HTTP Servers

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Learning goals

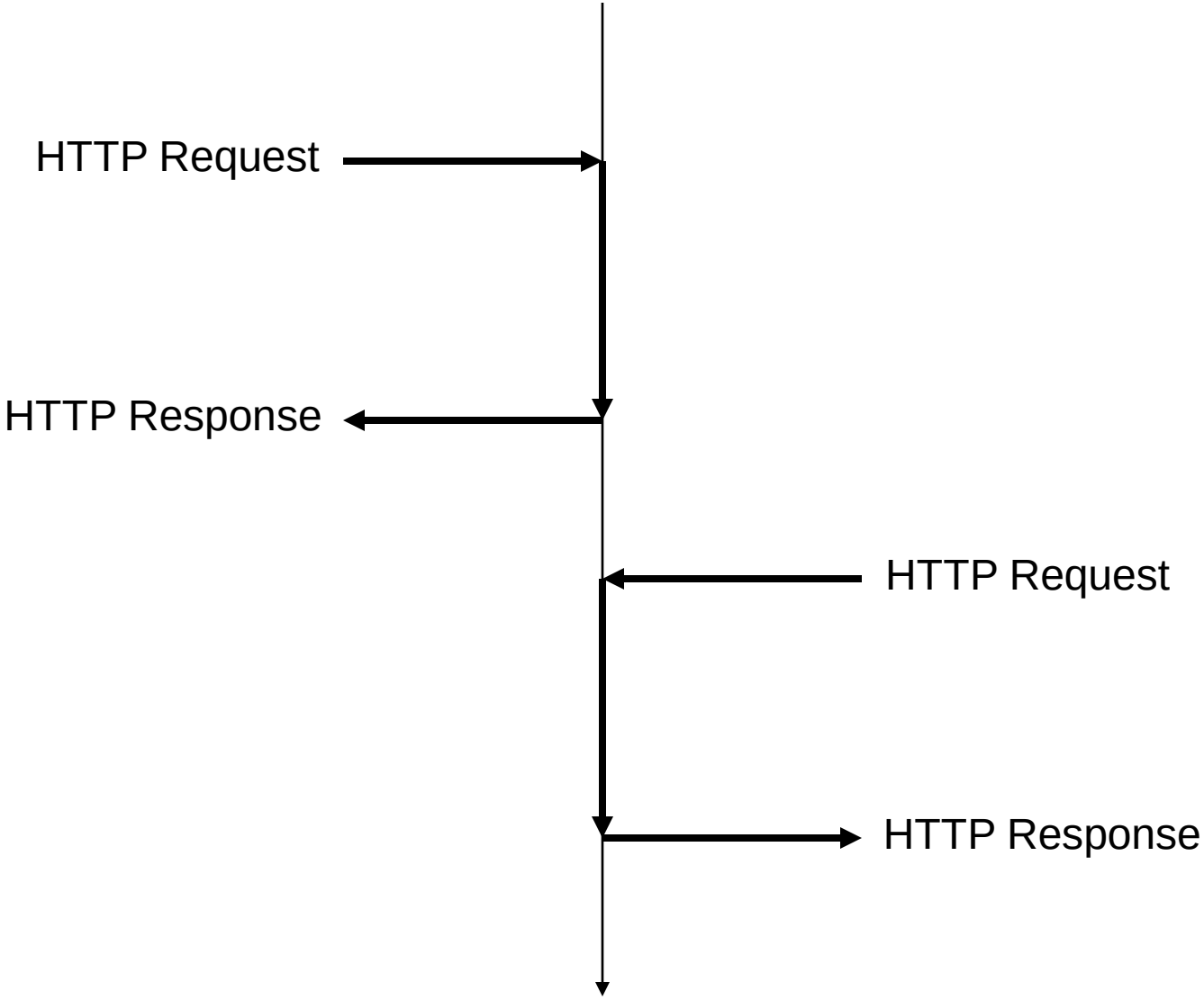
Understand:

- Basis HTTP server functionality
- Serving static content
  - from HTML and other files
- Serving dynamic content
  - from software within a HTTP server
  - from external software
- Security & privacy issues

HTTP: The Web's network protocol

- Early 90s: only a few HTTP servers, but many FTP servers helped bootstrapping the Web
  - Example: ftp://ftp.gnu.org/gnu/aspell/dict/en/
- HTTP servers based on the freely available *httpd* web server from NSCA
- NCSA stopped *httpd* support when the associated team left to start Netscape
- Webmasters started to send around software patches to further improve *httpd*
- Result was referred to as "a patchy server"
- Now the open source **Apache** server is one of the mostly used Web servers

HTTP server main loop



HTTP server main loop

```
while(forever)
  listen to TCP port 80 and wait
  read HTTP request from client
  send HTTP response to client
```

Seems not that complicated …

But: regular Apache HTTP server installation installs > 24Mb of software … ?!

What makes real servers so complex?

Static content

from files: HTML,
CSS, JavaScript, images, …

Example HTTP request

- **GET / HTTP/1.0**
-

Example HTTP request

- **`GET / HTTP/1.1`**
- **`Host: www.few.vu.nl`**

Why does the client need to tell the server the server's own hostname?

- because the server doesn't know its own name!
- **`www.cs.vu.nl`** is hosted on the same machine by the same server software
- server may need to send different responses for different host names
- "Virtual host" configuration allows web masters to tune server to do exactly this

Example HTTP request

```
GET / HTTP/1.1
Host: www.few.vu.nl
```

- Server needs to determine what resource is associated with '/'
- Also configurable, defaults to the file **`index.html`** in the server's "document root" directory, e.g. **`/var/www/www.few.vu.nl/html/index.html`**
- Security issues
  - **`GET ~yourname/../../../passwd HTTP/1.1`**
  - **`GET ~yourname/../~yourlogin/Mail HTTP/1.1`**
- Webmaster needs to configure which directories in the local file system may be served by the web server
  - Webmaster: "Oops, that dir should not have been on the Web"
  - User: "Oops, I didn't know this dir was on the Web too"

Example HTTP request

```
GET / HTTP/1.1
Host: www.few.vu.nl
```

- Server needs to send content of file **`index.html`** to the client
- Along with
  - length of the content
  - the current time/date
  - modification date
  - expiration date
  - MIME type of the content (e.g. text/html)
  - character encoding (e.g. UTF-8)
  - etc
- Most of these HTTP header values need to be looked up in a configurable way
- Results need to be **logged** in the server log for later analysis

Example: apache HTTP logs

access_log.2:**soling.few.vu.nl** - - [**11/Jan/2008:16:47:19 +0100**] "GET **/cgi-bin/wt-test?naam=&textarea=+** HTTP/1.0" 200 1341 "-" "Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6"

