Network Programming – Additional Slides

- **The material in this slide deck may be useful when you do proxy lab.**
- **We encourage you to review it on your own time.**

Tiny Web Server

- **Tiny Web server described in text**
  - Tiny is a sequential Web server
  - Serves static and dynamic content to real browsers
    - text files, HTML files, GIF, PNG, and JPEG images
  - 239 lines of commented C code
  - Not as complete or robust as a real Web server
    - You can break it with poorly-formed HTTP requests (e.g., terminate lines with "`\n`" instead of "`\r\n`")

Tiny Operation

- **Accept connection from client**
- **Read request from client (via connected socket)**
- **Split into <method> <uri> <version>**
  - If method not GET, then return error
- **If URI contains “`cgi-bin`” then serve dynamic content**
  - (Would do wrong thing if had file “**`abcgi-bingo.html`**”)
  - Fork process to execute program
- **Otherwise serve static content**
  - Copy file to output

Tiny Serving Static Content

```
void serve_static(int fd, char *filename, int filesize)
{
    int srcfd;
    char *srcp, filetype[MAXLINE], buf[MAXBUF];

    /* Send response headers to client */
    get_filetype(filename, filetype);
    sprintf(buf, "HTTP/1.0 200 OK\r\n");
    sprintf(buf, "%sServer: Tiny Web Server\r\n", buf);
    sprintf(buf, "%sConnection: close\r\n", buf);
    sprintf(buf, "%sContent-length: %d\r\n", buf, filesize);
    sprintf(buf, "%sContent-type: %s\r\n\r\n", buf, filetype);
    Rio_writen(fd, buf, strlen(buf));

    /* Send response body to client */
    srcfd = Open(filename, O_RDONLY, 0);
    srcp = Mmap(0, filesize, PROT_READ, MAP_PRIVATE, srcfd, 0);
    Close(srcfd);
    Rio_writen(fd, srcp, filesize);
    Munmap(srcp, filesize);
}
```

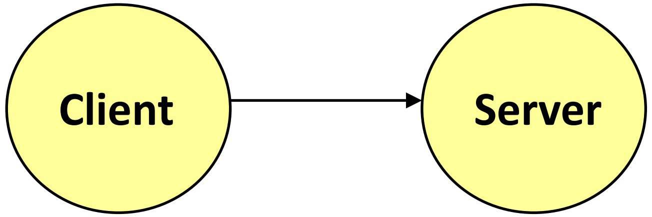
tiny.c

Serving Dynamic Content

- Client sends request to server

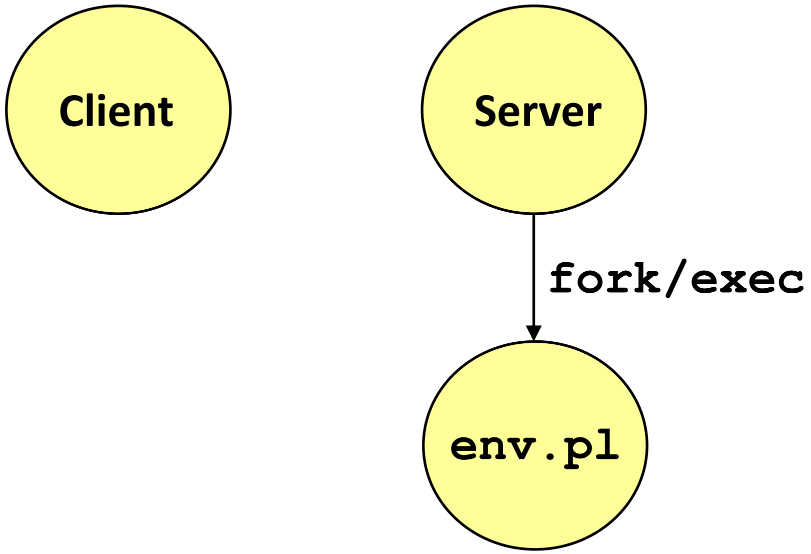
- If request URI contains the string "`/cgi-bin`", the Tiny server assumes that the request is for dynamic content

```
GET /cgi-bin/env.pl HTTP/1.1
```



