

# Web Server Design

## Lecture 4 – Long-lived Connections, Pipelines

Old Dominion University

Department of Computer Science

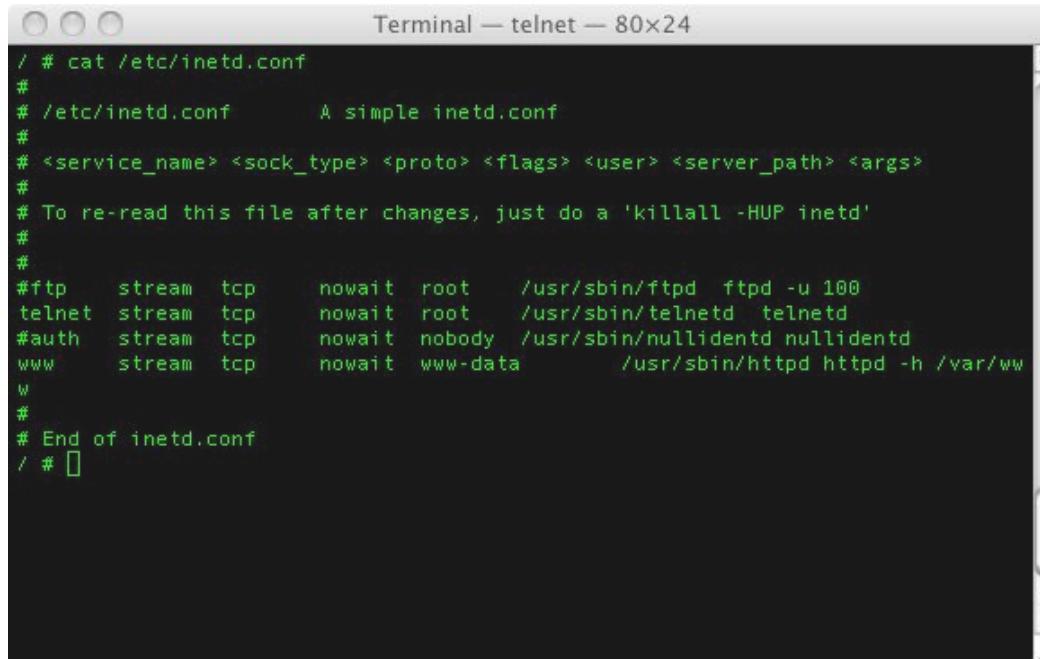
CS 431/531 Fall 2022

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Original slides by Michael L. Nelson

# History...

- In the prehistoric days, we used “inetd” to start net services
  - <http://en.wikipedia.org/wiki/Inetd>



A screenshot of a Mac OS X terminal window titled "Terminal — telnet — 80x24". The window displays the contents of the /etc/inetd.conf file. The text is in green on a black background. It includes comments, service definitions for ftp, telnet, auth, and www, and a final "# End of inetd.conf" line.

```
/ # cat /etc/inetd.conf
#
# /etc/inetd.conf      A simple inetd.conf
#
# <service_name> <sock_type> <proto> <flags> <user> <server_path> <args>
#
# To re-read this file after changes, just do a 'killall -HUP inetd'
#
#
#ftp    stream  tcp     nowait  root    /usr/sbin/ftpd  ftpd -u 100
telnet  stream  tcp     nowait  root    /usr/sbin/telnetd telnetd
#auth   stream  tcp     nowait  nobody  /usr/sbin/nullidentd nullidentd
www     stream  tcp     nowait  www-data /usr/sbin/httpd httpd -h /var/www
#
#
# End of inetd.conf
/ # []
```

# HTTP/1.0 Keep-Alive

- In the very early days, web pages had few images, so 1 TCP connection per URL was not so bad
- HTTP/1.0
  - Keep-Alive extension added (but unevenly supported) to say “don’t hang up”
  - See Roy Fielding’s early note:
    - <http://ftp.ics.uci.edu/pub/ietf/http/hypermail/1995q4/0063.html>
    - Now 404, see: <http://web.archive.org/web/20081008002735/http://ftp.ics.uci.edu/pub/ietf/http/hypermail/1995q4/0063.html>

