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Under the hood of Wslink's multilayered virtual machine

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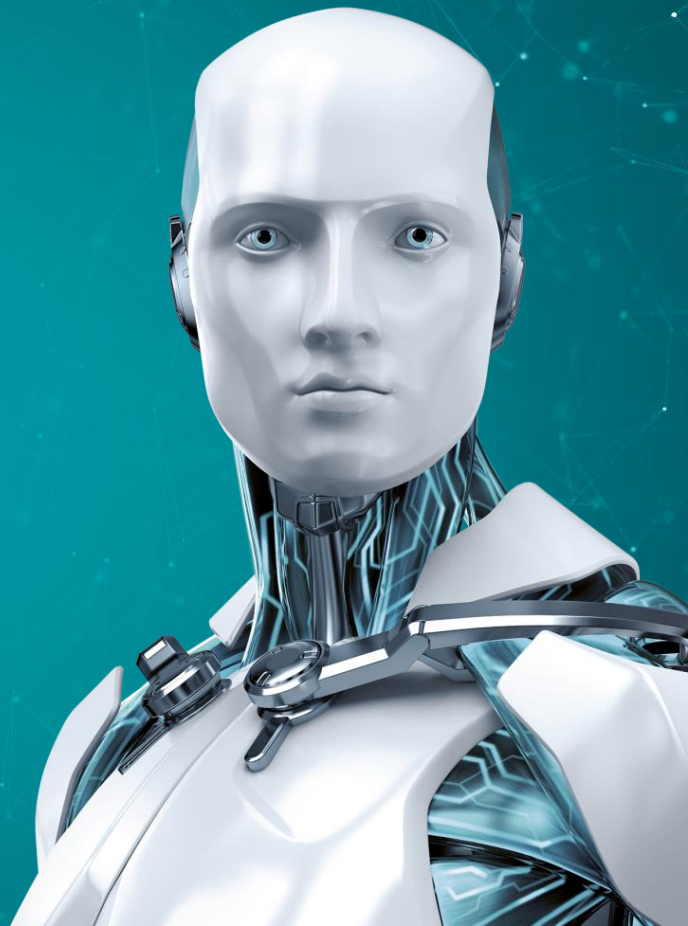

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Agenda

- Intro to VMs in general and symbolic execution
- Internals of the VM used in Wslink
- Our approach to dealing with the obfuscation
- Demonstration of the approach

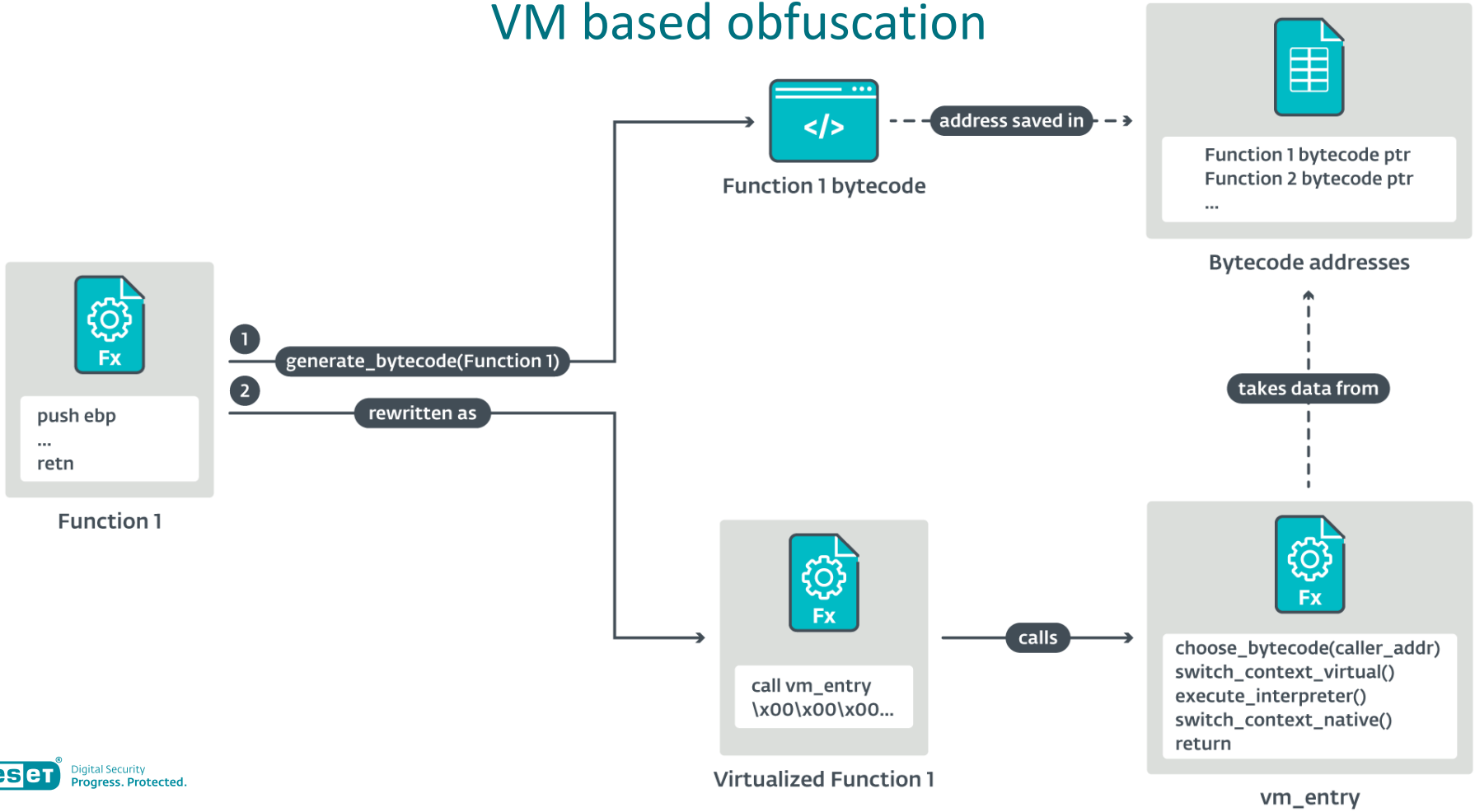
Process VMs basics

```python
def handler1(vm_ctx, bytecode):
    operand1 = bytecode[vm_ctx.PC]
    operand2 = bytecode[vm_ctx.PC+1]
    vm_ctx.PC += 2
    vm_ctx.gp_regs[operand1] = vm_ctx.gp_regs[operand2]

def handler2(vm_ctx, bytecode):
    operand1 = bytecode[vm_ctx.PC]
    vm_ctx.PC += 1
    vm_ctx.gp_regs[vm_ctx.stack.pop()] = operand1

def handler3(vm_ctx, bytecode):
    operand1 = bytecode[vm_ctx.PC]
    operand2 = bytecode[vm_ctx.PC+1]
    vm_ctx.PC += 2
    if vm_ctx.gp_regs[operand1] == operand2:
        exit()

...

handlers = [handler1, handler2, handler3, ...]

def vm_interpreter(vm_ctx, bytecode):
    while True:
        opcode = bytecode[vm_ctx.PC]
        vm_ctx.PC += 1
        handlers[opcode-1](vm_ctx, bytecode)
```

01	08	09	01	07	08	02	85	03	01	01

- Interpreter executes the bytecode
- Bytecode contains instructions with:
  - Opcodes
  - Operands
- Handlers define individual opcodes

VM based obfuscation



Symbolic execution in Miasm

- Expresses the code in mathematical formulas
- Registers and memory are treated as symbolic values
- Summarizes the code's effects on the symbolic values
- We will frequently use it

