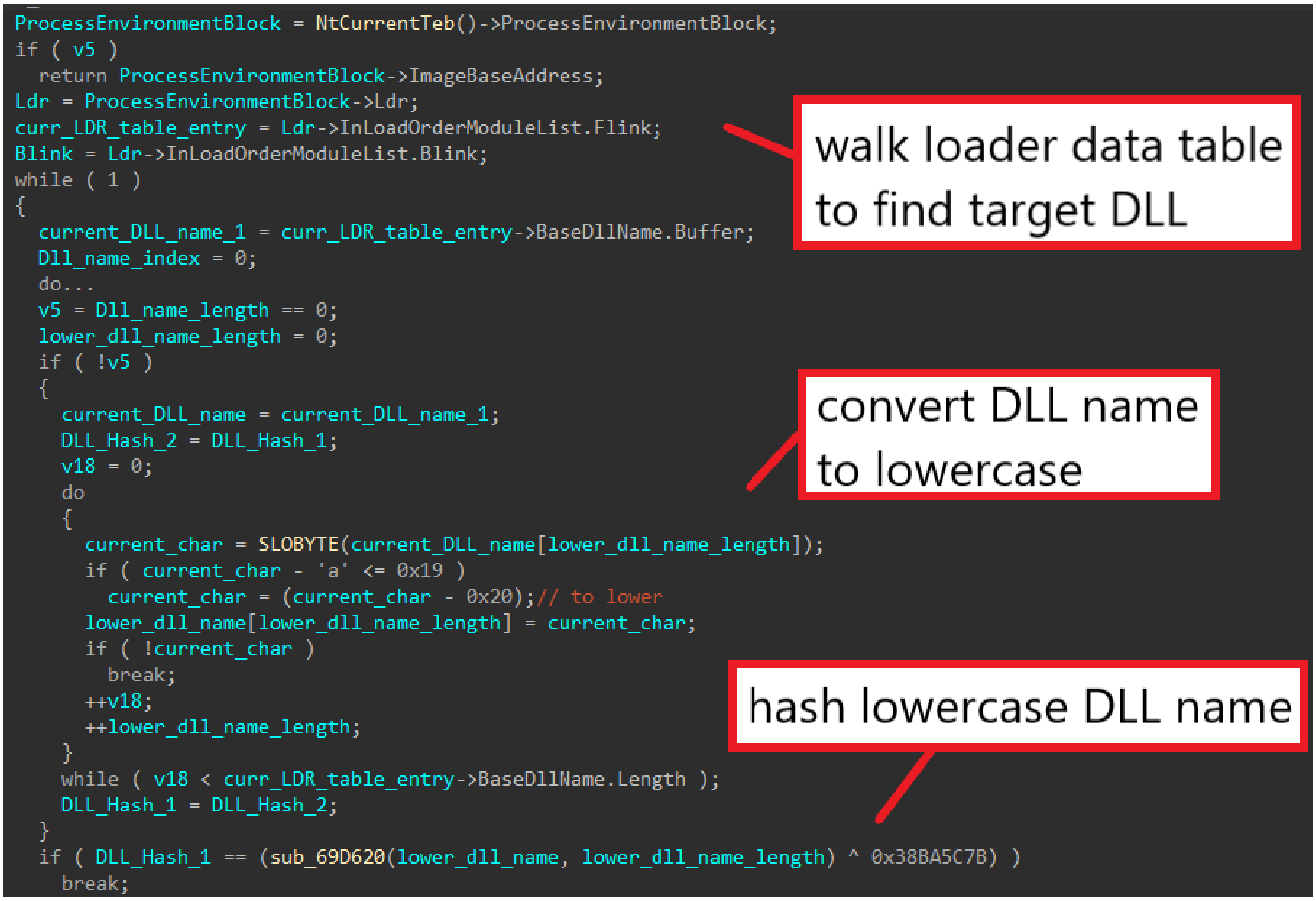
DRIDEX: Analysing API Obfuscation Through VEH

0ffset.net/reverse-engineering/malware-analysis/dridex-veh-api-obfuscation/

October 26, 2021

Offset Training Solutions



- Chuong Dong
- 26th October 2021
- No Comments

DRIDEX is one of the most famous and prevalent banking Trojans that dates back to around late 2014. Throughout its improvement and variations, DRIDEX has been successful in targeting the financial services sector to steal banking information and crucial user credentials. Typically, DRIDEX samples are delivered through phishing in the form of Word and Excel documents containing malicious VBA macros.

