Kernel Exploit Sample Hunting and Mining

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Introduction

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- Malware research particularly anti-HIPS techniques, providing countermeasure
- Focusing on 0-day exploit sample discovery
- Extremely interest into Windows exploit/vulnerability research
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Agenda

Mining

- EOP vs UAC
  - Abused by malware authors
  - Differences between them
- What is WWW primitive
  - Result of mining kernel exploit sample shows classic WWW primitive kernel exploitation, eg: CVE-2013-3660 by Tavis Ormandy
- Kernel exploit sample mining
- Case study of malware families with EOP
  - ***Dridex/Dyre***
  - *Carberp/Rovnix*
  - *Evotob*
  - ***Discpy***

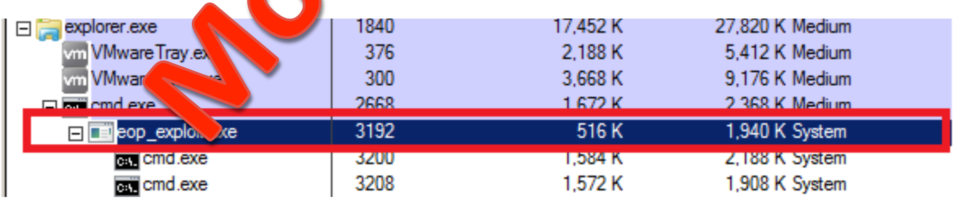
Hunting EoP anomalies

EOP vs UAC

Elevation of Privilege

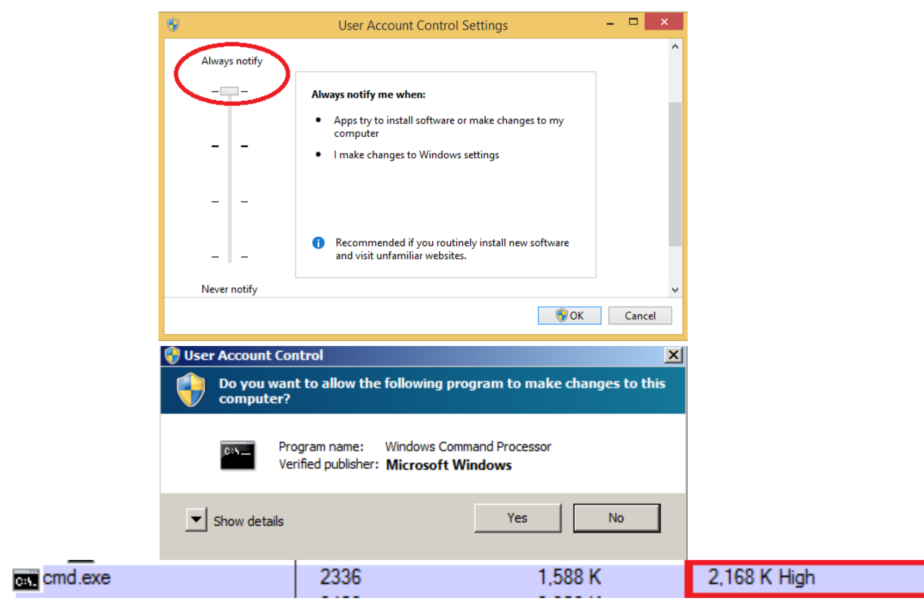
- Less reliable
- Less stable
- No limitation
- Full system privilege (System integrity level)

More Powerful!

