Introduction to Binary Reversing

using Radare 2

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December 12, 2017

Outline

Tools of the trade (1/2)

- Identification:
  - `md5sum`, `sha*sum`, ..., rahash2, ...
- Static Analysis
  - `strings`, rabin2, rafind2
  - `readelf`, rabin2
  - `objdump`, rasm2, radare2
  - radiff2
  - *decompilers*
    - *RetDec*, *Snowman*, *HexRays ($$$)*, ...

Tools of the trade (2/2)

- Dynamic Analysis
  - `ldd` / `lddtree`
    Beware! `ldd(1)`: . . . ldd may attempt to obtain the dependency information by directly executing the program . . .
  - `/proc/`*pid*`/maps`; see `proc(5)`
  - `strace`
  - `ltrace`
  - `gdb`
  - radare2
- *Spoiler alert. . .*
  Exploiting
  - ragg2
  - pwntools
  - ropper
  - libformatstr

Outline

The good

Radare (`http://www.radare.org`) is a portable open-source reversing framework

- that can...
  - disassemble (assemble for) *many* different architectures
  - debug/patch programs
  - run on Linux, *BSD, Windows, OSX, Android, iOS, ...
  - perform forensics on filesystems and data carving
  - be scripted in Python (2 at the moment), ...
  - use powerful analysis capabilities to speed up reversing ...
- Great and quite active community
  - `https://twitter.com/radareorg`
  - `https://telegram.me/joinchat/ACR-FkEK2owJSzMUYjt_NQ`
  - some great blog posts on how to perform many different tasks ...

