Cross Site Request Forgery

“Who Left Open the Cookie Jar”?

Partly based on Collin Jackson et al’s / OWASP slides

OWASP Top Ten (2013)

A-1	Injection	Untrusted data is sent to an interpreter as part of a command or query.
A-2	Authentication and Session Management	Attacks passwords, keys, or session tokens, or exploit other implementation flaws to assume other users' identities.
A-3	Cross-site scripting	An application takes untrusted data and sends it to a web browser without proper validation or escaping
…	Various implementation problems	…expose a file, directory, or database key without access control check, …misconfiguration, …missing function-level access control
A-8	Cross-site request forgery	A logged-on victim's browser sends a forged HTTP request, including the victim's session cookie and other authentication information

https://www.owasp.org/index.php/Top_10_2013-Top_10

More OWASP

- « Cross-Site Request Forgery (CSRF) is an attack that **forces an end user** to execute unwanted actions on a web application in which they’re **currently authenticated**… With a little help of social engineering (such as sending a link via email or chat), an attacker may trick the users of a web application into executing actions of the attacker’s choosing… »

2007: Gmail is hacked …

- While logged into Gmail, a user visiting a malicious site would generate a request understood as originating from the victim user
- This was used to inject an email filter forwarding the victim user’s email to attacker
- Allowed an attacker to gain control of davidairey.com (since the domain registrar used email based authentication …)

Browser execution model

- Each browser window / frame
  - Uploads web content
  - Renders web content, static (HTML, subframes) or dynamic(scripts) to display the page
    - including external resources like images
  - Responds to events (see below)
- Events
  - Rendering: OnLoad
  - Timing: setTimeout(), clearTimeout()
  - Reacting to user actions: OnClick, OnMouseover

Maintaining Client State

- Web interactions are stateless by nature
  - HTTP requests sent back and forth

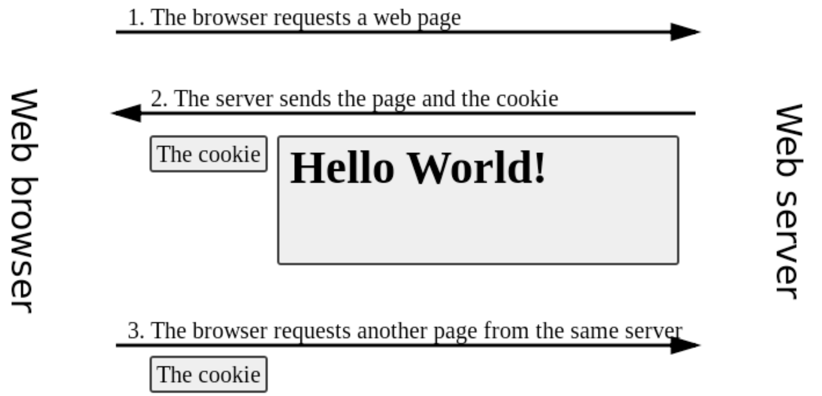
- How to know which browser connects?

- Methods for maintaining state:
  - Cookies: browser state
  - Sessions: server state
  - URL rewriting: browser state
  - Even more alternatives: cf. http://en.wikipedia.org/wiki/HTTP_cookie

State management: Cookies

- ”Small piece of information that scripts can store on a client-side machine"
- Can be set in HTTP header
  - Origin and expiration date
  - Example:

```
HTTP/1.0 200 OK
Content-type: text/html
Set-Cookie: name=value
Set-Cookie: name2=value2; Expires=Wed, 09 Jun 2021 10:18:14 GMT
 (content of page)
```


1. The browser requests a web page
2. The server sends the page and the cookie
The cookie
Hello World!
3. The browser requests another page from the same server
The cookie
Web browser
Web server

- Operation:
  - When browser connects to URL, it first checks for relevant cookie
  - If it finds a cookie for the URL, it sends the cookie info to server with the HTTP request
  - A web page can contain content from several web sites, hence several cookies can be sent during its browsing
- Long-lived: user identification (preferences, authentication, tracking …)
  - Cookie = user ID, may be secured (integrity, confidentiality)
- Temporary: session identification
  - Cookie = random number
- ”Secure” attribute instructs that cookie should only be sent over HTTPS (confidentiality to prevent man-in-the-middle attack)

HTTP Cookies Security History

- 1994: Netscape – cookies originate from and still largely based on that 4 page draft
- 1997: RFC 2109 – privacy issues, intention
- 2000: RFC 2965 – further recommendations on usage
- 2002: HttpOnly (XSS)
- 2011: RFC6265 -
- 2017-ongoing: RFC 6265bis (draft) - SameSite

State management: Sessions

- Generally handled by a web framework

- Helps to distinguish between other simultaneous sessions
- Data storage:
  - Session stores data from ongoing transactions (workflow, shopping cart, login)
  - Information can also be removed from a session
- Operation:
  - Start session
  - Session ID is set in the browser (cookie at the beginning, or URL rewriting later on)
  - Data stored and managed on web server (costly, does not scale)
  - End session (dispose of data)

