MODERN MALWARE:
OBFUSCATION AND EMULATION

DEF CON CHINA 1.0 (2019)



by Alexandre Borges

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Agenda:

- ❖ Introduction
- ❖ Anti-reversing
- ❖ METASM
- ❖ MIASM
- ❖ TRITON
- ❖ Radare2 + MIASM
- ❖ DTRACE on Windows
- ❖ Anti-VM
- ❖ Conclusion

INTRODUCTION

- ✓ Every single day we handle malware samples that use several known packers such as ASPack, Armadillo, Petite, FSG, UPX, MPRESS, NSPack, PECompact, WinUnpack and so on. For most of them, it is easy to write scripts to unpack them.

- ✓ We also know the main API functions, which are used to create and allocate memory such as:

  - ✓ VirtualAlloc/Ex( )
  - ✓ HeapCreate( ) / RtlCreateHeap( )
  - ✓ HeapReAlloc( )
  - ✓ GlobalAlloc( )
  - ✓ RtlAllocateHeap( )

- ✓ Additionally, we know how to unpack them using debuggers, breakpoints and dumping unpacked content from memory. Furthermore, pe-sieve from Hasherezade is excellent. ☺

- ✓ When we realize that the malware use some customized packing techniques, it is still possible to dump it from memory, fix the ImageAddress field using few lines in Python and its respective IAT using impscan plugin to analyze it in IDA Pro:

  - ✓ export VOLATILITY_PROFILE=Win7SP1x86
  - ✓ python vol.py -f memory.vmem procdump -p 2096 -D . --memory (to keep slack space)
  - ✓ python vol.py -f memory.vmem impscan --output=idc -p 2096

```
//#################################################################
//  FileName    :  dumpexe.txt (first draft)
//  Comment     :  Dump memory segments containing executables
//  Author      :  Alexandre Borges
//  Date        :  today
//#################################################################

entry:

msg "Program to dump modules containing executables."
msg "You must be at EP before continuing"
bc                  // Clear existing breakpoints
bphwc               // Clear existing hardbreakpoints
bp VirtualAlloc     // Set up a breakpoint at VirtualAlloc
erun                // run and pass all first exceptions to the application

core:

sti                 // Single-step
sti                 // Single-step
sti                 // Single-step
sti                 // Single-step
sti                 // Single-step
```

x64dbg script 1/3

x64dbg
script 2/3

```
find cip,"C2 1000“   // find the return point of VirtualAlloc
bp $result                    // set a breakpoint
erun                 // run and pass all first exceptions to the application
cmp eax,0                     // test if eax (no allocated memory) is equal to zero
je pcode             // jump to pcode label
bpm eax,0,x          // set executable memory breakpoint and restore it once hit.
erun                 // run and pass all first exceptions to the application

//try to find if there is the “This program” string within the module’s memory.
findall $breakpointexceptionaddress,"5468697320070726F6772616D”

cmp $result,0        // check if there isn’t any hit
je pcode             // jump to pcode label
$dumpaddr = mem.base($breakpointexceptionaddress)     //find the memory base.
$size = mem.size($breakpointexceptionaddress)         //find the size of memory base.
savedata :memdump:,$dumpaddr,$size                    //dump the segment.
msgyn "Memory dumped! Do you want continue?“          //show a dialog
cmp $result,1                                         //check your choice
je scode             // jump to scode label
bc                   // clear existing breakpoints
bphwc                // clear existing hardware breakpoints
ret                  // exit
```

x64dbg
script 3/3

```
pcode:

msgyn "There isn't a PE file! Do you want continue?"
cmp $result,0                   // check if we don’t want continue
je final
sti                             //single step.
erun                            // run and pass all first exceptions to the application
jmp core                        // jump to core label

scode:

msg "Let's go to next dump“     // shows a message box
erun                            // run and pass all first exceptions to the application
jmp core                        // jump to core label

final:

bc                              // clear existing breakpoints
bphwc                           // clear existing hardware breakpoints
ret                             // exit
```

ANTI-REVERSING

- ✓ Obfuscation aims to protect software of being reversed, intellectual property and, in our case, malicious code too. ☺ Honestly, obfuscation does not really protect the program, but it can make the reverser's life harder than usual.

- ✓ Thus, at end, obfuscation buys time by enforcing reversers to spend resources and time to break a code.

- ✓ We see obfuscated code every single day when we analyze commom userland malware, droppers written in VBA and Powershell, so it mightn't seem to be a big deal.

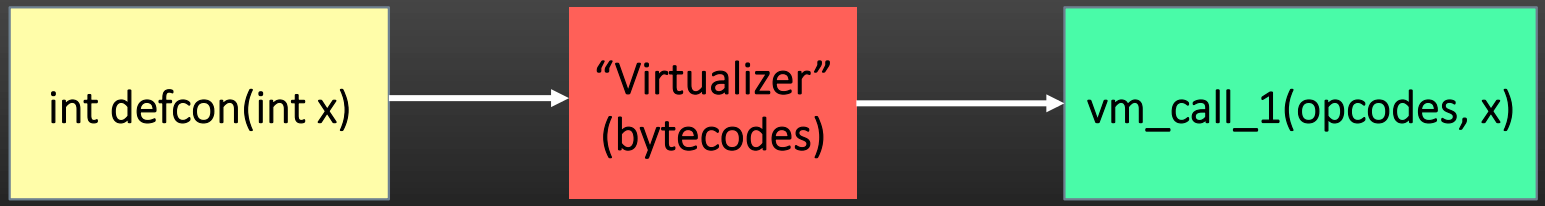
- ✓ We can use IDA Pro SDK to write plugins to extend the IDA Pro functionalities, analyze some code and data flow and even automatizing unpacking of strange malicious files.

- ✓ Additionally, if you are facing problems to analyze a modified MBR, so you could even write a loader to load the MBR structure and analyze it in IDA Pro. ☺

- ✓ Unfortunately, there are packers and protectors such as VMprotect, Themida, Arxan and Agile .NET that use modern obfuscation techniques, so making the procedure of reversing a code very complicated.

- ✓ Most protectors have used with 64-bit code (and malware).
- ✓ Original IAT is removed from the original code (as usually applied by any packer). However, IAT from packers like Themida keeps only one function (TlsSetValue).
- ✓ Almost all of them provide string encryption.
- ✓ They protect and check the memory integrity. Thus, it is not possible to dump a clean executable from the memory (using Volatility, for example) because original instructions are not decoded in the memory.
- ✓ Instructions (x86/x64 code) are virtualized and transformed into virtual machine instructions (RISC instruction).
- ✓ .NET protectors rename classes, methods, fields and external references.

- ✓ Some packers can use instruction encryption on memory as additional memory layer.
- ✓ Obfuscation is stack based, so it is hard to handle virtualized code statically.
- ✓ Virtualized code is polymorphic, so there are many representations referring the same CPU instruction.
- ✓ There are also fake push instructions.
- ✓ There are many dead and useless codes.
- ✓ There is some code reordering using unconditional jumps.
- ✓ All obfuscators use code flattening.
- ✓ Packers have few anti-debugger and anti-vm tricks. However, few months ago, I saw a not so common anti-vmware trick based on temperature (more about it later).

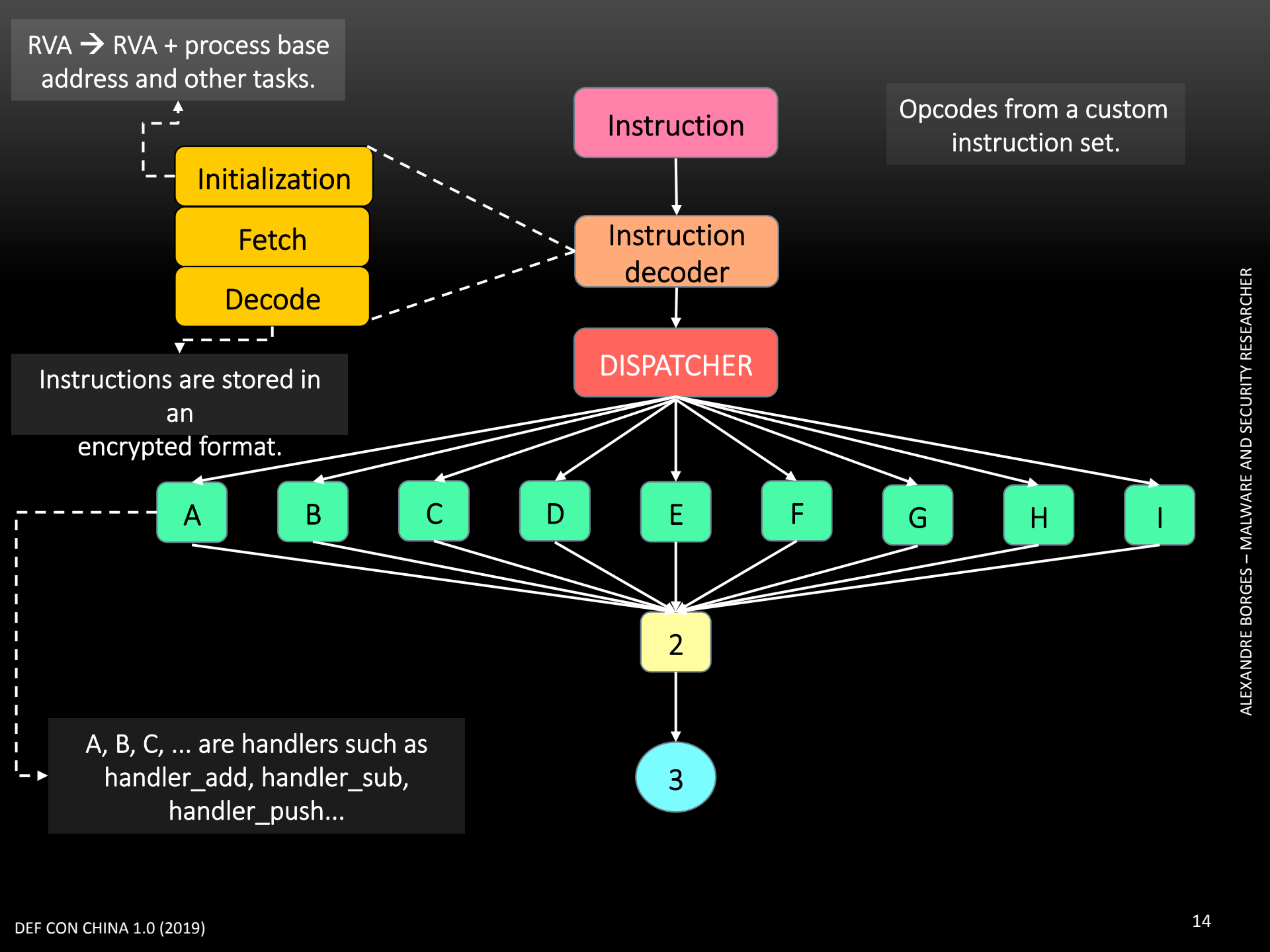


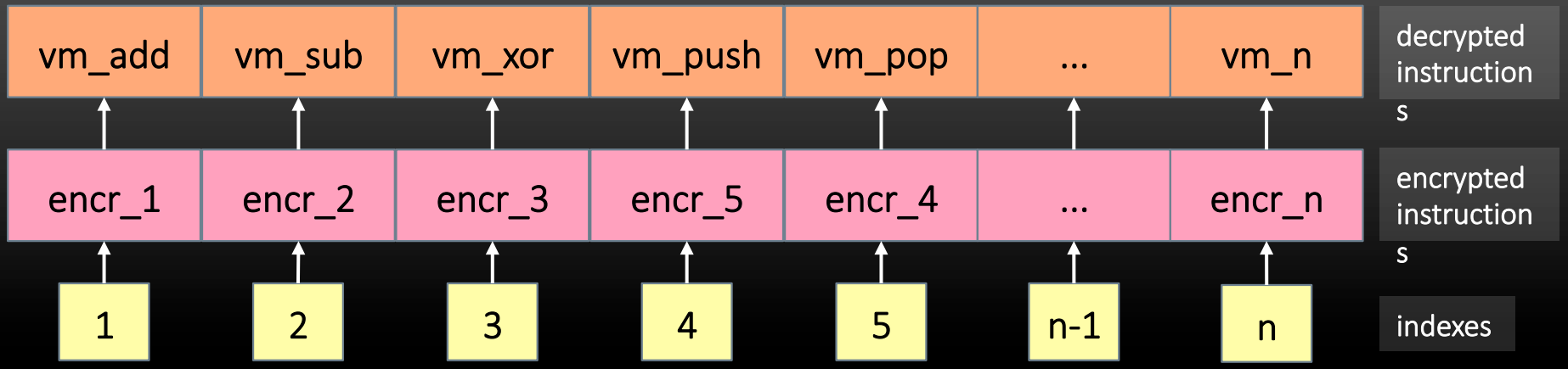
Fetches bytes, decodes them to instructions and dispatches them to handlers

- Protectors using virtual machines introduces into the obfuscated code:
  - ✓ A context switch component, which “transfers” registry and flag information into VM context (virtual machine). The oposite movement is done later from VM machine and native (x86/x64) context (suitable to keep within C structures during unpacking process ☺)
  - ✓ This “transformation” from native register to virtualized registers can be one to one, but not always.
- ✓ Inside of the virtual machine, the cycle is:
  - ✓ fetch instruction
  - ✓ decode it
  - ✓ find the pointer to instruction and lookup the associate opcode in a handler table
  - ✓ call the target handler

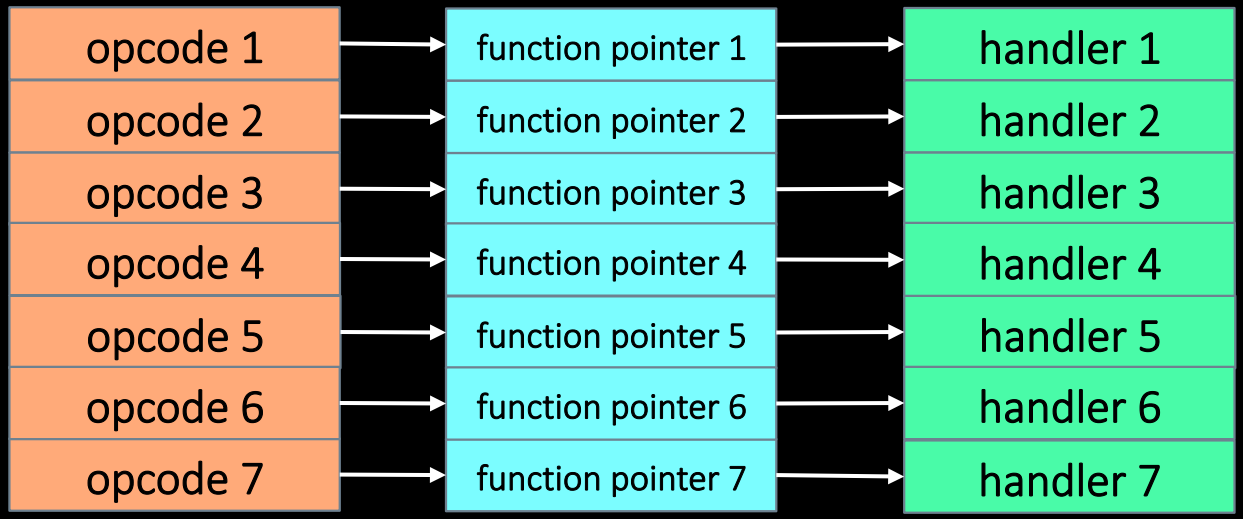
✓ Few interesting concepts:

- ✓ Fetching: the instruction to be executed by Virtual Machine is fetched.
- ✓ Decoding: the target x86 instruction is decoded using rules from Virtual Machine (remember: usually, the architecture is usually based on RISC instructions)
- ✓ Dispatcher: Once the handler is determined, so jump to the suitable handler. Dispatchers could be made by a jump table or switch case structure.
- ✓ Handler: In a nutshell, a handler is the implementation of the Virtual Machine instruction set.


RVA → RVA + process base address and other tasks.
Initialization
Fetch
Decode
Instructions are stored in an encrypted format.
Instruction
Instruction decoder
DISPATCHER
Opcodes from a custom instruction set.
A
B
C
D
E
F
G
H
I
2
3
A, B, C, ... are handlers such as handler_add, handler_sub, handler_push...



recovering and decrypting funcions



function pointer table (likely encrypted)

- ✓ Is it easy to reverse virtualized and packed code? Certainly, it is not. The number of challenges might be huge ☺
- ✓ Remember: obfuscating is transforming a code from A to B by using any tricks (including virtualization).
- ✓ It is not so easy to identify whether the program is virtualized or not.
- ✓ Handlers, which are independent of one each other, usually set up:
  - ✓ registers
  - ✓ a encryption key
  - ✓ memory

- ✓ There is usually one handler by instruction type.
- ✓ These handlers are “started” by the VM dispatcher.
- ✓ Instructions’ operands are encrypted using keys (initializing code) provided by handlers.
- ✓ Sometimes, keys have 4 bytes and are xor’ed with operands. ☺
- ✓ Prologues and epilogues from each function could be not virtualized. Take care. ☺

- ✓ Have you tried to open the packer in IDA Pro? First sight: only red and grey blocks (non-functions and data).
- ✓ Eventually, data blocks could hold VM handlers...
- ✓ Original code section could be “splitted” and “scattered” around the program (data and instructions are mixed in the binary, without having just one instruction block)
- ✓ Instructions which are referencing import functions could have been either zeroed or replaced by NOP. ☹ Most certainly, they will be restored (re-inserted) dynamically by the packer later.
- ✓ The “hidden” function code could be copied (memcpy( )) to memory allocated by VirtualAlloc( ) ☺ Of course, there must be a fixup in the code to get these instructions.

- ✓ Custom packers usually don't virtualize all x86 instructions.
- ✓ It is common to see a kind of mix between virtualized, native instructions and data after the packing procedure.
- ✓ Native APIs could be redirected to stub code, which forwards the call to (copied) native DLLs (from the respective APIs).
- ✓ API call instructions, which would make direct references to the IAT, are usually translated to short jumps using RVA, for the same import address ("IAT obfuscation") ☺
- ✓ Worse, the API names could be hashed (as used in shellcodes). ☺

- ✓ By the way, how many virtualized instructions exist?
- ✓ Are we able to classify virtualized instructions in groups according to operands and their purpose (memory access, arithmetic, general, an so on)?
- ✓ Pay attention to instruction's stem to put similar classes of instructions together (for example, jump instructions, direct calls, indirect calls and so on).
- ✓ Are virtualized instructions based (similar) to x86 instructions?
- ✓ Have the processor flags's meaning been modified?

- ✓ What are the “key instructions” that are responsible to make the transition from x86 mode to “virtualized mode”?
- ✓ Remember: usually, registers and flags (EFLAGS) are saved onto the stack before “crossing over” to the VM environment.
- ✓ What are the responsible instructions to transfer the control back to the x86 world?
- ✓ Most of the time, during the “context transition”, parameters are pushed on the stack. ☺

- ✓ The VM interpreter code, which is responsible for translating x86 instructions to VM instructions, is usually obfuscated.
- ✓ The own VM instructions are also compressed and encrypted (xor'ed, mostly)
- ✓ As I've mentioned previously, usually there are many VM instruction codes to only one x86 instructions.
- ✓ There are two stacks: one from x86 land and another from VM land.
- ✓ Stack from virtualized context may grow upward, different from x86 standard.
- ✓ Sometimes, the protector doesn't copy the x86 context into the Virtual Machine. In this case, it prefers to save the context (registers content + flag) to use later.

- ✓ It is interesting to find out the VM instruction's size, which we might fit into a structure that represents encryption key, data, RVA (location), opcode (type) and so on.

- ✓ As custom virtualized packers don't have a virtualized instruction to every single x86 instruction, so it is recommended to find handlers to native x86 instructions (non-virtualized instruction)

- ✓ Usually, handlers to non-virtualized instructions exit from VM environment from a short period, execute the x86 instruction and return to the virtual machine environment.

- ✓ In this case, x86 instructions are also kept encrypted and compressed together with the virtualized instructions.

- ✓ Constant unfolding: technique used by obfuscators to replace a contant by a bunch of code that produces the same resulting constant's value.
- ✓ Pattern-based obfuscation: exchange of one instruction by a set of equivalent instructions.
- ✓ Abusing inline functions.
- ✓ Anti-VM techniques: prevents the malware sample to run inside a VM.
- ✓ Dead (garbage) code: this technique is implemented by inserting codes whose results will be overwritten in next lines of code or, worse, they won't be used anymore.
- ✓ Code duplication: different paths coming into the same destination (used by virtualization obfuscators).

- ✓ Control indirection 1: call instruction → stack pointer update → return skipping some junk code after the call instruction (RET x).
- ✓ Control indirection 2: malware trigger an exception → registered exception is called → new branch of instructions.
- ✓ Opaque predicate: Although apparently there is an evaluation (conditional jump: jz/jnz), the result is always evaluated to true (or false), which means an unconditional jump. Thus, there is a dead branch.
- ✓ Anti-debugging: used as irritating techniques to slow the process analysis.
- ✓ Polymorphism: it is produced by self-modification code (like shellcodes) and by encrypting resources (similar most malware samples).

- ✓ Call stack manipulation: Changes the stack flow by using instruction tricks composed with the ret instruction, making the real ret hidden.

- ✓ Is it possible to deobfuscate virtualized instructions? Yes, it is possible using reverse recursive substitution (similar -- not equal -- to backtracking feature from Metasm).

- ✓ Additionally, symbolic equation system is another good approach (again...., Metasm and MIASM!).

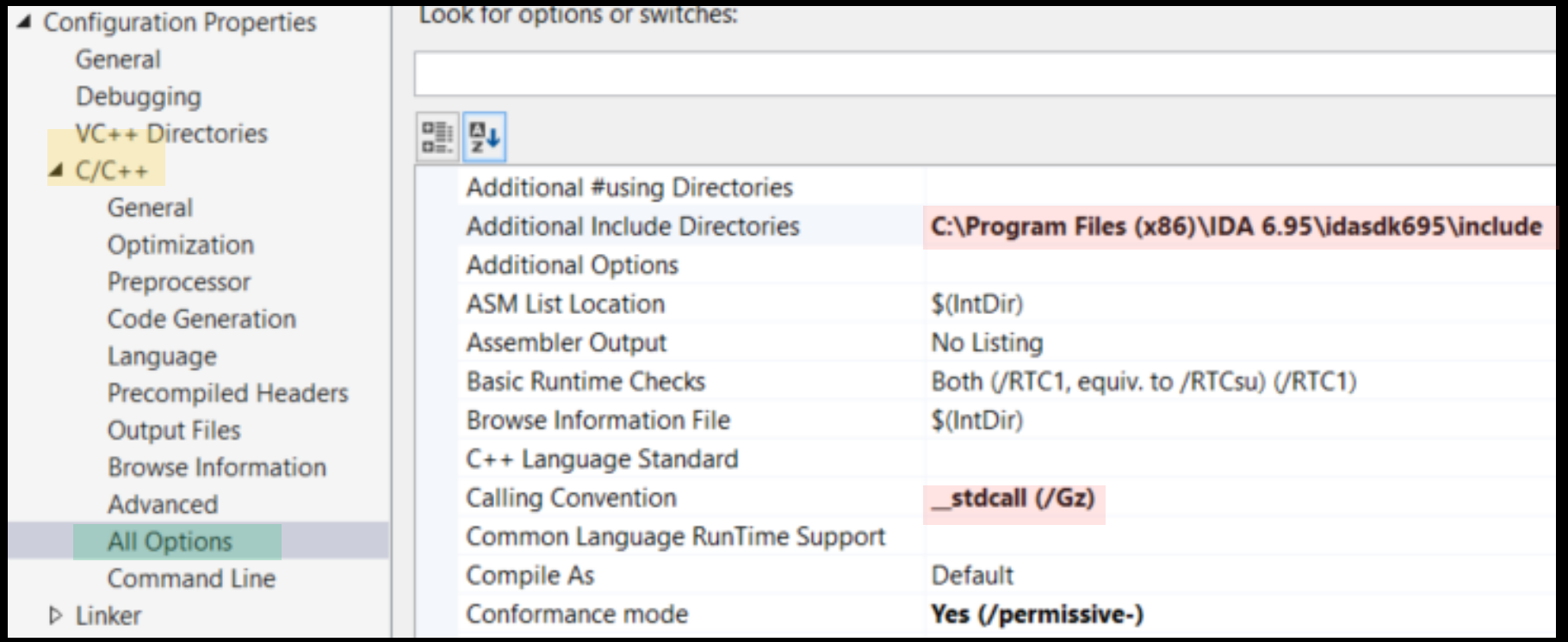
- ✓ There are many good plugins such as Code Unvirtualizer, VMAttack, VMSweeper, and so on, which could be used to handle simple virtualization problems.

