Malware Dynamic Analysis
Part 3

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http://opensecuritytraining.info/MalwareDynamicAnalysis.html

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Where are we at?

- Part 3: Maneuvering techniques
  - (How malware strategically positions itself to access critical resources)
  - DLL/code injection
  - DLL search order hijacking...
- Part 4: Malware functionality
  - Keylogging, Phone home, Security degrading, Self-destruction, etc.

See notes for citation

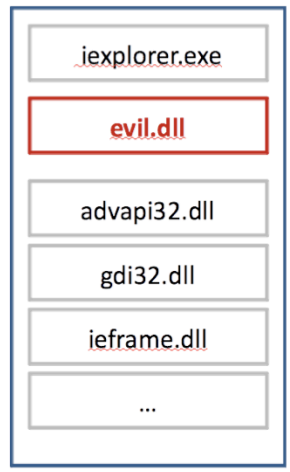
Maneuvering

- DLL injection
- Direct code injection
- DLL search order hijacking
- Asynchronous Procedure Call (APC) injection
- IAT/EAT hooking
- Inline hooking

See notes for citation

DLL/code Injection

- Load a malicious DLL/code into one or more processes
- Run malicious code on behalf of a legitimate process
- Bypass host-based security software
  - HIDS, Personal Firewall



IE process's memory

See notes for citation

DLL Injection Methods (1)

- AppInit_DLLs
  - HKLM\Software\Microsoft\Windows NT \CurrentVersion\Windows\AppInit_DLLs is set to a space or comma separated list of DLLs to load into processes that load user32.dll
  - On Windows Vista and newer you also have to set a few other values in that path like LoadAppInit_DLLs = 1 and RequireSignedAppInit_DLLs = 0

See notes for citation

[References]

- Michael Ligh et al., Chapter 9. Dynamic Analysis, Malware Analyst's Cookbook and DVD
- AppInit_DLLs in Windows 7 and Windows Server 2008 R2, http://msdn.microsoft.com/en-us/library/windows/desktop/dd744762(v=vs.85).aspx

Observing Parite's Maneuvering

- Using Regshot on the *victim* VM
  1) Start Regshot (MalwareClass/tools/ v5_regshot_1.8.3...)
  2) Click *1st shot* button→Shot
  3) Run parite/malware.exe
  4) Click *2nd shot* button→Shot
  5) Click *Compare* button

Q1. Which DLL is used for maneuvering?

Q2. Where is it maneuvering?

Q3. Open question:
Any theories why it's maneuvering to there?

See notes for citation

[References]

- Application programming interface, http://en.wikipedia.org/wiki/Application_programming_interface

Answers for Parite Lab

A1. “fmsiopcps.dll” is added to HKLM\Software\Microsoft\Windows NT\CurrentVersion\Windows\AppInit_DLLs

A2. All Windows applications, which use user32.dll

See notes for citation

Application Programming Interface (API)

- "Specifies a software component in terms of its operations, their inputs and outputs and underling types"

  http://en.wikipedia.org/wiki/Application_programming_interface

- char *strncpy(char *dest, const char *src, size_t n);
  - 3 inputs:
    - dest: destination string
    - src: source string
    - n: number of characters to copy from source string
  - 1 output: returns a pointer to the destination string

See notes for citation 9

[References]

- Application programming interface, http://en.wikipedia.org/wiki/Application_programming_interface
- strcpy(3) - Linux man page, http://linux.die.net/man/3/strcpy

DLL Injection Methods (2)

- CreateRemoteThread Windows API
  - Manipulate a victim process to call LoadLibrary with the malicious DLL name
  - Malicious code is located in DllMain, which is called once a DLL is loaded into memory
  - A common API call pattern:
    - OpenProcess→VirtualAllocEx→WriteProcessMemory→GetModuleHandle→GetProcAddress→CreateRemoteThread
- Also, a direct code injection method

See notes for citation

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[References]

- Michael Sikorski et al., Chapter 12. Covert Malware Launching, Practical Malware Analysis

