CS 253: Web Security
Same Origin Policy

```
<Cthon98> hey, if you type in your pw, it will show as stars
<Cthon98> ********* see!
<AzureDiamond> hunter2
<AzureDiamond> doesnt look like stars to me
<Cthon98> <AzureDiamond> *******
<Cthon98> thats what I see
<AzureDiamond> oh, really?
<Cthon98> Absolutely
<AzureDiamond> you can go hunter2 my hunter2-ing hunter2
<AzureDiamond> haha, does that look funny to you?
<Cthon98> lol, yes. See, when YOU type hunter2, it shows to us as *******
<AzureDiamond> thats neat, I didnt know IRC did that
<Cthon98> yep, no matter how many times you type hunter2, it will show to us as *******
<AzureDiamond> awesome!
<AzureDiamond> wait, how do you know my pw?
<Cthon98> er, I just copy pasted YOUR ******'s and it appears to YOU as hunter2 cause its your pw
<AzureDiamond> oh, ok.
```

What should be allowed?

- Should site A be able to **link to** site B?
- Should site A be able to **embed** site B?
- Should site A be able to **embed** site B and **modify** its contents?
- Should site A be able to **submit a form** to site B?
- Should site A be able to **embed images** from site B?
- Should site A be able to **embed scripts** from site B?
- Should site A be able to **read data** from site B?

Same Origin Policy

- This is the fundamental security model of the web
- **If you remember one thing from this class, this is it:**
  - Two pages from different sources should not be allowed to interfere with each other

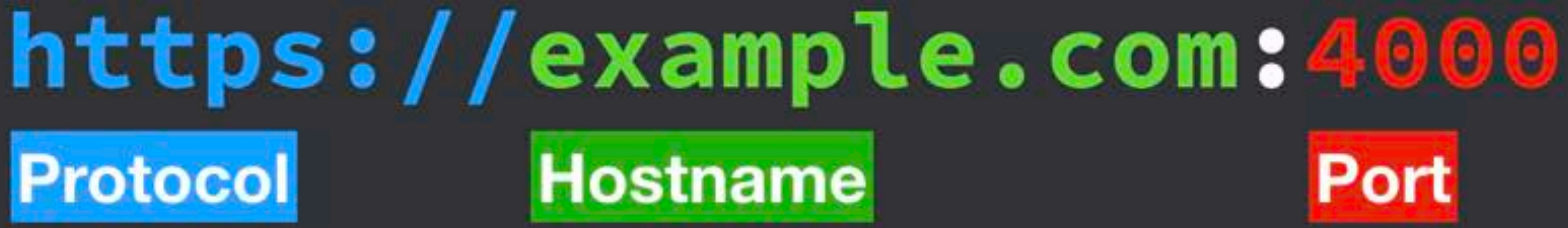
The web is an operating system

- An **origin** is analogous to an OS **process**
- The **web browser** itself is analogous to an OS **kernel**
- Sites rely on the browser to enforce all the system's security rules
  - Just like in OSes, if there's a bug in the browser itself then all these rules go out the window

The basic rule

- Given **two separate JavaScript execution contexts**, one should be able to access the other only if the **protocols, hostnames, and port numbers** associated with their host documents **match exactly**.
- This **"protocol-host-port tuple"** is called an **"origin"**.

```
https://example.com:4000/a/b.html?user=Alice&year=2019#p2
Protocol  Hostname  Port Path    Query              Fragment
```



```
https://example.com:4000
```

Same origin policy

```
function isSameOrigin (url1, url2) {
  return url1.protocol === url2.protocol &&
    url1.hostname === url2.hostname &&
    url1.port === url2.port
}
```

What should be allowed?

- Which actions should be subject to security checks?
- Where does one document begin or end?
- What is an origin?
- How much interaction should be allowed between non-cooperating origins?

Demo: Same origin policy

Recall

From **https://web.stanford.edu/class/cs106a/:**

```
document.cookie = 'sessionId=1234; Path=/class/cs106a/'
```

From **https://web.stanford.edu/class/cs253/:**

```
const iframe = document.createElement('iframe')
iframe.src = 'https://web.stanford.edu/class/cs106a/'
document.body.appendChild(iframe)
console.log(iframe.contentDocument.cookie)
```

Demo: Same origin policy + iframes

From **https://web.stanford.edu/class/cs253/:**

```
const iframe = document.createElement('iframe')
iframe.src = 'https://crypto.stanford.edu'
document.body.append(iframe)

console.log(iframe.contentDocument.cookie) // Not allowed!

iframe.src = 'https://example.com' // Allowed! Surprised?
```

Demo: Is cross-origin `fetch` allowed?

From **https://web.stanford.edu/class/cs253/**:

```
const res = await fetch('https://axess.stanford.edu')
const data = await res.body.text()
console.log(data)
```

- No! Would be a huge violation of Same Origin Policy.
- Any site in the world could read your grades if you're logged into Axess in another tab!

Same origin or not?

- `https://example.com/a/` → `https://example.com/b/`
  - Yes!
- `https://example.com/a/` → `https://www.example.com/b/`
  - No! Hostname mismatch!
- `https://example.com/` → `http://example.com/`
  - No! Protocol mismatch!
- `https://example.com/` → `https://example.com:81/`
  - No! Port mismatch!
- `https://example.com/` → `https://example.com:80/`
  - Yes!

Problems

- Sometimes policy is too **narrow**: Difficult to get **login.stanford.edu** and **axess.stanford.edu** to exchange data.
- Sometimes policy is too **broad**: No way to isolate **https://web.stanford.edu/class/cs106a/** from **https://web.stanford.edu/class/cs253/** ...much to CS 106A staff's disappointment! 😉
- Policy is not enforced for certain web features!
  - You need to know which ones!

document.domain

- Idea: Need a way around Same Origin Policy to allow two different origins to communicate
- Two cooperating sites can agree that for the purpose of Same Origin Policy checks, they want to be considered equivalent.
- Sites must share a common top-level domain.
- Example: both **login.stanford.edu** and **axess.stanford.edu** may perform the following assignment:

```
document.domain = 'stanford.edu'
```

`document.domain` requires opt-in

- Both origins must explicitly opt-in to this feature
- So, if **attacker.stanford.edu** runs:

```
document.domain = 'stanford.edu'
```

- Then **attacker.stanford.edu** still cannot access content on **stanford.edu**!
- **stanford.edu** also needs to run the same code to opt-in to this behavior:

```
document.domain = 'stanford.edu'
```

- This is not a no-op, despite how it looks!

Originating URL	`document.domain`	Accessed URL	`document.domain`	Allowed?
`http://www.example.com/`	`example.com`	`http://payments.example.com/`	`example.com`	?
`http://www.example.com/`	`example.com`	`https://payments.example.com/`	`example.com`	?
`http://payments.example.com/`	`example.com`	`http://example.com/`	(not set)	?
`http://www.example.com/`	(not set)	`http://www.example.com/`	`example.com`	?

Originating URL	`document.domain`	Accessed URL	`document.domain`	Allowed?
`http://www.example.com/`	`example.com`	`http://payments.example.com/`	`example.com`	Yes
`http://www.example.com/`	`example.com`	`https://payments.example.com/`	`example.com`	No
`http://payments.example.com/`	`example.com`	`http://example.com/`	(not set)	No
`http://www.example.com/`	(not set)	`http://www.example.com/`	`example.com`	No

`document.domain` is a bad idea

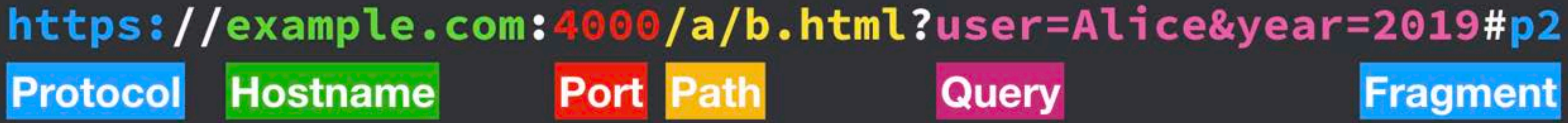
- In order for **login.stanford.edu** and **axess.stanford.edu** to communicate, they must set:

```
document.domain = 'stanford.edu'
```

- This allows anyone on **stanford.edu** to join the party
  - Example: **attacker.stanford.edu** can also set **`document.domain`** to **stanford.edu** to become same origin with the others

Send messages from a parent page to a child iframe

- Idea: Need a way around Same Origin Policy to allow two different origins to communicate
- What if we encoded data in URL fragment identifiers?
  - Gap in same origin policy!
  - Parent is allowed to navigate child iframes
  - Child can poll for changes to the fragment identifier



```
https://example.com:4000/a/b.html?user=Alice&year=2019#p2
```

Demo: Fragment identifier cross-origin communication

Demo: Fragment identifier cross-origin communication

parent.html:

```
<h1>localhost:4000</h1>
<input name='val' />
<br /><br />
<iframe src='http://localhost:4001/child.html'></iframe>
<script>
  const input = document.querySelector('input')
  const iframe = document.querySelector('iframe')
  input.addEventListener('input', () => {
    iframe.src = `http://localhost:4001/child.html#${encodeURIComponent(input.value)}`
  })
</script>
```

child.html:

```
<h1>localhost:4001</h1>
<div></div>
<script>
  const div = document.querySelector('div')
  setInterval(() => {
    div.textContent = decodeURIComponent(window.location.hash).slice(1)
  }, 100)
</script>
```

The `postMessage` API

- Secure cross-origin communications between cooperating origins
- Send strings and arbitrarily complicated data cross-origin
- Useful features:
  - "Structured clone" algorithm used for complicated objects. Handles cycles. Can't handle object instances, functions, DOM nodes.
  - "Transferrable objects" allows transferring ownership of an object. It becomes unusable (neutered) in the context it was sent from.

