paloalto NETWORKS

Writing malware configuration parsers

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- Love to go for long jogs

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- Based in London
- Joined Palo Alto Networks since 2022
- Experienced in malware detection and threat intelligence

OUTLINE

- Introduction
- MCE workflow
- Case Study 1 - Guloader
- Case Study 2 - RedLine
- Summary

WARNING!

1. Isolate infected systems: Disconnect from networks and external devices.

2. Utilize virtual machines

3. Backup data: Ensure critical data is safely backed up.

4. You release and hold harmless Palo Alto Networks and Virus Bulletin, its affiliates, and contributors from any liability, claims, or damages arising from handling live computer viruses.

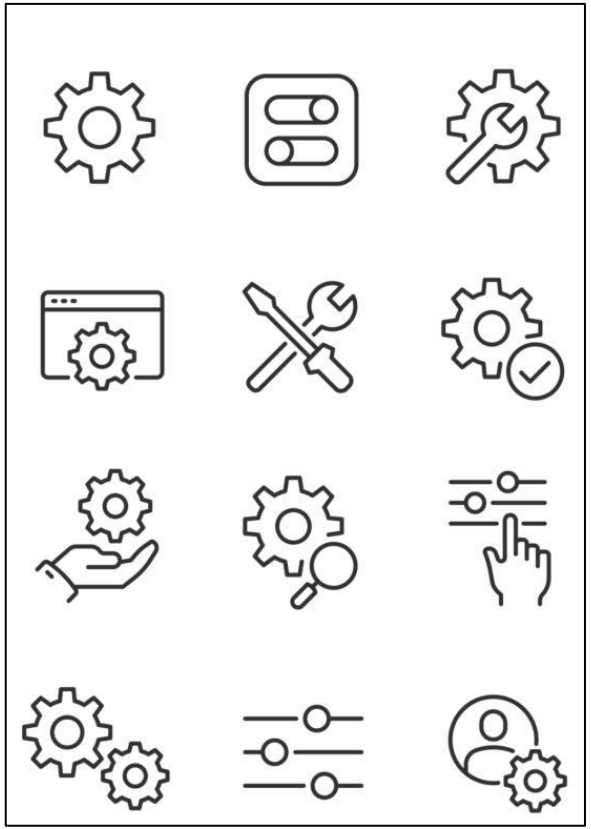
Get the stuff!

- https://tinyurl.com/VB2024MCE

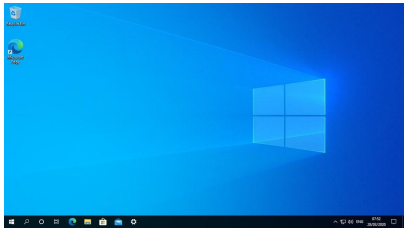
Background

What are malware configurations?

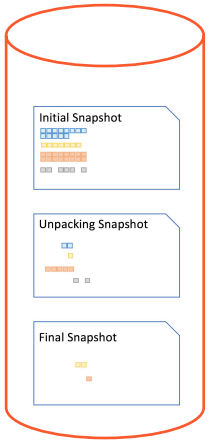
- Similar to ‘settings’ or ‘preferences’ in software
- Malware configuration defines the uniqueness of each instance
- C&C addresses, encryption keys, attack parameters and other IOCs
- Tough to obtain statically
- But can be extracted from process memory.



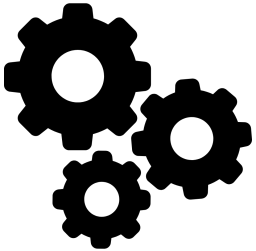
Malware Configuration Extraction Workflow



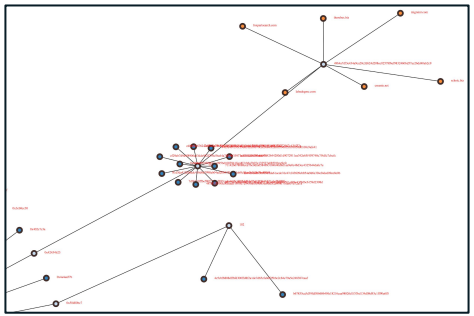
Sandbox



Snapshot Data



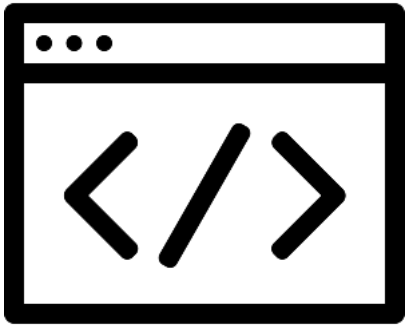
Memory Analysis and Malware Configuration Parsing



Malware Configs indexed

Malware Analysts Create Malware Config Extractors

Decrypting Malware Configuration



Encryption routine

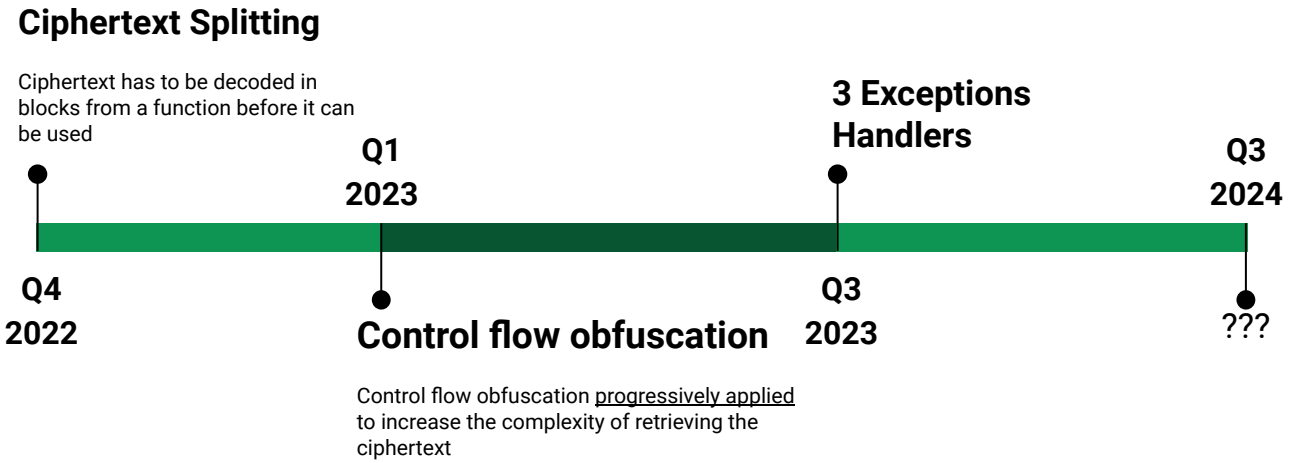
Encryption key

Ciphertext

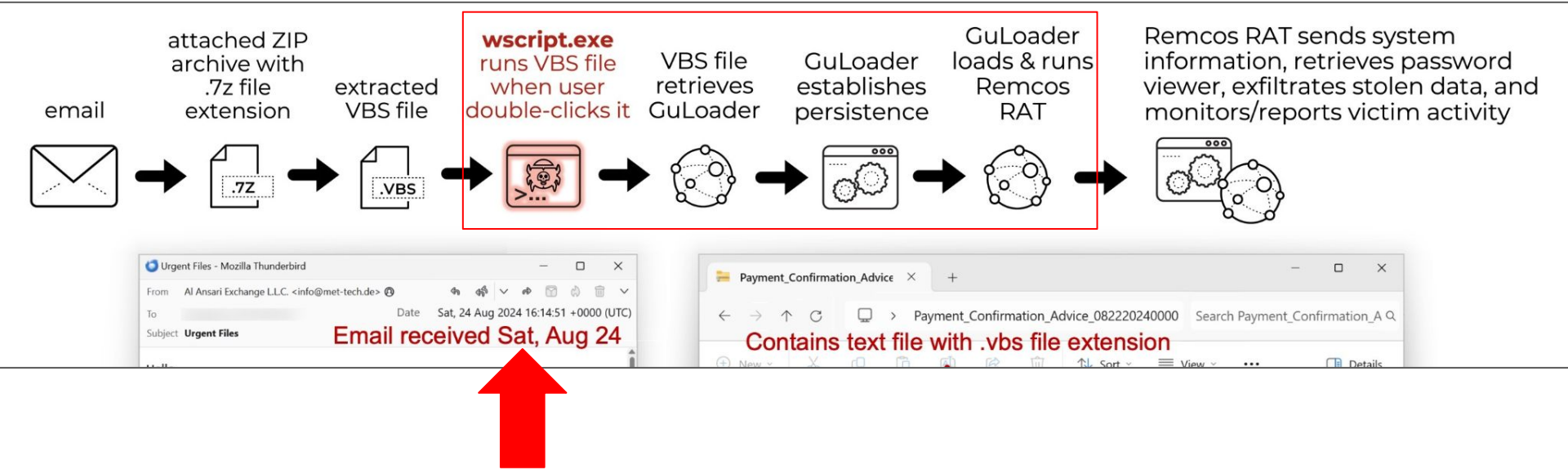
Case study:

Guloader

Evolutionary Journey Of Guloader's Configuration Tactics



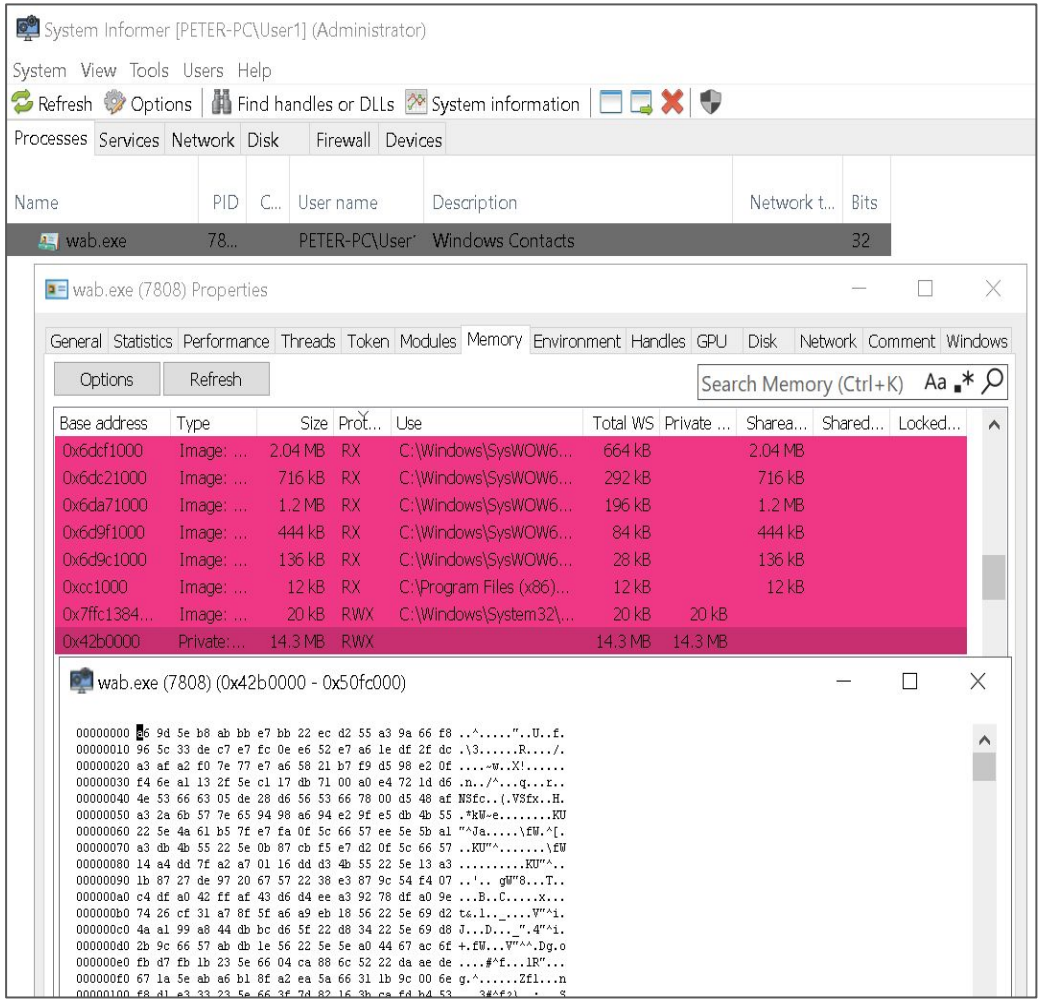
2024 August



https://x.com/Unit42_Intel/status/1828444963001995599

Dump Memory

1. Use System Informer (a.k.a. Process Hacker)
2. VBS -> Ps1 -> wab.exe
3. Look for wab.exe after Guloader is injected
4. Locate the RWX memory pages
5. Dump the memory pages after the sample has detonated



