Lecture 09 – Web Security

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Security on the web

- Risk #1: we want data stored on a web server to be protected from unauthorized access
- Defense: server-side security

Code Injection

```
<?php

echo system("ls " . $_GET["path"]);
```

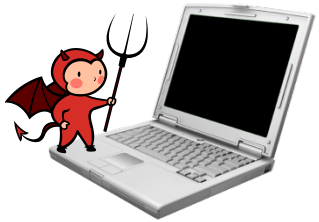
GET /?path=/home/user/ HTTP/1.1

HTTP/1.1 200 OK
...
Desktop
Documents
Music
Pictures

Code Injection

```
<?php

echo system("ls " . $_GET["path"]);
```

GET /?path=$(rm –rf /) HTTP/1.1




```
<?php

echo system("ls $(rm -rf /)");
```

Code Injection

```
<?php

echo system("ls $(rm -rf /)");
```

- Confusing **Data** and **Code**
  - Programmer thought user would supply data, but instead got (and unintentionally executed) code
- Common and dangerous class of vulnerabilities
  - Shell Injection
  - SQL Injection
  - Cross-Site Scripting (XSS)
  - Control-flow Hijacking (Buffer overflows)

SQL

- Structured **Query** Language
  - Language to ask (“query”) databases questions:

- How many users live in Ann Arbor?

“SELECT COUNT(*) FROM `users` WHERE location = ‘Ann Arbor’”

- Is there a user with username “bob” and password “abc123”?

“SELECT * FROM `users` WHERE username=‘bob’ and password=‘abc123’”

- Burn it down!

“DROP TABLE `users`”

SQL Injection

- Consider an SQL query where the attacker chooses $city:

```
SELECT * FROM `users` WHERE location='$city'
```

- What can an attacker do?

SQL Injection

- Consider an SQL query where the attacker chooses $city:

```
SELECT * FROM `users` WHERE location='$city'
```

- What can an attacker do?

$city = "Ann Arbor'; DELETE FROM `users` WHERE 1='1"

```
SELECT * FROM `users` WHERE location='Ann Arbor';
DELETE FROM `users` WHERE 1='1'
```

SQL Injection Defense

- Make sure **data** gets interpreted as **data**!
  - Basic approach: escape control characters (single quotes, escaping characters, comment characters)
  - Better approach: Prepared statements – declare what is data!

```
$pstmt = $db->prepare(
 "SELECT * FROM `users` WHERE
location=?");
$pstmt->execute(array($city)); // Data
```

Shellshock
a.k.a. Bashdoor / Bash bug
(Disclosed on Sep 24, 2014)

Acknowledgement: slides from Prof. Bruce Maggs

Bash Shell

- Released June 7, 1989.
- Unix shell providing built-in commands such as cd, pwd, echo, exec, builtin
- Platform for executing programs
- Can be scripted

Environment Variables

Environment variables can be set in the Bash shell, and are passed on to programs executed from Bash

export VARNAME=“value”

(use printenv to list environment variables)

Stored Bash Shell Script

An executable text file that begins with

#!program

Tells bash to pass the rest of the file to program to be executed.

Example:

```
#!/bin/bash
STR="Hello World!"
echo $STR
```

Hello World! Example

```
Bruce@Maggs-PC ~
$ cat ./hello
#!/bin/bash
STR="Hello World!"
echo $STR



Bruce@Maggs-PC ~
$ chmod +x ./hello

Bruce@Maggs-PC ~
$ ./hello
Hello World!

Bruce@Maggs-PC ~
$
```

Dynamic Web Content Generation

Web Server receives an HTTP request from a user.

Server runs a program to generate a response to the request.

Program output is sent to the browser.

Common Gateway Interface (CGI)

Oldest method of generating dynamic Web content (circa 1993, NCSA)

Operator of a Web server designates a directory to hold scripts (typically PERL) that can be run on HTTP GET, PUT, or POST requests to generate output to be sent to browser.

CGI Input

PATH_INFO environment variable holds any path that appears in the HTTP request after the script name

QUERY_STRING holds key=value pairs that appear after ? (question mark)

Most HTTP headers passed as environment variables

In case of PUT or POST, user-submitted data provided to script via standard input

CGI Output

Anything the script writes to standard output (e.g., HTML content) is sent to the browser.

Example Script (Wikipedia)

Bash script that evokes PERL to print out environment variables

```
#!/usr/bin/perl

print "Content-type: text/plain\r\n\r\n";
for my $var ( sort keys %ENV ) {
 printf "%s = \"%s\"\r\n", $var, $ENV{$var};
}
```

Put in file `/usr/local/apache/htdocs/cgi-bin/printenv.pl`

Accessed via `http://example.com/cgi-bin/printenv.pl`

Windows Web server running cygwin

http://example.com/cgi-bin/printenv.pl/foo/bar?var1=value1&var2=with%20percent%20encoding

```
DOCUMENT_ROOT="C:/Program Files (x86)/Apache Software Foundation/Apache2.2/htdocs“
GATEWAY_INTERFACE="CGI/1.1“
HOME="/home/SYSTEM" HTTP_ACCEPT="text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8“
HTTP_ACCEPT_CHARSET="ISO-8859-1,utf-8;q=0.7,*;q=0.7"
HTTP_ACCEPT_ENCODING="gzip, deflate“
HTTP_ACCEPT_LANGUAGE="en-us,en;q=0.5“
HTTP_CONNECTION="keep-alive“
HTTP_HOST="example.com“
HTTP_USER_AGENT="Mozilla/5.0 (Windows NT 6.1; WOW64; rv:5.0) Gecko/20100101 Firefox/5.0" PATH="/home/SYSTEM/bin:/bin:/cygdrive/c/progra~2/php:/cygdrive/c/windows/system32:...“
PATH_INFO="/foo/bar“
QUERY_STRING="var1=value1&var2=with%20percent%20encoding
```

Shellshock Vulnerability

Function definitions are passed as environment variables that begin with ()

Error in environment variable parser: executes “garbage” after function definition.

Cygwin Bash Shell Shows Vulnerability

```
Bruce@Maggs-PC ~
$ export X="() { :;}; echo vulnerable"

Bruce@Maggs-PC ~
$ bash -c "echo hello"
vulnerable
hello

Bruce@Maggs-PC ~
$ |
```

Crux of the Problem

- Any environment variable can contain a function definition that the Bash parser will execute before it can process any other commands.
- Environment variables can be inherited from other parties, who can thus inject code that Bash will execute.

Web Server Exploit

Send Web Server an HTTP request for a script with an HTTP header such as HTTP_USER_AGENT set to

```
'() { :;}; echo vulnerable'
```

When the Bash shell runs the script it will evaluate the environment variable HTTP_USER_AGENT and run the echo command

curl -H "User-Agent: () { :; }; echo vulnerable" http://example.com/

Security on the web

- Risk #2: we don't want a malicious (or compromised) sites to be able to trash files/ programs on our computers
  - Browsing to awesomevids.com (or evil.com) should not infect my computer with malware, read or write files on my computer, etc.
- Defense: Javascript is sandboxed;
  try to avoid security bugs in browser code;
  privilege separation; automatic updates; etc.

The Ghost In The Browser Analysis of Web-based Malware

Niels Provos
Dean McNamee
Panayiotis Mavrommatis
KeWang
Nagendra Modadugu

Introduction

- Internet essential for everyday life: ecommerce, etc.
- Malware used to steal bank accounts or credit cards
  - underground economy is very profitable
- Internet threats are changing:
  - remote exploitation and firewalls are yesterday
- Browser is a complex computation environment
- Adversaries exploit browser to install malware

