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Using Logs to Investigate – SQL Injection Attack Example

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A log file is an extremely valuable piece of information that is provided by a server. Almost all servers, services, and applications provide some sort of logging. A log file records events and actions that take place during the run time of a service or application.

chain of events that may have led to malicious activity.

Let's take a backend web server as an example. Usually, the Apache HTTP Server provides two main log files – *access.log* and *error.log*. The *access.log* records all requests for files. If a visitor requests *www.example.com/main.php*, the following entry will be added to the log file:

```
88.54.124.17 - - [16/Apr/2016:07:44:08 +0100] "GET /main.php HTTP/1.1" 200 203 "-" "Mozilla/5.0
(Windows NT 6.0; WOW64; rv:45.0) Gecko/20100101 Firefox/45.0"
```

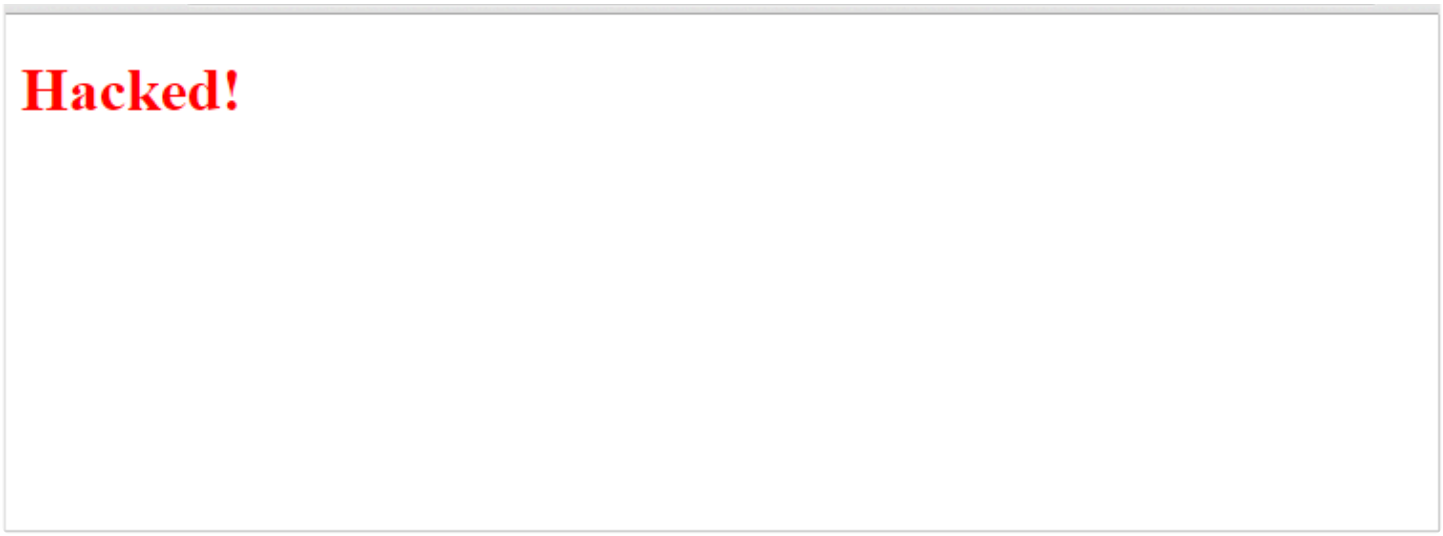
The above log shows that a visitor with an IP address *88.54.124.178* requested the *main.php* file on *April 16th 2016 07:44* and the request was *successful*.

This information might not be too interesting, but what if the log file has shown that a visitor with IP *88.54.124.178* requested the *dump_database.php* file on *April 16th 2016 07:44* and the request was successful? In the absence of that log file, you might have never known that someone discovered and ran a secret or restricted script that you have on your website and that dumps the database.

Having established that a log file is a critical asset, let's look at an everyday example of how a log file would help identify when, how and by whom a website was hacked.

