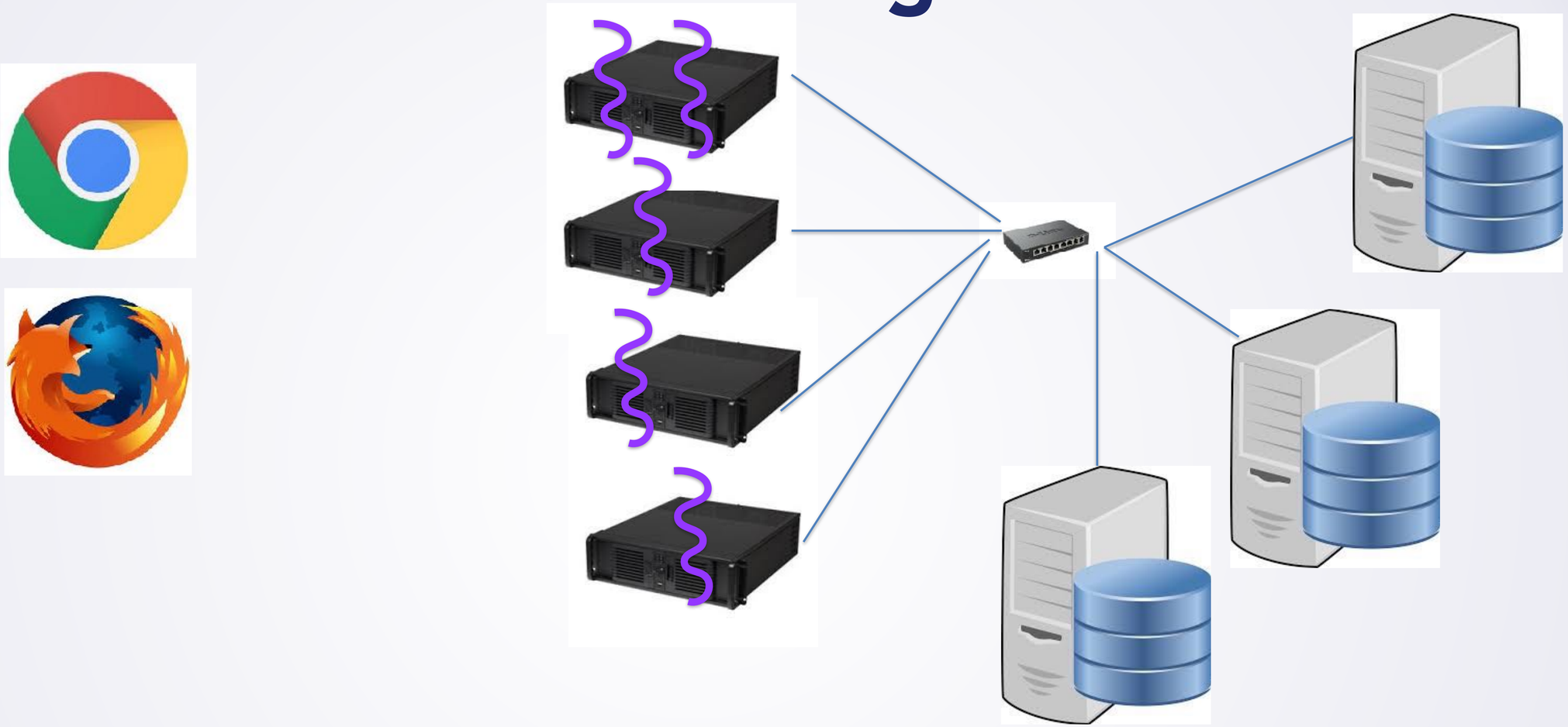
Engineering Robust Server Software

Web Protocols and Technologies

Web Protocols

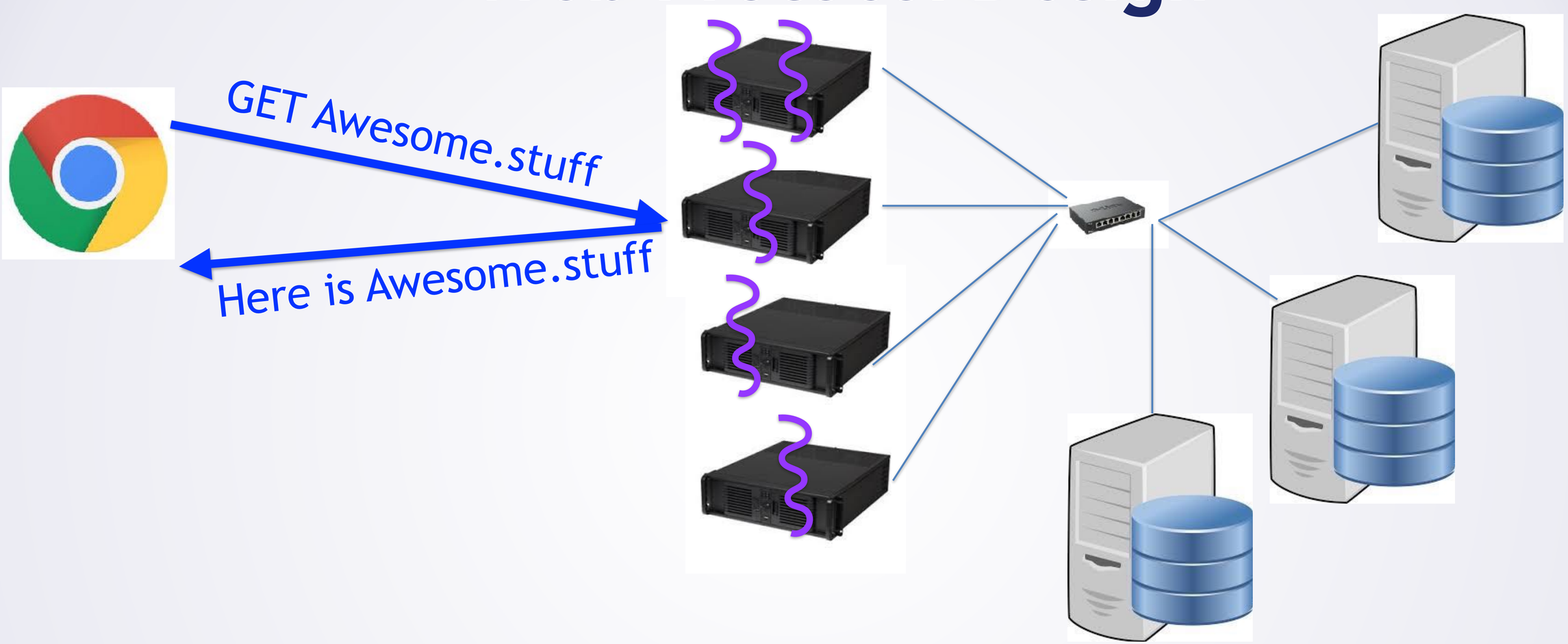
- REST Principles
- HTTP
- Data: XML, HTML, JSON
- Manipulation: JavaScript