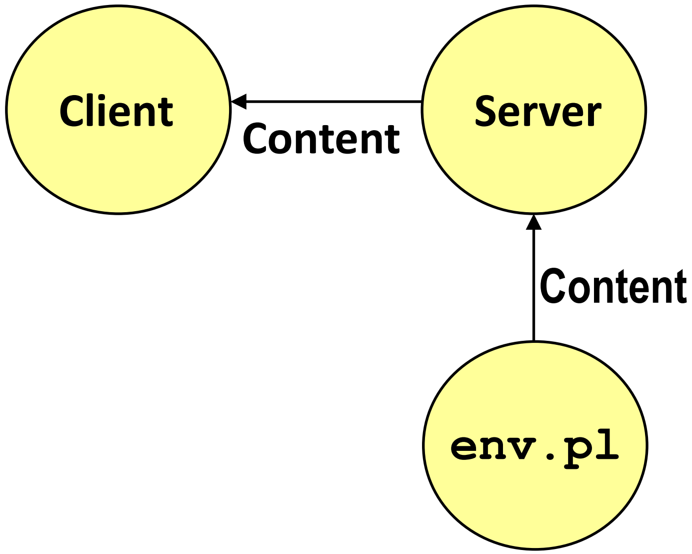
Serving Dynamic Content (cont)

- The server creates a child process and runs the program identified by the URI in that process



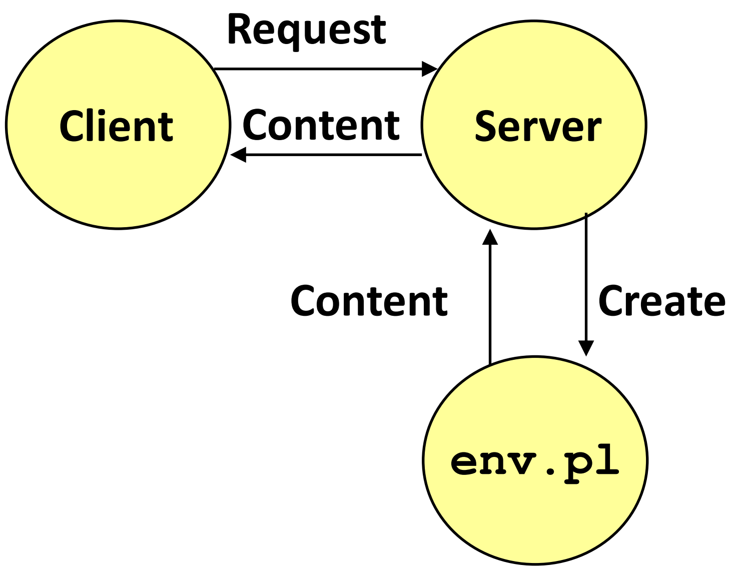
Serving Dynamic Content (cont)

- The child runs and generates the dynamic content
- The server captures the content of the child and forwards it without modification to the client



Issues in Serving Dynamic Content

- How does the client pass program arguments to the server?
- How does the server pass these arguments to the child?
- How does the server pass other info relevant to the request to the child?
- How does the server capture the content produced by the child?
- These issues are addressed by the Common Gateway Interface (CGI) specification.



