

GraceWire / FlawedGrace malware adventure

blog.codsec.com/posts/malware/gracewire_adventure/

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This is some note about the Gracewire malware that I come across in last year during some investigation. Maybe this will help people who are working on it. I've documented the persistence mechanism and the recovery mechanism for the Virtual File System (aka the configuration)

The persistence mechanism was well hidden beneath a lot of layers and allowed it to be fileless. They change the *ComHandler* of an existing Windows Task schedule. Tools like *autoruns* still think it's a Windows valid entry and hide it. The modification timestamp of the task schedule file can be used to find out the malware infection.

Gracewire is complex, [Rolf Rolles](#) publish a state-of-the-art IDB on one version of [FlawedGrace/Gracewire](#). His work saved me a lot of time in getting the information I needed.

Gracewire

Gracewire fileless loading version

This information comes from an infected system, where no malware was found directly on the disk.

Stage 1

The malware maintains persistence by updating an existing Windows task schedule `\Windows\System32\Tasks\Microsoft\Windows\Registry\RegIdleBackup` (this task is hard-coded inside the malware). It changes the *ComHandler* action with the UUID `{CF8C0CD5-8DAA-4899-91FE-DF8DD3D165DE}`.

They did not timestamp the file after updating it. So, it's possible to find the persistence with a timeline analysis.

In the registry, they create the key `HKLM:\Software\Classes\CLSID\{CF8C0CD5-8DAA-4899-91FE-DF8DD3D165DE}\TreatAs` is set to `{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}`. The execution of the task schedule will, in fact, execute the command saved in `HKLM:\Software\Classes\CLSID\{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}\LocalServer`.

LocalServer contains the command below

```
C:\Windows\SYSTEM32\WindowsPowerShell\v1.0\powershell.exe -WindowStyle Minimized -c "& {iex([System.Text.Encoding]::UTF8.GetString([Convert]::FromBase64String('...')))}"
```

I've to hide the payload a little. This command will load and execute the *PowerShell* script saved in `HKLM:\Software\Classes\CLSID\{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}\ProgID` under the name `{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}`

The two UUID derivate from a seed value, but we don't know the seed value.

Stage 2

Inside the key `HKLM:\Software\Classes\CLSID\{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}\ProgID` the entry name `{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}` has for value a *PowerShell* script.

```
function DJEKGLRA{param($DJEKGLRB)
[System.Text.Encoding]::UTF8.GetString([Convert]::FromBase64String($DJEKGLRB))....
```

This script loads a DLL from `HKLM:\Software\Classes\CLSID\{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}\VersionIndependentProgID` with the name `{972903D2-3A23-4C4D-A3D2-B6DE37AC983C}` and execute it inside the `powershell.exe` process.

Stage 3

This file is not on VT and I can't share it.

stage3.bin

file size	61440 (60.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
PE date	2012-12-28 02:58:07 GMT

This DLL is packed with a simple packer.

stage3.unpack.bin

file size	36864 (36.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
PE date	2010-12-14 15:47:25 GMT

This DLL assumes that it's running inside another thread than the main one; otherwise it will exit. The goal is to load the final payload from a registry key. The registry key used depends on the system information.

This file is later found in the VFS embed inside the installer (file `/c`) with this information. I provide it on the [GitHub repo in samples.zip](#).

c.embedded.stage3.dll

file size	36864 (36.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	18d1e87283eb975a76bb682e59dbaafa
sha1	24a7988b43b76bc19a814ba5d44a8bd5fa6f54fc

c.embedded.stage3.dll

sha256	0e82f50477a4df52bdee361ef155d3c0496f2cd87523c17f492216e8ebceff9a
imphash	c438b77d56d8a538d975960a500f2199
PE date	2014-08-07 02:26:11 GMT

It generates 3 UUID that derivate from a seed, a volume serial id, and computer name ([script is here](#)). Depending on the usage, it will be formatted or not.

```
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x6f3ad240; desc: loader_reg_key; val: {8D7B6772-6772-8D7B-1C17-07FB05037B8D}
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x91fa4e91; desc: loader_reg_name; val: {73BBFBA3-FBA3-73BB-80C6-C705D49FBB73}
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x350af376; desc: loader_enc_key; val: 44464bd744464bd7213d37a133224bd7
```

Seed **0x6f3ad240** is used to generate the registry key `SOFTWARE\Classes\CLSID\{8D7B6772-6772-8D7B-1C17-07FB05037B8D}`

Seed **0x91fa4e91** is used to generate the value name of the registry key.

The value will contain a payload encrypted. The key to decrypt it come from the value generated by the seed **0x350af376**. Due to how they implement it, the encryption is weak and can be simplified to a xor with a one-byte key. ([python unpacker here](#))

The payload extracted will be called *grace.loader.bin*

GraceWire loader payload

grace.loader.bin / 6f3ad240.dec.bin

file size	1146880 (1.1MiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	534362e1316c41dd0637f757c7766858
sha1	0377a70765062922e9b6a2363b958a2dfc8b62f7
sha256	a2da59241b1f6d898f0f32087b2684da2a38954063b2c0078a459171c27eab26
imphash	
PE date	2012-12-28 02:58:07 GMT

The same packer as stage 3 is used.

```
$ python3 grace_unpacker.py unpack -f ../samples/Gracewire_sample1/grace.loader.bin >
../samples/Gracewire_sample1/grace.loader.unpack.bin
$ file ../samples/Gracewire_sample1/grace.loader.unpack.bin
../samples/Gracewire_sample1/grace.loader.unpack.bin: MS-DOS executable PE32+ executable (DLL)
(GUI) x86-64, for MS Windows
```

grace.loader.unpack.bin / 6f3ad240.unpack.hd.bin

file size	1122304 (1.1MiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	0a8ebb14016dc90af35c6360d73e126a
sha1	cbaffd2383bf9fb518f7a7d13d25a7cc262c99ed
sha256	bb151716c5755f4ddb39ee16f0041e42044e3b408abad1300c7107f727093df9
imphash	f8f56226b601010b649b11718ebc7593
PE date	2015-05-28 06:31:14 GMT

This is the loader for the main module of *GraceWire/FlawedGrace*, which is in charge to get the configuration and the main module, migrate to another process and execute the main module.

To work on this file, I wrote [few scripts](#)

- [gracewire_loader_string_ida.py](#) decrypt and add in comment the string in the IDB
- [qiling_grace_loader_resolv.py](#) Qiling script to find out the id, name of import used. This script used to work, but now is failing. I update it to work on the recent Qiling version but during some decryption there is some junk, so it failed to resolv an import and don't get fully initialized.
- [grace_loader_generate_uuid.py](#) The script used to generate the UUID for a system common to the different layer.

They used some obfuscation probably with LLVM to add a lot of junk code, between real instruction

[grace_core_ida_obfuscation](#)

After removing some of the obfuscation with IDA

[grace_core_ida_deobfuscation](#)

At one moment my script was most likely okay and I try to be too aggressive in the deobfuscation so at the end that was removing useful information. I lost the working version. The script is here for [ida_grace_core_deobfucation.py](#) and [ida_grace_core_deobfucation_old.py](#).

The malware can load its configuration from at least two different places:

- From the resource of the DLL himself (resource name **N**) encryption is AES and key is **er0ewjflk3qrhj81**
- From the registry using a similar system as we saw in stage 3

In this file, the resource section is corrupt, probably on purpose, so it's not inside.

The configuration in the registry for the system can be found in **SOFTWARE\Classes\CLSID\{BB5B4C31-4C31-BB5B-3754-27CD46285BBB}** (seed **0x591af903**). This value is encrypted with AES-CBC (slightly modified see below) the key is derivate from seed **0x46ed5316** and only the first 16

bytes or the UUID without separator are used so 24E6ACA424E6ACA4.

I provide a copy of the decrypted registry key in `grace_vfs_from_reg_93f4d91a.vfs`

The decrypted data follow the `DataHive` structure describe latter.

