Web Security

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Goals for Today

- Web Security
- (Back later to asymmetric cryptography)
Browser and Network

- Browser
- OS
- Hardware

Network

website

request

reply
Types of problems

- **Web browser problems (client side)**
  - Exploit vulnerabilities in browsers
  - Install botnets, keyloggers
  - Exfiltrate data

- **Web application code (server side)**
  - Exploit vulnerabilities in code running on servers (and coming from servers)
  - Examples: XSS, XSRF, SQL injection, clickjacking, insecure parameters, security misconfigurations
  - Steal user credentials, data from databases, ...
Example Questions

- How do websites know who you are?
- How do you know who the website is?
- Can someone intercept traffic?
- Related: How can you better control flow of information?

- Our focus: High-level principles (lab focuses on pragmatics)
- Focus on a bit of history: How we got here
HTTP: HyperText Transfer Protocol

- Used to request and return data
  - Methods: GET, POST, HEAD, ...

- **Stateless** request/response protocol
  - Each request is independent of previous requests
  - Statelessness has a significant impact on design and implementation of applications

- Evolution
  - HTTP 1.0: simple
  - HTTP 1.1: more complex
  - ... HTML 5 ...
## HTTP Request

<table>
<thead>
<tr>
<th>Method</th>
<th>File</th>
<th>HTTP version</th>
<th>Headers</th>
</tr>
</thead>
<tbody>
<tr>
<td>GET</td>
<td>/default.asp</td>
<td>HTTP/1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accept: image/gif, image/x-bitmap, image/jpeg, <em>/</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accept-Language: en</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>User-Agent: Mozilla/1.22 (compatible; MSIE 2.0; Windows 95)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Connection: Keep-Alive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If-Modified-Since: Sunday, 17-Apr-96 04:32:58 GMT</td>
</tr>
</tbody>
</table>

Data – none for GET

Blank line
HTTP Response

HTTP version  Status code  Reason phrase  Headers

HTTP/1.0 200 OK
Date: Sun, 21 Apr 1996 02:20:42 GMT
Server: Microsoft-Internet-Information-Server/5.0
Connection: keep-alive
Content-Type: text/html
Last-Modified: Thu, 18 Apr 1996 17:39:05 GMT
Content-Length: 2543

<HTML> Some data... blah, blah, blah </HTML>
Primitive Browser Session

View catalog

www.e_buy.com

Select item

www.e_buy.com/shopping.cfm?pID=269

www.e_buy.com/shopping.cfm?pID=269&item1=102030405

Check out

www.e_buy.com/checkout.cfm?pID=269&item1=102030405

Store session information in URL; easily read on network
FatBrain.com circa 1999 [due to Fu et al.]

- User logs into website with his password, authenticator is generated, user is given special URL containing the authenticator

  https://www.fatbrain.com/HelpAccount.asp?t=0&p1=me@me.com&p2=540555758

  - With special URL, user doesn’t need to re-authenticate
    - Reasoning: user could not have not known the special URL without authenticating first. That’s true, BUT...

- Authenticators are global sequence numbers
  - It’s easy to guess sequence number for another user

  https://www.fatbrain.com/HelpAccount.asp?t=0&p1=SomeoneElse&p2=540555752

  - Partial fix: use random authenticators
Bad Idea: Encoding State in URL

- Unstable, frequently changing URLs
- Vulnerable to eavesdropping
- There is no guarantee that URL is private
Cookies
A **cookie** is a data blob created by an Internet site to store information on your computer.

HTTP is traditionally a stateless protocol; cookies add state.
What Are Cookies Used For?

- **Authentication**
  - Use the fact that the user authenticated correctly in the past to make future authentication quicker

- **Personalization**
  - Recognize the user from a previous visit

- **Tracking**
  - Follow the user from site to site; learn his/her browsing behavior, preferences, and so on
Web Authentication via Cookies

- Need authentication system that works over HTTP and does not require servers to store session data.

