Cookies and CSRF

CS 161 Spring 2022 - Lecture 14

Next: Cookies and CSRF

- Cookies
  - Parts of a cookie
- Cookie Policy
  - Setting cookies
  - Sending cookies
- Session Authentication
- CSRF
  - Defenses

Cookies

Customizing HTTP Responses

- HTTP is a request-response protocol
  - The web server processes each request independently of other requests
- What if we want our responses to be customized?
  - Example: If I enable dark mode on a website, I want future responses from the website to be in dark mode
  - Example: If I log in to a website, I want future responses from the website to be related to my account

Cookies: Definition

- **Cookie**: a piece of data used to maintain state across multiple requests
- Creating cookies
  - The server can create a cookie by including a `Set-Cookie` header in its response
  - JavaScript in the browser can create a cookie
  - Users can manually create cookies in their browser
- Storing cookies
  - Cookies are stored in the web browser (not the web server)
  - The browser's cookie storage is sometimes called a **cookie jar**
- Sending cookies
  - The browser *automatically* attaches relevant cookies in every request
  - The server uses received cookies to customize responses and connect related requests

Parts of a Cookie: Name and Value

- The actual data in the cookie is stored as a **name-value pair**
- The name and value can be any string
  - Some special characters can't be used (e.g. semicolons)

Name	`Theme`
Value	`Dark`
Domain	`toon.cs161.org`
Path	`/xorcist`
Secure	`True`
HttpOnly	`False`
Expires	`12 Aug 2021 20:00:00`
(*other fields omitted*)	

Parts of a Cookie: Domain and Path

- The **domain attribute** and **path attribute** define which requests the browser should attach this cookie for
- The domain attribute usually looks like the domain in a URL
- The path attribute usually looks like a path in a URL

Name	`Theme`
Value	`Dark`
Domain	`toon.cs161.org`
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Secure	`True`
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(*other fields omitted*)	

Parts of a Cookie: Secure and HttpOnly

- The Secure attribute and HttpOnly attribute restrict the cookie for security purposes
- Each attribute is either True or False
- If the **Secure attribute** is True, then the browser only sends the cookie if the request is made over HTTPS (not HTTP)
- If the **HttpOnly attribute** is True, then JavaScript in the browser is not allowed to access the cookie

Name	`Theme`
Value	`Dark`
Domain	`toon.cs161.org`
Path	`/xorcist`
Secure	`True`
HttpOnly	`False`
Expires	`12 Aug 2021 20:00:00`
(*other fields omitted*)	

Parts of a Cookie: Expires

- The **Expires attribute** defines when the cookie is no longer valid
- The expires attribute is usually a timestamp
- If the timestamp is in the past, then the cookie has expired, and the browser deletes it from the cookie jar

Name	`Theme`
Value	`Dark`
Domain	`toon.cs161.org`
Path	`/xorcist`
Secure	`True`
HttpOnly	`False`
Expires	`12 Aug 2021 20:00:00`
(*other fields omitted*)	

Cookie Policy

Cookies: Issues

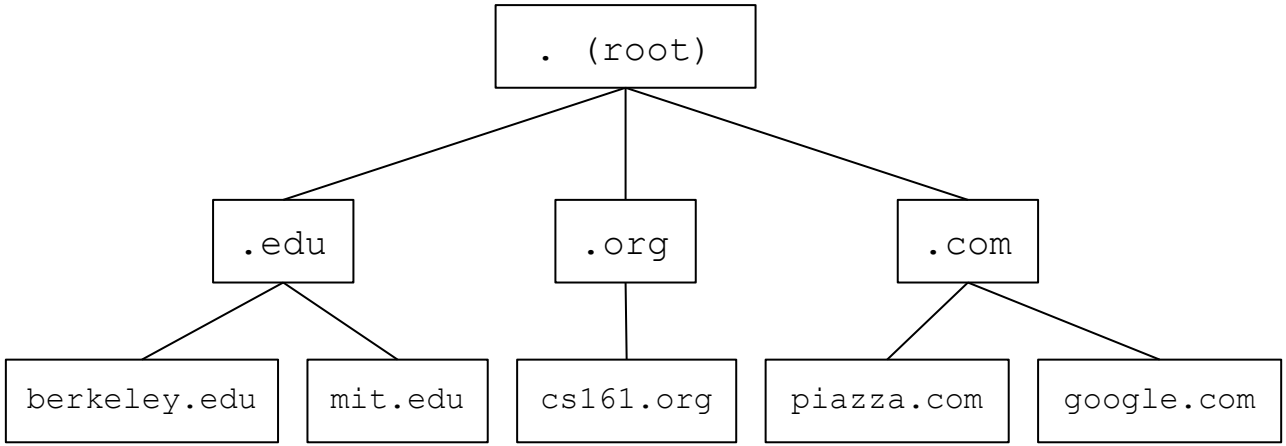
- Recall:
  - The server can create a cookie by including a **`Set-Cookie`** header in its response
  - The browser automatically attaches relevant cookies in every request
- Security issues:
  - A server should not be able to set cookies for unrelated websites
    - Example: **`evil.com`** should not be able to set a cookie that gets sent to **`google.com`**
  - Cookies shouldn't be sent to the wrong websites
    - Example: A cookie used for authenticating a user to Google should not be sent to evil.com
    - We'll see how cookies are used for logins later

Cookie Policy

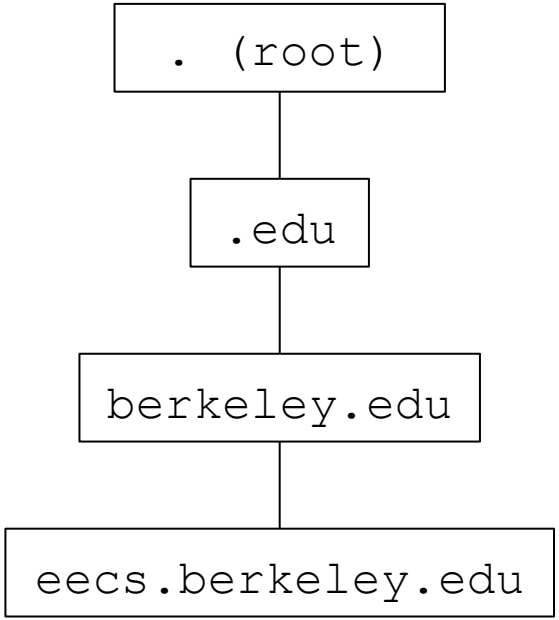
- **Cookie policy**: A set of rules enforced by the browser
  - When the browser receives a cookie from a server, should the cookie be accepted?
  - When the browser makes a request to a server, should the cookie be attached?
- Cookie policy is **not** the same as same-origin policy

Domain Hierarchy

- Recall: Domains
  - Located after the double slashes, but before the next single slash
  - Written as several phrases separated by dots
- Domains can be sorted into a hierarchy
  - The hierarchy is separated by dots



Domain Hierarchy



`.edu` is a **top-level domain** (TLD), because it is directly below the root of the tree.

