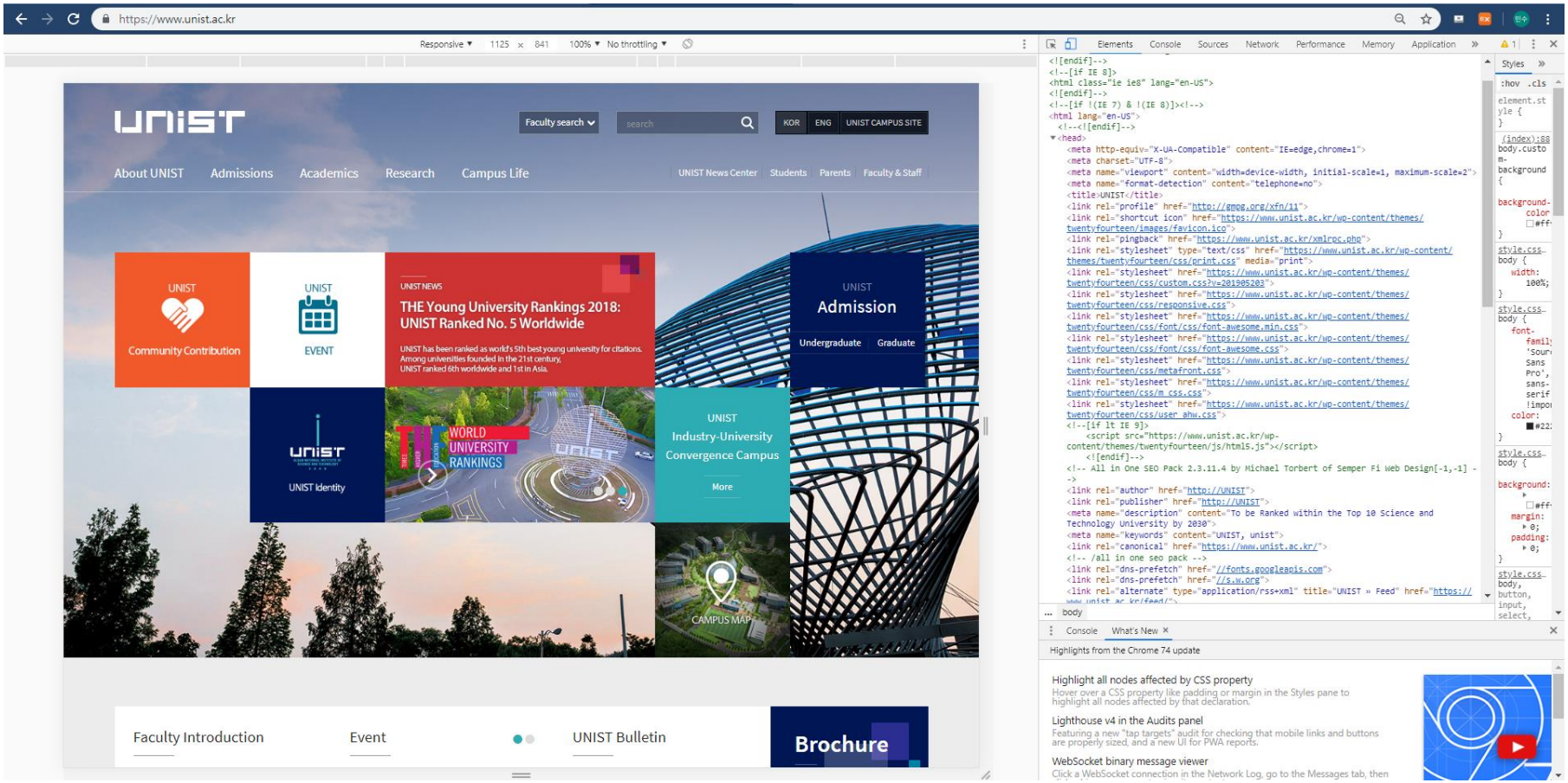


How the Web Really Works

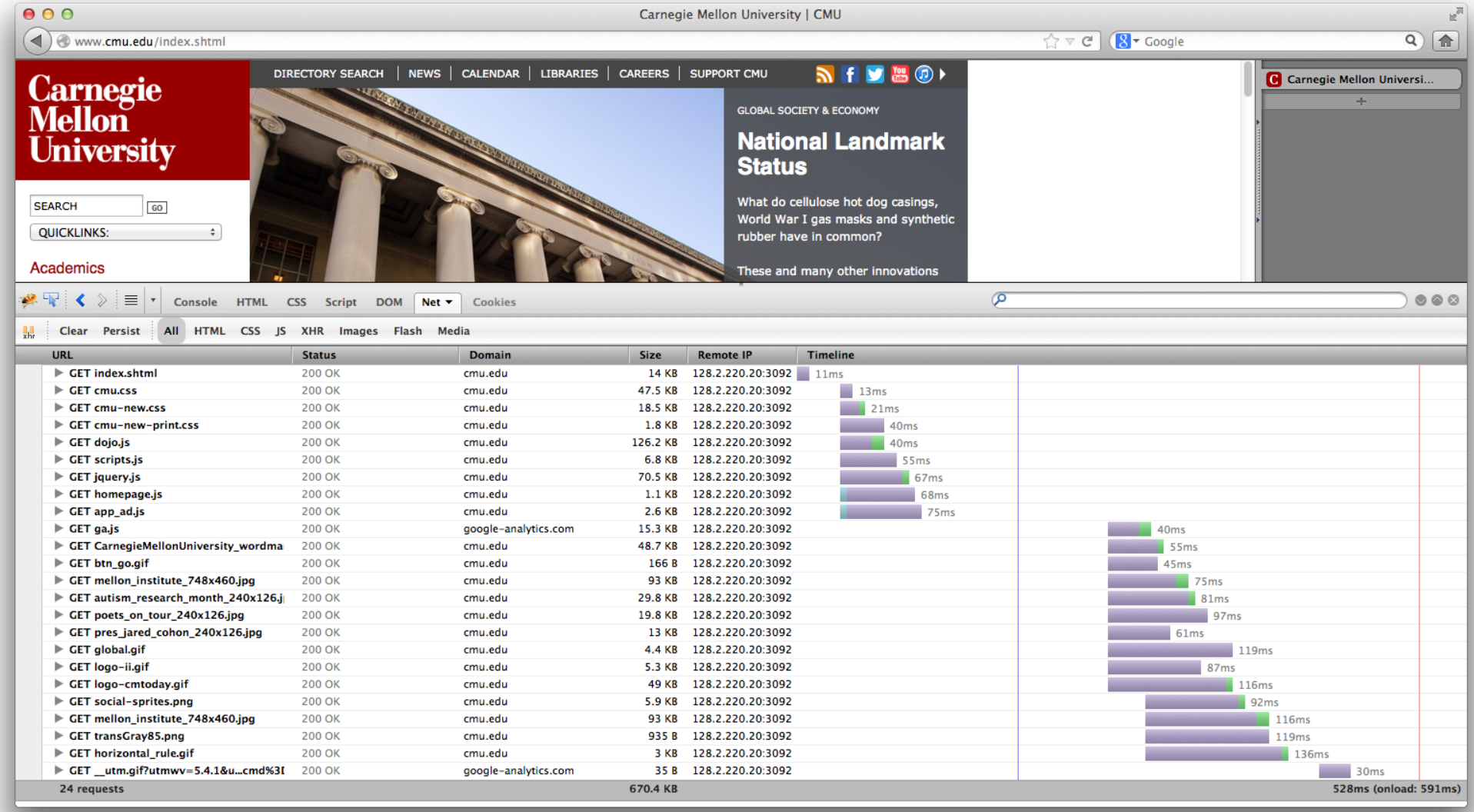
- **In reality, a single HTML page today may depend on 10s or 100s of support files (images, stylesheets, scripts, etc.)**
- **Builds a good argument for concurrent servers**
  - Just to load a single modern webpage, the client would have to wait for 10s of back-to-back request
  - I/O is likely slower 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 https://www.unist.ac.kr/:**