OpenProcess→VirtualAllocEx→ WriteProcessMemory→
GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
HANDLE WINAPI OpenProcess(
  _In_ DWORD dwDesiredAccess,
  _In_ BOOL bInheritHandle,
  _In_ DWORD dwProcessId
);
```

- dwProcessId [in]
  - The identifier of the local process to be opened...
- Return value
  - If the function succeeds, the return value is an open handle to the specified process...

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[References]

- OpenProcess function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms684320(v=vs.85).aspx

OpenProcess→VirtualAllocEx→ WriteProcessMemory→ GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
LPVOID WINAPI VirtualAllocEx(
  _In_       HANDLE hProcess,
  _In_opt_   LPVOID lpAddress,
  _In_       SIZE_T dwSize,
  _In_       DWORD flAllocationType,
  _In_       DWORD flProtect
);
```

- hProcess [in]
  - The handle to a process. The function allocates memory within the virtual address space of this process...
- dwSize [in]
  - The size of the region of memory to allocate, in bytes...
- Return value
  - If the function succeeds, the return value is the base address of the allocated region of pages...

See notes for citation 12

[References]

- VirtualAllocEx function, http://msdn.microsoft.com/en-us/library/windows/desktop/aa366890(v=vs.85).aspx

OpenProcess→VirtualAllocEx→ WriteProcessMemory→ GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
BOOL WINAPI WriteProcessMemory(
  _In_   HANDLE hProcess,
  _In_   LPVOID lpBaseAddress,
  _In_   LPCVOID lpBuffer,
  _In_   SIZE_T nSize,
  _Out_  SIZE_T *lpNumberOfBytesWritten
);
```

- hProcess [in]
  - A handle to the process memory to be modified…
- lpBaseAddress [in]
  - A pointer to the base address in the specified process to which data is written…
- lpBuffer [in]
  - A pointer to the buffer that contains data to be written in the address space of the specified process.
- nSize [in]
  - The number of bytes to be written to the specified process.

See notes for citation

[References]

- WriteProcessMemory function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms681674(v=vs.85).aspx

OpenProcess→VirtualAllocEx→ WriteProcessMemory→
GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
HMODULE WINAPI GetModuleHandle(
  _In_opt_  LPCTSTR lpModuleName
);
```

- pModuleName [in, optional]
  - The name of the loaded module (either a .dll or .exe file)…
- Return value
  - If the function succeeds, the return value is a handle to the specified module…

See notes for citation

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[References]

- GetModuleHandle function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms683199(v=vs.85).aspx

OpenProcess→VirtualAllocEx→ WriteProcessMemory→ GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
FARPROC WINAPI GetProcAddress(
  _In_  HMODULE hModule,
  _In_  LPCSTR lpProcName
);
```

- hModule [in]
  - A handle to the DLL module that contains the function or variable...
- lpProcName [in]
  - The function or variable name, or the function's ordinal value...
- Return value
  - If the function succeeds, the return value is the address of the exported function or variable...

See notes for citation 15

[References]

- GetProcAddress function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms683212(v=vs.85).aspx

OpenProcess→VirtualAllocEx→ WriteProcessMemory→ GetModuleHandle→ GetProcAddress→CreateRemoteThread

```
HANDLE WINAPI CreateRemoteThread(
  _In_  HANDLE hProcess,
  _In_  LPSECURITY_ATTRIBUTES lpThreadAttributes,
  _In_  SIZE_T dwStackSize,
  _In_  LPTHREAD_START_ROUTINE lpStartAddress,
  _In_  LPVOID lpParameter,
  _In_  DWORD dwCreationFlags,
  _Out_  LPDWORD lpThreadId
);
```

- hProcess [in]
  - A handle to the process in which the thread is to be created...
- lpStartAddress [in]
  - A pointer to the application-defined function of type LPTHREAD_START_ROUTINE to be executed by the thread and represents the starting address of the thread in the remote process...
- lpParameter [in]
  - A pointer to a variable to be passed to the thread function.

See notes for citation

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[References]

- CreateRemoteThread function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms682437(v=vs.85).aspx
- LPTHREAD_START_ROUTINE Function Pointer, http://msdn.microsoft.com/en-us/library/aa964928(v=vs.110).aspx

CreateRemoteThread() cont.

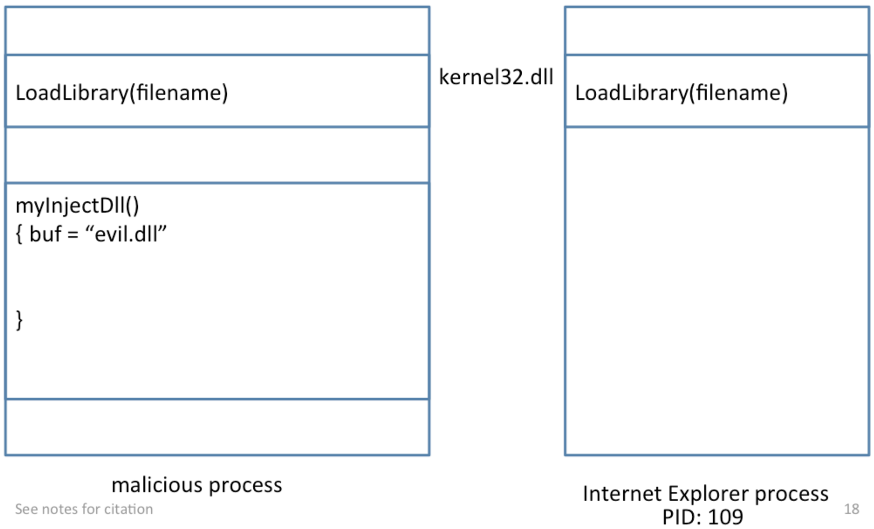
- lpStartAddress's type is LPTHREAD_START_ROUTINE, which is defined as