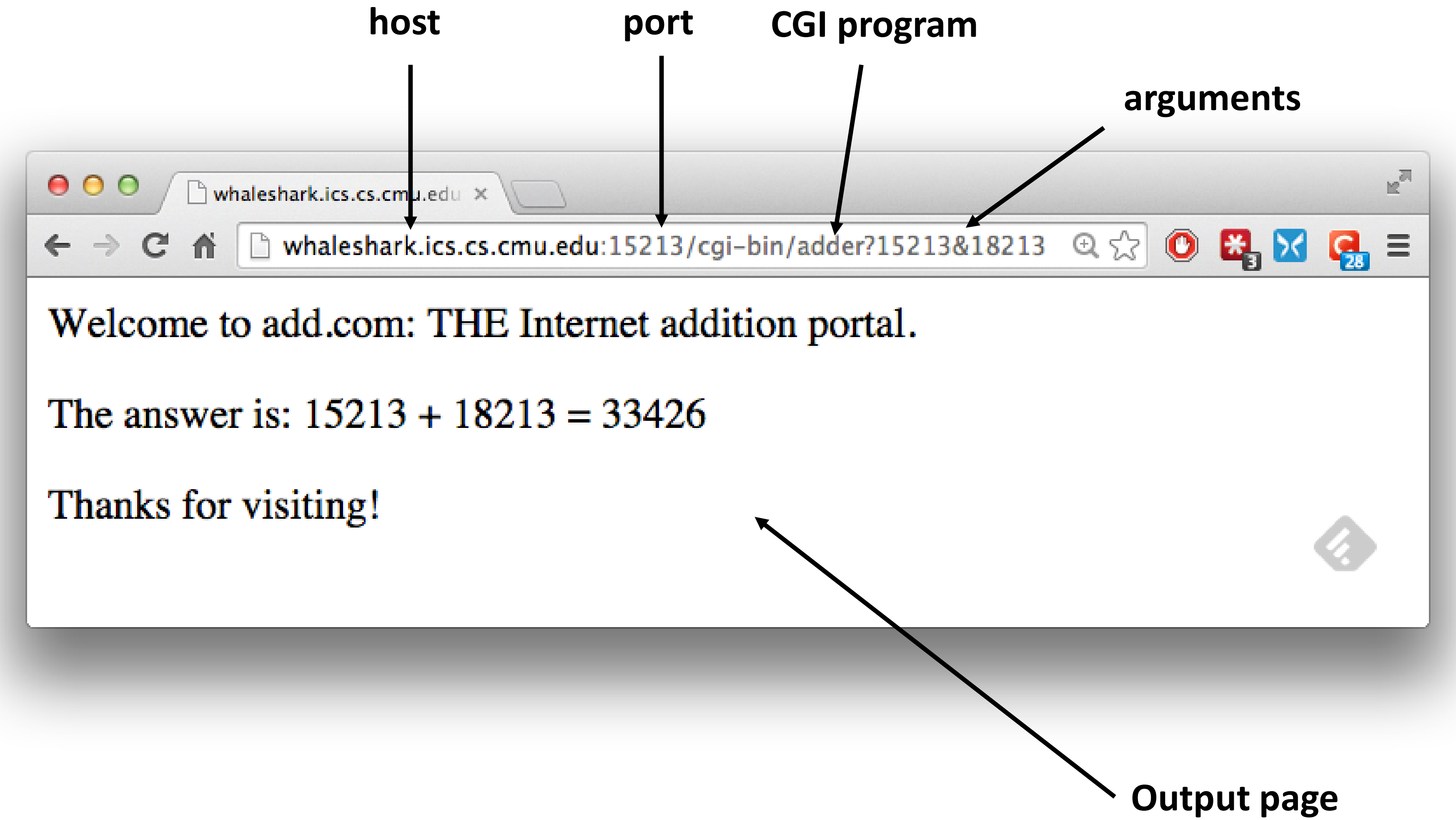
CGI

- **Because the children are written according to the CGI spec, they are often called *CGI programs.***

- **However, CGI really defines a simple standard for transferring information between the client (browser), the server, and the child process.**

- **CGI is the original standard for generating dynamic content. Has been largely replaced by other, faster techniques:**
  - E.g., fastCGI, Apache modules, Java servlets, Rails controllers
  - Avoid having to create process on the fly (expensive and slow).