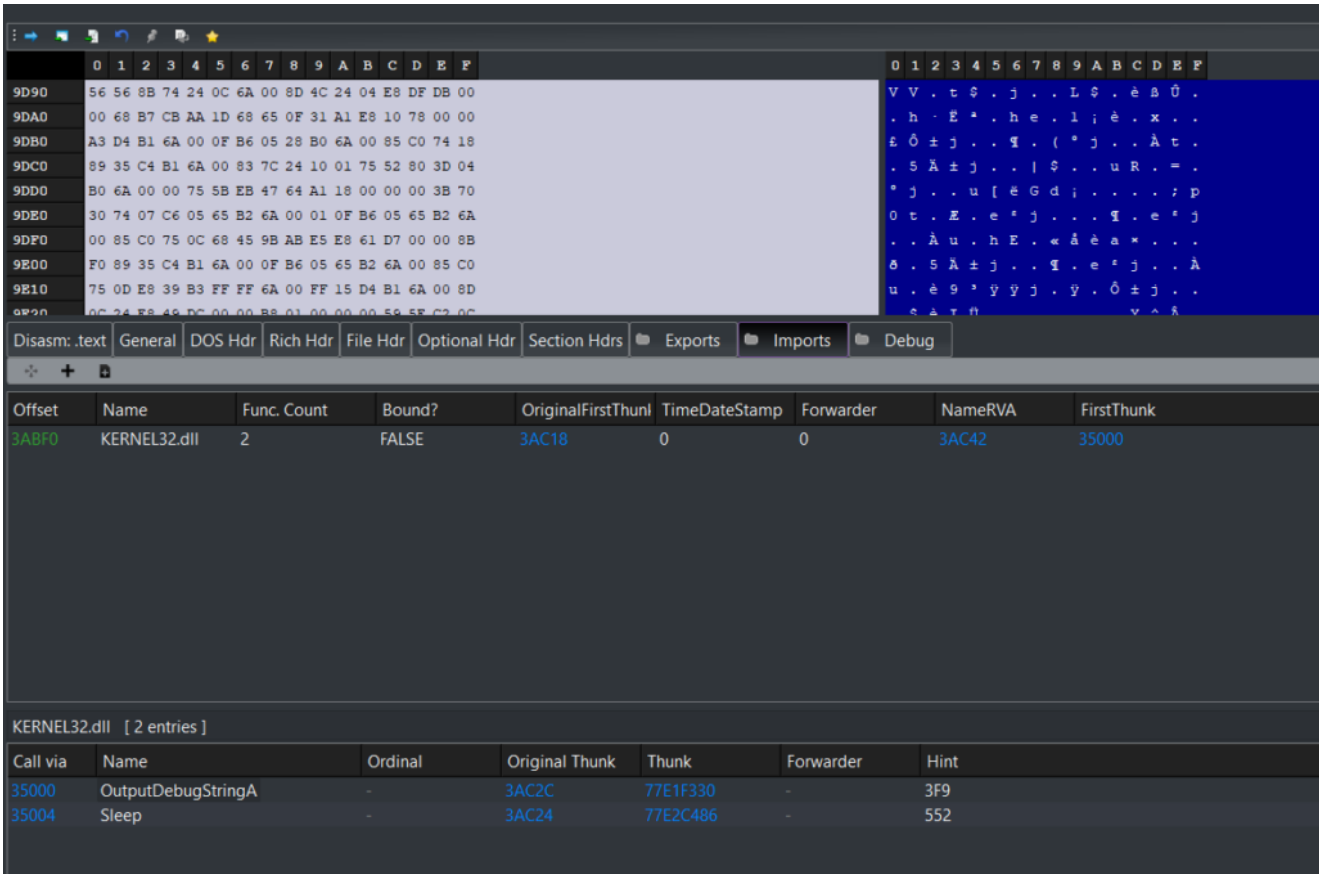
In this post particularly, we will dive into the theory behind DRIDEX's anti-analysis method of obfuscating Windows API calls using string hashing and Vectored Exception Handling.

To follow along, you can grab the sample on MalwareBazaar!

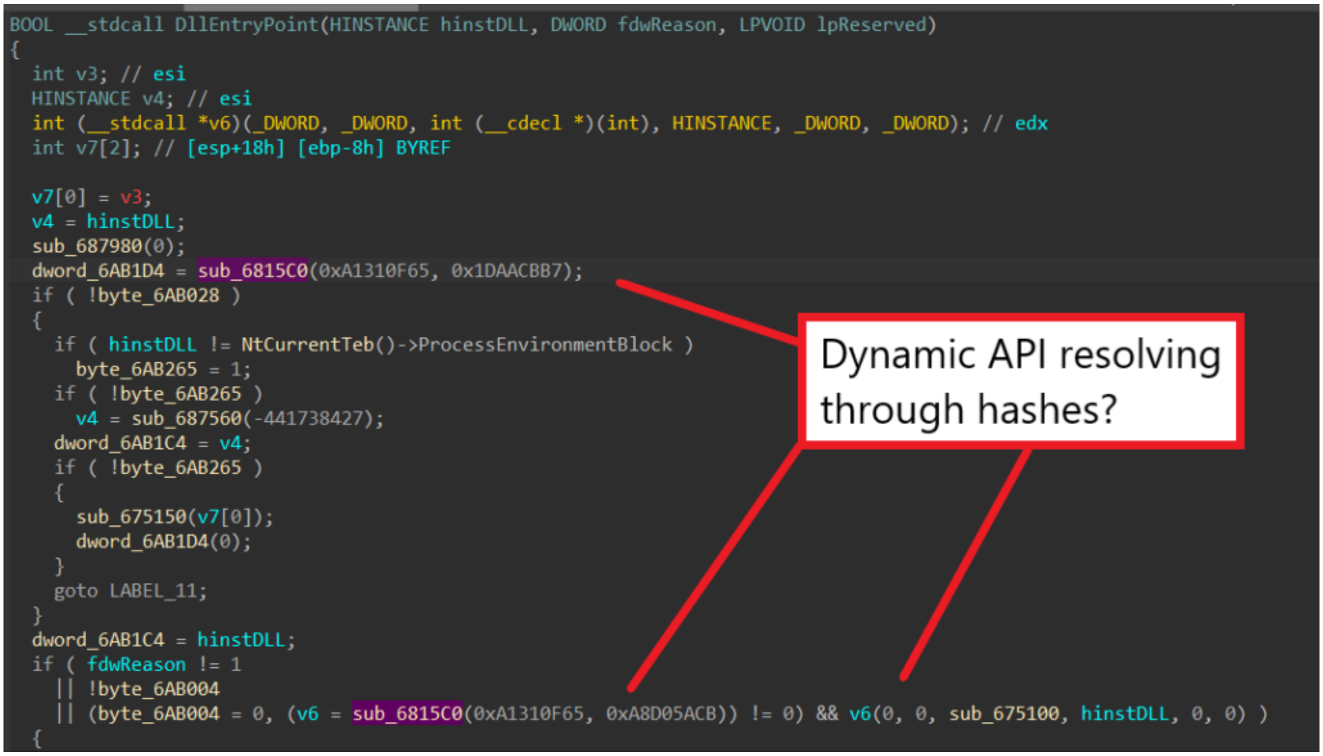
Sha256: ad86dbdd7edd170f44aac99eebf972193535a9989b06dccc613d065a931222e7

