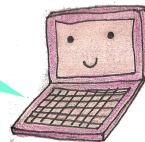


Server Farm to Table

(or, how the Internet works)

Jenna Zeigen
@zeigenvector
November 3, 2015

hey, sup?



Server Farm to Table

(or, how the Internet works)



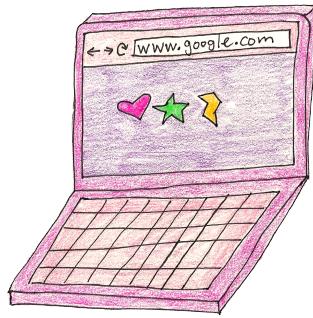
nm, u?

Jenna Zeigen
@zeigenvector
November 3, 2015

Engineering Manager
@ DigitalOcean

 zeigenvector





Jenna Zeigen • @zeigenvector

The OSI model is a really good way of thinking about processes like these. It details seven layers, from Layer 1 which talks about physical bits in the computer, through Layer 7, which is the full application layer, so things like the browser. This talk is going to start at Layer 4, which is transport. We won't be talking about anything lower than that, so no networking, though I'm sure there's plenty of stuff all over the Internet if you want to learn more about those lower layers.

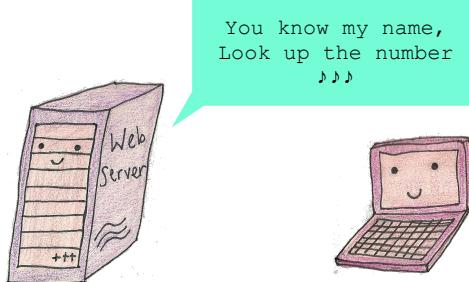
Overview

1. IP Address Lookup
2. Opening a socket
3. Security Stuff
4. HTTP Request
5. Server Things
6. HTTP Response
7. Parsing
8. Rendering

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I'm going to go through all of these and talk about optimizations along the way!

IP Address Lookup



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To do anything, we need to map the human readable URL "www.google.com" to the address of a computer to "talk to."

IP Address Lookup

Hey, I just met you
This is easy
I still know your number
Super breezy!



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IP Address Lookup

Is this name special?
So very special?



IP Address Lookup

Nope!

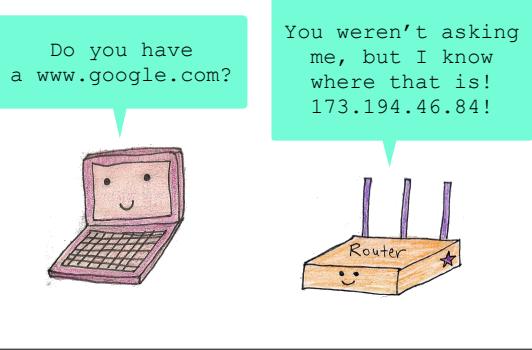


First, the browser checks its cache.

If not found, the browser calls the `gethostbyname` library function, the contents of which vary by OS, to do the lookup. This function checks if the hostname can be resolved by reference in the local hosts file, the location of which also varies by OS. On Macs, it's at `/etc/hosts`. This is how your computer knows what `localhost` should resolve to. If you wanna check it out, you can type `cat /etc/hosts` into your terminal and see what's in there!

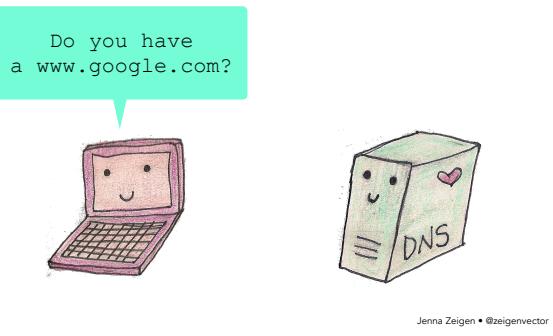
If `gethostbyname` does not have it cached and can't find it in the hosts file, then it makes a request to the DNS server configured in the network stack. This is typically the ISP's caching DNS server, but you could configure your computer to use any DNS server, i.e. Google's (8.8.8.8) if you wanted...

IP Address Lookup



The browser then kicks off a request to get the IP address for `www.google.com`, which goes through the local router, which also checks its cache.

IP Address Lookup

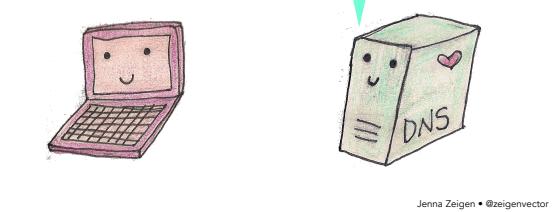


If the local router doesn't have anything cached, the browser ends up hitting the local ISP DNS server. This process uses UDP (User Datagram Protocol), or TCP if the request is too large.

UDP is kind of like the smallest bit of network you can use. It's great for unidirectional transactions, but delivery is not guaranteed in any order, or guaranteed at all. It's kind of like if you were to throw a bunch of balls at someone and hope that they catch them.

IP Address Lookup

Got a long list of these numbers
But if it's not in my "brain"
I'll ask some servers
And we'll find it by name
♪♪♪

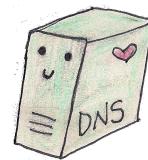


Upon receiving the request, the DNS server first checks its cache.

IP Address Lookup

Do you have
a www.google.com?

Hold on, lemme
phone a friend...

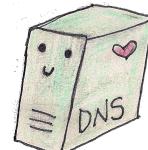


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If it doesn't have the address in its cache, it recursively looks up the address by asking some more servers...