- Original ASM:

```
MOV EAX, EBX
MOV ECX, DWORD PTR [EDX]
XOR ECX, 0x123
MOV AX, WORD PTR [ESI]
JMP ECX
```

- Performed symbolic execution:

```
EAX = {@16[ESI] 0 16, EBX[16:32] 16 32}
ECX = @32[EDX] ^ 0x123
zf = @32[EDX] == 0x123
nf = (@32[EDX] ^ 0x123)[31:32]
...
EIP = @32[EDX] ^ 0x123
IRDst = @32[EDX] ^ 0x123
```

Symbolic execution in Miasm

- Allows us to simply apply known concrete values
- Concrete values can simplify the expressions
- Performed Symbolic execution:

```
EAX = {@16[ESI] 0 16, EBX[16:3…
ECX = @32[EDX] ^ 0x123
zf = @32[EDX] == 0x123
nf = (@32[EDX] ^ 0x123)[31:32]
...
EIP = @32[EDX] ^ 0x123
IRDst = @32[EDX] ^ 0x123
```

- Applied `EDX = 0x96` and `@32[0x96] = 0xFEED`:

```
EAX = {@16[ESI] 0 16, EBX[16:3…
ECX = 0xFFCE
zf = 0x0
nf = 0x0
...
EIP = 0xFFCE
IRDst = 0xFFCE
EDX = 0x96
@32[0x96] = 0xFEED
```

End of introduction

Wslink: First contact

```
.text:000007FEEBCF2A70
.text:000007FEEBCF2A70
.text:000007FEEBCF2A70
.text:000007FEEBCF2A70                                  ; DWORD __stdcall StartAddress(LPVO
.text:000007FEEBCF2A70                                  StartAddress proc near
.text:000007FEEBCF2A70
.text:000007FEEBCF2A70                                  var_10= qword ptr -10h
.text:000007FEEBCF2A70
.text:000007FEEBCF2A70 000 40 53                        push    rbx
.text:000007FEEBCF2A72 008 48 83 EC 60                  sub     rsp, 60h
.text:000007FEEBCF2A76 068 48 8B 05 13 BD 0D 00         mov     rax, cs:qword_7FEEBDCE790
.text:000007FEEBCF2A7D 068 48 33 C4                     xor     rax, rsp
.text:000007FEEBCF2A80 068 48 89 44 24 58               mov     [rsp+68h+var_10], rax
.text:000007FEEBCF2A85 068 48 8B D9                     mov     rbx, rcx
.text:000007FEEBCF2A88 068 E8 E3 FD 0E 00               call    vm_entry
.text:000007FEEBCF2A8D 068 AE                           scasb
.text:000007FEEBCF2A8E 068 A3 CC 4F 24 B6 8C F7 CC 28   mov     ds:28CCF78CB6244FCCh, eax
.text:000007FEEBCF2A97 068 77 51
```

```
xlat
mov     ds:71974A04C5639
stosd
xchg    eax, ecx
out     0A7h, al
jge     short loc_7FEEBC
```

xrefs to vm_entry

Direction	Typ	Address	Text
Up	p	sub_7FEEBCF1C20+D	call vm_entry
Up	p	sub_7FEEBCF27B0+1E	call vm_entry
Up	p	sub_7FEEBCF2860+4	call vm_entry
	p	StartAddress+18	call vm_entry
Do...	p	sub_7FEEBCF2B20+22	call vm_entry
Do...	p	sub_7FEEBCF2E40+18	call vm_entry
Do...	p	ServiceMain+D	call vm_entry

- A virtualized function
- Virtualized functions contain:
  - Prologue
  - Call to VM entry
  - Gibberish code

Junk code

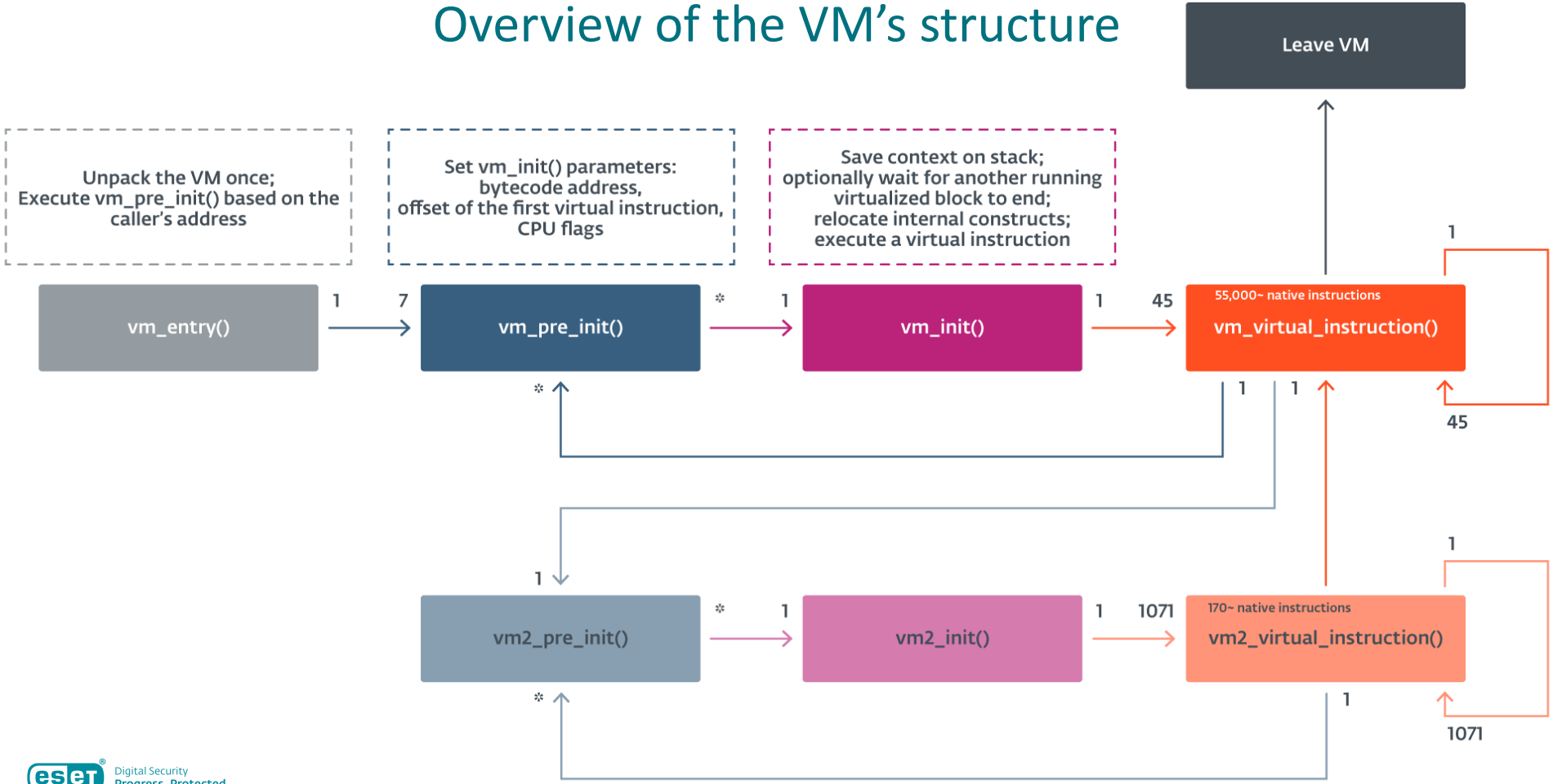
IDA View-A | Symbolic Execution - 0x11dfd8 to 0x11e842

```
RAX = call_func_ret(0x11DFDD, RSP_init, RCX_init, RDX_init, R8_init, R9_init)
RBX = 0x127
RCX = 0x1
RSP = call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF80
RBP = @64[call_func_stack(0x11DFDD, RSP_init)] + 0xFFFFFFFFFFFDB229
zf = RSI_init == 0x0
nf = (RSI_init)[63:64]
pf = parity(RSI_init & 0xFF)
of = 0x0
cf = 0x0
af = ((call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF78) ^ (call_func_sta
IRDst = loc_key_3
@64[call_func_stack(0x11DFDD, RSP_init)] = call_func_ret(0x11DFDD, RSP_init, RCX_
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF58] = RDX_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF60] = call_func_stack(0
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF68] = call_func_stack(0
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF70] = call_func_stack(0
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF78] = R12_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF80] = @64[call_func_sta
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF88] = R8_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF90] = R9_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFF98] = R10_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFA0] = R11_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFA8] = R12_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFB0] = R13_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFB8] = R14_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFC0] = R15_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFC8] = RDI_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFD0] = RSI_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFD8] = RBP_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFE0] = RBX_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFE8] = RBX_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFF0] = RDX_init
@64[call_func_stack(0x11DFDD, RSP_init) + 0xFFFFFFFFFFFFFFF8] = RCX_init
```