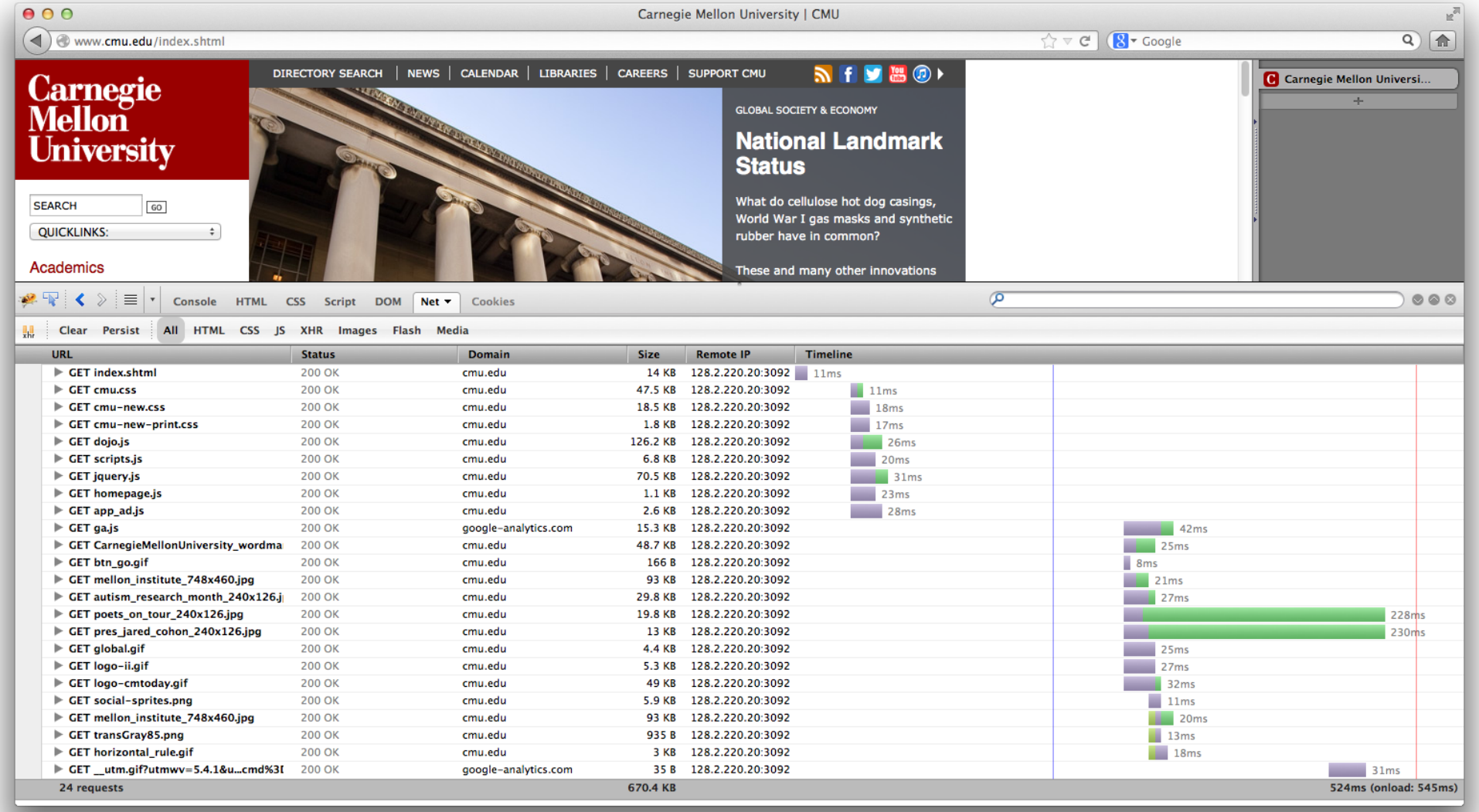
Sequential Proxy



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



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

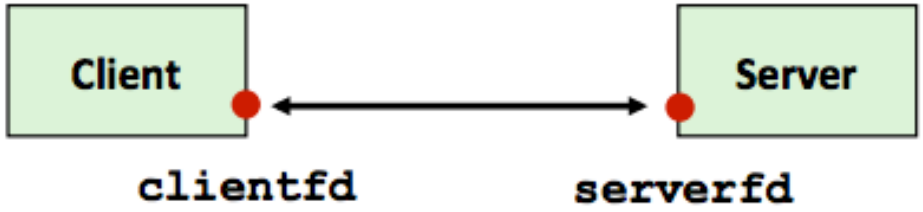
*AJAX: https://en.wikipedia.org/wiki/Ajax_(programming)