IP Address Lookup

You go talk to your friends,
talk to more friends,
talk to me
♪♪♪

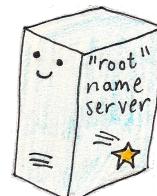
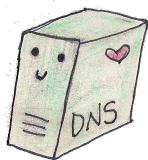


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(Meanwhile, the client has to wait a while for the answer...)

IP Address Lookup

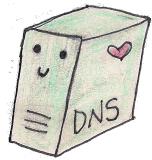
Do you know where
www.google.com is?



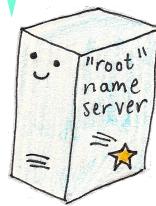
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IP Address Lookup

Do you know where
www.google.com is?



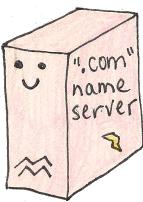
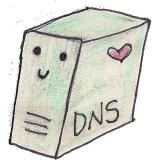
No, but maybe ask
.com?



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IP Address Lookup

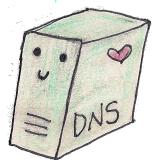
Do you know where
www.google.com is?



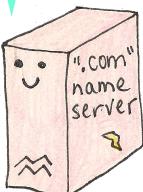
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IP Address Lookup

Do you know where
www.google.com is?



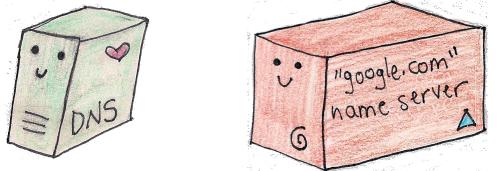
No, but maybe ask
google.com?



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IP Address Lookup

Do you know where
www.google.com is?

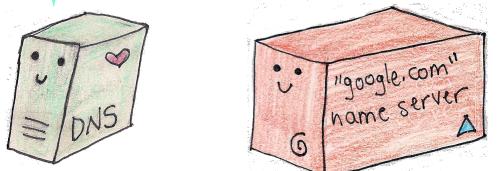


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IP Address Lookup

Do you know where
www.google.com is?

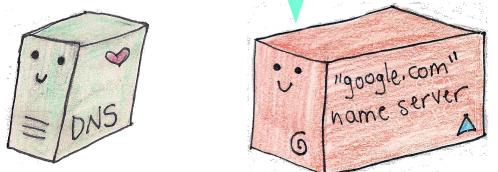
Yep!
173.194.46.84!



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IP Address Lookup

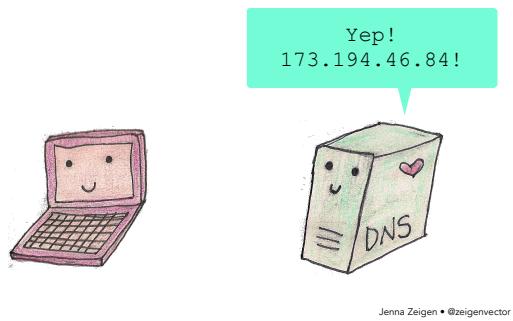
Say you'll remember me
Or at least this IP address
So we don't have to relive this mess
♪♪♪



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When the name server comes back to the DNS server with the IP address answer, it will also come back with a TTL (time to live), an amount of time that the DNS server should cache the IP address. The longer the TTL, the faster this process, but then it's harder to change things. Historically, this TTL was 24 hours, which is why it could take up to 24 hours for the URL corresponding to an IP to change.

IP Address Lookup



The DNS server then responds to the client with the found IP address.

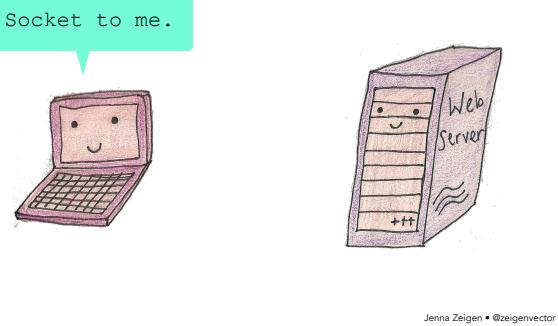
IP Address Lookup

A terminal window showing the output of the `dig` command. The output includes the question section for `www.google.com` and the answer section with multiple IP addresses. The terminal prompt is `zeiganspace:~ jenna$`.

```
; <>> DIG 9.8.3-P1 <>> www.google.com
;; global options: +cmd
;; Got answer:
;; -->HEADER--> opcode: QUERY, status: NOERROR, id: 45898
;; Flags: qr rd ra; QUERY: 1, ANSWER: 5, AUTHORITY: 0, ADDITIONAL: 0
;; QUESTION SECTION:
;www.google.com.      IN      A
;; ANSWER SECTION:
www.google.com.    251    IN      A      74.125.226.48
www.google.com.    251    IN      A      74.125.226.50
www.google.com.    251    IN      A      74.125.226.51
www.google.com.    251    IN      A      74.125.226.49
www.google.com.    251    IN      A      74.125.226.52
;; Query time: 16 msec
;; SERVER: 209.18.47.61#53(209.18.47.61)
;; WHEN: Sun Nov 1 17:10:36 2015
;; MSG SIZE rcvd: 112
```

If you want to check out this process hands-on, you can use the `dig` command in your terminal.

Opening a socket

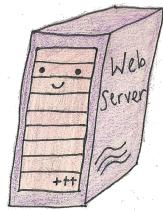


Once the client has the IP address, it takes it and the port number from the URL, and makes a call to the system library function named `socket` and requests a TCP socket stream. We don't usually see port numbers on the end of URLs, but the HTTP protocol defaults to Port 80, and HTTPS to Port 443.