`eecs.berkeley.edu` is a **subdomain** of `berkeley.edu`.

Cookie Policy: Setting Cookies

- When the browser receives a cookie from a server, should the cookie be accepted?
- Server with domain X can set a cookie with domain attribute Y if
  - The domain attribute is a **domain suffix** of the server's domain
    - X ends in Y
    - X is below Y on the hierarchy
    - X is more specific than Y)
  - The domain attribute Y is not a top-level domain (TLD)
  - No restrictions for the Path attribute (the browser will accept any path)
- Examples:
  - mail.**google.com** can set cookies for Domain=google.com
  - **google.com** can set cookies for Domain=google.com
  - google.**com** **cannot** set cookies for Domain=com, because com is a top-level domain

Cookie Policy: Sending Cookies

- When the browser makes a request to a server, should the cookie be attached?
- The browser sends the cookie if both of these are true:
  - The domain attribute is a **domain suffix** of the server's domain
  - The path attribute is a **prefix** of the server's path

Cookie Policy: Sending Cookies

(server URL)

https://toon.cs161.org/cryptoverse/oneshots/subway.html

cs161.org/cryptoverse

(cookie domain) (cookie path)

Quick method to check cookie sending: Concatenate the cookie domain and path. Line it up below the requested URL at the first single slash.

If the domains and paths all match, then the cookie is sent.

Cookie Policy: Sending Cookies

(server URL)

https://toon.cs161.org/cryptoverse/oneshots/subway.html

cs161.org/xorcist

(cookie domain) (cookie path)

Quick method to check cookie sending: Concatenate the cookie domain and path. Line it up below the requested URL at the first single slash.

If the domain or path doesn't match, then the cookie is not sent.

Attacks on Cookies

Cookie Ambiguity

- If two cookies should both be sent to a page with the same name, they are sent in an **undefined** order!
  - Consider two cookies:
    - `name=value1; Domain=bank.com; Path=/`
    - `name=value2; Domain=bank.com; Path=/page`
  - The browser would send both cookies to `bank.com/page` in an undefined order!
    - The server doesn't receive the Domain and Path attributes
    - The server might not be able to tell the cookies apart

Spectre Attack: Vulnerability

- Original browser design: Chrome isolated each tab in its own Unix process
  - Security sandboxing: The operating system (OS) makes sure that one process cannot access other processes
  - Makes attacks harder: To compromise another tab, you have to exploit the browser code and escape the Unix sandbox
  - Usability: If one tab crashes, the rest of the browser won't crash
- Issues with this design
  - There are many scenarios where a program wants to protect data from other parts of the same program
  - Notable example: If one tab includes multiple origins (e.g. from an iframe embed), the browser must enforce same-origin policy: JavaScript from one origin cannot read cookies related to the other origin

Spectre Attack: Exploiting browser design

- Spectre: An attack exploiting this browser design
  - The victim visits **`evil.com`** in a browser tab
  - **`evil.com`** opens an iframe with **`victim.com`**
  - Recall: JavaScript in **`evil.com`** should not be able to read any cookies from **`victim.com`**
  - **`evil.com`** and **`victim.com`** are now running in the same operating system process
  - No operating system sandboxing is active! The only memory protection is enforced by the JavaScript compiler
  - If we can break the JavaScript compiler, we can read memory from **`victim.com`**

Spectre Attack: Exploiting the processor

- Quick review: Modern processors
  - Designed to be very fast: High instructions per cycle (IPC)
  - Uses aggressive behavior to achieve high IPC
    - Aggressive caching
    - Branch prediction: Guess the outcome of a branch and start executing that branch before the outcome is known
    - Speculative execution: Execute some code if the processor thinks it'll be executed later
  - Note: Predictions are not always correct
- Spectre: Exploits a hardware side-channel attack
  - Use a side channel (e.g. timing, cache state) to detect the results of failed speculative execution
  - Use a side channel to see what the input to the speculative execution was
  - Idea: Force speculative execution by forcing the processor to make wrong predictions
  - Idea: Read the side channel to see the results of the speculative execution

Spectre Attack: Exploiting the processor

- Using the side-channel to break the JavaScript compiler's memory isolation
  - Recall: **`evil.com`** has loaded an iframe with **`victim.com`**
  - **`evil.com`** executes a repeated loop with legitimate instructions
  - The branch predictor is trained to think this loop will keep going (it will keep guessing the **`while`** condition is true)
  - On the last run of the loop, the processor incorrectly guesses it will keep going and starts running the loop one more time (speculative execution)
  - In the speculative run of the loop, do computation on illegal memory (e.g. **`victim.com`**'s cookies)
  - Use the side-channel to leak some information about the illegal memory being read
  - Repeat this process to leak all the desired information

```
i = 0
while i <= 1000:
  if i <= 1000:
    [legal things]
  else:
    [illegal things]
  i += 1
```

Speculative execution: The else case never runs, but the predictor will try to execute it after the last run of the loop

Spectre Attack: Defenses

- Chrome and Firefox now run each *origin*, not tab, in its own process
  - Known as "Site Isolation"
  - Recall: The operating system (OS) makes sure that one process cannot access other processes
- Security: Spectre attack is defeated
  - When **`evil.com`** loads an iframe with **`victim.com`**, the two frames are run in different processes
  - Speculative execution no longer works: the OS prevents the **`evil.com`** process from accessing memory of the **`victim.com`** process
  - The attack now requires breaking the OS isolation (much harder)
- Cost: Processes are expensive
  - Lots of memory overhead
  - Switching between processes is expensive: optimizations (e.g. caches) must be wiped