The add.com Experience



host

port

CGI program

arguments

whaleshark.ics.cs.cmu.edu:15213/cgi-bin/adder?15213&18213

Welcome to add.com: THE Internet addition portal.

The answer is: 15213 + 18213 = 33426

Thanks for visiting!

Output page

Serving Dynamic Content With GET

- **<u>Question:</u> How does the client pass arguments to the server?**
- **<u>Answer:</u> The arguments are appended to the URI**

- **Can be encoded directly in a URL typed to a browser or a URL in an HTML link**
  - **`http://add.com/cgi-bin/adder?15213&18213`**
  - **`adder`** is the CGI program on the server that will do the addition.
  - argument list starts with "**`?`**"
  - arguments separated by "**`&`**"
  - spaces represented by "**`+`**" `or` "**`%20`**"

Serving Dynamic Content With GET

- **URL suffix:**
  - `cgi-bin/adder?15213&18213`

- **Result displayed on browser:**

```
Welcome to add.com: THE Internet
addition portal.

The answer is: 15213 + 18213 = 33426

Thanks for visiting!
```

Serving Dynamic Content With GET

- Question: How does the server pass these arguments to the child?
- Answer: In environment variable QUERY_STRING
  - A single string containing everything after the "?"
  - For add: QUERY_STRING = "15213&18213"

```
    /* Extract the two arguments */
    if ((buf = getenv("QUERY_STRING")) != NULL) {
        p = strchr(buf, '&');
        *p = '\0';
        strcpy(arg1, buf);
        strcpy(arg2, p+1);
        n1 = atoi(arg1);
        n2 = atoi(arg2);
    }
```

adder.c

Serving Dynamic Content with GET

- **Question:** How does the server capture the content produced by the child?
- **Answer:** The child generates its output on `stdout`. Server uses `dup2` to redirect `stdout` to its connected socket.

```
void serve_dynamic(int fd, char *filename, char *cgiargs)
{
    char buf[MAXLINE], *emptylist[] = { NULL };

    /* Return first part of HTTP response */
    sprintf(buf, "HTTP/1.0 200 OK\r\n");
    Rio_writen(fd, buf, strlen(buf));
    sprintf(buf, "Server: Tiny Web Server\r\n");
    Rio_writen(fd, buf, strlen(buf));

    if (Fork() == 0) { /* Child */
        /* Real server would set all CGI vars here */
        setenv("QUERY_STRING", cgiargs, 1);
        Dup2(fd, STDOUT_FILENO);         /* Redirect stdout to client */
        Execve(filename, emptylist, environ); /* Run CGI program */
    }
    Wait(NULL); /* Parent waits for and reaps child */
}
```