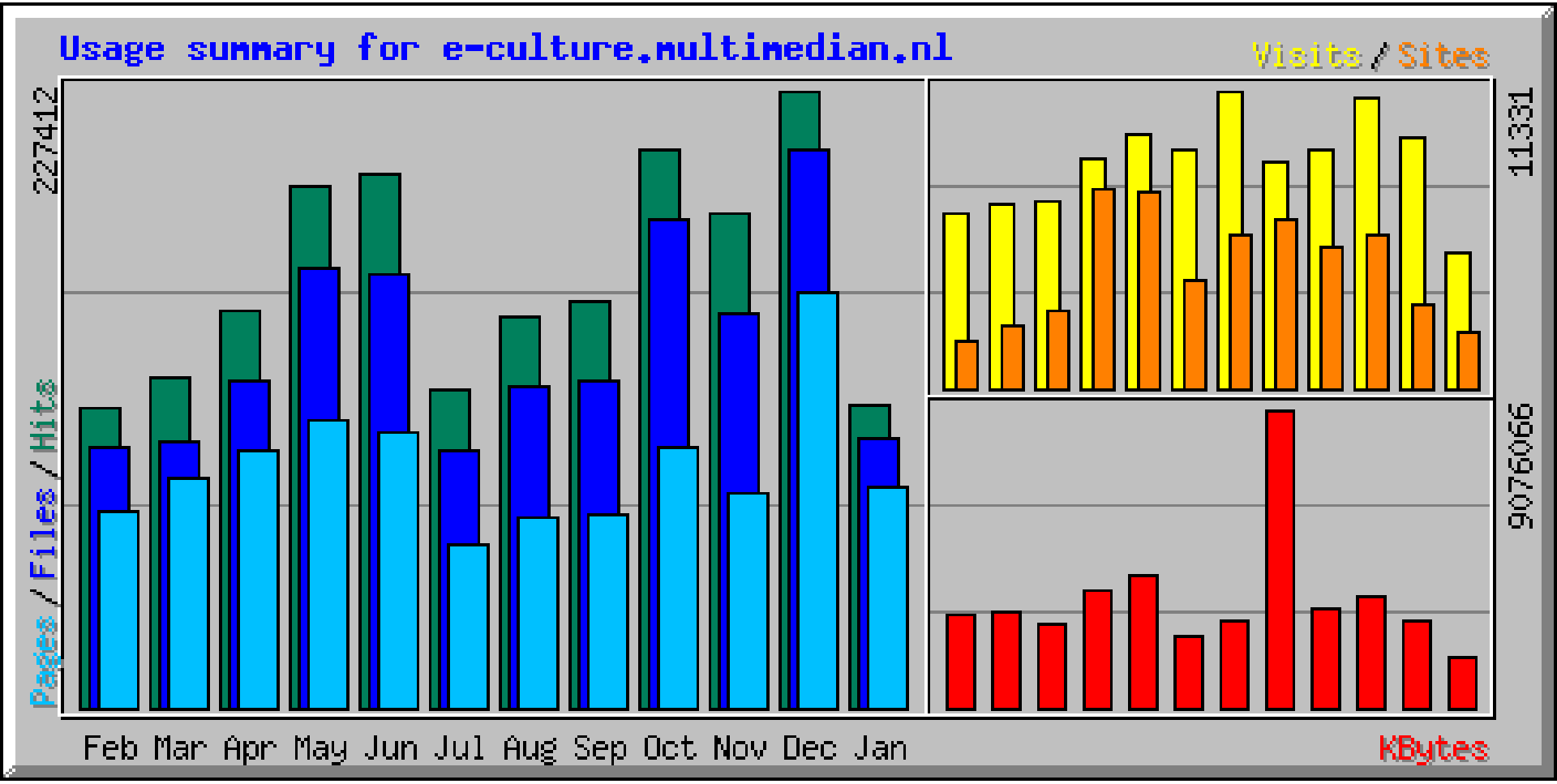
access_log.2:soling.few.vu.nl - - [11/Jan/2008:16:47:48 +0100] "GET /cgi-bin/wt-test?naam=&textarea=+ HTTP/1.0" 200 1341 "-" "Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6"

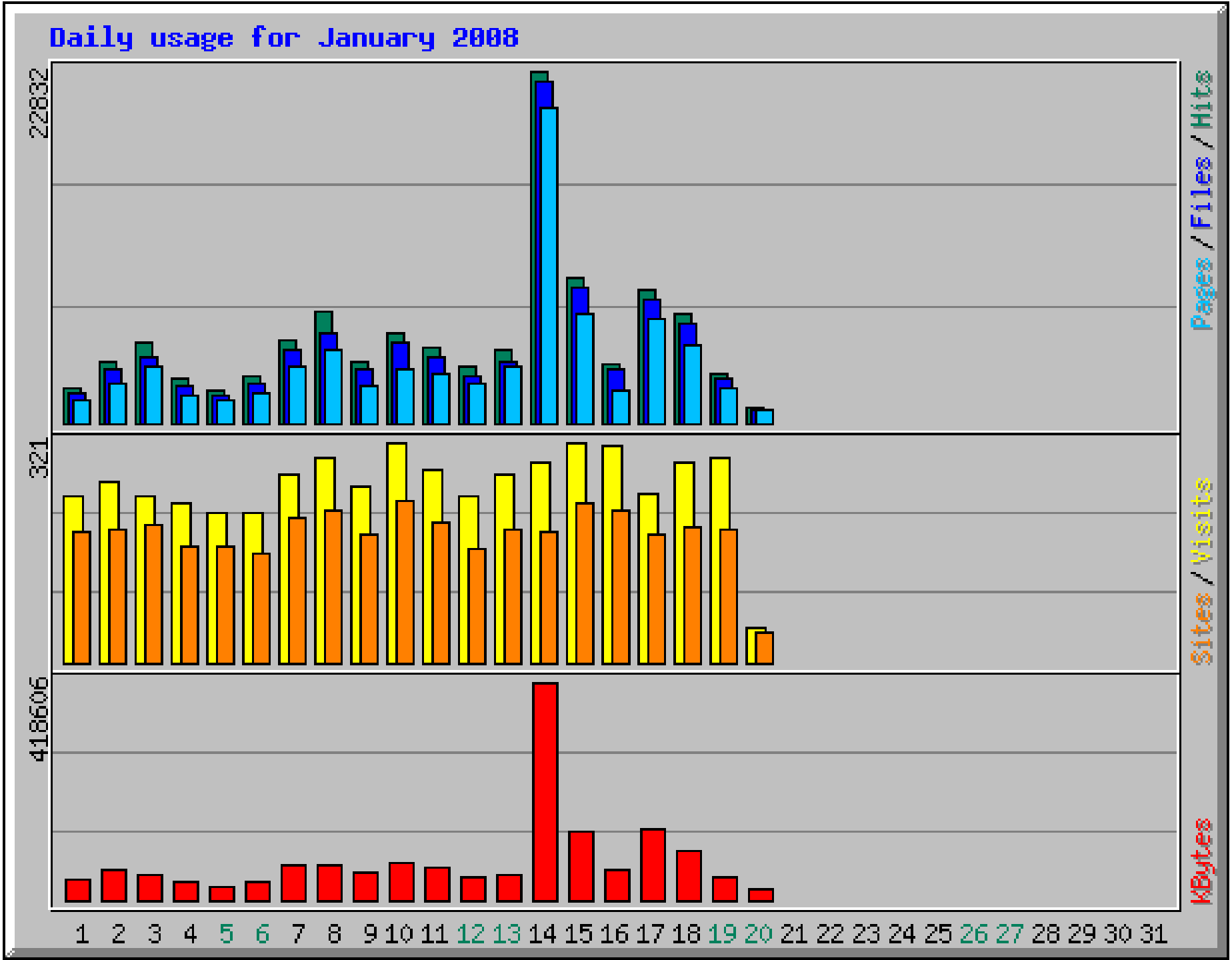
access_log.2:soling.few.vu.nl - - [11/Jan/2008:16:48:48 +0100] "GET /cgi-bin/wt-test?naam=&textarea=+ HTTP/1.0" 200 1341 "-" "Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6"

