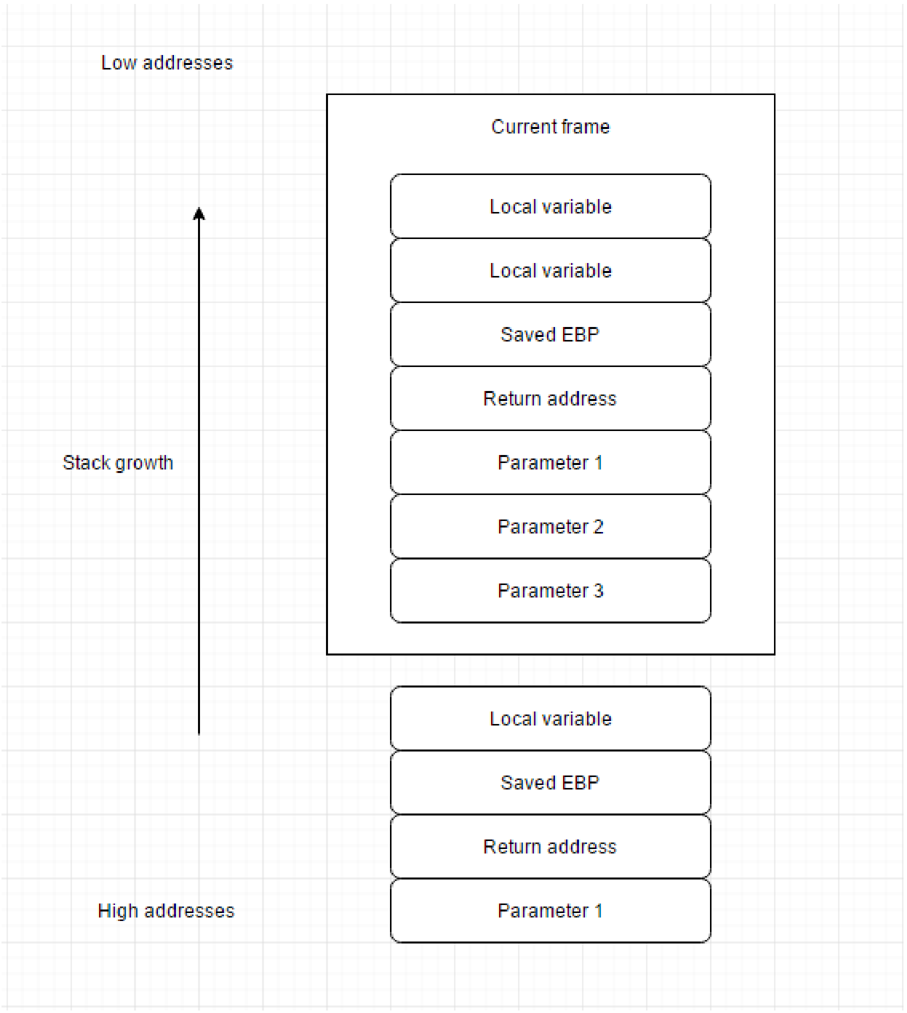
Lab 01 - Software Security

Resources

- Buffer overflow explained
- Shellcode explained

Overview



A buffer overflow occurs when data written to a buffer overruns its boundary and overwrites adjacent memory locations, due to insufficient bounds checking.

GDB tutorial

Loading a program

In order to start debugging using GDB, you need to specify the program to be inspected. There are two options for doing this:

- When launching GDB:

```
gdb prog
```

- After launching GDB:

```
gdb
```

```
(gdb) file prog
```

Once the debugging symbols from the executable were loaded, you can start executing your program using the `run` command.

```
(gdb) run
```

You do not need the specify the full command, GDB can fill in the rest of a word in a command for you, if there is only one possibility. E.g.: `r`, `ru` and `run` are equivalent; `c`, `co`, `continue` are equivalent.

In order to specify arguments for the debugged program, you can either:

- Specify them prior to starting the program:

```
(gdb) set args arg1 arg2
```

- Specify them when starting the program:

```
(gdb) run arg1 arg2
```

You do not need to specify the arguments each time: `run` with no arguments uses the same arguments used by the previous `run`, or those set by the `set args` command.