Spectre Attack: Takeaways

- **Takeaway**: Enforcing isolation between websites (same-origin policy, cookie policy) requires the browser to be securely designed. Getting this right can be very tricky!
- **Takeaway**: The web was not designed in security in mind. Many defenses (e.g. same-origin policy) were added afterwards, leading to awkward design and expensive performance costs

Session Authentication

Session Authentication

- **Session**: A sequence of requests and responses associated with the same authenticated user
  - Example: When you check all your unread emails, you make many requests to Gmail. The Gmail server needs a way to know all these requests are from you
  - When the session is over (you log out, or the session expires), future requests are not associated with you
- Naïve solution: Type your username and password before each request
  - Problem: Very inconvenient for the user!
- Better solution: Is there a way the browser can automatically send some information in a request for us?
  - Yes: Cookies!

Session Authentication: Intuition

- Imagine you're attending a concert
- The first time you enter the venue:
  - Present your ticket and ID
  - The doorman checks your ticket and ID
  - If they're valid, you receive a wristband
- If you leave and want to re-enter later
  - Just show your wristband!
  - No need to present your ticket and ID again

Session Tokens

- **Session token**: A secret value used to associate requests with an authenticated user
- The first time you visit the website:
  - Present your username and password
  - If they're valid, you receive a session token
  - The server associates you with the session token
- When you make future requests to the website:
  - Attach the session token in your request
  - The server checks the session token to figure out that the request is from you
  - No need to re-enter your username and password!

Session Tokens with Cookies

- Session tokens can be implemented with cookies
  - Cookies can be used to save *any* state across requests (e.g. dark mode)
  - Session tokens are just one way to use cookies
- The first time you visit a website:
  - Make a request with your username and password
  - If they're valid, the server sends you a cookie with the session token
  - The server associates you with the session token
- When you make future requests to the website:
  - The browser attaches the session token cookie in your request
  - The server checks the session token to figure out that the request is from you
  - No need to re-enter your username and password!
- When you log out (or when the session times out):
  - The browser and server delete the session token

Session Tokens: Security

- If an attacker steals your session token, they can log in as you!
  - The attacker can make requests and attach your session token
  - The browser will think the attacker's requests come from you
- Servers need to generate session tokens *randomly* and *securely*
- Browsers need to make sure malicious websites cannot steal session tokens
  - Enforce isolation with cookie policy and same-origin policy
- Browsers should not send session tokens to the wrong websites
  - Enforced by cookie policy

Session Token Cookie Attributes

- What attributes should the server set for the session token?
  - Domain and Path: Set so that the cookie is only sent on requests that require authentication
  - Secure: Can set to True to so the cookie is only sent over secure HTTPS connections
  - HttpOnly: Can set to True so JavaScript can't access session tokens
  - Expires: Set so that the cookie expires when the session times out

Name	`token`
Value	`{random value}`
Domain	`mail.google.com`
Path	`/`
Secure	`True`
HttpOnly	`True`
Expires	`{15 minutes later}`
(*other fields omitted*)	

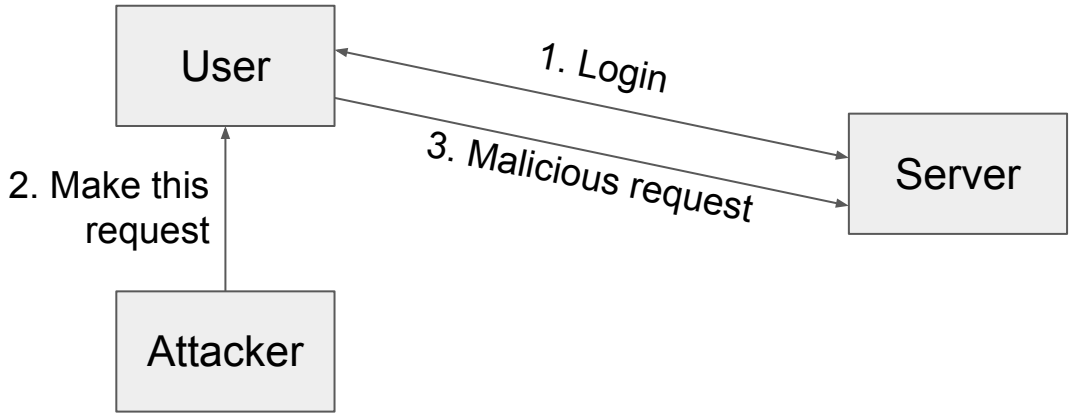
Cross-Site Request Forgery (CSRF)

Cross-Site Request Forgery (CSRF)

- Idea: What if the attacker tricks the victim into making an unintended request?
  - The victim's browser will automatically attach relevant cookies
  - The server will think the request came from the victim!
- **Cross-site request forgery** (**CSRF or XSRF**): An attack that exploits cookie-based authentication to perform an action as the victim

Steps of a CSRF Attack

1. User authenticates to the server
   - User receives a cookie with a valid session token
2. Attacker tricks the victim into making a malicious request to the server
3. The server accepts the malicious request from the victim
   - Recall: The cookie is automatically attached in the request



Steps of a CSRF Attack

1. User authenticates to the server
    - User receives a cookie with a valid session token
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3. The server accepts the malicious request from the victim
    - Recall: The cookie is automatically attached in the request

Executing a CSRF Attack

- How might we trick the victim into making a GET request?
- Strategy #1: Trick the victim into clicking a link
  - Later we'll see how to trick a victim into clicking a link
  - The link can directly make a GET request:

    `https://www.bank.com/transfer?amount=100&to=Mallory`
  - The link can open an attacker's website, which contains some JavaScript that makes the actual malicious request
- Strategy #2: Put some HTML on a website the victim will visit
  - Example: The victim will visit a forum. Make a post with some HTML on the forum
  - HTML to automatically make a GET request to a URL:

    `<img src="https://www.bank.com/transfer?amount=100&to=Mallory">`
    - This HTML will probably return an error or a blank 1 pixel by 1 pixel image, but the GET request will still be sent… with the relevant cookies!

