Malware | Smoke Loader malware improves after Microsoft spoils its Campaign

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Introduction

Early this year, in March 2018, Microsoft' Windows Defender Research Team in Redmond published some interesting insights into a massive malware campaign distributing a dropper/loader called Smoke Loader (also known as Dofoil). The main purpose of the documented campaign was to distribute a coin miner payload that is using infected machines to mine crypto currencies. Within 12 hours, Windows Defender recorded more than 400,000 instances, but could deploy appropriate countermeasures on computers running Windows within seconds. As further analysis from Spamhaus Malware Labs revealed, these countermeasures did not stay unattended by the malware authors behind Smoke Loader.

Apparently, as a reaction on Microsoft' countermeasures, the malware authors behind Smoke Loader made some significant code changes in order to bypass Windows Defender and other Antivirus software. These code changes include:

- Change in the infection techniques
- Introduction of 64bit payload

Anti-VM and Anti-Analysis techniques in the packer

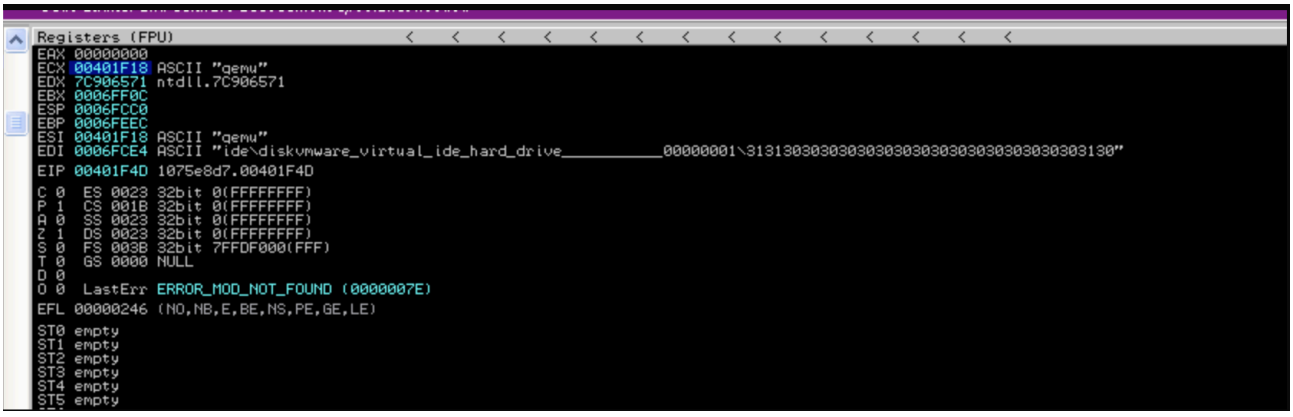
What stares out with Smoke Loader is that the packer and the main executable (unpacked payload) is related to each other. It is necessary for the unpacked payload to be loaded by the packer in order to run. In addition, the unpacked code checks for certain markers created by the packer in order to run. When Smoke Loader gets executed in a sandbox (for example a virtual environment), the sample fails to start. The reason for this are Anti-VM and Anti-Analysis techniques that Smoke Loader implemented in the code recently. An initial examination under IDA reveals that the code is obfuscated with *jump chains* whose sole purpose is to make the static analysis harder.

```
1   Address  Thread   Command                                  ; Registers and comments
2   0040291B Main     JNZ SHORT 1075e8d7.00402923
3   0040291D Main     JE SHORT 1075e8d7.00402923
4   00402923 Main     POP EBX                                  ; EBX=0040291B
5   00402924 Main     JMP SHORT 1075e8d7.00402930
6   00402930 Main     JMP SHORT 1075e8d7.00402927
7   00402927 Main     SUB EBX,291B                             ; EBX=00400000
8   0040292D Main     JMP SHORT 1075e8d7.00402934
9   00402934 Main     JE SHORT 1075e8d7.0040293D
10  00402936 Main     JNZ SHORT 1075e8d7.0040293D
11  0040293D Main     PUSH 30
12  0040293F Main     JNZ SHORT 1075e8d7.00402946
13  00402946 Main     POP EAX                                  ; EAX=00000030
14  00402947 Main     JMP SHORT 1075e8d7.00402951
15  00402951 Main     JMP SHORT 1075e8d7.0040294B
16  0040294B Main     MOV EAX,DWORD PTR FS:[EAX]               ; EAX=7FFDA000
17  0040294E Main     JMP SHORT 1075e8d7.00402954
18  00402954 Main     JMP SHORT 1075e8d7.0040295C
19  0040295C Main     CMP DWORD PTR DS:[EAX+A4],6
20  00402963 Main     JL SHORT 1075e8d7.004029B2
21  004029B2 Main     RETN
22  7C817067 Main     PUSH EAX
23  7C817068 Main     CALL kernel32.ExitThread
24
```