- Pros/Cons: data managed at and by server

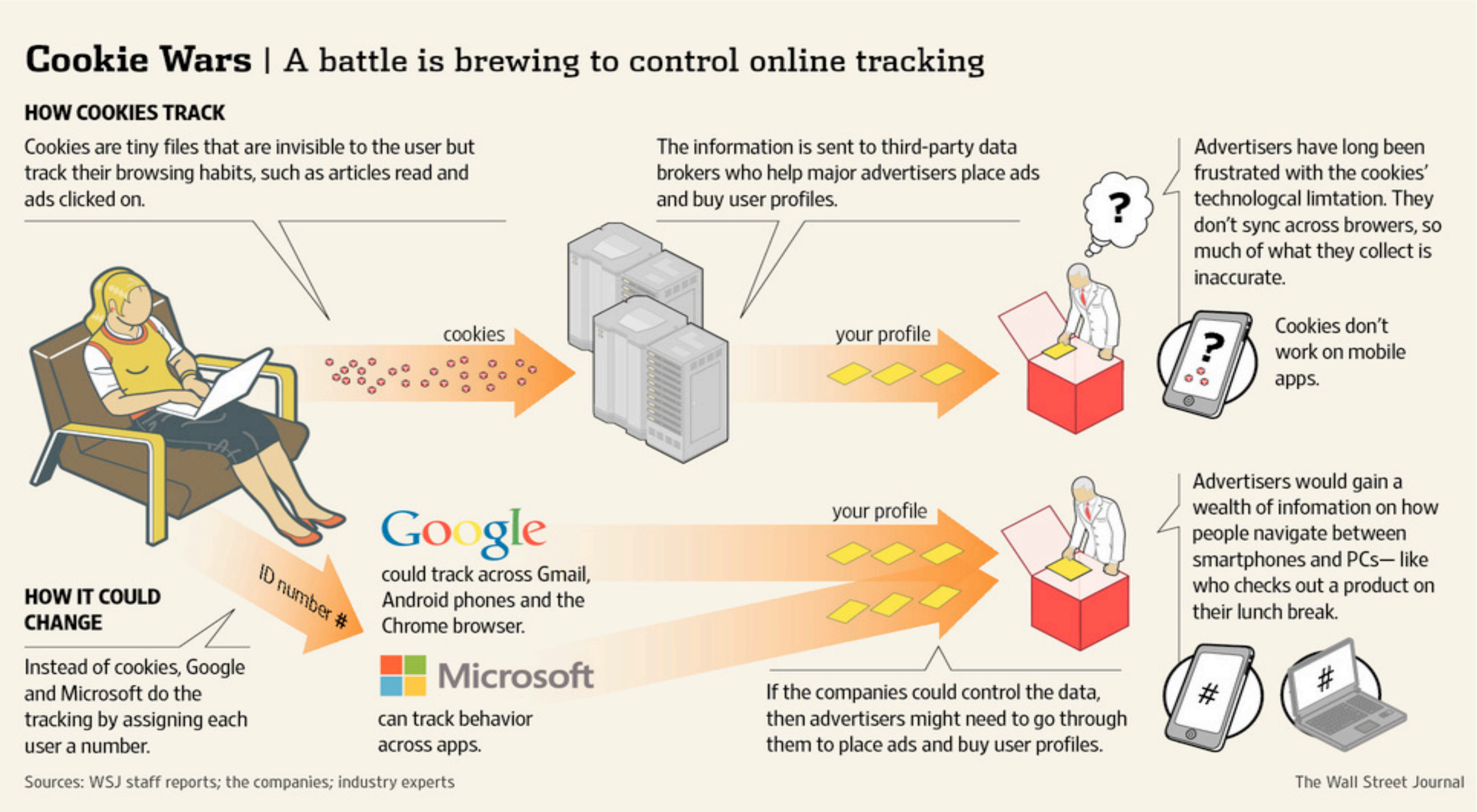
State management: URL rewriting

- URLs modified to:
  - store parameters (RESTful approach)
    E.g., http://host:port/shopping.html;sessionid=value
  - Force the use of a proxy: destination becomes a parameter

- Operation (example: Google)
  - Research result leads to:
    https://www.google.fr/url?q=http://fr.wikipedia.org/Cookie_(informatique)&sa=U&ei=U-9wU-27O8Gm0AWc2IGAAQ&usg=AFQjCNEItv3EUaJHvFL_fM-_7lmX9VzCLQ&sig2=Wdr5pg0cOye893nHZJO-hw&bvm=bv.66330100,d.bGQ
  - Instead of: http://fr.wikipedia.org/wiki/Cookie_%28informatique%29
  - Invisible on the page (link is not displayed in plain text), only in the link bar

- Pros: cannot be suppressed by client

Big Data Wars …



Cookie Wars | A battle is brewing to control online tracking

HOW COOKIES TRACK

Cookies are tiny files that are invisible to the user but track their browsing habits, such as articles read and ads clicked on.

The information is sent to third-party data brokers who help major advertisers place ads and buy user profiles.

Advertisers have long been frustrated with the cookies' technologcal limtation. They don't sync across browers, so much of what they collect is inaccurate.

Cookies don't work on mobile apps.

HOW IT COULD CHANGE

Instead of cookies, Google and Microsoft do the tracking by assigning each user a number.

Google could track across Gmail, Android phones and the Chrome browser.

Microsoft can track behavior across apps.

If the companies could control the data, then advertisers might need to go through them to place ads and buy user profiles.

Advertisers would gain a wealth of infomation on how people navigate between smartphones and PCs— like who checks out a product on their lunch break.

Sources: WSJ staff reports; the companies; industry experts

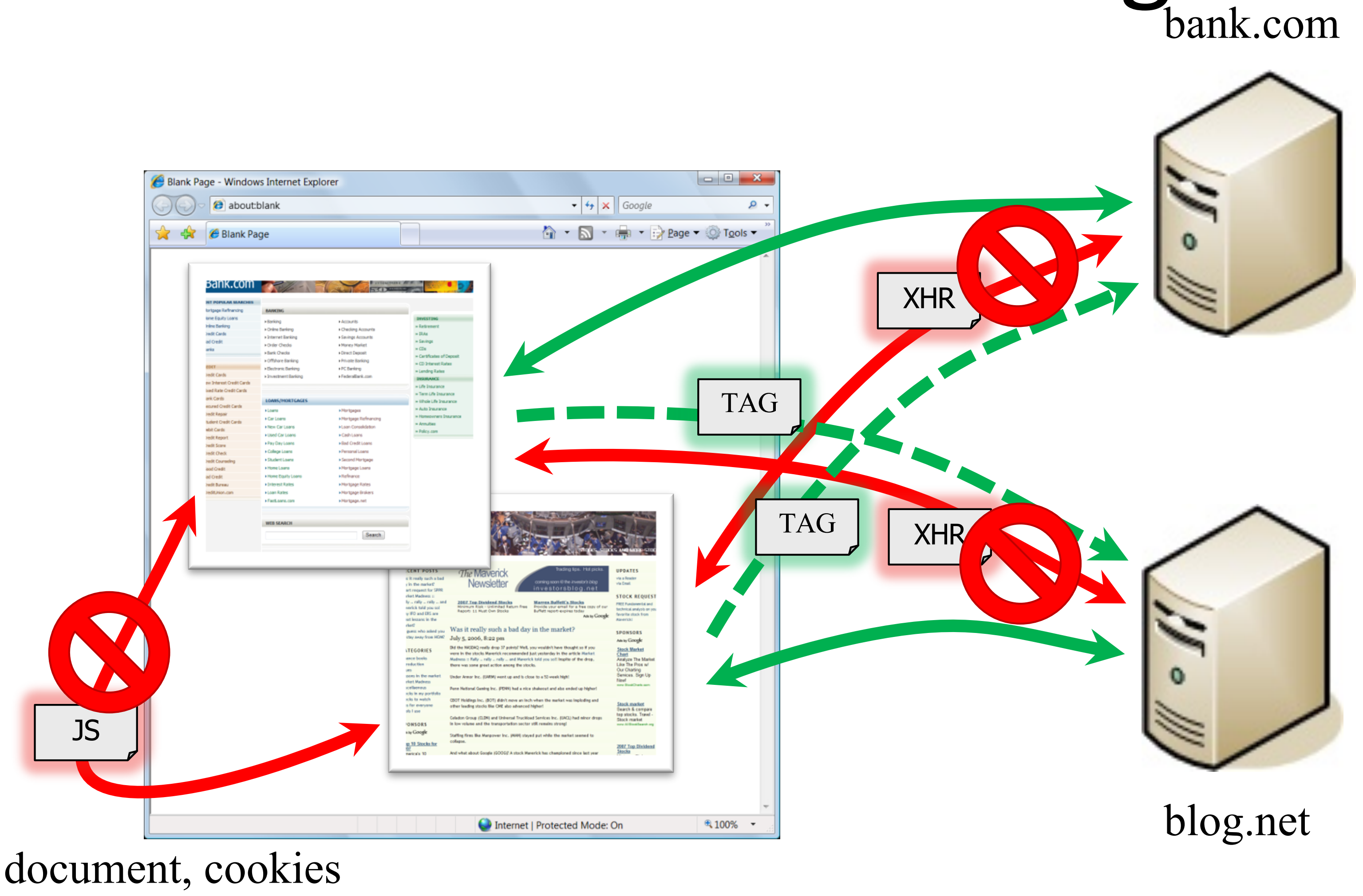
The Wall Street Journal

- Cookie lifetime too is a serious issue wrt. Privacy !
    - Expires / Max-Age attributes
- The application should invalidate irrelevant cookies and not rely on bowser for removing them