Step 1: API Resolving Function

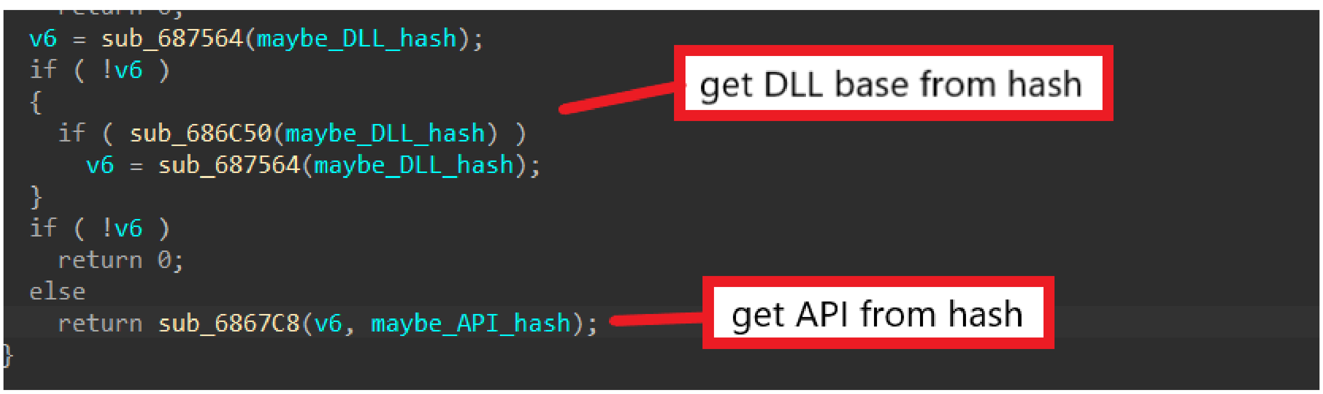
Upon performing some basic static analysis on the sample, we can quickly see that the DRIDEX DLL has two functions, **OutputDebugStringA** and **Sleep**, in its import address table. Considering how DRIDEX is a large piece of malware with many complex functionalities, the lack of imports hints to us that the malware resolves most of its API dynamically.



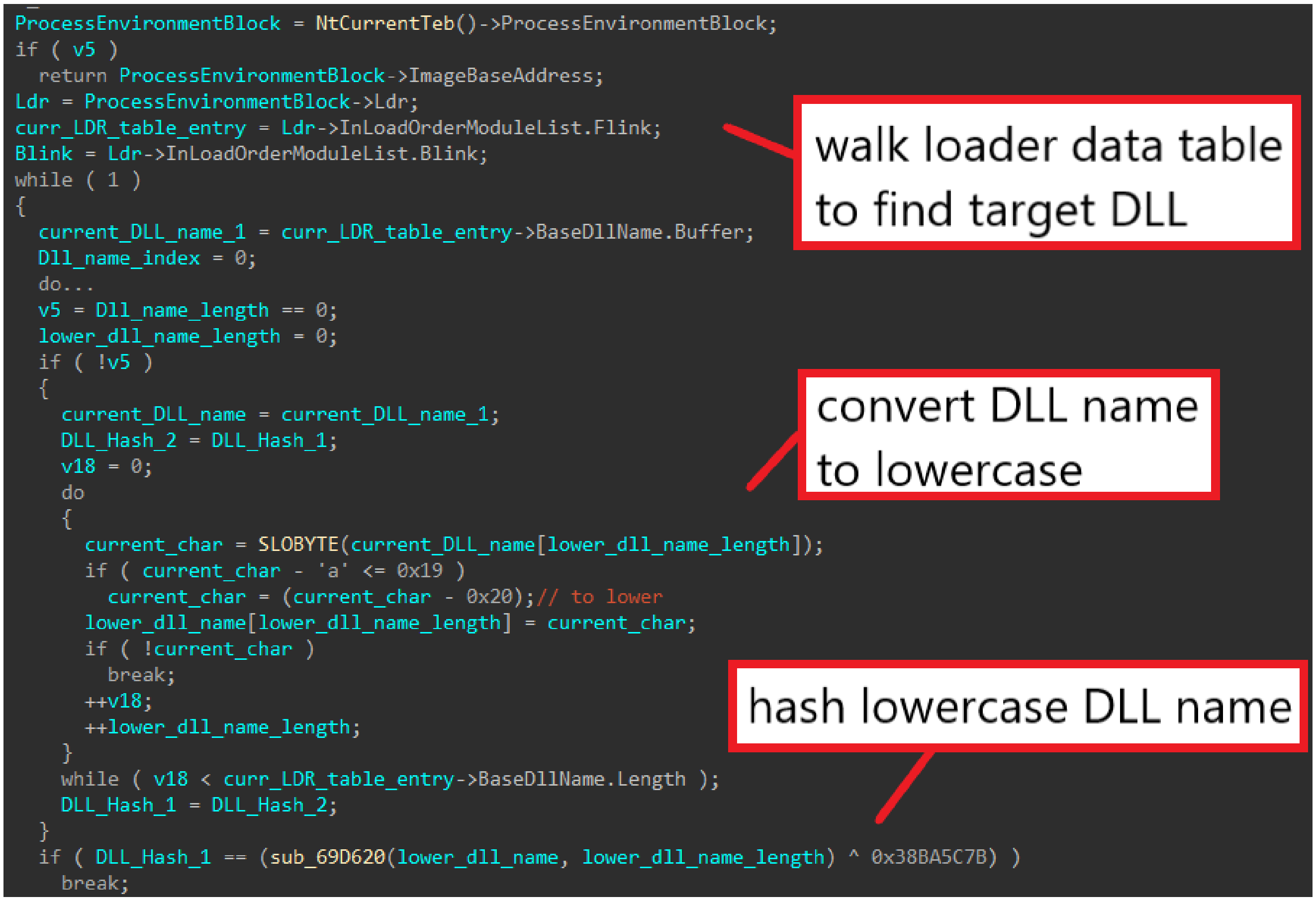
When entering the DLL's entry point, we can immediately see a function called with two hashes as parameters. This function is called twice from the entry point function, both times with the same value for the first parameters. For the second call, the return value is called as a function, so we know that **sub_6815C0** must be dynamically resolving API through the hashes from its parameters. Furthermore, since both calls share the same value for the first parameter but different values for the second one, we can assume that the first hash corresponds to a library name, and the second one corresponds to the name of the target API in that library.



