Web Security

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Historical Web

- Historically, the web was just a request response protocol
- HTTP is stateless, which means that the server essentially processes a request independent of prior history
- Envisioned as a way for exchanging information

HTTP Requests

- A request has the form:

```
<METHOD> /path/to/resource?query_string HTTP/1.1
<header>*

<BODY>
```

- HTTP supports a variety of methods, but only two matter in practice:
  - GET: intended for information retrieval
    - Typically the BODY is empty
  - POST: intended for submitting information
    - Typically the BODY contains the submitted information

Structure of HTTP GET request

- Connect to: www.example.com
  - TCP Port 80 is the default for http; others may be specified explicitly in the URL.
- Send: GET /index.html HTTP/1.1
- Server Response:

```
HTTP/1.1 200 OK
Date: Mon, 23 May 2005 22:38:34 GMT
Server: Apache/1.3.3.7 (Unix) (Red-Hat/Linux)
Last-Modified: Wed, 08 Jan 2003 23:11:55 GMT
Etag: "3f80f-1b6-3e1cb03b"
Content-Length: 438
Connection: close
Content-Type: text/html; charset=UTF-8
```

GET with parameters

- `GET /submit_order?sessionid=79adjadf888888768&pay=yes HTTP/1.1`
- User inputs sent as parameters to the request

POST Requests

- Another way of sending requests to HTTP servers
- Commonly used in FORM submissions
- Message written in the BODY of the request
- Sending links with malicious parameter values is difficult when a web site accepts only POST requests.
  - Such links are usually included in phishing emails
- But a script running on a malicious web site can as easily send a POST request (as a GET request) to another web site.

HTTP Response

- A response has the following form:

```
HTTP/1.1 <STATUS CODE> <STATUS MESSAGE>
<header>*

<BODY>
```

- important response codes:
  - **2XX**: Success, e.g., 200 OK
  - **3XX**: Redirection, e.g., 301 Moved Permanently
  - **4XX**: Client-side error, e.g., 404 Not Found
  - **5XX**: Server-side error, e.g., 500 Internal Server Error

HTTP Response

```
HTTP/1.1 200 OK
Date: Tue, 21 Oct 2014 16:21:44 GMT
Server: Apache/2.2.25 (Unix) mod_ssl/2.2.25 OpenSSL/1.0.1h PHP/5.2.17
Last-Modified: Tue, 21 Oct 2014 15:37:09 GMT
ETag: "3aaa5c-850-505f09ab7f211"
Accept-Ranges: bytes
Content-Length: 2128
Content-Type: text/html
<!DOCTYPE html PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN">
<html><head>
    <title>Is The Internet On Fire?</title>
    <meta http-equiv="content-type" content="text/html; charset=UTF-8">
    <link rev="made" href="mailto:jschauma@netmeister.org">
```

Cookies

- HTTP is stateless, so the client must remember state and send it with every request.
- Cookies are a common way to maintain state between client and server.
  - Client:

    ```
    GET /index.html HTTP/1.1
    ```

  - Server:

    ```
    HTTP/1.1 200 OK
    Content-type: text/html
    Set-Cookie: sess-id=3773777adbdad
    (content of page)
    ```

Cookies...

- Browsers send cookie with every subsequent request

```
GET /spec.html HTTP/1.1
 Host: www.example.org
 Cookie:  sess-id=3773777adbdad
```

- Now server can look up stored state through sess-id
- Alternative to cookies: hidden form fields.

What are Cookies used for ?

- Authentication
  - The cookie proves to the website that the client previously authenticated correctly
- Personalization
  - Helps the website recognize the user from a previous visit
- Tracking
  - Follow the user from site to site; learn his/her browsing behavior, preferences, and so on

Sessions

- As long as different users have different session identifiers (present in their cookies), the web server will be able to tell them apart
  - Regardless of their IP address
- When users delete their cookies, the browsers no longer send out the appropriate session identifier, and thus the web server “forgets” them

Session Identifiers

- Long pseudo-random strings
- Unique per visiting client
- Each identifier is associated with a specific visitor
  - ID A-> User A
- As sensitive as credentials (per session)

JavaScript

- Language executed by the Web browser
  - Scripts are embedded in webpages
  - Can run before HTML is loaded, before page is viewed, while it is being viewed, or when leaving the page
- Used to implement “active” webpages and Web applications
- A potentially malicious webpage gets to execute some code on user’s machine

JavaScript History

- Developed by Brendan Eich at Netscape
  - Scripting language for Navigator 2
- Later standardized for browser compatibility
  - ECMAScript Edition 3 (aka JavaScript 1.5)
- Related to Java in name only
  - Name was part of a marketing deal
  - "Java is to JavaScript as car is to carpet"
- Various implementations available:
  - SpiderMonkey, RhinoJava, Others

Aside: Java Security

- With binary code, memory and type safety issues complicate the problem of untrusted code
- Java and Javascript rely on safe languages to avoid low-level issues
  - avoid low-level issues arising in C, C++ and binary code
    - No buffer overflows
  - Code can only be created and executed through sanctioned pathways, e.g., class loader
  - Access-control restrictions associated with classes are strictly enforced
    - Can't circumvent public/private restrictions by casting etc.