```
typedef DWORD (__stdcall *LPTHREAD_START_ROUTINE) (
    [in] LPVOID lpThreadParameter
);
```

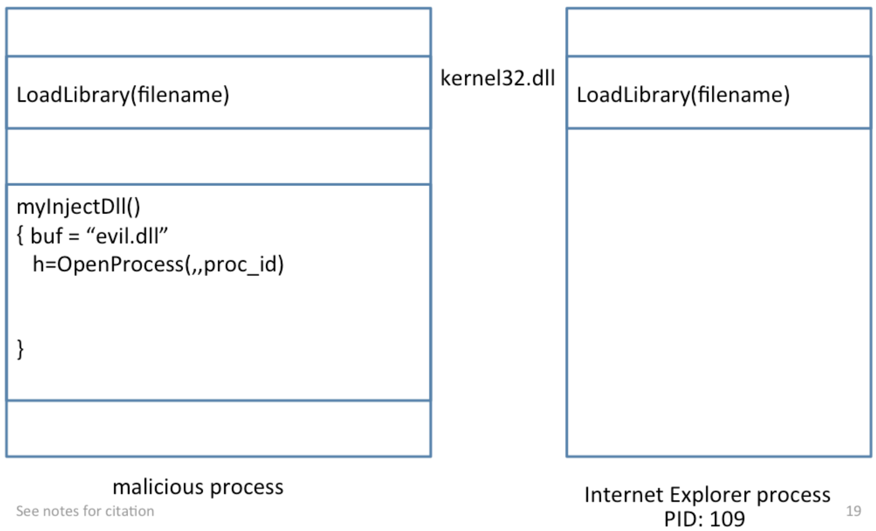
- You can't put any function as lpStartAddress. It has to be one which matches the above prototype.
- One (popular) example is