- Servers can use cookies to store state on client:
  - When session starts, server computes an authenticator and gives it back to browser in the form of a cookie.
    - Authenticator is a value that client cannot forge on his own.
    - Example: MAC(server’s secret key, session id).
  - With each request, browser presents the cookie.
  - Server recomputes and verifies the authenticator.
    - Server does not need to remember the authenticator.
Typical Session with Cookies

client

POST /login.cgi

Set-Cookie: authenticator

GET /restricted.html

Cookie: authenticator

Restricted content

server

Verify that this client is authorized

Check validity of authenticator (e.g., recompute hash(key,sessId))

Authenticators must be **unforgeable and tamper-proof**
(malicious client shouldn’t be able to compute his own or modify an existing authenticator)
Cookie Management

- **Cookie ownership**
  - Once a cookie is saved on your computer, only the website that created the cookie can read it (supposedly)

- **Variations**
  - **Session cookies**
    - Stored until you quit your browser
  - **Persistent cookies**
    - Remain until deleted or expire
  - **Third-party cookies**
    - Set by sites embedded within other sites (e.g., ads)
Privacy Issues with Cookies

◆ Cookie may include any information about you known by the website that created it
  • Browsing activity, account information, etc.

◆ Sites can share this information
  • Advertising networks

◆ Browser attacks could invade your privacy

November 8, 2001 (and many more since):
Users of Microsoft's browser and e-mail programs could be vulnerable to having their browser cookies stolen or modified due to a new security bug in Internet Explorer (IE), the company warned today.
Storing State in Browser

◆ Dansie Shopping Cart (2006)
  • “A premium, comprehensive, Perl shopping cart. Increase your web sales by making it easier for your web store customers to order.”

```html
<FORM METHOD=POST
ACTION="http://www.dansie.net/cgi-bin/scripts/cart.pl">
  Black Leather purse with leather straps<BR>Price: $20.00<BR>
  <INPUT TYPE=HIDDEN NAME=name     VALUE="Black leather purse">
  <INPUT TYPE=HIDDEN NAME=price    VALUE="20.00">
  <INPUT TYPE=HIDDEN NAME=sh       VALUE="1">
  <INPUT TYPE=HIDDEN NAME=img      VALUE="purse.jpg">
  <INPUT TYPE=HIDDEN NAME=custom1  VALUE="Black leather purse with leather straps">
  <INPUT TYPE=SUBMIT NAME="add" VALUE="Put in Shopping Cart">
</FORM>
```

Change this to 2.00
Many Web-based shopping cart applications use hidden fields in HTML forms to hold parameters for items in an online store. These parameters can include the item's name, weight, quantity, product ID, and price. Any application that bases price on a hidden field in an HTML form is vulnerable to price changing by a remote user. A remote user can change the price of a particular item they intend to buy, by changing the value for the hidden HTML tag that specifies the price, to purchase products at any price they choose.

Platforms Affected:

- 3D3.COM Pty Ltd: ShopFactory 5.8 and earlier
- Adgrafix: Check It Out Any version
- ComCity Corporation: SalesCart Any version
- Dansie.net: Dansie Shopping Cart Any version
- Make-a-Store: Make-a-Store OrderPage Any version
- McMurtrey/Whitaker & Associates: Cart32 3.0
- McMurtrey/Whitaker & Associates: Cart32 2.6
- Rich Media Technologies: JustAddCommerce 5.0
- Web Express: Shoptron 1.2
Storing State in Browser Cookies

- Set-cookie: price=299.99
- User edits the cookie... cookie: price=29.99
- What’s the solution?
- Add a MAC to every cookie, computed with the server’s secret key
  - Price=299.99; MAC(ServerKey, 299.99)
Storing State in Browser

romatic Dansie Shopping Cart (2006)