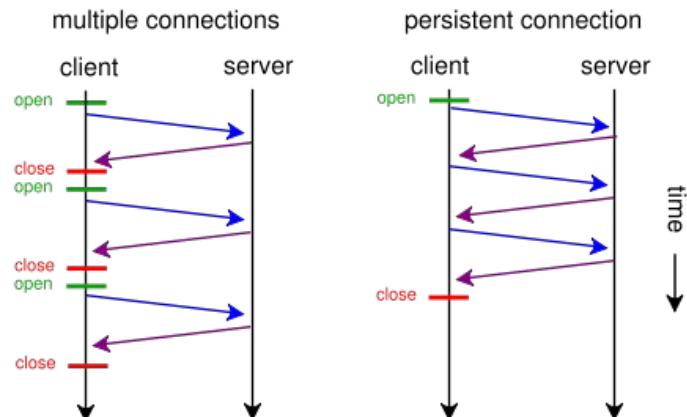


Image from: [http://en.wikipedia.org/wiki/File:HTTP\\_persistent\\_connection.svg](http://en.wikipedia.org/wiki/File:HTTP_persistent_connection.svg)

# Latency in HTTP/1.0

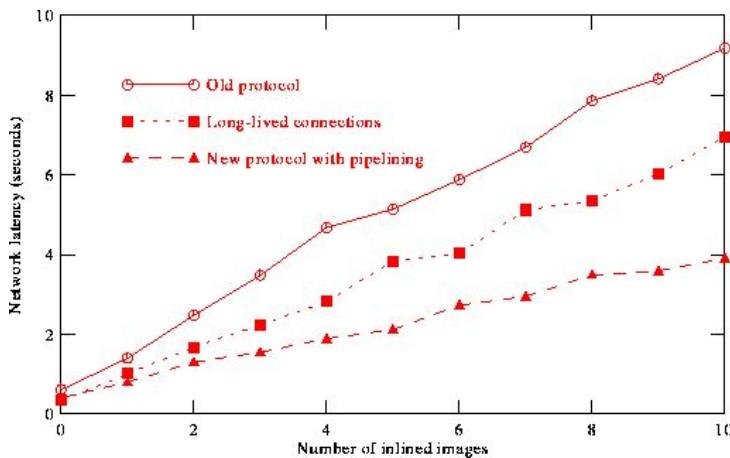


image size = 2.5k

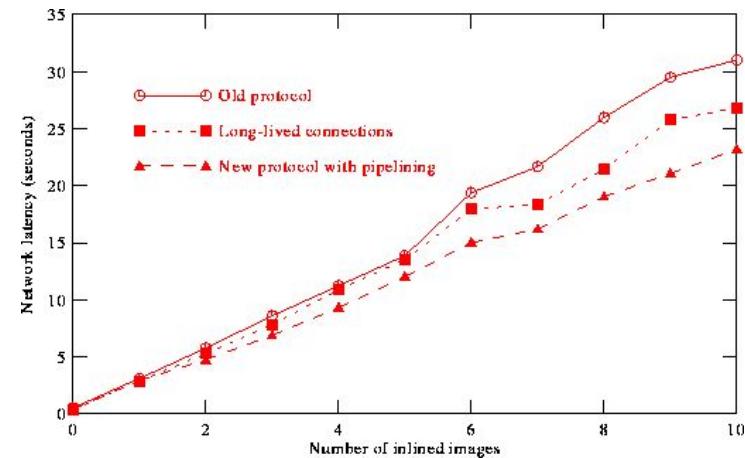


image size = 45k

Figs 6-1 & 6-2 from Padmanabhan & Mogul, "Improving HTTP Latency", Proceedings of 2nd WWW Conference, 1994  
[http://dx.doi.org/10.1016/0169-7552\(95\)00106-1](http://dx.doi.org/10.1016/0169-7552(95)00106-1)  
[http://scholar.google.com/scholar?cluster=319752692681403502&hl=en&as\\_sdt=0,47](http://scholar.google.com/scholar?cluster=319752692681403502&hl=en&as_sdt=0,47)

