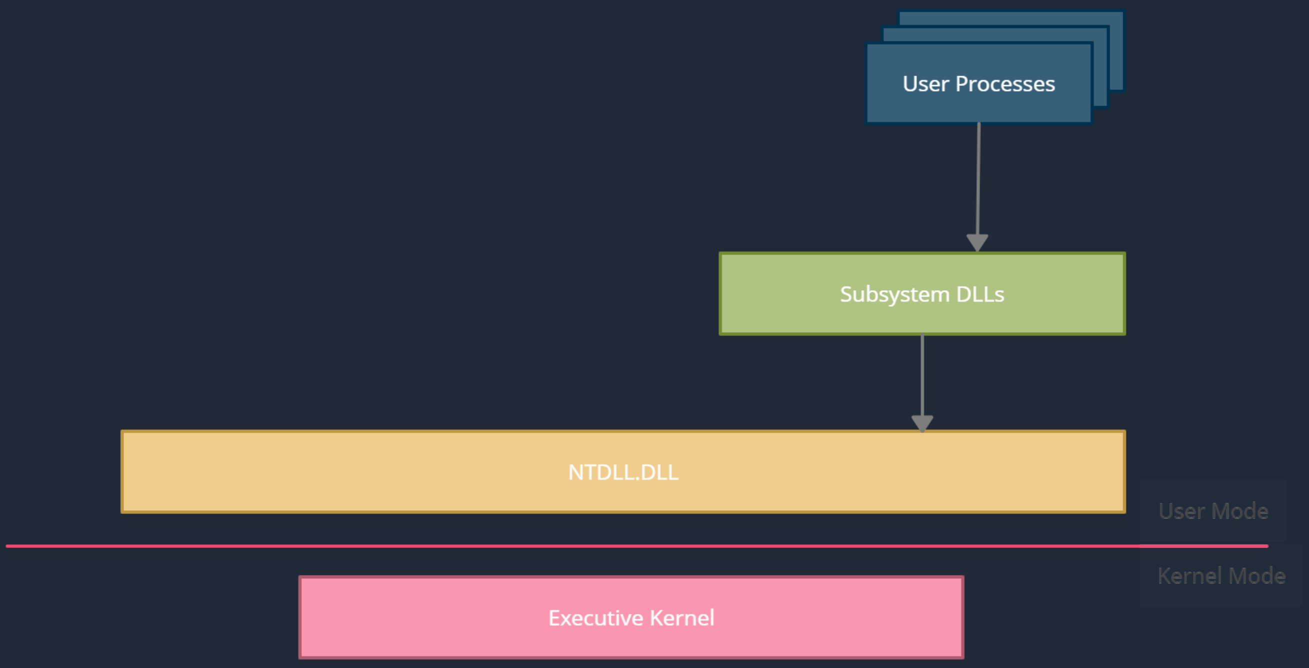
Windows Architecture

Introduction

This module explains the Windows architecture and what happens under the hood of Windows processes and applications.

Windows Architecture

A processor inside a machine running the Windows operating system can operate under two different modes: User Mode and Kernel Mode. Applications run in user mode, and operating system components run in kernel mode. When an application wants to accomplish a task, such as creating a file, it cannot do so on its own. The only entity that can complete the task is the kernel, so instead applications must follow a specific function call flow. The diagram below shows a high level of this flow.



