Weaponizing Privileged File Writes with the USO Service - Part 1/2

itm4n.github.io/usodllloader-part1

August 17, 2019

Posted *Aug 16, 2019*
By *itm4n*
11 min read

The DiagHub DLL loading technique found by James Forshaw (a.k.a. @tiraniddo) has become very famous. Whenever you found **an arbitrary file write as SYSTEM** in Windows or in some third-party software, you could use this trick to **get code execution on demand**, and without rebooting. Unfortunately (or fortunately depending on your point of view), this method was **mitigated by Microsoft in Windows 10 build 1903**. Andrea Pierini (aka @decoder_it) mentionned this briefly on Twitter. Here, I want to share an alternative method I found while looking for DLL hijacking weaknesses on the most recent version of Windows.

Foreword

I want to begin this article by clarifying a few things.

- **It is NOT a vulneratibilty**. As we will see, in order to be able to use this trick, a specifcally crafted DLL must be planted into the `C:\Windows\System32\` folder first, which only “privileged accounts” can do of course.
- My objective here is to **share some of the Research & Development work I do on my spare time**, and thus show that you don’t need to be a super-elite all-star researcher to find cool stuff.
- If you are already experienced with Reverse Engineering on Windows, there is a high chance you won’t learn much from this. Otherwise, I hope you’ll get a few things out of it.

That being said, let’s dive right into the main subject.

Starting point

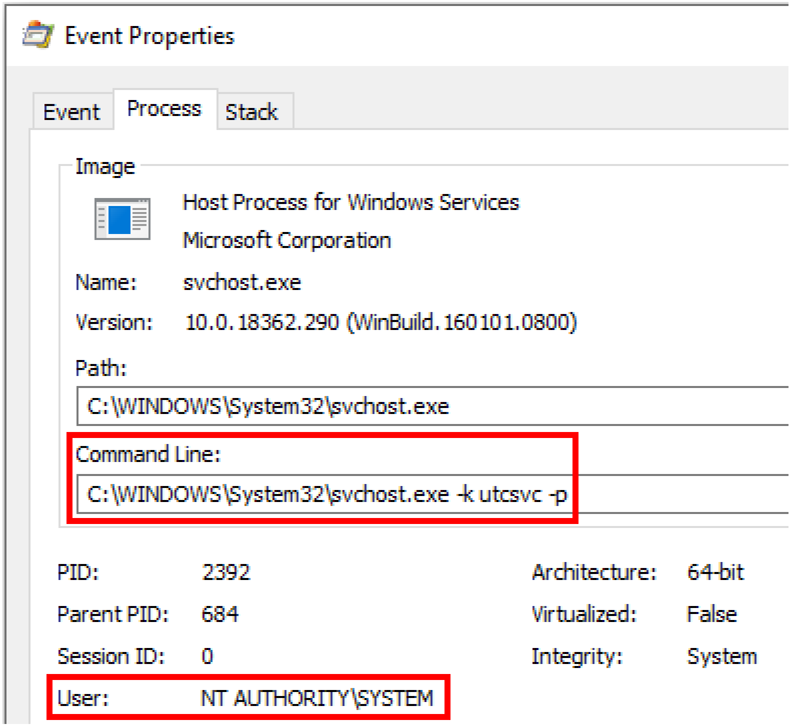
As a starting point, I decided to look for low hanging fruits, such as DLL hijacking in services running as `NT AUTHORITY\System`. The idea is to monitor services that can be started or at least “influenced” by a regular user. To do so, I made a very simple PowerShell script that checks whether a service has been started or stopped every second.

```
C:\Users\lab-user\Desktop>powershell -exec bypass -file .\ServiceTracker.ps1
[23:21:20] Initialization done.
[23:21:20] [Running] Computer Browser (Browser)
[23:21:24] [Stopped] Microsoft Passport (NgcSvc)
[23:21:36] [Running] GameDVR and Broadcast User Service_5d9b2 (BcastDVRUserService_5d9b2)
[23:21:45] [Running] Microsoft Passport (NgcSvc)
[23:21:47] [Stopped] GameDVR and Broadcast User Service_5d9b2 (BcastDVRUserService_5d9b2)
[23:22:13] [Stopped] Microsoft Account Sign-in Assistant (wlidsvc)
[23:23:24] [Stopped] Client License Service (ClipSVC) (ClipSVC)
[23:25:49] [Stopped] Microsoft Passport (NgcSvc)
[23:27:03] [Stopped] Group Policy Client (gpsvc)
[23:28:07] [Stopped] Windows Update (wuauserv)
[23:28:45] [Running] Microsoft Account Sign-in Assistant (wlidsvc)
[23:30:02] [Stopped] Windows Installer (msiserver)
[23:32:44] [Stopped] Microsoft Account Sign-in Assistant (wlidsvc)
[23:33:16] [Stopped] AppX Deployment Service (AppXSVC) (AppXSvc)
[17:58:09] [Running] Client License Service (ClipSVC) (ClipSVC)
[17:58:09] [Running] Windows PushToInstall Service (PushToInstall)
```

In the background, I always run `Process Monitor` to log filesystem operations. I simply configure the filter to only show operations involving `*.dll` files and returning a `NAME NOT FOUND` error code. Then, I tried to start every service I could without admin privileges one at a time. Unfortunately, I didn't find anything with this method. What I did find though is the following.

Time of Day	Process Name	PID	Operation	Path	Result	User
8:28:44.2314980 PM	svchost.exe	1832	CreateFile	C:\Windows\System32\WINDOWSCOREDEVICEINFO.DLL	NAME NOT FOUND	NT AUTHORITY\SYSTEM
8:28:48.3877799 PM	svchost.exe	1832	CreateFile	C:\Windows\System32\WINDOWSCOREDEVICEINFO.DLL	NAME NOT FOUND	NT AUTHORITY\SYSTEM
9:06:03.1874864 PM	svchost.exe	2392	CreateFile	C:\Windows\System32\windowscoredeviceinfo.dll	NAME NOT FOUND	NT AUTHORITY\SYSTEM
9:06:03.1886911 PM	svchost.exe	2392	CreateFile	C:\Windows\System32\windowscoredeviceinfo.dll	NAME NOT FOUND	NT AUTHORITY\SYSTEM
10:06:03.7147476 PM	svchost.exe	2392	CreateFile	C:\Windows\System32\windowscoredeviceinfo.dll	NAME NOT FOUND	NT AUTHORITY\SYSTEM
10:06:03.7177442 PM	svchost.exe	2392	CreateFile	C:\Windows\System32\windowscoredeviceinfo.dll	NAME NOT FOUND	NT AUTHORITY\SYSTEM

While `Process Monitor` was running in the background, it captured some attempts to open the file `windowscoredeviceinfo.dll` on a regular basis. The frequency varied, it could happen every hour or every 30 minutes for example. The properties of the event showed the Command Line of the process: `C:\WINDOWS\System32\svchost.exe -k utcsvc -p`.