We can further examine **sub_6815C0** to confirm this. The subroutine first starts with passing the DLL hash to the functions **sub_686C50** and **sub_687564**. The return value and the API hash are then passed into **sub_6867C8** as parameters. From this, we can assume the first two functions retrieve the base of the DLL corresponding to the DLL hash, and this base address is passed to the last function with the API hash to resolve the API.



When diving into **sub_687564**, we can see that DRIDEX accesses the loader data table from the Process Environment Block (PEB), which contains a doubly linked list of loader data table entries. Each of these entries contains information about a loaded library in memory, so by iterating through the table, the malware extracts the name of each library, converts it to lowercase, and finally hashes it with **sub_69D620** and XORs it with **0x38BA5C7B**. Each library's hash is compared against the target hash, and the base address of the target library is returned if found. This confirms that **sub_687564** retrieves the base of the DLL corresponding to the given DLL hash.



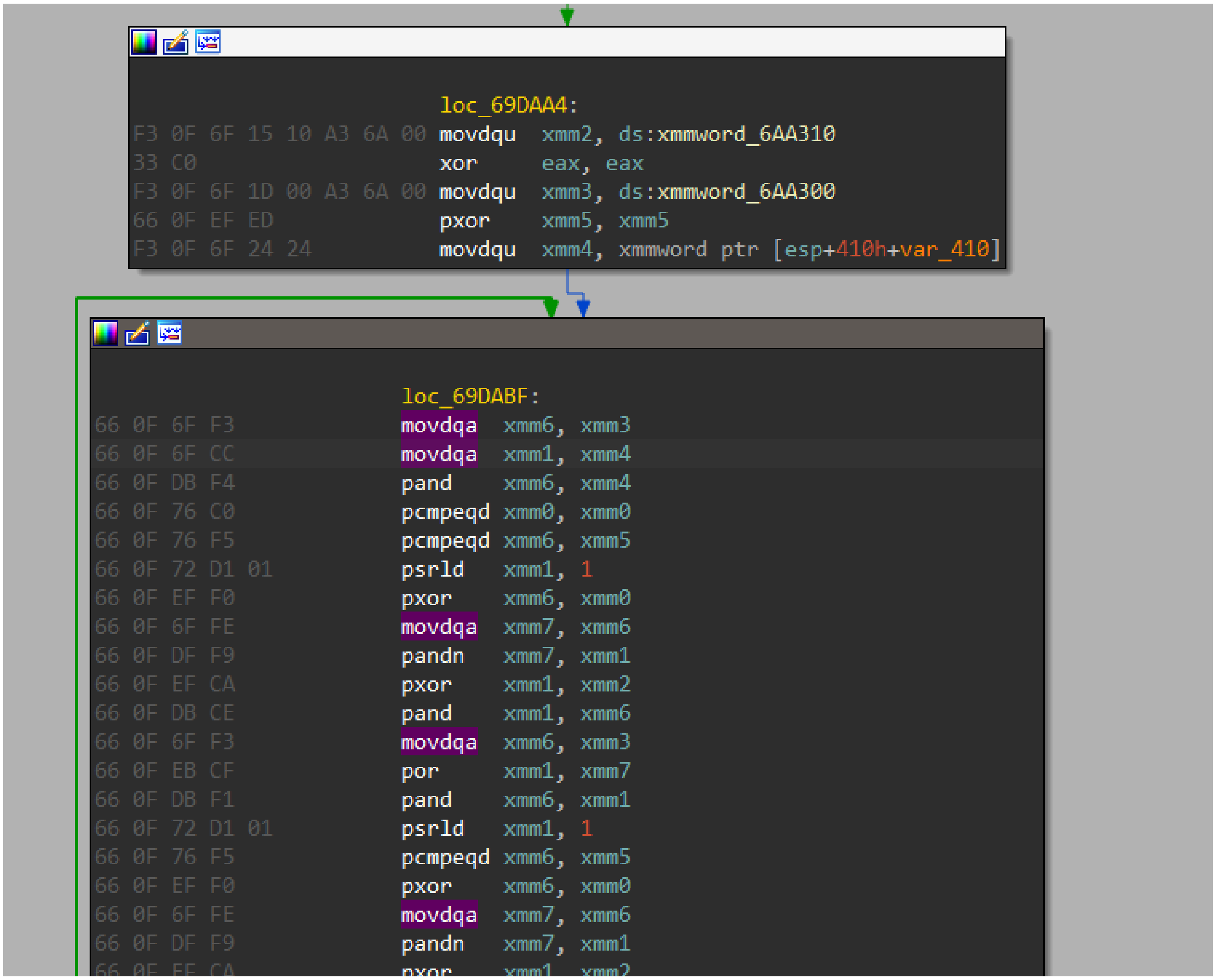
```
ProcessEnvironmentBlock = NtCurrentTeb()->ProcessEnvironmentBlock;
if ( v5 )
  return ProcessEnvironmentBlock->ImageBaseAddress;
Ldr = ProcessEnvironmentBlock->Ldr;
curr_LDR_table_entry = Ldr->InLoadOrderModuleList.Flink;
Blink = Ldr->InLoadOrderModuleList.Blink;
while ( 1 )
{
  current_DLL_name_1 = curr_LDR_table_entry->BaseDllName.Buffer;
  Dll_name_index = 0;
  do...
  v5 = Dll_name_length == 0;
  lower_dll_name_length = 0;
  if ( !v5 )
  {
    current_DLL_name = current_DLL_name_1;
    DLL_Hash_2 = DLL_Hash_1;
    v18 = 0;
    do
    {
      current_char = SLOBYTE(current_DLL_name[lower_dll_name_length]);
      if ( current_char - 'a' <= 0x19 )
        current_char = (current_char - 0x20);// to lower
      lower_dll_name[lower_dll_name_length] = current_char;
      if ( !current_char )
        break;
      ++v18;
      ++lower_dll_name_length;
    }
    while ( v18 < curr_LDR_table_entry->BaseDllName.Length );
    DLL_Hash_1 = DLL_Hash_2;
  }
  if ( DLL_Hash_1 == (sub_69D620(lower_dll_name, lower_dll_name_length) ^ 0x38BA5C7B) )
    break;
```


