System Programming Lab #6

2021-06-02

sp-tas

Lab Assignment #6 : Proxy Lab

- Download skeleton code & pdf from eTL

  proxylab-handout.tar, proxylab-handout.pdf

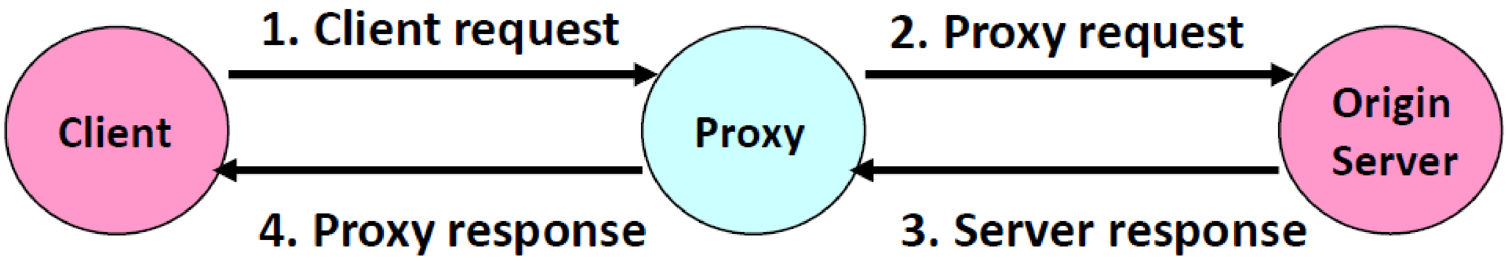
- Hand In
  - First change STUNO to yours defined in Makefile
  - ‘make handin’ command will generate a tarball automatically
    - 구현 디렉토리 압축파일: 학번-proxylab.tar   eg) 2021-12345-proxylab.tar
  - Upload your files eTL
    - 압축파일 양식 : [학번]_[이름]_proxylab.zip
    - Ex) 2021-12345_홍길동_proxylab.zip
  - A zip file should include
  - (1) a tarball of your implementation directory (2) report
    - tarball 양식 : [학번]-proxylab-handin.tar eg) 2021-12345-proxylab-handin.tar

      Report 양식 : [학번]_[이름]_proxylab_report.pdf (or .doc, .txt etc)

- Please, READ the Hand-out and Lab material thoroughly!
- Assigned : June 2nd
- Deadline : June 16th, 23:59:59 **(3 Day Delay Allowed)**

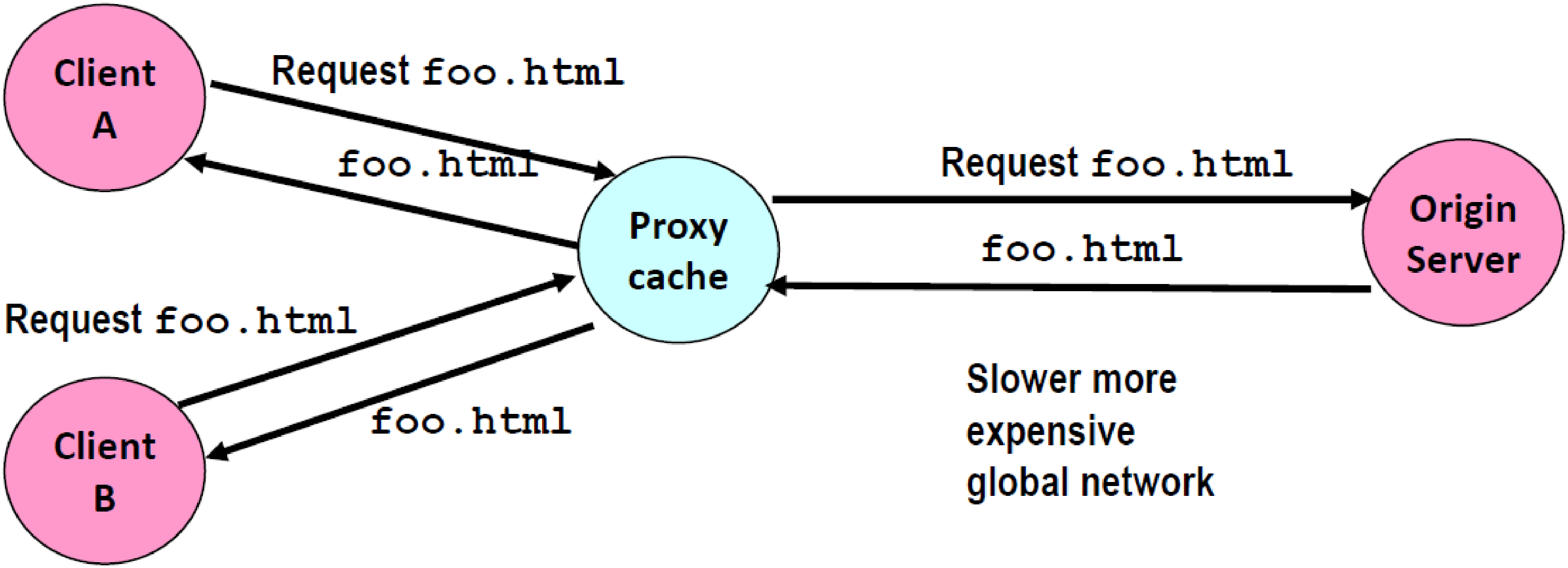
Proxies

- 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**
  - Examples: Caching, logging, anonymization, filtering, transcoding