Pseudocode-A

```
v32 = (__int64 *)(v86[0] ^ v31);
v86[0] = v20;
v85 = 0x4B6F99F2i64;
v84 = v28;
v83 = (__int64)v32;
v82 = (char *)v30;
v81 = (__int64)v32;
v33 = _InterlockedExchange64((volatile __int64 *)&v82, (
v84 = v20;
v34 = v83;
v83 = v21;
v82 = (char *)v23;
v81 = 0x2AF80900i64;
v80 = 0x50D361D3i64;
v79 = 0x78D1A8C6i64;
v78 = v25;
v77 = v24;
v35 = _InterlockedExchange64(&v78, (__int64)&v78);
v78 = v19;
v79 = (__int64)v22;
v82 = (char *)v22;
v81 = a2;
v36 = a2 ^ (unsigned __int64)&v81;
v81 ^= v36;
v37 = v81 ^ v36;
v80 = v33;
_InterlockedExchange64(&v80, (__int64)&v80);
v82 = (char *)v29;
v81 = 0x74E27FBEi64;
v80 = v37;
v38 = _InterlockedExchange64(&v80, (__int64)&v80);
v82 = (char *)v34;
v77 = v32;
v78 = (__int64)v32;
v81 = (__int64)v32;
v80 = 0x276C41B1i64;
v79 = (__int64)v24;
v39 = _InterlockedExchange64(&v79, (__int64)&v79);
v79 = a4;
v40 = _InterlockedExchange64(&v79, (__int64)&v79);
v81 = v26;
```

Overview of the VM's structure



VM2: The first executed virtual instruction

- Prepares the next virtual instruction
- Increases VPC (virtual program counter)
- Zeroes out a register

- `RBP_init` is context pointer
- Instruction table at offset `0xA4`
- VPC at offset `0x28`

Symbolic Execution - 0xe8a7a to 0xe8ad4

```
RAX = RBP_init + 0xB5
RCX = @64[@64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}]
RIP = @64[@64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}]
RSI = {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}
R10 = @64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}
R13 = RBP_init + 0x28
zf = @64[RBP_init + 0x28] == 0xFFFFFFFFFFFFFFFC
nf = (@64[RBP_init + 0x28] + 0x4)[63:64]
pf = parity((@64[RBP_init + 0x28] + 0x4) & 0xFF)
of = ((@64[RBP_init + 0x28] ^ (@64[RBP_init + 0x28] + 0x4)) & (@64[RBP_init + 0x28] ^ 0xFFFFFF
cf = (@64[RBP_init + 0x28] ^ ((@64[RBP_init + 0x28] ^ (@64[RBP_init + 0x28] + 0x4)) & (@64[RBP_
af = (@64[RBP_init + 0x28] ^ (@64[RBP_init + 0x28] + 0x4) ^ 0x4)[4:5]
IRDst = @64[@64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}]
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x4
@32[RBP_init + 0xB5] = 0x0
```

VM2: Virtual instructions 2 and 3

- Instruction 2
  - Zeroes out several virtual registers

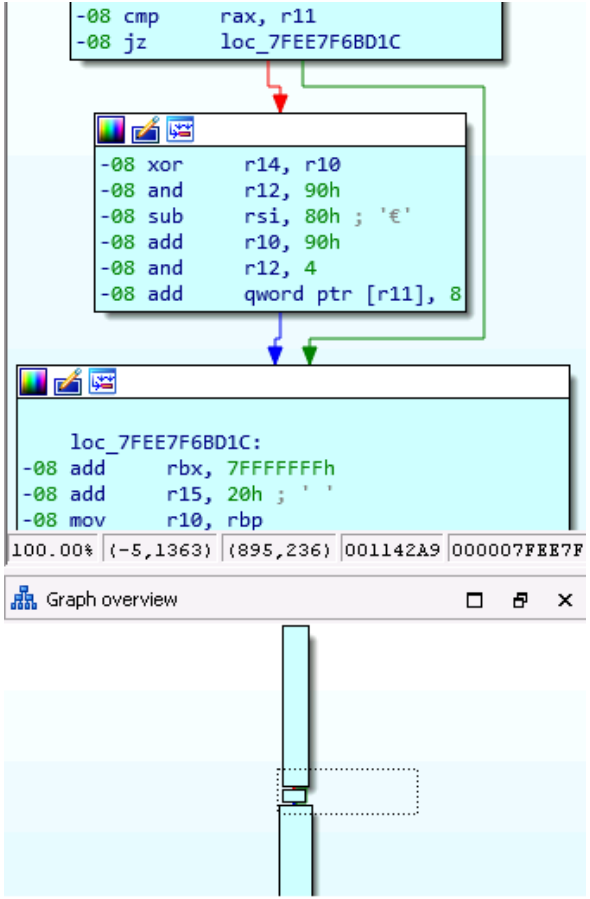
```
IRDst = @64[@64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28]], 3, 19, 0x0, 19, 64}]
@16[RBP_init + 0xB] = 0x0
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x2
@32[RBP_init + 0x48] = 0x0
@32[RBP_init + 0x70] = 0x0
@32[RBP_init + 0x94] = 0x0
@32[RBP_init + 0xA0] = 0x0
@32[RBP_init + 0xEE] = 0x0
@32[RBP_init + 0xFA] = 0x0
@16[RBP_init + 0x103] = 0x0
@32[RBP_init + 0x133] = 0x0
@16[RBP_init + 0x149] = 0x0
```

- Instruction 3
  - Stores RSP in a virtual register

```
IRDst = @64[@64[RBP_init + 0xA4] + {0x0, 0, 3, @16[@64[RBP_init + 0x28] + 0x2], 3, 19, 0x0, 19, 64}]
@64[RBP_init + {@16[@64[RBP_init + 0x28]], 0, 16, 0x0, 16, 64}] = RSP_init
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x4
```

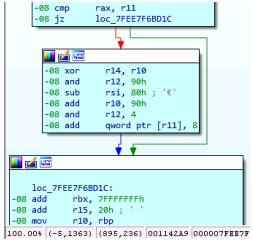
VM2: Virtual instruction 4

- Multiple basic blocks:



VM2: Virtual instruction 4

- Multiple basic blocks:

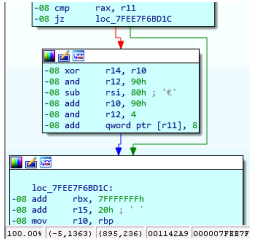


- Summary of the first block – memory assignments and IRDst:

```
IRDst = ({(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64} == {@16[@64[RBP_init + 0x28] + 0x6], 0,
@16[RBP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]
@32[RBP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})
@64[RBP_init + (@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64}] = @64[RSP_init]
```

VM2: Virtual instruction 4

- Multiple basic blocks:

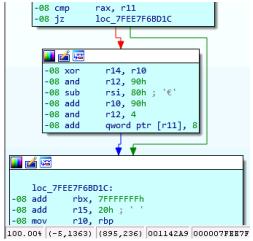


- Summary of the first block – memory assignments and IRDst:

```
IRDst = ({{(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_i
@16[RBP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@1
@32[RBP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@
@64[RBP_init + {(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64
```

VM2: Virtual instruction 4

- Multiple basic blocks:



- Summary of the first block – memory assignments and IRDst:

```
IRDst = ({{@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64} == {@16[@64[RBP_init + 0x28] + 0x6], 0,
@16[RBP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]
@32[RBP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})
@64[RBP_init + (@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64}] = @64[RSP_init]
```

- Rolling decryption – encryption of operands
  - Values of virtual registers at offsets `0x0B` and `0x70` were set earlier

"You're not allowed to use the sprinkler system to keep your audience awake."

