NtVDM 子系统拾趣

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SyScan(+)360, 2013

第一部分

议题简介

议题简介

- 关于作者（wangyu@360.cn）
- 议题背景

NtVDM 子系统是一个有趣但又不太引人注目的 Windows 组件。当我们在 Windows 平台享受着 DOS 游戏给我们带来美好回忆的同时，我们是否还应关注一下 NtVDM 子系统的安全性呢？从 CVE-2004-0208 开始到近期的 CVE-2012-2553 等漏洞都一再提醒着我们，该组件的安全性不容忽视。

本议题将分析 NtVDM 用户态与内核态的实现，阐述模拟器引擎的工作原理，解释上述漏洞的成因，以及我们可以从中得到的思考与启示。

议题简介

- 议题背景
  - Intel SDM-3B 8086 Emulation 概述
  - SoftPC / NtVDM 架构分析 — 子系统的用户态与内核态相关设计与实现
  - DOS 环境模拟、虚拟 8086 模式切换过程、BOP 机制与事件回调 — DOS 模拟器的工作细节
  - NtVDM 子系统安全性问题拾趣
  - 漏洞给我们带来的思考与启示
- 责任声明

第二部分

NtVDM 子系统的设计与实现

Intel SDM 8086 Emulation 概述

- IA-32 实模式相对 8086 处理器执行环境的扩展
  - 支持 FS、GS 段寄存器
  - 支持 32 位操作数前缀和 32 位地址前缀
  - 支持更多的指令 (LIDT / SIDT)
- 虚拟 8086 模式相对实模式执行环境的扩展
  - 复用保护模式的中断和异常处理机制
  - 复用保护模式分页机制

"Virtual-8086 mode always executes at CPL 3."

"Use the U/S flag of page-table entries to protect the virtual-8086 monitor and other system software in the virtual-8086 mode task space."

Intel SDM 8086 Emulation 概述

A virtual-8086-mode task consists of the following items:

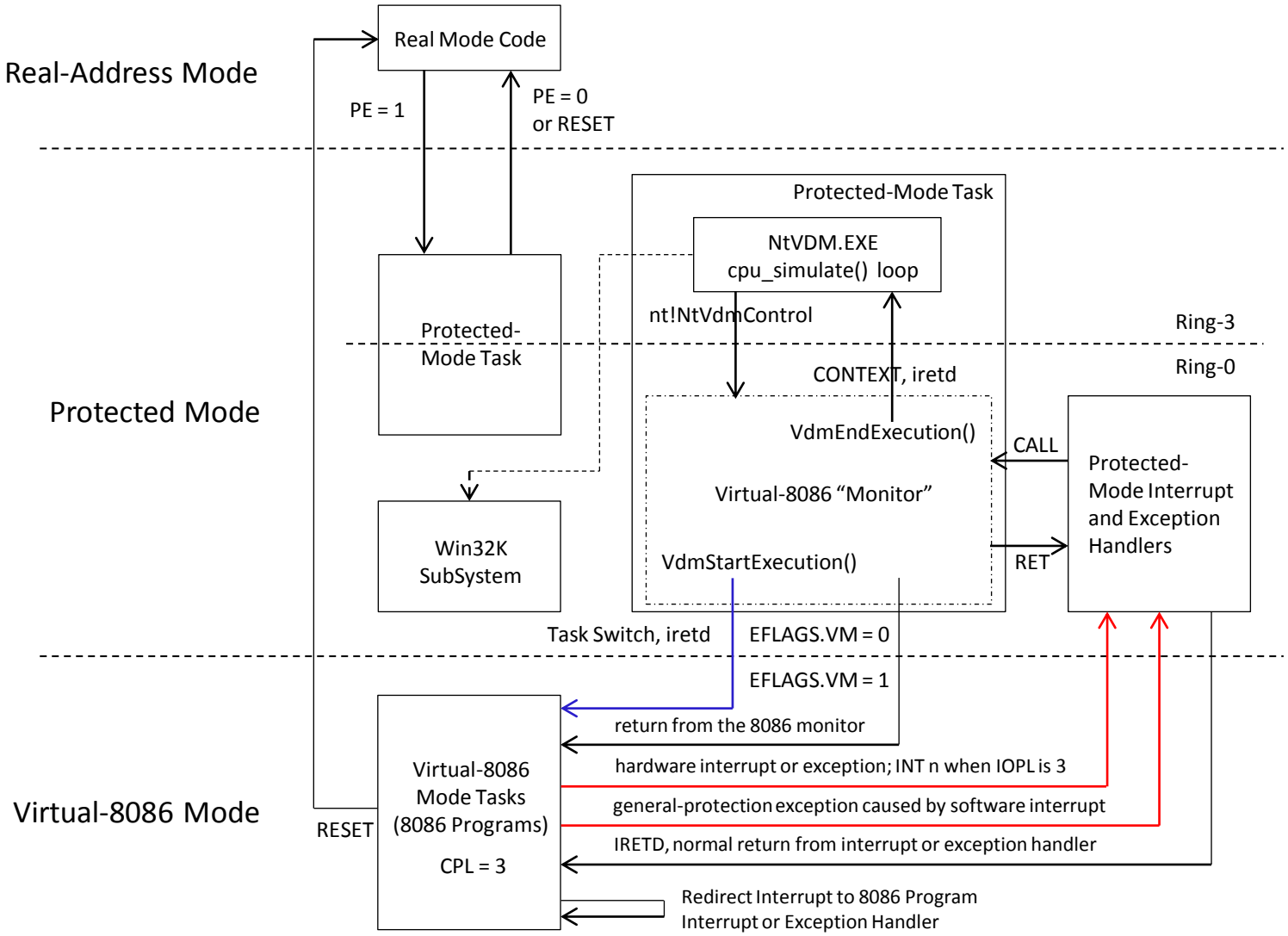
- A 32-bit TSS for the task.
- The 8086 program.
- 8086 operating-system services.
- A virtual-8086 monitor.

The processor enters virtual-8086 mode to run the 8086 program and returns to protected mode to run the virtual-8086 monitor.

The virtual-8086 monitor is a 32-bit protected-mode code module that runs at a CPL of 0. The monitor consists of initialization, interrupt- and exception-handling, and I/O emulation procedures that emulate a personal computer or other 8086-based platform.

The processor can leave the virtual-8086 mode only through an interrupt or exception.

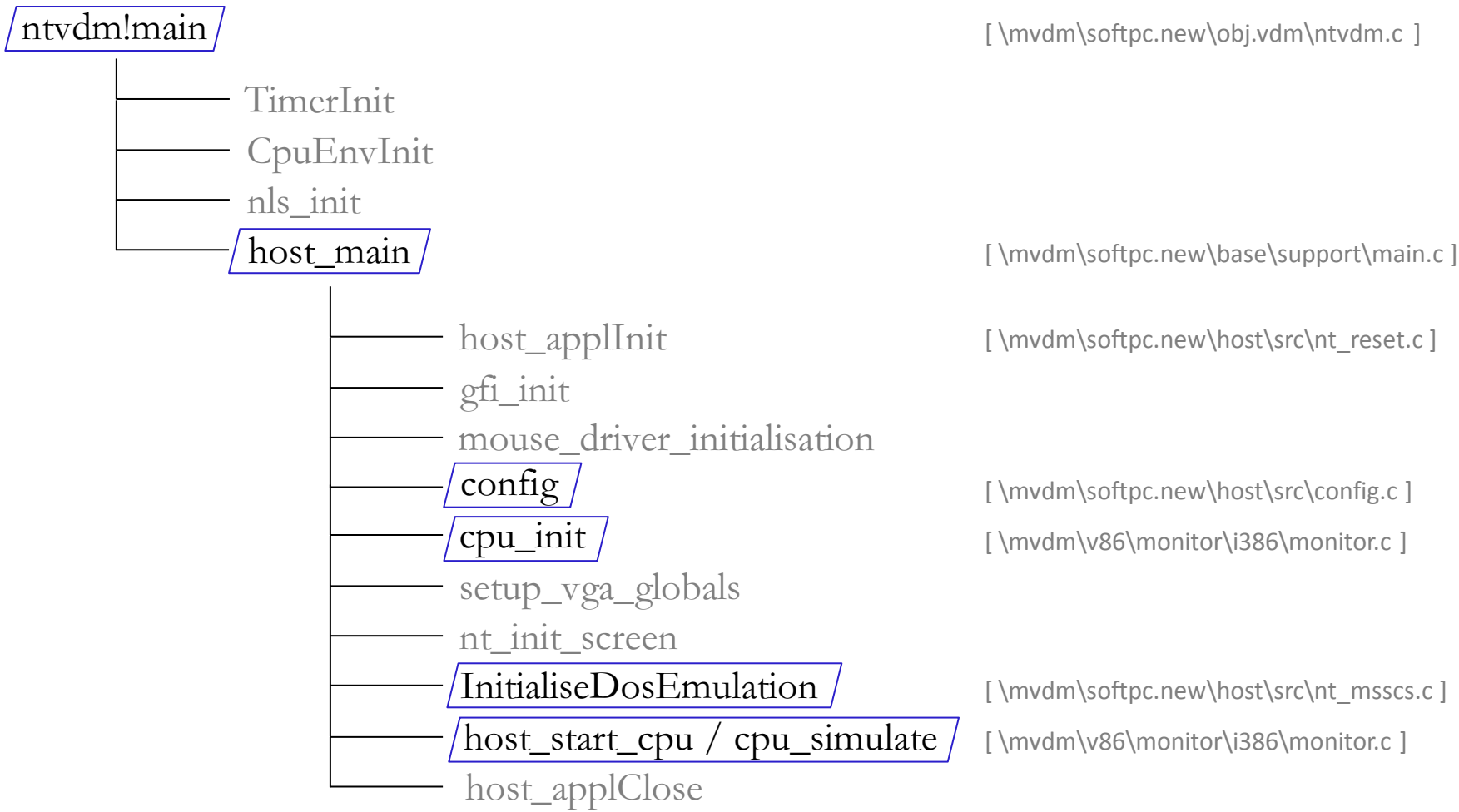
Intel SDM 8086 Emulation 概述



Reference : Figure 20-3. Entering and Leaving Virtual-8086 Mode

模拟器的用户态 — NtVDM 进程执行逻辑

NtVDM 进程函数执行序列概览



模拟器的用户态 — NtVDM 进程执行逻辑

host_main

- host_applInit
  - video_funcs、keybd_funcs、mouse_funcs 全局变量赋值
  - 查询 EPROCESS 标志位 PS_PROCESS_FLAGS_VDM_ALLOWED
  - 解析命令行参数，其中 -i 表示 DosSessionId
  - 创建线程 ConsoleEventThread
- gfi_init
- mouse_driver_initialisation
- config
  - 两次设置 DOS 窗口标题：
    其中第一次的格式为 "ntvdm - ProcessId . ThreadId . ConsoleHandle"
  - 填充 VDMINFO 结构调用 GetNextVDMCommand 例程异步查询 PIF 信息
    -> ntdll!CsrClientCallServer -> nt!ALPC -> SERVER CSRSS
    -> CSRSRV!CsrApiRequestThread -> basesrv!BaseSrvGetNextVDMCommand
  - 估算内存使用量，调用 GetROMsMapped 例程 - NtVdmControl(VdmInitialize)
    基于 _VDM_INITIALIZE_DATA 创建 VdmObjects(VDM_PROCESS_OBJECTS)
    基于 "\Device\PhysicalMemory" 初始化零地址

```
0: kd> da 011ff6f4
011ff6f4  "ntvdm-148.808.320001"
```

```
0: kd> db 0
00000000  53 ff 00 f0 53 ff 00 f0-c3 e2 00 f0 53 ff 00 f0  S...S.......S...
00000010  53 ff 00 f0 54 ff 00 f0-4a 82 00 f0 53 ff 00 f0  S...T...J...S...
00000020  a5 fe 00 f0 87 e9 00 f0-01 0b 00 f0 01 0b 00 f0  ................
```