# HTTP/1.1 Keep-Alive is Default

- HTTP/1.1
  - Persistent connections (as they are now called) are the norm
    - See section 19.7.1, RFC 2068; section 19.6.2, RFC 2616, sections 6.1 and A.1.2, RFC 7230
  - You now have to specify a non-persistent connection with Connection: close

Inspect Network Request

Request URL: http://www.cs.odu.edu/~min/teaching/cs595-s12/etag-test/  
Request Method: GET  
Status Code: HTTP/1.1 200 OK

Request Headers 10:10:49.870

Accept: text/html,application/xhtml+xml,application/xml;q=0.9,\*/\*;q=0.8  
Accept-Charset: ISO-8859-1,utf-8;q=0.7,\*;q=0.7  
Accept-Encoding: gzip, deflate  
Accept-Language: en-us,en;q=0.5  
Cache-Control: max-age=0  
Connection: keep-alive  
Host: www.cs.odu.edu  
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.6; rv:9.0.1)  
Gecko/20100101 Firefox/9.0.1

Sent Cookie

\_gads: ID  
\_qca: P0-590067448-1271083828001  
\_utma: 256360345.3091995045699391000.1243351964.1327929666.1327967489.80  
\_utmc: 35744766  
\_utmz: 35744766.1328279508.99.74.utmccn  
style: null

Response Headers Δ83ms

Connection: Keep-Alive  
Content-Length: 573  
Content-Type: text/html;charset=ISO-8859-1  
Date: Mon, 06 Feb 2012 15:10:49 GMT  
Keep-Alive: timeout=5, max=100  
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod\_ssl/2.2.17 OpenSSL/0.9.8q

# Old Headers Die Hard... (FF 9.0.1)

# Common Method Properties

<b>Safe</b>	GET, HEAD, OPTIONS, and TRACE
<b>Idempotent</b>	Safe methods + PUT and DELETE
<b>Cacheable</b>	GET, HEAD, and POST

# Long-lived Connections

- If the client does not send a “Connection: close” header, the server can assume the client wishes to maintain the TCP connection
- If the server sends a “Connection: close” header, the session is over

# Long-lived Connections

\$ telnet www.cs.odu.edu 80 | tee 6-1.out  
Trying 128.82.4.2...  
Connected to xenon.cs.odu.edu.  
Escape character is '^]'.  
**request**  
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1  
Host: www.cs.odu.edu

**response**  
HTTP/1.1 200 OK  
Date: Sun, 12 Feb 2006 20:58:49 GMT  
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4  
Content-Type: text/html

**request**  
HEAD /~mln/teaching/cs595-s06/a1-test/1/ HTTP/1.1  
Host: www.cs.odu.edu

**response**  
HTTP/1.1 200 OK  
Date: Sun, 12 Feb 2006 20:58:55 GMT  
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4  
Content-Type: text/html

**request**  
HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1  
Host: www.cs.odu.edu

**response**  
HTTP/1.1 200 OK  
Date: Sun, 12 Feb 2006 20:59:01 GMT  
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4  
Last-Modified: Sun, 29 Jan 2006 18:43:15 GMT  
ETag: "1f4de2-790-43dd0cc3"  
Accept-Ranges: bytes  
Content-Length: 1936  
Content-Type: text/html  
X-Pad: avoid browser bug

Connection closed by foreign host.

# Long-lived Connections

```
$ openssl s_client -connect www.cs.odu.edu:443  
CONNECTED(00000003)  
[much, much SSL detail]  
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1  
Host: www.cs.odu.edu
```

(Does not change with SSL)

```
HTTP/1.1 200 OK  
Server: nginx  
Date: Tue, 02 Oct 2018 18:19:41 GMT  
Content-Type: text/html; charset=UTF-8  
Connection: keep-alive  
Front-End-Https: on  
  
HEAD /~mln/teaching/cs595-s06/a1-test/1/ HTTP/1.1  
Host: www.cs.odu.edu
```

```
HTTP/1.1 200 OK  
Server: nginx  
Date: Tue, 02 Oct 2018 18:19:46 GMT  
Content-Type: text/html; charset=UTF-8  
Connection: keep-alive  
Front-End-Https: on
```

```
HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1  
Host: www.cs.odu.edu  
Connection: close
```

```
HTTP/1.1 200 OK  
Server: nginx  
Date: Tue, 02 Oct 2018 18:20:09 GMT  
Content-Type: text/html  
Connection: close  
Vary: Accept-Encoding  
Front-End-Https: on
```

closed

# Pipelining Requests

## 6.3.2. Pipelining

A client that supports persistent connections MAY "pipeline" its requests (i.e., send multiple requests without waiting for each response). A server MAY process a sequence of pipelined requests in parallel if they all have safe methods (Section 4.2.1 of [RFC7231]), but it MUST send the corresponding responses in the same order that the requests were received.