Demo: `postMessage` cross-origin communication

parent.html:

```
<h1>localhost:4000</h1>
<input name='val' />
<br /><br />
<iframe src='http://localhost:4001/child.html'></iframe>
<script>
  const input = document.querySelector('input')
  const iframe = document.querySelector('iframe')
  input.addEventListener('input', () => {
    iframe.contentWindow.postMessage(input.value, 'http://localhost:4001')
  })
</script>
```

child.html:

```
<h1>localhost:4001</h1>
<div></div>
<script>
  const div = document.querySelector('div')
  window.addEventListener('message', event => {
    if (event.origin !== 'http://localhost:4000') return
    div.textContent = event.data
  })
</script>
```

More realistic example

- **`axess.stanford.edu`** wants to display name of logged in user, so it registers a listener for messages:

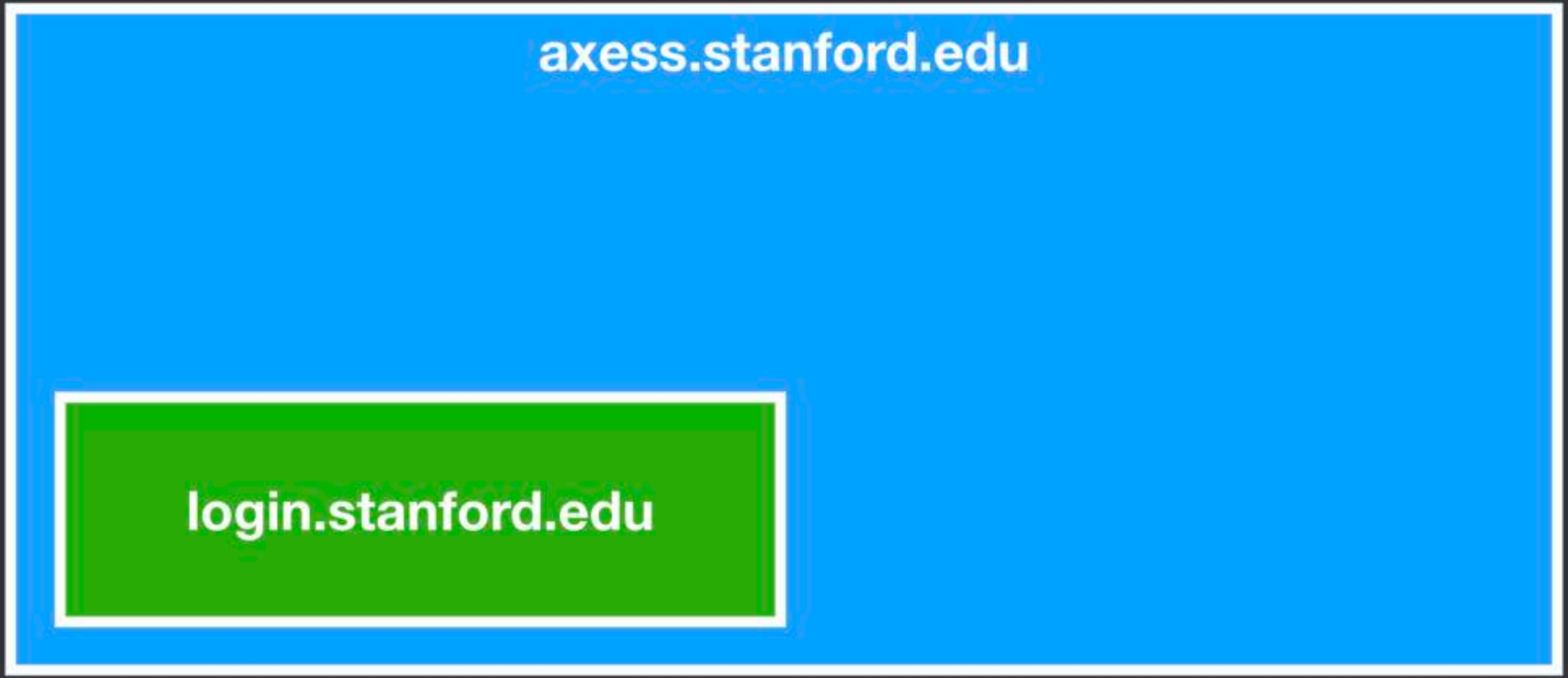
```
window.addEventListener('message', event => {
  setCurrentUser(event.data.name)
})
```

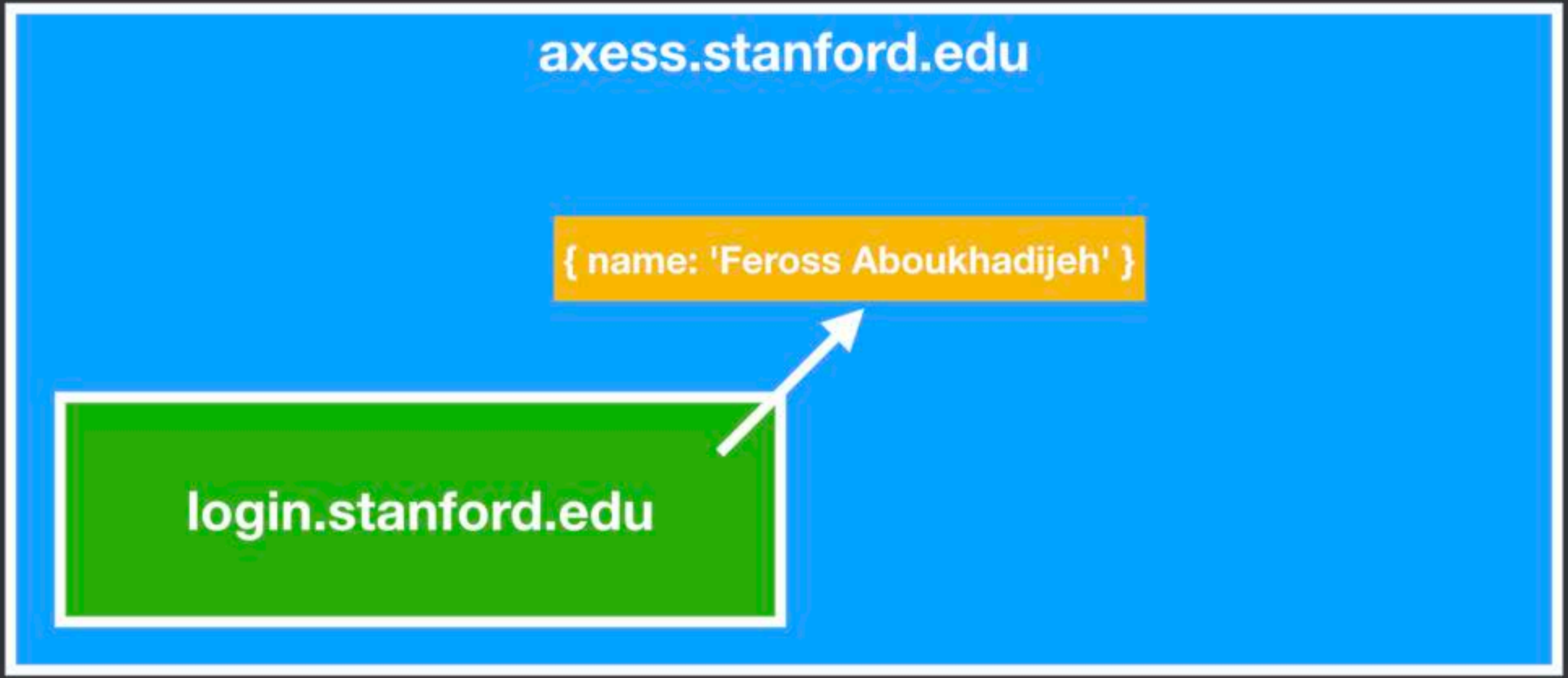
- Then it embeds an iframe to **`login.stanford.edu`** which runs:

```
const data = { name: 'Feross Aboukhadijeh' }
window.parent.postMessage(data, '*')
```

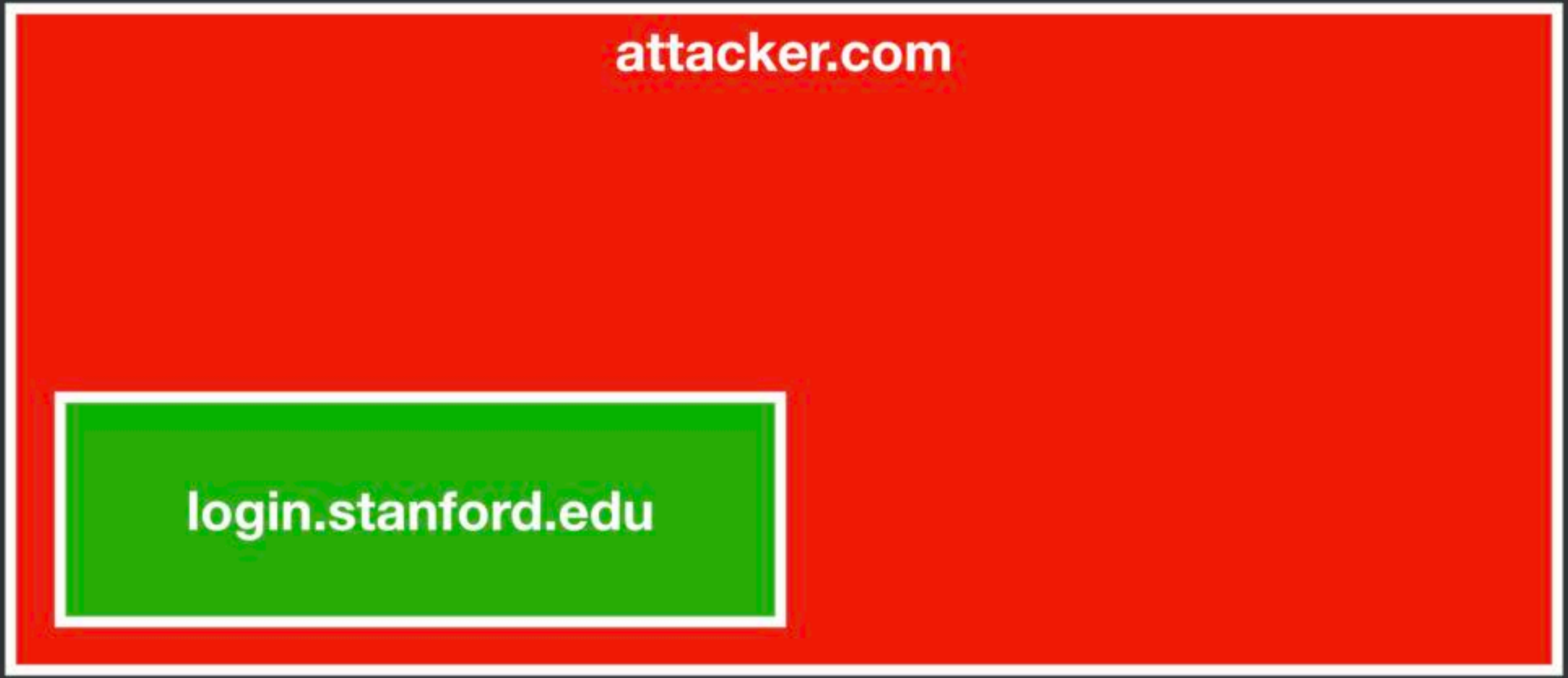
- This is insecure! Why?