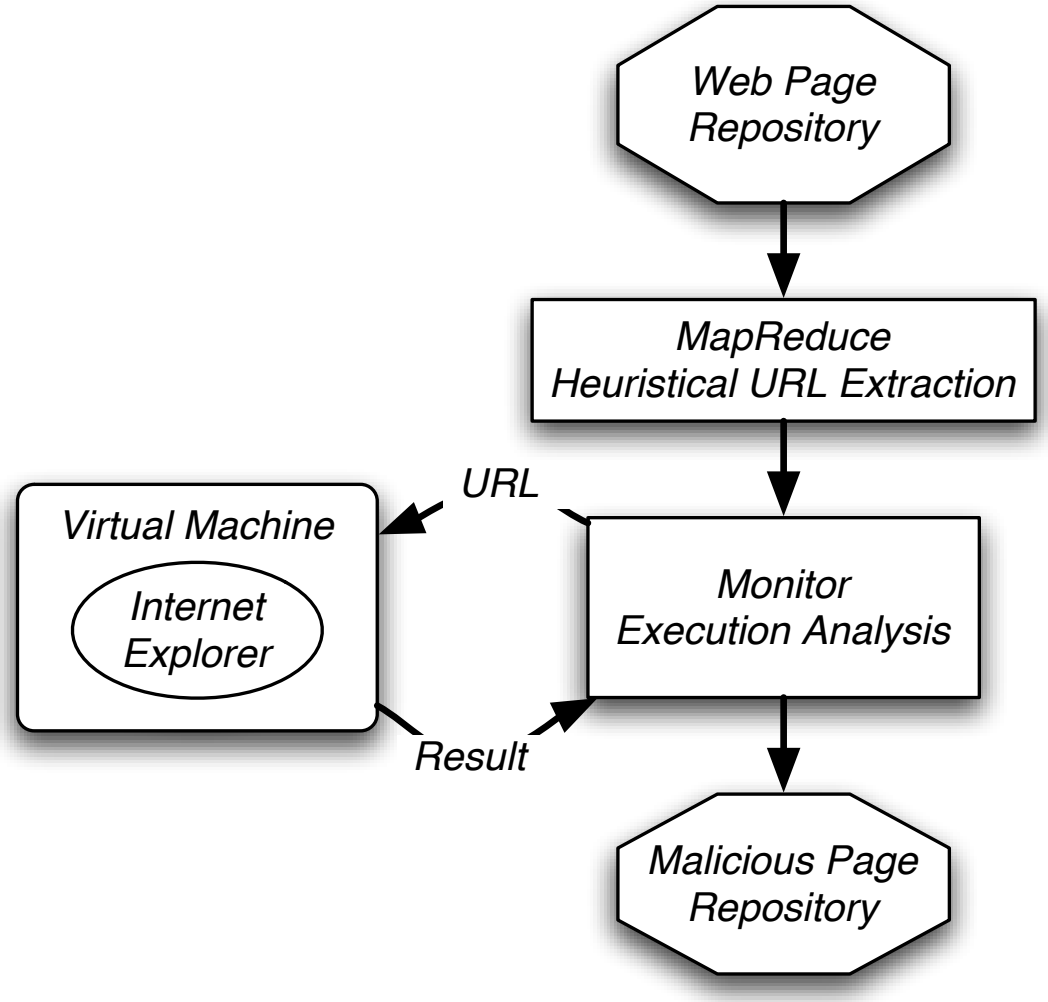
Introduction

- To compromise your browser, we need to compromise a web server you visit
- Very easy to set up new site on the Internet
- Very difficult to keep new site secure
  - insecure infrastructure: Php, MySql,Apache
  - insecure web applications: phpBB2, Invision, etc.

Detecting Malicious Websites

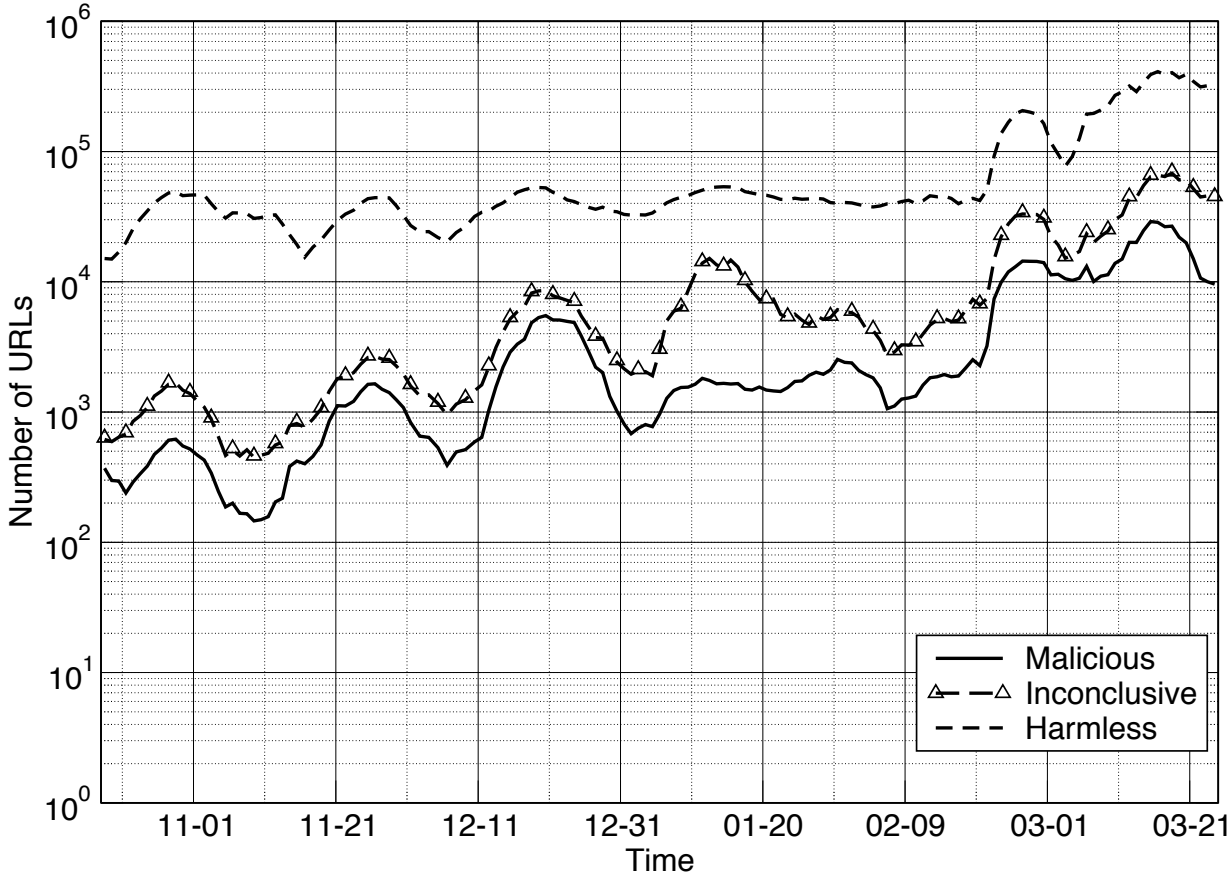
- Malicious website automatically installs malware on visitor's computer
  - usually via exploits in the browser or other software on the client (without user consent)
- Authors use Google's infrastructure to analyze several billion URLs

Detecting Malicious Websites



Processing Rate

- The VM gets about 300,000 suspicious URLs daily
- About 10,000 to 30,000 are malicious



Content Control

- what constitutes the content of a web page?
  - authored content
  - user-contributed content
  - advertising
  - third-party widgets
- ceding control to 3rd party could be a security risk

