

HTTP Protocol

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Reference

- Leon Shklor and Richard Rosen, **Web application architecture: principles, protocols, and practices**, John Wiley & Sons Ltd (2003)
- <https://httpwg.org/specs/>

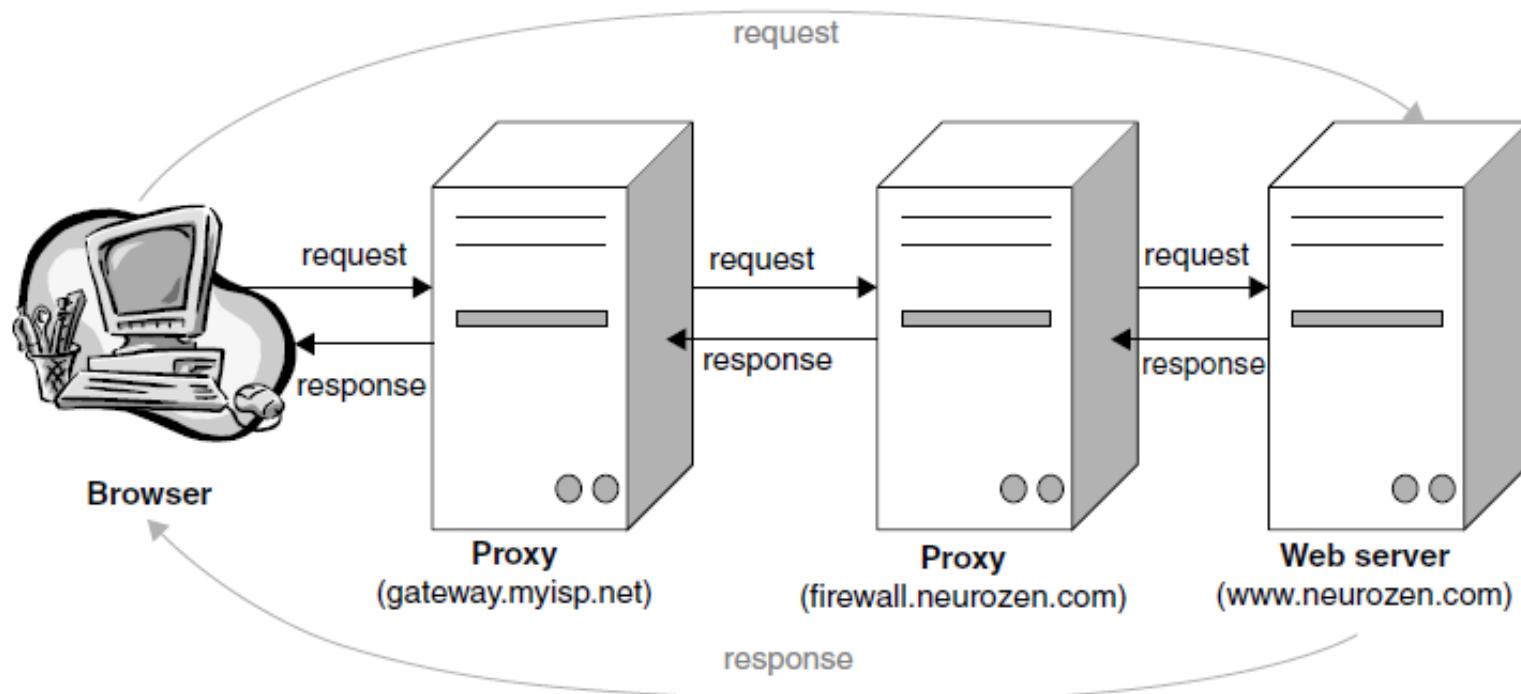
About HTTP

- Basic Ingredient Protocol for World Wide Web
- Simple – strength and weakness
- Doesn't manage the state with limited functionality
- Application Layer Protocol founded by TCP

