

RADARE2

Radare2 - a framework for reverse engineering

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Hack.lu 10-2015

- 22 y/o french expat @ Luxembourg
- Food, Travel and Languages <3
- I hate Bullshit
- Malware.lu CERT team leader (2days/week) and incident response @ European Commission CSIRC (3days/week)
- User of radare2 (impossibru!)
- I'm creating tests + documentation

- Living in Moscow, Russia
- Reverse Engineering, Languages and Travel
- Reverse engineer, firmware security analyst at SecurityCode Ltd.
- Member of r2 crew

- Living in Paris
- I like to reverse/pwn things
- Mostly bugfixer and warning silencer

- Boston, MA, USA
- Shellphish CTF

- r1 2006, r2 2009
- Multi-(OSes|Archs|Bindings|FileFormats|...)
- 10 tools based on the framework
- Around 149 contributors from various fields
- GSOC + RSOC
- CLI/VisualMode/GUI/WebGUI
- around 350K LOC

INSTALLATION

- Always use git version!
- Use the provided VM on SSH ([radare:radare](#) / [root:radare](#))
- git clone <http://github.com/radare/radare2> && cd radare2 && [./sys/install.sh](#)
- Use the Windows installer <http://bin.rada.re/radare2.exe>

UTILITIES

- rax2
- rabin2
- rasm2
- radiff2
- rafind2
- rahash2
- radare2
- r2pm
- rarun2/ragg2/ragg2-cc

- `rax2`
- `rabin2`
- `rasm2`
- `radiff2`
- `rafind2`
- `rahash2`
- `radare2`
- `r2pm`
- `rarun2/ragg2/ragg2-cc`

rax2 — Base converter

```
$ rax2 10
```

0xa

```
$ rax2 33 0x41 0101b
```

0x21 65 0x5

```
$ rax2 -s 4142434445
```

ABCDE

```
$ rax2 0x5*101b+5
```

30

- rax2
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- rasm2
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- r2pm
- rarun2/ragg2/ragg2-cc

rabin2 — Binary program info extractor

```
$ rabin2 -e
```

Entrypoints

```
$ rabin2 -i
```

Shows imports

```
$ rabin2 -zz
```

Shows strings

```
$ rabin2 -g
```

Show all possible information

- rax2
- rabin2
- rasm2
- radiff2
- rafind2
- rahash2
- radare2
- r2pm
- rarun2/ragg2/ragg2-cc

rasm2 — assembler and disassembler tool

```
$ rasm2 -a x86 -b 32 'mov eax, 33'
```

Assemble

```
$ rasm2 -d 9090
```

Disassemble

```
$ rasm2 -L
```

List supported asm plugins

```
$ rasm2 -a x86 -b 32 'mov eax, 33' -C
```

Output in C format

- rax2
- rabin2
- rasm2
- **radiff2**
- rafind2
- rahash2
- radare2
- r2pm
- rarun2/ragg2/ragg2-cc

radiff2 — unified binary diffing utility

```
$ radiff2 original patched
```

Code diffing

```
$ radiff2 -C original patched
```

Code diffing using graphdiff algorithm

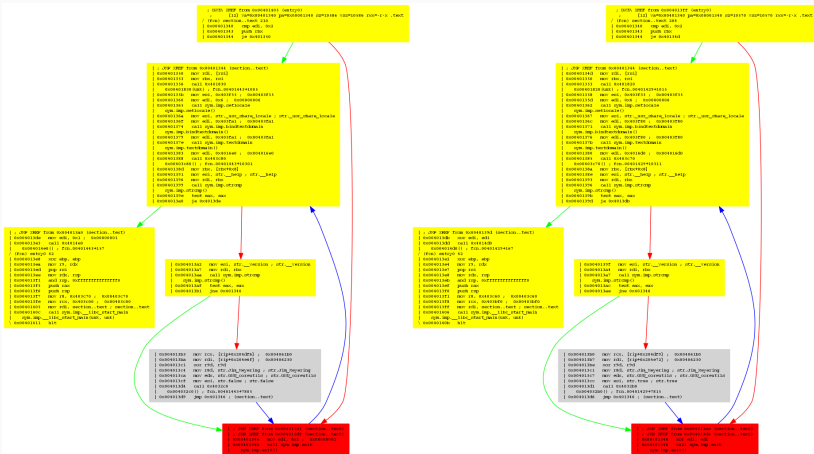
```
$ radiff2 -g main -a x86 -b32 original patched
```

Graph diff output of given symbol, or between two functions, at given offsets: one for each binary.