```
HMODULE WINAPI LoadLibrary(
    _In_  LPCTSTR lpFileName
);
```

DLL Injection API Call Example



DLL Injection API Call Example



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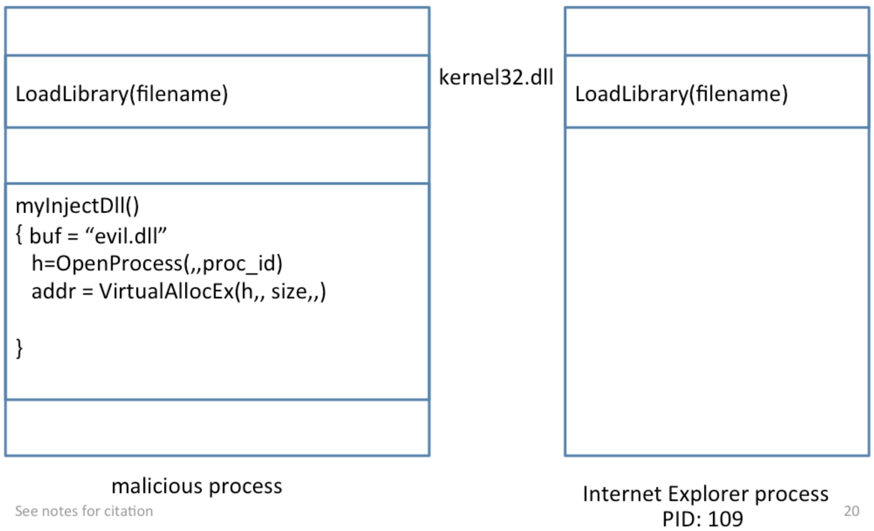
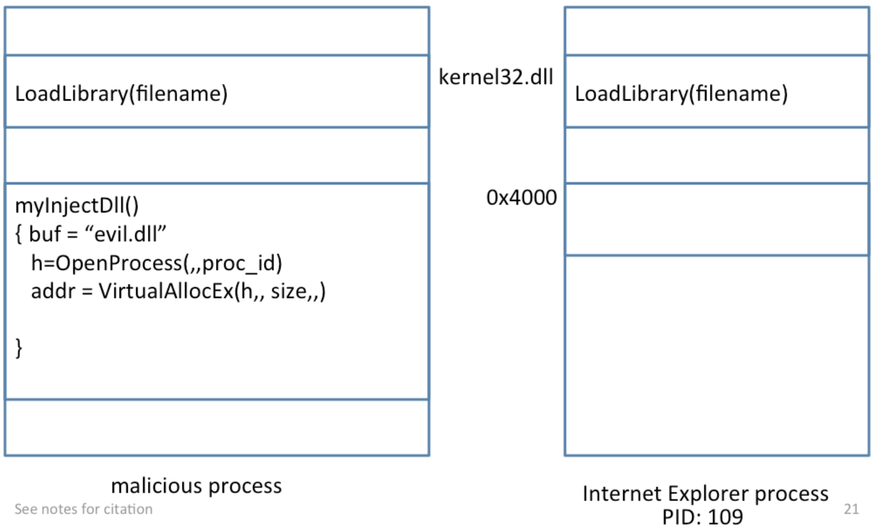
DLL Injection API Call Example



See notes for citation

DLL Injection API Call Example



See notes for citation

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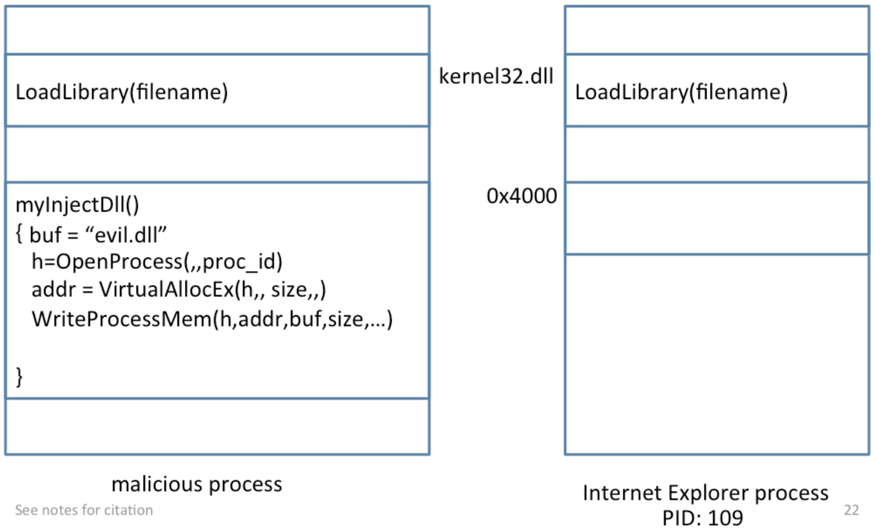
DLL Injection API Call Example



See notes for citation

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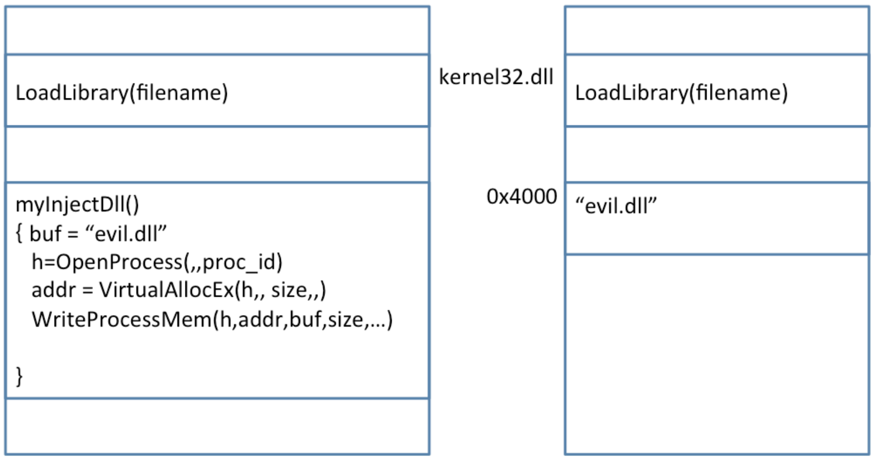
DLL Injection API Call Example

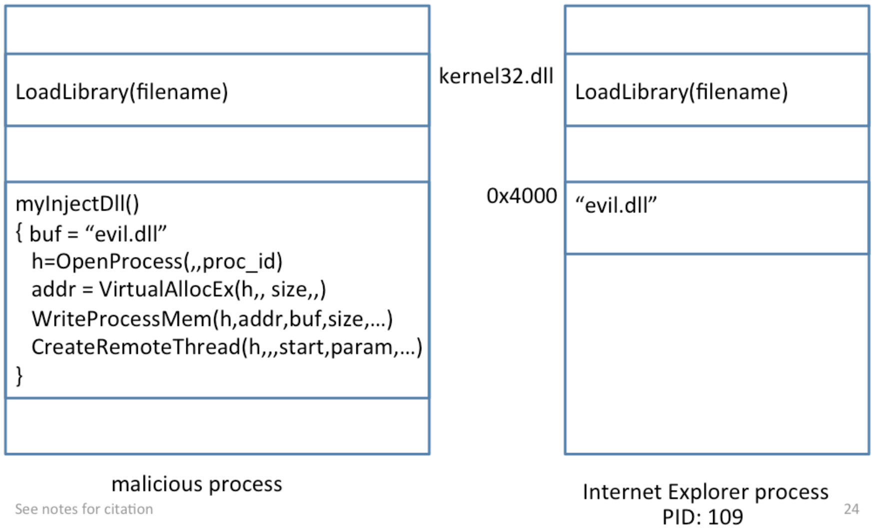


malicious process

Internet Explorer process
PID: 109

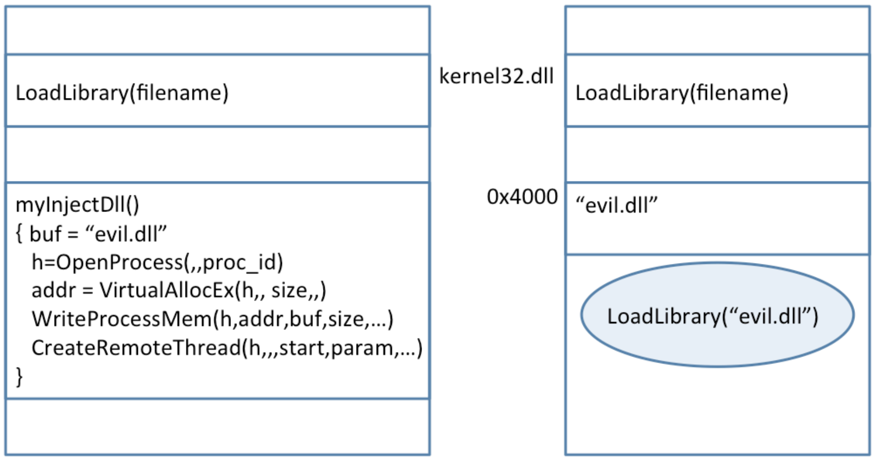
See notes for citation

DLL Injection API Call Example



