Carving the IcedId - Part 3

blog.techevo.uk/analysis/binary/2024/03/17/carving-the-icedid-part-3.html

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Welcome back to this series, analysing IcedId malware artefacts.

This is part 3 in the series, you can check out part 1 and part 2 to follow along from the beginning.

This post will focus on analysing a DLL file that was downloaded using a PowerShell script analysed in previously in part 2.

The data for this case was published by @malware_traffic over at **Malware Traffic Analysis**[1]. You can download all the samples from this case from here.

This analysis has really stretched my learning regarding unpacking, it has by far been the most challenging and rewarding sample I've come across to date. If there are any errors that you spot, I'd really welcome the feedback to understand better how this sample works.

In order to make this walk through as accessible as possible, I will once again be storing artefacts and output in a GitHub repository here.

The GitHub repository contains the extracted shellcode as seen in the various commands for your own experimentation, as well as the final payload.

TL;DR

This post is fairly detailed and as a result quite long. A quick overview of how the sample executes is listed below to provide some quick insight. If you want a more guided tour of the execution and other interesting observations, skip this section.

1. `rundll32.exe` executes a export on the dll.
2. The DLL routine allocates some memory and copies and unpacks data into shellcode from the `.reloc` section of the DLL.
3. The unpacking consists of a 4 byte XOR as well as the supplied string on the command line, for various stages.
4. The unpacked shellcode is patched with function addresses and creates some `syscall` stubs to avoid `ntdll.dll` hooks.

5. The `rundll32.exe` process opens `svchost.exe` and injects a payload using shared mapped views of sections and `NtQueueUserThread`
6. The `svchost.exe` process further unpacks a PE file which is then injected into memory at a fixed location.
7. The injected payload is then executed.
8. The final payload can be downloaded from the Bazaar or GitHub

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In the previous post, a PowerShell script was used to download a DLL named `r.dll` from a compromised WordPress instance.

Part of the script appended varying amounts of bytes to the file, ensuring the cryptographic hash changes with each download. You can find a copy of the DLL file on the Malware Bazaar, here The SHA1 hash for the copy we will be looking at in this post is: `1c6e76af95f2a17b8e518965d62b3c9d7ecba6d5`

For this explanation of the malware delivery, both static and dynamic analysis will be used in conjunction.

For static analysis I am using **radare2**[2] and for dynamic analysis **x64dbg**[3] both are freely available.

Binary File Triage

From the Powershell script we know there must be an export named `vcab`, we can use a **radare2** one-liner to show the various exports.

```
$ r2 -c 'iE' r.dll
```

```
[Exports]
nth paddr      vaddr        bind   type size lib            name
demangled
―――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――――
―――――――――――――――――――――

1   0x00000420 0x814e361020 GLOBAL FUNC 0    msys-edit-0.dll t_gcc_deregister_frame
2   0x00000400 0x814e361000 GLOBAL FUNC 0    msys-edit-0.dll t_gcc_register_frame
3   0x000151e0 0x814e375de0 GLOBAL FUNC 0    msys-edit-0.dll tel_fn_complete
4   0x000192c0 0x814e379ec0 GLOBAL FUNC 0    msys-edit-0.dll trl_abort_internal
5   0x00026338 0x814e38a138 GLOBAL FUNC 0    msys-edit-0.dll
trl_print_completions_horizontally
6   0x000192f0 0x814e379ef0 GLOBAL FUNC 0    msys-edit-0.dll trl_qsort_string_compare
7   0x00016bf0 0x814e3777f0 GLOBAL FUNC 0    msys-edit-0.dll tdd_history
8   0x000169a0 0x814e3775a0 GLOBAL FUNC 0    msys-edit-0.dll tppend_history
9   0x00000880 0x814e361480 GLOBAL FUNC 0    msys-edit-0.dll t__next_word
10  0x00000800 0x814e361400 GLOBAL FUNC 0    msys-edit-0.dll t__prev_word

[ TRUNCATED ]

152 0x000177a0 0x814e3783a0 GLOBAL FUNC 0    msys-edit-0.dll tistory_expand

[ TRUNCATED ]

430 0x00016fb0 0x814e377bb0 GLOBAL FUNC 0    msys-edit-0.dll there_history
431 0x000177a0 0x814e3783a0 GLOBAL FUNC 0    msys-edit-0.dll vcab
```

The above output is truncated, however you can see there are `431` exports on this DLL. The final export listed is the `vcab` export we already know about. You can find a full output of the command in the GitHub repository for this blog posts, here.

As well as the export names, the virtual addresses are also quite interesting. Looking at the export `tistory_expand`, ordinal `152`, we can see it has the same virtual address as the `vcab` export.

Given the large amount of exports I believe this is likely a legitimate DLL file that has been modified with some additional functionality. Searching for the DLL name `msys-edit-0.dll` also shows this is possibly related to the msys2 project.

Since we've looked at **Exports**, lets look at **Imports**, using the following command.

```
$ r2 -c 'ii' r.dll

[Imports]
nth vaddr        bind type lib          name
――――――――――――――――――――――――――――――――――――――――――――
1   0x814e391860 NONE FUNC KERNEL32.dll GetModuleHandleA
```

One import is not a lot to go off for understanding the functionality. The lack of imports is also quite suspicious, and something that indicates this DLL should be investigated further.

Statically analysing the DLL functions proved a little harder than expected. Forcing **Ghidra** to decompile the bytes was possible, but readability was not amazing.

To explore this sample further, I will be combining both static and dynamic analysis techniques.

Debugger Setup

For the dynamic analysis parts of this you will require some working knowledge of **x64dbg**. Primarily around setting breakpoints, although the commands are provided, just knowing what a breakpoint is and how to set it should be enough. If something isn't clear feel free to reach out and ask!

As well as the `vcab` entry point being supplied on the command line, a flag `/k` and string parameter were also provided as shown below.

> rundll32 r.dll, vcab /k chokopai723

To look into the execution of the DLL I'll be using **x64dbg**. It is possible to use the **x64dbg** DLL host binary, however for this analysis, debugging will be done with `rundll32.exe` executable in order to mimic the execution environment precisely.

Once you have opened the binary `C:\Windows\System32\rundll32.exe` with **x64dbg** change the command line to include the additional parameters as shown in *Figure 1*.

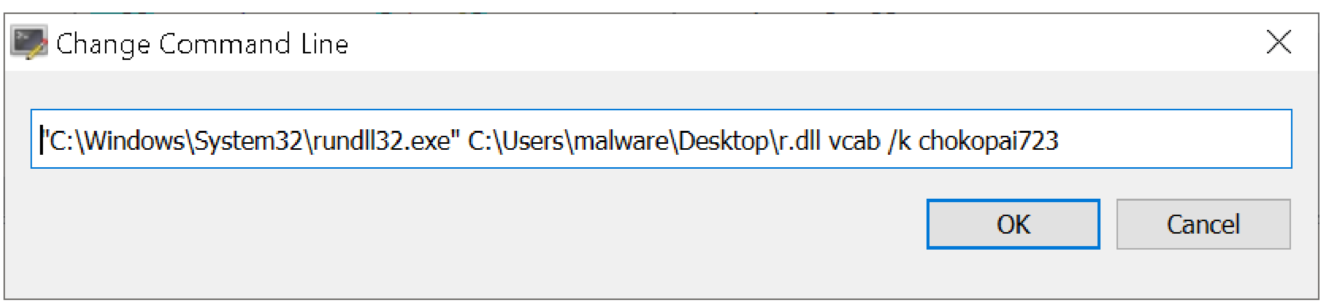


Figure 1: x64dbg - Additional command line parameters.

I find it helpful when analysing a new sample to setup breakpoints on DLL loads, which helpfully is a built in feature.

Navigating to **Options** and then **Preferences** you can enable the settings `User DLL Load` and `System DLL Load`.

Execute until the `r.dll` is loaded and then issuing the following command in will set a breakpoint on the `vcab` entry point.

```
bp r.vcab
```

We should also set some breakpoints for interesting API calls before starting, using the following commands. These API's specifically have been selected because `VirtualAlloc` is common in packed samples to aid in unpacking, and since the number of Imports was limited to a single `Kernel32.dll` library, there is a chance the sample will attempt to load more modules manually.

```
bp VirtualAlloc
bp LoadLibraryA
```

Command Line Validity Check

The first routine to highlight during this walk through is a check that the `/k` was supplied on the command line. Setting a breakpoint at `0x814e378887` and viewing the sample statically we can see the ASCII characters `0x6B` and `0x2F` being moved into a memory region, as shown in *Figure 2*.

```
 0x814e378887 [of]
; CODE XREF from fcn.814e378863 @ 0x814e3788b9(x)
; '/k'
; [0x6b2f:2]=0xffff
mov word [rax + 0x18], 0x6b2f
; arg1
mov rsi, rcx
jmp 0x814e378865

   v
   |

[0x814e378865]
; CODE XREF from fcn.814e378863 @ 0x814e378890(x)
mov byte [rax + 0x1a], 0
call fcn.814e378b95;[ob]
jmp 0x814e378870

   v
```

Figure 2: radare2 - r.dll command line check routine.

An instruction at `0x0814E378AAB` then copies these two bytes into the `RDX` register. The command line string is then iterated over scanning for the `/k` flag being present. If its not then the execution flow exits.

Memory Copy Routine

The next routine of interest is located at virtual address `0x0814E378B26`.

This routine is used throughout this portion of the loader to essentially move bytes from one location to another, much like the `memcpy`[4] function.

The function prototype for `memcpy` is shown below, and this is also used by the routine within the sample.

In x86_64 assembly the registers `RCX`, `RDX` and `R8` are used to store the destination , source and count (size) parameters.

```
void *memcpy(
   void *dest,
   const void *src,
   size_t count
);
```

Although the function is located at `0x0814E378B26`, the primary loop that moves data between source and destination can be seen at `0x814E378B71`. The disassembly for this routine is shown in *Figure 3* below. The register `RDX` is used as an index to then increment as it loops through the bytes being copied.

Figure 3: radare2 - IcedId memcpy shellcode routine.

Setting a breakpoint at `0x0814E378B26` will allow us to inspect the various bytes being moved around.

```
bp 0x0814E378B26
```

If we allow execution until the memory copy routine breakpoint, we first see a call to copy the string `chokopai723` from one area on the stack to another stack based memory location.

Figure 4 shows the source address `0x0F340F0F44A`, destination `0x0F340F0F5B0` and the number of bytes `0xB`

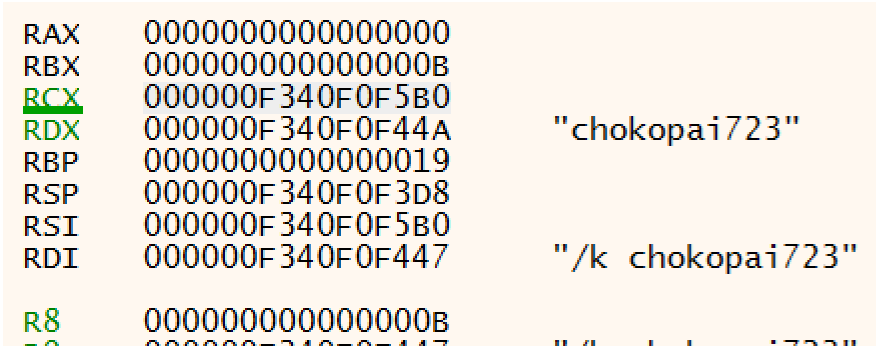


Figure 4: x64dbg - Memory copy routine register usage

Allowing the execution to proceed, the debugger will *break* at a call to `VirtualAlloc`[5]. If we examine the supplied parameters we can mock-up a call to `VirtualAlloc` with the following values.

```
VirtualAlloc(NULL, 0xE27, 0x3000, 0x4);
```

Converting some of the inputs to their constants[5] [6] makes it a little easier to understand what is happening.

```
VirtualAlloc(NULL, 0xE27, MEM_COMMIT|MEM_RESERVE, PAGE_READWRITE);
```

Here we can see at least `0xE27` (3623) bytes of memory is being requested, to be committed and reserved, with the page protection of Read and Write.

The value returned in the `EAX` register is going to be one to keep an eye on. This value is the address of an allocated region of memory. As this value changes from execution to execution I will refer to this as “memory region 1” throughout this post.

This allocated region of memory is then populated using the malware’s implementation of `memcpy` already covered (`0x0814E378B26`). The routine is called a total of 3 times, the total number of bytes copied matches the requested region size of `0xE27` (3623) bytes.

Each time, the source of the data is located in the `.reloc` section of the DLL.

The table below describes the source virtual address, the file physical offset, and number of bytes copied.