Control Flow Obfuscation

```
call    sub_40D945

mov     [ebp+18h], ebx
mov     ecx, [ebp+18h]
int     3                               ; Trap to Debugger
movsd
add     [esi+6F348E7Bh], cl

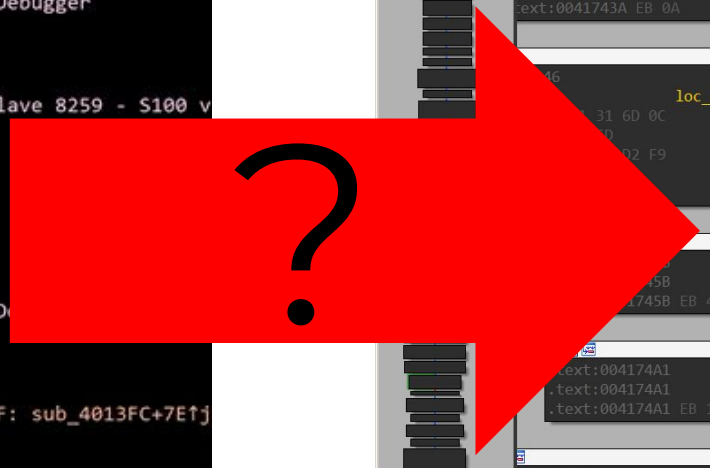
int     4Ch                             ; Z100 - Slave 8259 - S100 v
and     dh, [ebx-7465A846h]

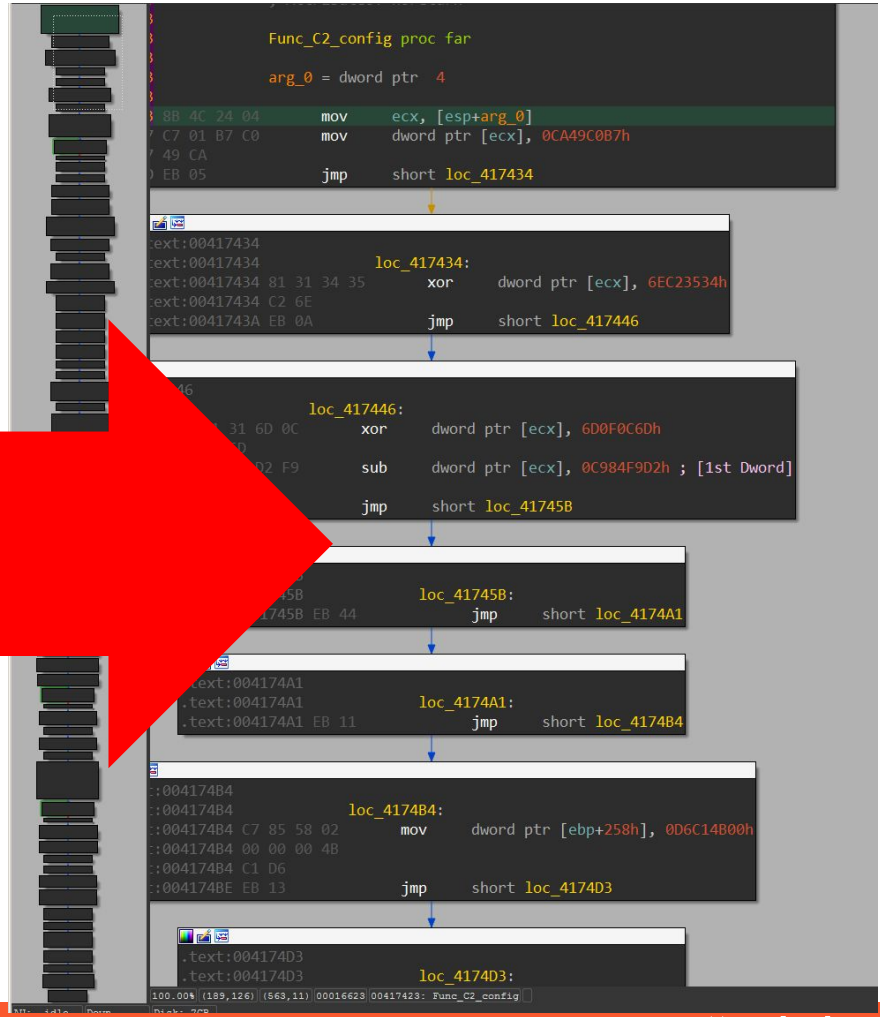
movsd
call    sub_40CE8A

mov     [ebp+98h], eax

int     3                               ; Trap to D
cmpsd
jle     short $+2

loc_40147C:                             ; CODE XREF: sub_4013FC+7E↑j
jb      short loc_40140B
test    al, 87h
push    ds
hlt
```





Diving into implementation of control flow obfuscation

1. SEH vs VEH
2. Locating the Vectored Exception Handler (VEH)
3. No easy way to do it via debugger unlike SEH
4. Locate VEH from NTDLL.dll walking the structure

Diving into implementation of control flow obfuscation

Demo 1.

- Locating VEH via the IDApython script

Analysing the VEH

1. **How VEH handles the exceptions ?**

2. How many junk bytes to skip ? (offset)

3. How is the EIP updated ?

Analysing the VEH

```
1  int __stdcall FN_VEH(PEXCEPTION_POINTERS ExceptionInfo)
2  {
3    DWORD ExceptionCode;
4
5    ExceptionCode = ExceptionInfo->ExceptionRecord->ExceptionCode;
6    if ( ExceptionCode != EXCEPTION_ACCESS_VIOLATION )
7    {
8      if ( ExceptionCode != EXCEPTION_ILLEGAL_INSTRUCTION
9        && ExceptionCode != EXCEPTION_PRIV_INSTRUCTION
10       && ExceptionCode != EXCEPTION_SINGLE_STEP
11       && ExceptionCode != EXCEPTION_BREAKPOINT )
12     {
13       return 0;                                  // exception NOT handled
14     }
15 FN_VEH_handles_exception:
16     FN_Get_Offset_Decode_key(ExceptionInfo);
17     FN_Get_Offset_Update_EIP();
18     return -1;                                   // exception handled
19   }
```

Analysing the VEH

```
pop     eax
xor     dword ptr [ebx], 0D62B9FCCh
int     3                       ; EXCEPTION_BREAKPOINT triggered!
-------------------------------------------------------------------
db 3,13h,19h,15h,'2',12h,0AFh,'IMp|',0E9h,4Dh,4Dh ; junk bytes
-------------------------------------------------------------------
add     dword ptr [ebx], 3FA3DA06h
```

EXCEPTION_BREAKPOINT

EXCEPTION_ACCESS_VIOLATION

```
mov     esi, 0D37212A5h
add     esi, 4C655390h
xor     esi, 1FD76635h          ; esi=0
mov     [esi], esi              ; EXCEPTION_ACCESS_VIOLATION
-------------------------------------------------------------------
db 1Ch,0C5h,74h,0C3h,4Ch,0F6h,8Fh,0FBh,0FAh,'36',92h,0Eh,0 ; junk bytes
-------------------------------------------------------------------
pop     esi
```

EXCEPTION_ILLEGAL_INSTRUCTION

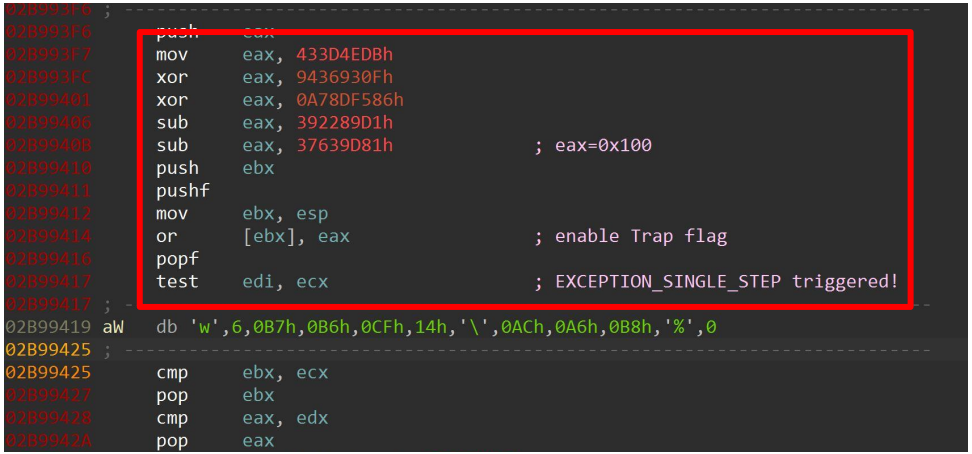
```
adc     byte ptr [ebx-781E6E5Ah], 3Ch ; '<'
test    [ebx-76655A7Bh], edx
;
db  65h ; e                         ; exception triggeered!
a4s db '4s',0FDh,0A0h,'%~',12h,'f9',0C8h,5Fh,85h,0CBh,5Ah,5,'N'
db 0C5h,0E5h,1Fh,0F3h,0CCh,0FBh,12h,0Dh,';',0EEh,0E4h,89h,0DCh,
```

EXCEPTION_PRIV_INSTRUCTION

```
mov     dword ptr [ebx], 0ACDB2BA7h
add     dword ptr [ebx], 9B37543h
xor     dword ptr [ebx], 80317A66h
sub     dword ptr [ebx], 36BFDA32h
sysret                          ; trigger exception!
;
aHz db 'Hz',0,0,0,0,0,0,0,0,0F7h,9Bh,19h,0D7h,'{',13h,1Ch,0A8h
;
```