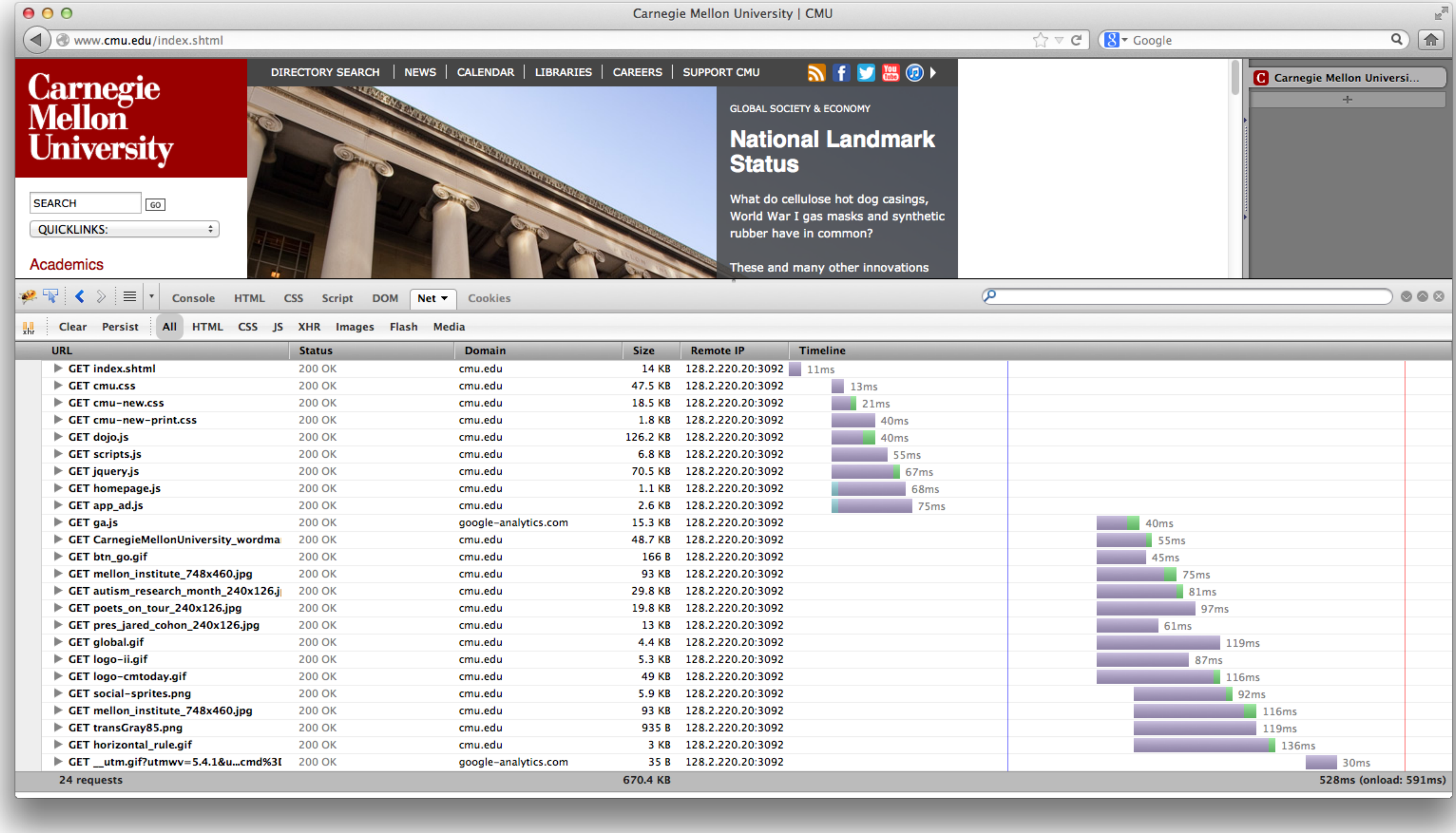


Fast inexpensive local network

How the Web Really Works

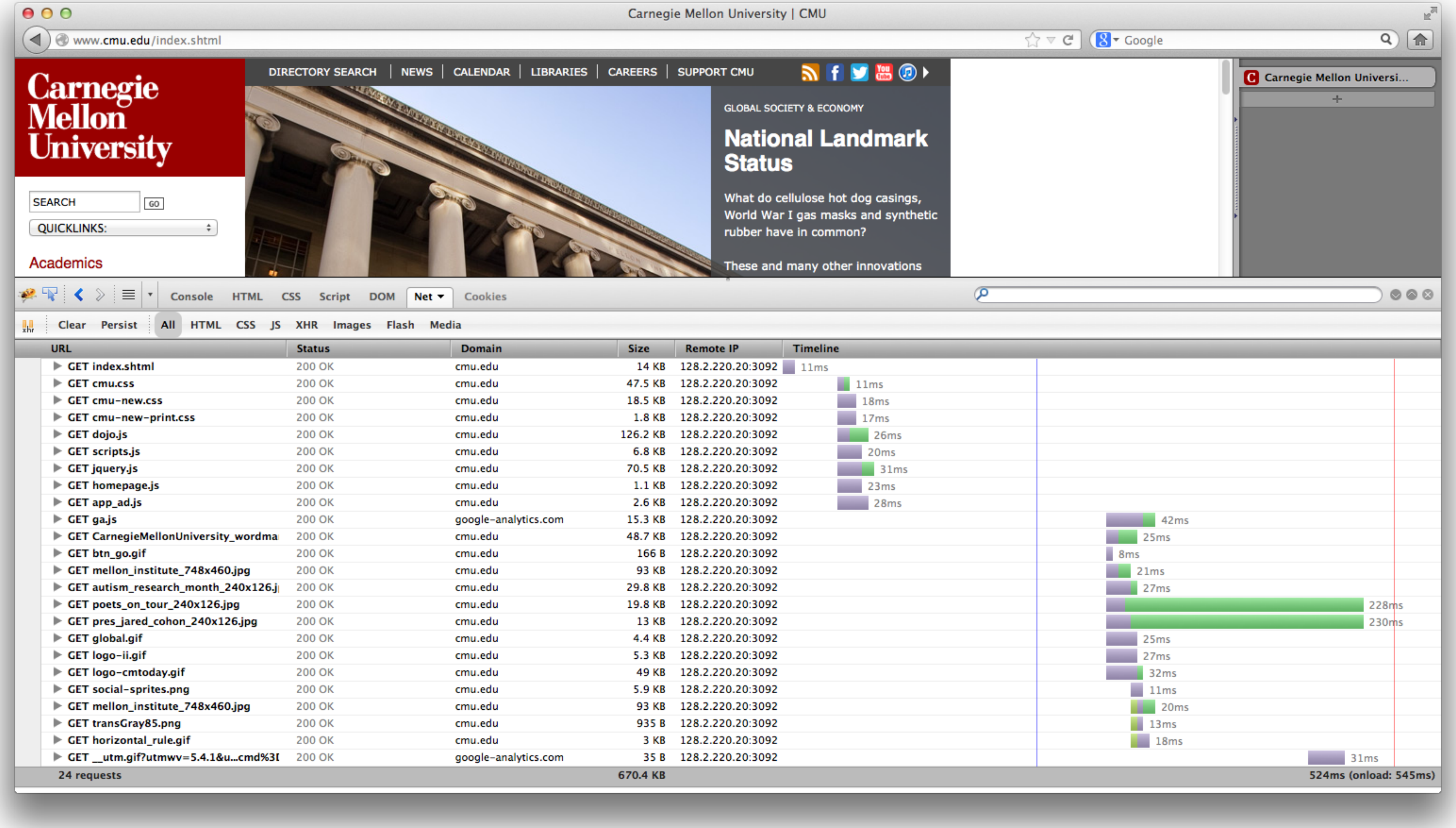
- In reality, a single HTML page today may depend on 10s or 100s of support files (images, stylesheets, scripts, etc.)
- Builds a good argument for concurrent servers
  - Just to load a single modern webpage, the client would have to wait for 10s of back-to-back request
  - I/O is likely slower than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