Executing a CSRF Attack

- How might we trick the victim into making a POST request?
  - Example POST request: Submitting a form
- Strategy #1: Trick the victim into clicking a link
  - Note: Clicking a link in your browser makes a GET request, not a POST request, so the link cannot directly make the malicious POST request
  - The link can open an attacker's website, which contains some JavaScript that makes the actual malicious POST request
- Strategy #2: Put some JavaScript on a website the victim will visit
  - Example: Pay for an advertisement on the website, and put JavaScript in the ad
  - Recall: JavaScript can make a POST request

Top 25 Most Dangerous Software Weaknesses (2020)

Rank	ID	Name	Score
[1]	CWE-79	Improper Neutralization of Input During Web Page Generation ('Cross-site Scripting')	46.82
[2]	CWE-787	Out-of-bounds Write	46.17
[3]	CWE-20	Improper Input Validation	33.47
[4]	CWE-125	Out-of-bounds Read	26.50
[5]	CWE-119	Improper Restriction of Operations within the Bounds of a Memory Buffer	23.73
[6]	CWE-89	Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection')	20.69
[7]	CWE-200	Exposure of Sensitive Information to an Unauthorized Actor	19.16
[8]	CWE-416	Use After Free	18.87
[9]	CWE-352	Cross-Site Request Forgery (CSRF)	17.29
[10]	CWE-78	Improper Neutralization of Special Elements used in an OS Command ('OS Command Injection')	16.44
[11]	CWE-190	Integer Overflow or Wraparound	15.81
[12]	CWE-22	Improper Limitation of a Pathname to a Restricted Directory ('Path Traversal')	13.67
[13]	CWE-476	NULL Pointer Dereference	8.35
[14]	CWE-287	Improper Authentication	8.17
[15]	CWE-434	Unrestricted Upload of File with Dangerous Type	7.38
[16]	CWE-732	Incorrect Permission Assignment for Critical Resource	6.95
[17]	CWE-94	Improper Control of Generation of Code ('Code Injection')	6.53

CSRF Example: Internet of Things (IoT)

- IoT devices often use default passwords
  - Example login URL: `http://10.1.1.1/login?user=admin&password=admin`
  - The attacker tricks the victim into making a request to this link, which gives the victim a session token cookie
- IoT devices often process commands with web requests
  - Example request URL: `http://10.1.1.1/set-dns-server?server=8.8.8.8`
  - These requests can perform actions that help the attacker mount other attacks
- IoT devices don't implement CSRF defenses
  - An attacker can publish an advertisement that makes these two requests
  - Any victim who opens a webpage with the advertisement will get their IoT device compromised!

CSRF Example: Malvertising

- Short for **malicious advertising**
- The attacker writes some JavaScript
  - The script opens a 1 pixel by 1 pixel frame (too small for human users to notice)
  - The frame opens a huge number of internal frames
  - Each frame launches possible CSRF attacks
- The attacker pays for advertisements to put this JavaScript on legitimate websites
- **Takeaway**: Many advertisers will publish malicious scripts for you as long as you pay for it

CSRF Example: YouTube

- 2008: Attackers exploit a CSRF vulnerability on YouTube
- By forcing the victim to make a request, the attacker could:
  - Add any videos to the victim's "Favorites"
  - Add any user to the victim's "Friend" or "Family" list
  - Send arbitrary messages as the victim
  - Make the victim flag any videos as inappropriate
  - Make the victim share a video with their contacts
  - Make the victim subscribe to any channel
  - Add any videos to the user's watchlist
- **Takeaway**: With a CSRF attack, the attacker can force the victim to perform a wide variety of actions!

CSRF Example: Facebook

InternetNews.com

Link

Facebook Hit by Cross-Site Request Forgery Attack

Sean Michael Kerner *August 21, 2009*

Nevertheless, that Facebook accounts were compromised in the wild is noteworthy because the attack used a legitimate HTML tag to violate users' privacy.

According to Zilberman's disclosure, the attack simply involved the malicious HTML image tag residing on any site, including any blog or forum that permits the use of image tags even in the comments section.

"The attack elegantly ends with a valid image so the page renders normally, and the attacked user does not notice that anything peculiar has happened," Zilberman said.

Takeaway: The HTML image tag can be used to execute a CSRF attack

CSRF Defenses

CSRF Defenses

- CSRF defenses are implemented by the server (not the browser)
- Defense: CSRF tokens
- Defense: Referer validation
- Defense: SameSite cookie attribute

