15-213

"The course that gives CMU its Zip!"

Web services
Nov 28, 2000

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

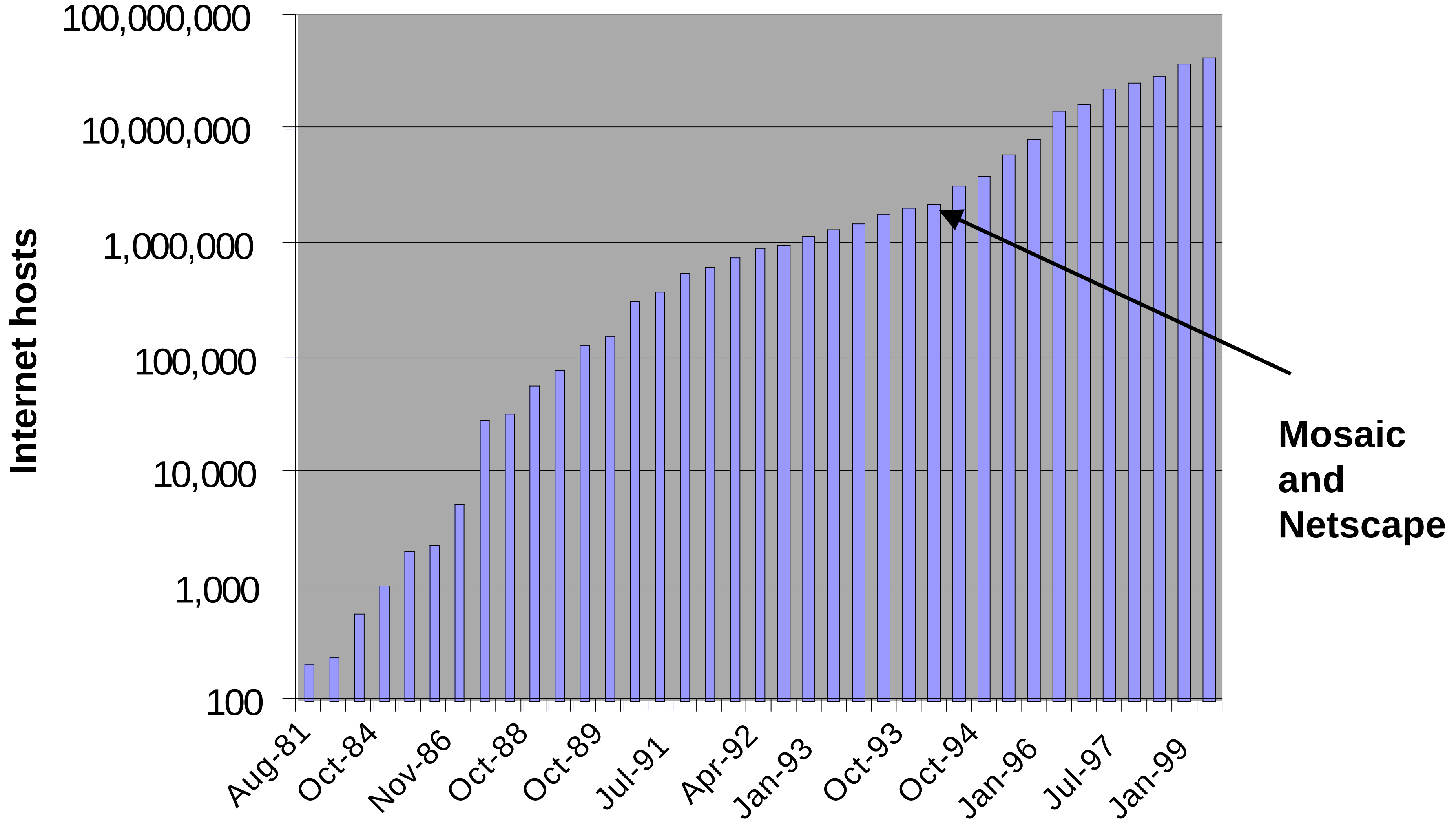
1993

- 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).