Sequential Proxy


Carnegie Mellon University | CMU
www.cmu.edu/index.shtml
Google
Carnegie Mellon University
DIRECTORY SEARCH | NEWS | CALENDAR | LIBRARIES | CAREERS | SUPPORT CMU
SEARCH
GO
QUICKLINKS:
Academics
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
Carnegie Mellon Universi...
Console HTML CSS Script DOM Net Cookies
Clear Persist All HTML CSS JS XHR Images Flash Media

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)

Concurrent 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	11ms
▶ GET cmu-new.css	200 OK	cmu.edu	18.5 KB	128.2.220.20:3092	18ms
▶ 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)

You will implement

- Write a simple HTTP proxy that caches web objects

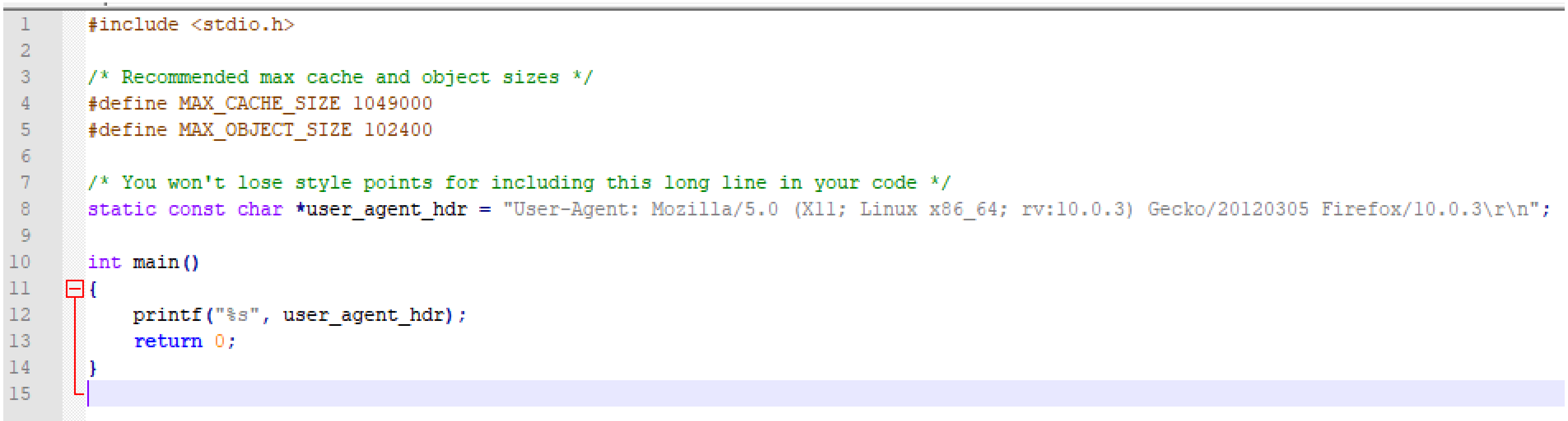
- Part 1: Implementing a sequential web Proxy
  - **Basic HTTP operation & socket programming**
    - set up the proxy to accept incoming connections
    - read and parse requests
    - forward requests to web servers
    - read the servers’ responses
    - forward those responses to the corresponding clients

- Part 2: Dealing with multiple concurrent requests
  - upgrade your proxy to deal with multiple **concurrent** connections
  - multi-threading

- Part 3: Caching web objects
  - add caching to your proxy using a simple main memory cache of recently accessed web content
  - cache individual objects, not the whole page
  - **Use an LRU eviction policy**
  - your caching system must allow for concurrent reads while maintaining consistency