UTILITIES: RADIFF2 — GRAPH EXAMPLE

```
/bin/true
```

```
/bin/false
```



- rax2
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rafind2 — Advanced commandline hexadecimal editor

```
$ rafind2 -X -s passwd dump.bin
```

Search for the string passwd

- rax2
- rabin2
- rasm2
- radiff2
- rafind2
- **rahash2**
- radare2
- rarun2
- r2pm
- rarun2/ragg2/ragg2-cc

rahash2 — block based hashing utility

```
$ rahash2 -a all binary.exe
```

Display hashes of the whole file with all algos

```
$ rahash2 -B -b 512 -a md5
```

Compute md5 per block of 512

```
$ rahash2 -B -b 512 -a entropy
```

Compute md5 per block of 512

```
$ echo -n "admin" | rahash2 -a md5 -s "
```

Compute md5 of the string admin

- rax2
- rabin2
- rasm2
- radiff2
- rafind2
- rahash2
- radare2
- rarun2
- r2pm
- rarun2/ragg2/ragg2-cc

RADARE2 — COMMAND LINE

1 COMMAND \longleftrightarrow 1 REVERSE-ENGINEERING' NOTION

Keep in mind that:

1. Every character has a meaning i.e (w = write, p = print)
2. Every command is a succession of character i.e pdf = p \leftrightarrow print d \leftrightarrow disassemble f \leftrightarrow function
3. Every command is documented with **cmd?**, i.e pdf?, ?, ???, ???, ?\$, ?@?

1. Open a file with radare2 `radare2 file.exe`
2. Get Usage on the command `#? Usage: #algo <size> @ addr`
3. List of all existing algorithms `##`
4. SHA1 `#sha1`
5. Hashing from the begin `#sha1 @ 0`
6. with a hash block size corresponding to the size of the file `#sha1 $s @ 0x0`

This command is same as `rahash2 -a sha1 file.exe`

- Flags are used to specify a name for an offset: `f?`.
 - Add a function `af+` hand craft a function (requires `afb+`)
 - `f. name @ offset` set local function label named 'blah'
-
- R2 is an block-based hexadecimal editor. Change the blocksize with the 'b' command.

1. Get Usage on the command `i?`
2. Same as `rabin2`
3. `izj` for displaying in json
4. internal commands: `~`, `ls`, `{}`, `..`

Quick Demo

Quick Demo

1. r2 -A or r2 then aaa : Analysis
2. s : Seek
3. pdf : Print disassemble function
4. af? : Analyse function
5. ax? : Analyse XREF
6. /? : Search
7. ps? : Print strings
8. C? : Comments
9. w? : Write

RADARE2 — VISUAL MODE

1. V? : Visual help
2. p/P : rotate print modes
3. move using arrows/hjkl
4. o : seek to
5. e : r2configurator
6. v : Function list
7. _ : HUD
8. V : ASCII Graph
9. 0-9 : Jump to function
10. u : Go back

RADARE2 — WEBUI

`r2 -A -c=H filename`



" -- When you sold that exploit, what they really bought, was your silence. "

Current Project

CurrentProject:

CurrentFile: /bin/ls

OtherProjects:

Layout: panels (desktop) ▾

Delete

Save As

Save

Open

Files

Open File ...

Choose File

No file chosen

Upload

RADARE2 — DEBUGGER

1. radare2 -d
2. Quickly switch to Visual debugger mode: Vpp
3. OllyDBG/IDApro shortcuts friendly

- rax2
- rabin2
- rasm2
- radiff2
- rafind2
- rahash2
- radare2
- rarun2
- r2pm
- rarun2/ragg2/ragg2-cc

R2PM — radare2 package manager

1. `r2pm -s` (list all plugins)
2. `r2pm -i retdec`

- Native local debug (r2 -d)
- r2 agent (rap:// protocol)
- GDB remote protocol support
- WinDBG remote protocol support

1. Will be shown in Julien and Crowell's parts

NOW YOUR TURN!

- **Crackmes**: IOLI-Crackme, flare-on 2015 challenges
- **Exploitation**: pwnablekr "bof", simple ret2libc demo, ropasaurus
- **Malware(1/3)**: Practical malware analysis samples
- **Malware(2/3)**: Any RAT samples see decoder on:
<https://github.com/kevthehermit/RATDecoders/>
- **Malware(3/3)**: AVCaesar.lu, MalekalDB
- **Firmware/BIOS/UEFI**: TODO

- Website: <http://rada.re/>
- Blog: <http://radare.today>
- Book: <http://radare.gitbooks.io/radare2book/content/>

Available for a lot of programming languages

Radare2 Bindings —

R2Pipe —

Demo time !