Java vs JavaScript

- Java originally developed to support "active web pages"
  - Applets were intended to allow local execution of untrusted code
  - Security was achieved by restricting access to local resources, e.g., files
- Drawbacks:
  - Poor integration with the browser environment
  - Focus on (OS) integrity rather than confidentiality
  - These factors led to the development of Javascript

Java vs JavaScript (continued)

- Javascript takes a different approach
  - Language safety is still the basis
  - Use this basis to provide a safe interface to the browser environment
  - The security model is object-oriented
  - What are the browser resources, which ones are accessible to untrusted code
- Browser is the platform, not the underlying OS
- It is not about whether untrusted code can access local files, but whether the browser permits it (“trusted dialogs”)
- Cookie-based model of browser security evolved in conjunction with Javascript, leading to excellent support for the same

Common Uses of JavaScript

- Page embellishments and special effects
- Dynamic content manipulation
- Form validation
- Numerous complex applications:
  - Office 360, Google Maps, …
- Most web pages today are mainly Javascript Single-Page Applications
  - “Content” fetched continuously and displayed under the control of (asynchronous) Javascript (AJAX)

JavaScript in Webpages

- Embedded in HTML as a `<script>` element:
  - Written directly inside a `<script>` element:

    ```
    <script> alert("Hello World!") </script>
    ```

  - In a file linked as the `src` attribute of a `<script>` element:

    ```
    <script type="text/JavaScript" src="functions.js"></script>
    ```

- As an event handler attribute:

  ```
  <a href="http://www.yahoo.com" onmouseover="alert('hi');">
  ```

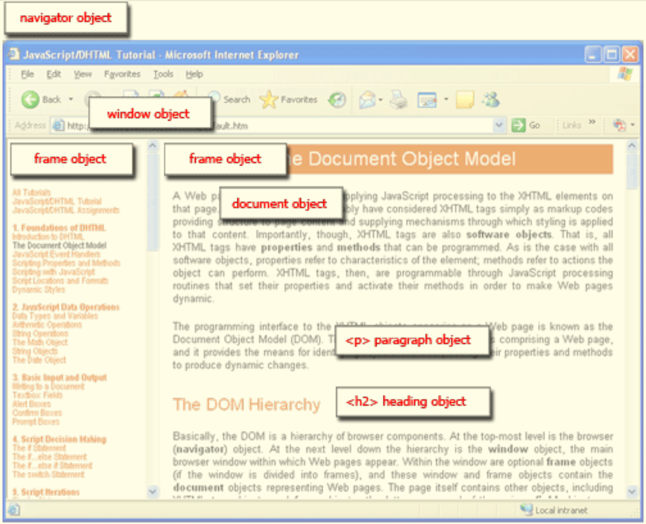
- As a pseudo-URL referenced by a link:

  ```
  <a href="javascript: alert('You clicked');">Click me</a>
  ```

Document Object Model (DOM)

- HTML page is structured data
- DOM is an object-oriented representation of the hierarchical HTML structure
- Properties include:
  - `document.alinkColor`
  - `document.URL`
  - `document.forms[ ]`
  - `document.links[ ]`
- Methods include:
  - `document.write(document.referrer)`
  - item These change the content of the page!
- Also includes the Browser Object Model (BOM):

Browser and Document Structure



Reading Properties with JavaScript

Sample script

```
1. document.getElementById('t1').nodeName
2. document.getElementById('t1').nodeValue
3. document.getElementById('t1').firstChild.nodeName
4. document.getElementById('t1').firstChild.firstChild.nodeName
5. document.getElementById('t1').firstChild.firstChild.nodeValue
```

Sample HTML

```
<ul id="t1">
<li> Item 1 </li>
</ul>
```

- Example 1 returns "ul"
- Example 2 returns "null"
- Example 3 returns "li"
- Example 4 returns "text"
  - A text node below the "li" which holds the actual text data as its value
- Example 5 returns " Item 1 "

Page Manipulation with JavaScript

- Some possibilities
  - createElement(elementName)
  - createTextNode(text)
  - appendChild(newChild)
  - removeChild(node)
- Example: add a new list item

```
var list = document.getElementById('t1')
var newitem = document.createElement('li')
var newtext = document.createTextNode(text)
list.appendChild(newitem)
newitem.appendChild(newtext)
```

Sample HTML

```
<ul id="t1">
<li> Item 1 </li>
</ul>
```

All the Functional Pieces are in Place

- Now we can create personalized and dynamic websites. Yay!
- But what about security?
  - How do we stop websites from snooping around in each other's business?

Goals of Web Security

- Safely browse the Web
  - A malicious website cannot steal information from or modify legitimate sites or otherwise harm the user …
    - …even if visited concurrently with a legitimate site - in a separate browser window, tab, or even iframe on the same webpage
    - Based on *Same Origin Policy (SOP)*
  - A malicious website cannot steal or modify information on the local machine, nor can it interact in any way with local applications
    - Based on JavaScript safety and web browser design and implementation (Browser security)

Web Security Concerns

Authentication: Securely identify users on top of the stateless HTTP protocol.

Confidentiality: Protect any sensitive data that websites serve to the browser from other websites, and the user's own sensitive data outside the browser from any website.

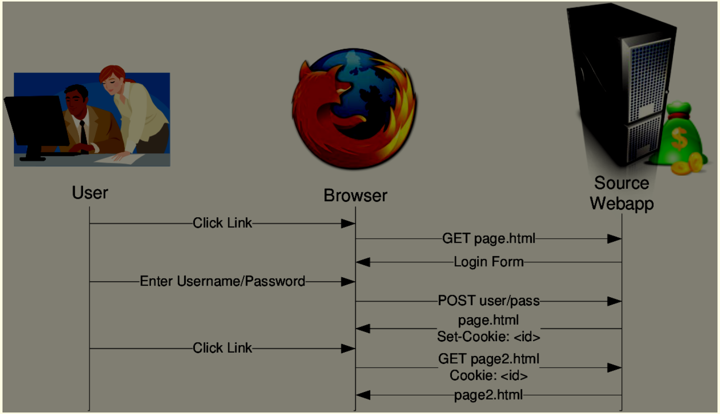
Integrity: ensure that the data and the code served to users cannot be tampered with.