Outline

- Getting content on the web: Telnet/cURL Demo
  - How the web really works
- **Networking Basics**
- Proxy
  - Due Wednesday, June 5th
- String Manipulation in C

Sockets

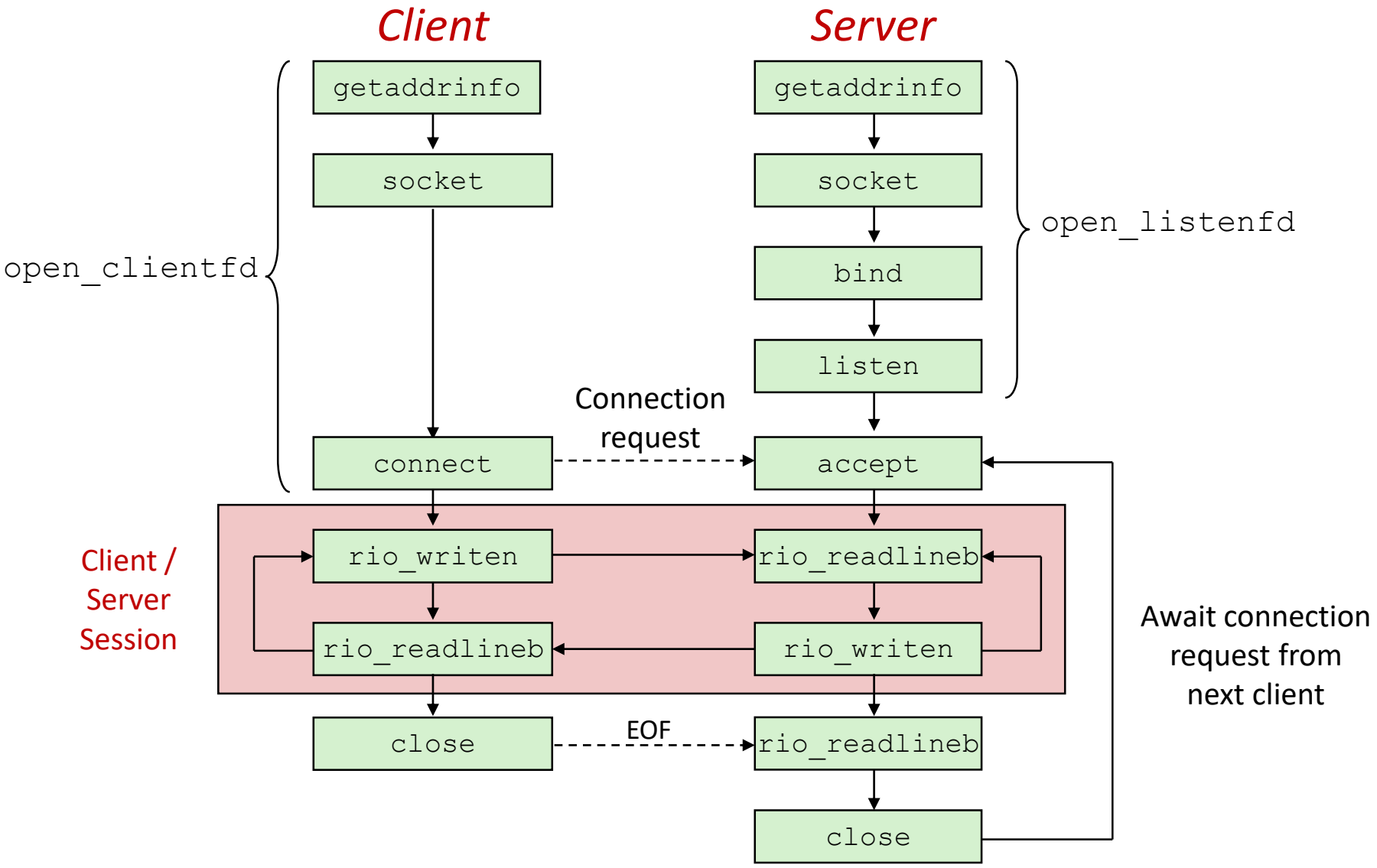
- **What is a socket?**
  - To an application, a socket is a *file descriptor that lets the application read/write from/to the network
  - (all Unix I/O devices, including networks, are modeled as files)
- **Clients and servers communicate with each other by reading from and writing to socket descriptors**



