Process Doppelgänging meets Process Hollowing in Osiris dropper

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One of the Holy Grails for malware authors is a perfect way to impersonate a legitimate process. That would allow them to run their malicious module under the cover, being unnoticed by antivirus products. Over the years, various techniques have emerged in helping them to get closer to this goal. This topic is also interesting for researchers and reverse engineers, as it shows creative ways of using Windows APIs.

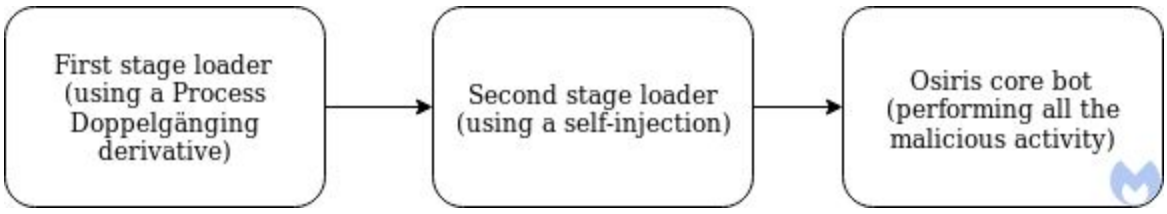
Process Doppelgänging, a new technique of impersonating a process, was published last year at the Black Hat conference. After some time, a ransomware named SynAck was found adopting that technique for malicious purposes. Even though Process Doppelgänging still remains rare in the wild, we recently discovered some of its traits in the dropper for the Osiris banking Trojan (a new version of the infamous Kronos). After closer examination, we found out that the original technique was further customized.

Indeed, the malware authors have merged elements from both Process Doppelgänging and Process Hollowing, picking the best parts of both techniques to create a more powerful combo.

In this post, we take a closer look at how Osiris is deployed on victim machines, thanks to this interesting loader.

Overview

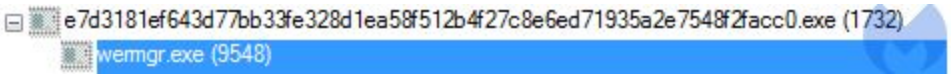
Osiris is loaded in three steps as pictured in the diagram below:



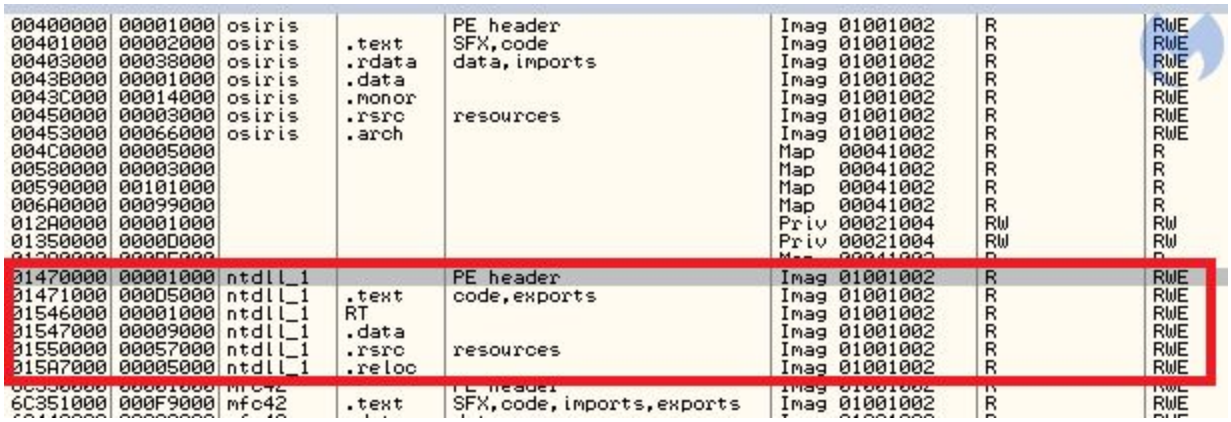
The first stage loader is the one that was inspired by the Process Doppelgänging technique but with an unexpected twist. Finally, Osiris proper is delivered thanks to a second stage loader.

Loading additional NTDLL

When ran, the initial dropper creates a new suspended process, wermgr.exe.



Looking into the modules loaded within the injector's process space, we can see this additional copy of NTDLL:



00400000	00001000	osiris		PE header	Imag 01001002	R	RWE
00401000	00002000	osiris	.text	SFX,code	Imag 01001002	R	RWE
00403000	00038000	osiris	.rdata	data,imports	Imag 01001002	R	RWE
0043B000	00001000	osiris	.data		Imag 01001002	R	RWE
0043C000	00014000	osiris	.monor		Imag 01001002	R	RWE
00450000	00003000	osiris	.rsrc	resources	Imag 01001002	R	RWE
00453000	00066000	osiris	.arch		Imag 01001002	R	RWE
004C0000	00005000				Map 00041002	R	R
00580000	00003000				Map 00041002	R	R
00590000	00101000				Map 00041002	R	R
006A0000	00099000				Map 00041002	R	R
012A0000	00001000				Priv 00021004	RW	RW
01350000	0000D000				Priv 00021004	RW	RW
01470000	00001000	ntdll_1		PE header	Imag 01001002	R	RWE
01471000	000D5000	ntdll_1	.text	code,exports	Imag 01001002	R	RWE
01546000	00001000	ntdll_1	RT		Imag 01001002	R	RWE
01547000	00009000	ntdll_1	.data		Imag 01001002	R	RWE
01550000	00057000	ntdll_1	.rsrc	resources	Imag 01001002	R	RWE
015A7000	00005000	ntdll_1	.reloc		Imag 01001002	R	RWE
6C351000	000F9000	mfc42	.text	SFX,code,imports,exports	Imag 01001002	R	RWE

This is a well-known technique that some malware authors use in order to evade monitoring applications and hide the API calls that they use. When we closely examine what functions are called from that additional NTDLL, we find more interesting details. It calls several APIs related to NTFS transactions. It was easy to guess that the technique of Process Doppelgänging, which relies on this mechanism, was applied here.

NTDLL is a special, low-level DLL. Basically, it is just a wrapper around syscalls. It does not have any dependencies from other DLLs in the system. Thanks to this, it can be loaded conveniently, without the need to fill its import table.