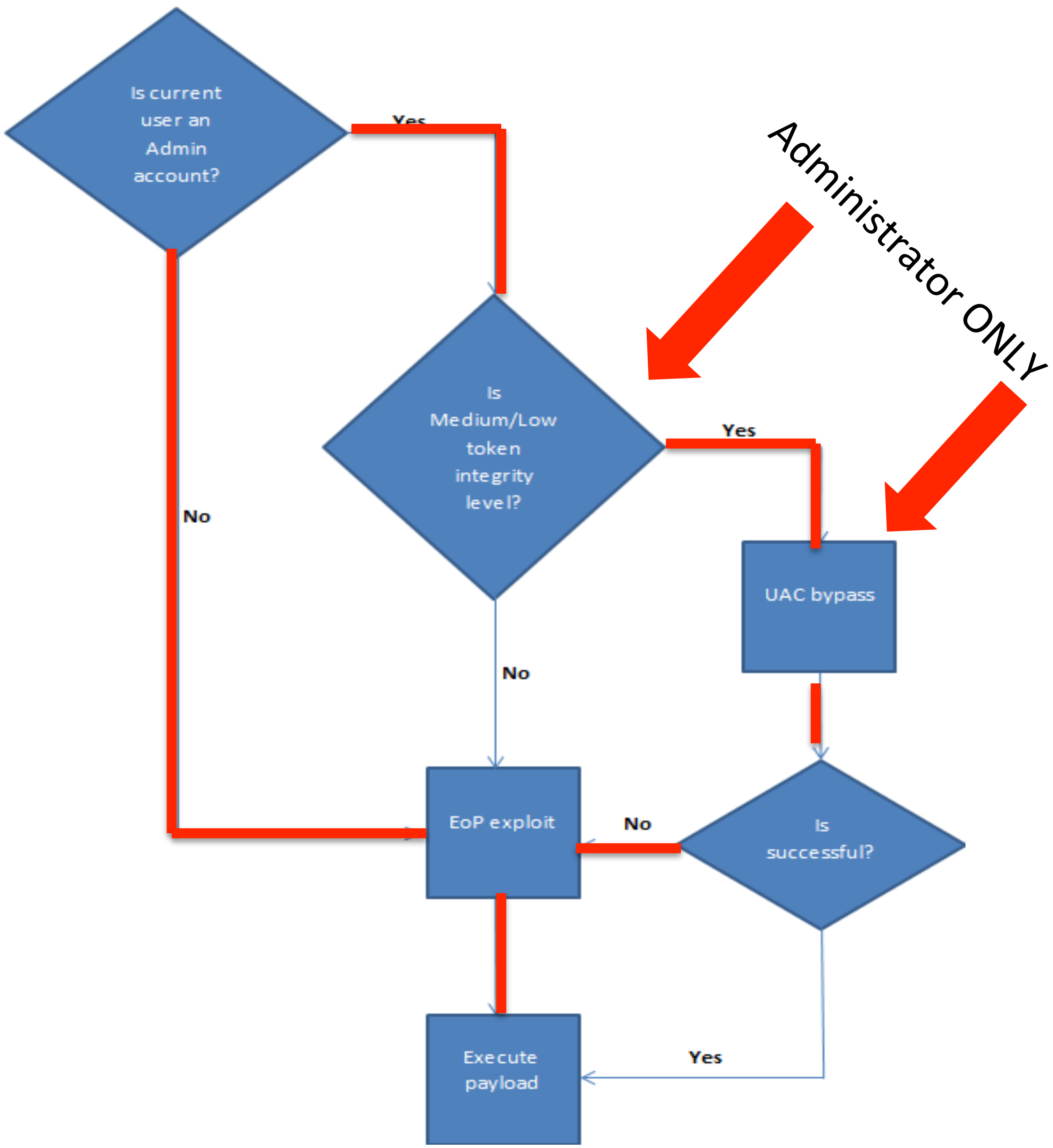


User account control

- More reliable
- More stable
- Has limitation
- Administrator privilege (High integrity level)