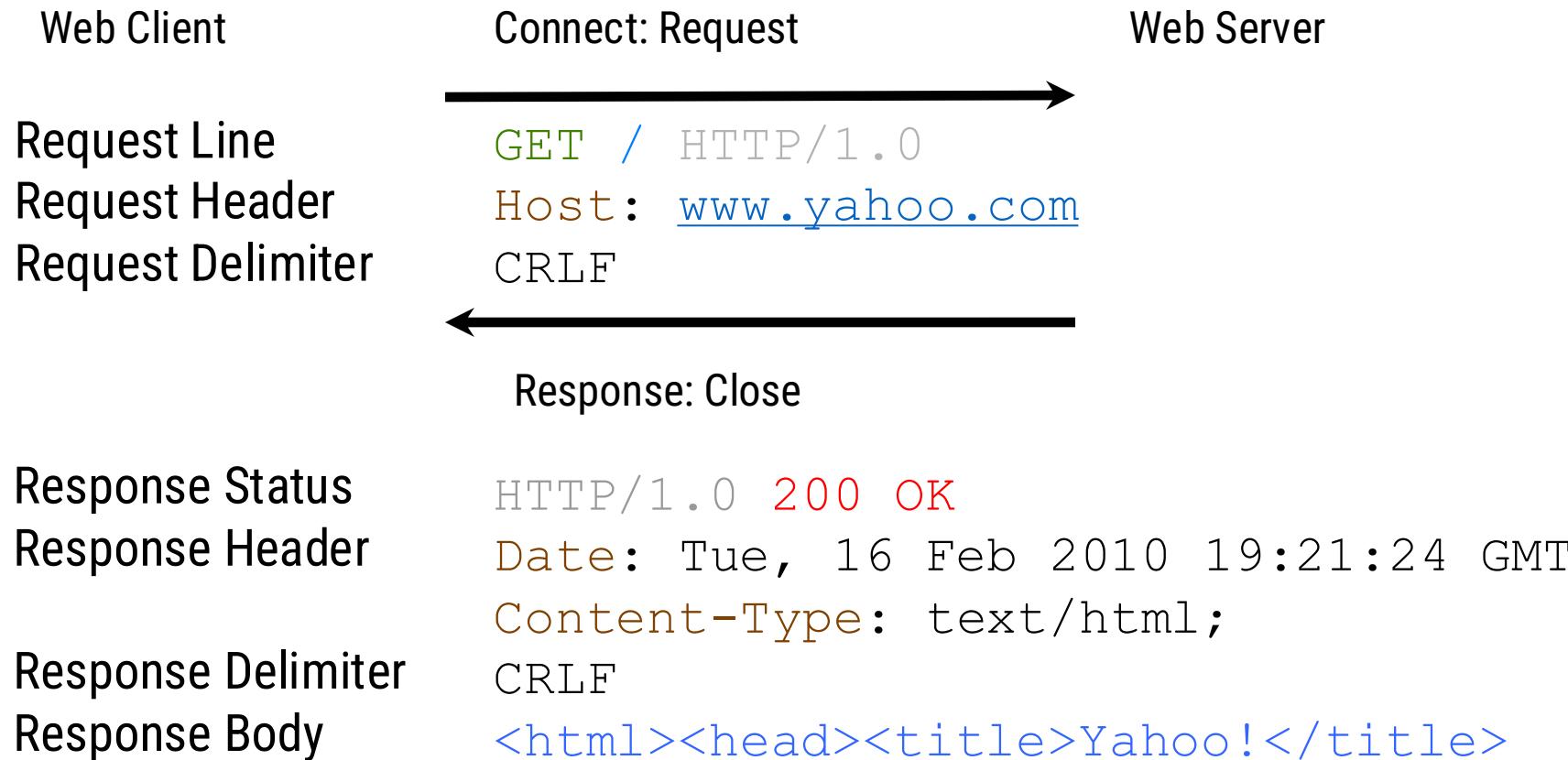
HTTP Protocol and Structure

- *request* and *response* paradigm
- *request* and *response* has similar structure
 - couple lines of *header*
 - empty line, followed *message body*
- *Stateless protocol* – a transaction is composed of a single *request* from *client* and a *response* from *server*

Request Response Virtual Circuit



Anatomy of HTTP 1.0



HTTP Request Structure

```
METHOD /path-to-resource HTTP/version-number  
Header-Name-1: value  
Header-Name-2: value  
  
[ optional request body ]
```

```
GET /q?s=YHOO HTTP/1.1  
Host: finance.yahoo.com  
User-Agent: Mozilla/4.75 [en] (WinNT; U)
```

```
HEAD http://www.cs.rutgers.edu/~shkclar/ HTTP/1.1  
Host: www.cs.rutgers.edu  
User-Agent: Mozilla/4.75 [en] (WinNT; U)
```

HTTP Request Structure

- *Request Line:*
 - *Request Methods:* **GET, POST, HEAD, PUT, DELETE, TRACE, OPTION, CONNECT, PATCH**
 - access URL
 - Version HTTP: 1.0 or 1.1
- Header – variable: value pairs
 - Host
 - Content-Type
 - Content-Length
 - User-Agent
 - Cookie, dll
- *Request body*