TCP stands for "Transmission Control Protocol." Unlike UDP, its job is to deliver a reliable, ordered, and error checked stream of packets across the network. It's more like a game of catch, to continue the ball metaphor. In fact,

Opening a socket

Hey! Will you talk to me?

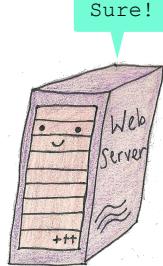


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The client then establishes TCP connection(s) with the server. It's kinda like this...

Opening a socket

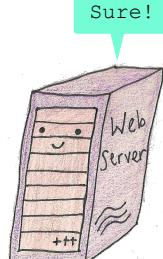
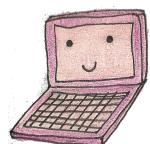
Hey! Will you talk to me?



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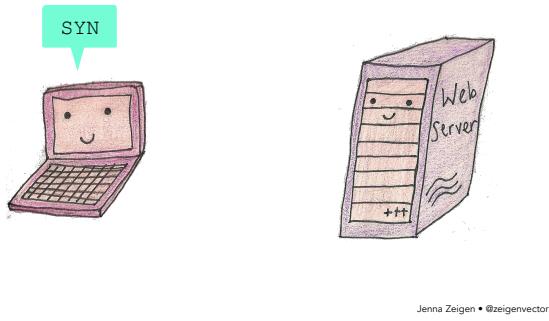
Opening a socket

Hey! Will you talk to me?



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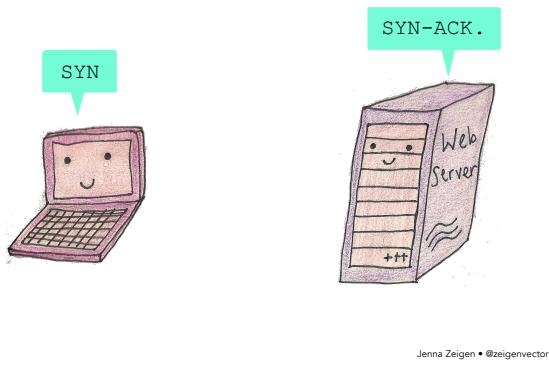
Opening a socket



Well, more specifically like this...

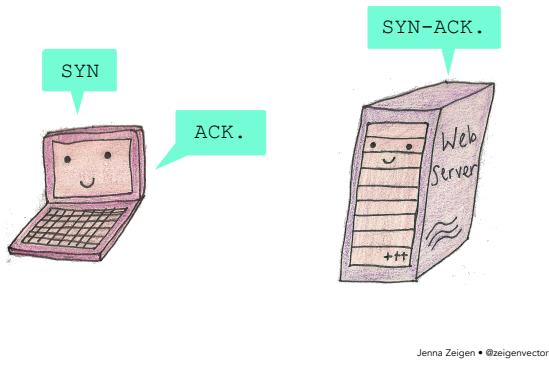
1. The client sends a SYN packet with a randomly-selected sequence number "x"

Opening a socket



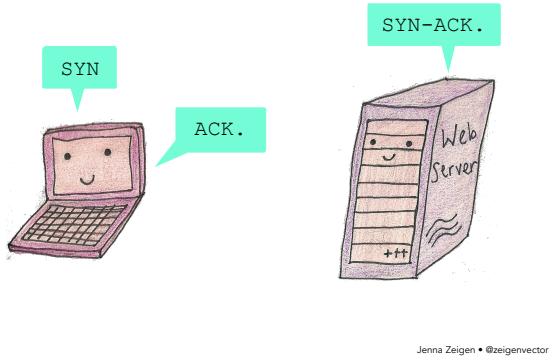
2. The server replies with a SYN-ACK packet with an acknowledgement number set to "x+1" and a different randomly-selected sequence number "y"

Opening a socket



3. The client responds with an ACK packet, with the sequence number set to the received acknowledgement number "x+1", and a new acknowledgement number set to "y+1"

Opening a socket



To prepare for the likely event that the client is going to need more things from the server, more than one connection will be opened.

TCP also has congestion control— requests start small and ramp up in size to make sure the network can support the requests. This is more of a relic from the past when networks weren't as reliable or fast.

In addition, TCP is where much the latency in this entire process comes from,

Opening a socket

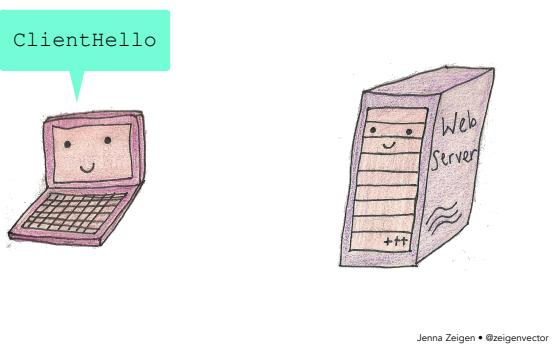
```
zeigenspace:~ jenna$ sudo tcpdump -c3 host www.google.com
tcpdump: data link type PKTAP
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on pktap, link-type PKTAP (Packet Tap), capture size 65535 bytes
01:05:42.209216 IP 192.168.0.23.52293 > lga25s40-in-f196.1e100.net.https: UDP, length 190
01:05:42.249138 IP lga25s40-in-f196.1e100.net.https > 192.168.0.23.52293: UDP, length 35
01:05:42.259526 IP lga25s40-in-f196.1e100.net.https > 192.168.0.23.52293: UDP, length 221

3 packets captured
16 packets received by filter
0 packets dropped by kernel
zeigenspace:~ jenna$ -
```



If you want to check out TCP for yourself, you can use `tcpdump` from your terminal. `tcpdump` will show you all the network traffic, which is why you see UDP packets here. If you prefer a GUI option, you can also use [Wireshark](#).