Runtrace The code at line number 19 (*0040295C Main CMP DWORD PTR DS:[EAX+A4],*) reveals that Smoke Loader checks the version of the operating system in PEB structure. In case the operating system where the malware sample gets executed on is less than version 6 (Windows NT 6, which equals to Windows Vista), the malware sample immediately stop the execution. In addition, there are a handful other checks based on debugging flags, which can be traced back using the same tracing technique.

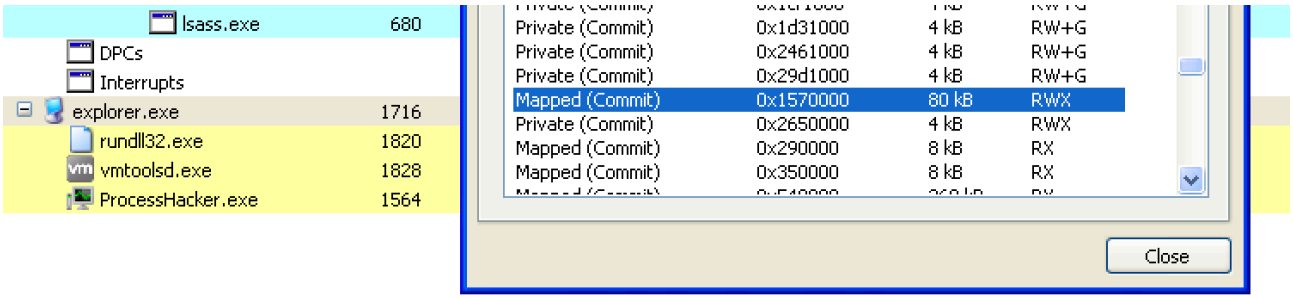
Furthermore, the recent Smoke Loader version also overwrites some of its own code section with new instruction that do also contain anti-analysis code and code related to packer loading.

A call trace helps to determine the functionality of that modified mode as shown below.

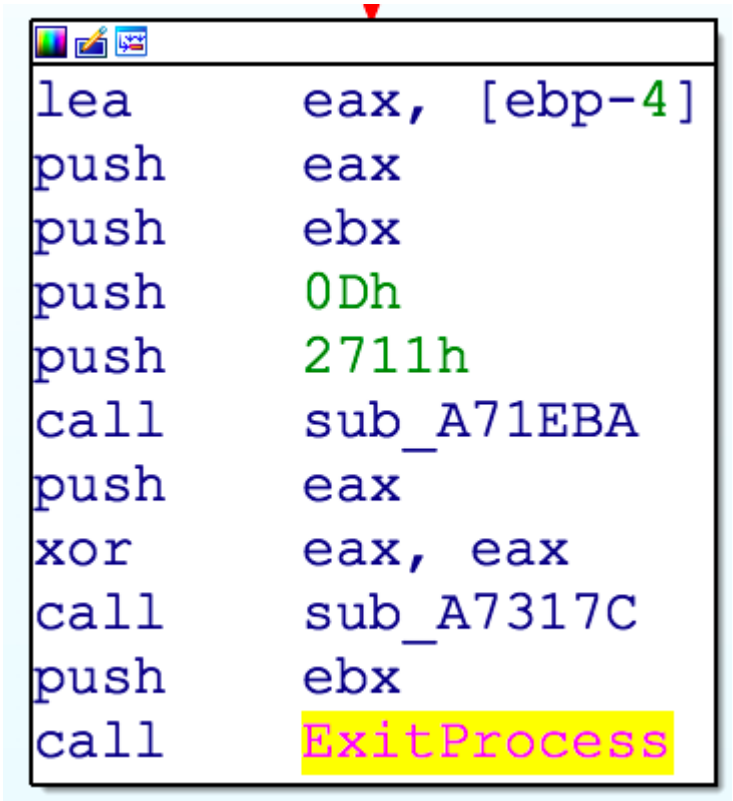


Anti-VM checks The code snipped shown above show code that checks for certain signs of a virtual environment, for example the presence of certain drivers of VirtualBox or certain strings that would trace the environment where the malware sample gets executed to Qemu.