Authentication Methods

- HTTP Authentication: Username/password supplied in HTTP headers.
- Cookie Authentication:
  - User submits login credentials via an HTML form.
  - Server verifies credentials and sets a session cookie.
  - Browser sends the cookie with each request to maintain the session.
- Hidden-Form Authentication
  - Similar to cookie authentication, but session information is stored in hidden form fields.

Cookie-Based Authentication

- HTTP is stateless, so cookies are used to manage user sessions.
  - User Authentication: Cookies are sent automatically for convenience.
  - Server Authentication: Uses SSL + Certification Authorities.

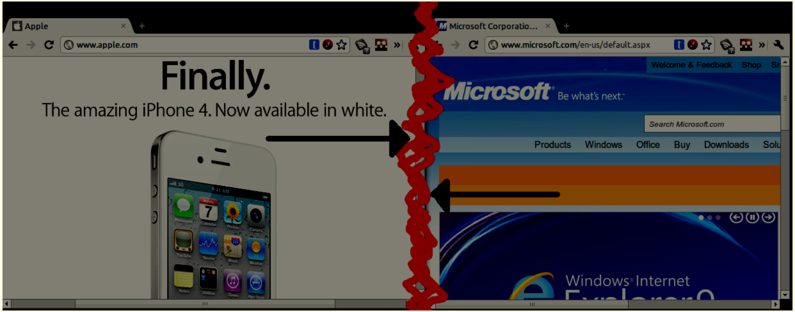


Lifetime of Cookies and HTTP Authentication Credentials

- Temporary cookies are cached until the browser shuts down. Persistent ones cached until their expiration date.
- HTTP authentication credentials are cached in memory and shared by all browser windows of a single browser instance.
- Caching depends only on browser instance lifetime, not on whether original window is open

Confidentiality

- No mutual trust among parties.
- Confidentiality achieved through Isolation: Same-Origin Policy (SOP).
  - Partition the Web into domains and isolate sensitive data such as cookies, network data and DOM nodes.



All of These Should Be Safe

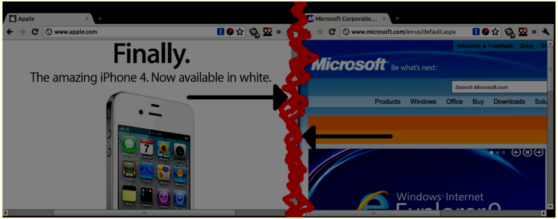
- Safe to visit an evil website

- Safe to visit two pages at the same time

- Safe delegation

Same-Origin Policy (SOP)

- The SOP partitions the web into domains (according to their DNS origin) and isolates sensitive data from scripts running in other domains.
- Sensitive data includes:
  - Cookies.
  - Web page content (DOM isolation).
  - Network responses (Network isolation).



SOP: Cookie Isolation

- Each domain has its own set of independently managed cookies, and these are embedded only in requests to the same domain.
- Only scripts running from the same domain and responses from the same domain can read and write cookies
- HTTP-Only cookies

SOP: Page Content Isolation

- The basic unit of isolation in a browser is a `<frame>`.
  - document.write refers to the current frame
- DOM Isolation:
  - Scripts can only access DOM elements from the same domain.
  - Frames embedded in a page are part of the DOM tree of the parent, but the policy still applies
  - `document.frames[0].title`
  - is only accessible if the parent is from the same origin.

Domains vs Subdomains

- Subdomains
  - E.g. **private.example.com** vs **forum.example.com**
  - Considered different origin
  - Possibility to relax the origin to **example.com** using document.domain
  - Possibility to use cookies on **example.com**
- Completely separate domains
  - E.g. **private.example.com** vs **exampleforum.com**
  - Considered different origin, without possibility of relaxation
  - No possibility of shared cookies

SOP: Network Isolation

- Scripts can send requests to arbitrary sites
  - Weakest aspect of SOP, but stricter isolation will prohibit many legitimate uses
- But scripts cannot read responses from any server
  - They can still send blind requests to other domains.
  - Is it safe for a malicious script to issue a request if it cannot read the response?
    - CSRF (discussed later)
- Exception: XmlHttpRequests (XHR) permit scripts to read responses from their origin server.

Embedding and SOP: Caveats

- For embedded content, origin of the content may be different from the domain used for SOP checks
  - Scripts retrieved from domain B and embedded in domain A run with A's privileges.
  - Akin to user A running an executable written by B in a UNIX environment.
    - Cross-site scripting attacks exploit this!
    - as do script inclusion attacks!

