How the Web Works

Goals

- High level: what happens when you visit a URL in browser
- Explain what IP and DNS are
- Describe the different parts of a URL
- Describe the request / response cycle
- Compare ***GET*** vs ***POST*** requests

An Introduction

What Happens When…

When I type ***http://site.com/some/page.html***

into a browser, what really happens?

This is a common interview question for software engineers.

How the Web Works

The internet is complicated.

Really, really complicated.

Fortunately, to be a software developer, you only need to know a bit.

For people who want to work in “development operations,” or as a system administrator, it’s typical to have to learn more about the details here.

Networks

A *network* is a set of computers that can intercommunicate.

The internet is just a really, really big network.

The internet is made up of smaller, “local” networks.

Hostnames

We often talk to servers by “hostname” — ***site.com*** or ***computer-a.site.com***.

That’s just a nickname for the server, though — and the same server can have many hostnames.

IP Addresses

On networks, computers have an “IP Address” — a unique address to find that computer on the network.

IP addresses look like `123.77.32.121`, four numbers (0-255) connected by dots.

There are a lot of advanced edges here that make this more complicated, but most of these details aren’t important for software engineers:

- there another whole way to specify networks, “IPv6”, that use a different numbering scheme.
- some computers can have multiple IP addresses they can be reached by
- under some circumstances, multiple computers can share an IP address and have this be handled by a special kind of router. If you’re interested in system administration details, you can learn about this by reading about “Network Address Translation”.

127.0.0.1

`127.0.0.1` is special — it’s “this computer that you’re on”.

In addition to their IP address on the network, all computers can reach themselves at this address.

The name ***localhost*** always maps to `127.0.0.1`.

URLs

http://site.com/some/page.html?x=1

turns into:

Protocol	Hostname	Port	Resource	Query
http	site.com	80	/some/page.html	?x=1

Protocols

Protocol	Hostname	Port	Resource	Query
http	site.com	80	/some/page.html	?x=1

"Protocols" are the conventions and ways of one thing talking to another.

http
Hypertext Transfer Protocol (standard web) (How browsers and servers communicate)

https
HTTP Secure (How browsers and servers communicate with encryption)

ftp
File transfer protocol (An older protocol for sending files over internet)

There are many others, but these are the common ones.

In this lecture, we'll be focusing only on HTTP.

Hostname

Protocol	Hostname	Port	Resource	Query
http	**site.com**	80	/some/page.html	?x=1

DNS (domain name service) turns this into an IP address

So ***site.com*** might resolve to `123.45.67.89`

Port

Protocol	Hostname	Port	Resource	Query
http	site.com	**80**	/some/page.html	?x=1

- Every server has 65,535 unique "ports" you can talk to

- Services tend to have a default port <https://en.wikipedia.org/wiki/List_of_TCP_and_UDP_port_numbers>
  - For HTTP, is port 80
  - For HTTPS, is port 443
  - You don't have to specify in URL unless you want a different port
    - To do: ***http://site.com:12345/some/page.html***

Resource

Protocol	Hostname	Port	Resource	Query
http	site.com	80	**/some/page.html**	?x=1

- This always talks to some "web server" program on the server
  - For some servers, may just have them read an actual file on disk: ***/some/page.html***
  - For many servers, "dynamically generates" a page

Query String

Protocol	Hostname	Port	Resource	Query
http	site.com	80	***/some/page.html***	**?x=1**

- This provides "extra information" — search terms, info from forms, etc
  - The server is provided this info; might use to change page
  - Sometimes, JavaScript will use this information in addition/instead
- Multiple arguments are separated by ***&***: `?x=1&y=2`
  - Argument can be given several times: `?x=1&x=2`

