# 15-213

*"The course that gives CMU its Zip!"*

# Web Services
# November 13, 2003

## Topics

- HTTP
- Serving static content
- Serving dynamic content

# Web History

## 1945:

- Vannevar Bush, “As we may think”, Atlantic Monthly, July, 1945.
  - Describes the idea of a distributed hypertext system.
  - A “memex” that mimics the “web of trails” in our minds.

## 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

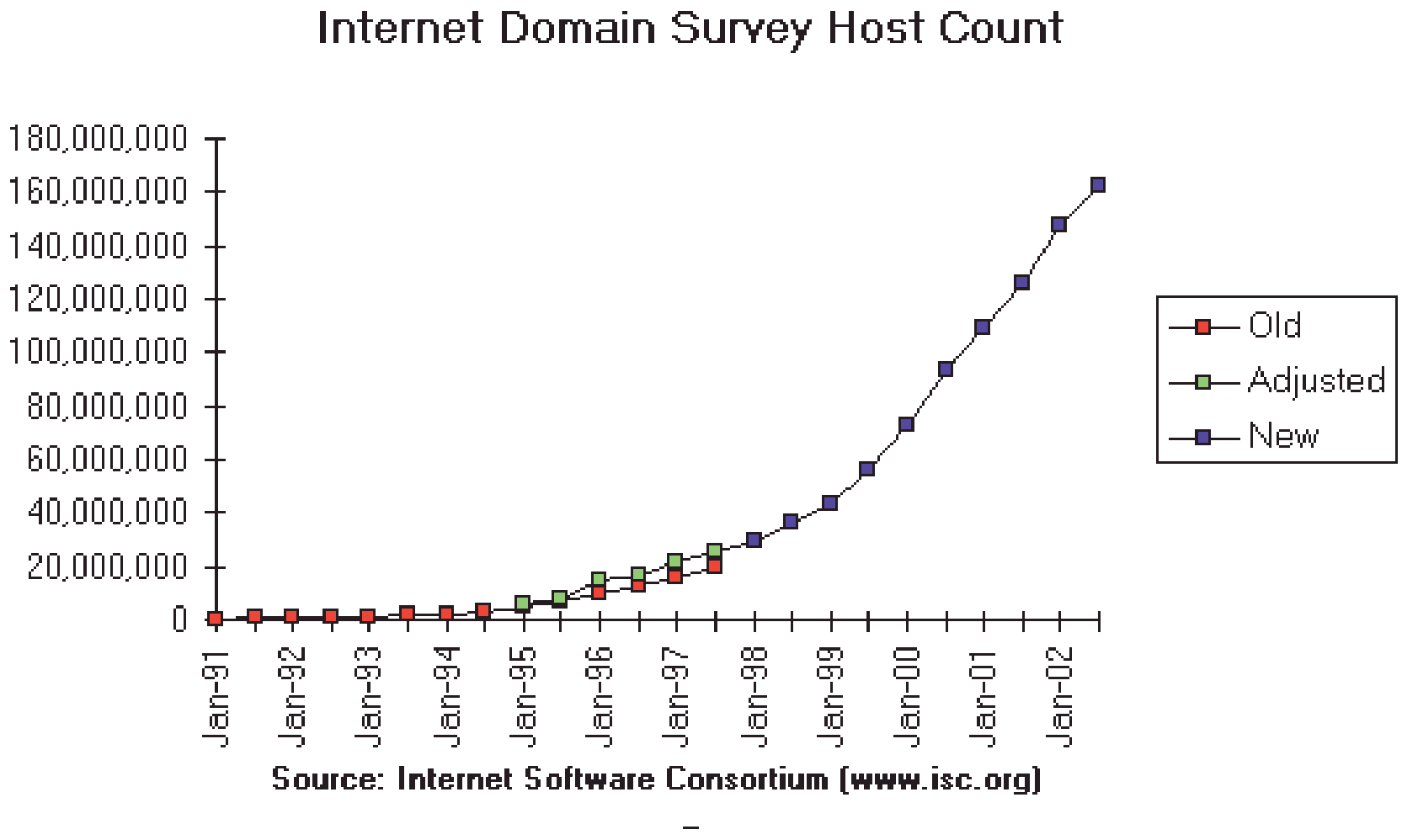
## 1993

- 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" (now Netscape).