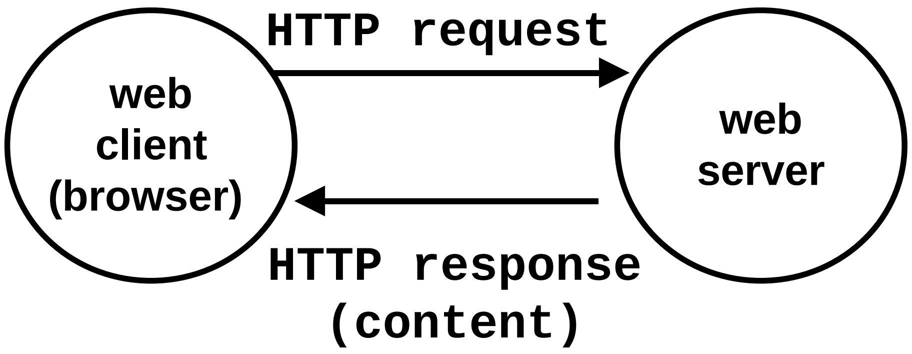
Internet Domain Survey (www.isc.org)



Web servers

Clients and servers communicate using the HyperText Transfer Protocol (HTTP)

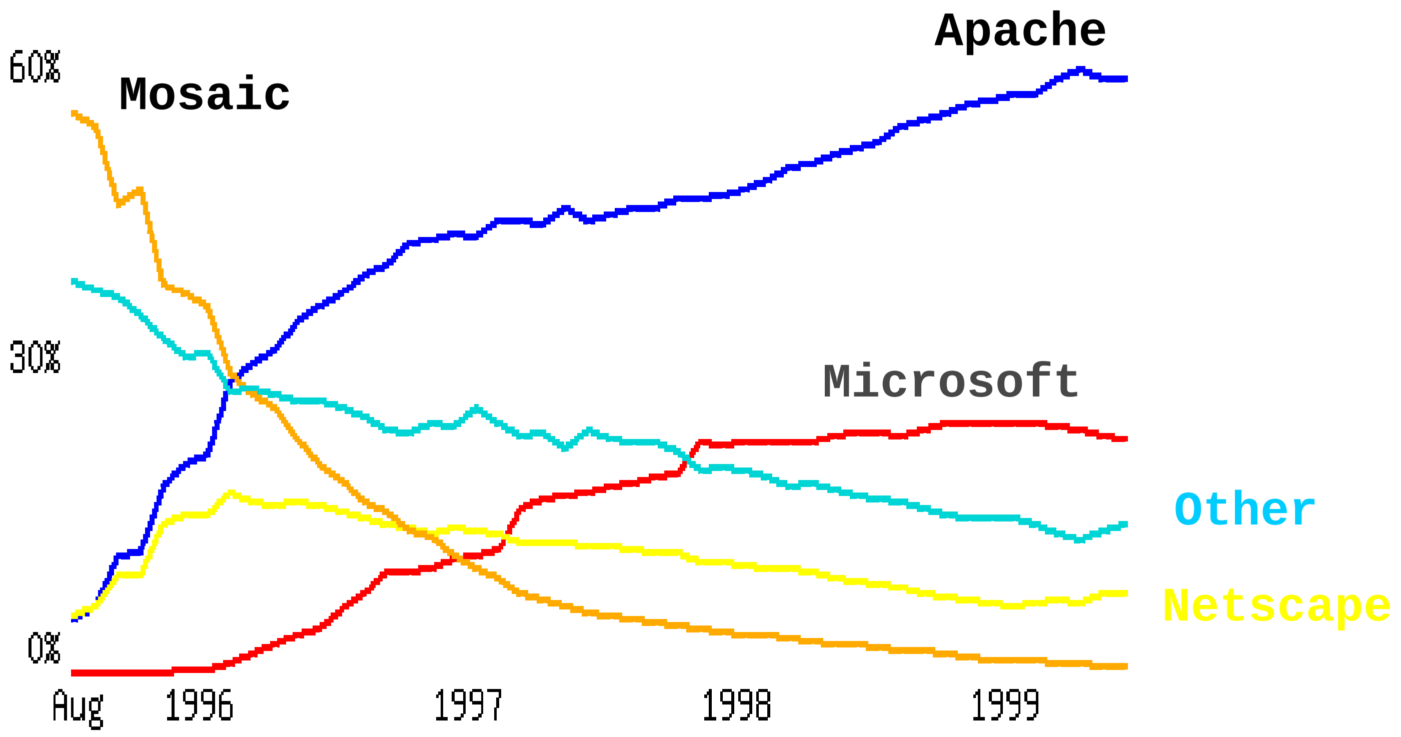
- **client and server establish TCP connection**
- **Client requests content**
- **Server responds with requested content**
- **client and server close connection (usually)**



Current version is HTTP/1.1

- **RFC 2616, June, 1999.**

Web server statistics



source: Netcraft Web Survey
www.netcraft.com/survey

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
  - HTML files
  - images
  - audio clips

Dynamic content:

- content produced on-the-fly in response to an HTTP request
  - Example: content produced by a CGI process executed by the server on behalf of the client.