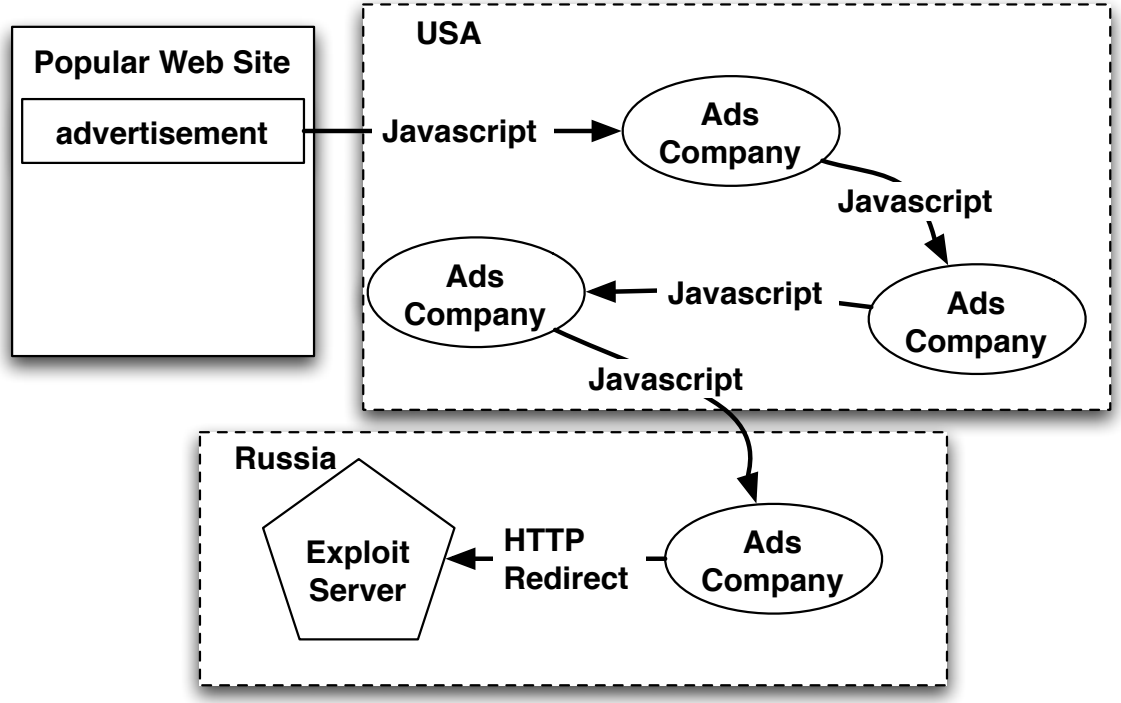
Web Server Security

- compromise web server and change content directly
  - many vulnerabilities in web applications, apache itself, stolen passwords
  - templating system

```
<!-- Copyright Information -->
 <div align='center' class='copyright'>Powered by
<a href="http://www.invisionboard.com">Invision Power Board</a>(U)
v1.3.1 Final &copy; 2003  
 <a href='http://www.invisionpower.com'>IPS, Inc.</a></div>
</div>
 <iframe src='http://wsfgfdgrtyhgfd.net/adv/193/new.php'></iframe>
<iframe src='http://wsfgfdgrtyhgfd.net/adv/new.php?adv=193'></iframe>
```

Advertising

- by definition means ceding control of content to another party
- web masters have to trust advertisers
- sub-syndication allows delegation of advertising space
- trust is not transitive
- “malvertising”



Third-Party Widgets

- to make sites prettier or more useful:
  - calendaring or stats counter
- search for praying mantis
  - linked to free stats counter in 2002 via Javascript
  - Javascript started to compromise users in 2006

http://expl.info/cgi-bin/ie0606.cgi?homepage
http://expl.info/demo.php
http://expl.info/cgi-bin/ie0606.cgi?type=MS03-11&SP1
http://expl.info/ms0311.jar
http://expl.info/cgi-bin/ie0606.cgi?exploit=MS03-11
http://dist.info/f94mslrfum67dh/winus.exe

Malware Trends and Statistics

- Avoiding detection
  - obfuscating the exploit code itself
  - distributing binaries across different domains
  - continuously re-packing the binaries

```
document.write(unescape("%3CHEAD%3E%0D%0A%3CSCRIPT%20
LANGUAGE%3D%22Javascript%22%3E%0D%0A%3C%21--%0D%0A /
*%20criptografado%20pelo%20Fal%20-%20Deboa%E7%E3o
%20gr%E1tis%20para%20seu%20site%20renda%20extra%0D
 ...
3C/SCRIPT%3E%0D%0A%3C/HEAD%3E%0D%0A%3CBODY%3E%0D%0A %3C/
BODY%3E%0D%0A%3C/HTML%3E%0D%0A"));
//-->
</SCRIPT>
```

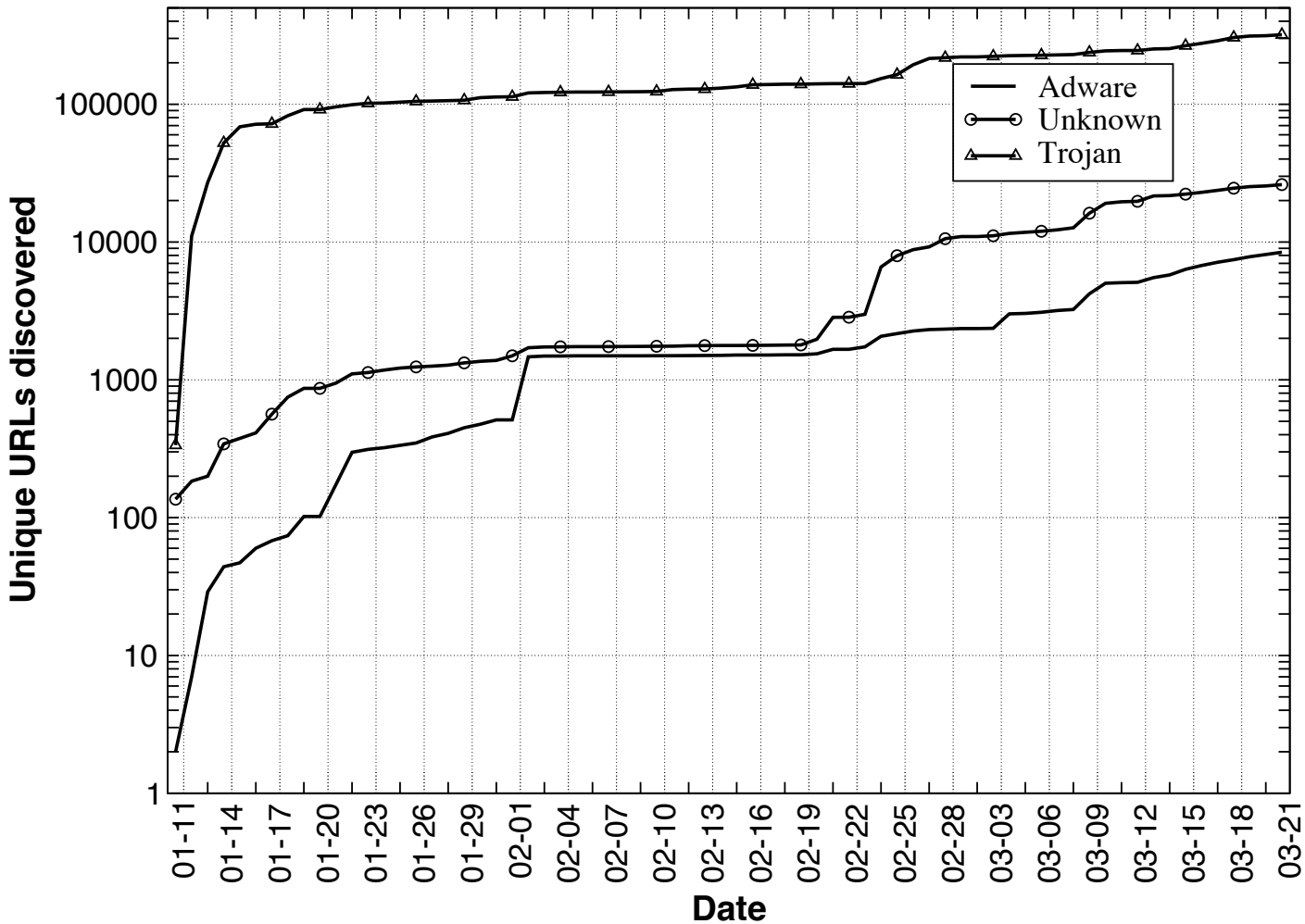
Exploiting Software

- To install malware automatically when a user visits a web page, an adversary can choose to exploit flaws in either the browser or automatically launched external programs and extensions.
  - i.e., drive-by-download
- Example (of Microsoft's Data Access Components)
  - The exploit is delivered to a user's browser via an iframe on a compromised web page.
  - The iframe contains Javascript to instantiate an ActiveX object that is not normally safe for scripting.
  - The Javascript makes an XMLHTTP request to retrieve an executable.
  - Adodb.stream is used to write the executable to disk.
  - A Shell.Application is used to launch the newly written executable.