Before passing the execution to the main module, the malware will copy the hive to a file in memory under the name `Global\7c1828b07c1828b0196354c60b7c28b0` or `Local\B028187C-187C-B028-6319-54C60B7C28B0`. This come from the seed `0x5269ad4e` but can be modified with the command line parameter `cs`. A mutex is created with the name `m1828B07C1828B0196354C60B7C28B0` using the seed `0x5269ad4e`. This allows modules to get access to the hive data.

UUID and seed value for this payload:

```
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x46ed5316; desc: config_enc_key; val: A4ACE624E624A4AC
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x591af903; desc: config_reg_key; val: {BB5B4C31-4C31-BB5B-3754-27CD46285BBB}
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x5269ad4e; desc: mutant; val: Local\B028187C-187C-B028-6319-54C60B7C28B0
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x5269ad4e; desc: mutant; val: Global\7c1828b07c1828b0196354c60b7c28b0
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x5269ad4e; desc: mutant; val: m1828B07C1828B0196354C60B7C28B0
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x93f4d91a; desc: unknown; val: {71B56C28-6C28-71B5-174D-C9075F08B571}
cn: WINDEV2210EVAL; vsn: 0xe241b532; seed: 0x6f6772e0; desc: unknown; val: {8D26C7D2-C7D2-8D26-BCB7-5AFBA5A3268D}
```

```
lpMem = (char *)DerivateSeedUuid(0x46ED5316u, 1, 0, 0);
if ( lpMem )
{
    qword_18009FB80 += 0x73B55B77D08048C8i64;
    qword_18009FB88 = (qword_18009FB80 + 0x262A41D2D8A31035i64)
    byte_18009FB70 = -113;
    strcpy_s(aConfigurationEnckKey, 0x40ui64, lpMem);
    byte_18009FB70 = -93 * qword_18009FB80;
```

```

while ( v5 < 8 )
{
    qword_18009F818 += 0x7994B5748E3BF2E4i64;
    qword_18009F818 &= 0x1289A3093ACFDDA9ui64;
    qword_18009F818 -= 0xB2AF4FA129EF55Di64;
    qword_18009F818 |= 0xAD6482DECA9BA6B7ui64;
    qword_18009F818 *= 0xC68AB67C3352BD42ui64;
    qword_18009F818 &= 0x6CC2C18E1AE22042ui64;
    qword_18009F818 -= 0x727D5525860F4D09i64;
    qword_18009F818 *= 0xBD71C5F39D52A80Aui64;
    qword_18009F818 |= 0x2B32926B69342BFui64;
    qword_18009F818 ^= 0x9A11F493D6E6383ui64;
    qword_18009F818 &= 0x751A1E7FB7F76A2Bui64;
    qword_18009F818 |= 0xFF79D974E0943AE0ui64;
    qword_18009F818 *= 0x528A339ADB49052i64;
    qword_18009F818 ^= 0x91361336D5A1AFDBui64;
    *((_BYTE *)&v8[2] + v5) = v9[v6] ^ v4 ^ *((_BYTE *)&v8 + v5);
    if ( v7 && v6 != v7 - 1 )
    {
        qword_18009F818 &= 0x1AE96348EC4AD886ui64;
        qword_18009F818 -= 0x3415ECA42AF57223i64;
        qword_18009F818 *= 0xB387E2087DB2B14Fui64;
        qword_18009F818 &= 0xF4F0E7BE3DE63896ui64;
        qword_18009F818 &= 0x7FAFDEC7E46E723ui64;
        qword_18009F818 &= 0x7ACF21E4B92C01F5ui64;
        qword_18009F818 |= 0xE3FEEC22569473CBui64;
        qword_18009F818 -= 0x359C58D7A7BBED8i64;
        qword_18009F818 ^= 0x66E52856B38ED6E1ui64;
        ++v6;
    }
    else

```

At that point, I knew that it was loading some sort of VFS, but due to the obfuscation in this version, I wasn't really able to make quick progress. Since I was seeing some sort of configuration and 5 PE files, at that point that was enough information.

A month or two later, I had some free time and decided to try reversing the VFS and found [Rolf Rolles's post](#) and [IDB](#). I was able to quickly write a python script to dump the VFS.

```

$ python3 grace_vfs.py -f ../samples/grace_vfs_from_reg_93f4d91a.vfs
ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
pack 0x00000018 | name =
  entry 0x000000db | name = v | 0x1
  entry 0x000000ec | name = l2 |
b'MZ\x90\x00\x03\x00\x00\x00\x04\x00\x00\x00\xff\xff\x00\x00\xb8\x00\x00\x00\x00\x00\x00\x00@\x
x00\x00\x00\x00\x00\x00\x00'
  entry 0x000aa0fe | name = p1 |
b'MZ\x90\x00\x03\x00\x00\x00\x04\x00\x00\x00\xff\xff\x00\x00\xb8\x00\x00\x00\x00\x00\x00\x00@\x
x00\x00\x00\x00\x00\x00\x00'
  entry 0x000af110 | name = p2 |
b'MZ\x90\x00\x03\x00\x00\x00\x04\x00\x00\x00\xff\xff\x00\x00\xb8\x00\x00\x00\x00\x00\x00\x00@\x
x00\x00\x00\x00\x00\x00\x00'
  entry 0x000b5122 | name = ni | AC0EF5AB240F4FA1E09AF46A4F789CD4
  entry 0x000b5183 | name = sr | 0x1
  entry 0x000b5195 | name = hv | 0x42b
  entry 0x000b51a7 | name = h |
b'MZ\x90\x00\x03\x00\x00\x00\x04\x00\x00\x00\xff\xff\x00\x00\xb8\x00\x00\x00\x00\x00\x00\x00@\x
x00\x00\x00\x00\x00\x00\x00'
  entry 0x001cf1b8 | name = avt | 0x1
  entry 0x002cc25b | name = tlc | 0x0
  entry 0x002cc26e | name = au | 0x0
  entry 0x00341292 | name = se | 0x99533bfb
  entry 0x003412a4 | name = ve | 0x1
  entry 0x003412b6 | name = c |
b'MZ\x90\x00\x03\x00\x00\x00\x04\x00\x00\x00\xff\xff\x00\x00\xb8\x00\x00\x00\x00\x00\x00\x00@\x
x00\x00\x00\x00\x00\x00\x00'
  entry 0x003b62c7 | name = lo | 0x2
pack 0x000b5154 | name = AC0EF5AB240F4FA1E09AF46A4F789CD4
  pack 0x00000038 | name = mt
    entry 0x0000005a | name = w | AC2696B99D5E44B21A9A4B5987DCC0E4
  pack 0x00000049 | name = se
    pack 0x0000008b | name = [0]
      entry 0x0000009d | name = p | 0x1bb
      entry 0x000000ae | name = h | 46.161.40.87
  pack 0x00000027 | name = mo
  pack 0x002cc1ed | name = us
    pack 0x002cc1fe | name = D08F22EDA5AB458E68B9C0D8508ECEDA
      entry 0x002cc22d | name = n | SYSTEM
      entry 0x002cc24a | name = p | 0x218
  pack 0x002cc280 | name = m

```

I dump the VFS, I provide a [copy in samples.zip samples/Gracewire_sample1/dump_vfs](#)

```
dump_vfs
├── AC0EF5AB240F4FA1E09AF46A4F789CD4
│   ├── mt
│   │   ├── se
│   │   │   └── [0]
│   │   │       ├── h
│   │   │       └── p
│   │   ├── us
│   │   │   └── D08F22EDA5AB458E68B9C0D8508ECEDA
│   │   │       ├── n
│   │   │       └── p
│   └── w
├── au
├── avt
├── c
├── h
├── hv
├── l2
├── lo
├── ni
├── p1
├── p2
├── se
├── sr
├── tlc
├── v
└── ve
```

Inside we have the 5 payloads and some configuration fields.