Limitations of SOP

- SOP is rigid and imposes an all-or-nothing approach:
  - Developers can embed the resource (allow all) or open it in an iframe (allow none)
  - Cannot import script libraries without blindly trusting them.
- SOP does not limit outgoing requests

Coping with SOP Limitations

- How to interact with cross-origin resources?
  - Network requests:
    - CORS (Cross-Origin Request Sharing for XHR)
  - JavaScript access: postMessage API
    - Allows interaction through a generic message-passing interface.
    - Suited to access components with a limited interface.
- Other alternatives for cross-origin script interaction
  - Embed scripts from other origin, but enforce policies to ensure security
    - Example: AdJail, AdSafe, FBJS (mostly, research efforts)
  - Technically feasible for full Javascript, but policy specification is difficult
  - Lighter-weight solutions possible if user is restricted to a subset of Javascript

Integrity

- Network data integrity: HTTPS/DNSSEC
  - Also used to authenticate the server (e.g Banks) and ensure network confidentiality.
  - Public-key protocol used to establish a session key to encrypt traffic.
- Browser data integrity: SOP
  - Think of integrity as write access on confidential resources. SOP protects from read as well as write accesses

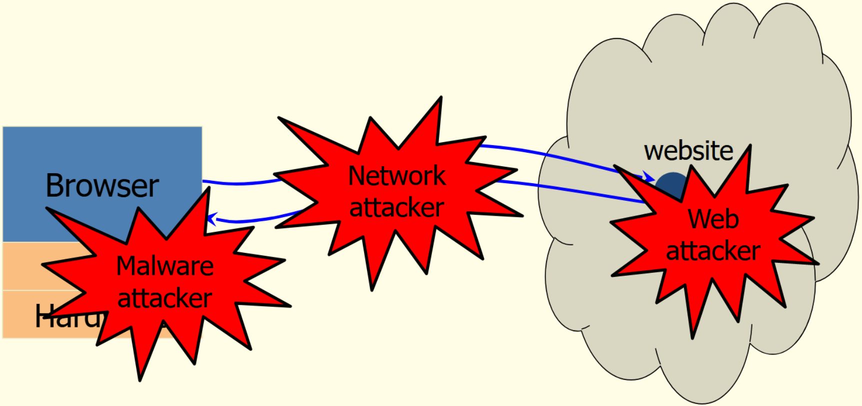
Despite the Same-Origin Policy

- Many vulnerabilities still exist:
  - Cross-site Scripting (XSS)
  - Cross-site Request Forgery (CSRF)
  - Session Hijacking
  - Session Fixation
  - SSL Stripping
  - Clickjacking
  - And more ...

Two Sides of Web Security

- Web browser
  - Responsible for securely confining Web content presented by visited websites
- Web applications
  - Online merchants, banks, blogs, Google Apps …
  - Mix of server-side and client-side code
    - Server-side code written in PHP, Ruby, ASP, JSP, ... runs on the Web server
    - Client-side code written in JavaScript... runs in the Web browser
  - Many potential bugs: XSS, CSRF, SQL injection

Where Does the Attacker Live ?



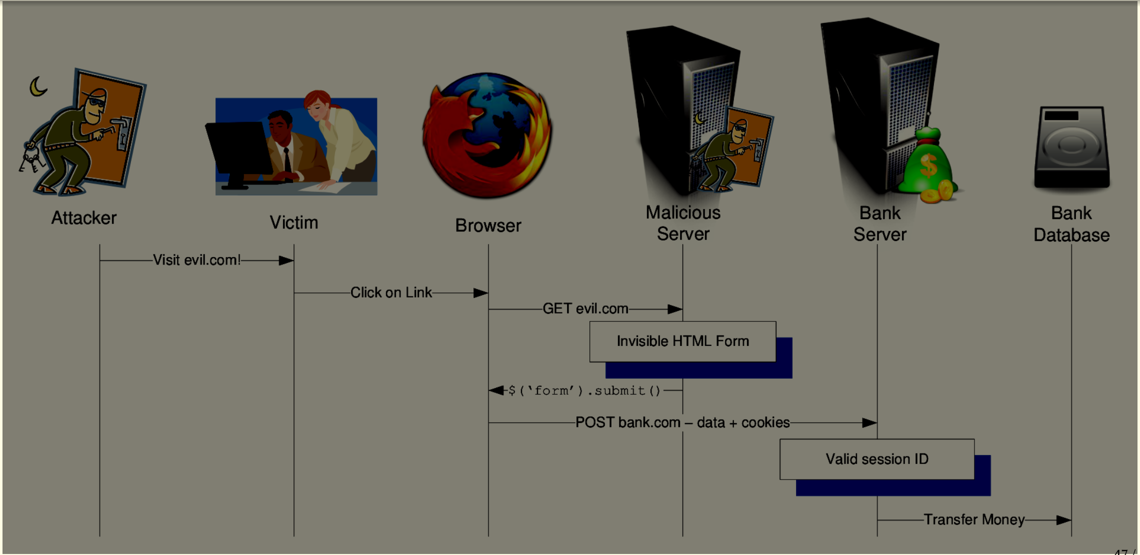
Threat Model 1: Web Attacker

- Benign actors: User, network, and the website.
- Malicious actor: An unrelated website "attacker.com."
  - Can obtain an SSL/TLS certificate ($0)
- Entice users to visit `attacker.com`
  - Phishing email, Search results, Ads or blind luck
  - Attacker's Facebook app
- Attacker has no other access to user machine!
- Variation: "iframe attacker"
  - An iframe with malicious content included in a otherwise honest webpage
    - Syndicated advertising, mashups, etc.