Analysing the VEH

EXCEPTION_SINGLE_STEP



Analysing the VEH

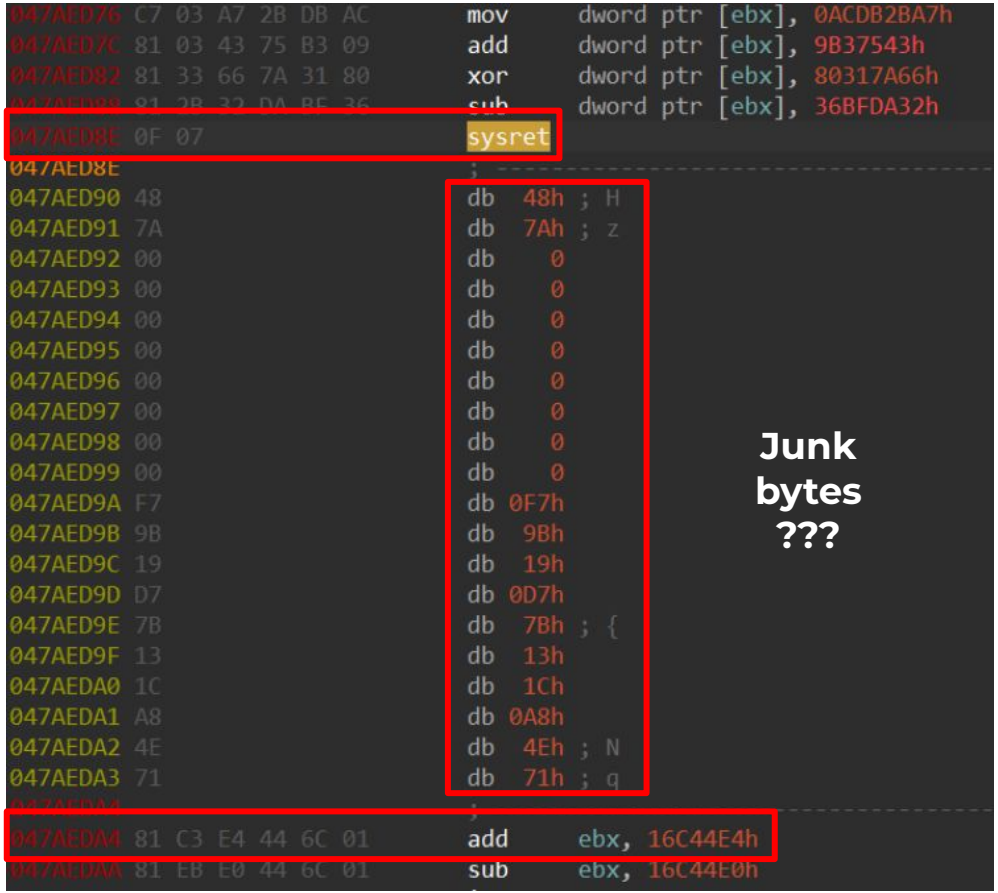
1. How VEH handles the exceptions ?

2. **How many junk bytes to skip ? (offset)**

3. How is the EIP updated ?

Analysing the VEH

Trigger !



Junk bytes ???

Updated EIP

Analysing the VEH

```
1  int __stdcall FN_VEH(PEXCEPTION_POINTERS ExceptionInfo)
2  {
3    DWORD ExceptionCode;
4
5    ExceptionCode = ExceptionInfo->ExceptionRecord->ExceptionCode;
6    if ( ExceptionCode != EXCEPTION_ACCESS_VIOLATION )
7    {
8      if ( ExceptionCode != EXCEPTION_ILLEGAL_INSTRUCTION
9        && ExceptionCode != EXCEPTION_PRIV_INSTRUCTION
10       && ExceptionCode != EXCEPTION_SINGLE_STEP
11       && ExceptionCode != EXCEPTION_BREAKPOINT )
12     {
13       return 0;                                  // exception NOT handled
14     }
15 FN_VEH_handles_exception:
16     FN_Get_Offset_Decode_key(ExceptionInfo);
17     FN_Get_Offset_Update_EIP();
18     return -1;                                   // exception handled
19   }
```

Analysing the VEH

```
1  int __usercall FN_Get_Offset_Decode_key@<ecx>(_EXCEPTION_POINTERS *a1@<eax>)
2  {
3    PCONTEXT ContextRecord; // eax
4    int result; // ecx
5    int count; // edx
6
7    ContextRecord = a1->ContextRecord;
8    result = 0x18;
9    count = 0;
10   while ( 1 )
11   {
12     count += 4;
13     if ( *(DWORD *)((char *)&ContextRecord->ContextFlags + count) )// check all HW BP registers are zero
14       break;
15     if ( count == 0x18 )
16       return 0xE1;                          // return offset decode key
17   }
18   return result;
19 }
```

Analysing the VEH

```
call    FN_Get_Offset_Decode_key
test    cl, cl
cmp     edx, ebx
mov     edx, 63C7099Ch
xor     edx, 6649E730h
test    ch, bh
add     edx, 1691B385h
cmp     ah, ch
add     edx, 0E3DF5E87h                 ; 0xB8
cmp     dx, 4070h
add     eax, edx                        ; _Context.EIP = _CONTEXT+0xB8
test    dl, cl
mov     edx, [eax]
add     edx, 0Ch                        ; Get enc offset*
cmp     dl, bl
call    FN_Get_Offset_Update_EIP
```

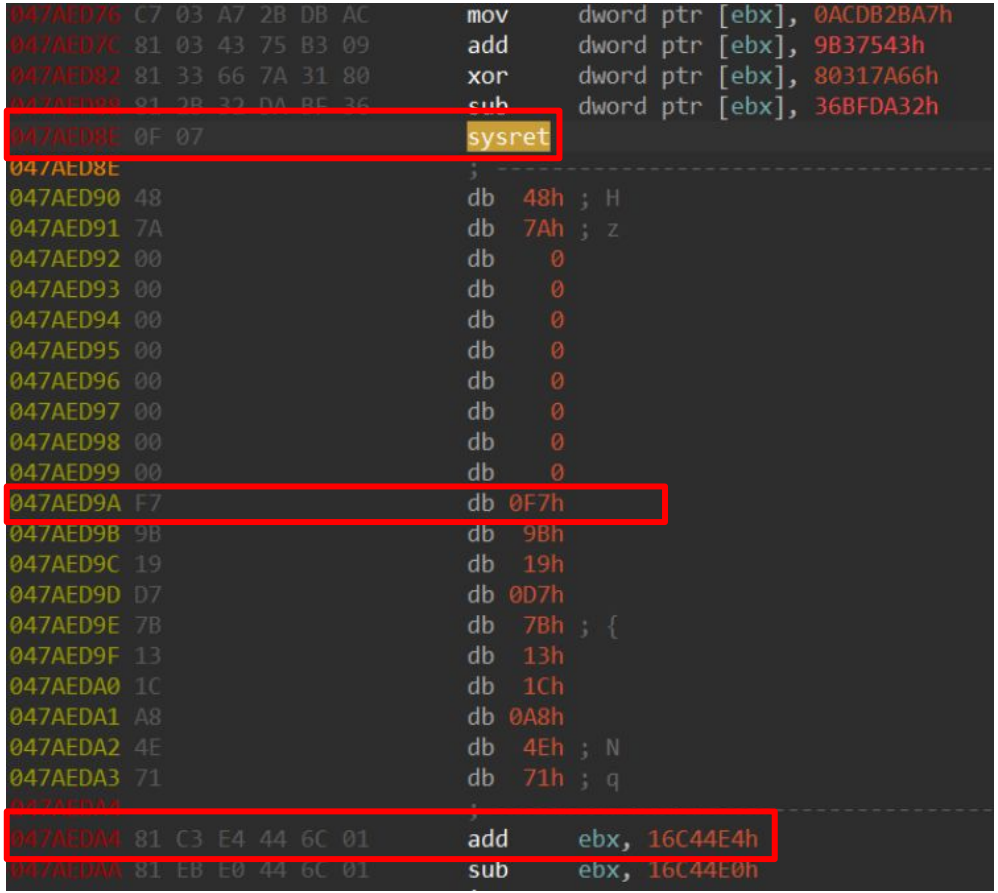
Analysing the VEH

Trigger !

0xC

Encrypted count

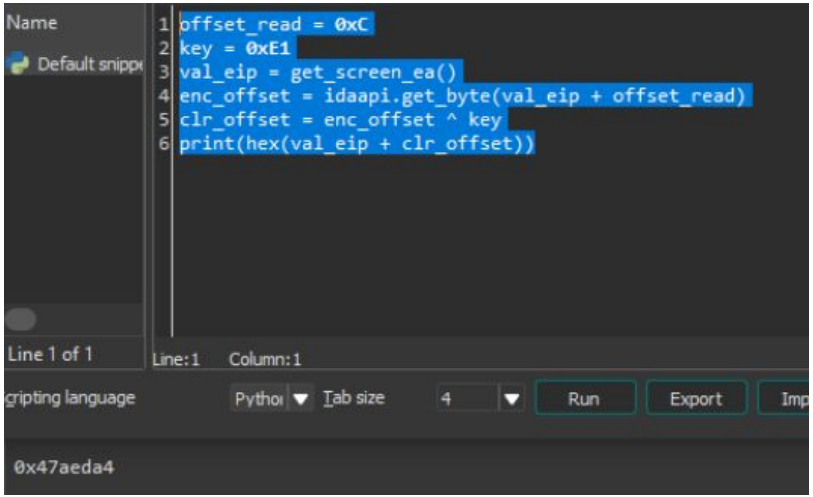
Updated EIP

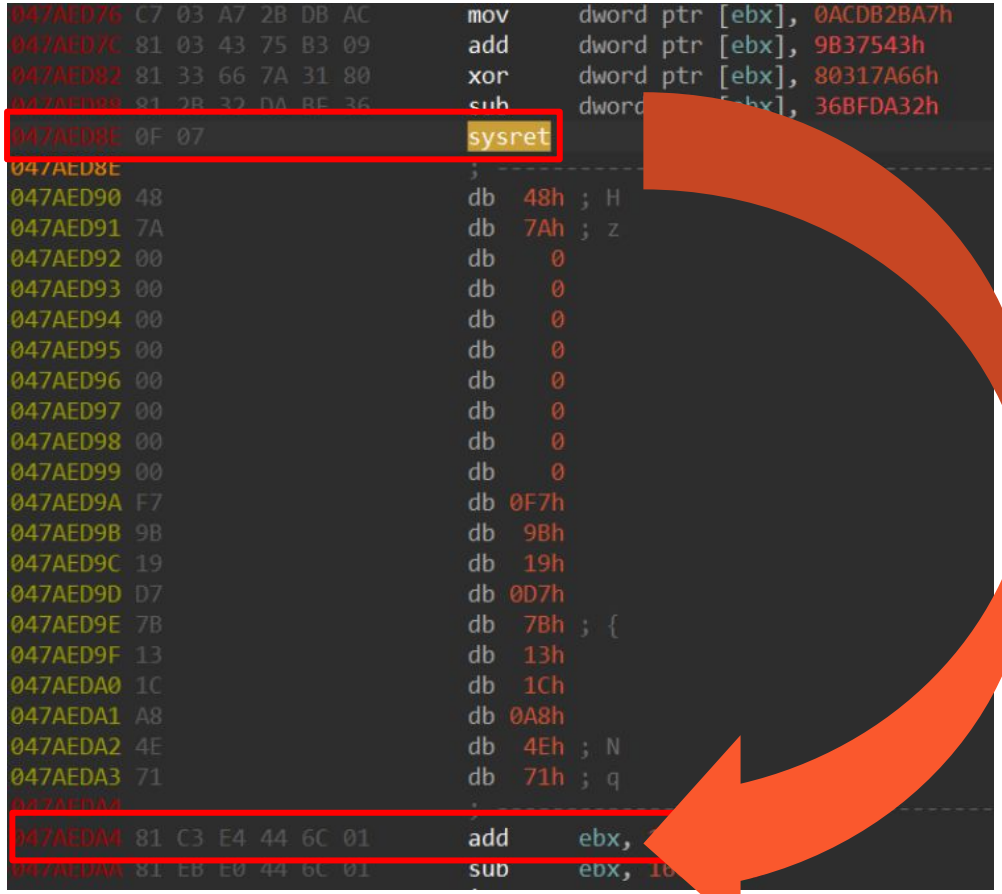


Analysing the VEH

```
1  _DWORD *__usercall FN_Get_Offset_Update_EIP@<eax>(
2          _DWORD *offset@<eax>,
3          unsigned __int8 *enc_offset@<edx>,
4          int offset_key@<ecx>)
5  {
6    *offset += offset_key ^ *enc_offset;
7    return offset;
8  }
```