l2

file size	696320 (680.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	562dd15f883320fa04c0b5a9bdb003cd
sha1	da74135a4c3630e6a5c7e0d7554bcdd370a76358
sha256	ca03ff2ab99e9d0bac8e92b0697a2fea0f06d5384648551bb8648efa31f61ed9
imphash	bbcf353adf7d223bba7b33576d501b1d
PE date	2014-09-05 01:38:14 GMT

l2 is GraceWire main module

p1

file size	20480 (20.0KiB)
file magic	PE32 executable (DLL) (GUI) Intel 80386, for MS Windows
md5	88695dbddd4fc57025b523f4fca268d7

p1

sha1	57ab5d9b5302644e91e3953062b40c5346b236e3
sha256	f92dbf7943590c2c4011f911ba9ba445010c9d5895b5c8b57a5da9c8708c221d
imphash	
PE date	2009-10-19 13:41:28 GMT

p1 is a 32bit DLL used to inject 32bit payload

p2

file size	24576 (24.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	b032fcb03d685b591054855572ac8f85
sha1	869b38a87802af5628fe8a318323bfc24229086
sha256	a0286ea3521167642cbc73dbe1c23bc9870bc7a3012ee521be98b38836ce834e
imphash	
PE date	2018-09-08 05:36:12 GMT

p2 is a 64bit DLL used to inject 64bit payload

h

file size	1155072 (1.1MiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows
md5	69d2507bbf73cf4fa6d6ca1647754f03
sha1	93eafaa180b5085babee7b2bb85c0a349131328f
sha256	0d37468eb7748e4f26f54e6858e2e5e2389ba3530552394abbd56bfeb873e5d0
imphash	
PE date	2018-09-08 05:36:12 GMT

h is the *GraceWire* Loader (packed) found in registry

c

file size	479232 (468.0KiB)
file magic	PE32+ executable (DLL) (GUI) x86-64, for MS Windows

c

md5	80a20106ced1a5d9f350b1401dbe7d14
sha1	753561bf6da3cbb75711d109ed0e38b7abb28db8
sha256	6d15a0807858dce0be652e480fa7f298482c7bbf2c1e116e6cf0a3d3df95180f
imphash	7edbb1f08aaa2756392c6eb6a6201489
PE date	2010-05-08 17:04:47 GMT

c is the installer to setup the stage3 ?? two DLLs embedded

Another older version

This was another file I took a look when I wanted to start looking at the VFS [this file efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74] [<https://www.virustotal.com/gui/file/efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74>].

efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74

file size	564040 (550.8KiB)
file magic	PE32 executable (GUI) Intel 80386, for MS Windows, Nullsoft Installer self-extracting archive
md5	4b9054475ff9aa15be35b42264715354
sha1	a088dfaee1779878353a1dc347a91a892e5dfd74
sha256	efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74
imphash	3abe302b6d9a1256e6a915429af4ffd2
PE date	2018-01-30 03:57:45 GMT

The first layer is pack, once unpack we get this version. The PE timestamp is legit the same timestamp is found in other PE directory entries. A date in strings Nov 20 2017 10:53:33 is used when building the system information for the field built

efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74_unpacked

file size	455680 (445.0KiB)
file magic	PE32 executable (GUI) Intel 80386, for MS Windows
md5	b405d76e325c20d951e74b33781540ba
sha1	eeb1313ae855af3642a56022eb6298a470d76671

sha256	efea3b1ccea2a9f592631b282b62ba542d5eb73fd4ee1cecfe4efc379d215305
--------	--

imphash	af1157c6aa4a47f92f955f129e023851
---------	----------------------------------

PE date	2017-11-20 18:54:59 GMT
---------	-------------------------

This sample doesn't have a VFS/configuration inside, this version doesn't load from the registry or resource.

The part in charge to load the configuration from the disk builds the path to the VFS by getting the value for `CSIDL_COMMON_APPDATA` (normally `C:\ProgramData`); then generate a UUID base on the drive serial number and computername. The algorithm to derivate the UUID is not the same in this one.

```
1 LPVOID __usercall GetVfsPath@<eax>(int a1@<ebp>)
2 {
3     HANDLE ProcessHeap; // eax
4     LPVOID result; // eax
5     LPVOID v3; // esi
6     WCHAR v4[260]; // [esp-248h] [ebp-254h] BYREF
7     char v5[64]; // [esp-40h] [ebp-4Ch] BYREF
8     int v6; // [esp+0h] [ebp-Ch]
9     int v7; // [esp+4h] [ebp-8h]
10    int retaddr; // [esp+Ch] [ebp+0h]
11
12    v6 = a1;
13    v7 = retaddr;
14    if ( SHGetFolderPathW(0, CSIDL_COMMON_APPDATA, 0, 0, v4) < 0 )
15        return 0;
16    ProcessHeap = GetProcessHeap();
17    result = HeapAlloc(ProcessHeap, 0, 0x104u);
18    v3 = result;
19    if ( !result )
20        return result;
21    strcpy(v5, "B597B8EF3F3F48DE683FEFEF6547980E");
22    GenerateUuid(v5);
23    v5[8] = 0;
24    sub_401730(v3, 260, L"%s\\%S.dat", v4);
25    return v3;
26 }
```

```

ComputerNameA = GetComputerNameA(Buffer, &nSize);
nSize &= -ComputerNameA;
result = GetWindowsDirectoryW(RootPathName, 0x104u);
if ( !result )
    return result;
v3 = wcschr(RootPathName, 0x5Cu);
if ( v3 )
    v3[1] = 0;
result = GetVolumeInformationW(RootPathName, 0, 0, &VolumeSerialNumber, 0, 0, 0, 0);
if ( !result )
    return result;
dwKey1 = 1664525 * VolumeSerialNumber + 1013904223;
dwKey2 = HIWORD(VolumeSerialNumber) ^ HIWORD(dwKey1);
i = nSize >= 2;
val[1] = VolumeSerialNumber ^ BYTE1(dwKey1) ^ Buffer[i];
if ( !nSize || i == nSize - 1 )
    j = 0;
else
    j = i + 1;
val[2] = VolumeSerialNumber ^ BYTE2(dwKey1) ^ Buffer[j];
if ( !nSize || j == nSize - 1 )
    v6 = 0;
else
    v6 = j + 1;
val[3] = VolumeSerialNumber ^ HIBYTE(dwKey1) ^ Buffer[v6];
if ( !nSize || v6 == nSize - 1 )
    v7 = 0;
else
    v7 = v6 + 1;
val[4] = VolumeSerialNumber ^ VolumeSerialNumber ^ (13 * VolumeSerialNumber + 95) ^ Buffer[v7];
if ( !nSize || v7 == nSize - 1 )
    v8 = 0;
else
    v8 = v7 + 1;
val[5] = VolumeSerialNumber ^ ((unsigned __int16)(VolumeSerialNumber ^ (26125 * VolumeSerialNumber - 3233)) >> 8) ^ Buffer[v8];
if ( !nSize || v8 == nSize - 1 )
    v9 = 0;
else
    v9 = v8 + 1;
val[6] = VolumeSerialNumber ^ dwKey2 ^ Buffer[v9];
if ( !nSize || v9 == nSize - 1 )
    v10 = 0;
else
    v10 = v9 + 1;
val[7] = VolumeSerialNumber ^ HIBYTE(dwKey2) ^ Buffer[v10];
val[0] = VolumeSerialNumber ^ dwKey1 ^ Buffer[0];
return sub_4320D0(
    this,
    0x21u,
    0x21u,
    0x21u,
    "%08x%04x%04x%04x%08x%04x",
    dwKey1,
    (unsigned __int16)(VolumeSerialNumber ^ (26125 * VolumeSerialNumber - 3233)),
    (unsigned __int16)(HIWORD(VolumeSerialNumber) ^ HIWORD(dwKey1)),
    *(unsigned __int16 *)val,
    *(DWORD *)&val[2],
    *(unsigned __int16 *)&val[6]);

```

The function GenerateUuid start at 0x004323D0 and ends at 0x004325E3.

I used [Qiling](#) to execute the function to be able to generate UUID for a targeted system.