URIs and URLs

network resources are identified by Universal Resource Indicators (URIs)

The most familiar is the absolute URI known as the HTTP URL:

- `http-url = “http:” “//” host [“:” port] [abs_path]`
- `port` defaults to “80”
- `abs_path` defaults to `“/”`
- `abs_path` ending in / defaults to …`/index.html`

Examples (all equivalent):

- `http://www.cs.cmu.edu:80/index.html`
- `http://www.cs.cmu.edu/index.html`
- `http://www.cs.cmu.edu`

HTTP/1.1 messages

An HTTP message is either a Request or a Response:

```
HTTP-message = Request | Response
```

Requests and responses have the same basic form:

```
generic-message = start-line
                  *message-header
                  CRLF
                  [message body]

start-line      = Request-line | Status line
message-header  = field-name “:” [field value] CRLF
message-body    = <e.g., HTML file>
```

HTTP/1.1 requests

```
Request = Method SP Request-URI SP HTTP-VERSION CRLF
          *(general-header | request-header | entity header)
          CRLF
          [ message-body ]
```

`Method`: tells the server what operation to perform, e.g.,

- **`GET`: serve static or dynamic content**
- **`POST`: serve dynamic content**
- **`OPTIONS`: retrieve server and access capabilities**

`Request-URI`: identifies the resource to manipulate

- **data file (HTML), executable file (CGI)**

`headers`: parameterize the method

- **`Accept-Language: en-us`**
- **`User-Agent: Mozilla/4.0 (compatible; MSIE 4.01; Windows 98)`**

`message-body`: text characters

HTTP/1.1 responses

```
Response = HTTP-Version SP Status-Code SP Reason-Phrase CRLF
           *(general-header | response-header | entity header)
           CRLF
           [ message-body ]
```

`Status code`: 3-digit number

`Reason-Phrase`: explanation of status code

`headers`: parameterize the response

- **Date: Thu, 22 Jul 1999 23:42:18 GMT**
- **Server: Apache/1.2.5 BSDI3.0-PHP/FI-2.0**
- **Content-Type: text/html**

`message-body`:

- **file**

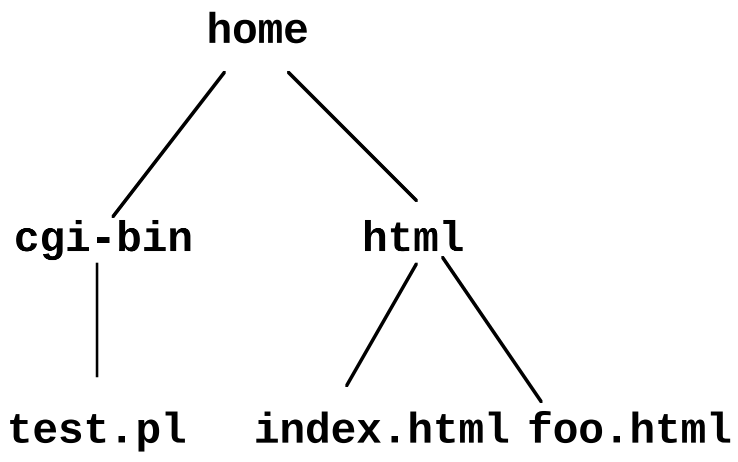
How servers interpret Request-URIs

`GET / HTTP/1.1`

- resolves to `home/html/index.html`
- action: retrieves index.html

`GET /index.html HTTP/1.1`

- resolves to `home/html/index.html`
- action: retrieves `index.html`



`GET /foo.html HTTP/1.1`

- resolves to `home/html/foo.html`
- action: retrieves `foo.html`

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

- resolves to `home/cgi-bin/test.pl`
- action: runs `test.pl`

`GET http://euro.ecom.cmu.edu/index.html HTTP/1.1`

- resolves to `home/html/index.html`
- action: retrieves `index.html`

Example HTTP/1.1 conversation

```
kittyhawk> telnet euro.ecom.cmu.edu 80
Connected to euro.ecom.cmu.edu.
Escape character is '^]'.
```

