Web Services

15-213 / 18-213: Introduction to Computer Systems
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Web History

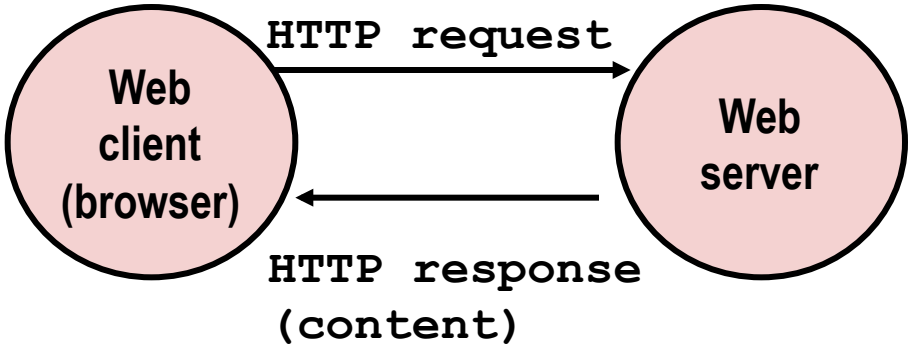
- **1989:**
  - Tim Berners-Lee (CERN) writes internal proposal to develop a distributed hypertext system
    - Connects “a web of notes with links”
    - Intended to help CERN physicists in large projects share and manage information
- **1990:**
  - Tim BL writes a graphical browser for Next machines

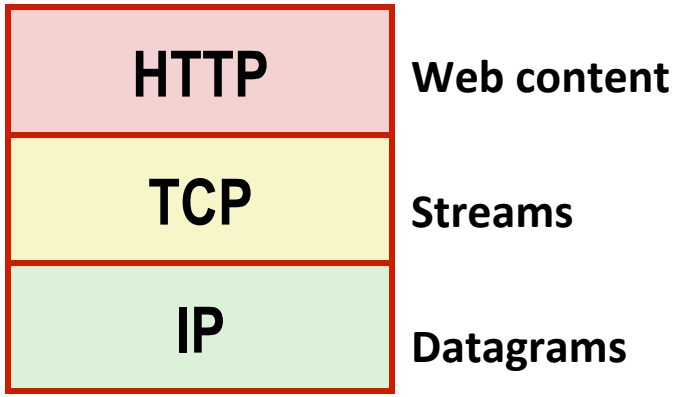
Web History (cont)

- **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)

Web Servers

- **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 (eventually)
- **Current version is HTTP/1.1**
  - RFC 2616, June, 1999.





`http://www.w3.org/Protocols/rfc2616/rfc2616.html`

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
`application/postscript`	Postcript document
`image/gif`	Binary image encoded in GIF format
`image/jpeg`	Binary image encoded in JPEG format

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
    - Request identifies which content file
  - *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
    - Request identifies which file containing executable code
- **Bottom line: *(most) Web content is associated with a file that is managed by the server***

URLs and how clients and servers use them

- **Unique name for a file: URL (Universal Resource Locator)**
- **Example URL: `http://www.cmu.edu:80/index.html`**
- **Clients use *prefix* (`http://www.cmu.edu:80`) to infer:**
  - What kind (protocol) of server to contact (HTTP)
  - Where the server is (`www.cmu.edu`)
  - 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 server expands to configured default filename (usually, `index.html`)

Example of an HTTP Transaction

```
unix> telnet www.cmu.edu 80
Trying 128.2.10.162...
Connected to www.cmu.edu.
Escape character is '^]'.
GET / HTTP/1.1
host: www.cmu.edu

HTTP/1.1 301 Moved Permanently
Location: http://www.cmu.edu/index.shtml

Connection closed by foreign host.
unix>
```

Client: open connection to server
Telnet prints 3 lines to the terminal

Client: request line
Client: required HTTP/1.1 HOST header
Client: empty line terminates headers .
Server: response line
Client should try again