access_log.2:soling.few.vu.nl - - [11/Jan/2008:16:55:59 +0100] "GET /cgi-bin/wt-test?naam=&radio=inhoudelijk&textarea=+vxfvsdfsdf%0D%0A HTTP/1.0" 200 1409 "-“ "Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.1.6) Gecko/20070725 Firfox/2.0.0.6"

access_log.2:soling.few.vu.nl - - [11/Jan/2008:16:56:08 +0100] "GET /cgi-bin/wt-test?naam=Cjijij&radio=inhoudelijk&checkbox1=checkbox1&textarea=+vxfvsdfsdf%0D0A%0D%0Afsdfsdf HTTP/1.0" 200 1487 "-" "Mozilla/5.0 (Windows; U; Windows NT 5.1 en-US; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6"

access_log.2:soling.few.vu.nl - - [11/Jan/2008:16:58:25 +0100] "GET /cgi-bin/wt-test?naam=&radio=structuur1&textarea=+ HTTP/1.0" 200 1375 "-" "Mozilla/5.0 (Windows; U; Windows NT 5.1; en-US; rv:1.8.1.6) Gecko/20070725 Firefox/2.0.0.6"


Usage summary for e-culture.multimedian.nl
Visits / Sites
227412
11331
Pages / Files / Hits
9076066
Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan
KBytes


Daily usage for January 2008
22832
321
418606
Pages / Files / Hits
Sites / Visits
KBytes
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Top N of ...

Top 10 of 2094 Total Sites

	#Hits		Files		Kbytes		Visits		Hostname
1	**28066**	25.26%	**27754**	27.89%	**529851**	34.02%	**50**	0.97%	*.search.live.com
2	**14434**	12.99%	**13899**	13.96%	**206962**	13.29%	**7**	0.14%	***.googlebot.com**
3	**8963**	8.07%	**5779**	5.81%	**47864**	3.07%	**17**	0.33%	*.speedy.telkom.net.id
4	**6142**	5.53%	**5871**	5.90%	**59502**	3.82%	**82**	1.59%	***.cwi.nl**
5	**1265**	1.14%	**1203**	1.21%	**6455**	0.41%	**3**	0.06%	ipXX.speed.planet.nl
6	**1237**	1.11%	**1228**	1.23%	**10163**	0.65%	**18**	0.35%	soling.few.vu.nl
7	**1169**	1.05%	**1026**	1.03%	**6181**	0.40%	**1**	0.02%	XX.demon.nl
8	**1050**	0.94%	**972**	0.98%	**16429**	1.05%	**5**	0.10%	XXadsl.sinica.edu.tw
9	**956**	0.86%	**904**	0.91%	**5634**	0.36%	**5**	0.10%	XX.adslsurfen.hetnet.nl
10	**908**	0.82%	**889**	0.89%	**13028**	0.84%	**21**	0.41%	XX.wise-guys.nl

Top 7 Search Strings

1	**60**	**37.97%**	**the scream**
2	**8**	**5.06%**	**vu**
3	**6**	**3.80%**	**scream**
4	**4**	**2.53%**	**eculture**
5	**4**	**2.53%**	**the scream painting**
6	**3**	**1.90%**	**the scream paintings**
7	**2**	**1.27%**	***.gif**

Example HTTP request

```
GET / HTTP/1.1
Host: www.few.vu.nl
```

- Server needs to send content of file **`index.html`** to the client
- Along with
  - length of the content
  - the current time/date
  - modification date
  - expiration date
  - MIME type of the content (e.g. text/html)
  - character encoding (e.g. UTF-8)
  - etc
- Most of these HTTP header values need to be looked up in a configurable way
- Results need to be **logged** in the server log for later analysis
  - Assume everything you do will be logged and will be traceable back to you

Example HTTP response

```
HTTP/1.1 200 OK
Date: Mon, 21 Jan 2008 10:18:49 GMT
Server: Apache/2.0.58 (Unix) mod_ssl/2.0.58
  OpenSSL/0.9.7d DAV/2 PHP/5.2.4 mod_python/3.3.1
  Python/2.4.3
X-Powered-By: PHP/5.2.4
Expires: Mon, 21 Jan 2008 16:18:49 GMT
Connection: close
Content-Type: text/html

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01
  Transitional//EN">
<html>
<head>
```

Example HTTP response

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Static vs dynamic content

- Not all requests are for **static content** stored in a file
  - some data needs to be requested by the server from other applications
    (e.g. from an organisation's database)
  - some data needs to be computed "on the fly" in response to the request
    (e.g. results of a query on a search engine)
- Need for **dynamic content** by **programmable** server behaviour
- Note: from the browser's perspective, static and dynamic content look syntactically exactly the same ("it's just a URI")

REST

Roy Fielding

- co-author of the HTTP specification
- co-founder of Apache
- described the key principles of WWW network architecture in his PhD thesis (UCI, 2000)
- He named these principles **REST** (**RE**presentational **S**tate **T**ransfer)
- Implementations are called **RESTful**
- REST strongly influenced the early network architecture of the Web…
- … and still does:
  - 15 Jan 2008:
    W3C published the SPARQL Recommendation, a web query language based on a RESTful design

REST: key principles

- **All** sources of information (files and applications) are **resources** that are uniquely addressable using a **URI**
- Clients and servers only need to know
  - the URI of the resource (e.g. **`http://www.few.vu.nl/`**)
  - the allowed actions (e.g. **`HTTP GET`**)
  - the allowed representations (e.g. **`text/html`**)
- Client does not need to know how the server generates the representation
- Server does not need to know how the client presents it
- Both client and server do not need to be aware of intermediate proxies or caches
- There is no communication state
  - HTTP response does not depend on previous request
  - Methods are **idempotent**: requesting the same resource multiply times will yield the same content
- Simplifies global design and improves performance …
- … but sometimes makes server programming more difficult

dynamic content

computed by other software
computed by the server

CGI: common gateway interface

- Commonly agreed upon way to run batch programs in response to a HTTP request
- HTTP server executes program
  - server recognizes a CGI request and determines which program from the URL
  - supplying details about the request to the program via (OS environment) variables
  - returning program's output verbatim to the client (output needs to supply content and all required HTTP headers)

CGI Example: form URL you used in assignment 1

```
<form action="http://eculture.cs.vu.nl/cgi-bin/wt1-test"
      method="get">
```

```
#!/usr/bin/perl
##
##  cgi-bin/wt1-test -- program which just prints its environment
##

print "Content-type: text/plain\n\n";
foreach $var (sort(keys(%ENV))) {
    $val = $ENV{$var};
    $val =~ s|\n|\\n|g;
    $val =~ s|"|\\"|g;
    print "${var}=\"${val}\"\n";
}
```