Request sent by client

```
GET /test.html HTTP/1.1   ;request line
Host: euro.ecom.cmu.edu   ;request hdr
CRLF
```

Response sent by server

```
HTTP/1.1 200 OK                             ;status line
Date: Thu, 22 Jul 1999 03:37:04 GMT   ;response hdr
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
Content-Type: text/html
CRLF
<html>   ;beginning of 79 byte message body (content)
<head><title>Test page</title></head>
<body><h1>Test page</h1>
</html>
```

`OPTIONS` method

Retrieves information about the server in general or resources on that server, without actually retrieving the resource.

Request URIs:

- if request URI = “*”, then the request is about the server in general
  - Is the server up?
  - Is it HTTP/1.1 compliant?
  - What brand of server?
  - What OS is it running?
- if request URI != “*”, then the request applies to the options that available when accessing that resource:
  - what methods can the client use to access the resource?

OPTIONS (euro.ecom)

Host is a required header in HTTP/1.1 but not in HTTP/1.0

```
kittyhawk> telnet euro.ecom.cmu.edu 80
Trying 128.2.218.2...
Connected to euro.ecom.cmu.edu.
Escape character is '^]'.

OPTIONS * HTTP/1.1
Host: euro.ecom.cmu.edu
CRLF                                     Request
---------------------------------------------
HTTP/1.1 200 OK                          Response
Date: Thu, 22 Jul 1999 06:12:11 GMT
Server: Apache/1.3.3 Ben-SSL/1.28 (Unix)
Content-Length: 0
Allow: GET, HEAD, OPTIONS, TRACE
```

OPTIONS (amazon.com)

```
kittyhawk> telnet amazon.com 80
Trying 208.216.182.15...
Connected to amazon.com.
Escape character is '^]'.

OPTIONS / HTTP/1.0
CRLF                                                    Request
----------------------------------------------------------------
HTTP/1.0 405 Because I felt like it.                    Response
Server: Netscape-Commerce/1.12
Date: Thursday, 22-Jul-99 04:17:32 GMT
Allow: GET, POST
Content-type: text/plain
```

`GET` method

Retrieves the information identified by the request URI.

- static content (HTML file)
- dynamic content produced by CGI program
  - passes arguments to CGI program in URI

Can also act as a conditional retrieve when certain request headers are present:

- `If-Modified-Since`
- `If-Unmodified-Since`
- `If-Match`
- `If-None-Match`
- `If-Range`

Conditional `GET`s useful for caching

GET (euro.ecom.cmu.edu)

```
kittyhawk> telnet euro.ecom.cmu.edu 80
Connected to euro.ecom.cmu.edu.
Escape character is '^]'.

GET /test.html HTTP/1.1
Host: euro.ecom.cmu.edu
CRLF                                                  Request
----------------------------------------------------------------
HTTP/1.1 200 OK                                       Response
Date: Thu, 22 Jul 1999 03:37:04 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
Content-Type: text/html
CRLF
<html>
<head><title>Test page</title></head>
<body><h1>Test page</h1>
</html>
```

GET request to euro.ecom (Internet Explorer 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
```

GET response from euro.ecom

```
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>
```

GET request to euro.ecom (Netscape browser)

```
GET /test.html HTTP/1.0
Connection: Keep-Alive
User-Agent: Mozilla/4.06 [en] (Win98; I)
Host: euro.ecom.cmu.edu
Accept: image/gif, image/x-xbitmap, image/jpeg, image/pjpeg,
 image/png, */*
Accept-Encoding: gzip
Accept-Language: en
Accept-Charset: iso-8859-1,*,utf-8
CRLF
```

GET response from euro.ecom

```
HTTP/1.1 200 OK
Date: Thu, 22 Jul 1999 06:34:42 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>
```

`HEAD` method

Returns same response header as a `GET` request would have...

But doesn’t actually carry out the request and returns no content

- some servers don’t implement this properly
- e.g., espn.com

Useful for applications that

- check for valid and broken links in Web pages.
- check Web pages for modifications.

HEAD (etrade.com)

```
kittyhawk> telnet etrade.com 80
Trying 198.93.32.75...
Connected to etrade.com.
Escape character is '^]'.