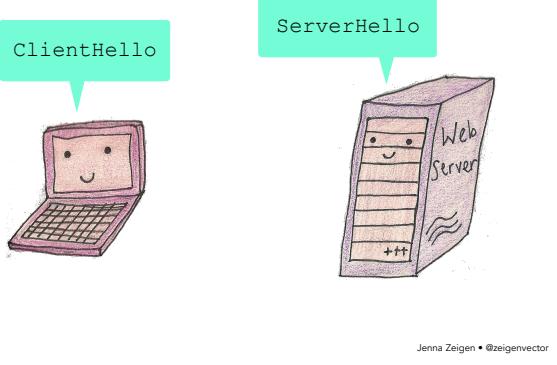
Security Stuff



If the request is over HTTPS, we need another step to ensure the security of the transaction. HTTPS uses TLS, or Transport Layer Security. TLS's predecessor was Secure Sockets Layer (SSL).

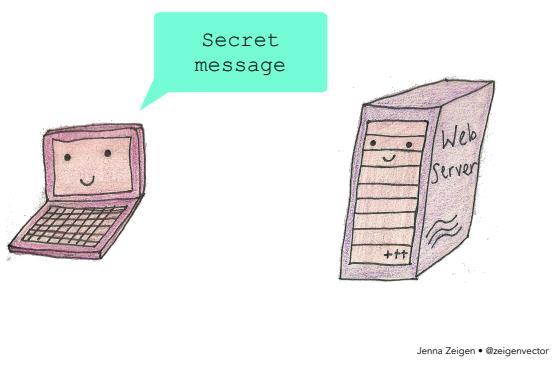
To kick off the process, the client computer sends a ClientHello message to the server with its TLS version, list of cipher algorithms and compression methods available.

Security Stuff



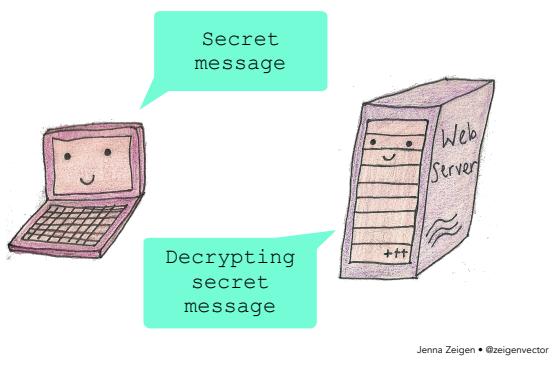
The server replies with a ServerHello message to the client with the TLS version, selected cipher, selected compression methods and the server's public certificate. The certificate contains a public key that will be used by the client to encrypt the rest of the handshake until a symmetric key can be agreed upon.

Security Stuff



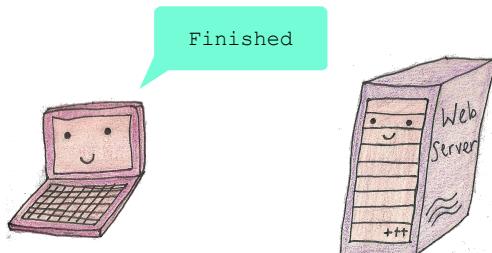
The client verifies the server digital certificate. If trust can be established, the client generates a string of pseudo-random bytes and encrypts this with the server's public key.

Security Stuff



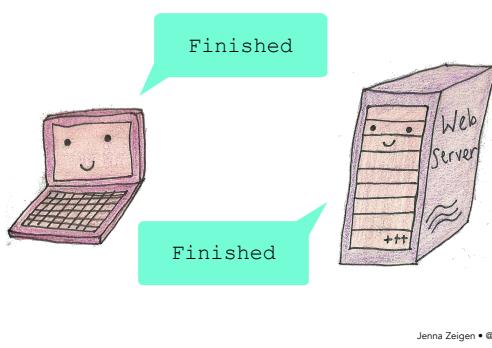
The server then decrypts the message and uses it to create its own version of the symmetric key.

Security Stuff



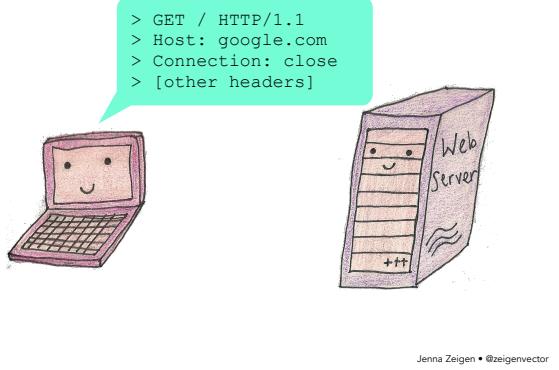
The client sends a Finished message to the server, encrypting a hash of the transmission up to this point with the symmetric key.

Security Stuff



The server generates its own hash, and then decrypts the client-sent hash to verify that it matches. If it does, it sends its own Finished message to the client, also encrypted with the symmetric key.