Recall: Server Big Picture



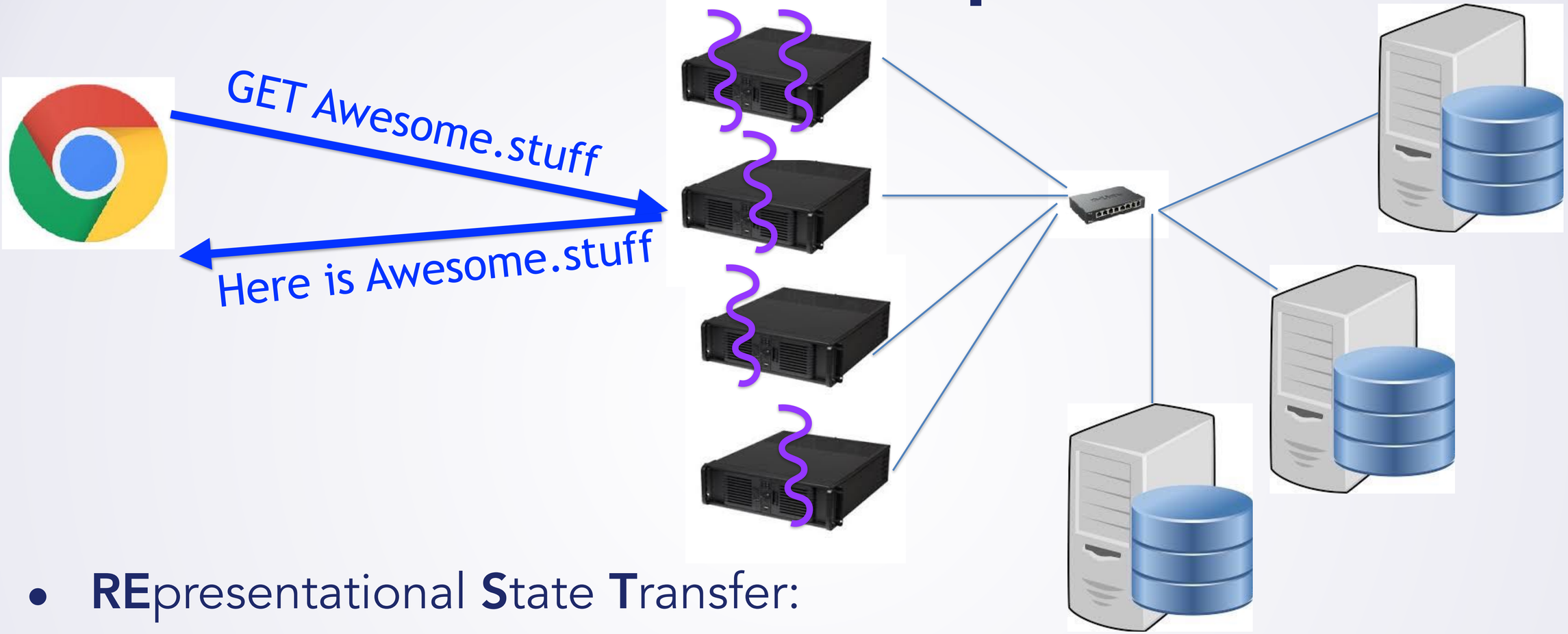
- Let's remember our view of the world

Web Protocol Design



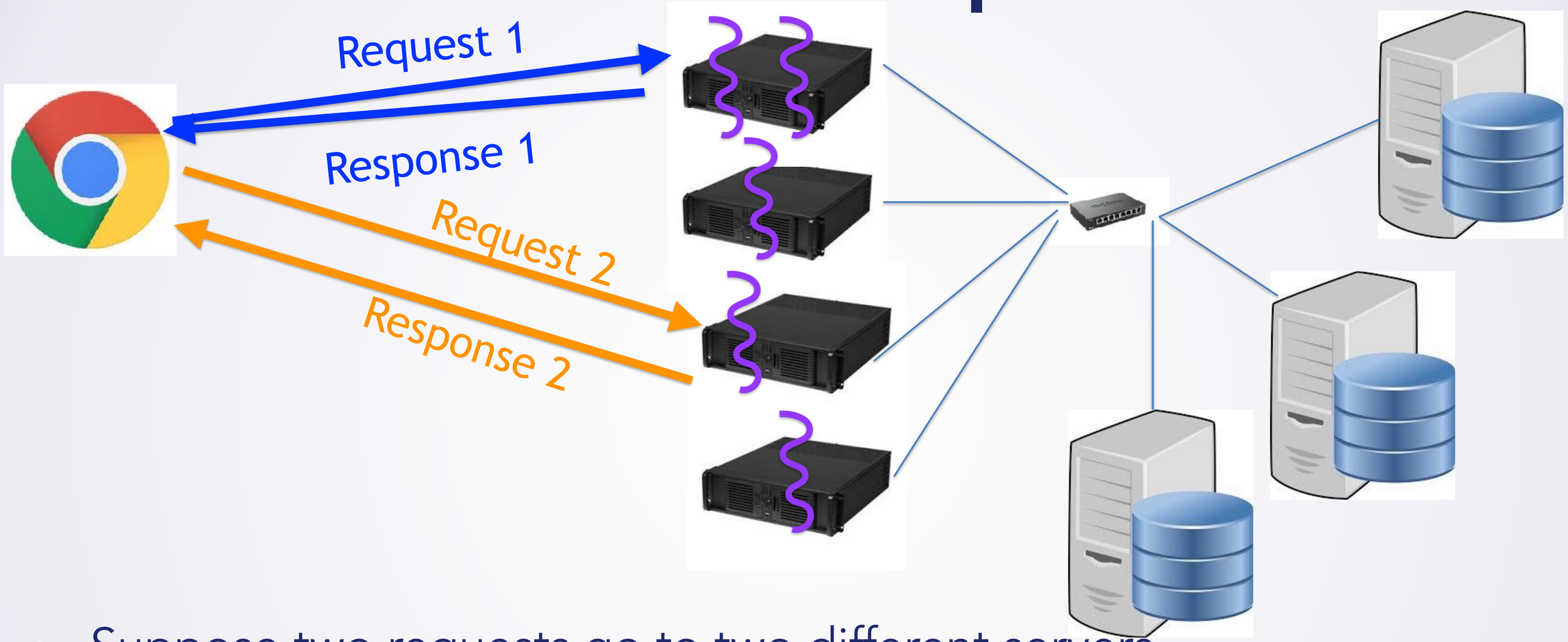
- How should such a protocol be designed?

REST Principles



- **RE**presentational **S**tate **T**ransfer:
  - Let us derive the principles…
  - Principle 1 (easy): Client/Server architecture

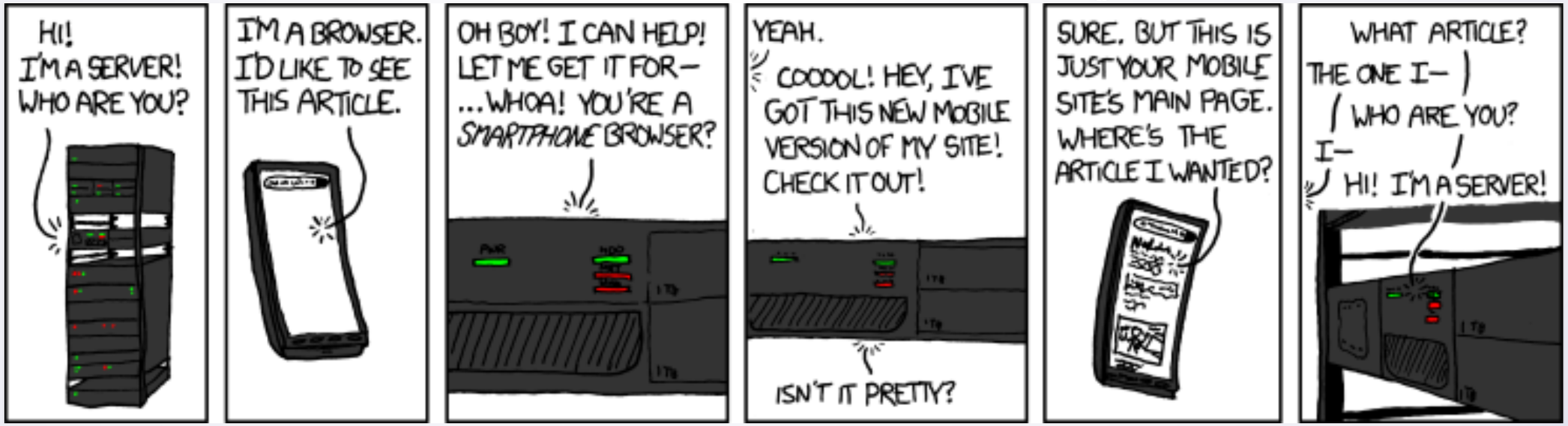
REST Principles



- Suppose two requests go to two different servers
  - Why?
  - What does this say about protocol design?

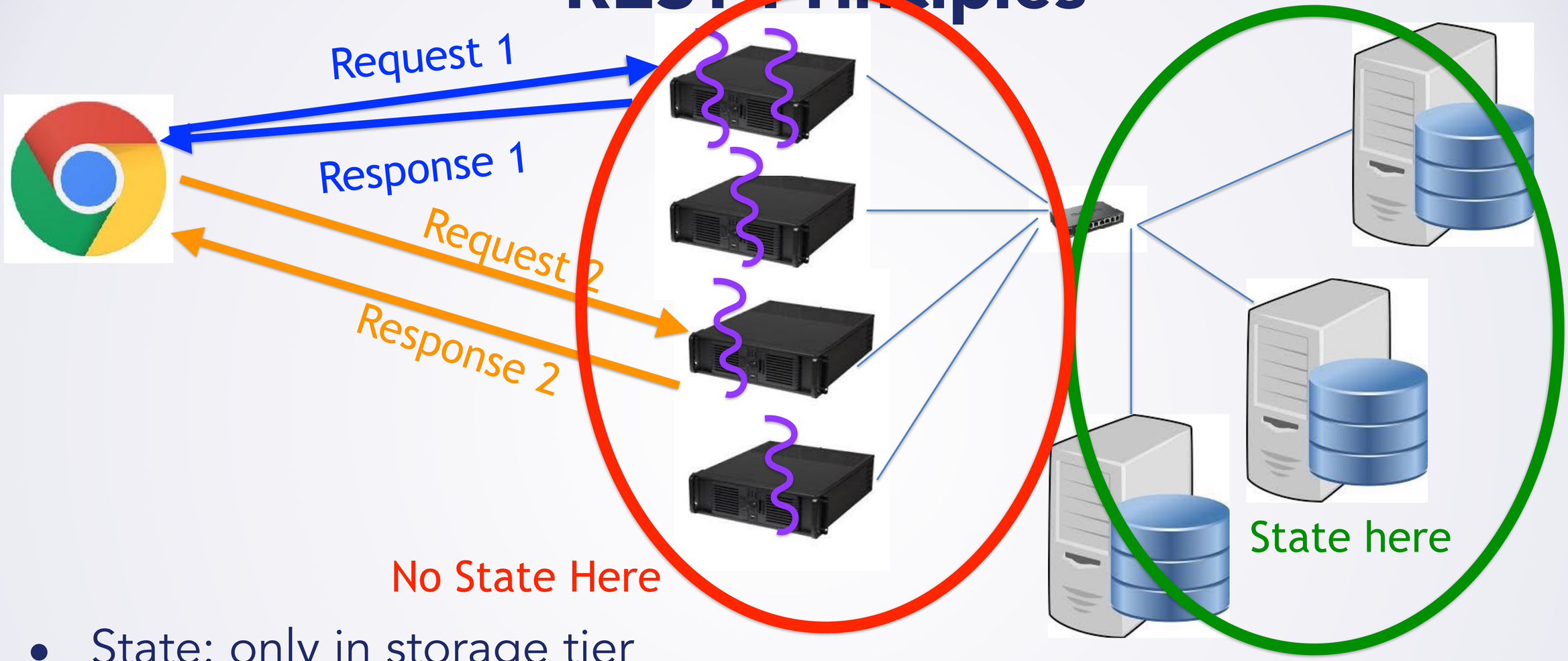
REST Principle 2: Stateless

- Why: **balance load**
- Protocol principle: **stateless**
  - Server side code does not remember anything about previous request
  - Each request needs all information to proceed
    - But wait… servers have to have some state, right?



https://xkcd.com/869/

REST Principles



- State: only in storage tier
  - User booked a flight: goes into storage tier (not application tier)

Stateless: Implications

- Need to identify user: include in request
  - But…

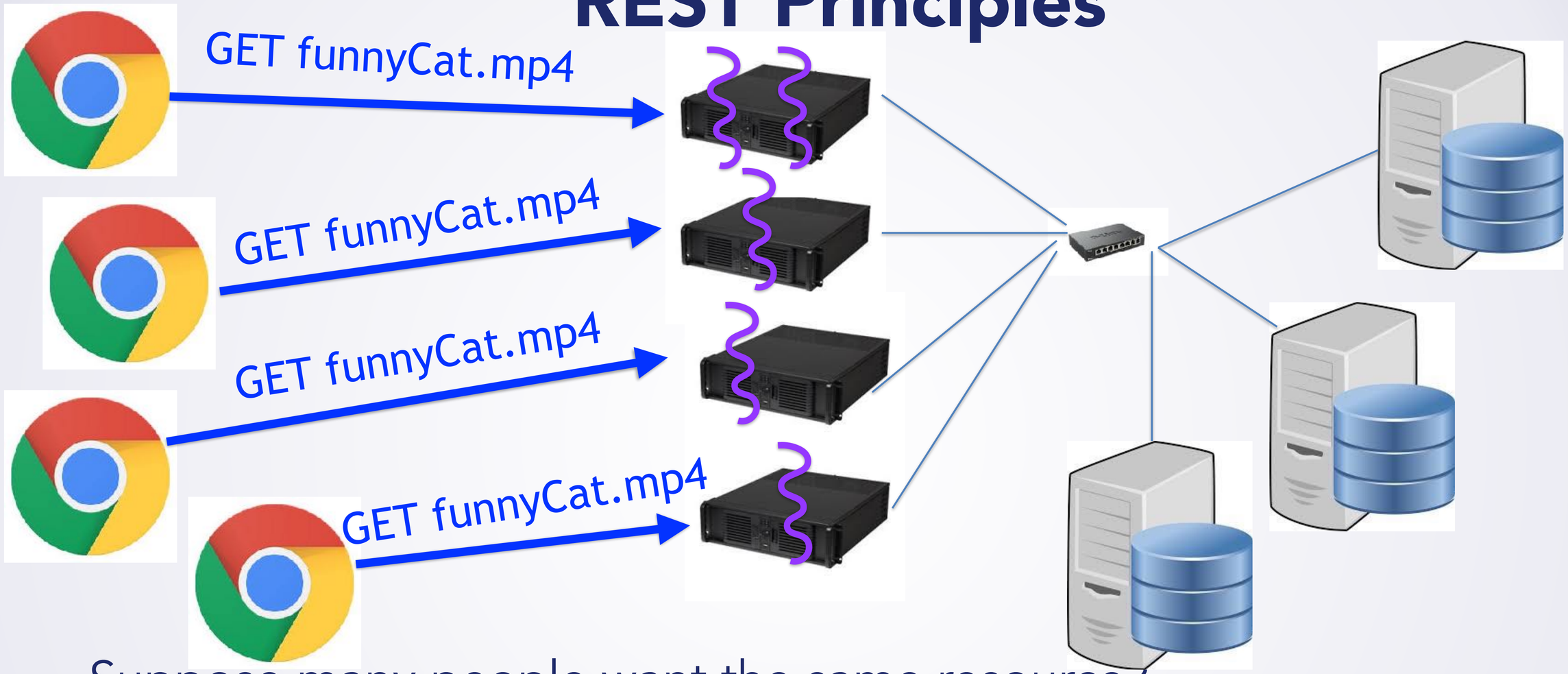
Stateless: Implications

- Need to identify user: include in request
  - But…don't we distrust everything from client?