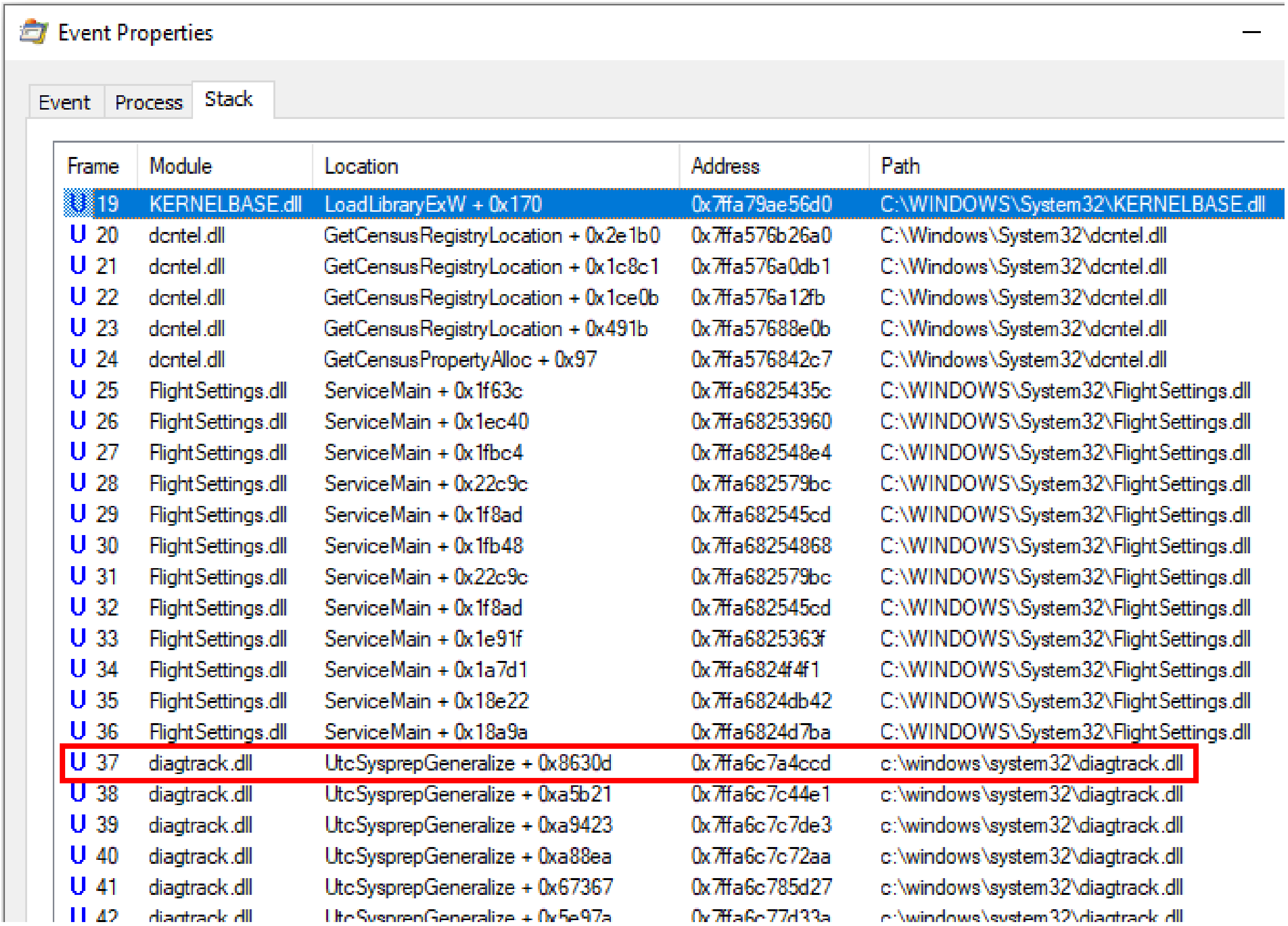
Knowing this, the corresponding service can easily be found with the following PowerShell command for example. In this case, it is **DiagTrack**.

Note: I could also have used the PID of the process and looked for it in the task manager for example. The downside of this method is that the process could terminate before you have the time to check.

```
PS C:\Users\lab-user> Get-WmiObject win32_service | ? { $_.PathName -eq "C:\WINDOWS\System32\svchost.exe -k utcsvc -p" }
 | Select Name,Caption,PathName,StartMode,Started,StartName


Name      : DiagTrack
Caption   : Connected User Experiences and Telemetry
PathName  : C:\WINDOWS\System32\svchost.exe -k utcsvc -p
StartMode : Auto
Started   : True
StartName : LocalSystem
```

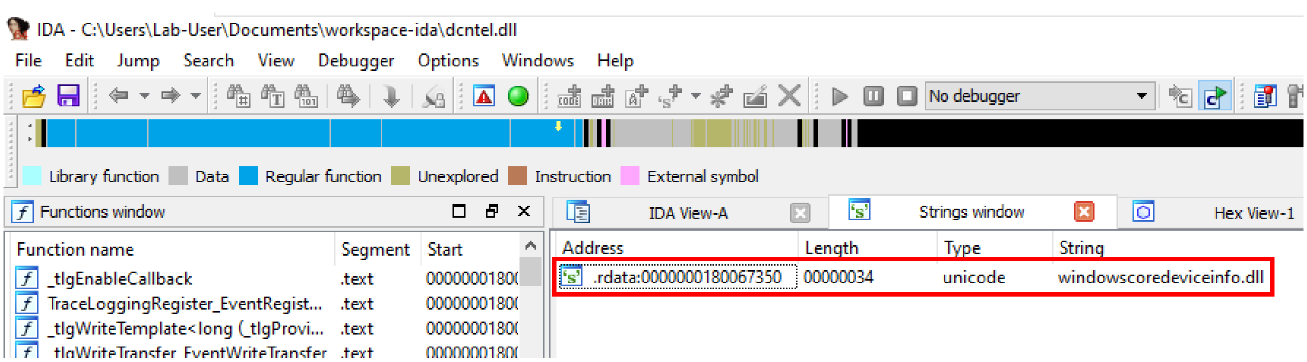
Our first target: DiagTrack

The Event Properties in `Process Monitor` revealed a bit more about how the DLL was loaded. The `Stack` tab shows the list of calls that lead to this operation. Here, we can see that the initial call was made from `diagtrack.dll`. That's where the DiagTrack service is implemented so this makes sense. The `FlightSettings.dll` file was loaded which, in turn, used the `GetCensusRegistryLocation()` method from `dcntel.dll`, and finally, `windowscoredeviceinfo.dll` was loaded using the standard `LoadLibraryEx()` WinApi call.

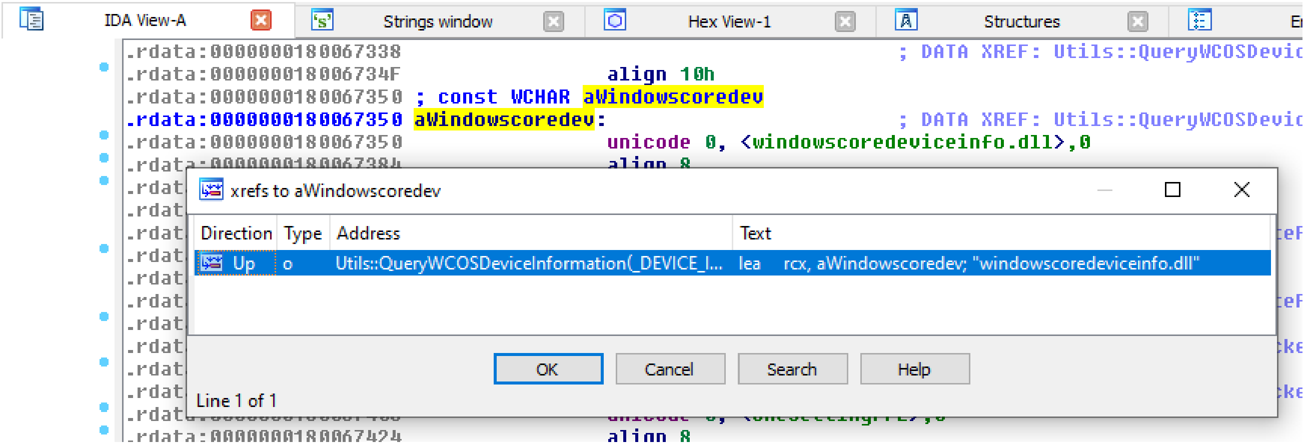


To be sure I was on the right track, I opened the last DLL in IDA and looked for occurences of `windowscoredeviceinfo.dll`. The `Strings` subview is really great for this kind of use case.