HTTP Response Structure

```
HTTP/version-number    status-code   message  
Header-Name-1: value  
Header-Name-2: value  
  
[ response body ]
```

```
HTTP/1.0 200 OK  
Date: Sat, 03 Feb 2001 22:48:35 GMT  
Connection: close  
Content-Type: text/html  
Set-Cookie: B=9ql5kgct7p2m3&b=2; expires=Thu, 15 Apr 2010 20:00:00 GMT;  
path=/; domain=.yahoo.com  
  
<HTML>  
<HEAD><TITLE>Yahoo! Finance - YHOO</TITLE></HEAD>  
<BODY>  
...  
</BODY>  
</HTML>
```

HTTP Response Structure

- *Status line:*
 - Version HTTP: 1.0 or 1.1
 - *Status Code* and some description
- Header – variable: value pairs
 - Content-Type
 - Content-Length
 - Set-Cookie
 - Date, dll
- *Response body*

- Once receive the document; browser parses the doc to define additional resources to be retrieved

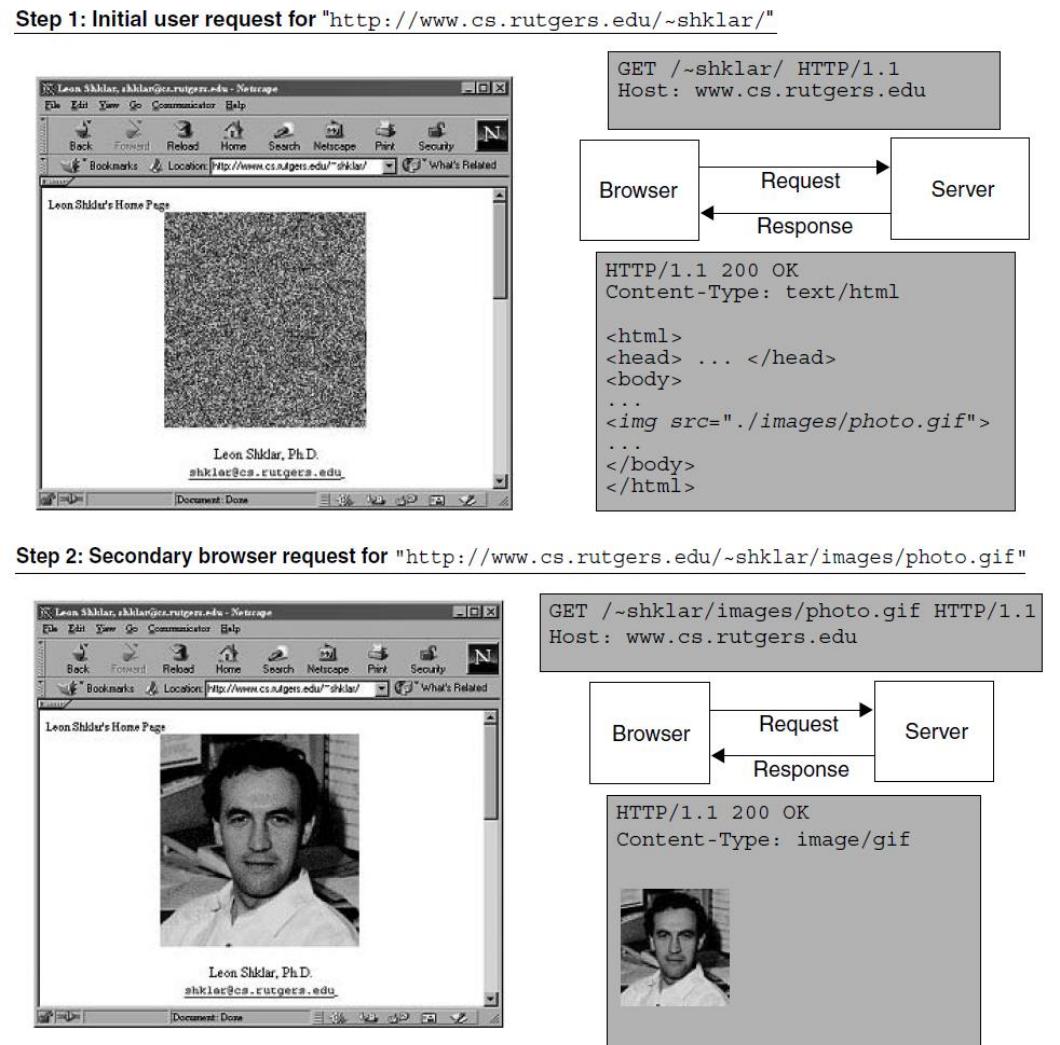


Figure 3.2 Sequence of browser requests for loading a sample page

Request Methods

- GET
 - most simple
 - doesn't contain *request body*
 - *request parameters* will be added in the URL *query string* (after "?")
 - Only retrieve the resource/data, without any other effects (inc. modification/deletion)
- POST
 - *request body* contains *request parameters*
 - Submits data to be processed to a specified resource
 - URL doesn't contain any data (suitable for submit FORM)