Source Virtual Address	File Offset	Byte Count
0x0814E3949E5	0x2B9E5	0x4A (74)
0x0814E394A2F	0x2BA2F	0x18F (399)

Source Virtual Address	File Offset	Byte Count
0x0814E394BBE	0x2BBBE	0xC4E (3150)

Table 1: Virtual Address and file offset mappings

The file offset can be calculated using the source address seen in the debugger, minus the virtual address of the section (`.reloc`). Then identifying the physical address of the section within the PE file using the headers, and adding the difference back.

Using **x64dbg**'s memory map tab you can save this memory region to a file, you can find a copy of the file `rundll32_memory_region_1.bin` in the Github repository here.

Either using the offsets identified or by dumping the memory region, we can examine the data copied in more detail. Data mysteriously copied into un-backed memory region has potential to be shellcode.

We can test this theory by attempting to disassemble the bytes in using this **radare2** one-liner.

Figure 5 shows the interpretation of the bytes as assembly. It appears to be junk as there is no obvious flow of execution present.

```
$ r2 -AA -c 'pd' rundll32_memory_region_1.bin
```

```
┌ 98: fcn.00000001 (int64_t arg1, int64_t arg3, int64_t arg7);
│           ; arg int64_t arg1 @ rdi
│           ; arg int64_t arg3 @ rdx
│           ; arg int64_t arg7 @ xmm0
│           0x00000001      39db           cmp ebx, ebx
│           0x00000003      4855           push rbp
│           0x00000005      5e             pop rsi
│           0x00000006      6f             outsd dx, dword [rsi]
│           0x00000007      3316           xor edx, dword [rsi]        ; arg3
│           0x00000009      fb             sti
│           0x0000000a      84c9           test cl, cl
│           0x0000000c      29fb           sub ebx, edi                ; arg1
│           0x0000000e      8e433e         mov es, word [rbx + 0x3e]
│           0x00000011      f734c0         div dword [rax + rax*8]
│           0x00000014      9f             lahf
│           0x00000015      3b44e09f       cmp eax, dword [rax + riz*8 - 0x61]
│           0x00000019      3b44d89f       cmp eax, dword [rax + rbx*8 - 0x61]
│           0x0000001d      3b44d05f       cmp eax, dword [rax + rdx*8 + 0x5f]
│           0x00000021      f623           mul byte [rbx]
│           0x00000023      309f3b54c06c   xor byte [rdi + 0x6cc0543b], bl ; [0x6cc0543b:1]=255 ; arg1
│           0x00000029      b207           mov dl, 7
│           0x0000002b      00c6           add dh, al
│           0x0000002d      fb             sti
│           0x0000002e      8e4b6e         mov cs, word [rbx + 0x6e]
│           0x00000031      fb             sti
│           0x00000032      8a4bce         mov cl, byte [rbx - 0x32]
│           0x00000035      fb             sti
│           0x00000036      8e43ce         mov es, word [rbx - 0x32]
│           0x00000039      fa             cli
│           0x0000003a      bfa57211a5     mov edi, 0xa51172a5
│           0x0000003f      a1d6b207ff06.  movabs eax, dword [0xc484fa06ff07b2d6]
```

Figure 5: radare2 - Disassembly view of allocated memory region #1

It's a good idea at this point to set an **Access** breakpoint on the memory region to see if there are any routines that may transform it in some way.

Executing the process again will break when the process attempts to **access** an address within the allocated region of memory.

The cause of this is an `XOR` operation at `0x0814E3784E8` as shown in *Figure 6*.

```
000000814E3784E4      8BC2         mov eax,edx
000000814E3784E6    ⌄ EB 12        jmp r.814E3784FA
000000814E3784E8      3041 FF      xor byte ptr ds:[rcx-1],al        xor routine memory region 1
000000814E3784EB      3BD6         cmp edx,esi
000000814E3784ED    ^ 72 F5        jb r.814E3784E4
000000814E3784EF    ⌄ EB 76        jmp r.814E378567
000000814E3784F1      FFC2         inc edx
000000814E3784F3      0FB64438 2C  movzx eax,byte ptr ds:[rax+rdi+2C]  byte ptr ds:[rax+rdi*1+2C]:tistory_expand+90A
000000814E3784F8    ^ EB EE        jmp r.814E3784E8
000000814E3784FA      48:8D49 01   lea rcx,qword ptr ds:[rcx+1]

Hide FPU
RAX   00000000000000D6   'Ö'
RBX   0000000000000000
RCX   000001A200C20001
RDX   0000000000000001
RBP   000000299508FB79
RSP   000000299508FAE0
RSI   0000000000000E27   L'ว'
RDI   000000814E378BA8   r.000000814E378BA8
```

Figure 6: x64dbg - XOR operation memory region #1

The screenshot in *Figure 6* above and in *Figure 7* below show this `XOR` taking place both from a dynamic and static perspective.

```
┌──> 0x814e3784e8      3041ff          xor byte [rcx - 1], al
│    0x814e3784eb      3bd6            cmp edx, esi
└──< 0x814e3784ed      72f5            jb 0x814e3784e4
┌──< 0x814e3784ef      eb76            jmp 0x814e378567
     ; CODE XREF from sym.msys_edit_0.dll_tistory_expand @ 0x814e378501(x)
┌──> 0x814e3784f1      ffc2            inc edx
│    0x814e3784f3      0fb644382c      movzx eax, byte [rax + rdi + 0x2c]
└──< 0x814e3784f8      ebee            jmp 0x814e3784e8
     ; CODE XREF from sym.msys_edit_0.dll_tistory_expand @ 0x814e3784e6(x)
     0x814e3784fa      488d4901        lea rcx, [rcx + 1]
     0x814e3784fe      83e003          and eax, 3
└──< 0x814e378501      ebee            jmp 0x814e3784f1
```

Figure 7: radare2 - XOR operation memory region #1

The `AL` register in this case is the lower 8 bytes of the `EAX` register.

The register pane on the right in *Figure 7* shows this to contain the value `0xD6`.

The address the operation is being carried out on in this case is shows as `ds:[rcx-1]` which if we take a look at the value in the `RCX` register should contain the address of the second byte within memory region 1, the `-1` them refers to the first byte of our mystery data.

If we step through the next few operations hitting the `XOR` instruction we eventually see the same 4 bytes rotating through the `AL` register: `0xD6B20700`

This raises an interesting question, where are these bytes coming from and can locate them within the DLL file?

We know from observing the routine, that the bytes used for the `XOR` key is being set in the `EAX` (`AL`) register.

Within the screen shot shown in *Figure 7* you may notice the operation at `0x0814E3784F3`, also shown below.

```
movzx eax,byte ptr ds:[rax+rdi+2C]
```

This is the operation setting the value of the `EAX`/`AL` register prior to the `XOR` operation. If we follow the address calculated at `RAX` + `RDI` + `2C` in a dump we can see the 4 bytes at the address `0x0814E378BD4` or file offset `0x17FD4`, as shown in *Figure 8*.

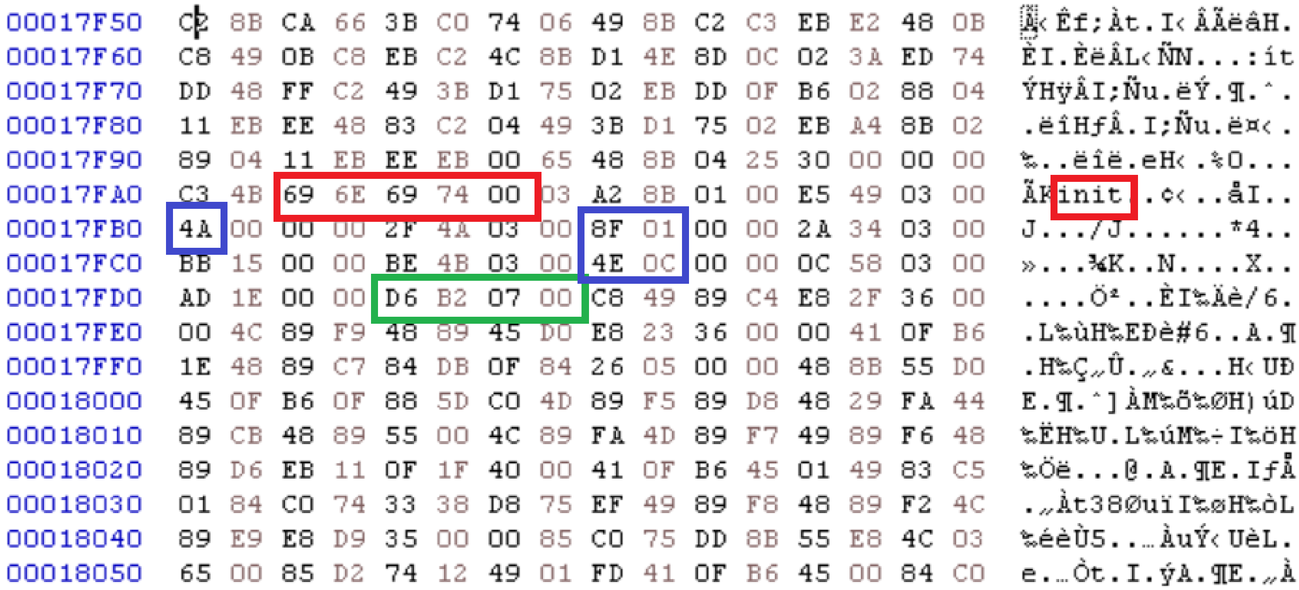


Figure 8: hxd - hexadecimal dump of potential configuration block

Shown in the **GREEN** box, is the XOR key. Also within short proximity, shown in **BLUE** there are the sizes (in little endian[7]) of the data transferred into the first allocated memory region.

Lastly within the **RED** box, there is a `NULL` terminated string of `init`. This could be a useful marker for what might turn out to be some kind of stored configuration.

If we allow the `XOR` routine to complete its rounds across the data, and repeat the steps from earlier to dump, and then attempt to show the disassembly it now prints some pretty convincing shellcode.

The file `rundll32_memory_region_1_xor.bin` can also be found in the GitHub repository here

```
$ r2 -AA -c 'pd' rundll32_memory_region_1_xor.bin
```

```
┌ 74: fcn.00000000 (int64_t arg3, int64_t arg4, int64_t arg6);
│           ; arg int64_t arg3 @ rdx
│           ; arg int64_t arg4 @ rcx
│           ; arg int64_t arg6 @ r9
│           ; var int64_t var_30h @ rsp+0x30
│           0x00000000      4c8bdc         mov r11, rsp
│           ; DATA XREF from fcn.00000609 @ 0x8a9(r)
│           0x00000003      4883ec68       sub rsp, 0x68
│           0x00000007      33c0           xor eax, eax
│           0x00000009      4983c9ff       or r9, 0xffffffffffffffff   ; arg6
│           0x0000000d      498943e8       mov qword [r11 - 0x18], rax
│           0x00000011      4533c0         xor r8d, r8d
│           ; DATA XREF from fcn.00000609 @ 0x95c(r)
│           0x00000014      498943e0       mov qword [r11 - 0x20], rax
│           0x00000018      498943d8       mov qword [r11 - 0x28], rax
│           0x0000001c      498943d0       mov qword [r11 - 0x30], rax
│           ; DATA XREFS from fcn.00000609 @ 0xa06(r), 0xad9(r)
│           0x00000020      89442430       mov dword [var_30h], eax
│           ; DATA XREF from fcn.00000609 @ 0x70d(r)
│           0x00000024      498953c0       mov qword [r11 - 0x40], rdx ; arg3
│           ; DATA XREFS from fcn.00000609 @ 0x7de(r), 0x81b(r), 0xa1f(r), 0xb2b(r)
│           0x00000028      ba00000010     mov edx, 0x10000000
│           0x0000002d      49894bb8       mov qword [r11 - 0x48], rcx ; arg4
│           0x00000031      498d4b18       lea rcx, [r11 + 0x18]
│           0x00000035      49894318       mov qword [r11 + 0x18], rax
│           0x00000039      48b8a5a4a3a2.  movabs rax, 0xa1a2a3a4a5
│           0x00000043      ffd0           call rax
│           0x00000045      4883c468       add rsp, 0x68
└           0x00000049      c3             ret
            0x0000004a      48895c2408     mov qword [rsp + 8], rbx
            0x0000004f      55             push rbp
            0x00000050      56             push rsi
            0x00000051      57             push rdi
            0x00000052      4154           push r12
            0x00000054      4157           push r15
```

Figure 9: radare2 - Shell code disassembly

We can validate that the `XOR` key is correct by applying it to the memory dump file we created previously and comparing the output. *Figure 10* shows the recipe required. You will notice the hexadecimal output matches the instruction bytes in the disassembly above, in *Figure 9*.