Other system DLLs, such as Kernel32, rely heavily on functions exported from NTDLL. This is why many user-land monitoring tools hook and intercept the functions exported by NTDLL: to watch what functions are being called and check if the process does not display any suspicious activity.

Of course malware authors know about this, so sometimes, in order to fool this mechanism, they load their own, fresh and unhooked copy of NTDLL from disk. There are several ways to implement this. Let's have a look how the authors of the Osiris dropper did it.

Looking at the memory mapping, we see that the additional NTDLL is loaded as an image, just like other DLLs. This type of mapping is typical for DLLs loaded by LoadLibrary function or its low-level version from NTDLL, LdrLoadDll. But NTDLL is loaded by default in every executable, and loading the same DLL twice is impossible by the official API.

Usually, malware authors decide to map the second copy manually, but that gives a different mapping type and stands out from the normally-loaded DLLs. Here, the authors made a workaround: they loaded the file as a section, using the following functions:

- ntdll.NtCreateFile – to open the ntdll.dll file
- ntdll.NtCreateSection – to create a section out of this file
- ntdll.ZwMapViewOfSection – to map this section into the process address space

```
0044F04B  MOV ECX,DWORD PTR SS:[EBP-0x8]
0044F04E  PUSH ECX                                  ntdll.ZwCreateSection
0044F04F  PUSH 0x1000000
0044F054  PUSH 0x2
0044F056  PUSH 0x0
0044F058  PUSH 0x0
0044F05A  PUSH 0xF001F
0044F05F  LEA EDX,DWORD PTR SS:[EBP-0xC]
0044F062  PUSH EDX
0044F063  MOV EAX,DWORD PTR SS:[EBP+0x8]
0044F066  MOV ECX,DWORD PTR DS:[EAX+0x30]         ntdll.ZwCreateSection
0044F069  CALL ECX                                ntdll.NtCreateSection
0044F06B  MOV DWORD PTR SS:[EBP-0x4],EAX
0044F06E  CMP DWORD PTR SS:[EBP-0x4],0x0
0044F072  JGE SHORT osiris.0044F084
0044F074  MOV EDX,DWORD PTR SS:[EBP-0x8]
0044F077  PUSH EDX
0044F078  MOV EAX,DWORD PTR SS:[EBP+0x8]
0044F07B  MOV ECX,DWORD PTR DS:[EAX+0x10]         ntdll.ZwClose
0044F07E  CALL ECX                                ntdll.ZwMapViewOfSection
0044F080  XOR EAX,EAX
0044F082  JMP SHORT osiris.0044F0C4
```

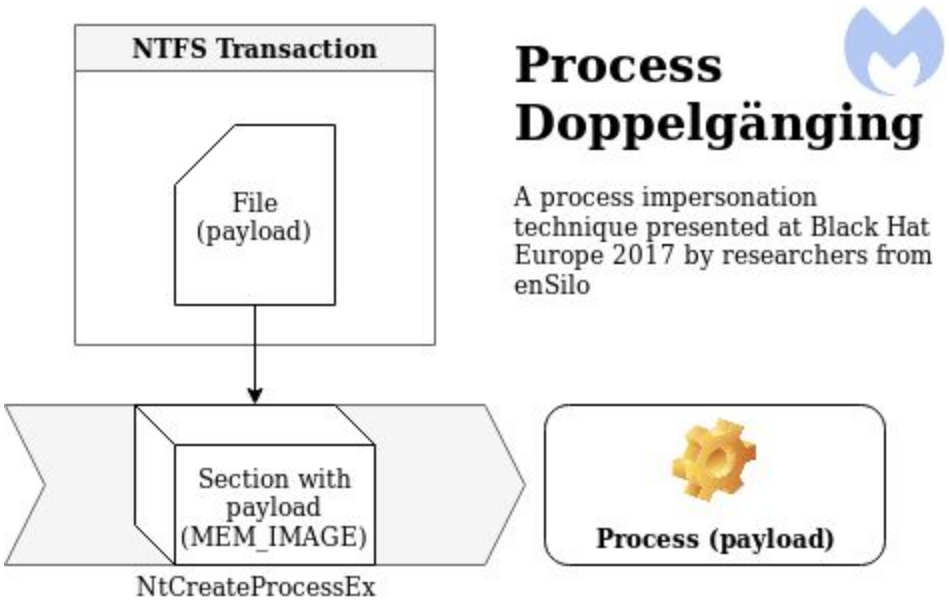
This was a smart move because the DLL is mapped as an image, so it looks like it was loaded in a typical way.

This DLL was further used to make the payload injection more stealthy. Having their fresh copy of NTDLL, they were sure that the functions used from there are not hooked by security products.

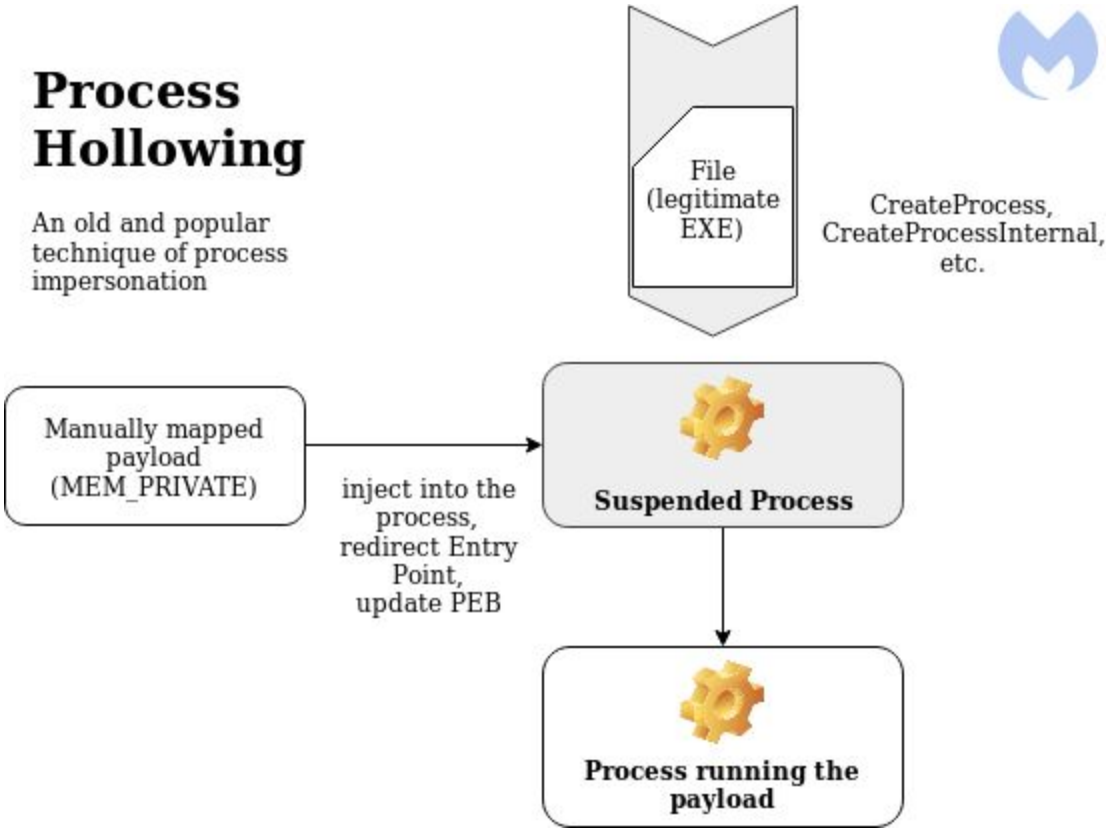
Comparison with Process Doppelgänging and Process Hollowing