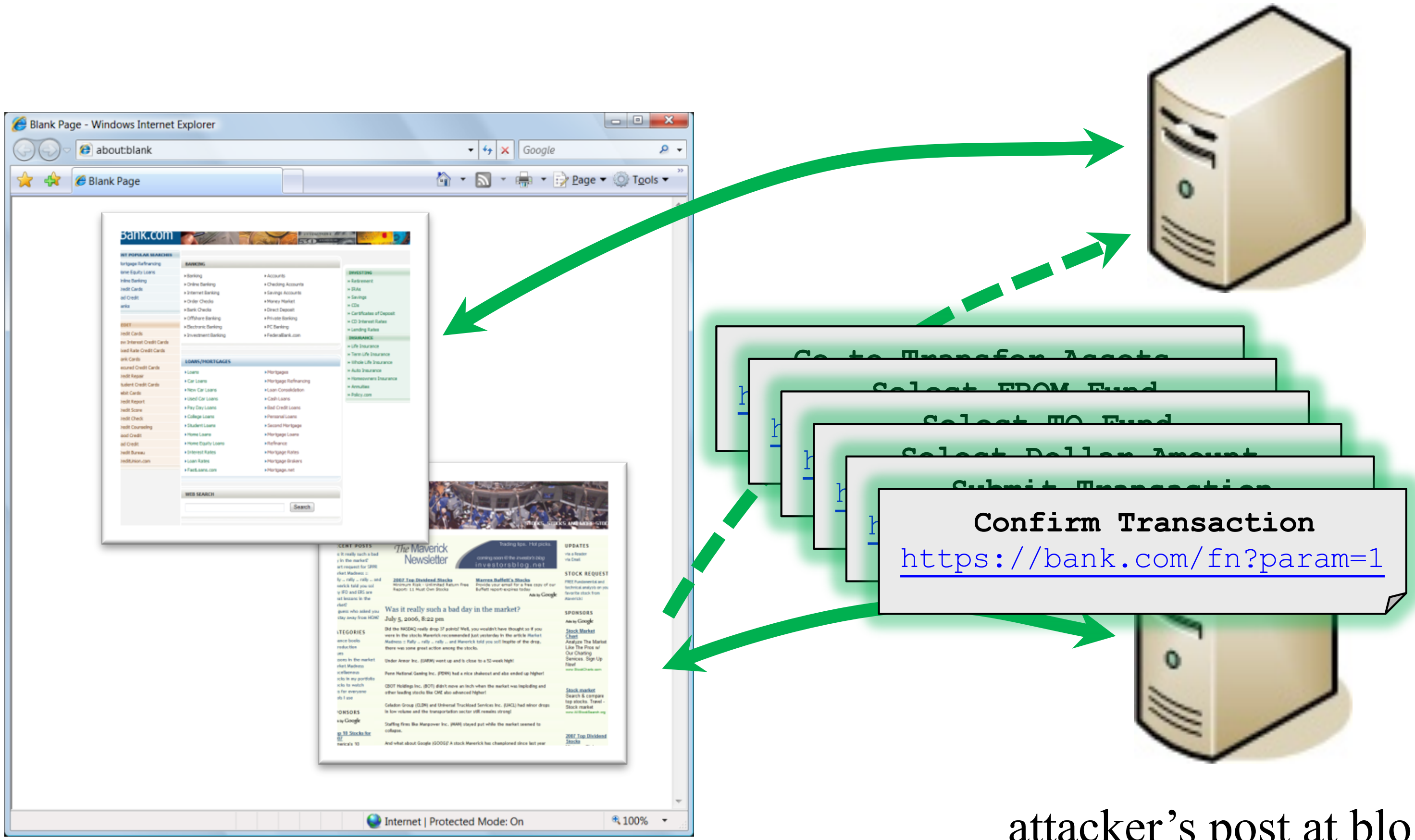
The Browser “Same Origin” Policy (SOP)

- Every frame in a browser is associated with a domain
  - A domain is determined by the server, protocol, and port from which the frame content was downloaded
  - If a frame explicitly includes external code, this code will execute within the frame domain even though it comes from another host
- A script can only access resources (and notably cookies) associated with the same origin
  - prevents hostile script from tampering with other pages in the browser
  - prevents script from snooping on input (passwords) of other windows
- Security Problems: mostly browser bugs
  - Especially in the late 1990s – early 2000s

The Browser “Same Origin” Policy



Cross-Site Request Forgery



bank.com

Go to Transfer Assets

Select FROM Fund

Select TO Fund

Select Dollar Amount

Submit Transaction

Confirm Transaction

https://bank.com/fn?param=1

attacker’s post at blog.net

How Does CSRF Work?

- Hijacks inherent browser functionality and some aspects of HTTP specification
  - SOP controls and cookies
- Privilege escalation type of attack
  - “Confused deputy”: browser thinks tag/form/XHR is from same origin as destination
- Attacker performs blind attacks (cannot see server responses)
  - Unless combined with XSS …

- Tags

```
<img src=“https://bank.com/fn?param=1”>
<iframe src=“https://bank.com/fn?param=1”>
<script src=“https://bank.com/fn?param=1”>
```