Stateless: Implications

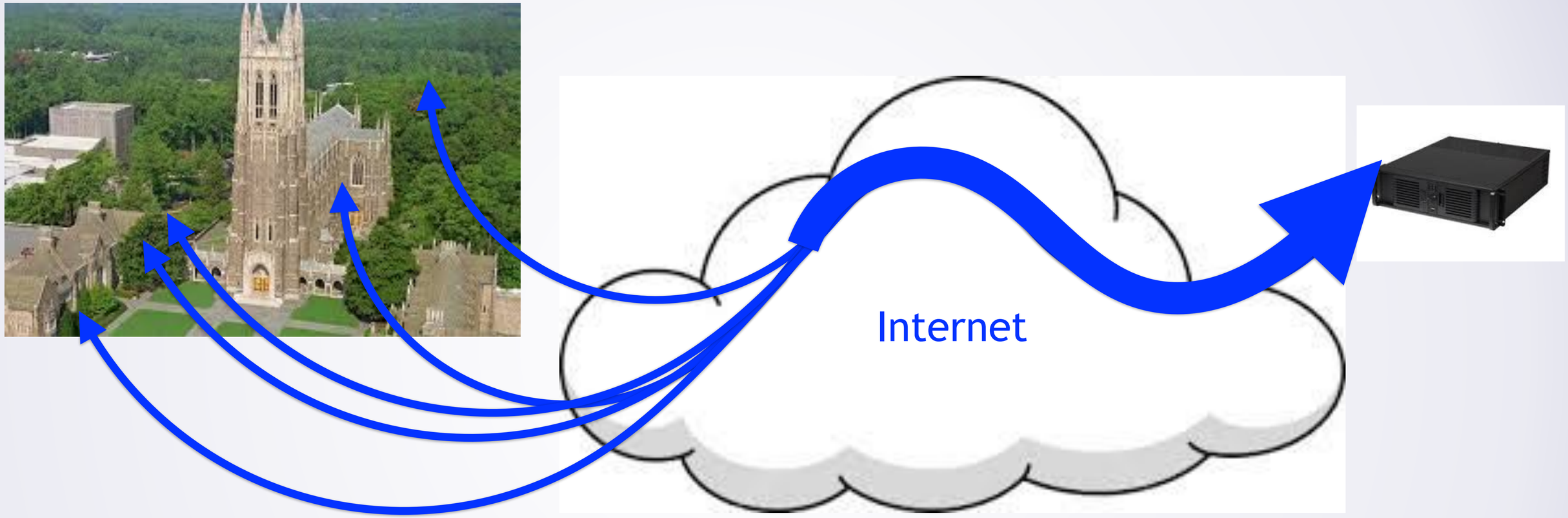
- Need to identify user: include in request
  - But…don't we distrust everything from client?
  - Yes! Distrust client:
    - Give session ID at login
    - Client must provide session ID with each request
    - Session ID should be hard to forge
    - How do you validate session ID?

REST Principles



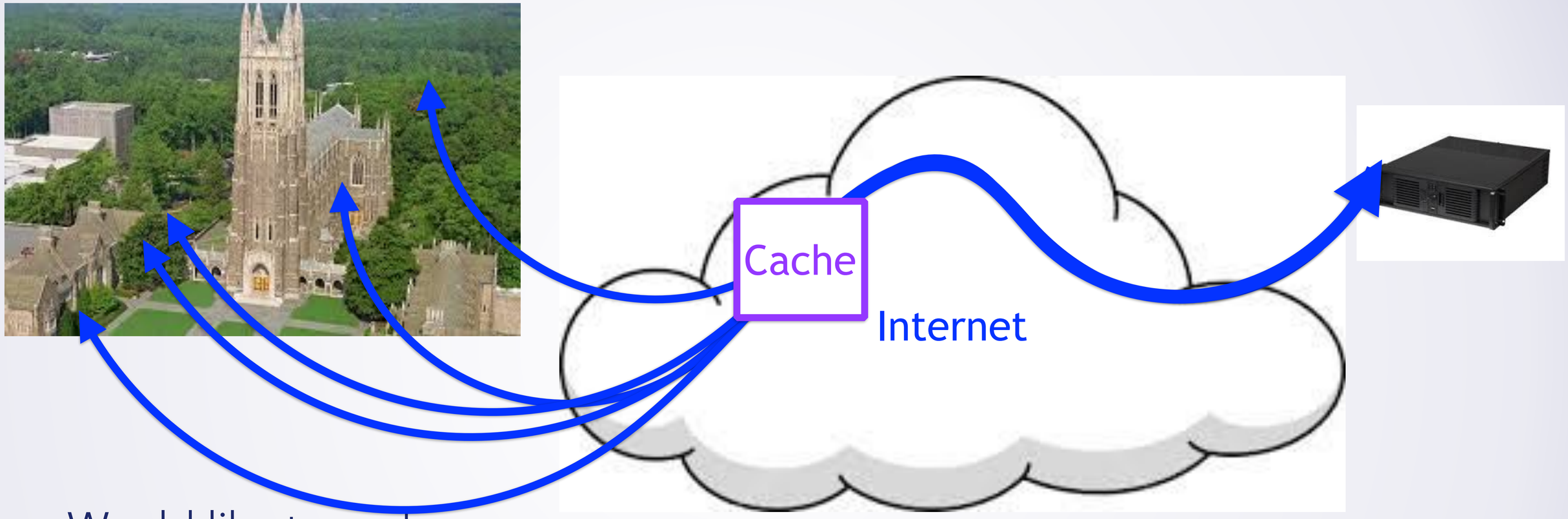
- Suppose many people want the same resource?
  - Asking for it frequently
  - What implication does this have?

Or Maybe…



- Many people at Duke decide to watch same video
  - What implications does this have?
  - How can we address this issue?

Or Maybe…

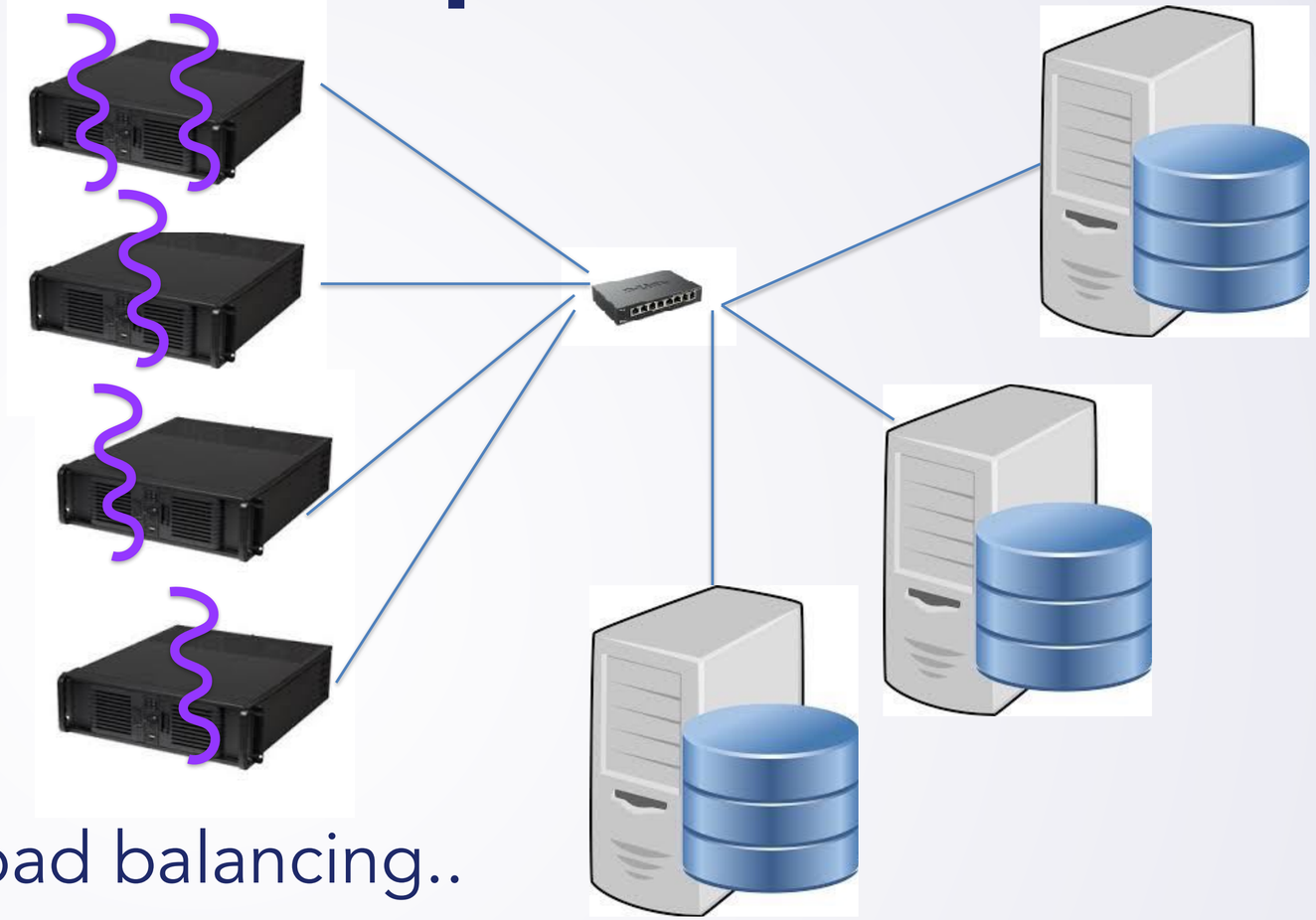


- Would like to cache responses
  - Reduce bandwidth + latency
  - Reduce load on servers
  - But, what difficulties?