模拟器的用户态 — NtVDM 进程执行逻辑

host_main

cpu_init
- 调用 NtVdmControl(VdmFeatures) 查询 KeI386VirtualIntExtensions 属性
- 给 FIXED_NTVDMSTATE_LINEAR (0x714) 赋初始状态
- fninit 初始化 FPU
- 分配 / 初始化核心数据结构 _VDM_TIB 于 _TEB.Vdm

```
ntvdm!VDM_TIB
   Size                : Uint4B
   VdmInterruptTable   : Ptr32
   VdmFaultTable       : Ptr32
   MonitorContext      : _CONTEXT
   VdmContext          : _CONTEXT
   EventInfo           : _VdmEventInfo
   ......
   ContinueExecution   : UChar
```

setup_vga_globals

nt_init_screen

InitialiseDosEmulation
- 准备 DOS 执行环境
- scs_init 例程调用 GetNextVDMCommand 异步查询 IsFirstVDM 信息
  -> ntdll!CsrClientCallServer -> nt!ALPC -> basesrv!BaseSrvIsClientVdm
- 加载 ntio***.sys 到 NTIO_LOAD_SEGMENT : NTIO_LOAD_OFFSET

```
0: kd> da 011ff524
011ff524  "C:\Windows\system32\ntio804.sys"
```

- setCS(NTIO_LOAD_SEGMENT); setIP(NTIO_LOAD_OFFSET);
  将执行点设置到 VdmTib.VdmContext，这里是虚拟 8086 模式执行的入口！

```
0: kd> dt _CONTEXT 0x02f32f30+0x2d8
   +0x0b8 Eip              : 0
   +0x0bc SegCs            : 0x70
   +0x0c0 EFlags           : 0x202
```

模拟器的用户态 — NtVDM 进程执行逻辑

host_main

host_start_cpu / cpu_simulate

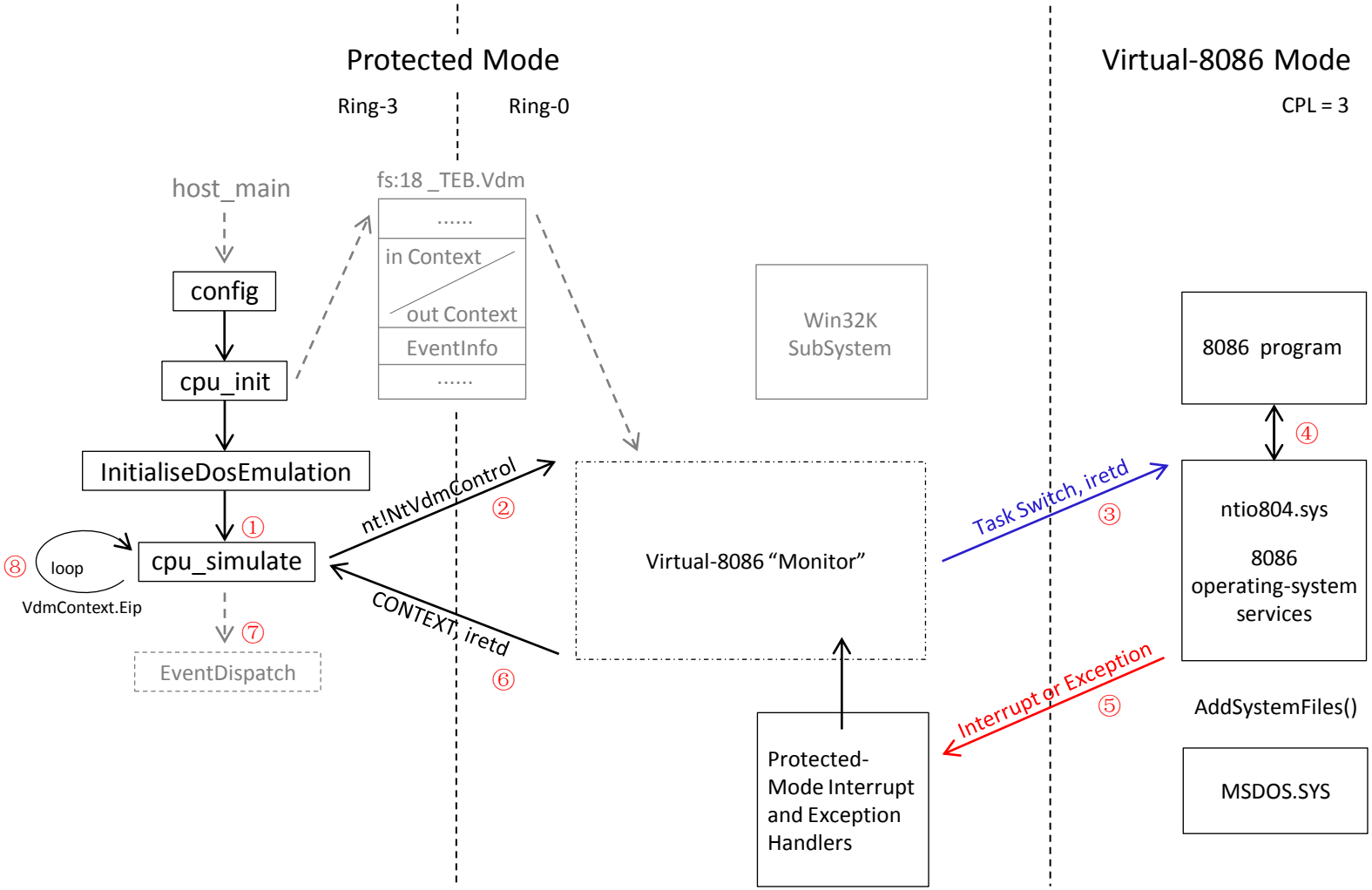
- 设置标志位，如 ContinueExecution = TRUE; 等
- 调用 NtVdmControl(VdmStartExecution) 进入内核，进而 iretd 切换至虚拟 8086 模式
- 虚拟 8086 模式由中断或异常退回到保护模式内核态，Monitor 相关代码设置 VDM_TIB.EventInfo 等域，标明事件类型和下一处执行指令等，最后代码退回用户态
- 修正 VdmTib.VdmContext.Eip，为下一次循环做准备
- 判断返回事件类型，调用事件对应处理例程

```
while (ContinueExecution) {
    ......
    if (*pNtVDMState & VDM_INTERRUPT_PENDING) {
            DispatchInterrupts();
        }
    ......
    Status = NtVdmControl(VdmStartExecution,NULL);
    ......
    if (!NT_SUCCESS(Status)) {
#if DBG
            DbgPrint("NTVDM: Could not start execution\n");
#endif
            return;
        }
 }
```

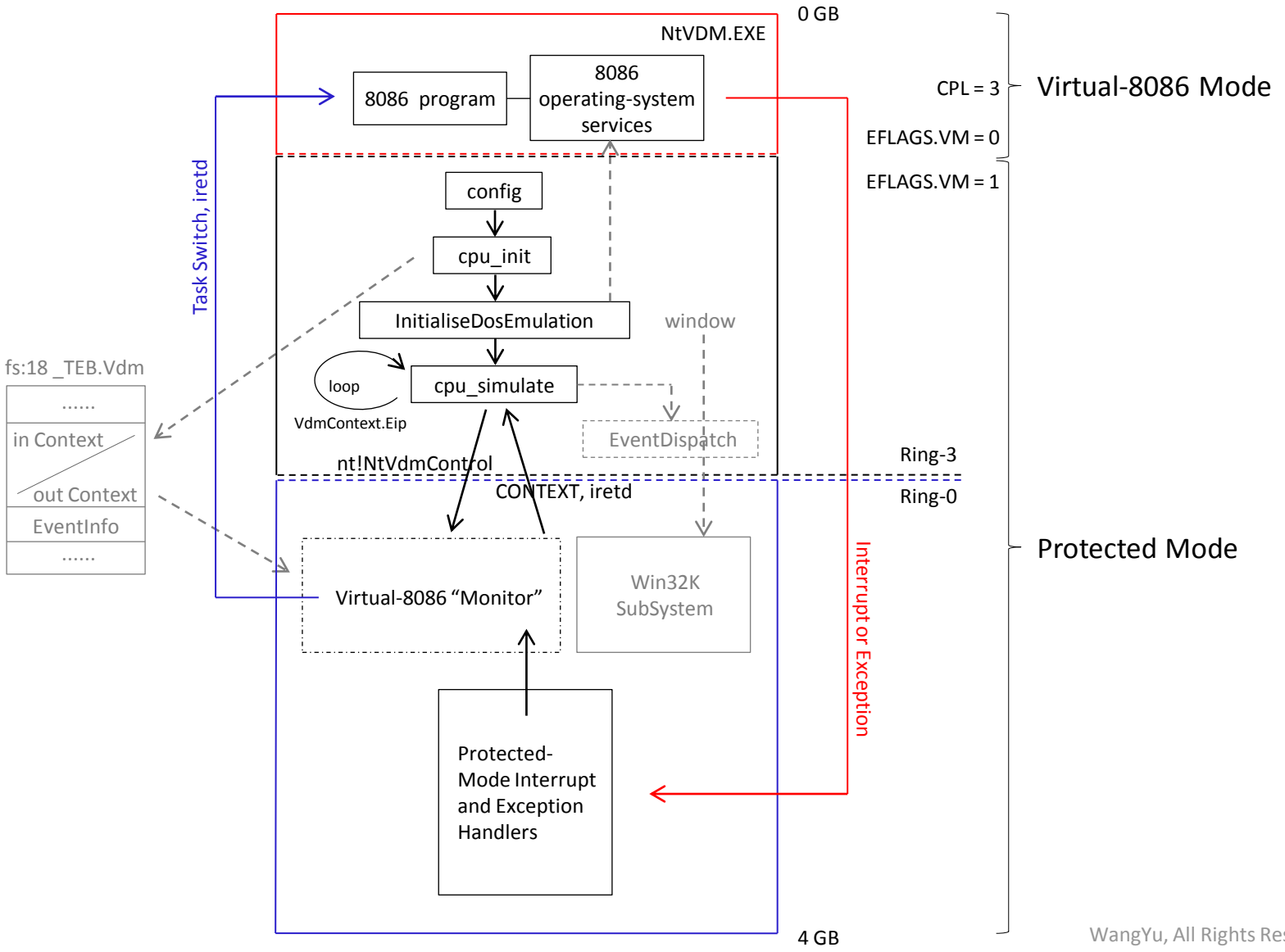
```
//
// Event Dispatch table
//

VOID (*EventDispatch[VdmMaxEvent])(VOID) = {
       ntvdm!EventVdmInterceptDiv
       ntvdm!EventVdmIo
       ntvdm!EventVdmStringIo
       ntvdm!EventVdmMemAccess
       ntvdm!EventVdmIntAck
       ntvdm!EventVdmHandShakeAck
       ntvdm!EventVdmBop
       ntvdm!EventVdmError
       ntvdm!EventVdmIrq13
       };
```