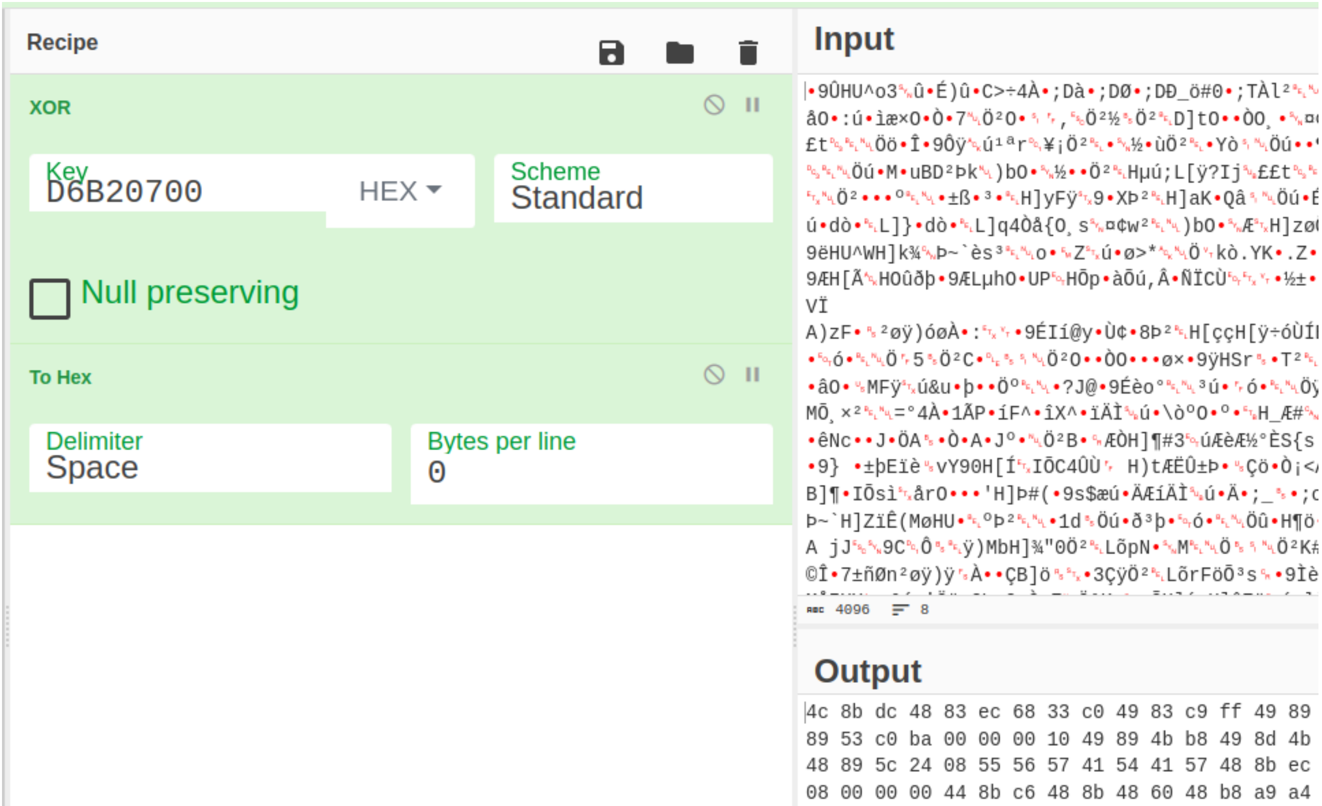


Figure 10: CyberChef - XOR routine.

If we remember the call to `VirtualAlloc` previously, the region was requested with `PAGE_READWRITE` protection, restricting the ability for execution. There are two possibilities for the shellcode now, the first is it will be executed in its current location or it will be copied somewhere else before executing.

Wherever the shellcode will be executed, the memory region will need its execute permission set. Just as `VirtualAlloc` was used to allocate the region, we can set a break point on `VirtualProtect` as shown below.

```
bp VirtualProtect
```

Sacrificial DLL Loading

Pressing on with the unpacking, there is a call to `LoadLibraryA` with the parameter to load the DLL `dpx.dll` from the default `C:\Windows\System32` directory.

Loading the `dpx.dll` library is followed by locating an exported function named `dpx.DpxCheckJobExists`. Based on my loose understanding of how the function is located, I believe this is chosen simply because it is the first function listed in the exports. This technique would allow the malware authors to potentially swap the `dpx.dll` for another fairly easily…

The address returned from for `dpx.DpxCheckJobExists` is then passed to `VirtualProtect`[8], executed via a `call r15` instruction at `0x0814E3786BE`.

The arguments passed to `VirtualProtect` can be arranged as shown.

This function call will mark `0x15BB` (5563) bytes as `PAGE_READWRITE` starting at the address of `dpx.DpxCheckJobExists`.

```
VirtualProtect(dpx.CheckJobExists, 0x15BB, 0x4)
```

The original protection was `PAGE_EXECUTE_READ`, so the additional permission to allow writing is enough to know we likely want to keep an eye on this region.

Moving on, we hit a familiar breakpoint for the malware's `memcpy` routine. This time, `0x15BB` bytes are being moved from the address `0x0814E39342A` once again located in the `.reloc` section, to the address of `dpx.DpxCheckJobExists`. The file offset for this data is `0x2A42A`.

Rather interestingly the bytes representing the amount of data transferred `0x15BB` are located in the output of *Figure 8* underneath the `0x4A` byte.

Extracting the `0x15BB` bytes from the newly copied location, we can take a look and see what the original code for `dpx.DpxCheckJobExists` has been replaced with.

```
$ r2 -AA -c 'pd' rundll32_dpx_checkjobexists.bin
```

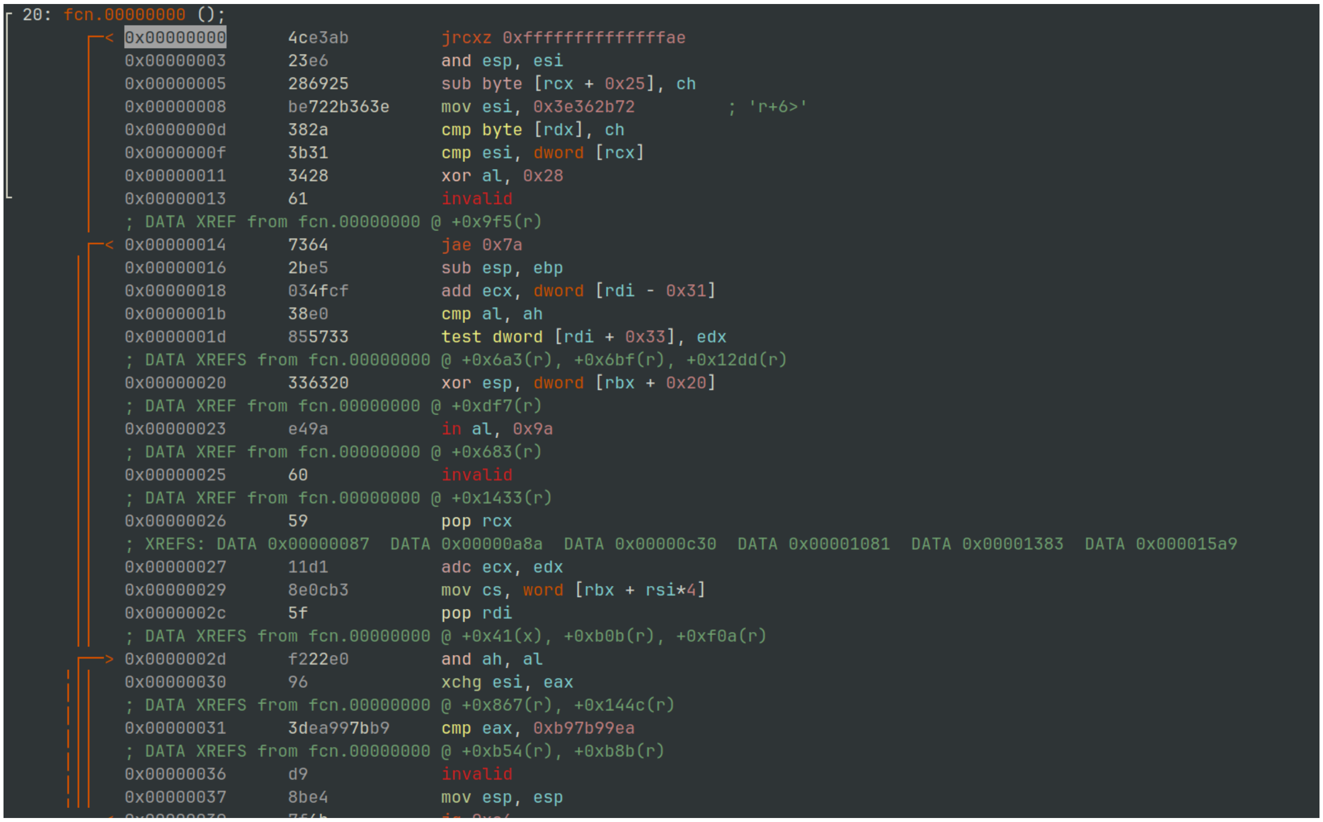


Figure 11: radare2 - Dpx.CheckJobExists overwritten data

It doesn't look shellcode, so likelihood is there will be an additional routine to de-obfuscate it.

Through setting some access breakpoints you will stumble elegantly upon yet another routine with an `XOR` instruction located at `0x0814E3786E1`. This routine iterates over the `dpx.DpxCheckJobExists` location using the string `chokopai723` as a key for all `0x15BB` bytes.

The string `chokopai732` was passed into the process via the command line flag `/k`.

If we take a look at the `dpx.DpxCheckJobExists` contents shown in *Figure 12*, once the `XOR` has been applied we get something more resembling shellcode.

```
$ r2 -AA -c 'pd' rundll32_dpx_checkjobexists_xor.bin
```

```
0x00000000      4c8bc4          mov r8, rsp                   ; int64_t arg_28h
; DATA XREF from fcn.00000000 @ 0x580(r)
0x00000003      48895808        mov qword [rax + 8], rbx
0x00000007      4c894018        mov qword [rax + 0x18], r8
; DATA XREF from fcn.000005f4 @ 0x81b(r)
0x0000000b      55              push rbp
0x0000000c      56              push rsi                      ; arg2
0x0000000d      57              push rdi                      ; arg1
0x0000000e      4154            push r12
; DATA XREF from fcn.000008ac @ 0xc13(r)
0x00000010      4155            push r13
0x00000012      4156            push r14
0x00000014      4157            push r15
0x00000016      488d6c24a0      lea rbp, [rsp - 0x60]
0x0000001b      4881ec600100.   sub rsp, 0x160
0x00000022      488bf1          mov rsi, rcx                  ; int64_t arg2
0x00000025      0f2970b8        movaps xmmword [rax - 0x48], xmm6
0x00000029      b93e803c9a      mov ecx, 0x9a3c803e           ; int64_t arg_20h
0x0000002e      4d8bf9          mov r15, r9                   ; arg6
0x00000031      4d8bf0          mov r14, r8
0x00000034      4c8bea          mov r13, rdx                  ; arg3
0x00000037      e88c100000      call fcn.000010c8
0x0000003c      b91808cc67      mov ecx, 0x67cc0818           ; int64_t arg_20h
0x00000041      488945b0        mov qword [var_50h], rax
0x00000045      e87e100000      call fcn.000010c8
0x0000004a      b91f1e5ad4      mov ecx, 0xd45a1e1f           ; int64_t arg_20h
0x0000004f      488bd8          mov rbx, rax
0x00000052      e871100000      call fcn.000010c8
0x00000057      65488b0c2530.   mov rcx, qword gs:[0x30]
; CALL XREF from fcn.000008ac @ 0xfe0(x)
0x00000060      4883cfff        or rdi, 0xffffffffffffffff
0x00000064      418b5708        mov edx, dword [r15 + 8]
; CALL XREFS from fcn.000008ac @ 0xc7e(x), 0x104b(x)
0x00000068      458b6628        mov r12d, dword [r14 + 0x28]
0x0000006c      81c260080000    add edx, 0x860
```

Figure 12: radare2 - Dpx.DpxCheckJobExists shellcode

The sample then makes another call to `VirtualProtect`, restoring the page protection on `dpx.DpxCheckJobExists` back to `PAGE_EXECUTE_READ`.

Now the code is executable again, the sample executes the newly laid out shellcode by `call rsi` operation at `0x0814E378421`. This can be intercepted by setting a breakpoint on the `dpx.DpxCheckJobExists` symbol.

Executing the shellcode located at `dpx.DpxCheckJobExists`, it uses an internal routine labelled below as `mw_resolve_api_hash_location` to locate the procedure addresses for 3 API's. The use of API hashes to resolve routines is quite common in malware, as it makes it much harder to see what is being used.

The hash values are usually fairly static, although there a few different methods employed, "search engine-ing" the hexadecimal values is the first step.

Special thanks to this GitHub project by **hidd3ncod3s** for supplying the hashes and corresponding API routines.