The way in which the loader injects the payload into a new process displays some significant similarities with Process Dopplegänging. However, if we analyze it very carefully, we can see also differences from the classic implementation proposed last year at Black Hat. The differing elements are closer to Process Hollowing.

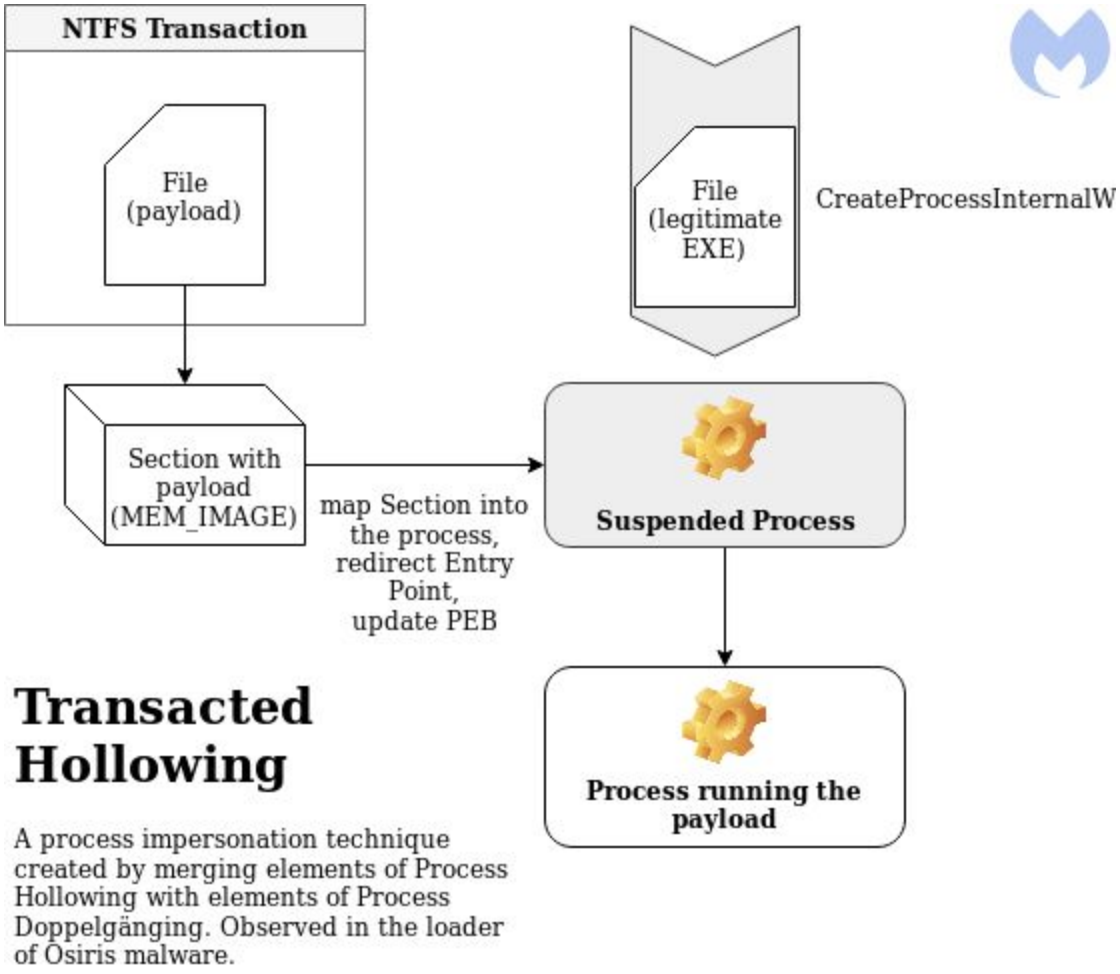
Classic Process Doppelgänging:



Process Hollowing:

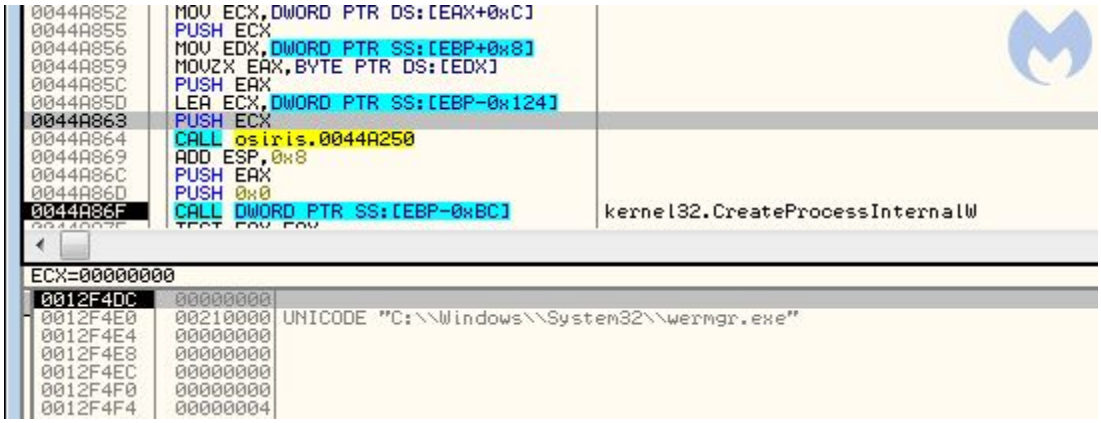


Osiris Loader:



Creating a new process

The Osiris loader starts by creating the process into which it is going to inject. The process is created by a function from Kernel32: CreateProcessInternalW:



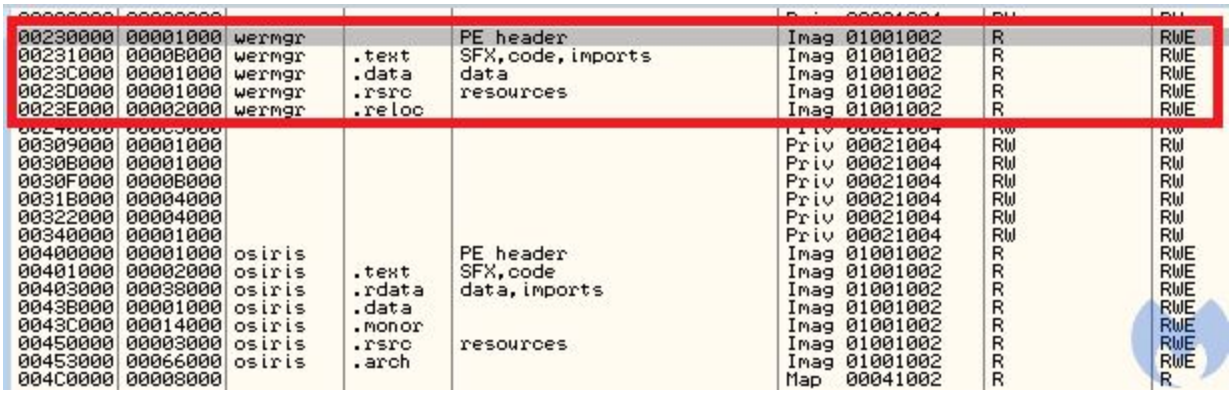
The new process (wermgr.exe) is created in a suspended state from the original file. So far, it reminds us of Process Hollowing, a much older technique of process impersonation.

In the Process Dopplegänging algorithm, the step of creating the new process is taken much later and uses a different, undocumented API: NtCreateProcessEx:

```
NTSTATUS NTAPI NtCreateProcessEx (
    OUT PHANDLE ProcessHandle,
    IN ACCESS_MASK  DesiredAccess,
    IN POBJECT_ATTRIBUTES   ObjectAttributes  OPTIONAL,
    IN HANDLE   ParentProcess,
    IN ULONG    Flags,
    IN HANDLE   SectionHandle OPTIONAL,
    IN HANDLE   DebugPort OPTIONAL,
    IN HANDLE   ExceptionPort OPTIONAL,
    IN BOOLEAN  InJob
);
```

This difference is significant, because in Process Doppelgänging, the new process is created not from the original file, but from a special buffer (section). This section was supposed to be created earlier, using an “invisible” file created within the NTFS transaction. In the Osiris loader, this part also occurs, but the order is turned upside down, making us question if we can call it the same algorithm.

After the process is created, the same image (wermgr.exe) is mapped into the context of the loader, just like it was previously done with NTDLL.



00230000	00001000	wermgr		PE header	Imag 01001002	R	RWE
00231000	0000B000	wermgr	.text	SFX,code,imports	Imag 01001002	R	RWE
0023C000	00001000	wermgr	.data	data	Imag 01001002	R	RWE
0023D000	00001000	wermgr	.rsrc	resources	Imag 01001002	R	RWE
0023E000	00002000	wermgr	.reloc		Imag 01001002	R	RWE
00309000	00001000				Priv 00021004	RW	RW
0030B000	00001000				Priv 00021004	RW	RW
0030F000	0000B000				Priv 00021004	RW	RW
0031B000	00004000				Priv 00021004	RW	RW
00322000	00004000				Priv 00021004	RW	RW
00340000	00001000				Priv 00021004	RW	RW
00400000	00001000	osiris		PE header	Imag 01001002	R	RWE
00401000	00002000	osiris	.text	SFX,code	Imag 01001002	R	RWE
00403000	00038000	osiris	.rdata	data,imports	Imag 01001002	R	RWE
0043B000	00001000	osiris	.data		Imag 01001002	R	RWE
0043C000	00014000	osiris	.monor		Imag 01001002	R	RWE
00450000	00003000	osiris	.rsrc	resources	Imag 01001002	R	RWE
00453000	00066000	osiris	.arch		Imag 01001002	R	RWE
004C0000	00008000				Map 00041002	R	R

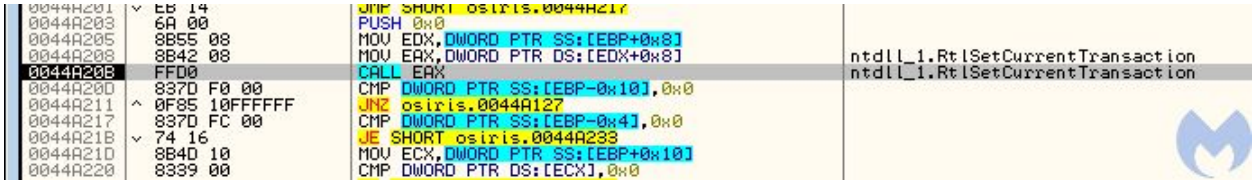
As it later turns out, the loader will patch the remote process. The local copy of the wermgr.exe will be used to gather information about where the patches should be applied.