Attacks on Authentication

- CSRF and Clickjacking
  - Confused deputy attacks that cause the victim browser to send authenticated requests for the attacker's benefit
  - CSRF: Cross-site request forgery: attacker sends requests to another web site, impersonating browser user
  - Clickjacking: User intends to click on one link, but the browser recognizes a link on another site
    - Achieved using overlaid frames and by manipulating visibility related attributes

CSRF



Attacker
Victim
Browser
Malicious Server
Bank Server
Bank Database
Visit evil.com!
Click on Link
GET evil.com
Invisible HTML Form
$('form').submit()
POST bank.com – data + cookies
Valid session ID
Transfer Money

Cross-site Request Forgery (CSRF)

```
<form method="POST" action="/changepass">
...
New Password: <input type="password" name="password">
</form>
```

- Browser makes the following request:

  ```
  GET http://www.examplesite.com/changepass?password=newpassword HTTP/1.1
  ```

- Let's say the application didn't authenticate password change request using any means other than cookies.
- An attacker can easily forge the request!
- Attack works because: (a) Cookies are sent by default, and (b) SOP does not restrict cross-origin submissions.

POST Example

- POST requests can also be forged
- Attacker lures the client to visit his/her web page

```
<iframe name="hiddenframe" style="display:none">
  <form method="POST" name="evilform" target="hiddenframe"
        action="http://www.examplesite.com/update_password">
    <input type="hidden" name="password" value="evilhax0r">
  </form>
  <script>document.evilform.submit()</script>
</iframe>
```

CSRF and Authentication status

- The classic CSRF attack abuses a user's existing session cookies with a victim website
- Does that mean that CSRF is a non-issue when a user is logged out?
  - No! (although many still think "yes")
  - In certain cases, an attacker can log in a victim with his credentials using an unprotected login form and still manage some sort of abuse
    - Login CSRF

Possible Targets of CSRF

- Banks
  - Transfer money from victim's account to attacker's account
- E-commerce Sites
  - Purchase items using the victim's account and ship them to the attacker
- Forums and Social Networks sites
  - Post articles using the victim's identity
- Home/Intranet Firewalls
  - Reconfigure firewall to permit connections from the Internet to a host behind the firewall
  - Note that victim user's location is exploited: the attacker (typically) cannot communicate with the firewall, but the user's browser can.

Preventing CSRF

- HTTP requests originating from user action are indistinguishable from those initiated by attacker
- Need methods to distinguish valid requests
  - Inspecting Referrer Headers.
  - Validation via User-Provided Secret.
  - Validation via Action Token.

Inspecting Referrer Headers

- Referrer header specifies the URI of document originating the request
- Assuming requests from our site are good, don't serve requests not from our site
- Unfortunately, Referrer information may be suppressed by browsers (or firewalls) for privacy reasons

Validation via User-Provided Secret

- Can require user to enter secret (e.g. login password) along with requests that make server-side state changes or transactions
- Example: The change password form could ask for the user's current password
- Security vs convenience: use only for infrequent, "high-value" transactions
  - Password or profile changes.
  - Expensive commercial/financial operations.

Validation via Action Token

- Add special action tokens as hidden fields to authorized forms to distinguish from forgeries
- Need to generate and validate tokens so that malicious 3rd party can't guess or forge token
  - Token should be a nonce that is unpredictable
  - Same-origin policy prevents 3rd party from inspecting the form to find the token
- This token can be used to distinguish genuine and forged forms

Clickjacking

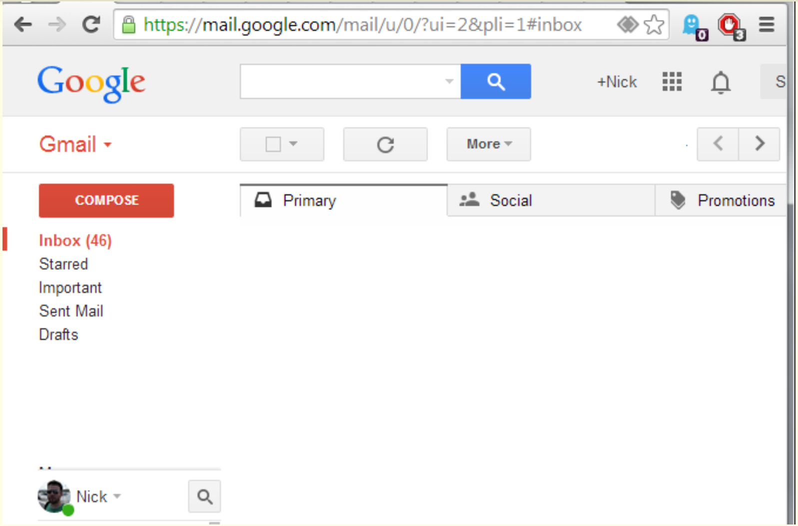
Win a free iphone!
Just click on red and green!

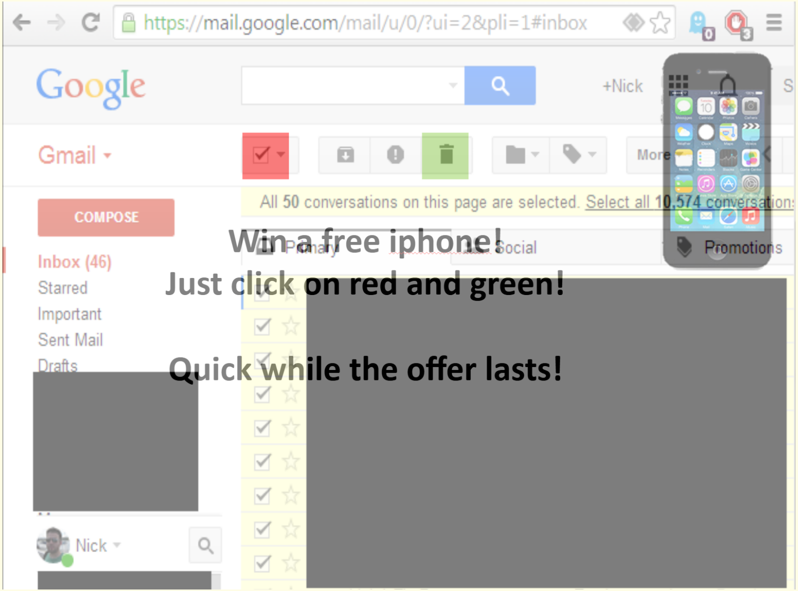
Quick while the offer lasts!