Analysing the VEH





Decrypting Malware Configuration

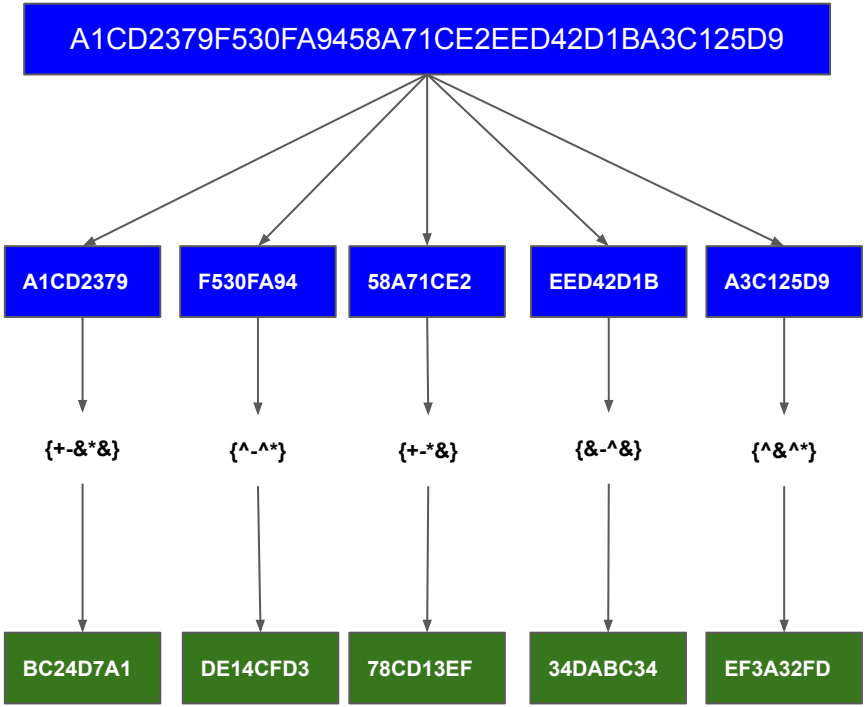
Simple
XOR

Predictable location of
encryption key

???

Ciphertext Splitting

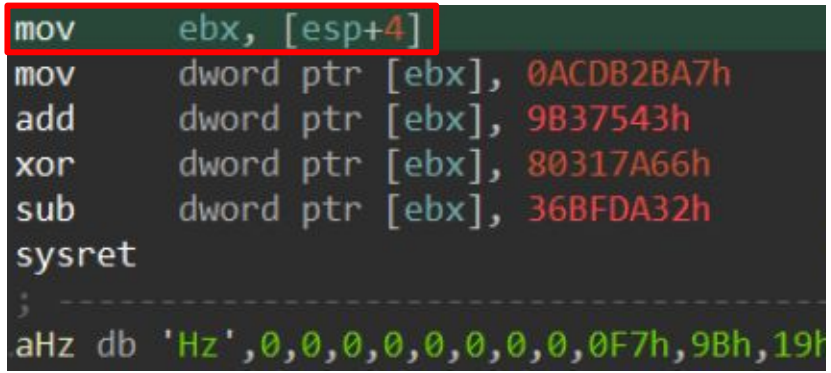
1. Ciphertext splitted into multiple DWORD
2. Each DWORD is encoded with different arithmetic operations
3. Stored as local variables in functions



Ciphertext Splitting

- Function starts with loading of address of encrypted cipher text

- Values from local variables are written into the address



Ciphertext Splitting

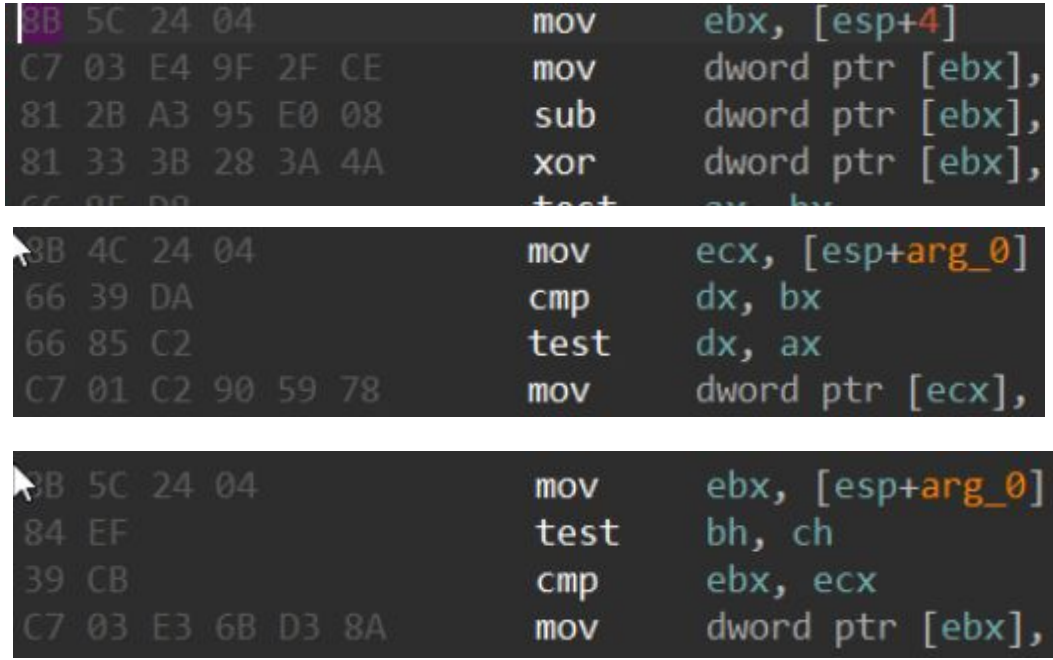
```
B = [0xACDB2BA7, 0x9B37543, 0x80317A66, 0x36BFDA32]
B1 = (B[0] + B[1]) & 0xFFFFFFFF
B2 = (B1 ^ B[2]) & 0xFFFFFFFF
result = (B2 - B[3]) & 0xFFFFFFFF
```

```
mov     ebx, [esp+4]
mov     dword ptr [ebx], 0ACDB2BA7h
add     dword ptr [ebx], 9B37543h
xor     dword ptr [ebx], 80317A66h
sub     dword ptr [ebx], 36BFDA32h
sysret
;
aHz db 'Hz',0,0,0,0,0,0,0,0,0F7h,9Bh,19h
```

First DWORD is the length of the ciphertext!

Locating the Encrypted Configs

- Function starts with “0x8B ?? 24 04”
- Yara it ?
- FP prone ?



Locating the Encrypted Configs

Demo 2 (DIY)

- Writing a yara rule to locate functions containing the encrypted configuration

- Using “Findcrypt-yara” IDA Pro plug-in https://github.com/polymorf/findcrypt-yara

Decrypting Malware Configuration

Simple
XOR

Predictable location of
encryption key

???

Locating the Decryption key

Demo 3

- Locate the decryption routine
- Locate the decryption key
- Locate the decryption key length

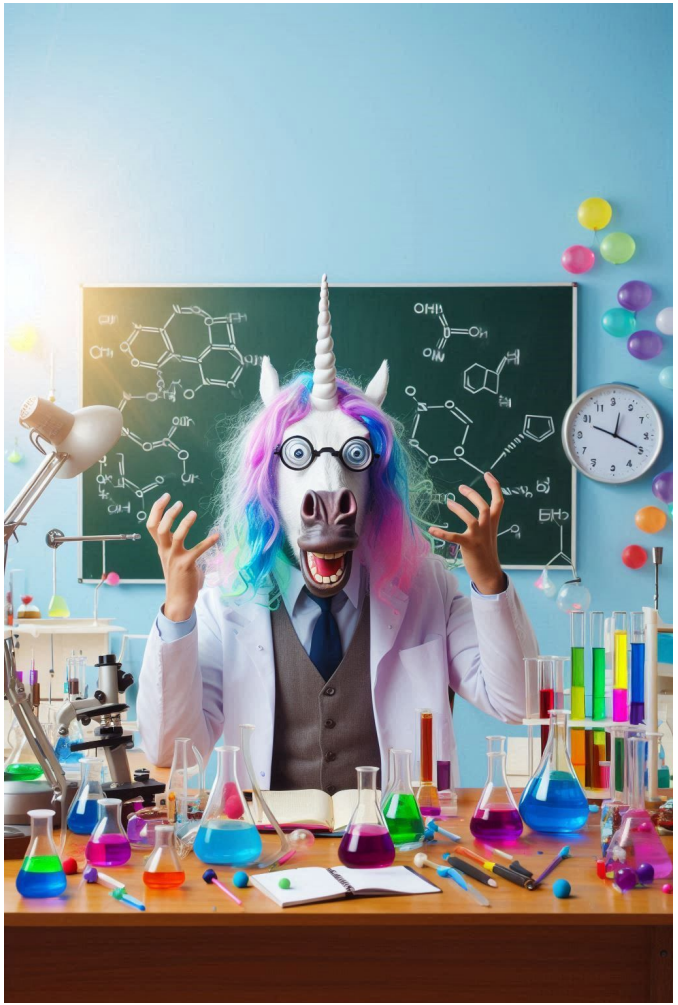
The Solution!

+

The Solution!

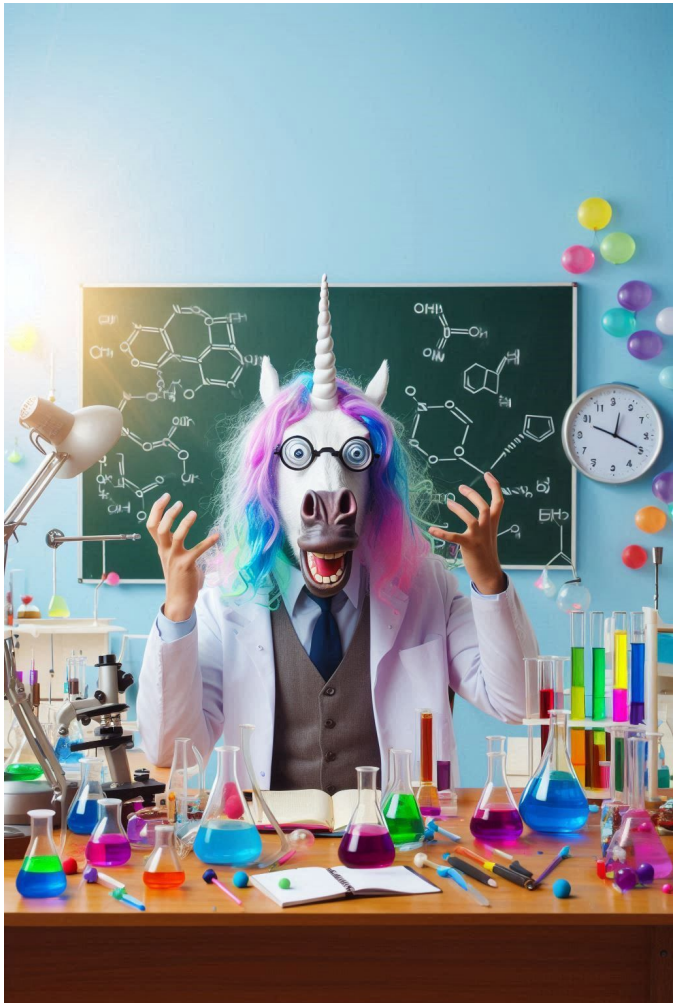
Demo 4

Putting it all together!