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

*file descriptor: https://stackoverflow.com/questions/30682057/socket-programming-what-is-fd-and-sd
https://en.wikipedia.org/wiki/File_descriptor#Sockets

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 for concurrency?**
  - 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?

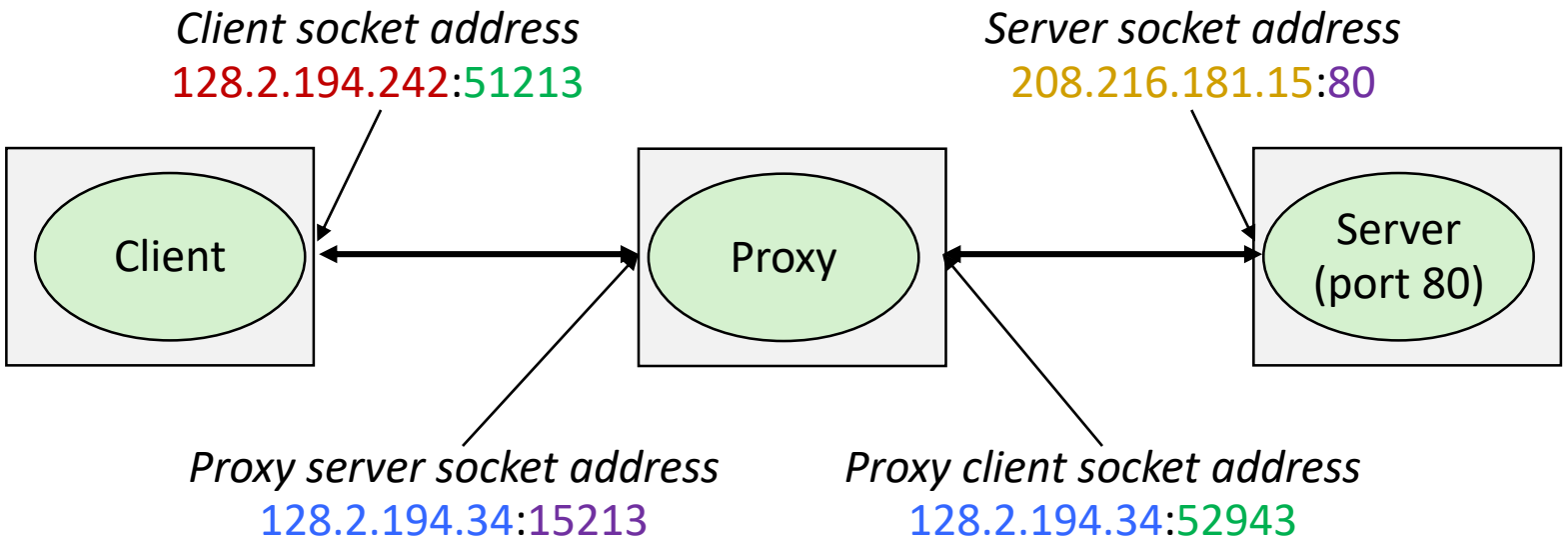
***multi-threaded: if you don't know about multi-threading, please refer slide 38**

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:**



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?

Proxy – Testing & Grading

- **New: Autograder**
  - ./driver.sh will run the same tests as autolab:
    - Ability to pull basic web pages from a server
    - Handle a (concurrent) request while another request is still pending
    - Fetch a web page again from your cache after the server has been stopped
  - This should help answer the question “is this what my proxy is supposed to do?”
  - Please don’t use this grader to definitively test your proxy; there are many things not tested here

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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**

Warnings!