Server: closes connection
Client: closes connection and terminates

Example of an HTTP Transaction, Take 2

```
unix> telnet www.cmu.edu 80
Trying 128.2.10.162...
Connected to www.cmu.edu.
Escape character is '^]'.
GET /index.shtml HTTP/1.1
host: www.cmu.edu

HTTP/1.1 200 OK
Date: Fri, 29 Oct 2010 19:41:08 GMT
Server: Apache/1.3.39 (Unix) mod_pubcookie/3.3.3 ...
Transfer-Encoding: chunked
Content-Type: text/html
...
Connection closed by foreign host.
unix>
```

Client: open connection to server
Telnet prints 3 lines to the terminal

Client: request line
Client: required HTTP/1.1 HOST header
Client: empty line terminates headers .
Server: responds with web page

Lots of stuff

Server: closes connection
Client: closes connection and terminates

HTTP Requests

- **HTTP request is a *request line*, followed by zero or more *request headers***

- **Request line: `<method> <uri> <version>`**
  - `<method>` is one of `GET`, `POST`, `OPTIONS`, `HEAD`, `PUT`, `DELETE`, or `TRACE`
  - `<uri>` is typically URL for proxies, URL suffix for servers
    - A URL is a type of URI (Uniform Resource Identifier)
    - See http://www.ietf.org/rfc/rfc2396.txt
  - `<version>` is HTTP version of request (`HTTP/1.0` or `HTTP/1.1`)

HTTP Requests (cont)

- **HTTP methods:**
  - `GET`: Retrieve static or dynamic content
    - Arguments for dynamic content are in URI
    - Workhorse method (99% of requests)
  - `POST`: Retrieve dynamic content
    - Arguments for dynamic content are in the request body
  - `OPTIONS`: Get server or file attributes
  - `HEAD`: Like `GET` but no data in response body
  - `PUT`: Write a file to the server!
  - `DELETE`: Delete a file on the server!
  - `TRACE`: Echo request in response body
    - Useful for debugging
- **Request headers: `<header name>: <header data>`**
  - Provide additional information to the server

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* (described later)
    - Transfer-Encoding: chunked
  - HTTP/1.1 adds additional support for caching

HTTP Responses

- **HTTP response is a *response line* followed by zero or more *response headers*, possibly followed by data**
- **Response line:**

  `<version> <status code> <status msg>`

  - <version> is HTTP version of the response
  - <status code> is numeric status
  - <status msg> is corresponding English text
    - 200 OK Request was handled without error
    - 301 Moved Provide alternate URL
    - 403 Forbidden Server lacks permission to access file
    - 404 Not found Server couldn't find the file
- **Response headers: `<header name>: <header data>`**
  - Provide additional information about response
  - `Content-Type:` MIME type of content in response body
  - `Content-Length:` Length of content in response body

GET Request to Apache Server From Firefox Browser

URI is just the suffix, not the entire URL

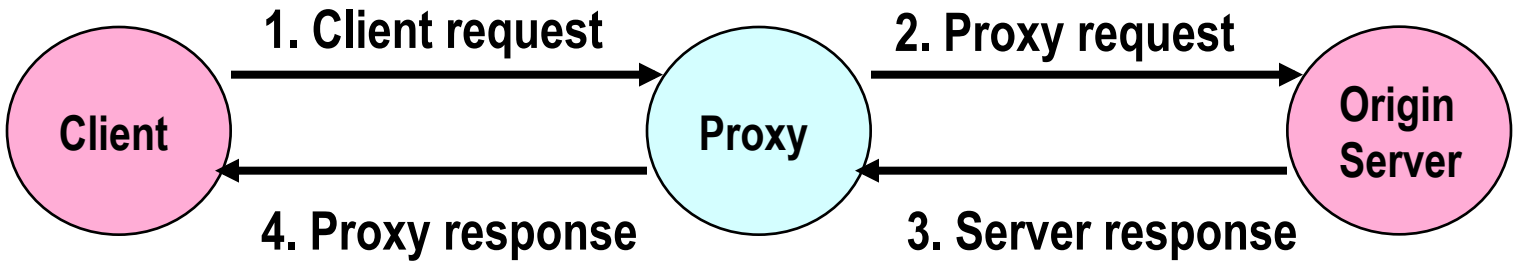
```
GET /~bryant/test.html HTTP/1.1
Host: www.cs.cmu.edu
User-Agent: Mozilla/5.0 (Windows; U; Windows NT 6.0; en-US; rv:
1.9.2.11) Gecko/20101012 Firefox/3.6.11
Accept: text/html,application/xhtml+xml,application/
xml;q=0.9,*/*;q=0.8
Accept-Language: en-us,en;q=0.5
Accept-Encoding: gzip,deflate
Accept-Charset: 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>
```