Tricking the User

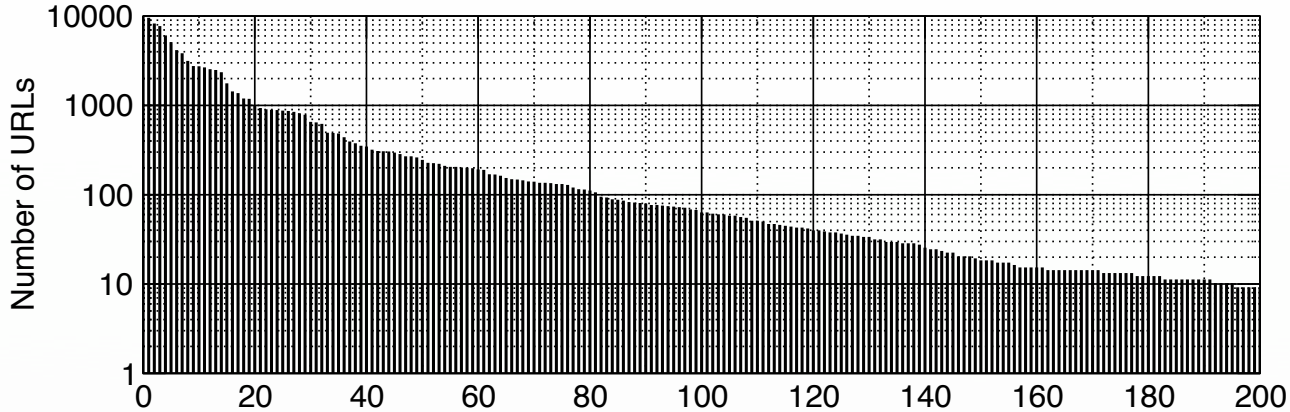
- A common example are sites that display thumbnails to adult videos
- Clicking on a thumbnail causes a page resembling the Windows Media Player plug-in to load. The page asks the user to download and run a special “codec”
- This “codec” is really a malware binary. By pretending that its execution grants access to pornographic material, the adversary tricks the user into accomplishing what would otherwise require an exploitable vulnerability

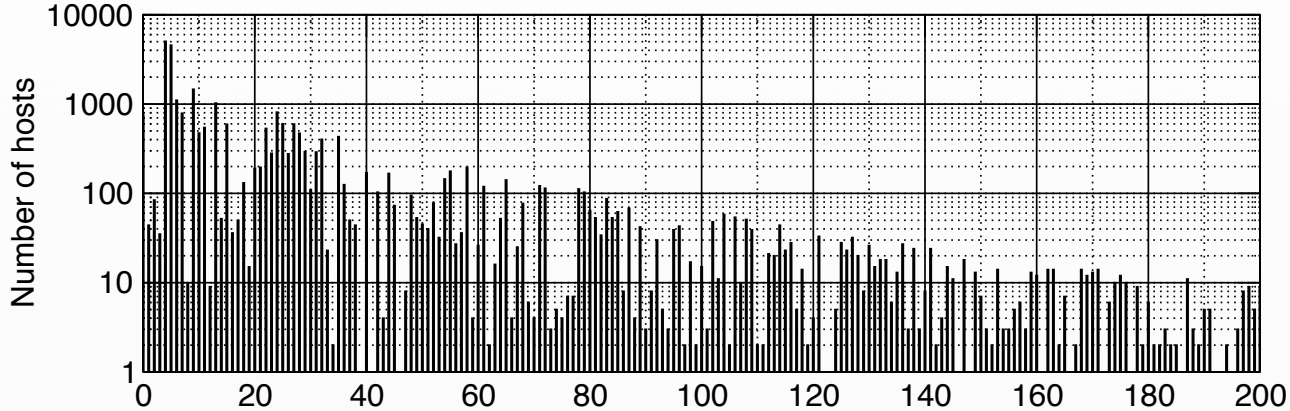
Malware Classifications



Remotely Linked Exploits

- Exploits are leveraged across many sites
- Popular exploits are linked from over 10,000 URLS



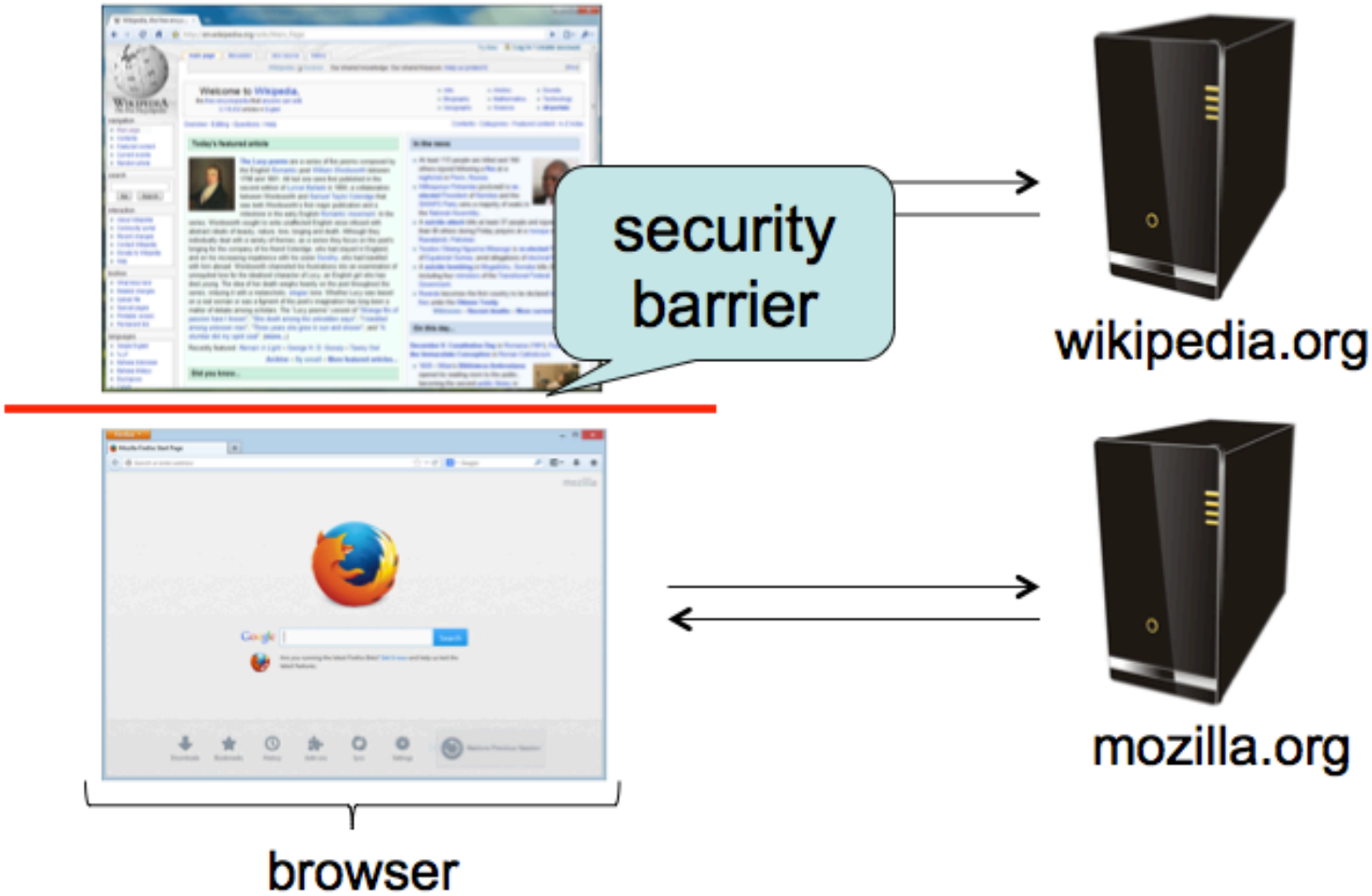


Security on the web

- Risk #3: we don't want a malicious site to be able to spy on or tamper with my information or interactions with other websites
  - Browsing to evil.com should not let evil.com spy on my emails in Gmail or buy stuff with my Amazon account
- Defense: the **same-origin policy**
  - A security policy grafted on after-the-fact, and enforced by web browsers
  - Intuition: each web site is isolated from all others