HTTP Request

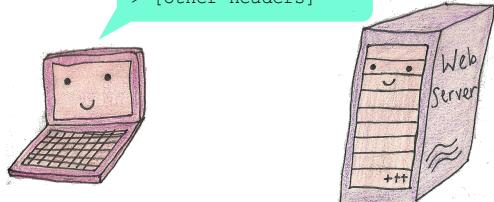


With all this done, the client is ready to send an HTTP request to the server. HTTP stands for “HyperText Transfer Protocol.” Unless the client and server negotiate using a more advanced version of HTTP, they’re going to use HTTP/1.1.

HTTP/1.1 is stateless, uses a request/response model, and is a plain-text protocol.

HTTP Request

```
> GET / HTTP/1.1  
> Host: google.com  
> Connection: close  
> [other headers]
```

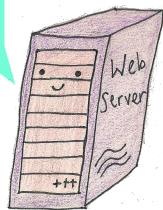


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The client will send a request like this, containing the request and headers, followed by a single blank newline to the server indicating that the content of the request is done.

Server Things...

Look inside
It's where my daemon hides
♪ ♪ ♪

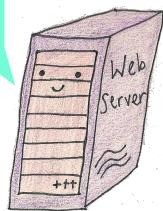


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The server then processes the request. The HTTPD (HTTP Daemon) server is the one handling the requests and responses on the server side. Some popular HTTPD servers are Apache and nginx.

Server Things...

I got racks on
racks on racks
♪ ♪ ♪

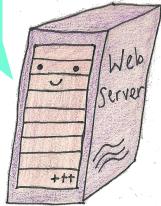


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The server is going to do a bunch of “server stuff” including load balancing, routing, and database calls.

Server Things...

Whatcha, whatcha,
whatcha want?
(Whatcha want?)
♪♪♪



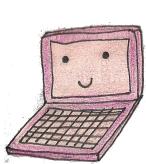
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The server breaks down the request to the following parameters:

1. HTTP Request Method (either GET, POST, PUT, etc.). In this case, with a URL entered directly into the address bar, this will be GET.
2. Domain. In this case the domain is "google.com."
3. Requested path/page. In this case, the path is "/" because no specific path or page was requested (/ is the default, root path, just like in the Unix file system).

HTTP Response

< HTTP/1.1 304 Not Modified
[other headers]



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If you've been to this site before, and the HTTP headers sent by the web browser included sufficient information for the server to determine if the version of the file cached by the web browser has been unmodified since the last retrieval, it may instead respond with something like this.

This is so much less work for the client and server at this point, but is the result of author work, making sure that the proper mechanisms are in place for the required data to be transmitted.

HTTP Response

Sorry, we had to change to that code
Updated that file and then changed its number
I guess you need the new stuff though
Now it's just some page that you used to know
♪♪♪



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For example, having ETags in the header will allow the server to determine if the cached version of a page is still valid. The first time the server sends the page, it will send an ETag, a unique identifier for the version of the page, in the header of the response. The client will then cache this. The next time the client needs this page, it will get the ETag from its cached version and send it to the server. If the ETags match, the server will send the 304 Not Modified status code.

HTTP Response

```
< HTTP/1.1 200 OK
[other headers]
<
<!doctype html><html>...</html>
```



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HTTP Response

HTTP Response

```
zeigenspace:~ jenna$ curl www.google.com  
<!doctype html><html itemscope="" itemtyp
```

My curl, my curl, my curl
Talkin' 'bout my curl.
My curl!



If they don't match, then there's much more to be done. An otherwise successful request and smooth servering process will prompt the server to send a response like this, with a 200 OK status code, other headers, a single blank newline, and then the payload, which in this case is the entire HTML document.

If something went wrong, you could also get less-happy status codes. The 400-series represents a client error like 403 Forbidden or 404 Not Found.

If you want to investigate what's going on in an HTTP request, you can use curl from your terminal.

HTTP Response



Shrink it down,
gzip it
(Don't reverse it...)
♪ ♪

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With HTTP, the size of the request directly correlates to the time it takes to finish the request. Because of this, compression helps a lot to get your page to the user as fast as possible. Gzip is most popular compression method for these web things. Gzip works by replacing repeated substrings with references to where the decompressor can find that substring, and this is great for HTML (think of how many times `div` appears in an HTML document!). In fact, gzipping generally reduces the response size by about 70%. And if you're worried your users don't have this fancy compression method enabled

HTML Parsing



We did everything right,
Bytes are on the client side
♪ ♪

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As soon as the browser starts receiving bytes, it starts parsing it. It usually receives it in 8kB chunks, and feeds those bytes right into the parser.

HTML Parsing



Come back server! I
need more things!

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Before the formal parsing for rendering, the bytes get passed through a speculative parser, or look-ahead pre-parser. This parser looks ahead for external resources like JS, CSS, and image files so it can start getting them from the server immediately. If it finds them, it'll use the extra TCP requests, if they're from the same host. Otherwise, the client has to do the whole DNS dance again. This optimization wasn't always in the stack, but when released, improved page load performance by about 20%.

HTML Parsing



```
1 <!doctype html>
2 <html>
3   <head>
4     <script type="text/javascript" src="library.js"></script>
5     <link rel="stylesheet" type="text/css" href="styles.css">
6     <script type="text/javascript" src="website.js"></script>
7   </head>
8   <body>
9     <div>Let's pretend this is all of google</div>
10   </body>
11 </html>
```

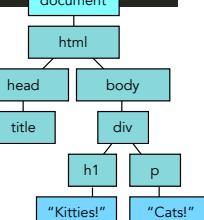


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HTML Parsing



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7   </head>
8   <body>
9     <div>Let's pretend this is all of google</div>
10   </body>
11 </html>
```



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HTML Parsing



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5     <link rel="stylesheet" type="text/css" href="styles.css">
6     <script type="text/javascript" src="website.js"></script>
7   </head>
8   <body>
9     <div>Let's pretend this is all of google</div>
10   </body>
11 </html>
```

Whatever, wherever
I'm gonna make it render!
♪ ♪

Jenna Zeigen • @zeigenvector

Meanwhile, the bytes are fed into the primary parser. The parsing algorithm is described in detail by the HTML5 specification. It goes something like this:

1. The browser reads the raw bytes of the HTML off the disk or network and translates them to individual characters based on specified encoding of the file, e.g. UTF-8.
2. The characters get broken up into tags, e.g. html, head, and div.
3. The tags then then get made into nodes.
4. The nodes are then arranged into the DOM tree.