从用户态视角审视模拟器工作流程



让我们换个角度看问题



模拟器的用户态 — BOP 机制

DEMO : Calling Win32 from DOS

BOP, for BIOS Operation

0xc4, 0xc4 - sort of LEA but with register-register operands which is invalid form

Command - Kernel 'com:pipe,port=\\.\pipe\com_1,baud=115200,

```
0: kd> bp nt!KiTrap06 "db (poi(esp+4)<<4)+poi(esp) l4;g"
0: kd> g
000024cd  c4 c4 09 58
00011c2a  c4 c4 58 01
000032c9  c4 c4 52 00
00008bf4  c4 c4 57 0f
001039f3  c4 c4 50 3c
001002eb  c4 c4 17 5a
0009624e  c4 c4 54 01
00000b27  c4 c4 5e 33
00000bac  c4 c4 50 11
00001626  c4 c4 12 b1
0008e2ac  c4 c4 50 3b
0009b18c  c4 c4 50 0f
0009b1d2  c4 c4 50 1b
0009b1de  c4 c4 50 32
0009b1eb  c4 c4 54 05
0009b2d6  c4 c4 50 46
0009b5f3  c4 c4 50 4a
0008e3a5  c4 c4 15 26
0008e3b7  c4 c4 50 0d
00097f8c  c4 c4 50 21
000967bc  c4 c4 50 1a
0008e482  c4 c4 54 0c
0009a90e  c4 c4 50 12
```

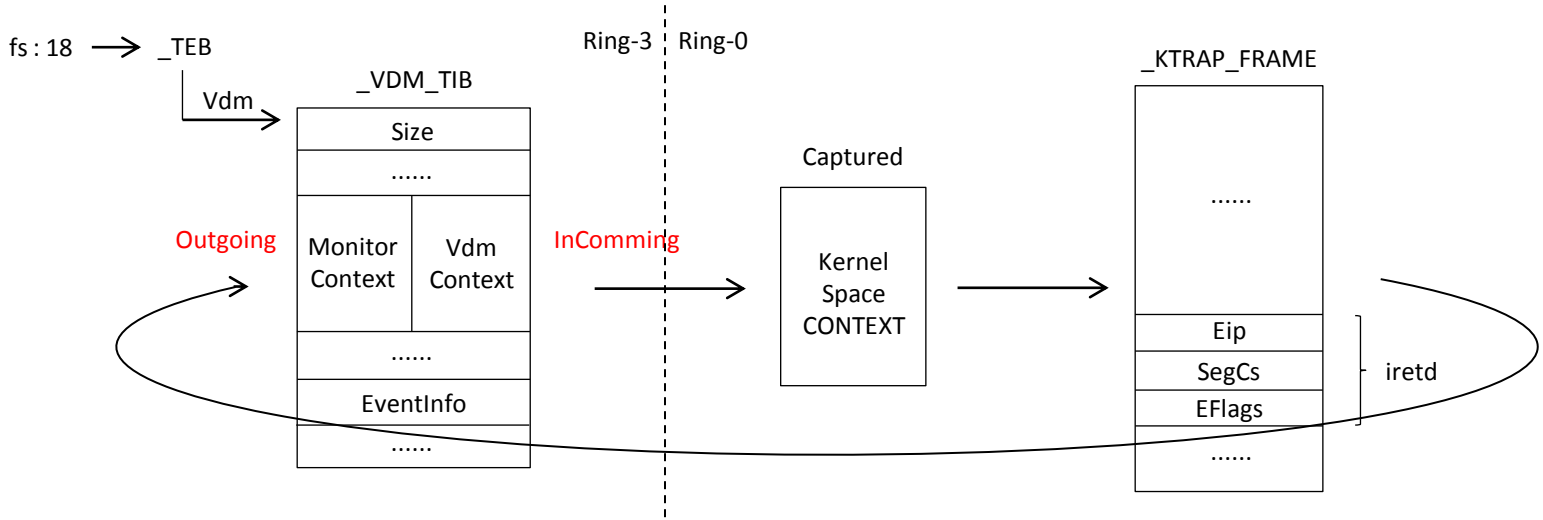
模拟器的内核态 — VdmpStartExecution 例程

NtVdmControl

└ VdmpStartExecution

- 判断 EPROCESS 结构 VdmAllowed、VdmObjects 等域
- 调用 VdmpGetVdmTib 例程检查用户态 _VDM_TIB 参数
- 从 _KTHREAD.InitialStack 开辟 TrapFrame 空间
- Capture _VDM_TIB.VdmContext 到内核，即 "InComming"
- 调用 VdmSwapContexts 例程交换 CONTEXT 信息

-> NtVdmControl -> VdmpStartExecution -> KiFastCallEntry
-> KiServiceExit -> Kei386EoiHelper -> iretd -> 虚拟 8086 模式



模拟器的内核态 — VdmSwapContexts 例程

Before

```
0: kd> dt 02f32f3c _context
nt!_CONTEXT
   +0x000 ContextFlags     : 0
   +0x004 Dr0              : 0
    .....
   +0x09c Edi              : 0
   +0x0a0 Esi              : 0
   +0x0a4 Ebx              : 0
   +0x0a8 Edx              : 0
   +0x0ac Ecx              : 0
   +0x0b0 Eax              : 0
   +0x0b4 Ebp              : 0
   +0x0b8 Eip              : 0
   +0x0bc SegCs            : 0
   +0x0c0 EFlags           : 0
   +0x0c4 Esp              : 0
   +0x0c8 SegSs            : 0
```

```
0: kd> dt _ktrap_frame 9dd48d64
nt!_KTRAP_FRAME
   +0x034 SegEs            : 0x23
   +0x038 SegDs            : 0x23
   +0x03c Edx              : 0x77bd9a94
   +0x040 Ecx              : 0x5dd09aec
   +0x044 Eax              : 0x7ffdf000
   +0x048 PreviousPreviousMode : 1
   +0x050 SegFs            : 0x3b
   +0x054 Edi              : 0x200
   +0x058 Esi              : 0x2f32f30
   +0x05c Ebx              : 0
   +0x060 Ebp              : 0x11ff738
   +0x064 ErrCode          : 0
   +0x068 Eip              : 0x77bd9a94
   +0x06c SegCs            : 0x1b
   +0x070 EFlags           : 0x246
   +0x074 HardwareEsp      : 0x11ff718
   +0x078 HardwareSegSs    : 0x23
```

After

```
0: kd> dt 02f32f3c _context
nt!_CONTEXT
   +0x000 ContextFlags     : 0
   +0x004 Dr0              : 0
    .....
   +0x09c Edi              : 0x200
   +0x0a0 Esi              : 0x2f32f30
   +0x0a4 Ebx              : 0
   +0x0a8 Edx              : 0x77bd9a94
   +0x0ac Ecx              : 0x5dd09aec
   +0x0b0 Eax              : 0x7ffdf000
   +0x0b4 Ebp              : 0x11ff738
   +0x0b8 Eip              : 0x77bd9a94
   +0x0bc SegCs            : 0x1b
   +0x0c0 EFlags           : 0x246
   +0x0c4 Esp              : 0x11ff718
   +0x0c8 SegSs            : 0x23
```

```
0: kd> u 0x77bd9a94
ntdll!KiFastSystemCallRet :
77bd9a94 c3              ret
```

```
0: kd> dt _ktrap_frame 9dd48d64
nt!_KTRAP_FRAME
   +0x034 SegEs            : 0x23
   +0x038 SegDs            : 0x23
   +0x03c Edx              : 0
   +0x040 Ecx              : 0
   +0x044 Eax              : 3
   +0x048 PreviousPreviousMode : 1
   +0x050 SegFs            : 0x3b
   +0x054 Edi              : 0
   +0x058 Esi              : 0
   +0x05c Ebx              : 0
   +0x060 Ebp              : 0
   +0x064 ErrCode          : 0
   +0x068 Eip              : 0
   +0x06c SegCs            : 0x70
   +0x070 EFlags           : 0xa0202
   +0x074 HardwareEsp      : 0
   +0x078 HardwareSegSs    : 0
```

```
0: kd> u 81874590
nt!Kei386EoiHelper+0x128 :
83c43c          add     esp,3Ch
5a              pop     edx
59              pop     ecx
58              pop     eax
8d6554          lea     esp,[ebp+54h]
5f              pop     edi
5e              pop     esi
5b              pop     ebx
5d              pop     ebp
66817c24088000  cmp     word ptr [esp+8],80h
7706            ja      818745ac
83c404          add     esp,4
cf              iretd
```

模拟器的内核态 — VdmEndExecution 例程

nt!KiTrap06 #UD

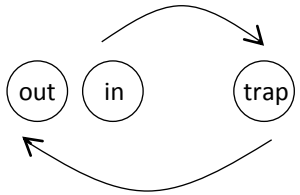
VdmEndExecution

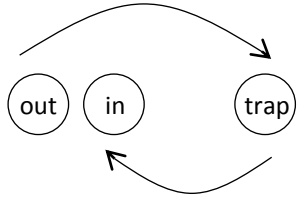
- 前提：由虚拟 8086 模式中断切换至此，此时栈上的三个参数分别是：
  EIP、CS、EFLAGS

```
0: kd> dd esp
9be4bdcc  00000427 00000070 000b0246 00000700

0: kd> db (70<<4)+427
00000b27  c4 c4 5e 33 d2 8e da 8e-c2 33 c0 bf 34 05 ab ab  ..^3.....3..4...
00000b37  8c c8 c7 06 6c 00 85 01-a3 6e 00 c7 06 a4 00 54  ....l....n.....T
```

- 从当前栈开辟 TrapFrame 空间，初始化 TrapFrame
- 调用 VdmDispatchBop 例程派发 BOP 事件，检查并读写 fs:18 _VDM_TIB 结构的 EventInfo 域
- 调用 VdmSwapContexts 例程交换 CONTEXT 信息
- 回退至用户态 ntvdm!cpu_simulate





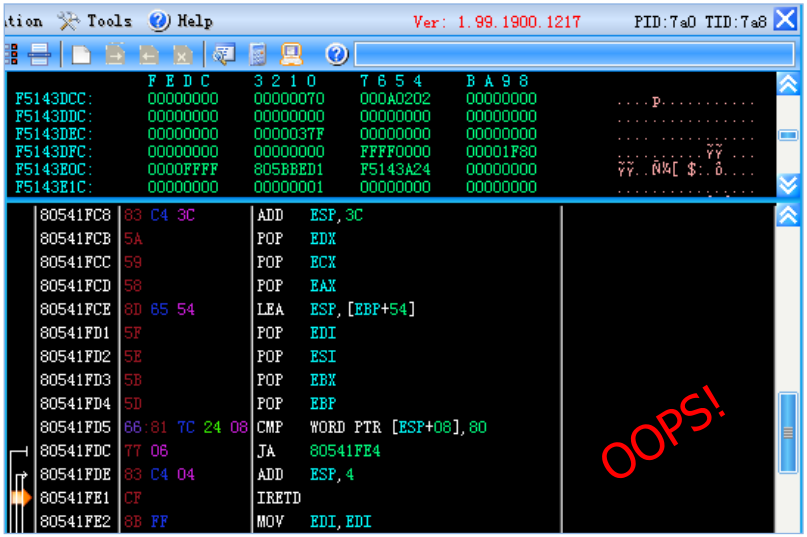
-> nt!KiTrap06 -> VdmDispatchBop -> VdmEndExecution
-> Kei386EoiHelper -> iretd -> ntvdm!cpu_simulate