# Internet Hosts



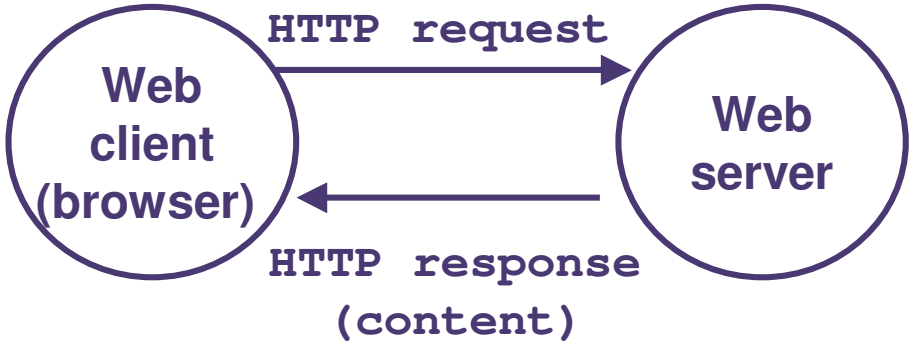
# Web Servers

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 (usually)

Current version is HTTP/1.1

- RFC 2616, June, 1999.



# 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.
- 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.

Bottom line: *All Web content is associated with a file that is managed by the server.*

# URLs

Each file managed by a server has a unique name called a URL (Universal Resource Locator)

URLs for static content:

- `http://www.cs.cmu.edu:80/index.html`
- `http://www.cs.cmu.edu/index.html`
- `http://www.cs.cmu.edu`
  - Identifies a file called `index.html`, managed by a Web server at `www.cs.cmu.edu` that is listening on port 80.

URLs for dynamic content:

- `http://www.cs.cmu.edu:8000/cgi-bin/adder?15000&213`
  - Identifies an executable file called `adder`, managed by a Web server at `www.cs.cmu.edu` that is listening on port 8000, that should be called with two argument strings: `15000` and `213`.

# How Clients and Servers Use URLs

## Example URL: `http://www.aol.com:80/index.html`

## Clients use *prefix* (`http://www.aol.com:80`) to infer:

- What kind of server to contact (Web server)
- Where the server is (`www.aol.com`)
- 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 all servers expand to some default home page (e.g., `index.html`).

# Anatomy of an HTTP Transaction

```
unix> telnet www.aol.com 80
Trying 205.188.146.23...
Connected to aol.com.
Escape character is '^]'.
GET / HTTP/1.1
host: www.aol.com

HTTP/1.0 200 OK
MIME-Version: 1.0
Date: Mon, 08 Jan 2001 04:59:42 GMT
Server: NaviServer/2.0 AOLserver/2.3.3
Content-Type: text/html
Content-Length: 42092

<html>
...
</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: response line*
*Server: followed by five response headers*
*Server: expect HTML in the response body*
*Server: expect 42,092 bytes in the resp body*
*Server: empty line ("\r\n") terminates hdrs*
*Server: first HTML line in response body*
*Server: 766 lines of HTML not shown.*
*Server: last HTML line in response body*
*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>`

- `<version>` is HTTP version of request (`HTTP/1.0` or `HTTP/1.1`)
- `<uri>` is typically URL for proxies, URL suffix for servers.
- `<method>` is either `GET`, `POST`, `OPTIONS`, `HEAD`, `PUT`, `DELETE`, or `TRACE`.

# 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.

# HTTP Requests (cont)

## Request headers: `<header name>: <header data>`

- Provide additional information to the server.

## 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: kittyhawk.cmcl.cs.cmu.edu`
- HTTP/1.1 adds additional support for caching

# HTTP Responses

HTTP response is a *response line* followed by zero or more *response headers*.

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
  - 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 IE Browser

```
GET /test.html HTTP/1.1
Accept: */*
Accept-Language: en-us
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0 (compatible; MSIE 4.01; Windows 98)
Host: euro.ecom.cmu.edu
Connection: Keep-Alive
CRLF (\r\n)
```

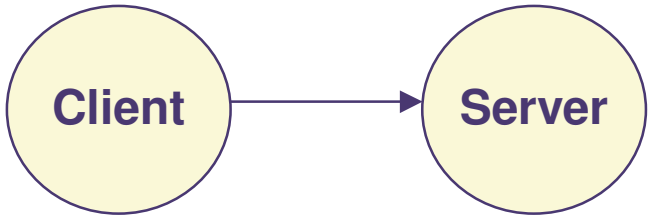
# GET Response From Apache Server