So you click …

- Nothing happens.
  - Or something happens
  - But you don't get that free iphone that you were promised
- Continue browsing
- Time to check email
  - Go to GMail

Where are my mails bro ?!?





Win a free iphone!

Just click on red and green!

Quick while the offer lasts!

Clickjacking Defenses

- Disallow hidden frames
  - There are many ways to make a frame imperceptible
- Restrict framing
- X-Frame-Options header
  - SAMEORIGIN
  - Allow-from <uri>
  - DENY;
- Content security policy(supercedes X-frame)
  - Content-Security-Policy: frame-ancestors ’self’
  - Content-Security-Policy: frame-ancestors a.com b.org
  - Content-Security-Policy: frame-ancestors ’none’

Cross-Site Scripting (XSS)

- Attacker manages to inject his/her script within the page delivered by another site
- Different types of XSS:
  - **Reflected:** Part of the URI used in the response.
  - **Persistent:** Stored data is used in the response.
  - **DOM-Based:** Data is used by client-side scripts.

What Can an Attacker Do with XSS?

- Short answer: “Almost anything”
  - Mother of all vulnerabilities (subsumes them all)
    - Naturally: this is attacker’s malicious code
- Long answer(non exhaustive):
  - Exfiltrate your cookies (session hijacking)
  - Make arbitrary changes to the page (phishing).
  - Steal all data available in the web application.
  - Make requests in your name
  - Redirect the browser to a malicious page.
  - Tunnel requests to other sites.

Reflected XSS Example

- Host www.vulnerable.site displays name submitted using a web form
- With benign data, the following request may result in:

```
GET /welcome.cgi?name=Joe%20Hacker HTTP/1.0
```

- And the website responds:

```
<HTML>
<Title>Welcome!</Title>
Hi Joe Hacker<BR>
Welcome to our system
</HTML>
```

- Malicious request:

```
GET /welcome.cgi?name=<script>...</script> HTTP/1.0
```

Reflected XSS Summary

- Attacker causes victim to click on maliciously crafted link
  - Typically contains a malicious script as a parameter
- request goes to vulnerable web site
- web site does not properly check its input
- returns a page that contains the malicious script
  - which operates with privileges of the vulnerable site
  - can perform any action that the user can perform
  - send the cookie (or other private info) to the attacker
  - perform sensitive action, e.g., withdraw money

Persistent XSS

- Malicious script permanently stored on server
- Still requires:
  - An attack that stores the script on the server
  - Script should be used in a page visited by victim user
- User totally unaware of the vulnerability/exploit
  - More stealthy, damaging and long-lasting
  - How can this be possible?
    - Think of a blog, or social networking web site: input from one user is rendered in the page shown to another

DOM-Based XSS

- DOM-Based refers to how the script comes about
  - Plain XSS: malicious script is already present in the page from server
- DOM-based XSS:
  - server delivers an initial page content and a legitimate script
  - execution of this script constructs the rest of the page using DOM operations
    - `document.write`, `document.appendChild`, etc.
- malicious script content manifests during this construction
- Orthogonal to reflected vs persistent categorization
  - DOM-based XSS can be of either kind

Preventing XSS

- Server should not send untrusted data to the browser that could result in the creation of an unintended (and unauthorized) script
- Easier said than done:
  - Scripts can appear in many contexts:
    - `<script>` tags: inline scripts
    - `src` attributes: refer to external scripts by name
    - javascript URLs
    - event handlers
  - Can be “injected” into non-script fields:
    - Usual “close the quotes and new content” trick

Defending Against XSS

- Blacklisting:
  - E.g. No <, >, `script`, `document.cookie`, etc.
  - Intuitively correct, but it should NOT be relied upon
    - There are too many ways to insert script content
    - See XSS Cheat Sheet for hundreds of possibilities
- Whitelisting: Whenever possible
  - E.g. this field should be a number, nothing more nothing less

Defending Against XSS

- Always escape user-input:
  - Neutralize “control” characters for all contexts
- Content Security Policy:
  - Whitelist for resources
  - Defense-in-depth: backup mechanism if primary defenses fail

Content Security Policy

- Example:

```
Content-Security-Policy: default-src https://cdn.example.net;
frame-src 'none'; object-src 'none'; image-src self;
```

- CSP is very powerful:
  - Great if you are writing something from scratch
  - Not so great if you have to rewrite something to CSP
    - E.g. Convert all inline JavaScript code to files

Content Security Policy v2

- CSP was great in theory but still hasn't caught up in practice
- CSP v2.0 supports two new features to help adopt CSP:
  - Script nonces for inline scripts
  - Hashes for inline scripts
  - Read more here:
    - https://blog.mozilla.org/security/2014/10/04/csp-for-the-web-we-have/