VM2: Virtual instruction 4 - deobfuscation

- The first original block

```
IRDst = ({(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64} == {@16[@64[RBP_init + 0x28] + 0x6], 0,
@16[RBP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]
@32[RBP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})
@64[RBP_init + {(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64}] = @64[RSP_init]
```

VM2: Virtual instruction 4 - deobfuscation

- The first original block

```
= ({(@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init
BP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@6
BP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@16[@
BP_init + {[@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP
```

VM2: Virtual instruction 4 - deobfuscation

- The first original block

```
IRDst = ({{@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64} == {@16[@64[RBP_init + 0x28] + 0x6], 0,
@16[RBP_init + 0xB] = @16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]
@32[RBP_init + 0x70] = @32[RBP_init + 0x70] & (@32[RBP_init + 0x70] ^ {@16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})
@64[RBP_init + {@16[RBP_init + 0xB] + -(@32[RBP_init + 0x70] ^ @16[@64[RBP_init + 0x28] + 0x4], 0, 16, 0x0, 16, 32})[0:16]) ^ 0x3038, 0, 16, 0x0, 16, 64}] = @64[RSP_init]
```

- Application of known values of the rolling decryption registers

```
IRDst = (-@16[@64[RBP_init + 0x28] + 0x4] ^ 0x3038 == @16[@64[RBP_init +
0x28] + 0x6])?(0x7FEC91ABD1C,0x7FEC91ABCF6)
@64[RBP_init + {-@16[@64[RBP_init + 0x28] + 0x4] ^ 0x3038, 0, 16, 0x0,
16, 64}] = @64[RSP_init]
```

- Application of known bytecode values reveals `POP`

```
IRDst = @64[@64[RBP_init + 0xA4] + 0x5A8]
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x8
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0x8
@64[RBP_init + 0x12A] = @64[RSP_init]
```

VM2: Deobfuscating bytecode chunks

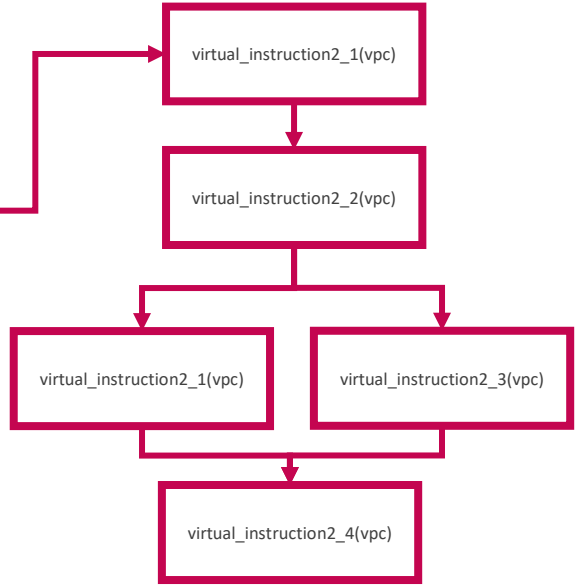
- Virtual instruction 4 summary:

```
IRDst = @64[@64[RBP_init + 0xA4] + 0x5A8]
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x8
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0x8
@64[RBP_init + 0x12A] = @64[RSP_init]
```

VM2: Deobfuscating bytecode chunks

- Virtual instruction 4 summary:

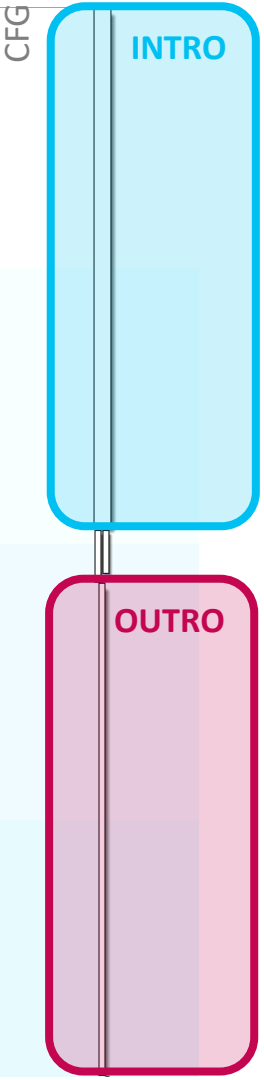
```
IRDst = @64[@64[RBP_init + 0xA4] + 0x5A8]
@64[RBP_init + 0x28] = @64[RBP_init + 0x28] + 0x8
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0x8
@64[RBP_init + 0x12A] = @64[RSP_init]
```



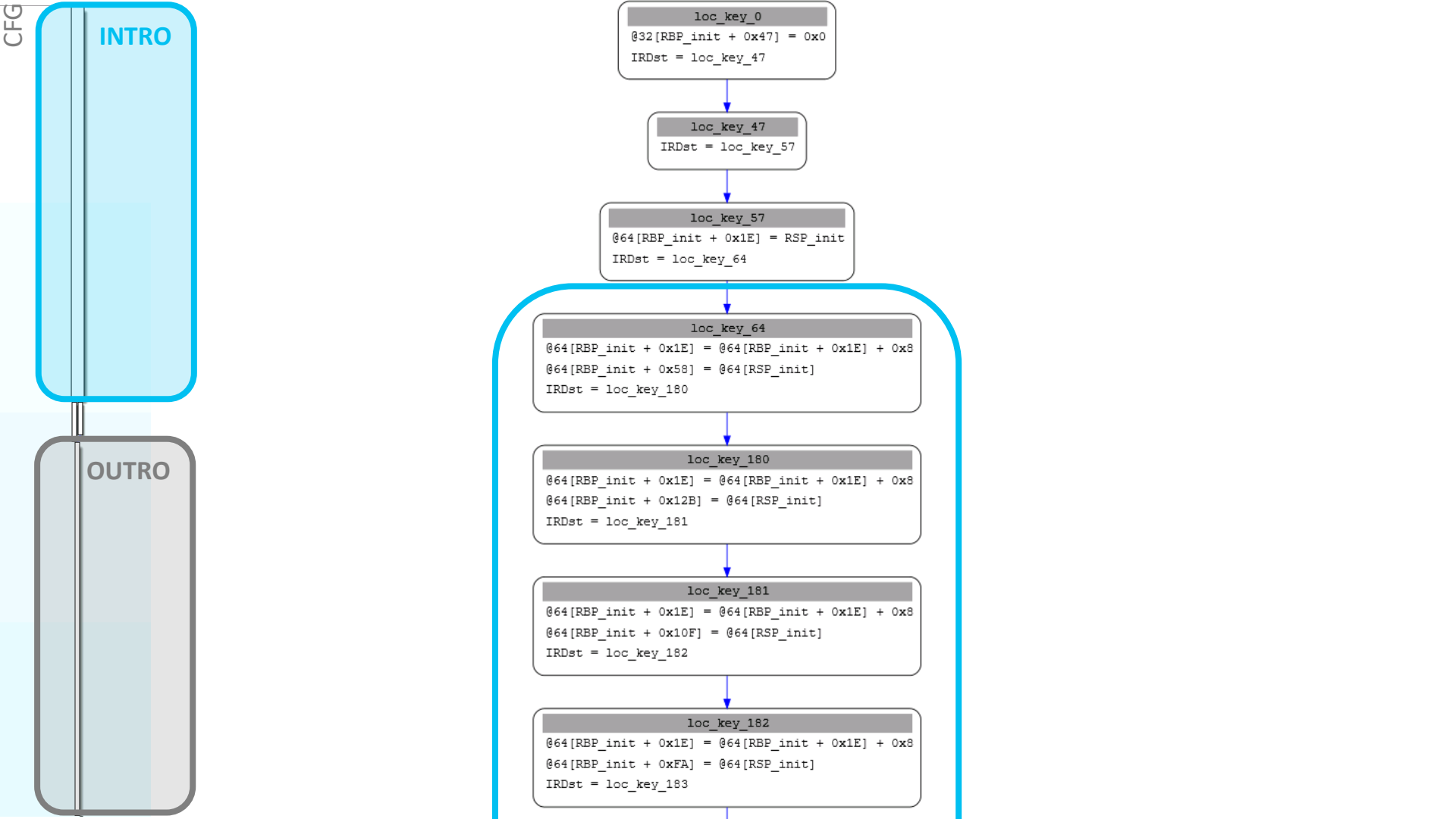
- Build a graph from summaries
- Treat some values as concrete:
  - Rolling decryption registers
  - Memory accesses relative to the bytecode pointer
- Preserve only decryption registers' values between blocks