```
HTTP/1.1 200 OK
Date: Thu, 22 Jul 1999 04:02:15 GMT
Server: Apache/1.3.3 Ben-SSL/1.28 (Unix)
Last-Modified: Thu, 22 Jul 1999 03:33:21 GMT
ETag: "48bb2-4f-37969101"
Accept-Ranges: bytes
Content-Length: 79
Keep-Alive: timeout=15, max=100
Connection: Keep-Alive
Content-Type: text/html
CRLF
<html>
<head><title>Test page</title></head>
<body>
<h1>Test page</h1>
</html>
```

# Serving Dynamic Content

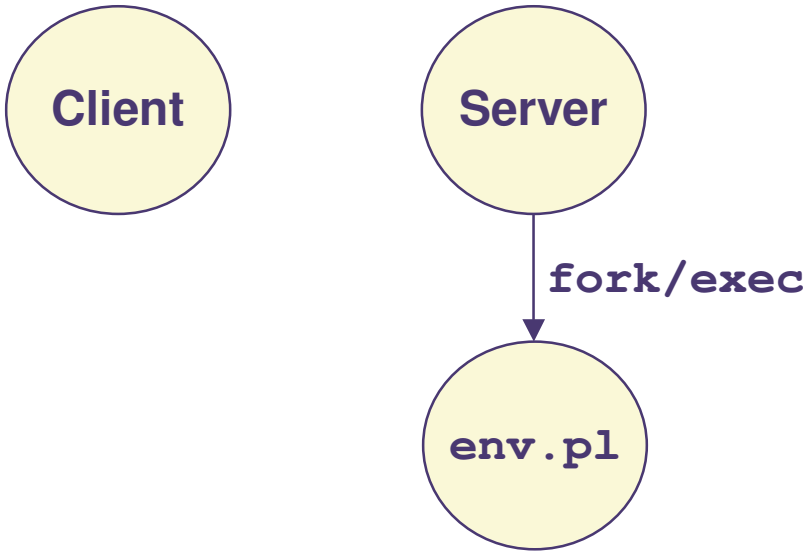
- Client sends request to server.
- If request URI contains the string "`/cgi-bin`", then the server assumes that the request is for dynamic content.

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



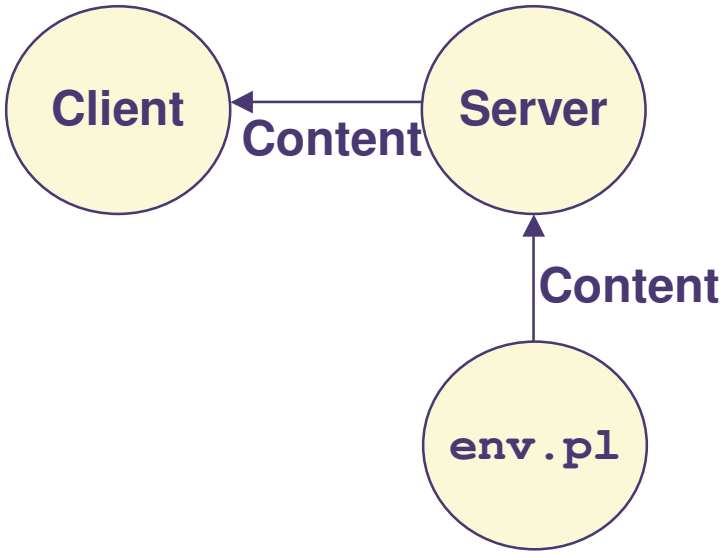
# Serving Dynamic Content (cont)

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



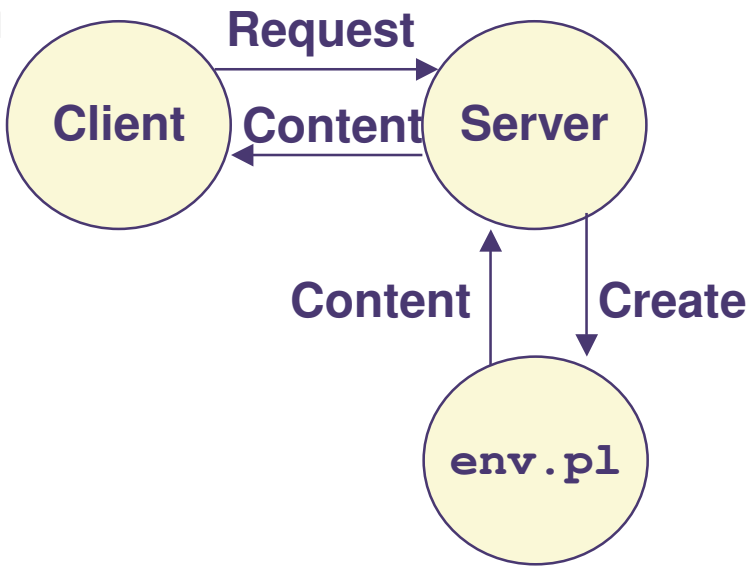