Usage of NTFS transactions

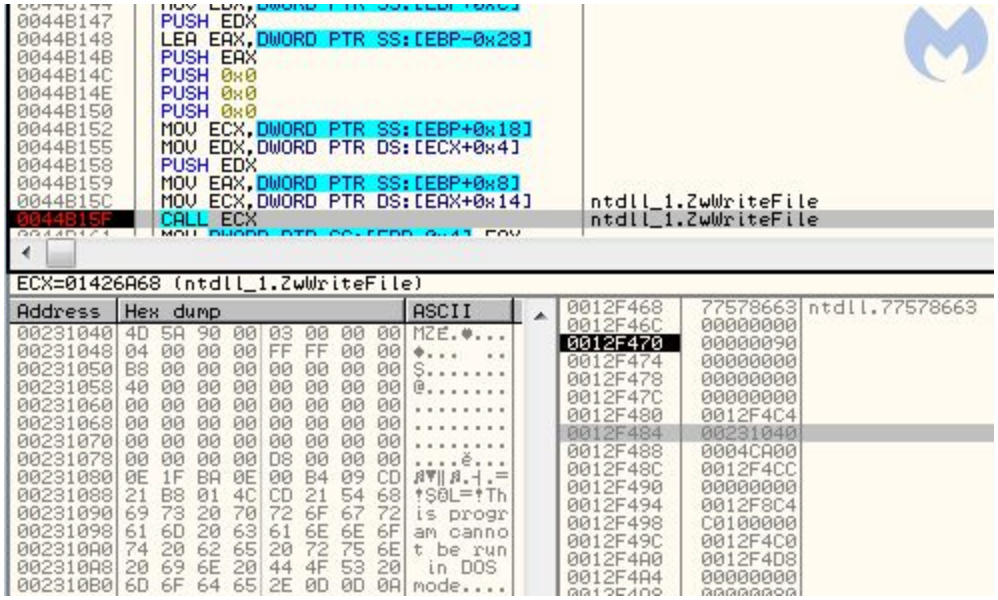
Let’s start from having a brief look at what are the NTFS transactions. This mechanism is commonly used while operating on databases—in a similar way, they exist in the NTFS file

system. The NTFS transactions encapsulate a series of operations into a single unit. When the file is created inside the transaction, nothing from outside can have access to it until the transaction is committed. Process Doppelgänging uses them in order to create invisible files where the payload is dropped.

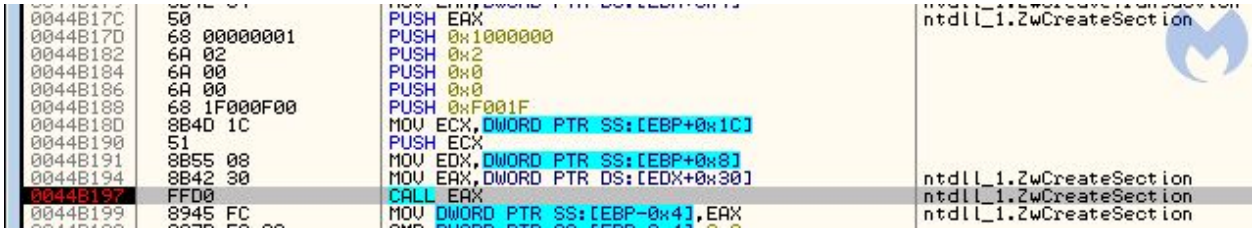
In the analyzed case, the usage of NTFS transactions is exactly the same. We can spot only small differences in the APIs used. The loader creates a new transaction, within which a new file is created. The original implementation used CreateTransaction and CreateFileTransacted from Kernel32. Here, they were substituted by low-level equivalents.



First, a function ZwCreateTransaction from a NTDLL is called. Then, instead of CreateFileTransacted, the authors open the transacted file by RtlSetCurrentTransaction along with ZwCreateFile (the created file is %TEMP%\\Liebert.bmp). Then, the dropper writes a buffer into to the file. Analogically, RtlSetCurrentTransaction with ZwWriteFile is used.



We can see that the buffer that is being written contains the new PE file: the second stage payload. Typically for this technique, the file is visible only within the transaction and cannot be opened by other processes, such as AV scanners.



This transacted file is then used to create a section. The function that can do it is available only via low-level API: ZwCreateSection/NtCreateSection.

After the section is created, that file is no longer needed. The transaction gets rolled back (by ZwRollbackTransaction), and the changes to the file are never saved on the disk.

So, the part described above is identical to the analogical part of Process Doppelgänging. Authors of the dropper made it even more stealthy by using low-level equivalents of the functions, called from a custom copy of NTDLL.

From a section to a process

At this point, the Osiris dropper creates two completely unrelated elements:

- A process (at this moment containing a mapped, legitimate executable wermgr.exe)
- A section (created from the transacted file) and containing the malicious payload

If this were typical Process Doppelgänging, this situation would never occur, and we would have the process created directly based on the section with the mapped payload. So, the question arises, how did the author of the dropper decide to merge the elements together at this point?

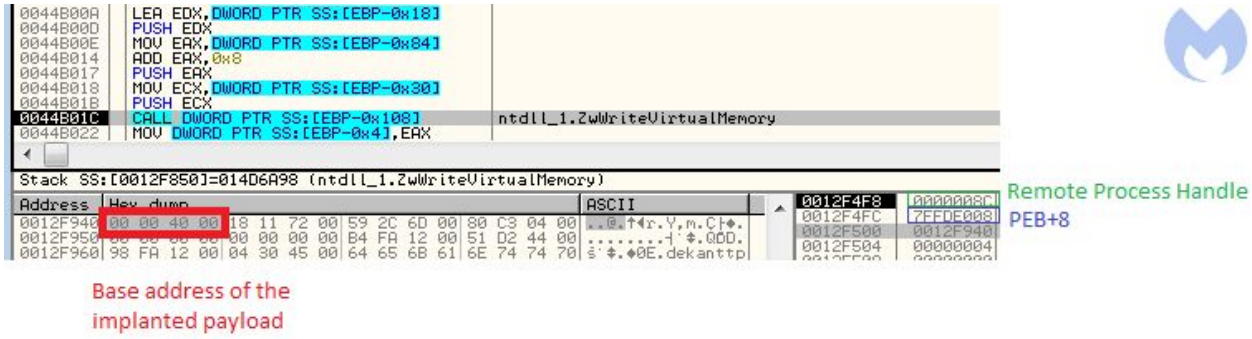
If we trace the execution, we can see following function being called, just after the transaction is rolled back (format: RVA;function):