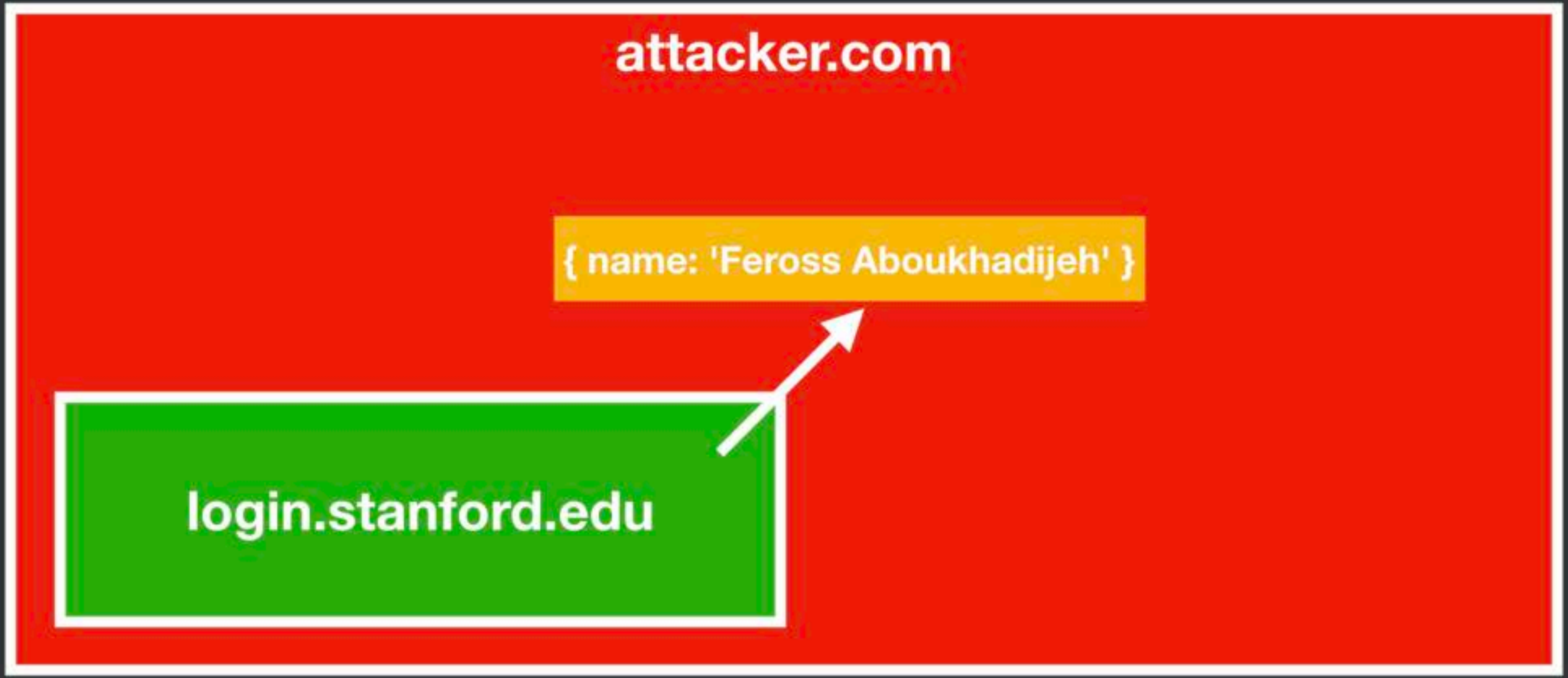
axess.stanford.edu


axess.stanford.edu
login.stanford.edu


axess.stanford.edu
{ name: 'Feross Aboukhadijeh' }
login.stanford.edu

attacker.com


attacker.com
login.stanford.edu

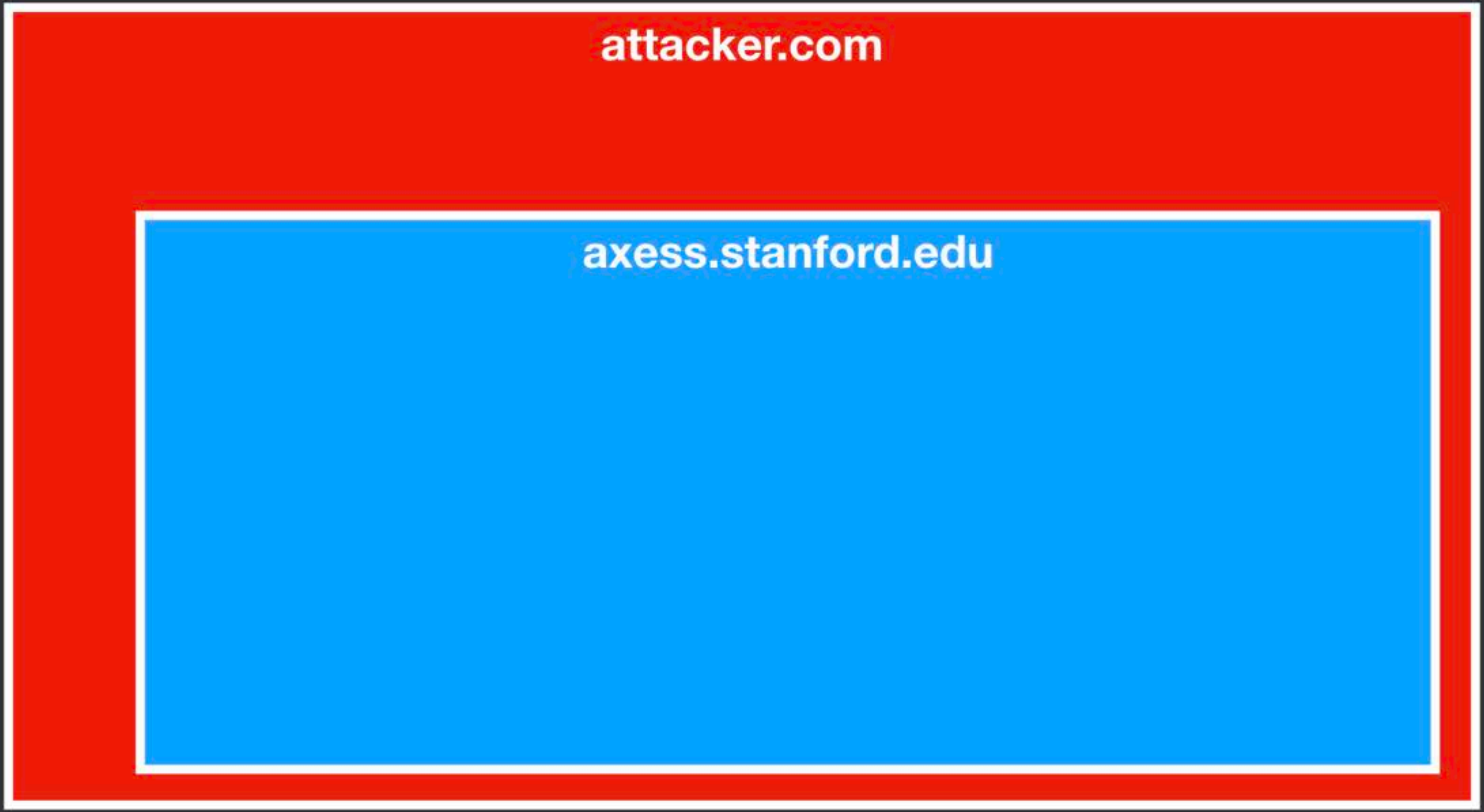

attacker.com
{ name: 'Feross Aboukhadijeh' }
login.stanford.edu

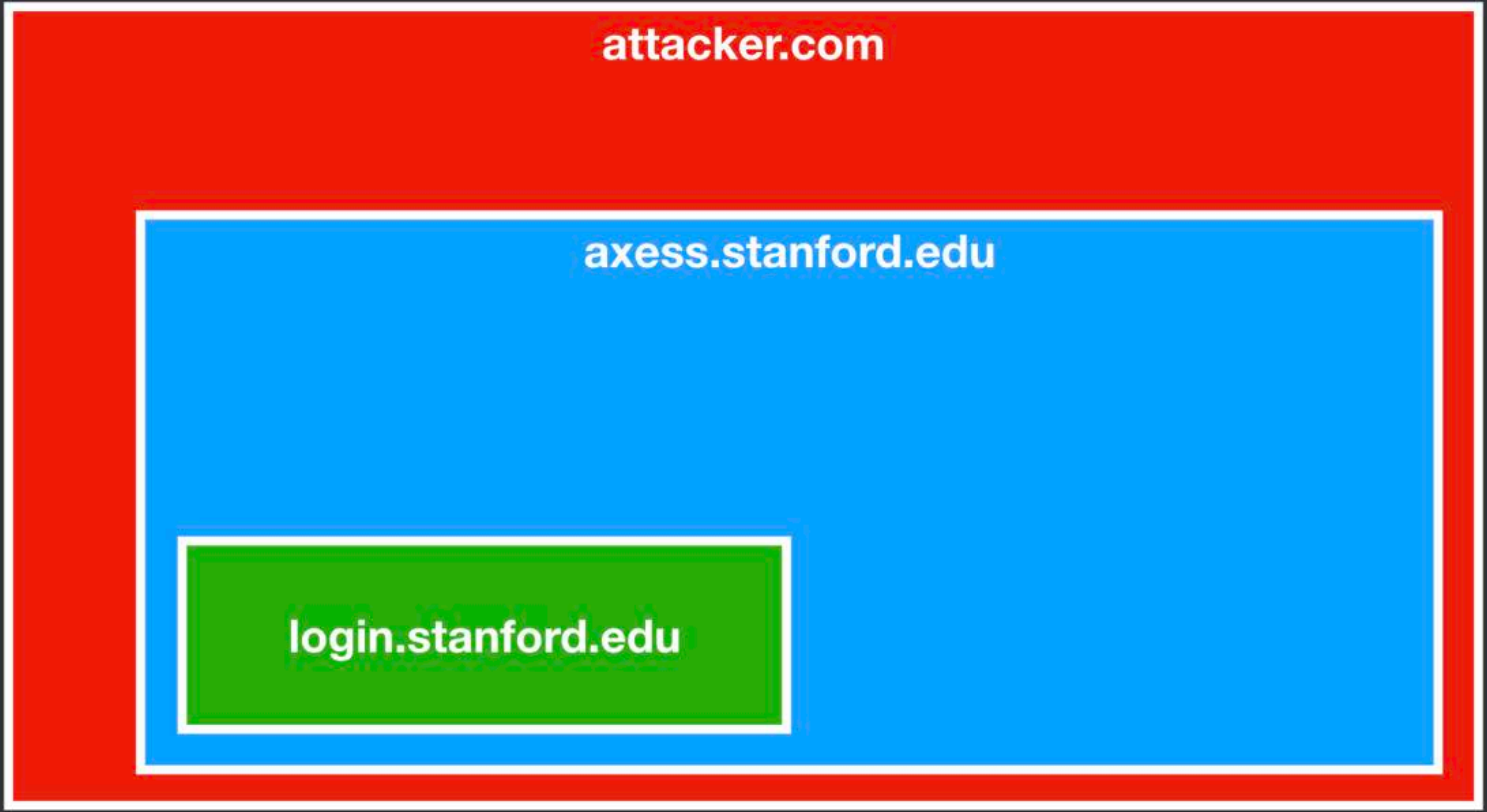
Need to validate destination of messages!