From the following disassembly we can see 3 values being moved into `ECX` before the function `mw_resolve_api_hash_location` is used. The labels in the disassembly, show the methods being passed:

- NtCreateThreadEx (`0x9a3c803e`)
- RtlAllocateHeap (`0x67cc0818`)
- RtlFreeHeap (`0xd45a1e1f`)

```
0x00000000      4c8bc4          mov r8, rsp                    ; int64_t arg_28h
; DATA XREF from fcn.00000000 @ 0x580(r)
0x00000003      48895808        mov qword [rax + 8], rbx
0x00000007      4c894018        mov qword [rax + 0x18], r8
; DATA XREF from fcn.000005f4 @ 0x81b(r)
0x0000000b      55              push rbp
0x0000000c      56              push rsi                       ; arg2
0x0000000d      57              push rdi                       ; arg1
0x0000000e      4154            push r12
; DATA XREF from fcn.000008ac @ 0xc13(r)
0x00000010      4155            push r13
0x00000012      4156            push r14
0x00000014      4157            push r15
0x00000016      488d6c24a0      lea rbp, [rsp - 0x60]
0x0000001b      4881ec600100.   sub rsp, 0x160
0x00000022      488bf1          mov rsi, rcx                   ; arg4
0x00000025      0f2970b8        movaps xmmword [rax - 0x48], xmm6
0x00000029      b93e803c9a      mov ecx, 0x9a3c803e            ; int64_t arg_20h ; NtCreateThreadEx or ZwCreateThreadEx
0x0000002e      4d8bf9          mov r15, r9                    ; arg6
0x00000031      4d8bf0          mov r14, r8
0x00000034      4c8bea          mov r13, rdx                   ; arg3
0x00000037      e88c100000      call mw_resolve_api_hash_location
0x0000003c      b91808cc67      mov ecx, 0x67cc0818            ; int64_t arg_20h ; RtlAllocateHeap
0x00000041      488945b0        mov qword [var_50h], rax
0x00000045      e87e100000      call mw_resolve_api_hash_location
0x0000004a      b91f1e5ad4      mov ecx, 0xd45a1e1f            ; int64_t arg_20h ; RtlFreeHeap
0x0000004f      488bd8          mov rbx, rax
0x00000052      e871100000      call mw_resolve_api_hash_location
```

Figure 13: radere2 - API hashes being resolved.

Once the API's have been resolved, the routine `RtlAllocateheap`[9] is called using the `call rbx` instruction, and `0x335B` (13147) bytes are requested.

```
00007FFB42D8F301   45:8BC4              mov r8d,r12d
00007FFB42D8F304   44:8965 D8           mov dword ptr ss:[rbp-28],r12d
00007FFB42D8F308   48:8B49 30           mov rcx,qword ptr ds:[rcx+30]
00007FFB42D8F30C   FFD3                 call rbx                           call rtlAllocateHeap
00007FFB42D8F30E   6548:8B0C25 60000000 mov rcx,qword ptr gs:[60]
00007FFB42D8F317   48:8BD8              mov rbx,rax                        rbx:RtlAllocateHeap, rax:RtlFree
00007FFB42D8F31A   48:8945 D0           mov qword ptr ss:[rbp-30],rax      rax:RtlFreeHeap
00007FFB42D8F31E   45:33C0              xor r8d,r8d
00007FFB42D8F321   48:8B51 18           mov rdx,qword ptr ds:[rcx+18]
00007FFB42D8F325   48:8B42 10           mov rax,qword ptr ds:[rdx+10]      rax:RtlFreeHeap
00007FFB42D8F329   48:8B48 30           mov rcx,qword ptr ds:[rax+30]      qword ptr ds:[rax+30]:RtlFreeHea
00007FFB42D8F32D   48:85C9              test rcx,rcx
00007FFB42D8F330   74 34                je dpx.7FFB42D8F366
00007FFB42D8F332   48:3BCE              cmp rcx,rsi
00007FFB42D8F335   74 05                je dpx.7FFB42D8F33C
00007FFB42D8F337   48:8B00              mov rax,qword ptr ds:[rax]         rax:RtlFreeHeap, qword ptr ds:[r
00007FFB42D8F33A   EB ED                jmp dpx.7FFB42D8F329
00007FFB42D8F33C   48:8BCB              mov rcx,rbx                        rbx:RtlAllocateHeap
00007FFB42D8F33F   48:8B50 50           mov rdx,qword ptr ds:[rax+50]      qword ptr ds:[rax+50]:RtlFreeHea

Hide FPU
RAX   00007FFB55974760   <ntdll.RtlFreeHeap>
RBX   00007FFB5597A9A0   <ntdll.RtlAllocateHeap>
RCX   0000011FBC370000
RDX   0000000000000008
RBP   0000001D8BE9F8E0
RSP   0000001D8BE9F7E0   <&RtlAllocateHeap>
RSI   000000814E360000   r.000000814E360000
RDI   FFFFFFFFFFFFFFFF

R8    000000000000335B
R9    0000000000000000
R10   00000000E290FD31
R11   00007FFB55ABC4D0   ntdll.00007FFB55ABC4D0
R12   000000000000335B
R13   000000814E378BA2   "init"
R14   0000001D8BE9FA20
R15   0000001D8BE9F9C0
```

Figure 14: x64dbg - RtlAllocate 0x335b Bytes

Once the region is allocated, the shellcode then accesses its own processes `Process Envonrment Block` aka the PEB, to retrieve the full command line given.

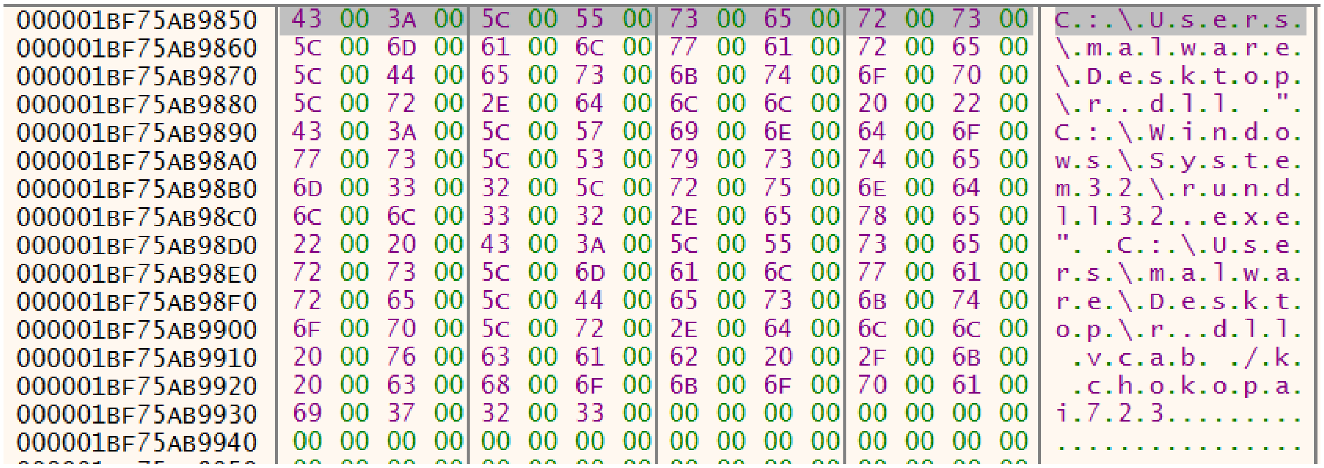


Figure 15: x64dbg - Command line copied from Process Environment Block

Probably not surprisingly, this second shellcode also implements a `memcpy` routine, as shown in *Figure 16*.

It is first used to copy `0x1EAD` (7853) bytes from `0x0814E39580C` (file offset `0x2C80C` within the `.reloc` section) to a heap allocated region. *Figure 8* above contains the value `0x1EAD` within the configuration block at offset `0x17FD0`.

For future reference, the screen shot below shows the destination address in the `RCX` register as `0x023D5D94A0B0`.

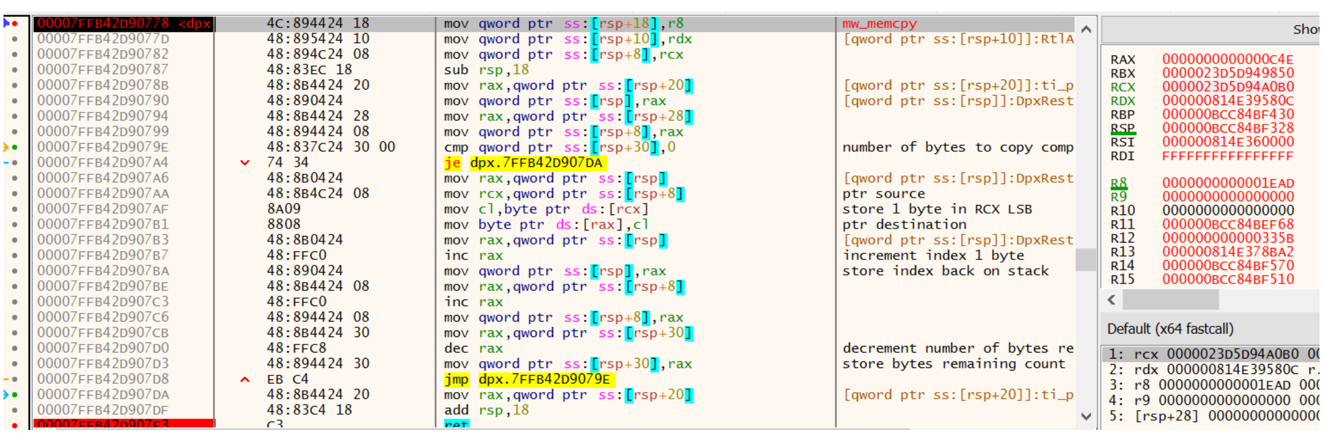


Figure 16: radare2 - DPX.dll shellcode memory routine.

Extracting the data that was just copied reveals not too much, and you might be able to spot a familiar pattern occurring.

Shellcode Patching

Moving on to the next call of the `memcpy` routine, the sample copies `0xC4E` (3150) bytes from the very first allocated memory region to the tail of the data written into the heap region previously described.

This second chunk of data being copied was originally transferred from `0x0814E394BBE` (file offset `0x2BBBE`) into memory region 1, where is was then de-obfuscated.

The data copied into this heap region becomes very relevant later on. At this stage there is some missing information so don't dump the memory region just yet. To clarify, the first chunk is obfuscated in some way, the second chunk is valid shellcode.

The next call the `memcpy` routine is used to copy a more 4 bytes containing the value `0x5B330000` into a location within the first allocated memory region. If we swap the endianness of `0x5B330000` we get `0x335B`, matching the size of a previously copied segment of shellcode… very interesting…

Next, the shellcode's routine for locating a procedure based on its hash is used to locate `CreateThread`. This location is then used to patch the shellcode that was written into the first region of allocated memory, using the `memcpy` routine.

Figure 17 shows the start of the `memcpy` routine with the shellcode to be patched in the lower pane. Currently, the 8 bytes to be patched contains `0xA1A2A3A4A5`

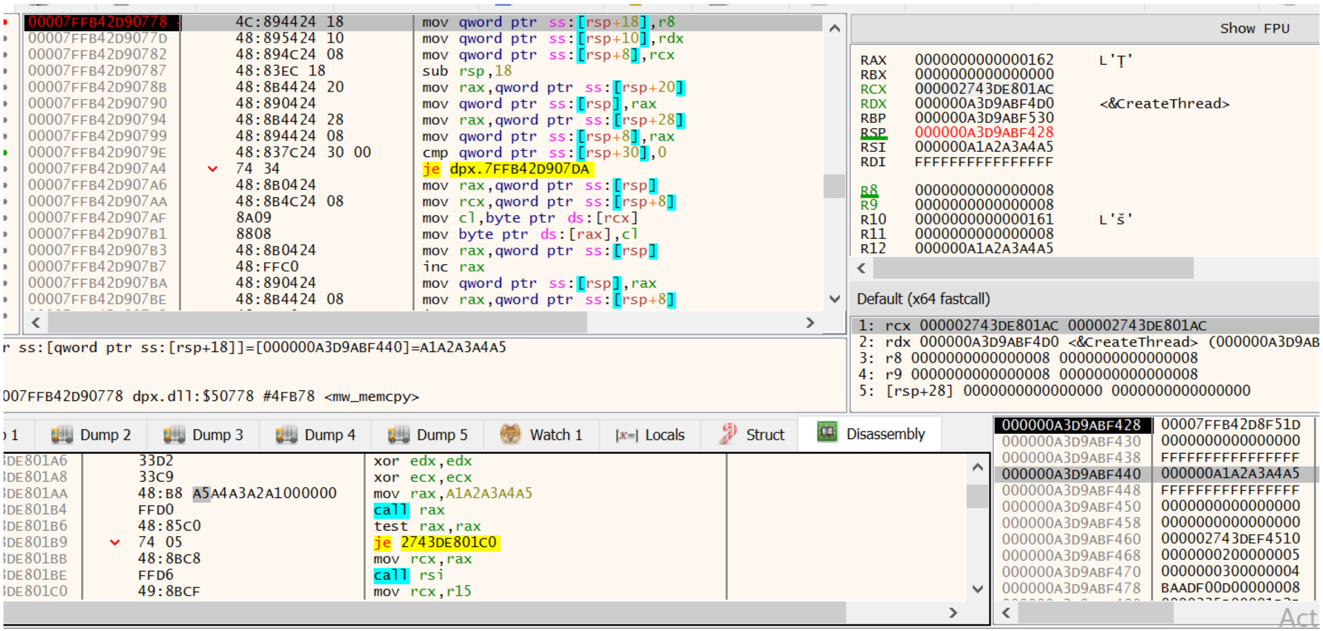


Figure 17: x64dbg - Shell code patching routine, before patch.