After this process, you end up with a DOM (Document Object Model) tree made from the HTML document. It has an almost one-to-one relationship with the markup.

HTML cannot be parsed using the regular top-down or bottom-up parsers because of the forgiving nature of the language. The parser isn't context free because the HTML spec requires the parser to be 100% fault-tolerant. Thus, a lot of the parser's code is for fixing the HTML author mistakes, like invalid tags, unclosed tags, incorrect nesting. This means the parser will never error, but it also means browsers create custom parsers and are like a million lines of C++, and a big chunk is related to this parser.

HTML Parsing



Just doing that
browser thing...

Jenna Zeigen • @zeigenvector

As the parser is parsing, it runs into inlined assets like images, scripts, and stylesheets. The client must request, parse, and execute them all as they are encountered. Hopefully the speculative parser has already started the fetching process!

HTML Parsing



Just doing that
browser thing...

Jenna Zeigen • @zeigenvector

The big hiccup here is that browsers have imposed limits on how many parallel downloads you can have from the same domain. It used to be 2, but now that limit is anywhere from 6 to 13 in modern browsers, depending on the browser. This is a huge bottleneck, but many of the optimizations we hear about stem from trying to get around this. One thing you can do here is to serve your images from multiple hostnames, you can get around the same hostname parallel download limit. Concatenating files together also helps alleviate some pain here.

HTML Parsing



Cache moneyyy.

Jenna Zeigen • @zeigenvector

Caching also comes into play here, because TTL in this case is determined by the headers sent with the asset, such as a far-future Expires header. This helps because the file does not need to be downloaded again, therefore not contributing to the download limit.

HTML Parsing

Better together.



Jenna Zeigen • @zeigenvector

Another popular optimization is to combine your files together. This includes concatenating JavaScript, making CSS sprites, and inlining your images as data:URLs. However, this might come back to bite you with caching because overtime you change just one file in your bundle, the cache gets invalidated. Because of this, some developers have two bundles—one for application code that is likely to change often and one for vendor code that is less likely to change.

HTML Parsing

Harder, Better,
Faster, Smaller
))))



Jenna Zeigen • @zeigenvector

Still with referenced assets the size of the request affect the time it takes to download, so developers often gzip and minify all their CSS and JavaScript, as well as optimize their images. SVGs especially have extra information that can be removed if run through an optimizer such as [svgo](#).

HTML Parsing

Stop, JavaScript time!
))))



```
<head>
<script src="library.js"></script>
<link href="styles.css">
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

As the parser is doing its parsing and it runs into a JavaScript include, further parsing stops. This is because JavaScript has the ability to manipulate the DOM, using `document.write`, and any HTML that gets added must be fed back into the main parser. The parsing of the document halts until the script has been downloaded, if necessary, and executed. While a script is downloading, the browser won't start any other downloads, even on different hostnames.

HTML Parsing

Just doing that browser thing...



```
<head>
<script defer src="library.js"></script>
<link href="styles.css">
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

There are also spec-approved ways to get around this blocking too. Authors can add a "defer" attribute to a script tag, in which case it will not halt document parsing and will execute after the document is parsed.

HTML Parsing

Just doing that browser thing...



```
<head>
<script async src="library.js"></script>
<link href="styles.css">
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

HTML5 adds an another option, to mark the script as asynchronous with the `async` attribute so it will be parsed and executed by a different thread, in parallel. With this, you're kinda promising you won't call `document.write`, or you're okay with it getting thrown out the window. (that was an attempt at a DOM pun...)

HTML Parsing

Just doing that browser thing...



```
<head>
<script src="library.js"></script>
<link href="styles.css">
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

CSS also does its own kind of blocking. It might seem that since CSS doesn't change the DOM tree, there's no reason to wait for it and stop the document parsing. There is an issue, though, of scripts asking for style information during the document parsing stage. If the styles aren't loaded and parsed yet, the scripts will get wrong answers and apparently this has caused lots of problems. It seems to be an edge case but is quite common.

Different browsers have different ways of dealing with this blocking though.

CSS Parsing

Just doing that browser thing...

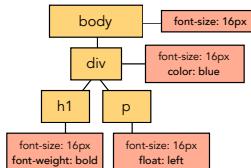


Jenna Zeigen • @zeigenvector

Just like with HTML, the browser needs to convert the CSS file into something it can work with. Instead of making a DOM tree though, it makes a CSSOM tree! The CSS parser, unlike the HTML parser, is context-free, though the steps in the process are largely the same.

CSS Parsing

'Cause we know how to style
We know how to style
♪ ♪ ♪



Jenna Zeigen • @zeigenvector

The tree data structure makes for CSS because of the recursive nature of style application, the “cascade.” It should be noted that the CSSOM tree only includes overrides to the browser’s default stylesheet, so things that are included in the application’s stylesheet and inlined in the HTML.