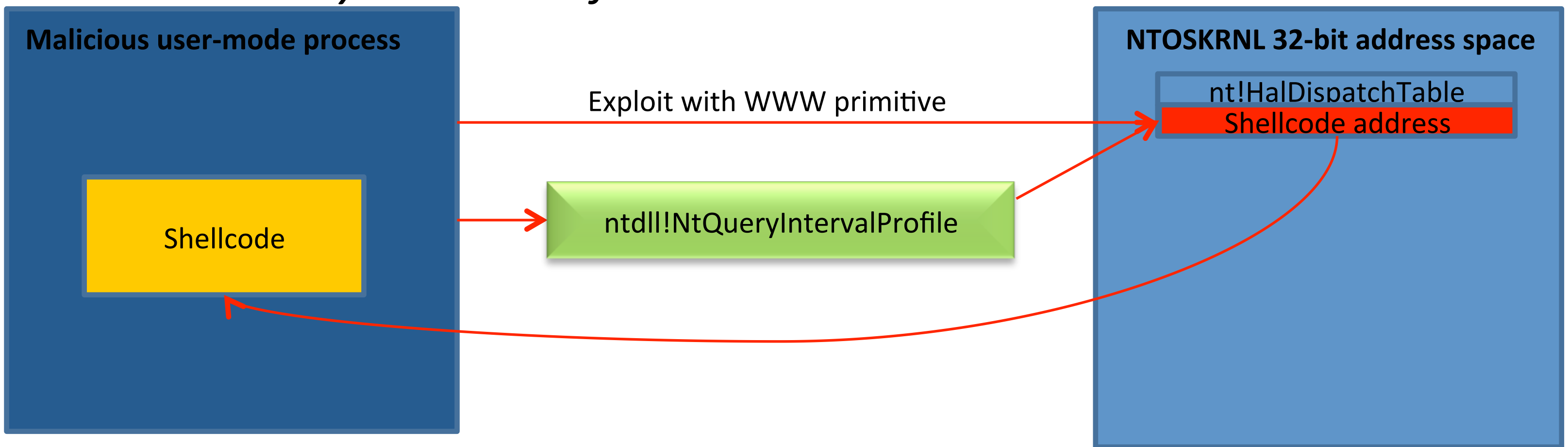
EOP + UAC



Is current user an Admin account?
Yes
No
Is Medium/Low token integrity level?
Yes
No
UAC bypass
Administrator ONLY
EoP exploit
No
Is successful?
Yes
Execute payload

What is WWW primitive

- Commonly used vector. Simple and straight forward
- Store (**write**) a specific value (**what**) to a specific kernel pointer address (**where**), eg: HalDispatchTable
- Traditional kernel exploit uses 3 steps:
  1. Prepares a user mode buffer to store the shellcode
  2. Uses write-what-where approach to overwrite *HalDispatchTable +sizeof(void*)* with shellcode address
  3. Redirects code execution to the prepared shellcode using *NtQueryIntervalProfile*



What is WWW primitive

- Limitation:
  - Counter measures from Intel®
    - Supervisor Mode Execution Prevention (SMEP)
    - Supervisor Mode Access Prevention (SMAP)
- Many workarounds:
  - N3phos's exploit in CVE-2015-0058
  - Alex Ionescu's kernel heap feng shui
- WWW primitive is prominent, but some exceptions ☹
  - CVE-2014-4113
  - CVE-2015-1701

Kernel EoP exploit sample hunting

- *NtQueryIntervalProfile & HalDispatchTable* still favorable for exploit writers ☺
- Some success stories
  - Discovery of Dridex's CVE-2015-0057 exploit
  - Other malware families leveraging public known EOP exploits
- How to do that?
  - Windows native API calls in the process of achieving EOP
    - String search in static binary
    - String search in dynamic process memory
  - No Windows native API function name
    - Kernel exploit behavioral detection methods

Kernel EoP exploit sample hunting – WWW primitive

- Rule #1 - Generic EoP leveraging WWW
  - VT yara rule for static binary string
  - Yara rule for dynamic analysis system
  - NtQueryIntervalProfile not used by user-mode application
  - Yara rule in VT with low FP rate

```
rule www_kernel_exploit
{
    meta:
    description = "Typical APIs used in Write-What-Where Windows kernel exploitation"

    strings:
    $NtQueryIntervalProfile = "NtQueryIntervalProfile" nocase
     $ZwQueryIntervalProfile = "ZwQueryIntervalProfile" nocase
     $HalDispatchTable = "HalDispatchTable" nocase

    condition:
    ($NtQueryIntervalProfile or $ZwQueryIntervalProfile) and $HalDispatchTable and
     not tags contains "native"
}
```

Kernel EoP exploit sample hunting – Token Stealing

- Remember the exceptional cases without using WWW primitive?
- Upon successfully exploiting kernel vulnerability, next thing exploit will do is:
  - Elevate itself to system privilege through token stealing
    - Let's take advantage of token stealing payload operation!
- Steps:
  - Get the EPROCESS structure of the System (process id=4) and subsequently obtains its corresponding access token address.
  - Get the EPROCESS structure of the exploit process and replace its access token address with the System's access token.
  - As a result the exploit process possesses the same access token as the System which has the highest privilege on Windows environment.
- Used to be in ASM code… but it is not portable to other versions of Windows
- Modern exploits use documented Windows kernel API

Kernel EoP exploit sample hunting - Token Stealing (continued)