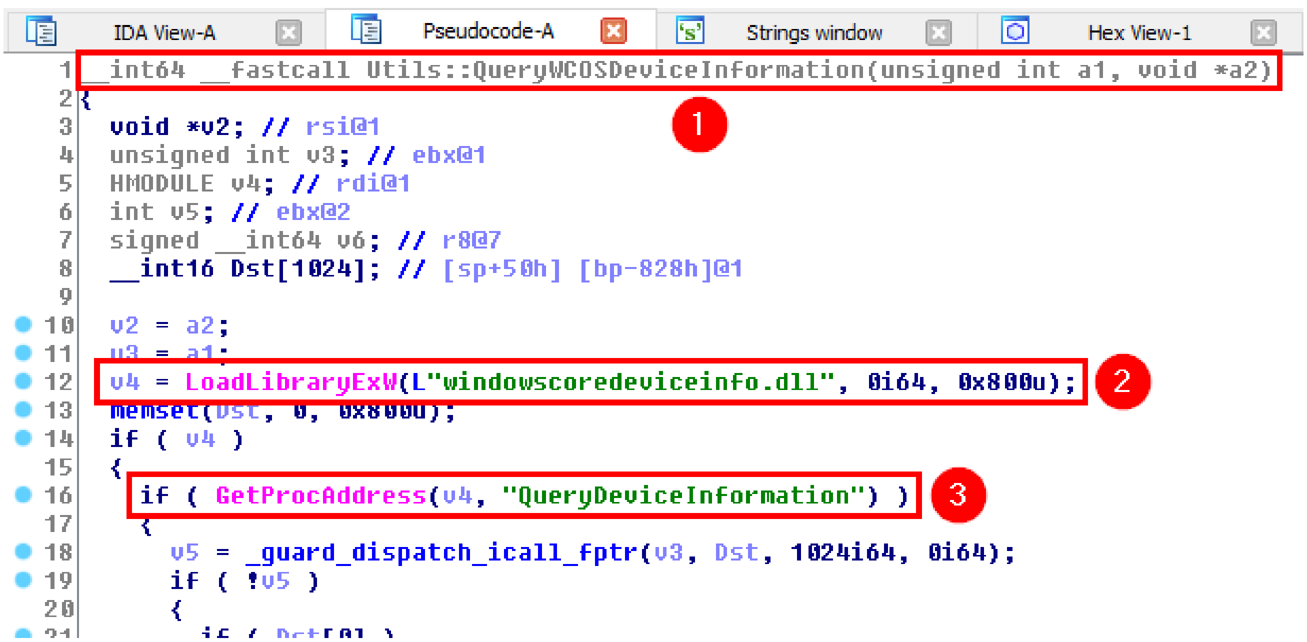
Note: you have to configure the view to include unicode strings because it's not the default setting in IDA...



Then, we can go straight to its location in the `.rdata` section and look for `Xrefs`. In this case, there is only one. This string is indeed used in the `QueryWCOSDeviceInformation()` method. Well, the name looks promising at least!



The pseudocode generated by IDA is pretty clear. We spot the `LoadLibraryEx("windowscoredeviceinfo.dll")` call we saw earlier with `Process Monitor`. Then, if the library is successfully loaded, the following call is made: `GetProcAddress("QueryDeviceInformation")`, which means that this function should be exported by `windowscoredeviceinfo.dll`.



Let’s sum up the situation. At this point, we know the following:

- An unkown task is run by the DiagTrack service on a regular basis (every 30 minutes or every hour).
- Each time, it tries to load a DLL called `windowscoredeviceinfo.dll`, which doesn’t exist by default.
- If it is successfully loaded, the `QueryDeviceInformation` function is imported.

That’s a good start but I’m missing some key elements. For example, I have no clue how this “task” is run. I don’t even know whether I would be able to trigger it as a regular user. So, rather than starting to reverse enginneer the service without really knowing what I was looking for, I decided to create a PoC DLL and verify if I could really get arbitrary code execution as `NT AUTHORITY\System`.

Crafting a PoC DLL

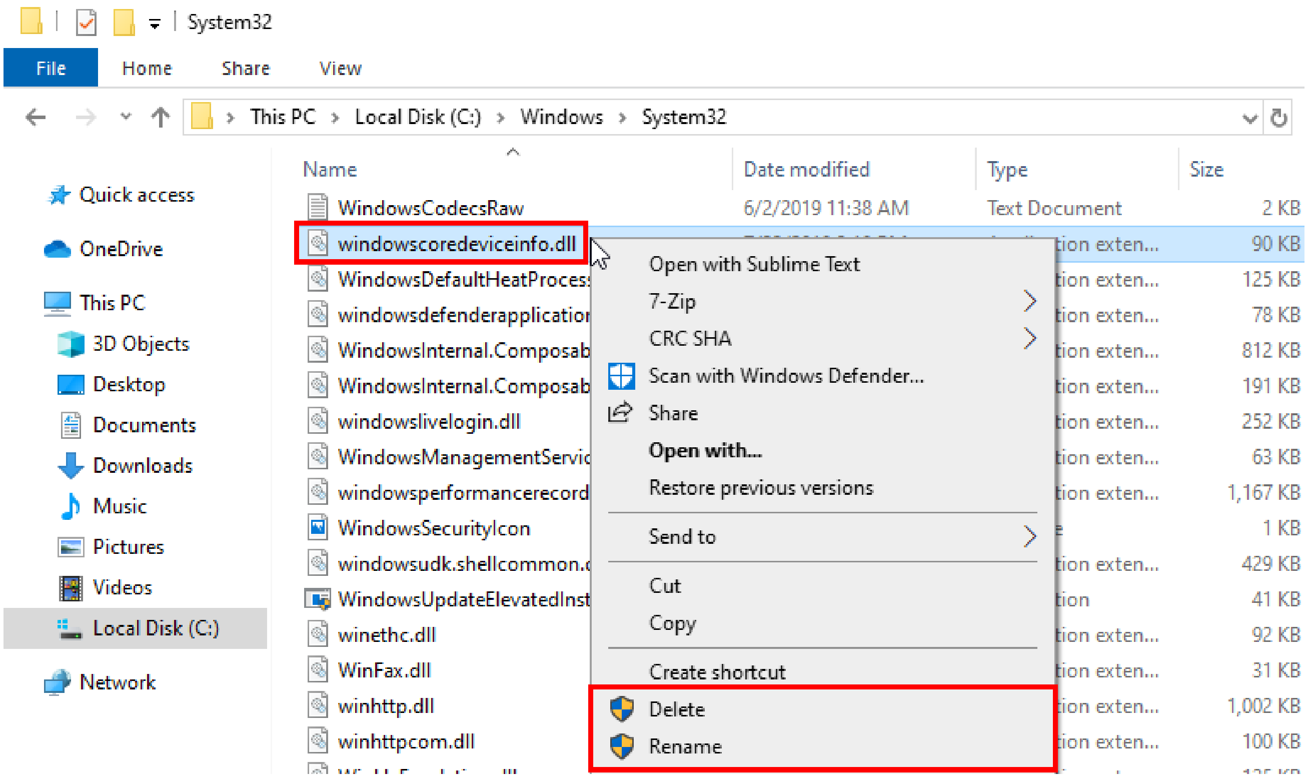
My objective for this PoC DLL was very simple. I wanted to **log some key information** about the process that loaded it: the **command line**, the **current username**, the **PID**, and the **PPID**. All of this would be logged to `C:\temp\dll.log`.

For a start, I came up with the following code. The `TrackCall()` function is responsible for gathering and logging the info. It is called from `DllMain()` and `QueryDeviceInformation()` to keep track of which function is called.