USING R2 FOR EXPLOIT

- gdb + peda - search memory, dereference stack/registers, debug.
- ida - find xrefs/calls, debug
- ropgadget - search for gadgets
- r2 can do all of this...

- "checksec" - get info : pie, stack canaries, nx
- find strings - find references to calls, etc.
- find writable/executable sections

GETTING BINARY INFO

```
[0x004048c5]> i~pic
pic      false
[0x004048c5]> i~canary
canary   true
[0x004048c5]> i~nx
nx       true
[0x004048c5]> iz~gnu.org
vaddr=0x00417278 paddr=0x00017278 ordinal=369 sz=39 len=38 section=.rodata type=ascii
ftware/coreutils/
vaddr=0x00418587 paddr=0x00018587 ordinal=422 sz=22 len=21 section=.rodata type=ascii
vaddr=0x004185b8 paddr=0x000185b8 ordinal=424 sz=203 len=202 section=.rodata type=ascii
GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>.\nThis is free software
edistribute it.\nThere is NO WARRANTY, to the extent permitted by law.\n\n
vaddr=0x004187d0 paddr=0x000187d0 ordinal=432 sz=64 len=63 section=.rodata type=ascii
U software: <http://www.gnu.org/gethelp/>\n
[0x004048c5]> is | grep perm=...x
idx=10 vaddr=0x00402168 paddr=0x00002168 sz=26 vsz=26 perm=--r-x name=.init
idx=11 vaddr=0x00402190 paddr=0x00002190 sz=1808 vsz=1808 perm=--r-x name=.plt
idx=12 vaddr=0x004028a0 paddr=0x000028a0 sz=64730 vsz=64730 perm=--r-x name=.text
idx=13 vaddr=0x0041257c paddr=0x0001257c sz=9 vsz=9 perm=--r-x name=.fini
idx=27 vaddr=0x00400000 paddr=0x00000000 sz=113364 vsz=2097152 perm=m-r-x name=phdr0
[0x004048c5]>
```

"TELESCOPING" REGISTER

- "telescoping" registers
- "telescoping" stack references
- we lose our analysis capabilities on gdb

```
gdb-peda$ context
-----registers-----
EAX: 0xf7fa20a0 --> 0xffffd1bc --> 0xffffd3dc ("COLORFGBG=15;0")
EBX: 0xf7fa0000 --> 0x1b6da4
ECX: 0x1cf8e285
EDX: 0xffffd144 --> 0xf7fa0000 --> 0x1b6da4
ESI: 0x0
EDI: 0x56555530 (<_start>: xor ebp,ebp)
EBP: 0xffffd118 --> 0x0
ESP: 0xffffd118 --> 0x0
EIP: 0x5655568d (<main+3>: and esp,0xffffffff)
EFLAGS: 0x292 (carry parity ADJUST zero SIGN trap INTERRUPT direction overflow)
-----code-----
0x56555689 <func+93>: ret
0x5655568a <main>: push ebp
0x5655568b <main+1>: mov ebp,esp
=> 0x5655568d <main+3>: and esp,0xffffffff
0x56555690 <main+6>: sub esp,0x10
0x56555693 <main+9>: mov DWORD PTR [esp],0xdeadbeef
0x5655569a <main+16>: call 0x5655562c <func>
0x5655569f <main+21>: mov eax,0x0
-----stack-----
0000| 0xffffd118 --> 0x0
0004| 0xffffd11c --> 0xf7e0172e (<__libc_start_main+222>: add esp,0x10)
0008| 0xffffd120 --> 0x1
0012| 0xffffd124 --> 0xffffd1b4 --> 0xffffd3b3 ("/home/jeff/ctf/wargame/pwnablekr/bof/bof")
0016| 0xffffd128 --> 0xffffd1bc --> 0xffffd3dc ("COLORFGBG=15;0")
0020| 0xffffd12c --> 0x0
0024| 0xffffd130 --> 0x0
0028| 0xffffd134 --> 0x0
-----
Legend: code, data, rodata, value
gdb-peda$
```