Guide to start your implementation

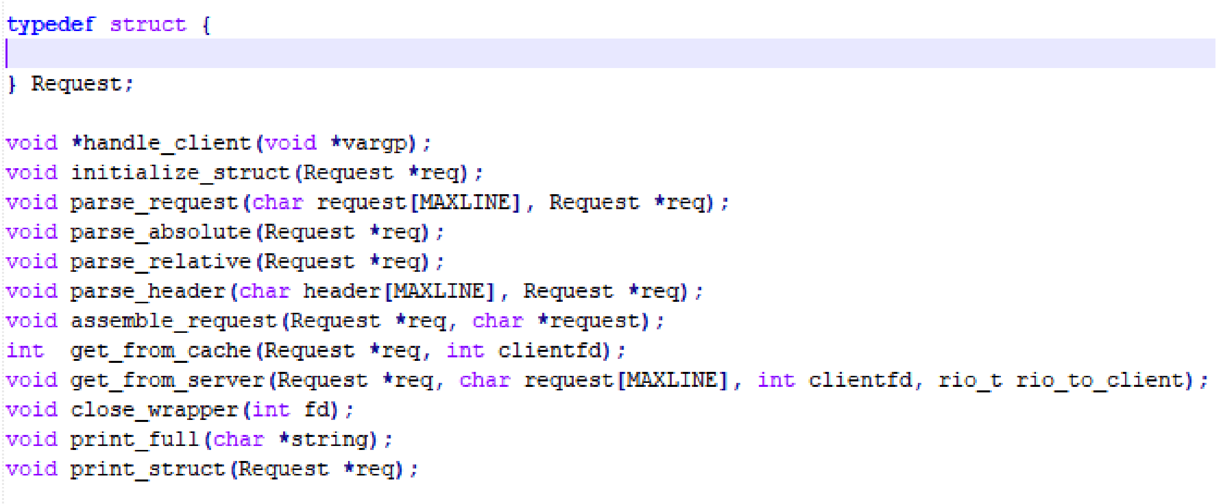
- int main(int argc, char *argv[])
    - initialize everything such as data structure
    - checking port number
    - establish listening requests
    - when a client connects, spawn a new thread to handle it



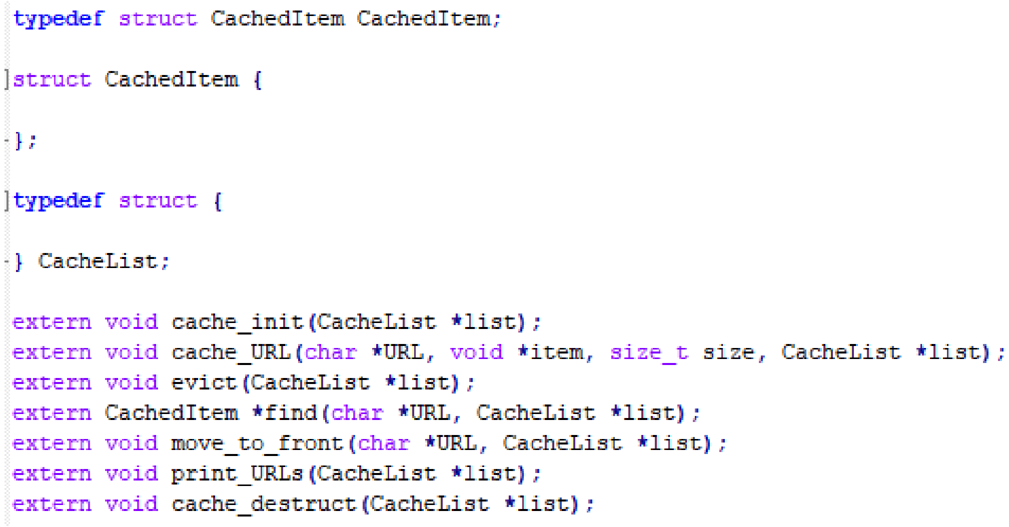
```c
#include <stdio.h>

/* Recommended max cache and object sizes */
#define MAX_CACHE_SIZE 1049000
#define MAX_OBJECT_SIZE 102400

/* You won't lose style points for including this long line in your code */
static const char *user_agent_hdr = "User-Agent: Mozilla/5.0 (X11; Linux x86_64; rv:10.0.3) Gecko/20120305 Firefox/10.0.3\r\n";

int main()
{
    printf("%s", user_agent_hdr);
    return 0;
}

```

Guide to start your implementation

- TAs implemented following structures and functions



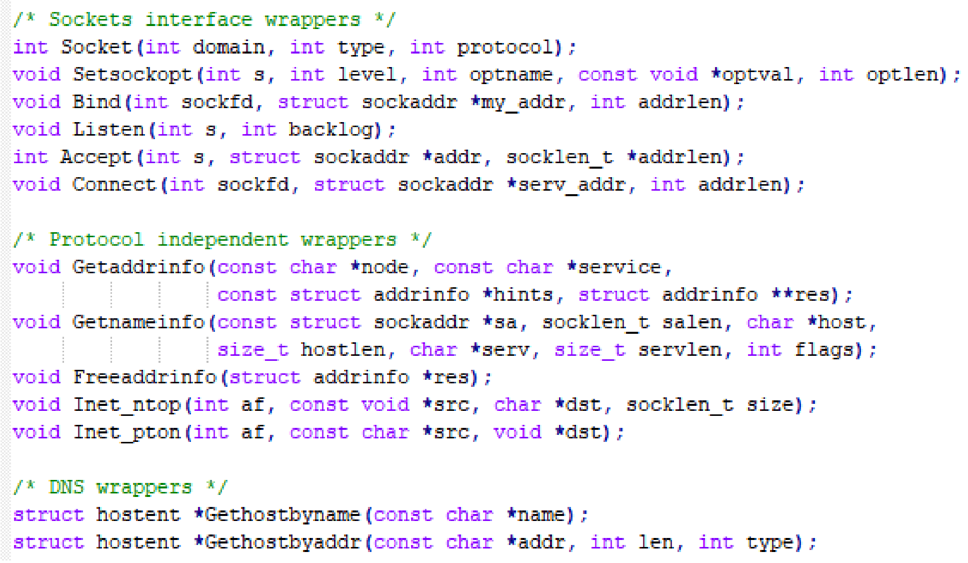
```c
typedef struct {

} Request;

void *handle_client(void *vargp);
void initialize_struct(Request *req);
void parse_request(char request[MAXLINE], Request *req);
void parse_absolute(Request *req);
void parse_relative(Request *req);
void parse_header(char header[MAXLINE], Request *req);
void assemble_request(Request *req, char *request);
int  get_from_cache(Request *req, int clientfd);
void get_from_server(Request *req, char request[MAXLINE], int clientfd, rio_t rio_to_client);
void close_wrapper(int fd);
void print_full(char *string);
void print_struct(Request *req);
```