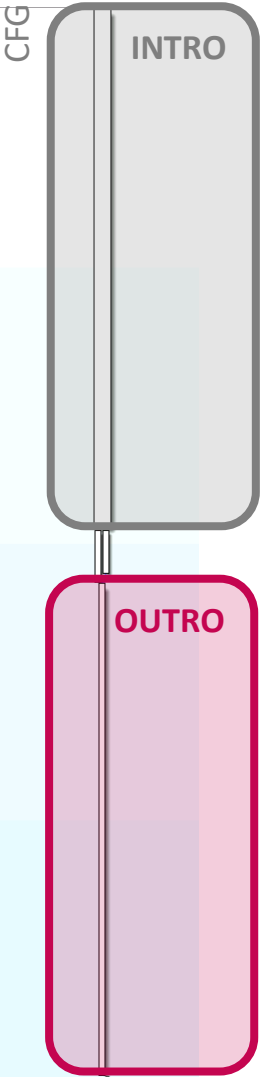
VM1: Deobfuscated virtual instruction structure

CFG



VM1: Deobfuscated virtual instruction structure


CFG
INTRO
OUTRO
loc_key_0
@32[RBP_init + 0x47] = 0x0
IRDst = loc_key_47
loc_key_47
IRDst = loc_key_57
loc_key_57
@64[RBP_init + 0x1E] = RSP_init
IRDst = loc_key_64
loc_key_64
@64[RBP_init + 0x1E] = @64[RBP_init + 0x1E] + 0x8
@64[RBP_init + 0x58] = @64[RSP_init]
IRDst = loc_key_180
loc_key_180
@64[RBP_init + 0x1E] = @64[RBP_init + 0x1E] + 0x8
@64[RBP_init + 0x12B] = @64[RSP_init]
IRDst = loc_key_181
loc_key_181
@64[RBP_init + 0x1E] = @64[RBP_init + 0x1E] + 0x8
@64[RBP_init + 0x10F] = @64[RSP_init]
IRDst = loc_key_182
loc_key_182
@64[RBP_init + 0x1E] = @64[RBP_init + 0x1E] + 0x8
@64[RBP_init + 0xFA] = @64[RSP_init]
IRDst = loc_key_183




```
...
@64[RSP_init + 0xFFFFFFFFFFFFFFF8] = @64[RBP_init + 0x98]
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0xFFFFFFFFFFFFFFF8

@64[RSP_init + 0xFFFFFFFFFFFFFFF8] = @64[RBP_init + 0x10D]
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0xFFFFFFFFFFFFFFF8
...
R10 = @64[RSP_init + 0x10]
R11 = @64[RSP_init + 0x18]
R12 = @64[RSP_init + 0x20]
R13 = @64[RSP_init + 0x28]
R14 = @64[RSP_init + 0x30]
R15 = @64[RSP_init + 0x38]
zf = @32[RSP_init + 0x78][6:7]
...
exception_flags = @32[RSP_init + 0x78][8:9]?(0x2,exception_flags_init)
IRDst = @64[RBP_init + 0x74]
@32[RBP_init + 0xFF] = 0x0
```

Legend:

Yellow – Push virtual registers

Red – Pop virtual registers; switch context

Green – Jump to register

VM1: Initially executed virtual instructions

- Virtual instructions 1, 2, 3
  - The same behavior as in VM2

VM1: Virtual instruction 4

VM1: Virtual instruction 4

- Instruction merging – contains, e.g., `POP` and `PUSH` operations
- Operands decide which instruction is executed
- `PUSH`:

```
loc_key_386
@8[RBP_init] = 0x1
@64[RSP_init + 0xFFFFFFFFFFFFFFF8] = @64[RBP_init + 0x30]
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0xFFFFFFFFFFFFFFF8
IRDst = loc_key_396
```

```
loc_key_387
@8[RBP_init] = 0x0
@16[RSP_init + 0xFFFFFFFFFFFFFFFE] = @16[RBP_init + 0x30]
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0xFFFFFFFFFFFFFFFE
IRDst = loc_key_396
```

VM1: Virtual instruction 4

- Instruction merging – contains, e.g., `POP` and `PUSH` operations
- Operands decide which instruction is executed
- `POP`:

```
loc_key_420
@8[RBP_init] = 0x1
IRDst = (@64[RBP_init + 0x30] == (RBP_init + 0x141))?(loc_key_58
```

```
loc_key_585
@64[@64[RBP_init + 0x30]] = @64[RSP_init]
@64[RBP_init + 0x141] = @64[RBP_init + 0x141] + 0x8
IRDst = loc_key_434
```

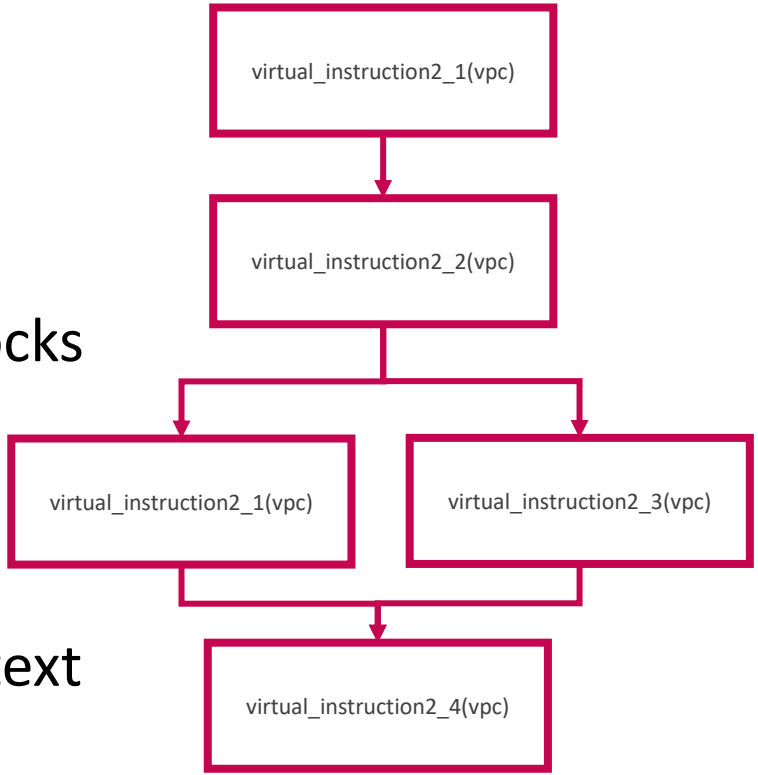
```
loc_key_586
@64[@64[RBP_init + 0x30]] = @64[RSP_init]
IRDst = loc_key_434
```