- ✓ Some evolution of the instruction virtualizers has risen using simple and efficient concepts of crytpography as Substitution Boxes (S-Boxes).

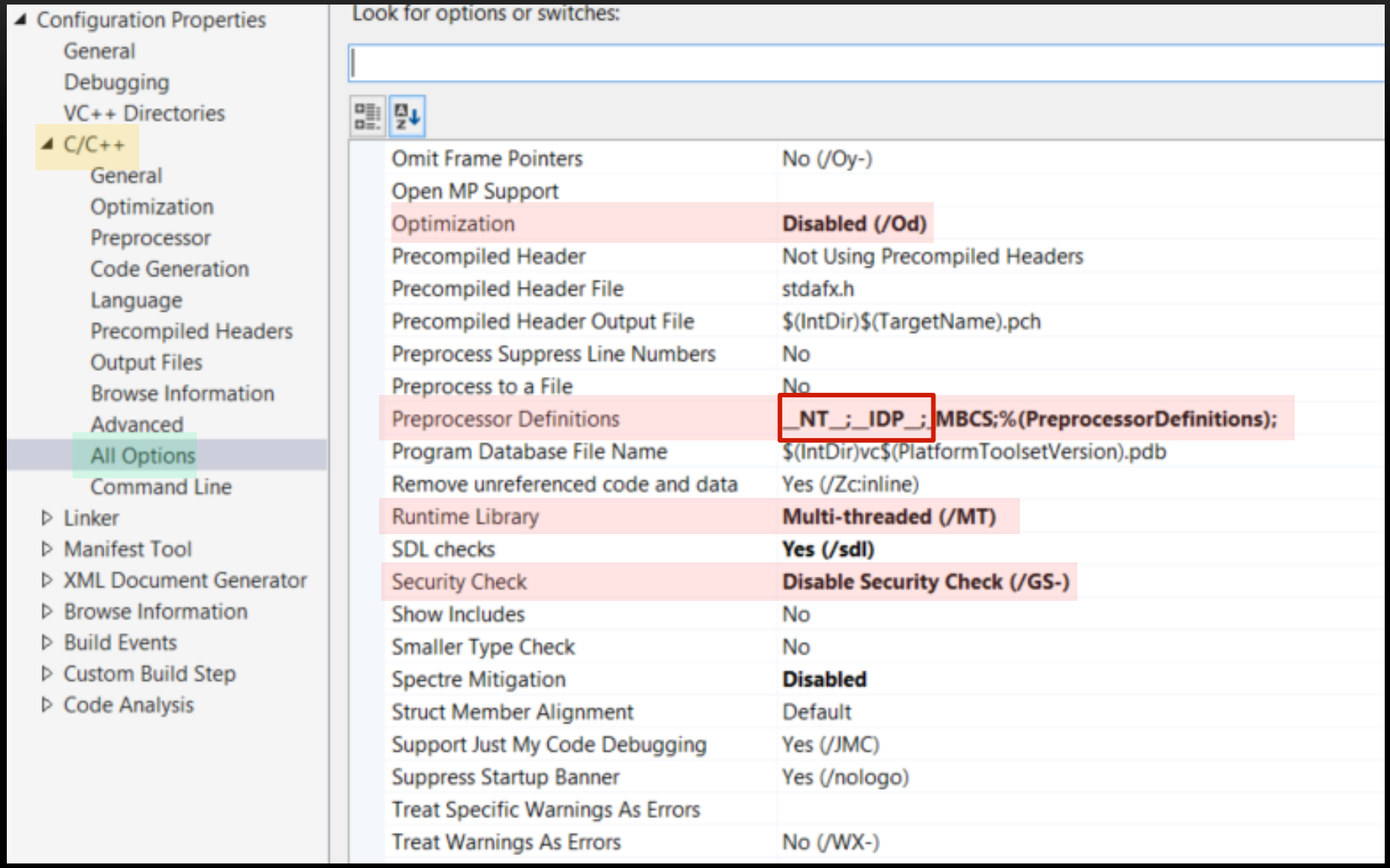
- ✓ It is quick to create a simple IDA Pro plugin. Download the IDA SDK from https://www.hex-rays.com/products/ida/support/download.shtml (likely, you will need a professional account). Copy it to a folder (idasdk695/) within the IDA Pro installation directory.

- ✓ Create a project in Visual Studio 2017 (File → New → Create Project → Visual C++ → Windows Desktop → Dynamic-Link Library (DLL)).

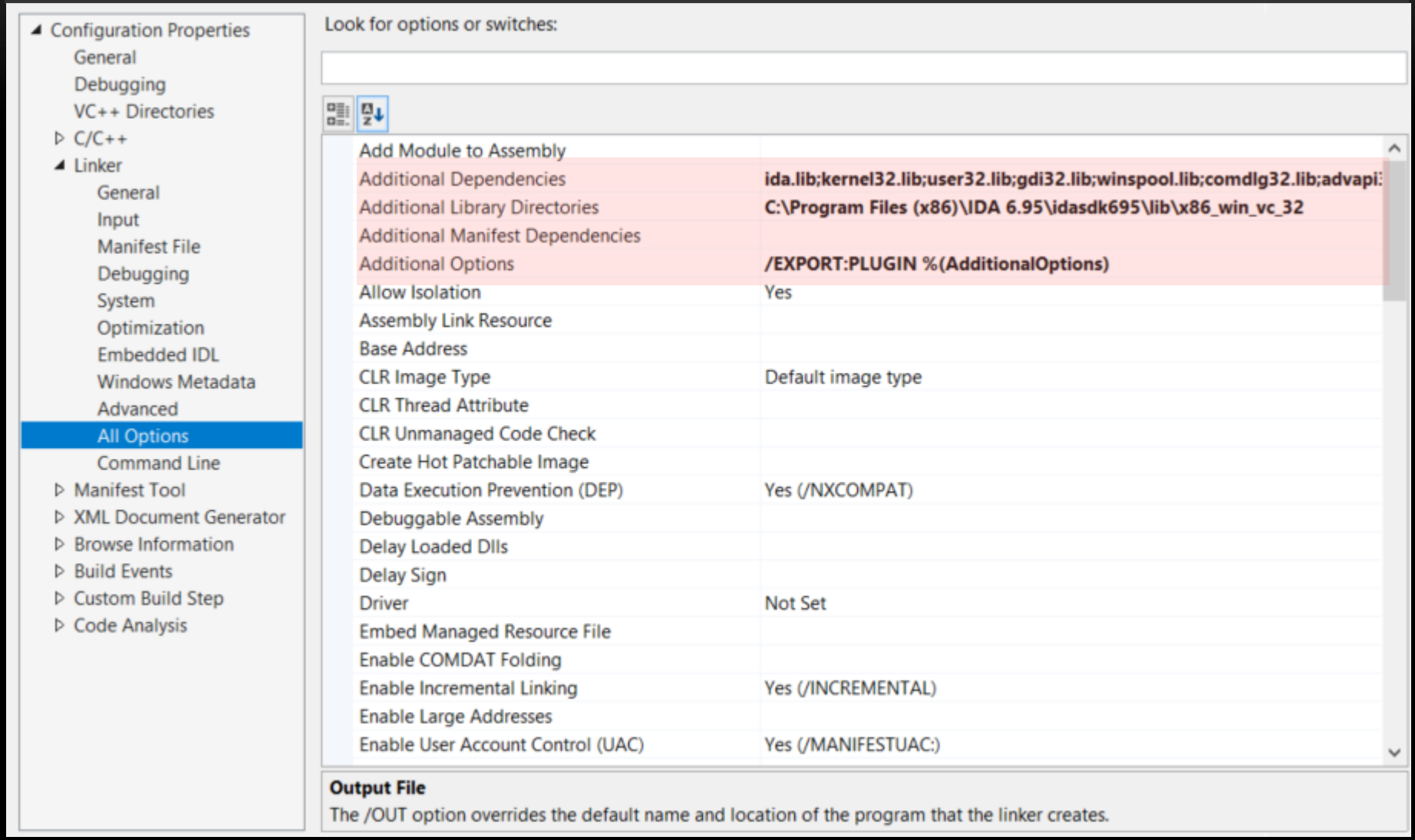
- ✓ Change few project properties as shown in this slide and next ones.



✓ Include the "__NT__;__IDP__" in Processor Definitions and change Runtime Library to "Multi-threaded" (MT) (take care: it is NOT /MTd).



- ✓ Add ida.lib (from C:\Program Files (x86)\IDA 6.95\idasdk695\lib\x86_win_vc_32) to Additional Dependencies and its folder to Additional Library Directories.
- ✓ Add "/EXPORT:PLUGIN" to Additional Options.



```
1   #include <ida.hpp>
2   #include <idp.hpp>
3   #include <loader.hpp>
4   #include <allins.hpp>
5   #include <strlist.hpp>
6   #include <search.hpp>
7
8
9   int IDAP_init()
10  {
11      return PLUGIN_KEEP;
12  }
13
14  void IDAP_term(void)
15  {
16
17  }
18
19  void IDAP_run(int arg)
20  {
21      msg("Hello DEFCON CHINA! We love IDA Pro :)\n\n");
22
23      char defcon[MAXSTR];
24      string_info_t strinfo;
25      char s[] = "[a-z0-9]+[\.]{1,}[a-zA-Z0-9_-]+[\.]{1,}[a-z]{2,}";
26      auto last = BADADDR;
27      auto ea = 0;
28      auto urlcount = 1;
```

Don't forget necessary headers. ☺

Initialization function.

Make the plugin available to this idb and keep the plugin loaded in memory.

Clean-up tasks.

Function to be called when user activates the plugin.

Simple (and incomplete) URL regex. ☺

```
30      for (int x = 0; x < get_strlist_qty(); x++) {
31
32          get_strlist_item(x, &strinfo);
33          if (strinfo.length < sizeof(defcon)) {
34
35              get_many_bytes(strinfo.ea, defcon, strinfo.length);
36
37              {
38                  ea = 0;
39                  ea = find_text(strinfo.ea, 0, 0, s, SEARCH_REGEX);
40
41                  if (ea == strinfo.ea) {
42                      msg("Address 0x%x - URL %d: %s\n", strinfo.ea, urlcount, defcon);
43                      urlcount++;
44                  }
45              }
46          }
47      }
48
49      return;
50
51  }
52
53  char IDAP_comment[] = "The simplest possible plugin";
54  char IDAP_help[] = "DEFCON plugin";
55  char IDAP_name[] = "DEFCON plugin";
56  char IDAP_hotkey[] = "ALT-X";
57
58  plugin_t PLUGIN =
59  {
60      IDP_INTERFACE_VERSION,
61      0,
62      IDAP_init,
63      IDAP_term,
64      IDAP_run,
65      IDAP_comment,
66      IDAP_help,
67      IDAP_name,
68      IDAP_hotkey
69  };
```

It gets the number of strings from "Strings view".

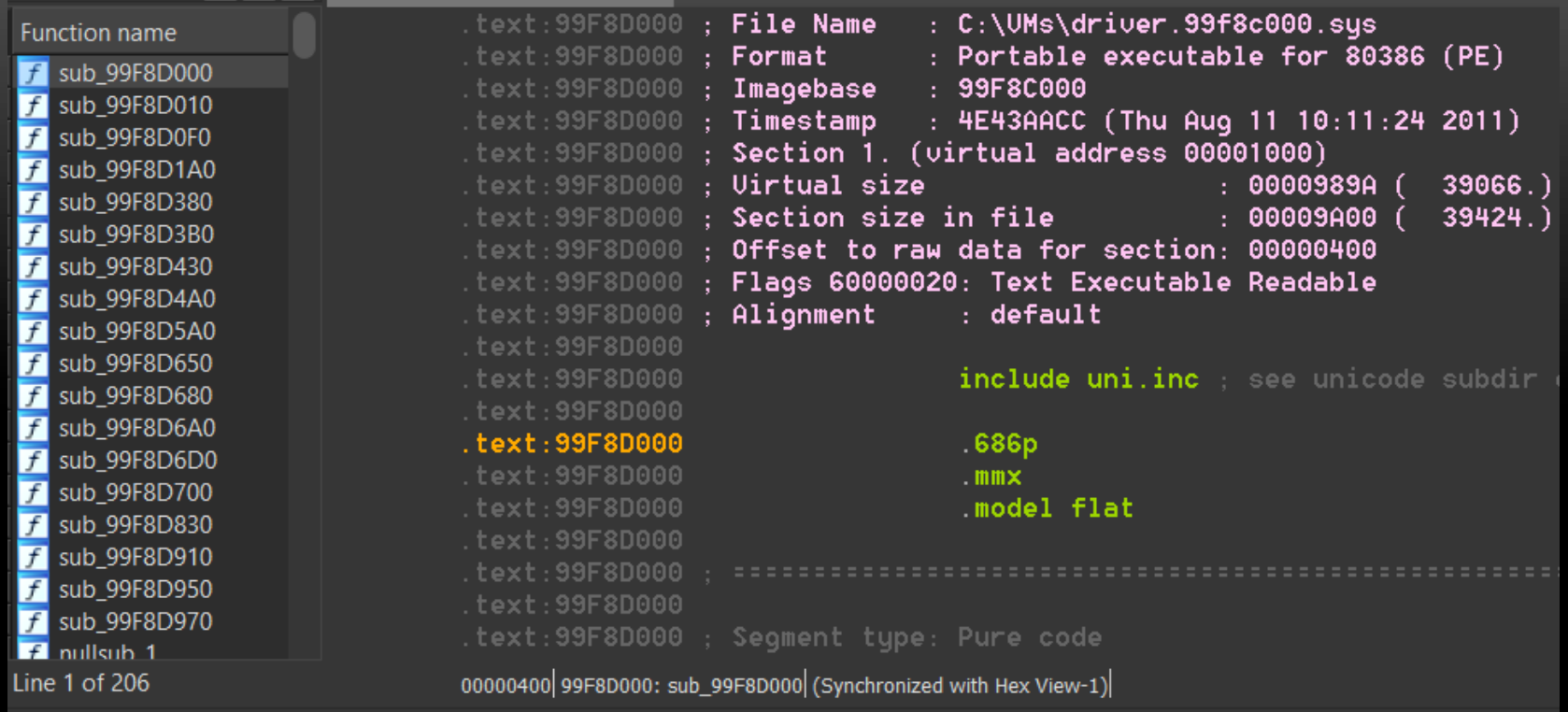
It gets the string.

The core logic is only it. It checks whether the string matches to the URL regex.

If checks, so ea == strinfo.ea. ☺

Plugin will be activated by combination ALT-X. ☺

Plugin structure.

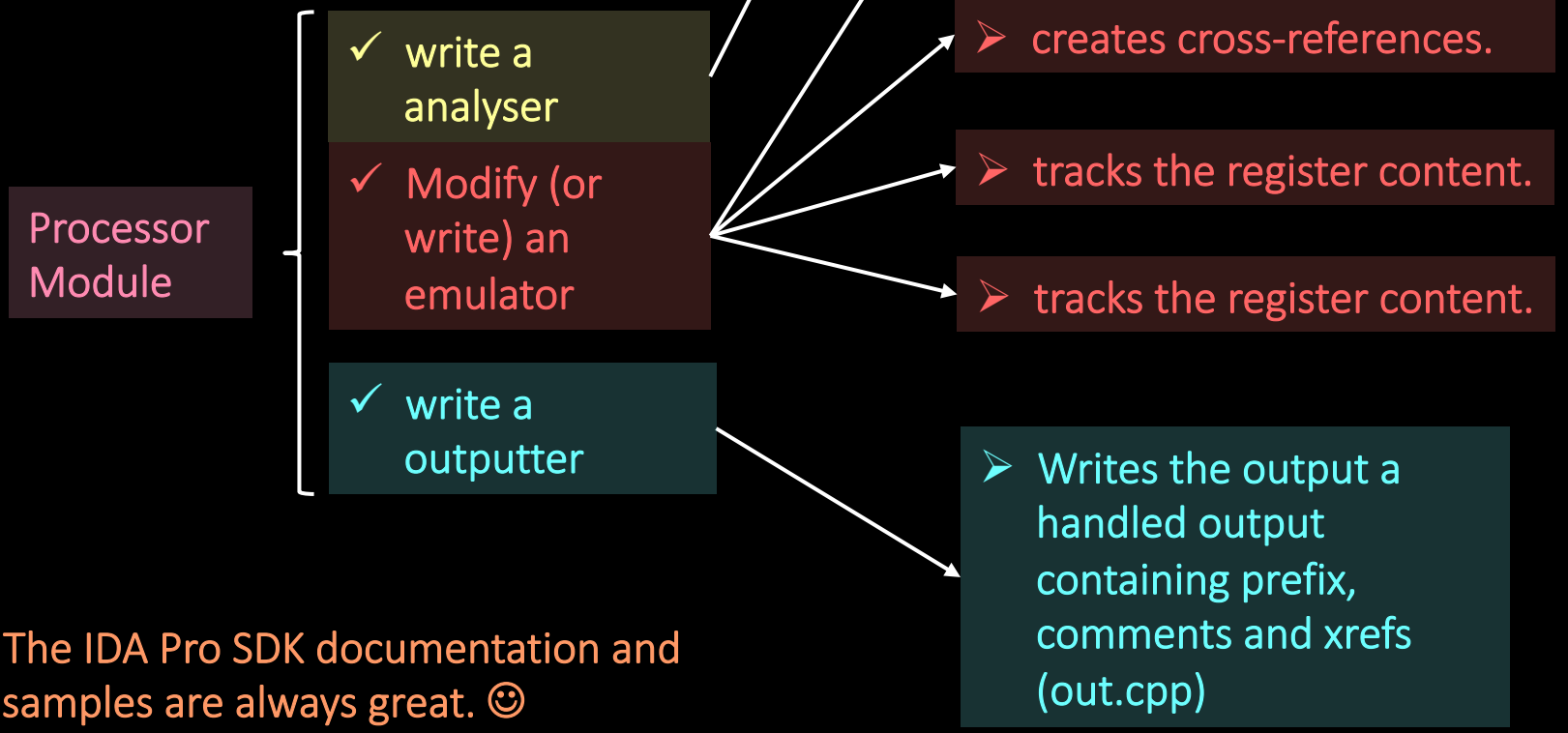



```
Hello DEFCON CHINA! We love IDA Pro :)

Address 0x99f990d8 - URL 1: ntp2.usno.navy.mil
Address 0x99f990eb - URL 2: ntp.adc.am
Address 0x99f990f6 - URL 3: tock.usask.ca
Address 0x99f99104 - URL 4: ntp.crifo.org
Address 0x99f99112 - URL 5: ntp1.arnes.si
Address 0x99f99120 - URL 6: ntp.ucsd.edu
Address 0x99f9912d - URL 7: ntp.duckcorp.org
Address 0x99f9913e - URL 8: www.nist.gov
Address 0x99f9914b - URL 9: clock.isc.org
Address 0x99f99159 - URL 10: time.windows.com
Address 0x99f9916a - URL 11: time2.one4vision.de
Address 0x99f9917e - URL 12: time.cerias.purdue.edu
Address 0x99f99195 - URL 13: clock.fihn.net
```

URLs found within this malicious driver.
☺

ALT + X

- ✓ IDA processor modules continue being the one of best approach to handle virtualized packers.
- ✓ Please, you should remember on few important points (as mentioned by Ilfak from Hex-Rays) about how to write an IDA processor modules:



- ✓ The IDA Pro SDK documentation and samples are always great. ☺

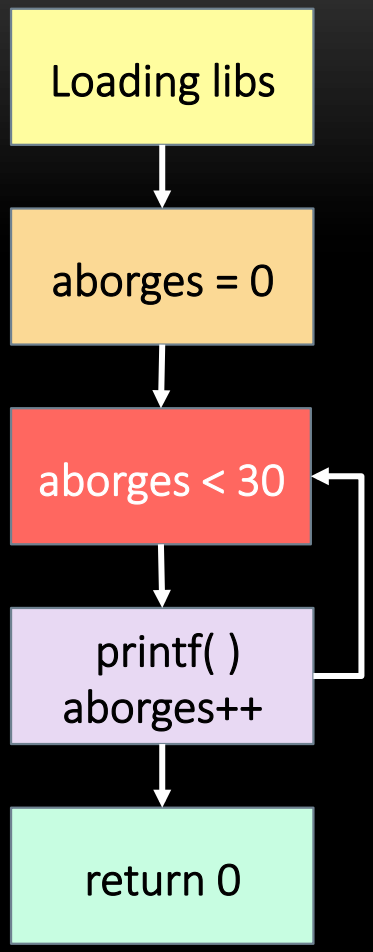
✓ Code-flow graph flattening:

- ✓ This technique is used to hide the real control flow of a program.
- ✓ In a general way, the idea is to break the control-flow by removing if-statements and loops, transforming the flow in a series of switch-case statements.

- ✓ Thus, there is a dispatcher handing over the control flow to handlers, which each handler updates the instruction pointer to the value of the next handler to be executed (virtualize the flow control).
- ✓ Usually there is an invocation stub, which makes the transition to from native instructions to the virtualized instruction.