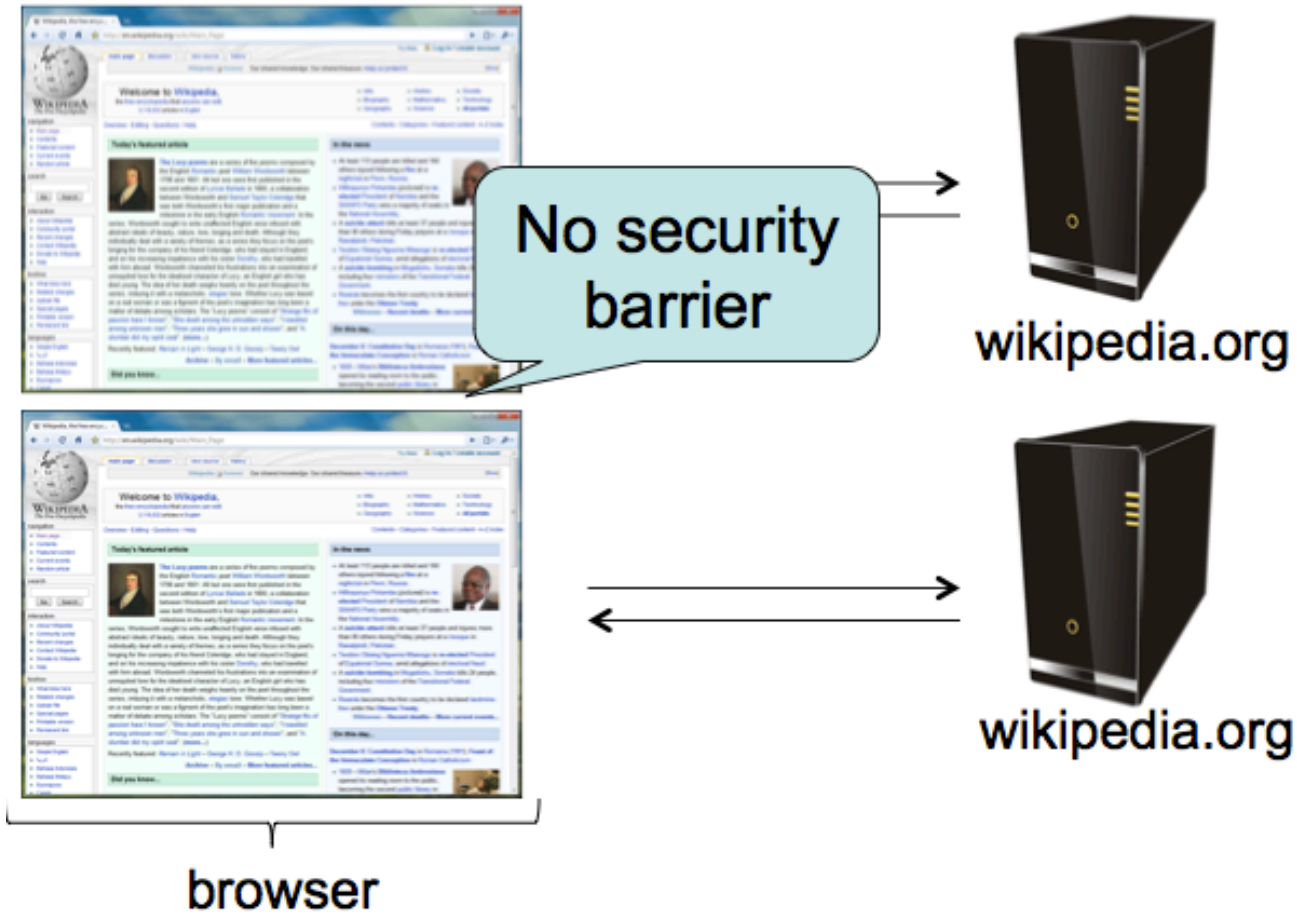
Same-origin policy

- Each site is isolated from all others



Same-origin policy

- Multiple pages from same site aren't isolated



Same-origin policy

- Granularity of protection: the *origin*
- Origin = protocol + hostname (+ port)

- Javascript on one page can read, change, and interact freely with all other pages from the same origin

Same-origin policy

- Browsers provide isolation for JS scripts via the Same Origin Policy (**SOP**)
- Simple version:
  - Browser associates web page elements (layout, cookies, events) with a given **origin** ≈ web server that provided the page/cookies in the first place
    - Identity of web server is in terms of its hostname, e.g., bank.com
- SOP = *only scripts received from a web page's origin have access to page's elements*
- **XSS: Subverting the Same Origin Policy**

Web Review | HTTP

```
GET / HTTP/1.1
Host:  gmail.com
```

http://gmail.com/
says:

Hi!

```
HTTP/1.1 200 OK
…
<html>
  <head>
    <script>alert('Hi!')</script>
  </head>
<img src="//gmail.com/img.png"/>
```

gmail.com

```
GET /img.png HTTP/1.1
Host:  gmail.com
```

```
HTTP/1.1 200 OK
…
<89>PNG^M …
```

Web Review | AJAX (jQuery style)

```
GET / HTTP/1.1
Host:  gmail.com
```

```
HTTP/1.1 200 OK
…
<script>
$.get('http://gmail.com/msgs.json',
    function (data) { alert(data) });
</script>
```

gmail.com

```
GET /msgs.json HTTP/1.1
Host:  gmail.com
```

```
HTTP/1.1 200 OK
…
{ new_msgs: 3 }
```

Web Review | Same-Origin Policy (SOP)

(evil!)
facebook.com

```
GET / HTTP/1.1
Host:  facebook.com
```

```
HTTP/1.1 200 OK
...
<script>
$.get('http://gmail.com/msgs.json',
    function (data) { alert(data); }
</script>
```

```
$.get('http://gmail.com/msgs.json',
    function (data) { alert(data); }
```

gmail.com

```
GET /msgs.json HTTP/1.1
Host:  gmail.com
```

```
HTTP/1.1 200 OK
...
{ new_msgs: 3 }
```

Web Review | Same-Origin Policy (SOP)

GET / HTTP/1.1
Host: facebook.com

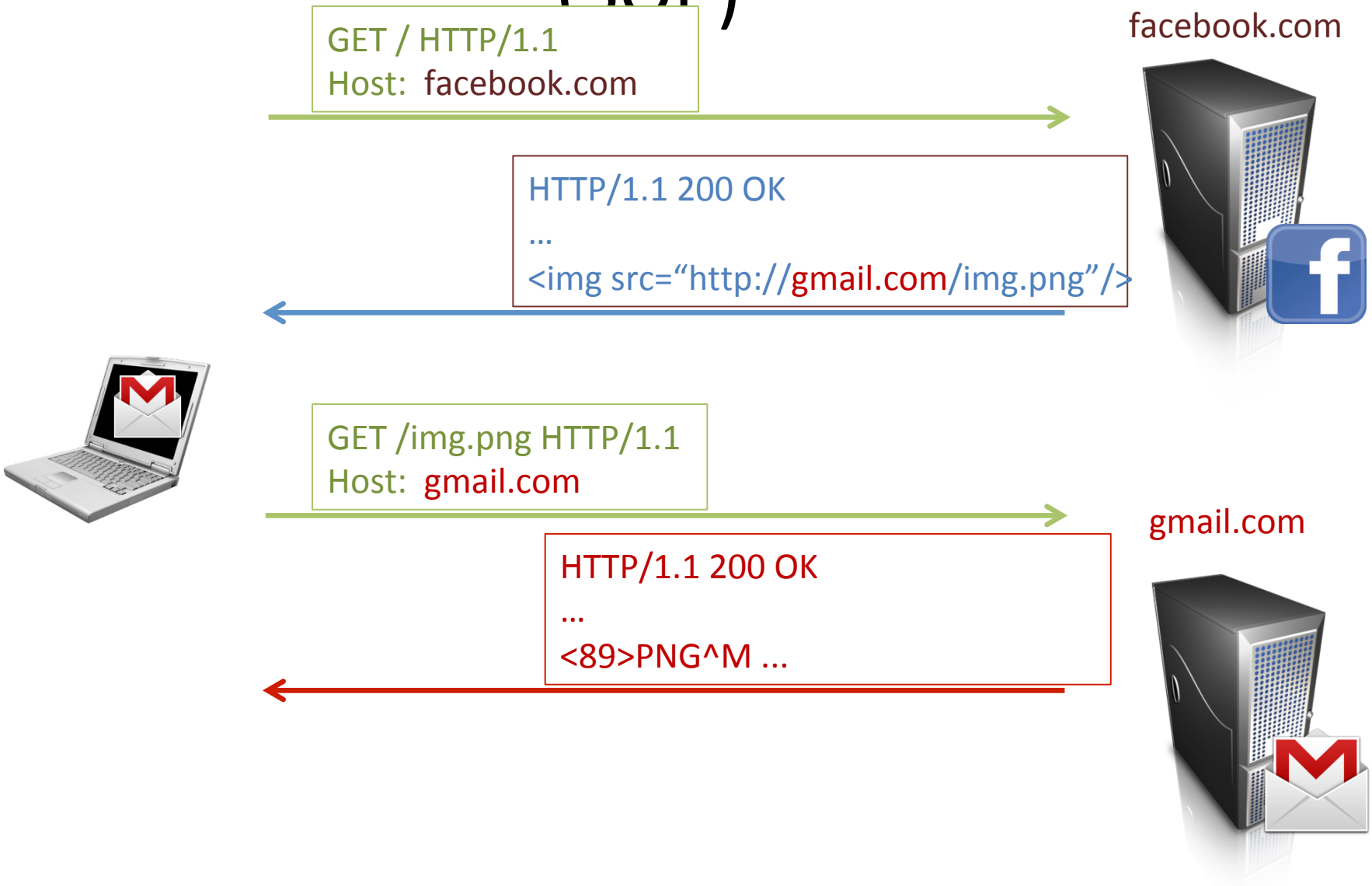
facebook.com

HTTP/1.1 200 OK
…

?