VM1: Virtual instruction 4

- Instruction merging – contains, e.g., `POP` and `PUSH` operations
- Operands decide which instruction is executed
- `PUSH/POP`
- Can be simplified by making the **operands concrete**

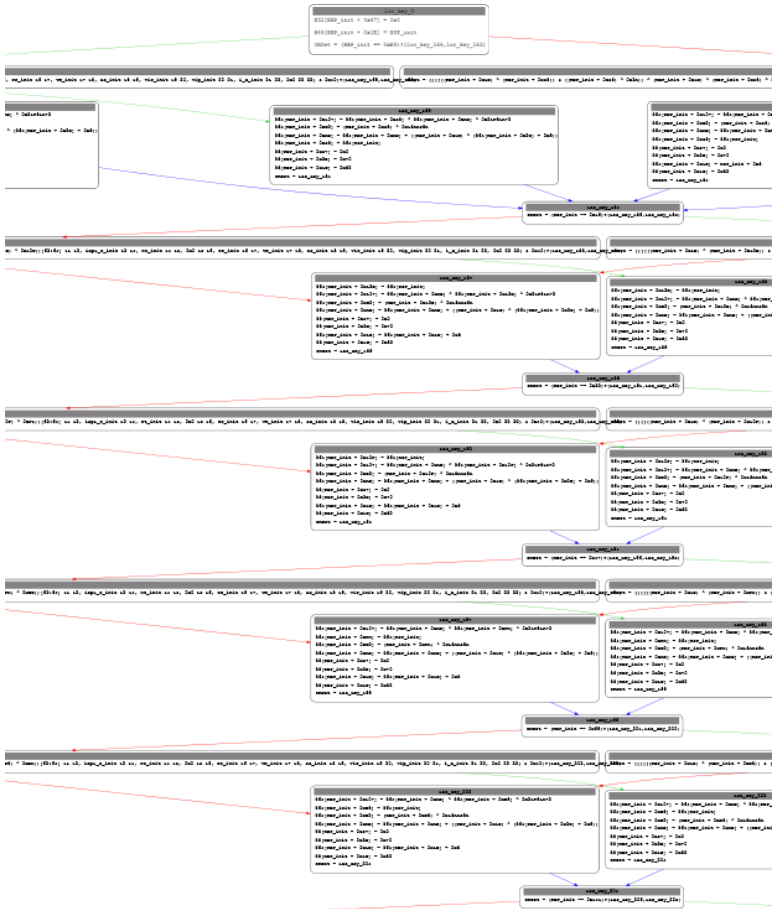
VM1: Deobfuscating bytecode chunks

- Use the same approach as in VM2:
  - Build a graph from summaries
  - Treat certain values as concrete
  - Preserve certain values between blocks
- Process both VMs at once:
  - Additionally make the entire VM2 concrete
  - Ignore assignments to the VM2 context



VM1: Issue with opaque predicates during deobfuscation

Resulting graph contained unexpected branches instead of a series of `POP`s



VM1: Issue with opaque predicates during deobfuscation

```
loc_key_0
@32[RBP_init + 0x47] = 0x0

@64[RBP_init + 0x1E] = RSP_init

IRDst = (RBP_init == 0xE9)?(loc_key_164,loc_key_163)
```

- The branches check a known value
  - We can apply the value and simplify it
  - This is a sort of opaque predicates

Does the approach work?

Analyzing results

Bytecode block	VM1	VM2
Size in bytes	695	1,145
Total number of processed virtual instructions	62	109
Total number of underlying native instructions	3,536,427	17,406
Total number of resulting IR instructions (including IRDsts)	192	307
Execution time in seconds	382	10

Processed ServiceMain bytecode

```
ServiceMain     proc near               ; DATA XREF: .rda
                                        ; .rdata:00000001

arg_8           = qword ptr  10h

                mov     [rsp+arg_8], rbx
                push    rdi
                sub     rsp, 20h
                mov     rbx, rdx
                call    sub_1800F2870
                fdivr   st, st(6)
; ---------------------------------------------------------
                dd 628D92C7h
```

```
public ServiceMain
ServiceMain proc near

arg_0= qword ptr  8
arg_8= qword ptr  10h

mov     [rsp+10h], rbx
push    rdi
sub     rsp, 20h
mov     rbx, [rdx]
mov     eax, 28
lea     rdi, ServiceStatus
nop     dword ptr [rax+00000000h]
```

```
loc_180003060:
dec     rax
mov     byte ptr [rax+rdi], 0
```

OBFUSCATED

NON-OBFUSCATED SAMPLE*

DEOBFUSCATED

```
@64[RBP_init+ 0x15] = @64[RSP_init]
@64[RBP_init+ 0x11F] = @64[RSP_init]
@64[RBP_init+ 0x1E] = RSP_init+ 0x78
@64[RBP_init+ 0x4F] = @64[RSP_init]
@64[RBP_init+ 0x1E] = RSP_init+ 0x80
@64[RBP_init+ 0xCC] = @64[RSP_init]
@64[RBP_init+ 0x1E] = RSP_init+ 0x88
@64[RBP_init+ 0x1E] = RSP_init+ 0x98
@64[RBP_init+ 0x13F] = @64[@64[RBP_init+ 0x13F]]
@32[RBP_init+ 0x53] = 0x0
@32[RBP_init+ 0x4F] = 0x1C
@64[RBP_init+ 0x133] = 0x3092
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0x3092
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0xE3808
@64[RBP_init+ 0x74] = @64[RBP_init+ 0x80] + 0xE3808
IRDst= loc_key_291
```

```
loc_key_291
== 0x1, 6, 7, (@64[RBP_init+ 0x4F] + 0xFFFFFFFFFFFFFFFF)[63:64], 7, 8, (@32[RBP_init+ 0xCC])[8:11], 8, 11, (@64[RBP_init+ 0x4F] ^ (@64[RBP_init+ 0x4F] + 0xFFFFFFFFFFFFFFFF)) & (@64[RBP_init+ 0x4F] ^ 0x1))[63:64], 11, 12, (@32[RBP_init+ 0xCC])[12:15], 12, 15, 0x0, 15, 16, (0
```

```
9, vif_init, 19, 20, vip_init, 20, 21, i_d_init, 21, 22, 0x0, 22, 32) & 0x40,(0x2, 0, 2, parity(@32[RBP_init+ 0xCC] & 0x40), 2, 3, 0x8, 3, 8, tf_init, 8, 9, i_f_init, 9, 10, df_init, 10, 11, 0x0, 11, 12, iopl_f_init, 12, 14, nt_init, 14, 15, 0x0, 15, 16, rf_init, 16, 17, vm_init,
```

```
loc_key_318
@64[RBP_init+ 0x133] = 0x30A2
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0x30A2
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0x2FB0
@64[RBP_init+ 0x15] = @64[RBP_init+ 0x80] + 0x2FB0
@64[RBP_init+ 0x11F] = @64[RBP_init+ 0x13F]
@64[RBP_init+ 0x133] = 0x30AB
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0x30AB
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0x8C038
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0x4F]
@64[RBP_init+ 0x1E] = @64[RBP_init+ 0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0x4F]
@64[RBP_init+ 0x1E] = @64[RBP_init+ 0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0xCC]
@64[RBP_init+ 0x1E] = @64[RBP_init+ 0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0x4F]
@64[RBP_init+ 0x1E] = @64[RBP_init+ 0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0x11F]
@64[RBP_init+ 0x1E] = @64[RBP_init+ 0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+ 0xFFFFFFFFFFFFFFF8] = @64[RBP_init+ 0x15]
```

```
@64[RBP_init+  0x15] = @64[RSP_init]

@64[RBP_init+  0x11F] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x78

@64[RBP_init+  0x4F] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x80

@64[RBP_init+  0xCC] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x88

@64[RBP_init+  0x1E] = RSP_init+  0x98

@64[RBP_init+  0x13F] = @64[@64[RBP_init+  0x13F]]

@32[RBP_init+  0x53] = 0x0
@32[RBP_init+  0x4F] = 0x1C

@64[RBP_init+  0x133] = 0x3092

@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x3092

@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0xE3808

@64[RBP_init+  0x74] = @64[RBP_init+  0x80] + 0xE3808
IRDst=  loc_key_291
```

```
public ServiceMain
ServiceMain proc near

arg_0= qword ptr  8
arg_8= qword ptr  10h

5C 24 10          mov     [rsp+10h], rbx
                  push    rdi
EC 20             sub     rsp, 20h
1A                mov     rbx, [rdx]
00 00 00          mov     eax, 28
3D AF 07 0E 00    lea     rdi, ServiceStatus
80 00 00 00 00    nop     dword ptr [rax+00000000h]

                  loc_180003060:
FF C8             dec     rax
04 38 00          mov     byte ptr [rax+rdi], 0
F7                jnz     short loc_180003060

10 FF FF FF       lea     rdx, HandlerProc ; lpHandlerPr
                  mov     rcx, rbx         ; lpServiceNam
8F 08 00          call    cs:RegisterServiceCtrlHandlerW
B0 07 0E 00       mov     cs:hServiceStatus, rax
                  test    rax, rax
                  jz      short loc_1800030FD
```

```
mov   R0, [R0]
mov   R1, 28
```