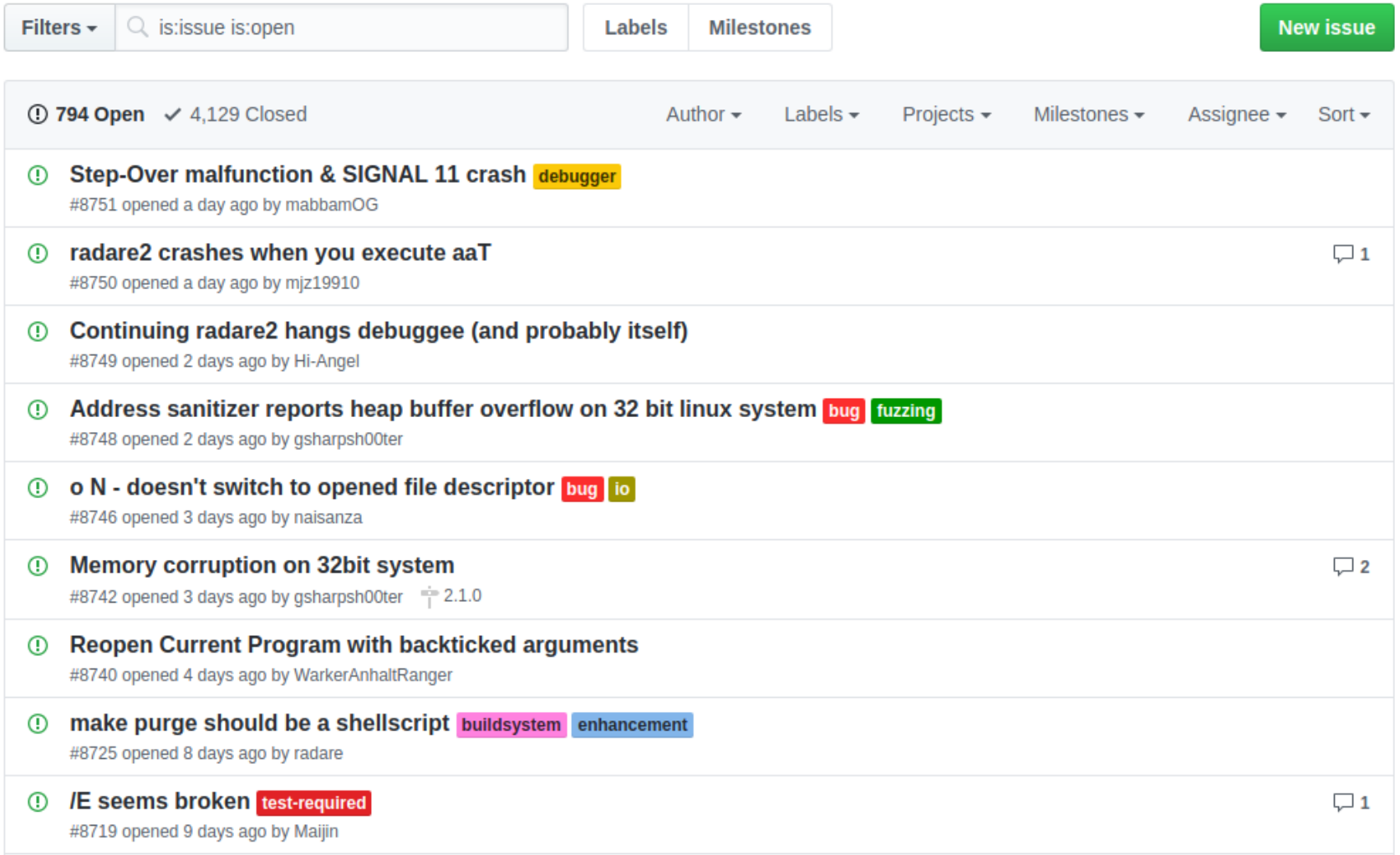
The bad

- Usability issues
  - silent failures (no feedback or error messages in many cases)
  - poor command parsing
  - no GUI
- Scarce "official" documentation, especially about *internals*

So, extremely steep learning curve

https://it.pinterest.com/pin/461407924294118013/

The ugly



`https://github.com/radare/radare2/issues` on 29^{th} October 2017

However. . . love is blind ☺

https://twitter.com/b1ack0wl/status/902525610173628416

Getting started

- e-books
  - R2 book
    `https://radare.gitbooks.io/radare2book/content/`
  - Radare2 Explorations
    `https://monosource.gitbooks.io/radare2-explorations/content/`
- blog posts
  - Defeating IOLI with radare2 in 2017
    `https://dustri.org/b/defeating-ioli-with-radare2-in-2017.html`
  - A journey into Radare 2
    - `https://www.megabeets.net/a-journey-into-radare-2-part-1/`
    - `https://www.megabeets.net/a-journey-into-radare-2-part-2/`
  - Radare 2 in 0x1E minutes
    `blog.techorganic.com/2016/03/08/radare-2-in-0x1e-minutes/`
- cheatsheet
  - strongly biased: a useful (the best, actually ☺) cheatsheet:
    `https://github.com/zxgio/r2-cheatsheet`
    direct download:
    `github.com/zxgio/r2-cheatsheet/raw/master/r2-cheatsheet.pdf`

Installation on Ubuntu-derived distro

1. remove (outdated distro) versions, if any:
   ```
   sudo apt purge radare2 radare2-plugins libradare2-dev
   ```
2. install some tools:
   ```
   sudo apt install build-essential git python python-dev
   python-virtualenv xdot gcc-multilib
   ```
3. clone the official repository:
   ```
   git clone https://github.com/radare/radare2.git
   ```
4. build and install
   - `cd radare2`
   - `git checkout tags/2.0.1 # checkout a stable release`
   - `sys/user.sh --without-pull`
   - add `export PATH=$PATH:~/bin` to your `.bashrc`
5. install r2pipe (and other tools we'll use later) inside some virtualenv, e.g. `r2py`:
   ```
   cd && python -mvirtualenv r2py && .  r2py/bin/activate
   pip install --upgrade pip
   pip install r2pipe pwntools ropper libformatstr
   ```

An example of ~/.radarerc

```
e asm.bytes=0
e asm.cmtright=true
e cmd.stack=px 32
e dbg.slow=true
e scr.wheel=false
e scr.utf8=true
e scr.utf8.curvy=true
eco solarized
```

Sanity check

To try it out:

```
. ~/r2py/bin/activate # activate Python virtual-env
python # start Python interpreter
import r2pipe
r2 = r2pipe.open("/bin/ls") # open /bin/ls through r2
print(r2.cmd('pd 10 @ main')) # print the first 10
                              # instructions of main
```

ASLR

In order to prevent an attacker from reliably jumping to, for example, a particular exploited function in memory, ASLR randomly arranges the address space positions of key data areas of a process, including the base of the executable and the positions of the stack, heap and libraries

`https://en.wikipedia.org/wiki/Address_space_layout_randomization`

Checking ASLR

from `proc(5)`; `/proc/sys/kernel/randomize_va_space` contains:

0. ASLR off
   - default for architectures that don't support ASLR, and
   - when the kernel is booted with `norandmaps` parameter
1. `mmap(2)` allocations, stack, and vDSO (virtual Dynamic Shared Object) page are randomized
   - shared libraries will be loaded at randomized addresses
   - text segment of PIE-linked binaries will also be randomized
   - default if the kernel was configured with `CONFIG_COMPAT_BRK`
2. also support heap randomization
   - default if the kernel was not configured with `CONFIG_COMPAT_BRK`

rabin2

Use `rabin2 -I` to see if a binary has PIC or other mitigations enabled
The same informations can be obtained with `i` *(yep, lowercase)* inside r2