Figure 18 shows the shellcode after being patched, containing the address of `CreateThread` ready for it to be copied into `RAX` and then called.

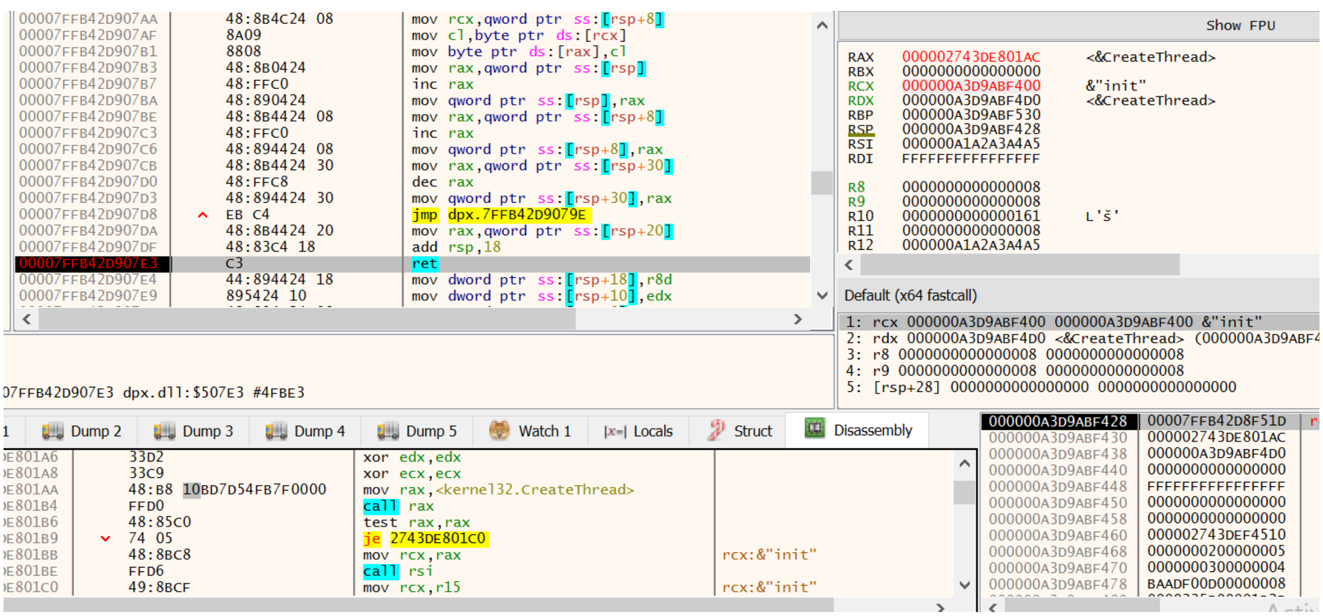


Figure 18: x64dbg - Shell code patching routine, after patch.

The same process of locating a function, and then patching shellcode is also carried out for additional functions.

The complete list of functions resolved and patched is:

- CreateThread
- LoadLibraryA

- ReadProcessMemory
- VirtualProtect
- RtlAllocateHeap
- NtClose
- ZwCreateThreadEx

Next comes a routine that appears (at least to me), to parse the `ntdll.dll` module for the various syscall operations.

Continuing the execution again we hit another call to the `memcpy` routine, this time copying `0xB` (11) bytes from a stack based address into a location within the first allocated memory region.

```
4C 8B D1 B8 00 00 00 00 0F 05 C3
```

At first glance the purpose of the byte sequence is not obvious, it's certainly not an address as previously observed. If you continue to view the disassembler during the `memcpy` routine, you would have seen a patch applied to call a syscall directly.

We can quickly check the above hexadecimal opcodes using the **CyberChef**[10] recipe to `Disasemble X86` or use the following **rasm2** command.

```
$ rasm2 -a x86 -b 64 -d '4C 8B D1 B8 00 00 00 00 0F 05 C3'

mov r10, rcx
mov eax, 0
syscall
ret
```

This syscall related activity has a lot of similarities with what is described here over at www.ired.team

Once the syscalls stubs have been copied over, the function `ZwAllocateVirtualMemory`, is then used to request `0x3841` (14401) bytes of memory with the protection constant `PAGE_WRITECOPY`, this region will be labelled and hence forth known as memory region 2.

Figure 19 shows the call to `ZwAllocateVirtualMemory` being made. The registers `RDX` and `R8` are being used to provide the address and protection flags. As can be seen in the display, `RCX` contains the location of memory, which contains the location in memory that is being altered....aka a pointer.

The address being altered here is stored in little-endian, and is `0x29E3E670000` as shown in the lower dump 2 pane.

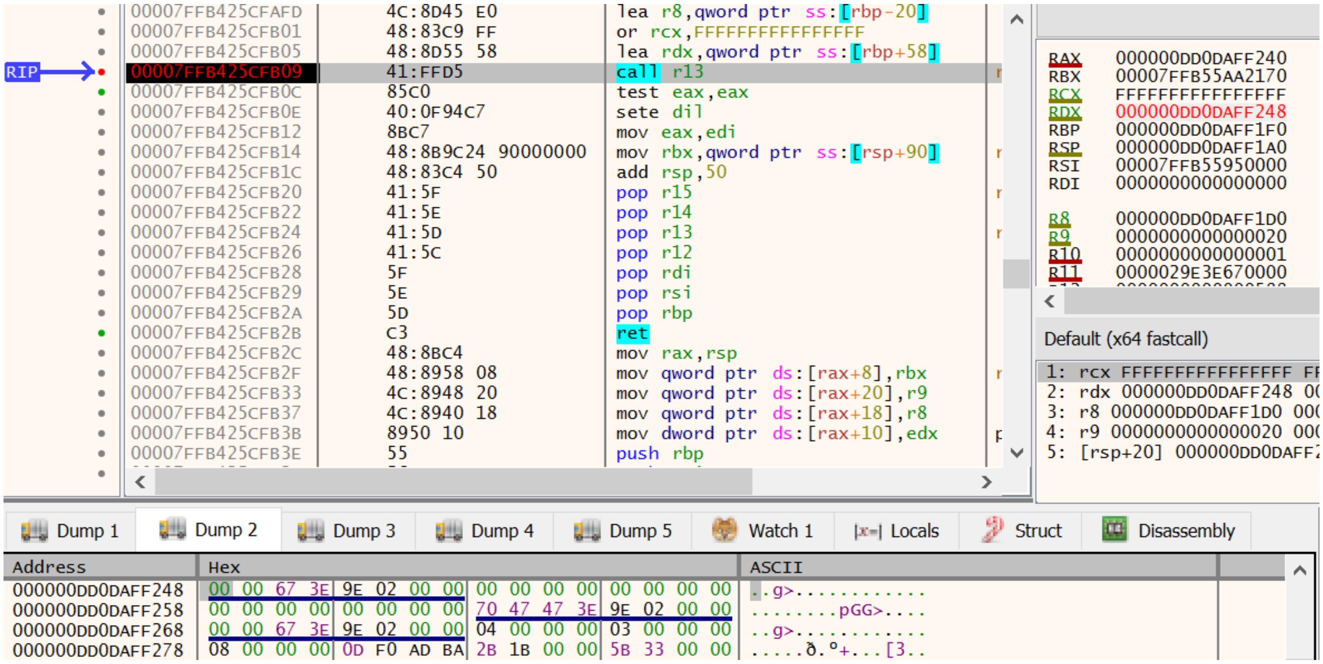


Figure 19: x64dbg - ZwProtectVirtualMemory from R13 register

After building the syscall routines and patching the shellcode in memory region 1, more API's are resolved.

- NtOpenProcess
- NtClose
- RtlFreeHeap

The malware went to a lot of trouble to generate the syscall stubs, it finally begins to use them starting with a call via the `RSI` register.

Setting an execution breakpoint on the region of memory containing the syscall stubs will allow you to step through the next procedure.

Figure 20 shows the call via the `RSI` register, with a value of `0x5` being passed in on the `RCX` register. In the disassembly view in the bottom pane, you can see the syscall ID being loaded into `RAX`, the value `0x36` resolves to `NtQuerySystemInformation`[11]

Taking a look at the documentation for `NtQuerySystemInformation` here provided by Geoff Chappell, the value `0x5` is the constant for `SystemProcessInformation`. This is being used to generate a process listings, more details can be found here

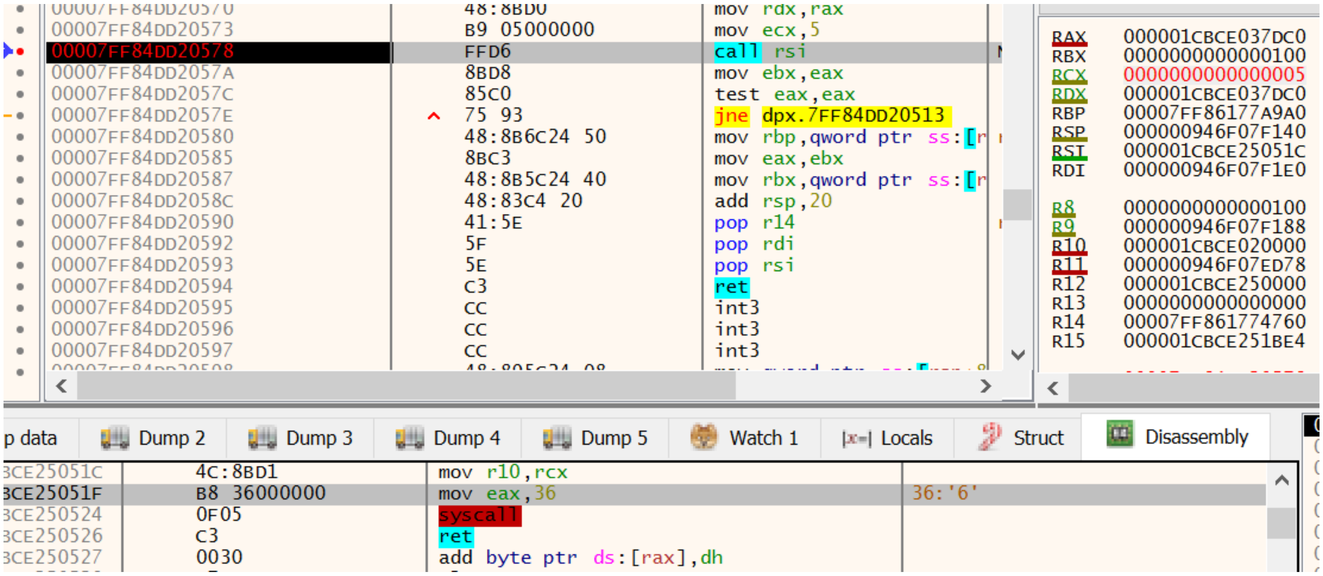


Figure 20: x64dbg - NtQuerySystemInformation native syscall

Once the PID for `explorer.exe` is located, it is passed to the `NtOpenProcess` syscall. Opening the `rundll32.exe` process in **ProcessHacker** we can see the handle to `explorer.exe` has been opened, as shown in *Figure 21*.