"TELESCOPING" REGISTER

- we can do the same thing with r2
- display references to code/ascii/etc. from registers/stack
- quite useful for dynamic analysis.
- keep flags, symbols, etc.
- drr (registers) pxx N @ esp/rsp (stack)

```
[0xf779d68a]> drr;pd 8 @ esp - 4;pxr 24 @ ebp
eip 0xf779d68d eip program R X 'and esp, 0xffffffff' 'bof' (.text) (/home/jeff/ctf/margame/pwnablekr/bof/bof)
eax 0xffffffff eax
ebx 0xf77410a0 ebx R W [0]=0x80950020 (unkl)
ecx 0xf773f000 ecx library R W [0]=0x80950020 (/lib/1386-linux-gnu/libc-2.21.so)
edx 0xc9c3f90 ecx
edx 0xf7fd69244 edx stack R W [0]=0x80950020 ([stack])
esp 0xf7fd69218 ebp stack R W [0]=0x80950020 ([stack])
ebp 0xf7fd69218 ebp stack R W [0]=0x80950020 ([stack])
esi 0x00000000 esi
edi 0xf779d530 edi program R X 'xor ebp, ebp' 'bof' (.text) (/home/jeff/ctf/margame/pwnablekr/bof/bof)
eflags 0x00000292 eflags (.syntab)
0xf779d689 c3 ret
;-- main:
0xf779d68a 55 push ebp
0xf779d68b 89e5 mov ebp, esp
;-- esp:
0xf779d68d 83e4f0 and esp, 0xffffffff
0xf779d690 83ec10 sub esp, 0x10
0xf779d693 c70424efbead. mov dword [esp], 0xdeadbeef ; [0xdeadbeef:4]=1
0xf779d69a e88dffff call sym.func
~ 0xf779d62c1 : sym.func
0xf779d69f b8000000 mov eax, 0
0xf7fd69218 .... esi
0xf7fd6921c .... Z library R X 'add esp, 0x10' 'libc-2.21.so' (/lib/1386-linux-gnu/libc-2.21.so)
0xf7fd69220 .... (.comment)
0xf7fd69224 .... stack R W [0]=0x7fd1615e ([stack])
0xf7fd69228 .... stack R W [0]=0x7fd1615e ([stack])
0xf7fd6922c .... esi
[0xf779d68a]>
```

- does your register point to a string you control?
- what's in the stack?
- keep flags, symbols, etc.
- use from within visual mode `'e dbg.slow = true'`

- DeBruijn patterns.
- made famous by metasploit `pattern_create.rb`
- cyclic patterns, find offset in string.
- Where's our faked struct/string/etc. being referenced?
- Where did we crash?
- `ragg2 -P -r` or `woD` to write
- `ragg2 -q` or `woO` to find your offset.

- `r2 -de dbg.profile=file.rr2 exec.elf`
- set custom arguments, redirect stdin/out to files/sockets
- useful for reproducing environments

- bof from pwnable.kr
- super simple challenge, overflow a buffer
- offset at a certain place must be.
- let's use rarun2 + references + patterns!

CONTEXT + PATTERNS

```
minishwoods bof/bof » r2 -de dbg.profile=bof.rr2 bof
Error: provided size must be size > 0
Error: provided size must be size > 0
Process with PID 16015 started...
Attached debugger to pid = 16015, tid = 16015
Debugging pid = 16015, tid = 16015 now
Using BADDR 0xf7726000
Assuming filepath ./bof
bits 32
Attached debugger to pid = 16015, tid = 16015
-- I script in C, because I can.
[0xf7702a90]> dcu (sym.func+40)
Continue until 0xf7726654
overflow me :
hit breakpoint at: f7726654
Debugging pid = 16015, tid = 1 now
[0xf7726654]> pd 1
;-- eip:
0xf7726654 817d08bebafe. cmp dword [ebp + 8], 0xcafebabe ; [0xcafebabe:4]--1
[0xf7726654]> pxx 4 @ ebp+8
0xffd0cad0 0x41534141 AASA ascii
[0xf7726654]> wo0 0x41534141
52
[0xf7726654]> █

minishwoods Documents/backlog-master » okular slides.pdf
```

- write your own expl ;)

- ragg2 isn't just for generating patterns
- front-end for generating shellcodes
- still up to you to ensure null-free, etc.

- relocatable
- testable (compile directly into elf)
- call arbitrary syscalls easily!
- x86, amd64, arm, windows, mac, linux, ios

```
execve@syscall(59) # name@syscall(#)  
main@global(32) { # name (stacksize)  
    .var0 = "/bin/sh" #.var(offset)  
    execve(.var0, 0, 0); #call!  
}
```

- `ragg2 file.r -s` to show the emitted asm.