- Examples of privilege elevation payload routine taken from modern exploits
- it becomes:
  - Cleaner and portable

```
int __stdcall elevate_system_privilege()
{
  int result;
  PEPROCESS currentEproc;
  PEPROCESS systemEproc;

  ptrPsLookupProcessByProcessId(g_dwCurrentPid, &currentEproc);
  ptrPsLookupProcessByProcessId(g_dwSystemPid, &systemEproc);
  result = g_dwOffsetEprocToken;
  *(_DWORD *)((char *)currentEproc + g_dwOffsetEprocToken) =
  *(_DWORD *)((char *)systemEproc + g_dwOffsetEprocToken);
  return result;
}
```

```
int elevate_privilege()
{
  PACCESS_TOKEN currentToken;
  PACCESS_TOKEN SystemToken;
  PEPROCESS currentEproc;

  g_boolExploited = 1;
  *(_DWORD *)(g_pHalDispatchTable + 4) = g_origNtQueryIntervalProfile;
  if ( !ptrPsLookupProcessByProcessId(g_dwCurrentPid, &currentEproc) )
  {
    currentToken = pfnPsReferencePrimaryToken(currentEproc);
    SystemToken = pfnPsReferencePrimaryToken(*(_DWORD *)g_PsInitialSystemProcess);
    replace_token(currentToken, SystemToken);
  }
  return 0;
}
```

Kernel EoP exploit sample hunting - Token Stealing (continued)

- Rule #2
  - Detect token stealing operation using PsLookupProcessByProcessId and NtQuerySystemInformation
  - Specific to Win32k kernel exploit

```
rule generic_um_win32k_kernel_exploitation

{

        meta:

        description = "Typical APIs used in user-mode exploit to leverage win32k kernel
mode vulnerability"


        strings:

          $PsLookupProcessByProcId = "PsLookupProcessByProcessId" nocase

          $NtQuerySystemInformation = "NtQuerySystemInformation" nocase

          $ZwQuerySystemInformation = "ZwQuerySystemInformation" nocase


        condition:

          ($NtQuerySystemInformation or $ZwQuerySystemInformation) and

          $PsLookupProcessByProcId and (pe.imports("user32.dll") or
pe.imports("gdi32.dll")) and

          tags contains "peexe" and

          not tags contains "native"

}
```

Kernel EoP exploit sample hunting - Token Stealing (continued)

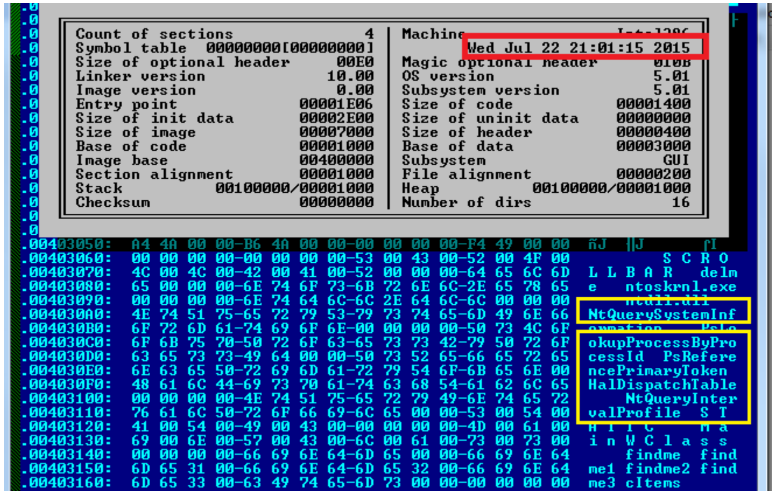
- Rule #3
  - Detect token stealing operation using PsReferencePrimaryToken
  - Not specific to Win32k kernel exploit

```
rule generic_um_kernel_exploitation

{

        meta:

        description = "Typical APIs used in user-mode exploit to leverage kernel mode
vulnerability"


        strings:

        $NtQuerySystemInformation = "NtQuerySystemInformation" nocase

         $ZwQuerySystemInformation = "ZwQuerySystemInformation" nocase

         $PsLookupProcessByProcId = "PsLookupProcessByProcessId" nocase

         $PsReferencePrimaryToken = "PsReferencePrimaryToken" nocase


        condition:

        ($NtQuerySystemInformation or $ZwQuerySystemInformation) and

         ($PsLookupProcessByProcId or $PsReferencePrimaryToken) and

         tags contains "peexe" and

         not tags contains "native"

}
```

?