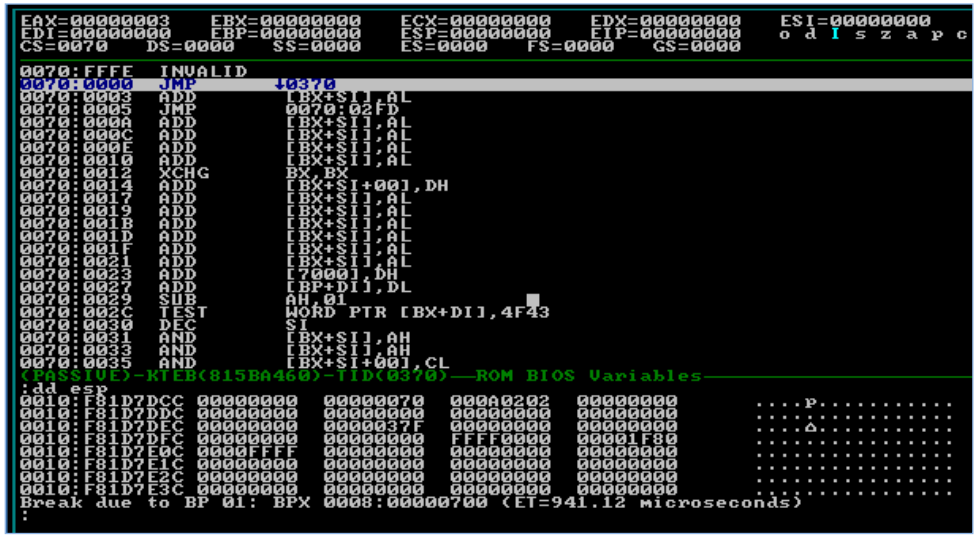
```
1: kd> dt _ktrap_frame 9be4bd64
nt!_KTRAP_FRAME
   +0x068 Eip              : 0x427
   +0x06c SegCs            : 0x70
   +0x070 EFlags           : 0xb0246
```

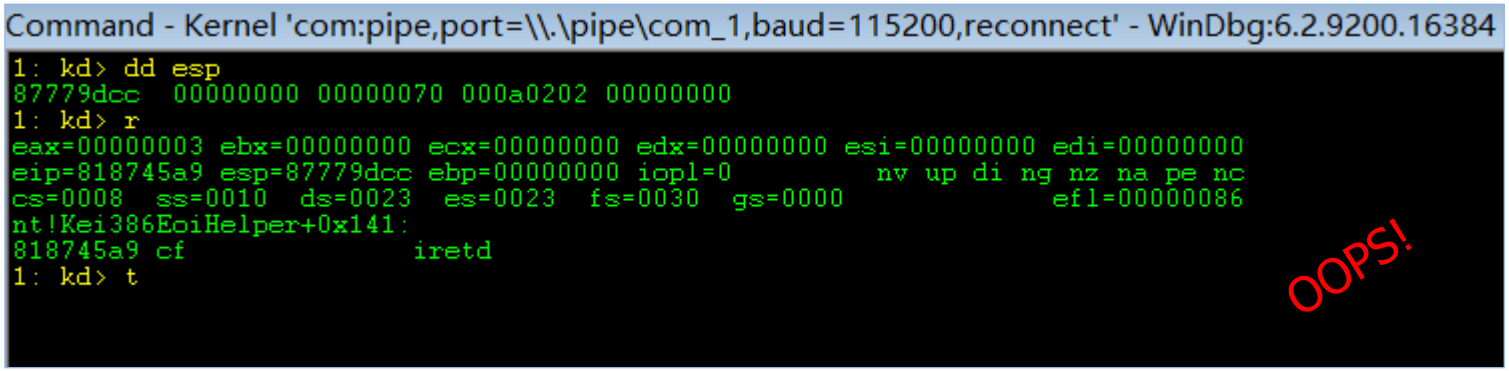
→

```
1: kd> dt _ktrap_frame 9be4bd64
nt!_KTRAP_FRAME
   +0x068 Eip              : 0x77bd9a94
   +0x06c SegCs            : 0x1b
   +0x070 EFlags           : 0x246
```

调试器对于虚拟 8086 模式的支持

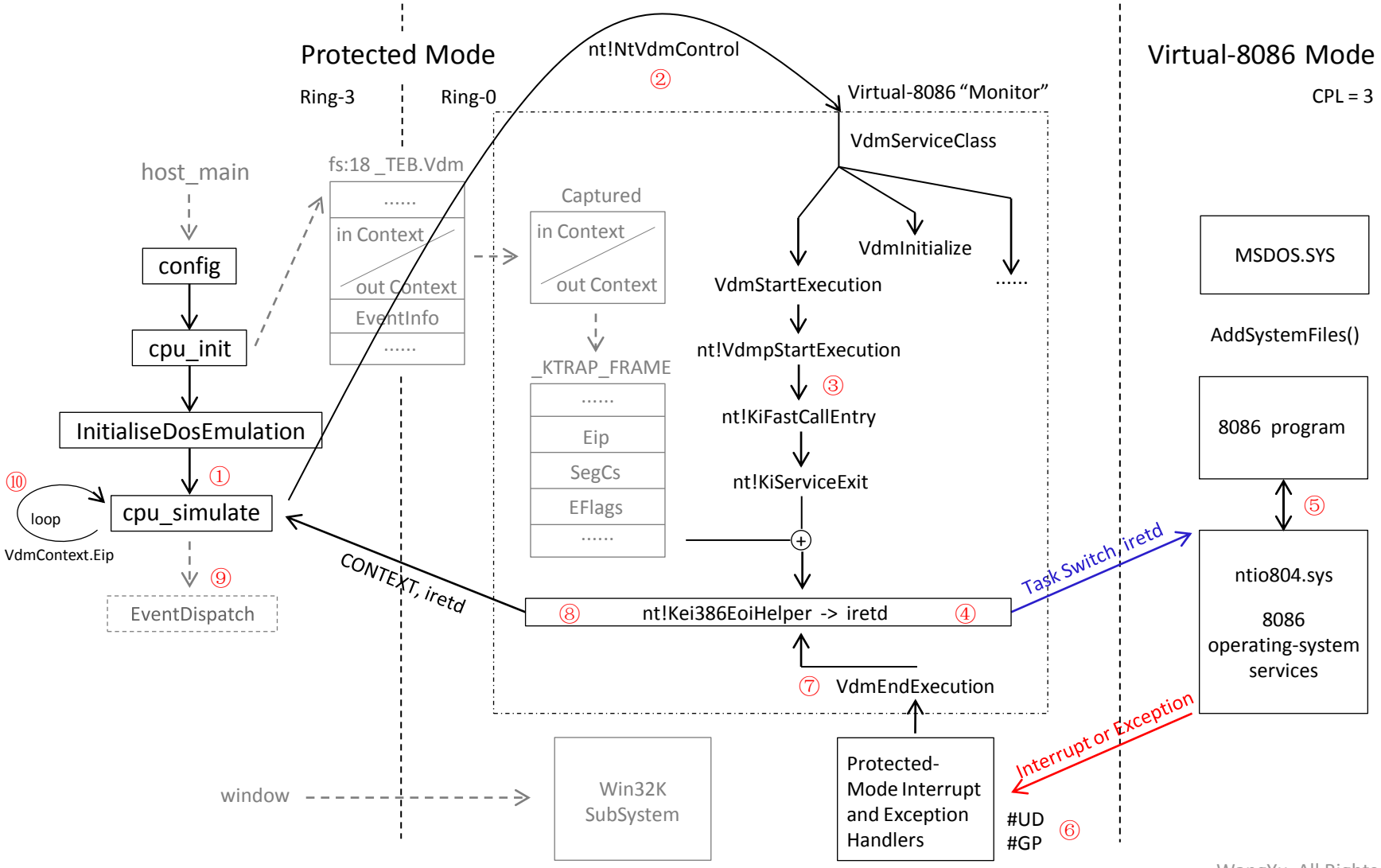






您是否有点怀念 SoftICE 了呢？ ;-)

再度审视模拟器工作流程



第三部分

NtVDM 子系统安全性问题拾趣

Where is the ELSE ?

您认为代码质量怎么样？;-)

```
                    WRK : base\ntos\ps\i386\psvdm.c   (Line:1551)
                         from Windows NT-4.0 to Windows Blue

NTSTATUS
Psp386CreateVdmIoListHead(
    IN PEPROCESS Process
    )
{
    PVDM_PROCESS_OBJECTS pVdmObjects = Process->VdmObjects;
    NTSTATUS Status;
    PVDM_IO_LISTHEAD HandlerListHead=NULL;
    KIRQL    OldIrql;
    PAGED_CODE();

    Status = STATUS_SUCCESS;

    // if there isn't yet a head, grab the resource lock and create one
    if (pVdmObjects->VdmIoListHead == NULL) {
        KeRaiseIrql(APC_LEVEL, &OldIrql);
        ExAcquireResourceExclusiveLite(&VdmIoListCreationResource, TRUE);

        // if no head was created while we grabbed the spin lock
        if (pVdmObjects->VdmIoListHead == NULL) {

            ......

        }
    }
    return STATUS_SUCCESS;
}
```

CVE-2004-0208 (nt!KiTrap06 / #UD)

Working out the details, however, is left as an exercise for the reader.