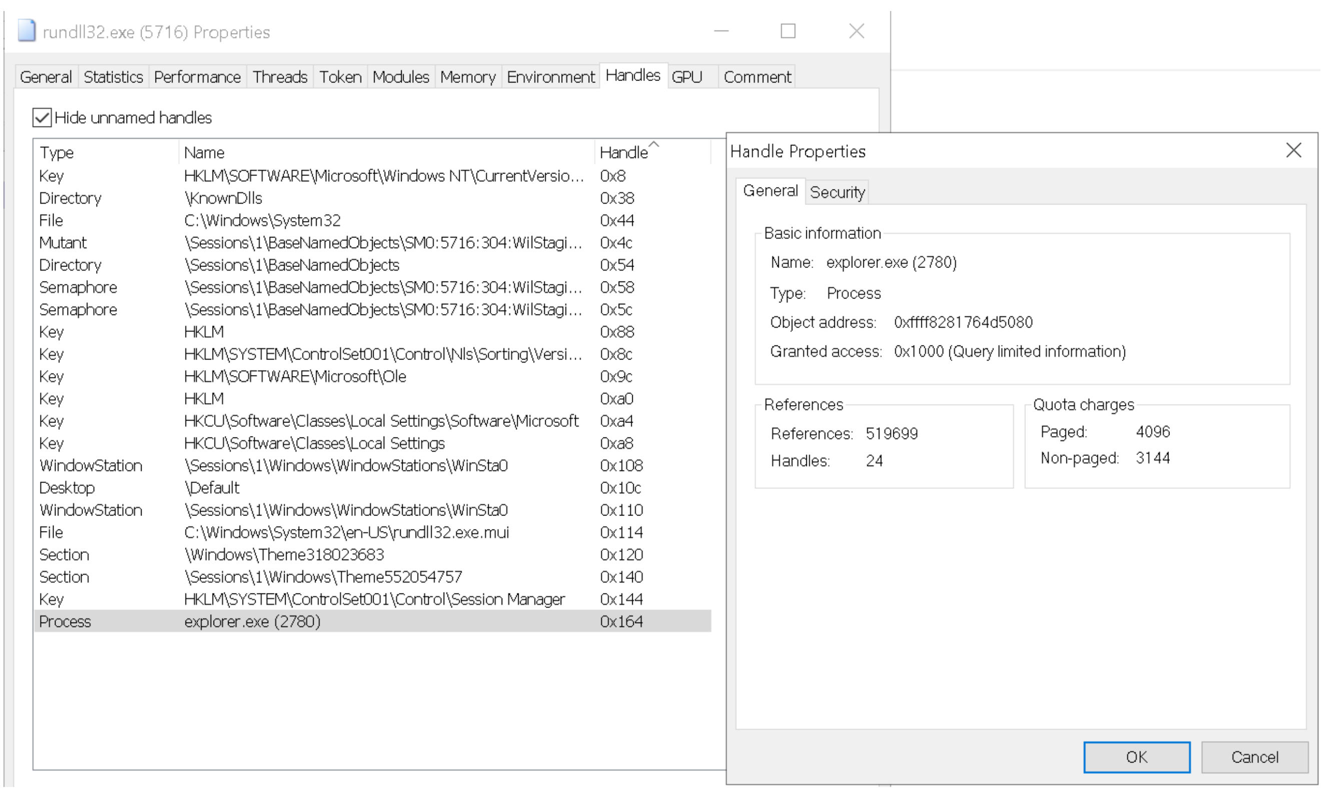


Figure 21: ProcessHacker - Handle to explorer process opened.

The handle on `explorer.exe` is then used by a call to `NtOpenProcessToken`. The returned handle for the token is passed to `NtQueryInformationToken` before being closed with `NtClose`.

The syscall `NtSystemQueryInformation` is then used as it was previously to generate a list of processes running on the system.

A series of calls to `NtOpenProcess` is then issued against all `svchost.exe` processes until one can be successfully opened. As the process is running in a non-privileged context, calls to `svchost.exe` processes running as `NT AUTHORITY\SYSTEM` are responded to with an access denied value in `EAX` as shown in *Figure 22*

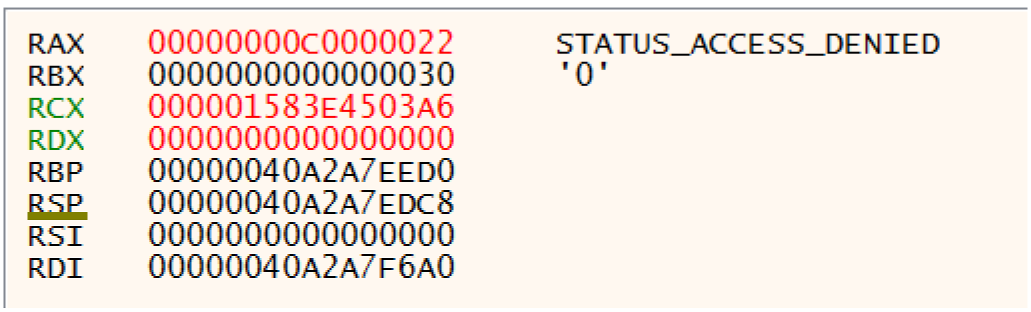


Figure 22: x64dbg - NtOpenProcess Access Denied.

Note: The `sihost.exe` process is also attempted if the `svchost.exe` process list becomes exhausted.

Once a handle to an `svchost.exe` process is opened, the token information is harvested using `NtOpenProcessToken` and `NtQueryInformationToken`.

To determine if the target `svchost.exe` process is the correct architecture, `NtQueryInformationProcess` is used to check the `ProcessWow64Information` details.

For each thread on the `svchost.exe` process the following routines are called:

- NtOpenThread
- NtCreateEvent
- NtDuplicateObject
- NtQueueApcThread
- SetEvent

Once each thread has been setup, there is a call to `NtQuerySystemTime`.

The shellcode residing in memory region 1, is further patched with the value `0xB18` forming the first argument to `ReadProcessMemory` as shown in *Figure 23*.

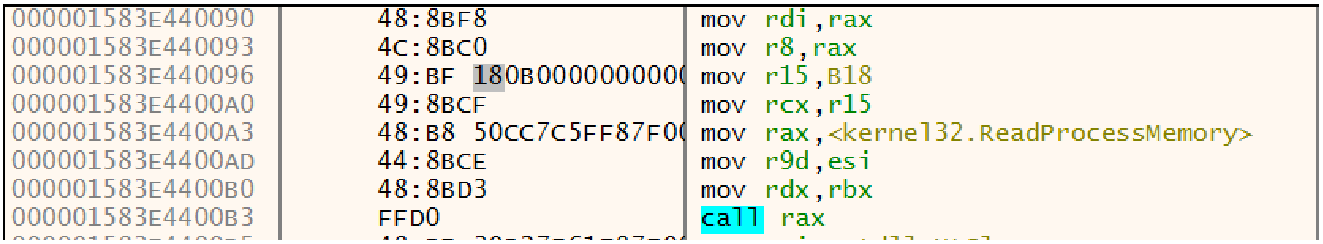


Figure 23: x64dbg - Length value being patched in shellcode

Using the handle to `svchost.exe`, the `rundll32.exe` process makes a call to `NtVirtualProtect` targeting the address of `WinHelpW` from `user32.dll`.

Looking at the `R9` register in *Figure 24* you can see the value `0x40`, which corresponds to the memory protection constant `PAGE_EXECUTE_READWRITE`.

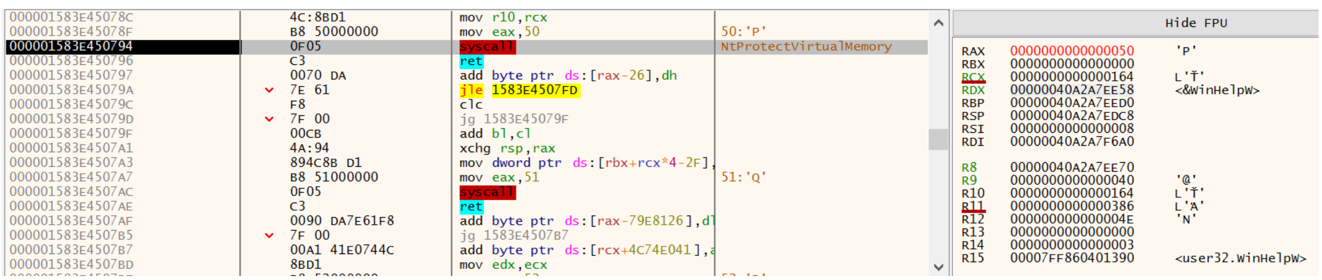


Figure 24: x64dbg - NtVirtualProtect WinHelpW

Payload Transfer

The `rundll32.exe` process then calls `NtCreateSection` to create a section within the `svchost.exe` process. This section is then mapped into view of the `rundll32.exe` process using `NtMapViewOfSection`.

With the section accessible to the `rundll32.exe` process, the `memcpy` implementation is called twice. The first transfer copies `0x4A` bytes, and the second transfers `0x18F` bytes from the first memory region.

You'll notice the byte sizes align with the blocks of data transferred from the `.reloc` section into "memory region 1", which has been decoded and subsequently patched.

The original bytes from both `WinHelpW` (0x4A) and `WinHelpA` (0x18F) are copied into a location of memory, possibly for restoring later.

Once data has been written by the `rundll32.exe` process, `NtUnMapviewofSection` is called on the section.

Using the handle to the `svchost.exe` process, the section is mapped into memory using `NtMapViewOfSection`.

Now comes a really interesting process, to avoid using heavily monitored API's the `rundll32.exe` process such as `WriteProcessMemory`.

The `rundll32.exe` processes calls the `NtQueueApcThread` routine to schedule an execution of `RtlCopyMemory` within the `svchost.exe` process. The source parameter is the location of the mapped memory region of the shared section, the destination parameter contains the address of the `WinHelpW` routine within `user32.dll`.

Thus when the queued APC routine executes, the `WinHelpW` routine will be replaced with shellcode.

The setup for this can be seen in *Figure 25* below.

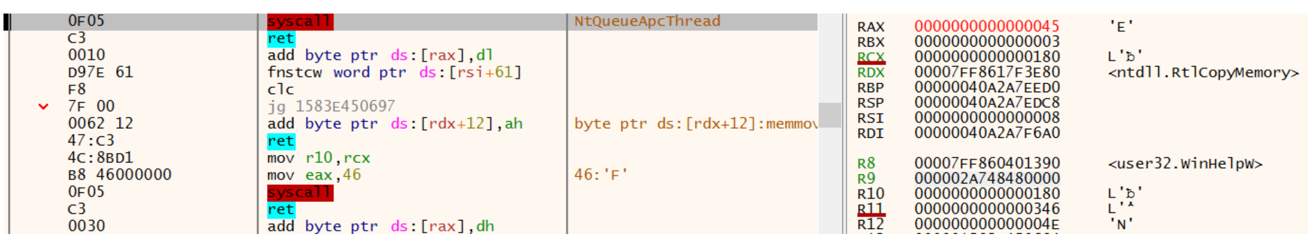


Figure 25: x64dbg - WinHelpW execution after NtDelayExecution

The same technique is then used to copy data from the mapped section, to overwrite the `WinHelpA` routine. The shellcode at `WinHelpW` is then scheduled to execute using the `NtQueueApcThread` routine as well as `Sleep` and a call to `NtDelayExecution`.

Both the `WinHelpW` and `WinHelpA` locations have their memory protection restored back to `PAGE_EXECUTE_READ` using `NtVirtualProtectMemory`, and the section becomes unmapped in the `svchost.exe` process with a call to `NtUnMapviewofSection`.

Execution from this point will continue from within the perspective of the `svchost.exe` process.

Setting a breakpoint on the `WinHelpW` routine, we can examine this further.

Executing WinHelpW Shellcode

```
$ r2 -AA -c 'pdf' svchost_user32_injected.bin
```

```
┌ 74: fcn.00000000 (int64_t arg3, int64_t arg4, int64_t arg6);
│           ; arg int64_t arg3 @ rdx
│           ; arg int64_t arg4 @ rcx
│           ; arg int64_t arg6 @ r9
│           ; var int64_t var_30h @ rsp+0x30
│           0x00000000      4c8bdc         mov r11, rsp
│           0x00000003      4883ec68       sub rsp, 0x68
│           0x00000007      33c0           xor eax, eax
│           0x00000009      4983c9ff       or r9, 0xffffffffffffffff   ; arg6
│           ; DATA XREF from _x0000004f @ +0x219(r)
│           0x0000000d      498943e8       mov qword [r11 - 0x18], rax
│           0x00000011      4533c0         xor r8d, r8d
│           0x00000014      498943e0       mov qword [r11 - 0x20], rax
│           0x00000018      498943d8       mov qword [r11 - 0x28], rax
│           0x0000001c      498943d0       mov qword [r11 - 0x30], rax
│           0x00000020      89442430       mov dword [var_30h], eax
│           0x00000024      498953c0       mov qword [r11 - 0x40], rdx ; arg3
│           0x00000028      ba00000010     mov edx, 0x10000000
│           0x0000002d      49894bb8       mov qword [r11 - 0x48], rcx ; arg4
│           0x00000031      498d4b18       lea rcx, [r11 + 0x18]
│           0x00000035      49894318       mov qword [r11 + 0x18], rax
│           0x00000039      48b880e87e61.  movabs rax, 0x7ff8617ee880
│           0x00000043      ffd0           call rax                    ; ZwCreateThreadEx
│           0x00000045      4883c468       add rsp, 0x68
└           0x00000049      c3             ret
[0x00000000]>
```

Figure 26: radare2 - svchost.exe User32.dll WinHelpW Shellcode

Calls to `OpenProcess` on the `rundll32.exe` process. Then `ReadProcessMemory` from the `rundll32.exe` process, the heap allocated data previously described.