Disabling ASLR

Under Linux you can disable ASLR:

- writing 0 into `/proc/sys/kernel/randomize_va_space`
  - you need to be root
  - this change has (a non-permament) effect on the whole system, which is something you probably don't want
    - to make it permanent, see `sysctl(8)`
- using `gdb`: `set disable-aslr on`
- using `rarun2`: `asrl=no`
  - it writes 0 to `/proc/sys/kernel/randomize_va_space`
- using the command `setarch`; for instance:

  ```
  setarch $(uname --machine) --addr-no-randomize bash
  ```

  Unless in VM, use this one

Let's see this in action

- no ASLR
- ASLR, no PIE
- ASLR, PIE

IOLI crackmes

- As an example, we'll reverse the IOLI crackmes
  - by Pau Oliva (`https://twitter.com/pof`)
    "I wrote IOLI crackmes to teach my wife a bit of reversing around 10 years ago, I'm amazed they are still useful nowadays..."
- This part of tutorial is heavily influenced/inspired by:
  `https://dustri.org/b/defeating-ioli-with-radare2-in-2017.html`
  by Julien Voisin

Always debug/run inside VMs

IOLI crackmes are absolutely *safe*; however, whenever you reverse an unknown binary, do it inside a VM

Crackme0x00

(Very simple) Static analysis is enough ☺

- `rahash2 -a md5,sha1,sha256 crackme0x00`

```
crackme0x00: 0x00000000-0x00001d70 md5: 99327411dd72a11d71...
crackme0x00: 0x00000000-0x00001d70 sha1: f2bf1c7758c7b1e22...
crackme0x00: 0x00000000-0x00001d70 sha256: 3aed9a3821134a2...
```

- `strings`
- `rabin2 -z`
- of course, r2:
  - `iz` (same as `rabin -z`)
  - `aa; pdf @ main`
    - there are *a lot* of different analyses; see `a?`

Some information

- r2 gives name to interesting offset; these *bookmarks* are called flags
  - `fs`, `f`
  - in many places, flag names can be expanded by using *tab-completion*
- strings can be seen with `iz` and `izz`
  - to see where they are used `axt @@ str.*`
- after the analysis, `afl` lists the functions

Crackme0x00 - dynamic analysis

Not actually needed in this example, obviously

- `rarun2 -h > crackme0x00.rr2`
- on another terminal `rarun2 -t`
- edit `crackme0x00.rr2`
- run with: `rarun crackme0x00.rr2`
- debug with:
  `r2 -A -d -e dbg.profile=crackme0x00.rr2 ./crackme0x00`
  the following should be equivalent (but broken at the time of writing):
  `r2 -A -d -r crackme0x00.rr2 ./crackme0x00`

Crackme0x00: a bit of refactoring

My approach to reversing is to *iteratively*:

- explore
- (re)name things / add comments
- restart

saving refactor commands into "a poor man's project"; that is:

- write all refactoring commands inside a `.r2` file
- for each (interesting) function:
  - seek to beginning address: `s`
  - give the function a meaningful name: `afn`
  - when necessary, remove (wrongly) inferred locals: `afv-`
  - rename (some) locals: `afvn`
  - set some comments: `CCu`
  - set some flags (=bookmarks): `f`
  - go back to the previous seek: `s-`
- reload the "project" with `.` *filename*`.r2`

Crackme0x00: debugging

In visual mode:

- step with `S` (*step-over*; `s` for *stepping-in*)
- before calling `sym.imp.strcmp` you can inspect the stack:
  - `:` to get into *normal mode (à la vi)*
  - `pxW 8 @ esp; ps @ eax; ps @ [esp]; ps @ str.250382`
  - `pxr 8 @ esp`
  - `pf ss @ esp`

Crackme0x01

- no luck with `strings` or `rabin2`
- `aa; s main; V`
  - `imp....` stands for *imports*
  - `str....` stands for *strings*
- to "decode" (from hex) from
  - visual mode
    - `did` or
    - `:?`
  - normal mode
    - `ahi d @`
    - `?`

Crackme0x02 and Crackme0x03

- check them with `rabin2`; what is the difference?
- crack the first one
  - can you do it statically?
  - ESIL VM can be handy: `aeim`, `aepc`, `aesu`
  - then, `?vi`
- for the second one
  - try `ag sym.test | xdot -`
  - try `s sym.test; VV`
  - reverse obfuscation algorithm of Crackme0x03, and write a small a deobfuscator

Crackme0x04

- I think that `-A`/`aa` do too much; do you remember `afv-`?