DEOBFUSCATED SIMPLIFIED ORIGINAL SAMPLE

```
@64[RBP_init+  0x15] = @64[RSP_init]

@64[RBP_init+  0x11F] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x78

@64[RBP_init+  0x4F] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x80

@64[RBP_init+  0xCC] = @64[RSP_init]
@64[RBP_init+  0x1E] = RSP_init+  0x88

@64[RBP_init+  0x1E] = RSP_init+  0x98

@64[RBP_init+  0x13F] = @64[@64[RBP_init+  0x13F]]

@32[RBP_init+  0x53] = 0x0
@32[RBP_init+  0x4F] = 0x1C

@64[RBP_init+  0x133] = 0x3092

@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x3092

@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0xE3808

@64[RBP_init+  0x74] = @64[RBP_init+  0x80] + 0xE3808
IRDst=  loc_key_291
```

```
                                    public ServiceMain
                                    ServiceMain proc near

                                    arg_0= qword ptr  8
                                    arg_8= qword ptr  10h

5C 24 10                            mov     [rsp+10h], rbx
                                    push    rdi
EC 20                               sub     rsp, 20h
1A                                  mov     rbx, [rdx]
00 00 00                            mov     eax, 28
3D AF 07 0E 00                      lea     rdi, ServiceStatus
80 00 00 00 00                      nop     dword ptr [rax+00000000h]

                                    loc_180003060:
FF C8                               dec     rax
04 38 00                            mov     byte ptr [rax+rdi], 0
F7                                  jnz     short loc_180003060

10 FF FF FF                         lea     rdx, HandlerProc ; lpHandlerPr
                                    mov     rcx, rbx         ; lpServiceNam
8F 08 00                            call    cs:RegisterServiceCtrlHandlerW
B0 07 0E 00                         mov     cs:hServiceStatus, rax
                                    test    rax, rax
                                    jz      short loc_1800030FD
```

lea R2, BASE+0xE3808

```
.data:000007FEB5FF3808      ; struct _SERVICE_STATUS ServiceStatus
.data:000007FEB5FF3808      ServiceStatus _SERVICE_STATUS <0>
.data:000007FEB5FF3808
```

DEOBFUSCATED SIMPLIFIED ORIGINAL SAMPLE

```
0x4F] + 0xFFFFFFFFFFFFFFFF)) & (@64[RBP_init+  0x4F] ^ 0x1))[63:64], 1,

t, 8, 9, i_f_init, 9, 10, df_init, 10, 11, 0x0, 11, 12, iopl_f_init, 12, 1
```

```
public ServiceMain
ServiceMain proc near

arg_0= qword ptr  8
arg_8= qword ptr  10h

48 89 5C 24 10          mov     [rsp+10h], rbx
57                      push    rdi
48 83 EC 20             sub     rsp, 20h
48 8B 1A                mov     rbx, [rdx]
B8 1C 00 00 00          mov     eax, 28
48 8D 3D AF 07 0E 00    lea     rdi, ServiceStatus
0F 1F 80 00 00 00 00    nop     dword ptr [rax+00000

                        loc_180003060:
28 48 FF C8             dec     rax
28 C6 04 38 00          mov     byte ptr [rax+rdi]
28 75 F7                jnz     short loc_18000306

8D 15 10 FF FF FF       lea     rdx, HandlerProc ; lpHa
8B CB                   mov     rcx, rbx         ; lpSer
15 BF 8F 08 00          call    cs:RegisterServiceCtrlH
89 05 B0 07 0E 00       mov     cs:hServiceStatus, rax
85 C0                   test    rax, rax
78                      jz      short loc_1800030FD
```

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ORIGINAL SAMPLE

```
@64[RBP_init+ 0x13F] = @64[RSP_init]
@64[RBP_init+ 0x1E] = RSP_init+ 0x60

@64[RBP_init+ 0x13F] = @64[RSP_init]
@64[RBP_init+ 0x1E] = RSP_init+ 0x68

@64[RBP_init+ 0x1E] = RSP_init+ 0x70
```

```
@64[RBP_init + 0xCC] = {@32[RBP_init + 0xCC][0:1] 0 1, 0x1 1 2, parit
@64[RBP_init + 0x4F] = @64[RBP_init + 0x4F] + 0xFFFFFFFFFFFFFFFE
@64[RBP_init + 0x133] = @64[RBP_init + 0x4F]
@64[RBP_init + 0x133] = @64[RBP_init + 0x4F] + @64[RBP_init + 0x74]
@8[@64[RBP_init + 0x4F] + @64[RBP_init + 0x74]] = 0x0
IRDst = ((@32[RBP_init + 0xCC] & 0x40)?({0x2 0 2, parity(@32[RBP_init
```

```
@64[RBP_init+ 0x133] = @64[RBP_init+ 0x80] + 0xE3808
@64[RBP_init+ 0x74] = @64[RBP_init+ 0x80] + 0xE3808
IRDst= loc_key_291
```

```
48 89 5C 24 10      mov     [rsp+10h], rbx
57                  push    rdi
48 83 EC 20         sub     rsp, 20h
48 8B 1A            mov     rbx, [rdx]
B8 1C 00 00 00      mov     eax, 28
48 8D 3D AF 07 0E 00  lea   rdi, ServiceStatus
0F 1F 80 00 00 00 00  nop   dword ptr [rax+00000000h]
```

```
loc_180003060:
48 FF C8            dec     rax
C6 04 38 00         mov     byte ptr [rax+rdi], 0
75 F7               jnz     short loc_180003060
```

```
8D 15 10 FF FF FF   lea     rdx, HandlerProc ; lpHandlerPr
8B CB               mov     rcx, rbx         ; lpServiceNam
15 BF 8F 08 00      call    cs:RegisterServiceCtrlHandlerW
89 05 B0 07 0E 00   mov     cs:hServiceStatus, rax
85 C0               test    rax, rax
78                  jz      short loc_1800030FD
```

```
loc_key_291
[RBP_init+ 0x4F] + 0xFFFFFFFFFFFFFFFF)[63:64], 7, 8, (@32[RBP_init+ 0xCC])[8:11], 8, 11, ((@64[RBP_init+ 0x4F] ^ (@64[RBP_init+ 0x4F] + 0xFFFFFFFFFFFFFFFF)) & (@64[RBP_init+ 0x4F] ^ 0x1))[63:64], 11, 12, (@32[RBP_
20, vip_init, 20, 21, i_d_init, 21, 22, 0x0, 22, 32} & 0x40,{0x2, 0, 2, parity(@32[RBP_init+ 0xCC] & 0x40), 2, 3, 0x8, 3, 8, tf_init, 8, 9, i_f_init, 9, 10, df_init, 10, 11, 0x0, 11, 12, iopl_f_init, 12, 14, nt_init, 1
```