- Autoposting Forms

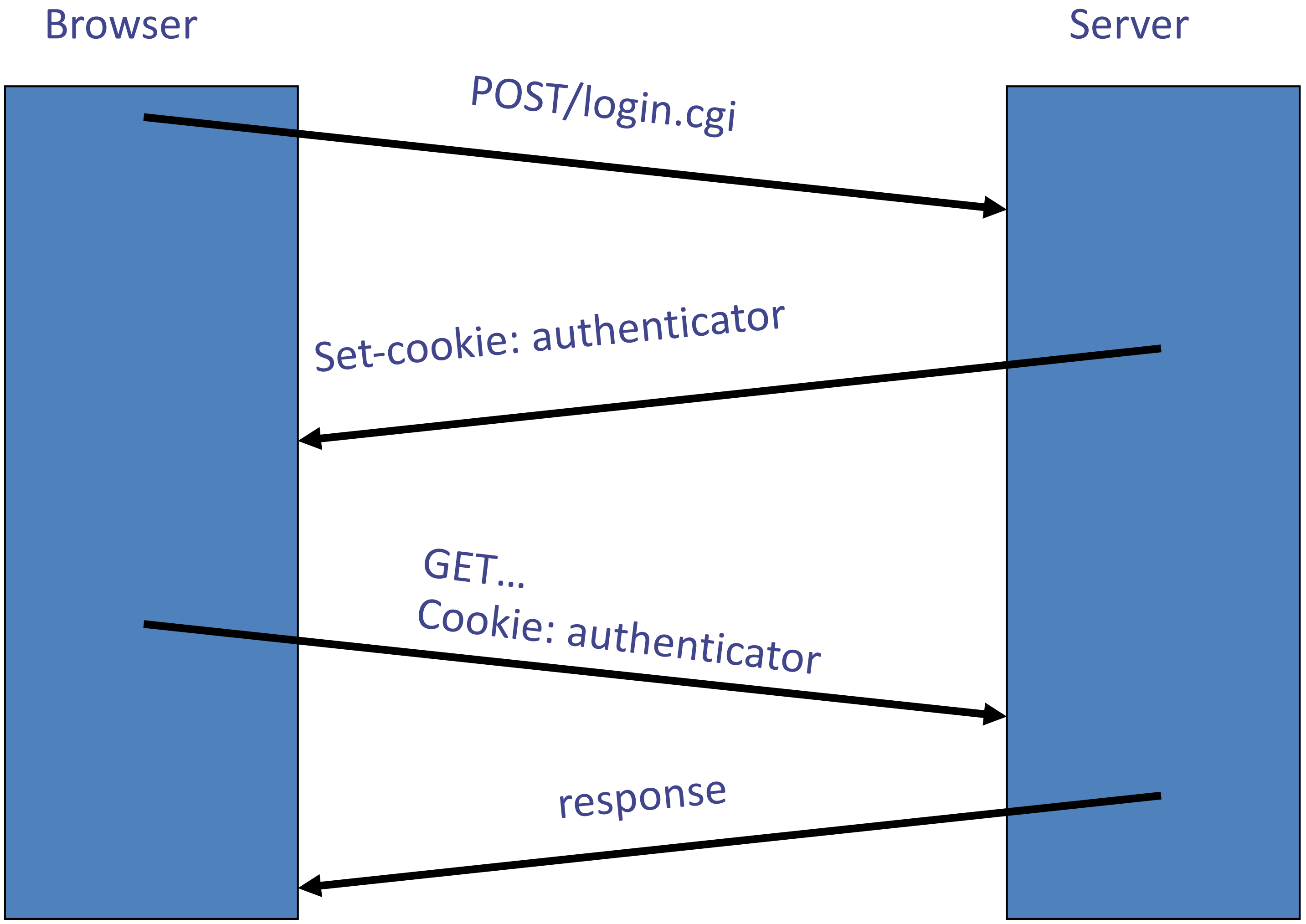
```
<body onload="document.forms[0].submit()">
<form method="POST" action=“https://bank.com/fn”>
   <input type="hidden" name="sp" value="8109"/>
</form>
```

- GET requests are the most dangerous, but any request is vulnerable (POST too)

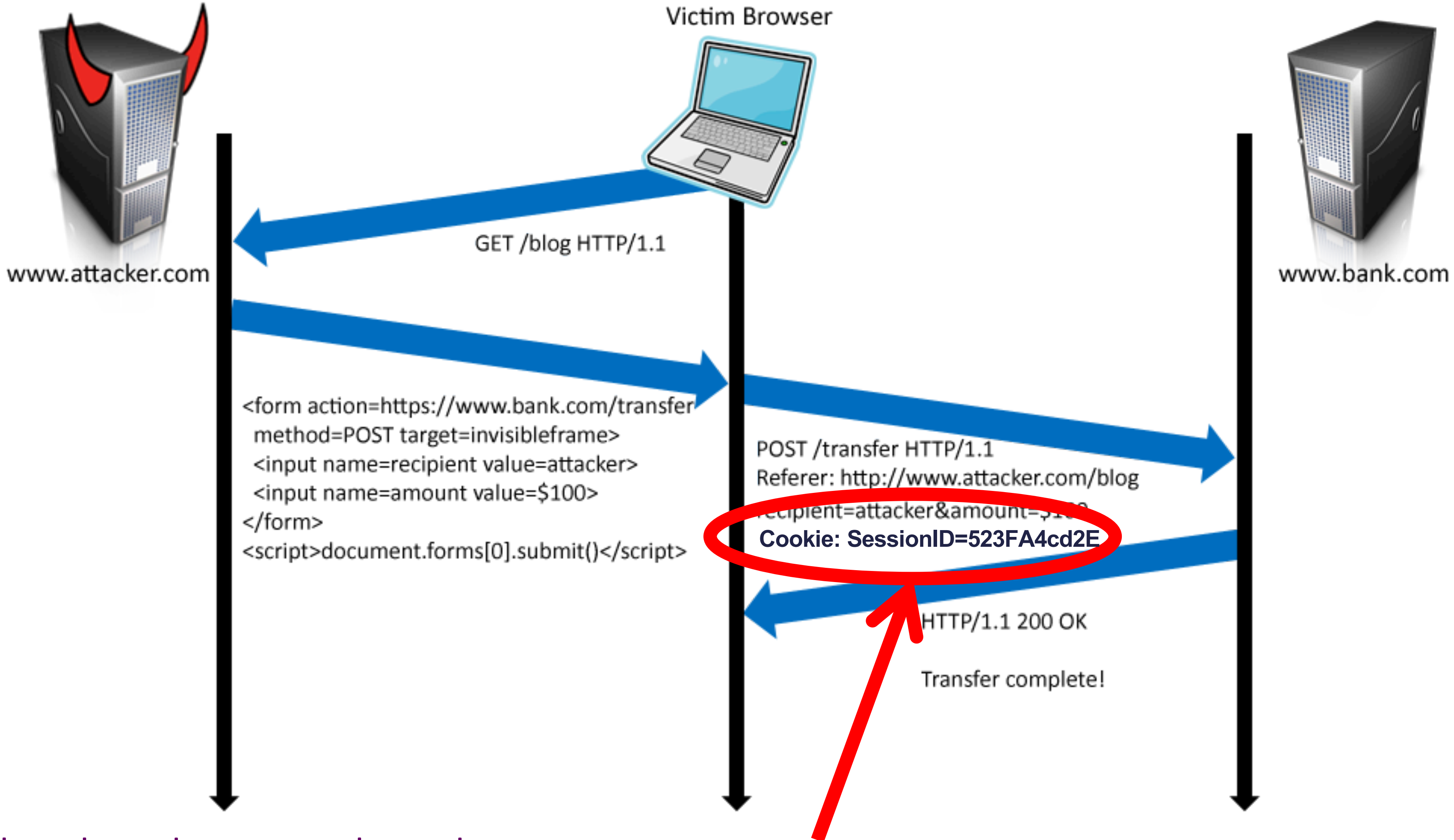
- XmlHttpRequest (AJAX)
  - Normally subject to same origin policy
  - But poorly managed CORS (Cross-Origin Resource Sharing) may relax these constraints …
  - May be fooled by a proxy too

Authentication: session using cookies

- Browser behavior: automatically attaches cookie previously set by server



CSRF: Form post with cookie



```
<form action=https://www.bank.com/transfer
  method=POST target=invisibleframe>
  <input name=recipient value=attacker>
  <input name=amount value=$100>
</form>
<script>document.forms[0].submit()</script>
```

```
POST /transfer HTTP/1.1
Referer: http://www.attacker.com/blog
recipient=attacker&amount=$100
Cookie: SessionID=523FA4cd2E
```