Similarly, in **sub_6867C8**, DRIDEX uses the base address of the target library to access its export table and iterate through the list containing the address of exports' names. Since API names are stored as UNICODE strings in the export table, the malware converts each API's name to ASCII and hashes it using the same hashing function **sub_69D620**. The target API hash is XOR-ed with **0x38BA5C7B** before being compared to the hash of each API name. This confirms to us that **sub_6867C8** dynamically retrieves an API from the target library using a given hash.

```
export_index = 0;
target_CRC32_hash = API_hash_1 ^ 0x38BA5C7B;
v46 = export_AddressOfNameOrdinals;
v45 = export_dir_size;
v44 = export_dir_addr;
while ( 1 )
{
  wchar_API_name = (DLL_Base + export_AddressOfNames[export_index++]);
  API_name[0] = *wchar_API_name;
  if ( API_name[0] )
  {
    export_index_1 = export_index;
    v15 = 0;
    export_AddressOfNames_1 = export_AddressOfNames;
    do
    {
      v16 = SHIBYTE(wchar_API_name[v15++]);
      API_name_len = 2 * v15 - 1;
      API_name[2 * v15 - 1] = v16;
      if ( !v16 )
        break;
      v18 = SLOBYTE(wchar_API_name[v15]);
      API_name_len = 2 * v15;
      API_name[2 * v15] = v18;
    }
    while ( v18 );
    export_index = export_index_1;
    export_AddressOfNames = export_AddressOfNames_1;
  }
  else
  {
    API_name_len = 0;
  }
  current_API_hash = sub_69D620(API_name, API_name_len);
  if ( current_API_hash == target_CRC32_hash )
```


Step 2: Identifying API Hashing Algorithm

At this point, we know that **sub_69D620** is the hashing algorithm, and the final hash is produced by XOR-ing the function’s return value with **0x38BA5C7B**. The core functionality of this function contains SSE data transfer instructions to deal with XMM registers.

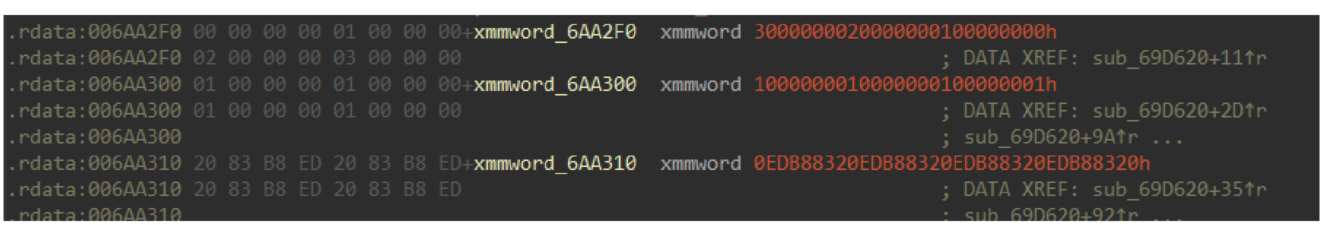


```
loc_69DAA4:
F3 0F 6F 15 10 A3 6A 00 movdqu  xmm2, ds:xmmword_6AA310
33 C0                   xor     eax, eax
F3 0F 6F 1D 00 A3 6A 00 movdqu  xmm3, ds:xmmword_6AA300
66 0F EF ED             pxor    xmm5, xmm5
F3 0F 6F 24 24          movdqu  xmm4, xmmword ptr [esp+410h+var_410]

loc_69DABF:
66 0F 6F F3             movdqa  xmm6, xmm3
66 0F 6F CC             movdqa  xmm1, xmm4
66 0F DB F4             pand    xmm6, xmm4
66 0F 76 C0             pcmpeqd xmm0, xmm0
66 0F 76 F5             pcmpeqd xmm6, xmm5
66 0F 72 D1 01          psrld   xmm1, 1
66 0F EF F0             pxor    xmm6, xmm0
66 0F 6F FE             movdqa  xmm7, xmm6
66 0F DF F9             pandn   xmm7, xmm1
66 0F EF CA             pxor    xmm1, xmm2
66 0F DB CE             pand    xmm1, xmm6
66 0F 6F F3             movdqa  xmm6, xmm3
66 0F EB CF             por     xmm1, xmm7
66 0F DB F1             pand    xmm6, xmm1
66 0F 72 D1 01          psrld   xmm1, 1
66 0F 76 F5             pcmpeqd xmm6, xmm5
66 0F EF F0             pxor    xmm6, xmm0
66 0F 6F FE             movdqa  xmm7, xmm6
66 0F DF F9             pandn   xmm7, xmm1
66 0F EF CA             pxor    xmm1, xmm2
```