# Serving Dynamic Content (cont)

- 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*.

Because many CGI programs are written in Perl, they are often called *CGI scripts*.

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

# add.com: THE Internet addition portal!

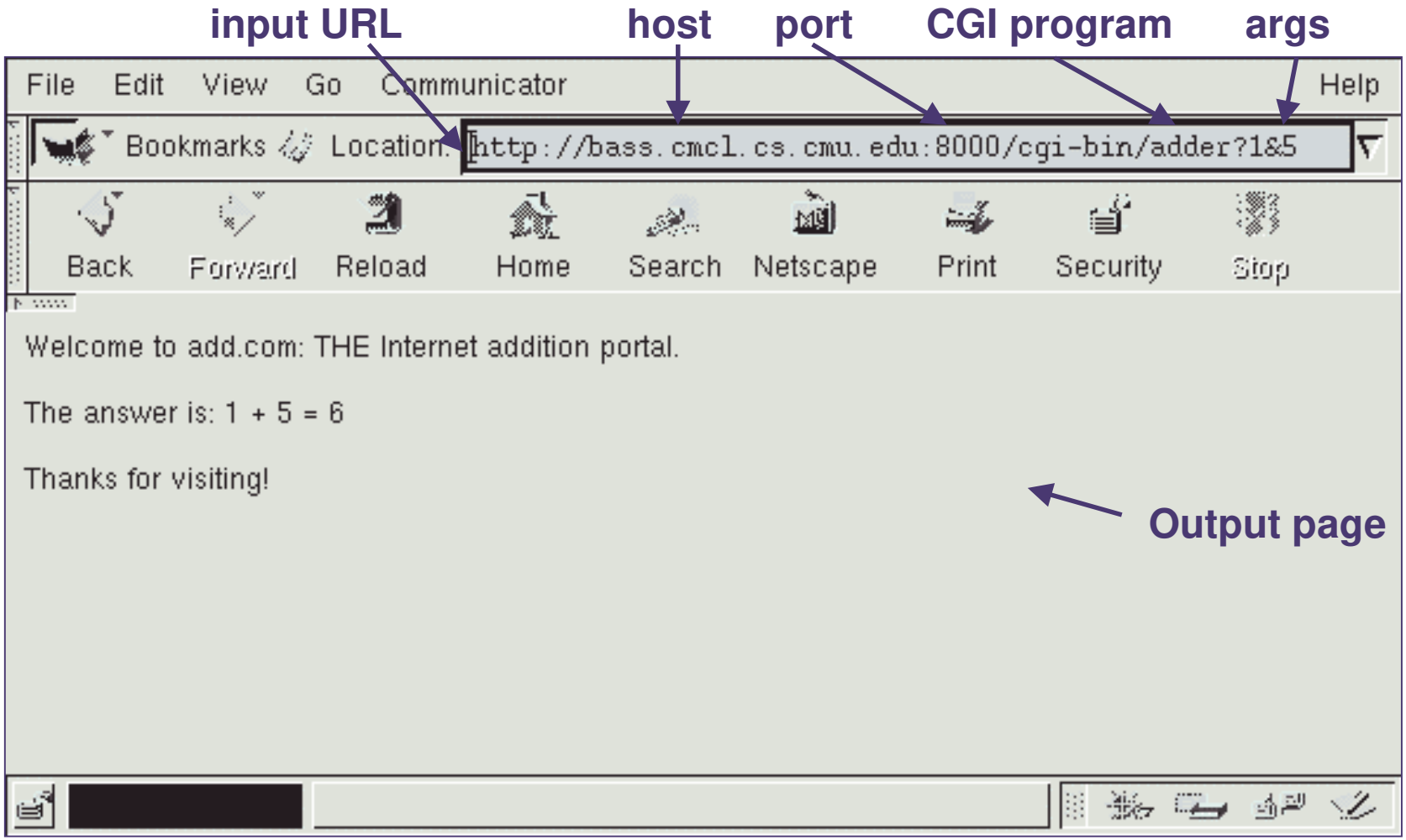
Ever need to add two numbers together and you just can't find your calculator?

Try Dr. Dave's addition service at "add.com: THE Internet addition portal!"

- Takes as input the two numbers you want to add together.
- Returns their sum in a tasteful personalized message.

After the IPO we'll expand to multiplication!

# 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?1&2`
- `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"`

Can also be generated by an HTML form