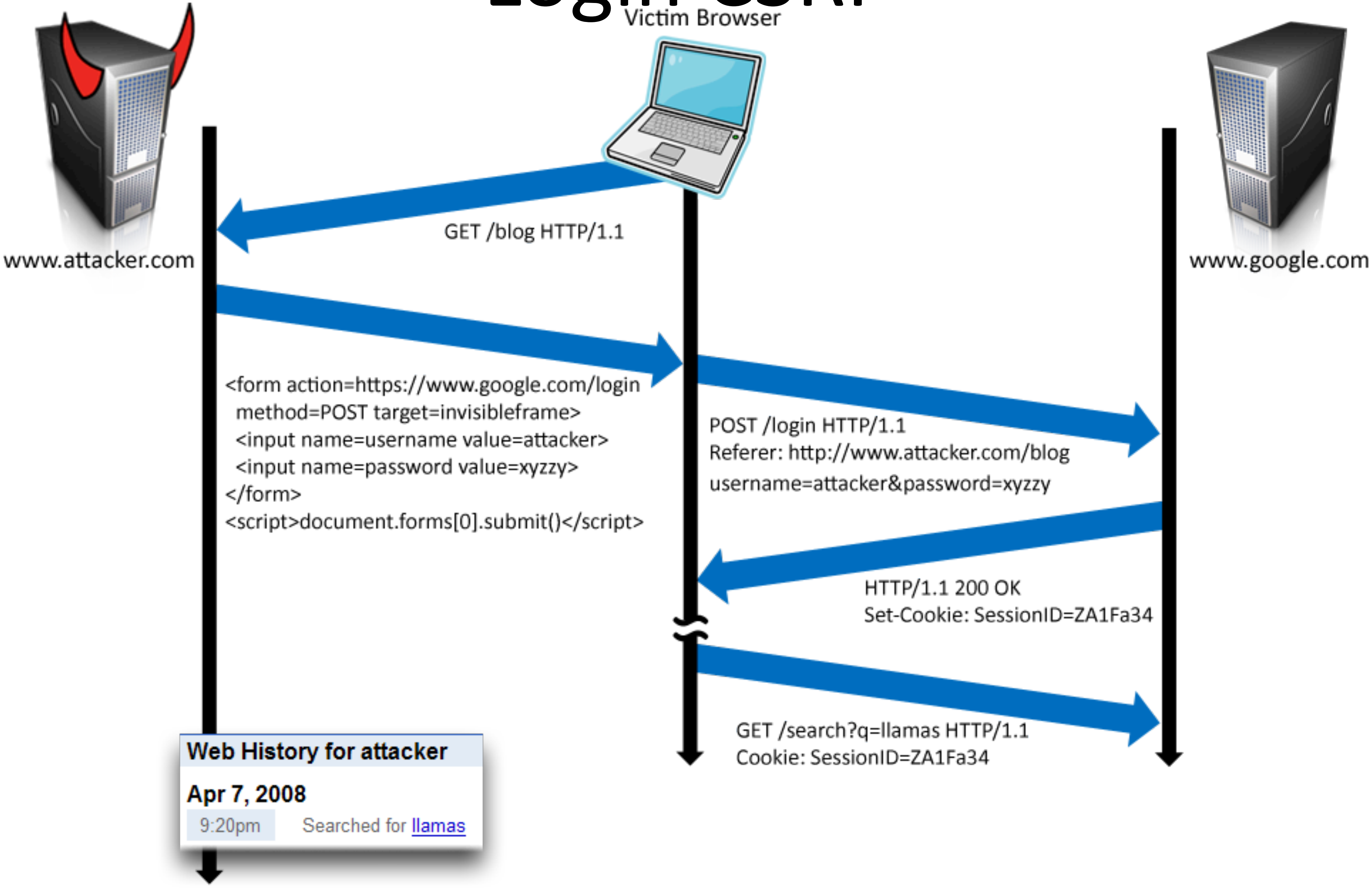
```
HTTP/1.1 200 OK

Transfer complete!
```

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

User credentials

Login CSRF



Victim Browser

www.attacker.com

www.google.com

GET /blog HTTP/1.1

```
<form action=https://www.google.com/login
  method=POST target=invisibleframe>
  <input name=username value=attacker>
  <input name=password value=xyzzy>
</form>
<script>document.forms[0].submit()</script>
```

POST /login HTTP/1.1
Referer: http://www.attacker.com/blog
username=attacker&password=xyzzy

HTTP/1.1 200 OK
Set-Cookie: SessionID=ZA1Fa34

GET /search?q=llamas HTTP/1.1
Cookie: SessionID=ZA1Fa34

Web History for attacker

Apr 7, 2008

9:20pm Searched for llamas

Not just Web Servers:
Attacks on Home Router

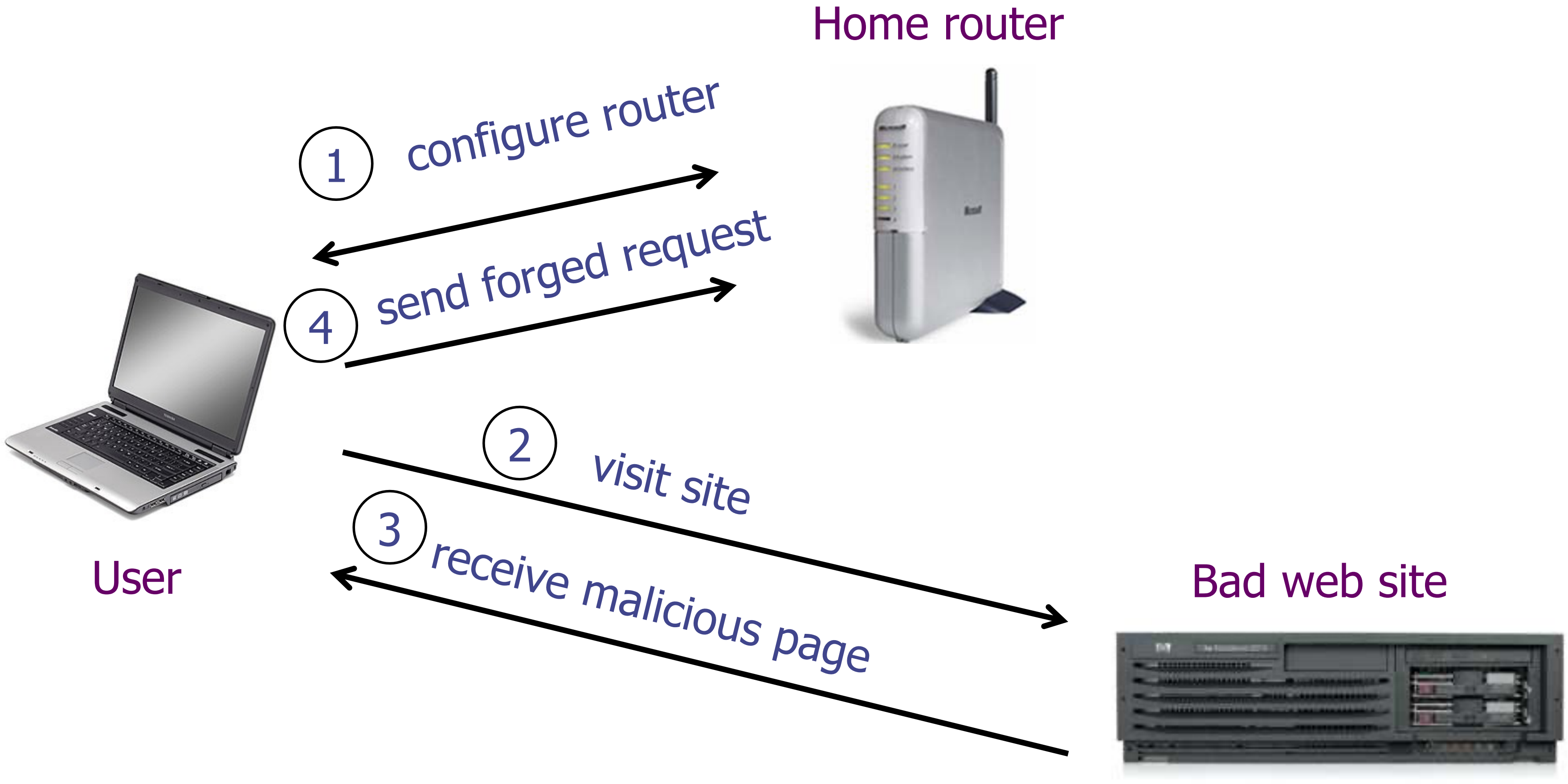
[Stamm, Ramzan, Jakobsson 2006]