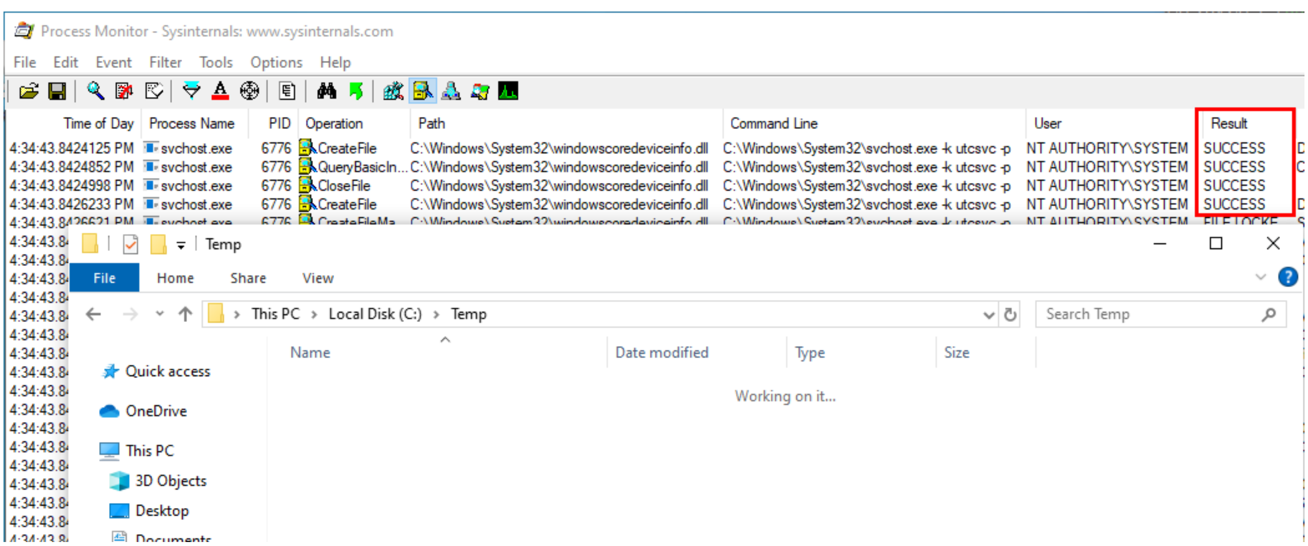
```
#include <Windows.h>
#include <iostream>
#include <Lmcons.h> // UNLEN + GetUserName
#include <tlhelp32.h> // CreateToolhelp32Snapshot()

int TrackCall(const wchar_t * callingFrom)
{
    WCHAR strSt[4096], strUsername[UNLEN + 1];
    WCHAR * strComandLine;
    SYSTEMTIME st;
    HANDLE hFile, hToolhelpSnapshot;
    PROCESSENTRY32 stProcessEntry;
    DWORD dwPcbBuffer = UNLEN, dwBytesWritten, dwProcessId, dwParentProcessId;
    BOOL bResult;

    strComandLine = GetCommandLine(); // Get Command line of the current process
    bResult = GetUserName(strUsername, &dwPcbBuffer); // Get current user name
    dwProcessId = GetCurrentProcessId(); // Get PID

    // Get PPID
    hToolhelpSnapshot = CreateToolhelp32Snapshot(TH32CS_SNAPPROCESS, 0);
    stProcessEntry = { 0 };
    stProcessEntry.dwSize = sizeof(PROCESSENTRY32);
    dwParentProcessId = 0;
    if (Process32First(hToolhelpSnapshot, &stProcessEntry)) {
        do {
            if (stProcessEntry.th32ProcessID == dwProcessId) {
                dwParentProcessId = stProcessEntry.th32ParentProcessID;
                break;
            }
        } while (Process32Next(hToolhelpSnapshot, &stProcessEntry));
    }
    CloseHandle(hToolhelpSnapshot);

    // Create log entry
    GetLocalTime(&st);
    wsprintfW(strSt, L"[%.2u:%.2u:%.2u] - PID=%d - PPID=%d - USER='%s' -
CMD='%s' - METHOD='%s'\n", st.wHour, st.wMinute, st.wSecond, dwProcessId,
dwParentProcessId, strUsername, strComandLine, callingFrom);
```

```
    // Save to log file
    hFile = CreateFile(L"C:\\Temp\\dll.log", FILE_APPEND_DATA, 0, NULL,
OPEN_ALWAYS, FILE_ATTRIBUTE_NORMAL, NULL);
    if (hFile != INVALID_HANDLE_VALUE)
        bResult = WriteFile(hFile, strSt, lstrlenW(strSt)*sizeof(WCHAR),
&dwBytesWritten, NULL);

    CloseHandle(hFile);

    return S_OK;
}

HRESULT __stdcall QueryDeviceInformation()
{
    TrackCall(L"QueryDeviceInformation()");

    return S_OK;
}

BOOL APIENTRY DllMain(HMODULE hModule, DWORD ul_reason_for_call, LPVOID
lpReserved)
{
    switch (ul_reason_for_call)
    {
    case DLL_PROCESS_ATTACH:
        TrackCall(L"DllMain()");
        break;
    case DLL_THREAD_ATTACH:
    case DLL_THREAD_DETACH:
    case DLL_PROCESS_DETACH:
        break;
    }
    return TRUE;
}
```

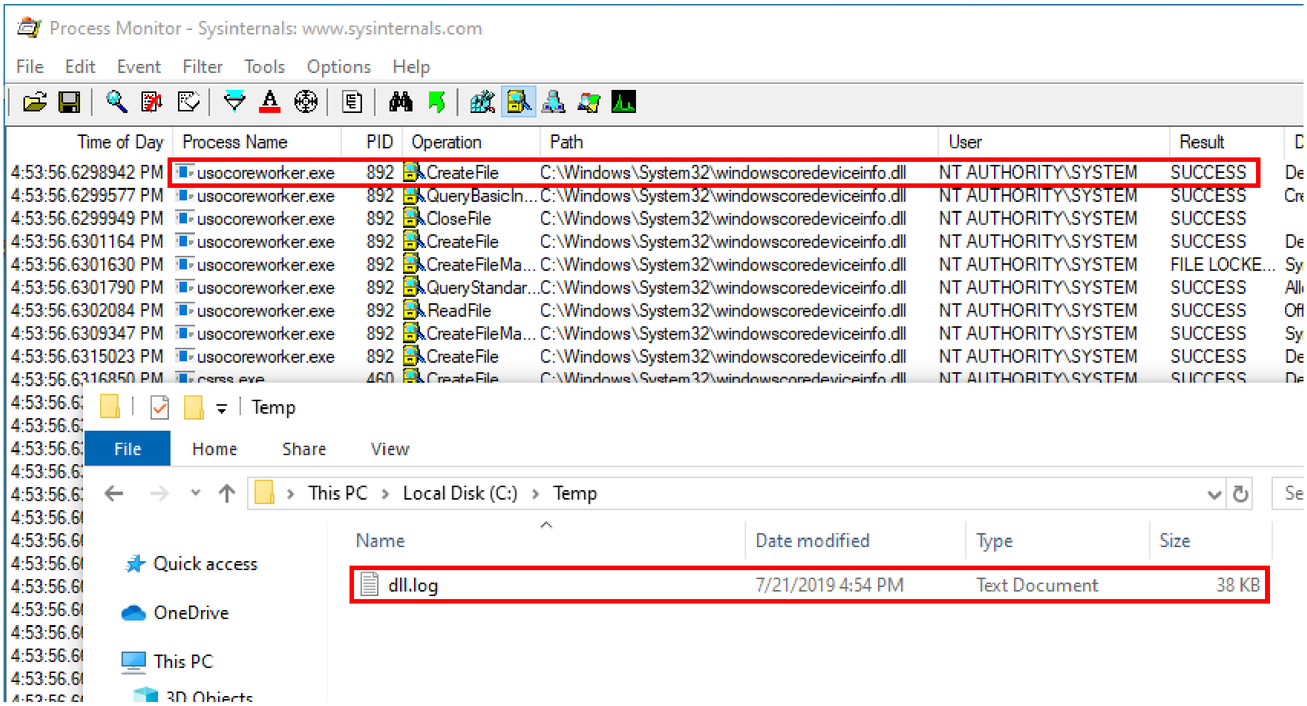
Then, **as an administrator**, I copied this DLL to `C:\Windows\System32\` and, I waited…