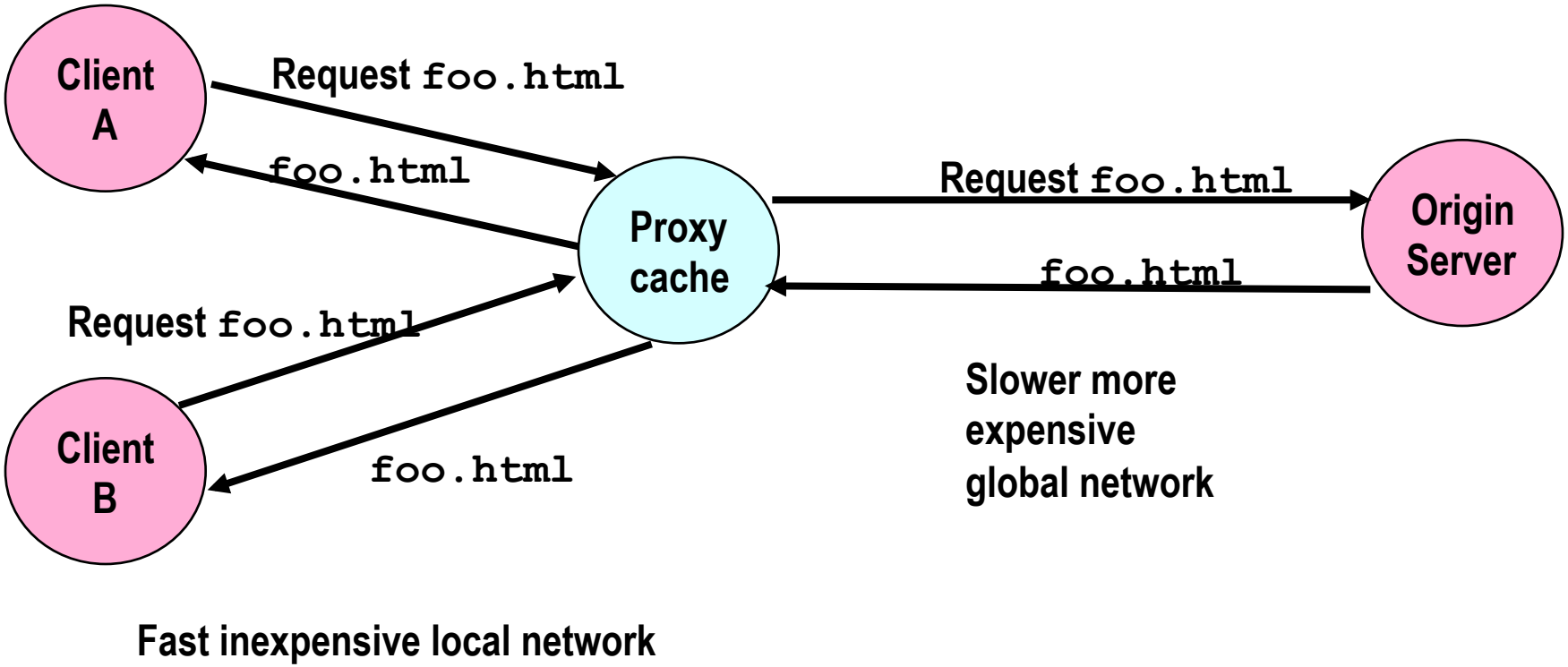
Proxies

- **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



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 and JPEG images
  - 226 lines of commented C code
  - Not as complete or robust as a real web server

Tiny Operation

- **Accept connection from client**
- **Read request from client (via connected socket)**
- **Split into method / uri / version**
  - If 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