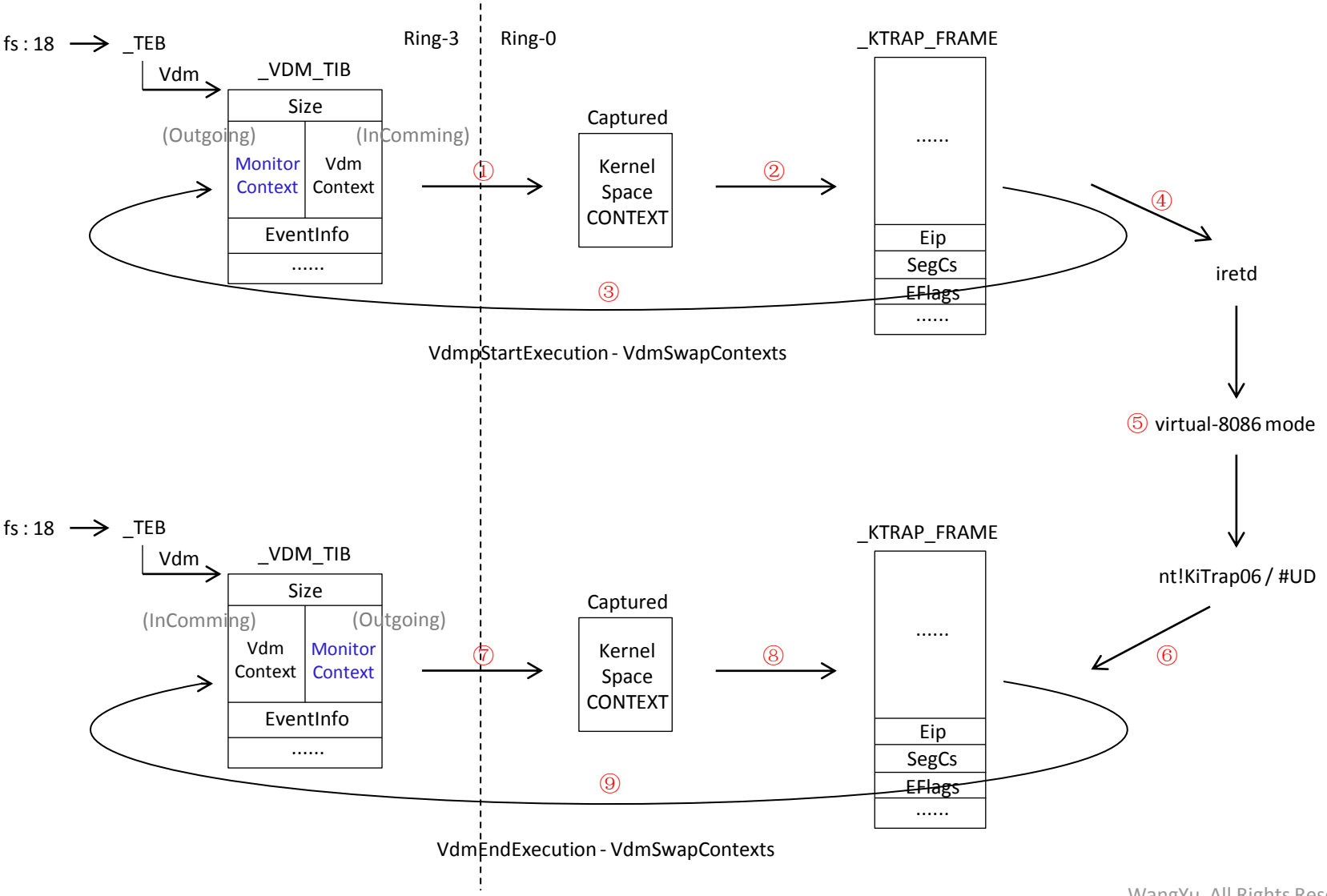
Just kidding. — Derek Soeder

CVE-2004-0208 / AD20041012
Windows VDM #UD Local Privilege Escalation

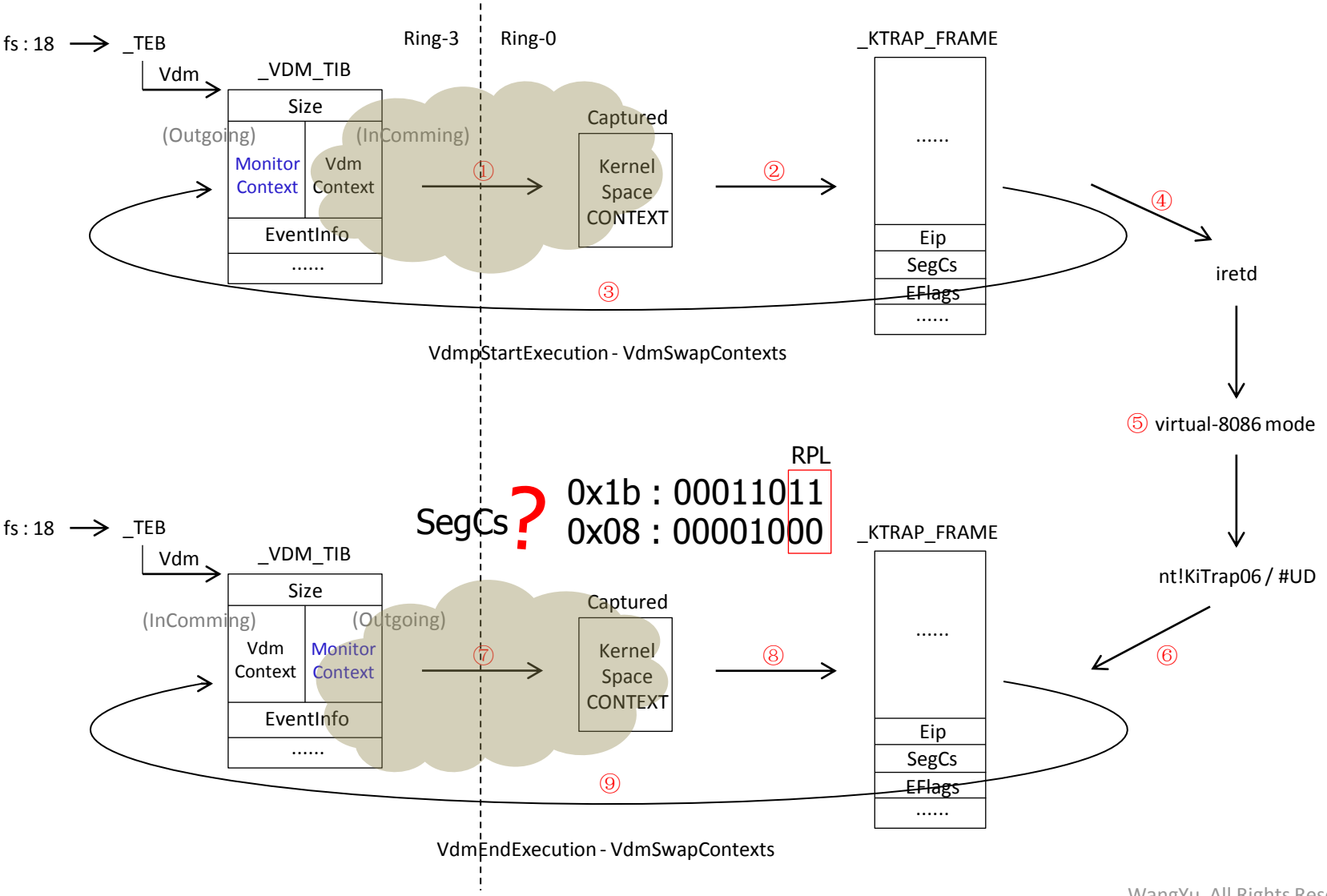
"(Outgoing) context is contained in user memory but is not sanitized in any way by the #UD handler, so any process with or without a formally-initialized VDM can place arbitrary values in the host execution context and get the handler to IRETD to any CS:EIP, allowing kernel privileges to be retained while user-supplied code is executed."

eEye Digital Security, 2004.

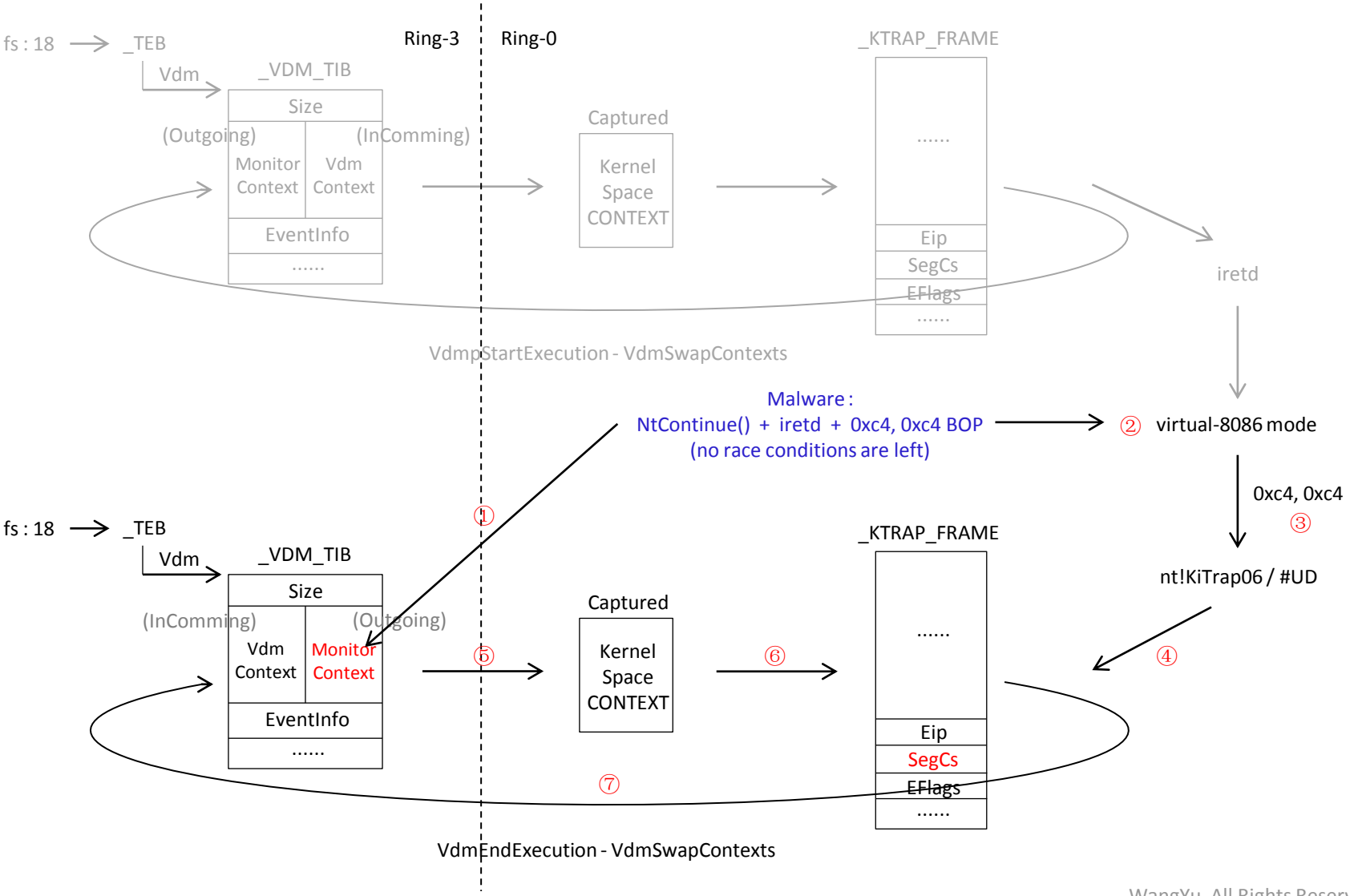
CVE-2004-0208 (nt!KiTrap06 / #UD)



CVE-2004-0208 (nt!KiTrap06 / #UD)



CVE-2004-0208 (nt!KiTrap06 / #UD)



CVE-2004-0208 (nt!KiTrap06 / #UD)