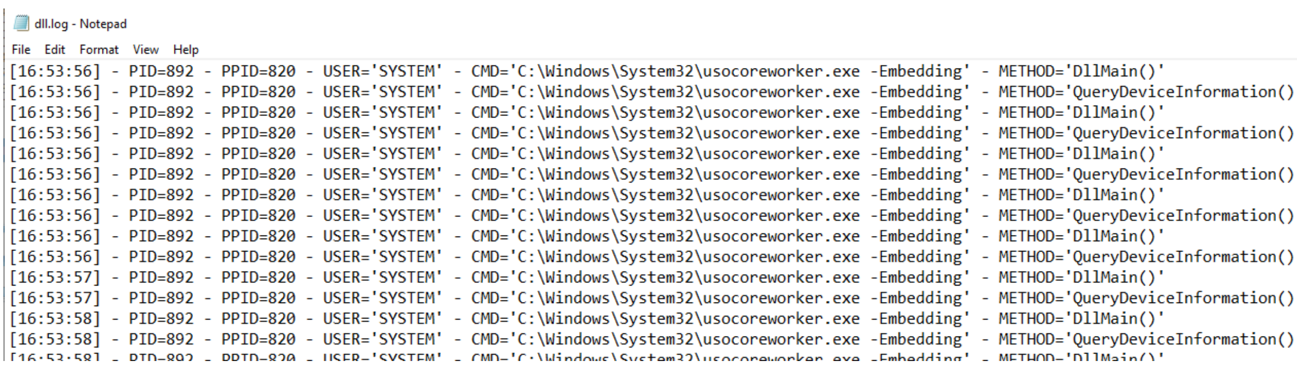
After a moment, the first hits finally showed up in `Process Monitor`. All the `CreateFile` operations returned successfully. However, there was no sign of a log file being created in `C:\temp\`. Of course, this means that the DLL wasn't properly loaded, the question is: why? My assumption was that the DLL I created didn't export all the functions that were required by the process.



At this point, I wasn't sure how to proceed but, when I got back to `Process Monitor`, I saw some events that I hadn't seen before.



The file `windowscoredeviceinfo.dll` was also loaded by a process called `usocoreworker.exe` as `NT AUTHORITY\System`. This time, some information was logged to `C:\Temp\dll.log`, which means that the code was properly executed.



```
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
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[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:56] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
[16:53:57] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:57] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
[16:53:58] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='DllMain()'
[16:53:58] - PID=892 - PPID=820 - USER='SYSTEM' - CMD='C:\Windows\System32\usocoreworker.exe -Embedding' - METHOD='QueryDeviceInformation()'
```
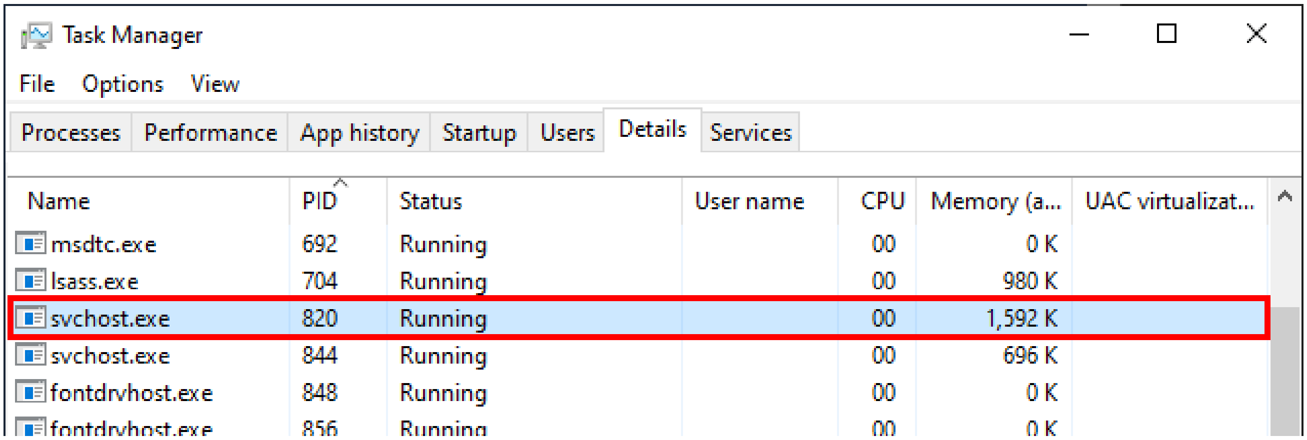
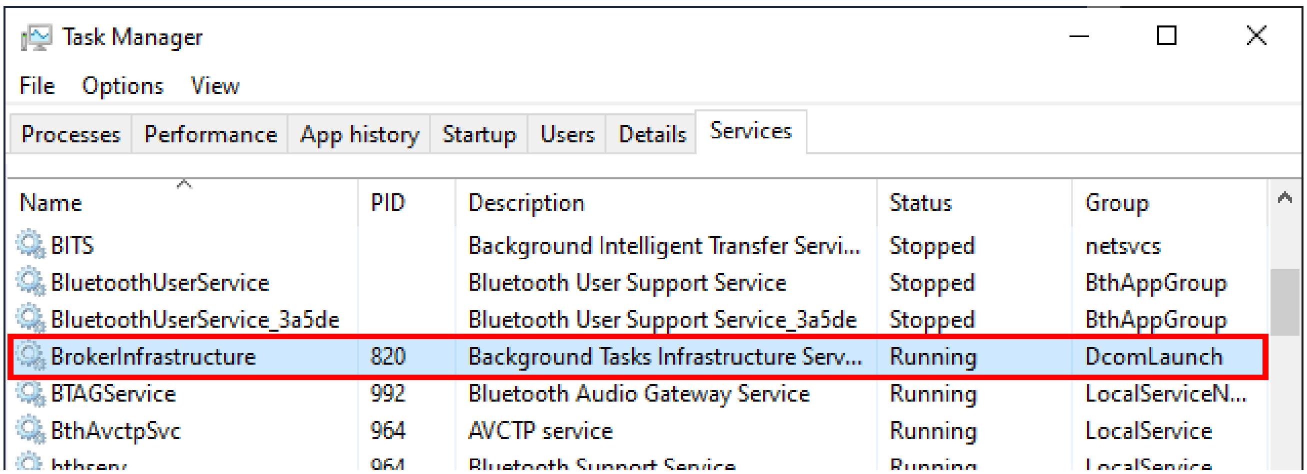

This looked much more promising so I decided to leave the DiagTrack service aside and take a look at this new target.

Moving on to the next target…

We are back to square one. We need to find out how the `usocoreworker.exe` process was created. To do so, we can look for the process corresponding to the PPID that was written to the log file. According to the task manager, it's an instance of `svchost.exe`, just like most of Windows services, so it's not very helpful.