Principle 3: Cacheability

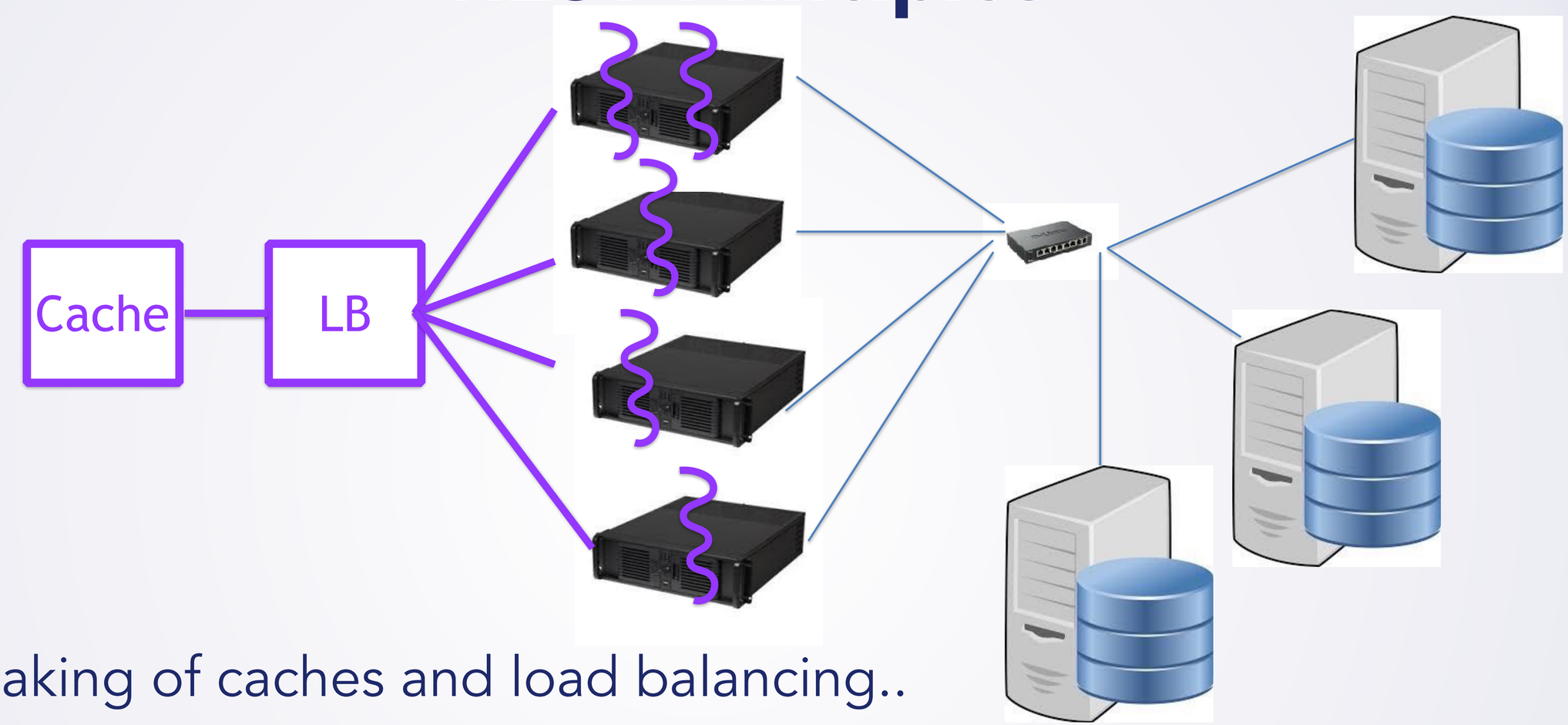
- Responses should be cacheable
- …Except when this creates problems
  - Explicit cache control
    - Label responses as non-cacheable
    - Label responses as expiring at a certain time
    - Provide a way to validate that response is still current

REST Principles



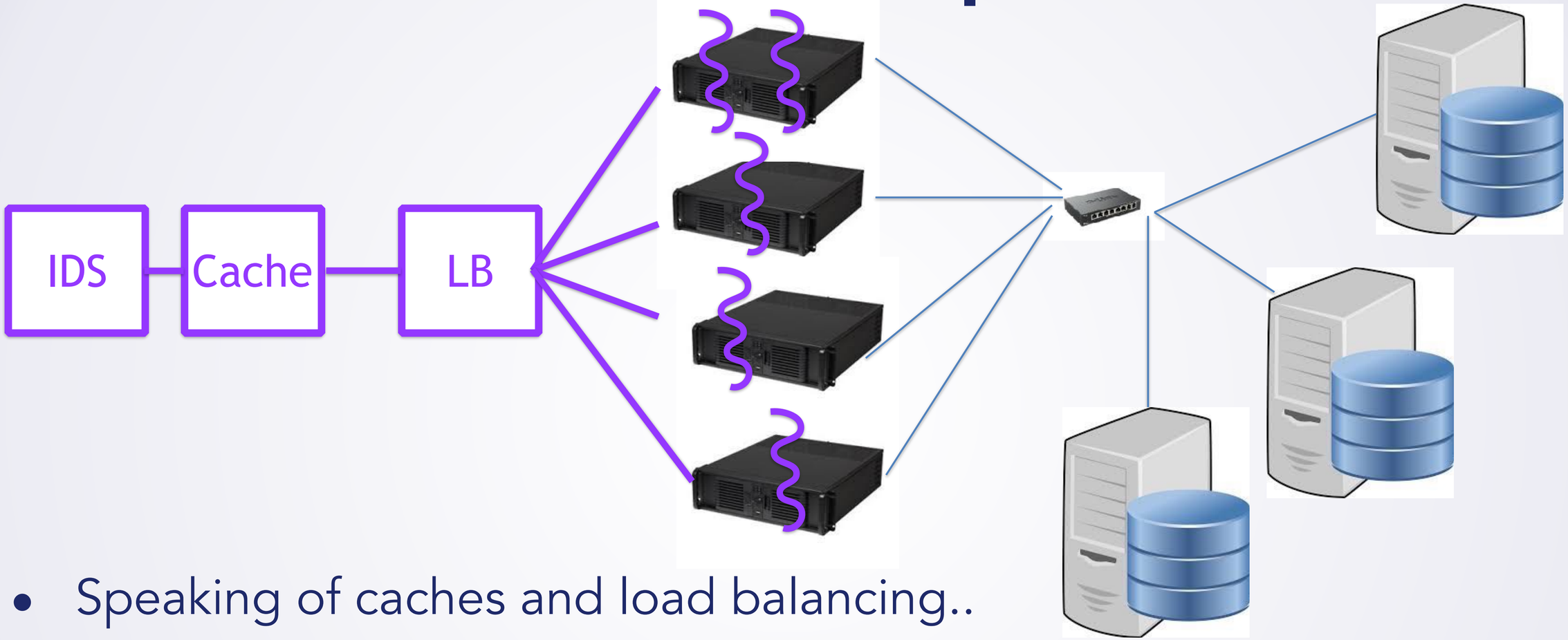
- Speaking of caches and load balancing..

REST Principles



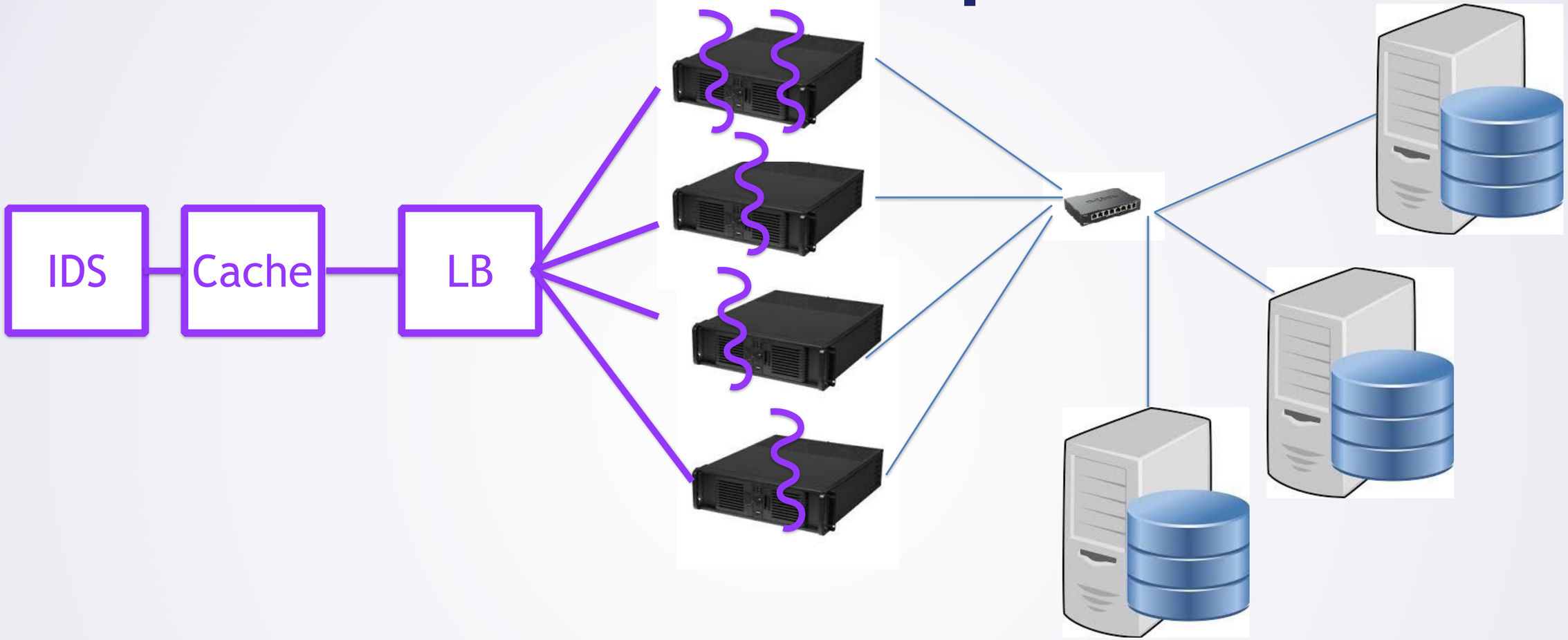
- Speaking of caches and load balancing..
  - We decide to add a cache and a hw load balancer…

REST Principles



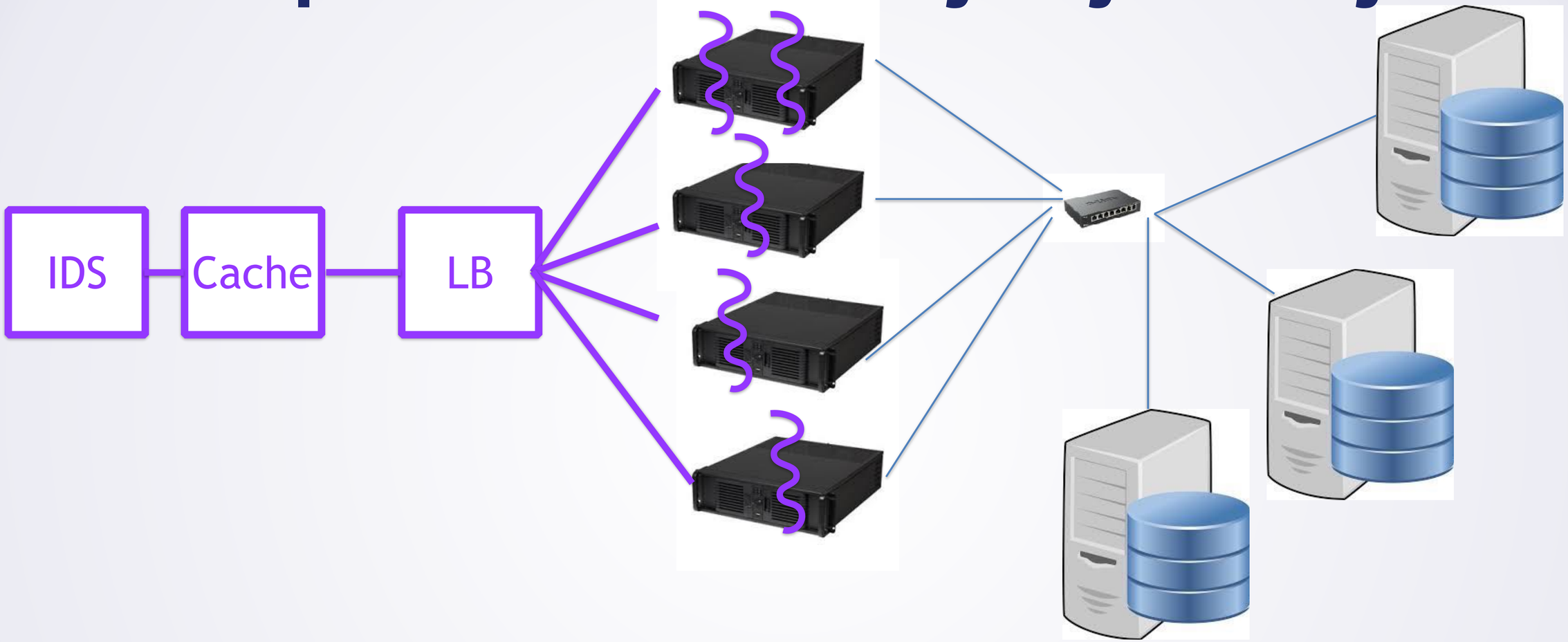
- Speaking of caches and load balancing..
  - We decide to add a cache and a hw load balancer…
  - And maybe some other things (e.g., IDS)