- Fact:
  - 50% of home users have broadband router with a default or no password
- Drive-by Pharming attack:
  - Scenario: user visits malicious site
  - Attacker script scans home network for broadband router:
    - SOP allows "send only" messages
    - Detect success using onError and likely address (e.g., 192.168.0.1):

```
<IMG   SRC=192.168.0.1   onError = do() >
```

  - Attacker script can login to router and change DNS server
    - Takes control of user navigation
  - Attacker can distribute malware to router
  - Attacker can block virus definition updates
  - Attacker can advertise vulnerable hosts

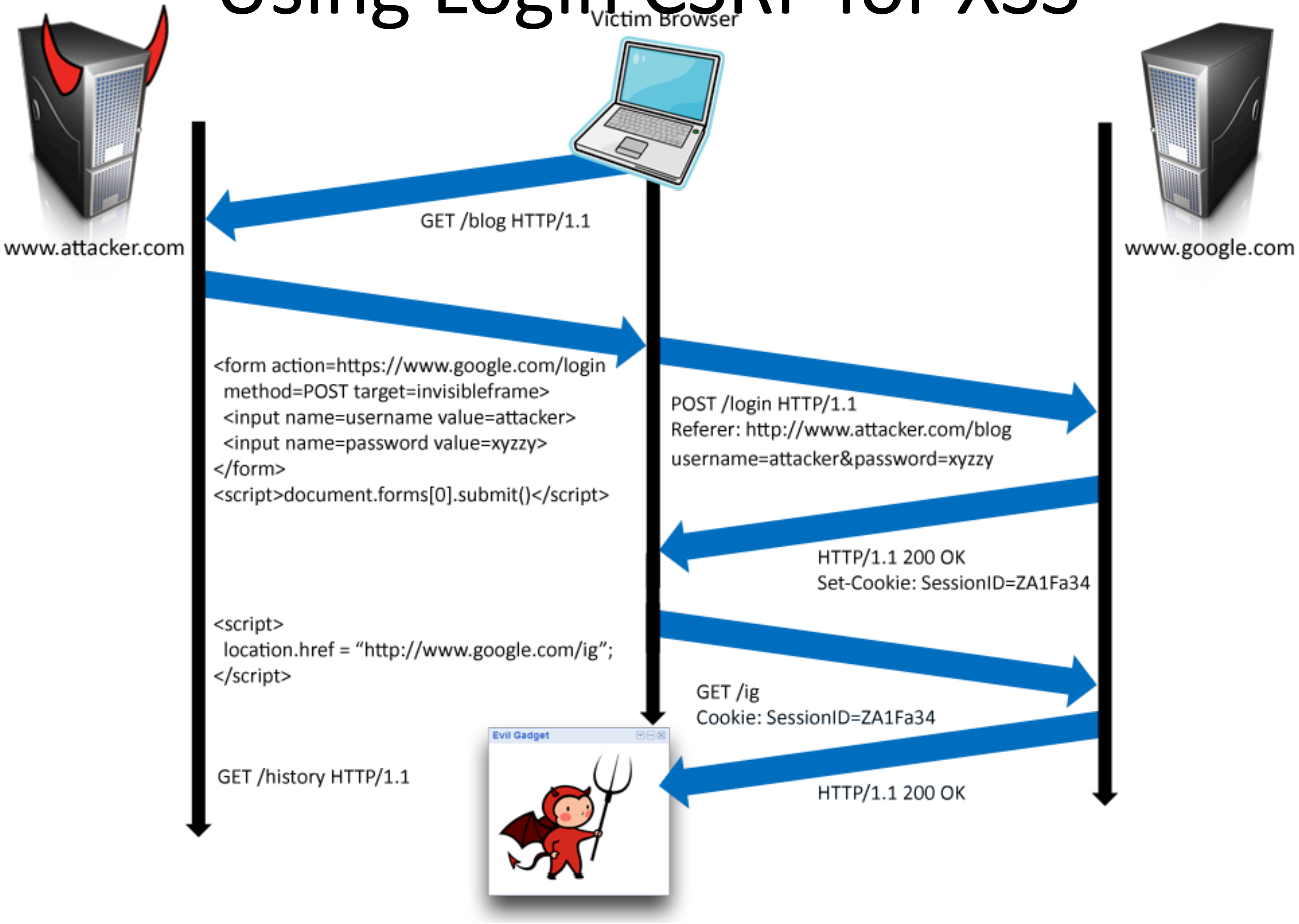
Cookieless Example: Home Router



Broader view of CSRF

- Abuse of cross-site data export feature
  - From user’s browser to honest server
  - Disrupts integrity of user’s session
- Why mount a CSRF attack?
  - Network connectivity
  - Read browser state
  - Write browser state
- Not just “session riding”

Using Login CSRF for XSS



```
GET /blog HTTP/1.1
```

```
<form action=https://www.google.com/login
  method=POST target=invisibleframe>
  <input name=username value=attacker>
  <input name=password value=xyzzy>
</form>
<script>document.forms[0].submit()</script>
```

```
POST /login HTTP/1.1
Referer: http://www.attacker.com/blog
username=attacker&password=xyzzy
```

```
HTTP/1.1 200 OK
Set-Cookie: SessionID=ZA1Fa34
```

```
<script>
  location.href = “http://www.google.com/ig”;
</script>
```

```
GET /ig
Cookie: SessionID=ZA1Fa34
```

```
HTTP/1.1 200 OK
```

```
GET /history HTTP/1.1
```