The interesting part is here, the complete [script is here](#).

```

# Set hook on GetVolumeInformationW because Qiling
# implementation set a string instead of a DWORD in lpVolumeSerialNumber
# I should push a pull request
ql.os.set_api("GetVolumeInformationW", my_GetVolumeInformationW, QL_INTERCEPT.CALL)

# We allocate a buffer and set it as arg0 of the target function
# IDA detect the calling convention as __thiscall so arg0 is ecx
ptr = ql.mem.map_anywhere(256, minaddr=0x1000)
# this string is set the default one set by the malware
ql.mem.string(ptr, "B597B8EF3F3F4BDE683FEFEF65479B0E")
ql.arch.regs.write("ecx", ptr)
#ql.arch.stack_push(ptr)

# We set the sandbox profile to match the target VSN and computername
ql.os.profile["VOLUME"]["serial_number"] = f'{vsn:d}'
ql.os.profile["SYSTEM"]["computername"] = computername

# The unpack version as a bug in the CRT (maybe a bad unpack)
# we have to stop before the vsnprintf and dump the fmt parameter by hand
# ql.run(begin=0x4323d0, end=0x4325d7)
# data = ql.mem.read(ptr, 128)

ql.run(begin=0x4323d0, end=0x4325c7)

# We are at the call to vsnprintf we can dump the parameters
[buffer, buffercount, maxcount, ptr_fmt, arg0, arg1, arg2, arg3, arg4, arg5] = \
    [ ql.arch.stack_pop(), ql.arch.stack_pop(), ql.arch.stack_pop(),
      ql.arch.stack_pop(), ql.arch.stack_pop(), ql.arch.stack_pop(),
      ql.arch.stack_pop(), ql.arch.stack_pop(), ql.arch.stack_pop(),
      ql.arch.stack_pop()]

# We read the format string from the ptr and format it
fmt = ql.mem.string(ptr_fmt)
uuid = fmt % ( arg0, arg1, arg2, arg3, arg4, arg5 )
return uuid

```

```

$ export QL_ROOTFS=$HOME/truenas/lab-re/qiling/rootfs
$ python3 qiling_grace_uuid.py
../efcee275d23b6e71589452b1cb3095ff92b10ab68cd07957b2ad6be587647b74/efcee275d23b6e71589452b1cb
3095ff92b10ab68cd07957b2ad6be587647b74_unpacked 0xe241b532 WINDEV2210EVAL
WINDEV2210EVAL ; 0xe241b532 ; 99d912e9a7db7b98698cc3acefa57b98

```

For the test system, the file will be in **C:\ProgramData\99d912e9a7db7b98698cc3acefa57b98.dat**

Now we can locate the VFS file.

The VFS for this version is encrypted in **AES CBC** and used the key **c30eCSIfx0J6UtcV**

```

VfsPath = GetVfsPath((int)&savedregs);
Aes::Encrypt::KeySchedule("c3oeCSIfx0J6UtcV", 16, &g_AesEncryptCtx);
Aes::Decrypt::KeySchedule("c3oeCSIfx0J6UtcV", 16, &g_AesDecryptCtx);
if ( !VfsPath )
    return 0;
lpDecVfsData = 0;
dwSizeVfs = 0;
v3 = (void (__stdcall *)(HANDLE, DWORD, LPVOID))HeapFree;
v4 = OpenReadfileAt(0, &lpVfsFileContent);
if ( v4 )
{
    v5 = lpVfsFileContent;
    AES::DecryptCBC((char *)lpVfsFileContent, v4, (char **)&lpDecVfsData, &dwSizeVfs);
    if ( v5 )
    {
        ProcessHeap = GetProcessHeap();
        HeapFree(ProcessHeap, 0, v5);
    }
    v8 = lpDecVfsData;
    if ( lpDecVfsData )
    {
        v9 = LoadVFS(lpDecVfsData, dwSizeVfs, v6);
        v14 = v8;
    }
}

```

Custom AES implementation

The implementation of AES CBC have a subtlety for the last block.

```

import aes # https://raw.githubusercontent.com/boppreh/aes/master/aes.py

###
# Grace custom AES
###
class GraceAes(aes.AES):
    def decrypt_cbc(self, data):
        fp = io.BytesIO(data)
        dwLen = len(data)

        previous = fp.read(0x10)
        dst = b''

        while True:
            if fp.tell() >= dwLen - 0x20:

                # Read last full block and decrypt it
                d = fp.read(0x10)
                val = self.decrypt_block(d)

                # Read the final block and xor with decrypted last full block
                d2 = fp.read(0x10)
                val2 = aes.xor_bytes(val, d2)

                # Append the decrypted block bytes to get a full block
                d2 += bytes(val[-(0x10-len(d2)):])

                # decrypt and CBC
                val = self.decrypt_block(d2)
                val = aes.xor_bytes(previous, val)

                dst += val
                dst += val2
                break
            # last case

            d = fp.read(0x10)
            val = self.decrypt_block(d) # decrypt
            val = aes.xor_bytes(previous, val) # do CBC
            dst += val
            previous = d

        return dst

```

The VFS

Now that's when I found [Rolf Rolles's IDB](#) saved me a lot of time.

He calls those functions [DataHive](#).

Modalities			
Standalone			
Configuration			
Virtual File System			
HiveHeap			
ByteStream			
DataHive			
Constructors, Destructor			
<code>DataHive__ConstructEmpty</code>	.text	00430930	
<code>DataHive__ConstructFromRawUseHiveHeap</code>	.text	004309C0	
<code>DataHive__ConstructFromRaw</code>	.text	00430860	
<code>DataHive__Constructor</code>	.text	00435B00	
<code>DataHive__Destructor</code>	.text	00430A80	
High-Level Interface			
Store Data			
Retrieve Data			
Create Packs, Entries			
<code>DataHive__CopyPackIntoOtherHive</code>	.text	0042FFC0	
<code>DataHive__ReadEntireStreamContents</code>	.text	0042FF10	
Internals			
Pack, Entry Metadata Management			
Construction from Bytes			
<code>DataHive__BuildEntryMetaData32</code>	.text	004355F0	
<code>DataHive__BuildEntryMetaData64</code>	.text	00435450	
<code>DataHive__BuildPackMetaData32</code>	.text	00435950	
<code>DataHive__BuildPackMetaData64</code>	.text	00435790	
Stream Backing Storage			
<code>DataHive__SerializeEntryToStream</code>	.text	00434570	
<code>DataHive__SerializePackToStream</code>	.text	00433C60	
<code>DataHive__WriteSerializedDataForEntry</code>	.text	00434AC0	
<code>DataHive__ReadSerializedDataForEntry</code>	.text	00434C80	
<code>DataHive__FreePackEntries</code>	.text	00434310	
<code>DataHive__FreeEntryStreamData</code>	.text	004349A0	
Index Management			
Removal			
Stream Data Management			
Retrieval			
Indexes			
<code>DataHive__FindChildPackIndexByName</code>	.text	00433DD0	
<code>DataHive__FindStoredEntryIndexByName</code>	.text	00434690	
<code>DataHive__GetIndexOffFirstChildOfPack</code>	.text	00430BB0	
<code>DataHive__GetPackIndexByStructuredName</code>	.text	004340E0	
<code>DataHive__GetPackIndexByStructuredNarrowName</code>	.text	00430B10	
Names			
<code>DataHive__ReadEntryNameByIndex</code>	.text	004349F0	
<code>DataHive__RetrievePackName</code>	.text	004341C0	
<code>DataHive__GetPackDetails</code>	.text	00430B40	
<code>IterativeCrackDataHivePathA</code>	.text	00436110	
<code>IterativeCrackDataHivePathW</code>	.text	004361B0	