Form Processing

- Form w/ POST method, will use HTTP POST to send data, with
content-type: application/x-www-form-urlencoded
- Query parameter will be provided as pairs of type: value
- File upload uses
content-type: multipart/form-data

Form Processing

```
POST /enlighten/calais.asmx/Enlighten HTTP/1.1
Host: api.opencalais.com
Content-Type: application/x-www-form-urlencoded
Content-Length: length

licenseID=string&content=string&paramsXML=string
```

GET vs POST

GET

- can be cached
- remain in the browser history
- can be bookmarked
- Data is visible to everyone in the URL
- have length restrictions
- should be used only to retrieve data
- Only ASCII characters allowed

POST

- never be cached
- do not remain in the browser history
- cannot be bookmarked
- Data is not displayed in the URL
- have no restrictions on data length
- No restrictions. Binary data is also allowed

Request Methods

- HEAD
 - Similar to GET, but server MUST NOT return a message body in the response
 - Server only returns *header*
 - To support *cache* with *content modification information (Last-Modified)*

Request Methods

- **PUT**
 - to store a resource on a particular URI
 - if the URI refers to existing resource then the resource is being updated
- **DELETE**
 - to delete a resource.
- **TRACE**
 - send back the request received by the server
 - client can identify what the additional info added in a HTTP request (e.g., by http proxy)

Request Methods

- OPTIONS
 - return HTTP methods supported by the server on a particular URL
- CONNECT
 - convert request into a transparent TCP/IP tunnel,
 - used in SSL-encrypted used in HTTPS
- PATCH
 - used in modification on a part of the resource

Status Code

- Inform browser or proxy whether *response* is as expected
 - 1xx information
 - 2xx success
 - 3xx redirection
 - 4xx client request error
 - 5xx server error

HTTP Header

- **General Header**
 - Date: Sun, 11 Feb 2001 22:28:31 GMT
Date time created message
 - Connection: Close
Client or Server define whether the connection is maintained/not
- **Request Header**
 - User-Agent: Mozilla/4.75 [en] (WinNT; U)
browser user agent
 - Host: www.neurozen.com
to support virtual host
 - Referer: http://www.cs.rutgers.edu/index.html
URL of the referral

HTTP Header

- **Response Header**
 - Location: `http://www.mywebsite.com/Page.html`
Page intended to visit (*redirect*)
 - Server: Apache/1.2.5
Server ID
- **EntityHeader**
 - Content-Type: mime-type/mime-subtype
type of message body
 - Content-Length: xxx
length of message body
 - Last-Modified: Sun, 11 Feb 2001 22:28:31 GMT
modification date of the content

Virtual Hosting

```
GET http://finance.yahoo.com/q?s=YHOO HTTP/1.1  
Host: finance.yahoo.com
```

```
GET /q?s=YHOO HTTP/1.1  
Host: finance.yahoo.com
```

Authentication

```
HTTP/1.1 401 Authenticate
Date: Mon, 05 Feb 2001 03:41:23 GMT
Server: Apache/1.2.5
WWW-Authenticate: Basic realm="Chapter3"
```

```
GET /book/chapter3/index.html HTTP/1.1
Date: Mon, 05 Feb 2001 03:41:24 GMT
Host: www.neurozen.com
Authorization: Basic eNCoDED-uSErId:pA$swORd
```

Session Management

```
GET /movies/register HTTP/1.1
Host: www.sample-movie-rental.com
Authorization:...
```

```
HTTP/1.1 200 OK
Set-Cookie: CLIENT=Rich; path=/movies
...
```

```
GET /movies/rent-recommended HTTP/1.1
Host: www.sample-movie-rental.com
Cookie: CLIENT=Rich
```

Caching control

```
GET /~shklar/ HTTP/1.1
Host: www.cs.rutgers.edu
If-Modified-Since: Fri, 11 Feb 2001 22:28:00 GMT
```

