15-213

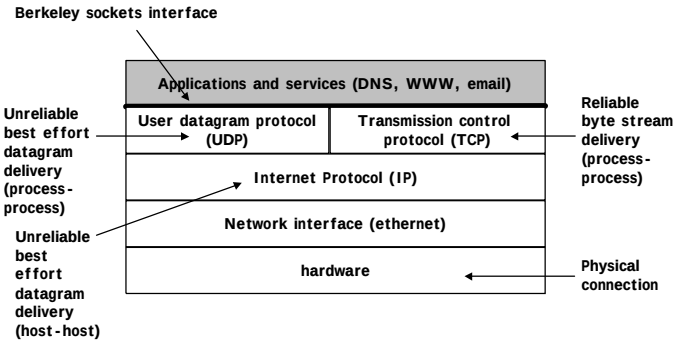
Internet Services I

April 25, 2000

Topics

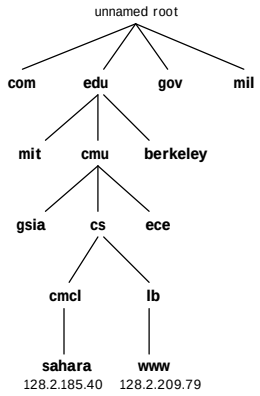
- Domain Naming System (DNS)
- World Wide Web
  - Web servers
  - HTTP (static content)

Internet protocol stack



Hierarchical domain name space

- Until 198x, domain name/IP address mapping maintained in HOSTS.TXT file at SRI.
- Each new host manually entered and copied to backbone routers.
- Explosive growth rendered HOSTS.TXT approach impractical.
- Replaced by Domain Name System in 198x.



DNS

- Worldwide distributed system for mapping domain names to IP addresses (and vice versa).
- Implemented as a collection of cooperating servers called *name servers*.
- Name servers perform lookups for DNS clients
  - user programs
    - `gethostbyname(), gethostbyaddr()`
  - `nslookup`
    - stand-alone client with command line interface

```
kittyhawk> nslookup bass.cmcl
Server:  localhost
Address:  127.0.0.1

Non-authoritative answer:
Name:    bass.cmcl.cs.cmu.edu
Address:  128.2.222.85
```

Zones

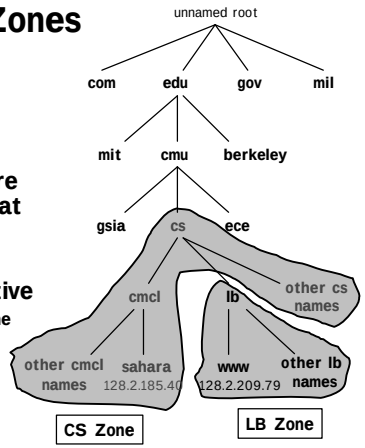
Domains are partitioned into zones.

Each zone has multiple name servers that store info about names in that zone.

- CS zone has 4 servers

One server is authoritative

- the others get copies of the authoritative server's data



Zone databases

Each name server keeps a database with information about each name in its zone.

Examples of info (`type`: description)

- `A`: IP address
- `NS`: name servers for zone
- `SOA`: "start of authority" indicates authoritative server
- `WKS`: well known services running on that host
- `HINFO`: host info (OS and machine type)
- `PTR`: domain name ptr (if this subdomain has its own server)

Zone transfers

Clients can inspect the contents of a zone database via a copy operation called a *zone transfer*.

- all info of a particular type or types (`A`, `NS`, etc) of info for each domain name in the entire zone is copied from server to client.

Servers can control which client machines are allowed to perform zone transfers

Example: zone transfer of `cs.cmu.edu` (Types `A` & `PTR`)
(note: this is the default for `nslookup`)

```
...
SAHARA.CMCL      128.2.185.40
...
LB               server = ALMOND.SRV.CS.CMU.EDU
LB               server = PECAN.SRV.CS.CMU.EDU
...
POSTOFFICE       128.2.181.62
...
```


Zone transfers (cont)

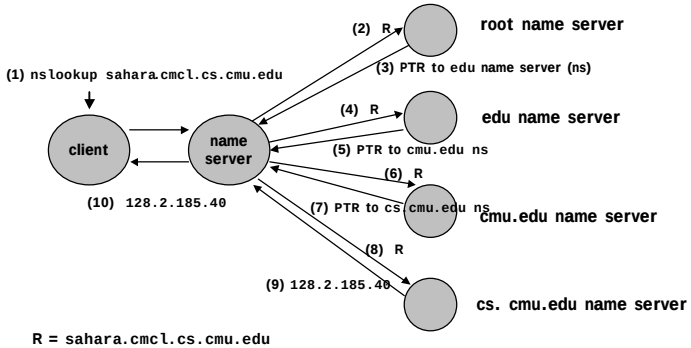
Example: zone transfer of `cs.cmu.edu` (Type `HINFO`)

```
...
SAHARA.CMCL      DEC-600-5/333 UNIX
...
AMEFS.SRV        INTEL-486 UNIX
...
```

Note: no `HINFO` for `POSTOFFICE` or `LB`

Mapping domain names to IP addrs

Used by `gethostbyname()` and `nslookup`



R = sahara.cmcl.cs.cmu.edu

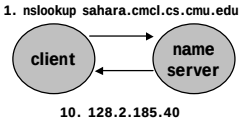
DNS Caching

Servers cache (keep a copy of) of information they receive from other servers as part of the name resolution process.

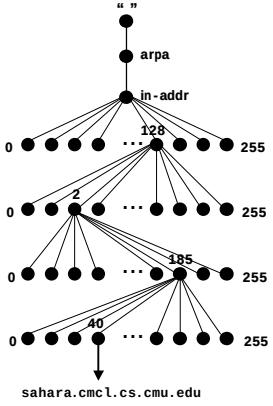
This greatly reduces the number of queries.