From `tiny.c`

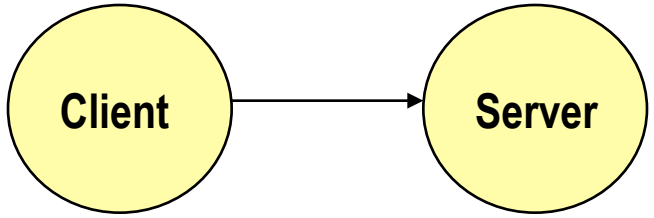
```
/* Send response headers to client */
    get_filetype(filename, filetype);
    sprintf(buf, "HTTP/1.0 200 OK\r\n");
    sprintf(buf, "%sServer: Tiny Web Server\r\n", buf);
    sprintf(buf, "%sContent-length: %d\r\n", buf, filesize);
    sprintf(buf, "%sContent-type: %s\r\n\r\n",
            buf,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

- Serve file specified by `filename`
- Use file metadata to compose header
- “Read” file via mmap
- Write to output

Serving Dynamic Content

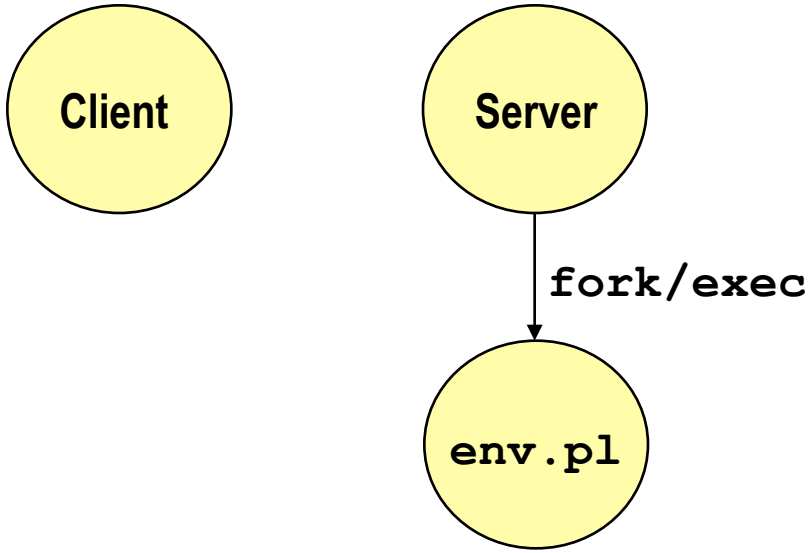
- Client sends request to server
- If request URI contains the string "`/cgi-bin`", then the server assumes that the request is for dynamic content

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



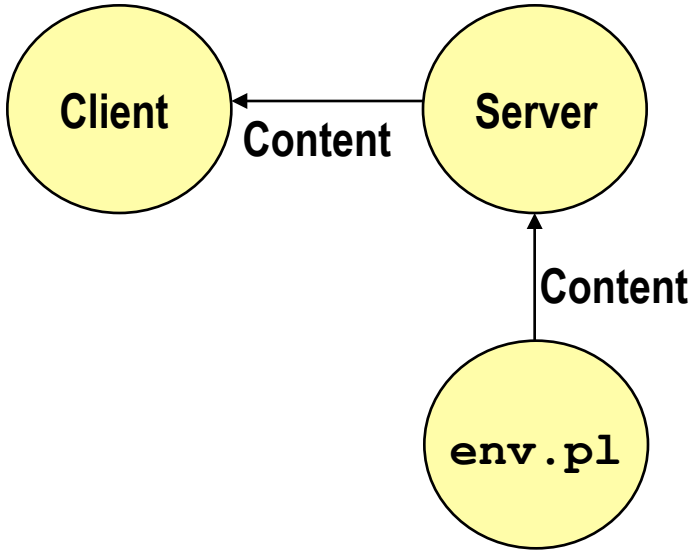
Serving Dynamic Content (cont)