The attacker’s perspective

- The attacker can:
  - Control the form/XHR payload
  - Control the content type (« enctype » attribute)
  - Control the method (GET or POST)
- The attacker cannot:
  - Control other headers
  - Control cookies

CSRF Basic Defenses

- Referer Validation

```
Referer: http://www.facebook.com/home.php
```

- Persistent authentication (login/session data):
  - Client-Side Storage of session information (not effective)
    - But vulnerable to XSS attacks …
    - … and user manipulation of server state !
  - Server-Side session ID + Secret Token Validation

```
<input type=hidden value=23a3af01b>
```

- Custom HTTP Header: simpler approach for AJAX/XHR

```
X-Requested-By: XMLHttpRequest
```

Referer Validation Defense

- HTTP Referer header
  - Referer: http://www.gmail.com/ OK
  - Referer: http://www.bad.com/evil.html KO
  - Referer: ???
- Lenient Referer validation
  - Doesn’t block request if Referer is missing
- Strict Referer validation
  - Secure, but Referer is sometimes absent…

Referer Privacy Problems

- Referer may also leak privacy-sensitive information!

```
http://intranet.corp.apple.com/
projects/iphone/competitors.html
```

- May be removed based on user preference in browser
- Site often cannot afford to block these users

So … Lenient Referer Checking?

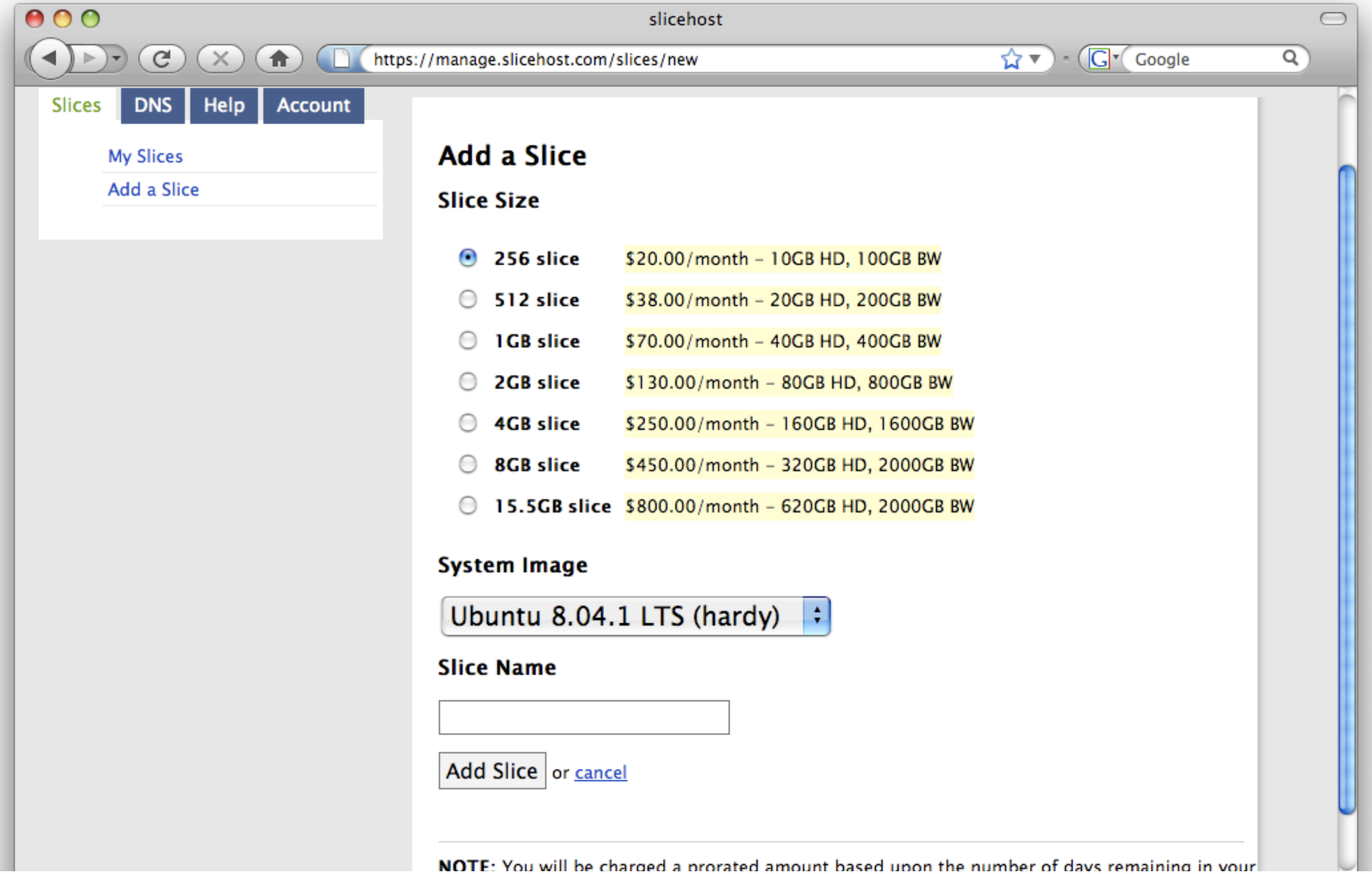
- Other common sources of blocking:
  - Network stripping by the organization (proxy)
  - Network stripping by local machine
  - Stripped by browser for HTTPS -> HTTP transitions
  - Buggy user agents
- Insecure: attacker may strip referrer, e.g.:

```
ftp://www.attacker.com/index.html
        javascript:"<script> /* CSRF */ </script>"
        data:text/html,<script> /* CSRF */ </script>
```

Secret Token Validation

- Requests include a hard-to-guess secret
  - Unguessability replaces unforgeability
- Variations
  - Session identifier
  - Session-independent token
  - Session-dependent token
  - HMAC / MD5 / SHA-1 of session identifier for integrity protection

Secret Token Validation



Add a Slice

Slice Size

●	**256 slice**	$20.00/month – 10GB HD, 100GB BW
○	**512 slice**	$38.00/month – 20GB HD, 200GB BW
○	**1GB slice**	$70.00/month – 40GB HD, 400GB BW
○	**2GB slice**	$130.00/month – 80GB HD, 800GB BW
○	**4GB slice**	$250.00/month – 160GB HD, 1600GB BW
○	**8GB slice**	$450.00/month – 320GB HD, 2000GB BW
○	**15.5GB slice**	$800.00/month – 620GB HD, 2000GB BW

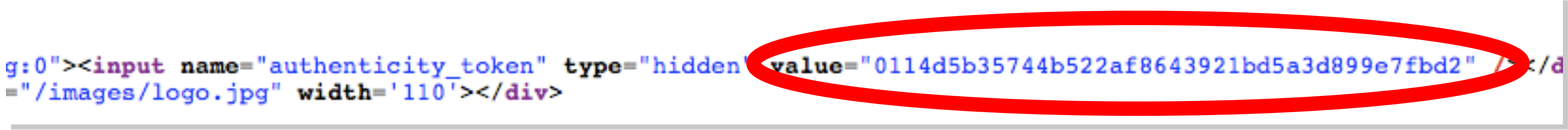
System Image

Ubuntu 8.04.1 LTS (hardy)