CGI response

```
HTTP/1.1 200 OK
Date: Fri, 18 Jan 2008 14:09:18 GMT
Server: Apache/2.2.9
Connection: close
Content-Type: text/plain

DOCUMENT_ROOT="/export/data1/httpd/htdocs"
GATEWAY_INTERFACE="CGI/1.1"
HTTP_ACCEPT_LANGUAGE="en"
HTTP_HOST=”eculture.cs.vu.nl"
QUERY_STRING="name=value"
REMOTE_ADDR=“80.127.61.144"
REMOTE_HOST=“plan.xs4all.nl“
…
```

CGI: pros & cons

- ✓ Very flexible
  - can use programs written in any interpreted or compiled programming language
  - easy way to reuse existing software in a Web context
- – Creates a new process to re-execute program for every request
  - – very expensive: too slow for popular sites
  - – hard to maintain state between requests

    (we will look deeper into the concept of state later)
- – Mixes program logic and HTML generation
  - – hard to maintain by programmers and designers
- – Not convenient to get data from databases

CGI alternatives

- server-side scripting:
  - server has a module that keeps the language interpreter running over multiple requests
  - running little scripts at the server (“servlets”) is then relatively cheap
- Use general purpose scripting languages
  - Apache comes standard with modules for many languages: mod_python, mod_perl, …

Example HTTP response

```
HTTP/1.1 200 OK
Date: Fri, 18 Jan 2008 11:18:49 GMT
Server: Apache/2.0.58 (Unix) mod_ssl/2.0.58
  OpenSSL/0.9.7d DAV/2 PHP/5.2.4 mod_python/3.3.1
  Python/2.4.3
X-Powered-By: PHP/5.2.4
Expires: Fri, 21 Jan 2008 17:18:49 GMT
Connection: close
Content-Type: text/html

<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01
  Transitional//EN">
<html>
<head>
```

CGI alternatives: scripting

- Server-side scripting:
  - server has a module that keeps the language interpreter running over multiple requests
  - running little scripts at the server is then relatively cheap
- Use general purpose scripting languages:
  - mod_python, mod_perl, …
  - need rules to determine which URLs are deferred to script module (e.g. **`http://www.example.org/file.py`**)
- Compiled Java bytecode programs
  - server modules running a Java Virtual Machine are known as a web or **servlet** container (e.g. tomcat)
  - servlets typically use standard Java extensions to simplify programming (javax.servlet.*)
- All these solutions result in files that look like programs
  - HTML markup deeply hidden in "print" statements
  - hard to maintain by non-programmers

Example: code with hidden HTML

```
print “<html>”
…
print “<body>”
print “<ul>”
for (i=1; i<N; i++) {
     data = get_item(i);
     print “<li>” + data +</li>
}
print “</ul>”
…
```

Dedicated frameworks

- Use dedicated scripting frameworks
  - *PHP: Hypertext Preprocessor*
    - Used to implement WordPress, MediaWiki
    - mixes html, program code & database queries
  - *JSP: Java Server Pages*
    - mixes html & java
- These approaches typically result in files that look like HTML pages, with embedded code and custom tags processed by the server
  - complex func. still requires programming
  - but results are easier to reuse
  - easier to maintain, also by non-programmers

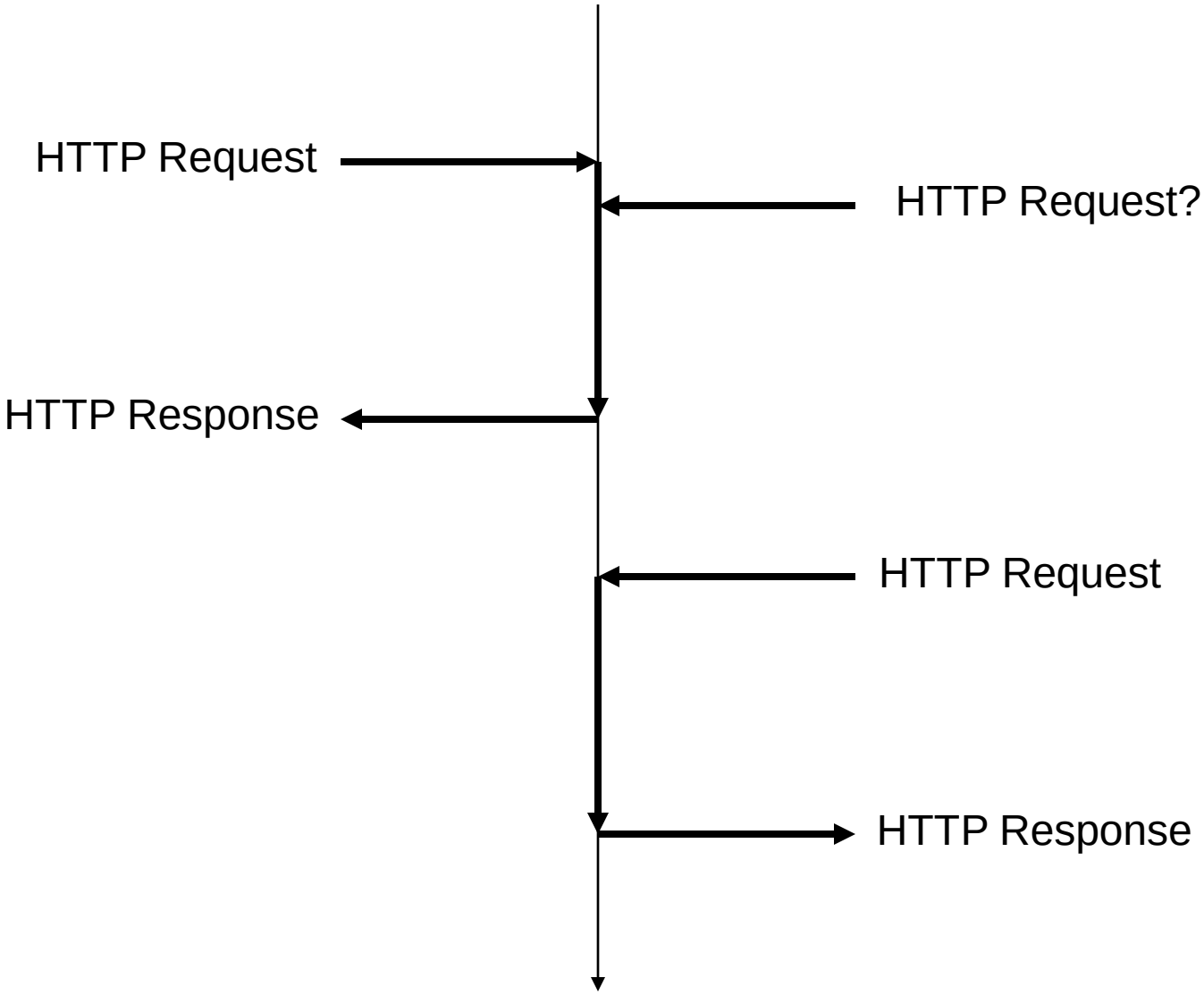
Example: HTML with hidden code

```
<html>
…
<body>
<ul>
<? generate_items(N) ?>
</ul>
</body>
</html>
```