HEAD / HTTP/1.1
Host: etrade.com
CRLF                                                   Request
---------------------------------------------------------------
HTTP/1.0 200 OK                                        Response
Server: Netscape-Enterprise/2.01-p100
Date: Fri, 23 Jul 1999 03:18:57 GMT
RequestStartUsec: 780328
RequestStartSec: 932699937
Accept-ranges: bytes
Last-modified: Tue, 20 Jul 1999 00:59:26 GMT
Content-length: 15370
Content-type: text/html
```

HEAD (espn.com)

Modern browsers transparently connect to the new `espn.go.com` location

```
kittyhawk> telnet espn.com 80
Trying 204.202.136.31...
Connected to espn.com.
Escape character is '^]'.

HEAD / HTTP/1.1
Host: espn.com
CRLF
```

Request

Response

```
HTTP/1.1 301 Document Moved
Server: Microsoft-IIS/4.0
Date: Fri, 23 Jul 1999 03:22:32 GMT
Location: http://espn.go.com/
Content-Type: text/html
CRLF
<html>
Is now part of the http://espn.go.com service<br>
</html>
```

`POST` method

Another technique for producing dynamic content.

Executes program identified in request URI (the CGI program).

Passes arguments to CGI program in the message body

- unlike `GET`, which passes the arguments in the URI itself.

Responds with output of the CGI program.

Advantage over GET method:

- unlimited argument size

Disadvantages:

- more cumbersome
- can’t serve static content

POST request

```
POST /cgi-bin/post.pl HTTP/1.1
Accept: image/gif, image/x-xbitmap, image/jpeg,
 image/pjpeg, application/vnd.ms-excel, application/msword,
 application/vnd.ms-powerpoint, */*
Referer: http://www.cs.cmu.edu/~droh/755/form.html
Accept-Language: en-us
Content-Type: application/x-www-form-urlencoded
Accept-Encoding: gzip, deflate
User-Agent: Mozilla/4.0 (compatible; MSIE 4.01; Windows 98)
Host: kittyhawk.cmcl.cs.cmu.edu:8000
Content-Length: 25
CRLF
first=dave&last=ohallaron
```

POST response

```
HTTP/1.1 200 OK
Date: Fri, 23 Jul 1999 05:42:30 GMT
Server: Apache/1.3.4 (Unix)
Transfer-Encoding: chunked
```

Generated by server