See notes for citation

DLL Injection API Call Example



malicious process

Internet Explorer process
PID: 109

See notes for citation

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Observing "Onlinegame2" Maneuvering

- For this lab, we will use WinApiOverride (an API monitor) to analyze onlinegames/**2**/malware.exe
- Hint: new process will be invoked

Q1. What is the address of LoadLibrary()?

Q2. Where is it maneuvering to?

Q3. What's the path of the DLL being injected?

See notes for citation

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Answers for "Onlinegame2" Lab

A1. 0x7C801D7B

A2. Explorer.exe, OpenProcess takes PID as its parameter

A3. C:\WINDOWS\system32\ailin.dll

See notes for citation

Observing "Onlinegame1" Maneuvering

- Spot the direct code injection
- Use WinApiOverride (an API monitor) to analyze onlinegames/**1**/malware.exe

Q1. What is the size of the code being injected?

Q2. Where is it maneuvering?

Q3. What's the path of DLL being injected?

- Take a dump of the process using Process Explorer.

See notes for citation

Answers for "Onlinegame1" Lab

A1. 0x457

A2. Explorer.exe, OpenProcess takes PID as its parameter

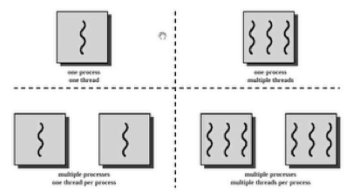
A3. C:\Windows\System32\nmdfgds0.dll

- Process Explorer provides process memory dump. In order to open the dump file, use windbg's File→Open Dump menu option

See notes for citation

Thread

- AKA light weight process who has own program counter (EIP), a register set, and a stack
- Multiple threads can exist in a process and share a process's resources, such as opened file and network connection, concurrently
- Thread context switching is much cheaper than process context switching

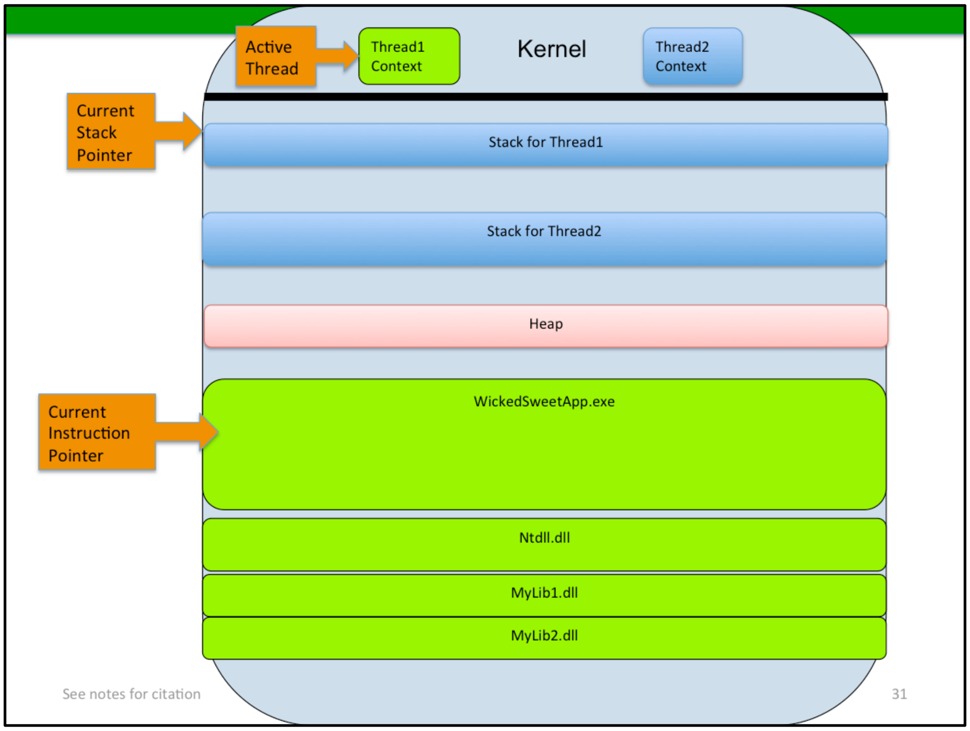