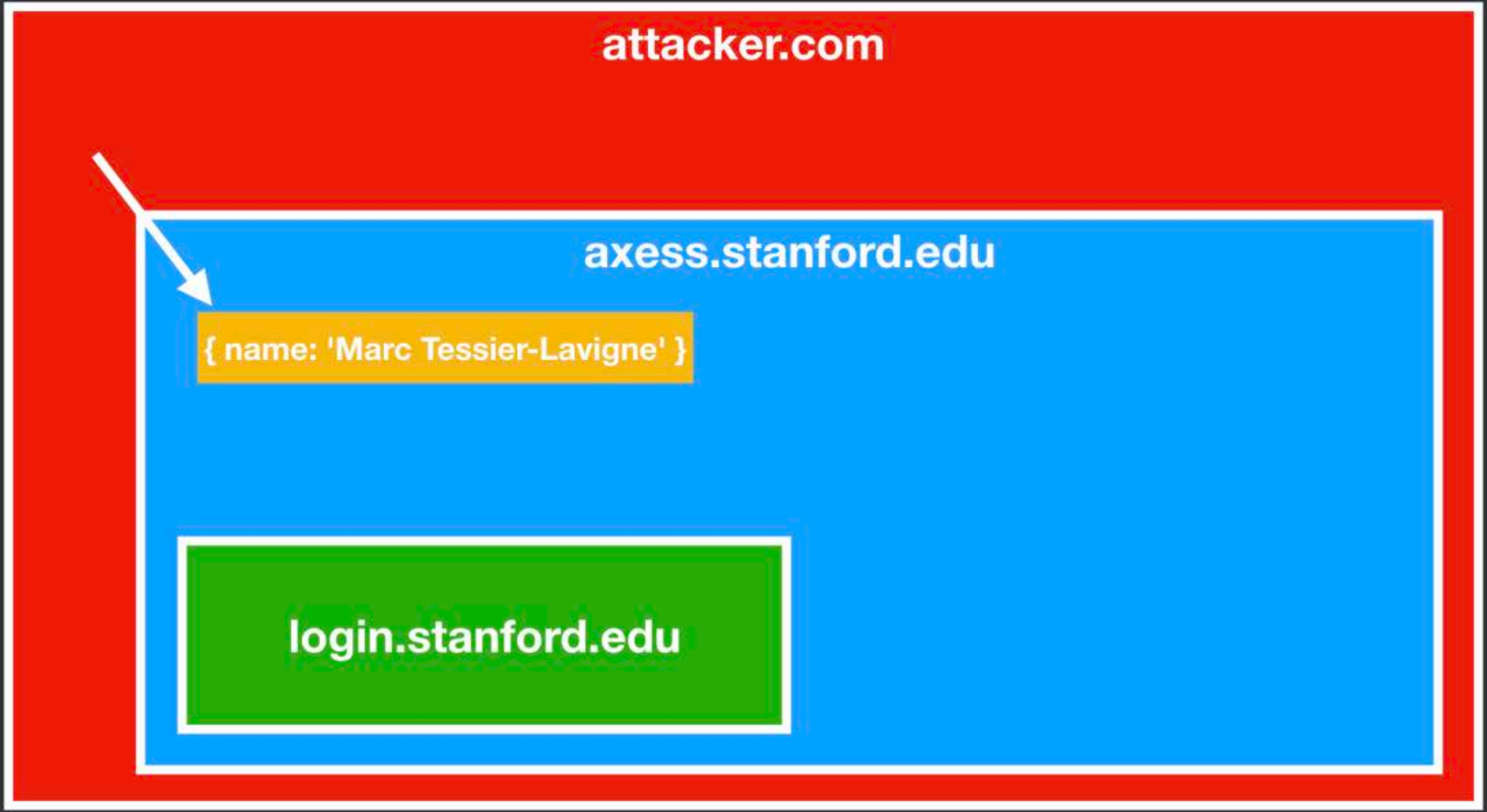
- If an attacker embeds **login.stanford.edu**, they can listen to it's message which reveals the name of the logged in user!
- Solution: **login.stanford.edu** should specify intended recipient origin. Browser will enforce this.

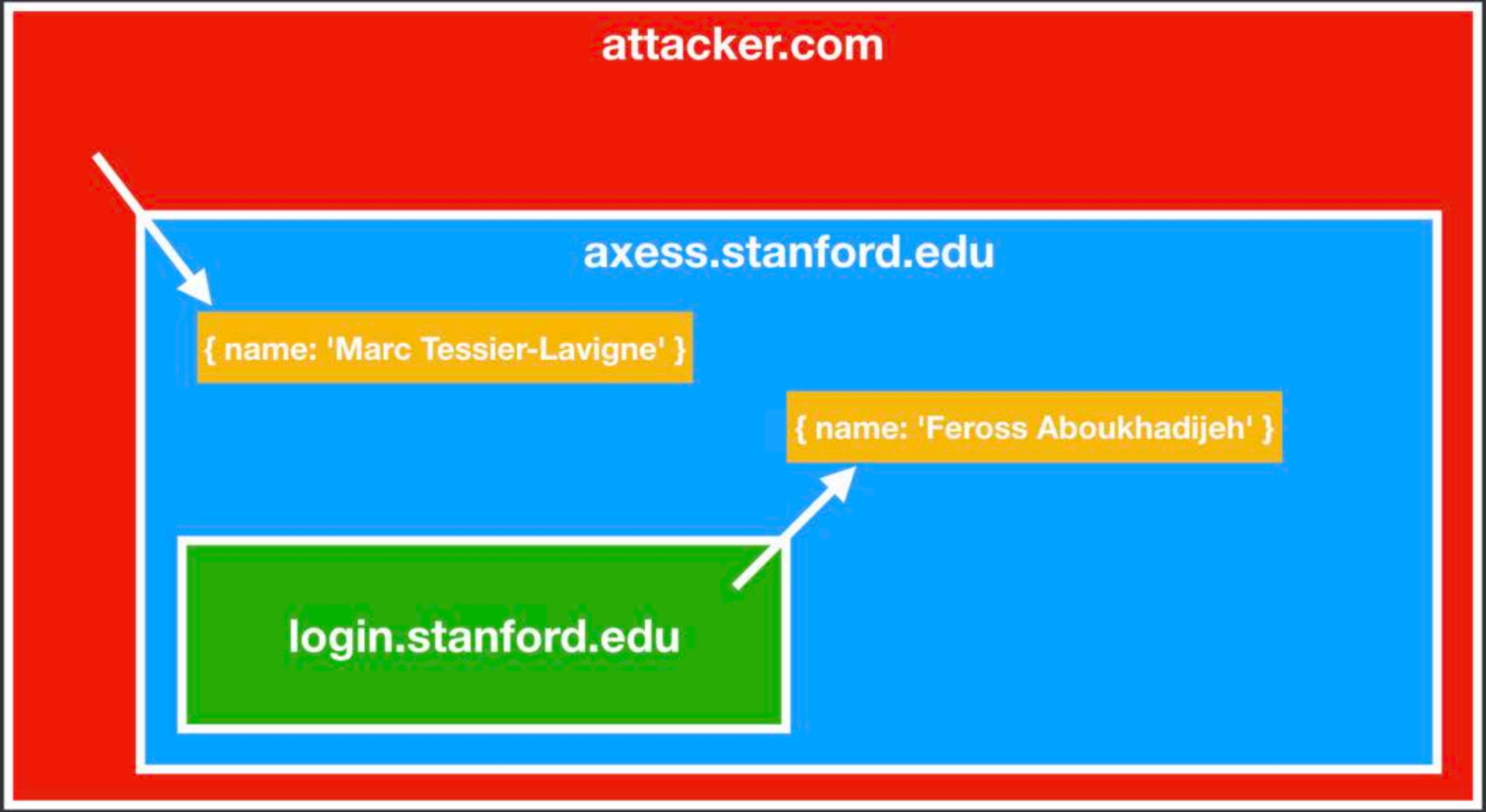
```
const data = { name: 'Feross Aboukhadijeh' }
window.parent.postMessage(data, 'https://axess.stanford.edu')
```