REST Principles



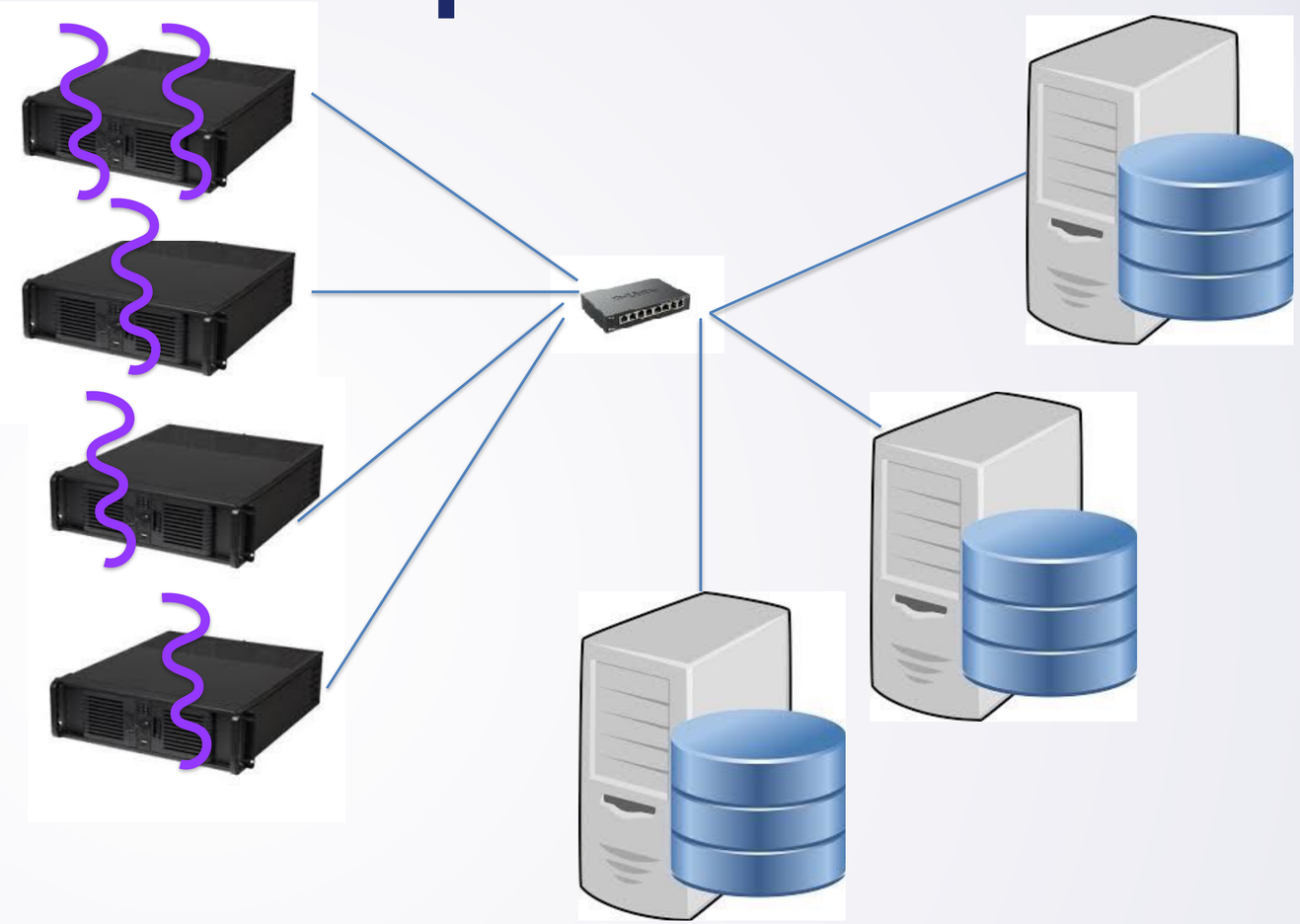
- What should client do differently in response to changes?

Principle 4: Transparently Layered System



- Principle 4: Transparently Layered System
  - Client should do **nothing** differently

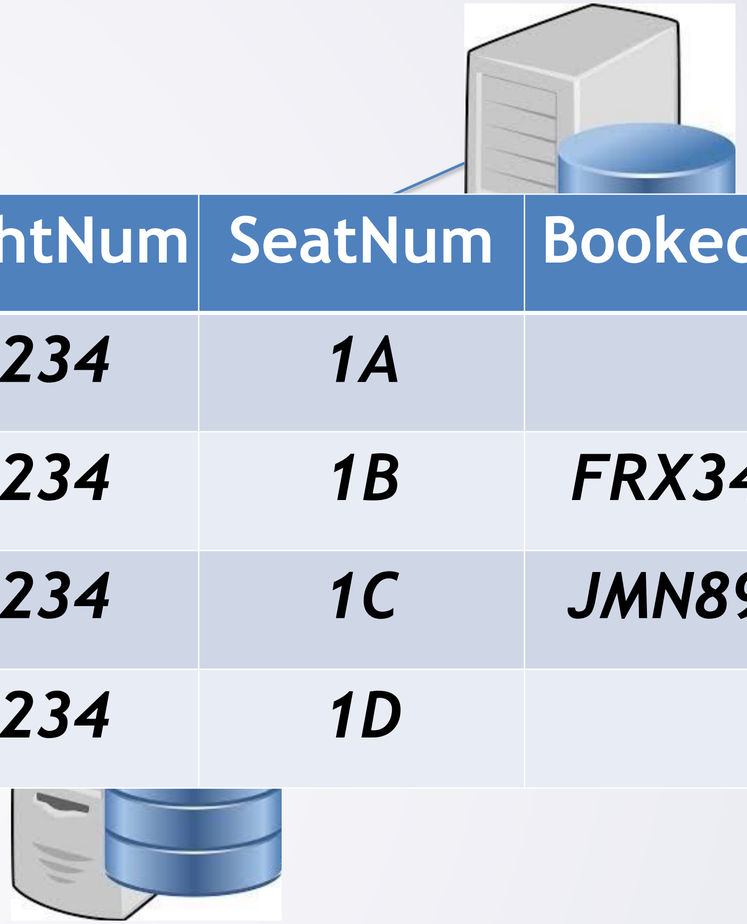
REST Principles



- Storage Tier: has data we want to manipulate

REST Principles

Should client know about this?



FlightNum	SeatNum	BookedBy
1234	*1A*	
1234	*1B*	*FRX345*
1234	*1C*	*JMN895*
1234	*1D*	

- Storage Tier: has data we want to manipulate
  - E.g., table of seats on flights + who booked them (or nobody)

REST Principles

FlightNum	SeatNum	BookedBy
1234	*1A*	
1234	*1B*	*FRX345*
1234	*1C*	*JMN895*
1234	*1D*	

Should client know about this?

- No (for many reasons)
- …but needs to be able to **manipulate** that resource

Sub-principle 5.1: Manipulate Representations

- Manipulate **representations** of resources
  - Client gets a representation of the resource (XML, JSON,…)
  - Works with that representation
  - And can make any appropriate changes based on what it has
    - E.g., book a seat (send back XML, JSON, etc…) request

Remainder of Principle 5

FlightNum	SeatNum	BookedBy
1234	*1A*	
1234	*1B*	*FRX345*
1234	*1C*	*JMN895*
1234	*1D*	

- How does client even know flight numbers?
- How does it refer to particular flight?

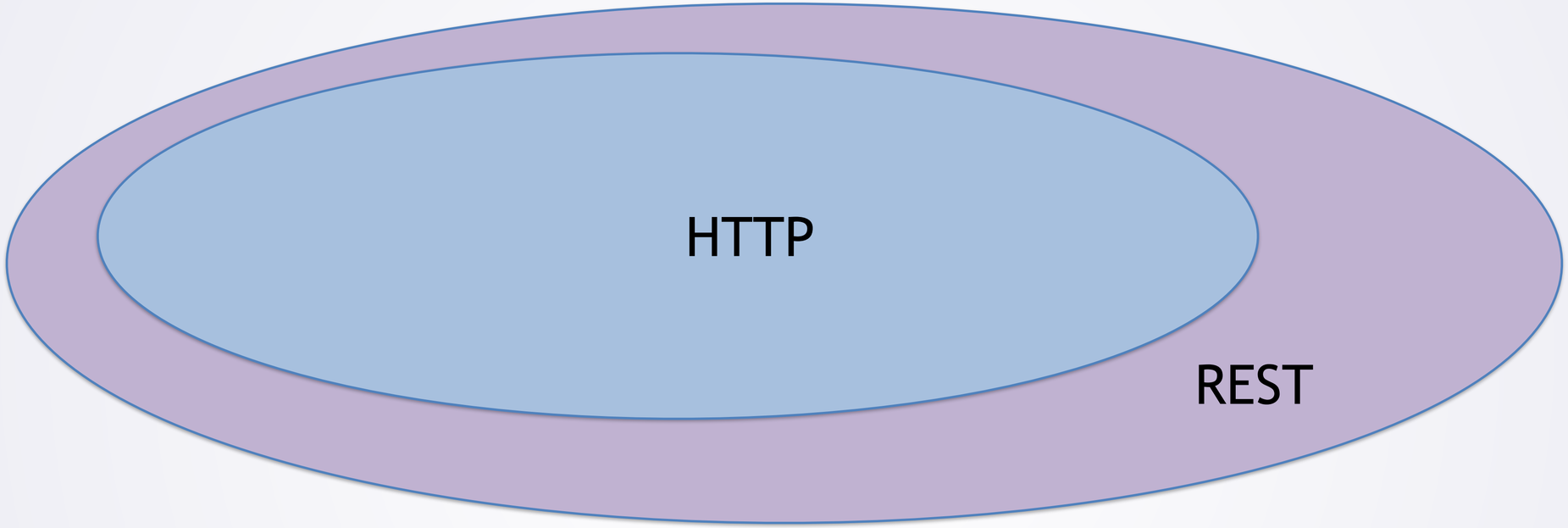
Principle 5: Uniform Interface

- Manipulate representations of resources
  - HTML, XML, JSON,…
- Uniform resource identification in request
  - HTTP: /flights /flights/1234/seats
- Self-descriptive messages
  - Messages have metadata (HTML: MIME type)
- "Hypermedia As The Engine Of Application State"
  - Can "find" other (appropriate) resources from root
  - In HTML: hyperlinks