POC && Mitigation

```
FAST_V86_TRAP_6  MACRO  (Line:515)
...
;
; Load Monitor context
;
add   eax, VtMonitorContext - VtVdmContext ; (eax)->monitor context
mov   ebx, [eax].CsSegSs
mov   esi, [eax].CsEsp
mov   edi, [eax].CsEFlags
mov   edx, [eax].CsSegCs
mov   ecx, [eax].CsEip
sub   esp, 20
mov   [esp + 16], ebx
mov   [esp + 12], esi
mov   [esp + 8], edi
mov   [esp + 4], edx
mov   [esp + 0], ecx
mov   ebx, [eax].CsEbx
mov   esi, [eax].CsEsi
mov   edi, [eax].CsEdi
mov   ebp, [eax].CsEbp
...
iretd


kd> p
nt!KiTrap06+0x1cf:
80467039 cf              iretd
kd> dd esp
f82a7d98  016c0000 00000008 00000202 0105fc40
```

```
TrapFrame->Eip = InContext->Eip;
EFlags = InContext->EFlags;

if ( !(EFlags & 0x20000) )
{
  TrapFrame->SegCs |= 3u;
  SegCs = TrapFrame->SegCs;
  TrapFrame->HardwareSegSs |= 3u;

  if ( SegCs < 8 )
    TrapFrame->SegCs = 0x1Bu;
}
VdmSwapContexts:60
```

CVE-2004-0118 (nt!VdmDispatchIntAck / #GP)

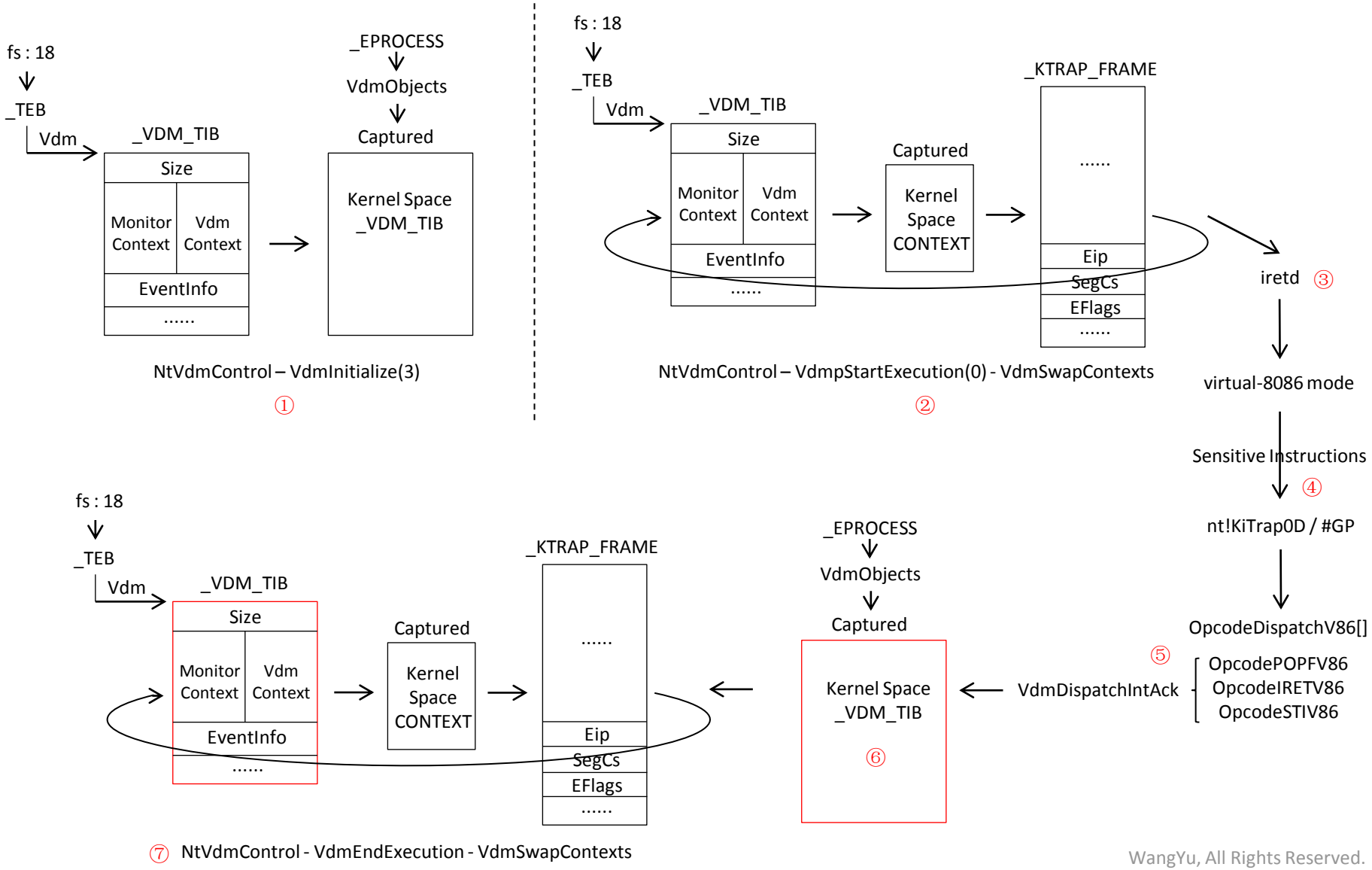
CVE-2004-0118 / AD20040413E
Windows VDM TIB Local Privilege Escalation

"The problem lies in a certain area of the Windows kernel that supports 16-bit code executing in a Virtual DOS Machine (VDM).

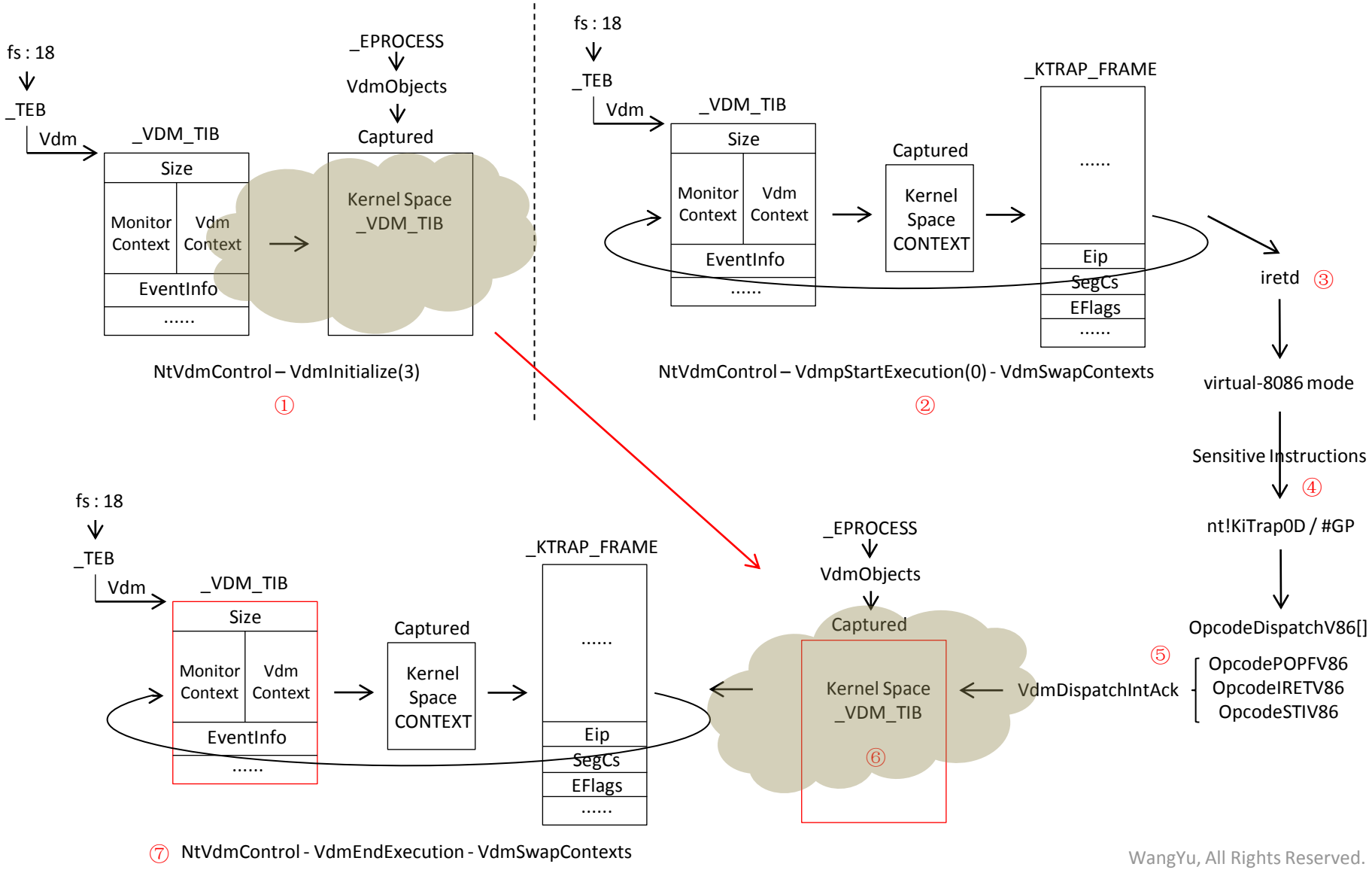
By causing the processor to execute code in Virtual86 (essentially "16-bit emulation") mode without first initializing a VDM for the process, specific routines in the Windows 2000 kernel code may be caused to dereference a null pointer, which actually functions as a pointer to attacker-controlled data if memory is allocated at virtual address 0."

eEye Digital Security, 2004.

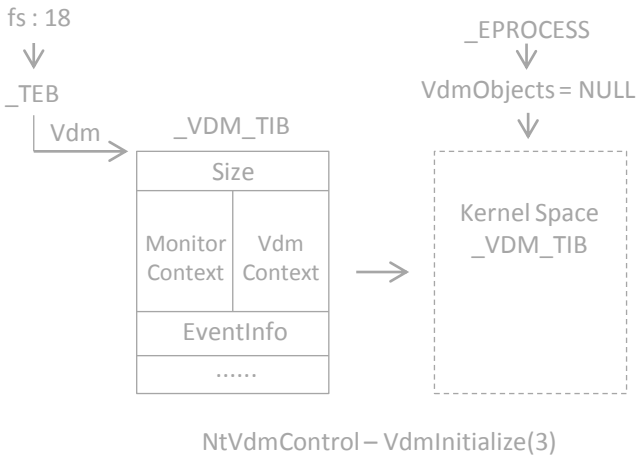
CVE-2004-0118 (nt!VdmDispatchIntAck / #GP)



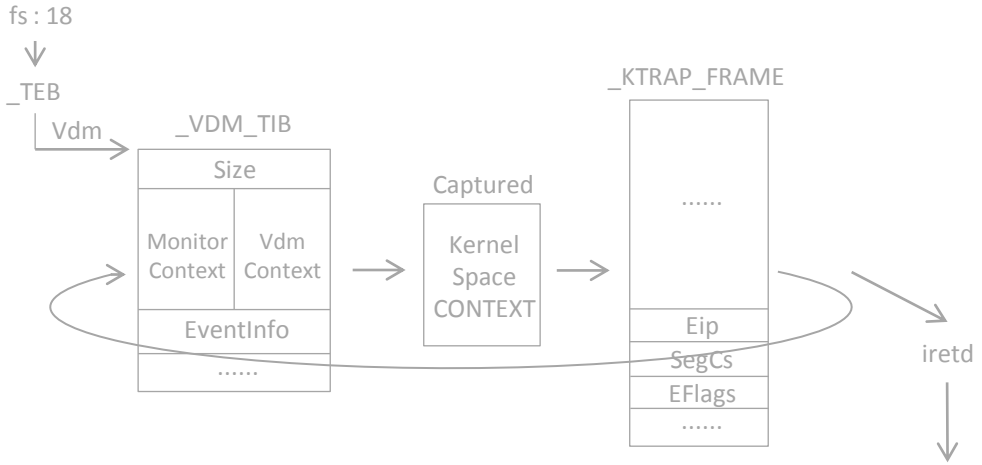
CVE-2004-0118 (nt!VdmDispatchIntAck / #GP)



