Penetration Testing for Web Applications (Part One)

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This is the first in a series of three articles on penetration testing for Web applications. The first installment provides the penetration tester with an overview of Web applications - how they work, how they interact with users, and most importantly how developers can expose data and systems with poorly written and secured Web application front-ends.

Note: It is assumed that the reader of this article has some knowledge of the HTTP protocol - specifically, the format of HTTP GET and POST requests, and the purpose of various header fields. This information is available in RFC2616.

Web applications are becoming more prevalent and increasingly more sophisticated, and as such they are critical to almost all major online businesses. As with most security issues involving client/server communications, Web application vulnerabilities generally stem from improper handling of client requests and/or a lack of input validation checking on the part of the developer.

The very nature of Web applications - their ability to collate, process and disseminate information over the Internet - exposes them in two ways. First and most obviously, they have total exposure by nature of being publicly accessible. This makes security through obscurity impossible and heightens the requirement for hardened code. Second and most critically from a penetration testing perspective, they process data elements from within HTTP requests - a protocol that can employ a myriad of encoding and encapsulation techniques.

Most Web application environments (including ASP and PHP, which will both be used for examples throughout the series), expose these data elements to the developer in a manner that fails to identify how they were captured and hence what kind of validation and sanity checking should apply to them. Because the Web "environment" is so diverse and contains so many forms of programmatic content, input validation and sanity checking is the key to Web applications security. This involves both identifying and enforcing the valid domain of every user-definable data element, as well as a sufficient understanding of the source of all data elements to determine what is potentially user definable.

The Root of the Issue: Input Validation

Input validation issues can be difficult to locate in a large codebase with lots of user interactions, which is the main reason that developers employ penetration testing methodologies to expose these problems. Web applications are, however, not immune to the more traditional forms of attack. Poor authentication mechanisms, logic flaws, unintentional disclosure of content and environment information, and traditional binary application flaws (such as buffer overflows) are rife. When approaching a Web application as a penetration tester, all this must be taken into account, and a methodical process of input/output or "blackbox" testing, in addition to (if possible) code auditing or "whitebox" testing, must be applied.

What exactly is a Web application?

A Web application is an application, generally comprised of a collection of scripts, that reside on a Web server and interact with databases or other sources of dynamic content. They are fast becoming ubiquitous as they allow service providers and their clients to share and manipulate information in an (often) platform-independent manner via the infrastructure of the Internet. Some examples of Web applications include search engines, Webmail, shopping carts and portal systems.

How does it look from the users perspective?

Web applications typically interact with the user via FORM elements and GET or POST variables (even a 'Click Here' button is usually a FORM submission). With GET variables, the inputs to the application can be seen within the URL itself, however with POST requests it is often necessary to study the source of form-input pages (or capture and decode valid requests) in order to determine the users inputs.

An example HTTP request that might be provided to a typical Web application is as follows:

```
GET /sample.php?var=value&var2=value2 HTTP/1.1   | HTTP-METHOD REQUEST-URI PROTOCOL/VERSION
Session-ID: 361873127da673c                      | Session-ID Header
Host: www.webserver.com                          | Host Header
```

```
<CR><LF><CR><LF>                                    | Two carriage
                                                    return line feeds
```

Every element of this request can potentially be used by the Web application processing the request. The REQUEST-URI identifies the unit of code that will be invoked along with the query string: a separated list of &variable=value pairs defining input parameters. This is the main form of Web applications input. The Session-ID header provides a token identifying the client's established session as a primitive form of authentication. The Host header is used to distinguish between virtual hosts sharing the same IP address and will typically be parsed by the Web server, but is, in theory, within the domain of the Web application.

As a penetration tester you must use all input methods available to you in order to elicit exception conditions from the application. Thus, you cannot be limited to what a browser or automatic tools provide. It is quite simple to script HTTP requests using utilities like curl, or shell scripts using netcat. The process of exhaustive blackbox testing a Web application is one that involves exploring each data element, determining the expected input, manipulating or otherwise corrupting this input, and analysing the output of the application for any unexpected behaviour.

The Information Gathering Phase

Fingerprinting the Web Application Environment

One of the first steps of the penetration test should be to identify the Web application environment, including the scripting language and Web server software in use, and the operating system of the target server. All of these crucial details are simple to obtain from a typical Web application server through the following steps:

1. **Investigate the output from HEAD and OPTIONS http requests**

   The header and any page returned from a HEAD or OPTIONS request will usually contain a `SERVER:` string or similar detailing the Web server software version and possibly the scripting environment or operating system in use.