Slice Name

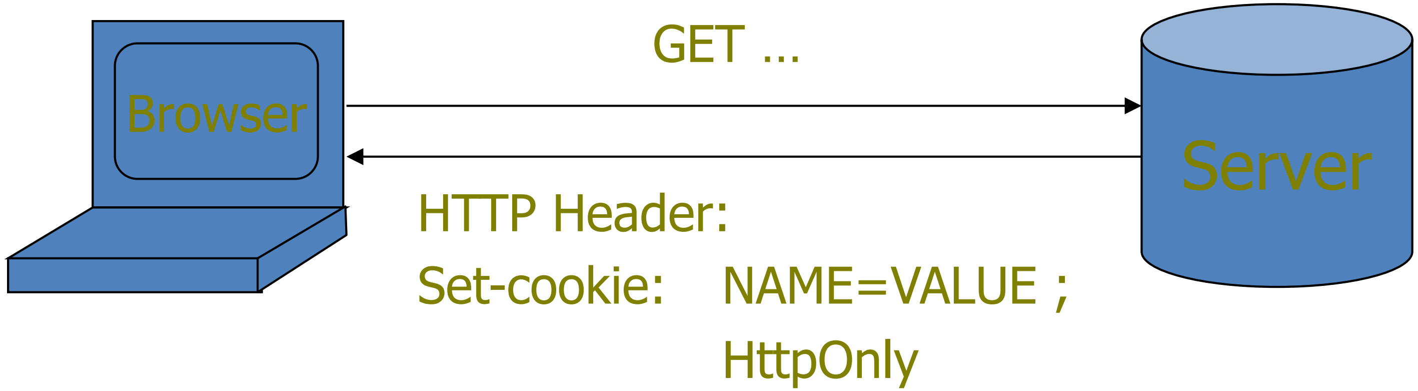
Add Slice or cancel

NOTE: You will be charged a prorated amount based upon the number of days remaining in your



```
g:0"><input name="authenticity_token" type="hidden" value="0114d5b35744b522af8643921bd5a3d899e7fbd2" /></d
="/images/logo.jpg" width='110'></div>
```

XSS: HttpOnly Cookies



Browser

GET …

Server

HTTP Header:

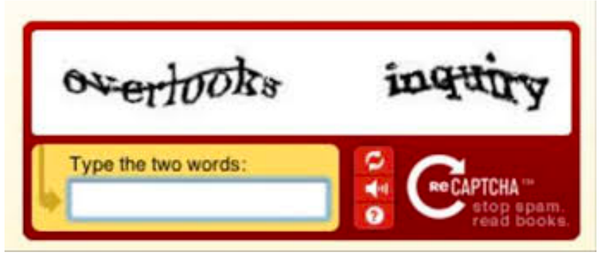
Set-cookie: NAME=VALUE ; HttpOnly

- Cookie sent over HTTP(s), but not accessible to scripts
  - cannot be read via document.cookie
    - Also blocks access from XMLHttpRequest headers
  - Helps prevent cookie theft via XSS

… but does not stop most other risks: typical attack is to overflow cookie repository (replace cookie with attacker value)! This is dependent on browser implementation …

Other Mitigation Strategies

- Tokens: double-submission if maintaining CSRF token on server-side is problematic: token to be sent in header (request parameter) + cookie in body
  - Strong requirements (notably HTTPS to prevent attackers from injecting cookies, encrypted cookies)
- Additional anti-CSRF HTML elements
  - Origin header
  - SameSite cookies (draft RFC 6265bis since 2017)
  - Check https://cheatsheetseries.owasp.org/cheatsheets/Cross-Site_Request_Forgery_Prevention_Cheat_Sheet.html
- Use libraries and frameworks with built-in anti-CSRF mechanisms
  - E.g. Angular: “X-XSRF-TOKEN”
- User Interaction Based CSRF Defense before critical operation
  - Captchas: make sure a human intervenes (no automated spoofing)
  - One-time token
  - Re-authentication (Login/Password)



Defense in Depth: Origin Header

```
Origin: http://www.evil.com
```

- Alternative to Referer with fewer privacy problems
- Sent only on POST, sends only necessary data
- Defense against redirect-based attacks
- Privacy
  - Identifies only principal that initiated the request (not path or query)
  - Sent only for POST requests; following hyperlink reveals nothing
- Usability
  - Authorize subdomains and affiliate sites with simple firewall rule

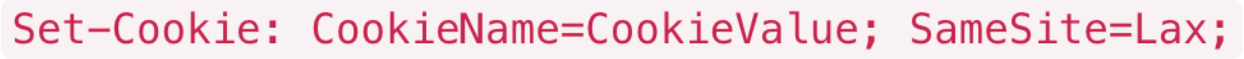
```
SecRule REQUEST_HEADERS:Host !^www\.example\.com(:\d+)?$ deny,status:403
SecRule REQUEST_METHOD ^POST$ chain,deny,status:403
SecRule REQUEST_HEADERS:Origin !^(https?://www\.example\.com(:\d+)?)?$
```

  - No need to manage secret token state
  - used with existing defenses to support legacy browsers (e.g. Referer)
- Standardization
  - Supported by W3C XHR2 and JSONRequest

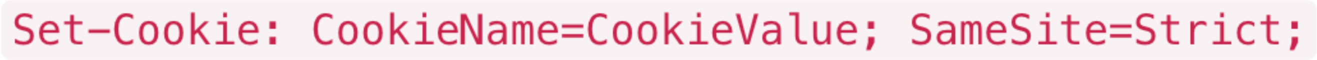
Defense in Depth: SameSite Cookie

draft-ietf-httpbis-rfc6265bis-latest (Oct 8, 2019)

- Setting:



```
Set-Cookie: CookieName=CookieValue; SameSite=Lax;
```



```
Set-Cookie: CookieName=CookieValue; SameSite=Strict;
```

  - Strict: the cookie will not be included in requests sent by third-parties (can affect browsing experience negatively)
  - Lax: the cookie will be sent along with the GET request initiated by third party website, but only for top-level navigation requests (URL has to be changed in browser)
  - Browsers are progressively integrating this feature

One more thing…

- Cookie Scope:
  - based on Path attribute + Host/domain
  - Restricts usage of cookie to some application on the website
  - This is separate from SOP which is based on Host/domain+port
  - May further restrict cookie abuse

Take-away message

- Cookie protection can be tricky, browser-specific, and is still investigated and standardized
- The prototype of a « secure » cookie ?

Set-Cookie:__Host-SessionID=43a2; Path=/myapplication;Secure;HttpOnly;SameSite=Strict

- … that is, until the next release of RFC 6265bis…
- … plus Tokens…
- … and over HTTPS !
- Beware of XSS and MITM that may endanger cookie integrity (writing attack)
- …. And privacy !!!