Breakpoints

Breakpoints represent places in your program where the execution should be stopped. They are added using the break command and its variants. Here are the most common usages:

- `break function` - Set a breakpoint at entry to function function. When using source languages that permit overloading of symbols, such as C++, function may refer to more than one possible place to break. See section Breakpoint menus, for a discussion of that situation.
- `break linenum` - Set a breakpoint at line linenum in the current source file. The current source file is the last file whose source text was printed. The breakpoint will stop your program just before it executes any of the code on that line.
- `break filename:linenum` - Set a breakpoint at line linenum in source file filename.
- `break filename:function` - Set a breakpoint at entry to function function found in file filename. Specifying a file name as well as a function name is superfluous except when multiple files contain similarly named functions.
- `break *address` - Set a breakpoint at address address. You can use this to set breakpoints in parts of your program which do not have debugging information or source files.

You can see an overview of the current breakpoints using the `info break` command.

```
(gdb) info break

Num     Type           Disp Enb Address    What

1      breakpoint     keep y   0x0804856d in main at buggy.c:33
```

```
2     breakpoint    keep y   0x080484d1 in print_message at buggy.c:12

3     breakpoint    keep y   0x080484d1 in print_message at buggy.c:12
```

In order to remove breakpoints, you can use the clear or the delete command. With the clear command you can delete breakpoints according to where they are in your program. With the delete command you can delete individual breakpoints by specifying their breakpoint numbers.

```
(gdb) delete 2

(gdb) clear buggy.c:33

Deleted breakpoint 1
```

Once you want to resume execution, you can use the continue command.

```
(gdb) continue

Continuing.

[Inferior 1 (process 5809) exited normally]
```

Step

There might be situations when you only want to execute one line of source code, or one machine instruction from your program. This action is called a step and can be categorized as follows:

- Step into - step: Continue running your program until control reaches a different source line, then stop it and return control to GDB. If the line you are stepping over represents a function call, this command will step inside it.
- Step over - next: Continue to the next source line in the current stack frame. This is similar to step, but function calls that appear within the line of code are executed without stopping.

There are also equivalent functions fo the machine instructions: stepi, nexti.

If you stepped into a function and you want to continue the execution until the function returns, you can use the finish command.

Printing registers and variables

You can display a summary of the current registers and flags using the info register command:

```
(gdb) info register

eax          0x0        0

ecx          0x6f       111

edx          0xffffcf32 -12494

ebx          0x0        0
```

```
esp            0xffffcf00 0xffffcf00

ebp            0xffffcf18 0xffffcf18

esi            0xf7fb0000          -134545408

edi            0xf7fb0000          -134545408

eip            0x80484d1           0x80484d1 <print_message+6>

eflags         0x286     [ PF SF IF ]

cs             0x23      35

ss             0x2b      43

ds             0x2b      43

es             0x2b      43

fs             0x0       0

gs             0x63      99
```

If you want to print the value of one specific register, you can use the `print` command:

```
(gdb) print $esp

$1 = (void *) 0xffffcf00
```

You can print the content of a variable in a similar manner:

```
(gdb) print input

$6 = 0
```

The `print` command allows you to specify the format of the output like this (you can find a full list of possible format specifiers here):

```
(gdb) p/x $esp

$3 = 0xffffcf00

(gdb) p/d $esp

$4 = 4294954752

(gdb) p/s buf

$9 = "OK Bye!\n"

(gdb) p/x buf

$10 = {0x4f, 0x4b, 0x2e, 0x20, 0x42, 0x79, 0x65, 0x21, 0xa, 0x0}
```

Reading and modifying memory

You can use the command x (for “examine”) to examine memory in any of several formats, independently of your program's data types.

```
x/nfu addr
```

n, f, and u are all optional parameters that specify how much memory to display and how to format it; addr is an expression giving the address where you want to start displaying memory.