- return to libc
- rop
- r2 can make this easy

- magic shell-spawning gadget
- thanks dragon sector for making this well-known
- exists in amd64 glibc, libruby, and more...
- let's find it with r2

- demo
- `r2 -A /path/to/libc`
- `axt sym.execve`
- through xrefs, find it.
- simple demo program on vm does 1 call of your base10 input address

- can't always use this magic gadget
- rsi must point to something argv-like
- sometimes need to find some odd bespoke gadget!
- r2 can dump gadgets
- regular expression search
- dump to json, write your own tool via r2pipe.

- when you "ret"
- ebp is increased by 4, jump to new_ebp - 4
- add esp,4
- jmp dword ptr [esp-4]

- sequence of instructions followed by "end/stop" gadget
- (arbitrary instructions) - ret/call/jmp/etc...
- finding the right ones is hard, r2 has regexp support
- we can set variable filters.

- super basic rop expl.
- combine finding sections, patterns, rop search.
- r2 makes this easy

SEARCHING FOR GADGETS

```
[0x08048340]> "/R/ pop;pop;pop;ret$"
0x080484b3      c41c5b  les  ebx, [ebx + ebx*2]
0x080484b6      5e     pop  esi
0x080484b7      5f     pop  edi
0x080484b8      5d     pop  ebp
0x080484b9      c3     ret

0x080484b4      1c5b   sbb  al, 0x5b
0x080484b6      5e     pop  esi
0x080484b7      5f     pop  edi
0x080484b8      5d     pop  ebp
0x080484b9      c3     ret

0x080484b5      5b     pop  ebx
0x080484b6      5e     pop  esi
0x080484b7      5f     pop  edi
0x080484b8      5d     pop  ebp
0x080484b9      c3     ret
```

DEBUGGING

Just run gdbserver somewhere

and connect r2 to it:

```
r2 -D gdb -d /bin/ls gdb://99.44.23.50:4589
```

Winedbg allows to run windows command

using the gdbserver too:

```
winedbg -gdb -no-start malware.exe
```

```
r2 -a x86 -b 32 -D gdb -d malware.exe gdb://localhost:44840
```

r2 allows to connect WinDBG/KD

For example, to debug windows kernel via the serial port:

```
bcdedit /debug on
```

```
bcdedit /dbgsettings serial debugport:1 baudrate:115200
```

then connect r2:

```
r2 -a x86 -b 32 -D wind windbg:///tmp/windbg.pipe
```

For now, connecting to the QEMU and VirtualBox are tested

Just run it in the modified qemu <https://github.com/XVilka/qemu>

```
./configure --target-list=arm-softmmu ; make ; sudo make install
```

```
qemu-system-arm -M milestone -m 256 -L . -bios bootrom.bin  
-mtdblock mbmloader-1.raw -d in_asm,cpu,exec -nographic -s -S
```

```
r2 -D gdb -b arm gdb://localhost:9999
```

Same approach could be used for any customized hardware

Winedbg allows to run windows command

using the gdbserver too:

```
winedbg -gdb -no-start malware.exe
```

```
r2 -a x86 -b 32 -D gdb -d malware.exe gdb://localhost:44840
```

FIRMWARE ANALYSIS

- Dump the image using flashrom or hardware
- Unpack the image using UEFITool
- Open the selected PE or TE file using r2

- Load the whole image or unpack it using `bios_extract`
- Open it using the correct segment and offset
- `r2` load the whole BIOS image automatically
- `r2 asrock_p4i65g.bin`
- `>. asrock_p4i65g.r2`

1. Get Usage on the command `t?`
2. `to` to load the types from the C header file
3. `tl` link type to the memory, `tf` shows it like the `pf`
4. add `j` to get the output in the json format

Lets start from the static analysis

```
r2 -a 8051 ite_it8502.rom
```

```
>. ite_it8502.r2
```

Lets start from the static analysis

```
r2 -a 8051 ite_it8502.rom
```

```
. ite_it8502.r2
```

run 'e io.cache=true' to use the cache for write operations

run 'aei' command to init ESIL VM

run 'aeim' command to init ESIL VM stack

run 'aeip' command to start from the current offset

run 'aecu [addr]' to emulate until the [addr] is reached

Lets start again from the same place

```
r2 -a 8051 ite_it8502.rom
```

```
. ite_it8502.r2
```

run 'pae 36' to show the esil expression of the 'set_SMBus_frequency'

run 'aetr `pae 36' to convert the previous esil output to REIL

store this to some file and use the 'openreil' utility to SMT it

- **Website:** <http://rada.re/>
- **Blog:** <http://radare.today>
- **Book:** <http://mai jin.gitbooks.io/radare2book/content/>