Investigation

Let's assume that a website that we administer got defaced. Let's also assume that the site was a simple and up-to-date WordPress website running on a fully-patched Ubuntu Server.



After reaching out for help, the forensic team took the server offline to be able to proceed with the investigation.

The server is isolated to preserve the current state of the system and its logs, block remote access to the attacker (in the case a backdoor was installed), as well as prevent interaction with any other machines on the network.

To identify malicious activity on the web server, you often create a forensically sound copy of the server and then proceed with the investigation. However, since there are no plans to pursue legal action against the attacker, in this case, the forensic team can work on original data.

Evidence to Look For in an Investigation

In order to start an investigation, the investigator needs to identify what evidence to look for. Usually, evidence of an attack involves direct access to hidden or unusual files, access to the administration area with or without authentication, remote code execution, SQL injection, file inclusion, cross-site scripting (XSS), and other unusual behavior that might indicate vulnerability scanning or reconnaissance.

Let us assume that in our example, the web server *access.log* is available.

```
root@secureserver:/var/log/apache2# less access.log
```

```
a/5.0 (Windows NT 6.0; WOW64; rv:45.0) Gecko/20100101 Firefox/45.0"
84.55.41.57 - - [16/Apr/2016:20:21:56 +0100] "GET /john/assets/js/skel.min.js HTTP/1.1" 200 3532
"http://www.example.com/john/index.php" "Mozilla/5.0 (Windows NT 6.0; WOW64; rv:45.0) Gecko/20100
101 Firefox/45.0"
84.55.41.57 - - [16/Apr/2016:20:21:56 +0100] "GET /john/images/pic01.jpg HTTP/1.1" 200 9501 "htt
p://www.example.com/john/index.php" "Mozilla/5.0 (Windows NT 6.0; WOW64; rv:45.0) Gecko/20100101
Firefox/45.0"
84.55.41.57 - - [16/Apr/2016:20:21:56 +0100] "GET /john/images/pic03.jpg HTTP/1.1" 200 5593 "htt
p://www.example.com/john/index.php" "Mozilla/5.0 (Windows NT 6.0; WOW64; rv:45.0) Gecko/20100101
Firefox/45.0"
```

Checking every single line would be impractical, so we need to filter out data that would most probably be of no interest. That usually includes resources such as images and CSS stylesheets. Some investigators also prefer to strip out JavaScript files too.

In this case, however, since the website is running the WordPress web application, we will use a slightly different approach. Instead of ruling out some data, we will filter *access.log* for WordPress-specific characteristics.

```
root@secureserver:~#cat /var/log/apache2/access.log | grep -E "wp-admin|wp-login|POST /"
```

The above command filters *access.log* and shows only records with strings containing *wp-admin*, which is the default administration folder of WordPress, *wp-login*, which is part of the login file of WordPress (*wp-login.php*), and finally, `POST`, which will show HTTP requests sent to the server using the POST method, which are most likely login form submissions.

The output returns a number of results. After sifting through them, we'll concentrate on the following single record:

```
84.55.41.57 - - [17/Apr/2016:06:52:07 +0100] "GET /wordpress/wp-admin/ HTTP/1.1" 200 12349 "htt
p://www.example.com/wordpress/wp-login.php" "Mozilla/5.0 (Windows NT 6.0; WOW64; rv:45.0) Gecko/2
0100101 Firefox/45.0"
```

We see that the IP *84.55.41.57* accessed the WordPress administration interface successfully. Let's see what else the user with this IP address did. We'll use `grep` once again to filter the *access.log* with