Browser XSS Filters

- Some browsers try to help by attempting to detect reflected XSS and stop them
  - Internet Explorer was the first to introduce this
  - Chrome followed a bit later, with a more complete approach that addressed some of IE's problems
    - Unfortunately, Chrome's filter regressed in some aspects, stopping fewer attacks than IE in tests
  - Firefox invested in an XSS filter but later abandoned its efforts
    - PaleMoon, a Firefox clone, imported the XSS filter developed at Stony Brook

Browser XSS filters

- Attempt 1: Use string (or regexp) matching to identify suspicious content within request parameters (NoScript)
  - Example: excise "<script>", "data:", etc. from parameters

    Problem: High False Positives make it unsuitable for general use
- Attempt 2: Filter only if suspicious parameter is reflected, i.e., its value appears in the HTML response (IE/Edge)
  - FPs can still be too high

    Mitigate using very strict matching rules (IE/Edge, Chrome)

    Unfortunately, this leads to false negatives and filter evasion

Browser XSS filters

- Attempt 3: Filter if suspicious reflected content is used in a dangerous context in the HTML response (Firefox filter)
  - Example: “data:” can safely appear outside HTML tags

    In our filter, this reduces FPs sufficiently to enable use of approximate matching

    Result: Evasion resistant XSS filtering

Script Inclusion

- What if an attacker can't find an XSS vulnerability in a website
  - Can he somehow still get to run malicious JavaScript?
- Perhaps... by abusing existing trust between the target site and other sites

mybank.com

```
<html>
...
<script src=http://www.foo.com/a.js>
</script>
...
</html>
```

Remote JavaScript libraries

- This means that if, foo.com, decides to send you malicious JavaScript, the code can do anything in the mybank.com domain
- Why would foo.com send malicious code?
  - Why not?
  - Change of control of the domain
  - Compromised

Timing attacks

- Scenario: I want to know if you are logged into your Gmail
  - I may, or may not be able to load the page in an iframe, depending on the Xframe-options
  - Even if I can load it, I still can't peek in it
- What if I try to load mail.google.com as an image?
  - `<img src=https://mail.google.com onError="func()"/>`
  - The browser will fetch the page with your cookies and then the parser will at some point throw an error that this is not an image

Timing attacks

- The size of a page is often dependent on whether you are logged in or not
- (Over)simplified attack:
  - Fast error: not-logged in
  - Slow error: logged-in

Getting one measurement

```
<html><body><img id="test" style="display: none">
<script>
  var test = document.getElementById('test');
  var start = new Date();
  test.onerror = function() {
    var end = new Date();
    alert("Total time: " + (end - start));
  }
  test.src = "http://www.example.com/page.html";
</script>
</body></html>
```

Figure 3: Example JavaScript timing code

[1]

[1] Code sample from: Exposing Private Information by Timing Web Applications By Bortz et al.

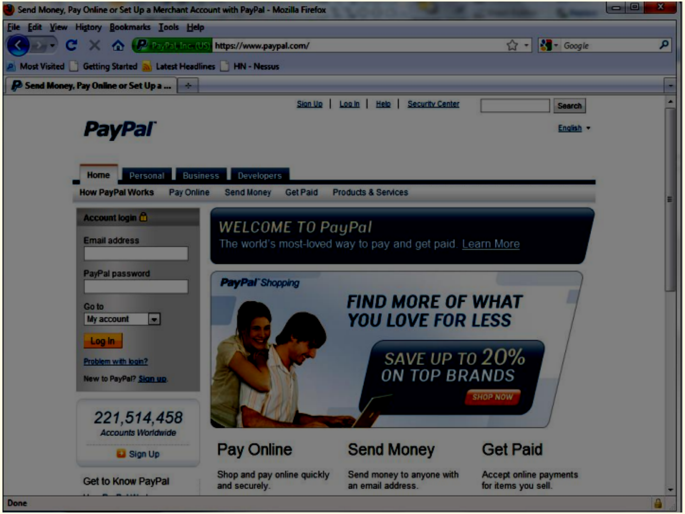
Web Threat Models

- Web attacker
- Network attacker
  - Passive: wireless eavesdropper
  - Active: evil Wi-Fi router, DNS poisoning
- Malware attacker
  - Malicious code executes directly on victim's computer
  - To infect victim's computer, can exploit software bugs (e.g., buffer overflow) or convince user to install malicious content (how?)
  - Masquerade as an antivirus program, video codec, etc.

SSL Stripping

- Let's say that a website exists only over HTTPS
  - No HTTP pages
- Two scenarios
  1. User types **https://www.securesite.com** and the browser directly tries to communicate the remote server over a secure channel
  2. User types **http://www.securesite.com** (or just securesite .com) and the site will redirect the user to the secure version (using an HTTP redirection/Meta header)

Normal page load

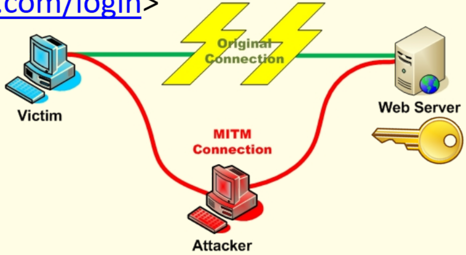


Page load when attacker is present

SSL Stripping

- Same thing can happen when sites deliver HTTPS-targeted forms over an HTTP connection (typically for performance or outsourcing purposes)

<form action=http~~s:~~//example.com/login>
<input .... username>
<input.... password>
</form>