*(more retry/failure guidance in this section)*

# Pipelined Requests

3 Requests

```
$ telnet www.cs.odu.edu 80 | tee 6-2.out
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^']'.
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/1/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu
```

3 Responses

```
HTTP/1.1 200 OK
Date: Sun, 12 Feb 2006 21:08:44 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Content-Type: text/html

HTTP/1.1 200 OK
Date: Sun, 12 Feb 2006 21:08:44 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Content-Type: text/html

HTTP/1.1 200 OK
Date: Sun, 12 Feb 2006 21:08:44 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Last-Modified: Sun, 29 Jan 2006 18:43:15 GMT
ETag: "1f4de2-790-43dd0cc3"
Accept-Ranges: bytes
Content-Length: 1936
Content-Type: text/html
X-Pad: avoid browser bug
```

Connection closed by foreign host.

# Pipelined Requests

```
$ openssl s_client -connect www.cs.odu.edu:443
CONNECTED(00000003)
[much, much SSL detail]
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/1/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu
Connection: close

HTTP/1.1 200 OK
Server: nginx
Date: Tue, 02 Oct 2018 18:46:24 GMT
Content-Type: text/html; charset=UTF-8
Connection: keep-alive
Front-End-Https: on

HTTP/1.1 200 OK
Server: nginx
Date: Tue, 02 Oct 2018 18:46:24 GMT
Content-Type: text/html; charset=UTF-8
Connection: keep-alive
Front-End-Https: on

HTTP/1.1 200 OK
Server: nginx
Date: Tue, 02 Oct 2018 18:46:24 GMT
Content-Type: text/html
Connection: close
Vary: Accept-Encoding
Front-End-Https: on

closed
```

(Also does not change with SSL)

# Error on a safe method? Keep processing...

```
$ telnet www.cs.odu.edu 80 | tee 6-3.out
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^]'.
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/XASDFASDASDF/ HTTP/1.1
Host: www.cs.odu.edu
```

```
HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu
```

```
HTTP/1.1 200 OK
Date: Sun, 12 Feb 2006 21:19:37 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Content-Type: text/html
```

```
HTTP/1.1 404 Not Found
Date: Sun, 12 Feb 2006 21:19:37 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Content-Type: text/html; charset=iso-8859-1
```

```
HTTP/1.1 200 OK
Date: Sun, 12 Feb 2006 21:19:38 GMT
Server: Apache/1.3.26 (Unix) ApacheJServ/1.1.2 PHP/4.3.4
Last-Modified: Sun, 29 Jan 2006 18:43:15 GMT
ETag: "1f4de2-790-43dd0cc3"
Accept-Ranges: bytes
Content-Length: 1936
Content-Type: text/html
X-Pad: avoid browser bug
```

Connection closed by foreign host.

This error does not  
terminate the session

# Error on a non-idempotent method? Keep processing...

```
$ telnet www.cs.odu.edu 80
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^].
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

POST /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu

HTTP/1.1 200 OK
Date: Mon, 06 Feb 2012 15:27:35 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Content-Type: text/html; charset=ISO-8859-1

HTTP/1.1 404 Not Found
Date: Mon, 06 Feb 2012 15:27:35 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Content-Length: 348
Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
[deletia]
</body></html>

HTTP/1.1 200 OK
Date: Mon, 06 Feb 2012 15:27:35 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Last-Modified: Sun, 29 Jan 2006 18:43:15 GMT
ETag: "790-40b83b3fa76c0"
Accept-Ranges: bytes
Content-Length: 1936
Content-Type: text/html

Connection closed by foreign host.
```

This error does not  
terminate the session  
(and why is it 404?!  
-- probably should be a  
405 – or a 400?)