Case study - Dridex

- Discovered by Rule #1
- First exploit CVE-2015-0057
  - Exploited 3 months after MS patched in Feb 2015
  - No public exploit code available that time
- Disappeared after July 2015
- Modular architecture
  - EOP exploit module downloadable from C&C as mod5

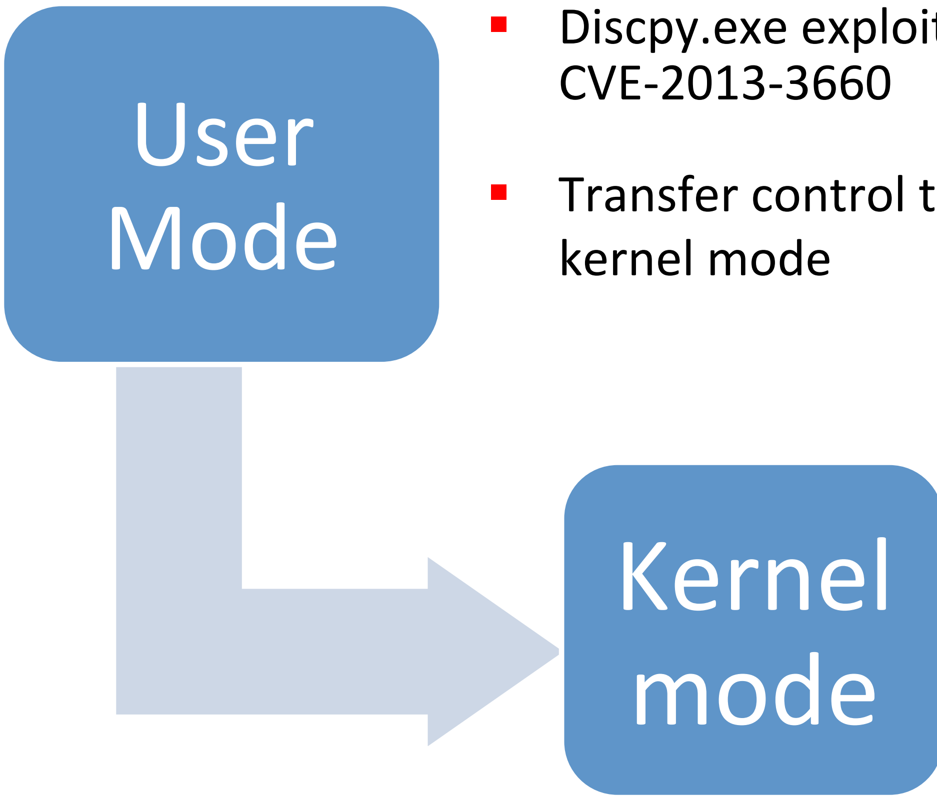


- UAC bypass module downloadable from C&C as mod4
  - Exploiting known and patched UAC vulnerability
  - Eg: AppCompat whitelisting

Case study - Discpy

- Discovered by Rule #1
- Interesting post kernel exploit payload
  - No regular token stealing
- Not a new technique but interesting idea
  - Do we really need to elevate privileges for the exploit process?
  - Other options:
    - Nullify DACL of Security Descriptor for a privileged Windows process, “Easy Local Windows Kernel Exploitation” by Cesar Cerrudo
- How about inject code to remote process from kernel mode?
  - No modification to kernel data structure
  - Kernel exploit enables code execution under kernel mode context
  - Execute APC injection routine from kernel mode
    - APC injection routine traverse active process list to find target process (eg: svchost.exe)
    - Inject APC thread to svchost.exe to run main payload
    - More stealthy
    - Bypass most of the HIPS solutions by antimalware vendors
- **Update:** 30 April 2016 Trend Micro discovered similar post kernel exploit payload used in Locky

Case study - Discpy



- Discpy.exe exploits CVE-2013-3660
- Transfer control to kernel mode
  - Allocate kernel buffer via *ExAllcoatePool*
  - Prepares APC injector routine in kernel buffer
  - Transfer code execution to kernel buffer
  - Enumerate and find active svchost.exe and inject APC thread to targeted thread
  - Trigger APC thread via *KeInsertQueueApc* that will perform final downloader/dropper routine

Hunting EoP Anomalies

- Look for unauthorized elevated processes
  - Non-system services having system integrity level
  - Processes having system integrity level with non-system Integrity level parent process
  - Processes with administrative windows privileges but < high integrity level
  - Processes Accessing Objects with Higher Integrity Level

Conclusion

- Usually means game over when reach Kernel mode
- Does not mean we have to make it easy
  - Actively hunt for them