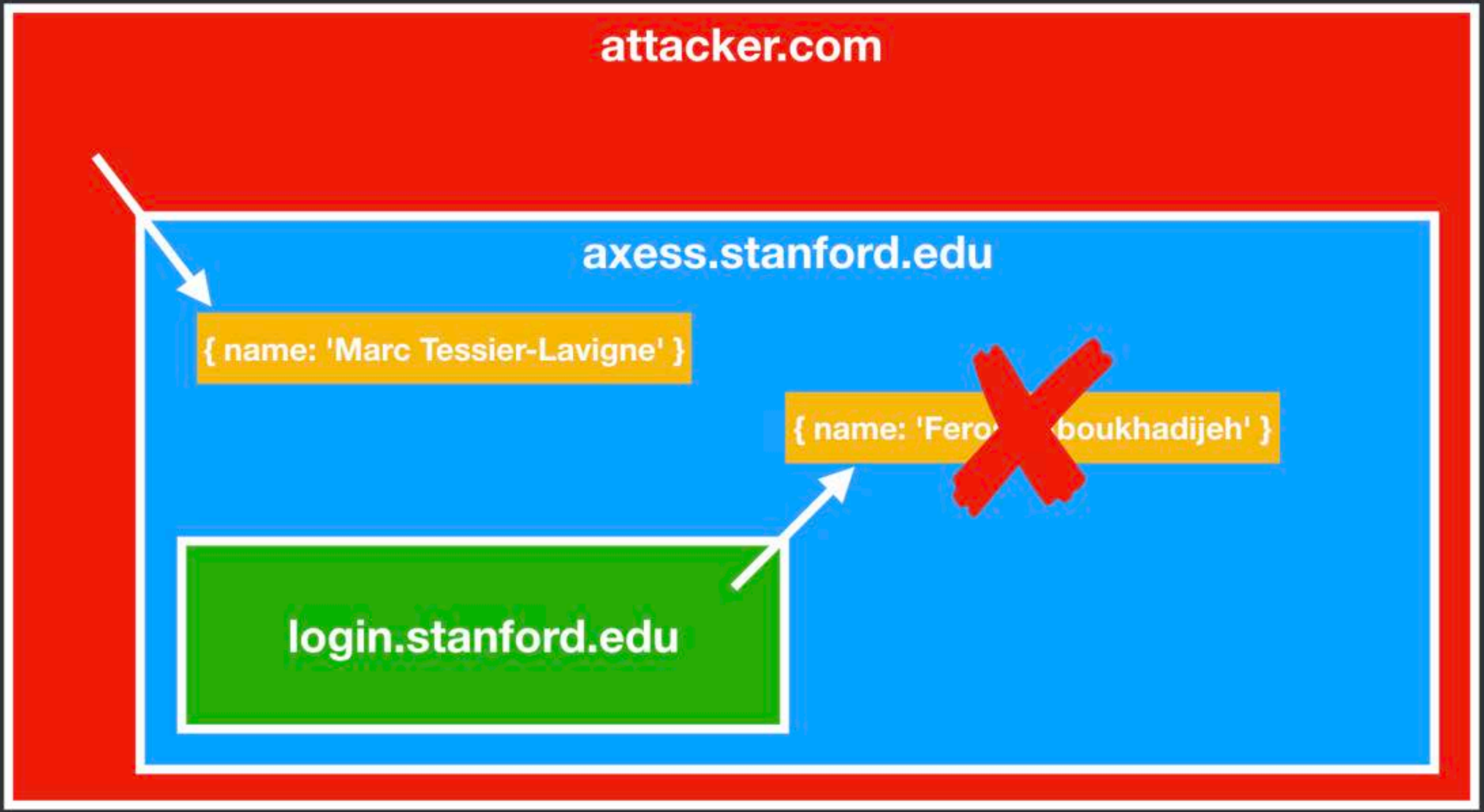
attacker.com


attacker.com
axess.stanford.edu


attacker.com
axess.stanford.edu
login.stanford.edu


attacker.com
axess.stanford.edu
{ name: 'Marc Tessier-Lavigne' }
login.stanford.edu


attacker.com
axess.stanford.edu
{ name: 'Marc Tessier-Lavigne' }
{ name: 'Feross Aboukhadijeh' }
login.stanford.edu


attacker.com
axess.stanford.edu
{ name: 'Marc Tessier-Lavigne' }
{ name: 'Fero boukhadijeh' }
login.stanford.edu

Need to validate source of messages!

- If an attacker has a reference to a **axess.stanford.edu** window (by e.g. embedding it in an iframe), they can send a message to it to trick it!
- Solution: **axess.stanford.edu** should verify source origin of message!

```
window.addEventListener('message', event => {
  if (event.origin !== 'https://login.stanford.edu') return
  setCurrentUser(event.data.name)
})
```

Integrity of `postMessage`

- **Sender** must specify origin which is permitted to receive message
  - In case the URL of the target window has changed
- **Recipient** must validate the identity of the sender
  - In case some other window is sending the message
- ***Remember:*** *Always specify intended recipient or expected sender!*

Same origin policy exceptions

- **Summary:** There are **explicit opt-out** mechanisms like **`document.domain`**, fragment identifier communication, and the **`postMessage`** API
- There are also **automatic exceptions**
  - Need to be aware of these!
  - Source of many security issues!

Same origin policy exceptions

- Which of these requests from **example.com** are allowed?

```html
<!doctype html>
<html lang='en'>
  <head>
    <meta charset='utf-8' />
    <link rel='stylesheet' href='https://other1.com/style.css' />
  </head>
  <body>
    <img src='https://other2.com/image.png' />
    <script src='https://other3.com/script.js'></script>
  </body>
</html>
```

Same origin policy exceptions

- **Answer:** All of them!
- Embedded static resources can come from another origin
  - Images (e.g. hotlinking to memes)
  - Scripts (e.g. Facebook like button, ads, tracking scripts)
  - Styles (e.g. Google Fonts)
- Why was it designed this way?

Same origin policy exceptions + ambient authority

- Remember: Ambient authority is implemented by cookies
- One consequence: **attacker.com** can embed user's real avatar from **target.com**:

```
<h1>Welcome to your account!</h1>
<img src='https://target.com/avatar.png' />
```

Solution: `SameSite` cookies

- Use **`SameSite`** cookie attribute to prevent cookie from being sent with requests initiated by other sites

From **target.com:**

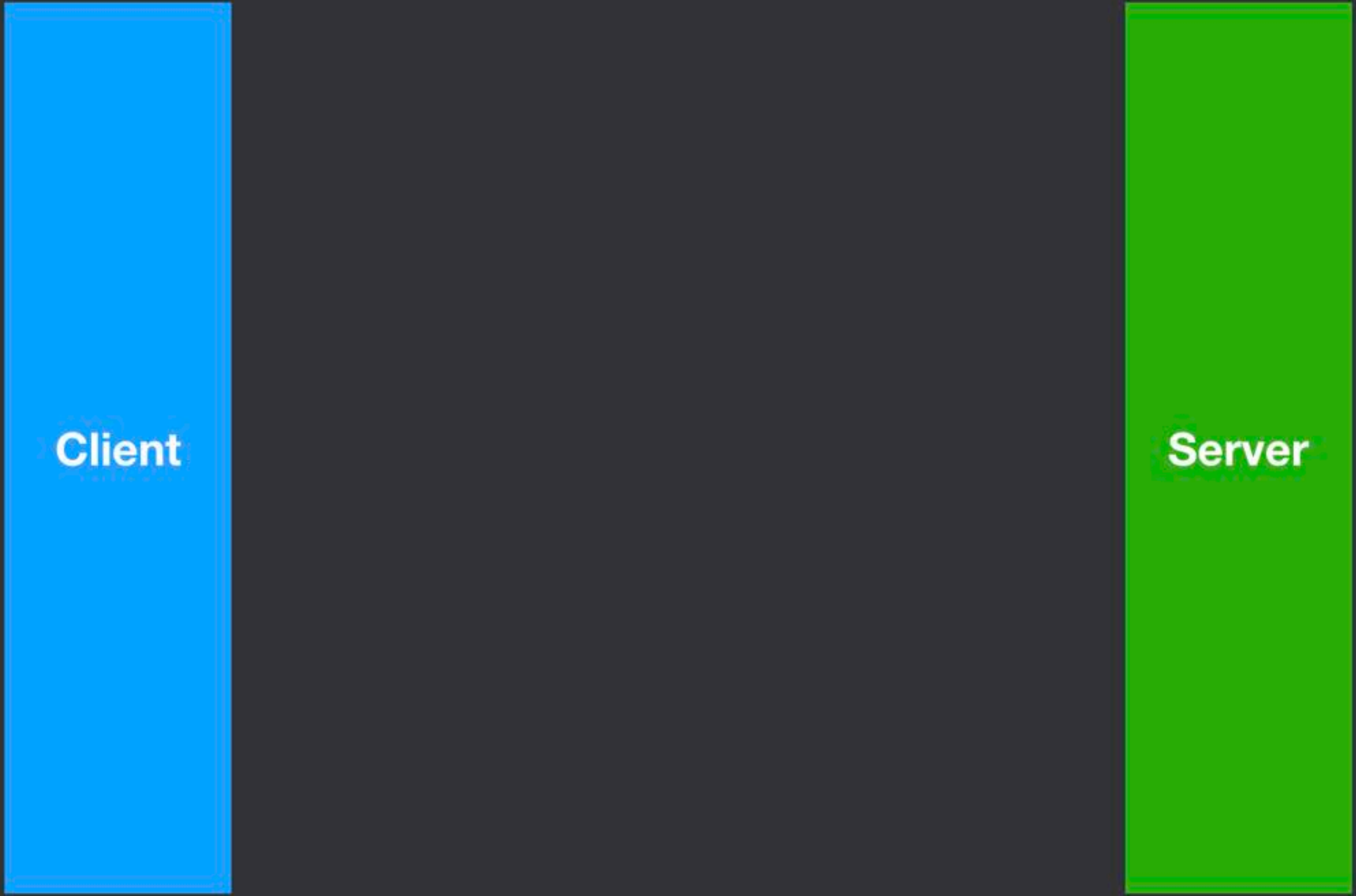
```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```

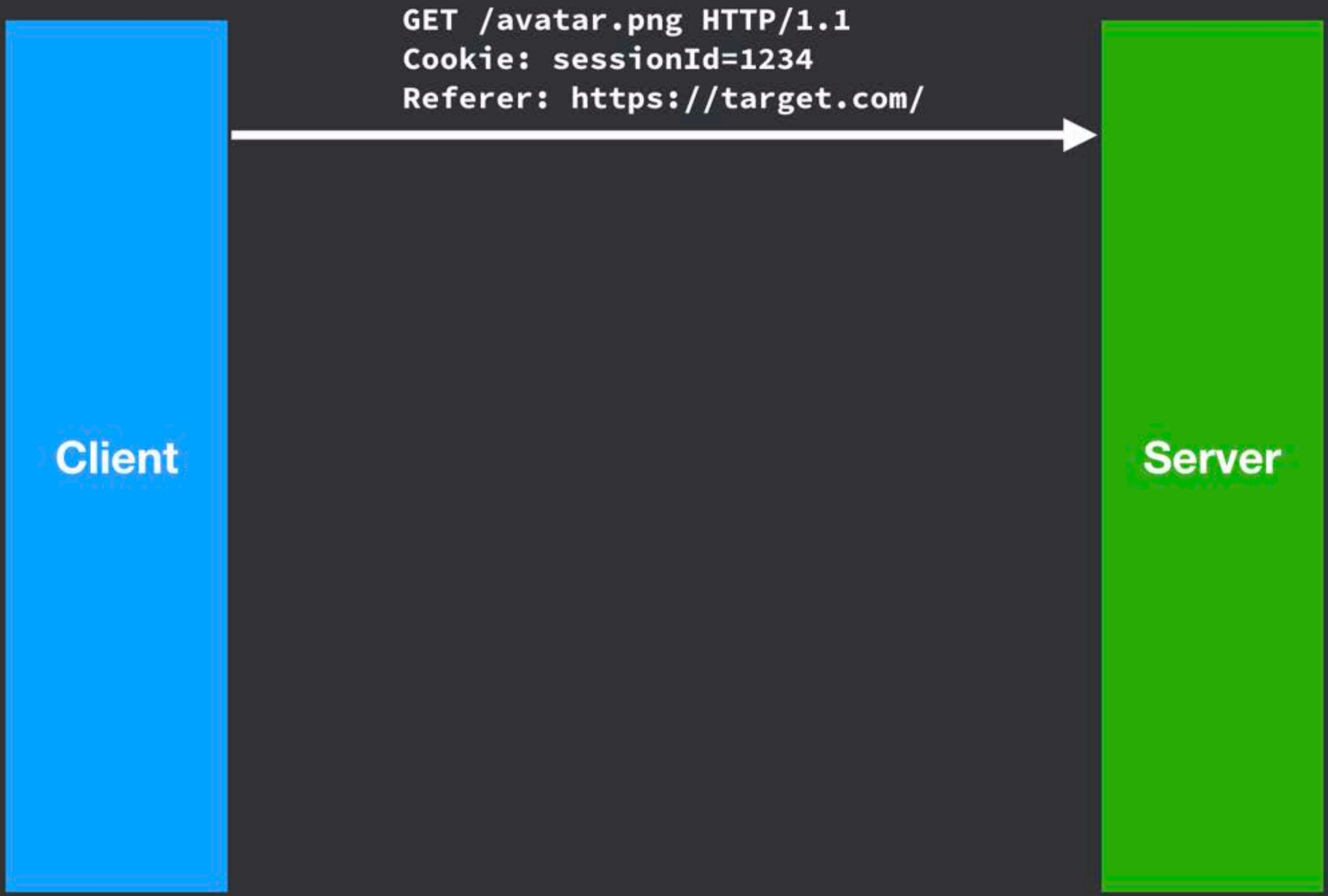
From **attacker.com:**