DEOBFUSCATED

ORIGINAL SAMPLE

```
loc_key_318
@64[RBP_init+  0x133] = 0x30A2
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x30A2
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x2FB0
@64[RBP_init+  0x15] = @64[RBP_init+  0x80] + 0x2FB0
@64[RBP_init+  0x11F] = @64[RBP_init+  0x13F]
@64[RBP_init+  0x133] = 0x30AB
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x30AB
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x8C03
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0xCC
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x11F]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
```

```
.text:000007FEB5F12FB0
.text:000007FEB5F12FB0
.text:000007FEB5F12FB0      sub_7FEB5F12FB0 proc near
.text:000007FEB5F12FB0
.text:000007FEB5F12FB0      var_8= qword ptr -8
.text:000007FEB5F12FB0
.text:000007FEB5F12FB0 000 sub     rsp, 28h
.text:000007FEB5F12FB4 028 cmp     ecx, 1
.text:000007FEB5F12FB7 028 jnz     loc_7FEB5F13065
```

```
48 89 5C 24 10          mov     [rsp+10h], rbx
57                      push    rdi
48 83 EC 20             sub     rsp, 20h
48 8B 1A                mov     rbx, [rdx]
B8 1C 00 00 00          mov     eax, 28
48 8D 3D AF 07 0E 00    lea     rdi, ServiceStatus
0F 1F 80 00 00 00 00    nop     dword ptr [rax+00000000h]
```

```
loc_180003060:
28 48 FF C8             dec     rax
28 C6 04 38 00          mov     byte ptr [rax+rdi], 0
28 75 F7                jnz     short loc_180003060
```

```
8D 15 10 FF FF FF       lea     rdx, HandlerProc ; lpHandlerPr
8B CB                   mov     rcx, rbx         ; lpServiceNam
15 BF 8F 08 00          call    cs:RegisterServiceCtrlHandlerW
89 05 B0 07 0E 00       mov     cs:hServiceStatus, rax
85 C0                   test    rax, rax
78                      jz      short loc_1800030FD
```

lea R2, BASE+0x2FB0

mov R3, R0

DEOBFUSCATED

SIMPLIFIED

ORIGINAL SAMPLE

```
loc_key_318
@64[RBP_init+  0x133] = 0x30A2
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x30A2
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x2FB0
@64[RBP_init+  0x15] = @64[RBP_init+  0x80] + 0x2FB0
@64[RBP_init+  0x11F] = @64[RBP_init+  0x13F]
@64[RBP_init+  0x133] = 0x30AB
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x30AB
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x8C038
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0xCC]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64
@64[RBP_init+  0x1E] = @64[RBP_init+  0x
```

```
48 89 5C 24 10      mov     [rsp+10h], rbx
57                  push    rdi
48 83 EC 20         sub     rsp, 20h
48 8B 1A            mov     rbx, [rdx]
B8 1C 00 00 00      mov     eax, 28
48 8D 3D AF 07 0E 00  lea   rdi, ServiceStatus
0F 1F 80 00 00 00 00  nop   dword ptr [rax+00000000h]
```

```
                    loc_180003060:
28 48 FF C8         dec     rax
28 C6 04 38 00      mov     byte ptr [rax+rdi], 0
28 75 F7            jnz     short loc_180003060
```

```
8D 15 10 FF FF FF   lea     rdx, HandlerProc ; lpHandlerPr
8B CB               mov     rcx, rbx
15 BF 8F 08 00      call    cs:RegisterServiceCtrlHandlerW
89 05 B0 07 0E 00   mov     cs:hServiceStatus, rax
85 C0               test    rax, rax
78                  jz      short loc_1800030FD
```

lea Rdest, BASE+0x8C038

```
.idata:000007FEB5F9C038    ; SERVICE_STATUS_HANDLE __stdcall RegisterServiceCtrlH
.idata:000007FEB5F9C038    RegisterServiceCtrlHandlerW dq offset advapi32_Registe
.idata:000007FEB5F9C040    db 0, 0, 0, 0, 0, 0, 0, 0
```

DEOBFUSCATED SIMPLIFIED ORIGINAL SAMPLE

```
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x30AB
@64[RBP_init+  0x133] = @64[RBP_init+  0x80] + 0x8C038
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
```

lea Rdest, BASE+0x8C038

```
.idata:000007FEB5F9C038      ; SERVICE_STATUS_HANDLE __stdcall RegisterServiceCtrlH
.idata:000007FEB5F9C038      RegisterServiceCtrlHandlerW dq offset advapi32_Registe
.idata:000007FEB5F9C040      db 0, 0, 0, 0, 0, 0, 0, 0
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x4F]
```

...

```
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0xFFFFFFFFFFFFFFF8] = @64[RBP_init+  0x58]
@64[RBP_init+  0x1E] = @64[RBP_init+  0x1E] + 0xFFFFFFFFFFFFFFF8
@64[RSP_init+  0x88] = @64[RBP_init+  0x80] + 0x21EA5C
@32[RBP_init+  0x12
RAX.0=  @64[RSP_ini
RSP.0=  RSP_init+
exception_flags= ( @32[RSP_init+  0x78])
IRDst=  @64[@64[RBP_init+  0x133]]
```

RETaddr = &vm_pre_initX()

jmp Rdest

```
48 89 5C 24 10          mov     [rsp+10h], rbx
57                      push    rdi
48 83 EC 20             sub     rsp, 20h
48 8B 1A                mov     rbx, [rdx]
B8 1C 00 00 00          mov     eax, 28
48 8D 3D AF 07 0E 00    lea     rdi, ServiceStatus
0F 1F 80 00 00 00 00    nop     dword ptr [rax+00000000h]

                        loc_180003060:
28 48 FF C8             dec     rax
28 C6 04 38 00          mov     byte ptr [rax+rdi], 0
28 75 F7                jnz     short loc_180003060

8D 15 10 FF FF FF       lea     rdx, HandlerProc ; lpHandlerPr
8B CB                   mov     rcx, rbx
15 BF 8F 08 00          call    cs:RegisterServiceCtrlHandlerW
89 05 B0 07 0E 00       mov     cs:hServiceStatus, rax
85 C0                   test    rax, rax
78                      jz      short loc_1800030FD
```

DEOBFUSCATED

ORIGINAL SAMPLE

Limitations

- Symbolic execution cannot process **unbounded loops**
- Instructions using such loops need to be addressed **by other means**

Takeaway

Symbolic execution can help **devirtualize** advanced unknown VMs in a **reasonable time** if we treat the right values as concrete

Links

You can read the whitepaper at

WeLiveSecurity.com

Full source code is available in

ESET git repository

Digital Security
Progress. Protected.

Questions?

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