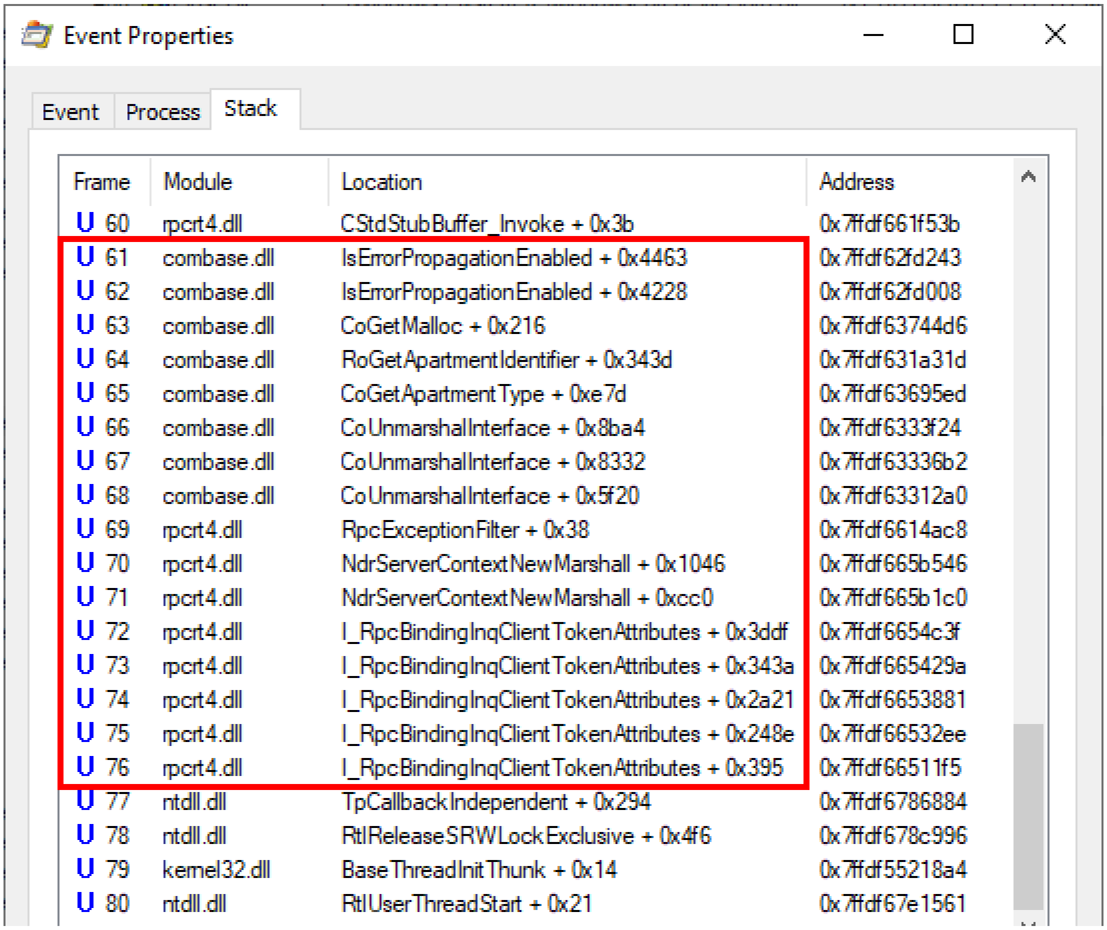


The corresponding service is `BrokerInfrastructure`, which "handles background tasks" as its description states. Well, that's not really helpful either…



Let's see what we can learn from `Process Monitor`. Accessing the properties of an event related to this process and, going to the `Stack` tab will show the following. We can see that there is a lot of references to `rpcrt4.dll` and `combase.dll`. This is potentially a very good news! Indeed, it probably means that this process was triggered by a COM-related RPC call. If so, it might also be possible to trigger it as a regular user, depending on the permissions of the remote object and interface.

Note: COM is used for Inter Process Communications (IPC). Therefore it can provide the ability for a low privilege process to run high privilege actions thanks to RPC calls (more details about this in the second part…).