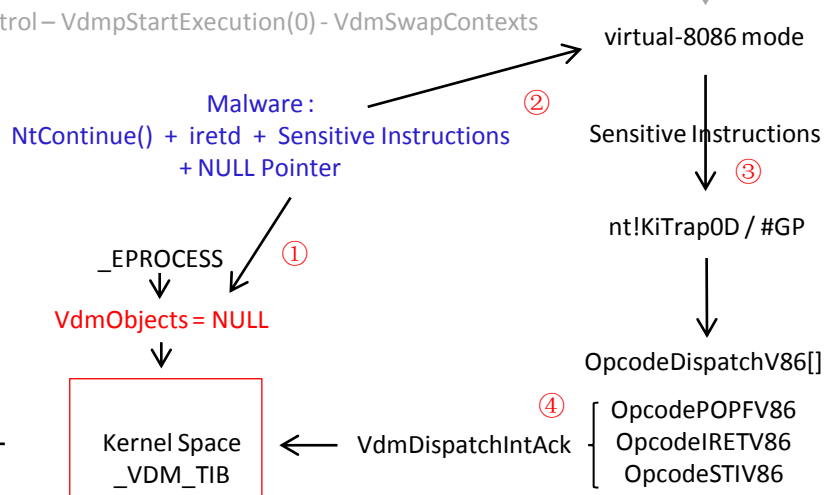
CVE-2004-0118 (nt!VdmDispatchIntAck / #GP)

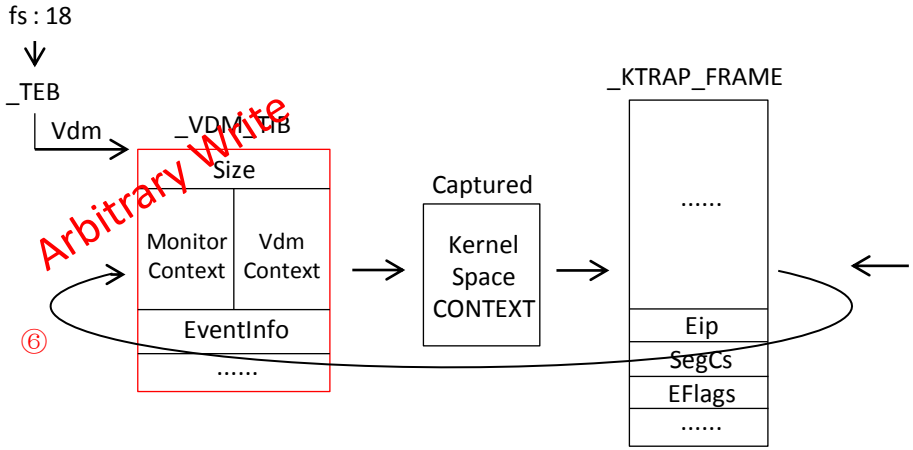


NtVdmControl – VdmInitialize(3)



NtVdmControl – VdmpStartExecution(0) - VdmSwapContexts





NtVdmControl - VdmEndExecution - VdmSwapContexts

Sensitive Instructions

20.2.7 Sensitive Instructions

When an IA-32 processor is running in virtual-8086 mode, the CLI, STI, PUSHF, POPF, INT *n*, and IRET instructions are sensitive to IOPL.
The IN, INS, OUT, and OUTS instructions, which are sensitive to IOPL in protected mode, are not sensitive in virtual-8086 mode.

Intel IA-32 Architectures SDM Vol.3B 20-10

```
FAST_V86_TRAP_D  MACRO  (Line:761)
...
mov   eax, [esp].TsSegCs      ; (eax) = H/W Cs
shl   eax,4
add   eax,[esp].TsEip         ; (eax) -> flat faulted addr
xor   edx, edx
mov   ecx, ss:[eax]           ; (ecx) = faulted instruction
mov   dl, cl
mov   dl, ss:OpcodeIndex[edx] ; (edx) =  opcode index
jmp   ss:V86DispatchTable[edx * type V86DispatchTable]
...

; V86DispatchTable - table of routines used to
; emulate instructions in v86 mode.

dtBEGIN V86DispatchTable,V86PassThrough
        dtS    VDM_INDEX_PUSHF           , V86Pushf
        dtS    VDM_INDEX_POPF            , V86Popf
        dtS    VDM_INDEX_INTnn           , V86Intnn
        dtS    VDM_INDEX_IRET            , V86Iret
        dtS    VDM_INDEX_CLI             , V86Cli
        dtS    VDM_INDEX_STI             , V86Sti
dtEND   MAX_VDM_INDEX
```

CVE-2004-0118 (nt!VdmDispatchIntAck / #GP)

POC && Mitigation

```
VdmDispatchIntAck proc  (Line:1551)

mov     eax,_VdmFixedStateLinear
test    [eax],VDM_INT_HARDWARE
mov     eax,PCR[PcPrcbData+PbCurrentThread]
mov     eax,[eax]+ThApcState+AsProcess
mov     eax,[eax].EpVdmObjects
mov     eax,[eax].VpVdmTib    ; get pointer to VdmTib
jz      short dia20

...

;
; Switch to monitor context
;

mov     dword ptr [eax].VtEIEvent,VdmIntAck
mov     dword ptr [eax].VtEIInstSize,0
mov     dword ptr [eax].VtEiIntAckInfo,0
stdCall _VdmEndExecution, <ebp, eax>
jmp short dia10

...
```

```
VdmTib = *(_Vdm_Tib **)(__readfsdword(24) + 0xF18);

if ( v714 & 1 )  // *VdmFixedStateLinear & VDM_INT_HARDWARE
{
  if ( (unsigned int)VdmTib < (unsigned int)MmUserProbeAddress )
    VdmDispatchInterrupts(TrapFrame, VdmTib);
}
else
{
  if ( (unsigned int)VdmTib < (unsigned int)MmUserProbeAddress )
  {
    VdmTib->EventInfo.Event = 3;
    VdmTib->EventInfo.InstructionSize = 0;
    *(_DWORD *)&VdmTib->EventInfo.___u3.IoInfo.PortNumber = 0;

    VdmEndExecution(TrapFrame, VdmTib);
  }
}
```

VdmDispatchIntAck:22

CVE-2010-0232 (nt!KiTrap0D / #GP)

Working out the details of the attack is left as an exercise for the reader.

Just kidding, that was an homage to Derek Soeder :-)

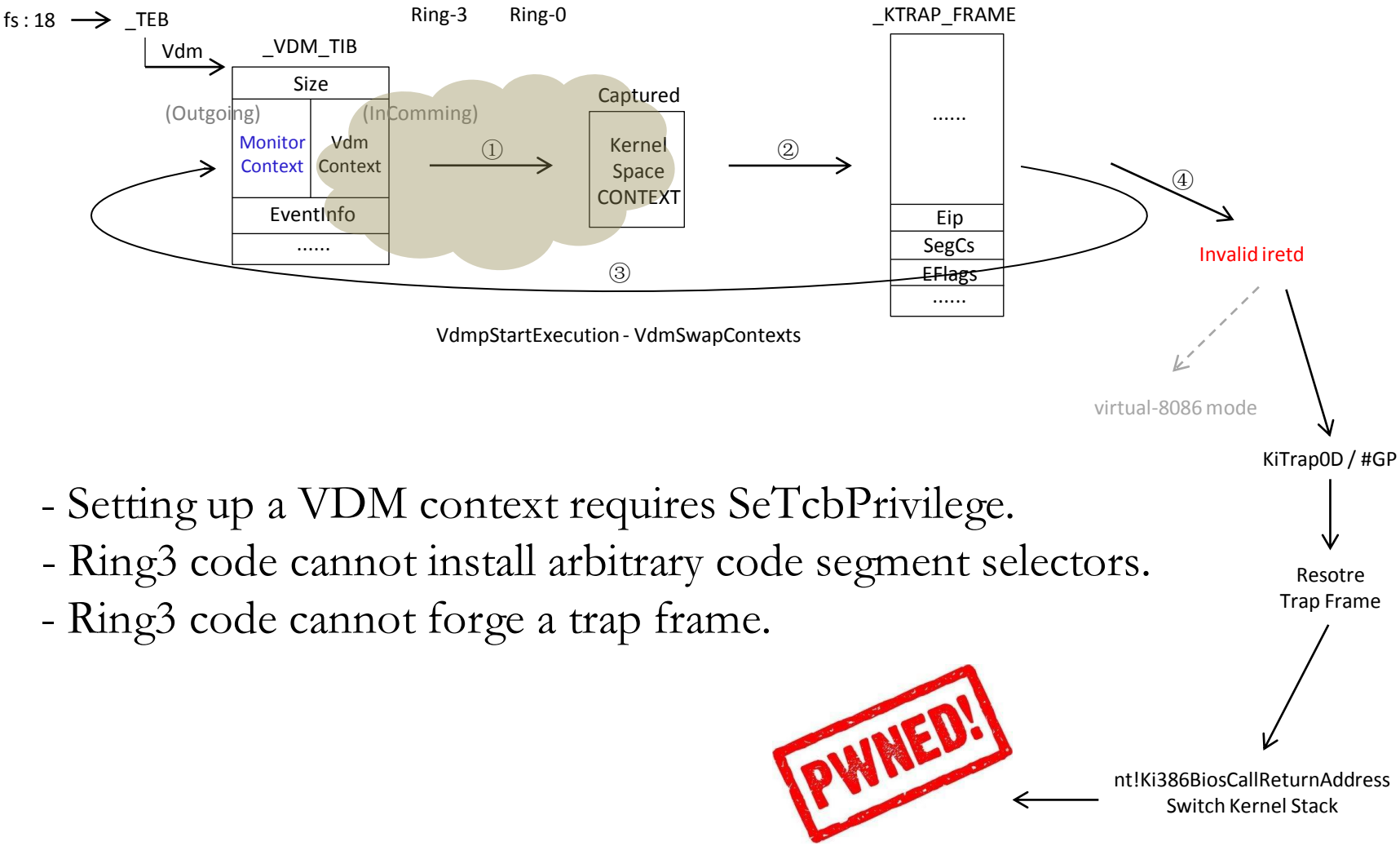
— Tavis Ormandy

CVE-2010-0232
Microsoft Windows NT #GP Trap Handler
Allows Users to Switch Kernel Stack
Best Privilege Escalation Bug, 2010.

"It's one of those rare, but fascinating design-level errors dealing with low-level system internals. Its exploitation requires skills and ingenuity.

what is important is that the two stages must be perfectly synchronised, if the kernel transitions to the second stage incorrectly, a hostile user can take advantage of this confusion to take control of the kernel and compromise the system."