Since he reversed all the internal structure, decoding the VFS was just a matter of copying the structure in a python script and follow the `DataHive::Constructor` method.

```

class VFS_ByteStreamHeaderPattern(CStruct_):
    __def__ = """
        struct {
            uint32_t magic;
            uint16_t fixed4;
            uint8_t m64BitFlag;
            uint8_t dummy0;
            uint64_t dwHeaderLen;
            uint64_t zero;
        }
    """

class VFS_SerializedEntry32(CStruct_):
    __def__ = """
        struct {
            uint32_t dwNextEntryStreamPos;
            uint32_t dwDataStreamPos;
            uint32_t dwSerializedSize;
            uint8_t bValueType;
            uint8_t bEntryNameIsWideString;
            uint8_t wEntryNameLen;
            uint8_t dummy;
        }
    """

class VFS_SerializedPack32(CStruct_):
    __def__ = """
        struct {
            uint32_t dwStreamPos_NextSiblingPack;
            uint32_t dwStreamPos_FirstChildPack;
            uint32_t dwStreamPos_FirstEntry;
            uint8_t bEntryNameIsWideString;
            uint8_t wEntryNameLen;
            uint8_t dummy;
        }
    """

class VFS_SerializedPack64(CStruct_):
    __def__ = """
        struct {
            uint64_t dwStreamPos_NextSiblingPack;
            uint64_t dwStreamPos_FirstChildPack;
            uint64_t dwStreamPos_FirstEntry;
            uint8_t bEntryNameIsWideString;
            uint16_t wEntryNameLen;
        }
    """

def VFS_StrData(data):
    if isinstance(data, bytes):
        return f'{data[0:0x10]}'
    elif isinstance(data, int):
        return f'0x{data:x}'
    else:
        return f'{data}'

```

```

def VFS_UnserializedData(fp, se):
    fp.seek(se.dwDataStreamPos)
    if se.bValueType == 0: # Bytes
        return fp.read(se.dwSerializedSize)
    elif se.bValueType == 1: # Int
        return se.dwDataStreamPos
        #return struct.unpack('<I', fp.read(se.dwSerializedSize))[0]
    elif se.bValueType == 2: # Int64
        return struct.unpack('<Q', fp.read(se.dwSerializedSize))[0]
    elif se.bValueType == 3: # String
        return fp.read(se.dwSerializedSize).decode()
    elif se.bValueType == 4: # WString
        return fp.read(se.dwSerializedSize).decode()
    return None

def VFS_BuildEntryMetaData32(fp, pos, depth=0, path='', cb=None):
    s = VFS_SerializedEntry32()
    while(True):
        fp.seek(pos)
        try:
            s.unpack(fp)
        except:
            return

        name = fp.read(s.wEntryNameLen)
        try:
            name = name.decode()
        except:
            logger.debug('failed to decode name')
            pass

        try:
            data = VFS_UnserializedData(fp, s)
            try:
                if cb: cb(f'{path}/{name}', data)
            except Exception:
                logger.exception("cb")

            logger.debug(f'{" " * depth}entry 0x{pos:08x} | name = {name} |
{VFS_StrData(data)}')
        except:
            logger.exception("failed to UnserializedData")
            logger.debug(f'{" " * depth}entry 0x{pos:08x} | name = {name}')
        if not s.dwNextEntryStreamPos:
            return

        pos = s.dwNextEntryStreamPos

def VFS_BuildPackMetaData32(fp, pos, depth=0, path='', cb=None):
    s = VFS_SerializedPack32()
    while(True):
        fp.seek(pos)
        s.unpack(fp)

        fp.seek(pos + s.size -1)
        name = fp.read(s.wEntryNameLen)

```

```

try:
    name = name.decode()
except:
    pass

# First name is empty so we want to avoid //
if name != '':
    path_ = f'{path}/{name}'
else:
    path_ = ''

logger.debug(f'{" " * depth}pack 0x{pos:08x} | name = {name}')

if s.dwStreamPos_FirstEntry:
    VFS_BuildEntryMetaData32(fp, s.dwStreamPos_FirstEntry, depth+1, path_, cb)
if s.dwStreamPos_FirstChildPack:
    VFS_BuildPackMetaData32(fp, s.dwStreamPos_FirstChildPack, depth+1, path_, cb)
if not s.dwStreamPos_NextSiblingPack:
    return

pos = s.dwStreamPos_NextSiblingPack

```

Something interesting in the `DataHive::Constructor` is that the VFS start with a magic `0xE6F49DC4`.

```

// Set stream position to 0
v19 = 0;
vfpStreamFunc = apByteStream->pFunc;
*(_QWORD *)&vStreamPortionSize = 0i64;
vfpStreamFunc(apByteStream, Stream_SetCurPos, &vStreamPortionSize, (DWORD *)&v19);
// Get the first 24 bytes
vStreamPortionSize = sizeof(ByteStreamHeaderPattern);
if ( apByteStream->pFunc(apByteStream, Stream_GetBytes, (DWORD *)&vStreamHeaderPattern, &vStreamPortionSize) != sizeof(ByteStreamHeaderPattern) )
    return vpDataHive;
// Sanity check the results of the above/the predefined contents
if ( vStreamHeaderPattern.fixed0 != 0xE6F49DC4 )
    return vpDataHive;
if ( vStreamHeaderPattern.fixed4 > 3u )
    return vpDataHive;

```

The hunt

I decide to try to find new samples in the hope to collect some VFS so I wrote some Yara rules and run it on VT

```

import "pe"

rule gracewire_rsrc_names
{
    condition:
        pe.number_of_resources >= 1 and
        for any y in (0..pe.number_of_resources - 1): (
            pe.resources[y].name_string == "XC\x00\x00\x00")
}

rule gracewire_vfs_header
{
    strings:
        $magic = { c4 9d f4 e6 03 00 00 00 }
    condition:
        $magic
}

rule gracewire_packer_01
{
    strings:
        $name = "c.dll"
        $ldrloaddll = { C6 44 ?? ?? 4C
                        C6 44 ?? ?? 64
                        C6 44 ?? ?? 72
                        C6 44 ?? ?? 4c
                        C6 44 ?? ?? 6f
                        C6 44 ?? ?? 61
                        C6 44 ?? ?? 64
                        C6 44 ?? ?? 44
                        C6 44 ?? ?? 6c
                        C6 44 ?? ?? 6c }

    condition:
        $name and $ldrloaddll
}

// content:"f93j5RFRjhf2ASfy" or content:"er0ewjflk3qrhj81" or content:"c3oeCSIfx0J6UtcV" or
content:"kwREgu73245Nwg7842h" or content:{12 20 A5 16 76 E7 79 BD 87 7C BE CA C4 B9 B8 69 6D
1A 93 F3 2B 74 3A 3E 67 90 E4 0D 74 56 93 DE 58 B1 DD 17 F6 59 88 BE FE 1D 6C 62 D5 41 6B 25
BB 78 EF 06 22 B5 F8 21 4C 6B 34 E8 07 BA F9 AA }
rule gracewire_keys
{
    strings:
        $k1 = "f93j5RFRjhf2ASfy"
        $k2 = "er0ewjflk3qrhj81"
        $k3 = "c3oeCSIfx0J6UtcV"
        $k4 = "kwREgu73245Nwg7842h"
        $k5 =
"1220A51676E779BD877CBECAC4B9B8696D1A93F32B743A3E6790E40D745693DE58B1DD17F65988BEFE1D6C62D5416
B25BB78EF0622B5F8214C6B34E807BAF9AA"
        $k6 = {12 20 A5 16 76 E7 79 BD 87 7C BE CA C4 B9 B8 69 6D 1A 93 F3 2B 74 3A 3E 67 90
E4 0D 74 56 93 DE 58 B1 DD 17 F6 59 88 BE FE 1D 6C 62 D5 41 6B 25 BB 78 EF 06 22 B5 F8 21 4C
6B 34 E8 07 BA F9 AA }
    condition:

```

```
    any of them  
}
```

The `gracewire_keys` are keys that I've collected. They are most of the time used to decrypt the resources or VFS.

I get some hits, and I still get some from time to time, but everything is mostly old. Some samples have a small VFS in the resource, but the IOC are known and old. If it's in the resource after the decryption, we need to inflate it *lznt1* before parsing the VFS (@todo verify).