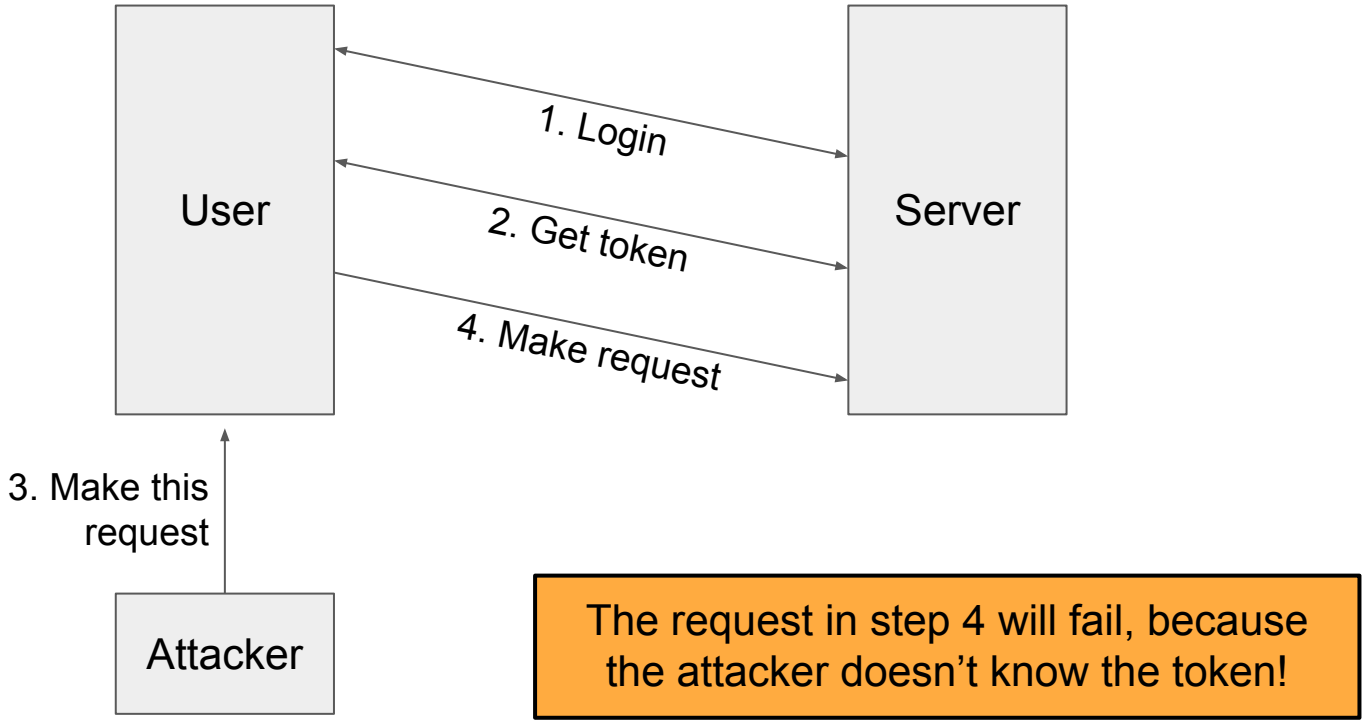
CSRF Tokens

- Idea: Add a secret value in the request that the attacker doesn't know
  - The server only accepts requests if it has a valid secret
  - Now, the attacker can't create a malicious request without knowing the secret
- **CSRF token**: A secret value provided by the server to the user. The user must attach the same value in the request for the server to accept the request.
  - CSRF tokens cannot be sent to the server in a cookie!
    - The token must be sent somewhere else (e.g. a header, GET parameter, or POST content)
  - CSRF tokens are usually valid for only one or two requests

CSRF Tokens: Usage

- Example: HTML forms
  - Forms are vulnerable to CSRF
    - If the victim visits the attacker's page, the attacker's JavaScript can make a POST request with a filled-out form
- CSRF tokens are a defense against this attack
  - Every time the user requests a form from the legitimate website, the server attaches a CSRF token as a *hidden form field* (in the HTML, but not visible to the user)
  - When the user submits the form, the form contains the CSRF token
  - The attacker's JavaScript won't be able to create a valid form, because they don't know the CSRF token!
  - The attacker can try to fetch their own CSRF token, but it will only be valid for the attacker, not the victim

CSRF Tokens: Usage



The request in step 4 will fail, because the attacker doesn't know the token!

Referer Header

- Idea: In a CSRF attack, the victim usually makes the malicious request from a different website
- Referer header: A header in an HTTP request that indicates which webpage made the request
  - “Referer” is a 30-year typo in the HTTP standard (supposed to be “Referrer”)!
  - Example: If you type your username and password into the Facebook homepage, the Referer header for that request is `https://www.facebook.com/`
  - Example: If an `img` HTML tag on a forum forces your browser to make a request, the Referer header for that request is the forum’s URL
  - Example: If JavaScript on an attacker’s website forces your browser to make a request, the Referer header for that request is the attacker’s URL

Referer Header

- Checking the Referer header
  - Allow **same-site requests**: The Referer header matches an expected URL
    - Example: For a login request, expect it to come from `https://bank.com/login`
  - Disallow **cross-site requests**: The Referer header does not match an expected URL
- If the server sees a cross-site request, reject it

Referer Header: Issues

- The Referer header may leak private information
  - Example: If you made the request on a top-secret website, the Referer header might show you visited `http://intranet.corp.apple.com/projects/iphone/competitors.html`
  - Example: If you make a request to an advertiser, the Referer header gives the advertiser information about how you saw the ad
- The Referer header might be removed before the request reaches the server
  - Example: Your company firewall removes the header before sending the request
  - Example: The browser removes the header because of your privacy settings
- The Referer header is optional. What if the request leaves the header blank?
  - Allow requests without a header?
    - Less secure: CSRF attacks might be possible
  - Deny requests without a header?
    - Less usable: Legitimate requests might be denied
  - Need to consider fail-safe defaults: No clear answer

SameSite Cookie Attribute

- Idea: Implement a flag on a cookie that makes it unexploitable by CSRF attacks
  - This flag must specify that **cross-site** requests will not contain the cookie
- **SameSite flag**: A flag on a cookie that specifies it should be sent only when the domain of the cookie **exactly** matches the domain of the origin
  - SameSite=None: No effect
  - SameSite=Strict: The cookie will not be sent if the cookie domain does not match the origin domain
  - Example: If `https://evil.com/` causes your browser to make a request to `https://bank.com/transfer?to=mallory`, cookies for bank.com will not be sent if SameSite=Strict, because the origin domain (`evil.com`) and cookie domain (`bank.com`) are different
- Biggest issue: Not yet implemented on all browsers!
  - This is true for pretty much every web defense…