4b1e6;ntdll_1.ZwQuerySection
4b22b;ntdll.NtClose
4b239;ntdll.NtClose
4aab8;ntdll_1.ZwMapViewOfSection
4af27;ntdll_1.ZwProtectVirtualMemory
4af5b;ntdll_1.ZwWriteVirtualMemory

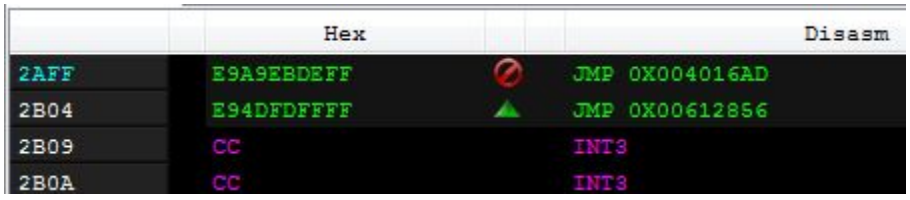
4af8a;ntdll_1.ZwProtectVirtualMemory
4b01c;ntdll_1.ZwWriteVirtualMemory
4b03a;ntdll_1.ZwResumeThread

So, it looks like the newly created section is just mapped into the new process as an additional module. After writing the payload into memory and setting the necessary patches, such as Entry Point redirection, the process is resumed:

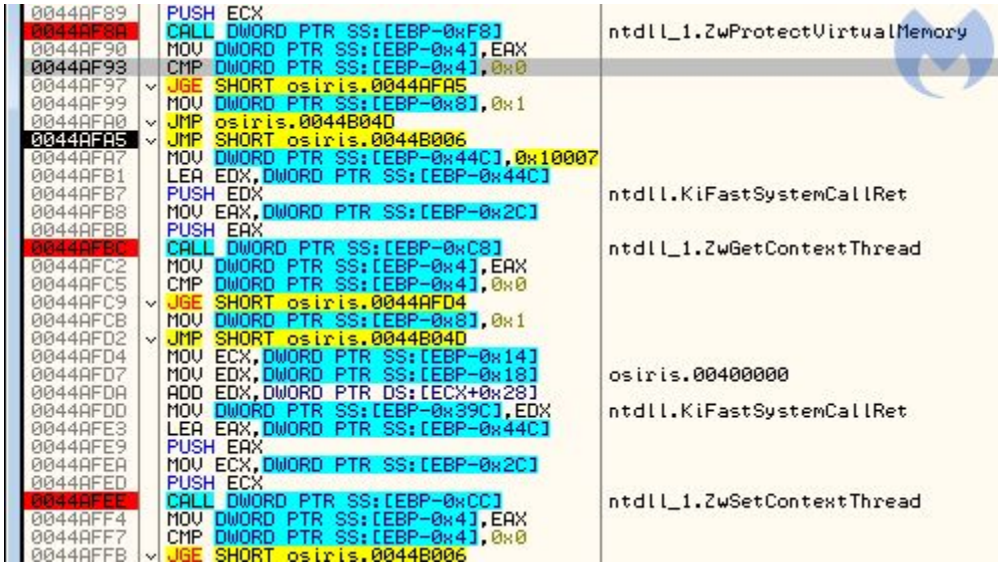
The way in which the execution was redirected looks similar to variants of Process Hollowing. The PEB of the remote process is patched, and the new module base is set to the added section. (Thanks to this, imports will get loaded automatically when the process resumes.)



The Entry Point redirection is, however, done just by a patch at the Entry Point address of the original module. A single jump redirects to the Entry Point of the injected module:



In case patching the Entry Point has failed, the loader contains a second variant of Entry Point redirection, by setting the new address in the thread context (ZwGetThreadContext -> ZwSetThreadContext), which is a classic technique used in Process Hollowing:



Best of both worlds

As we can see, the author merged some elements of Process Doppelgänging with some elements of Process Hollowing. This choice was not accidental. Both of those techniques have strong and weak points, but by merging them together, we get a power combo.

The weakest point of Process Hollowing is about the protection rights set on the memory space where the payload is injected (more info here). Process Hollowing allocates memory pages in the remote process by VirtualAllocEx, then writes the payload there. It gives one undesirable effect: the access rights (MEM_PRIVATE) were different than in the executable that is normally loaded (MEM_IMAGE).

Example of a payload loaded using Process Hollowing:

◢ 0x60000	Private	116 kB	RW
0x60000	Private: Commit	4 kB	R
0x61000	Private: Commit	64 kB	RX
0x71000	Private: Commit	28 kB	R
0x78000	Private: Commit	8 kB	RW
0x7a000	Private: Commit	12 kB	R

The major obstacle in loading the payload as an image is that, to do so, it has to be first dropped on the disk. Of course we cannot do this, because once dropped, it would easily be picked by an antivirus.

Process Doppelgänging on the other hand provides a solution: invisible transacted files, where the payload can be safely dropped without being noticed. This technique assumes that the

transacted file will be used to create a section (MEM_IMAGE), and then this section will become a base of the new process (using NtCreateProcessEx).

Example of a payload loaded using Process Doppelgänging:

0x10000000	Image	20 kB	WCX
0x10000000	Image: Commit	4 kB	R
0x10001000	Image: Commit	4 kB	RX
0x10002000	Image: Commit	4 kB	R
0x10003000	Image: Commit	4 kB	WC
0x10004000	Image: Commit	4 kB	R

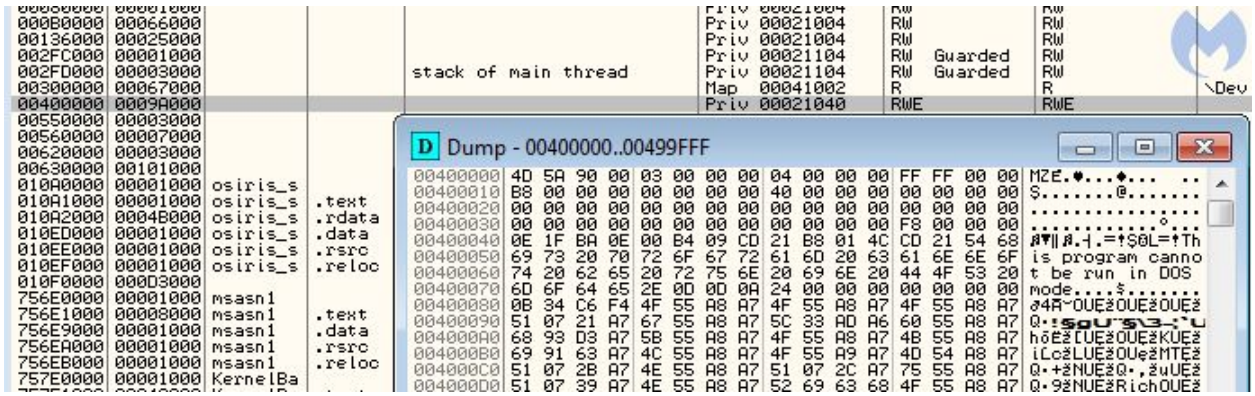
This solution works well, but requires that all the process parameters have to be also loaded manually: first creating them by RtlCreateProcessParametersEx and then setting them into the remote PEB. It was making it difficult to run a 32-bit process on 64-bit system, because in case of WoW64 processes, there are 2 PEBs to be filled.