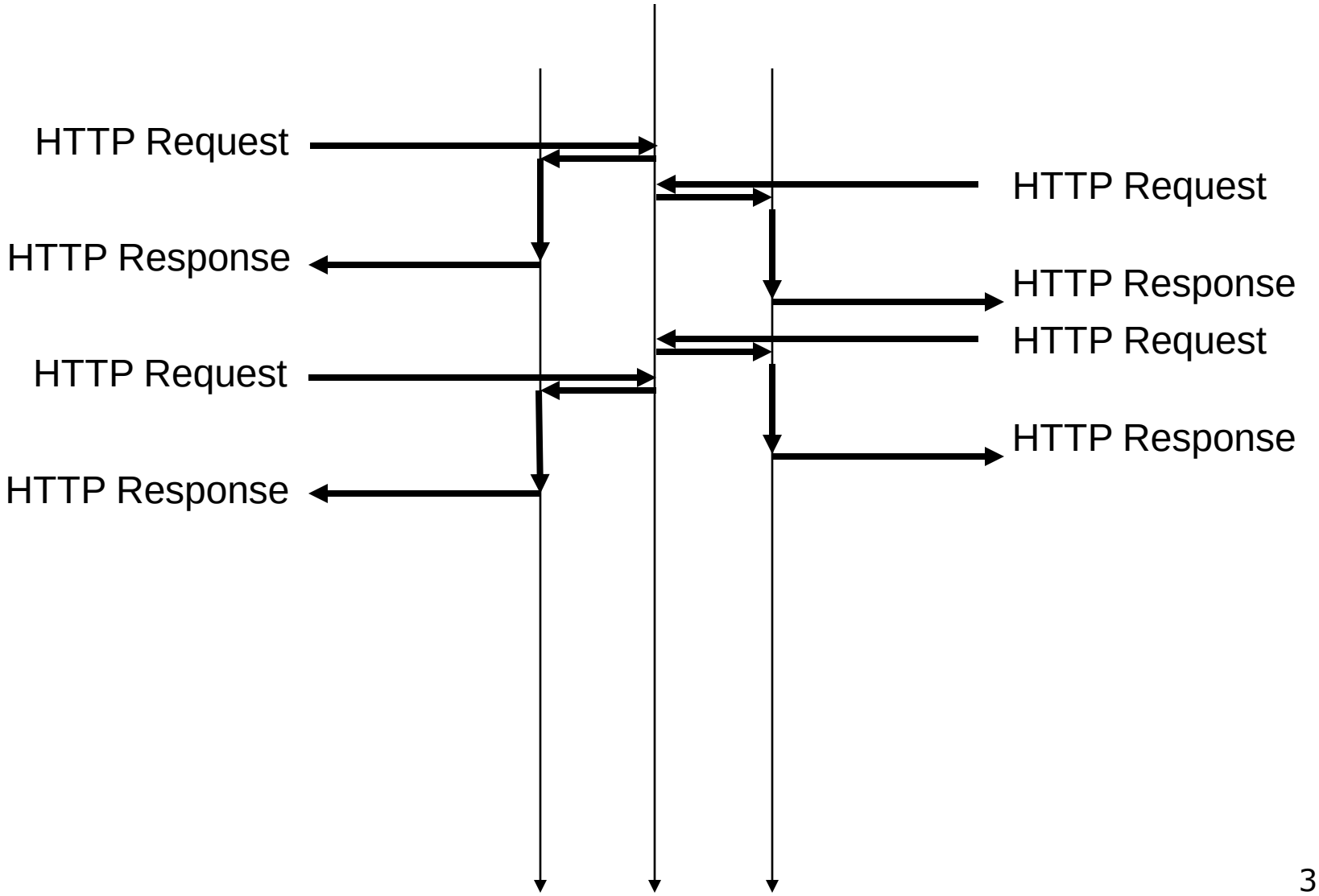
Typical problems in server programming

- Concurrency
- Session management & cookies
- Authentication & security
- Interfacing with other software (generating HTML from database content)