This results in the following interesting records.

```
84.55.41.57 - - [17/Apr/2016:06:57:24 +0100] "GET /wordpress/wp-login.php HTTP/1.1" 200 1568 "-"
84.55.41.57 - - [17/Apr/2016:06:57:31 +0100] "POST /wordpress/wp-login.php HTTP/1.1" 302 1150 "ht
tp://www.example.com/wordpress/wp-login.php"
84.55.41.57 - - [17/Apr/2016:06:57:31 +0100] "GET /wordpress/wp-admin/ HTTP/1.1" 200 12905 "htt
p://www.example.com/wordpress/wp-login.php"
84.55.41.57 - - [17/Apr/2016:07:00:32 +0100] "POST /wordpress/wp-admin/admin-ajax.php HTTP/1.1" 2
00 454 "http://www.example.com/wordpress/wp-admin/"
84.55.41.57 - - [17/Apr/2016:07:00:58 +0100] "GET /wordpress/wp-admin/theme-editor.php HTTP/1.1"
200 20795 "http://www.example.com/wordpress/wp-admin/"
84.55.41.57 - - [17/Apr/2016:07:03:17 +0100] "GET /wordpress/wp-admin/theme-editor.php?file=404.p
hp&theme=twentysixteen HTTP/1.1" 200 8092 "http://www.example.com/wordpress/wp-admin/theme-edito
r.php"
84.55.41.57 - - [17/Apr/2016:07:11:48 +0100] "GET /wordpress/wp-admin/plugin-install.php HTTP/1.
1" 200 12459 "http://www.example.com/wordpress/wp-admin/plugin-install.php?tab=upload"
84.55.41.57 - - [17/Apr/2016:07:16:06 +0100] "GET /wordpress/wp-admin/update.php?action=install-p
lugin&plugin=file-manager&_wpnonce=3c6c8a7fca HTTP/1.1" 200 5698 "http://www.example.com/wordpres
s/wp-admin/plugin-install.php?tab=search&s=file+permission"
84.55.41.57 - - [17/Apr/2016:07:18:19 +0100] "GET /wordpress/wp-admin/plugins.php?action=activate
&plugin=file-manager%2Ffile-manager.php&_wpnonce=bf932ee530 HTTP/1.1" 302 451 "http://www.exampl
e.com/wordpress/wp-admin/update.php?action=install-plugin&plugin=file-manager&_wpnonce=3c6c8a7fc
a"
84.55.41.57 - - [17/Apr/2016:07:21:46 +0100] "GET /wordpress/wp-admin/admin-ajax.php?action=conne
ctor&cmd=upload&target=l1_d3AtY29udGVudA&name%5B%5D=r57.php&FILES=&_=1460873968131 HTTP/1.1" 200
731 "http://www.example.com/wordpress/wp-admin/admin.php?page=file-manager_settings"
84.55.41.57 - - [17/Apr/2016:07:22:53 +0100] "GET /wordpress/wp-content/r57.php HTTP/1.1" 200 903
6 "-"
84.55.41.57 - - [17/Apr/2016:07:32:24 +0100] "POST /wordpress/wp-content/r57.php?14 HTTP/1.1" 200
8030 "http://www.example.com/wordpress/wp-content/r57.php?14"
84.55.41.57 - - [17/Apr/2016:07:29:21 +0100] "GET /wordpress/wp-content/r57.php?29 HTTP/1.1" 200
8391 "http://www.example.com/wordpress/wp-content/r57.php?28"
84.55.41.57 - - [17/Apr/2016:07:57:31 +0100] "POST /wordpress/wp-admin/admin-ajax.php HTTP/1.1" 2
00 949 "http://www.myw ebsite.com/wordpre ss/wp-admin/admin.php?page=file-manager_settings"
```

Let's analyze these records a bit further. The attacker accessed the login page.

```
84.55.41.57 - GET /wordpress/wp-login.php 200
```

```
84.55.41.57 - POST /wordpress/wp-login.php 302
```

The attacker was redirected to *wp-admin* (the WordPress dashboard), which means that authentication was successful.

```
84.55.41.57 - GET /wordpress/wp-admin/ 200
```

The attacker navigated to the theme editor.

```
84.55.41.57 - GET /wordpress/wp-admin/theme-editor.php 200
```

The attacker tried to edit the file *404.php*, which is a very common tactic used to inject malicious code into the file. The attacker most probably failed in doing so due to a lack of write permissions.

```
84.55.41.57 - GET /wordpress/wp-admin/theme-editor.php?file=404.php&theme= twentysixteen 200
```