Persistent Connection

- HTTP 1.0 uses TCP separately for each request
 - not efficient
 - slow (i.e., high-latency)
- HTTP 1.1 uses a persistent connection, can be used by several requests

`Connection: Close`

`Connection: Keep-Alive`

HTTP 1.1 vs 1.0

- Additional Methods (PUT, DELETE, TRACE, CONNECT + GET, HEAD, POST)
- Additional Headers
- Transfer Coding (chunk encoding)
- Persistent Connections (content-length matters)
- Request Pipelining

HTTP Sometime Back

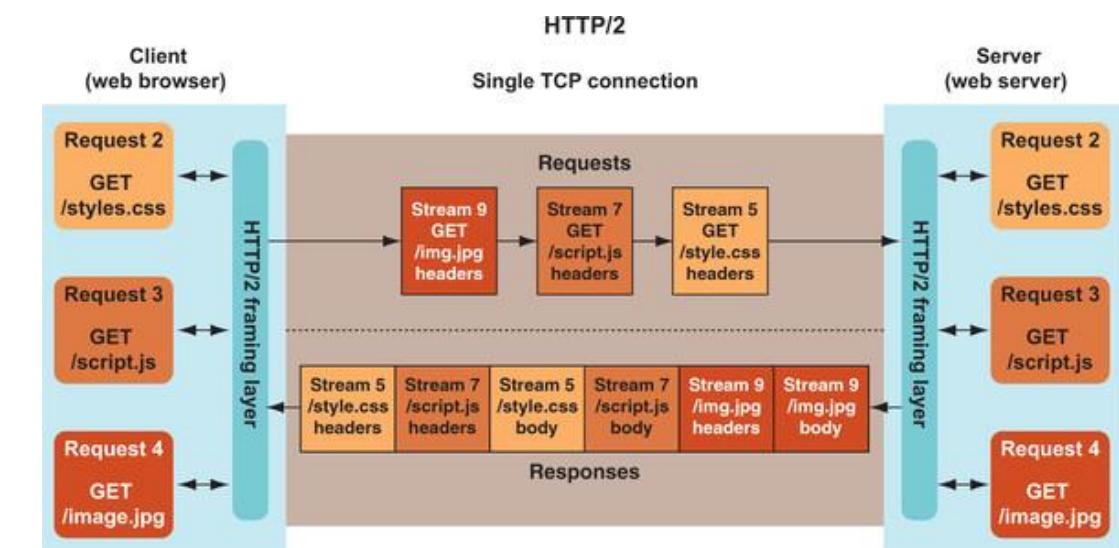
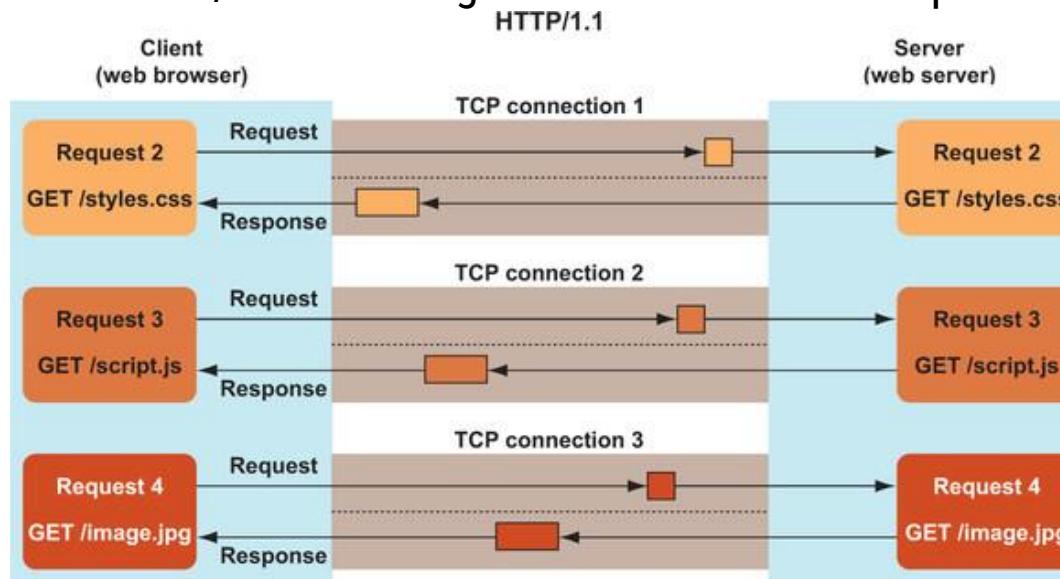
- Using HTTP 1.1 since 1997 / 1999
 - Connection: keep-alive
 - Head of Line Blocking
- But we still use N TCP Connections per origin
- No Header Compression
- And Many Hacks because requests are evil
 - Spriting of Images
 - Resource Inlining
 - Concatenation of files
 - Domain Sharding
 - CDNs