Principle 6 (Optional): Code on Demand

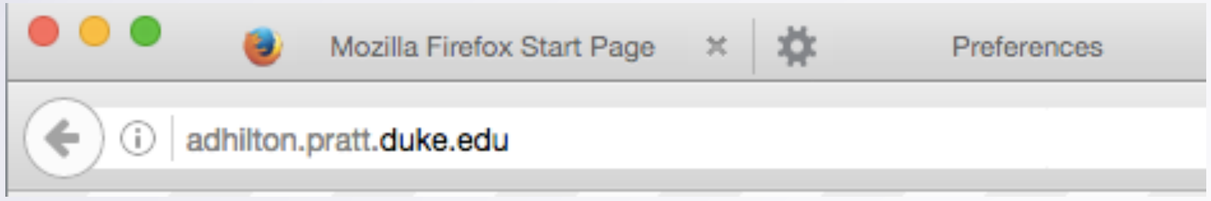
- Server can send code to client
- E.g., Can send JavaScript to client to run client-side code

HTTP and REST



- HTTP protocol obeys REST principles
  - But could make other protocols that are RESTful too
  - Speaking of HTTP…

The Life of a Web Request



- I enter a URL in my browser…

The Life of a Web Request

```
GET / HTTP/1.1
User-Agent: Wget/1.17.1 (linux-gnu)
Accept: */*
Accept-Encoding: identity
Host: adhilton.pratt.duke.edu
Connection: Keep-Alive
```

- Browser sends an HTTP "GET" request to the server
  - Which is running a web server daemon, listening on port 80

HTTP Request Basics

- HTTP Requests have a "verb" and a URI (and then a version number)

```
GET / HTTP/1.1
POST /home/drew HTTP/1.1
PUT /foo/bar/xyz  HTTP/1.1
DELETE /blah/blah/blah HTTP/1.1
```

- Read about HTTP "verbs" (aka methods):
  - https://tools.ietf.org/html/rfc7231#section-4.3
- Most common for web browsers: GET + POST
  - Others useful for web-based APIs

RFC 7231 will be your best friend on hwk2

The Life of a Web Request

```
HTTP/1.1 200 OK
Date: Tue, 17 Jan 2017 02:08:36 GMT
Server: Apache/2.2.15 (Scientific Linux)
Etag: "1484618676-0"
Content-Language: en
Cache-Control: public, max-age=3600
Last-Modified: Tue, 17 Jan 2017 02:04:36 GMT
Expires: Sun, 19 Nov 1978 05:00:00 GMT
Content-Type: text/html; charset=utf-8
….
```

- Server responds (in this case: 200 OK)
- With headers and data
  - The data (in this case) is HTML—could be anything (JSON, XML, image,…)

HTTP Responses

- Responses come with response code
  - 1xx = informational
  - 2xx = successful
  - 3xx = redirection
  - 4xx = error
  - …
  - https://tools.ietf.org/html/rfc7231#section-6
- Headers, give meta-data about response
  - E.g, content length, encoding,…
- Also, (if appropriate), the data

So What Do We Transfer?

- Could transfer pretty much anything over HTTP
  - HTML
  - CSS
  - XML
  - JSON
  - Text
  - Images
  - Videos
  - ….

So What Do We Transfer?

- Could transfer pretty much anything over HTTP
  - HTML - describes content
  - CSS
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  - Images
  - Videos
  - ….

So What Do We Transfer?

- Could transfer pretty much anything over HTTP
  - HTML - describes content
  - CSS - describes styling
  - XML
  - JSON
  - Text
  - Images
  - Videos
  - ....

So What Do We Transfer?

- Could transfer pretty much anything over HTTP
  - HTML - describes content
  - CSS - describes styling
  - XML - good for APIs
  - JSON - good for APIs
  - Text
  - Images
  - Videos
  - ....

Web Technologies

HTML

Content
- Tree structured data
- Server code will generated from data (Probably use templates)

Style
- How to draw elements

CSS

JavaScript

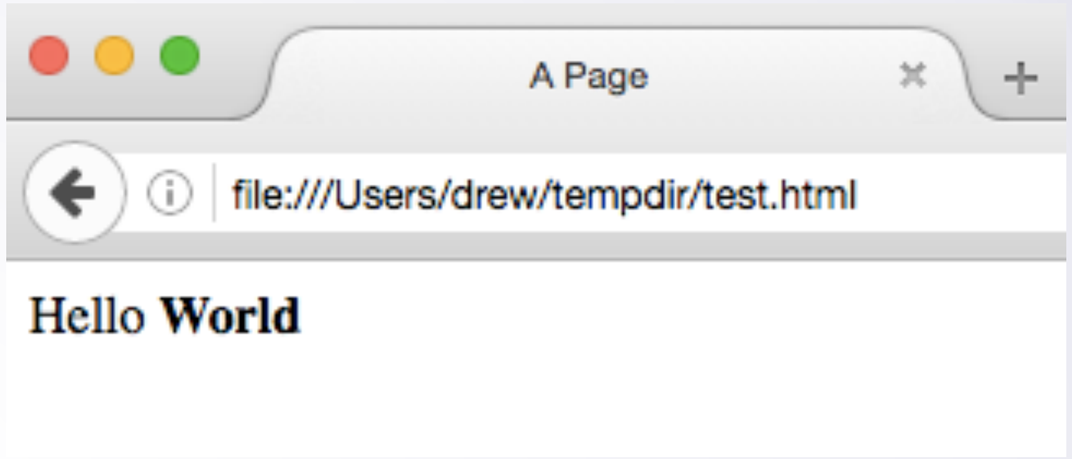
Code: Manipulate HTML
- Alter tree (DOM)

Use library
- e.g., Bootstrap

- Note: we are NOT focusing on front-end stuff
  - This is not a UI/UX class
  - Strongly encouraged to make things look nice (show off your work)

HTML

```
<!DOCTYPE html>
<html>
  <head>
    <title>A Page</title>
  </head>
  <body>
    Hello <b>World</b>
  </body>
</html>
```



- Hypertext Markup Language:
  - Not a programming language (does not execute things)
  - Marks up content (describes how to format it)

Fancier Page?

- Most common fancier things:
  - link text
  - …
  - …
  - <h1>…</h1> <h2>…</h2> etc
  -   thing1   thing 2 …
  -   thing1   thing 2 …
  - <img src="cats.png">
- https://developer.mozilla.org/en-US/docs/Web/HTML/Element

Elements can have Attributes

- <a **href="http://foo.bar.com/xyz/blah.html"**>link text
- <img **src="cats.png"**>
- A few interesting ones:
  - **class**: for use with CSS
  - **name**: for use with forms
  - **id**: for use with JavaScript (also CSS)

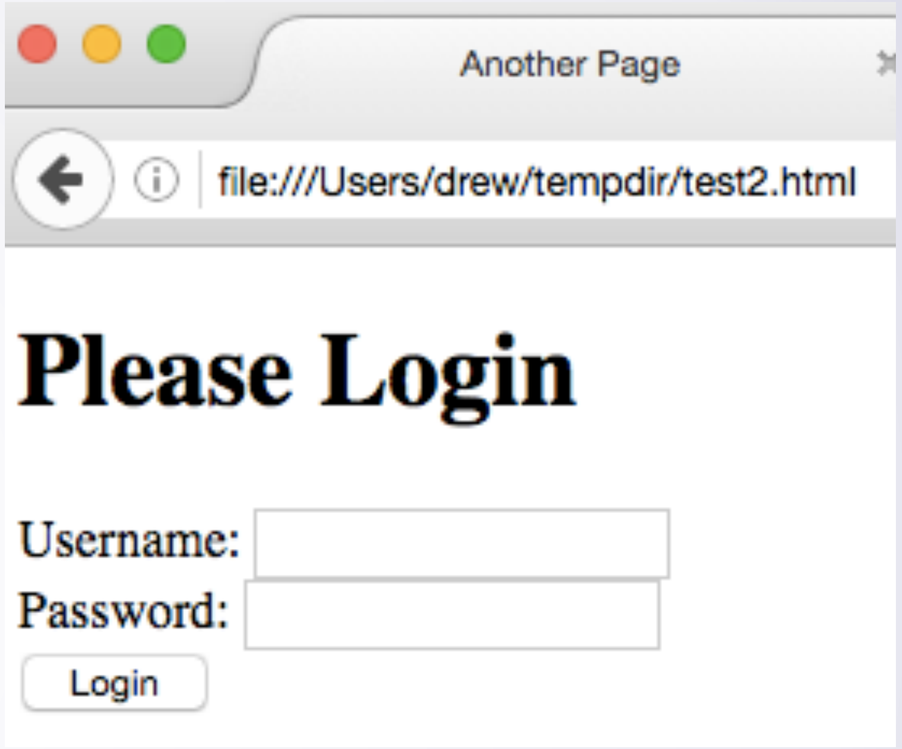
- https://developer.mozilla.org/en-US/docs/Web/HTML/Attributes

HTML Forms

- Often we want to submit data to the server
  - E.g., when the user presses a "submit" button
- Use HTML "forms"
  - Use <form> tag to enclose the inputs for the form
    - Has attributes of where to send data, whether to GET or POST
  - Put input elements (and others) inside:
    - <textarea>, <select>, <button>, <input>, …
  - Give each input a **name** attribute
    - Will be how you identify which data is which on the server

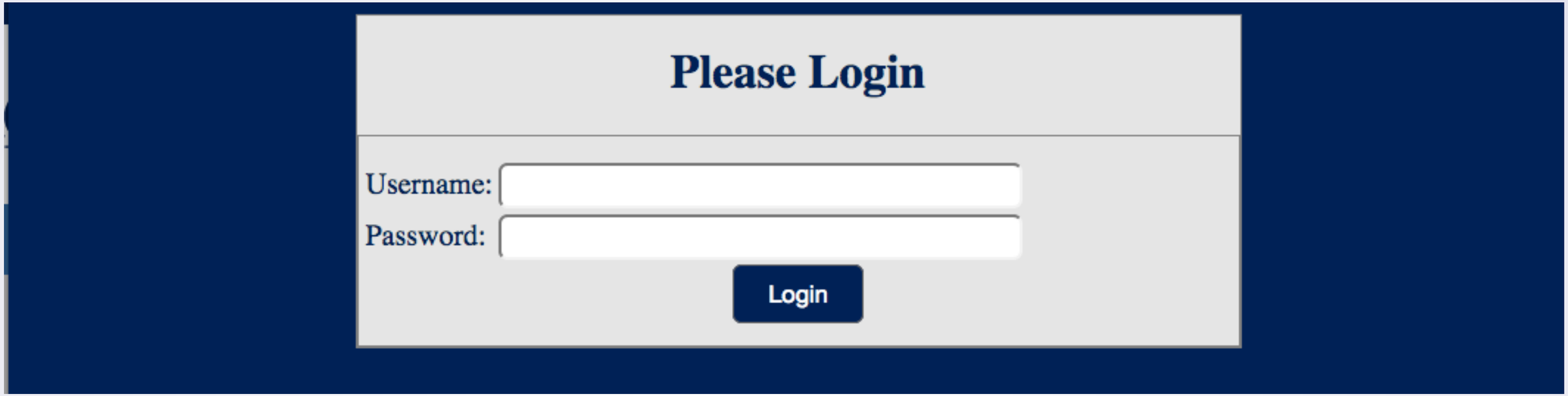
Cascading Style Sheets

```
<!DOCTYPE html>
<html>
  <head>
    <title>Another Page</title>
  </head>
  <body>
    <h1>Please Login</h1>
    <form>
      Username: <input> </input><br/>
      Password: <input> </input><br/>
      <button>Login</button>
    </form>
  </body>
</html>
```