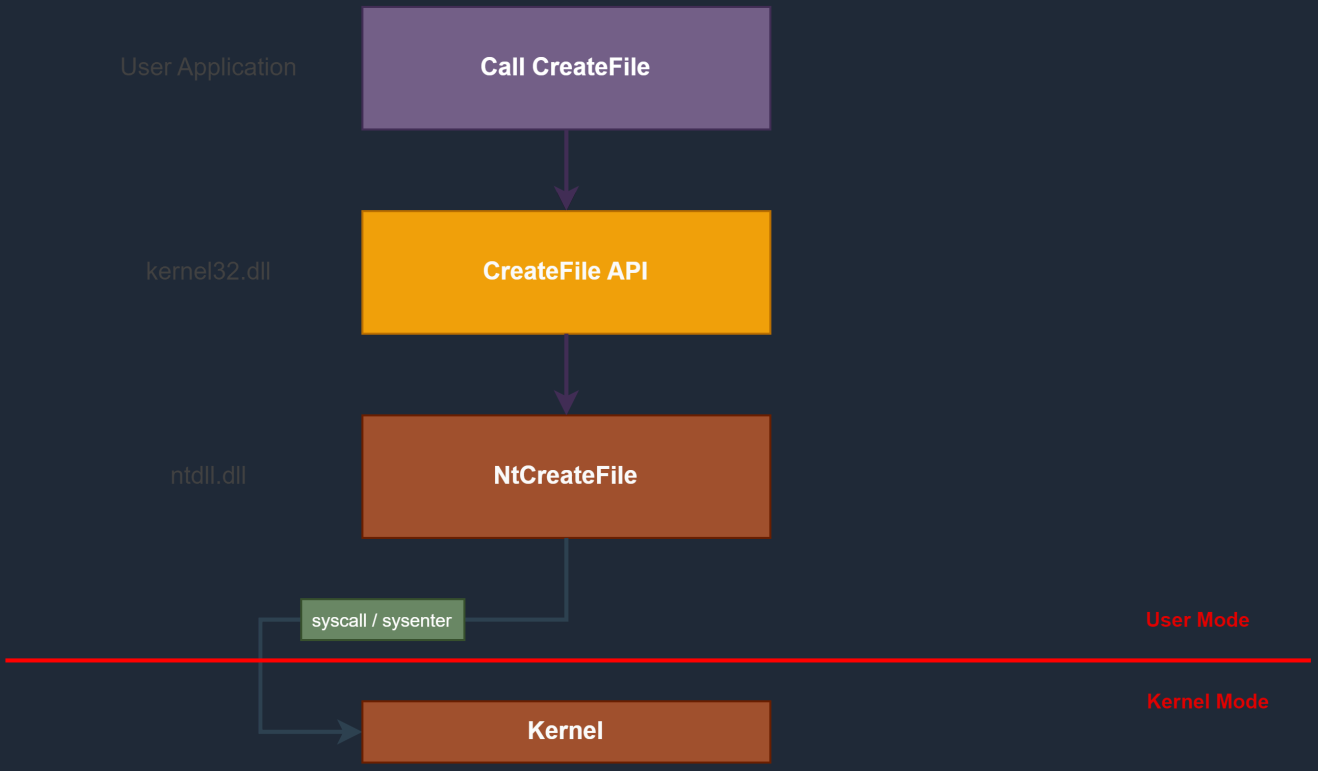
1. **User Processes** - A program/application executed by the user such as Notepad, Google Chrome or Microsoft Word.
2. **Subsystem DLLs** - DLLs that contain API functions that are called by user processes. An example of this would be `kernel32.dll` exporting the CreateFile Windows API (WinAPI) function, other common subsystem DLLs are `ntdll.dll`, `advapi32.dll`, and `user32.dll`.
3. **Ntdll.dll** - A system-wide DLL which is the lowest layer available in user mode. This is a special DLL that creates the transition from user mode to kernel mode. This is often

referred to as the Native API or NTAPI.

4. **Executive Kernel** - This is what is known as the Windows Kernel and it calls other drivers and modules available within kernel mode to complete tasks. The Windows kernel is partially stored in a file called `n#krnl.exe` under "C:\Windows\System32".