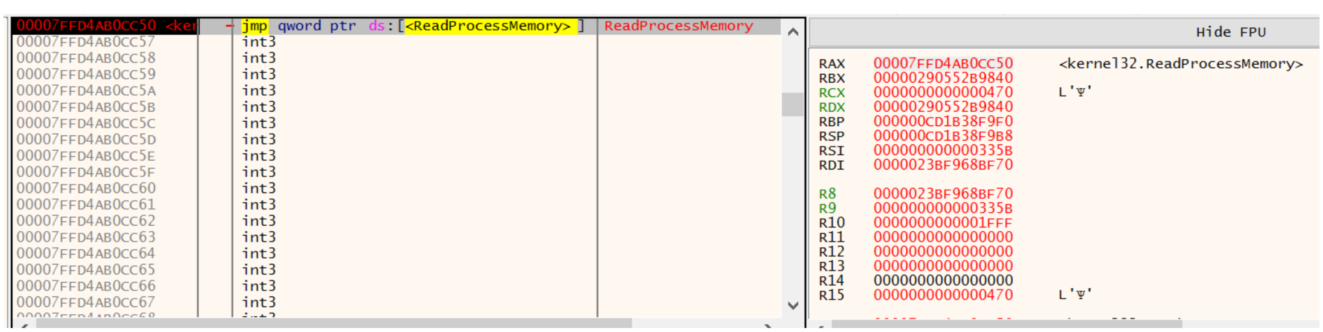


Figure 27: x64dbg - ReadProcessMemory called from svchost.exe

As you can see from the screen shot in *Figure 28*, some of the data copied may contain a similar configuration block identified with the `init` keyword. Further down into the bytes you may also spot the bytes `0xD6`, `0xB2`, `0x07` and `0x00` which was the XOR key used within the `rundll32.exe` unpacking staged.

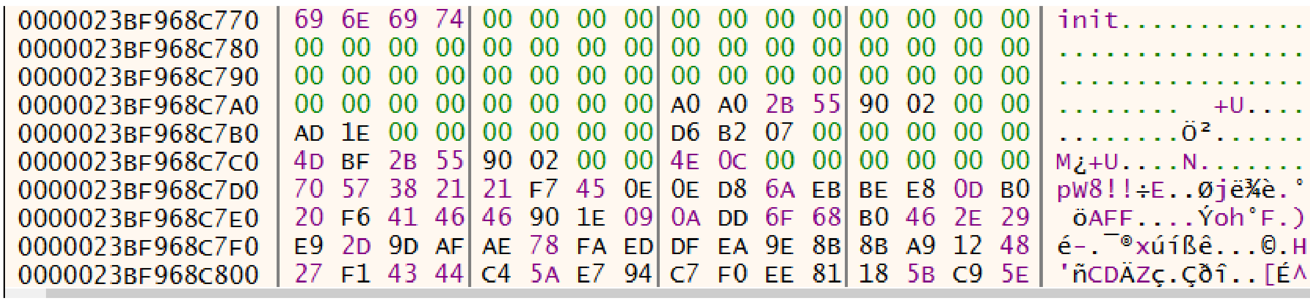
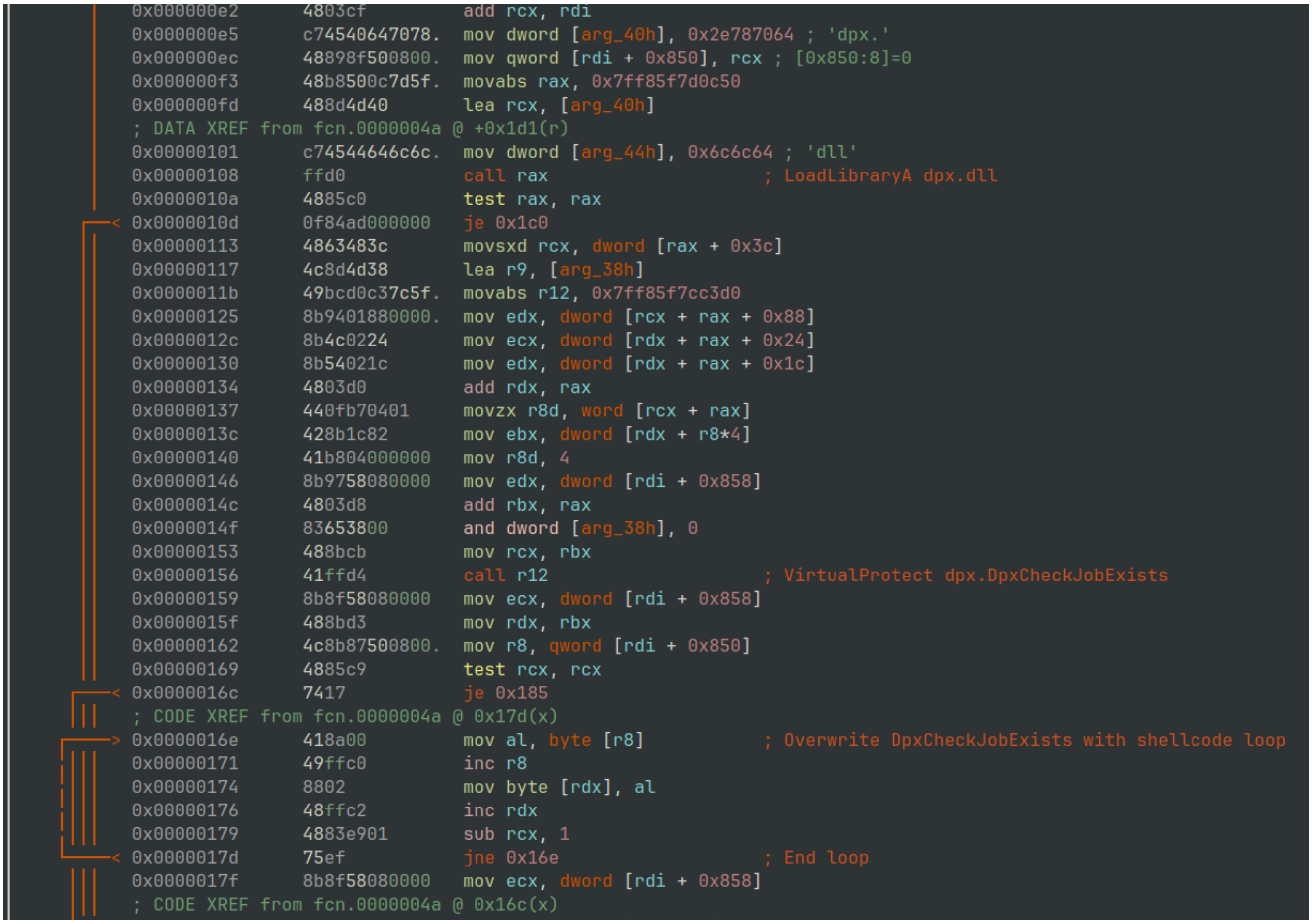


Figure 28: x64dbg - svchost.exe init configuration block

Taking a look at the shellcode that was placed at `WinHelpA` statically in *Figure 29*, we can see it contains the string `dpx.dll` and will call `LoadLibraryA` to load it.

It then calls `VirtualProtect` on the routine `DpxCheckJobExists` to allow a byte copying routine to overwrite its contents, replicating the behaviour from earlier in the unpacking routine.

```
$ r2 -AA -c 's 0xe2; pd 40' svchost_user32_injected.bin
```



```
0x000000e2      4803cf         add rcx, rdi
0x000000e5      c74540647078.  mov dword [arg_40h], 0x2e787064 ; 'dpx.'
0x000000ec      48898f500800.  mov qword [rdi + 0x850], rcx ; [0x850:8]=0
0x000000f3      48b8500c7d5f.  movabs rax, 0x7ff85f7d0c50
0x000000fd      488d4d40       lea rcx, [arg_40h]
; DATA XREF from fcn.0000004a @ +0x1d1(r)
0x00000101      c74544646c6c.  mov dword [arg_44h], 0x6c6c64 ; 'dll'
0x00000108      ffd0           call rax                   ; LoadLibraryA dpx.dll
0x0000010a      4885c0         test rax, rax
0x0000010d      0f84ad000000   je 0x1c0
0x00000113      4863483c       movsxd rcx, dword [rax + 0x3c]
0x00000117      4c8d4d38       lea r9, [arg_38h]
0x0000011b      49bcd0c37c5f.  movabs r12, 0x7ff85f7cc3d0
0x00000125      8b9401880000.  mov edx, dword [rcx + rax + 0x88]
0x0000012c      8b4c0224       mov ecx, dword [rdx + rax + 0x24]
0x00000130      8b54021c       mov edx, dword [rdx + rax + 0x1c]
0x00000134      4803d0         add rdx, rax
0x00000137      440fb70401     movzx r8d, word [rcx + rax]
0x0000013c      428b1c82       mov ebx, dword [rdx + r8*4]
0x00000140      41b804000000   mov r8d, 4
0x00000146      8b9758080000   mov edx, dword [rdi + 0x858]
0x0000014c      4803d8         add rbx, rax
0x0000014f      83653800       and dword [arg_38h], 0
0x00000153      488bcb         mov rcx, rbx
0x00000156      41ffd4         call r12                   ; VirtualProtect dpx.DpxCheckJobExists
0x00000159      8b8f58080000   mov ecx, dword [rdi + 0x858]
0x0000015f      488bd3         mov rdx, rbx
0x00000162      4c8b87500800.  mov r8, qword [rdi + 0x850]
0x00000169      4885c9         test rcx, rcx
0x0000016c      7417           je 0x185
; CODE XREF from fcn.0000004a @ 0x17d(x)
0x0000016e      418a00         mov al, byte [r8]          ; Overwrite DpxCheckJobExists with shellcode loop
0x00000171      49ffc0         inc r8
0x00000174      8802           mov byte [rdx], al
0x00000176      48ffc2         inc rdx
0x00000179      4883e901       sub rcx, 1
0x0000017d      75ef           jne 0x16e                  ; End loop
0x0000017f      8b8f58080000   mov ecx, dword [rdi + 0x858]
; CODE XREF from fcn.0000004a @ 0x16c(x)
```

Figure 29: radare2 - LoadLibraryA dpx.dll and overwrite DpxCheckJobExists

If you are viewing this dynamically then, you will observe `0xC4E` (3150) bytes from the second chunk of data copied from the `rundll32.exe` process into `dpx.DpxCheckJobExists` routine.

A call to `CreateThread` is then issued with a base address of `dpx.DpxCheckJobExists`

The shellcode located at `dpx.DpxCheckJobExists` then kicks of a routine to XOR decode some of the remaining data originally sourced from `rundll32.exe`.

Payload Decrypting

In *Figure 30* below we can see the static disassembly output of the XOR routine used.

```
$ r2 -AA -c 's 0x57; pd 72' svchost_dpx_dpxcheckjobexists.bin
```

```
0x00000057      448d52ff        lea r10d, [rdx - 1]
; CODE XREF from fcn.00000000 @ 0xc9(x)
0x0000005b      488bc1          mov rax, rcx
0x0000005e      488d7101        lea rsi, [rcx + 1]
0x00000062      4899            cqo
0x00000064      49f7fe          idiv r14
0x00000067      488bc1          mov rax, rcx
0x0000006a      4c63da          movsxd r11, edx
0x0000006d      4899            cqo
0x0000006f      83e203          and edx, 3
0x00000072      4803c2          add rax, rdx
0x00000075      83e003          and eax, 3
0x00000078      482bc2          sub rax, rdx
0x0000007b      4863c8          movsxd rcx, eax
0x0000007e      430fb6040b      movzx eax, byte [r11 + r9]
0x00000083      440fb6841948.   movzx r8d, byte [rcx + rbx + 0x848]
0x0000008c      4433c0          xor r8d, eax
0x0000008f      488bc6          mov rax, rsi
0x00000092      4899            cqo
0x00000094      49f7fe          idiv r14
0x00000097      4863c2          movsxd rax, edx
0x0000009a      420fb60c08      movzx ecx, byte [rax + r9]
0x0000009f      442bc1          sub r8d, ecx
0x000000a2      4181c0000100.   add r8d, 0x100
0x000000a9      4181e0ff0000.   and r8d, 0x800000ff
0x000000b0      7d0d            jge 0xbf
0x000000b2      41ffc8          dec r8d
0x000000b5      4181c800ffff.   or r8d, 0xffffff00          ; 4294967040
0x000000bc      41ffc0          inc r8d
; CODE XREF from fcn.00000000 @ 0xb0(x)
0x000000bf      4788040b        mov byte [r11 + r9], r8b
0x000000c3      488bce          mov rcx, rsi
0x000000c6      493bf2          cmp rsi, r10
0x000000c9      7e90            jle 0x5b
```

