# GreHack 2015 - Weak Up Panda

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Verimag

## 1 Reversing

The challenge is a 64 bit ELF binary, when executes, it prints badboy and quits. A quick analysis with ltrace reveals that it reads an environment variable named INPUT (cf. Figure 1a). So we try to set a value for this variable (our shell is fish<sup>1</sup>):

set -x INPUT abcdef

Listing 1: Setting INPUT

and execute the crackme again (cf. Figure 1b); still badboy though. There is no useful information yet, except that there are two rand calls, each followed by a malloc, maybe for storing the returned values of rand(s) (?); but we are not sure at this step .



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(a) INPUT is unset

(b) INPUT is set

Figure 1: Executing crackme with unset/set INPUT

We take a more detail analysis by drop this crackme into IDA, the main function can be quickly recognized from the familiar pattern: looking from the entry point, the address of main is passed as the first parameter for libc\_start\_main; here this address is 0x41806c. At the first look, the structure of main seems simple, but it is not  $\odot$ . The nightmare commence from functions called by main: any of them has a *tail call* to another function, and this called function, in its turn, has also tail to another one, so on and so forth; we even cannot believe into our eyes when seeing the function call graph generated by IDA.

We try next to run the crackme step-by-step in IDA, but we give up soon since it is too long; moreover the semantics of most functions (in this calling chain) are quite simple; then they do not give useful information. This crackme maybe has intention to push the idea of *continuation passing style* to the extreme.

Black-box analysis The manual analysis with IDA does not work well, so we try our Pintool which is developed in BinSec project [1]: this Pintool has capability of tracing only instructions executed in a range of addresses (here we set them as the first and the last address of main: 0x41806c and 0x4181f6), and tracing only internal instructions of the crackme (i.e. the instructions of external calls rand, malloc, etc will be not counted). The following sequence shows the numbers of executed instructions where lengths of INPUT is 1, 2, 3, 4, 5, 6, 7, 8:

 $51886,66187,80511,\ldots,137771,168055$ 

<sup>1</sup>http://fishshell.com/

and if the length of INPUT then the number instructions is always 168055. The first 7 numbers form an arithmetic progression with the difference 14301, but the difference between 7th to 8th is 30284. These observations suggest that the good INPUT should have the length 8 (or the crackme does consider only 8 first characters of INPUT).

# 2 Differential analysis

We now focus on values of INPUT with length 8, but observing that the execution trace of the crackme for this length is 168055, so manually examining such a number of instructions is not a good idea ©. Moreover, by manually examining several functions with IDA, we observe that most of them do not compute anything, moreover many of them are identical!!!. One way to filter out unimportant instructions is to compare the execution traces result in from different values of INPUT. We choose, for example, "abcdefgh" and "HGFEDCBA", the differences between two traces (generated by our Pintool) disclosure how the crackme work.

Each character of the input is consumed by a loop which starts from 0x4181b5 (and backs to this address by a leave instruction). The prediction that the crackme considers only first 8 characters is confirmed by the following instructions (the order of current examined character is stored in [rbp - 0x34]):

```
mov eax, dword ptr [rbp-0x34]
0x4181b5
0x4181b8
          and eax, 0xfffffff7
0x4181bb
         mov edx, eax
0x4181bd mov eax, dword ptr [rbp-0x34]
0x4181c0
          xor eax, 0xfffffff7
0x4181c3
          mov ecx, eax
          mov eax, dword ptr [rbp-0x34]
0x4181c5
0x4181c8
          sub eax, 0x8
0x4181cb
          and eax, ecx
0x4181cd
          or eax, edx
0x4181cf
          test eax, eax
```

Listing 2: Checking if length is 8

The crackme uses unusual codes to check whether a character is NULL or not (cf. Listing 3; the character is stored in [rax]). We note that there are several irrelevant instructions between 0x418175 and 0x418183 (maybe for an obfuscation purpose  $\odot$ )

```
0x41816d movzx eax, byte ptr [rax]
0x418170 movsx eax, al
0x418173
         not eax
0x418175
         mov ecx, eax
0x418183
         movzx eax, byte ptr [rax]
0x418186
         movsx eax, al
0x418189
         sub eax, 0x1
0x41818c
          and eax, ecx
0x41818e
         test eax, eax
```

Listing 3: Checking if character is NULL

Checksum algorithm Each loop consume a character of INPUT, this character and an additional value are used to calculate a checksum; this checksum is used as the additional value for the next loop. In summary, the checksum is calculated by:

Listing 4: Calculating checksum

then is verified by (see also Listing 6):

Listing 5: Verifying checksum

```
0x41d74f mov rdx, qword ptr [rax]
0x41d752
         mov rax, 0x122d4d05a4299633
0x41d75c lea rcx, ptr [rdx+rax*1]
0x41d760 mov rax, qword ptr [rbp-0x8]
0x41d764 mov rdx, qword ptr [rax]
0x41d767
         mov rax, 0x122d4d05a4299633
0x41d771
         add rax, rdx
0x41d774 sar rax, 0x3f
0x41d778 xor rcx, rax
0x41d77b mov rax, qword ptr [rbp-0x8]
0x41d77f
         mov rdx, qword ptr [rax]
         mov rax, 0x122d4d05a4299633
0x41d782
0x41d78c
         add rax, rdx
0x41d78f
          shr rax, 0x3f
0 \times 41d793
          add rax, rcx
0x41d796
          sub rax, 0x1
0x41d79a
          shr rax, 0x3f
```

Listing 6: Instructions verifying checksum

Once the checksum calculation and verification are known, the calculation for good input is direct. We give a file panda.smt2<sup>1</sup> of SMT format, use Z3 to check satisfiability and interpreted values, we obtain a value for INPUT: g!r3h4ck; that makes the crackme print: goodboy.

Control flow graph reconstruction We can also recover the control flow graph of this crackme (cf. Figure 2) using tools of BinSec[1]. The CFG is quite simple (so the obfuscation's purpose is not the CFG) but one should notice that each basic block consists dozens of thousand instructions.

#### 3 Conclusion

### References

[1] BinSec. Binary Code Analysis for Security. 2015. URL: http://binsec.gforge.inria.fr/.

 $<sup>^{1}</sup> h ttps://github.com/tathanhdinh/write-ups/blob/master/Weak\_Up\_Panda\_GreHack2015/panda.smt2$ 

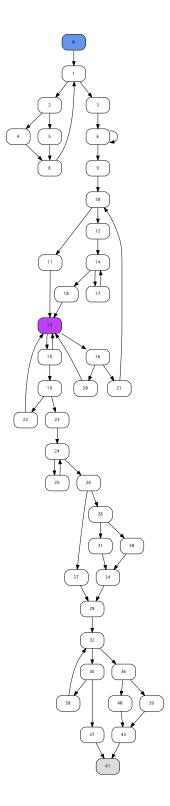


Figure 2: Control flow graph