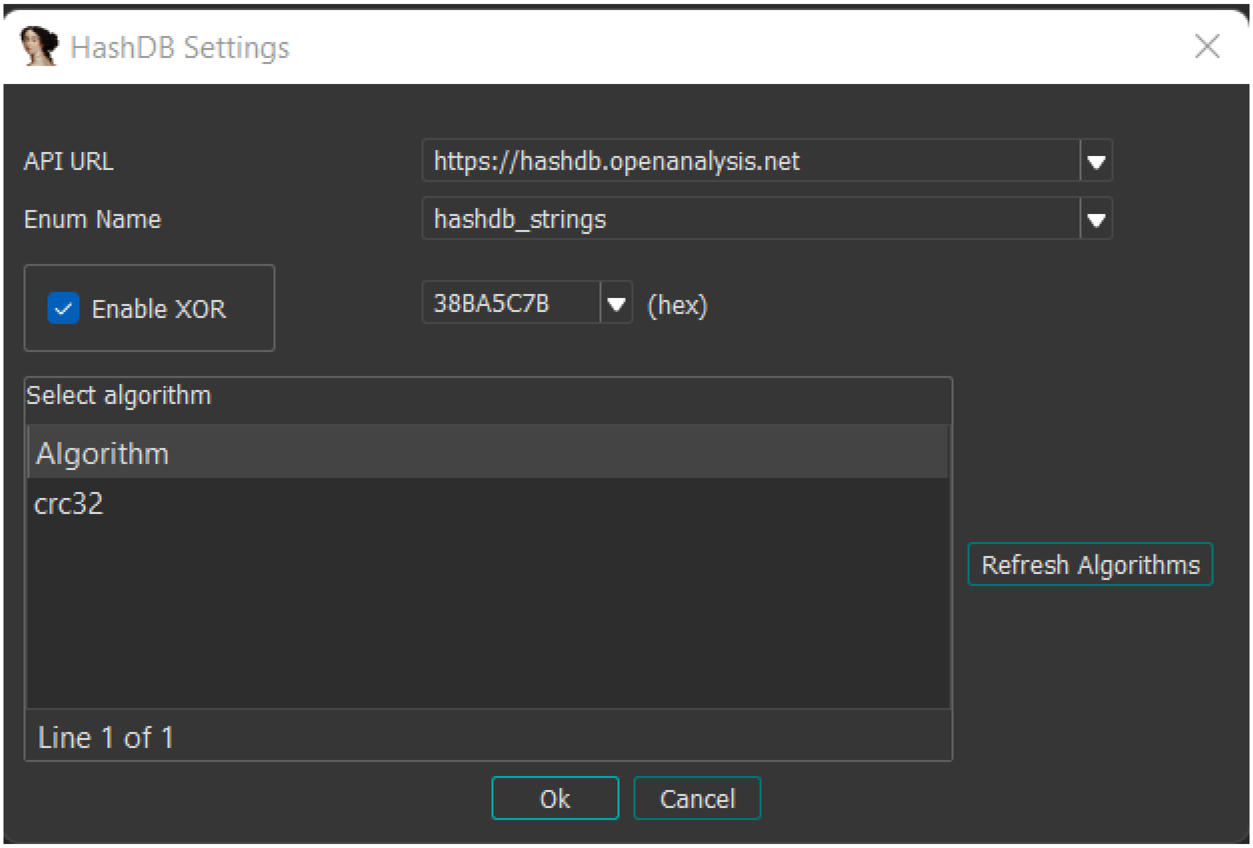
Typically, it's not worth the time to analyze the assembly instructions in these cryptographic functions. For most cases, we can depend on constant values being loaded or used in the program to pick out the correct algorithm, and tools like Mandiant's capa are awesome in helping us automate this process. Unfortunately, capa fails to identify this specific algorithm, so we have to analyze the constants on our own.

Fortunately, among the three constants being used in this function, one stands out with the repetition of the value **0x0EDB8832**, which is typically used in the **CRC32** hashing algorithm. As a result, we can assume that **sub_69D620** is a function to generate a **CRC32** hash from a given string, and the API hashing algorithm of DRIDEX boils down to XOR-ing the **CRC32** hash of API/DLL names with **0x38BA5C7B**.

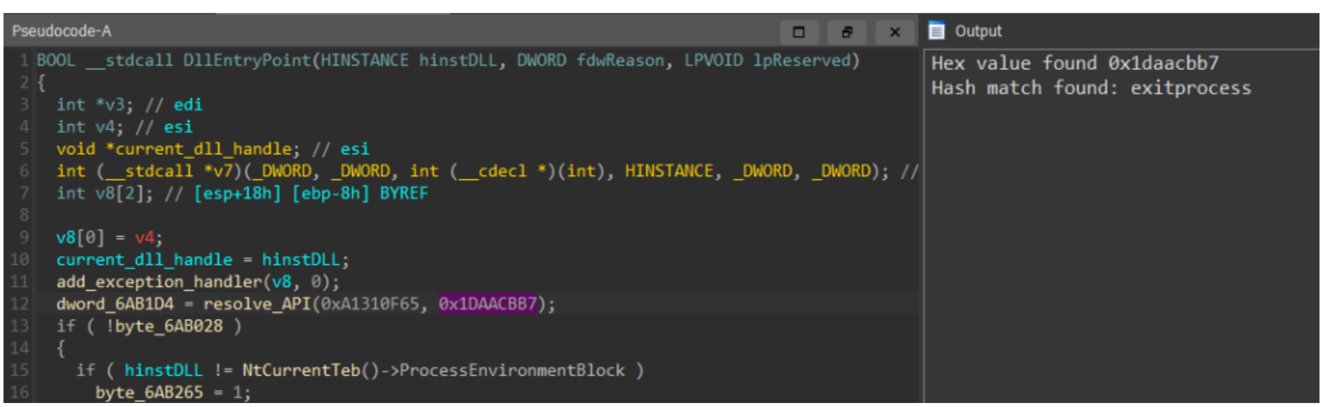


```
.rdata:006AA2F0 00 00 00 00 01 00 00 00+xmmword_6AA2F0  xmmword 300000002000000010000000h
.rdata:006AA2F0 02 00 00 00 03 00 00 00                           ; DATA XREF: sub_69D620+11↑r
.rdata:006AA300 01 00 00 00 01 00 00 00+xmmword_6AA300  xmmword 1000000010000000100000001h
.rdata:006AA300 01 00 00 00 01 00 00 00                           ; DATA XREF: sub_69D620+2D↑r
.rdata:006AA300                                                   ; sub_69D620+9A↑r ...
.rdata:006AA310 20 83 B8 ED 20 83 B8 ED+xmmword_6AA310  xmmword 0EDB88320EDB88320EDB88320EDB88320h
.rdata:006AA310 20 83 B8 ED 20 83 B8 ED                           ; DATA XREF: sub_69D620+35↑r
.rdata:006AA310                                                   ; sub_69D620+92↑r ...
```

To quickly check if this hashing algorithm is correct, we can use OALabs's hashdb plugin for IDA to test resolving the API resolved in the DLL's entry point function. First, since DRIDEX's hashes have an additional layer of XOR, we must set **0x38BA5C7B** as hashdb's XOR key before looking the hashes up using **CRC32**.