HTML Parsing

Just doing that browser thing...



```
<head>
<script src="library.js"></script>
<link href="styles.css" /> ✓
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

So, once the CSS is done, the JavaScript can definitely continue to load.

HTML Parsing

Just doing that browser thing...



```
<head>
<script src="library.js"></script>✓
<link href="styles.css">✓
<script src="website.js"></script>
</head>
<body></body>
```

Jenna Zeigen • @zeigenvector

HTML Parsing

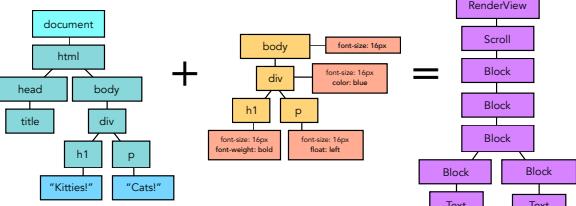
Just doing that browser thing...



```
<head>
<script src="library.js"></script>✓
<link href="styles.css">✓
<script src="website.js"></script>✓
</head>
<body></body>
```

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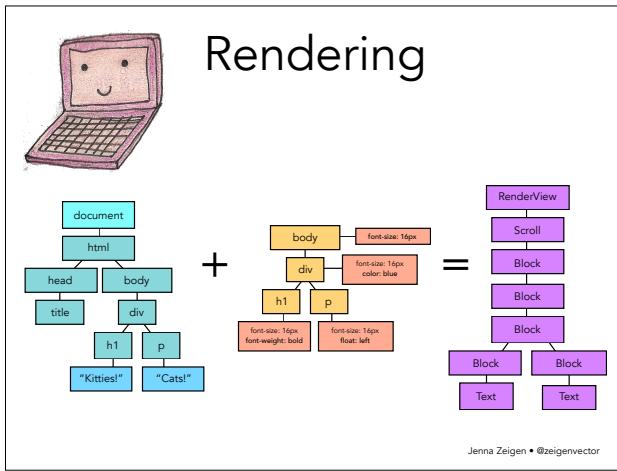
Rendering



Jenna Zeigen • @zeigenvector

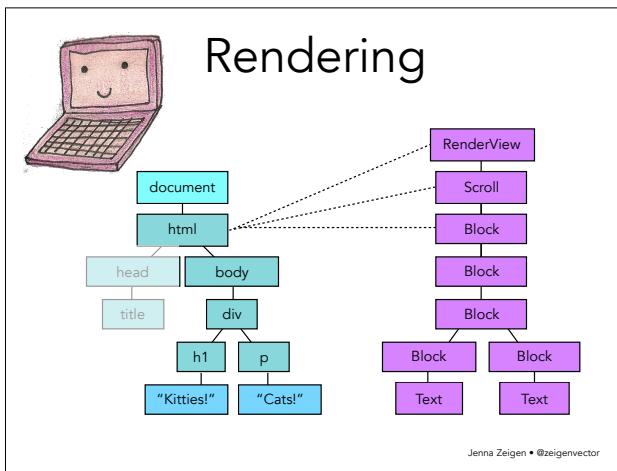
Successive assets then can be downloaded and parsed.

While it's important to download all the assets in the right order, rendering is just as integral a job for the browser. To kick off rendering the page, CSSOM and DOM trees are combined into a render tree, which is then used to compute the layout of each visible element and serves as an input to the paint process which renders the pixels to screen.

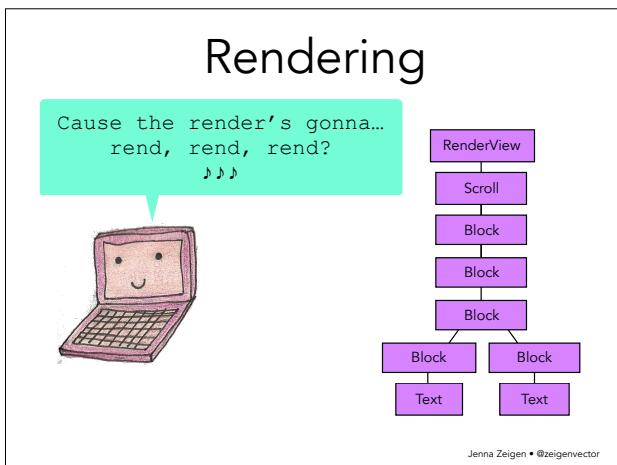


Because of this, HTML and CSS are both render-blocking resources, which means that the browser will hold rendering of any processed content until the DOM and CSSOM trees are constructed.

This is one reason why stylesheets are supposed to go at the top of your HTML document, in `<head>`. Putting stylesheets near the bottom of the document prohibits progressive rendering in many browsers. These browsers block rendering to avoid having to redraw elements of the page if their styles



Elements in the render tree correspond to elements in the DOM tree, but it's not 1:1. The render tree only includes things to be rendered, so no non-visual DOM elements like `<script>` or elements with the style `display: none`. Elements with the style `visibility: hidden` will be in the render tree, because it leaves the space for it.

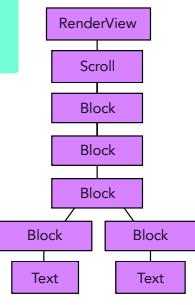


While the render tree contains information about what nodes are visible and computed styles, we haven't yet figured out where all these elements are supposed to go or how big they're supposed to be. This is all part of the "layout" process, also called "reflow."

Layout is a recursive process, starting at the root renderer, which corresponds to the `<html>` element of the HTML document, continuing to compute geometric information for each renderer that requires it. All renderers have a

Rendering

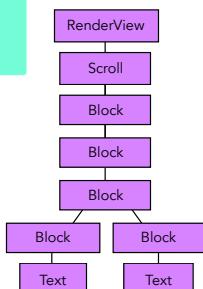
Cause the render's gonna
rend, rend, rend?
♪♪♪



Jenna Zeigen • @zeigenvector

Rendering

And the painter's gonna
paint, paint, paint...
♪♪♪



Jenna Zeigen • @zeigenvector

HTML Parsing