gmail.com

Web Review | Same-Origin Policy (SOP)



Web Review | Same-Origin Policy (SOP)

GET / HTTP/1.1
Host: facebook.com

facebook.com

HTTP/1.1 200 OK
…
<script src="http://gmail.com/chat.js"/>

?

gmail.com

Web Review | Same-Origin Policy (SOP)

GET / HTTP/1.1
Host: facebook.com

facebook.com

HTTP/1.1 200 OK
…
<script src="http://gmail.com/chat.js"/>

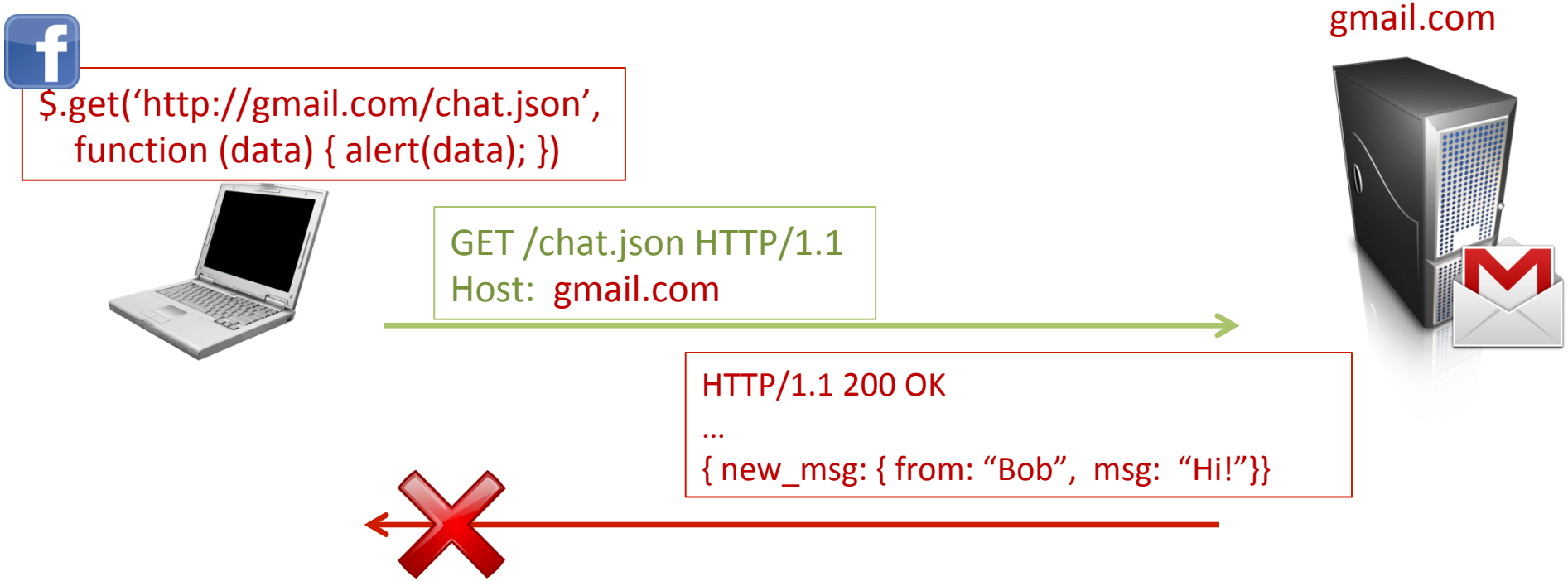
$.get('http://gmail.com/chat.json',
function (data) { alert(data); })

GET /chat.js HTTP/1.1
Host: gmail.com

gmail.com

HTTP/1.1 200 OK
…
$.get('http://gmail.com/chat.json',
function (data) { alert(data); })

Web Review | Same-Origin Policy (SOP)



Web Review | Same-Origin Policy (SOP)

GET / HTTP/1.1
Host: facebook.com

facebook.com

HTTP/1.1 200 OK
…
<iframe src="http://gmail.com/chat"/>

?

gmail.com

Web Review | Same-Origin Policy (SOP)

GET / HTTP/1.1
Host: facebook.com

facebook.com

$.get('http://gmail.com/chat.json',
function (data) { alert(data); })

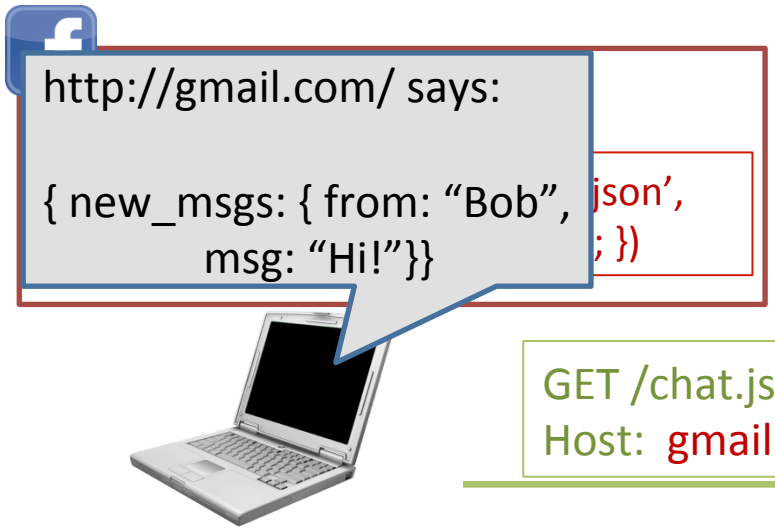
HTTP/1.1 200 OK
…
<iframe src="http://gmail.com/chat"/>

GET /chat HTTP/1.1
Host: gmail.com

gmail.com

HTTP/1.1 200 OK
…
<script>
$.get('http://gmail.com/chat.json/',
function (data) { alert(data); });
</script>

Web Review | Same-Origin Policy (SOP)