```
<form method=get action="http://add.com/cgi-bin/postadder">
```

# Serving Dynamic Content With GET

## URL:

- `http://add.com/cgi-bin/adder?1&2`

## Result displayed on browser:

Welcome to add.com: THE Internet addition portal.

The answer is: 1 + 2 = 3

Thanks for visiting! Tell your friends.

# 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.com: `QUERY_STRING` = "`1&2`"

```
/* child code that accesses the argument list */
if ((buf = getenv("QUERY_STRING")) == NULL) {
  exit(1);
}

/* extract arg1 and arg2 from buf and convert */
...
n1 = atoi(arg1);
n2 = atoi(arg2);
```

# Serving Dynamic Content With GET

**Question:** How does the server pass other info relevant to the request to the child?

**Answer:** In a collection of environment variables defined by the CGI spec.

# Some 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)

# Some 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:
  - `HTTP_ACCEPT`
  - `HTTP_HOST`
  - `HTTP_USER_AGENT` (any "-" is changed to "_")

# 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.

```
/* child generates the result string */
sprintf(content, "Welcome to add.com: THE Internet addition portal\
        <p>The answer is: %d + %d = %d\
        <p>Thanks for visiting!\r\n",
       n1, n2, n1+n2);

/* child generates the headers and dynamic content */
printf("Content-length: %d\r\n", strlen(content));
printf("Content-type: text/html\r\n");
printf("\r\n");
printf("%s", content);
```

# Serving Dynamic Content With GET

```
bass> ./tiny 8000
GET /cgi-bin/adder?1&2 HTTP/1.1
Host: bass.cmcl.cs.cmu.edu:8000
<CRLF>
```

HTTP request received by Tiny Web server

---

```
kittyhawk> telnet bass 8000
Trying 128.2.222.85...
Connected to BASS.CMCL.CS.CMU.EDU.
Escape character is '^]'.
GET /cgi-bin/adder?1&2 HTTP/1.1
Host: bass.cmcl.cs.cmu.edu:8000
<CRLF>
```

HTTP request sent by client

---

```
HTTP/1.1 200 OK
Server: Tiny Web Server
```

HTTP response generated by the server

---

```
Content-length: 102
Content-type: text/html
<CRLF>
Welcome to add.com: THE Internet addition portal.
<p>The answer is: 1 + 2 = 3
<p>Thanks for visiting!
```

HTTP response generated by the CGI program

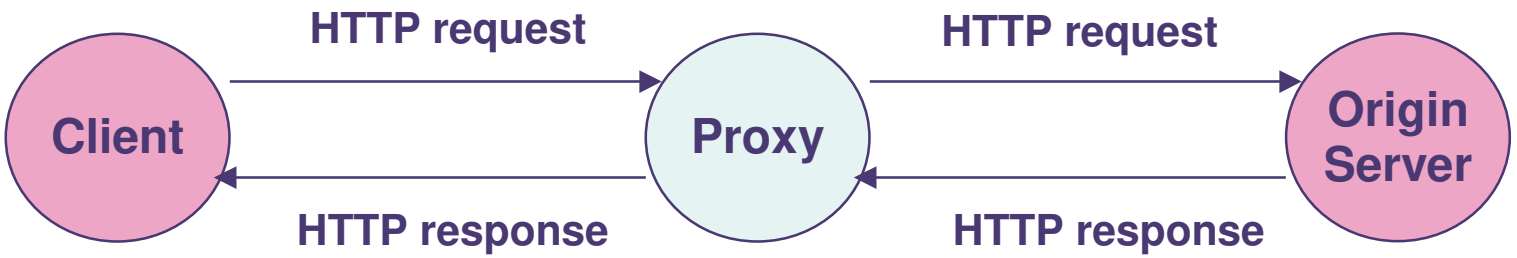
---