```
Content-Type: text/html
CRLF
<p>first=dave&last=ohallaron
```

Generated by CGI script post.pl

TRACE, PUT, and DELETE methods

TRACE

- Returns contents of request header in response message body.
- HTTP’s version of an echo server.
- Useful for debugging.

PUT:

- add a URI to the server’s file system

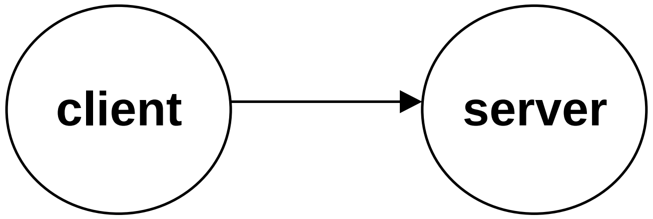
DELETE

- delete a URI from the server’s file system

Serving dynamic content

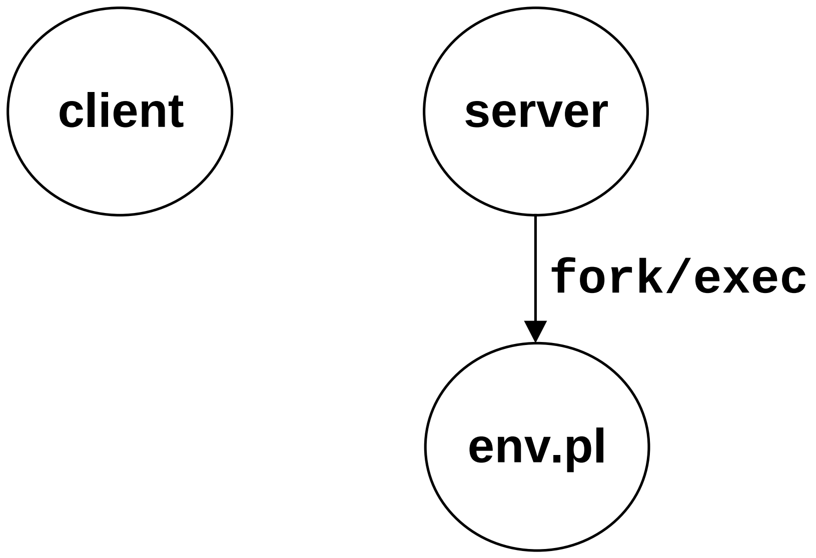
- Client sends request to server.
- If request URI contains the string "`/cgi-bin`", then the server assumes that the request is for dynamic content.

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



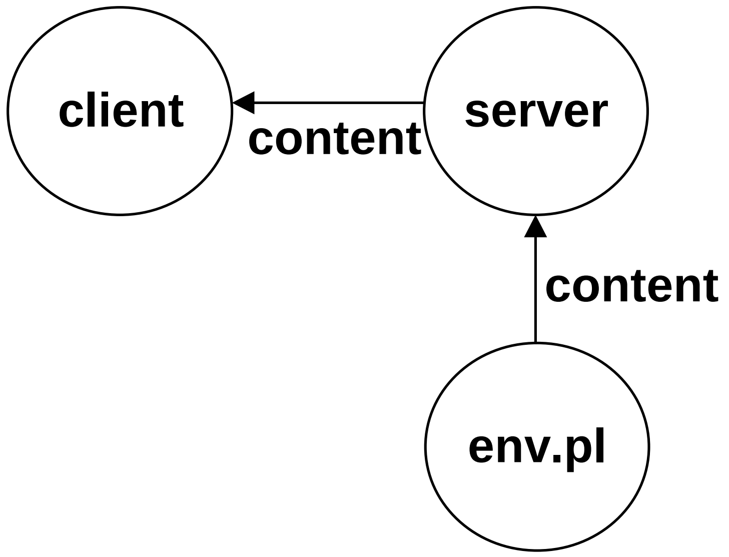
Serving dynamic content

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



Serving dynamic content

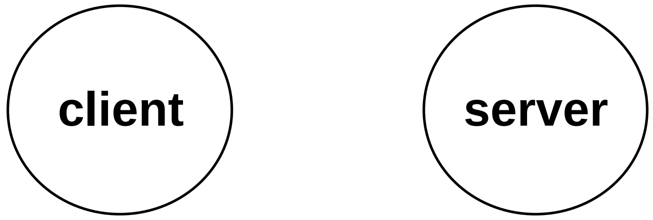
- The child runs and generates the dynamic content.