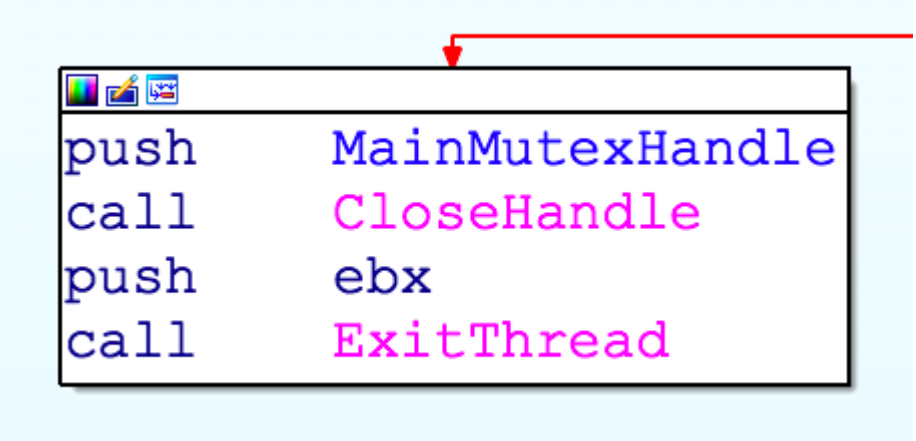
In previous versions, Smoke Loader would create a hollow process and then inject the unpacked code into it. However, after Microsoft spoiled the massive Smoke Loader campaign in March 2018, the most recent version of Smoke Loader injects itself into a running instance of Windows Explorer (explorer.exe) instead of creating a hollow process. The injection is now based on the same technique as used by PowerLoader, which uses *SendNotifyMessage* for code injection. Also, while previous versions of Smoke Loader were using 32bit code, the most recent version of Smoke Loader contains 64bit code in order to inject itself into explorer.exe on computers that are running a 64bit operating system.



Smoke Loader injecting into explorer.exe The following code change highlights that the final payload is supposed to be run as thread instead of a separate process.



Previous version (process based)



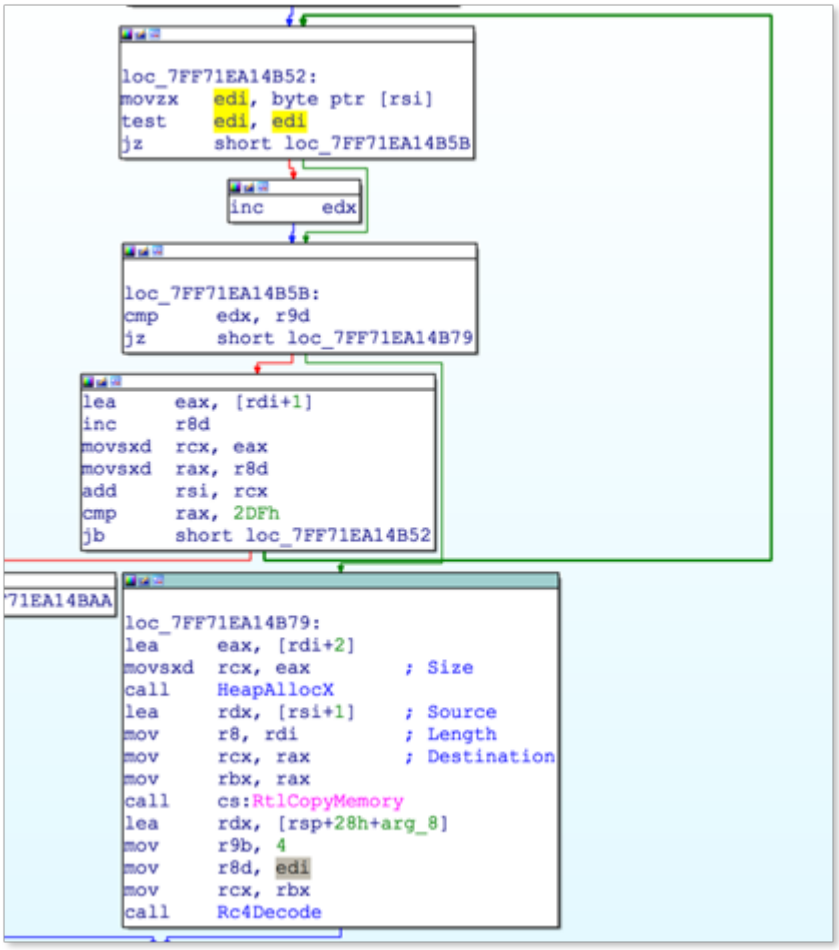
Recent version (thread based) The packer creates a shared file map which contains various information on the initial infection, such as the packed binary. This file map is later being used by the executing thread.