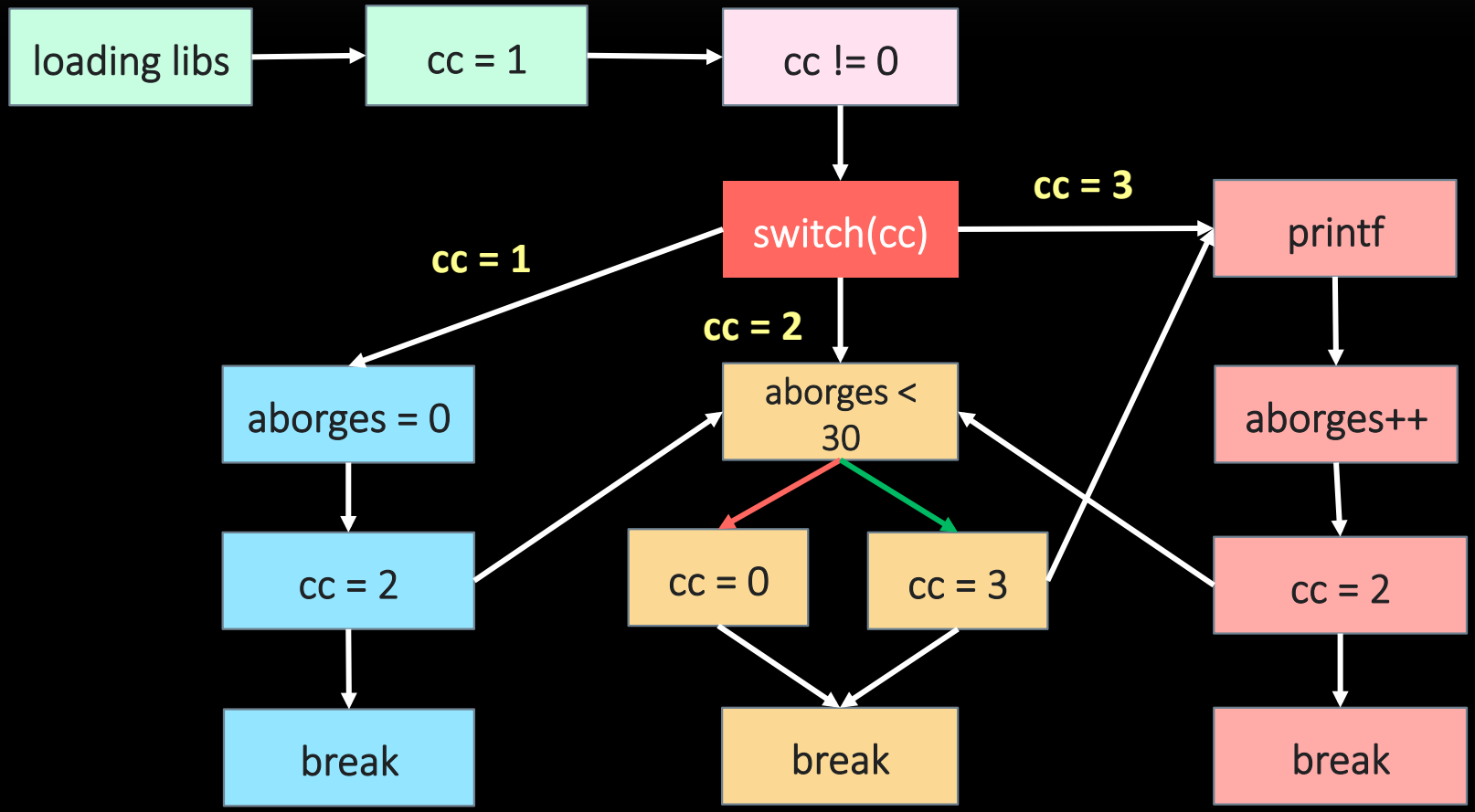
- ✓ This approach presents two reversing problems: the mapping can be from CISC to RISC instruction and the original registers can be turned into special registers from VM.
- ✓ Because trade-offs, CFG is only applied to specific functions

```
#include <stdio.h>

int main (void)

{
        int aborges = 0;
        while (aborges <  30)
        {
                printf("%d\n", aborges);
                aborges++;
        }

        return 0;

}
```

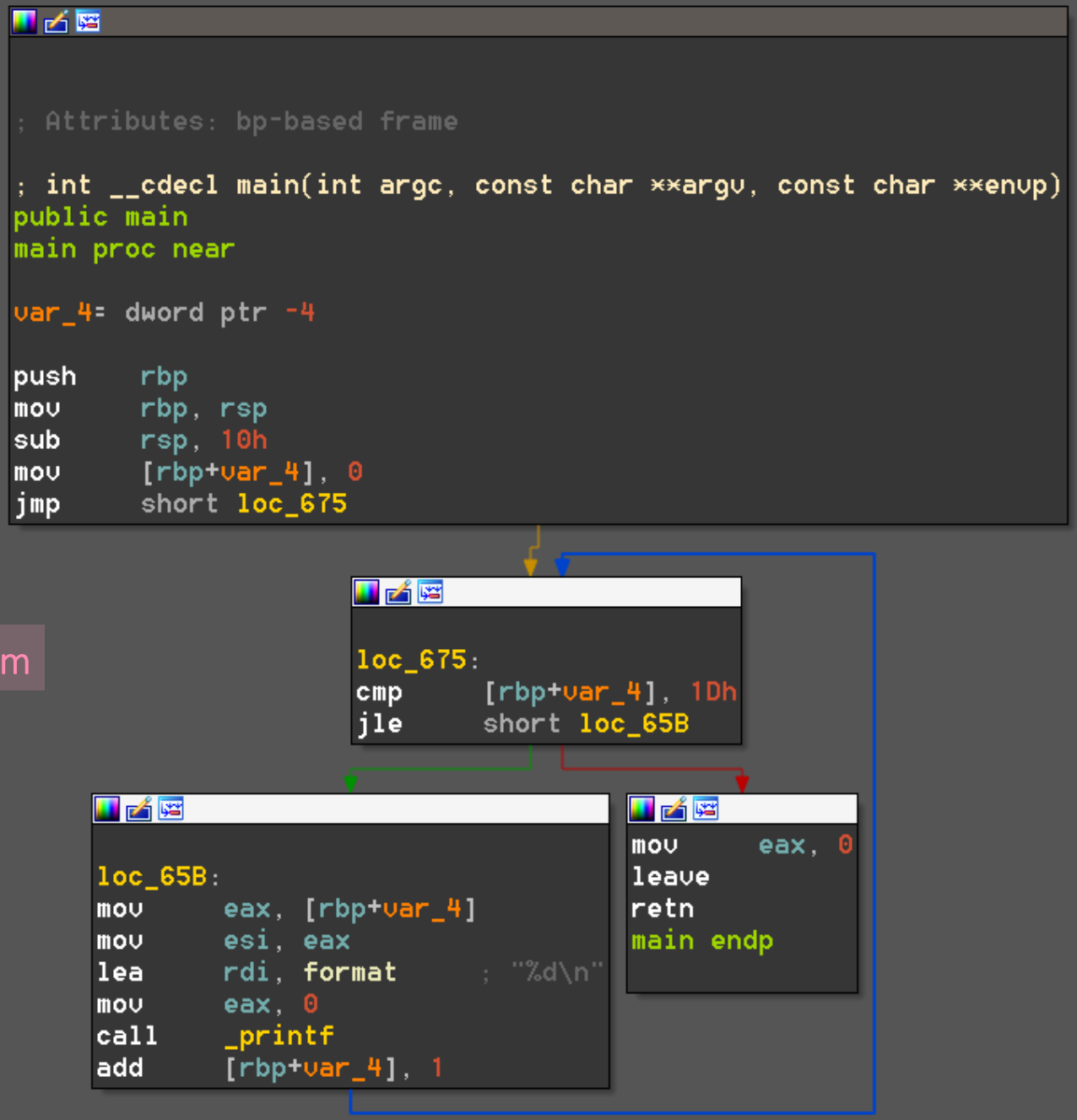


❖ Disavantages:

- ✓ Loss of performance
- ✓ Easy to identify the CFG flattening



Original Program



- ✓ The obfuscator-llvm is an excellent project to be used for code obsfuscation. To install it, it is recommended to add a swap file first (because the linkage stage):

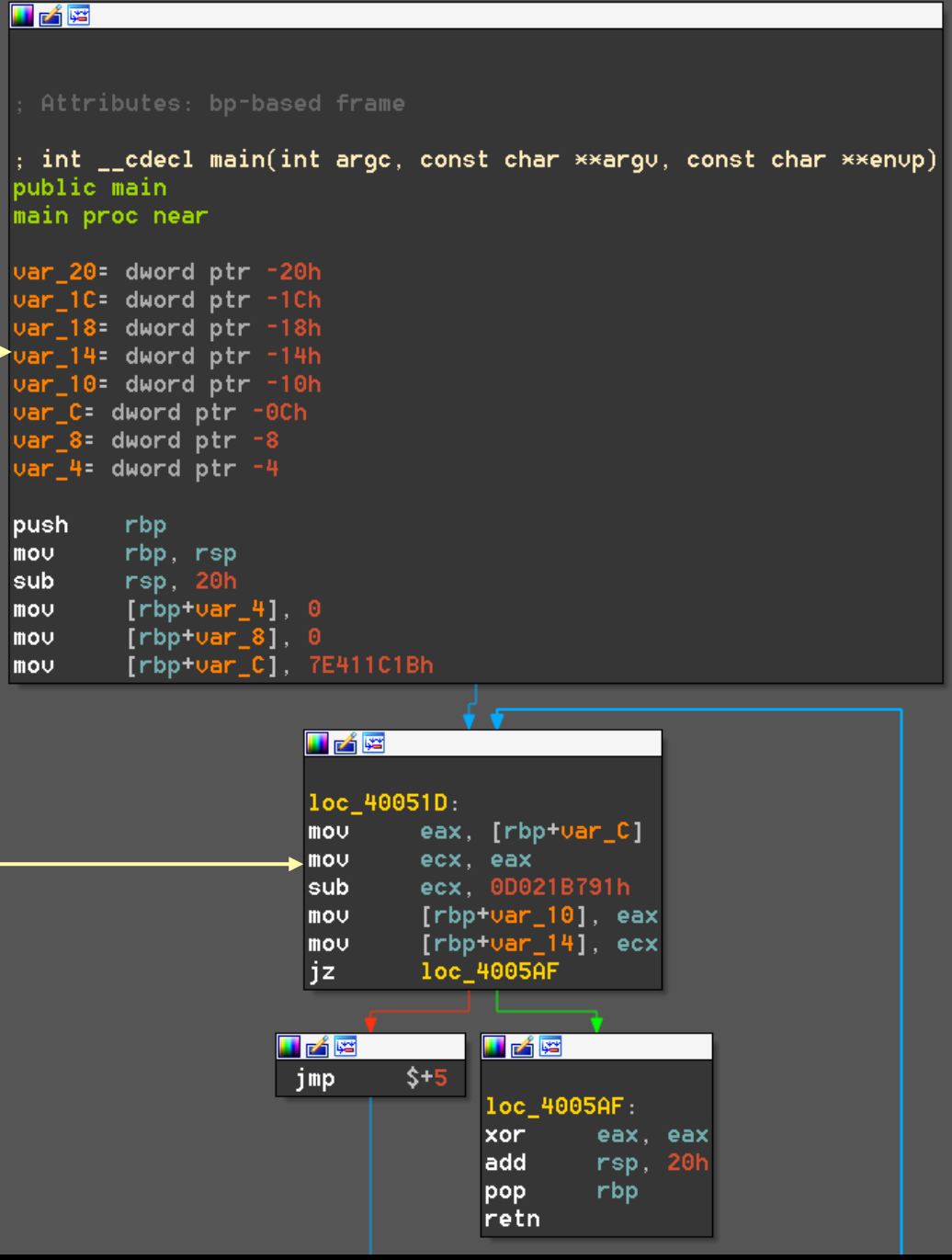
  - ✓ fallocate -l 8GB /swapfile
  - ✓ chmod 600 /swapfile
  - ✓ mkswap /swapfile
  - ✓ swapon /swapfile
  - ✓ swapon --show
  - ✓ apt-get install llvm-4.0
  - ✓ apt-get install gcc-multilib (install gcc lib support to 32 bit)
  - ✓ git clone -b llvm-4.0 https://github.com/obfuscator-llvm/obfuscator.git
  - ✓ mkdir build ; cd build/
  - ✓ cmake -DCMAKE_BUILD_TYPE=Release -DLLVM_INCLUDE_TESTS=OFF ../obfuscator/
  - ✓ make -j7

- ✓ Possible usages:

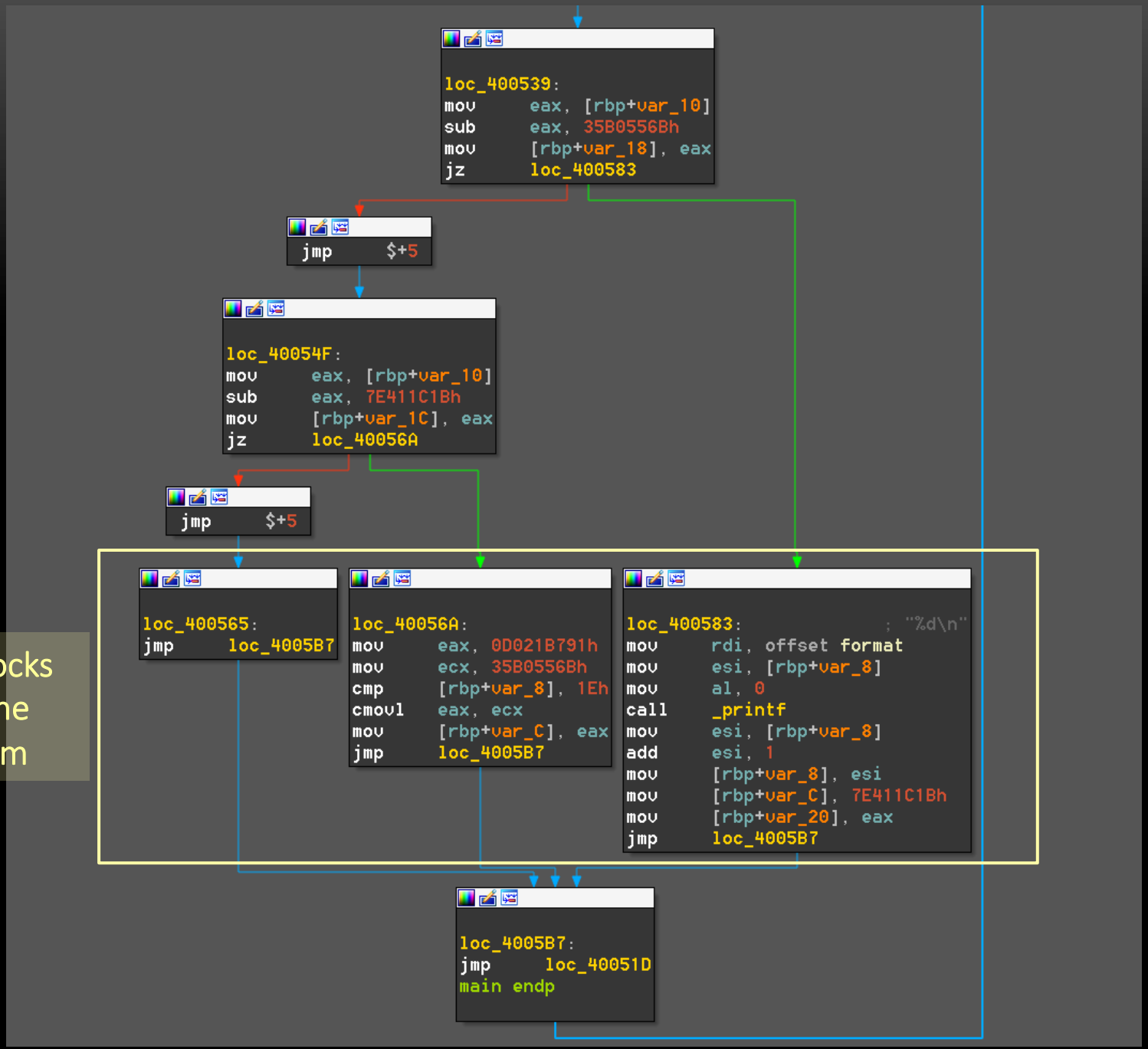
  - ✓ ./build/bin/clang alexborges.c -o alexborges -mllvm -fla
  - ✓ ./build/bin/clang alexborges.c -m32 -o alexborges -mllvm -fla
  - ✓ ./build/bin/clang alexborges.c -o alexborges -mllvm -fla -mllvm -sub

Prologue and initial assignment

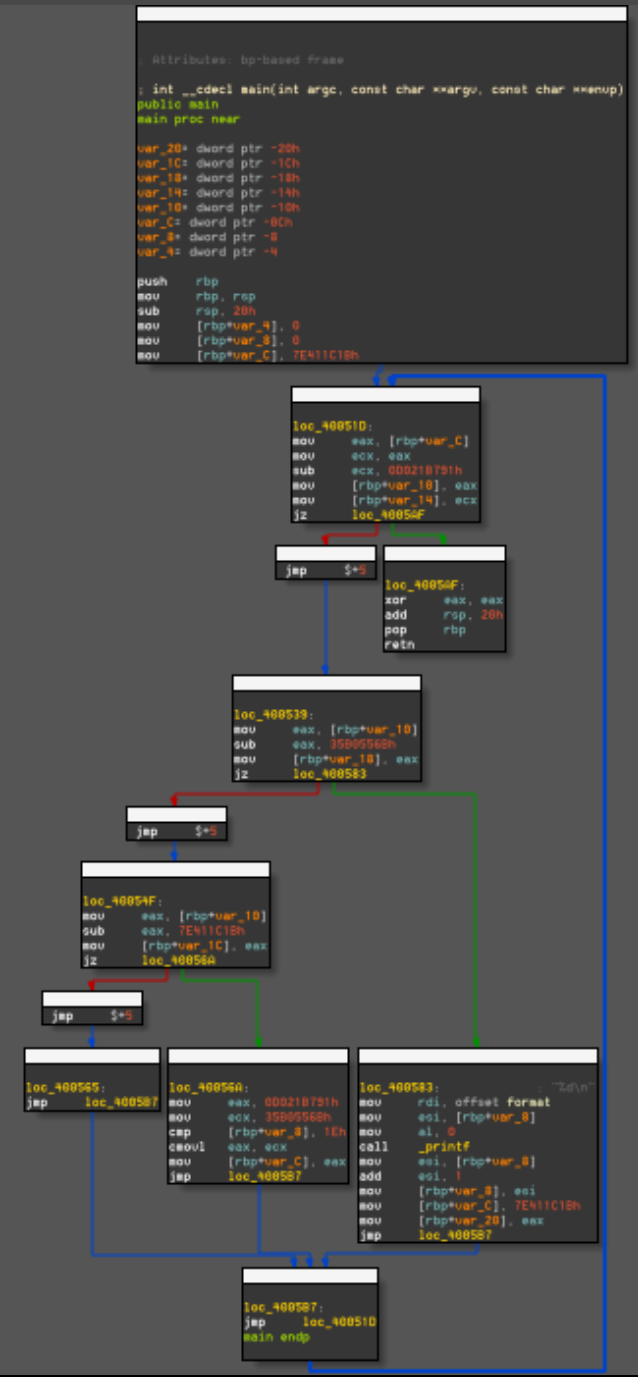
Main dispatcher



Main blocks from the program



General overview
of the obfuscate code



```
1 int __cdecl main(int argc, const char **argv, const char **envp)
2 {
3   signed int v3; // eax@5
4   int v4; // eax@8
5   __int64 v6; // [rsp+0h] [rbp-20h]@0
6   signed int v7; // [rsp+14h] [rbp-Ch]@1
7   signed int v8; // [rsp+18h] [rbp-8h]@1
8
9   v8 = 0;
10  v7 = 2118196251;
11  while ( v7 != -803096687 )
12  {
13    if ( v7 == 900748651 )
14    {
15      v4 = printf("%d\n", (unsigned int)v8++, envp, v6, 731796000415206604 8LL);
16      v7 = 2118196251;
17      LODWORD(v6) = v4;
18    }
19    else
20    {
21      HIDWORD(v6) = v7 - 2118196251;
22      if ( v7 == 2118196251 )
23      {
24        v3 = -803096687;
25        if ( v8 < 30 )
26          v3 = 900748651;
27        v7 = v3;
28      }
29    }
30  }
31  return 0;
32 }
```

Simple opaque predicate and anti-disassembly technique

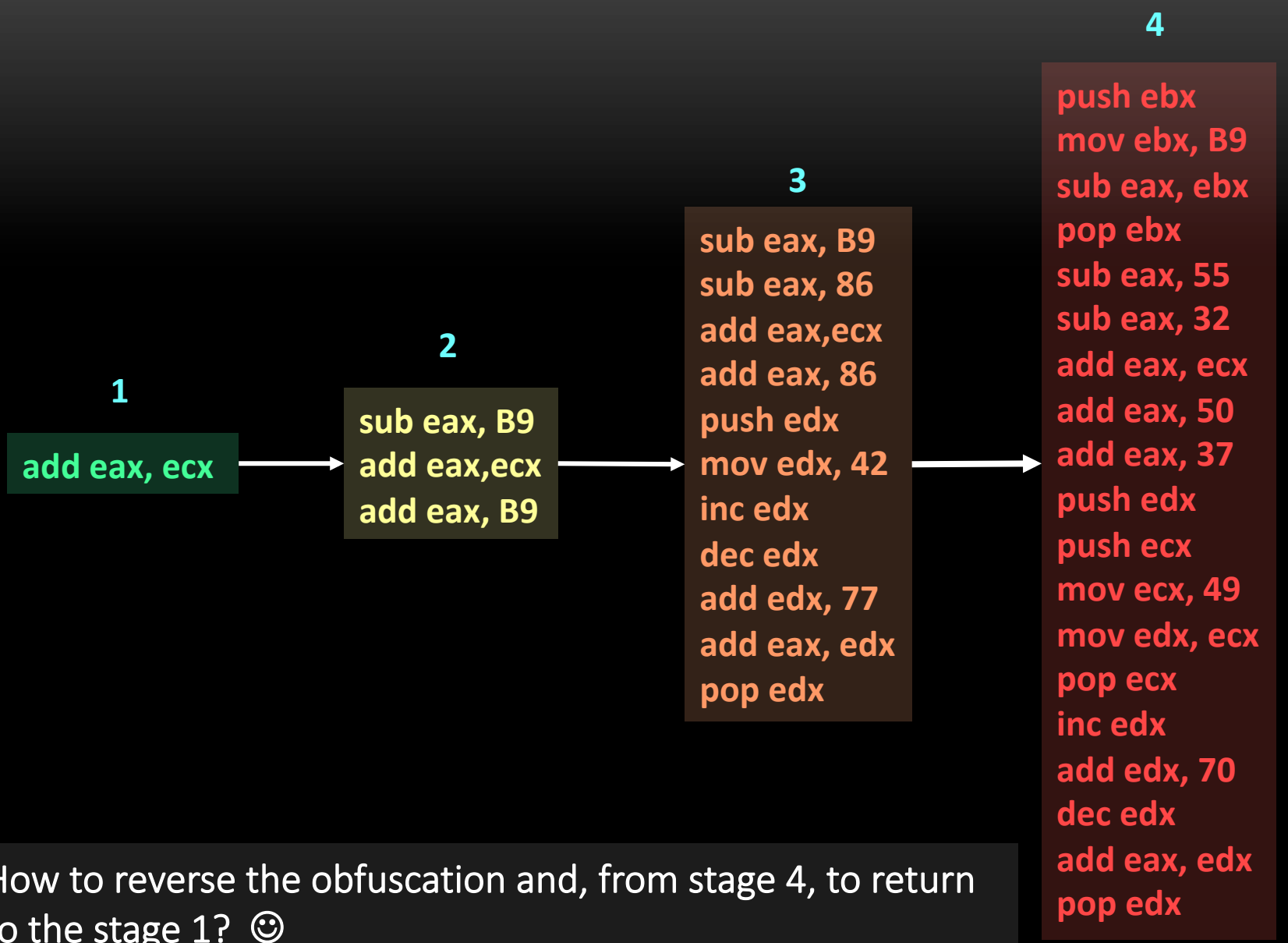
```
.text:00401000 loc_401000:                          ; CODE XREF: _main+Fp

.text:00401000                  push    ebp
.text:00401001                  mov     ebp, esp
.text:00401003                  xor     eax, eax
.text:00401005                  jz      short near ptr loc_40100D+1
.text:00401007                  jnz     near ptr loc_40100D+4

.text:0040100D
.text:0040100D loc_40100D:                          ; CODE XREF: .text:00401005j
.text:0040100D                                      ; .text:00401007j

.text:0040100D                  jmp     near ptr 0D0A8837h
```


seg000:0000020C loc_20C:
seg000:0000020C lodsb
seg000:0000020D mov dl, al
seg000:0000020F sub dl, 41h ; 'A'
seg000:00000212 shl dl, 4
seg000:00000215 lodsb
seg000:00000216 sub al, 41h ; 'A'
seg000:00000218 add al, dl
seg000:0000021A stosb
seg000:0000021B dec ecx
seg000:0000021C jnz short loc_20C
seg000:0000021E retn
seg000:0000021E sub_208 endp
seg000:0000021F ; ----------
seg000:0000021F loc_21F:
seg000:0000021F call sub_208
seg000:00000224 mov ebp, esp
seg000:00000226 sub esp, 40h
seg000:0000022C jmp loc_364
seg000:00000231 ; =============== S U B R O U T I N E ===============
seg000:00000231 sub_231 proc near
seg000:00000231 arg_0 = dword ptr 4
seg000:00000231 push esi
seg000:00000232 push edi
seg000:00000233 mov esi, [esp+8+arg_0]
seg000:00000237 xor edi, edi
seg000:00000239 cld
seg000:0000023A loc_23A:
seg000:0000023A xor eax, eax
seg000:0000023C lodsb
seg000:0000023D cmp al, ah
seg000:0000023F jz short loc_24B
seg000:00000241 ror edi, 0Dh
seg000:00000244 add edi, eax
seg000:00000246 jmp loc_23A
seg000:0000024B ; ----------
seg000:0000024B loc_24B:
seg000:0000024B mov eax, edi
seg000:0000024D pop edi
seg000:0000024E pop esi
Decryption instructions ☺
Decrypted shellcode

```
00401040    call + $5
00401045    pop ecx
00401046    inc ecx
00401047    inc ecx
00401048    add ecx, 4
00401049    add ecx, 4
0040104A    push ecx
0040104B    ret
0040104C    sub ecx, 6
0040104D    dec ecx
0040104E    dec ecx
0040104F    jmp 0x401320
```

- Call stack manipulation:
  - ✓ Do you know what's happening here? ☺

METASM
(keystone + capstone + unicorn)



How to reverse the obfuscation and, from stage 4, to return to the stage 1? ☺

- ✓ METASM works as disassembler, assembler, debugger, compiler and linker.