Finally, we can use hashdb to look up the hashes in the sample. Here, we can see that the hash **0x1DAACBB7** corresponds correctly to the **ExitProcess** API, which confirms to us that our assumption about the hashing algorithm is correct.



Step 3: Vectored Exception Handler

Unlike most malware, DRIDEX does not use the **call** instruction to call APIs. Instead, the malware uses a combination of **int3** and **retn** instructions to call its Windows APIs after dynamically resolving them.

This feature is a great anti-analysis trick because it makes both static and dynamic analysis harder. Due to the **retn** instruction, IDA treats every API call as the end of the parent function. This makes all instructions behind it unreachable and breaks up the control flow of the function's decompiled code.

```
int __fastcall sub_69E170(int a1, int a2)
{
  int result; // eax
  int v5; // ebp
  int v6[5]; // [esp+0h] [ebp-14h] BYREF

  v6[1] = 0;
  result = resolve_API(985220999, 1680656271);
  if ( result )
  {
    __debugbreak();
  }
  else
  {
    sub_680B70(v6, 0, 4);
    if ( a2 )
    {
      v5 = v6[0] % (a2 - a1) + a1;
      v6[0] = v5;
    }
    else if ( a1 )
    {
      v5 = v6[0] + a1;
      v6[0] = v5;
    }
    else
    {
      return v6[0];
    }
    return v5;
  }
  return result;
}
```

The **int3** instruction also slows down dynamic analysis since debuggers like **x64dbg** register the interrupt as an exception instead of swallowing it as a normal breakpoint to avoid debugger detection. This requires the analyst to manually skip over the **int3** instruction or pass it to the system's exception handlers while debugging.

To properly call an API, DRIDEX resolves it from hashes dynamically, stores the API's address in **eax**, pushes the API's parameters on the stack, and executes **int3** as shown above. However, instead of using the system's exception handlers to handle this interrupt, the malware registers its own custom handler by calling **sub_687980** at the beginning of the DLL entry point function.

The function **sub_687980** dynamically resolves **RtlAddVectoredExceptionHandler** and calls it to register **sub_687D40** as a vectored exception handler. This means that when the program encounters an **int3** instruction, **sub_687D40** is invoked by the kernel to handle the interrupt and transfer control to the API stored in **eax**.

```
LABEL_9:
    ntdll_handle = get_DLL_handle_from_hash(1485485034, 1485485034);
    if ( !ntdll_handle && get_DLL_handle_from_hash_0(1485485034) )
      ntdll_handle = get_DLL_handle_from_hash(1485485034, 1485485034);
    if ( ntdll_handle )
      RtlAddVectoredExceptionHandler = get_API_from_hash(ntdll_handle, rtladdvectoredexceptionhandler);
    else
      RtlAddVectoredExceptionHandler = 0;
LABEL_12:
    dword_6AB210 = sub_687A60(RtlAddVectoredExceptionHandler);
    byte_6AB26C = 0;
```

```
                    ; int __thiscall sub_687A60(int (__stdcall *this)(int, int (__stdcall *)(int)))
                    sub_687A60 proc near
68 40 7D 68 00      push    offset sub_687D40
6A 01               push    1
FF D1               call    ecx             ; RtlAddVectoredExceptionHandler
C3                  retn
                    sub_687A60 endp
```

The handler code first checks the exception information structure to see the exception type it's handling. If the type is **EXCEPTION_ACCESS_VIOLATION**, **EXCEPTION_STACK_OVERFLOW**, **STATUS_HEAP_CORRUPTION**, DRIDEX resolves the **TerminateProcess** API and calls it to terminate itself by interrupting with **int3**.

For Vectored Exception Handling, system handlers and user-registered handlers are placed in a vector or chain. An exception is passed through handlers on this chain until one properly handles it and returns control to the point at which it occurred. In DRIDEX's handler, if the type is anything else but **EXCEPTION_BREAKPOINT** (which is invoked by **int3)**, the handler returns 0 (**EXCEPTION_CONTINUE_SEARCH**) to pass the exception along to another handler.