Type	Name	Handle
Desktop	\Default	0x20
Directory	\KnownDlls	0x8
Directory	\Windows	0x14
Directory	\BaseNamedObjects	0x34
Event	\BaseNamedObjects\S8702B746697FD55	0x4c
File	C:\Documents and Settings\Administrator\Desktop\API Call Logger	0xc
File	C:\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83	0x40
Key	HKLM	0x30
Key	HKLM\SYSTEM\ControlSet001\Services\Disk\Enum	0x3c
KeyedEvent	\KernelObjects\CritSecOutOfMemoryEvent	0x4
Section	\BaseNamedObjects\98702B746697FD55	0x48
Semaphore	\BaseNamedObjects\shell.{A48F1A32-A340-11D1-BC6B-00A0C90312E1}	0x38
Token	RAASHID-D3927DE\Administrator: 0xfcd1	0x44
WindowStation	\Windows\WindowStations\WinSta0	0x1c
WindowStation	\Windows\WindowStations\WinSta0	0x24

Shared file map The name of the shared file map is generated from VolumeSerialNumber of root drive of the infected machine. This shared file map can be used as an indicator of compromise (IOC).

Additional changes in the code

While the previously string encoding algorithm used by Smoke Loader was based on xor, the most recent version includes an RC4 based string encryption as highlighted on the screenshot above.



RC4 based string decryption The following IDA python script can help with static decoding of Smoke Loader: download

In earlier versions of Smoke Loader, the botnet controller domain names (C&C) were encoded using an algorithm that was based on a simple xor subtraction:

```
def Decodec2(data):
   XorKey = struct.unpack("<B", data[0])[0]
   dst = array.array("B")
   base = data[5:]
   PackLen = struct.unpack("<B", data[4])[0]
   print PackLen
   for i in range(0, PackLen - 1, 2):
       #print  chr(   (   ( ord (base[i]) ^ XorKey) & 0xff) - ((ord(base[i + 1] ) ^ XorKey) & 0xff) & 0xff ),
       dst.append((   ( ord (base[i]) ^ XorKey) & 0xff) - ((ord(base[i + 1] ) ^ XorKey) & 0xff) & 0xff )
   return dst.tostring()
```

The most recent version of Smoke Loader has been modified by the authors to make use of a more complex encoding scheme which is based on multiple operations:

```
 def swap32(x):
    return (((x << 24) & 0xFF000000) |
            ((x <<  8) & 0x00FF0000) |
            ((x >>  8) & 0x0000FF00) |
            ((x >> 24) & 0x000000FF))
def Decodec2(buf):
    BufLen = struct.unpack("<B", buf[0])[0]
    print "[] Buf len = %d" % BufLen
    XORDword = struct.unpack("<I", buf[BufLen + 1 : BufLen + 1 + 4])[0]
    print "[] XorDword is %d" % XORDword
    XORDword = swap32(XORDword)
    print hex(XORDword)
    x = 0
    dst = array.array("B")

    for i in buf[1:BufLen + 1]:
        x = ord(i)

        x =  x ^ (XORDword & 0xff)

        XORDword =  (XORDword >> 8 )
        x = x ^ (XORDword & 0xff)

        XORDword =  (XORDword >> 8 )
        x = x ^ (XORDword & 0xff)

        XORDword = (XORDword >> 8 )
        x = x ^ (XORDword & 0xff)

        x = x - (1 << 8)
        x = -x & 0xff
        print chr(x- 1),
        dst.append ((x-1))
        XORDword  = swap32(struct.unpack("<I", buf[BufLen + 1 : BufLen + 1 + 4])[0])
    return dst.tostring()
```