CVE-2010-0232 (nt!KiTrap0D / #GP)



- Setting up a VDM context requires SeTcbPrivilege.
- Ring3 code cannot install arbitrary code segment selectors.
- Ring3 code cannot forge a trap frame.

CVE-2010-0232 (nt!KiTrap0D / #GP)

```
1: kd> p
nt!KiSystemCallExit:
80541710 cf              iretd
1: kd> dd esp
f519bdcc  80502903 0000000b 00000300 56565656
```

①

```
nt!KiTrap0D:
1: kd> dt _KTRAP_FRAME f519bd58
nt!_KTRAP_FRAME
   +0x030 SegGs            : 0
   +0x034 SegEs            : 0x23
   +0x038 SegDs            : 0x23
   +0x03c Edx              : 0x56565656
   +0x040 Ecx              : 0x56565656
   +0x044 Eax              : 0x56565656
   +0x050 SegFs            : 0x30
   +0x054 Edi              : 0x56565656
   +0x058 Esi              : 0x0217e814
   +0x05c Ebx              : 0x56565656
   +0x060 Ebp              : 0x56565656
   +0x064 ErrCode          : 8
   +0x068 Eip              : 0x80541710
   +0x06c SegCs            : 8
   +0x070 EFlags           : 0x10002
   +0x074 HardwareEsp      : 0x80502903
   +0x078 HardwareSegSs    : 0xb
```

②

```
trap.asm:
mov   eax, OFFSET FLAT:Ki386BiosCallReturnAddress
cmp   eax, [edx]                    ; [edx]= trapped eip
                                    ; Is eip what we're expecting?
jne   short Kt0d0005                ; No, continue

mov   eax, [edx]+4                  ; (eax) = trapped cs
cmp   ax, KGDT_R0_CODE OR RPL_MASK  ; Is Cs what we're exptecting?
jne   short Kt0d0005                ; No

jmp   Ki386BiosCallReturnAddress    ; with interrupts off
```

③

```
1: kd> r
eax=0000000b ebx=56565656 ecx=56560008 edx=f519bdcc esi=0217e814 edi=80541710
eip=80502903 esp=f519bd58 ebp=f519bd58 iopl=0         nv up di pl zr na pe nc
cs=0008  ss=0010  ds=0023  es=0023  fs=0030  gs=0000             efl=00000046
nt!Ki386BiosCallReturnAddress:
80502903 64a11c000000    mov     eax,dword ptr fs:[0000001Ch]
```

④

```
nt!Ki386BiosCallReturnAddress+0x18:
8050291b 8b6558          mov     esp,dword ptr [ebp+58h]
8050291e 83c404          add     esp,4
```

⑤

```
1: kd> r
eax=f78e8d70 ebx=4b4b4b4b ecx=815164e8 edx=00007ffd esi=4b4b4b4b edi=4b4b4b4b
eip=8050295b esp=0217e830 ebp=4b4b4b4b iopl=0         nv up ei pl nz na po cy
cs=0008  ss=0010  ds=0023  es=0023  fs=0030  gs=0000             efl=00000203
nt!Ki386BiosCallReturnAddress+0x58:
8050295b c20400          ret     4
```

CVE-2010-0232 (nt!KiTrap0D / #GP)

思考:

请试比较 CVE-2010-0232 和 CVE-2012-0217 的相似点。

CVE-2012-0217 : Intel's sysret Kernel Privilege Escalation

Non-canonical Address -> sysret -> #GP (with User Stack)

Invalid CS:IP -> iret -> #GP (with User Stack)

CVE-2012-2553 (ppi->pwpi Pointer Overwrite)

CVE-2012-2553
Windows Kernel VDM Use-After-Free

"As you can imagine, the code quality of the vulnerable routine wasn't (perhaps still isn't) exceptionally good; it assumed that a process would only call it once during its entire lifespan ..."

```
xxxRegisterUserHungAppHandlers:

//
//  if sucess then intialize the pwpi, ppi structs
//  else free allocated memory
//
if (bRetVal) {
    pwpi->hEventWowExecClient = hEventWowExec;
    pwpi->lpfnWowExitTask = (DWORD)pfnW32EndTask;
    ppi = PpiCurrent();
    ppi->pwpi = pwpi;

    // add to the list, order doesn't matter
    pwpi->pwpiNext = gpwpiFirstWow;
    gpwpiFirstWow  = pwpi;
    }

.....
```

```
xxxInitTask, Windows NT-4.0:

/*
* Alloc and Link in new task into the task list
*/
if ((ptdb = (PTDB)UserAllocPoolWithQuota(
                        sizeof(TDB), TAG_WOW)) == NULL)
        return STATUS_NO_MEMORY;

pti->ptdb = ptdb;

......
```

CVE-2012-2553 (ppi->pwpi Pointer Overwrite)

Mitigation

```
if ( *(_DWORD *)(v2 + 0xB0)
  || ZwQueryInformationProcess((HANDLE)0xFFFFFFFF,
  || !ProcessInformation )
{
  result = 0;
}
else
{
  pwpi = ExAllocatePoolWithQuotaTag((POOL_TYPE)41,
  result = 0;
  if ( pwpi )
  {
    memset(pwpi, 0, 0x28u);
    v5 = 1;
    v6 = ObReferenceObjectByHandle(Handle, 0x1F000
    *((_DWORD *)pwpi + 4) = Object;
    if ( v6 < 0 )
    {
      v5 = 0;
      ExFreePoolWithTag(pwpi, 0);
    }
    else
    {
      *((_DWORD *)pwpi + 5) = Handle;
      *((_DWORD *)pwpi + 3) = a1;
      *(_DWORD *)(v2 + 0xB0) = pwpi;
      *(_DWORD *)pwpi = gpwpiFirstWow;
```

xxxRegisterUserHungAppHandlers:11

效(jié)率(cāo),何在？

```
int __stdcall NtUserCallHwnd(int a1, int a2)
{
  int v2; // eax@1
  int v3; // esi@3
  int v5; // [sp+4h] [bp-Ch]@2
  int v6; // [sp+8h] [bp-8h]@2

  gptiCurrent = (struct tagBWL *)ExEnterPriorityRegionAndAcquireResourceExclusive(gpresUser);
  gbValidateHandleForIL = 1;
  v2 = ValidateHwndEx(a1, 1);
  if ( v2 )
  {
    v5 = *((_DWORD *)gptiCurrent + 48);
    *((_DWORD *)gptiCurrent + 48) = &v5;
    v6 = v2;
    ++*(_DWORD *)(v2 + 4);
    if ( (unsigned int)(a2 - 77) > 4 )
      v3 = 0;
    else
      v3 = ((int (__stdcall *)(int))apfnSimpleCall[a2])(v2);
```

Never Stop Exploring !

CVE-2007-1206, Derek Soeder

CVE-2010-3941, Tarjei Mandt

CVE-2013-3196, j00ru

CVE-2013-3197, j00ru

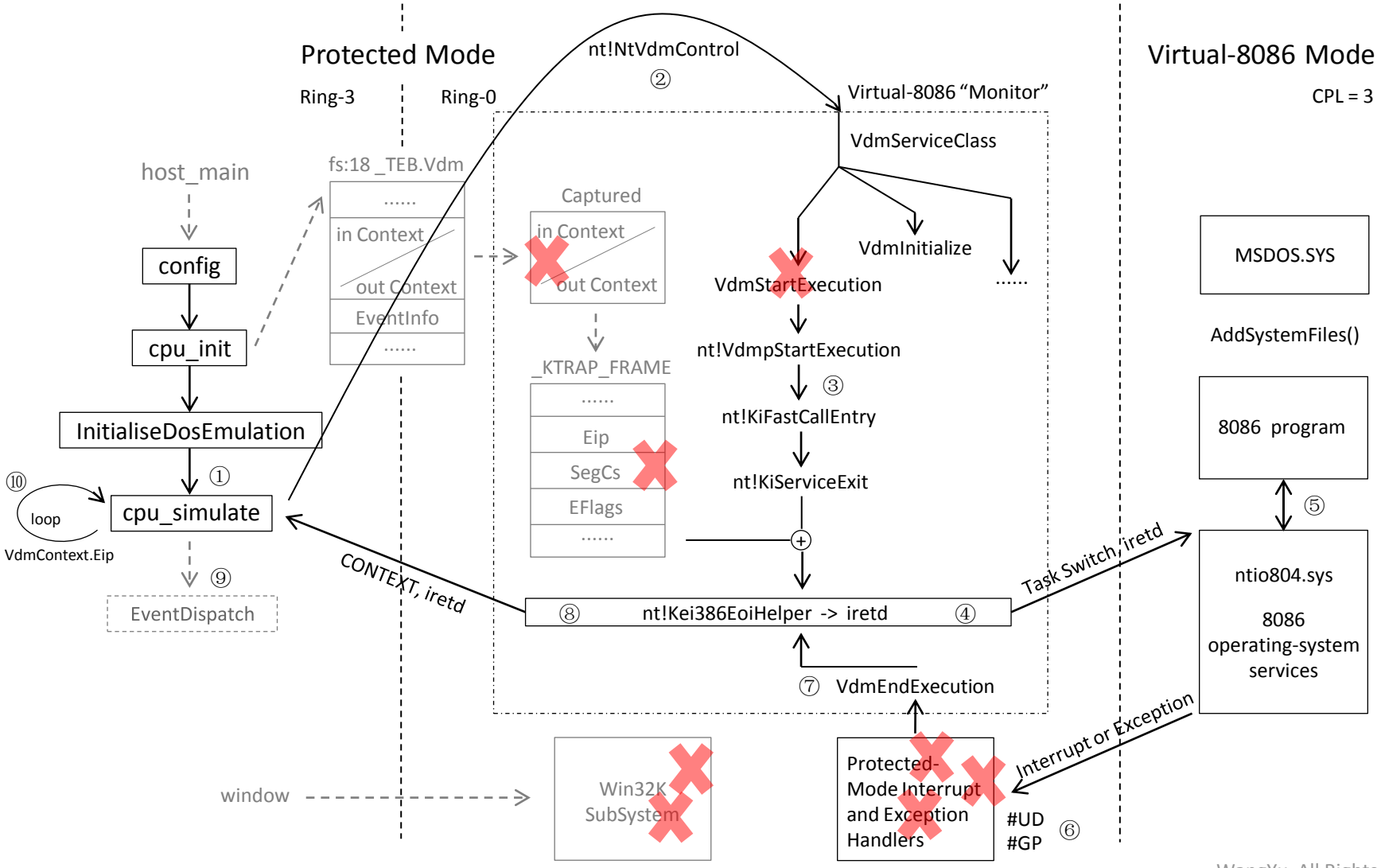
CVE-2013-3198, j00ru

……

第四部分

思考与启示

思考与启示



思考与启示

从架构的角度看待：

一切输入都是有害的，守好你的代码边界

从攻击的角度看待：

扎实基础，注重积累，将攻击知识融会贯通

从防御的角度看待：

无知者无畏，未知攻焉知防？

Welcome to the Cyberwar Arms Race.

— Bruce Schneier

致谢!

P1P1Winner PJF Bugvuln Royce Lu

MJ0011 Yajin Zhou Xuxian Jiang Prof.

360 Wireless Security Research Institute

360 Safe Team SyScan Fan.Tuan

Q&A

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