# Error on an unsafe but idempotent method? Keep processing...

```
$ openssl s_client -connect www.cs.odu.edu:443
CONNECTED(00000003)
[much, much SSL deletia]
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

PUT /~mln/teaching/cs595-s06/a1-test/1/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu
Connection: close

HTTP/1.1 200 OK
Server: nginx
Date: Tue, 02 Oct 2018 18:59:00 GMT
Content-Type: text/html; charset=UTF-8
Connection: keep-alive
Front-End-Https: on

HTTP/1.1 405 Method Not Allowed
Server: nginx
Date: Tue, 02 Oct 2018 18:59:00 GMT
Content-Type: text/html; charset=iso-8859-1
Transfer-Encoding: chunked
Connection: keep-alive
Allow: GET,HEAD,POST,OPTIONS

[html deletia]

HTTP/1.1 200 OK
Server: nginx
Date: Tue, 02 Oct 2018 18:59:00 GMT
Content-Type: text/html
Connection: close
Vary: Accept-Encoding
Front-End-Https: on

closed
```

This error does not  
terminate the session  
since PUT is idempotent  
(also note the correct 405)

# Unknown method? Stop processing

```
$ telnet www.cs.odu.edu 80
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^]'.
HEAD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

NOTAMETHOD /~mln/teaching/cs595-s06/a1-test/ HTTP/1.1
Host: www.cs.odu.edu

HEAD /~mln/teaching/cs595-s06/a1-test/2/ HTTP/1.1
Host: www.cs.odu.edu

HTTP/1.1 200 OK
Date: Mon, 06 Feb 2012 15:25:41 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Content-Type: text/html; charset=ISO-8859-1

HTTP/1.1 501 Method Not Implemented
Date: Mon, 06 Feb 2012 15:25:41 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Allow: GET,HEAD,POST,OPTIONS
Content-Length: 362
Connection: close
Content-Type: text/html; charset=iso-8859-1

<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<html><head>
<title>501 Method Not Implemented</title>
</head><body>
<h1>Method Not Implemented</h1>
<p>NOTAMETHOD to /~mln/teaching/cs595-s06/a1-test/ not supported.<br />
</p>
<hr>
<address>Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q Server
at www.cs.odu.edu Port 80</address>
</body></html>
Connection closed by foreign host.
```

← This error **does** terminate the session

# Timeout Not Specified in RFCs 2616 or 7230

## (But see 6.5 of 7230)

### KeepAliveTimeout Directive

Description: Amount of time the server will wait for subsequent requests on a persistent connection

Syntax:     KeepAliveTimeout seconds

**Default:**    **KeepAliveTimeout 15**

Context:    server config, virtual host

Status:     Core

Module:    core

The number of seconds Apache will wait for a subsequent request before closing the connection.

Once a request has been received, the timeout value specified by the Timeout directive applies.

Setting KeepAliveTimeout to a high value may cause performance problems in heavily loaded servers. The higher the timeout, the more server processes will be kept occupied waiting on connections with idle clients.

<http://httpd.apache.org/docs/2.0/mod/core.html#keepalivetimeout>

# Apache Gives a 400 on Timeout

```
$ telnet www.cs.odu.edu 80
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^]'.
GET / HTTP/1.1
Host: www.cs.odu.edu
HTTP/1.1 400 Bad Request ←
Date: Mon, 06 Feb 2012 04:56:12 GMT
Server: Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q
Content-Length: 344
Connection: close
Content-Type: text/html; charset=iso-8859-1
```

After waiting the timeout value,  
Apache just gives up and sends  
a 400

```
<!DOCTYPE HTML PUBLIC "-//IETF//DTD HTML 2.0//EN">
<html><head>
<title>400 Bad Request</title>
</head><body>
<h1>Bad Request</h1>
<p>Your browser sent a request that this server could not understand.<br />
</p>
<hr>
<address>Apache/2.2.17 (Unix) PHP/5.3.5 mod_ssl/2.2.17 OpenSSL/0.9.8q Server at
www.cs.odu.edu Port 80</address>
</body></html>
Connection closed by foreign host.
```