- ✓ Key features:

  - ✓ Written in Ruby
  - ✓ C compiler and decompiler
  - ✓ Automatic backtracking
  - ✓ Live process manipulation
  - ✓ Supports the following architecture:

    - ✓ Intel IA32 (16/32/64 bits)
    - ✓ PPC
    - ✓ MIPS

  - ✓ Supports the following file format:

    - ✓ MZ and PE/COFF
    - ✓ ELF
    - ✓ Mach-O
    - ✓ Raw (shellcode)

- ✓ root@kali:~/programs# git clone https://github.com/jjyg/metasm.git
- ✓ root@kali:~/programs# cd metasm/
- ✓ root@kali:~/programs/metasm# make
- ✓ root@kali:~/programs/metasm# make all

✓Include the following line into .bashrc file to indicate the Metasm directory installation:

✓export RUBYLIB=$RUBYLIB:~/programs/metasm

```
#!/usr/bin/env ruby
#

require "metasm"
include Metasm

mycode = Metasm::Shellcode.assemble(Metasm::Ia32.new, <<EOB)

entry:
        push ebx
        mov ebx, 0xb9
        sub eax, ebx
        pop ebx
        sub eax, 0x55
        sub eax, 0x32
        add eax, ecx
        add eax, 0x50
        add eax, 0x37
        push edx
        push ecx
        mov ecx, 0x49
        mov edx, ecx
        pop ecx
        inc edx
        add edx, 0x70
        dec edx
        add eax, edx
        pop edx
        jmp eax

EOB
```

- based on metasm.rb file and Bruce Dang code.

This instruction was inserted to make the eax register evaluation easier. ☺

```
addrstart = 0
asmcode = mycode.init_disassembler
asmcode.disassemble(addrstart)
defcon_di = asmcode.di_at(addrstart)
defcon = defcon_di.block
puts "\n<!!!> DEF CON China 1.0:\n "
puts defcon.list


defcon.list.each{|aborges|
        puts "\n<!!!> #{aborges.instruction}"
        back = aborges.backtrace_binding()
        v = back.values
        k = back.keys
        j = k.zip(v)
        puts "DEF CON China data flow follows below:\n"
        j.each do |mykeys, myvalues|

            puts " Processing: #{mykeys} ==> #{myvalues}"

            if aborges.opcode.props[:setip]
              puts "\nDEF CON China control flow follows below:\n"
              puts " >>> #{asmcode.get_xrefs_x(aborges)}"
            end
        end
}

addrstart2 = 0
asmcode2 = mycode.init_disassembler
asmcode2.disassemble(addrstart2)
```

initialize and disassemble code since beginning (start).

list the assembly code.

initialize the backtracking engine.

determines which is the final instruction to walk back from there. ☺

```
dd = asmcode2.block_at(addrstart2)
final = asmcode2.get_xrefs_x(dd.list.last).first
puts "\n[+] final output: #{final}"

values = asmcode2.backtrace(final, dd.list.last.address, {:log => backtracing_log = [] ,
 :include_start => true})
backtracing_log.each{|record|
        case type = record.first
        when :start
                record, expression, addresses = record
                puts "[start] Here is the sequence of expression evaluations  #{expressi
on} from 0x#{addresses.to_s(16)}\n"

        when :di
                record, new, old, instruction = record
                puts "[new update] instruction #{instruction},\n --> updating expression
 once again from #{old} to #{new}\n"

        end
}

effective = backtracing_log.select{|y| y.first==:di}.map{|y| y[3]}.reverse
puts "\nThe effective instructions are:\n\n"
puts effective
```

Backtracking from the last instruction.

logs the sequence of backtracked instructions

Show only the effective instructions, which really can alter the final result.

```
root@kali:~/programs/metasm# ./defcon.rb

<!!!> DEF CON China 1.0:

0 push ebx
1 mov ebx, 0b9h
6 sub eax, ebx
8 pop ebx
9 sub eax, 55h
0ch sub eax, 32h
0fh add eax, ecx
11h add eax, 50h
14h add eax, 37h
17h push edx
18h push ecx
19h mov ecx, 49h
1eh mov edx, ecx
20h pop ecx
21h inc edx
22h add edx, 70h
25h dec edx
26h add eax, edx
28h pop edx
29h jmp eax

<!!!> push ebx
DEF CON China data flow follows below:
 Processing: esp ==> esp-4
 Processing: dword ptr [esp] ==> ebx

<!!!> mov ebx, 0b9h
DEF CON China data flow follows below:
 Processing: ebx ==> 0b9h
```

Remember: this is our obfuscated code. ☺

```
<!!!> sub eax, ebx
DEF CON China data flow follows below:
 Processing: eax ==> eax-ebx
 Processing: eflag_z ==> (((eax&0ffffffffh)-(ebx&0ffffffffh))&0ffffffffh)==0
 Processing: eflag_s ==> ((((eax&0ffffffffh)-(ebx&0ffffffffh))&0ffffffffh)>>1fh)!=0
 Processing: eflag_c ==> (eax&0ffffffffh)<(ebx&0ffffffffh)
 Processing: eflag_o ==> ((((eax&0ffffffffh)>>1fh)!=0)==(!(((ebx&0ffffffffh)>>1fh)!=0)))
&&((((eax&0ffffffffh)>>1fh)!=0)!=(((((eax&0ffffffffh)-(ebx&0ffffffffh))&0ffffffffh)>>1fh
)!=0))

<!!!> pop ebx
DEF CON China data flow follows below:
 Processing: esp ==> esp+4
 Processing: ebx ==> dword ptr [esp]

<!!!> sub eax, 55h
DEF CON China data flow follows below:
 Processing: eax ==> eax-55h
 Processing: eflag_z ==> (((eax&0ffffffffh)-((55h)&0ffffffffh))&0ffffffffh)==0
 Processing: eflag_s ==> ((((eax&0ffffffffh)-((55h)&0ffffffffh))&0ffffffffh)>>1fh)!=0
 Processing: eflag_c ==> (eax&0ffffffffh)<((55h)&0ffffffffh)
 Processing: eflag_o ==> ((((eax&0ffffffffh)>>1fh)!=0)==(!(((55h)&0ffffffffh)>>1fh)!=0)
))&&((((eax&0ffffffffh)>>1fh)!=0)!=(((((eax&0ffffffffh)-((55h)&0ffffffffh))&0ffffffffh)>
>1fh)!=0))

<!!!> sub eax, 32h
DEF CON China data flow follows below:
 Processing: eax ==> eax-32h
 Processing: eflag_z ==> (((eax&0ffffffffh)-((32h)&0ffffffffh))&0ffffffffh)==0
 Processing: eflag_s ==> ((((eax&0ffffffffh)-((32h)&0ffffffffh))&0ffffffffh)>>1fh)!=0
 Processing: eflag_c ==> (eax&0ffffffffh)<((32h)&0ffffffffh)
 Processing: eflag_o ==> ((((eax&0ffffffffh)>>1fh)!=0)==(!(((32h)&0ffffffffh)>>1fh)!=0)
))&&((((eax&0ffffffffh)>>1fh)!=0)!=(((((eax&0ffffffffh)-((32h)&0ffffffffh))&0ffffffffh)>
>1fh)!=0))
```

```
[+] final output: eax
[start] Here is the sequence of expression evaluations  eax from 0x29
[new update] instruction 26h add eax, edx,
 --> updating expression once again from eax to eax+edx
[new update] instruction 25h dec edx,
 --> updating expression once again from eax+edx to eax+edx-1
[new update] instruction 22h add edx, 70h,
 --> updating expression once again from eax+edx-1 to eax+edx+6fh
[new update] instruction 21h inc edx,
 --> updating expression once again from eax+edx+6fh to eax+edx+70h
[new update] instruction 1eh mov edx, ecx,
 --> updating expression once again from eax+edx+70h to eax+ecx+70h
[new update] instruction 19h mov ecx, 49h,
 --> updating expression once again from eax+ecx+70h to eax+0b9h
[new update] instruction 14h add eax, 37h,
 --> updating expression once again from eax+0b9h to eax+0f0h
[new update] instruction 11h add eax, 50h,
 --> updating expression once again from eax+0f0h to eax+140h
[new update] instruction 0fh add eax, ecx,
 --> updating expression once again from eax+140h to eax+ecx+140h
[new update] instruction 0ch sub eax, 32h,
 --> updating expression once again from eax+ecx+140h to eax+ecx+10eh
[new update] instruction 9 sub eax, 55h,
 --> updating expression once again from eax+ecx+10eh to eax+ecx+0b9h
[new update] instruction 6 sub eax, ebx,
 --> updating expression once again from eax+ecx+0b9h to eax-ebx+ecx+0b9h
[new update] instruction 1 mov ebx, 0b9h,
 --> updating expression once again from eax-ebx+ecx+0b9h to eax+ecx
```

Game over. ☺

The effective instructions are:

```
1 mov ebx, 0b9h
6 sub eax, ebx
9 sub eax, 55h
0ch sub eax, 32h
0fh add eax, ecx
11h add eax, 50h
14h add eax, 37h
19h mov ecx, 49h
1eh mov edx, ecx
21h inc edx
22h add edx, 70h
25h dec edx
26h add eax, edx
```


Output originated from backtracing_log.select command (in reverse)

ALEXANDRE BORGES – MALWARE AND SECURITY RESEARCHER

- ✓ Emulation is always an excellent method to solve practical reverse engineering problems and , fortunately, we have the uEmu and also could use the Keystone Engine assembler and Capstone Engine disassembler. ☺

- ✓ Keystone Engine acts an assembler and:

  - ✓ Supports x86, Mips, Arm and many other architectures.
  - ✓ It is implemented in C/C++ and has bindings to Python, Ruby, Powershell and C# (among other languages).

- ✓ Installing Keystone:

  - ✓ root@kali:~/Desktop# wget https://github.com/keystone-engine/keystone/archive/0.9.1.tar.gz
  - ✓ root@kali:~/programs# cp /root/Desktop/keystone-0.9.1.tar.gz .
  - ✓ root@kali:~/programs# tar -zxvf keystone-0.9.1.tar.gz
  - ✓ root@kali:~/programs/keystone-0.9.1# apt-get install cmake
  - ✓ root@kali:~/programs/keystone-0.9.1# mkdir build ; cd build
  - ✓ root@kali:~/programs/keystone-0.9.1/build# apt-get install time
  - ✓ root@kali:~/programs/keystone-0.9.1/build# ../make-share.sh
  - ✓ root@kali:~/programs/keystone-0.9.1/build# make install
  - ✓ root@kali:~/programs/keystone-0.9.1/build# ldconfig
  - ✓ root@kali:~/programs/keystone-0.9.1/build# tail -3 /root/.bashrc
  - ✓ export PATH=$PATH:/root/programs/phantomjs-2.1.1-linux-x86_64/bin:/usr/local/bin/kstool
  - ✓ export RUBYLIB=$RUBYLIB:~/programs/metasm
  - ✓ export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:/usr/local/lib

```c
#include <stdio.h>
#include <keystone/keystone.h>

#define DEFCON "push ebx; mov ebx, 0xb9; sub eax, ebx; pop ebx; sub eax, 0x55; sub eax,
 0x32; add eax, ecx; add eax, 0x50; add eax, 0x37; push edx; push ecx; mov ecx, 0x49; m
ov edx, ecx; pop ecx; inc edx; add edx, 0x70; dec edx; add eax, edx; pop edx"

int main(int argc, char **argv)
{
    ks_engine *keyeng;
    ks_err keyerr = KS_ERR_ARCH;
    size_t count;
    unsigned char *encode;
    size_t size;

    keyerr = ks_open(KS_ARCH_X86, KS_MODE_32, &keyeng);
    if (keyerr != KS_ERR_OK) {
        printf("ERROR: A fail occurred while calling ks_open(), quit\n");
        return -1;
    }

    if (ks_asm(keyeng, DEFCON, 0, &encode, &size, &count)) {
        printf("ERROR: A fail has occured while calling ks_asm() with count = %lu, erro
r code = %u\n", count, ks_errno(keyeng));
    } else {
        size_t i;

        for (i = 0; i < size; i++) {
            printf("%02x ", encode[i]);
        }

    }

    ks_free(encode);
    ks_close(keyeng);

    return 0;
}
```

instructions from the original obsfuscated code

Creating a keystone engine

Assembling our instructions using keystone engine.

Freeing memory and closing engine.

```
root@kali:~/programs/defcon#
root@kali:~/programs/defcon# more Makefile
.PHONY: all clean

KEYSTONE_LDFLAGS = -lkeystone -lstdc++ -lm

all:
	${CC} -o defcon2019 defcon2019.c ${KEYSTONE_LDFLAGS}

clean:
	rm -rf *.o defcon2019
root@kali:~/programs/defcon#
root@kali:~/programs/defcon# make
cc -o defcon2019 defcon2019.c -lkeystone -lstdc++ -lm
root@kali:~/programs/defcon#
root@kali:~/programs/defcon# ./defcon2019
53 bb b9 00 00 00 29 d8 5b 83 e8 55 83 e8 32 01 c8 83 c0 50 83 c0 37 52 51 b9 49
00 00 00 89 ca 59 42 83 c2 70 4a 01 d0 5a root@kali:~/programs/defcon#
root@kali:~/programs/defcon#
root@kali:~/programs/defcon# ./defcon2019 | xxd -r -p - > defcon2019.bin
root@kali:~/programs/defcon#
root@kali:~/programs/defcon# hexdump -C defcon2019.bin
00000000  53 bb b9 00 00 00 29 d8  5b 83 e8 55 83 e8 32 01  |S.....).[..U..2.|
00000010  c8 83 c0 50 83 c0 37 52  51 b9 49 00 00 00 89 ca  |...P..7RQ.I.....|
00000020  59 42 83 c2 70 4a 01 d0  5a                       |YB..pJ..Z|
00000029
root@kali:~/programs/defcon# _
```

```c
#include <stdio.h>
#include <inttypes.h>
#include <capstone/capstone.h>

#define CODE "\x53\xbb\xb9\x00\x00\x00\x29\xd8\x5b\x83\xe8\x55\x83\xe8\x32\x01\xc
8\x83\xc0\x50\x83\xc0\x37\x52\x51\xb9\x49\x00\x00\x00\x89\xca\x59\x42\x83\xc2\x70
\x4a\x01\xd0\x5a"

int main(void)
{
        csh cs_handle;
        cs_insn *instruction;
        size_t count;

        if (cs_open(CS_ARCH_X86, CS_MODE_32, &cs_handle) != CS_ERR_OK)
                return -1;
        count = cs_disasm(cs_handle, CODE, sizeof(CODE)-1, 0x0001, 0, &instructio
n);
        if (count > 0) {
                size_t j;
                for (j = 0; j < count; j++) {
                        printf("0x%"PRIx32":\t%s\t\t%s\n", instruction[j].address
, instruction[j].mnemonic, instruction[j].op_str);
                }

                cs_free(instruction, count);
        } else
                printf("Error: It's happened an error during the disassembling!\n
");

        cs_close(&cs_handle);

    return 0;
}
```

To install Capstone: apt-get install libcapstone3 libcapstone-dev ☺

ALEXANDRE BORGES – MALWARE AND SECURITY RESEARCHER

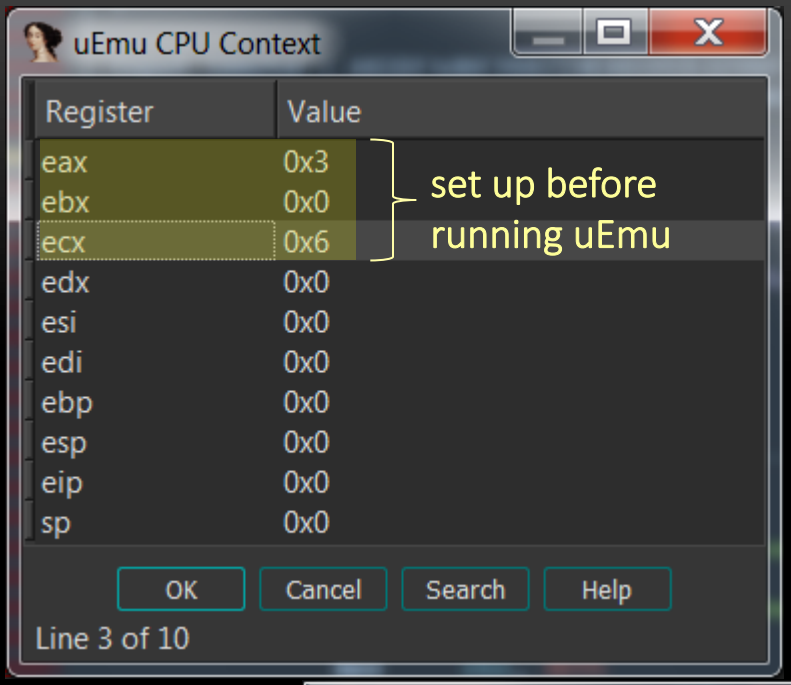
```
root@kali:~/programs/defcon/capstone# more Makefile
.PHONY: all clean

CAPSTONE_LDFLAGS = -lcapstone -lstdc++ -lm

all:
        ${CC} -o defcon2019_rev defcon2019_rev.c ${CAPSTONE_LDFLAGS}

clean:
        rm -rf *.o defcon2019_rev
root@kali:~/programs/defcon/capstone#
root@kali:~/programs/defcon/capstone# make
cc -o defcon2019_rev defcon2019_rev.c -lcapstone -lstdc++ -lm
root@kali:~/programs/defcon/capstone#
root@kali:~/programs/defcon/capstone# ./defcon2019_rev
0x1:    push            ebx
0x2:    mov             ebx, 0xb9
0x7:    sub             eax, ebx
0x9:    pop             ebx
0xa:    sub             eax, 0x55
0xd:    sub             eax, 0x32
0x10:   add             eax, ecx
0x12:   add             eax, 0x50
0x15:   add             eax, 0x37
0x18:   push            edx
0x19:   push            ecx
0x1a:   mov             ecx, 0x49
0x1f:   mov             edx, ecx
0x21:   pop             ecx
0x22:   inc             edx
0x23:   add             edx, 0x70
0x26:   dec             edx
0x27:   add             eax, edx
0x29:   pop             edx
root@kali:~/programs/defcon/capstone# _
```

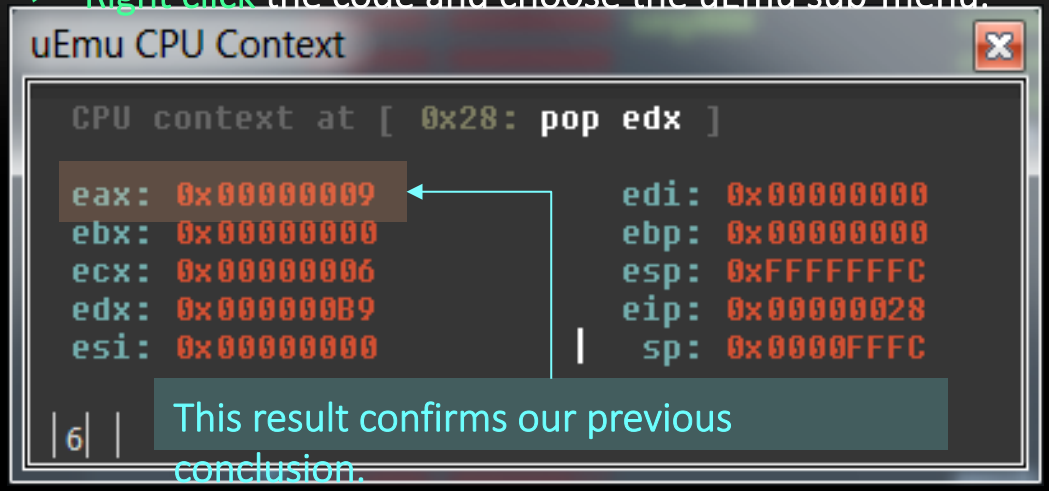
Original code disassembled by Capstone. ☺

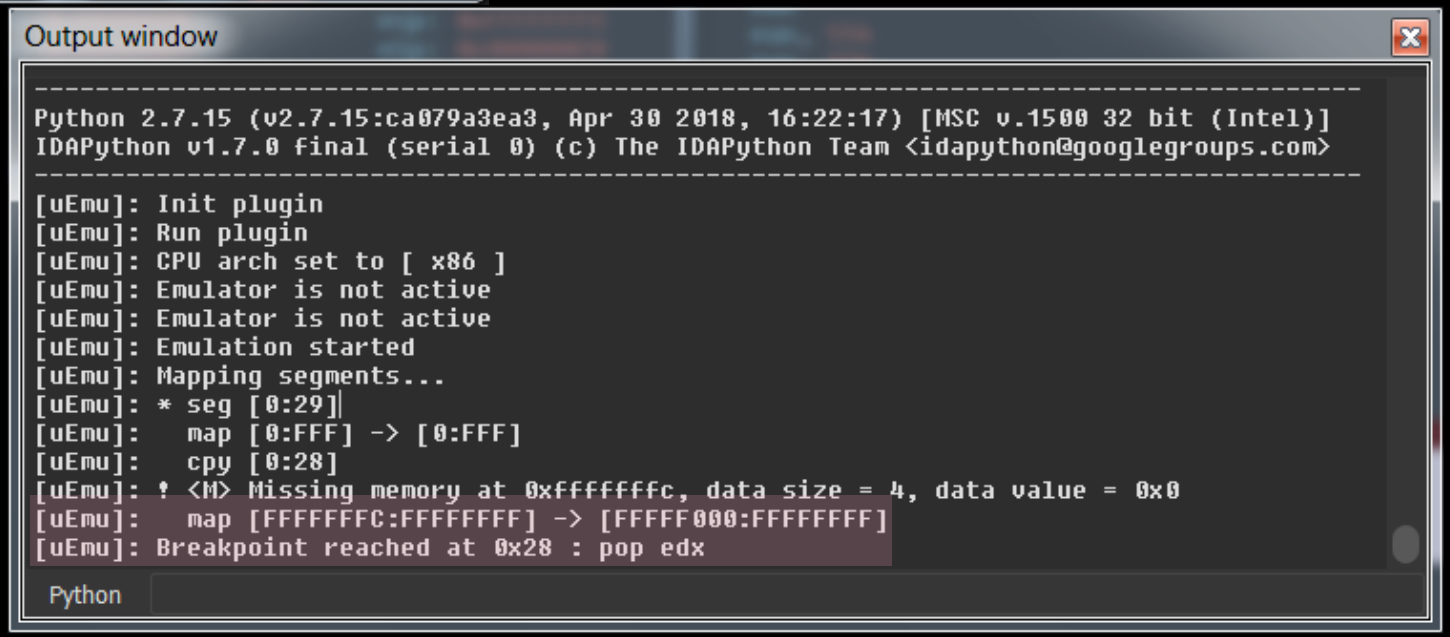
```
seg000:00000000 ; File Name   : C:\VMs\defcon2019.bin
seg000:00000000 ; Format      : Binary file
seg000:00000000 ; Base Address: 0000h Range: 0000h - 0029h Loaded length: 0029h
seg000:00000000
seg000:00000000                 .686p
seg000:00000000                 .mmx
seg000:00000000                 .model flat
seg000:00000000
seg000:00000000 ; ===========================================================
seg000:00000000
seg000:00000000 ; Segment type: Pure code
seg000:00000000 seg000          segment byte public 'CODE' use32
seg000:00000000                 assume cs:seg000
seg000:00000000                 assume es:nothing, ss:nothing, ds:nothing, fs:nothing,
seg000:00000000                 push    ebx
seg000:00000001                 mov     ebx, 0B9h
seg000:00000006                 sub     eax, ebx
seg000:00000008                 pop     ebx
seg000:00000009                 sub     eax, 55h
seg000:0000000C                 sub     eax, 32h
seg000:0000000F                 add     eax, ecx
seg000:00000011                 add     eax, 50h
seg000:00000014                 add     eax, 37h
seg000:00000017                 push    edx
seg000:00000018                 push    ecx
seg000:00000019                 mov     ecx, 49h
seg000:0000001E                 mov     edx, ecx
seg000:00000020                 pop     ecx
seg000:00000021                 inc     edx
seg000:00000022                 add     edx, 70h
seg000:00000025                 dec     edx
seg000:00000026                 add     eax, edx
seg000:00000028                 pop     edx
seg000:00000028 seg000          ends
```

IDA Pro confirms our disassembly task. ☺

- ✓ Download uEmu from https://github.com/alexhude/uEmu
- ✓ Install Unicorn: pip install unicorn.
- ✓ Load uEmu in IDA using ALT+F7 hot key.
- ✓ Right click the code and choose the uEmu sub-menu.