   ```
   OPTIONS / HTTP/1.0

   HTTP/1.1 200 OK
   ```

```
Server: Microsoft-IIS/5.0
Date: Wed, 04 Jun 2003 11:02:45 GMT
MS-Author-Via: DAV
Content-Length: 0
Accept-Ranges: none
DASL: <DAV:sql>
DAV: 1, 2
Public: OPTIONS, TRACE, GET, HEAD, DELETE, PUT, POST, COPY, MOVE, MKCOL,
PROPFIND, PROPPATCH, LOCK, UNLOCK, SEARCH
Allow: OPTIONS, TRACE, GET, HEAD, COPY, PROPFIND, SEARCH, LOCK, UNLOCK
Cache-Control: private
```

2. **Investigate the format and wording of 404/other error pages**

   Some application environments (such as ColdFusion) have customized and therefore easily recognizable error pages, and will often give away the software versions of the scripting language in use. The tester should deliberately request invalid pages and utilize alternate request methods (POST/PUT/Other) in order to glean this information from the server.

   Below is an example of a ColdFusion 404 error page:

3. **Test for recognised file types/extensions/directories**

   Many Web services (such as Microsoft IIS) will react differently to a request for a known and supported file extension than an unknown extension. The tester should attempt to request common file extensions such as .ASP, .HTM, .PHP, .EXE and watch for any unusual output or error codes.

```
GET /blah.idq HTTP/1.0

HTTP/1.1 200 OK
Server: Microsoft-IIS/5.0
Date: Wed, 04 Jun 2003 11:12:24 GMT
Content-Type: text/html

<HTML>The IDQ file blah.idq could not be found.
```

4. **Examine source of available pages**

   The source code from the immediately accessible pages of the application front-end may give clues as to the underlying application environment.

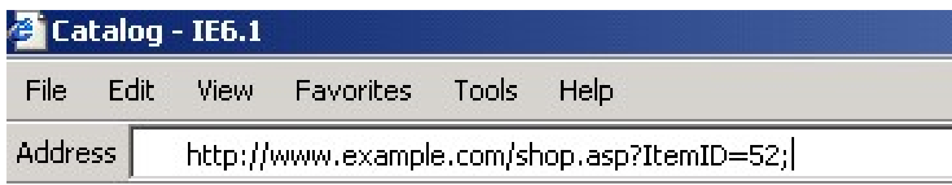
```
<title>Home Page</title>
<meta content="Microsoft Visual Studio 7.0" name="GENERATOR">
```

```
<meta content="C#" name="CODE_LANGUAGE">
<meta content="JavaScript" name="vs_defaultClientScript">
```

In this situation, the developer appears to be using MS Visual Studio 7. The underlying environment is likely to be Microsoft IIS 5.0 with .NET framework.

5. **Manipulate inputs in order to elicit a scripting error**

   In the example below the most obvious variable (ItemID) has been manipulated to fingerprint the Web application environment:

   Microsoft VBScript runtime error '800a000d'

   Type mismatch: 'CLng'

   /shop.asp, line 792

6. **TCP/ICMP and Service Fingerprinting** Using traditional fingerprinting tools such as Nmap and Queso, or the more recent application fingerprinting tools Amap and WebServerFP, the penetration tester can gain a more accurate idea of the underlying operating systems and Web application environment than through many other methods. NMAP and Queso examine the nature of the host's TCP/IP implementation to determine the operating system and, in some cases, the kernel version and patch level. Application fingerprinting tools rely on data such as Server HTTP headers to identify the host's application software.

Hidden form elements and source disclosure

In many cases developers require inputs from the client that should be protected from manipulation, such as a user-variable that is dynamically generated and served to the client, and required in subsequent requests. In order to prevent users from seeing and possibly

manipulating these inputs, developers use form elements with a HIDDEN tag. Unfortunately, this data is in fact only hidden from view on the rendered version of the page - not within the source.