Defenses

- Use full-site SSL in combination with Secure cookie and HTTP-only Cookie
- HSTS: HTTP Strict Transport Security
  - Force the browser to always contact the server over an encrypted channel , regardless of what the user asks
- HTTP Header

```
Strict-Transport-Security:  max-age=31536000
```

Defenses

- What about the very first time you visit a website?
  - What if a MITM is located on your network and will therefore strip SSL and suppress HSTS?
- Answer:
  - Preloaded HSTS: Websites can ask browsers to mark them as HSTS in a special browser-vendor-updated database

Threat model 3: Malicious Client

- In these scenarios:
  - The server is benign
  - The client is malicious
    - The client can send arbitrary requests to the server, not bound by the HTML interfaces
- The attacker is after information at the server-side
  - Steal databases
  - Gain access to server
  - Manipulate server-side programs for gain

OWASP Top 10

- A1 – Injection
- A2 – Broken Auth and Session Management
- A3 – Cross-site Scripting
- A4 – Insecure Direct Object References
- A5 – Security misconfiguration
- A6 – Sensitive Data Exposure
- A7 – Missing function level access control
- A8 – Cross-site Request Forgery
- A9 – Using components with kn. vulnerabilities
- A10 – Unvalidated redirects and Forwards

Injection Attacks

- SQL injection
  - Steal sensitive data about specific user
  - All username, password (hashes) info
  - ...
- Command injection
  - Install malware on server, run reconnaissance commands, probe serverside network,inject into command streams for backend servers, ...
- We discussed these attacks and their defenses before
  - Defenses need to be mindful of trust boundaries, e.g., don't rely on client-side sanitization if the attacker is the client

Redirects, Cookies, and Header Injection

- Need to filter and validate user input inserted into HTTP response headers
- Ex: servlet returns HTTP redirect

```
HTTP/1.1 302 Moved
Content-Type: text/html; charset=ISO-8859-1
Location: %(redir_url)s
<html>
<head><title>Moved</title></head>
<body>Moved <a href='%(redir_url)s'>here</a></body> </html>
```

- Attacker Injects:(URI-encodes newlines)

```
oops:foo\r\nSet-Cookie: SESSION=13af..3b;
domain=mywwservice.com\r\n\r\n
<script>evil()</script>
```

Logic Vulnerabilities

- HTTP parameter tampering vulnerabilities are a subset of logic vulnerabilities in web applications
- Logic vulnerabilities typically rely on breaking assumptions made by architects and developers
  - Step 2 can only be performed after Step 1
  - Users cannot change parameters that they cannot see
  - Etc.

Examples of logic vulnerabilities

- Unlike vulnerabilities discussed so far, logic vulnerabilities don't have a clear, narrow definition
- This makes them hard to identify, especially by automated vulnerability discovery tools
- We will see a few real-world examples based on the book "The Web Application Hackers Handbook"

Case Study: Password change

- A website allows its users to change their password, by filling out a form with their current password, and their new password
- Administrators can also change a user's password but they don't need to provide a user's current password

```
String existingPassword = request.getParameter("existingPassword");
if(null == existingPassword){
    trace("Old password not supplied, must be an administrator");
    return true;
}
else{
    trace("veryifying user's old password");
    ...
}
```

Case Study: Password change

- The code that handles these two cases is the same and the developer assumes that if the “existingPassword” parameter is not present, this must be because the current request came from an administrative UI
- All the attackers has to do is drop the “existingPassword” HTTP parameter from the outgoing request

Case Study: Bulk Discounts

- An online shop gives users discounts when they buy some products together
  - E.g. If you purchase an antivirus solution, and a personal firewall, and antispam software then you are entitled to 25% discount on each product
- Abuse
  - Add all products in your basket to get the discount and then remove the ones you don't want

Case Study: Escaping from escaping

- A web application has to pass user-controllable input as an argument to an operating system command.
- The developer creates a list of special shell metacharacters that need escaping
  - ; | & < > ‘ space and newline
- If any of these are present in the input, the code escapes them by prepending them with a backslash
  - -\

Case Study: Escaping from escaping

- If an attacker types
  - `foo;ls`
- The code converts it to
  - `foo\;ls`
- What if an attacker types an escape character
  - `foo\;ls`
- Will become
  - `foo\\;ls`
- Which amounts to escaping the backslash but not the semicolon.

Weaknesses Leading to Attacks

- Trusting embedded content
  - Embedded scripts have same privilege as surrounding page (XSS)
  - Embedded content can target browser flaws, e.g., buffer overflows in the browser or JS engine
- Not restricting outgoing network requests
  - Unauthorized requests to third-party sites (CSRF)
  - Include trusted party content in a frame
    - Abuse trust in third party, e.g., to improve odds of successful phishing
    - Clickjacking
  - Attacking third-party sites, e.g., portscanning or launching exploits
  - Ease of leaking sensitive data acquired (e.g., send cookie to attacker)

Weaknesses Leading to Attacks

- Allowing Turing-complete computation for arbitrary sites
  - Bitcoin mining
  - Side-channel attacks
  - Heapspray, JIT-spray and JIT-ROP attacks
- Weaknesses in lower layers
  - In-network attacks, e.g., man-in-the-middle
  - DNS compromise

Weaknesses Leading to Attacks

- Application development environments that blur trust boundaries
  - Trusting client-side: browser and/or scripts running on a web page (Parameter tampering, …)
- Good old application logic or implementation vulnerabilities
  - SQL injection, command injection, HTTP parameter pollution, …

Credits

- Many of the slides here are the courtesy of Nick Nikiforakis and Venkat Venkatakrishnan