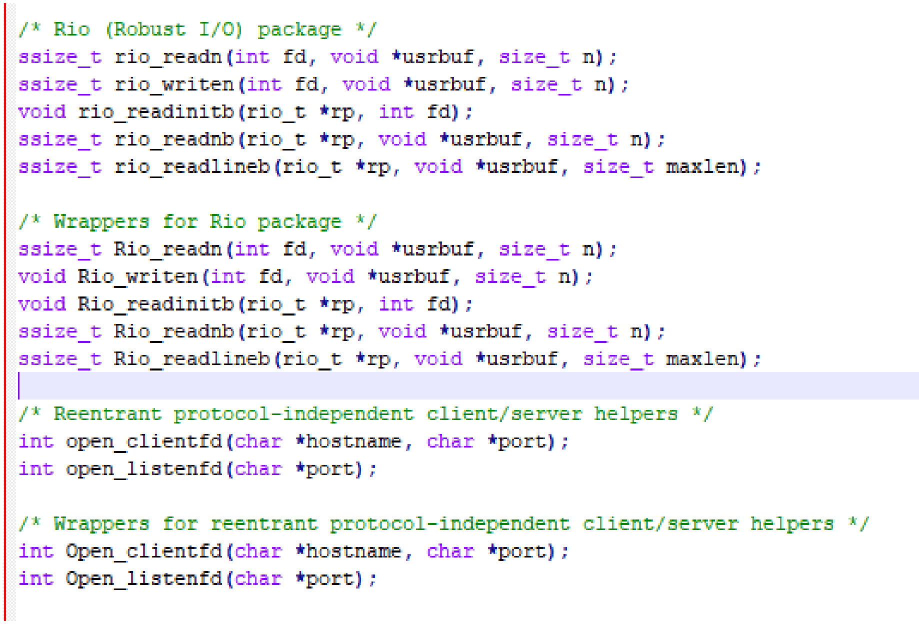
```c
typedef struct CachedItem CachedItem;

struct CachedItem {

};

typedef struct {

} CacheList;

extern void cache_init(CacheList *list);
extern void cache_URL(char *URL, void *item, size_t size, CacheList *list);
extern void evict(CacheList *list);
extern CachedItem *find(char *URL, CacheList *list);
extern void move_to_front(char *URL, CacheList *list);
extern void print_URLs(CacheList *list);
extern void cache_destruct(CacheList *list);
```

Use csapp.[ch] functions

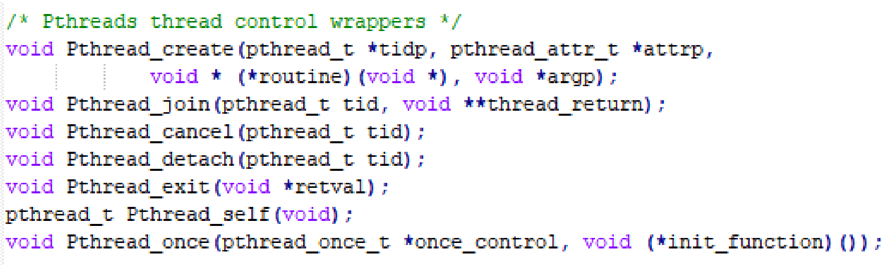
- Also, csapp.[ch] codes are included! yeah!



```
/* Sockets interface wrappers */
int Socket(int domain, int type, int protocol);
void Setsockopt(int s, int level, int optname, const void *optval, int optlen);
void Bind(int sockfd, struct sockaddr *my_addr, int addrlen);
void Listen(int s, int backlog);
int Accept(int s, struct sockaddr *addr, socklen_t *addrlen);
void Connect(int sockfd, struct sockaddr *serv_addr, int addrlen);

/* Protocol independent wrappers */
void Getaddrinfo(const char *node, const char *service,
                 const struct addrinfo *hints, struct addrinfo **res);
void Getnameinfo(const struct sockaddr *sa, socklen_t salen, char *host,
                 size_t hostlen, char *serv, size_t servlen, int flags);
void Freeaddrinfo(struct addrinfo *res);
void Inet_ntop(int af, const void *src, char *dst, socklen_t size);
void Inet_pton(int af, const char *src, void *dst);

/* DNS wrappers */
struct hostent *Gethostbyname(const char *name);
struct hostent *Gethostbyaddr(const char *addr, int len, int type);
```



```
/* Rio (Robust I/O) package */
ssize_t rio_readn(int fd, void *usrbuf, size_t n);
ssize_t rio_writen(int fd, void *usrbuf, size_t n);
void rio_readinitb(rio_t *rp, int fd);
ssize_t rio_readnb(rio_t *rp, void *usrbuf, size_t n);
ssize_t rio_readlineb(rio_t *rp, void *usrbuf, size_t maxlen);

/* Wrappers for Rio package */
ssize_t Rio_readn(int fd, void *usrbuf, size_t n);
void Rio_writen(int fd, void *usrbuf, size_t n);
void Rio_readinitb(rio_t *rp, int fd);
ssize_t Rio_readnb(rio_t *rp, void *usrbuf, size_t n);
ssize_t Rio_readlineb(rio_t *rp, void *usrbuf, size_t maxlen);

/* Reentrant protocol-independent client/server helpers */
int open_clientfd(char *hostname, char *port);
int open_listenfd(char *port);

/* Wrappers for reentrant protocol-independent client/server helpers */
int Open_clientfd(char *hostname, char *port);
int Open_listenfd(char *port);
```



```
/* Pthreads thread control wrappers */
void Pthread_create(pthread_t *tidp, pthread_attr_t *attrp,
            void * (*routine)(void *), void *argp);
void Pthread_join(pthread_t tid, void **thread_return);
void Pthread_cancel(pthread_t tid);
void Pthread_detach(pthread_t tid);
void Pthread_exit(void *retval);
pthread_t Pthread_self(void);
void Pthread_once(pthread_once_t *once_control, void (*init_function)());
```