- **Please read the instruction carefully!**
  - Please “README.md” and “proxylab.pdf” , then you will get to know how to do.
- **You may utilize pre-implemented functions in csapp.c and cache.c file.**
  - Utilize them as much as you can!
  - Or you can implement your own code , but I don’t recommend it.
- **Do proxy lab in a linux machine**
- **Got in a serious trouble?**
  - Please email me (minsu@unitst.ac.kr) (only for a serious trouble)

```
[minsu@uni06 proxylab]$ ./driver.sh
*** Basic ***
Starting tiny on 19448
Starting proxy on 17315
1: home.html
   Fetching ./tiny/home.html into ./.proxy using the proxy
   Fetching ./tiny/home.html into ./.noproxy directly from Tiny
   Comparing the two files
   Success: Files are identical.
2: csapp.c
   Fetching ./tiny/csapp.c into ./.proxy using the proxy
   Fetching ./tiny/csapp.c into ./.noproxy directly from Tiny
   Comparing the two files
   Success: Files are identical.
3: tiny.c
   Fetching ./tiny/tiny.c into ./.proxy using the proxy
   Fetching ./tiny/tiny.c into ./.noproxy directly from Tiny
   Comparing the two files
   Success: Files are identical.
4: godzilla.jpg
   Fetching ./tiny/godzilla.jpg into ./.proxy using the proxy
   Fetching ./tiny/godzilla.jpg into ./.noproxy directly from Tiny
   Comparing the two files
   Success: Files are identical.
5: tiny
   Fetching ./tiny/tiny into ./.proxy using the proxy
   Fetching ./tiny/tiny into ./.noproxy directly from Tiny
   Comparing the two files
   Success: Files are identical.
Killing tiny and proxy
basicScore: 40/40

*** Concurrency ***
Starting tiny on port 16068
Starting proxy on port 22691
Starting the blocking NOP server on port 29653
Trying to fetch a file from the blocking nop-server
Fetching ./tiny/home.html into ./.noproxy directly from Tiny
Fetching ./tiny/home.html into ./.proxy using the proxy
Checking whether the proxy fetch succeeded
Success: Was able to fetch tiny/home.html from the proxy.
Killing tiny, proxy, and nop-server
concurrencyScore: 15/15

*** Cache ***
Starting tiny on port 12323
Starting proxy on port 14826
Fetching ./tiny/tiny.c into ./.proxy using the proxy
Fetching ./tiny/home.html into ./.proxy using the proxy
Fetching ./tiny/csapp.c into ./.proxy using the proxy
Killing tiny
Fetching a cached copy of ./tiny/home.html into ./.noproxy
Success: Was able to fetch tiny/home.html from the cache.
Killing proxy
cacheScore: 15/15

totalScore: 70/70
```

<Results of proxy lab>

Questions?

Some Useful References

- **Regarding Proxy Lab**
  - **Network Programming in C**
    - Article

      https://www.geeksforgeeks.org/socket-programming-cc/
    - Video Lecture (Socket Programming Tutorial using C)

      https://www.youtube.com/watch?v=LtXEMwSG5-8
  - **Multithreading in C**
    - Article

      https://www.geeksforgeeks.org/multithreading-c-2/
    - Video Lecture (Threading Basics in C)

      https://www.youtube.com/watch?v=nVESQQg-Oiw

Some Useful References

- **Other Materials**
  - For completing proxy lab, you don't need to know deeply about concepts which were represented in the following links, but I think learning them will be helpful to you.
  - **Process vs Thread**
    - https://www.backblaze.com/blog/whats-the-diff-programs-processes-and-threads/
  - **Multiprocessing vs Multithreading**
    - https://www.youtube.com/watch?v=oIN488Ldg9k
  - **OSI 7 Layer**
    - https://www.youtube.com/watch?v=vv4y_uOneC0
  - **Differences between TCP and UDP**
    - https://www.howtogeek.com/190014/htg-explains-what-is-the-difference-between-tcp-and-udp/