Function Call Flow

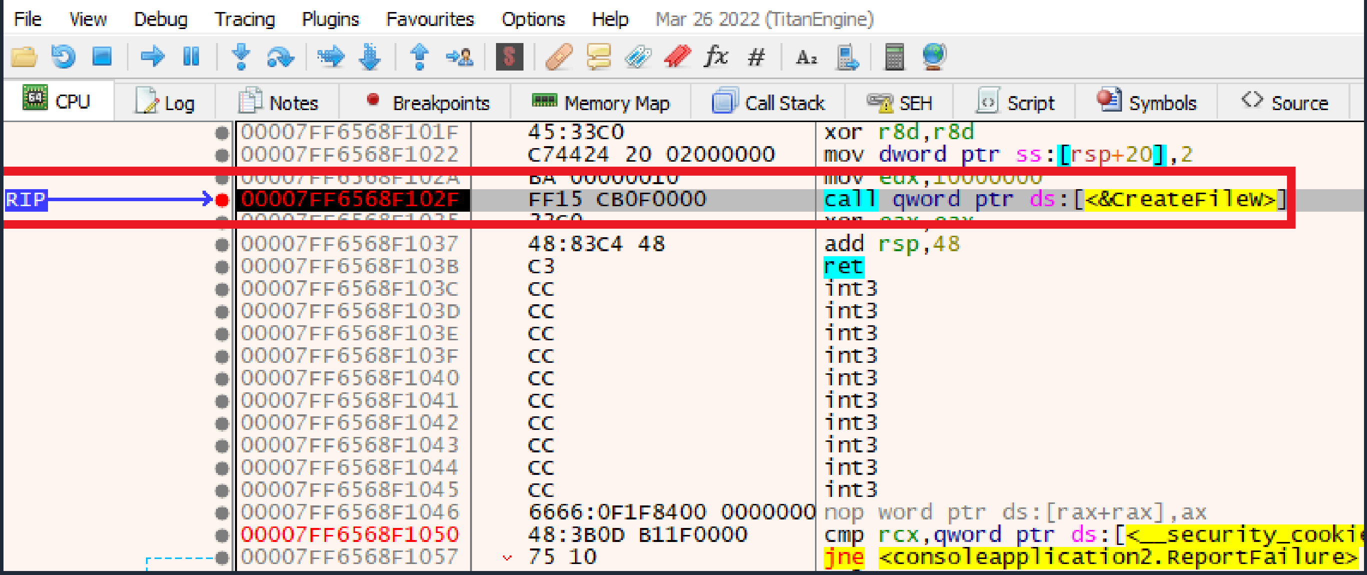
The image below shows an example of an application that creates a file. It begins with the user application calling the `CreateFile` WinAPI function which is available in `kernel32.dll`. `Kernel32.dll` is a critical DLL that exposes applications to the WinAPI and is therefore can be seen loaded by most applications. Next, `CreateFile` calls its equivalent NTAPI function, `NtCreateFile`, which is provided through `ntdll.dll`. `Ntdll.dll` then executes an assembly `sysenter` (x86) or `syscall` (x64) instruction, which transfers execution to kernel mode. The kernel `NtCreateFile` function is then used which calls kernel drivers and modules to perform the requested task.



Function Call Flow Example

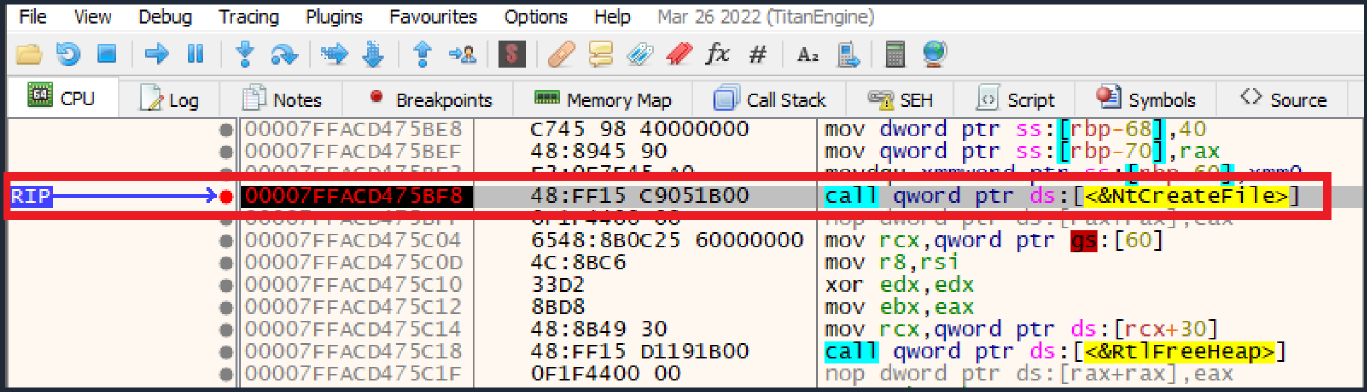
This example shows the function call flow happening through a debugger. This is done by attaching a debugger to a binary that creates a file via the `CreateFileW` Windows API.

The user application calls the `CreateFileW` WinAPI.