So

http://site.com/some/page.html?x=1

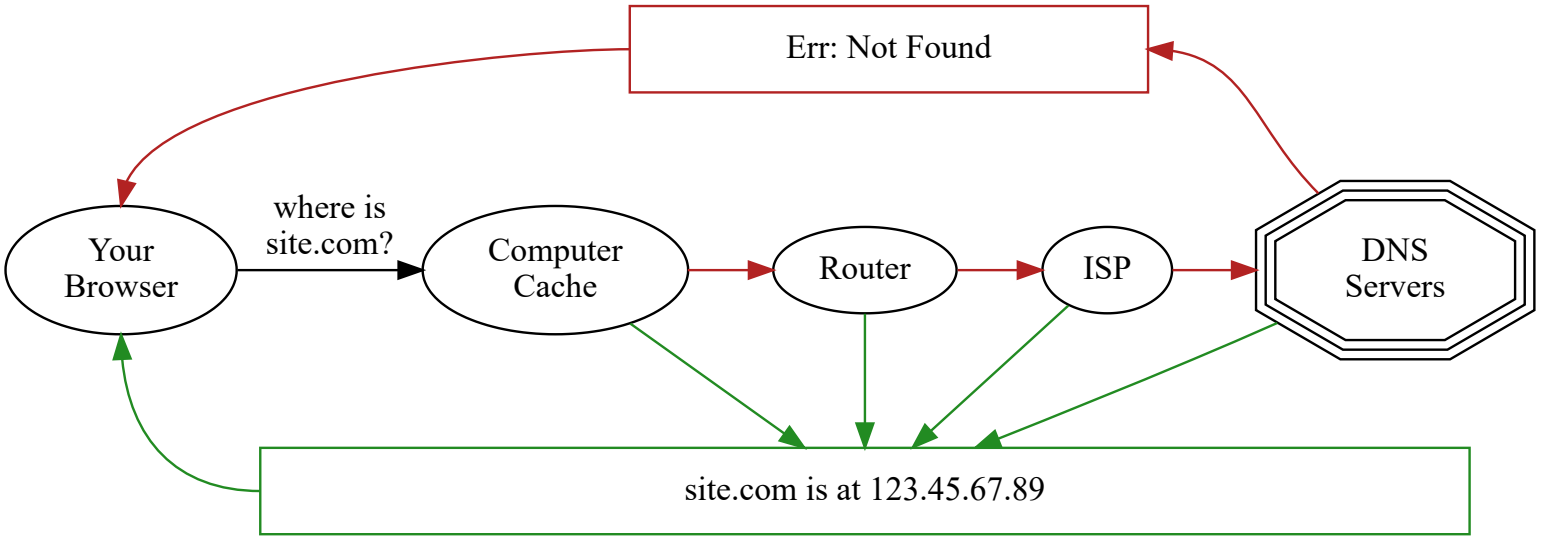
means

- Turn "site.com" into `123.45.67.89`
- Connect to `123.45.67.89`
- On port 80 (the default)

- Using the HTTP protocol
- Ask for ***/some/page.html***
- Pass along query string: ***x*** = 1

DNS

"I want to talk to site.com"



Unix (and OSX and Linux) systems ship with a utility, ***dig***, which will translate a hostname into an IP address for you, and provide debugging information about the process by which it answered this.

```
$ dig site.com

; <<>> DiG 9.8.3-P1 <<>> site.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 959
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDTL: 0

;; QUESTION SECTION:
;site.com.        IN  A

;; ANSWER SECTION:
```

```
site.com.       631  IN  A  123.45.67.89 # Answer

;; Query time: 28 msec
;; SERVER: 10.0.1.1#53(10.0.1.1)
;; WHEN: Mon Apr 20 00:48:16 2018
;; MSG SIZE  rcvd: 46
```