Those problems of Process Doppelgänging can be solved easily if we create the process just like Process Hollowing does it. Rather than using low-level API, which was the only way to create a new process out of a section, the authors created a process out of the legitimate file, using a documented API from Kernel32. Yet, the section carrying the payload, loaded with proper access rights (MEM_IMAGE), can be added later, and the execution can get redirected to it.

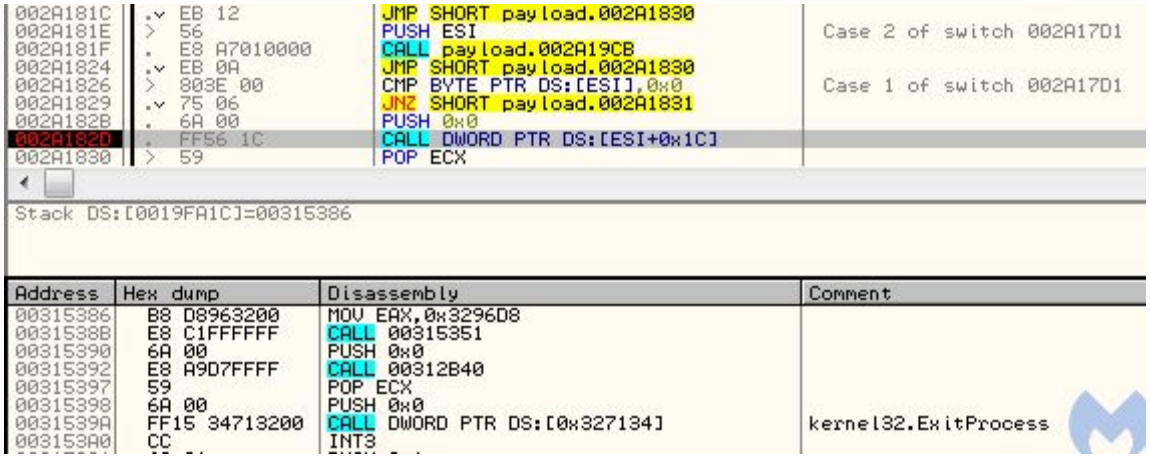
Second stage loader

The next layer (8d58c731f61afe74e9f450cc1c7987be) is not the core yet, but the next stage of the loader. It imports only one DLL, Kernel32.

Its only role is to load the final payload. At this stage, we can hardly find something innovative. The Osiris core is unpacked piece by piece and manually loaded along with its dependencies into a newly-allocated memory area within the loader process.

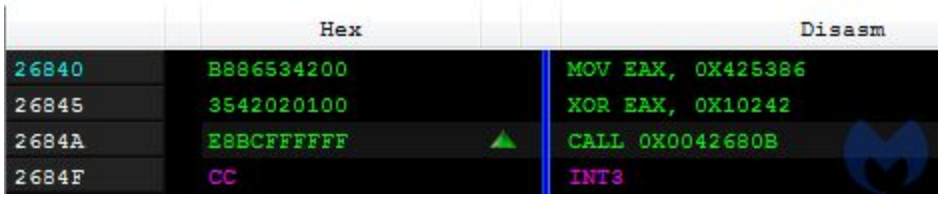


After this self-injection, the loader jumps into the payload's entry point:

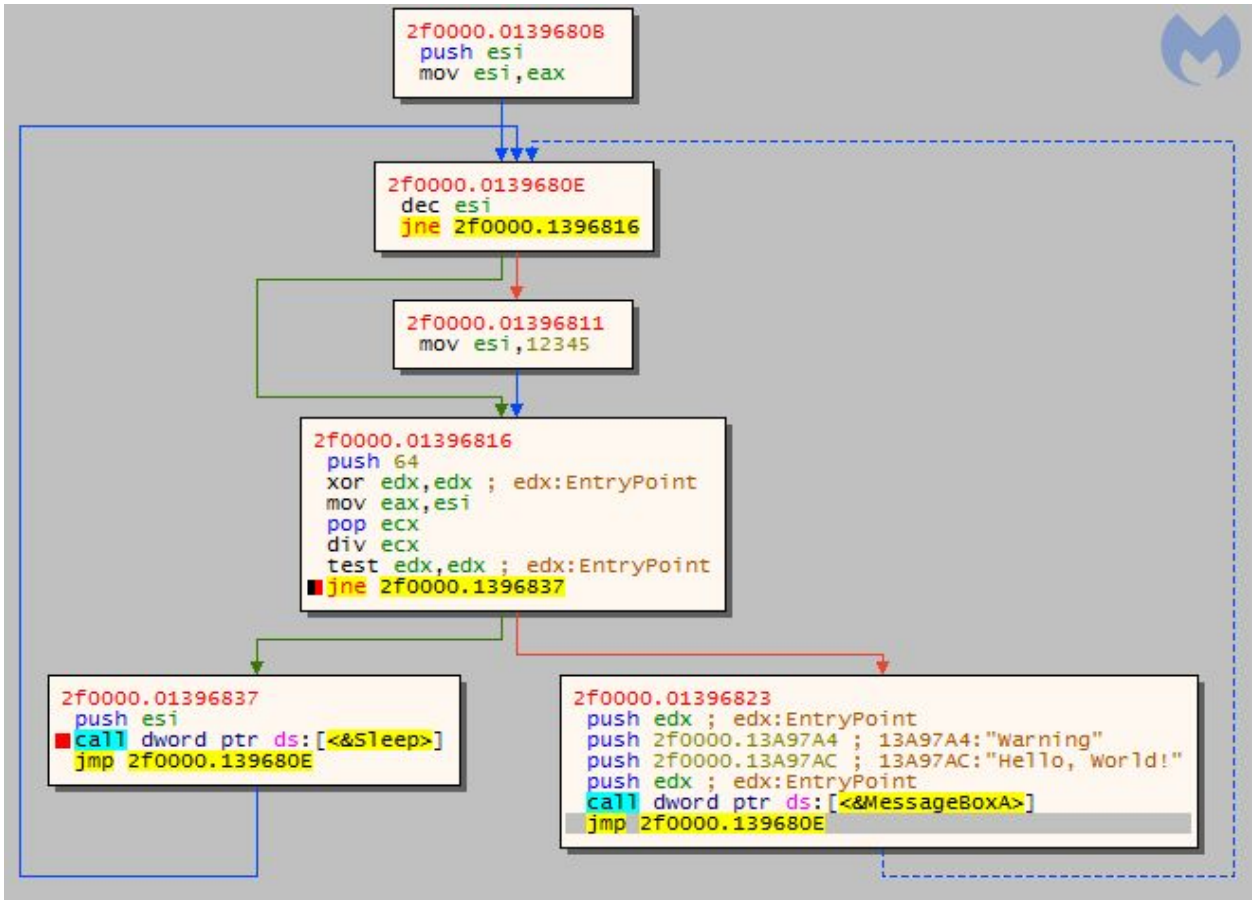


The interesting thing is that the application's entry point is different than the entry point saved in the header. So, if we dump the payload and try to run it interdependently, we will not get the same code executed. This is an interesting technique used to misguide researchers.

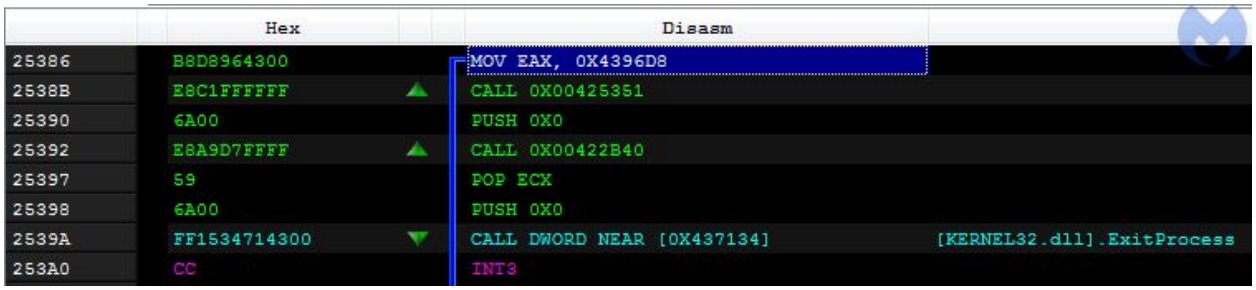
This is the entry point that was set in the headers is at RVA 0x26840:



The call leads to a function that makes the application go in an infinite sleep loop:



The real entry point, from which the execution of the malware should start, is at 0x25386, and it is known only to the loader.



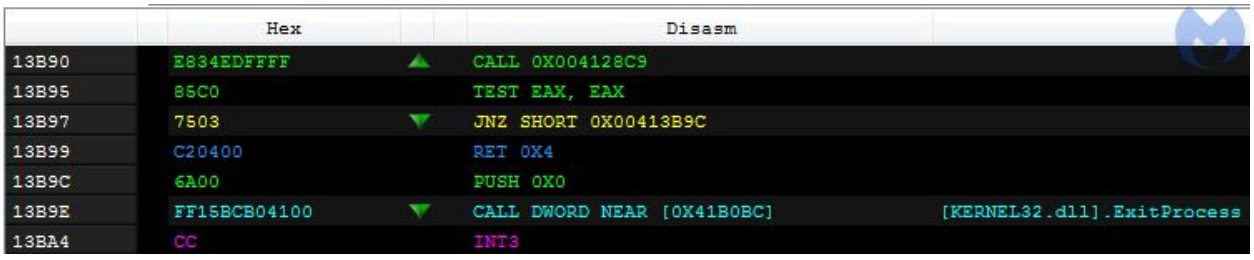
The second stage versus Kronos loader

A similar trick using a hidden entry point was used by the original Kronos (2a550956263a22991c34f076f3160b49). In Kronos' case, the final payload is injected into svchost. The execution is redirected to the core by patching the entry point in svchost:

In this case, the entry point within the payload is at RVA 0x13B90, while the entry point saved in the payload's header (d8425578fc2d84513f1f22d3d518e3c3) is at 0x15002.

Offset	Name	Value	Value
100	Magic	10B	NT32
102	Linker Ver. (Major)	9	
103	Linker Ver. (Minor)	0	
104	Size of Code	1A000	
108	Size of Initialized Data	31200	
10C	Size of Uninitialized Data	0	
110	Entry Point	15002	

The code at the real Kronos entry point displays similarities with the analogical point in Osiris. Yet, we can see they are not identical:



A precision implementation

The first stage loader is strongly inspired by Process Dopplegänging and is implemented in a clean and professional way. The author adopted elements from a relatively new technique and made the best out of it by composing it with other known tricks. The precision used here reminds us of the code used in the original Kronos. However, we can't be sure if the first layer is written by the same author as the core bot. Malware distributors often use third-party crypters to pack their malware. The second stage is more tightly coupled with the payload, and here we can say with more confidence that this layer was prepared along with the core.

Malwarebytes can protect against this threat early on by breaking its distribution chains that includes malicious documents sent in spam campaigns and drive-by downloads, thanks to our anti-exploit module. Additionally, our anti-malware engine detects both the dropper and Osiris core.

Indicators of Compromise (IOCs)

Stage 1 (original sample)

e7d3181ef643d77bb33fe328d1ea58f512b4f27c8e6ed71935a2e7548f2facc0

Stage 2 (second stage loader)

40288538ec1b749734cb58f95649bd37509281270225a87597925f606c013f3a

Osiris (core bot)

d98a9c5b4b655c6d888ab4cf82db276d9132b09934a58491c642edf1662e831e