Checking Your Work

- Auto grader
  - `./driver.sh` will run the tests:
    - 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

Checking Your Work

- Test your proxy liberally
  - The web is full of special cases that want to break your proxy
  - Generate a port for yourself with `./port-for-user.pl [sp ID]`
  - Generate more ports for web servers and such with `./free-port.sh`

- Create a handin file with `make handin`
  - First you should change STUNO defined in `Makefile` to your student number
  - Will create a tar file for you with the contents of your proxylab-handin folder

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

```
ta@sp0:~$ telnet snu.ac.kr 80
Trying 147.46.10.58...
Connected to snu.ac.kr.
Escape character is '^]'.
GET /index.html HTTP/1.0

GET /index.html HTTP/1.0

HTTP/1.1 200 OK
Date: Tue, 22 May 2018 08:43:50 GMT
Set-Cookie: PHPSESSID=rlribnfbe9qj2n4if54scm2dr2; path=/; domain=.snu.ac.kr
Expires: Thu, 19 Nov 1981 08:52:00 GMT
Cache-Control: no-store, no-cache, must-revalidate, post-check=0, pre-check=0
Pragma: no-cache
Connection: close
Content-Type: text/html

<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN“ ……
<html xmlns="http://www.w3.org/1999/xhtml" lang="ko" xml:lang="ko">
<head>

........
```

Telnet/cURL Demo

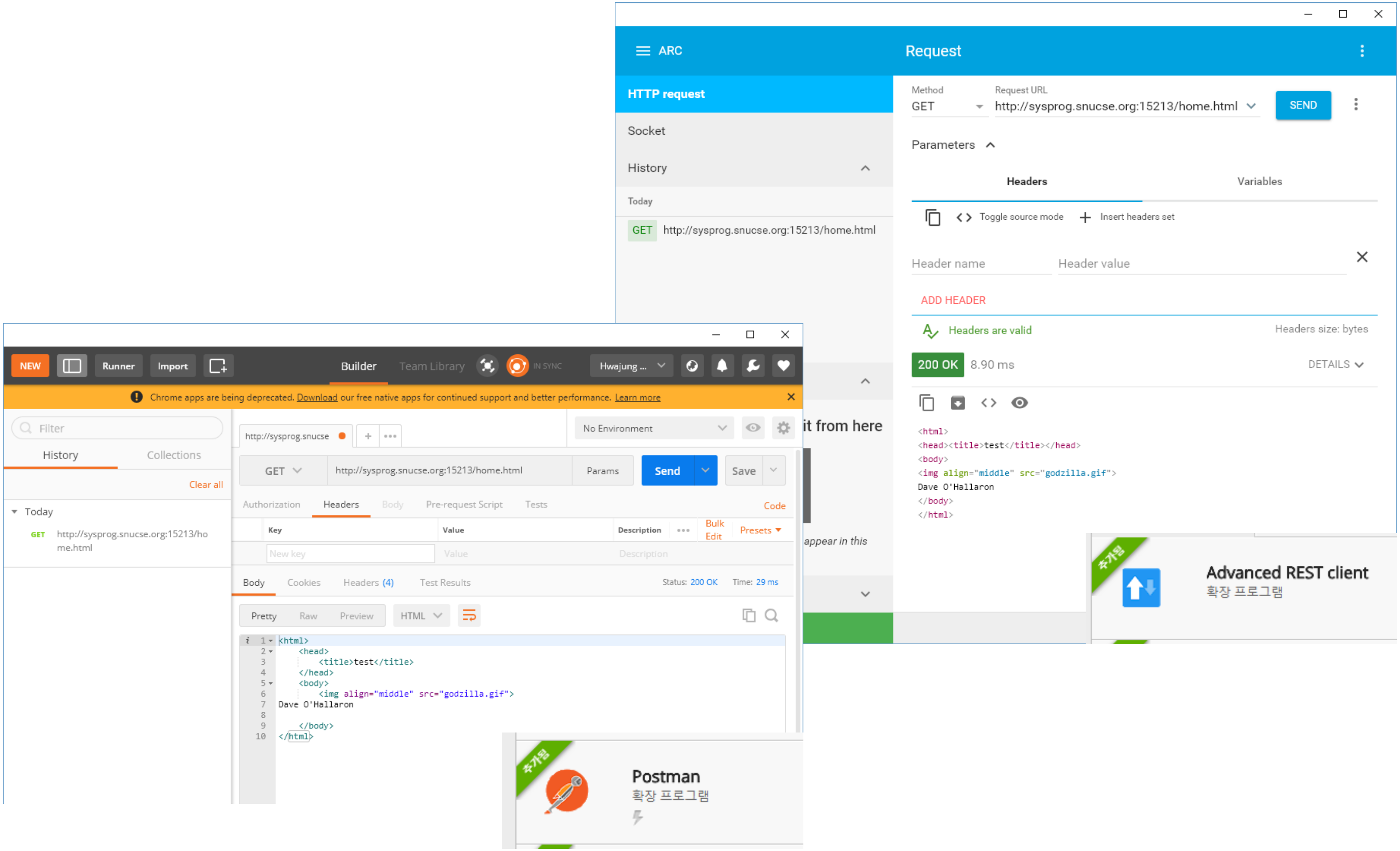
- cURL
  - “URL transfer library” with a command line program
  - Builds valid HTTP requests for you!

```
ta@sp1:~$ curl http://snu.ac.kr/index.html
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN“ ……
<html xmlns="http://www.w3.org/1999/xhtml" lang="ko" xml:lang="ko">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
<meta http-equiv="X-UA-Compatible" content="IE=edge" />
<title>서울대학교</title>
<meta name="author" content="SEOUL NATIONAL UNIVERSITY" />
<meta name="robots" content="all" />

........
```

