Adding State to HTTP

• Recall: no inherent state in HTTP
  • server does not keep any state after TCP connection is closed

• For static content sites, no problem
  • developing "applications" is impossible though
  • e.g., shopping cart on Amazon

• Need to introduce state in HTTP
  • in the form of "sessions"
Option 1: HTTP Authentication

• Associate user with state on server
  • unclear when the "sessions" ends

• Authentication done by Web server
  • Not by the application served via the server

• Implements "pulling" of credentials
  • User: "Please give me resource X"
  • Server: "No, please tell me who you are"
  • User: "Ok, I am alice and my password is nu7^yjUtaw"

• Logout non-trivial
  • browser always sends along authentication header
Option 2: Session Identifier in URL

- Generate random token on first page visit
- Ensure that session ID is in all links
- Potential for accidental leakage is high
  - "Here is the link to the product on Amazon"
- URL is transmitted in Referer header
  - Session leaked to all included third-party sites

http://example.org/cart.html?sess=9b2dac168331
Option 3: Cookies

• Generate random token on first page visit
• Sent to client via Set-Cookie header
• Client always sends along cookies in every request to the server
  • important: regardless of initiating site
• Cookies are persisted in the browser
  • controllable by Expires option in cookie
  • default: delete on session end (when browser is closed)
• Ending session: delete cookie
Cookie directives

- `<name>=<value>`
- `Expires=<Date>`, determines when cookie should be deleted
- `Max-Age=<Seconds>`, determines when cookie should be deleted
- `Domain=<domain>`, defaults to current host
  - Can be set for parent domains (and their subdomains)
  - If nothing is specifically set, cookie is only set for current domain without subdomains
  - `Domain=example.com` on `websec.example.com` sets cookie for `*.example.com` and `example.com`
- `Path=<path>`, only set cookie for this path (and sub-paths)
Cookie directives

- HttpOnly, disallows access from JavaScript via document.cookie
- Secure, only transmit cookie over secure connection
  - Can only be set from HTTPS connections
- SameSite=None/Strict/Lax
  - Strict: do not transmit cookies on any cross-site request
  - Lax: only transmit cookies on "safe" top-level navigation
    - Safe methods (per RFC 7231): GET, HEAD, OPTIONS, (TRACE)
  - None: explicit opt-in for cross-site requests, requires Secure
- Browsers will default to SameSite=Lax soon (Chrome already does so, FF and Edge warn)
Cookie examples

- Set-Cookie: test=1; Domain=.example.com; Secure; HttpOnly; SameSite=none
  - Sets a cookie with name "test" to the value "1"
  - Cookie will be sent to any HTTPS request made to example.com and any subdomain
  - Cookie is not accessible from JavaScript
  - Cookie will be sent on cross-site requests as well
  - Cookie will be deleted on browser close (no explicit expiry date)
- Set-Cookie: test=1; Domain=.example.com; HttpOnly; SameSite=none
  - Chrome will not accept this (SameSite= None requires Secure)
  - FF and Edge will warn
Form-based authentication

• Default today: HTML forms
  • Server provides form with username and password fields
  • User fills and submits form
  • Server decides if credentials were correct, and "upgrades" session
    • actually better: create new session (more on that later)

• Password fields hide input with ***
  • besides this, not different than any other input field
  • accessible via JavaScript
  • sent in clear text via GET or POST to server
  • can be sent cross-domain (a.com can send data to b.com)
Form-based authentication
Authentication with cookies - caveats

- Cookies were not designed with security in mind
  - cookies readable and writeable from JavaScript (unless HttpOnly is used)
  - if set for a given domain, valid for all sub-domains
  - added to all requests, regardless of the origin of requesting site
- Several security problems from this (which we cover later)
  - Session Hijacking
  - Session Fixation
  - Cross-Site Request Forgery
  - Cross-Site Script Inclusion
JavaScript

```javascript
var simple = type.slice();
forward = type.slice();
ofType = what === "of-type";
return first === 1 && last === 0 ?
// Shortcut for :nth-*(n)
function( elem ) {
  return !!elem.parentNode;
}

function( elem, context, xml ) {
  var cache, outerCache, node, diff, nodeIndex, start,
  dir = simple !== forward ? "nextSibling" : "
  previousSibling",
  parent = elem.parentNode,
  name = ofType && elem.nodeName.toLowerCase(),
  useCache = !xml && !ofType;
  if ( parent ) {
    ...
  }
}
```
What is JavaScript in the browser?

- JavaScript core
  - ECMAScript specified language
  - initially developed for Netscape in 1995 as LiveScript/JavaScript
- The Document Object Model (DOM)
  - provides access to the rendered HTML document
  - allows controlling the browsing window via JavaScript
- Browser-based standard APIs
  - Math, WebStorage, XMLHttpRequest, …
JavaScript Core

- Functional programming language
  - object model is prototype-based
  - no class hierarchy
  - allows for closures and anonymous functions
- No native concurrency model
  - JavaScript in an execution context (e.g., a Web document) is single-threaded
  - Concurrency is event-driven
    - Do something, yield process, wait for wake-up
    - e.g., implemented by setTimeout with (potentially anonymous) callback function
    - loading the same page twice might not execute instructions in the same order
JavaScript in Web documents

• JavaScript can be included in script tags or event handlers
  • `<script>var hello="world";</script>`
  • `<script src="http://hello.world"></script>`
  • `<a onclick='var hello="world";'>Click me</a>`