```
1 <!doctype html>
2 <html>
3   <head>
4     <script type="text/javascript" src="library.js"></script>
5     <link rel="stylesheet" type="text/css" href="styles.css">
6   </head>
7   <body>
8     <div>Let's pretend this is all of google</div>
9   </body>
10 </html>
```



Whoa, oh, oh, oh, oh
Whoa, oh, oh, oh,
The DOM's interactive
DOM's interactive
♪♪♪

Jenna Zeigen • @zeigenvector

In order not to do a full layout for every small change, browsers use a "dirty bit" system. A renderer that is changed or added marks itself and its children as "dirty", which just means that it needs laying out. There are actually two flags: "dirty" and "children are dirty." The latter means that while the actual renderer may be "clean," it has at least one child that needs a layout.

Layouts can be either global or incremental. Incremental layouts are done in async batches based on a timer in the browser.

Once we know the location and dimensions of all the elements in the render tree, we can then start representing everything as pixels on the page — painting! In the painting stage, the render tree is traversed recursively and the renderer's "paint" method is called to display the content.

Like layout, painting can also be global or incremental, where only dirty regions are repainted. This is where "region-specific repainting" comes from!

When the HTML document is fully downloaded and parsed, the page is marked as "interactive" and `DOMContentLoaded` is fired, without waiting for all the assets to finish loading. At this point, you can click around the page — it's interactive!

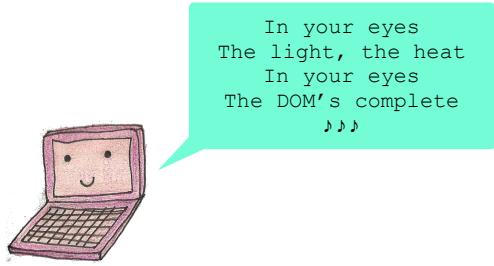
HTML Parsing



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At this point, scripts marked with the defer attribute are downloaded, parsed, and executed.

HTML Parsing



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Finally, once every resource has been downloaded and parsed, the document is marked as complete, and the load event is fired.

HTTP/2



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HTTP/2 is a new HTTP specification that grew out of Google's work on SPDY ("speedy"). It serves to fix a bunch of the aspects of HTTP/1.1 that we need to optimize around all the time. So, once HTTP/2 is implemented across the board, most the of the optimizations I discussed today will be obsolete.

Features include:

- HTTP header compression (no repeated headers being passed back and forth)
- Server push technologies (sends assets with the HTML, because it knows

Overview

1. IP Address Lookup
2. Opening a socket
3. Security Stuff
4. HTTP Request
5. Server Things
6. HTTP Response
7. Parsing
8. Rendering

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Resources

General

- [What Happens When \(Github\)](#)

Transport

- [DNS \(Wikipedia\)](#)
- [UDP \(Wikipedia\)](#)
- [TCP \(Wikipedia\)](#)
- [TLS \(Wikipedia\)](#)



Parsing, Rendering, and Painting

- [How Browsers Work \(HTML5 Rocks\)](#)
- [Critical Rendering Path \(Google Developers\)](#)

Performance

- [Best Practices for Speeding Up Your Web Site \(Yahoo Developer Network\)](#)
- [Raul Fraile: How GZIP compression works \(JSConfEU 2014\)](#)

HTTP/2

- [Andy Davies: The Case for HTTP/2 \(TXJS 2015\)](#)

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Complete Tracklist

The Beatles - You Know My Name (Look Up The Number)

Carly Rae Jepsen - Call Me Maybe

Radiohead - Creep

Taylor Swift - Blank Space

Taylor Swift - We Are Never Ever Getting Back Together

Taylor Swift - Wildest Dreams

Imagine Dragons - Demons

Young Chris - Racks

Beastie Boys - So What'cha Want

Gotye - Somebody That I Used To Know

The Temptations - My Girl

Missy Elliot - Work It

Calvin Harris ft. Elie Goulding - Outside

Shakira - Wheneva, Wherever

Daft Punk - Harder, Better, Faster, Stronger

MC Hammer - U Can't Touch This

Taylor Swift - Style

Taylor Swift - Shake It Off

Imagine Dragons - Radioactive

Peter Gabriel - In Your Eyes



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Complete Tracklist

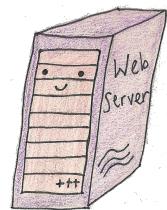
The Beatles - You Know My Name (Look Up The Number)
Carly Rae Jepsen - Call Me Maybe
Radiohead - Creep
Taylor Swift - Blank Space
Taylor Swift - We Are Never Ever Getting Back Together
Taylor Swift - Wildest Dreams
Imagine Dragons - Demons
Young Chris - Racks
Beastie Boys - So What'cha Want
Gotye - Somebody That I Used To Know
The Temptations - My Girl
Missy Elliot - Work It
Calvin Harris ft. Elie Goulding - Outside
Shakira - Whenever, Wherever
Daft Punk - Harder, Better, Faster, Stronger
MC Hammer - U Can't Touch This
Taylor Swift - Style
Taylor Swift - Shake It Off
Imagine Dragons - Radioactive
Peter Gabriel - In Your Eyes

*something
witty about a
POP server...*



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jenna.is/thunderplains



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Thanks!



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