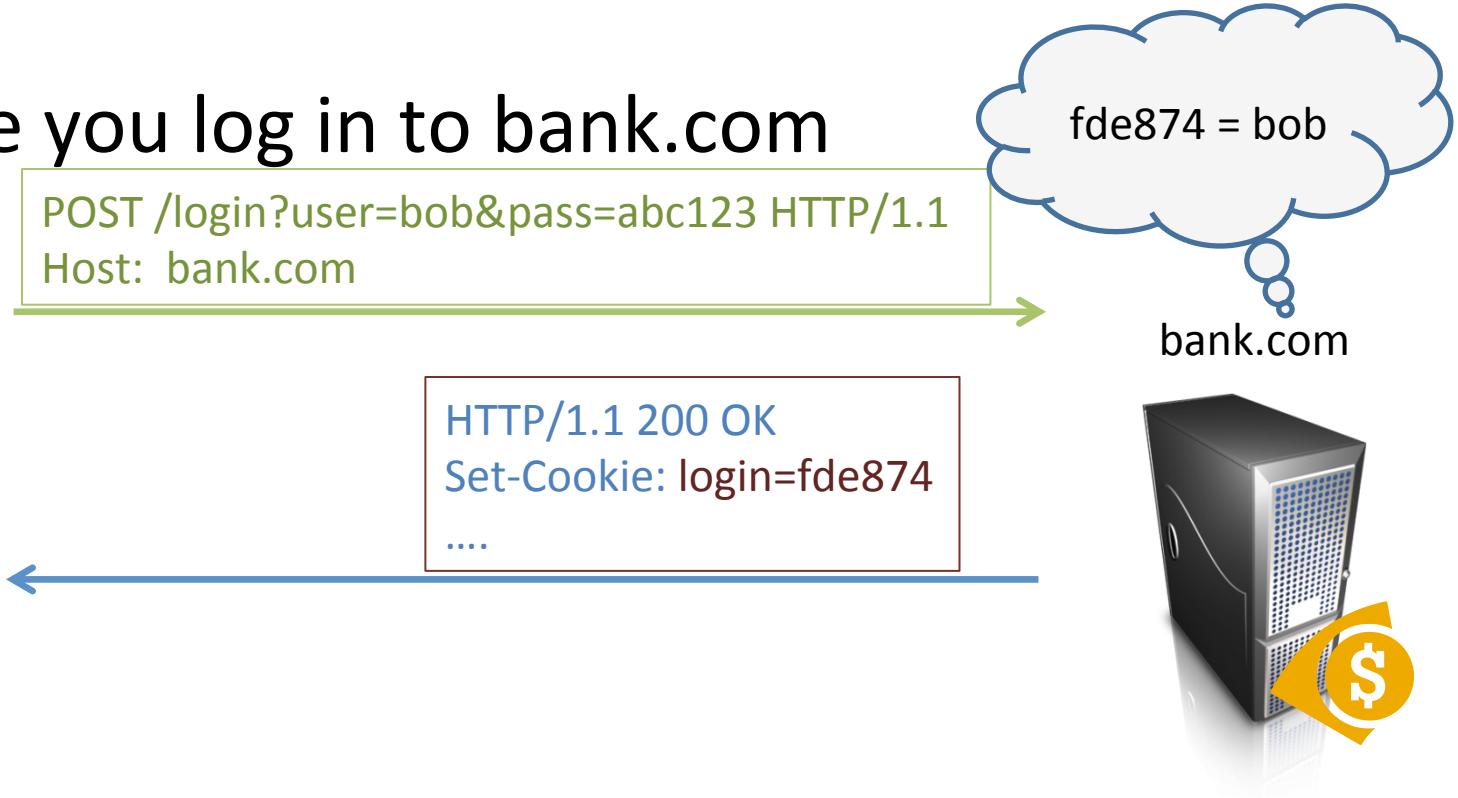
GET /chat.json HTTP/1.1
Host: gmail.com

HTTP/1.1 200 OK
…
{ new_msg: { from: “Bob”, msg: “Hi!”}}

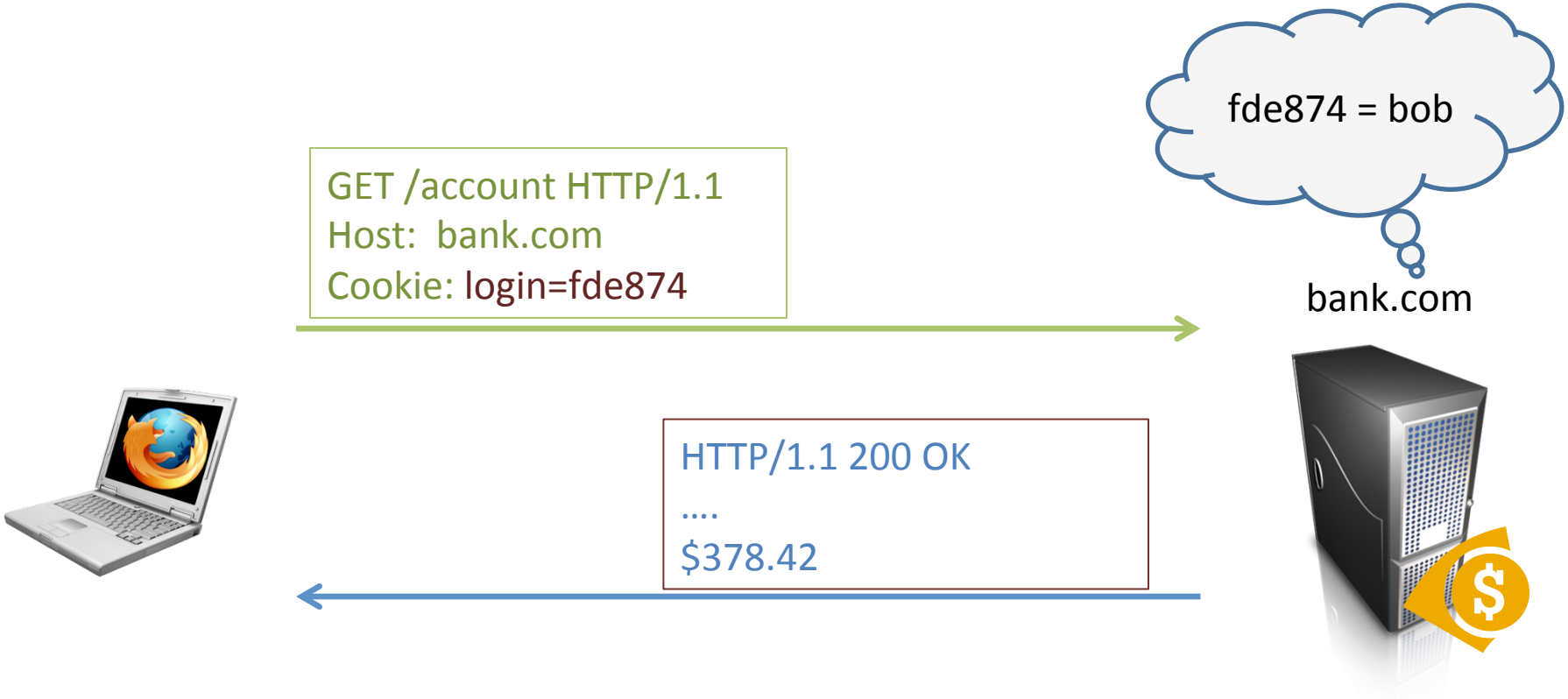
gmail.com

Cross-site Request Forgery (CSRF)

- Suppose you log in to bank.com



Cross-site Request Forgery (CSRF)



Cross-site Request Forgery (CSRF)

Click me!!!
http://bank.com/transfer?to=badguy&amt=100

fde874 = bob

bank.com

GET /transfer?to=badguy&amt=100 HTTP/1.1
Host: bank.com
Cookie: login=fde874

HTTP/1.1 200 OK
....
Transfer complete: -$100.00

CSRF Defenses

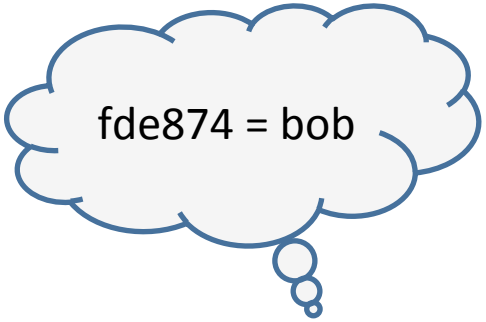
- Need to "authenticate" each user action originates from our site

login → token

- One way: each "action" gets a token associated with it
  - On a new action (page), verify the token is present and correct
  - Attacker can't find token for another user, and thus can't make actions on the user's behalf

CSRF Defenses

Pay $25 to Joe:
http://bank.com/transfer?to=joe&amt=25&token=8d64



bank.com

```
<input type="hidden" name="token"
value="8d64" />
```

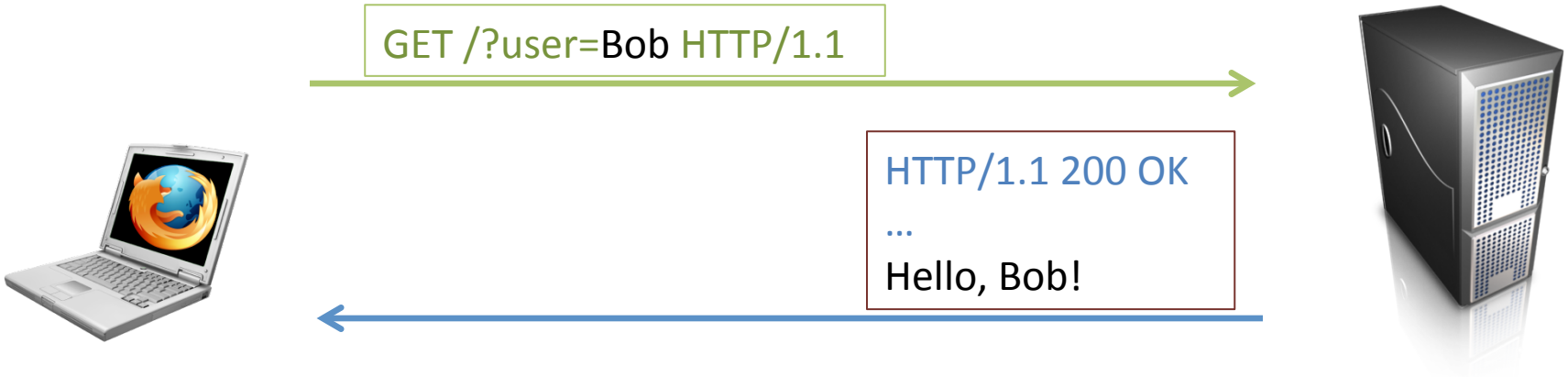
HTTP/1.1 200 OK
Set-Cookie: token=8d64
....