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



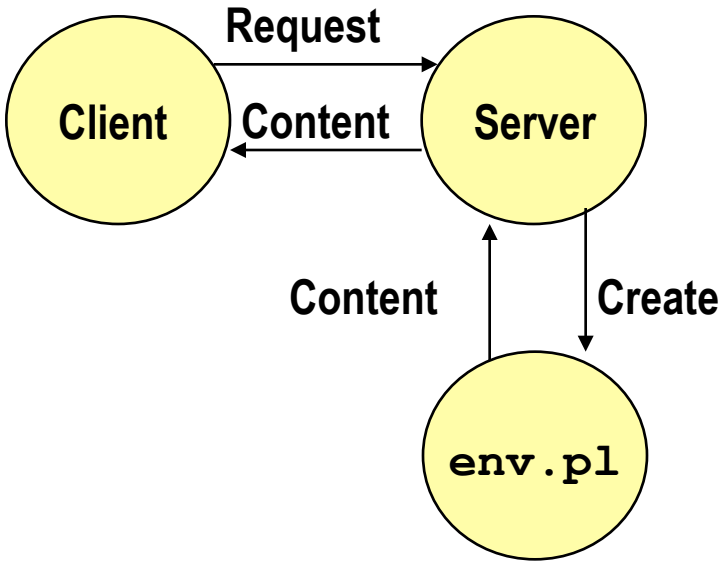
Serving Dynamic Content (cont)

- 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.



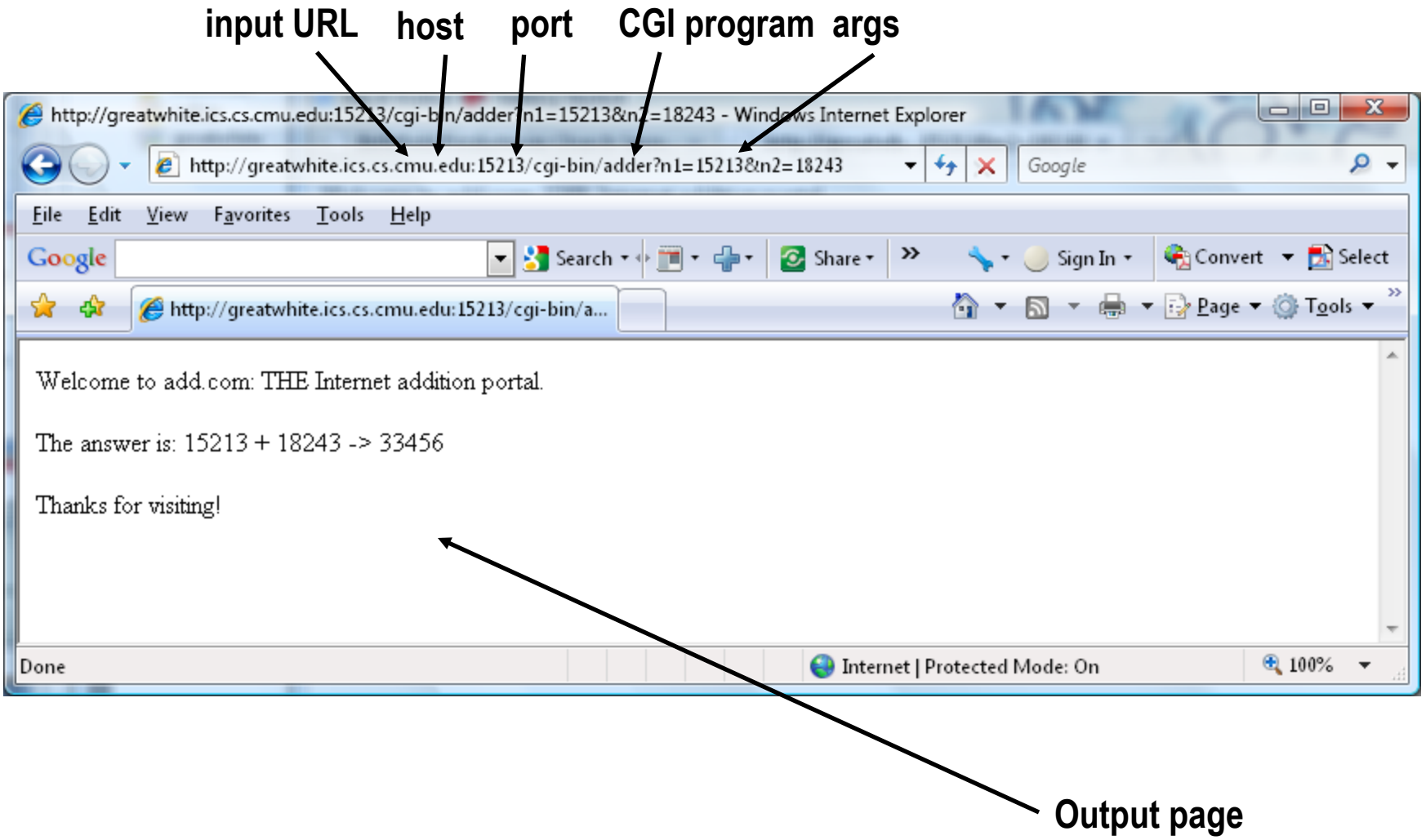
CGI

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

- **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
  - Avoid having to create process on the fly.

The add.com Experience



Serving Dynamic Content With GET

- **Question: How does the client pass arguments to the server?**
- **Answer: 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?n1=15213&n2=18243`
  - `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:**
  - `cgi-bin/adder?n1=15213&n2=18243`

- **Result displayed on browser:**

Welcome to add.com: THE Internet addition portal. The answer is: 15213 + 18243 -> 33456
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` = "`n1=15213&n2=18243`"

From `adder.c`