Example

- In our previous example, the next query for `sahara.cmcl` can be answered immediately because the server kept a copy of the address.



Mapping IP addrs to domain names



A separate hierarchy exists in the `in-addr.arpa` domain that maps IP addresses to domain names.

Used by `gethostbyaddr()` and `nslookup`

Example:

- **IP address**: 128.2.185.40
- Corresponding domain name `sahara.cmcl.cs.cmu.edu` stored at `40.185.2.128.in-addr.arpa`

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 graphical browser for Next machines.

Web history (cont)

1992

- NCSA server released
- 26 WWW servers worldwide

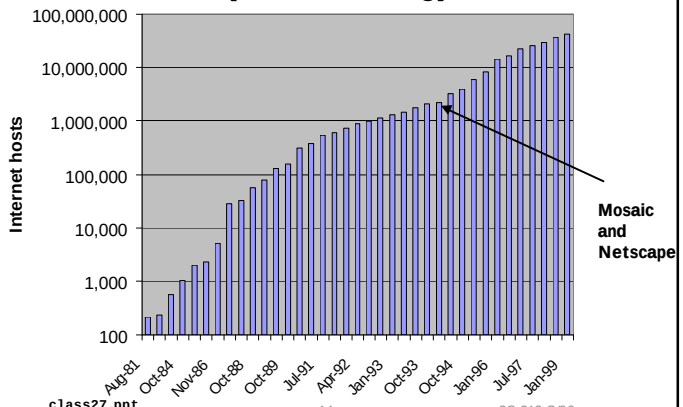
1993

- Marc Andreessen releases first version of NCSA Mosaic (Feb)
- 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)



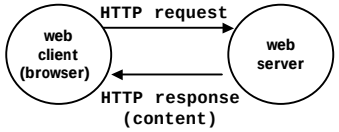
Web servers

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

(Figure showing that Apache is now the dominant web server has been deleted because it was too large; see either the Powerpoint source file or a hardcopy handout.)

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:

- `http://euro.ecom.cmu.edu:80/index.html`
- `http://euro.ecom.cmu.edu/index.html`
- `http://euro.ecom.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

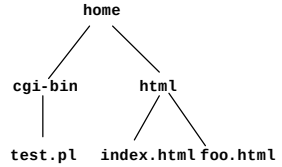
GET / HTTP/1.1
- resolves to home/html/index.html
- action: retrieves index.html

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 BennSSL/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 BennSSL/1.28 (Unix)
Content-Length: 0
Allow: GET, HEAD, OPTIONS, TRACE
```


OPTIONS (euro.ecom)

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

OPTIONS /cgi-bin/fixit.pl HTTP/1.1
Host: euro.ecom.cmu.edu
CRLF                                          Request
-------------------------------------------------------
HTTP/1.1 200 OK                               Response
Date: Thu, 22 Jul 1999 22:09:11 GMT
Server: Apache/1.3.3 BennSSL/1.28 (Unix)
Content-Length: 0
Allow: GET, HEAD, POST, OPTIONS, TRACE
```


OPTIONS (microsoft.com)

```
kittyhawk> telnet microsoft.com 80
Trying 207.46.131.137...
Connected to microsoft.com.
Escape character is '^]'.

OPTIONS * HTTP/1.1
Host: microsoft.com
CRLF                                          Request
-------------------------------------------------------
HTTP/1.0 200 OK                               Response
Server: Microsoft-IIS/4.0
Date: Thu, 22 Jul 1999 04:13:34 GMT
Public: OPTIONS, TRACE, GET, HEAD, POST, PUT, DELETE
Content-Length: 0
```


OPTIONS (microsoft.com)

```
kittyhawk> telnet microsoft.com 80
Trying 207.46.130.150...
Connected to microsoft.com.
Escape character is '^]'.

OPTIONS / HTTP/1.1
Host: microsoft.com
CRLF                                          Request
-------------------------------------------------------
HTTP/1.0 200 OK                               Response
Server: Microsoft-IIS/4.0
Date: Thu, 22 Jul 1999 22:13:46 GMT
Public: OPTIONS, TRACE, GET, HEAD, POST, PUT, DELETE
Allow: OPTIONS, TRACE, GET, HEAD
Content-Length: 0
```

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
```


OPTIONS (etoys.com)

```
kittyhawk> telnet etoys.com 80
Trying 206.251.23.116...
Connected to etoys.com.
Escape character is '^]'.

OPTIONS * HTTP/1.1
Host: etoys.com
CRLF                                                    Request
-------------------------------------------------------------
HTTP/1.1 200 OK                                         Response
Date: Thu, 22 Jul 1999 04:52:59 GMT
Server: Etoys Web server 1.0
Content-Length: 0
Allow: GET, HEAD, OPTIONS, TRACE
```


OPTIONS (etoys.com)

```
kittyhawk> telnet etoys.com 80
Trying 206.251.23.116...
Connected to etoys.com.
Escape character is '^]'.

OPTIONS /index.html HTTP/1.1
Host: etoys.com
CRLF                                                    Request
-------------------------------------------------------------
HTTP/1.1 200 OK                                         Response
Date: Thu, 22 Jul 1999 22:04:43 GMT
Server: Etoys Web server 1.0
Content-Length: 0
Allow: GET, HEAD, POST, OPTIONS, TRACE
```


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 GETs 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 BennSSL/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 BennSSL/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 BennSSL/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
-------------------------------------------------------
HTTP/1.1 301 Document Moved                   Response
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