  - Can also be used to generate HTTP proxy requests:

```
 ta@sp1:~$ curl --proxy localhost:15214 http://snu.ac.kr/index.html
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN“ ……
<html xmlns="http://www.w3.org/1999/xhtml" lang="ko" xml:lang="ko">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
<meta http-equiv="X-UA-Compatible" content="IE=edge" />
<title>서울대학교</title>
<meta name="author" content="SEOUL NATIONAL UNIVERSITY" />
<meta name="robots" content="all" />

........
```

Testing with Web Browser (chrome, REST Client)



Method: GET

Request URL: http://sysprog.snucse.org:15213/home.html

Headers are valid

200 OK 8.90 ms

```
<html>
<head><title>test</title></head>
<body>
<img align="middle" src="godzilla.gif">
Dave O'Hallaron
</body>
</html>
```

History — Today — GET http://sysprog.snucse.org:15213/home.html

Advanced REST client
확장 프로그램

GET http://sysprog.snucse.org:15213/home.html

Status: 200 OK Time: 29 ms

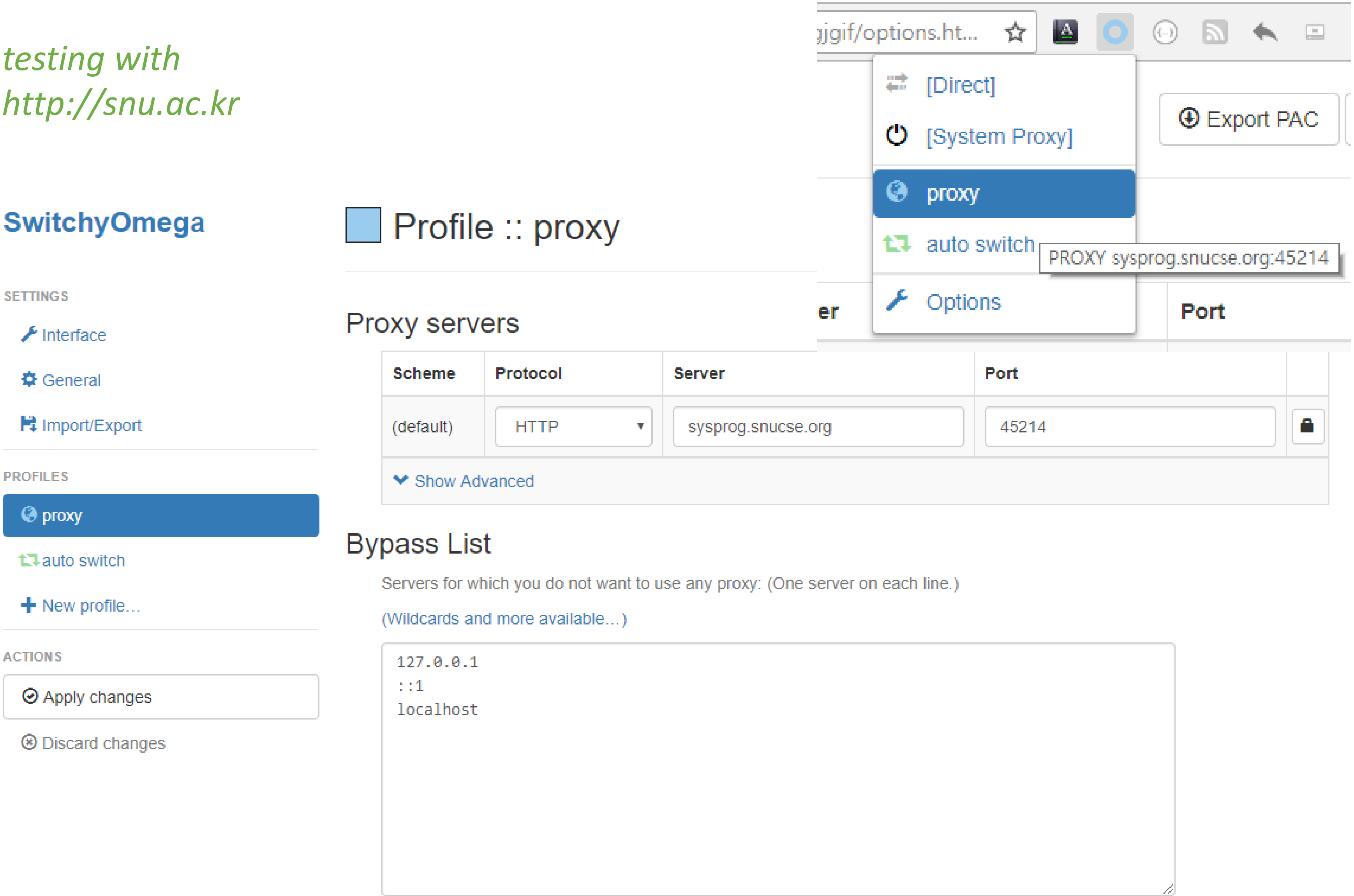
```
<html>
    <head>
        <title>test</title>
    </head>
    <body>
        <img align="middle" src="godzilla.gif">
Dave O'Hallaron

    </body>
</html>
```

Chrome apps are being deprecated. Download our free native apps for continued support and better performance. Learn more