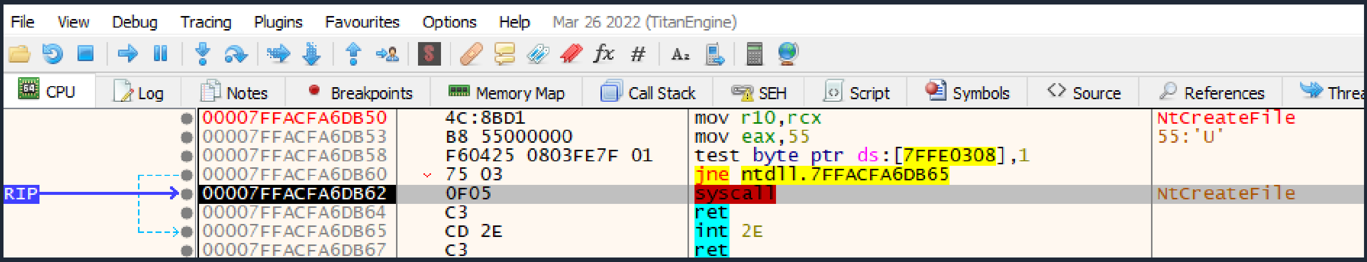
```
00007FF6568F101F   45:33C0              xor r8d,r8d
00007FF6568F1022   C74424 20 02000000   mov dword ptr ss:[rsp+20],2
00007FF6568F102A   BA 00000010          mov edx,10000000
RIP → 00007FF6568F102F   FF15 CB0F0000   call qword ptr ds:[<&CreateFileW>]
00007FF6568F1035   33C0                 xor eax,eax
00007FF6568F1037   48:83C4 48           add rsp,48
00007FF6568F103B   C3                   ret
00007FF6568F103C   CC                   int3
00007FF6568F103D   CC                   int3
00007FF6568F103E   CC                   int3
00007FF6568F103F   CC                   int3
00007FF6568F1040   CC                   int3
00007FF6568F1041   CC                   int3
00007FF6568F1042   CC                   int3
00007FF6568F1043   CC                   int3
00007FF6568F1044   CC                   int3
00007FF6568F1045   CC                   int3
00007FF6568F1046   6666:0F1F8400 0000000 nop word ptr ds:[rax+rax],ax
00007FF6568F1050   48:3B0D B11F0000     cmp rcx,qword ptr ds:[<__security_cooki
00007FF6568F1057   75 10                jne <consoleapplication2.ReportFailure>
```

Next, `CreateFileW` calls its equivalent NTAPI function, `NtCreateFile`.



```
00007FFACD475BE8   C745 98 40000000     mov dword ptr ss:[rbp-68],40
00007FFACD475BEF   48:8945 90           mov qword ptr ss:[rbp-70],rax
00007FFACD475BF2   F3:0F7F45 A0         movdqu xmmword ptr ss:[rbp-60],xmm0
RIP → 00007FFACD475BF8   48:FF15 C9051B00   call qword ptr ds:[<&NtCreateFile>]
00007FFACD475BFF   0F1F4400 00          nop dword ptr ds:[rax+rax],eax
00007FFACD475C04   6548:8B0C25 60000000 mov rcx,qword ptr gs:[60]
00007FFACD475C0D   4C:8BC6              mov r8,rsi
00007FFACD475C10   33D2                 xor edx,edx
00007FFACD475C12   8BD8                 mov ebx,eax
00007FFACD475C14   48:8B49 30           mov rcx,qword ptr ds:[rcx+30]
00007FFACD475C18   48:FF15 D1191B00     call qword ptr ds:[<&RtlFreeHeap>]
00007FFACD475C1F   0F1F4400 00          nop dword ptr ds:[rax+rax],eax
```

Finally, the `NtCreateFile` function uses a `syscall` assembly instruction to transition from user mode to kernel mode. The kernel will then be the one that creates the file.



```
00007FFACFA6DB50   4C:8BD1              mov r10,rcx                    NtCreateFile
00007FFACFA6DB53   B8 55000000          mov eax,55                     55:'U'
00007FFACFA6DB58   F60425 0803FE7F 01   test byte ptr ds:[7FFE0308],1
00007FFACFA6DB60   75 03                jne ntdll.7FFACFA6DB65
RIP → 00007FFACFA6DB62   0F05            syscall                        NtCreateFile
00007FFACFA6DB64   C3                   ret
00007FFACFA6DB65   CD 2E                int 2E
00007FFACFA6DB67   C3                   ret
```

Directly Invoking The Native API (NTAPI)

It's important to note that applications can invoke syscalls (i.e. NTDLL functions) directly without having to go through the Windows API. The Windows API simply acts as a wrapper for the Native API. With that being said, the Native API is more difficult to use

Previous Modules Undo Next

warning.

Future modules will explore the benefits of directly invoking the Native API.