```
GET /avatar.png HTTP/1.1
Referer: https://attacker.com/
```

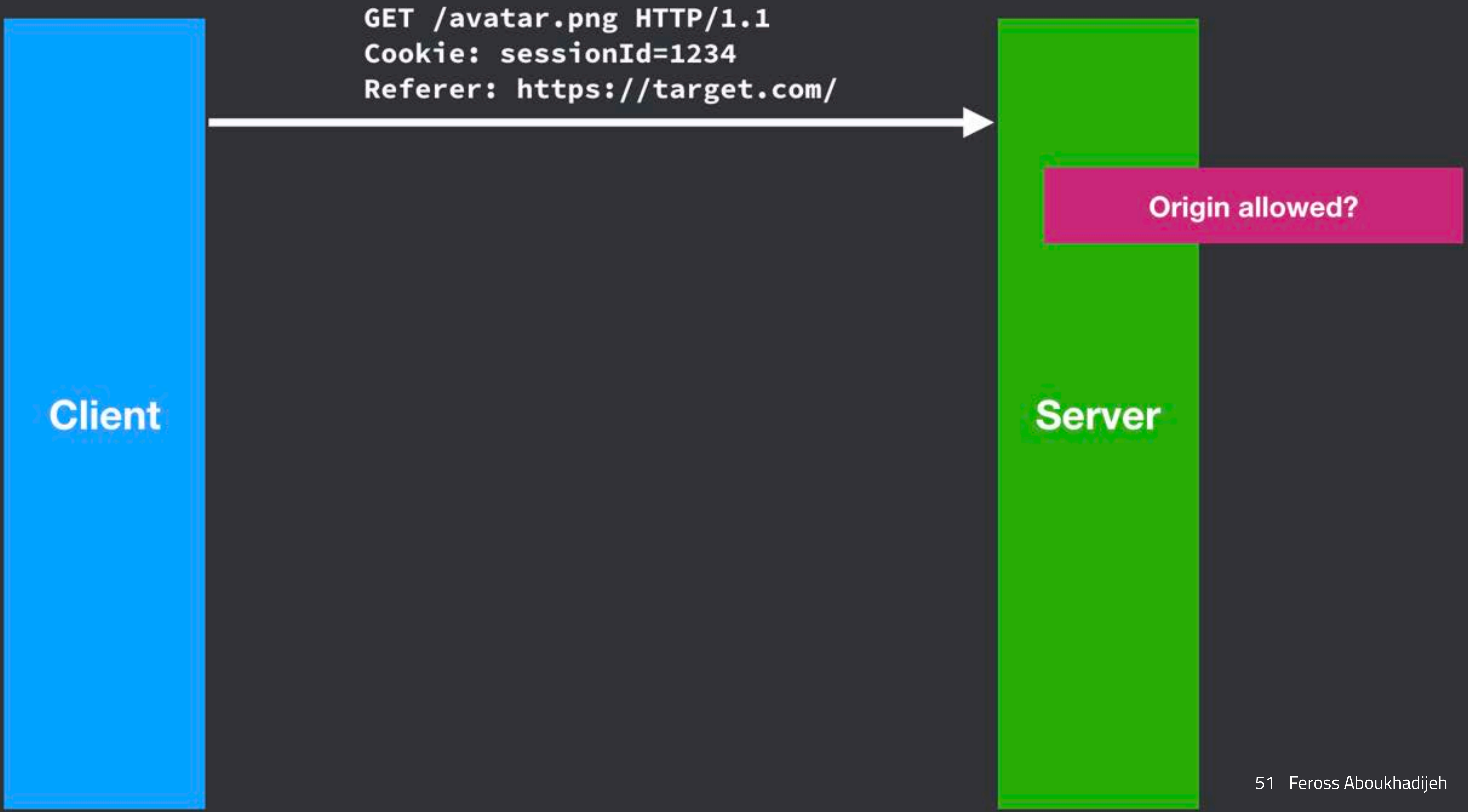
Solution: `Referer` header

- Inspect the **`Referer`** HTTP header
- Reject any requests from origins not on an "allowlist"
- One gotcha: Watch out for HTTP caches!

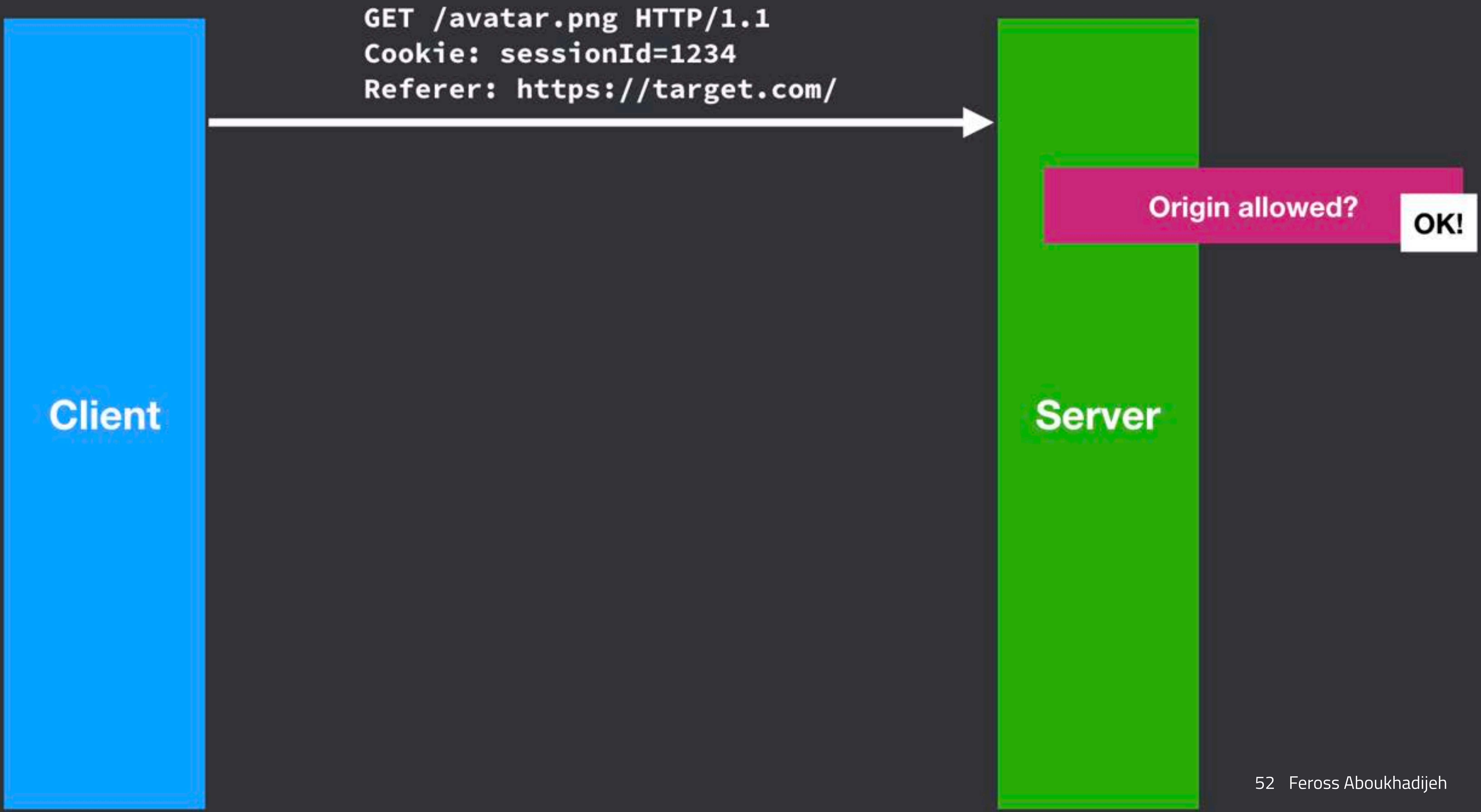

Client
Server



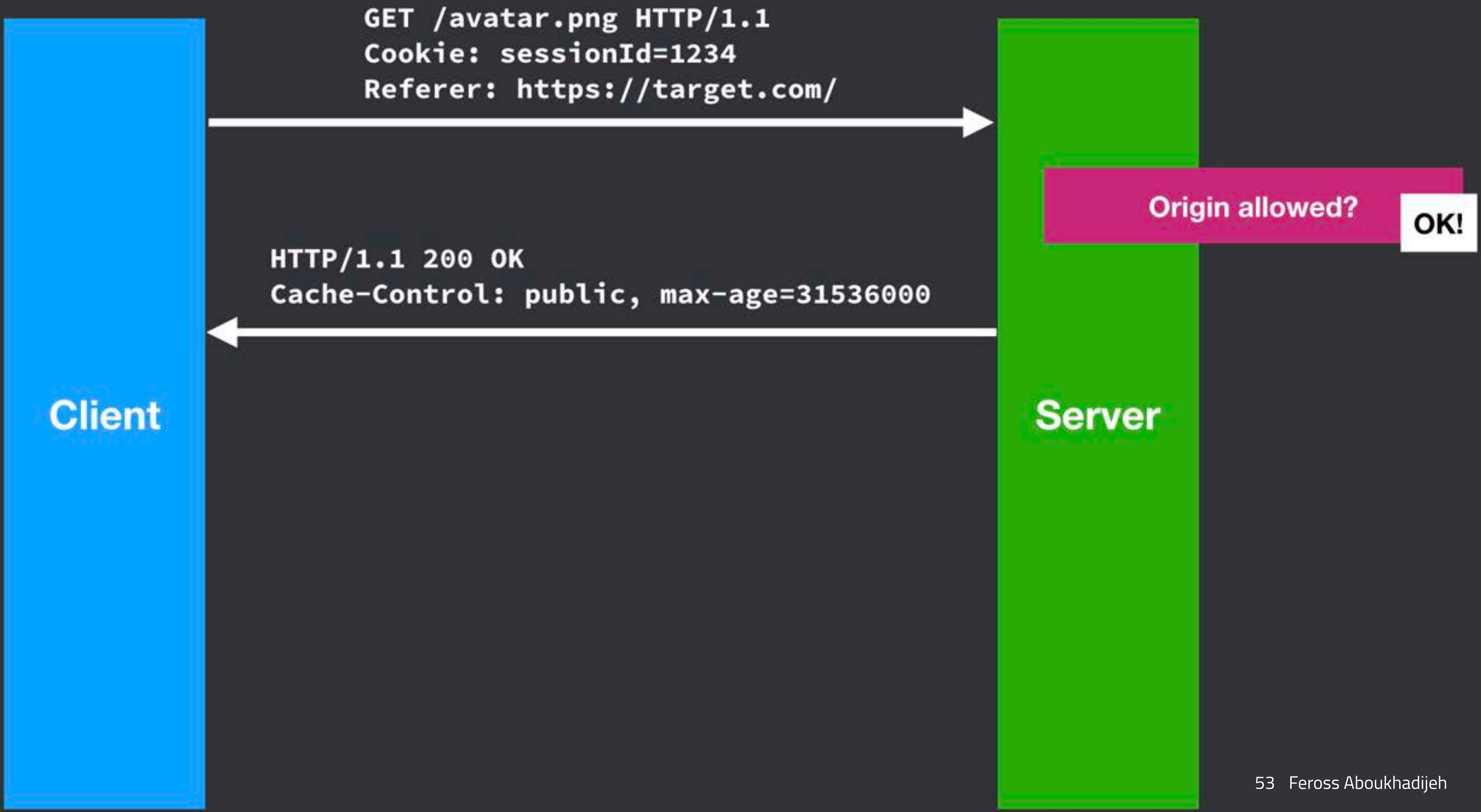
```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```



```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```

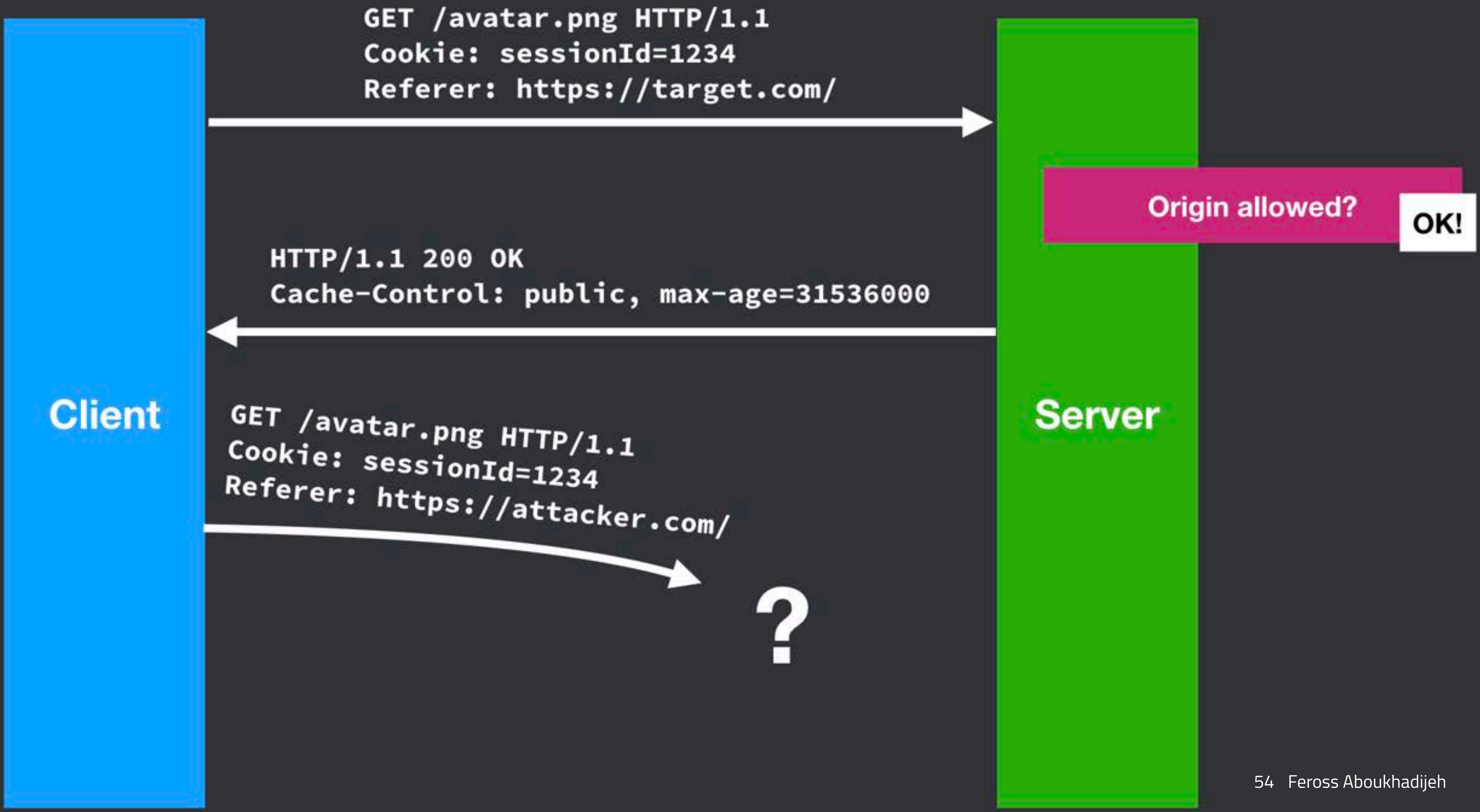