There have been numerous examples of poorly written ordering systems that would allow users to save a local copy of order confirmation pages, edit HIDDEN variables such as price and delivery costs, and resubmit their request. The Web application would perform no further authentication or cross-checking of form submissions, and the order would be dispatched at a discounted price!

```
<FORM METHOD="LINK" ACTION="/shop/checkout.htm">
<INPUT TYPE="HIDDEN" name="quoteprice" value="4.25">Quantity: <INPUT TYPE="text"
NAME="totalnum"> <INPUT TYPE="submit" VALUE="Checkout">
</FORM>
```

This practice is still common on many sites, though to a lesser degree. Typically only non-sensitive information is contained in HIDDEN fields, or the data in these fields is encrypted. Regardless of the sensitivity of these fields, they are still another input to be manipulated by the blackbox penetration tester.

All source pages should be examined (where feasible) to determine if any sensitive or useful information has been inadvertently disclosed by the developer - this may take the form of active content source within HTML, pointers to included or linked scripts and content, or poor file/directory permissions on critical source files. Any referenced executables and scripts should be probed, and if accessible, examined.

Javascript and other client-side code can also provide many clues as to the inner workings of a Web application. This is critical information when blackbox testing. Although the whitebox (or 'code-auditing') tester has access to the application's logic, to the blackbox tester this information is a luxury which can provide for further avenues of attack. For example, take the following chunk of code:

```
<INPUT TYPE="SUBMIT" onClick="
if (document.forms['product'].elements['quantity'].value >= 255) {
   document.forms['product'].elements['quantity'].value='';
   alert('Invalid quantity');
   return false;
```

```
} else {
   return true;
}
">
```

This suggests that the application is trying to protect the form handler from quantity values of 255 of more - the maximum value of a `tinyint` field in most database systems. It would be trivial to bypass this piece of client-side validation, insert a long integer value into the 'quantity' GET/POST variable and see if this elicits an exception condition from the application.

Determining Authentication Mechanisms

One of the biggest shortcomings of the Web applications environment is its failure to provide a strong authentication mechanism. Of even more concern is the frequent failure of developers to apply what mechanisms are available effectively. It should be explained at this point that the term Web applications environment refers to the set of protocols, languages and formats - HTTP, HTTPS, HTML, CSS, JavaScript, etc. - that are used as a platform for the construction of Web applications. HTTP provides two forms of authentication: *Basic* and *Digest*. These are both implemented as a series of HTTP requests and responses, in which the client requests a resource, the server demands authentication and the client repeats the request with authentication credentials. The difference is that *Basic* authentication is clear text and *Digest* authentication encrypts the credentials using a `nonce` (time sensitive hash value) provided by the server as a cryptographic key.

Besides the obvious problem of clear text credentials when using *Basic*, there is nothing inherently wrong with HTTP authentication, and this clear-text problem be mitigated by using HTTPS. The real problem is twofold. First, since this authentication is applied by the Web server, it is not easily within the control of the Web application without interfacing with the Web server's authentication database. Therefore custom authentication mechanisms are frequently used. These open a veritable Pandora's box of issues in their own right. Second, developers often fail to correctly assess every avenue for accessing a resource and then apply authentication mechanisms accordingly.

Given this, penetration testers should attempt to ascertain both the authentication mechanism that is being used and how this mechanism is being applied to every resource within the Web application. Many Web programming environments offer session capabilities, whereby a user

provides a cookie or a Session-ID HTTP header containing a psuedo-unique string identifying their authentication status. This can be vulnerable to attacks such as brute forcing, replay, or re-assembly if the string is simply a hash or concatenated string derived from known elements.

Every attempt should be made to access every resource via every entry point. This will expose problems where a root level resource such as a main menu or portal page requires authentication but the resources it in turn provides access to do not. An example of this is a Web application providing access to various documents as follows. The application requires authentication and then presents a menu of documents the user is authorised to access, each document presented as a link to a resource such as:

```
http://www.server.com/showdoc.asp?docid=10
```

Although reaching the menu requires authentication, the showdoc.asp script requires no authentication itself and blindly provides the requested document, allowing an attacker to simply insert the docid GET variable of his desire and retrieve the document. As elementary as it sounds this is a common flaw in the wild.

Conclusions

In this article we have presented the penetration tester with an overview of web applications and how web developers obtain and handle user inputs. We have also shown the importance of fingerprinting the target environment and developing an understanding of the back-end of an application. Equipped with this information, the penetration tester can proceed to targeted vulnerability tests and exploits. The next installment in this series will introduce code and content-manipulation attacks, such as PHP/ASP code injection, SQL injection, Server-Side Includes and Cross-site scripting.

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