- "A premium, comprehensive, Perl shopping cart. Increase your web sales by making it easier for your web store customers to order."

```
<FORM METHOD=POST
    ACTION="http://www.dansie.net/cgi-bin/scripts/cart.pl">

    Black Leather purse with leather straps<BR>Price: $20.00<BR>
    <INPUT TYPE=HIDDEN NAME=name VALUE="Black leather purse">
    <INPUT TYPE=HIDDEN NAME=pricemac VALUE="F13A3....B2" A319F...3C>
    <INPUT TYPE=HIDDEN NAME=sh VALUE="1">
    <INPUT TYPE=HIDDEN NAME=img VALUE="purse.jpg">
    <INPUT TYPE=HIDDEN NAME=custom1 VALUE="Black leather purse  with leather straps">

    <INPUT TYPE=SUBMIT NAME="add" VALUE="Put in Shopping Cart">

</FORM>
```

Better: MAC(K, "$20,Black leather purse, product number 12345, ...")
WSJ.com circa 1999  [due to Fu et al.]

- **Idea:** use `user,hash(user||key)` as authenticator
  - Key is secret and known only to the server. Without the key, clients can’t forge authenticators.
  - `||` is string concatenation

- **Implementation:** `user,crypt(user||key)`
  - `crypt()` is UNIX hash function for passwords
  - `crypt()` truncates its input at 8 characters
  - Usernames matching first 8 characters end up with the same authenticator
  - No expiration or revocation

- **It gets worse…** This scheme can be exploited to extract the server’s secret key
### Attack

<table>
<thead>
<tr>
<th>username</th>
<th>crypt(username,key,&quot;00&quot;)</th>
<th>authenticator cookie</th>
</tr>
</thead>
<tbody>
<tr>
<td>AliceBob1</td>
<td>008H8LRfzUXvk</td>
<td>AliceBob1008H8LRfzUXvk</td>
</tr>
<tr>
<td>AliceBob2</td>
<td>008H8LRfzUXvk</td>
<td>AliceBob2008H8LRfzUXvk</td>
</tr>
</tbody>
</table>

“Create” an account with a 7-letter user name...

<table>
<thead>
<tr>
<th>username</th>
<th>crypt(username,key,&quot;00&quot;)</th>
<th>authenticator cookie</th>
</tr>
</thead>
<tbody>
<tr>
<td>AliceBoA</td>
<td>0073UYEre5rBQ</td>
<td>Try logging in: access refused</td>
</tr>
<tr>
<td>AliceBoB</td>
<td>00bkHcfOXBKno</td>
<td>Access refused</td>
</tr>
<tr>
<td>AliceBoC</td>
<td>00ofSVJ6An1QE</td>
<td>Login successful! 1st key symbol is C</td>
</tr>
</tbody>
</table>

Now a 6-letter user name...

<table>
<thead>
<tr>
<th>username</th>
<th>crypt(username,key,&quot;00&quot;)</th>
<th>authenticator cookie</th>
</tr>
</thead>
<tbody>
<tr>
<td>AliceBCA</td>
<td>001mBnBErXRuc</td>
<td>Access refused</td>
</tr>
<tr>
<td>AliceBCB</td>
<td>00T3JLLfuspdo</td>
<td>Access refused... and so on</td>
</tr>
</tbody>
</table>

- Only need 128 x 8 queries instead of intended $128^8$
- Minutes with a simple Perl script vs. billions of years
Better Cookie Authenticator

- Capability
- Expiration

MAC(server secret, capability, expiration)

Describes what user is authorized to do on the site that issued the cookie

Cannot be forged by malicious user; does not leak server secret

◆ Main lesson: be careful rolling your own
  - Homebrewed authentication schemes are easy to get wrong
◆ There are standard cookie-based schemes
Web Applications

- Online banking, shopping, government, etc.
- Website takes input from user, interacts with back-end databases and third parties, outputs results by generating an HTML page
- Often written from scratch in a mixture of PHP, Java, Perl, Python, C, ASP, ...
- Security is a potential concern.
  - Poorly written scripts
  - Sensitive data stored in world-readable files
General issue: Inadequate Input Validation

- copy.php includes
  ```
  system("cp temp.dat $name.dat")
  ```
- User calls
  ```
  http://victim.com/copy.php?name="a; rm *
  ```
- copy.php executes
  ```
  system("cp temp.dat a; rm *.dat");
  ```