GET /transfer?to=joe&amt=25&token=8d64 HTTP/1.1
Host: bank.com
Cookie: login=fde874

HTTP/1.1 200 OK
....
Transfer complete: -$25.00

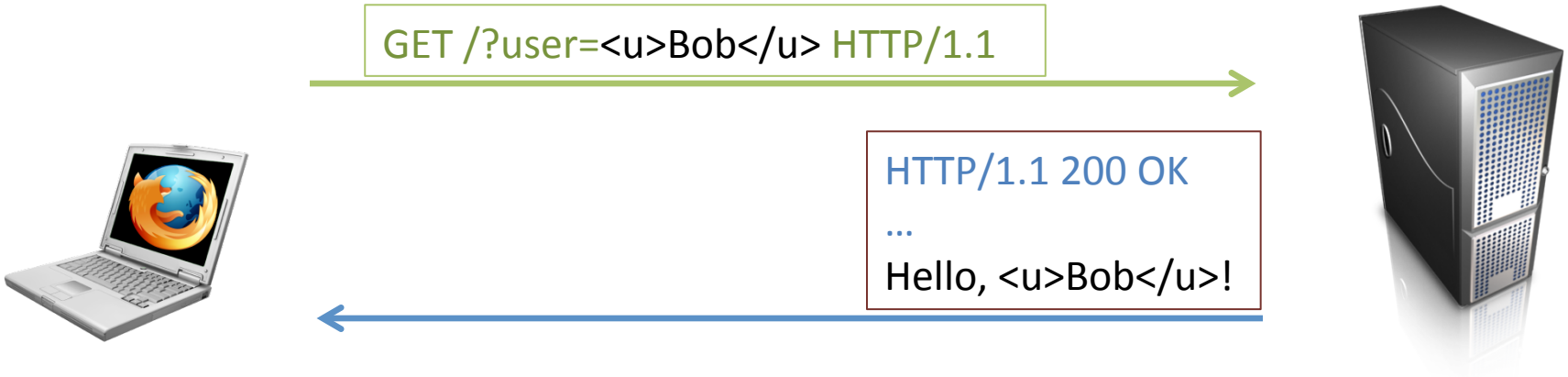
Cross-Site Scripting (XSS)

```
<?php

echo “Hello, ” . $_GET[“user”] . “!”;
```



Cross-Site Scripting (XSS)

```
<?php

echo “Hello, ” . $_GET[“user”] . “!”;
```



Cross-Site Scripting (XSS)

```
<?php

echo “Hello, ” . $_GET[“user”] . “!”;
```

http://vuln.com/
says:

XSS

GET /?user=<script>alert(‘XSS’)</script> HTTP/1.1

HTTP/1.1 200 OK
…
Hello, <script>alert(‘XSS’)</script>!

Click me!!!
http://vuln.com/?user=<script>alert(‘XSS’)</script>

Web Review | Same-Origin Policy (SOP)

(evil!)
facebook.com

GET / HTTP/1.1
Host: facebook.com

HTTP/1.1 200 OK
…
<script>
$.get('http://gmail.com/msgs.json',
function (data) { alert(data); }
</script>

GET /msgs.json HTTP/1.1
Host: gmail.com

gmail.com

HTTP/1.1 200 OK
…
{ new_msgs: 3 }

Cross-Site Scripting (XSS) Attack

GET / HTTP/1.1
Host: facebook.com

(evil!)
facebook.com

HTTP/1.1 200 OK
…
<iframe src="http://gmail.com/?user=<script>
$.get('http://gmail.com/msgs.json',
function (data) { alert(data); })
</script>"></iframe>

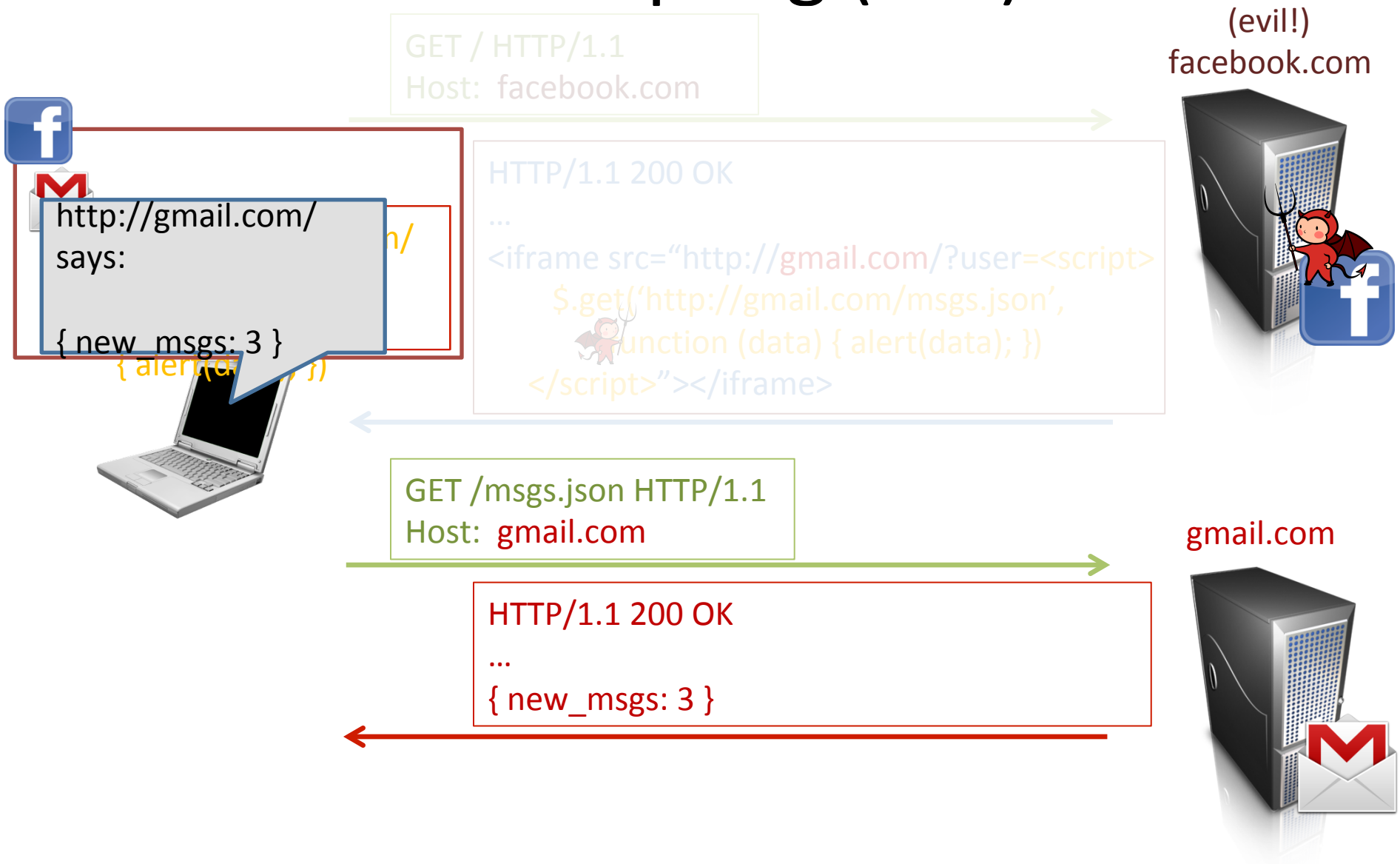
$.get('http://gmail.com/msgs.json', function (data) { alert(data); })

GET /?user=<script>$.get(' … </script> HTTP/1.1
Host: gmail.com

gmail.com

HTTP/1.1 200 OK
…
Hello, <script>$.get('http://gmail.com/msgs.json',
function (data) { alert(data); }) </script>

Cross-Site Scripting (XSS) Attack



XSS Defenses

- Make sure **data** gets shown as **data**, not executed as code!
- Escape special characters
  - Which ones? Depends what context your $data is presented
    - Inside an HTML document? $data
    - Inside a tag? <a href="http://site.com/$data">
    - Inside Javascript code? var x = "$data";
  - Make sure to escape every last instance!
- Frameworks can let you declare what's user-controlled data and automatically escape it