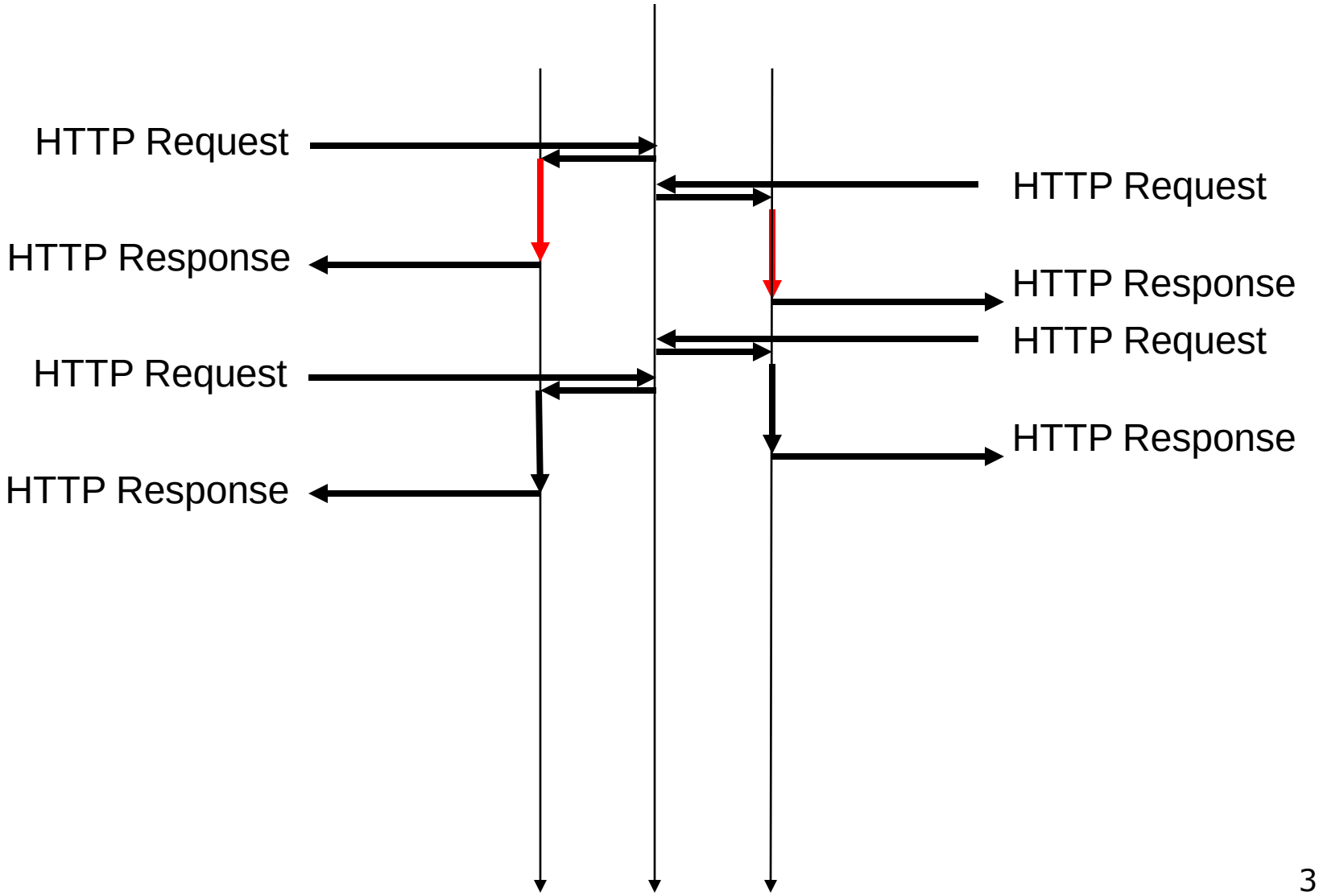
HTTP server main loop



HTTP server concurrency



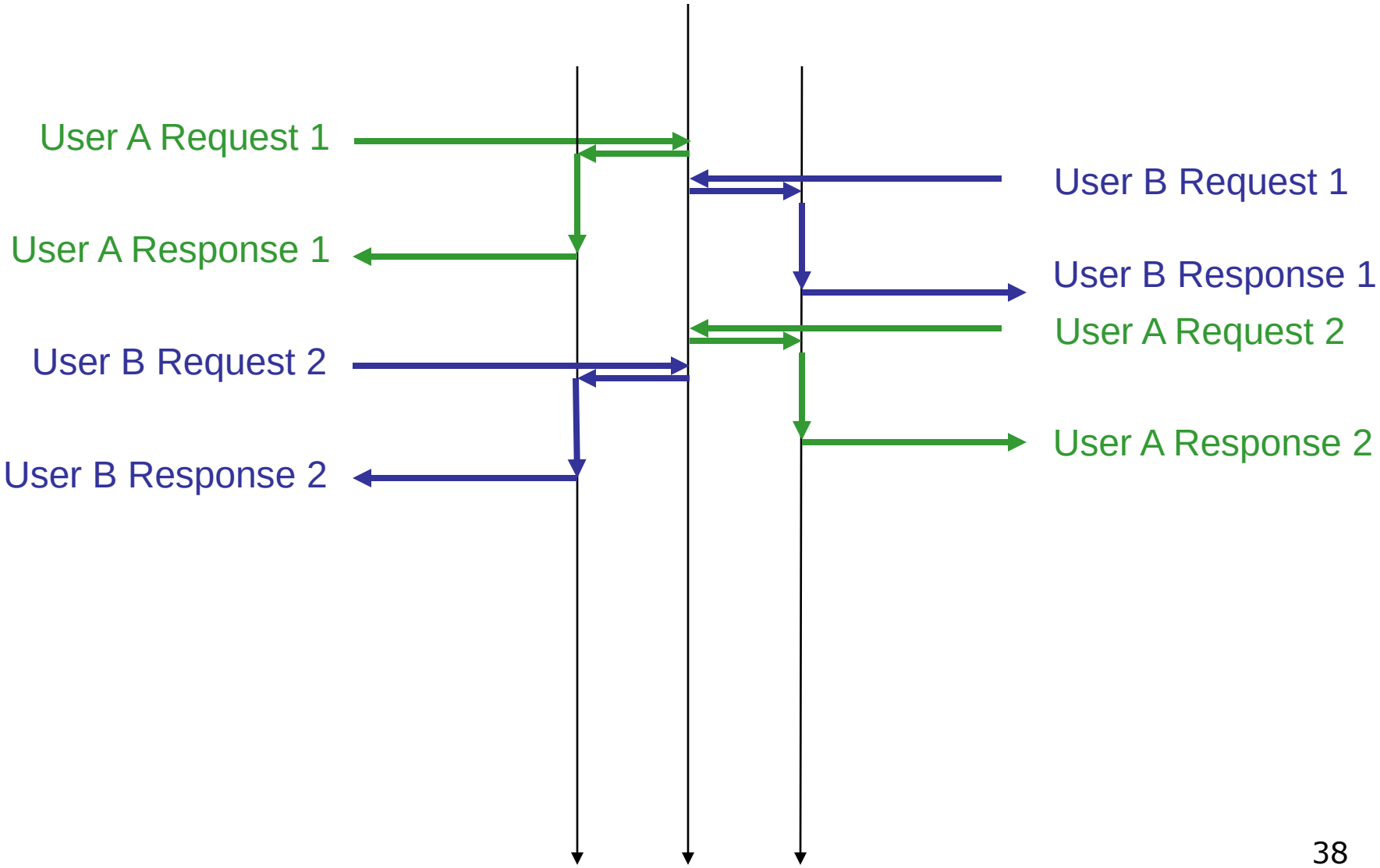
HTTP server concurrency



HTTP server concurrency

- Server-side software needs to be aware that other processes/threads processing other request **may** run at the same time ("multi-threading", "MT-safe")
  - makes accessing global resources (variables, databases, files) more complicated and error prone