An HTTP request from Smoke Loader to the botnet controller (C&C server) consists of some internals constants as well as system information from the infected machine. The request is formatted as shown below.

```
RequestType = a2;
v6 = 63;
v13 = 63;
if ( SavedPayloadHash )
{
  v7 = lstrlenA(SavedPayloadHash);
  v6 = v7 + 63;
  v13 = v7 + 63;
}
AllocHeapX(v6 + 1);
v9 = (int)v8;
*v8 = 2018;
lstrcatA(v8 + 1, &MutexName_HexBuffer);
lstrcatA(v9 + 43, &unk_10005079);
*(_BYTE *)(v9 + 49) = unk_10005293 + 16 * unk_1000528F;
*(_BYTE *)(v9 + 50) = unk_1000539F;
*(_BYTE *)(v9 + 51) = ProcessTokenInfo;
*(_WORD *)(v9 + 52) = RequestType;
*(_DWORD *)(v9 + 54) = Const2;
*(_DWORD *)(v9 + 58) = InstByte;
if ( SavedPayloadHash )
  lstrcatA(v9 + 62, SavedPayloadHash);
v10 = ConnectToC2((int)&v13, (void *)1, 1);
```

C2 packet format The HTTP response from the botnet controller (C&C server) is typically an RC4 encrypted payload that can include multiple, so called “plugins” (such as the coin miner mentioned by the Windows Defender Team). The RC4 encrypted payload also includes one of the following commands:

- **i** - Download a file from http location field from using command ID 102
- **r** - Uninstall Dofoil from system (followed by ack packet using command ID 114)
- **u** - Update dofoil (download from http location field updated binary)