The Solution!

1. Using memory dump
2. Locate function containing splitted cipher text using yara
3. Using Unicorn CPU emulator framework
4. Emulate the function containing the DWORD
5. Handle the 5 types of exceptions



Analysing the VEH

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4    int result; // ecx
5    int count; // edx
6
7    ContextRecord = a1->ContextRecord;
8    result = 0x18;
9    count = 0;
10   while ( 1 )
11   {
12     count += 4;
13     if ( *(DWORD *)((char *)&ContextRecord->ContextFlags + count) )// check all HW BP registers are zero
14       break;
15     if ( count == 0x18 )
16       return 0xE1;                          // return offset decode key
17   }
18   return result;
19 }
```

Analysing the VEH

```
call    FN_Get_Offset_Decode_key
test    cl, cl
cmp     edx, ebx
mov     edx, 63C7099Ch
xor     edx, 6649E730h
test    ch, bh
add     edx, 1691B385h
cmp     ah, ch
add     edx, 0E3DF5E87h                 ; 0xB8
cmp     dx, 4070h
add     eax, edx                        ; _Context.EIP = _CONTEXT+0xB8
test    dl, cl
mov     edx, [eax]
add     edx, 0Ch                        ; Get enc offset*
cmp     dl, bl
call    FN_Get_Offset_Update_EIP
```

The Solution! (unicorn_hello_world.py)

```
PS C:\Users\User1\Desktop> python -V
Python 3.11.9
PS C:\Users\User1\Desktop> pip list
Package      Version
------------ -------
capstone     5.0.3
pip          24.0
setuptools   65.5.0
unicorn      2.1.1
yara-python  4.5.1
```

The Solution! (unicorn_hello_world.py)

```
8B 54 24 04                         mov     edx, [esp+4]
C7 02 D9 1C 40 91                   mov     dword ptr [edx], 91401CD9h
81 32 9F 0D B0 5A                   xor     dword ptr [edx], 5AB00D9Fh
0F C7 3B                            vmptrst qword ptr [ebx]       ; invalid instruction
                                    ; ---------------------------------------------------------------------------
CF 00 00 00 00 00 00 00 00 F2…      db 0CFh, 8 dup(0), 0F2h, 3Eh, 0B2h, 71h, 17h, 0ECh,
                                    ; ---------------------------------------------------------------------------
81 32 54 80 FB 26                   xor     dword ptr [edx], 26FB8054h
51                                  push    ecx
B9 6C 4B BD FE                      mov     ecx, 0FEBD4B6Ch
81 F1 D0 E9 76 97                   xor     ecx, 9776E9D0h
81 F1 4A CC B4 55                   xor     ecx, 55B4CC4Ah
81 C1 0A 92 80 C3                   add     ecx, 0C380920Ah       ; ECX=0x100
56                                  push    esi
9C                                  pushf
89 E6                               mov     esi, esp
01 0E                               add     [esi], ecx
9D                                  popf                          ; enable Trap Flag!
39 CA                               cmp     edx, ecx
                                    ; ---------------------------------------------------------------------------
75 16 96 E6 5D 07 09 1E 46 C0…aU    db 'u',16h,96h,0E6h,5Dh,7,9,1Eh,'F',0C0h,0E7h,9Bh,0F
EF 9D B1 9E C5 1A 3B 52 81 07…      db '□',9Eh,0C5h,1Ah,';R',81h,7,0B8h,80h,0FCh,0B1h,'^
                                    ; ---------------------------------------------------------------------------
81 02 00 6F F4 12                   add     dword ptr [edx], 12F46F00h
```

The Solution! (emulate_config_dump.py)

```
python3.11 emulate_config_dmp.py
INFO:__main__:C2 url = https://softiq.ro/event/update/mCNQZhDQboPBW61.bin enc config addr = 0x7A54BF
```

Agenda for part 2

- We will deep dive into .NET and how configuration extraction can be achieved
- Most of the samples are not very difficult to extract config, but we got to learn .NET runtime to achieve it.

- We will be going through:
  - Identify .NET
  - .NET structure
  - Tools
  - Sources for research
  - Unpacking .NET payloads
  - Locate configs
  - Understanding CLR tokens
  - Extract configs

Introduction to .NET

- .NET is a free and open-source application platform supported by Microsoft.
  - The initial .NET release was 2016. It's also getting attentions among threat actors.
- C# is the main programming language for .NET
- Terminology:
  - CLR (Common Language **Runtime**)
  - CIL: Common **Intermediate Language** is the bytecode language that the just-in-time (JIT) compiler of the .NET Framework interprets.
- There are awful lot of malwares written in .NET (especially infostealer)

How to identify .NET?

Cmd command: $ file sample.exe

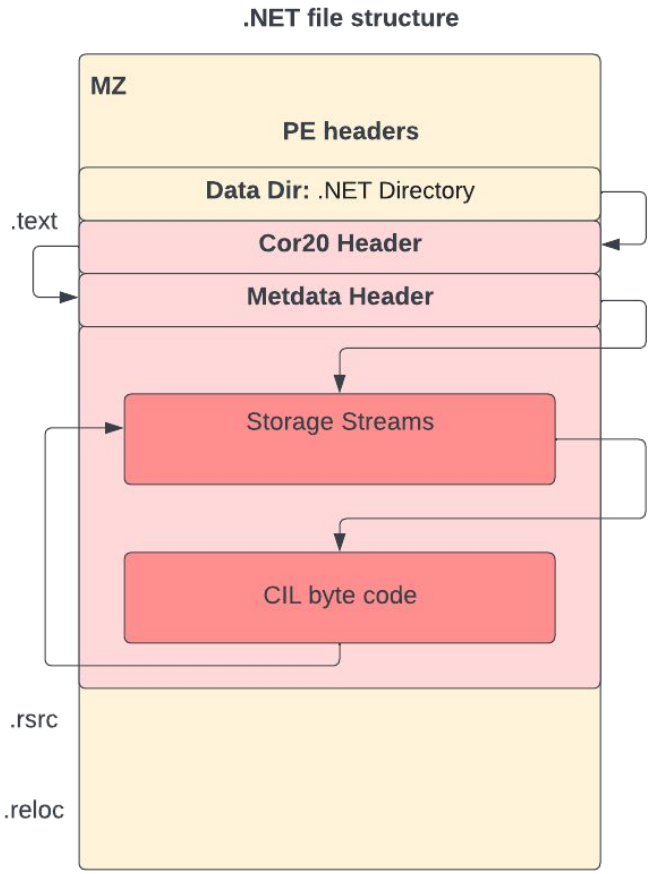
```
sample.exe: PE32+ executable (GUI) x86-64 Mono/.Net assembly, for MS Windows
```

YARA has ***is_donet*** in dotnet module. Let's take a look at how it's implemented