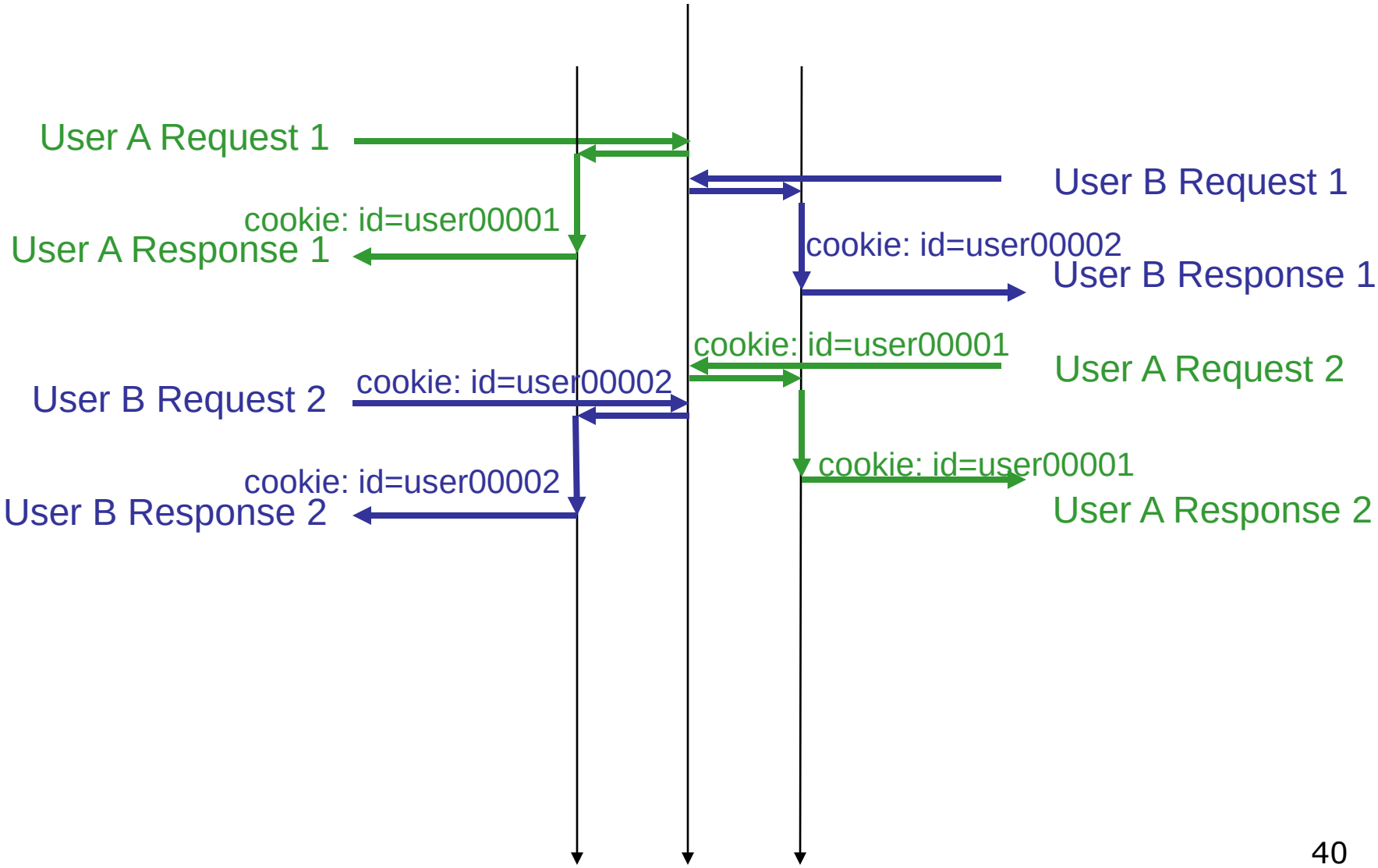
HTTP server sessions



HTTP server sessions

- How to recognize which requests belong to the same user?
  - look at client's IP address
  - in first response, send client a small but unique piece of data
  - ask client to send this back as part of the HTTP header of all following requests
  - piece of data is known as a (magic) **cookie**

HTTP server sessions



Cookie: bb.vu.nl response

```
HTTP/1.1 302 Moved Temporarily
Set-Cookie: ARPT=IZJNJNSbb3CYUQ; path=/
Date: Sun, 20 Jan 2008 20:24:23 GMT
Server: Apache/1.3.33 (Unix) mod_ssl/2.8.21 OpenSSL/0.9.7e
  mod_jk/1.2.4
Pragma: no-cache
Cache-Control: no-cache
Set-Cookie: session_id=@@BCCF1515B166A6BE2FF476EB20E9774F
Location: http://bb.vu.nl/nocookies.html
Content-Length: 0
Connection: close
Content-Type: application/octet-stream;charset=ISO-8859-1
```

Cookies

- Introduced in Mosaic browser (1994)
  - cookies were enabled by default
  - users were not informed when a site set a cookie
  - most users did not know about cookies at all
- Privacy issues became serious issue in 1996 after a publication in the Financial Times
- Now all major browsers allow users to delete cookies and to be alerted when cookies are set
- Many sites make privacy policies public on their site (P3P)

Cookies

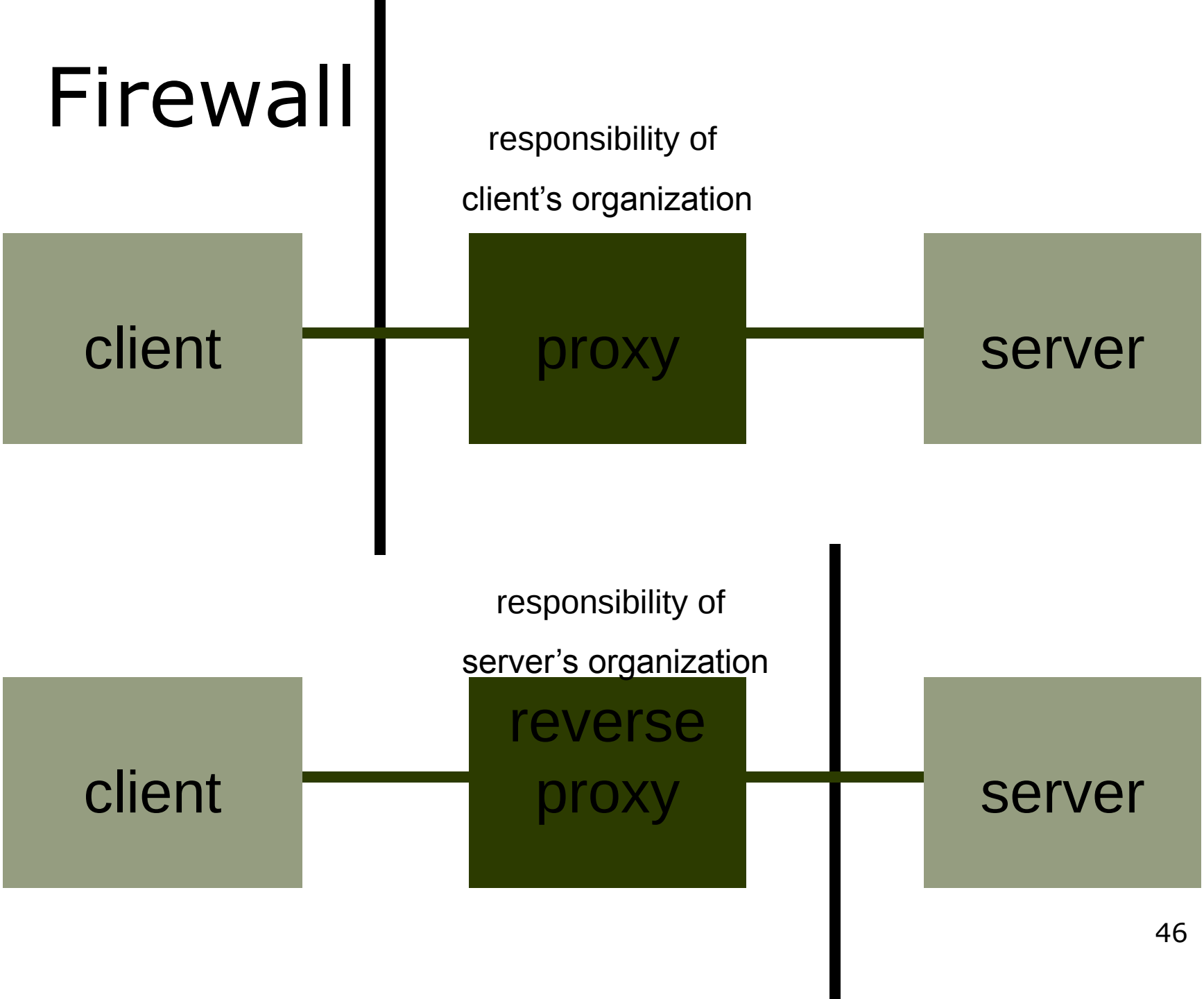
- Handy
  - Electronic shopping basket
  - Personalisation
    - user preferences
    - user profile
  - Authentication
- Tricky
  - User tracking across websites
  - Direct marketing
  - Privacy issues
- Note: sites may set cookies without knowing it or even using them…
- Check the cookies stored in your browser

Security issues

see also
guest lecture Thursday

Proxies & firewalls

- Some clients have no direct internet access to contact servers
  - Browser can use a **proxy** server
  - Content servers do not need to know
- Some servers have no direct internet access to be contacted (!)
  - Server can use a **reverse proxy** server
  - Clients do not need to know


Firewall
responsibility of
client's organization
client
proxy
server
responsibility of
server's organization
client
reverse
proxy
server