One hit was exciting because the rule was `gracewire_vfs_header` so an embed VFS without encryption.

`gracewire_vfs_header` P2P/926b145b5bda585657326e0f08c9aebb1be698e4f617c08352da50532a989244

It was a sample I had never encountered before, but with the style of the Grace's developer.

A P2P botnet

	926b145b5bda585657326e0f08c9aebb1be698e4f617c08352da50532a989244
file size	548352 (535.5KiB)
file magic	PE32 executable (DLL) (GUI) Intel 80386, for MS Windows
md5	029338d01927c127d703625a3cd3d46d
sha1	61ea8be635f0e6b62e618fe4e4d23f3238847eb4
sha256	926b145b5bda585657326e0f08c9aebb1be698e4f617c08352da50532a989244
imphash	1ec7c4f47b9b2cc9fc83c06310bc0b21
PE date	2021-05-24 12:27:57 GMT
VT ratio	detection $\frac{5}{67}$
VT scan_date	2022-01-09 23:15:54
VT link	link

I start looking around the internet and I found out this was not very new, NCC Group had already published some information on it.

<https://research.nccgroup.com/2021/12/01/tracking-a-p2p-network-related-with-ta505/>

The structures they provide help me to start writing a P2P client in Python, but at the end I was unable to finish it.

At the time of writing this post ($\frac{2022}{11}$) everything seem offline, and I was unable to find new IOC on VT to bootstrap the network.

The node configuration

The first configuration inside the sample is

```
$ python3 ../tools2/grace_vfs.py -f
926b145b5bda585657326e0f08c9aebb1be698e4f617c08352da50532a989244.vfs.config
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /cx/nid 1CF094259E06664DA5504A5E1C551759
4       <class 'int'>   /cx/dgx 0x4
4       <class 'int'>   /cx/exe 0x2
451     <class 'bytes'> /cx/key b'-----BEGIN PUBLI'
4       <class 'int'>   /cx/port          0xce5d
4       <class 'int'>   /va/45.129.137.237    0x84ac
4       <class 'int'>   /va/78.128.112.139    0x84ac
```

- **/cx/nid** is the network id
- **/cx/exe** DLL/exe
- **/cx/key** a RSA public key
- **/cx/port** the port to listen to on UDP
- **/va** the filename is the IP and the content of the entry the port to connect

The second one is

```
$ python3 ../tools2/grace_vfs.py -f
926b145b5bda585657326e0f08c9aebb1be698e4f617c08352da50532a989244.vfs2.config
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
4       <class 'int'>   /meta/app          0x1
4       <class 'int'>   /meta/mod          0x1
4       <class 'int'>   /meta/bld          0x1
4       <class 'int'>   /meta/api          0x1
4       <class 'int'>   /meta/llr          0x1
4       <class 'int'>   /meta/llt          0x1
```

Records

I was able to recover some records from peers.

This based on my vague souvenir.

This record is an update command received from one of the peers:

- **/meta/pwd** is the password to decrypt the record
- **/meta/seal** is some kind of signature (RSA ?) to avoid hijacking the botnet
- **/meta/cfg** is a another VFS inside
- **/hash** is the information to ask for file block for the update, each block is 0x1000 bytes and a hash is provided.
- **/drop** I don't remember, maybe some kind of blacklist to remove bad node?

```

$ python3 ../../tools2/grace_vfs.py -f record_997378FCD959AA48893CB3BB84541841.bin
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>      /meta/net      1CF094259E06664DA5504A5E1C551759
32      <class 'str'>      /meta/id       997378FCD959AA48893CB3BB84541841
6       <class 'str'>      /meta/tag      update
4       <class 'int'>      /meta/sta      0x1d7523c51f1de80
4       <class 'int'>      /meta/load      0x1df35
4       <class 'int'>      /meta/snc      0x1d7523c51e5f7a0
4       <class 'int'>      /meta/utl      0x0
12      <class 'str'>      /meta/uni      update.block
32      <class 'str'>      /meta/pwd      D486BB2FAB71BB44821A327124CA9233
256     <class 'bytes'>    /meta/seal     b'\x89oy\xed\x24\xfcL\xe5uN\xf2sM\xe4\xd2'
125     <class 'bytes'>    /meta/cfg      b'\xc4\x9d\xf4\xe6\x03\x00\x00\x00\x18\x00\x00\x00\x00\x00\x00'
4       <class 'int'>      /hash/dgst      0x4
4       <class 'int'>      /hash/size      0x20
4       <class 'int'>      /hash/0/ofs      0x0
4       <class 'int'>      /hash/0/size     0x1000
32      <class 'bytes'>    /hash/0/hash     b'\x82\x8e\xa2\xa6w\xbf\x80g\x1c\x0b\x99w\xc3)\x99\xa5'
4       <class 'int'>      /hash/1/ofs      0x1000
4       <class 'int'>      /hash/1/size      0x1000
32      <class 'bytes'>    /hash/1/hash      b'=\x82"2\xd7^\xbb\x8d:[\xeb\xef\xf9\x1c\xbb\xc0'
4       <class 'int'>      /hash/2/ofs      0x2000
4       <class 'int'>      /hash/2/size      0x1000
32      <class 'bytes'>    /hash/2/hash      b't\xfc\x82\xfb\xe4M}\xe1\x14\xb1\xe6r\x0f\xf0G\xbe'
4       <class 'int'>      /hash/3/ofs      0x3000
4       <class 'int'>      /hash/3/size      0x1000
32      <class 'bytes'>    /hash/3/hash      b'NU\xf2\x00\x9ea1\x8dvi\xcc\x82\xb38\xe\xc0'
4       <class 'int'>      /hash/4/ofs      0x4000
4       <class 'int'>      /hash/4/size      0x1000
32      <class 'bytes'>    /hash/4/hash      b'#j\x9c\xe7\xac\xea\xc7\x8a\n\xf0\xf7\x98\x95<\x01Q'
4       <class 'int'>      /hash/5/ofs      0x5000
4       <class 'int'>      /hash/5/size      0x1000
32      <class 'bytes'>    /hash/5/hash      b'\xb9\x97\xa1jK<\xa8in)R\xd2\x87\x8cLR'
4       <class 'int'>      /hash/6/ofs      0x6000
4       <class 'int'>      /hash/6/size      0x1000
32      <class 'bytes'>    /hash/6/hash      b'\xd6Eil\xa7\xb4\x8c\x0e\xb4\x97\x91\xdb\x8eC\x155'
4       <class 'int'>      /hash/7/ofs      0x7000
4       <class 'int'>      /hash/7/size      0x1000
32      <class 'bytes'>    /hash/7/hash      b'\xea\x06\xb0WF\x06\xfeUh\xe5o\xf5\xab\tH'
4       <class 'int'>      /hash/8/ofs      0x8000
4       <class 'int'>      /hash/8/size      0x1000
32      <class 'bytes'>    /hash/8/hash      b'\xe1*\x06\xd6-\xad\xe5\x9b\xcb?
\x96\x11\xf6\x88\x86\xe'
4       <class 'int'>      /hash/9/ofs      0x9000
4       <class 'int'>      /hash/9/size      0x1000
32      <class 'bytes'>    /hash/9/hash      b'J\x96[\x05\xafs2Q\xed&\xb7$\xf8\nL\x12'
4       <class 'int'>      /hash/A/ofs      0xa000
4       <class 'int'>      /hash/A/size      0x1000
32      <class 'bytes'>    /hash/A/hash      b'\xd9\x9c\xa4L\xbe\xe3\xe9\x87\x8a\xd2\x99J\xe6P4\x9a'
4       <class 'int'>      /hash/B/ofs      0xb000
4       <class 'int'>      /hash/B/size      0x1000
32      <class 'bytes'>    /hash/B/hash      b'|\xfb<\x10Y\xceV\xe3C\x97\xa2\xc0E\xae\x16'
4       <class 'int'>      /hash/C/ofs      0xc000