- ✓ # git clone https://github.com/unicorn-engine/unicorn.git
- ✓ # cd unicorn ; ./make.sh
- ✓ # ./make.sh install

```
1  #include <unicorn/unicorn.h>
2  #include <string.h>
3
4  // Our code to be emulated.
5
6  #define DEFCON_CODE "\x53\xbb\xb9\x00\x00\x00\x29\xd8\x5b\x83\xe8\x55\x83\xe8\x32
   \x01\xc8\x83\xc0\x50\x83\xc0\x37\x52\x51\xb9\x49\x00\x00\x00\x89\xca\x59\x42\x83\
   xc2\x70\x4a\x01\xd0\x5a"
7
8  // Emulation start address and a simple macro.
9
10 #define ADDR 0x1000000
11 #define MIN(x, y) (x < y? x : y)
12
13 // Hook the instruction execution.
14
15 static void hook_code(uc_engine *uc, uint64_t address, uint32_t size, void *user_
   data)
16 {
17         int r_eip;
18         int r_eax;
19         int r_ebx;
20         int r_ecx;
21         int r_edx;
22
23         uint8_t instr_size[16];
24
```

```
25          printf("\nTracing instruction at 0x%x , instruction size = 0x%x\n", addre
    ss, size);
26
27          uc_reg_read(uc, UC_X86_REG_EIP, &r_eip);
28          uc_reg_read(uc, UC_X86_REG_EAX, &r_eax);
29          uc_reg_read(uc, UC_X86_REG_EBX, &r_ebx);
30          uc_reg_read(uc, UC_X86_REG_ECX, &r_ecx);
31          uc_reg_read(uc, UC_X86_REG_EDX, &r_edx);
32
33  // Print the initial values of registries.
34
35          printf("\n>> EIP=0x%x ", r_eip);
36          printf(" | EAX=0x%x ", r_eax);
37          printf(" | EBX=0x%x ", r_ebx);
38          printf(" | ECX=0x%x ", r_ecx);
39          printf(" | EDX=0x%x ", r_edx);
40          printf("\n>> Executed hex code: ");
41
42          size = MIN(sizeof(instr_size), size);
43          if (!uc_mem_read(uc, address, instr_size, size)) {
44                  uint32_t i;
45                  for (i=0; i<size; i++) {
46                          printf("%x ", instr_size[i]);
47                  }
48                  printf("\n");
49          }
50  }
51
52  int main(int argc, char **argv, char **envp)
53  {
54
```

```
55 // Declare and initialize few variables
56
57         uc_engine *uc;
58         uc_hook traceinstr;
59         uc_err err;
60
61 // Set up the initial registry values.
62 // We have to set up the ESP register for emulating PUSH/POP instructions.
63
64         int r_eax = 0x4;
65         int r_ebx = 0x0;
66         int r_ecx = 0x7;
67         int r_edx = 0x0;
68         int r_esp = ADDR + 200000;
69
70         printf("\nInitial register values: \n");
71
72         printf("\n>> EAX = %x ", r_eax);
73         printf("\n>> EBX = %x ", r_ebx);
74         printf("\n>> ECX = %x ", r_ecx);
75         printf("\n>> EDX = %x ", r_edx);
76
77         printf("\n\nOur emulated code is: \n");
78
79
80 // We are emulating a 32-bit application in x86 emulator, so initialize the emula
   tor in X86-32bit mode :)
81 // If we wished to emulate in a x64 emulator, so we would use UC_MODE_64.
82
83         err = uc_open(UC_ARCH_X86, UC_MODE_32, &uc);
84         if (err != UC_ERR_OK) {
85                 printf("A fail to use uc_open() has occured and the error returne
   d is: %u\n", err);
86                 return -1;
87         }
```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```
88
89 // We are reserving 4MB memory for this emulation. Additionally, UC_PROT_ALL mean
   s: RWX.
90
91         uc_mem_map(uc, ADDR, 4 * 1024 * 1024, UC_PROT_ALL);
92
93 // write machine code to be emulated to memory
94
95         if (uc_mem_write(uc, ADDR, DEFCON_CODE, sizeof(DEFCON_CODE) - 1)) {
96                 printf("It has happened a fail during the write emulation code to
    memory!\n");
97                 return -1;
98 }
99
100 // We need to initialize the machine registers
101
102         uc_reg_write(uc, UC_X86_REG_EAX, &r_eax);
103         uc_reg_write(uc, UC_X86_REG_EBX, &r_ebx);
104         uc_reg_write(uc, UC_X86_REG_ECX, &r_ecx);
105         uc_reg_write(uc, UC_X86_REG_EDX, &r_edx);
106         uc_reg_write(uc, UC_X86_REG_ESP, &r_esp);
107
108 // uc: hook handle ; traceinstr: reference to uc_hook ; UC_HOOK_CODE: hook type ;
    hook_code: callback function
109
110         uc_hook_add(uc, &traceinstr, UC_HOOK_CODE, hook_code, NULL, 1, 0);
111
112
```

```
112
113 // Start the emulation engine and emulate code in infinite time (first zero
     below) & unlimited instructions (second zero below).
114
115         err=uc_emu_start(uc, ADDR, ADDR + sizeof(DEFCON_CODE) - 1, 0, 0);
116         if (err) {
117
118                 printf("The uc_emu_start() function has failed with error r
    eturning %u: %s\n", err, uc_strerror(err));
119
120 }
121
122 // Finally, print out the final registers values.
123
124         printf("\nThe final CPU registers contain the following content: \n
    \n");
125
126         uc_reg_read(uc, UC_X86_REG_EAX, &r_eax);
127         uc_reg_read(uc, UC_X86_REG_EBX, &r_ebx);
128         uc_reg_read(uc, UC_X86_REG_ECX, &r_ecx);
129         uc_reg_read(uc, UC_X86_REG_EDX, &r_edx);
130         printf(">>> EAX = 0x%x", r_eax);
131         printf("\n>>> EBX = 0x%x", r_ebx);
132         printf("\n>>> ECX = 0x%x", r_ecx);
133         printf("\n>>> EDX = 0x%x\n\n", r_edx);
134
135         uc_close(uc);
136
137         return 0;
138 }
```

```
root@kali:~/programs/defcon/unicorn# ./unicorn_defcon

Initial register values:

>> EAX = 4
>> EBX = 0
>> ECX = 7
>> EDX = 0

Our emulated code is:

Tracing instruction at 0x1000000 , instruction size = 0x1

>> EIP=0x1000000  | EAX=0x4  | EBX=0x0  | ECX=0x7  | EDX=0x0
>> Executed hex code: 53

Tracing instruction at 0x1000001 , instruction size = 0x5

>> EIP=0x1000001  | EAX=0x4  | EBX=0x0  | ECX=0x7  | EDX=0x0
>> Executed hex code: bb b9 0 0 0

Tracing instruction at 0x1000006 , instruction size = 0x2

>> EIP=0x1000006  | EAX=0x4  | EBX=0xb9  | ECX=0x7  | EDX=0x0
>> Executed hex code: 29 d8

Tracing instruction at 0x1000008 , instruction size = 0x1

>> EIP=0x1000008  | EAX=0xffffff4b  | EBX=0xb9  | ECX=0x7  | EDX=0x0
>> Executed hex code: 5b
```

```
Tracing instruction at 0x1000021 , instruction size = 0x1

>> EIP=0x1000021  | EAX=0xffffff52  | EBX=0x0  | ECX=0x7  | EDX=0x49
>> Executed hex code: 42

Tracing instruction at 0x1000022 , instruction size = 0x3

>> EIP=0x1000022  | EAX=0xffffff52  | EBX=0x0  | ECX=0x7  | EDX=0x4a
>> Executed hex code: 83 c2 70

Tracing instruction at 0x1000025 , instruction size = 0x1

>> EIP=0x1000025  | EAX=0xffffff52  | EBX=0x0  | ECX=0x7  | EDX=0xba
>> Executed hex code: 4a

Tracing instruction at 0x1000026 , instruction size = 0x2

>> EIP=0x1000026  | EAX=0xffffff52  | EBX=0x0  | ECX=0x7  | EDX=0xb9
>> Executed hex code: 1 d0

Tracing instruction at 0x1000028 , instruction size = 0x1

>> EIP=0x1000028  | EAX=0xb  | EBX=0x0  | ECX=0x7  | EDX=0xb9
>> Executed hex code: 5a

The final CPU registers contain the following content:

>>> EAX = 0xb
>>> EBX = 0x0
>>> ECX = 0x7
>>> EDX = 0x0
```

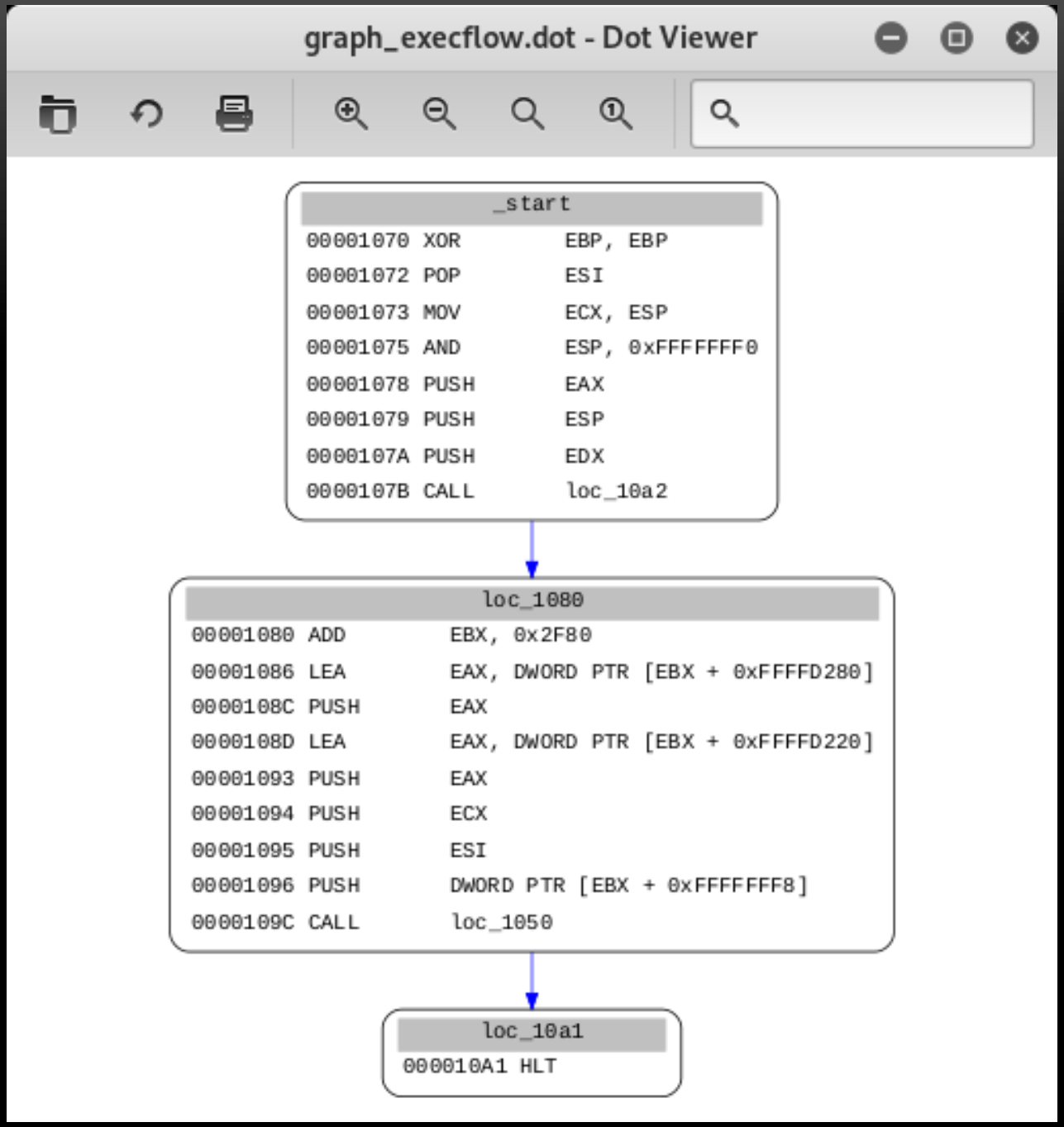
MIASM

- ✓ MIASM is one of most impressive framework for reverse engineering, which is able to analyze, generate and modify several different types of programs.
- ✓ MIASM supports assembling and disassembling programs from different platforms such as ARM, x86, MIPS and so on, and it also is able to emulate by using JIT.
- ✓ Therefore, MIASM is excellent to de-obfuscation.
- ✓ Installing MIASM:
  - ✓ git clone https://github.com/serpilliere/elfesteem.git elfesteem
  - ✓ cd elfesteem/
  - ✓ python setup.py build
  - ✓ python setup.py install
  - ✓ apt-get install clang texinfo texi2html
  - ✓ apt-get remove libtcc-dev
  - ✓ apt-get install llvm
  - ✓ cd ..
  - ✓ git clone http://repo.or.cz/tinycc.git
  - ✓ cd tinycc/
  - ✓ git checkout release_0_9_26
  - ✓ ./configure --disable-static
  - ✓ make
  - ✓ make install

- ✓ pip install llvmlite
- ✓ apt-get install z3
- ✓ apt-get install python-pycparser
- ✓ git clone https://github.com/cea-sec/miasm.git
- ✓ root@kali:~/programs/miasm# python setup.py build
- ✓ root@kali:~/programs/miasm# python setup.py install
- ✓ root@kali:~/programs/miasm/test# python test_all.py
- ✓ apt-get install graphviz
- ✓ apt-get install xdot
- ✓ (testing MIASM) root@kali:~/programs# python /root/programs/miasm/example/disasm/full.py -m x86_32 /root/programs/shellcode

```
INFO : Load binary
INFO : ok
INFO : import machine...
INFO : ok
INFO : func ok 0000000000001070 (0)
INFO : generate graph file
INFO : generate intervals
[0x1070 0x10A2]
INFO : total lines 0
```

- ✓ (testing MIASM) xdot graph_execflow.dot


graph_execflow.dot - Dot Viewer
_start
00001070 XOR EBP, EBP
00001072 POP ESI
00001073 MOV ECX, ESP
00001075 AND ESP, 0xFFFFFFF0
00001078 PUSH EAX
00001079 PUSH ESP
0000107A PUSH EDX
0000107B CALL loc_10a2
loc_1080
00001080 ADD EBX, 0x2F80
00001086 LEA EAX, DWORD PTR [EBX + 0xFFFFD280]
0000108C PUSH EAX
0000108D LEA EAX, DWORD PTR [EBX + 0xFFFFD220]
00001093 PUSH EAX
00001094 PUSH ECX
00001095 PUSH ESI
00001096 PUSH DWORD PTR [EBX + 0xFFFFFFF8]
0000109C CALL loc_1050
loc_10a1
000010A1 HLT

```
1  from miasm2.analysis.binary import Container
2  from miasm2.analysis.machine import Machine
3  from miasm2.jitter.csts import PAGE_READ, PAGE_WRITE
4
5  with open("defcon2019.bin") as fdesc:
6      cont=Container.from_stream(fdesc)
7
8  machine=Machine('x86_32')
9  mdis=machine.dis_engine(cont.bin_stream)
10 ourblocks = mdis.dis_multiblock(0)
11 for block in ourblocks:
12     print block
13 jitter = machine.jitter("llvm")
14 jitter.init_stack()
15 s = open("defcon2019.bin").read()
16 run_addr = 0x40000000
17 jitter.cpu.EAX=3
18 jitter.cpu.ECX=6
19 jitter.vm.add_memory_page(run_addr, PAGE_READ | PAGE_WRITE, s)
20 def code_sentinelle(jitter):
21     jitter.run = False
22     jitter.pc = 0
23     return True
24 jitter.add_breakpoint(0x40000028, code_sentinelle)
25 jitter.push_uint32_t(0x40000028)
26 jitter.jit.log_regs = True
27 jitter.jit.log_mn = True
28 jitter.init_run(run_addr)
29 jitter.continue_run()
30
31 open('defcon2019_cfg.dot', 'w').write(ourblocks.dot())
32
```

Opens our file. The Container provides the byte source to the disasm engine.

Instantiates the assemble engine using the x86 32-bits architecture.

Runs the recursive transversal disassembling since beginning.

Set “llvm” as Jit engine to emulation and initialize the stack.

Set the virtual start address, register values and memory protection.

Adds a breakpoint at the last line of code.

Run the emulation.

Generates a dot graph.

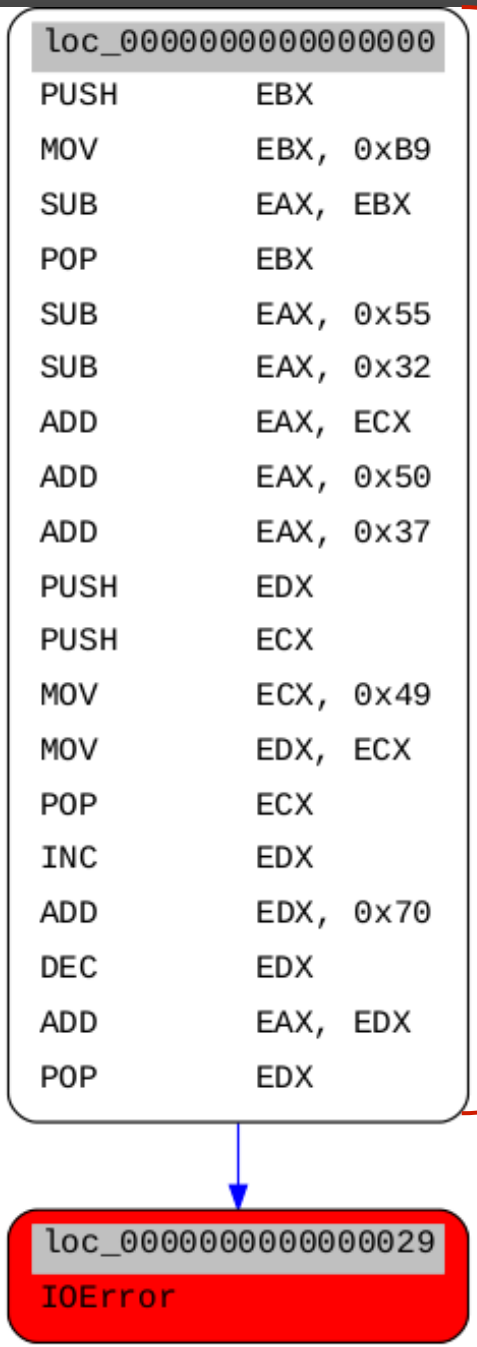
```
root@kali:~/programs/defcon# python miasm.py
WARNING: not enough bytes in str
WARNING: cannot disasm at 29
WARNING: not enough bytes in str
WARNING: cannot disasm at 29
loc_000000000000000:0x00000000
PUSH        EBX
MOV         EBX, 0xB9
SUB         EAX, EBX
POP         EBX
SUB         EAX, 0x55
SUB         EAX, 0x32
ADD         EAX, ECX
ADD         EAX, 0x50
ADD         EAX, 0x37
PUSH        EDX
PUSH        ECX
MOV         ECX, 0x49
MOV         EDX, ECX
POP         ECX
INC         EDX
ADD         EDX, 0x70
DEC         EDX
ADD         EAX, EDX
POP         EDX
->      c_next:loc_000000000000029:0x00000029
loc_000000000000029:0x00000029
```

Disassembling our code (again) ☺

```
40000000 PUSH        EBX
EAX 00000003 EBX 00000000 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 0
40000001 MOV         EBX, 0xB9
EAX 00000003 EBX 000000B9 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 0
40000006 SUB         EAX, EBX
EAX FFFFFF4A EBX 000000B9 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 1 of 0 cf 1
40000008 POP         EBX
EAX FFFFFF4A EBX 00000000 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFFC EBP 00000000 EIP 40000000 zf 0 nf 1 of 0 cf 1
40000009 SUB         EAX, 0x55
EAX FFFFFEF5 EBX 00000000 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFFC EBP 00000000 EIP 40000000 zf 0 nf 1 of 0 cf 0
4000000C SUB         EAX, 0x32
EAX FFFFFEC3 EBX 00000000 ECX 00000006 EDX 00000000 ESI 00000000 EDI 00000000
ESP 0123FFFC EBP 00000000 EIP 40000000 zf 0 nf 1 of 0 cf 0



EAX FFFFFF50 EBX 00000000 ECX 00000006 EDX 00000049 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 1 of 0 cf 0
40000021 INC         EDX
EAX FFFFFF50 EBX 00000000 ECX 00000006 EDX 0000004A ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 0
40000022 ADD         EDX, 0x70
EAX FFFFFF50 EBX 00000000 ECX 00000006 EDX 000000BA ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 0
40000025 DEC         EDX
EAX FFFFFF50 EBX 00000000 ECX 00000006 EDX 000000B9 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 0
40000026 ADD         EAX, EDX
EAX 00000009 EBX 00000000 ECX 00000006 EDX 000000B9 ESI 00000000 EDI 00000000
ESP 0123FFF8 EBP 00000000 EIP 40000000 zf 0 nf 0 of 0 cf 1
```



Our proposed code.
☺

```
root@kali:~/programs/defcon# python
Python 2.7.16 (default, Apr  6 2019, 01:42:57)
[GCC 8.3.0] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> from miasm2.analysis.binary import Container
>>> from miasm2.analysis.machine import Machine
>>> from miasm2.jitter.csts import PAGE_READ, PAGE_WRITE
>>> with open("defcon2019.bin") as fdesc:
...     cont=Container.from_stream(fdesc)
...
>>> defconmach=Machine('x86_32')
>>> defcondis=defconmach.dis_engine(cont.bin_stream)
>>> myblocks = defcondis.dis_multiblock(0)
WARNING: not enough bytes in str
WARNING: cannot disasm at 29
WARNING: not enough bytes in str
WARNING: cannot disasm at 29
>>> sym = defconmach.ira( )
>>> for block in myblocks:
...     sym.add_block(block)
...
[<miasm2.ir.ir.IRBlock object at 0x7f0fde22b870>]
[]
>>> from miasm2.ir.symbexec import SymbolicExecutionEngine
>>> symb = SymbolicExecutionEngine(sym,defconmach.mn.regs.regs_init)
>>> symbolic_pc = symb.run_at(0, step=True)
```

Get the IRA converter.

Initialize and run the Symbolic Execution Engine.