```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```



```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```

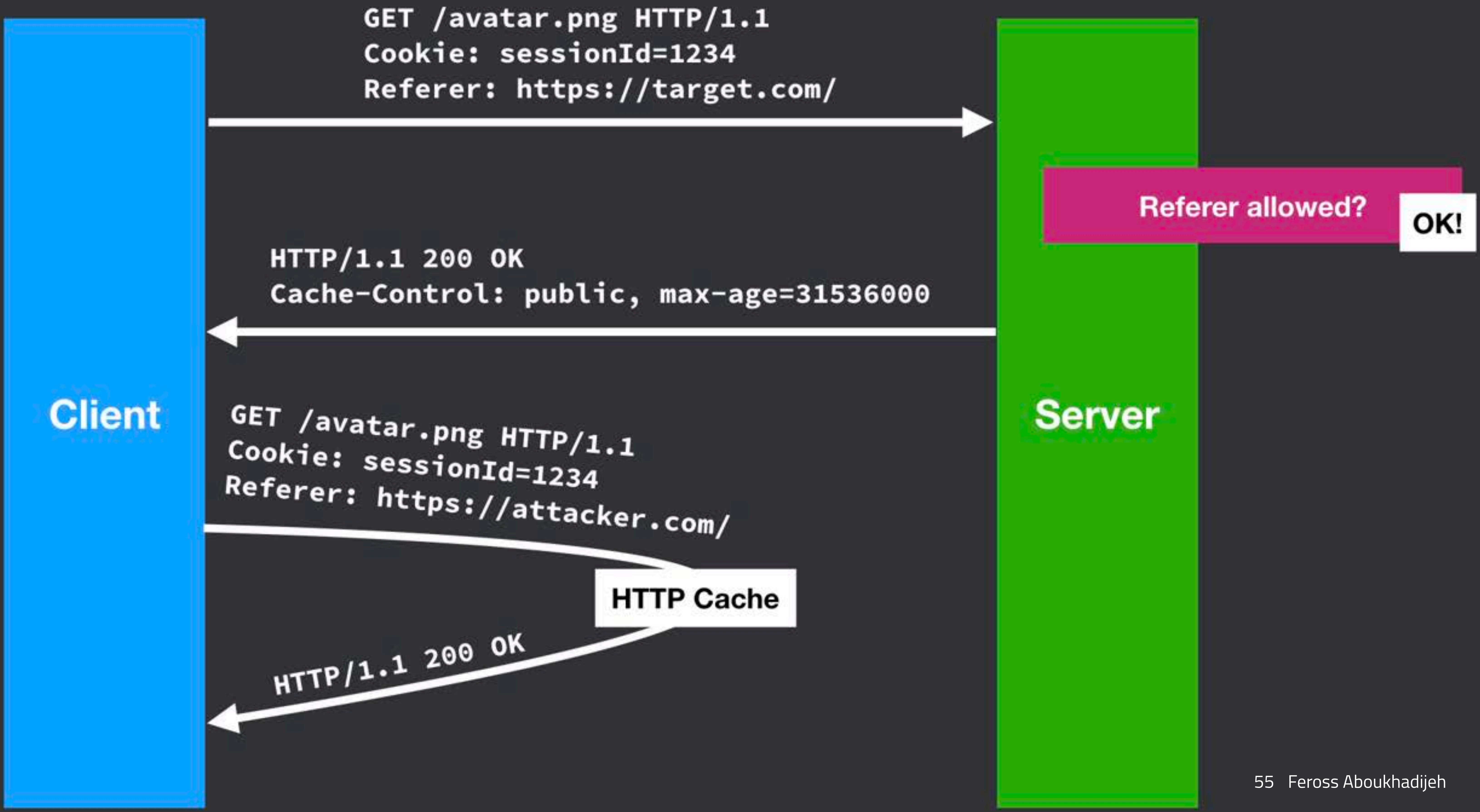
```
HTTP/1.1 200 OK
Cache-Control: public, max-age=31536000
```