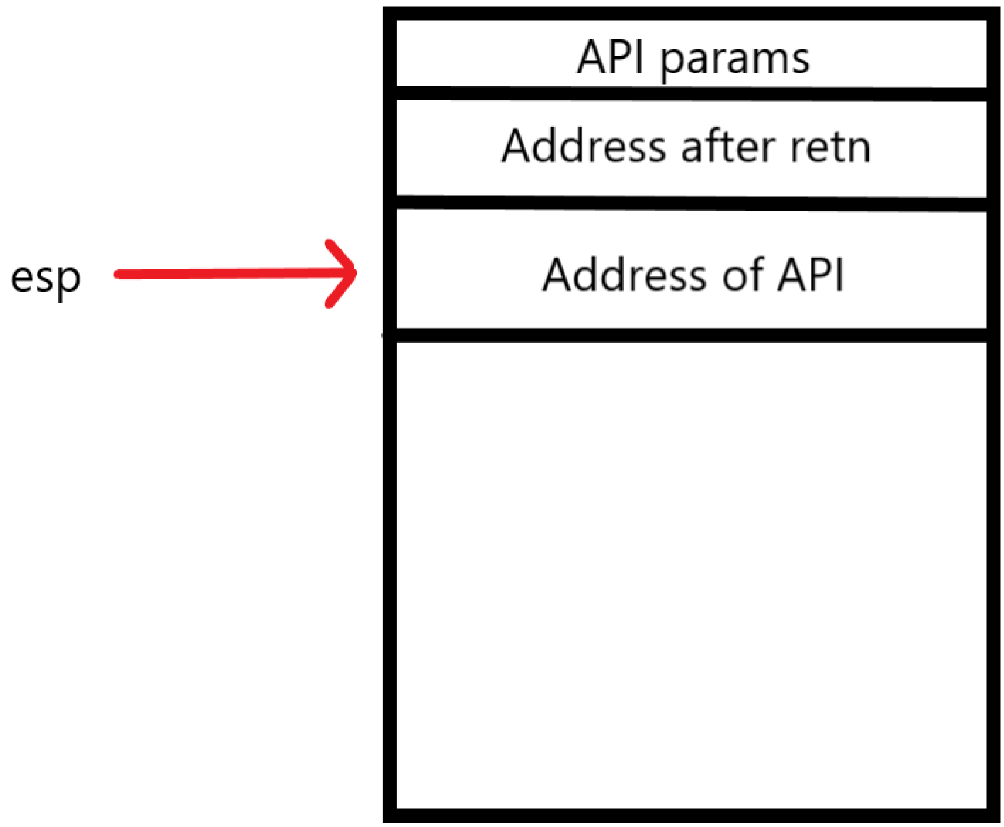
```
  ExceptionCode = ExceptionInfo->ExceptionRecord->ExceptionCode;
  if ( ExceptionCode == EXCEPTION_ACCESS_VIOLATION
    || ExceptionCode == EXCEPTION_STACK_OVERFLOW
    || ExceptionCode == STATUS_HEAP_CORRUPTION )
  {
    v3 = dword_6AB1F4;
    if...
    if...
LABEL_13:
    kernel32_base = get_DLL_handle_from_hash(KERNEL32_DLL, KERNEL32_DLL);
    if ( !kernel32_base )
    {
      if ( get_DLL_handle_from_hash_0(KERNEL32_DLL) )
        kernel32_base = get_DLL_handle_from_hash(KERNEL32_DLL, KERNEL32_DLL);
    }
    if ( kernel32_base )
    {
      TerminateProcess = get_API_from_hash(kernel32_base, terminateprocess);
LABEL_16:
      if ( TerminateProcess )
      {
        __debugbreak();
        return TerminateProcess;
      }
    }
  }
  else if ( ExceptionCode != EXCEPTION_BREAKPOINT )
  {
    return 0;
  }
```

Finally, if the exception type is **EXCEPTION_BREAKPOINT**, the handler sets up the API in **eax** to be called. When an exception occurs, the system transfers control from the user thread that triggers the exception to a kernel thread to execute the exception handlers. As context switching happens, the system saves all registers from the user thread in memory before executing the kernel thread, in order to properly restore them when the handlers finish. For Vectored Exception Handling, the context record of the user thread containing its registers is stored in the **EXCEPTION_POINTERS** structure that is passed as a parameter to handlers.

Using this structure, DRIDEX's handler accesses the context record and increments the **eip** value to have it points to the **retn** instruction after **int3**. Because **eip** is restored from context record after handlers finish, this sets the user thread to begin executing at the **retn** instruction after exception handling. Next, the address of the instruction after **retn** and the address of the API from **eax** are consecutively pushed on the stack.

```
++ExceptionInfo->ContextRecord->Eip;
ExceptionInfo->ContextRecord->Esp -= 4;
*ExceptionInfo->ContextRecord->Esp = ExceptionInfo->ContextRecord->Eip + 1;// addr after ret
ExceptionInfo->ContextRecord->Esp -= 4;
*ExceptionInfo->ContextRecord->Esp = ExceptionInfo->ContextRecord->Eax;// eax = API call
return EXCEPTION_CONTINUE_EXECUTION;
```

Below is what the current user stack looks like at the end of this handler.



After the handler returns the **EXCEPTION_CONTINUE_EXECUTION** code, the user thread's context is restored and the malware begins executing at the **retn** instruction. Because the **retn** instruction pops the value at the top of the stack and jumps to it, the malware will jump to the address of the resolved API. This becomes a normal stack frame for a function call with **esp** pointing to the return address and parameters being properly set up on the stack. When the API returns, DRIDEX continues executing at the address after the **retn** instruction.

Step 4: Writing Script To Patch DLL

After understanding how DRIDEX uses VEH to call APIs, we can programmatically patch the sample to bypass this anti-analysis feature in IDA and debuggers by modifying all "**int3, retn"** sequences (0xCCC3) to **call eax** instructions (0xFFD0) in the sample **.text** section. This should make IDA's decompilation work nicely while preventing the execution from being interrupted in our debuggers!

```
import pefile

file_path = '<DRIDEX SAMPLE PATH>'

file = open(file_path, 'rb')
file_buffer = file.read()
file.close()

dridex_pe = pefile.PE(data=file_buffer)

text_sect_start = 0
text_sect_size = 0
for section in dridex_pe.sections:
    if section.Name.decode('utf-8').startswith('.text'):
        text_sect_start = dridex_pe.get_offset_from_rva(section.VirtualAddress)
        text_sect_size = section.SizeOfRawData

patched_text_sect =
file_buffer[text_sect_start:text_sect_start+text_sect_size].replace(b'\xCC\xC3',
b'\xFF\xD0')

file_buffer = file_buffer[0:text_sect_start] + patched_text_sect +
file_buffer[text_sect_start+text_sect_size:]

out_path = '<OUTPUT PATH>'
out_file = open(out_path, 'wb')
out_file.write(file_buffer)
out_file.close()
```

If you have any questions regarding the analysis, feel free to reach out to me via Twitter.