```
Connection closed by foreign host.
kittyhawk>
```

# Proxies

A *proxy* is an intermediary between a client and an *origin server*.

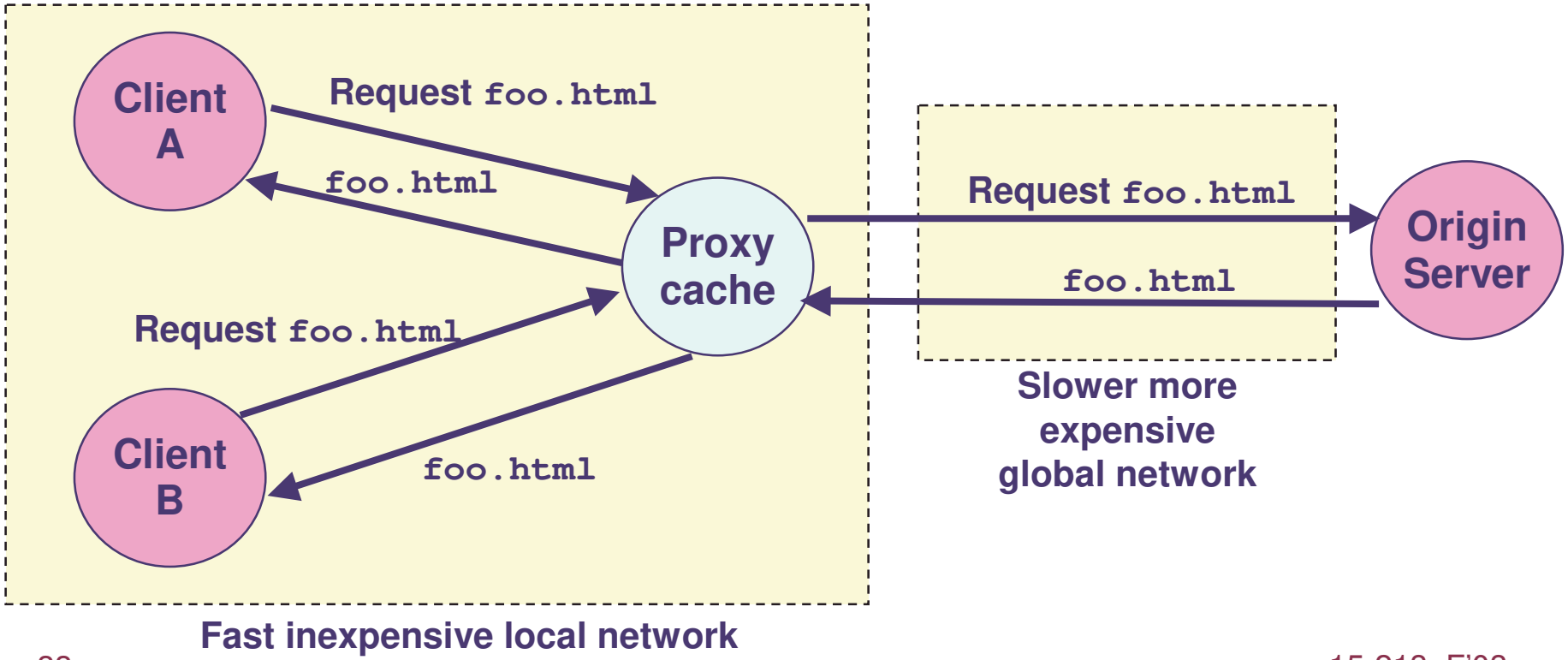
- To the client, the proxy acts like a server.
- To the server, the proxy acts like a client.



# Why Proxies?

## Can perform useful functions as requests and responses pass by

- Examples: Caching, logging, anonymization



# 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.