HTTP/2

- Addressing HTTP 1.1 Performance Issues:
 - Binary rather than textual protocol
 - Multiplexed rather than synchronous
 - Flow control
 - Stream prioritization
 - Header compression
 - Server push

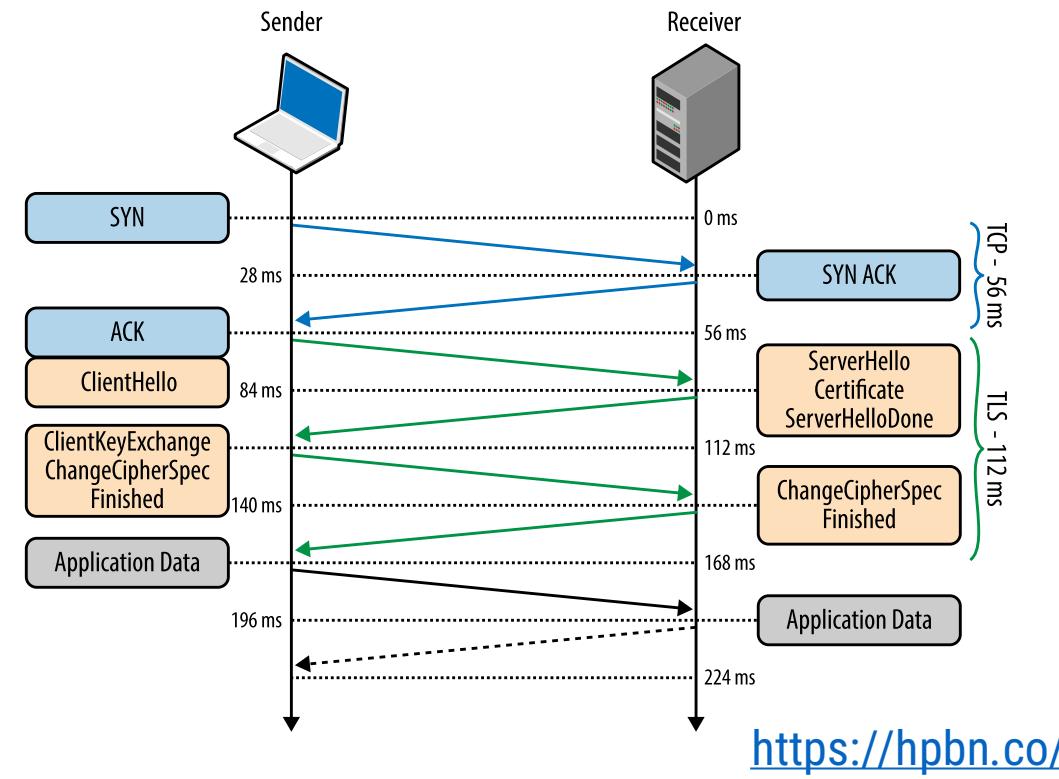
Multiple TCP connection vs Single Connection

- Multiple HTTP/1 requests in parallel require multiple TCP connections.
- Most browsers open up to six connections per domain in parallel for this reason.
- But when the max. connection reached => blocking occurs. Also, TCP connections are expensive.
- A technique called domain sharding splits resources into many domains to address this limitation.
- HTTP/1 may allow "persistent connection": using connection:keep-alive header to use one connection for several requests. However this introduce *head-of-line blocking*: the current request must complete before the next one can be sent.
- HTTP/2 allows single TCP connection multiplex streams of resources over frames which may be interleaved.



HTTPS

- Is HTTP over TLS over TCP
- Hence, TCP 3 way handshake and certificate exchange is performed before actual HTTP protocol application data.