The attacker accessed the plugin installer.

```
84.55.41.57 - GET /wordpress/wp-admin/plugin-install.php 200
```

The attacker installed and activated the *file-manager* plugin.

```
84.55.41.57 - GET /wordpress/wp-admin/update.php?action=install-plugin&plugin= file-manager &_wpn
once=3c6c8a7fca 200
84.55.41.57 - GET /wordpress/wp-admin/plugins.php?action=activate&plugin=file-manager%2Ffile-mana
ger.php&_wpnonce=bf932ee530 200
```

The attacker used the *file-manager* plugin to upload *r57.php*, which is a PHP web shell script.

The log indicates that the attacker ran the *r57* shell script. The query strings `?1` (the attacker ran *phpinfo();*) and `?28` (the attacker got a list of services) indicate navigation through the different sections of the shell script. It appears that they didn't find anything interesting.

```
84.55.41.57 - GET /wordpress/wp-content/r57.php 200
84.55.41.57 - POST /wordpress/wp-content/r57.php?1 200
84.55.41.57 - GET /wordpress/wp-content/r57.php?28 200
```

The attacker's last action was to edit the index file of the theme through the *file-manager* plugin and replace its contents with the word *HACKED!*

```
84.55.41.57 - POST /wordpress/wp-admin/admin-ajax.php 200 - http://www.
example.com/wordpress/wp-admin/admin.php?page=file-manager_settings
```

Based on the above information, we now have a timeline of the attacker's actions that led to the defacement of the website. However, there is a missing piece in the puzzle. How did the attacker get the login credentials in the first place or did they bypass authentication?

Assuming that we are certain that the administrator password was not leaked or brute-forced, let's go back and see if we can find anything regarding this matter.

The current *access.log* did not contain any clues on what might have happened. However, there is more than just the one *access.log* file that we can investigate. The Apache HTTP Server log rotation algorithm archives old log files. Listing the */var/log/apache2/* directory shows four additional log files.

First, we need to filter the logs to see if any actions were taken by the IP *84.55.41.57*. One of the logs was bombarded with records containing a lot of SQL commands that clearly indicate an SQL injection attack on what seems to be a custom plugin that works with the SQL server.

```
84.55.41.57- - [14/Apr/2016:08:22:13 0100] "GET /wordpress/wp-content/plugins/custom_plugin/check
_user.php?userid=1 AND (SELECT 6810 FROM(SELECT COUNT(*),CONCAT(0x7171787671,(SELECT (ELT(6810=68
10,1))),0x71707a7871,FLOOR(RAND(0)*2))x FROM INFORMATION_SCHEMA.CHARACTER_SETS GROUP BY x)a) HTT
P/1.1" 200 166 "-" "Mozilla/5.0 (Windows; U; Windows NT 6.1; ru; rv:1.9.2.3) Gecko/20100401 Firef
```

```
1" 200 166 "-" "Mozilla/5.0 (Windows; U; Windows NT 6.1; ru; rv:1.9.2.3) Gecko/20100401 Firefox/
4.0 (.NET CLR 3.5.30729)"
84.55.41.57- - [14/Apr/2016:08:22:13 0100] "GET /wordpress/wp-content/plugins/custom_plugin/check
_user.php?userid=(SELECT CONCAT(0x7171787671,(SELECT (ELT(1399=1399,1))),0x71707a7871)) HTTP/1.1"
200 166 "-" "Mozilla/5.0 (Windows; U; Windows NT 6.1; ru; rv:1.9.2.3) Gecko/20100401 Firefox/4.0
(.NET CLR 3.5.30729)"
84.55.41.57- - [14/Apr/2016:08:22:27 0100] "GET /wordpress/wp-content/plugins/custom_plugin/check
_user.php?userid=1 UNION ALL SELECT CONCAT(0x7171787671,0x537653544175467a724f,0x71707a7871),NUL
L,NULL-- HTTP/1.1" 200 182 "-" "Mozilla/5.0 (Windows; U; Windows NT 6.1; ru; rv:1.9.2.3) Gecko/20
100401 Firefox/4.0 (.NET CLR 3.5.30729)"
```

Let's assume that this plugin was created by copy-and-pasting some code that the system administrator found online. The script was meant to check user validity based on a given ID. The plugin had a form exposed on the main web page, which was sending an AJAX GET request to */wordpress/wp-content/plugins/custom_plugin/check_user.php*.