tiny.c

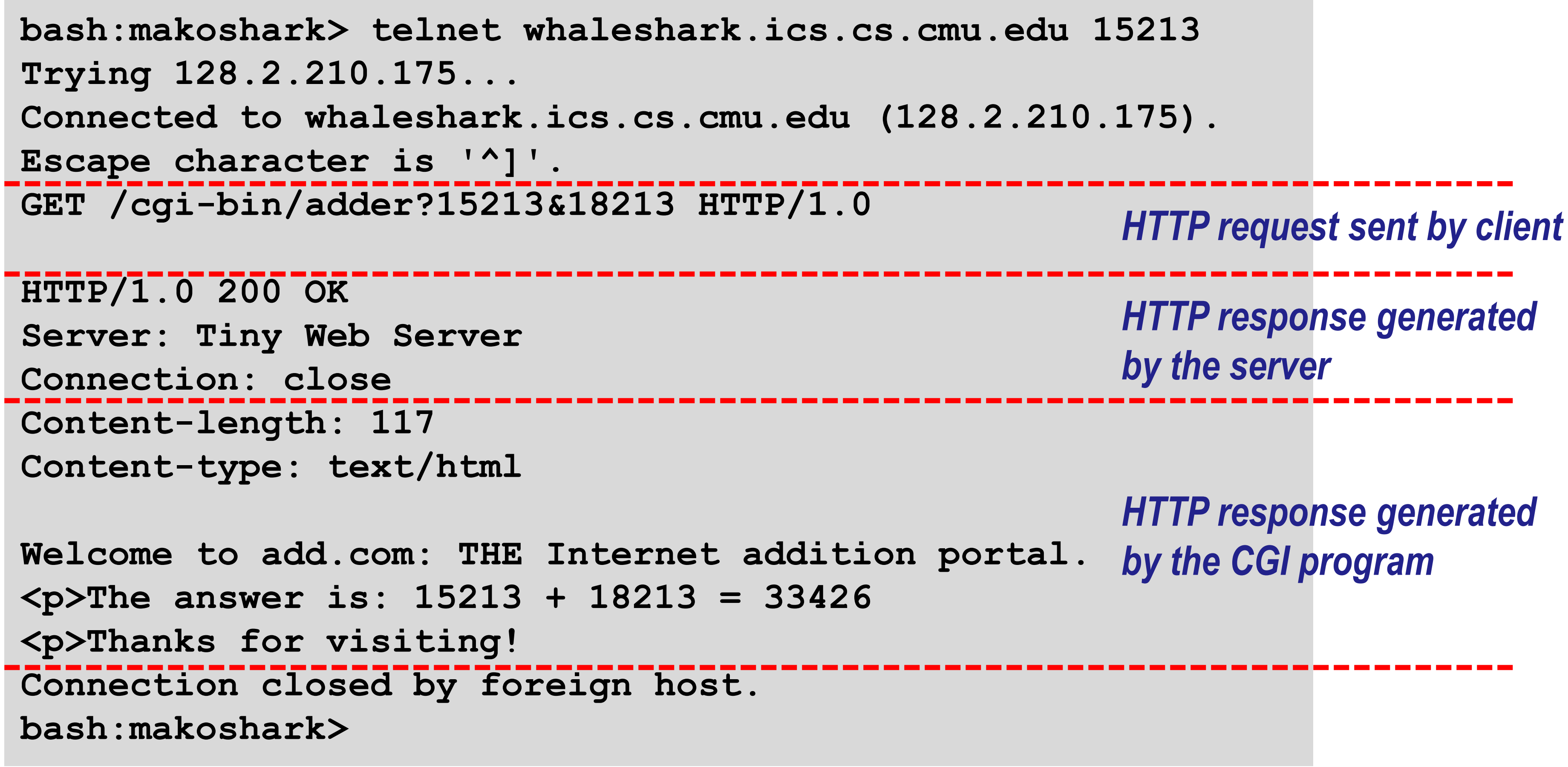
Serving Dynamic Content with GET

- Notice that only the CGI child process knows the content type and length, so it must generate those headers.

```
/* Make the response body */
sprintf(content, "Welcome to add.com: ");
sprintf(content, "%sTHE Internet addition portal.\r\n<p>", content);
sprintf(content, "%sThe answer is: %d + %d = %d\r\n<p>",
        content, n1, n2, n1 + n2);
sprintf(content, "%sThanks for visiting!\r\n", content);

/* Generate the HTTP response */
printf("Content-length: %d\r\n", (int)strlen(content));
printf("Content-type: text/html\r\n\r\n");
printf("%s", content);
fflush(stdout);

exit(0);
```

adder.c

Serving Dynamic Content With GET



```
bash:makoshark> telnet whaleshark.ics.cs.cmu.edu 15213
Trying 128.2.210.175...
Connected to whaleshark.ics.cs.cmu.edu (128.2.210.175).
Escape character is '^]'.
GET /cgi-bin/adder?15213&18213 HTTP/1.0

HTTP/1.0 200 OK
Server: Tiny Web Server
Connection: close
Content-length: 117
Content-type: text/html

Welcome to add.com: THE Internet addition portal.
<p>The answer is: 15213 + 18213 = 33426
<p>Thanks for visiting!
Connection closed by foreign host.
bash:makoshark>
```