- **n** - the repeat count: The repeat count is a decimal integer; the default is 1. It specifies how much memory (counting by units u) to display.
- **f** - the display format: The display format is one of the formats used by print
- **u** - the unit size: The unit size is any of b (bytes), h (halfwords), w (words)

E.g.: Print 10 words in hexadecimal format, starting from the address of the current stack pointer.

```
(gdb) x/10xw $esp

0xffffcf00: 0xffffcf58  0x4b4fcf10          0x7942202e          0x000a2165

0xffffcf10: 0xffffcf32  0xf7ffd918          0xffffcf58  0x080485b8

0xffffcf20: 0x00000000            0x080486b8
```

In order to change the value of a variable or of a specific memory area, you can use the set command:

```
(gdb) set g=4

(gdb) set {int}0x83040 = 4
```

Stack info

A backtrace is a summary of how your program got where it is. It shows one line per frame, for many frames, starting with the currently executing frame (frame zero), followed by its caller (frame one), and on up the stack.

backtrace: Print a backtrace of the entire stack: one line per frame for all frames in the stack.
E.g.:

```
(gdb) bt

#0  print_message (input=0) at buggy.c:16

#1  0x080485b8 in main () at buggy.c:38
```

It is also possible to move up or down the stack using the following commands:

- up n: Move n frames up the stack. For positive numbers n, this advances toward the outermost frame, to higher frame numbers, to frames that have existed longer. n defaults to one.

- `down n`: Move n frames down the stack. For positive numbers n, this advances toward the innermost frame, to lower frame numbers, to frames that were created more recently. n defaults to one.

Another useful command for printing information related to the current stack frame is `info frame`. This command prints a verbose description of the selected stack frame, including:

- the address of the frame
- the address of the next frame down (called by this frame)
- the address of the next frame up (caller of this frame)
- the language in which the source code corresponding to this frame is written
- the address of the frame's arguments
- the address of the frame's local variables
- the program counter saved in it (the address of execution in the caller frame)
- which registers were saved in the frame

Exercises

00. Setup

Compile the following code:

```
#include <stdio.h>

#include <unistd.h>

#include <string.h>

void wanted(){

        puts("Well done!");

}

void copy(char *arg){

        char buf[5];

        strcpy(buf, arg);

        printf("%s\n", buf);

}

int main(int argc, char **argv) {

        char buf[] = "Hello";

        printf("%s\n", buf);

        copy(argv[1]);

        return 0;
}
```

like this:

```
gcc buffovf.c -o buffovf -fno-stack-protector -m32 -g
```

You may need to install `libc6-dev-i386` for 64-bit systems.

01. Run, break, step

Run the program using GDB, setting the argument “AAA”. Set a breakpoint at the beginning of the `main` function. Continue execution until you hit the breakpoint. Try to reach the beginning of the `copy` function without setting another breakpoint.
Hint: use step over and step into.

02. Printing stuff

Remove the existing breakpoint and set a new one at the beginning of the `copy` function. Run again the program and continue execution until you hit the breakpoint. Print the value of `arg`. Print the address of `buf`.

03. ASLR

Start again the execution (do not exit GDB) and print again the address of `buf`. What do you notice? Check in another tab if ASLR is enabled on your PC. What happens and how can you fix it?
Hint: http://visualgdb.com/gdbreference/commands/set_disable-randomization

04. Address investigation

Run until the beginning of the `copy` function. Display stack info (`bt`, `info frame`). At what address is `buf` located? At what address is the saved return address located? How many bytes of input do you need in order to overwrite the return address?

05. Buffer overflow

Disable again address randomization in gdb. Run the program with a string such that the return address of the copy function is overwritten with AAAA. Check the address where the program fails.

06. Call the "wanted" function

We want to create an attack which invokes the wanted function. What is the address of this function? Adjust the input so that the return address is overwritten with the address of the `wanted` function.
hint1: use *objdump -d ./exec* to list all the addresses from the binary. Look for the wanted address.
hint2: use *python -c 'print “A” * NR + “\xGH\xEF\xCD\xAB”'* to generate the payload for calling the function with address 0xABCDEFGH. You have to find the value of NR.

07. Writing memory

We want to use our new GDB skills to make the application print two times `Hello`, even if we run it having `AAA` as argument.

1. Find out the address of the buffer containing the `Hello` string.
2. Continue the execution until the beginning of the `copy` function, disassemble the code and go step by step through the assembly instructions until the `call` instruction (do not execute the call).

3. Print the value of the stack pointer. Dump 2 values on the stack. What are the two values representing?
4. Overwrite the second value on the stack with the address of the buffer containing the `Hello!` string and then continue the execution. What happened?