Why HTTP/2

- Performance matters
 - HTTP/2 reduces the impact of latency on web applications
- TLS is becoming the default
 - HTTP/2 amortizes TLS costs for the entire application
- Enabling new web development
- User perceivable improvement in web site performance
- Work with today's internet
- Remain compatible with existing content

What is HTTP/2

- Used SPDY3 as its first draft
- Main Driven by Performance
- But also includes
 - Security
 - Reliability

HTTP 1.x vs HTTP/2

HTTP 1.x

Text protocol

Verb & Resource Semantics

Headers and body

Headers repeated

SSL Optional

Single connection – single request

HTTP 2

Binary protocol

Verb & Resource Semantics

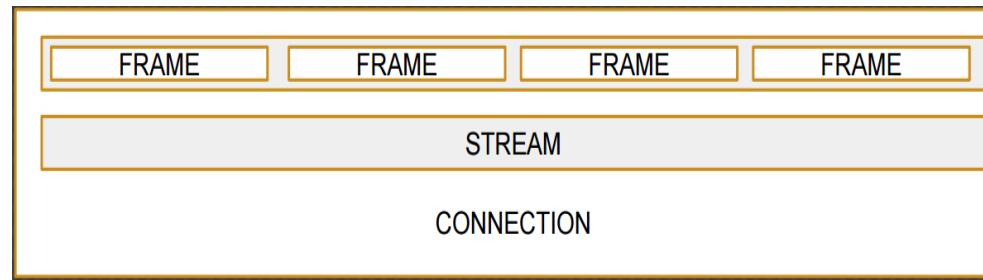
Headers and body

Headers optimized

SSL optional (mostly used)

Single connection – multiple request

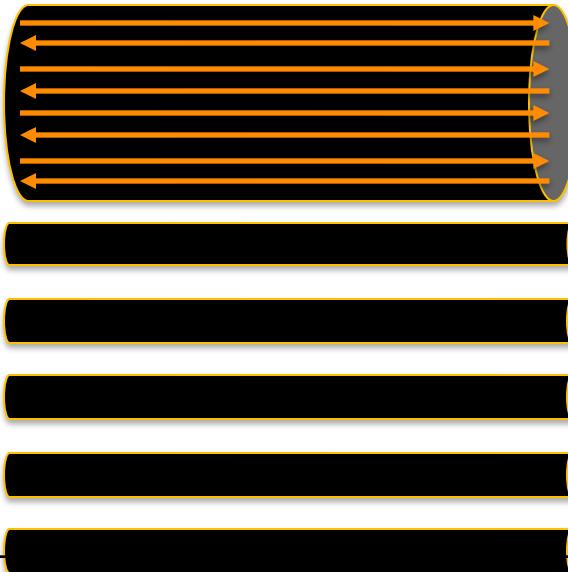
HTTP/2 Units



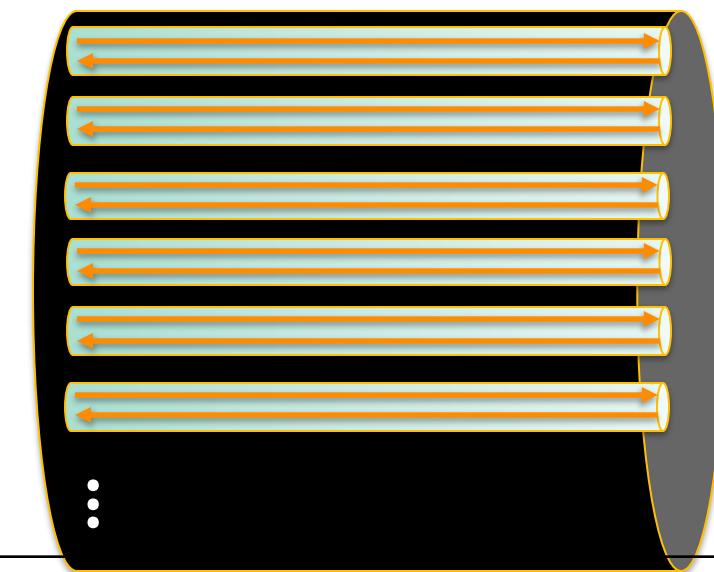
Frames	Streams	Connections
<ul style="list-style-type: none">• Flags• Type• Stream Identifier• Payload• Length	<ul style="list-style-type: none">• Identifier• State• Priority• Flow Control	<ul style="list-style-type: none">• Flow Control

HTTP/2 Connections and Streams

HTTP/1.1 – Request =
Connection



HTTP/2 – Request =
Stream



Each request required dedicated TCP connection	TCP connection can have multiple streams (requests)
Responses come in order per connection	Responses can come out of order, server can optimize
Each connection requires setup + slow start	No connection setup for new streams, no slow start
Application sees “connections”	Streams are represented as “connections” to apps

Header Compression

▶ HPACK

Static Table

:path: /
accept-encoding:
gzip,deflate
user-agent:
:authority:
...