```
if ((buf = getenv("QUERY_STRING")) != NULL) {
   if (sscanf(buf, "n1=%d&n2=%d\n", &n1, &n2) == 2)
     sprintf(msg, "%d + %d -> %d\n", n1, n2, n1+n2);
   else
     sprintf(msg, "Can't parse buffer '%s'\n", buf);
 }
```

Additional CGI Environment Variables

- **General**
  - `SERVER_SOFTWARE`
  - `SERVER_NAME`
  - `GATEWAY_INTERFACE` (CGI version)
- **Request-specific**
  - `SERVER_PORT`
  - `REQUEST_METHOD` (`GET`, `POST`, etc)
  - `QUERY_STRING` (contains `GET` args)
  - `REMOTE_HOST` (domain name of client)
  - `REMOTE_ADDR` (IP address of client)
  - `CONTENT_TYPE` (for `POST`, type of data in message body, e.g., `text/html`)
  - `CONTENT_LENGTH` (length in bytes)

Even More CGI Environment Variables

- **In addition, the value of each header of type *type* received from the client is placed in environment variable `HTTP_`*type***
  - Examples (any "-" is changed to "_") :
    - `HTTP_ACCEPT`
    - `HTTP_HOST`
    - `HTTP_USER_AGENT`

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.**
  - Notice that only the child knows the type and size of the content. Thus the child (not the server) must generate the corresponding headers.

From `adder.c`

```
/* 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: %s\r\n<p>",
            content, msg);
    sprintf(content, "%sThanks for visiting!\r\n", content);

    /* Generate the HTTP response */
    printf("Content-length: %u\r\n", (unsigned) strlen(content));
    printf("Content-type: text/html\r\n\r\n");
    printf("%s", content);
```

Serving Dynamic Content With GET

```
linux> telnet greatwhite.ics.cs.cmu.edu 15213
Trying 128.2.220.10...
Connected to greatwhite.ics.cs.cmu.edu (128.2.220.10).
Escape character is '^]'.
GET /cgi-bin/adder?n1=5&n2=27 HTTP/1.1
host: greatwhite.ics.cs.cmu.edu
<CRLF>
HTTP/1.0 200 OK
Server: Tiny Web Server
Content-length: 109
Content-type: text/html

Welcome to add.com: THE Internet addition portal.
<p>The answer is: 5 + 27 -> 32

<p>Thanks for visiting!
Connection closed by foreign host.
```

HTTP request sent by client

HTTP response generated by the server

HTTP response generated by the CGI program

Tiny Serving Dynamic Content

From `tiny.c`

```
/* 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 prog  */
    }
    Wait(NULL); /* Parent waits for and reaps child */
```

- Fork child to execute CGI program
- Change stdout to be connection to client
- Execute CGI program with execve

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)

For More Information

- **Study the Tiny Web server described in your text**
  - Tiny is a sequential Web server.
  - 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 add.com addition portal.

- **See the HTTP/1.1 standard:**
  - `http://www.w3.org/Protocols/rfc2616/rfc2616.html`