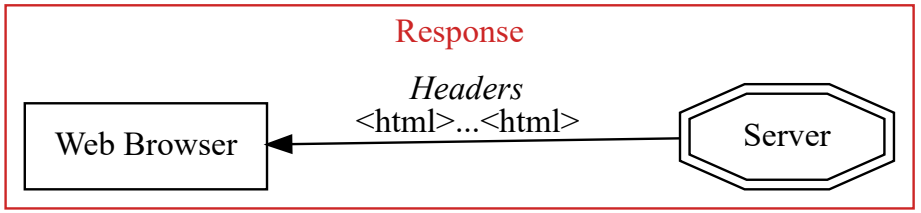
Browsers and Servers

Request and Response

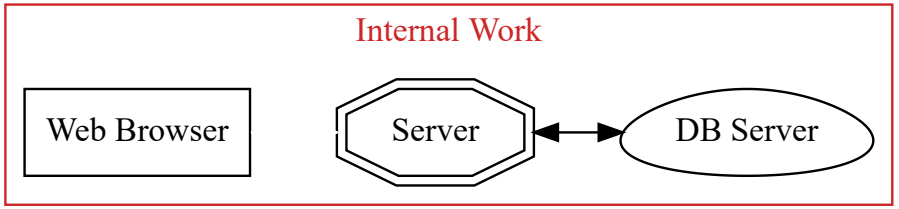
When you point your browser to a webpage on a server, your browser makes a ***request*** to that server.

This is almost always a ***GET*** request and it contains the exact URL you want.

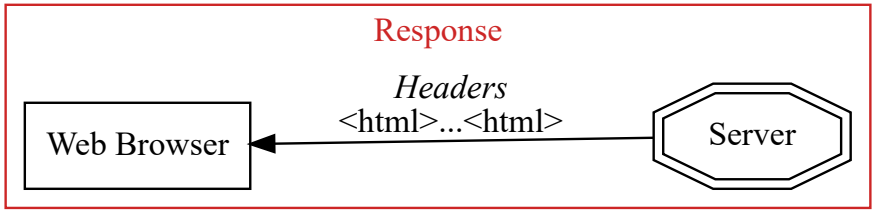
The server then responds with the exact HTML text for that page:



It's often the case, though, that the web server itself will have to do some work to get the page you want, often interacting with other things, such as database servers.



And then it can give back the response you want:



What's in a Request?

- Method (ex: ***GET***)
- HTTP protocol version (almost always 1.1)
- Resource URL you want
- Headers
  - Hostname you're asking about
  - Date your browser thinks it is
  - Language your browser wants information in
  - Any cookies that server has sent
  - And more!

What's in a Response

- HTTP protocol version (almost always 1.1)
- Response Status Code (200, 404, etc)
- Headers
  - Content Type (typically `text/html` for web pages)
  - Date/time the server thinks it is
  - Any cookies server wants to set
  - Any caching information
  - And more!

Watch a Request/Response

```
$ telnet 123.45.67.89 80
Trying 123.45.67.89...
Connected to site.com.
Escape character is '^]'.
GET / HTTP/1.1                      # GET request for /
Host: site.com                      # Header in request

HTTP/1.1 200 OK                         # HTTP Ver & Response Code
Date: Mon, 20 Apr 2018 07:09:16 GMT     # Date Header
Server: Apache                          # Server version
Content-Type: text/html                 # This is HTML content

<!doctype html>                         # Body of response
<html>
  <head>
    <title>The Site</title>
  </head>
  <body>
    ...
  </body>
</html>
```

Response Codes

200

OK

301
: What you requested is elsewhere

404
: Not Found

500
: Server had an internal problem

There are more <https://en.wikipedia.org/wiki/List_of_HTTP_status_codes>, but these are the most important ones.

Serving Over HTTP

Just opening an HTML file in browser uses ***file*** protocol, not ***http***

Some things don't work same (esp security-related stuff)

It's often useful to start a simple HTTP server for testing

You can start a simple, local HTTP server with Python:

```
$ python3 -m http.server
```

Serve files in current directory (& below):

```
$ python3 -m http.server
Serving HTTP on 0.0.0.0 port 8000 (http://0.0.0.0:8000/ <http://0.0.0.0:8000/>) ...
```

Multiple Requests

Sample HTML

demo/demo.html

```
<!doctype html>
<html>
```

```
<head>
  <link rel="stylesheet" href="demo.css">
</head>
<body>
<h1>Hi There!</h1>
<img src="http://tinyurl.com/rithm-logo">
<script src="demo.js"></script>
</body>
</html>
```

CSS

demo/demo.html

```
<!doctype html>
<html>
<head>
  <link rel="stylesheet" href="demo.css">
</head>
<body>
<h1>Hi There!</h1>
<img src="http://tinyurl.com/rithm-logo">
<script src="demo.js"></script>
</body>
</html>
```