HTTP request sent by client

HTTP response generated by the server

HTTP response generated by the CGI program

For More Information

- **W. Richard Stevens et. al. “Unix Network Programming: The Sockets Networking API”, Volume 1, Third Edition, Prentice Hall, 2003**
  - THE network programming bible.
- **Michael Kerrisk, “The Linux Programming Interface”, No Starch Press, 2010**
  - THE Linux programming bible.
- **Complete versions of all code in this lecture is available from the 213 schedule page.**
  - **`http://www.cs.cmu.edu/~213/schedule.html`**
  - csapp.{.c,h}, hostinfo.c, echoclient.c, echoserveri.c, tiny.c, adder.c
  - You can use any of this code in your assignments.

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)

HTTP Versions

- **Major differences between HTTP/1.1 and HTTP/1.0**
  - HTTP/1.0 uses a new connection for each transaction
  - HTTP/1.1 also supports *persistent connections*
    - multiple transactions over the same connection
    - `Connection: Keep-Alive`
  - HTTP/1.1 requires `HOST` header
    - `Host: www.cmu.edu`
    - Makes it possible to host multiple websites at single Internet host
  - HTTP/1.1 supports *chunked encoding*
    - `Transfer-Encoding: chunked`
  - HTTP/1.1 adds additional support for caching

GET Request to Apache Server From Firefox Browser

URI is just the suffix, not the entire URL

```
GET /~bryant/test.html HTTP/1.1
Host: www.cs.cmu.edu
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 6.0; en-US;
rv:1.9.2.11) Gecko/20101012 Firefox/3.6.11
Accept:
text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
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: 115
Connection: keep-alive
CRLF (\r\n)
```