Postman
확장 프로그램

Testing with Web Browser (chrome, set proxy)

testing with http://snu.ac.kr



PROXY sysprog.snucse.org:45214

SwitchyOmega

Profile :: proxy

Proxy servers

Scheme	Protocol	Server	Port	
(default)	HTTP	sysprog.snucse.org	45214	

Bypass List

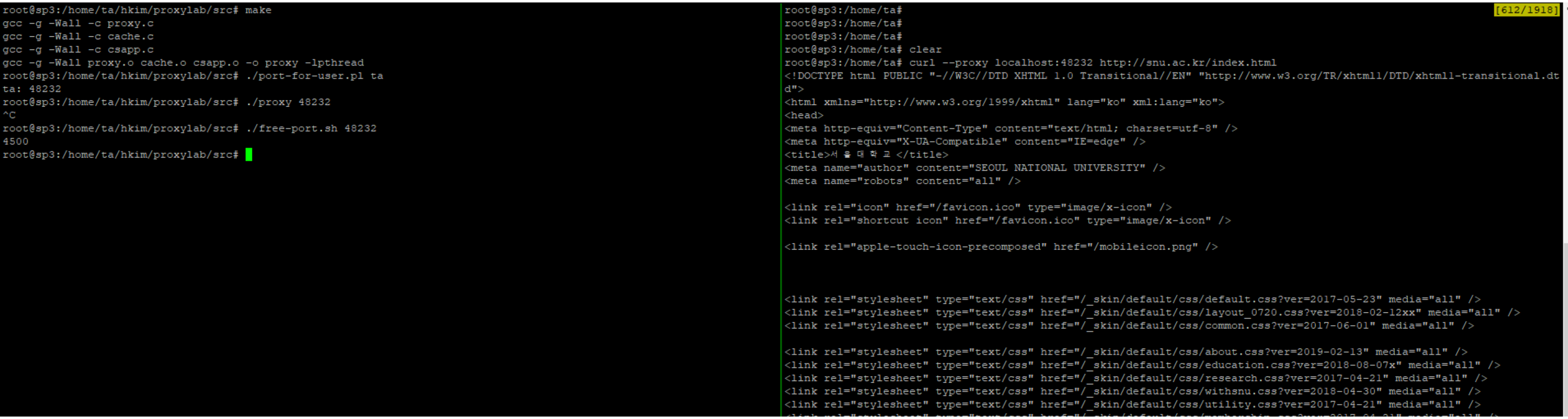
Servers for which you do not want to use any proxy: (One server on each line.)

(Wildcards and more available...)

```
127.0.0.1
::1
localhost
```

Test manually using curl

- Manually testing following real pages
  - http://www.snu.ac.kr/index.html
  - http://csapp.cs.cmu.edu
  - http://www.sk.co.kr
  - http://www.culture.go.kr
- You should always use **`./port-for-user.pl`** ***`username`*** and **`./free-port.sh`** ***`port`*** when testing your proxy manually



```
root@sp3:/home/ta/hkim/proxylab/src# make
gcc -g -Wall -c proxy.c
gcc -g -Wall -c cache.c
gcc -g -Wall -c csapp.c
gcc -g -Wall proxy.o cache.o csapp.o -o proxy -lpthread
root@sp3:/home/ta/hkim/proxylab/src# ./port-for-user.pl ta
ta: 48232
root@sp3:/home/ta/hkim/proxylab/src# ./proxy 48232
^C
root@sp3:/home/ta/hkim/proxylab/src# ./free-port.sh 48232
4500
root@sp3:/home/ta/hkim/proxylab/src#
```

```
root@sp3:/home/ta#                                                     [612/1918]
root@sp3:/home/ta#
root@sp3:/home/ta#
root@sp3:/home/ta# clear
root@sp3:/home/ta# curl --proxy localhost:48232 http://snu.ac.kr/index.html
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dt
d">
<html xmlns="http://www.w3.org/1999/xhtml" lang="ko" xml:lang="ko">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=utf-8" />
<meta http-equiv="X-UA-Compatible" content="IE=edge" />
<title>서 울 대 학 교 </title>
<meta name="author" content="SEOUL NATIONAL UNIVERSITY" />
<meta name="robots" content="all" />

<link rel="icon" href="/favicon.ico" type="image/x-icon" />
<link rel="shortcut icon" href="/favicon.ico" type="image/x-icon" />

<link rel="apple-touch-icon-precomposed" href="/mobileicon.png" />



<link rel="stylesheet" type="text/css" href="/_skin/default/css/default.css?ver=2017-05-23" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/layout_0720.css?ver=2018-02-12xx" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/common.css?ver=2017-06-01" media="all" />

<link rel="stylesheet" type="text/css" href="/_skin/default/css/about.css?ver=2019-02-13" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/education.css?ver=2018-08-07x" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/research.css?ver=2017-04-21" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/withsnu.css?ver=2018-04-30" media="all" />
<link rel="stylesheet" type="text/css" href="/_skin/default/css/utility.css?ver=2017-04-21" media="all" />
```

Evaluation

- Total Score: 100 points

- Basic Correctness (40 points)
  - basic proxy operation (auto graded)
- Concurrency (15 points)
  - handling concurrent requests (auto graded)
- Cache (15 points)
  - working cache (auto graded)
- Real Pages (20 points)
  - correctly serving the real pages (5 points each)
- Report (10 points)
  - describes the goal of proxy lab and how to implement for each part
  - what you learn in this lab
  - what was difficult, surprising, and so on

Don’t forget!

Last year's FAQ

- Q1. Do I need to implement GET request only?
  - A1. Yes. Other requests (e.g., POST) are optional.
- Q2. Do I have to consider chunked responses?
  - A2. No, this is also optional.
- Q3. May I assume that the URI of a GET request is an absolute path? (e.g., `http://example.com/index.html`)
  - A3. Yes, relative paths(e.g., `/index.html`)are not tested.
- Q4. Which size is used for calculating the cache size?
  - A4. The size of a response message from the server is used.

Last year's FAQ

- Q5. Does the response of the same request can be changed?
    - A5. In our evaluation, the response will be the same.
- Q6. Timeout bug in `driver.sh`?
    - A6. Check if `python` and `netstat` are installed properly.
- Q7. Does the ordering of the header fields affect the response?
    - A7. No, it does not affect the response of a request.

Fin.

- Questions
  - eTL Q&A Board

- Read the handout thoroughly & start early!

- Next time (Jun. 9th)
  - Proxy LAB Q&A session on Zoom

- This is our last LAB session

  Cheer up till the end!