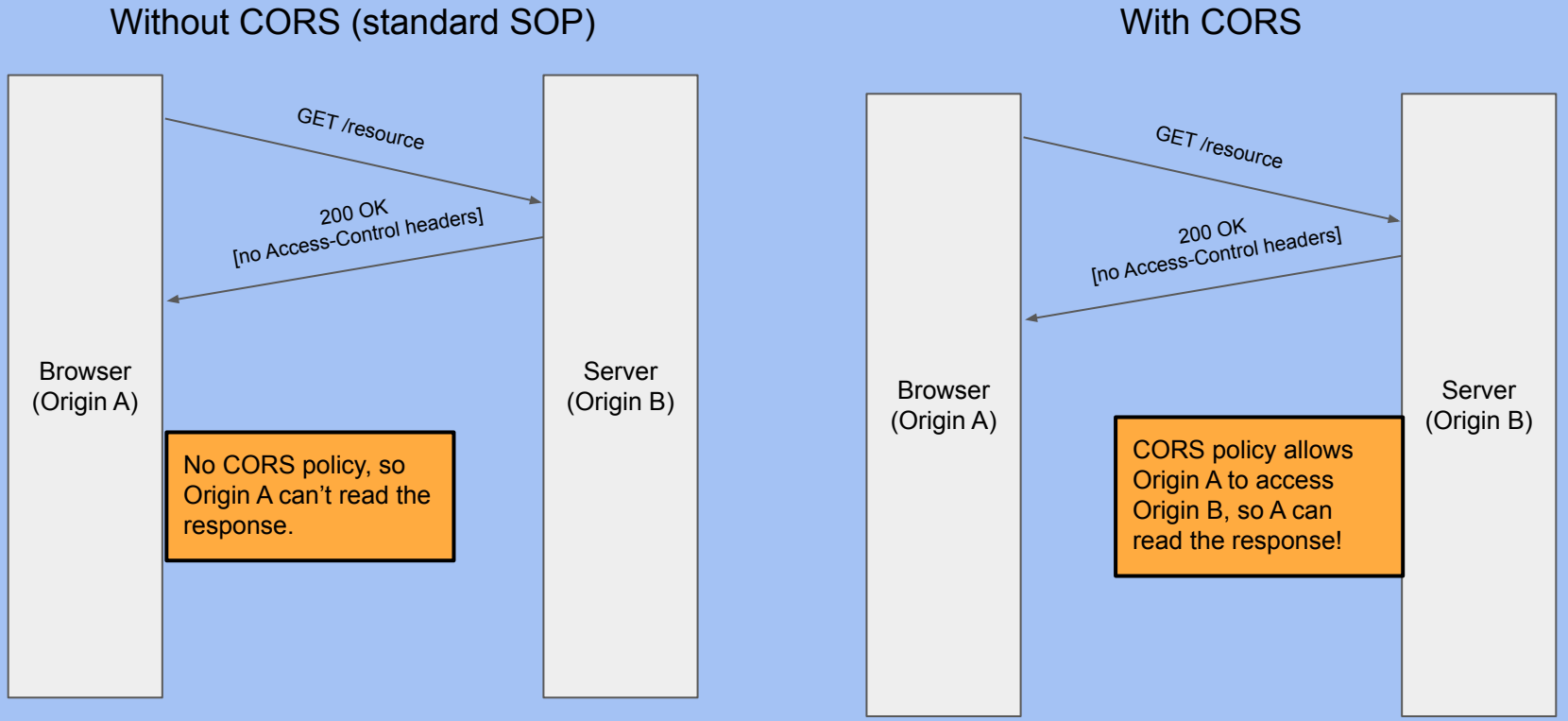
Avoid GET Requests

- By default, cross-origin HTTP GET requests are allowed
  - Images, iframes, etc. use GET requests
  - GET requests are assumed to be “nondestructive,” so SOP allows cross-origin GET requests to be made since they *shouldn’t* affect the remote origin
    - SOP disallows reading the response, though
  - If `GET https://www.bank.com/transfer?amount=100&to=Mallory` causes money to be transferred, this is “destructive”!
- For destructive requests, use POST or PUT requests instead
  - SOP disallows cross-origin POST or PUT requests since they *should* affect the remote origin
  - `POST https://www.bank.com/transfer` is destructive, so it would be blocked