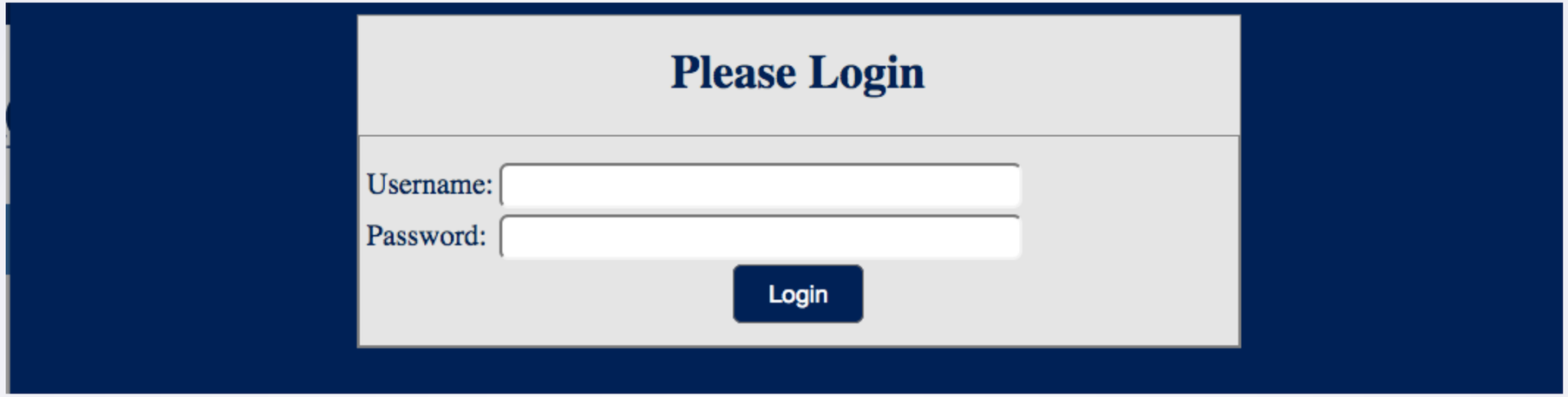
- Even if we put more stuff on our page, it doesn't look nice

With CSS…



- CSS lets us change how the browser **styles** the HTML
  - Positioning, colors, shapes, font sizes,…

CSS Basics




```
body {
    background: #001A57;
}
```

```
h1 {
    text-align: center;
    color: #001A57;
}
```

- Can re-style any occurrence of a tag (e.g., body, h1…)

CSS Basics

```
div.container {
    border: 1px solid gray;
    background: #E5E5E5;
    margin: auto;
    min-width: 350px;
    max-width: 600px;
}
div.box {
    border: 1px solid gray;
    margin: auto;
    padding: 15px 2px;
}
```

```
<div class="container">
  <h1>Please Login</h1>
  <div class="box">
```

- Can re-style a tag by class

CSS Basics

```
.label {
    font-size: 20px;
    color: #001A57;
}
```

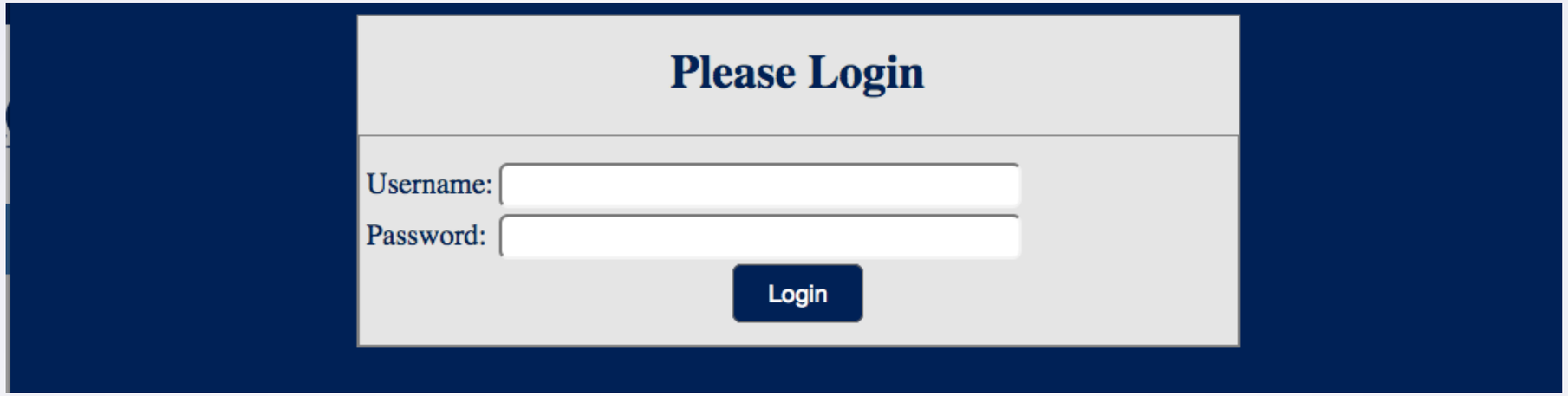
- Can re-style by class (can use with any tag)

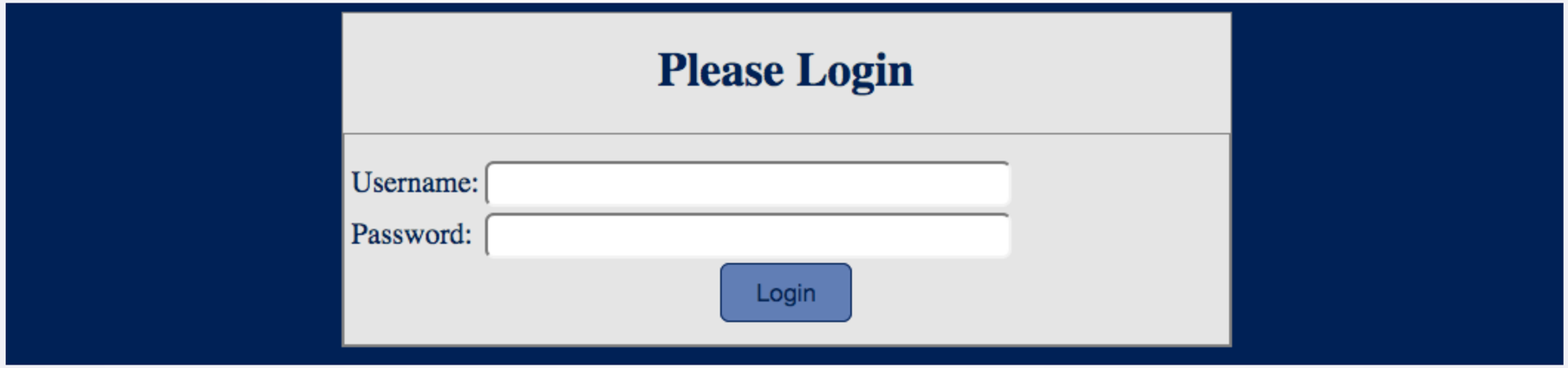
CSS Basics: Include External Stylesheet

```
<html>
  <head>
    <title>Another Page</title>
    <link type="text/css" rel="stylesheet" href="style.css" />
  </head>
```

- Generally want to load CSS from another file (on server)
  - Lets you easily use same style for many pages (same look + feel)
  - Lets you easily change style of all pages at once

CSS: Can Do Fancier Things





- Reformat button when hovered over
  - With :hover

Fancier CSS

```
.btn {
    border-radius: 6px;
    background-color: #001A57;
    border: 1pt solid #666666;
    color: white;
    padding: 8px 20px;
    text-align: center;
    text-decoration: none;
    font-size: 16px;
    margin: 0 auto;
    display: block;
}
.btn:hover {
    background-color: #607AB7;;
    border: 1pt solid #001A57;
    color: #001A57;
}
```

- Our button from this page
- Several properties to make
  - Nice curved corners
  - Large, centered text
  - Centered in parent area
- .btn:hover
  - Changes colors on hover

More Fancy CSS?

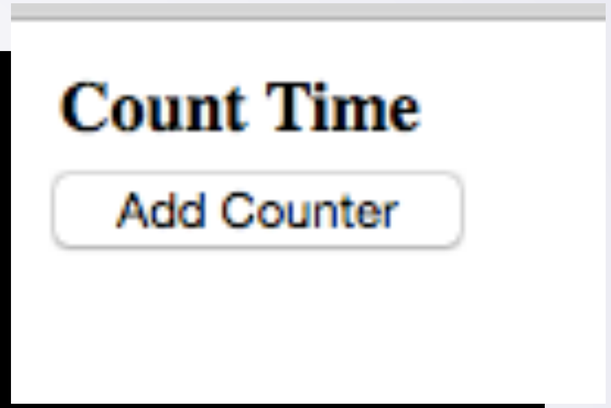
- Much more you can do with CSS
  - We aren't going to be too picky about fancy looking sites
    - (not a UI/UX class)
  - More interested in server side
  - …but you should be able to make it look nicer than black + white
- https://developer.mozilla.org/en-US/docs/Web/CSS

Ok, but… It Still Doesn't Do Anything..

- HTML + CSS: can make a nice looking page
- Won't "do" anything.
  - Could send data to server with **form**s, load a whole new page
  - This is how everything worked in the mid 1990s…
- Modern webpages are interactive, do things with no reload
  - Use JavaScript (actual programming language)