```
3229    static bool dotnet_is_dotnet(PE* pe)
3230    {
3231      PIMAGE_DATA_DIRECTORY directory = pe_get_directory_entry(
3232          pe, IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR);
3233
3234      if (!directory)
3235        return false;
3236
3237      int64_t offset = pe_rva_to_offset(pe, yr_le32toh(directory->VirtualAddress));
3238
3239      if (offset < 0 || !struct_fits_in_pe(pe, pe->data + offset, CLI_HEADER))
3240        return false;
3241
3242      CLI_HEADER* cli_header = (CLI_HEADER*) (pe->data + offset);
```

.NET header structure

- Reuse PE structure
- A special .NET data directory **IMAGE_DIRECTORY_ENTRY_COM_DESCRIPTOR** can be found for referencing the Cor20 header



.NET malware analysis tool I personally like

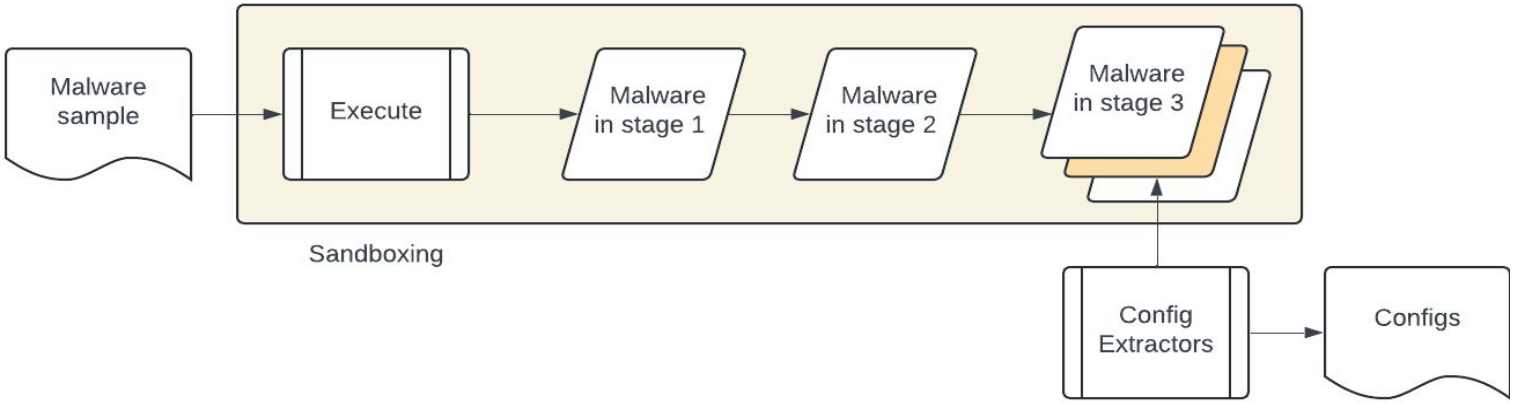
- dnSpy: a debugger and .NET assembly editor
  - The decompliation function is provided by ILSpy
  - The repo was archived since 2020; but it's still arguably the most popular tool for analysing .NET malware
- Megadumper: a handy .NET payload memory dump tool.
  - Very useful for unpacking
- IDAPro: not necessary, it's just my prefer tool to show CIL and decompiled code side-by-side.
- x32/x64 dbg: sometimes, when sample jumps from managed into unmanaged and vice versa. Most of the time I use dnSpy to debug .NET malwares.

Where to find .NET samples for research

- VirusTotal
- Malware bazaar Abuse.ch https://bazaar.abuse.ch/browse/

Fact is most of the samples are packed

- This means the Redline sample you downloaded from VT or malware bazaar doesn't look like Redline.
- However, configuration extractor requires Redline payload to work on.
- To defeat packing, in a production environment, the extractor is run on top of memory analysis framework:



Today, let’s exercise unpack .NET samples

Terminology:

- packer/crypter/protector: the tool hides the real payload

Pre-requirement:

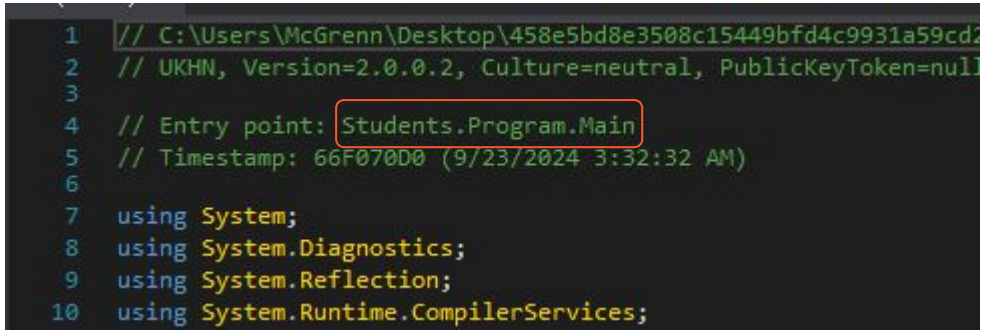
- A windows Virtual Machine with dnSpy installed

Sample:

- 458e5bd8e3508c15449bfd4c9931a59cd2a6a95ed9e6bb5b0090aa6641a29c77
  - It’s a fresh sample on malware bazaar which is labeled as Agent-Tesla

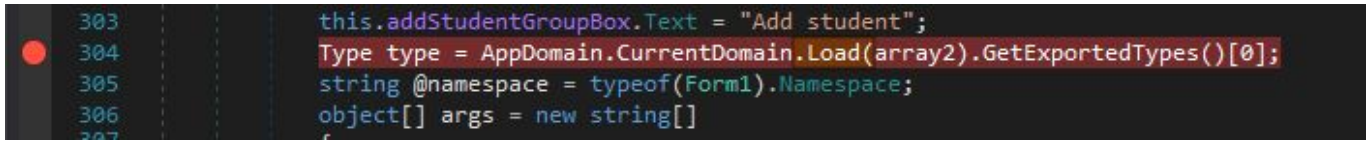
Let’s exercise how to unpack .NET samples (cont)

Step 1. Throw the sample into dnSpy and find the entrypoint



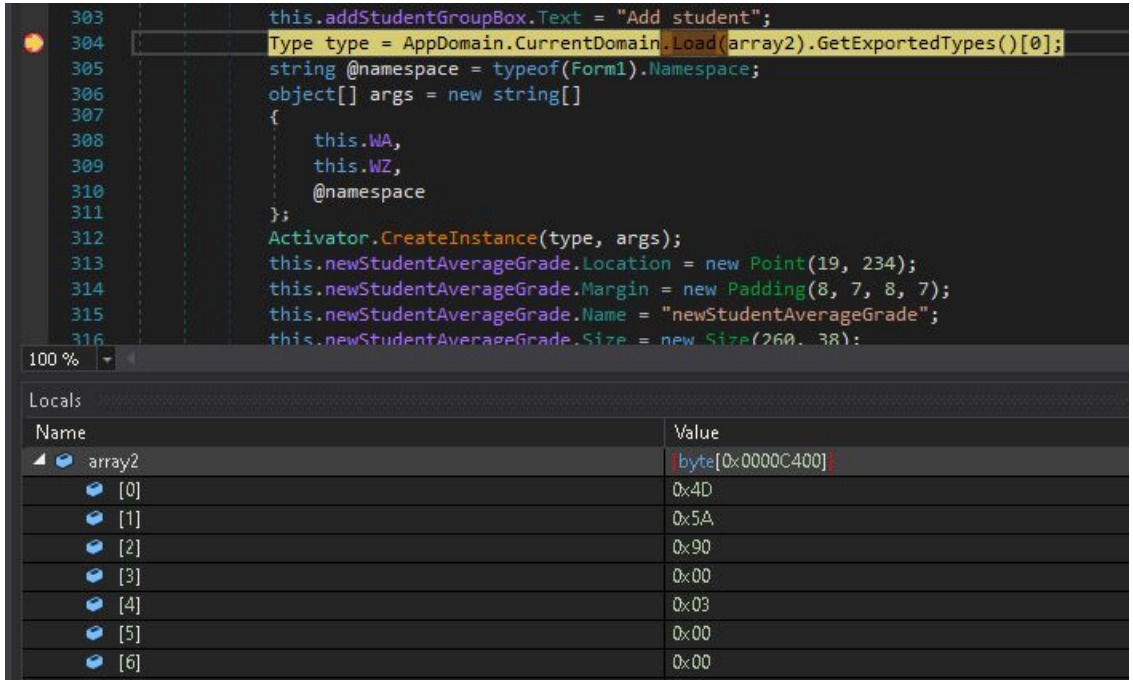
Step 2. Search for dynamic IL loading APIs and place a breakpoint at the instruction

- typeof(Assembly).InvokeMember, assembly.GetTypes, .CurrentDomain.Load(), etc



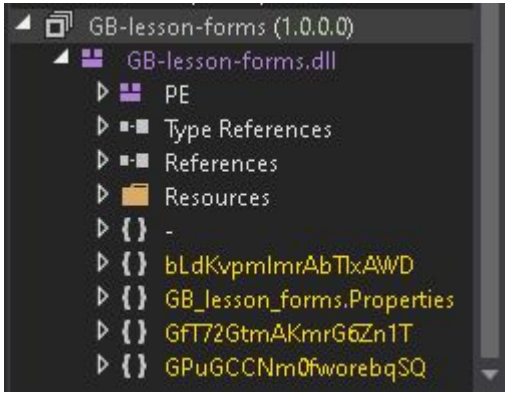
Let’s exercise how to unpack .NET samples (cont)

Step 3. Run the sample and hope we are lucky enough to intercept the payload.



Let’s exercise how to unpack .NET samples (cont)

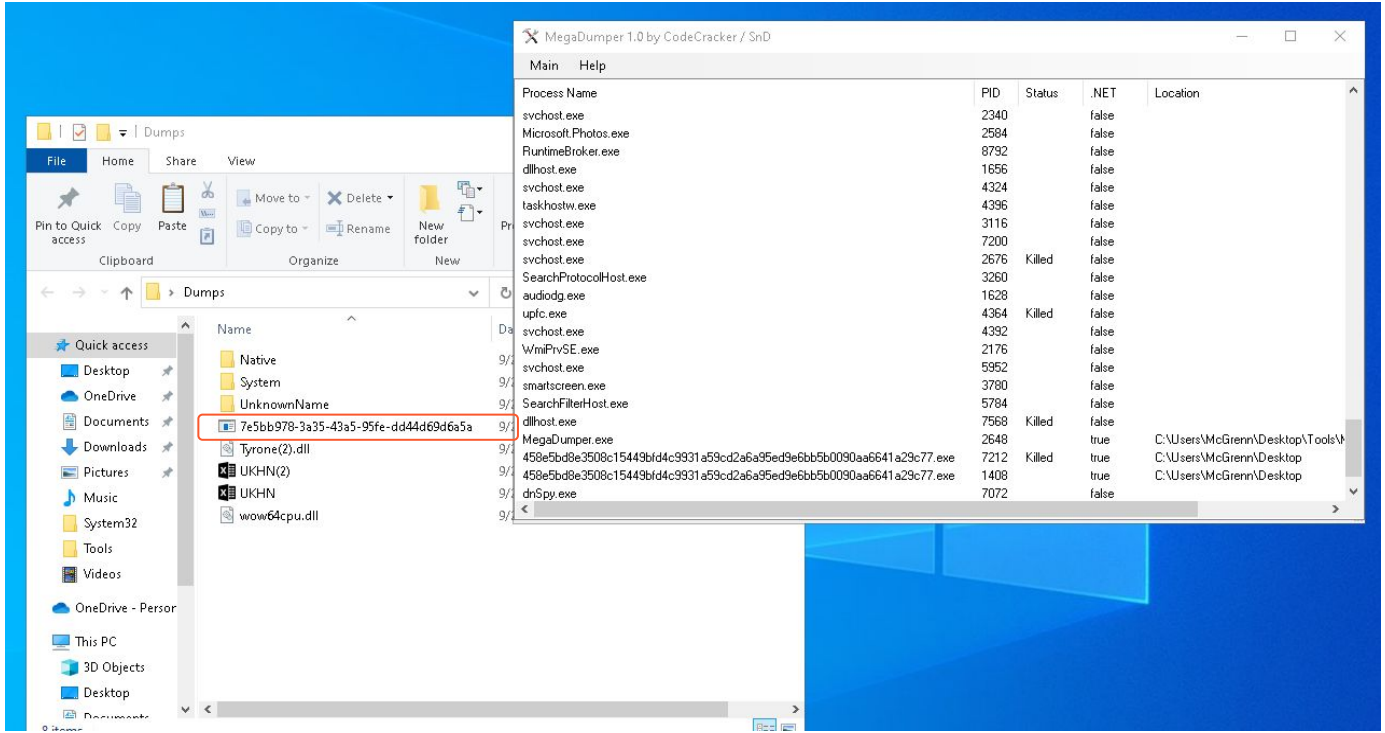
Step 4. Right click on the `array2` and save it to the disk. Reload the payload back to dnSpy.



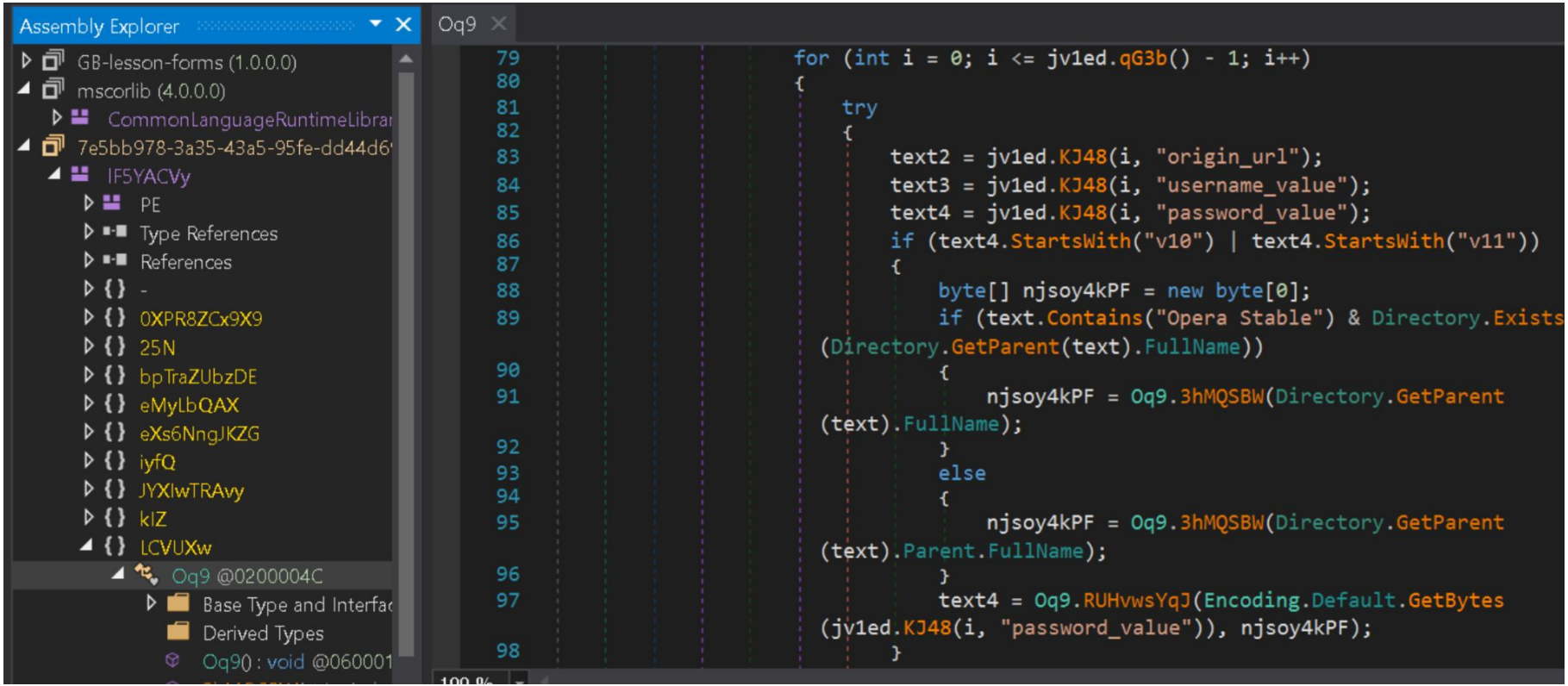
- It is not Agent-Tesla that we long for. We demonstrated that malware nowadays are multistage and **manually unpack them seems not easy to scale up**. So what’s now?

Let’s exercise how to unpack .NET samples (cont)

- Use my holy grail .NET unpacking tool: MegaDumper!



Let’s exercise how to unpack .NET samples (cont)



Preparing to extract a configuration

Sample: 101b9564ba11aa44372b37b1143eac0d5dd1e3f38c6a35517de843b9f23b3704

Family: RedLine v2

Unpacks to 47d6bf807e275d25a63015ef106fb2548b5394342ec8fdfc7f809e1699810330

The sample gives away it's a RedLine:

```
using System;

// Token: 0x02000081 RID: 129
public static class Program
{
    // Token: 0x060002AC RID: 684 RVA: 0x00007E92 File Offset: 0x00006092
    private static void Main()
    {
        Program.ReadLine();
    }

    // Token: 0x060002AD RID: 685 RVA: 0x00018AE8 File Offset: 0x00016CE8
    public static void ReadLine()
    {
        try
        {
            if (SystemInfoHelper.Close())
            {
                Delegate311.smethod_0(0, Delegate311.delegate311_0);
            }
            GClass1 gclass = new GClass1();
            bool flag = false;
            while (!flag)
            {
                foreach (string address in Delegate42.smethod_0(Strings.Get(0), new char[]
                {
```

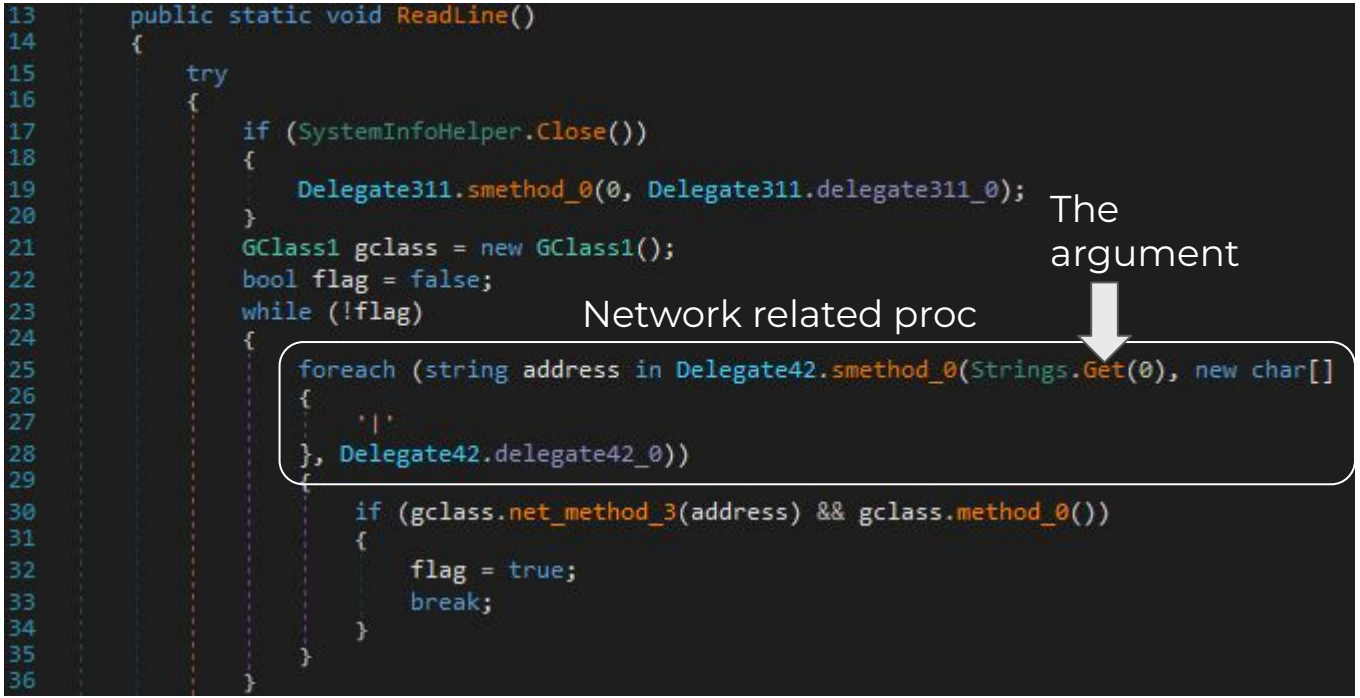
Where is the configuration:

Each malware family has their own design; but a general approach to find the config is:

- Configuration entries are always together. Because config controls the program, config is prepared altogether when sample is produced.
  - In .NET sample, configs can likely to be all in one class
- If the configuration is encrypted, malware is likely calling a same decryption routine over-and-over.
- Configuration often is associated with network connection part.
  - A trick is to locate the API that is related network and trace where the argument come from.

Where is the configuration in the sampe:

Sample: 101b9564ba11aa44372b37b1143eac0d5dd1e3f38c6a35517de843b9f23b3704




```
13      public static void ReadLine()
14      {
15          try
16          {
17              if (SystemInfoHelper.Close())
18              {
19                  Delegate311.smethod_0(0, Delegate311.delegate311_0);
20              }
21              GClass1 gclass = new GClass1();
22              bool flag = false;
23              while (!flag)
24              {
25                  foreach (string address in Delegate42.smethod_0(Strings.Get(0), new char[]
26                  {
27                      '|'
28                  }, Delegate42.delegate42_0))
29                  {
30                      if (gclass.net_method_3(address) && gclass.method_0())
31                      {
32                          flag = true;
33                          break;
34                      }
35                  }
36              }
```

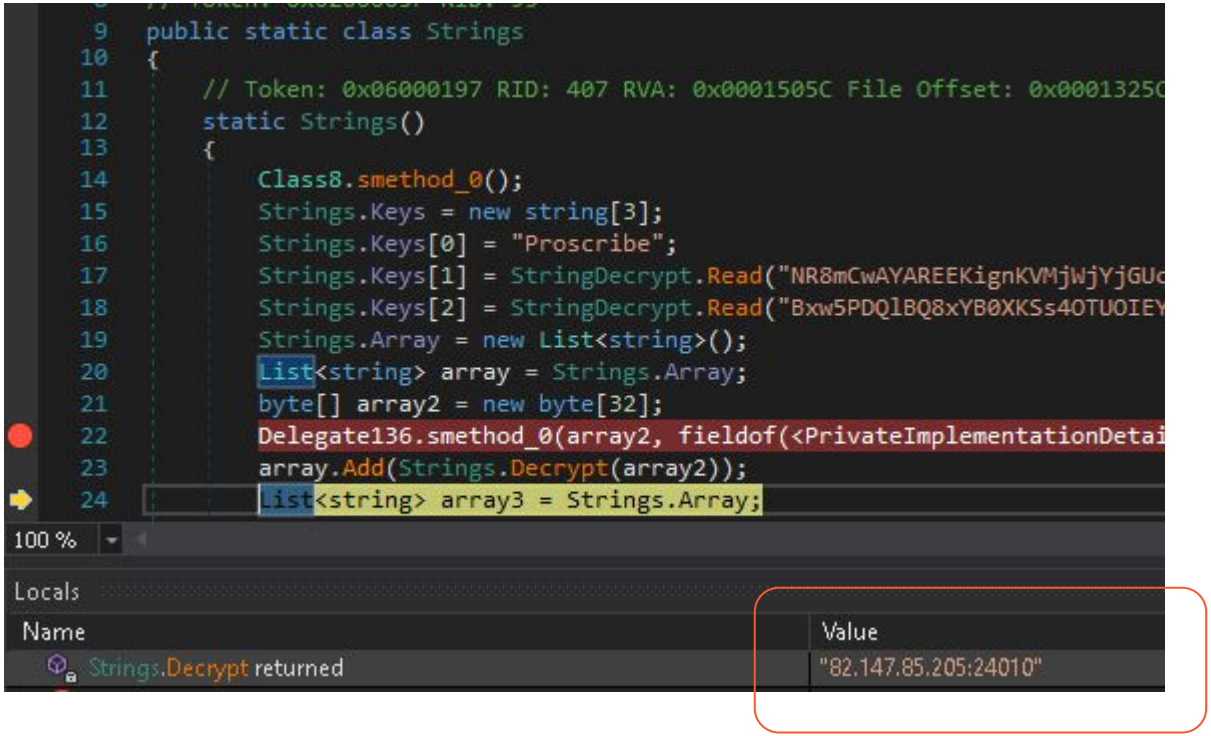
Where is the configuration in the sampe (cont):

- Config entries are together
- Config is encrypted
  - call the same decryption func

```
9   public static class Strings
10  {
11      // Token: 0x06000197 RID: 407 RVA: 0x0001505C File Offset: 0x0001325C
12      static Strings()
13      {
14          Class8.smethod_0();
15          Strings.Keys = new string[3];
16          Strings.Keys[0] = "Proscribe";
17          Strings.Keys[1] = StringDecrypt.Read("NR8mCwAYAREEKignKVMjWjYjGUciHylGOFMjADw
18          Strings.Keys[2] = StringDecrypt.Read("Bxw5PDQlBQ8xYB0XKSs4OTUOIEY6JTUAJDQ/JiM
19          Strings.Array = new List<string>();
20          List<string> array = Strings.Array;
21          byte[] array2 = new byte[32];
22          Delegate136.smethod_0(array2, fieldof(<PrivateImplementationDetails>.F495C984
23          array.Add(Strings.Decrypt(array2));
24          List<string> array3 = Strings.Array;
25          byte[] array4 = new byte[16];
26          Delegate136.smethod_0(array4, fieldof(<PrivateImplementationDetails>.struct2_
27          array3.Add(Strings.Decrypt(array4));
28          List<string> array5 = Strings.Array;
29          byte[] array6 = new byte[16];
30          Delegate136.smethod_0(array6, fieldof(<PrivateImplementationDetails>.struct2_
31          array5.Add(Strings.Decrypt(array6));
32          List<string> array7 = Strings.Array;
33          byte[] array8 = new byte[16];
34          Delegate136.smethod_0(array8, fieldof(<PrivateImplementationDetails>.struct2_
35          array7.Add(Strings.Decrypt(array8));
36          List<string> array9 = Strings.Array;
37          byte[] array10 = new byte[16];
38          Delegate136.smethod_0(array10, fieldof(<PrivateImplementationDetails>.D814B26
39          array9.Add(Strings.Decrypt(array10));
```

How config works?

- Set BreakPoint at line 22 and step over until line 24

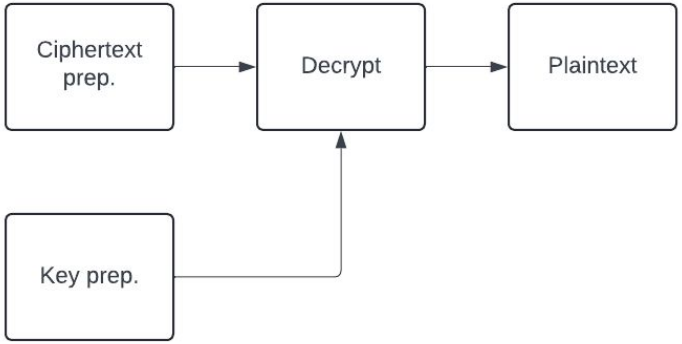


Observations:

1. Key prep.
2. Ciphertext prep.
3. Decryption

Steps to extract config

- Config init.



1. **Get the ciphertext from binary**
2. Prepare the key
3. Reverse engineer the decryption

Extract config: get the ciphertext

Ciphertext is at <PrivateImplementationDetails>.F495C9...DA