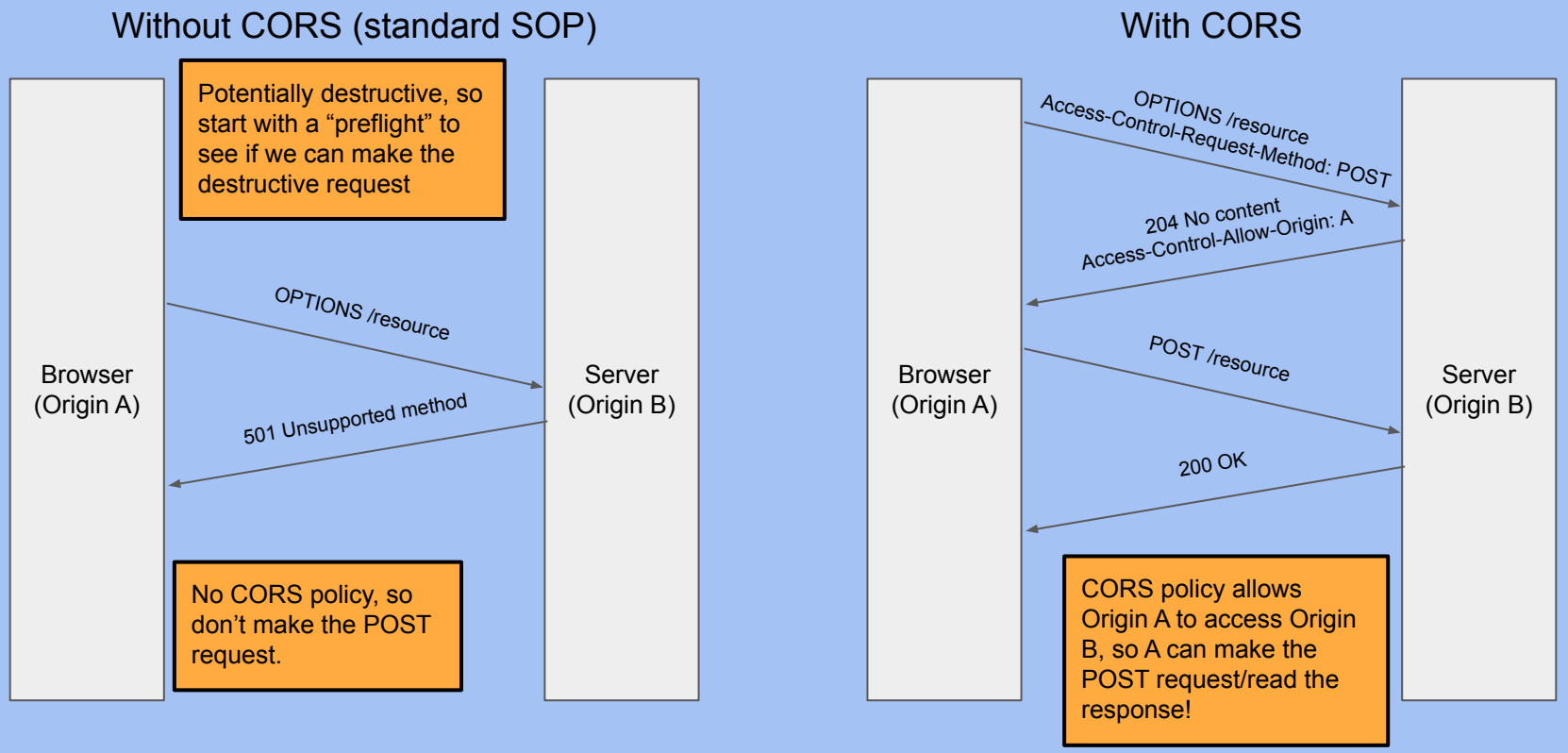
Relaxing Same-Origin Policy: CORS

- Sometimes, sites want to allow other origins to bypass the same-origin policy
  - HTTP databases, public resource distribution sites (CDNs), etc.
- **Cross-Origin Resource Sharing** (**CORS**): A set of response headers to for sites to specify exceptions to the same-origin policy
  - **Access-Control-Allow-Origin**: Allow these origins to access my origin
  - **Access-Control-Allow-Methods**: Allow these requests to be made to my origin
  - Other headers exist to tune fine-grained access control!
- For destructive requests (POST/PUT/etc.), we can't risk sending a POST request since we don't know if it's allowed yet, so start with an additional OPTIONS "preflight" request and see if the appropriate Access-Control headers are returned

Example: Cross-Origin GET



Example: Cross-Origin POST



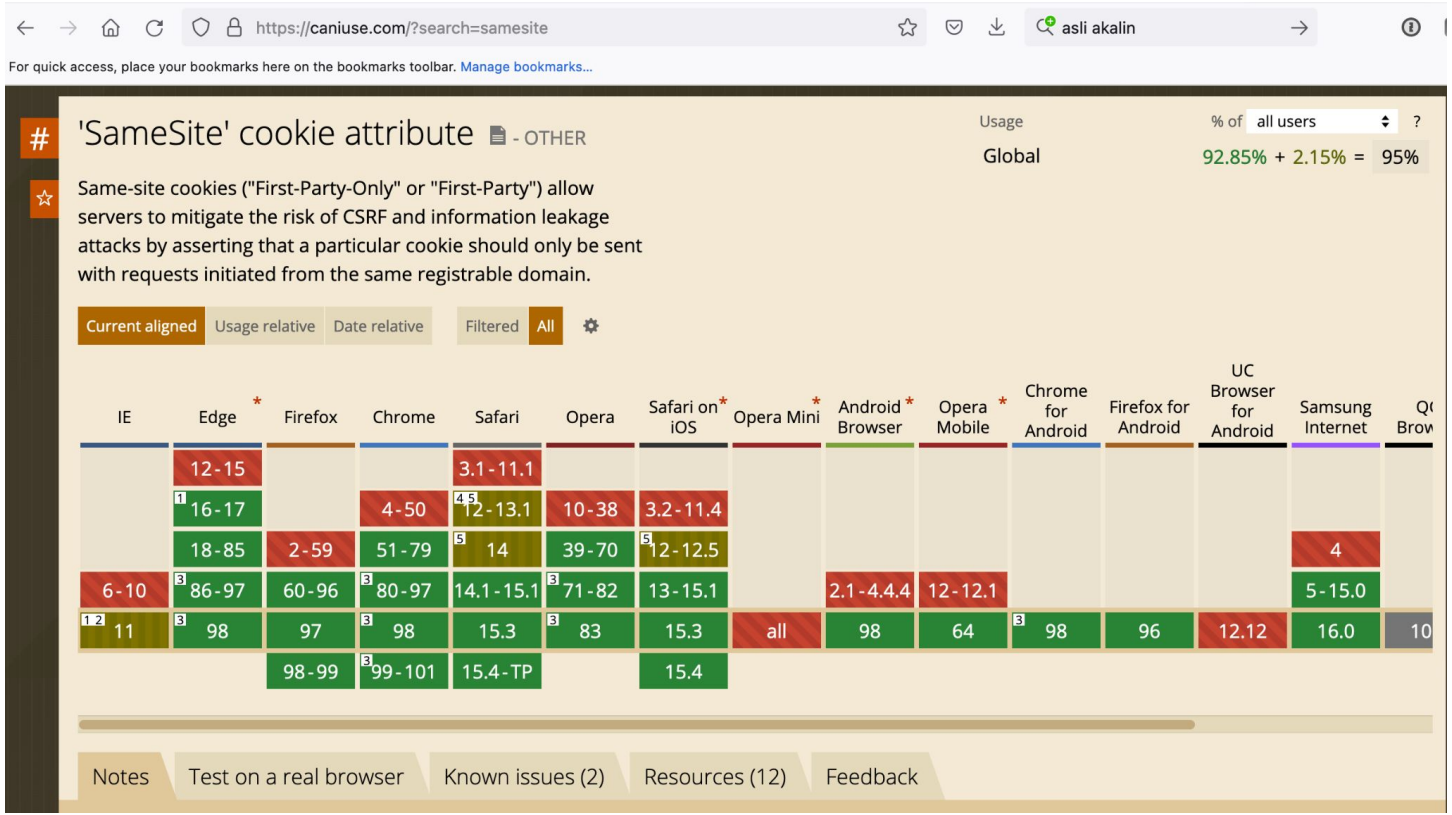
CORS

- **Takeaway**: Sometimes security measures can get in the way. Security and usability are always traded off.
  - Option 1: Find workarounds that fit within the security constraints
    - Example: Cross-origin image GETs are used to exfiltrate information in the URL
  - Option 2: Find ways to relax the security measures *securely*
    - CORS allows cross-origin requests when both sides consent
    - A remote origin must opt-in to resource sharing, with very fine access controls