```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```

```
HTTP/1.1 200 OK
Cache-Control: public, max-age=31536000
```

```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://attacker.com/
```



```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://target.com/
```

```
HTTP/1.1 200 OK
Cache-Control: public, max-age=31536000
```

```
GET /avatar.png HTTP/1.1
Cookie: sessionId=1234
Referer: https://attacker.com/
```

```
HTTP/1.1 200 OK
```

Solution: `Referer` header

- Inspect the **`Referer`** HTTP header
- Reject any requests from origins not on an "allowlist"
- One gotcha: Watch out for HTTP caches!
  - Add a **`Vary: Referer`** header
  - Or, add a **`Cache-Control: no-store`** header
- Another gotcha: Sites can opt out of sending the **`Referer`** header!
  - Defeats this whole mechanism. So, just use **`SameSite`** cookies!

Same origin policy exceptions + ambient authority

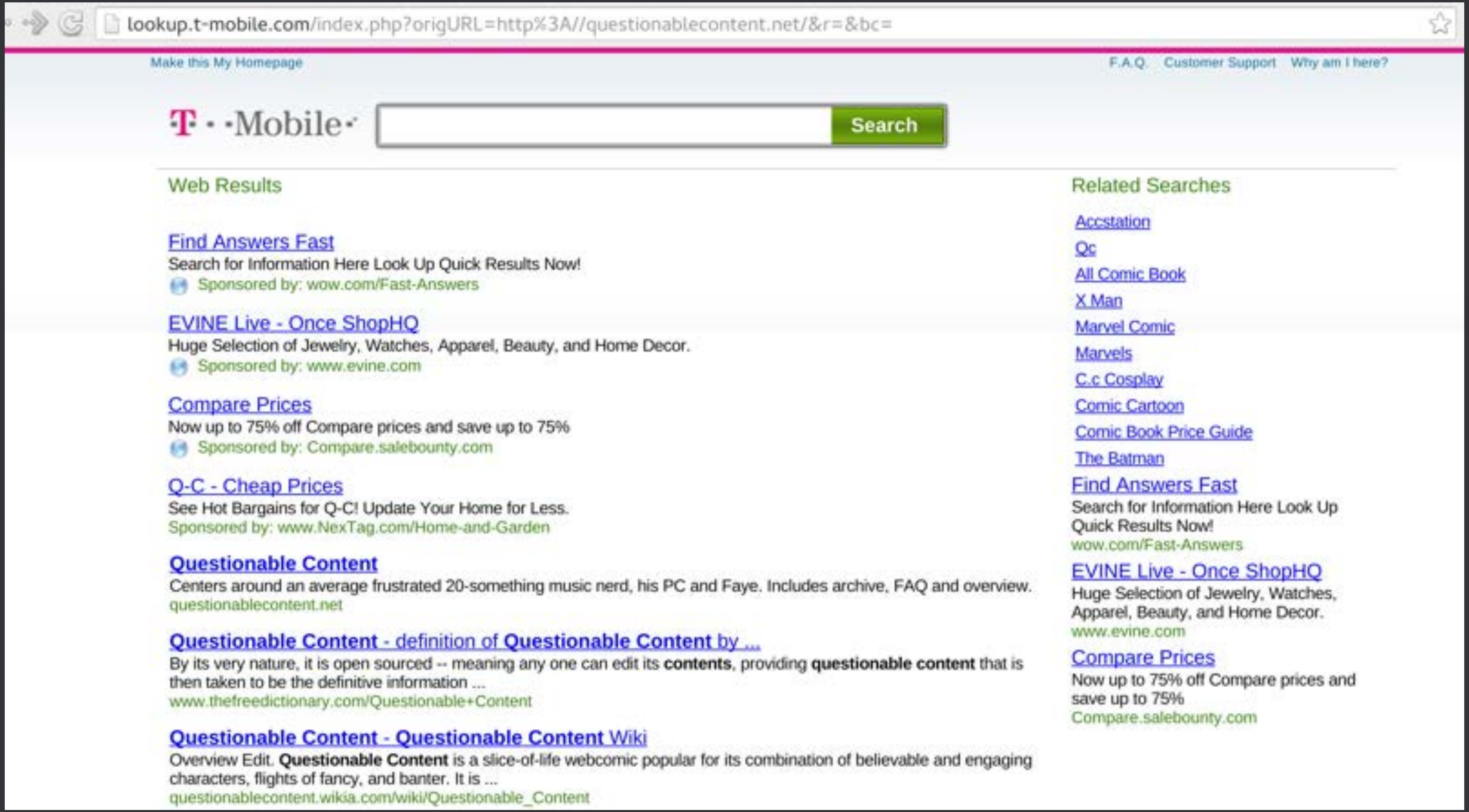
- Remember: Forms are allowed to post to another origin!

```
<form method='POST' action='http://localhost:4000/transfer'>
  <input name='amount' value='100' />
  <input name='to' value='alice' />
  <input type='submit' value='Send' />
</form>
<script>
  document.forms[0].submit()
</script>
```

Cookies don't obey Same Origin Policy

- Cookies were created before Same Origin Policy so have different security model
- Cookies are **more specific** than Same Origin Policy
  - **`Path`** is ineffective because same origin pages can access each other's DOMs
- Cookies are **less specific** than Same Origin Policy
  - Different origins can mess with each others cookies (e.g. **`attacker.stanford.edu`** can set cookies for **`stanford.edu`**)
  - This is why Stanford login is **`login.stanford.edu`** and not **`stanford.edu/login`**

Cookies + "legitimate" DNS hijacking



lookup.t-mobile.com/index.php?origURL=http%3A//questionablecontent.net/&r=&bc=

Make this My Homepage

F.A.Q. Customer Support Why am I here?

T · ·Mobile·

Search

Web Results

Find Answers Fast
Search for Information Here Look Up Quick Results Now!
Sponsored by: wow.com/Fast-Answers

EVINE Live - Once ShopHQ
Huge Selection of Jewelry, Watches, Apparel, Beauty, and Home Decor.
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Compare Prices
Now up to 75% off Compare prices and save up to 75%
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Q-C - Cheap Prices
See Hot Bargains for Q-C! Update Your Home for Less.
Sponsored by: www.NexTag.com/Home-and-Garden

Questionable Content
Centers around an average frustrated 20-something music nerd, his PC and Faye. Includes archive, FAQ and overview.
questionablecontent.net

Questionable Content - definition of **Questionable Content** by ...
By its very nature, it is open sourced -- meaning any one can edit its **contents**, providing **questionable content** that is then taken to be the definitive information ...
www.thefreedictionary.com/Questionable+Content

Questionable Content - **Questionable Content** Wiki
Overview Edit. **Questionable Content** is a slice-of-life webcomic popular for its combination of believable and engaging characters, flights of fancy, and banter. It is ...
questionablecontent.wikia.com/wiki/Questionable_Content

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The Batman

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wow.com/Fast-Answers

EVINE Live - Once ShopHQ
Huge Selection of Jewelry, Watches, Apparel, Beauty, and Home Decor.
www.evine.com

Compare Prices
Now up to 75% off Compare prices and save up to 75%
Compare.salebounty.com

Cookies + "legitimate" DNS hijacking

- If advertising page wants, it can steal cookies
  - **nonexistent.example.com** is different origin than **example.com**, yet can access cookies
- If advertising page contains a malicious third-party script, the script can steal cookies
- If advertising page contains a cross-site scripting issue (but **example.com** doesn't), then ***anyone*** can steal cookies
  - Attacker causes user to visit **nonexistent.example.com/<some-attack-code>**
  - DNS is hijacked by advertising page which includes **<some-attack-code>** in page
  - As before, **nonexistent.example.com** can access **example.com** cookies, even though it's another origin

What is allowed?

- Is site A allowed to **link to** site B? ***Yes!***
- Is site A allowed to **embed** site B? ***Yes!***
- Is site A allowed to **embed** site B and **modify** its contents? ***No!***
- Is site A allowed to **submit a form** to site B? ***Yes!***
- Is site A allowed to **embed images** from site B? ***Yes!***
- Is site A allowed to **embed scripts** from site B? ***Yes!***
- Is site A allowed to **read data** from site B? ***No!***

Final thoughts

- Same Origin Policy is the security model of the web
  - Two pages from different sources should not be allowed to interfere with each other
- To make your site secure, understand:
  - There are important exceptions to the Same Origin Policy (images, scripts, iframes, form POSTs)
  - Avoid using broken mechanisms like cookie **`Path`** and **`document.domain`**

END

Credits: Michal Zalewski. “The Tangled Web.”