:method: GET
:scheme: http
:path: /
:authority:
www.example.com

Dynamic Table

:authority:
www.example.com

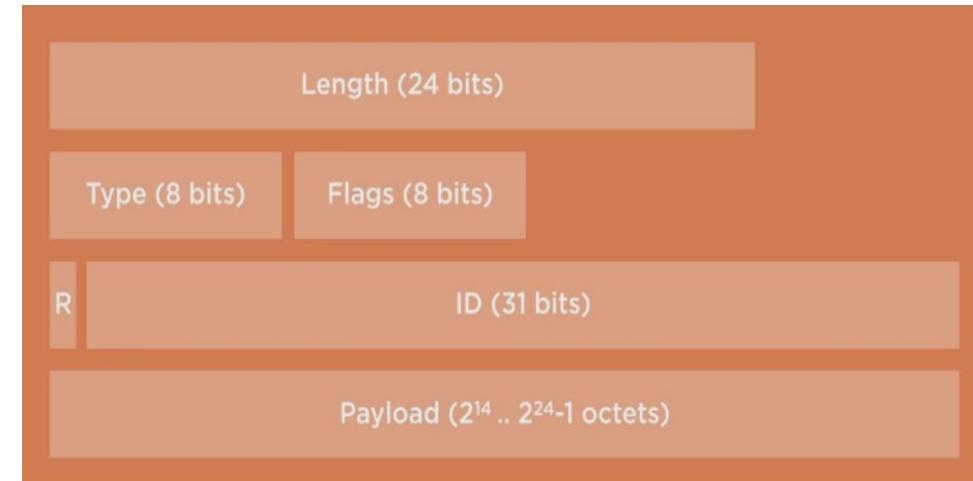
Lit-Index	Name	Value (Huffman-encoded string)
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Header Compression

- **Each header is expressed as either...**
 - **Indexed:** Reference to full header in static or dynamic table
 - **Literal:**
 - Name as reference to static/dynamic table entry, or as Huffman-encoded string
 - Value as Huffman-encoded string
 - Indexing behavior:
 - Add to dynamic table
 - Don't add to dynamic table
 - NEVER add to dynamic table (supposed to be persisted through intermediaries)

HTTP/2 Frame Types

1. DATA
2. HEADERS
3. PRIORITY
4. RST_STREAM
5. SETTINGS
 1. SETTINGS_HEADER_TABLE_SIZE
 2. SETTINGS_ENABLE_PUSH
 3. SETTINGS_MAX_CONCURRENT_STREAMS
 4. SETTINGS_INITIAL_WINDOW_SIZE
 5. SETTINGS_MAX_FRAME_SIZE
 6. SETTINGS_MAX_HEADER_LIST_SIZE
6. PUSH_PROMISE
7. PING
8. GOAWAY
9. WINDOW_UPDATE



HTTP/2 GET

```
GET /resource HTTP/1.1          HEADERS
Host: example.org               ==> + END_STREAM
Accept: image/jpeg               + END_HEADERS
                                         :method = GET
                                         :scheme = https
                                         :path = /resource
                                         host = example.org
                                         accept = image/jpeg
```

```
HTTP/1.1 304 Not Modified      HEADERS
ETag: "xyzzy"                  ==> + END_STREAM
Expires: Thu, 23 Jan ...        + END_HEADERS
                                         :status = 304
                                         etag = "xyzzy"
                                         expires = Thu, 23 Jan ...
```

HTTP/2 POST Request

```
POST /resource HTTP/1.1          HEADERS
Host: example.org      ==>    - END_STREAM
Content-Type: image/jpeg        - END_HEADERS
Content-Length: 123           :method = POST
                             :path = /resource
{binary data}                  :scheme = https

CONTINUATION
+ END_HEADERS
content-type = image/jpeg
host = example.org
content-length = 123

DATA
+ END_STREAM
{binary data}
```

HTTP/2 POST Response

```
HTTP/1.1 200 OK          HEADERS
Content-Type: image/jpeg  ==> - END_STREAM
Content-Length: 123       + END_HEADERS
                         :status = 200
{binary data}             content-type = image/jpeg
                         content-length = 123
```

```
DATA
+ END_STREAM
{binary data}
```

Request Reliability

- In HTTP no retry a request when an error occurs
 - Re-Attempt: It is only possible to some server to do some processing prior to the error which could result in undesired effects
- HTTP/2 Provides 2 mechanisms as guarantee to a client that a request has not been processing
 - GOAWAY: the highest stream number that has been processed
 - REFUSED_STREAM: error code can be included in a RST_STREAM frame