Connects to ***site.com*** on port 80 and requests:

```
GET /demo.css HTTP/1.1
Host: site.com
Date: [date browser thinks it is]
Cookie: [any cookies browser is storing for that host]
...
```

Response:

```
HTTP/1.1 200 OK
Date: [date server thinks it is]
Content-Type: text/css
Cookie: [any cookies server wants you to set]
...

body {
```

```
  background-color: lightblue;
}
...
```

Image

demo/demo.html

```
<!doctype html>
<html>
<head>
  <link rel="stylesheet" href="demo.css">
</head>
<body>
<h1>Hi There!</h1>
<img src="http://tinyurl.com/rithm-logo">
<script src="demo.js"></script>
</body>
</html>
```

Connects to ***tinyurl.com*** on port 80 and requests:

```
GET /rithm-logo HTTP/1.1
Host: tinyurl.com
Date: [date browser thinks it is]
Cookie: [any cookies browser is storing for tinyurl.com]
...
```

Javascript

demo/demo.html

```
<!doctype html>
<html>
<head>
  <link rel="stylesheet" href="demo.css">
</head>
<body>
<h1>Hi There!</h1>
<img src="http://tinyurl.com/rithm-logo">
<script src="demo.js"></script>
</body>
</html>
```

Connects to ***site.com*** on port 80 and requests:

```
GET /demo.js HTTP/1.1
Host: site.com
Date: [date browser thinks it is]
Cookie: [any cookies browser is storing for that host]
...
```

Hey, That's a Lot of Work!

- Yes, it is
- Requesting 1 webpage often involves many separate requests!
- Browsers issue these requests asynchronously
  - They'll assemble the final result as requests come back
- You can view this in the browser console → Network

Trying on Command Line

Curl (OSX)

OSX systems come with a utility, ***curl***, which will make an HTTP request on the command line.

```
$ curl -v site.com
* Rebuilt URL to: http://site.com/ <http://site.com/>
*   Trying 123.45.67.89...
* Connected to site.com (123.45.67.89) port 80 (#0)
> GET / HTTP/1.1
> User-Agent: curl/7.41.0
> Host: site.com
>
< HTTP/1.1 200 OK
< Date: Mon, 20 Apr 2018 08:28:50 GMT
< Server: Apache/2.4.7 (Ubuntu)
< Vary: Accept-Encoding
< Transfer-Encoding: chunked
< Content-Type: text/html; charset=UTF-8
<
```

```
<!doctype html>
<html>
<head>
  <link rel="stylesheet" href="demo.css">
</head>
...
```

Hey...

Everything is a string!

Methods: GET and POST

GET vs POST

- ***GET***: requests without side effects (ie, don't change server data)
  - Typically, arguments are passed along in query string
    - If you know the arguments, you can change the URL
  - Entering-URL-in-browser, clicking links, and *some* form submissions
- ***POST***: requests with side effects (ie, change data on server)
  - Typically, arguments sent as body of the request (not in query string)
  - *Some* form submissions (but never entering-URL-in-browser or links)
  - Always do this if there's a side-effect: sending mail, charge credit card, etc
  - "Are you sure you want to resubmit?"

Sample GET Requests

```
<a href="/about-us">About Us</a>

<a href="/search?q=lemurs">Search For Lemurs!</a>

<!-- will submit to URL like /search?q=value-in-input -->
<form action="/search" method="GET">
  Search for <input name="q">
```

```
  <button type="submit">Search!</button>
</form>
```

Sample POST Request

POST requests are always form submissions:

```
<!-- will submit to URL add-comment, with value in body -->
<form action="add-comment" method="POST">
  <input name="comment">
  <button type="submit">Add</button>
</form>
```

HTTP Methods

GET and ***POST*** are “HTTP methods” (also called “HTTP verbs”)

They’re the most common, by far, but there are others

Further Study

- How the Internet Works: A Code.org Video Series <https://www.youtube.com/playlist?list=PLzdnOPI1iJNfMRZm5DDxco3UdsFegvuB7>
- How Does the Internet Work? <https://web.stanford.edu/class/msande91si/www-spr04/readings/week1/InternetWhitepaper.htm>
- A cute webcomic about how DNS works <https://howdns.works/>