```

```

4      <class 'int'> /hash/C/size 0x1000
32     <class 'bytes'> /hash/C/hash b')7\xcdN\xfe\xc2\x80\xc32\xf5Tu`\x83\xc5\xd3'
4      <class 'int'> /hash/D/ofs 0xd000
4      <class 'int'> /hash/D/size 0x1000
32     <class 'bytes'> /hash/D/hash
b'\xa5\xdc\xf1D\x86\x9f\x80\x9c\x7f\xb7D\xcd\x19\xea\xd1Q'
4      <class 'int'> /hash/E/ofs 0xe000
4      <class 'int'> /hash/E/size 0x1000
32     <class 'bytes'> /hash/E/hash b'\xcf\xea, -)\xf8!`8*\xd7\xabEW&v'
4      <class 'int'> /hash/F/ofs 0xf000
4      <class 'int'> /hash/F/size 0x1000
32     <class 'bytes'> /hash/F/hash b'\x83\\1WI\x86\x1aq\x88~\xdd\xdf\xc5+\x9b3'
4      <class 'int'> /hash/10/ofs 0x10000
4      <class 'int'> /hash/10/size 0x1000
32     <class 'bytes'> /hash/10/hash
b'\xd2\xe1\xac/\x83\xe5\xf9\xe2\xd3\xde\x119\xe1\xe4\xb44'
4      <class 'int'> /hash/11/ofs 0x11000
4      <class 'int'> /hash/11/size 0x1000
32     <class 'bytes'> /hash/11/hash
b'\xf6\xb7\xed\x8a\xda\x80\xed\x06\x8e\xa9\xc9\x9c<\x15m\xd7'
4      <class 'int'> /hash/12/ofs 0x12000
4      <class 'int'> /hash/12/size 0x1000
32     <class 'bytes'> /hash/12/hash
b'\x03\x11\xff\xf8\xeb\xd5\xba20\xcdi\x90\xf5^\xcc\x8a'
4      <class 'int'> /hash/13/ofs 0x13000
4      <class 'int'> /hash/13/size 0x1000
32     <class 'bytes'> /hash/13/hash
b'<\xddY\x13\xedI\x11\xa0\xd1\xaa\xc5\xd9\xe2I\xc4\xe9'
4      <class 'int'> /hash/14/ofs 0x14000
4      <class 'int'> /hash/14/size 0x1000
32     <class 'bytes'> /hash/14/hash b'\xad%-e\xccU\xbc\x97\xf5\xe7#\xe7[\x1b\xd36'
4      <class 'int'> /hash/15/ofs 0x15000
4      <class 'int'> /hash/15/size 0x1000
32     <class 'bytes'> /hash/15/hash b'\xee\xe2\xf72\xc5\x8aJ\x0ci0S\xf8[\xfc\xbb8'
4      <class 'int'> /hash/16/ofs 0x16000
4      <class 'int'> /hash/16/size 0x1000
32     <class 'bytes'> /hash/16/hash
b'1\x90\xcbu\xdf7\xbb\xd6\n\xd8\xf8\x18\xb6\xf2\x18\xe0'
4      <class 'int'> /hash/17/ofs 0x17000
4      <class 'int'> /hash/17/size 0x1000
32     <class 'bytes'> /hash/17/hash b'\xda\xbc\xecZ\x93j\xda\x8ay\x14\xd5_\xc4\xa7\xa5"'
4      <class 'int'> /hash/18/ofs 0x18000
4      <class 'int'> /hash/18/size 0x1000
32     <class 'bytes'> /hash/18/hash b'\x8f\xdd\xf9d\xc0\x1fq0_\xe7\xb1\xf9.\xec\xef\x18'
4      <class 'int'> /hash/19/ofs 0x19000
4      <class 'int'> /hash/19/size 0x1000
32     <class 'bytes'> /hash/19/hash b'\xed/#\x85\xf4\xf1\xfe)\xdah\xe4Sw\xad\xf9\xc2'
4      <class 'int'> /hash/1A/ofs 0x1a000
4      <class 'int'> /hash/1A/size 0x1000
32     <class 'bytes'> /hash/1A/hash b'\x882`x*\xf3\xf8\\\x80\x05m=>4\xac\xab'
4      <class 'int'> /hash/1B/ofs 0x1b000
4      <class 'int'> /hash/1B/size 0x1000
32     <class 'bytes'> /hash/1B/hash b'\xc2\xd36,\xeb\xeaN\xc4BD\xac\xd9\xf2k\xe1\x92'
4      <class 'int'> /hash/1C/ofs 0x1c000
4      <class 'int'> /hash/1C/size 0x1000
32     <class 'bytes'> /hash/1C/hash b'\xf6<\xf50\xd0\xa9\x1ez}f_B\x12\xc7g\x1c'
4      <class 'int'> /hash/1D/ofs 0x1d000

```

```
4      <class 'int'>    /hash/1D/size    0xf35
32     <class 'bytes'> /hash/1D/hash    b'm\x96\xcfC\xd0Z88Ar\xd3\xce\xa8\x03\xe8\xbd'
13     <class 'str'>    /drop/0/host    194.165.16.94
4      <class 'int'>    /drop/0/port    0x8ad5
```

From [/meta/cfg](#)

```
32     <class 'str'>    /fp      B88763DF8318F4962F0EFD398234DF96
4      <class 'int'>    /rs      0x1
4      <class 'int'>    /md      0x0
```

Packet handler

I rewrite kind of pkt_handler in python

```

def pkt_handler(self, addr, pkt, pkt_data, data):
    if pkt.bFrameId == 0x10:
        logging.info(f'[#] echo recv')
    elif pkt.bFrameId == 0x7:
        logging.info(f'[#] fit one packet')
        hdr = NodePktDataHeader()
        hdr.unpack(data)
        logging.info(f'{hdr}')
        if hdr.bCmdId == 0x1:
            logging.info(f'  [#] invitation packet')
            inv = NodePktInvitation()
            inv.unpack(data)
            logging.info(f'    {inv}')
        elif hdr.bCmdId == 0x2:
            logging.info(f'  [#] add node to probes')
            inv = NodePktInvitation()
            inv.unpack(data)
            logging.info(f'    {inv}')
        elif hdr.bCmdId == 0x03:
            logging.info(f'  [#] Get a ping request')
            node_info = unserialized(data[hdr.size:])
            logging.info(f'    node_info: {node_info} | {node_info[1]}/{node_info[0]}
connections | {node_info[2]} records')
            # @todo implement response
        elif hdr.bCmdId == 0x4:
            logging.info(f'  [#] node info')
            node_info = unserialized(data[hdr.size:])
            logging.info(f'    node_info: {node_info} | {node_info[1]}/{node_info[0]}
connections | {node_info[2]} records')
        elif hdr.bCmdId == 0x05:
            logging.info(f'  [#] Get a new node')
            fp = io.BytesIO(data[hdr.size:])
            node_id = fp.read(0x10)
            node_port = struct.unpack('<H', fp.read(2))[0]
            node_ip = fp.read(ord(fp.read(1))).decode()
            logging.info(f'    node_id: {node_id.hex()} node: {node_ip}:{node_port:d}')
            n = { 'addr': [node_ip, node_port], 'node_id': node_id.hex()}

            is_exist = False
            for v in self.store['nodes']:
                if v['node_id'] == node_id.hex():
                    is_exist = True
                    break

            if not is_exist:
                logging.info(f'    adding node to store')
                self.store['nodes'].append(n)
                self.send_invitation(n['addr'])

        elif hdr.bCmdId == 0x06:
            logging.info(f'  [#] Get a record metadata')
            record_id = data[hdr.size:hdr.size+0x10]
            record_info = unserialized(data[hdr.size+0x10:])
            logging.info(f'    record_id: {record_id.hex()} record_info: {record_info}')
        elif hdr.bCmdId == 0xa:
            logging.info(f'  [#] Get a record')