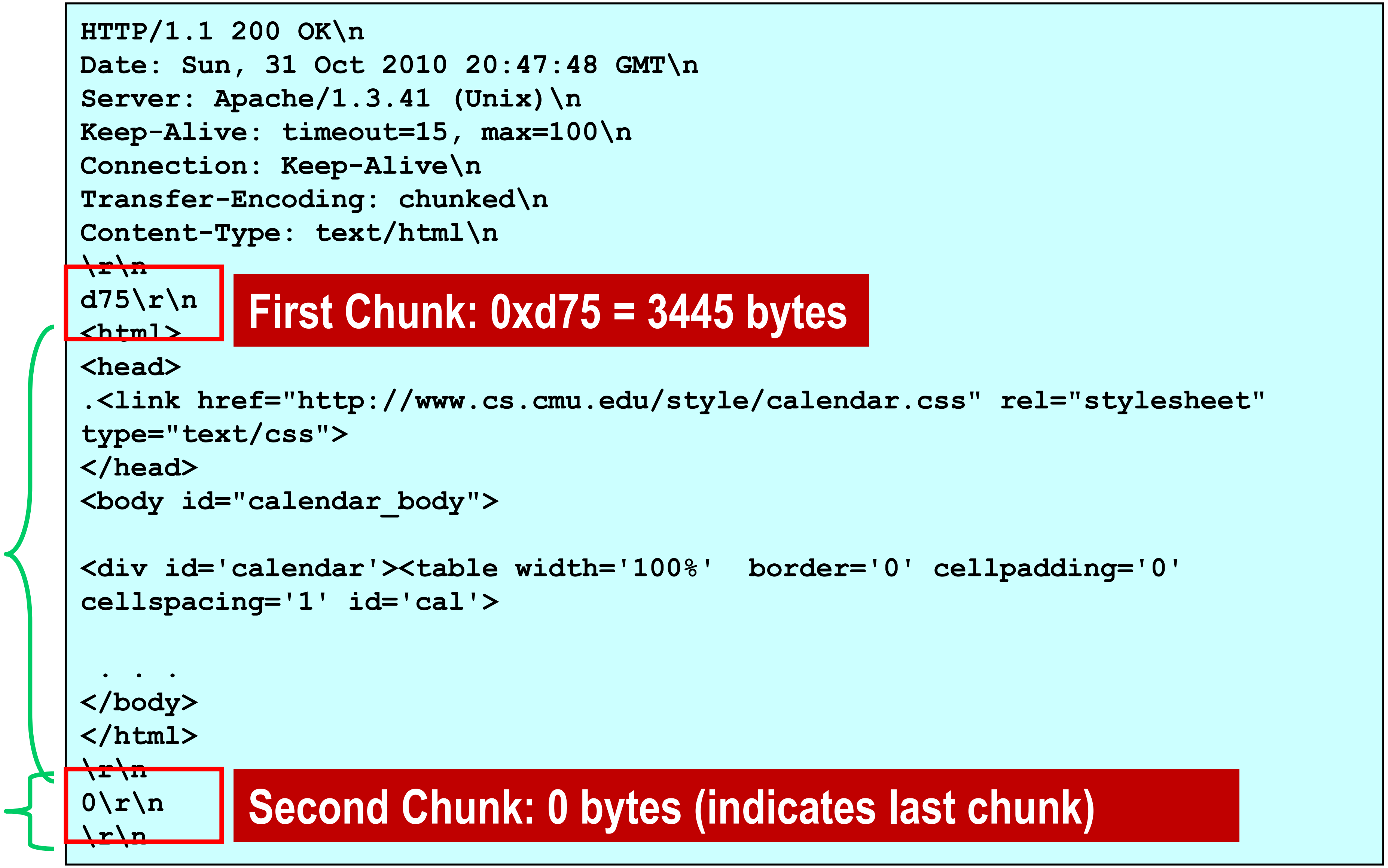
GET Response From Apache Server

```
HTTP/1.1 200 OK
Date: Fri, 29 Oct 2010 19:48:32 GMT
Server: Apache/2.2.14 (Unix) mod_ssl/2.2.14 OpenSSL/0.9.7m
mod_pubcookie/3.3.2b PHP/5.3.1
Accept-Ranges: bytes
Content-Length: 479
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html
<html>
<head><title>Some Tests</title></head>

<body>
<h1>Some Tests</h1>
 . . .
</body>
</html>
```

Data Transfer Mechanisms

- **Standard**
  - Specify total length with content-length
  - Requires that program buffer entire message
- **Chunked**
  - Break into blocks
  - Prefix each block with number of bytes (Hex coded)

Chunked Encoding Example



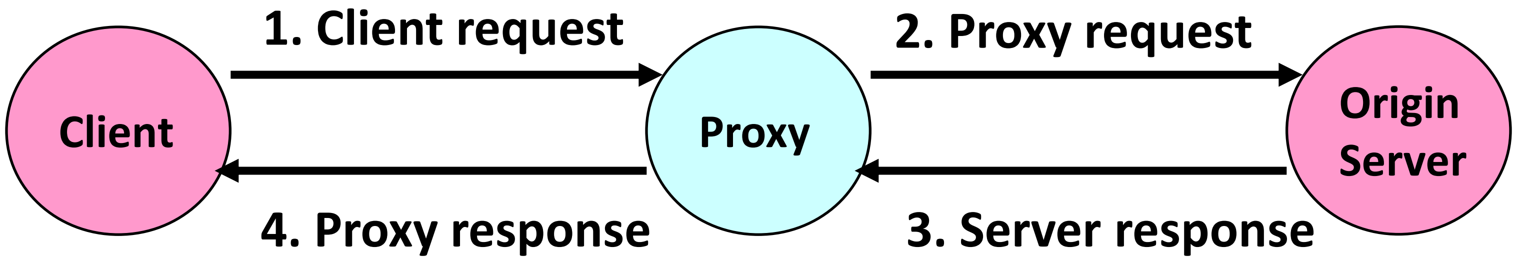
```
HTTP/1.1 200 OK\n
Date: Sun, 31 Oct 2010 20:47:48 GMT\n
Server: Apache/1.3.41 (Unix)\n
Keep-Alive: timeout=15, max=100\n
Connection: Keep-Alive\n
Transfer-Encoding: chunked\n
Content-Type: text/html\n
\r\n
d75\r\n
<html>
<head>
.<link href="http://www.cs.cmu.edu/style/calendar.css" rel="stylesheet"
type="text/css">
</head>
<body id="calendar_body">

<div id='calendar'><table width='100%'  border='0' cellpadding='0'
cellspacing='1' id='cal'>


 . . .
</body>
</html>
\r\n
0\r\n
\r\n
```