```
>>> symbolic_pc = symb.run_at(0, step=True)
Instr PUSH       EBX
Assignblk:
ESP = ESP + -0x4
@32[ESP + -0x4] = EBX

________________________________________________________________________________
ESP                 = ESP_init + 0xFFFFFFFC
@32[ESP_init + 0xFFFFFFFC] = EBX_init

________________________________________________________________________________
Instr MOV        EBX, 0xB9
Assignblk:
EBX = 0xB9

________________________________________________________________________________
ESP                 = ESP_init + 0xFFFFFFFC
EBX                 = 0xB9
@32[ESP_init + 0xFFFFFFFC] = EBX_init

________________________________________________________________________________
Instr SUB        EAX, EBX
Assignblk:
zf = (EAX + -EBX)?(0x0,0x1)
nf = (EAX + -EBX)[31:32]
pf = parity((EAX + -EBX) & 0xFF)
of = ((EAX ^ (EAX + -EBX)) & (EAX ^ EBX))[31:32]
cf = (((EAX ^ EBX) ^ (EAX + -EBX)) ^ ((EAX ^ (EAX + -EBX)) & (EAX ^ EBX)))[31:32
]
af = ((EAX ^ EBX) ^ (EAX + -EBX))[4:5]
EAX = EAX + -EBX
```

```
EAX                 = EAX_init + ECX_init
cf                  = ((((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF4
7)) & ((EAX_init + ECX_init + 0xFFFFFF47) ^ 0xFFFFFF46)) ^ (EAX_init + ECX_init)
 ^ (EAX_init + ECX_init + 0xFFFFFF47) ^ 0xB9)[31:32]
pf                  = parity((EAX_init + ECX_init) & 0xFF)
zf                  = (EAX_init + ECX_init)?(0x0,0x1)
af                  = ((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF47)
 ^ 0xB9)[4:5]
of                  = (((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF47
)) & ((EAX_init + ECX_init + 0xFFFFFF47) ^ 0xFFFFFF46))[31:32]
nf                  = (EAX_init + ECX_init)[31:32]
@32[ESP_init + 0xFFFFFFF8] = ECX_init
@32[ESP_init + 0xFFFFFFFC] = EDX_init

Instr POP         EDX
Assignblk:
IRDst = loc_0000000000000029:0x00000029

EAX                 = EAX_init + ECX_init
cf                  = ((((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF4
7)) & ((EAX_init + ECX_init + 0xFFFFFF47) ^ 0xFFFFFF46)) ^ (EAX_init + ECX_init)
 ^ (EAX_init + ECX_init + 0xFFFFFF47) ^ 0xB9)[31:32]
pf                  = parity((EAX_init + ECX_init) & 0xFF)
zf                  = (EAX_init + ECX_init)?(0x0,0x1)
af                  = ((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF47)
 ^ 0xB9)[4:5]
IRDst               = 0x29
of                  = (((EAX_init + ECX_init) ^ (EAX_init + ECX_init + 0xFFFFFF47
)) & ((EAX_init + ECX_init + 0xFFFFFF47) ^ 0xFFFFFF46))[31:32]
nf                  = (EAX_init + ECX_init)[31:32]
@32[ESP_init + 0xFFFFFFF8] = ECX_init
@32[ESP_init + 0xFFFFFFFC] = EDX_init
```

The same conclusion from our previous tests. ☺

TRITON

❑ TRITON

- ✓ It can be downloaded from https://triton.quarkslab.com/
- ✓ Based on Intel Pin instrumentation tool: https://software.intel.com/en-us/articles/pin-a-dynamic-binary-instrumentation-tool

- ✓ Triton offers a C/C++/Python interface provides:
  - ✓ dynamic symbolic execution
  - ✓ run time registry information and memory modification
  - ✓ taint engine
  - ✓ Z3 interface to handle contraints
  - ✓ snapshot engine (it is not necessary to restart the program every time, but only restores memory and register states)
  - ✓ access to Pin funtions
  - ✓ symbolic fuzzing
  - ✓ gather code coverage

- ✓ Supports x86 and x64 architecture.

- ✓ Triton supports:
  - ✓ symbolic execution mode:
    - ✓ emulates instruction effects.
    - ✓ allows us to emulate only part of the program (excellent for analyzing branches).
  - ✓ concolic execution mode:
    - ✓ allows us to analyze the program only from start.
- ✓ Taint analysis is amazing because we are able to using in fuzzing tasks to know what registers and memory address are “affected” by the user data input. ☺
- ✓ During Virtual Machine’s decoding, it is interesting to distinguish which instructions are related to user input and which are not. ☺

❖ Installing Triton without Pin (Ubuntu 19):

- ✓ apt-get install libboost-all-dev
- ✓ apt-get install libpython-dev
- ✓ apt-get install libcapstone-dev
- ✓ Take care: DO NOT install libz3-dev. If this package is already installed, so remove it.
- ✓ git clone https://github.com/Z3Prover/z3
- ✓ cd z3/
- ✓ python scripts/mk_make.py
- ✓ cd build/
- ✓ make
- ✓ make install
- ✓ git clone https://github.com/JonathanSalwan/Triton.git
- ✓ cd Triton/
- ✓ mkdir build
- ✓ cd build/
- ✓ cmake ..
- ✓ make -j install (my recommendation: 8 GB RAM + 8 GB swapfile)

✓ Installing Triton with Pin (Ubuntu 19):

- ✓ Install the same packages from last slide.
- ✓ Install Z3 as shown in the last slide.
- ✓ wget https://software.intel.com/sites/landingpage/pintool/downloads/pin-2.14-71313-gcc.4.4.7-linux.tar.gz
- ✓ tar zxvf pin-2.14-71313-gcc.4.4.7-linux.tar.gz
- ✓ cd pin-2.14-71313-gcc.4.4.7-linux/source/tools
- ✓ git clone https://github.com/JonathanSalwan/Triton.git
- ✓ cd Triton/
- ✓ mkdir build
- ✓ cd build
- ✓ cmake -DPINTOOL=on -DKERNEL4=on ..
- ✓ make
- ✓ cd ..
- ✓ ./build/triton ./src/examples/pin/ir.py /usr/bin/host (only to test the installation).

```
1  #!/usr/bin/env python2
2  ## -*- coding: utf-8 -*-
3  ##
4
5  from __future__ import print_function
6  from triton     import TritonContext, ARCH, Instruction, MemoryAccess, CPUSI
   ZE, OPERAND, REG
7
8  import sys
9
10 # We define the code to be handled and symbolic executed
11
12 mycode = [
13
14         (0x400000, b"\x53"),                    # push ebx
15         (0x400001, b"\xbb\xb9\x00\x00\x00"),    # mov ebx, 0xB9
16         (0x400006, b"\x29\xd8"),                # sub eax, ebx
17         (0x400008, b"\x5b"),                    # pop ebx
18         (0x400009, b"\x83\xe8\x55"),            # sub eax, 0x55
19         (0x40000c, b"\x83\xe8\x32"),            # sub eax, 0x32
20         (0x40000f, b"\x01\xc8"),                # add eax, ecx
21         (0x400011, b"\x83\xc0\x50"),            # add eax, 0x50
22         (0x400014, b"\x83\xc0\x37"),            # add eax, 0x37
23         (0x400017, b"\x52"),                    # push edx
24         (0x400018, b"\x51"),                    # push ecx
25         (0x400019, b"\xb9\x49\x00\x00\x00"),    # mov ecx, 0x49
26         (0x40001e, b"\x89\xca"),                # mov edx, ecx
27         (0x400020, b"\x59"),                    # pop ecx
28         (0x400021, b"\x42"),                    # inc edx
29         (0x400022, b"\x83\xc2\x70"),            # add edx, 0x70
30         (0x400025, b"\x4a"),                    # dec edx
31         (0x400026, b"\x01\xd0"),                # add eax, edx
32         (0x400028, b"\x5a"),                    # pop edx
33         (0x400029, b"\xff\xe0"),                # jmp eax
34
35 ]
36
```

```
37
38 if __name__ == '__main__':
39
40     #Set the context for Triton functions
41     context = TritonContext()
42
43     # Set the architecture. In our case, we are using x86 32-bit
44     context.setArchitecture(ARCH.X86)
45
46     for (addr, opcode) in mycode:
47         # Build an instruction object.
48         instruction = Instruction()
49
50         # Setup the opcode
51         instruction.setOpcode(opcode)
52
53         # Setup start  address
54         instruction.setAddress(addr)
55
56         # Process our code
57         context.processing(instruction)
58
59         print('----------------------------------------')
60         print('The current IP: ', instruction)
61         pc = context.getRegisterAst(context.registers.eip).evaluate()
62         print ('The next IP is: ', hex(pc))
63         print('----------------------------------------\n\n')
64
65         # Display each instruction, determine the operation type and show opcode in
   formation
66         print('>>> %s'% instruction)
67
68         print('\n  ----------------------------')
69         print('    Is a memory read?  :', instruction.isMemoryRead())
70         print('    Is a memory write? :', instruction.isMemoryWrite())
71         print('    --------------------------\n')
```

```
72
73          for op_entry in instruction.getOperands():
74              print('    %s' % (op_entry))
75              if op_entry.getType() == OPERAND.MEM:
76                  print('        segment :', op_entry.getSegmentRegister())
77                  print('          base  : %s' % (op_entry.getBaseRegister()))
78                  print('          index : %s' % (op_entry.getIndexRegister()))
79                  print('          disp  : %s' % (op_entry.getDisplacement()))
80                  print('          scale : %s' % (op_entry.getScale()))
81          print('')
82
83
84          # Display each one of the symbolic expressions
85          for expression in instruction.getSymbolicExpressions():
86              print('\t', expression)
87
88          print()
89
90      print()
91      print('Registers information')
92      print('*********************************')
93      for k, v in list(context.getSymbolicRegisters().items()):
94          print(context.getRegister(k), v)
95
96      print()
97      print('Summary Memory information')
98      print('*****************************')
99      for k, v in list(context.getSymbolicMemory().items()):
100         print(hex(k), v)
101
102     print()
103
104     sys.exit(0)
```

```
root@kali:~# rasm2 -a x86 -b 32 "push ebx"
53
root@kali:~# rasm2 -a x86 -b 32 "mov ebx, 0xb9"
bbb9000000
root@kali:~# rasm2 -a x86 -b 32 "sub eax, ebx"
29d8
root@kali:~# rasm2 -a x86 -b 32 "pop ebx"
5b
root@kali:~# rasm2 -a x86 -b 32 "sub eax, 0x55"
83e855
root@kali:~# rasm2 -a x86 -b 32 "sub eax, 0x32"
83e832
root@kali:~# rasm2 -a x86 -b 32 "add eax, ecx"
01c8
root@kali:~# rasm2 -a x86 -b 32 "add eax, 0x50"
83c050
root@kali:~# rasm2 -a x86 -b 32 "add eax, 0x37"
83c037
root@kali:~# rasm2 -a x86 -b 32 "push edx"
52
root@kali:~# rasm2 -a x86 -b 32 "push ecx"
51
root@kali:~# rasm2 -a x86 -b 32 "mov ecx, 0x49"
b949000000
root@kali:~# rasm2 -a x86 -b 32 "mov edx, ecx"
89ca
root@kali:~# rasm2 -a x86 -b 32 "pop ecx"
59
root@kali:~# rasm2 -a x86 -b 32 "inc edx"
42
root@kali:~# rasm2 -a x86 -b 32 "add edx, 0x70"
83c270
root@kali:~# rasm2 -a x86 -b 32 "dec edx"
4a
root@kali:~# rasm2 -a x86 -b 32 "add eax, edx"
01d0
root@kali:~# rasm2 -a x86 -b 32 "pop edx"
5a
root@kali:~# rasm2 -a x86 -b 32 "jmp eax"
ffe0
```

This is an educational way to show how to find the hexadecimal representation for each instruction.

However, there are much better ways to do it by opening the binary on IDA Pro, Radare2, Ghidra or even using distorm3.

```
root@ubuntu19:~/pin214/source/tools/Triton/src/examples/python# python defcon_sym.py | more
----------------------------------------
The current IP:  0x400000: push ebx
The next IP is:  0x400001
----------------------------------------


>>> 0x400000: push ebx

  ----------------------------
    Is a memory read?  : False
    Is a memory write? : True
    ----------------------------

    ebx:32 bv[31..0]

        (define-fun ref!0 () (_ BitVec 32) (bvsub (_ bv0 32) (_ bv4 32))) ; Stack alig
nment
        (define-fun ref!1 () (_ BitVec 8) ((_ extract 31 24) (_ bv0 32))) ; Byte refer
ence - PUSH operation
        (define-fun ref!2 () (_ BitVec 8) ((_ extract 23 16) (_ bv0 32))) ; Byte refer
ence - PUSH operation
        (define-fun ref!3 () (_ BitVec 8) ((_ extract 15 8) (_ bv0 32))) ; Byte refere
nce - PUSH operation
        (define-fun ref!4 () (_ BitVec 8) ((_ extract 7 0) (_ bv0 32))) ; Byte referen
ce - PUSH operation
        (define-fun ref!5 () (_ BitVec 32) (concat ((_ extract 31 24) (_ bv0 32)) ((_
extract 23 16) (_ bv0 32)) ((_ extract 15 8) (_ bv0 32)) ((_ extract 7 0) (_ bv0 32))))
 ; Temporary concatenation reference - PUSH operation
        (define-fun ref!6 () (_ BitVec 32) (_ bv4194305 32)) ; Program Counter

----------------------------------------
The current IP:  0x400001: mov ebx, 0xb9
The next IP is:  0x400006
----------------------------------------
```

byte by byte ☺

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```
>>> 0x400001: mov ebx, 0xb9

  ----------------------------
    Is a memory read?  : False
    Is a memory write? : False
    ---------------------------

    ebx:32 bv[31..0]
    0xb9:32 bv[31..0]

         (define-fun ref!7 () (_ BitVec 32) (_ bv185 32)) ; MOV operation
         (define-fun ref!8 () (_ BitVec 32) (_ bv4194310 32)) ; Program Counter

----------------------------------------
The current IP:  0x400006: sub eax, ebx
The next IP is:  0x400008
----------------------------------------

>>> 0x400006: sub eax, ebx

  ----------------------------
    Is a memory read?  : False
    Is a memory write? : False
    ---------------------------

    eax:32 bv[31..0]
    ebx:32 bv[31..0]

         (define-fun ref!9 () (_ BitVec 32) (bvsub (_ bv0 32) ref!7)) ; SUB operation
         (define-fun ref!10 () (_ BitVec 1) (ite (= (_ bv16 32) (bvand (_ bv16 32) (bvxor ref!9 (bvxor (_ bv0 32)
ref!7)))) (_ bv1 1) (_ bv0 1))) ; Adjust flag
         (define-fun ref!11 () (_ BitVec 1) ((_ extract 31 31) (bvxor (bvxor (_ bv0 32) (bvxor ref!7 ref!9)) (bvan
d (bvxor (_ bv0 32) ref!9) (bvxor (_ bv0 32) ref!7))))) ; Carry flag
         (define-fun ref!12 () (_ BitVec 1) ((_ extract 31 31) (bvand (bvxor (_ bv0 32) ref!7) (bvxor (_ bv0 32) r
ef!9)))) ; Overflow flag
         (define-fun ref!13 () (_ BitVec 1) (bvxor (bvxor (bvxor (bvxor (bvxor (bvxor (bvxor (bvxor (_ bv1 1) ((_
extract 0 0) (bvlshr ((_ extract 7 0) ref!9) (_ bv0 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!9) (_ bv1
8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!9) (_ bv2 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!
9) (_ bv3 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!9) (_ bv4 8)))) ((_ extract 0 0) (bvlshr ((_ extract
 7 0) ref!9) (_ bv5 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!9) (_ bv6 8)))) ((_ extract 0 0) (bvlshr (
(_ extract 7 0) ref!9) (_ bv7 8))))) ; Parity flag
         (define-fun ref!14 () (_ BitVec 1) ((_ extract 31 31) ref!9)) ; Sign flag
         (define-fun ref!15 () (_ BitVec 1) (ite (= ref!9 (_ bv0 32)) (_ bv1 1) (_ bv0 1))) ; Zero flag
         (define-fun ref!16 () (_ BitVec 32) (_ bv4194312 32)) ; Program Counter
```

0xb9 == 185 ☺

eax

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```
Registers information
******************************
esp:32 bv[31..0] (define-fun ref!112 () (_ BitVec 32) (bvadd ref!79 (_ bv4 32))) ; Stack align
ment
cf:1 bv[0..0] (define-fun ref!105 () (_ BitVec 1) ((_ extract 31 31) (bvxor (bvand ref!52 ref!
96) (bvand (bvxor (bvx
or ref!52 ref!96) ref!103) (bvxor ref!52 ref!96))))) ; Carry flag
eip:32 bv[31..0] (define-fun ref!114 () (_ BitVec 32) ref!103) ; Program Counter
of:1 bv[0..0] (define-fun ref!106 () (_ BitVec 1) ((_ extract 31 31) (bvand (bvxor ref!52 (bvn
ot ref!96)) (bvxor ref
!52 ref!103)))) ; Overflow flag
eax:32 bv[31..0] (define-fun ref!103 () (_ BitVec 32) (bvadd ref!52 ref!96)) ; ADD operation
sf:1 bv[0..0] (define-fun ref!108 () (_ BitVec 1) ((_ extract 31 31) ref!103)) ; Sign flag
ebx:32 bv[31..0] (define-fun ref!17 () (_ BitVec 32) (concat ref!1 ref!2 ref!3 ref!4)) ; POP o
peration
zf:1 bv[0..0] (define-fun ref!109 () (_ BitVec 1) (ite (= ref!103 (_ bv0 32)) (_ bv1 1) (_ bv0
 1))) ; Zero flag
ecx:32 bv[31..0] (define-fun ref!78 () (_ BitVec 32) (concat ref!68 ref!69 ref!70 ref!71)) ; P
OP operation
af:1 bv[0..0] (define-fun ref!104 () (_ BitVec 1) (ite (= (_ bv16 32) (bvand (_ bv16 32) (bvxo
r ref!103 (bvxor ref!5
2 ref!96)))) (_ bv1 1) (_ bv0 1))) ; Adjust flag
edx:32 bv[31..0] (define-fun ref!111 () (_ BitVec 32) (concat ref!61 ref!62 ref!63 ref!64)) ;
POP operation
pf:1 bv[0..0] (define-fun ref!107 () (_ BitVec 1) (bvxor (bvxor (bvxor (bvxor (bvxor (bvxor (b
vxor (bvxor (_ bv1 1)
((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!103) (_ bv0 8)))) ((_ extract 0 0) (bvlshr ((_ e
xtract 7 0) ref!103) (
_ bv1 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!103) (_ bv2 8)))) ((_ extract 0 0) (
bvlshr ((_ extract 7 0
) ref!103) (_ bv3 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!103) (_ bv4 8)))) ((_ ex
tract 0 0) (bvlshr ((_
 extract 7 0) ref!103) (_ bv5 8)))) ((_ extract 0 0) (bvlshr ((_ extract 7 0) ref!103) (_ bv6
8)))) ((_ extract 0 0)
 (bvlshr ((_ extract 7 0) ref!103) (_ bv7 8))))) ; Parity flag
```

```python
#!/usr/bin/env python2
## -*- coding: utf-8 -*-
##

from __future__ import print_function
from triton     import TritonContext, ARCH, Instruction, MODE

import sys

#Define the code to be emulated

mycode = {

        0x400000: b"\x53",                      # push ebx
        0x400001: b"\xbb\xb9\x00\x00\x00",      # mov ebx, 0xB9
        0x400006: b"\x29\xd8",                  # sub eax, ebx
        0x400008: b"\x5b",                      # pop ebx
        0x400009: b"\x83\xe8\x55",              # sub eax, 0x55
        0x40000c: b"\x83\xe8\x32",              # sub eax, 0x32
        0x40000f: b"\x01\xc8",                  # add eax, ecx
        0x400011: b"\x83\xc0\x50",              # add eax, 0x50
        0x400014: b"\x83\xc0\x37",              # add eax, 0x37
        0x400017: b"\x52",                      # push edx
        0x400018: b"\x51",                      # push ecx
        0x400019: b"\xb9\x49\x00\x00\x00",      # mov ecx, 0x49
        0x40001e: b"\x89\xca",                  # mov edx, ecx
        0x400020: b"\x59",                      # pop ecx
        0x400021: b"\x42",                      # inc edx
        0x400022: b"\x83\xc2\x70",              # add edx, 0x70
        0x400025: b"\x4a",                      # dec edx
        0x400026: b"\x01\xd0",                  # add eax, edx
        0x400028: b"\x5a",                      # pop edx
        0x400029: b"\xff\xe0",                  # jmp eax
}

#Define the context object to be applied the Triton functions
context = TritonContext()

```

```
39
40 # This function emulates the code.
41 def defcon(pc):
42     while pc in mycode:
43         # Build an instruction
44         instruction = Instruction()
45
46         # Setup the opcode
47         instruction.setOpcode(mycode[pc])
48
49         # Setup start address
50         instruction.setAddress(pc)
51
52         # Process the opcodes
53         context.processing(instruction)
54
55         # Display the instruction
56         print('Curr pc:', instruction)
57
58         # Set the IP to next instruction and update the some registers
59         pc = context.getRegisterAst(context.registers.eip).evaluate()
60         eax = context.getRegisterAst(context.registers.eax).evaluate()
61         ebx = context.getRegisterAst(context.registers.ebx).evaluate()
62         ecx = context.getRegisterAst(context.registers.ecx).evaluate()
63         edx = context.getRegisterAst(context.registers.edx).evaluate()
64         print('Next pc: ', hex(pc))
65         print('Next eax:', hex(eax))
66         print('Next ebx:', hex(ebx))
67         print('Next ecx:', hex(ecx))
68         print('Next edx:', hex(edx))
69         print()
70     return
71
```

```
72 # This function initializes the context memory. EAX and ECX was randomly chosen.
73 def startCtx():
74     context.setConcreteRegisterValue(context.registers.esp, 0x7fffffff)
75     context.setConcreteRegisterValue(context.registers.ebp, 0x7fffffff)
76     context.setConcreteRegisterValue(context.registers.eax, 0x2)
77     context.setConcreteRegisterValue(context.registers.ebx, 0x0)
78     context.setConcreteRegisterValue(context.registers.ecx, 0x7)
79     context.setConcreteRegisterValue(context.registers.edx, 0x0)
80     return
81
82 if __name__ == '__main__':
83     # Set the architecture. In our case, we have chosen x86 32-bit.
84     context.setArchitecture(ARCH.X86)
85
86     # Align the memory
87     context.enableMode(MODE.ALIGNED_MEMORY, True)
88
89     # Define the entry point address
90     entrypoint = 0x400000
91
92     # Set the memory context
93     startCtx()
94
95     # Run the emulation
96     defcon(entrypoint)
97
98     sys.exit(0)
99
```

```
root@ubuntu19:~/pin214/source/tools/Triton/src/examples/python# python defcon_sym_2.py
Curr ip: 0x400000: push ebx
Next ip: 0x400001
Next eax: 0x2
Next ebx: 0x0
Next ecx: 0x7
Next edx: 0x0

Curr ip: 0x400001: mov ebx, 0xb9
Next ip: 0x400006
Next eax: 0x2
Next ebx: 0xb9
Next ecx: 0x7
Next edx: 0x0

Curr ip: 0x400006: sub eax, ebx
Next ip: 0x400008
Next eax: 0xffffff49
Next ebx: 0xb9
Next ecx: 0x7
Next edx: 0x0


Curr ip: 0x400028: pop edx
Next ip: 0x400029
Next eax: 0x9
Next ebx: 0x0
Next ecx: 0x7
Next edx: 0x0

Curr ip: 0x400029: jmp eax
Next ip: 0x9
Next eax: 0x9
Next ebx: 0x0
Next ecx: 0x7
Next edx: 0x0
```

RADARE2 + MIASM

```
root@kali:~/programs/defcon# r2 -b 32 defcon2019.bin
 -- EIP = 0x41414141
[0x00000000]> aaa
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze function calls (aac)
[x] Analyze len bytes of instructions for references (aar)
[x] Use -AA or aaaa to perform additional experimental analysis.
[x] Constructing a function name for fcn.* and sym.func.* functions (aan)
[0x00000000]> ec comment green
[0x00000000]> e asm.emu=true
[0x00000000]> pdf
┌ (fcn) fcn.00000000 41
│   fcn.00000000 ();
│           0x00000000      53             push ebx                    ; esp=0xfffffffffffffffc
│           0x00000001      bbb9000000     mov ebx, 0xb9               ; 185 ; ebx=0xb9
│           0x00000006      29d8           sub eax, ebx                ; eax=0xffffffffffffff47 ; of=0x0 ; sf
=0x1 -> 0xb9bb ; zf=0x0 ; pf=0x1 -> 0xb9bb ; cf=0x1 -> 0xb9bb
│           0x00000008      5b             pop ebx                     ; ebx=0xffffffff ; esp=0x100000000
│           0x00000009      83e855         sub eax, 0x55               ; 'U' ; eax=0xffffef2 ; of=0x0 ; sf=0
x1 -> 0xb9bb ; zf=0x0 ; pf=0x0 ; cf=0x0
│           0x0000000c      83e832         sub eax, 0x32               ; '2' ; eax=0xffffec0 ; of=0x0 ; sf=0
x1 -> 0xb9bb ; zf=0x0 ; pf=0x1 -> 0xb9bb ; cf=0x0
│           0x0000000f      01c8           add eax, ecx                ; eax=0xffffec0 ; of=0x0 ; sf=0x1 ->
0xb9bb ; zf=0x0 ; cf=0x0 ; pf=0x1 -> 0xb9bb
│           0x00000011      83c050         add eax, 0x50               ; 'P' ; eax=0xffffff10 ; of=0x0 ; sf=0
x1 -> 0xb9bb ; zf=0x0 ; cf=0x0 ; pf=0x0
│           0x00000014      83c037         add eax, 0x37               ; '7' ; eax=0xffffff47 ; of=0x0 ; sf=0
x1 -> 0xb9bb ; zf=0x0 ; cf=0x0 ; pf=0x1 -> 0xb9bb
│           0x00000017      52             push edx                    ; esp=0xfffffffffffffffc
│           0x00000018      51             push ecx                    ; esp=0xfffffff8
│           0x00000019      b949000000     mov ecx, 0x49               ; 'I' ; 73 ; ecx=0x49
│           0x0000001e      89ca           mov edx, ecx                ; edx=0x49
│           0x00000020      59             pop ecx                     ; ecx=0xffffffff ; esp=0xfffffffc
│           0x00000021      42             inc edx                     ; edx=0x4a ; of=0x0 ; sf=0x0 ; zf=0x0
; pf=0x0
│           0x00000022      83c270         add edx, 0x70               ; 'p' ; edx=0xba ; of=0x0 ; sf=0x0 ; z
f=0x0 ; cf=0x0 ; pf=0x0
│           0x00000025      4a             dec edx                     ; edx=0xb9 ; of=0x0 ; sf=0x0 ; zf=0x0
; pf=0x0
│           0x00000026      01d0           add eax, edx                ; eax=0x100000000 ; of=0x0 ; sf=0x0 ;
zf=0x1 -> 0xb9bb ; cf=0x1 -> 0xb9bb ; pf=0x1 -> 0xb9bb
└           0x00000028      5a             pop edx                     ; edx=0xffffffff ; esp=0x100000000
```

ESIL comment