```

```

        r = NodePktRecord()
        r.unpack(data)
        logging.info(f' {r}')

    else:
        logging.info(f' [#] unsupported hdr.bCmdId 0x{hdr.bCmdId:x}')
    elif pkt.bFrameId == 0xd:
        open(f'record_{pkt_data.dwUnk}_{pkt_data.dwCurId}_{pkt_data.dwTotal}.bin',
'wb').write(data)
        pass
    else:
        logging.info(f' [#] unsupported pkt.bFrameId 0x{pkt.bFrameId:x}')

```

File store on the filesystem

On execution, the malware use the file system to store information about the P2P network state. Most of the file follow the VFS structure. In [fs_files_from_sandbox.zip](#)

```

├─ net.dsx
├─ node
│   ├── 997378FCD959AA48893CB3BB84541841
│   │   ├── l
│   │   ├── m
│   │   └─ p
│   └─ BBBD9035B2A3CE4FB2A563F5FC6572DF
│       ├── l
│       ├── m
│       └─ p
├─ probes.dsx
├─ reports.dsx
├─ sessions
│   └─ 40DFE0CD66457646B3990B9B2160F622
├─ trash
├─ units
│   ├── block
│   │   └─ block.dll
│   └─ exec
│       └─ exec.dll
├─ units.dsx
└─ updates

```

- [net.dsx](#) contain the node id
- [node](#) contains record received from node, the sub key is the record id
 - [l](#) unknown
 - [m](#) contains the record meta data
 - [p](#) is the record data
 - [session](#) the files inside are VFS, but I don't remember
 - [probe.dsx](#) contains other node information
 - [units](#) contains the *unit* it's the payload recover from the record download from node in [p](#)

```

$ python3 ../../tools2/grace_vfs.py -f net.dsx
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /gx/id    67E3945FF45AC644982765568986F30A

$ python3 ../../tools2/grace_vfs.py -f units.dsx
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /blo/rec    997378FCD959AA48893CB3BB84541841
100     <class 'str'>    /blo/exec    C:\Users\John\Desktop\target\units\block\block.dll
4       <class 'int'>    /blo/meta/app    0x1
4       <class 'int'>    /blo/meta/mod    0x2
10      <class 'str'>    /blo/meta/name    block
4       <class 'int'>    /blo/meta/bld    0x1
4       <class 'int'>    /blo/meta/hlt    0x1
4       <class 'int'>    /blo/meta/api    0x1
32      <class 'str'>    /ex/rec    BBBD9035B2A3CE4FB2A563F5FC6572DF
96      <class 'str'>    /ex/exec    C:\Users\John\Desktop\target\units\exec\exec.dll
4       <class 'int'>    /ex/meta/app    0x1
4       <class 'int'>    /ex/meta/mod    0x2
8       <class 'str'>    /ex/meta/name    exec
4       <class 'int'>    /ex/meta/bld    0x1
4       <class 'int'>    /ex/meta/hlt    0x1
4       <class 'int'>    /ex/meta/api    0x1

$ python3 ../../tools2/grace_vfs.py -f probes.dsx
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
4       <class 'int'>    /78.128.112.139/33964/curr    0x2
4       <class 'int'>    /78.128.112.139/33964/max    0x5
4       <class 'int'>    /78.128.112.139/33964/next    0x1d8228c5da8f7b0

$ python3 ../../tools2/grace_vfs.py -f reports.dsx
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /0536FC541A7AC84DA4D94C46541B475A/rec
997378FCD959AA48893CB3BB84541841
13      <class 'str'>    /0536FC541A7AC84DA4D94C46541B475A/ah    194.165.16.94
4       <class 'int'>    /0536FC541A7AC84DA4D94C46541B475A/ap    0x8ad5
4       <class 'int'>    /0536FC541A7AC84DA4D94C46541B475A/ec    0x0
4       <class 'int'>    /0536FC541A7AC84DA4D94C46541B475A/atm    0x3e8
4       <class 'int'>    /0536FC541A7AC84DA4D94C46541B475A/last    0x0
4       <class 'int'>    /0536FC541A7AC84DA4D94C46541B475A/es    0x1d8228c1b9030f0

$ python3 ../../tools2/grace_vfs.py -f sessions/40DFE0CD66457646B3990B9B2160F622
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
4       <class 'int'>    /g/c    0x1d8228bf4c4b400
4       <class 'int'>    /g/l    0x1d8228c4b60f1c0
16      <class 'bytes'>  /a/x    b'\x02\x00\x84\xac-
\x81\x89\xed\x00\x00\x00\x00\x00\x00\x00\x00'

$ python3 ../../tools2/grace_vfs.py -f node/997378FCD959AA48893CB3BB84541841/m
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /meta/net    1CF094259E06664DA5504A5E1C551759

```

```

32      <class 'str'>    /meta/id      997378FCD959AA48893CB3BB84541841
6       <class 'str'>    /meta/tag      update
4       <class 'int'>    /meta/sta      0x1d7523c51f1de80
4       <class 'int'>    /meta/load      0x1df35
4       <class 'int'>    /meta/snc      0x1d7523c51e5f7a0
4       <class 'int'>    /meta/utl      0x0
12      <class 'str'>    /meta/uni      update.block
32      <class 'str'>    /meta/pwd      D486BB2FAB71BB44821A327124CA9233
256     <class 'bytes'> /meta/seal      b'\x89oy\xed\xa24\xfcL\xe5uN\xfsM\xe4\xd2'
125     <class 'bytes'> /meta/cfg
b'\xc4\x9d\xf4\xe6\x03\x00\x00\x00\x18\x00\x00\x00\x00\x00\x00'
4       <class 'int'>    /hash/dgst      0x4
4       <class 'int'>    /hash/size      0x20
4       <class 'int'>    /hash/0/ofs      0x0
4       <class 'int'>    /hash/0/size     0x1000
32      <class 'bytes'> /hash/0/hash
b'\x82\x8e\xa2\xa6w\xbf\x80g\x1c\x0b\x99W\xc3)\x99\xa5'
4       <class 'int'>    /hash/1/ofs      0x1000
4       <class 'int'>    /hash/1/size     0x1000
...

$ python3 ../../tools2/grace_vfs.py -f node/BBBD9035B2A3CE4FB2A563F5FC6572DF/m
VFS_ByteStreamHeaderPattern(magic=0xe6f49dc4, fixed4=0x3, m64BitFlag=0x0, dummy0=0x0,
dwHeaderLen=0x18, zero=0x0)
32      <class 'str'>    /meta/net      1CF094259E06664DA5504A5E1C551759
32      <class 'str'>    /meta/id      BBBD9035B2A3CE4FB2A563F5FC6572DF
6       <class 'str'>    /meta/tag      update
4       <class 'int'>    /meta/sta      0x1d7523c51fb7b70
4       <class 'int'>    /meta/load      0x20d2f
4       <class 'int'>    /meta/snc      0x1d7523c51f6c080
4       <class 'int'>    /meta/utl      0x0
11      <class 'str'>    /meta/uni      update.exec
32      <class 'str'>    /meta/pwd      2ECDEA5A357B5D4F968AD1EBF2B86B39
256     <class 'bytes'> /meta/seal      b'!\xb2N\xc7*\xcf\xb3D/\xea[\xfc\x0e\xa5N\xca'
125     <class 'bytes'> /meta/cfg
b'\xc4\x9d\xf4\xe6\x03\x00\x00\x00\x18\x00\x00\x00\x00\x00\x00'
4       <class 'int'>    /hash/dgst      0x4
4       <class 'int'>    /hash/size      0x20
4       <class 'int'>    /hash/0/ofs      0x0
4       <class 'int'>    /hash/0/size     0x2000
32      <class 'bytes'> /hash/0/hash
b'\xf5\xf3\xe2\x91\xd3\x07\x05\xdb8\xde_\xb3\x12E\xe2'
4       <class 'int'>    /hash/1/ofs      0x2000
4       <class 'int'>    /hash/1/size     0x2000
...

```

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