When we analyze *check_user.php*, it is immediately obvious that the script is poorly written and vulnerable to an SQL injection attack.

```php
<?php

//Include the WordPress header
include('/wordpress/wp-header.php');

global $wpdb;

// Use the GET parameter 'userid' as user input
$id=$_GET['userid'];

// Make a query to the database with the value the user supplied in the SQL statement
$users = $wpdb->get_results( "SELECT * FROM users WHERE user_id=$id");

?>
```

The number of records in the *access.log* and the pattern indicate that the attacker used an SQL injection exploitation tool to exploit an SQL injection vulnerability. The logs of the attack that may look like gibberish, however, they are SQL queries typically designed to extract data via an SQL injection

We will not dig deeper into the SQL injection attack, or how to fix SQL injection vulnerabilities (for example, using prepared statements) as this is outside the scope of this article. However, the records in the log would resemble the following:

```
/wordpress/wp-content/plugins/my_custom_plugin/check_user.php?userid=-6859 UNION ALL SELECT (SELE
CT CONCAT(0x7171787671,IFNULL(CAST(ID AS CHAR),0x20),0x616474686c76,IFNULL(CAST(display_name AS C
HAR),0x20),0x616474686c76,IFNULL(CAST(user_activation_key AS CHAR),0x20),0x616474686c76,IFNULL(CA
ST(user_email AS CHAR),0x20),0x616474686c76,IFNULL(CAST(user_login AS CHAR),0x20),0x616474686c76,
IFNULL(CAST(user_nicename AS CHAR),0x20),0x616474686c76,IFNULL(CAST(user_pass AS CHAR),0x20),0x61
6474686c76,IFNULL(CAST(user_registered AS CHAR),0x20),0x616474686c76,IFNULL(CAST(user_status AS C
HAR),0x20),0x616474686c76,IFNULL(CAST(user_url AS CHAR),0x20),0x71707a7871) FROM wp.wp_users LIMI
T 0,1),NULL,NULL--
```

The above SQL code is a very strong indication that the WordPress database has been compromised and that all sensitive information in that SQL database has potentially been stolen.

Analysis

Through this investigation, we can now create the chain of events that have led to this attack.

Some questions still remain, such as who was behind the attack. At this point, it is only possible to know the attacker's IP address. It is very difficult, and probably infeasible to attempt to attribute most attacks unless the attacker left concrete evidence that ties to a real person's identity. Bear in mind that attackers frequently make use of proxies and anonymity networks such as Tor to conduct most attacks in order to mask their real location.

The bottom line is that unsafe code that led to an SQL injection attack was present in a custom WordPress plugin. Had the site been tested for security vulnerabilities before being deployed in a production environment, it would have not been possible for the attacker to take advantage of the security vulnerability that caused the defacement.

The attacker in the above fictitious example was very sloppy and left a significant amount of evidence and tracks, which made the investigation very easy. Bear in mind, however, that it is not always the case, especially when dealing with more sophisticated attacks.

What log files do you need to investigate a web application attack?

How do you begin an investigation regarding a web application attack?

What tools can you use to investigate a web application attack?

How to protect yourself against web application attacks?

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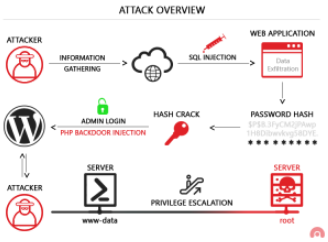

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