First Chunk: 0xd75 = 3445 bytes

Second Chunk: 0 bytes (indicates last chunk)

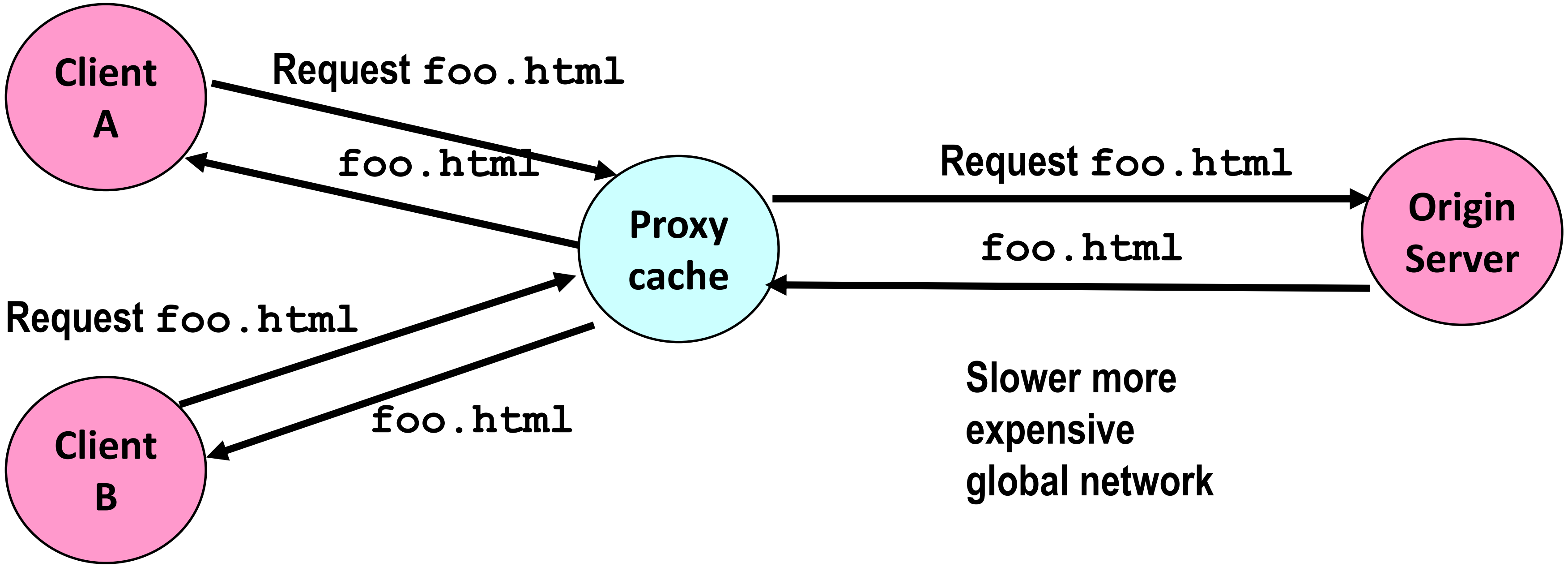
Proxies

- **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