```
Delegate136.smethod_0(array2, fieldof(<PrivateImplementationDetails>.F495C984B051BFF089D74440FC9FD44D1B9C4BDA).
array.Add(Strings.Decrypt(array2));
List<string> array3 = Strings.Array;
```

PrivateImplementationDetails is a class with all the structure inside:

```
6   [CompilerGenerated]
7   internal sealed class <PrivateImplementationDetails>
8   {
9       // Token: 0x0400018C RID: 396 RVA: 0x00002050 File Offset: 0x00000250
10      internal static readonly <PrivateImplementationDetails>.Struct2 struct2_0;
11
12      // Token: 0x0400018D RID: 397 RVA: 0x00002060 File Offset: 0x00000260
13      internal static readonly <PrivateImplementationDetails>.Struct10 struct10_0;
14
```

Pay attention to the comment in dnSpy.

Extract config: get the ciphertext, CIL view, p1

dnSpy decompiled view of accessing C&C ciphertext

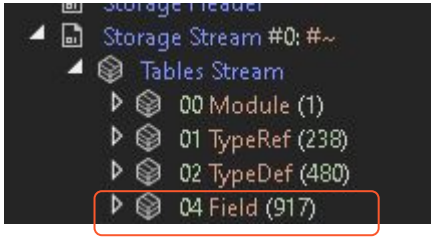
```
Delegate136.smethod_0(array2, fieldof(<PrivateImplementationDetails>.F495C984B051BFF089D74440FC9FD44D1B9C4BDA).
array.Add(Strings.Decrypt(array2));
List<string> array3 = Strings.Array;
```

In C, every object is reference by pointer. However, in .NET, ever object is accessed by token.

```
seg000:BF32 25             dup
seg000:BF33 D0 1F 02 00 04 ldtoken  valuetype Struct4 <PrivateImplementationDetails>::F495C984B051BFF089D74440FC9FD44D1B9C4BDA
seg000:BF38 7E D2 02 00 04 ldsfld   class Delegate136 Delegate136::delegate136_0
seg000:BF3D 28 E0 04 00 06 call     void Delegate136::smethod_0(class [mscorlib]System.Array array_0, valuetype [mscorlib]Syste
seg000:BF42 28 99 01 00 06 call     string Strings::Decrypt(unsigned int8[] chiperText)
```

Token(little endian) = 04 00 02 1F

- 04 is referencing Field Table Stream in #~
- The token is indexed 0x021F in Field Table



Extract config: get the ciphertext, CIL view, p2

In order to get the token, we want to anchor the code where C&C ciphertext token is access.

- Here is an example of YARA rule which we can use to anchor the offset of the instr
  - Or you can use regex
- Access the offset of YARA rule matches + 25 for the opcode of D0 (ldtoken), then the followed 4 bytes are ciphertext token

```
rule sig_redline_v2_c2
{
    strings:
        $ = {
            A2
            73 [3] 0A
            80 [3] 04
            7E [3] 04
            1F 20
            8D [3] 01
            25
            D0 [3] 04
            7E [3] 04
        }
    condition:
        all of them
}
```

```
seg000:BF32 25                dup
seg000:BF33 D0 1F 02 00 04    ldtoken  valuetype Struct4 <PrivateImplementationDetails>::F495C984B051BFF089D74440FC9FD44D1B9C4BDA
seg000:BF38 7E D2 02 00 04    ldsfld   class Delegate136 Delegate136::delegate136_0
seg000:BF3D 28 E0 04 00 06    call     void Delegate136::smethod_0(class [mscorlib]System.Array array_0, valuetype [mscorlib]Syste
seg000:BF42 28 99 01 00 06    call     string Strings::Decrypt(unsigned int8[] chiperText)
```

Extract config: get the ciphertext, CIL view, p3

To get the data from the token, I found two different library are achievable

- https://github.com/pan-unit42/dotnetfile
- https://github.com/malwarefrank/dnfile

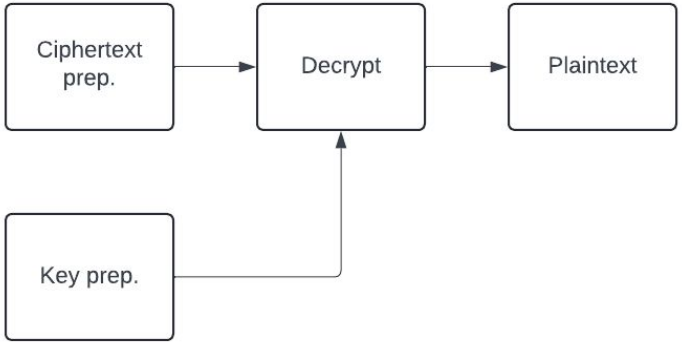
I'm using dnfile as an example for today. But they worked quite the same way.

By calling get_field_data_from_token, we get the actual data of C&C ciphertext

```
58 def get_field_data_from_token(token: int, dn: dnfile, size: int) -> Optional[bytes]:
59     token_mask = 0xFFFFFF
60     rva: Optional[int] = get_field_rva_by_index(index=token & token_mask, dn=dn)
61     if rva is None:
62         return None
63     return dn.get_data(rva, size)
64
65
66 def get_field_rva_by_index(index: int, dn: dnfile.dnPE) -> Optional[int]:
67     if not hasattr(dn, 'net') or not hasattr(dn.net, 'mdtables'):
68         return None
69
70     mdtables = dn.net.mdtables
71     for row in mdtables.FieldRva.rows:
72         if row.Field.row_index == index:
73             return row.Rva
74
75     return None
```

Steps to extract config

- Config init.



1. Get the ciphertext from binary
2. **Prepare the key**
3. **Reverse engineer the decryption**

Extract config: prepare the key and implement decryption, part 1

There's no trick, just pure reverse engineering.

One tip is debugger is helpful. I always make some guess, and prove my assumptions in debugging.

```
class RedlineV2Crypto:

    def __init__(self, key: bytes, iv: bytes, keykey: bytes):
        self.key: Optional[bytes] = self.xor_decrypt(data=key, key=keykey)
        self.iv: Optional[bytes] = self.xor_decrypt(data=iv, key=keykey)

    @property
    def ready(self) -> bool:
        return None not in [self.key, self.iv]

    @staticmethod
    def xor_decrypt(data: bytes, key: bytes) -> Optional[bytes]:
        try:
            return b64decode(b64decode(bytes([a ^ b for a, b in zip(b64decode(data), cycle(key))])))
        except ValueError:
            return None

    def decrypt(self, ciphertext: bytes) -> Optional[bytes]:
        cipher = AES.new(self.key, AES.MODE_CBC, self.iv)
        try:
            plaintext: bytes = unpad(cipher.decrypt(bytes(reversed(bytearray(ciphertext)))), 16)
            return plaintext
        except ValueError:
            return None
```

Extract config: prepare the key and implement decryption, part 2

Now, the same problem. We need to get the data for key prep.

```
Strings.Keys = new string[3];
Strings.Keys[0] = "Proscribe";
Strings.Keys[1] = StringDecrypt.Read("NR8mCwAYAREEKignKVMjWjYjGUciHylGOFMjADwnKhsjBDA/HEE9PwY2BSYyBjg3JTY4OiwxBicNCVNP", Strings.Keys[0]);
Strings.Keys[2] = StringDecrypt.Read("Bxw5PDQlBQ8xYB0XKSs4OTUOIEY6JTUAJDQ/JiM7Q1o=", Strings.Keys[0]);
```

These data looks plaintext and static. However, we can expect every sample comes with different keys.

So, same approach. Looking at CIL first.

Token: 07 00 02 A7

07 is US (user) Table

```
seg000:BEE6 72 A7 02 00 70    ldstr    aProscribe     // "Proscribe"
seg000:BEEB A2                stelem.ref
seg000:BEEC 7E EE 00 00 04    ldsfld   string[] Strings::Keys
seg000:BEF1 17                ldc.i4.1
seg000:BEF2 72 BB 02 00 70    ldstr    aNr8mcwayareeki // "NR8mCwAYAREEKignKVMjWjYjGUciHylGOFMjADw"..
seg000:BEF7 7E EE 00 00 04    ldsfld   string[] Strings::Keys
seg000:BEFC 16                ldc.i4.0
seg000:BEFD 9A                ldelem.ref
seg000:BEFE 28 39 01 00 06    call     string StringDecrypt::Read(string b64, string stringKey)
seg000:BF03 A2                stelem.ref
seg000:BF04 7E EE 00 00 04    ldsfld   string[] Strings::Keys
seg000:BF09 18                ldc.i4.2
seg000:BF0A 72 5E 03 00 70    ldstr    aBxw5pdqlbq8xyb // "Bxw5PDQlBQ8xYB0XKSs4OTUOIEY6JTUAJDQ/JiM"..
seg000:BF0F 7E EE 00 00 04    ldsfld   string[] Strings::Keys
```

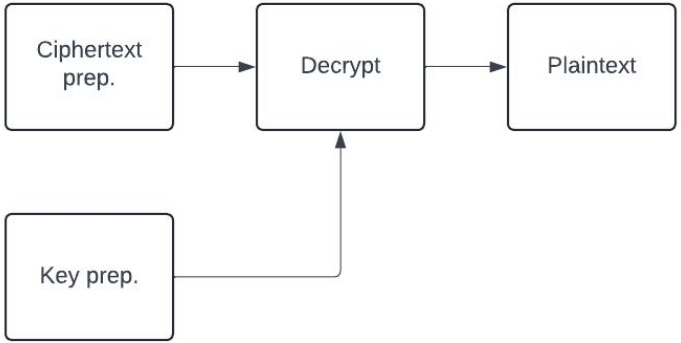
Extract config: prepare the key and implement decryption, part 3

To access the US stream, refer to this example:

```
34  def get_us_stream_by_token(token: int, dn: dnfile.dnPE) -> Optional[bytes]:
35      token_mask = 0xFFFFFF
36      return get_us_stream_by_offset(offset=token & token_mask, dn=dn)
37
38
39  def get_us_stream_by_offset(offset: int, dn: dnfile.dnPE) -> Optional[bytes]:
40      if not hasattr(dn, "net"):
41          return None
42
43      # get the (first) UserStrings stream
44      us: dnfile.stream.UserStringHeap = dn.net.metadata.streams.get(b"#US", None)
45      if us:
46          if not us.sizeof():
47              return None
48          ret = us.get_with_size(offset)
49          if ret is None:
50              return None
51          buf, _ = ret
52          try:
53              return dnfile.stream.UserString(buf[:-1]).value.encode()
54          except UnicodeDecodeError:
55              return None
```

Steps to extract config for .NET: rewind

1. Locate the config and analyse the configuration
2. Study CIL and prepare the anchor to get the token for ciphertext and keys
3. Get the data that token is pointing by the help of dnfile or dotnetfile
4. Reverse engineer the decryption routine
5. Put everything together



Thank you