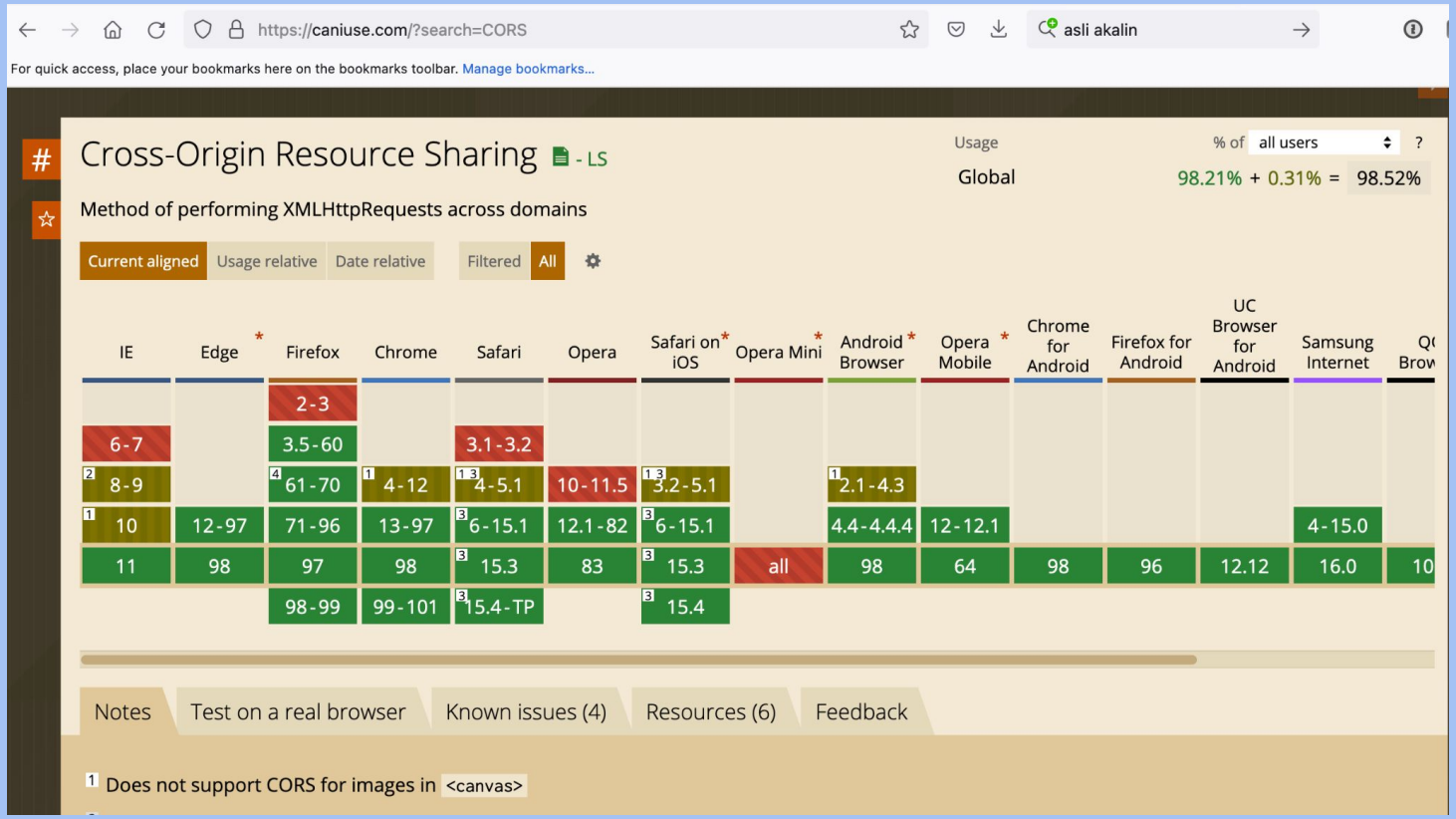
Inconsistencies Across Browsers

- All the different web browsers are subtly different
  - They may or may not support various features and protocol extensions
- This is especially critical on a set of security extensions
  - Example: Is the “SameSite” cookie attribute supported?
  - What happens if a browser does **not** support a given feature?
- **caniuse.com**: A website that aggregates data on browser support for features
  - Outputs the percentage of users that use a browser that supports the feature
  - Look it up!
  - Run tests on a large number of browsers to see what works and what doesn't

Can I Use SameSite Cookies?



Can I Use CORS?



Mitigating Browser Inconsistency

- There are many security features added to browsers in recent years
  - Example: Per-origin isolation, rather than just per-tab isolation
  - Example: SameSite cookie attributes
  - Lots of others we will see…
- If you are deploying something where security matters, **strongly** consider mandating that only “modern” browsers are supported
  - Latest Firefox, Edge, Chrome, Safari, and the mobile versions
  - Users of older browsers must either update or not use the site

Cookies: Summary

- Cookie: a piece of data used to maintain state across multiple requests
  - Set by the browser or server
  - Stored by the browser
  - Attributes: Name, value, domain, path, secure, HttpOnly, expires
- Cookie policy
  - Server with domain X can set a cookie with domain attribute Y if the domain attribute is a **domain suffix** of the server's domain, and the domain attribute Y is not a top-level domain (TLD)
  - The browser attaches a cookie on a request if the domain attribute is a **domain suffix** of the server's domain, and the path attribute is a **prefix** of the server's path

Session Authentication: Summary

- Session authentication
  - Use cookies to associate requests with an authenticated user
  - First request: Enter username and password, receive session token (as a cookie)
  - Future requests: Browser automatically attaches the session token cookie
- Session tokens
  - If an attacker steals your session token, they can log in as you
  - Should be randomly and securely generated by the server
  - The browser should not send tokens to the wrong place

CSRF: Summary

- Cross-site request forgery (CSRF or XSRF): An attack that exploits cookie-based authentication to perform an action as the victim
  - User authenticates to the server
    - User receives a cookie with a valid session token
  - Attacker tricks the victim into making a malicious request to the server
  - The server accepts the malicious request from the victim
    - Recall: The cookie is automatically attached in the request
- Attacker must trick the victim into creating a request
  - GET request: click on a link
  - POST request: use JavaScript

CSRF Defenses: Summary

- CSRF token: A secret value provided by the server to the user. The user must attach the same value in the request for the server to accept the request.
  - The attacker does not know the token when tricking the user into making a request
- Referer Header: Allow same-site requests, but disallow cross-site requests
  - Header may be blank or removed for privacy reasons
- Same-site cookie attribute: The cookie is sent only when the domain of the cookie exactly matches the domain of the origin
  - Not implemented on all browsers
- Avoid GET requests: Same-origin policy allows GET requests to be made but not PUT or POST requests
  - CORS allows origins to opt in to more relaxed origin policy