```
[0x00000000]> aer eax=0x7
[0x00000000]> aer ecx=0x2
[0x00000000]> e io.cache = true
[0x00000000]> aes
[0x00000000]> aer
oeax = 0x00000000
eax = 0x00000007
ebx = 0x00000000
ecx = 0x00000002
edx = 0x00000000
esi = 0x00000000
edi = 0x00000000
esp = 0xfffffffc
ebp = 0x00000000
eip = 0x00000001
eflags = 0x00000000
```

- ✓ aer: handle ESIL registers (set and show)
- ✓ aes: perform emulated debugger step
- ✓ aecu: continue until address

```
[0x00000000]> e asm.emu=true
[0x00000000]> aecu 0x00000028
[0x00000000]> aer
oeax = 0x00000000
eax = 0x00000009
ebx = 0x00000000
ecx = 0x00000002
edx = 0x000000b9
esi = 0x00000000
edi = 0x00000000
esp = 0xfffffffc
ebp = 0x00000000
eip = 0x00000028
eflags = 0x00000005
```

R2M2 bridges the radare2 and miasm2 communities: radare2 being the graphical interface of miasm2, and miasm2 simplifying the implementation of new architectures.

How to install it?

- ✓ apt-get install docker
- ✓ git clone https://github.com/radare/radare2.git
- ✓ cd radare2/
- ✓ sys/install.sh
- ✓ Install MIASM
- ✓ pip install cffi
- ✓ pip install jinja2
- ✓ docker pull guedou/r2m2
- ✓ docker run --rm -it -e 'R2M2_ARCH=x86_32' guedou/r2m2 bash

- ✓ [r2m2@fd5662d151e4 ~]$ pwd

- ✓ (another terminal) docker ps -a
- ✓ (another terminal) docker cp /root/defcon2019.bin fd5662d151e4:/home/r2m2/defcon2019.bin

- ✓ [r2m2@fd5662d151e4 ~]$ export R2M2_ARCH=x86_32
- ✓ [r2m2@fd5662d151e4 ~]$ r2 -A -b 32 -a r2m2 defcon2019.bin

```
[r2m2@fd5662d151e4 ~]$ r2 -A -b 32 -a r2m2 defcon2019.bin
[/home/r2m2/miasm/miasm/expression/expression.py:924: UserWarning:
  warnings.warn('DEPRECATION WARNING: use exprmem.ptr instead of e
[x] Analyze all flags starting with sym. and entry0 (aa)
[x] Analyze function calls (aac)
[x] find and analyze function preludes (aap)
[x] Analyze len bytes of instructions for references (aar)
[x] Check for objc references
[x] Check for vtables
[x] Finding xrefs in noncode section with anal.in = 'io.maps
[x] Analyze value pointers (aav)
[x] Value from 0x00000000 to 0x00000029 (aav)
[x] 0x00000000-0x00000029 in 0x0-0x29 (aav)
[Warning: No SN reg alias for current architecture.
[x] Emulate code to find computed references (aae)
[WARNING: r_reg_get: assertion 'reg && name' failed (line 279)
[x] Type matching analysis for all functions (aaft)
[x] Use -AA or aaaa to perform additional experimental analysis.
 -- Warning, your trial license is about to expire.
[0x00000000]>
[0x00000000]> ec comment yellow
[0x00000000]>
[0x00000000]> e asm.emu=true
[0x00000000]>
[0x00000000]> pd 20
```

```
(fcn) fcn.00000000 41
  fcn.00000000 (int32_t arg_4h);
          ; arg int32_t arg_4h @ esp+0x4
          0x00000000      53              PUSH        EBX                 ; esp=0x177ffc
          0x00000001      bbb9000000      MOV         EBX, 0xB9           ; ebx=0xb9
          0x00000006      29d8            SUB         EAX, EBX
          0x00000008      5b              POP         EBX                 ; esp=0x178004 ; ebx=0xffffffff
          0x00000009      83e855          SUB         EAX, 0x55
          0x0000000c      83e832          SUB         EAX, 0x32
          0x0000000f      01c8            ADD         EAX, ECX
          0x00000011      83c050          ADD         EAX, 0x50
          0x00000014      83c037          ADD         EAX, 0x37
          0x00000017      52              PUSH        EDX                 ; esp=0x177ffc
          0x00000018      51              PUSH        ECX                 ; esp=0x177ffc
          0x00000019      b949000000      MOV         ECX, 0x49           ; ecx=0x49
          0x0000001e      89ca            MOV         EDX, ECX            ; edx=0x0
          0x00000020      59              POP         ECX                 ; esp=0x178004 ; ecx=0xffffffff
          0x00000021      42              INC         EDX
          0x00000022      83c270          ADD         EDX, 0x70
          0x00000025      4a              DEC         EDX
          0x00000026      01d0            ADD         EAX, EDX
          0x00000028      5a              POP         EDX                 ; esp=0x178004 ; edx=0xffffffff
          0x00000029      ffff            /!\ buffer too long /!\
```

DTRACE on WINDOWS

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- ✓ DTrace is a dynamic tracing framework, which is very efficient and famous on Solaris operating system.
- ✓ Dtrace was initially written by Mike Shapiro, Adam Leventhal and Brian Cantrill at Sun Microsystems. Although they were developing DTrace since 2003, it was only introduced in Solaris 10 03/05.
- ✓ It is used to get a real time overview of a system in user and kernel mode. Furthermore, it can be used to understand how application and systems are behaving.
- ✓ Few months ago, DTrace was ported to Windows: https://github.com/opendtrace/opendtrace/tree/windows
- ✓ DTrace is could be summarized as a set of probes (sensors) scattered over the key point in th kernel. Thus, every time that a probe is "activated", it is possible to register and understand the application behavior.
- ✓ Using DTrace makes easier to trace the profile of a process and the system, find which system calls are "called", how many bytes are written/read by a process, file opened by a process, tracing the sequence of called system calls and so on.

- ✓ DTrace scripts are written in D language (similar to awk).
- ✓ Probe names are described by the following syntaxe:

  provider:module:function:name

where:

- ✓ provider: library of probes used to instrument an area of the system. On Windows, the existing providers are syscall, etw, profile, pid and dtrace.
- ✓ module: kernel module where we find the probe.
- ✓ function: function contaning the probe.
- ✓ name: specific name or description of the target probe.

- ✓ Key concepts:
  - ✓ predicates: user defined conditions.
  - ✓ actions: tasks that are run when a probe fires.
  - ✓ aggregations: coalesce data using aggregation functions.

- ✓ To install DTrace:
  - ✓ Windows 10 x64 (build 18342 or later) from Windows Insider Program.
  - ✓ bcdedit.exe /set dtrace on
  - ✓ Download DTrace package: http://download.microsoft.com/download/B/D/4/BD4B95A5-0B61-4D8F-837C-F889AAD8DAA2/DTrace.amd64.msi
  - ✓ _NT_SYMBOL_PATH=srv*C:\symbols*https://msdl.microsoft.com/download/symbols
  - ✓ Reboot the system.
  - ✓ Open a command prompt as administrator.
  - ✓ If you are using fbt (function boundary tracing), so it is necessary to attach the WinDbg and boot the Windows in debug mode. ☺

```
C:\Users\Administrator>dtrace -l | more
   ID   PROVIDER            MODULE                          FUNCTION NAME
    1     dtrace                                                     BEGIN
    2     dtrace                                                     END
    3     dtrace                                                     ERROR
    4    syscall                                NtLockProductActivationKeys entry
    5    syscall                                NtLockProductActivationKeys return
    6    syscall                                    NtWaitHighEventPair entry
    7    syscall                                    NtWaitHighEventPair return
    8    syscall                              NtRegisterThreadTerminatePort entry
    9    syscall                              NtRegisterThreadTerminatePort return
   10    syscall                           NtAssociateWaitCompletionPacket entry
   11    syscall                           NtAssociateWaitCompletionPacket return
   12    syscall                                NtQueryPerformanceCounter entry
   13    syscall                                NtQueryPerformanceCounter return
   14    syscall                                        NtCompactKeys entry
   15    syscall                                        NtCompactKeys return
   16    syscall                              NtQuerySystemInformationEx entry
   17    syscall                              NtQuerySystemInformationEx return
   18    syscall                                        NtResetEvent entry
   19    syscall                                        NtResetEvent return
   20    syscall                                    NtGetContextThread entry
   21    syscall                                    NtGetContextThread return
   22    syscall                             NtQueryInformationThread entry
```

```
C:\>dtrace -V
dtrace: Sun D 1.13

C:\>dtrace -l | grep -v "syscall" | grep -v "etw"
   ID   PROVIDER            MODULE                          FUNCTION NAME
    1     dtrace                                                     BEGIN
    2     dtrace                                                     END
    3     dtrace                                                     ERROR
 2997    profile                                                     profile-97
 2998    profile                                                     profile-199
 2999    profile                                                     profile-499
 3000    profile                                                     profile-997
 3001    profile                                                     profile-1999
 3002    profile                                                     profile-4001
 3003    profile                                                     profile-4999
 3004    profile                                                     tick-1
 3005    profile                                                     tick-10
 3006    profile                                                     tick-100
 3007    profile                                                     tick-500
 3008    profile                                                     tick-1000
 3009    profile                                                     tick-5000
 3044    profile                                                     tick-5sec
```

```
C:\>dtrace -ln "syscall::*Read*:entry"
   ID   PROVIDER            MODULE                          FUNCTION NAME
   30    syscall                                    NtReadOnlyEnlistment entry
  140    syscall                                     NtReadRequestData entry
  170    syscall                                NtWorkerFactoryWorkerReady entry
  234    syscall                                     NtReadFileScatter entry
  608    syscall                                   NtReadVirtualMemory entry
  614    syscall                                              NtReadFile entry

C:\>dtrace -ln "syscall::*Write*:entry"
   ID   PROVIDER            MODULE                          FUNCTION NAME
   40    syscall                                             NtWriteFile entry
  116    syscall                                          NtGetWriteWatch entry
  224    syscall                                NtFlushProcessWriteBuffers entry
  332    syscall                                   NtWriteVirtualMemory entry
  356    syscall                                      NtFlushWriteBuffer entry
  370    syscall                                     NtWriteRequestData entry
  532    syscall                                      NtWriteFileGather entry
  632    syscall                                       NtResetWriteWatch entry

C:\>dtrace -ln "syscall::*View*:entry"
   ID   PROVIDER            MODULE                          FUNCTION NAME
  516    syscall                                    NtUnmapViewOfSectionEx entry
  518    syscall                                       NtMapViewOfSection entry
  638    syscall                                  NtAlpcCreateSectionView entry
  704    syscall                                  NtAlpcDeleteSectionView entry
  878    syscall                                    NtUnmapViewOfSection entry
  918    syscall                                       NtMapViewOfSectionEx entry
```

```
C:\>dtrace -Fn "syscall:::entry /execname==\"notepad.exe\"/ { @num[probefunc] = count(); }"
dtrace: description 'syscall:::entry ' matched 464 probes


  NtCreateFile                                                  1
  NtQueryAttributesFile                                         1
  NtQueryInformationFile                                        1
  NtQueryValueKey                                               1
  NtWriteFile                                                   1
  NtEnumerateKey                                                2
  NtQueryInformationToken                                       2
  NtSetInformationFile                                          2
  NtSetInformationProcess                                       2
  NtSetTimer2                                                   2
  NtWaitForWorkViaWorkerFactory                                 2
  NtTraceEvent                                                  4
  NtClearEvent                                                  6
  NtOpenKeyEx                                                   6
  NtOpenEvent                                                   7
  NtQueryKey                                                   10
  NtAssociateWaitCompletionPacket                              12
  NtSetInformationThread                                       16
  NtAlpcSendWaitReceivePort                                    30
  NtOpenFile                                                  135
  NtQueryDirectoryFileEx                                      135
  NtClose                                                     138
  NtQueryInformationProcess                                   138
  NtCallbackReturn                                            616
```

```
C:\>dtrace -n "syscall:::entry { @num[pid,execname] = count(); }"
dtrace: description 'syscall:::entry ' matched 464 probes


     5492  RuntimeBroker.                                  1
        0  DismHost.exe                                    2
        0  VSSVC.exe                                       2
        0  svchost.exe                                     2
     8376  smartscreen.ex                                  3
     1248  TrustedInstall                                  6
     1544  svchost.exe                                     6
     9260  wimserv.exe                                     6
     3584  vmtoolsd.exe                                    7
     8000  vmtoolsd.exe                                   11
     7560  cmd.exe                                        14
     1380  svchost.exe                                    15
     1568  RuntimeBroker.                                 20
     4144  svchost.exe                                    20
     3564  vmms.exe                                       24
     9408  WinRAR.exe                                     27
     4528  vmcompute.exe                                  30
      480  svchost.exe                                    46
     1988  svchost.exe                                    89
     3184  svchost.exe                                    98
     1152  ctfmon.exe                                    108
     4844  wuauclt.exe                                   126
```

```
C:\>dtrace -Fn "tick-5sec { exit(0);} syscall:::entry { @num[probefunc] = count(); }" | tail -20
dtrace: description 'tick-5sec ' matched 465 probes
  NtCreateFile                                                  771
  NtReleaseMutant                                               860
  NtQueryVirtualMemory                                          878
  NtSetInformationKey                                          1094
  NtSetInformationFile                                         1152
  NtEnumerateKey                                               1215
  NtOpenThreadToken                                            1286
  NtCreateKey                                                  1295
  NtEnumerateValueKey                                          1312
  NtQueryInformationFile                                       1953
  NtWriteFile                                                  2476
  NtQuerySecurityObject                                        2669
  NtQueryValueKey                                              3089
  NtWaitForSingleObject                                        3380
  NtQueryDirectoryFileEx                                       4225
  NtOpenFile                                                   4237
  NtQueryInformationToken                                      6111
  NtOpenKeyEx                                                  7470
  NtClose                                                     14041
  NtQueryKey                                                  15949
```

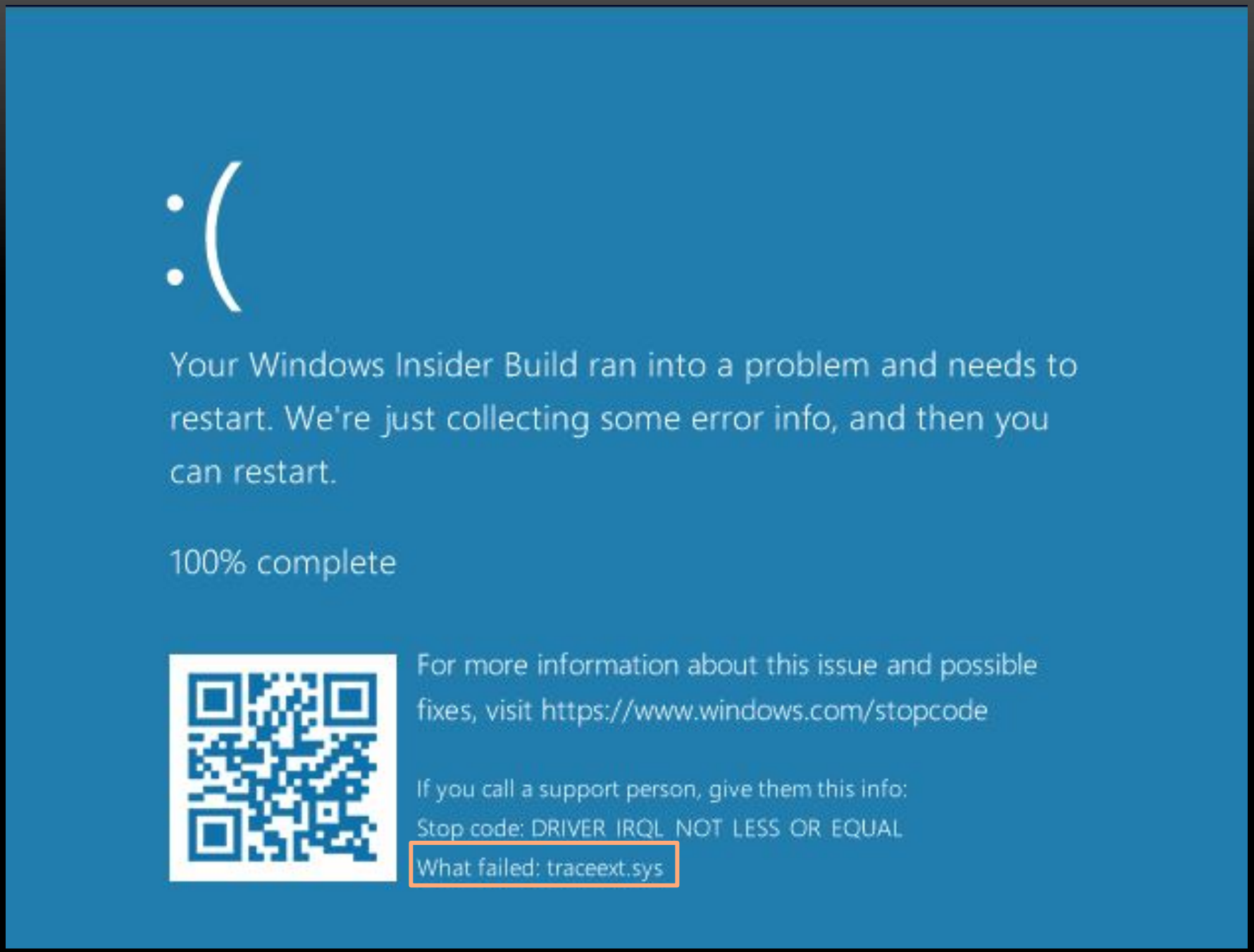
- ✓ It is possible to use a different type of provider named "fbt" (function boundary tracing), which tracks the sequence of system calls being executed through the NTFS in the kernel.

- ✓ The "fbt" provider only it is available when there is kernel debugger attached to the Windows 10.

```
C:\>dtrace -Fn "tick-5sec { exit(0);} syscall:::entry /execname == \"chr
ome.exe\"/ { @num[probefunc] = count(); }" | tail -25
dtrace: description 'tick-5sec ' matched 465 probes
  NtDeviceIoControlFile                                    32
  NtDuplicateObject                                        40
  NtFreeVirtualMemory                                      50
  NtAllocateVirtualMemory                                  56
  NtQueryInformationThread                                 75
  NtFindAtom                                              163
  NtSetTimerResolution                                    187
  NtQuerySystemInformation                                202
  NtCreateEvent                                           328
  NtClose                                                 381
  NtQueryInformationProcess                               396
  NtClearEvent                                            428
  NtAlertThreadByThreadId                                 604
  NtWaitForAlertByThreadId                                604
  NtSetIoCompletionEx                                     684
  NtAssociateWaitCompletionPacket                        1020
  NtSetIoCompletion                                      1050
  NtDelayExecution                                       1215
  NtFlushProcessWriteBuffers                             1335
  NtRemoveIoCompletionEx                                 1702
  NtReadFile                                             2175
  NtWriteFile                                            2242
  NtSetEvent                                             2824
  NtWaitForSingleObject                                  4319
  NtRemoveIoCompletion                                   8600
```

```
C:\>dtrace -n "profile-997hz { @[pid, execname] = count( ); }"
dtrace: description 'profile-997hz ' matched 1 probe


     0  audiodg.exe                                                    1
   440  smss.exe                                                       1
   872  fontdrvhost.ex                                                 1
  1028  wlrmdr.exe                                                     1
  1136  svchost.exe                                                    1
  1368  svchost.exe                                                    1
  1400  svchost.exe                                                    1
  1532  svchost.exe                                                    1
  1652  svchost.exe                                                    1
  1728  userinit.exe                                                   1
  2176  svchost.exe                                                    1
  2512  RuntimeBroker.                                                 1
  2528  svchost.exe                                                    1
  2672  svchost.exe                                                    1
  3756  dasHost.exe                                                    1
  5004  svchost.exe                                                    1
  5828  RuntimeBroker.                                                 1
  6192  svchost.exe                                                    1
  6276  svchost.exe                                                    1
  6784  SkypeBackgroun                                                 1
  7944  SecurityHealth                                                 1
  8312  MicrosoftEdgeS                                                 1
  9084  svchost.exe                                                    1
 10052  svchost.exe                                                    1
```

```
C:\>dtrace -Fn "fbt:ntfs::/execname==\"WinRAR.exe\"/{}" | more
dtrace: description 'fbt:ntfs::' matched 7752 probes
CPU FUNCTION
  0  -> NtfsFsdDispatchWait
  0    -> memset
  0    <- memset
  0    -> NtfsFsdDispatchSwitch
  0      -> NtfsInitializeTopLevelIrp
  0      <- NtfsInitializeTopLevelIrp
  0      -> memset
  0      <- memset
  0      -> NtfsInitializeIrpContextInternal
  0      <- NtfsInitializeIrpContextInternal
  0      -> NtfsUpdateIrpContextWithTopLevel
  0      <- NtfsUpdateIrpContextWithTopLevel
  0      -> NtfsPreRequestProcessingExtend
  0      <- NtfsPreRequestProcessingExtend
  0      -> NtfsCommonQueryInformation
  0        -> NtfsAcquireExclusiveFcb
  0        <- NtfsAcquireExclusiveFcb
  0        -> TxfSetupTransactionContextFromCcb
  0        <- TxfSetupTransactionContextFromCcb
  0        -> NtfsQueryNameInfo
```


:(
Your Windows Insider Build ran into a problem and needs to restart. We're just collecting some error info, and then you can restart.
100% complete
For more information about this issue and possible fixes, visit https://www.windows.com/stopcode
If you call a support person, give them this info:
Stop code: DRIVER_IRQL_NOT_LESS_OR_EQUAL
What failed: traceext.sys

```
1: kd> k
 # Child-SP          RetAddr           Call Site
00 fffffd8d`c02a0198 fffff802`21fe5469 nt!KeBugCheckEx
01 fffffd8d`c02a01a0 fffff802`21fe17a5 nt!KiBugCheckDispatch+0x69
02 fffffd8d`c02a02e0 fffff802`217b8e1e nt!KiPageFault+0x465
03 fffffd8d`c02a0478 fffff803`01e932bf traceext!StpGetArgVal+0xe
04 fffffd8d`c02a0480 fffff803`01e95e2c DTrace!dtrace_dif_variable+0x1e7
05 fffffd8d`c02a0540 fffff803`01e972d8 DTrace!dtrace_dif_emulate+0x754
06 fffffd8d`c02a0760 fffff802`217b76cd DTrace!dtrace_probe+0x478
07 fffffd8d`c02a0930 fffff802`217c16cc traceext!dtrace_probe+0x29
08 fffffd8d`c02a0980 fffff802`226949d4 traceext!StpCallbackEntry+0x7c
09 fffffd8d`c02a09e0 fffff802`21fe534d nt!KiTrackSystemCallEntry+0xd4
0a fffffd8d`c02a0a40 00007ff9`2edfc164 nt!KiSystemServiceExitPico+0x238
0b 000000ac`bc7fb918 00000000`00000000 0x00007ff9`2edfc164
1: kd> .lastevent
Last event: Break instruction exception - code 80000003 (first/second chance not available)
  debugger time: Sun Apr 28 22:00:04.067 2019 (UTC - 7:00)
1: kd> lmv m traceext
Browse full module list
start             end                 module name
fffff802`217b6000 fffff802`217d1000   traceext   (pdb symbols)          c:\symbols\traceext
    Loaded symbol image file: traceext.sys
    Image path: traceext.sys
    Image name: traceext.sys
    Browse all global symbols  functions  data
    Image was built with /Brepro flag.
    Timestamp:        414AF89D (This is a reproducible build file hash, not a timestamp)
    CheckSum:         00016962
    ImageSize:        0001B000
    Translations:     0000.04b0 0000.04e4 0409.04b0 0409.04e4
    Information from resource tables:
1: kd> x /D traceext!s*
 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

fffff802`217b8e10 traceext!StpGetArgVal (void)
fffff802`217c1770 traceext!StpDisable (void)
fffff802`217c1880 traceext!StpProvide (void)
fffff802`217c1710 traceext!StpEnable (void)
fffff802`217b8e50 traceext!StpGetContext (void)
fffff802`217c17c0 traceext!StpGetArgType (void)
fffff802`217c1970 traceext!StpDestroy (void)
fffff802`217c1650 traceext!StpCallbackEntry (<no parameter info>)
fffff802`217b9146 traceext!strcmp (<no parameter info>)
fffff802`217c16e0 traceext!StpCallbackReturn (<no parameter info>)
```

Traceext.sys: exposes functionality used by DTrace to tracing.