Figure 30: radare2 - XOR Routine

This routine is used to reveal the **FINAL** PE file payload in its original memory buffer copied over from `rundll32.exe`, as shown in *Figure 31* there is an MZ header and DOS stub visible.

```
000001AC4A052011 | AD 1E 00 00 | 00 34 00 00 | 00 82 2D 80 | 4D 5A 90 00 | .....4....-.MZ..
000001AC4A052021 | 03 00 00 00 | 04 10 FF FF | 00 00 B8 20 | C6 00 40 12 | ......ÿÿ..¸ Æ.@.
000001AC4A052031 | 02 EB 01 00 | D0 10 0E 1F | BA 0E 00 B4 | 09 CD 21 00 | .ë..Ð...º..´.Í!.
000001AC4A052041 | 00 00 80 B8 | 01 4C CD 21 | 54 68 69 73 | 20 70 72 6F | ...¸.LÍ!This pro
000001AC4A052051 | 67 72 61 6D | 20 63 61 6E | 6E 6F 74 20 | 62 65 20 72 | gram cannot be r
000001AC4A052061 | 75 6E 00 00 | 02 84 20 69 | 6E 20 44 4F | 53 20 6D 6F | un.... in DOS mo
000001AC4A052071 | 64 65 2E 0D | 0D 0A 24 12 | 11 21 C9 10 | 93 65 A8 7E | de....$..!É..e¨~
000001AC4A052081 | C0 16 01 42 | 6E 05 C0 82 | 88 A0 B0 67 | 20 16 CA 7F | À..Bn.À.. °g .Ê.
000001AC4A052091 | C1 6E 0A 05 | 7F C0 4F 20 | 83 CC 7A 0A | 04 83 CC 7E | Án...ÀO .Ìz...Ì~
000001AC4A0520A1 | C1 64 0A 02 | 7C 0A 02 52 | 69 63 68 06 | 0E 16 25 50 | Ád..|..Rich...%P
000001AC4A0520B1 | 00 08 40 A9 | 45 00 00 64 | 86 07 00 9A | 9E 87 63 16 | ..@©E..d......c.
```

Figure 31: x64dbg - Decoded DOS stub header

As well as the executable file, there also resides some configuration data that is used to allow shellcode to map the PE into the address space.

Value `0x3400` taken from payload structure and passed to `RtlAllocateHeap` The PE file is the seemingly copied into this allocated memory region.

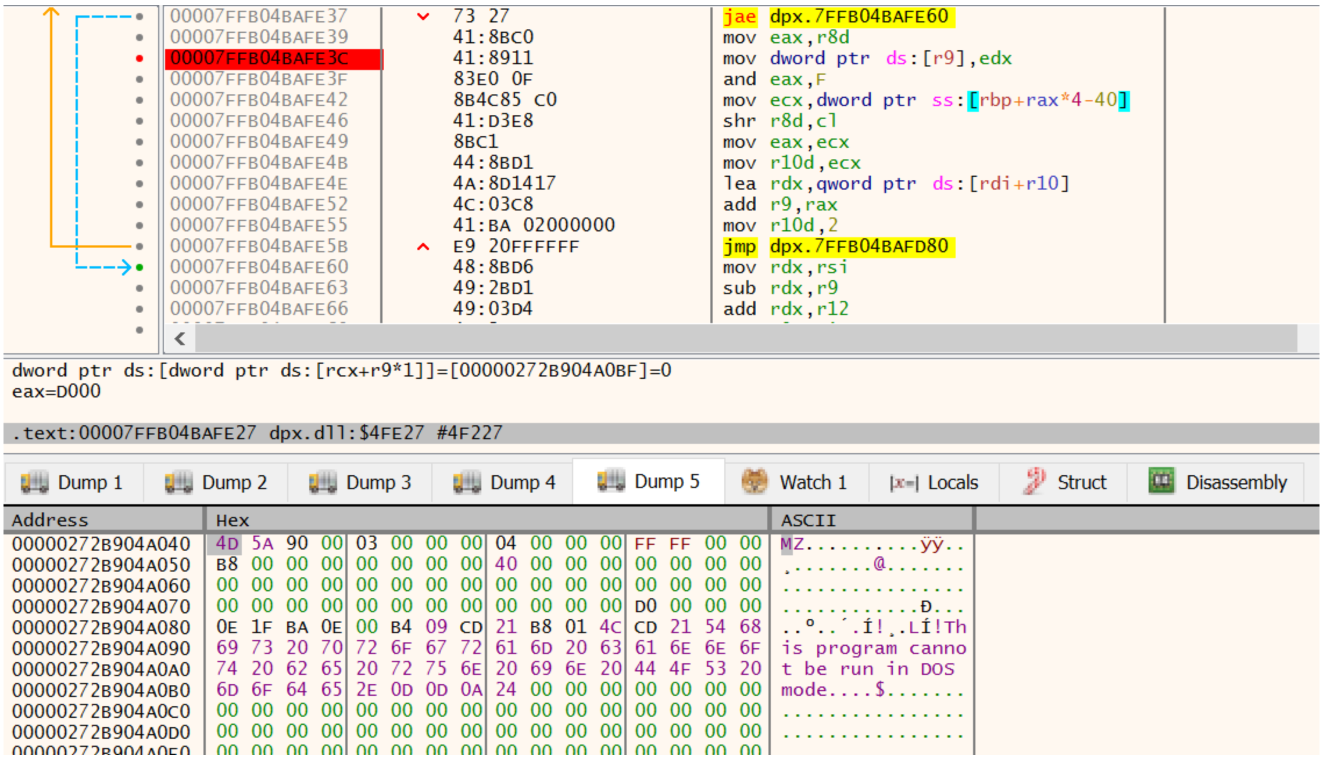


Figure 32: x64dbg - MZ header being copied into allocated Heap region

Pausing the debugger here, will allow you to extract the executable file before it gets mapped into memory.

As the shellcode within the `dpx.DpxCheckJobExists` area executes, it calls `VirtualAlloc` with a base region of `0x0180000000`, a size of `0x3000` (12288) bytes and a page protection flag of `0x40` (`PAGE_EXECUTE_READWRITE`).

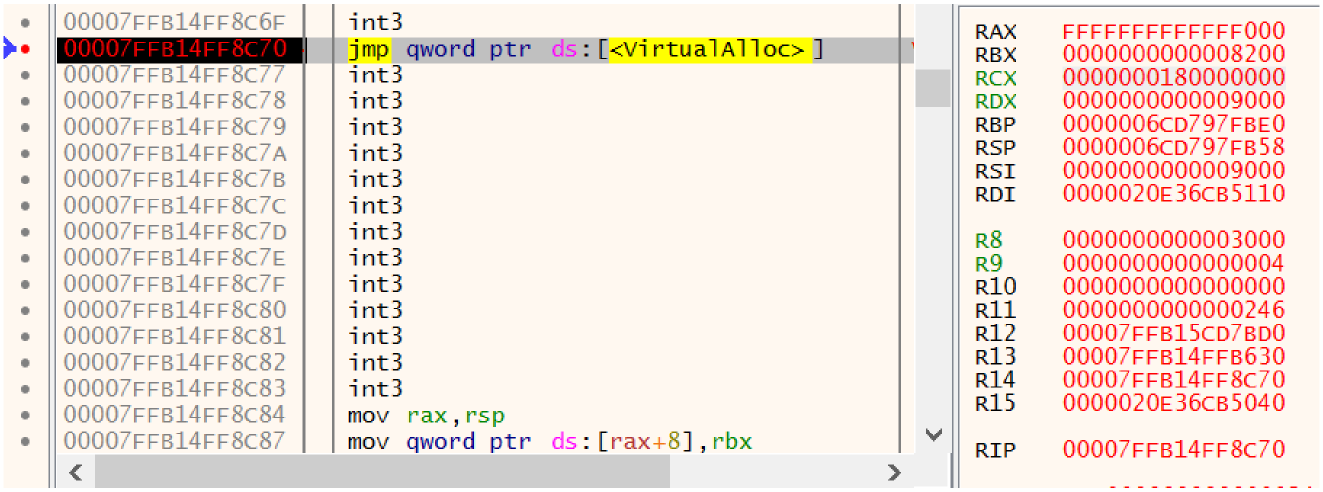


Figure 33: x64dbg - VirtualAlloc hardcoded 0x0180000000

Once this very specific location of memory is allocated the PE file is mapped into execute, the process for this is well documented elsewhere.

Once mapped, execution is started using a call to `CreateThread` using the `0x01800028D4` address as the entry point.

Figure 34: x64dbg - CreateThread hardcoded 0x0180000000

Unpacked Payload

Now we have jumped through the many hoops to unpack the final payload, we can validate the contents by loading it into PE-Bear[12].

As you can see from *Figure 35*, the binary lists some imports from the `WINHTTP.dll` that look like might be worthy some additional analysis.

You can find a copy of the file `svchost_icedid_unpacked.bin` in the GitHub repository for this blog post here, or on the malware Bazaar here.

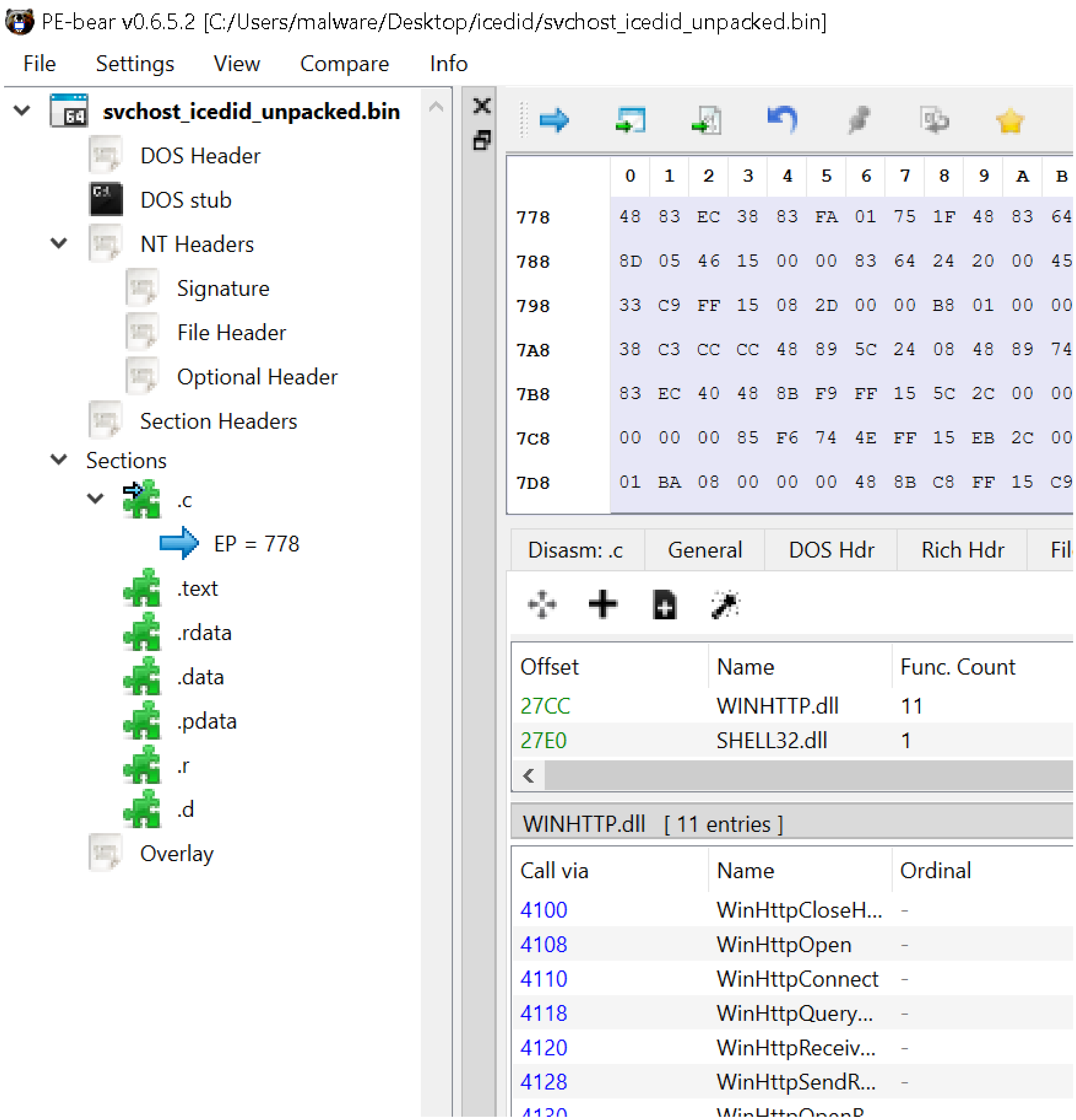


Figure 35: PE Bear - Unpacked icedid payload from svchost.exe

Final Words

That’s it for this blog post, its been quite in depth and low-level. If you want to understand anything covered, or maybe not covered in this post feel free to reach out.

I’m planning to do a part 4 taking a look into the extracted PE file so keep an eye out for that, and in the meantime keep evolving.

@techevo_

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