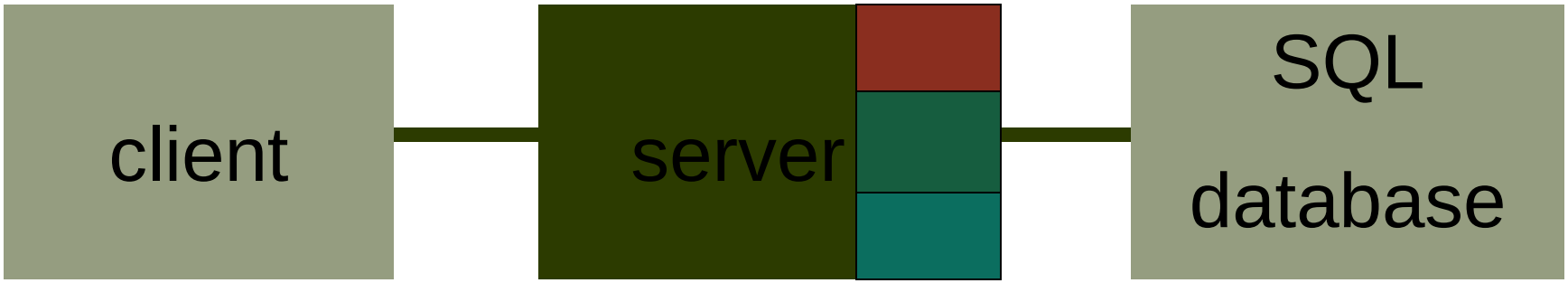
Authentication & encryption

- HTTP 1.0 Basic Access Authentication
  - username, password, content sent in plain text
- HTTP Digest Access Authentication
  - username, password encrypted
  - content still sent plain text
- HTTPS: HTTP entirely over secure layer
  - public key encryption, also for content
  - less vulnerable to man in the middle attacks

Man in the middle attack

- HTTPS requires web site to authenticate itself using a **certificate** stating its identity
- How do you know how to trust **certificate authority**?
  - many generally trusted authorities are known by your browser

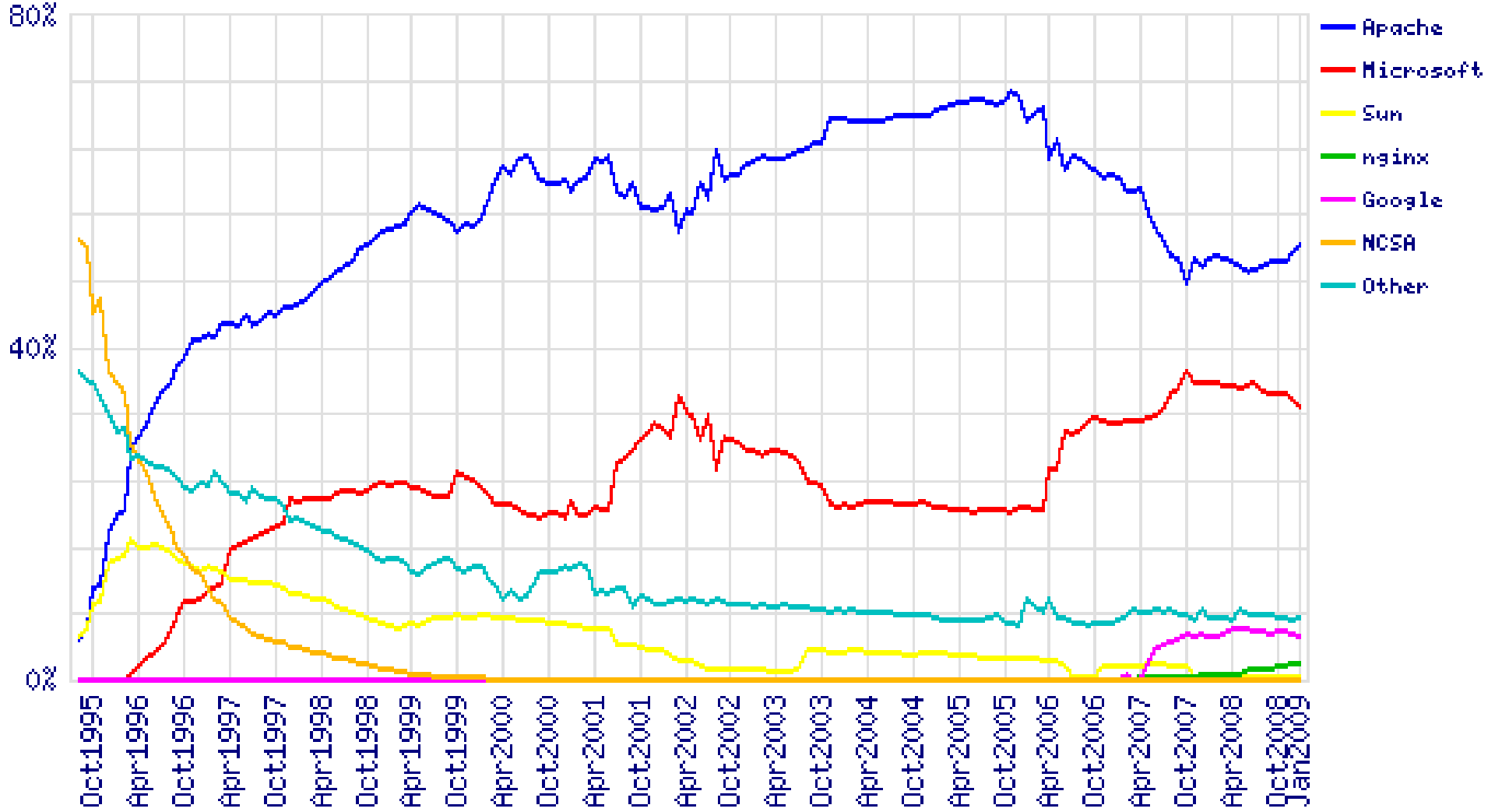
Database connectivity



- All frameworks provide ways to simplify generating HTML out of database content
  - Java Servlets, JSP
  - PHP
  - Content management systems
  - …

LAMP and the ubiquity of HTTP servers

- Typical web server needs:
  1. Operating system with good TCP/IP support
  2. HTTP server implementation
  3. Database to store content
  4. Framework for creating web pages from database content
- All these ingredients are currently commonly available (as open source software) and run on commodity PCs
- Frequently used combination is **L**inux, **A**pache, **M**ySQL and **P**HP (**LAMP**)
- Many sites are served by LAMP software running on old PC hardware …
- A "web server" is nothing special anymore!
  > 185 million servers (Netcraft, Jan 2009)


80%
40%
0%
Apache
Microsoft
Sun
nginx
Google
NCSA
Other
Oct1995
Apr1996
Oct1996
Apr1997
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Apr1998
Oct1998
Apr1999
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Apr2000
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Apr2004
Oct2004
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Apr2007
Oct2007
Apr2008
Oct2008
Jan2009

Learning goals

- Understand
  - Basis HTTP server functionality
  - Serving static HTML and other files
  - Serving dynamic content from software within a HTTP server
  - Serving dynamic content from external software
  - Be aware of security & privacy issues