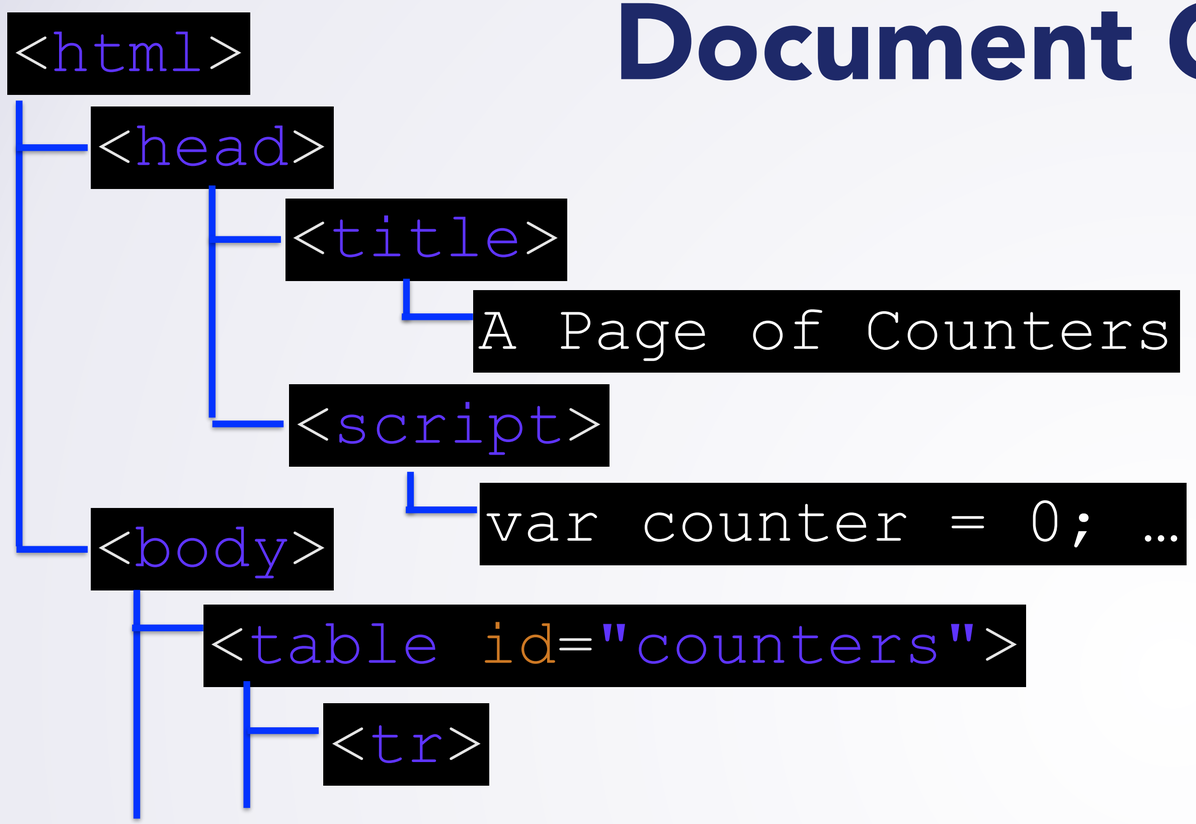
JavaScript Example: A Page With Some JS

```
<body>
  <table id="counters">
    <tr>
      <th>Count</th>
      <th>Time</th>
    </tr>
  </table>
  <button onClick="addCounter()">Add Counter</button>
</body>
```



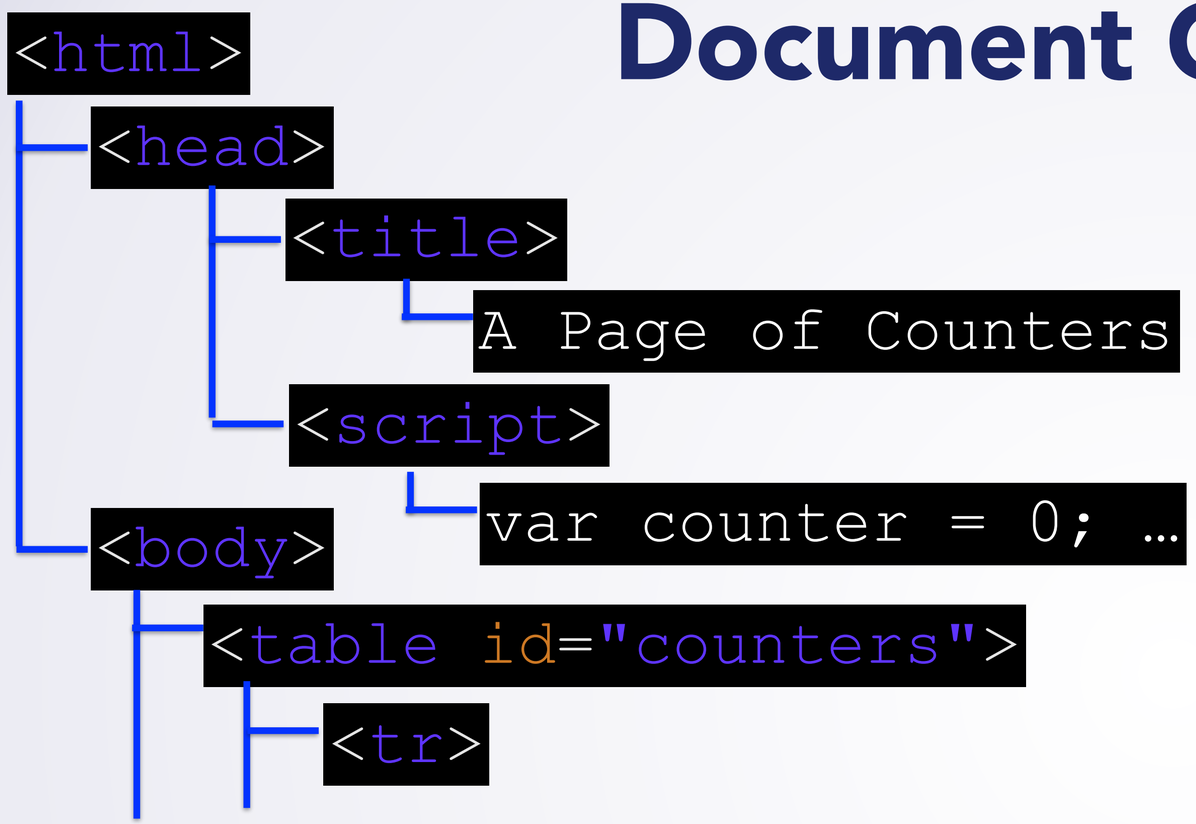
- Here is the body of a page. Has:
  - A table (with only a header row)
  - A button (whose onClick is some JavaScript—-calls a function not shown here)

Document Object Model



- To understand what happened, you need to know about the **DOM**
  - **Document Object Model**: API for HTML + XML documents
    - Language agnostic (same API in JavaScript, C, Java, Python,…)
- Think of HTML as describing a **tree** of objects

Document Object Model



- DOM specifies ways to manipulate the tree
  - Find elements meeting some criteria
  - Get children of a particular element
  - Modify an element
  - Create an element

JavaScript Example Revisited

```
<head>
    <title>A Page of Counters</title>
    <script>
      var counter=0;
      function addCounter() {
        var elt = document.getElementById("counters");
        elt.innerHTML = elt.innerHTML + "<tr><td> " +
          counter + " </td> <td>  " +
          new Date().toLocaleString() + "</td></tr>";
        counter++;
      }
    </script>
  </head>
```

JavaScript Example: Revisited

```
<body>
  <table id="counters">
    <tr>
      <th>Count</th>
      <th>Time</th>
    </tr>
  </table>
  <button onClick="addCounter()">Add Counter</button>
</body>
```

elt

elt.innerHTML

JavaScript Example Revisited

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<head>
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        counter++;
      }
    </script>
  </head>
```

Accomplish Same Task w/o Reparsing

```
<script>
  var counter=0;
  function addCounter() {
    var elt = document.getElementById("counters");
    var tr = document.createElement("tr");
    var td1 = document.createElement("td");
    var td2 = document.createElement("td");
    td1.textContent = counter;
    td2.textContent = new Date().toLocaleString();
    tr.appendChild(td1);
    tr.appendChild(td2);
    elt.appendChild(tr);
    counter++;
  }
</script>
```

More JavaScript

- As a programming language:
  - First class functions
  - Dynamically typed
  - Has Objects
  - C-/Java- like syntax (mostly)
- See:
  - https://developer.mozilla.org/en-US/docs/Web/JavaScript/A_re-introduction_to_JavaScript
  - https://developer.mozilla.org/en-US/docs/Web/JavaScript

JSON: JavaScript Object Notation

- In JavaScript, you write down objects like this:
  - var pt = { x : 3, y: 4, moveLeft: function() { this.x — ; } };
  - i.e., A comma separated sequence of **field: value**
  - Note that methods are just fields whose values are functions!
- JavaScript Object Notation (JSON) is a common data format
  - Can't put function values in
  - Only string, number, true, false, arrays, objects, null
  - Arrays are written with [], objects with {}
  - Field names are quoted: { "x" : 3, "y" : 4 , "colors": ["orange", "pink"] }

XML

```
<?xml version="1.0" encoding="UTF-8"?>
<transactions>
  <merchant id="1234" password="xyz"/>
  <create ref="t0">
    <name>Joe Smith</name>
    <num>123456789</num>
    <expires>2018-12-05</expires>
    <cvn>123</cvn>
    <amount>45.23</amount>
  </create>
  <commit ref="t1">
    <id>adsf234ASdr234Z</id>
  </commit>
</transactions>
```

- Similar looking to HTML (tags, attributes, nesting)
  - No predefined tags: make any tags with any meaning you want
  - Stricter /more uniform rules (all tags must be closed)

XML

- Why XML?
  - Extensible
  - Human readable
  - Ubiquitous: parsers for it in most languages
    - DOM: similar to HTML (but different)
- C++: xerces
  - You'll use later
- Other XML tools
  - E.g., XSLT (not going to use/cover, but you might find useful sometime)

…but How to Interact With Server?

- JavaScript can also contact the server
  - Get a response (later), and then do something with it
  - Server can send responses that are not HTML
    - Could send JSON, or XML -> easy to parse
    - JS on client can take data, show in appropriate way
- AJAX: Asynchronous JavaScript And XML
  - What idea that we covered before does this relate to?

AJAX Basics

```
function someJSFun() {
  //whatever code…

   var xhttp = new XMLHttpRequest();
```

This is the object to contact
the server and get a response…

AJAX Basics

```
function someJSFun() {
  //whatever code…

   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
           //some other code in here…
   };
```

Set its
onreadystatechange
to be notified when stuff happens

AJAX Basics

```
function someJSFun() {
  //whatever code…

   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
           //some other code in here…
   };
```

Yes, you can write one function inside another.
JavaScript has **lexical scope**.
This makes a **closure**.

AJAX Basics

```
function someJSFun() {
  //whatever code…
  var xyz = something;
   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
                 …xyz…
  };
```

AJAX Basics

```
function someJSFun() {
  //whatever code…

   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
           //some other code in here…
   };
   xhttp.open("GET", "/api/foo/bar/42", true);
```

.open() specifies where to connect:
HTTP Request Method
URL to request
Asynchronous (usually true)

AJAX Basics

```
function someJSFun() {
  //whatever code…

   var xhttp = new XMLHttpRequest();
   xhttp.onreadystatechange = function() {
           //some other code in here…
   };
   xhttp.open("GET", "/api/foo/bar/42", true);
   xhttp.send();
}
```

.send() makes the actual request.

Will make callback to our function when state changes

AJAX Basics

```
xhttp.onreadystatechange = function() {

};
```

Now let us look inside our ready state change callback

AJAX Basics

```
xhttp.onreadystatechange = function() {
    if (this.readyState == 4 }
```

Typically inspect this.readyState first

this is our XMLHttpRequest

readyState: 0—4. 4 is Done

AJAX Basics

```
xhttp.onreadystatechange = function() {
   if (this.readyState == 4 && this.status == 200) {

   }
};
```

May also want to inspect

this.status (HTML response status)

200 = OK

AJAX Basics

```
xhttp.onreadystatechange = function() {
   if (this.readyState == 4 && this.status == 200) {
          …this.responseText…

   }
};
```

Once we have our response, generally want to use

this.responseText

which has the text we received

AJAX Basics

```
xhttp.onreadystatechange = function() {
   if (this.readyState == 4 && this.status == 200) {
         var resp = JSON.parse(this.responseText);

   }
};
```

If our response is JSON, can use

JSON.parse to turn into JavaScript object!

Wrap Up

- Today:
  - REST: protocol principles
  - Super quick intro to HTML/CSS/JavaScript/JSON/XML
    - Not main focus of this class, but you will need
  - AJAX: ties to previous ideas!
- Next time:
  - UNIX Daemons
- Homework 1:
  - Out now!