```
1: kd> uf fffff802`217b8e10
traceext!StpGetArgVal:
fffff802`217b8e10 488b542428      mov     rdx,qword ptr [rsp+28h]
fffff802`217b8e15 4885d2          test    rdx,rdx
fffff802`217b8e18 742a            je      traceext!StpGetArgVal+0x34 (fffff802`217b8e44)  Branch

traceext!StpGetArgVal+0xa:
fffff802`217b8e1a 4983e0fe        and     r8,0FFFFFFFFFFFFFFFEh
fffff802`217b8e1e 410fb74008      movzx   eax,word ptr [r8+8]
fffff802`217b8e23 443bc8          cmp     r9d,eax
fffff802`217b8e26 7d1c            jge     traceext!StpGetArgVal+0x34 (fffff802`217b8e44)  Branch

traceext!StpGetArgVal+0x18:
fffff802`217b8e28 8b4210          mov     eax,dword ptr [rdx+10h]
fffff802`217b8e2b 443bc8          cmp     r9d,eax
fffff802`217b8e2e 7d0c            jge     traceext!StpGetArgVal+0x2c (fffff802`217b8e3c)  Branch

traceext!StpGetArgVal+0x20:
fffff802`217b8e30 488b4208        mov     rax,qword ptr [rdx+8]

traceext!StpGetArgVal+0x24:
fffff802`217b8e34 4963c9          movsxd  rcx,r9d
fffff802`217b8e37 488b04c8        mov     rax,qword ptr [rax+rcx*8]
fffff802`217b8e3b c3              ret

traceext!StpGetArgVal+0x2c:
fffff802`217b8e3c 442bc8          sub     r9d,eax
fffff802`217b8e3f 488b02          mov     rax,qword ptr [rdx]
fffff802`217b8e42 ebf0            jmp     traceext!StpGetArgVal+0x24 (fffff802`217b8e34)  Branch

traceext!StpGetArgVal+0x34:
fffff802`217b8e44 33c0            xor     eax,eax
fffff802`217b8e46 c3              ret
1: kd> vertarget
Windows 10 Kernel Version 18362 MP (2 procs) Free x64
Product: WinNt, suite: TerminalServer SingleUserTS
Built by: 18362.1.amd64fre.19h1_release.190318-1202
Machine Name:
Kernel base = 0xfffff802`21e17000 PsLoadedModuleList = 0xfffff802`2225a290
Debug session time: Sun Apr 28 19:11:07.480 2019 (UTC - 7:00)
System Uptime: 0 days 2:40:06.813
```

ANTI-VM

- ✓ It is extremely easy writing malware samples using anti-VM techniques designed to detect VMWare (checking I/O port communication), VirtualBox, Parallels, SeaBIOS emulator, QEMU emulator, Bochs emulator, QEMU emulator, Hyper-V, Innotek VirtualBox, sandboxes (Cuckoo).

- ✓ Furthermore, there are dozens of techniques that could be used for detection Vmware sandboxes:

  - ✓ Examing the registry (OpenSubKey( ) function) to try to find entries related to tools installed in the guest (HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\VirtualMachine\Guest\Parameters).

  - ✓ Using WMI to query the Win32_BIOS management class to interact with attributes from the physical machine.

- ✓ We have already know every single anti-VM technique around the world and all of them are documented.

- ✓ Most current techniques use WMI and it is quick to write a C# program using them.

```
using System;
using System.Management;

namespace Test_VM
{
    class Program
    {
        static void Main(string[] args)
        {
            ManagementClass biosClass =
            new ManagementClass("Win32_BIOS");
            ManagementObjectCollection biosc =
                biosClass.GetInstances();
            ManagementObjectCollection.ManagementObjectEnumerator
                biosEnumerator =
                biosc.GetEnumerator();
            while (biosEnumerator.MoveNext())
            {
                ManagementObject biosc1 =
                    (ManagementObject)biosEnumerator.Current;
                Console.WriteLine(
                    "Attributes:\n\n" + "Version:\t " + biosc1["version"].ToString( ));
                Console.WriteLine(
                    "SerialNumber:\t " + biosc1["SerialNumber"].ToString());
                Console.WriteLine(
                    "OperatingSystem:\t " + biosc1["TargetOperatingSystem"].ToString());
                Console.WriteLine(
                    "Manufacturer:\t " + biosc1["Manufacturer"].ToString());
            }
            //return 0;
        }
    }
}
```

- ✓ The code from last slide does not have any news:
  - ✓ The ManagementClass class represents a Common Information Model (CIM) management class.
  - ✓ Win32_BIOS WMI class represents the attributes of BIOS and members of this class enable you to access WMI data using a specific WMI class path.
  - ✓ GetInstances( ) acquires a collection of all instances of the class.
  - ✓ GetEnumerator( ) returns the enumerator (IEnumerator) for the collection.
  - ✓ IEnumerator.Current( ) returns the same object.
  - ✓ IEnumerator.MoveNext( ) advances the enumerator to the next element of the collection.

❑ Physical host:

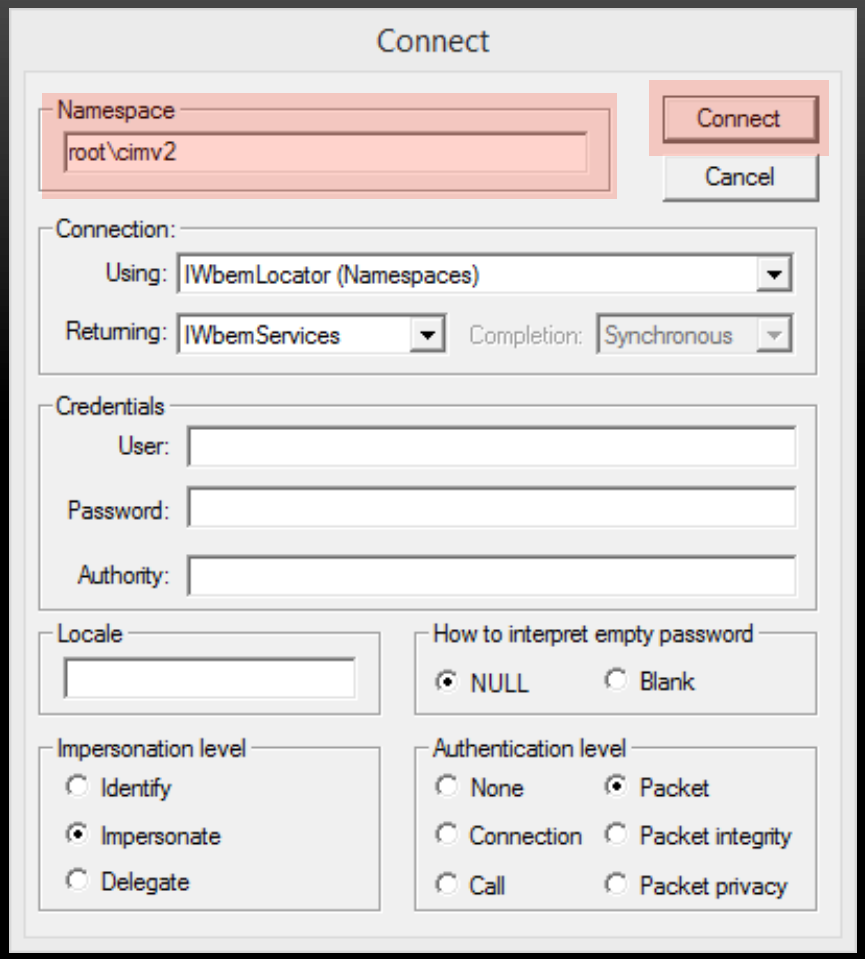
```
C:\> Test_VM.exe
Attributes:
Version:        DELL   - 6222004
SerialNumber:   D5965S1
OperatingSystem:        0
Manufacturer:   Dell Inc.
```

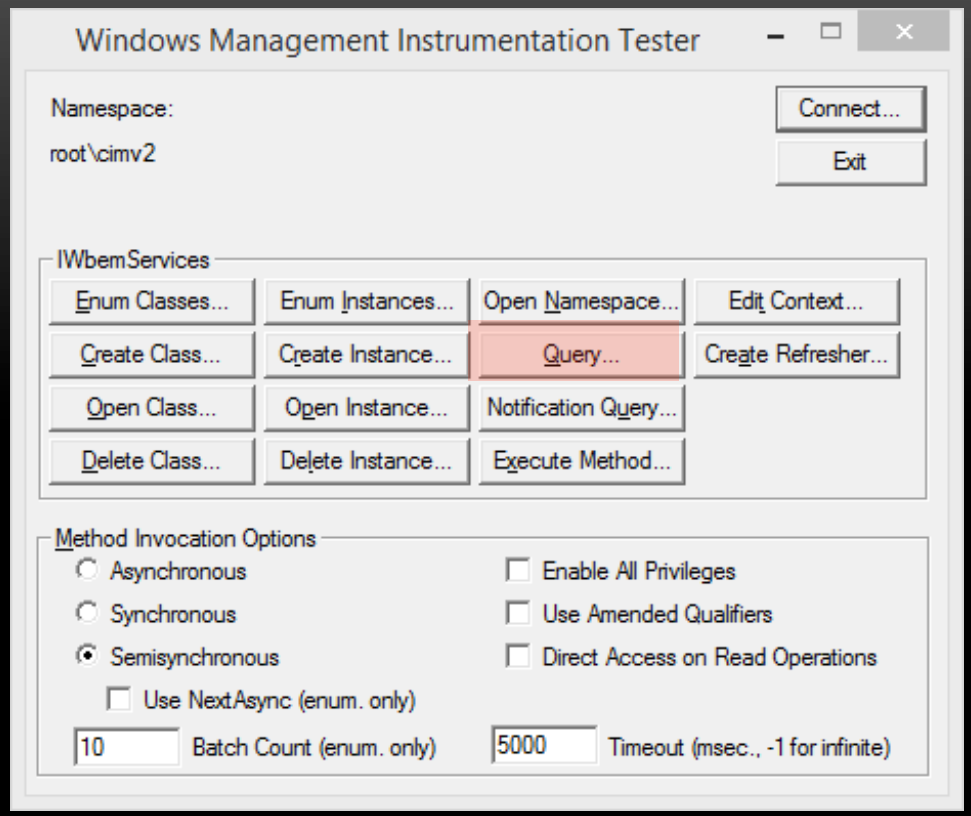
❑ Guest virtual machine:

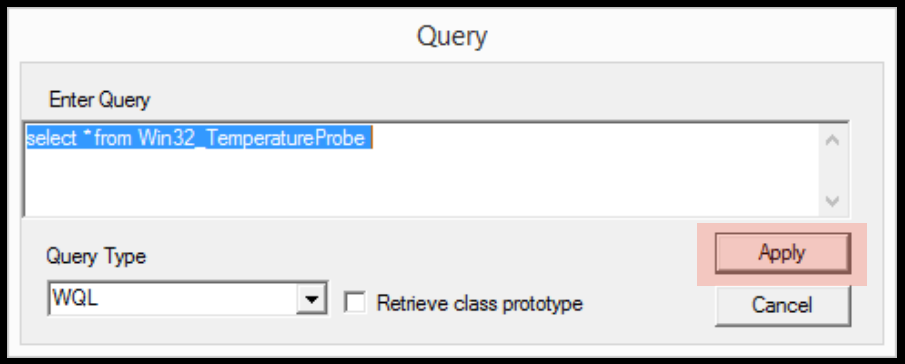
```
E:\> Test_VM.exe
Attributes:
Version:        LENOVO - 6040000
SerialNumber:   VMware-56 4d 8d c3 a7 c7
e5 2b-39 d6 cc 93 bf 90 28 2d
OperatingSystem:        0
Manufacturer:   Phoenix Technologies LTD
```

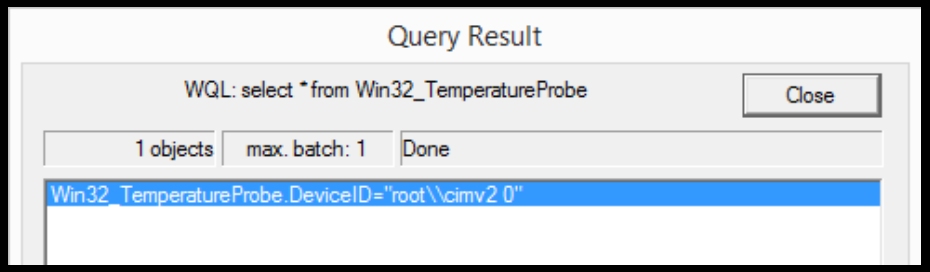
```
namespace TestVM_3
{
    class Program
    {
        static void Main(string[] args)
        {
            ManagementClass tempClass =
            new ManagementClass("Win32_TemperatureProbe");
            ManagementObjectCollection tempinstance =
                tempClass.GetInstances() ;
            foreach (ManagementObject aborges in tempinstance)
            {
                string buffer = aborges.GetPropertyValue("CurrentReading").ToString( );
                {

                    Console.WriteLine("Temperature:\t" + buffer);

                }
            }
        }
    }
}
```

```
c:\Users\Administrador\source\repos\TestVM_3\TestVM_3\bin\Debug>TestVM_3.exe

Unhandled Exception: System.NullReferenceException: Object reference not set to an instance of an object.
   at TestVM_3.Program.Main(String[] args) in c:\users\administrador\source\repos\TestVM_3\TestVM_3\Program.cs:line 16
```



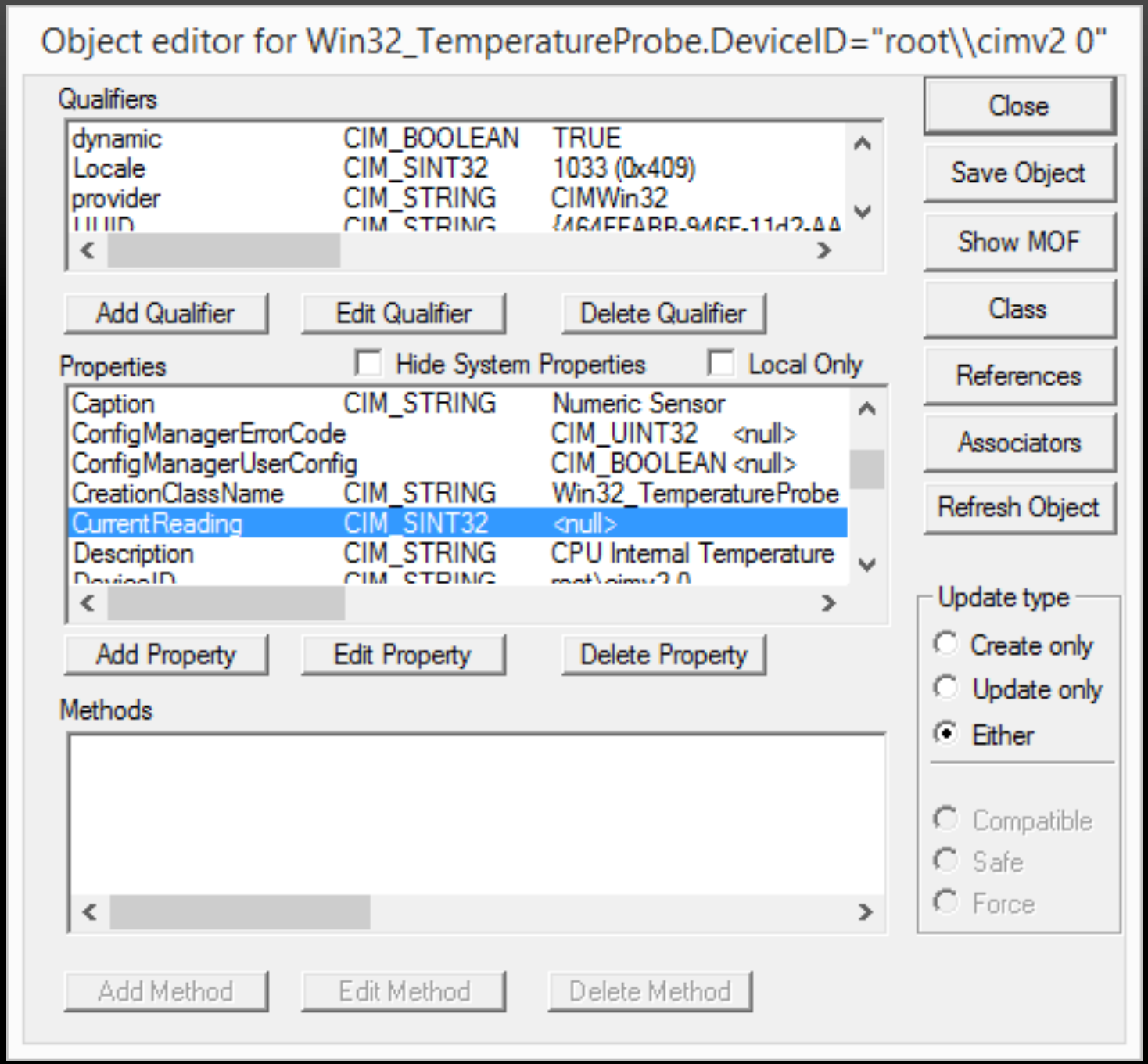






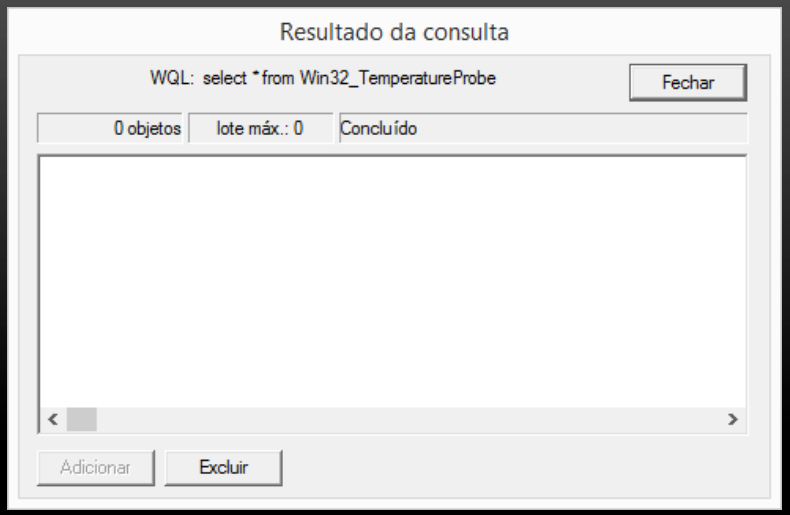
Double-click the result....

ALEXANDRE BORGES – MALWARE AND SECURITY RESEARCHER

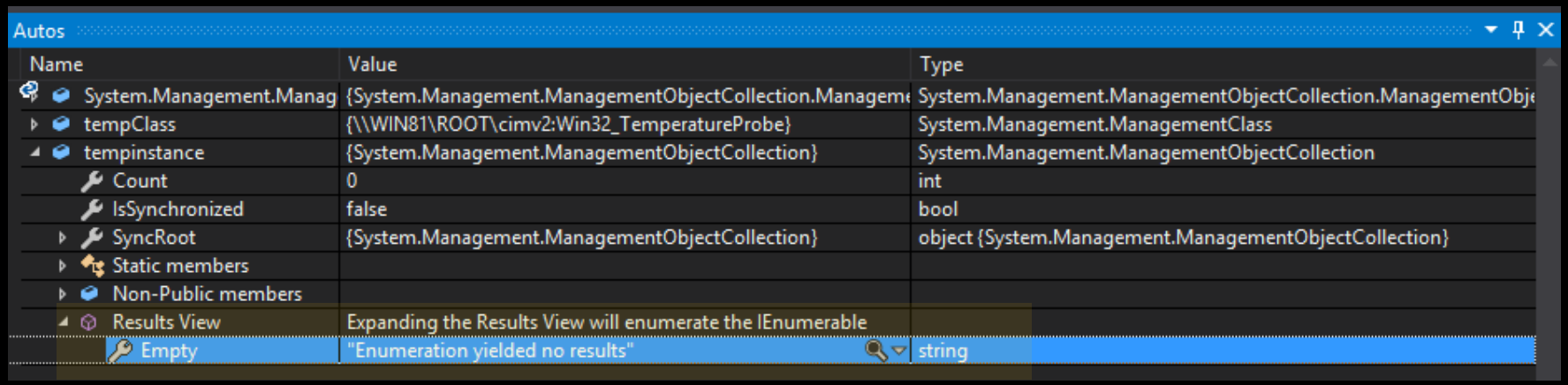

Object editor for Win32_TemperatureProbe.DeviceID="root\\cimv2 0"
Qualifiers
dynamic CIM_BOOLEAN TRUE
Locale CIM_SINT32 1033 (0x409)
provider CIM_STRING CIMWin32
Add Qualifier
Edit Qualifier
Delete Qualifier
Properties
Hide System Properties
Local Only
Caption CIM_STRING Numeric Sensor
ConfigManagerErrorCode CIM_UINT32 <null>
ConfigManagerUserConfig CIM_BOOLEAN <null>
CreationClassName CIM_STRING Win32_TemperatureProbe
CurrentReading CIM_SINT32 <null>
Description CIM_STRING CPU Internal Temperature
Add Property
Edit Property
Delete Property
Methods
Add Method
Edit Method
Delete Method
Close
Save Object
Show MOF
Class
References
Associators
Refresh Object
Update type
Create only
Update only
Either
Compatible
Safe
Force

```
using System;
using System.Management;

namespace TestVM_3
{
    public class Program
    {
        public static void Main(string[] args)
        {
            ManagementClass tempClass =
            new ManagementClass("Win32_TemperatureProbe");
            ManagementObjectCollection tempinstance = tempClass.GetInstances();

            foreach (ManagementObject aborges in tempinstance)
            {
                try
                {
                    if (!string.IsNullOrWhiteSpace(aborges.GetPropertyValue("Status").ToString()))
                    {
                        string buffer = aborges.GetPropertyValue("Status").ToString();
                        Console.WriteLine("\nStatus: " + buffer + "  Thus, the program is running in a physical host!");
                    }
                            }
                catch (NullReferenceException e)
                {
                    Console.WriteLine("\nSomething Wrong Happened!", e);
                }
            }
            Console.WriteLine("This program IS RUNNING in a virtual machine!");
        }
    }
}
```

[26]	{System.Management.PropertyData}	object {System.Management.PropertyData}
[27]	{System.Management.PropertyData}	object {System.Management.PropertyData}
IsArray	false	bool
IsLocal	true	bool
Name	"Status"	string
Origin	"CIM_ManagedSystemElement"	string
Qualifiers	{System.Management.QualifierDataCollection}	System.Management.QualifierDataCollection
Type	String	System.Management.CimType
Value	"OK"	object {string}
Non-Public membe		



- ✓ There is not support for acquiring temperature data in virtual machines.
- ✓ Therefore, malwares are able to know whether they are running on virtual machines or not. ☺



✓ Physical Host:

C:\> VM_Test2.exe

Status: OK Thus, the program is running in a physical host!

✓ Virtual Machine:

C:\> VM_Test2.exe

This program IS RUNNING in a virtual machine!

❑ FEW CONCLUSIONS:

- ✓ Before trying to unpack modern protectors, it is really necessary to understand the common anti-reversing techniques.
- ✓ MIASM, METASM and TRITON are amazing tools to handle and deobfuscate complex codes.
- ✓ Emulation is an possible alternative to understand small and complicated piece of codes.
- ✓ DTrace has done an excellent job on Solaris and it may be an excellent tool on Windows operating system. Stay tuned. ☺
- ✓ Although excellent researches have found sophisticated anti-vm techniques, many other simples and smart ones exist. Take care.

❖ Acknowledgments to:

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- ✓You, who reserved some time attend my talk.

✓Remember: the best of this life are people. ☺



- ✓ Malware and Security Researcher.
- ✓ Speaker at DEFCON USA 2018
- ✓ Speaker at HITB2019 Amsterdam
- ✓ Speaker at CONFidence Conf. 2019
- ✓ Speaker at BSIDES 2018/2017/2016
- ✓ Speaker at H2HC 2016/2015
- ✓ Speaker at BHACK 2018
- ✓ Consultant, Instructor and Speaker on Malware Analysis, Memory Analysis, Digital Forensics and Rookits.
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THANK YOU FOR ATTENDING MY TALK. ☺

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