# Now it seems to do nothing...

(in both examples below the magic blank line is not sent)

```
$ telnet www.cs.odu.edu 80
Trying 128.82.4.2...
Connected to xenon.cs.odu.edu.
Escape character is '^]'.
HEAD / HTTP/1.1
Host: www.google.com
Connection closed by foreign host.
```

After waiting the timeout value,  
Apache now just gives up

```
$ openssl s_client -connect www.cs.odu.edu:443
CONNECTED(00000003)
[much, much SSL deleted]
HEAD /~mln/teaching/cs595-s06/a1-test/
HTTP/1.1
Host: www.cs.odu.edu
read:errno=0
```

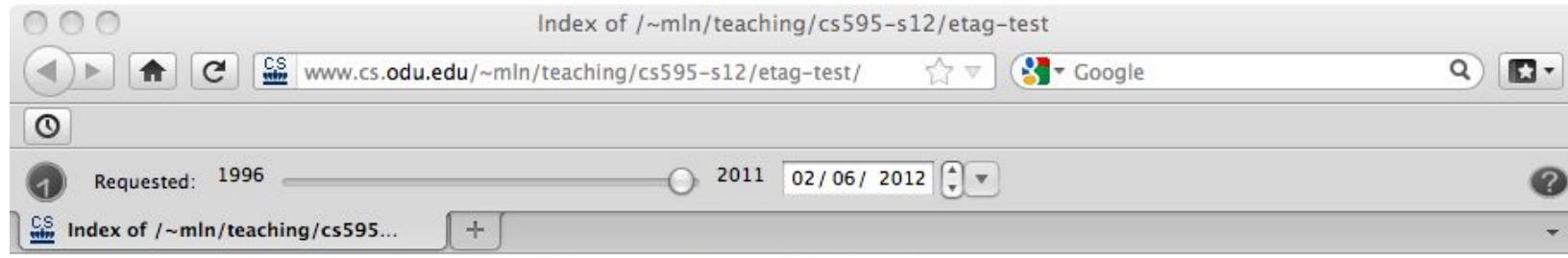
# Why Not a 408?

## 6.5.7. 408 Request Timeout

The 408 (Request Timeout) status code indicates that the server did not receive a complete request message within the time that it was prepared to wait. A server SHOULD send the "close" connection option (Section 6.1 of [RFC7230]) in the response, since 408 implies that the server has decided to close the connection rather than continue waiting. If the client has an outstanding request in transit, the client MAY repeat that request on a new connection.

I haven't seen a 408 in the wild,  
but we will implement it in A2

# Directory Listings



## Index of /~mln/teaching/cs595-s12/etag-test

- [Parent Directory](#)
- [bar1.txt](#)
- [bar2.txt](#)
- [bar3.txt](#)
- [foo.txt](#)

Apache/2.2.17 (Unix) PHP/5.3.5 mod\_ssl/2.2.17 OpenSSL/0.9.8q Server at www.cs.odu.edu Port 80

# Fancy Directory Listings



## Index of /~mln/teaching/cs595-s12/etag-test

Name	Last modified	Size	Description
<a href="#">Parent Directory</a>		-	
<a href="#">bar1.txt</a>	06-Feb-2012 09:25	0	
<a href="#">bar2.txt</a>	06-Feb-2012 09:25	0	
<a href="#">bar3.txt</a>	06-Feb-2012 09:26	12	Click me! Forget the o>
<a href="#">foo.txt</a>	09-Jan-2012 19:02	16	

Apache/2.2.17 (Unix) PHP/5.3.5 mod\_ssl/2.2.17 OpenSSL/0.9.8q Server at www.cs.odu.edu Port 80



```
$ pwd  
/home/mln/public_html/teaching/cs595-s12/etag-test  
$ cat .htaccess  
FileETag INode MTime Size  
IndexOptions FancyIndexing  
AddDescription "Click <b>me</b>! Forget the other files!" bar3.txt
```

<http://www.cs.odu.edu/~mln/teaching/cs595-s12/etag-test/>

[http://httpd.apache.org/docs/current/mod/mod\\_autoindex.html](http://httpd.apache.org/docs/current/mod/mod_autoindex.html)