• Each script tag or event handler is separate parsing block
  • code not executed when parsing error occurs
  • other scripts’ execution is not interrupted

• Rendering of document stops until script is executed
  • especially important when HTML is written by JavaScript

• All scripts run in same global space (of including page)
JavaScript Objects

- JavaScript is highly flexible
  - Dynamic typing at its best
  - Lots of implicit type casting
    - "a" + 1 => "a1"
    - "a" + undefined => "aundefined"
    - alert(42) => alert(42.toString())
- Primitives types (strings, numerical, ..) and Object types
- New properties can be added to existing objects

```js
var myObj = new myObject();
myObj.a = 1;
```
JavaScript Prototype-based Object Model

- All objects have a prototype
  - Prototype can have prototype as well
  - so-called prototype chaining
- Function call is propagated along chain until either
  - corresponding function is found
  - prototype is null (for Object)

```javascript
var a = "a";
a.__proto__
// > String {length: 0, constructor: function,...}
a.__proto__.__proto__
// > Object {__defineGetter__: function, ...}
a.__proto__.__proto__.__proto__
// > null
```
JavaScript Prototype-based Object Model

- Prototypes can be set and manipulated during runtime

```javascript
Number.prototype.toString = function() {
  return "Gotcha";
};

// This will display "Gotcha" instead of 42
alert(new Number(42));
```

- Prototype changes also affect existing objects

```javascript
var fortytwo = new Number(42);
// This will display "42"
alert(fortytwo);
Number.prototype.toString = function() {
  return "Gotcha again";
};

// This will display "Gotcha again"
alert(fortytwo);
```
JavaScript Objects

- Objects are instances of functions

function myObj(p1, p2) {
  this.m1 = p1;
  this.m2 = p2;
}

var x = new myObj(1, 2);
// > myObj {m1: 1, m2: 2}

- Also true for built-in objects

Number
// > function Number() { [native code] }
Number.constructor
// > function Function() { [native code] }

- Almost everything has a toString()

myObj.toString()
"function myObj(p1, p2) {
  this.m1 = p1;
  this.m2 = p2;
}"
JavaScript Variable Scoping

• Variables **without** `var` keyword always in global scope
• Variables **with** `var` keyword as specified in current scope (function-level)
  • Gotcha: in top-level script code, that is the global scope
• Public members of object use `this` keyword, private members `var`

```javascript
function Container(param) {
    var member = param;
}

var a = new Container(1);
a.member // > undefined
```

```javascript
function Container(param) {
    this.member = param;
}

var a = new Container(1);
a.member // > 1
```

```javascript
function Container(param) {
    var member = param;
    this.getmember = function() {
        return member;
    }
}

var a = new Container(1);
a.getmember() // > 1
```
Getters, Setters, and Freezing

- ECMAScript introduced the `Object.defineProperty` method
  - `get` and `set` to allow read/write access to properties
  - `configurable` to prevent redefinition for the property

```javascript
var obj = new Container(1);
var mValue = 42;

Object.defineProperty(obj, "member", {
  get: function() { return mValue; },
  set: function(newValue) { mValue = newValue; },
  configurable: false
});

obj.member // > 42
obj.member = 43
mValue // > 43
Object.defineProperty(obj, "member", {get: function() { return 1; }});
// > Uncaught TypeError: Cannot redefine property: member
```
(Almost) everything in JavaScript can be overwritten/deleted

```javascript
eval("var a='hello'")
a
// > "hello"

eval = alert;

eval("var a='hello'");
// opens alert box
```

```javascript
var oAlert = alert;
alert = function(x) {
  console.log(x);
  oAlert(x);
}
alert(1);
// log 1 to console
// opens alert box
```

```javascript
var oAlert = alert;
delete alert;

alert(1);
// Uncaught ReferenceError: alert is not defined

oAlert(1)
// opens alert box
```
Document Object Model (DOM) and Browser APIs

- Exposed to JavaScript through global objects
  - `document`: Access to the document (e.g., cookies, head/body)
  - `navigator`: Information about the browser (e.g., UA, plugins)
  - `screen`: Information about the screen (e.g., dimension, color depth)
  - `location`: Access to the URL (read and modify)
  - `history`: Navigation

- Global object is called `window`, current object is `self`

```javascript
a = "Hello";
a === window.a;
> true

document.location === location;
> true

self === window;
> true
```
Manipulating the rendered document

- HTML represented by a tree of HTMLElement objects
- Element attributes of HTML nodes map to properties of HTMLElement object
  - `document.body.children[1].style.color = "red"`
- Several methods/properties to change document
  - `document.write`
  - `element.innerHTML/element.outerHTML`
  - `element.attribute`
  - `element.appendChild`
- Elements with id automatically in global scope
Access to other documents

• Handles to other frames in same browsing window
  • parent
  • top
  • frames[]
• Handles to popup windows
  • var handle = window.open("http://example.org")
  • window.opener
• Initially no security considerations...
The location object

- `location.href`: complete URL including fragment
- `location.host`: HTTP host, including port (if any)
  - `location.hostname`: only HTTP host
  - `location.port`: only the port (if non-standard)
- `location.protocol`: protocol
- `location.pathname`: path
- `location.search`: URL query
- `location.hash`: URL fragment
Summary

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Credits

- Original slide deck by Ben Stock
- Modified by Nick Nikiforakis