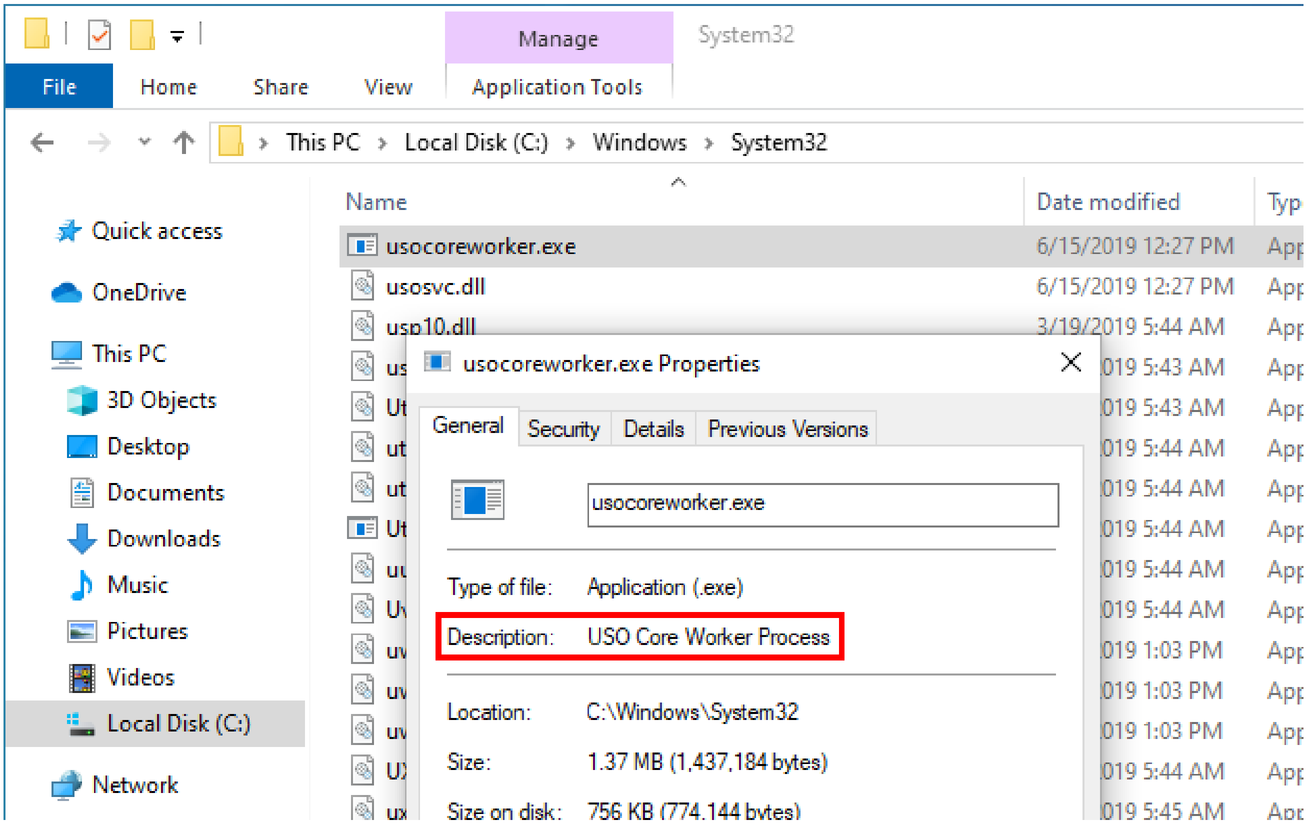


Event Properties

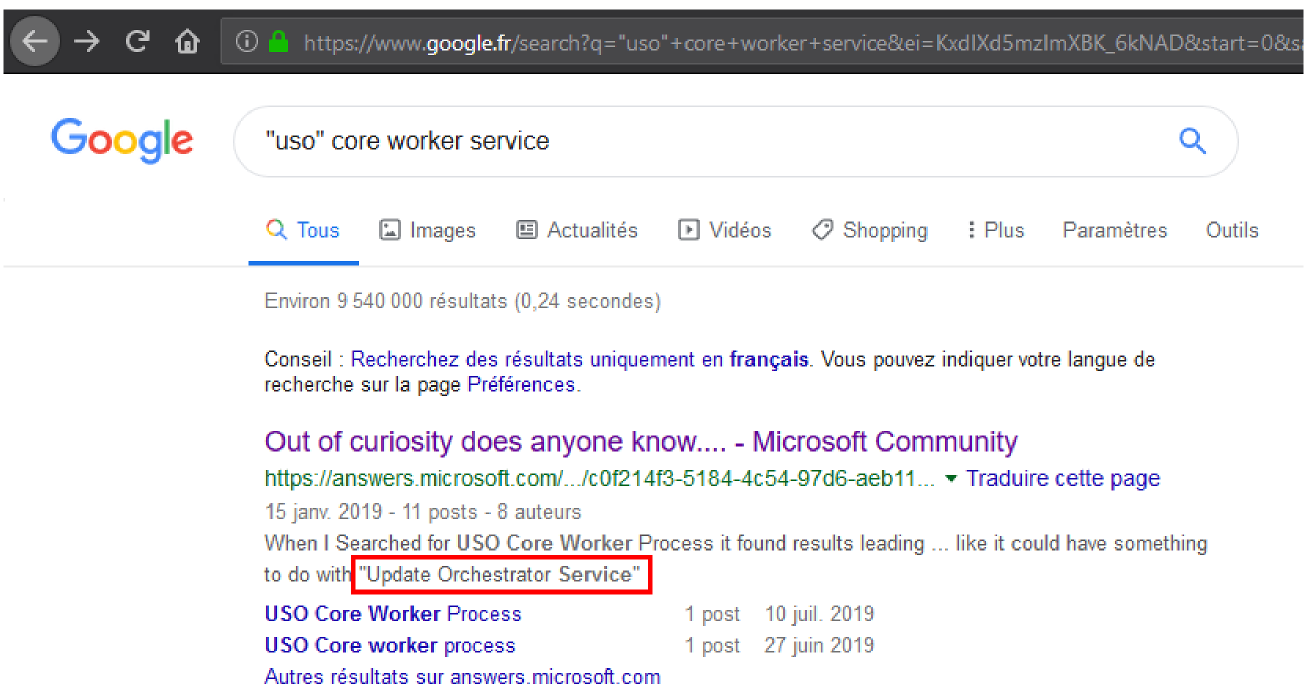
Event | Process | Stack

Frame	Module	Location	Address
U 60	rpcrt4.dll	CStdStubBuffer_Invoke + 0x3b	0x7ffdf661f53b
U 61	combase.dll	IsErrorPropagationEnabled + 0x4463	0x7ffdf62fd243
U 62	combase.dll	IsErrorPropagationEnabled + 0x4228	0x7ffdf62fd008
U 63	combase.dll	CoGetMalloc + 0x216	0x7ffdf63744d6
U 64	combase.dll	RoGetApartmentIdentifier + 0x343d	0x7ffdf631a31d
U 65	combase.dll	CoGetApartmentType + 0xe7d	0x7ffdf63695ed
U 66	combase.dll	CoUnmarshalInterface + 0x8ba4	0x7ffdf6333f24
U 67	combase.dll	CoUnmarshalInterface + 0x8332	0x7ffdf63336b2
U 68	combase.dll	CoUnmarshalInterface + 0x5f20	0x7ffdf63312a0
U 69	rpcrt4.dll	RpcExceptionFilter + 0x38	0x7ffdf6614ac8
U 70	rpcrt4.dll	NdrServerContextNewMarshall + 0x1046	0x7ffdf665b546
U 71	rpcrt4.dll	NdrServerContextNewMarshall + 0xcc0	0x7ffdf665b1c0
U 72	rpcrt4.dll	I_RpcBindingInqClientTokenAttributes + 0x3ddf	0x7ffdf6654c3f
U 73	rpcrt4.dll	I_RpcBindingInqClientTokenAttributes + 0x343a	0x7ffdf665429a
U 74	rpcrt4.dll	I_RpcBindingInqClientTokenAttributes + 0x2a21	0x7ffdf6653881
U 75	rpcrt4.dll	I_RpcBindingInqClientTokenAttributes + 0x248e	0x7ffdf66532ee
U 76	rpcrt4.dll	I_RpcBindingInqClientTokenAttributes + 0x395	0x7ffdf66511f5
U 77	ntdll.dll	TpCallbackIndependent + 0x294	0x7ffdf6786884
U 78	ntdll.dll	RtlReleaseSRWLockExclusive + 0x4f6	0x7ffdf678c996
U 79	kernel32.dll	BaseThreadInitThunk + 0x14	0x7ffdf55218a4
U 80	ntdll.dll	RtlUserThreadStart + 0x21	0x7ffdf67e1561

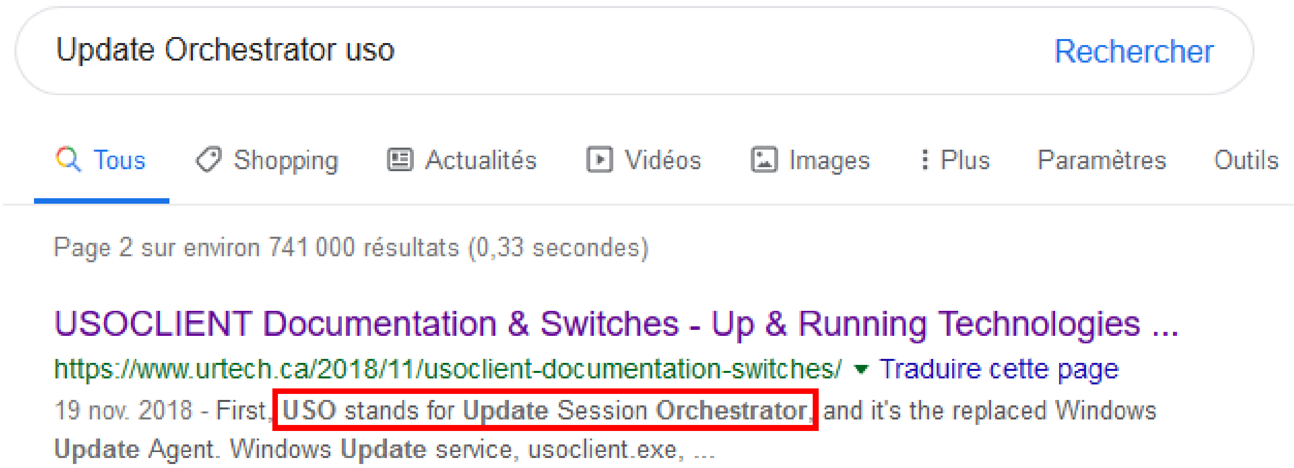
Looking at the properties of the binary file, we can see the following description: `USO Core Worker Process`.



Based on these first few elements, I tried to find more information on Google. The first result lead me to a thread on `answsers.microsoft.com`. According to one of the messages, this file is related to the "Update Orchestrator Service".



Refining the research, I found this very interesting unofficial documentation about the "USO client". First, we learn that "USO" stands for "Update Session Orchestrator".



Update Orchestrator uso Rechercher

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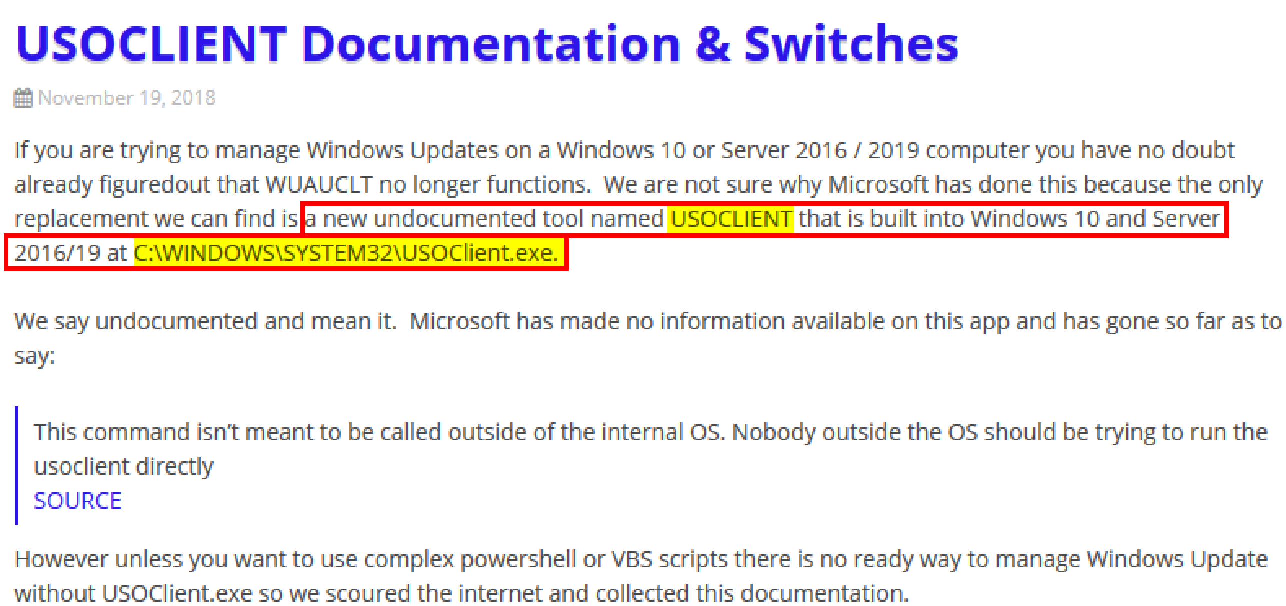
Page 2 sur environ 741 000 résultats (0,33 secondes)

USOCLIENT Documentation & Switches - Up & Running Technologies ...
https://www.urtech.ca/2018/11/usoclient-documentation-switches/ ▾ Traduire cette page
19 nov. 2018 - First, **USO** stands for **Update** Session **Orchestrator**, and it's the replaced Windows **Update** Agent. Windows **Update** service, usoclient.exe, ...