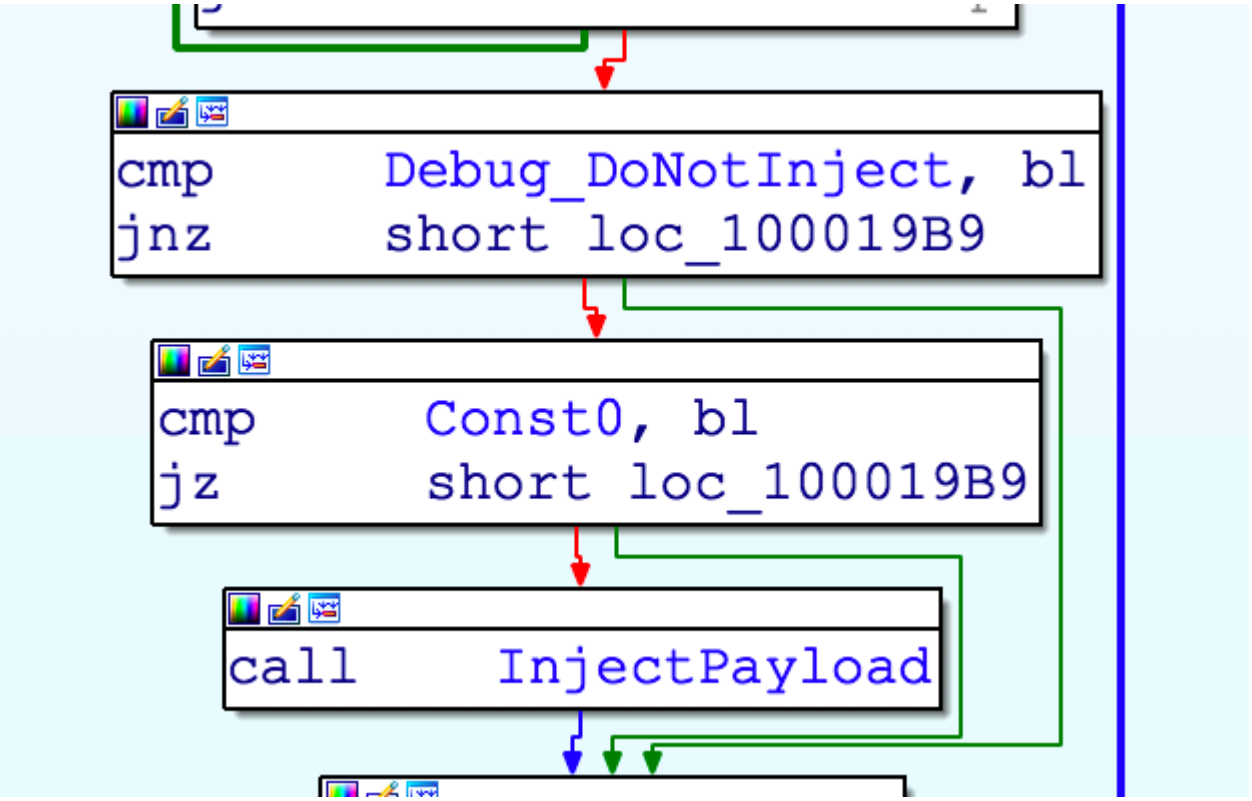
Based on way Smoke Loader calculates the mutex name an infected machine, we can create a vaccine to prevent Smoke Loader from infecting a machine:

```
 #define WIN32_LEAN_AND_MEAN
#include <windows.h>

#include <wincrypt.h>

void MD5(BYTE* data, ULONG len, unsigned char *out)
{
        HCRYPTPROV hProv = 0;
        HCRYPTPROV hHash = 0;
        BYTE rgbHash[16]= {0};
        DWORD cbHash = 16;
```

```
        char hash[3] = {0};
        int i = 0;
        CryptAcquireContext(&hProv, NULL, NULL, PROV_RSA_FULL, CRYPT_VERIFYCONTEXT);
        CryptCreateHash(hProv, CALG_MD5, 0, 0, &hHash);

        CryptHashData(hHash, data, len, 0);



        CryptGetHashParam(hHash, HP_HASHVAL, rgbHash, &cbHash, 0);
        for (i = 0 ; i < 16; i++)
        {
                sprintf(hash, "%.2X", rgbHash[i]);
                strcat(out, hash);
        }
        CryptDestroyHash(hHash);
        CryptReleaseContext(hProv, 0);


}

int main(int argc, char **argv)
{
        unsigned char *Source = (unsigned char *) malloc(sizeof(char) * 265);
        unsigned char *md5Sum = (unsigned char *) malloc(sizeof(char) * 34);
        DWORD lpVolumeSerialNumber = 0;

        unsigned char *FtString = (unsigned char *) malloc(sizeof(char) * 34);

        int ComNameSize = 16;
        char CompName[MAX_COMPUTERNAME_LENGTH + 0x10] = {0};

        memset(md5Sum, 0x00, 34);
        memset(FtString, 0x00, 34);
        memset(Source, 0x00, 265);

        GetComputerName(CompName,&ComNameSize);

        GetSystemDirectoryA(Source, 260);

        Source[3] = 0x00;
        GetVolumeInformationA(Source, 0, 0, &lpVolumeSerialNumber, 0, 0, 0, 0);

        sprintf(FtString, "%s%08X%08X", CompName, 0xFEE7D621, lpVolumeSerialNumber);

        MD5(FtString, strlen(FtString), md5Sum);

        sprintf(md5Sum, "%s%08X", md5Sum, lpVolumeSerialNumber);
```

```
        printf("%s", md5Sum);
        CreateMutex(0,0,md5Sum);
        while(1) Sleep(0x1000);


}
```

During the binary code analysis, Spamhaus Malware Labs found some sections in the code that are obviously being used by the author of Smoke Loader for debug purpose. This proves that Smoke Loader is still under heavy development of its authors and is constantly evolving.



Debug variables

Conclusion

Since late 2017, Spamhaus Malware Labs could identify more than 8,000 smoke loader malware samples which call out to over 1,000 unique botnet controllers (C&C servers). In addition, to the latest code changes made by the authors of Smoke Loader in response to the countermeasures by Windows Defender, we do also see a trend in certain Smoke Loader campaigns that are shifting away from the official TLDs over to decentralized TLDs (dTLDs) such as Namecoins .bit. By using decentralized TLDs for botnet C&C hosting, botnet operators try to make their botnet C&C infrastructure more resilient against takedown attempts by security researchers and law enforcement agencies (LEA).

Spamhaus Malware Labs continues to follow the further development of Smoke Loader and takes the appropriate actions to protect Spamhaus users from this threat.

Further reading

- Microsoft Secure: Behavior monitoring combined with machine learning spoils a massive Dofoil coin mining campaign
- Microsoft Secure: Poisoned peer-to-peer app kicked off Dofoil coin miner outbreak
- Microsoft Secure: Hunting down Dofoil with Windows Defender ATP
- abuse.ch: .bit - The next Generation of Bulletproof Hosting
- Spamhaus Botnet Threat Report 2017