- The server captures the content of the child and forwards it without modification to the client



Serving dynamic content

The child terminates.

Server waits for the next client request.



Issues in serving dynamic content

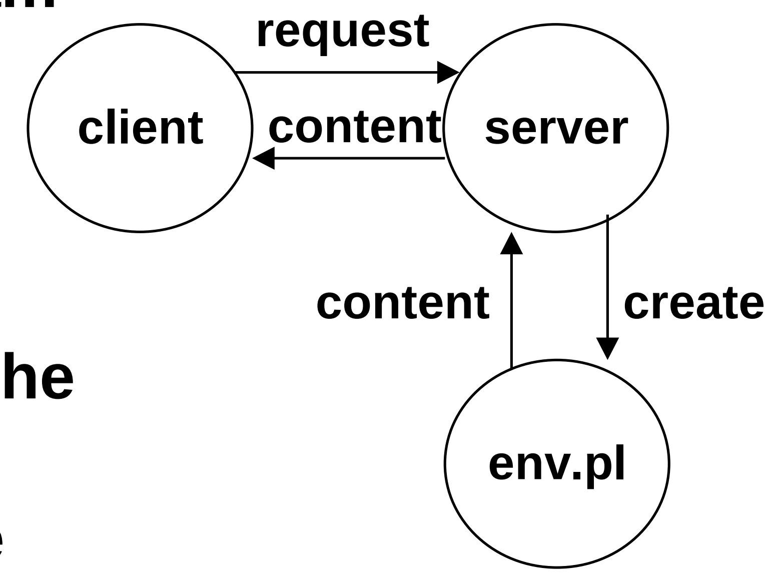
How does the client pass program arguments to the server?

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!

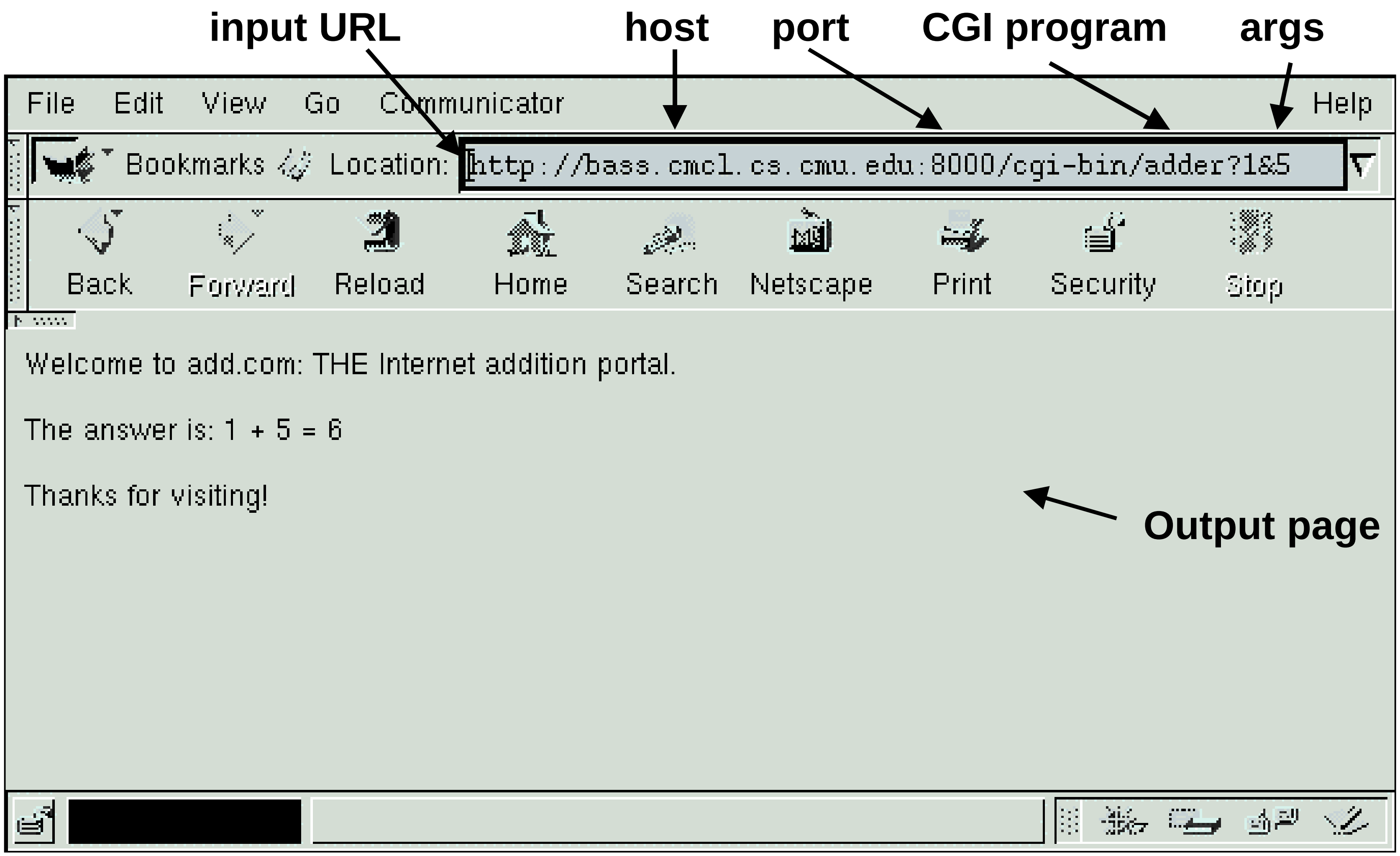
Ever need to add two numbers together and you just can't find your calculator?

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



```
http://bass.cmcl.cs.cmu.edu:8000/cgi-bin/adder?1&5
```

Welcome to add.com: THE Internet addition portal.

The answer is: 1 + 5 = 6

Thanks for visiting!

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 writes its headers and content to stdout.

- Server maps socket descriptor to stdout (more on this later).
- 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!\n",
       n1, n2, n1+n2);

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