We also learn that the “USO client” (`usoclient.exe`) is the tool that replaced “WUAUCLT”, which was used to manage Windows updates in previous versions of Windows. Actually, this tool is well known by Windows System Administrators because, although it is not officialy supported by Microsoft, it enables them to automate the update management process.



USOCLIENT Documentation & Switches

November 19, 2018

If you are trying to manage Windows Updates on a Windows 10 or Server 2016 / 2019 computer you have no doubt already figuredout that WUAUCLT no longer functions. We are not sure why Microsoft has done this because the only replacement we can find is a new undocumented tool named USOCLIENT that is built into Windows 10 and Server 2016/19 at C:\WINDOWS\SYSTEM32\USOClient.exe.

We say undocumented and mean it. Microsoft has made no information available on this app and has gone so far as to say:

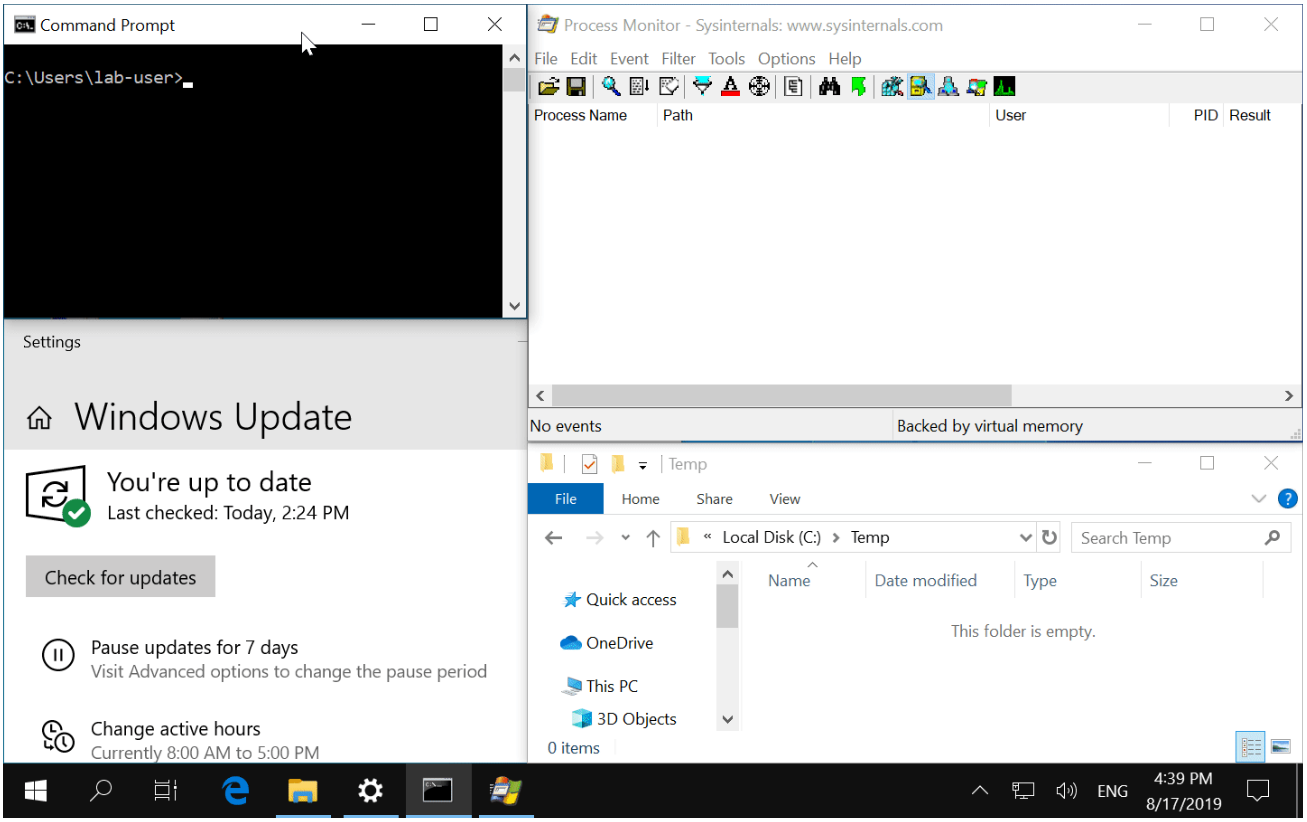
> This command isn't meant to be called outside of the internal OS. Nobody outside the OS should be trying to run the usoclient directly
> SOURCE

However unless you want to use complex powershell or VBS scripts there is no ready way to manage Windows Update without USOClient.exe so we scoured the internet and collected this documentation.

Note: they even quoted a reply from a Microsoft employee on TechNet, which says that you shouldn’t run this tool directly. This is getting interesting. We love to do what we are not supposed to, don’t we?! :)

The documentation lists all the options you can use. So, I tried to play around with the `usoclient` command to see if I could trigger the same behavior I observed previously. I started with `StartScan` which seemed to be the less invasive option according to the description. It is supposed to trigger a scan that will simply fetch available updates.

With `Process Monitor` running in the background as usual, I ran the command and… … victory!



Conclusion

With a simple command, we are able to have the Update Orchestrator service run arbitrary code as `NT AUTHORITY\System`. Another benefit of this method is the fact that we can run our code outside of `DllMain` (i.e. outside of the loader lock).

Note: According to Microsoft, running code within DllMain should be avoided because it *can cause an application to deadlock*. More info here: Dynamic-Link Library Best Practices.

However, this technique also comes with some drawbacks:

- It requires a privileged file creation or move operation that you're are able to control.
- Vulnerabilities which result in ACL overwrites for example won't be enough.
- As a regular user, we don't know if the DLL has been successfully loaded or not.

Being dependant on the `usoclient` tool without understanding how it worked was also something I didn't like about this technique. So, I reverse engineered both the client and the service in order to produce an open source tool I could reuse in future projects: UsoDllLoader. I'll try to explain this process in the second part of this article. Stay tuned!

Links & Resources

- Windows Exploitation Tricks: Exploiting Arbitrary File Writes for Local Elevation of Privilege
  https://googleprojectzero.blogspot.com/2018/04/windows-exploitation-tricks-exploiting.html
- Twitter - MS finally fixed the "Diag Hub Collector" exploit on Win 10 1903
  https://twitter.com/decoder_it/status/1131247394031579138
- Unofficial USO client documentation
  https://www.urtech.ca/2018/11/usoclient-documentation-switches/
- Thread about the "USO client" tool on TechNet
  https://social.technet.microsoft.com/Forums/en-US/7619f7fa-ffc1-433b-a885-12e26f9762bf/usoclientexe-usage?forum=win10itprogeneral
- Dynamic-Link Library Best Practices
  https://docs.microsoft.com/en-us/windows/win32/dlls/dynamic-link-library-best-practices

Windows