See notes for citation

30

[References]
- Silberscharz Galvin, Chapter 5 Threads, Operating System Concepts 5th Edition

[Image Sources]
- http://www.cs.cf.ac.uk/Dave/C/mthread.gif


Active Thread
Thread1 Context
Kernel
Thread2 Context
Current Stack Pointer
Stack for Thread1
Stack for Thread2
Heap
Current Instruction Pointer
WickedSweetApp.exe
Ntdll.dll
MyLib1.dll
MyLib2.dll
See notes for citation
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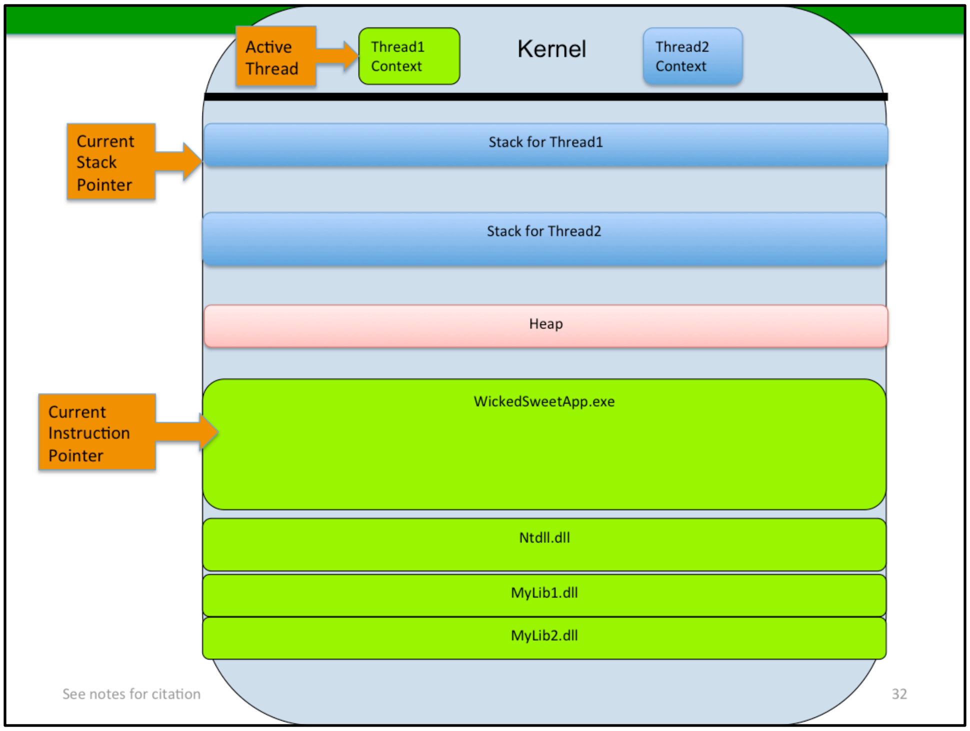
Active Thread
Thread1 Context
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Current Stack Pointer
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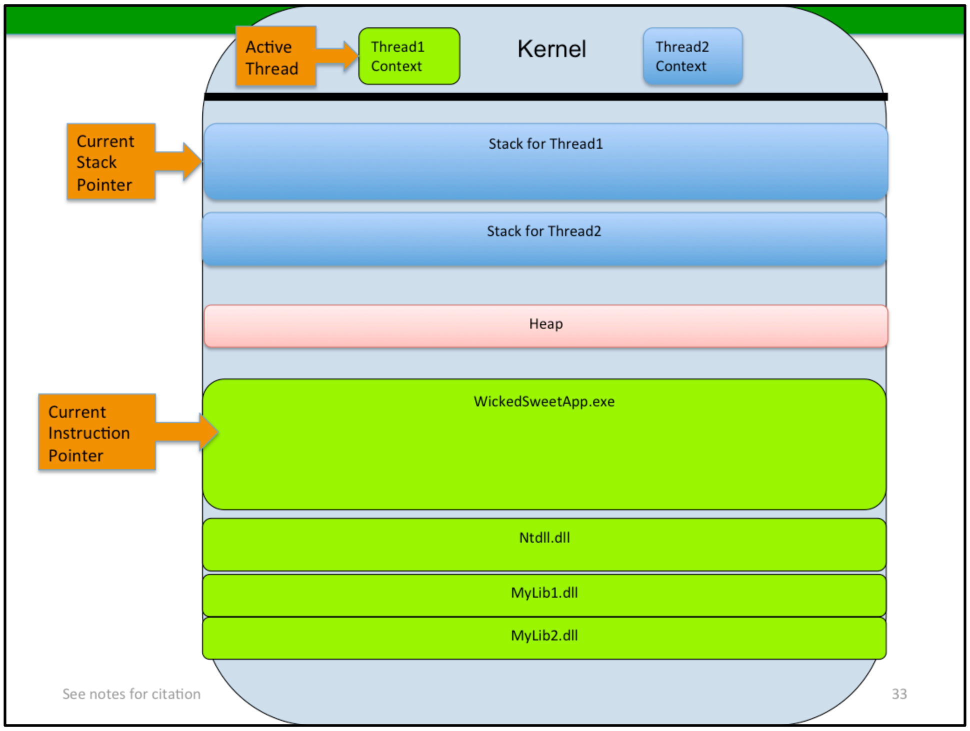
See notes for citation
32


Active Thread
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WickedSweetApp.exe
Ntdll.dll
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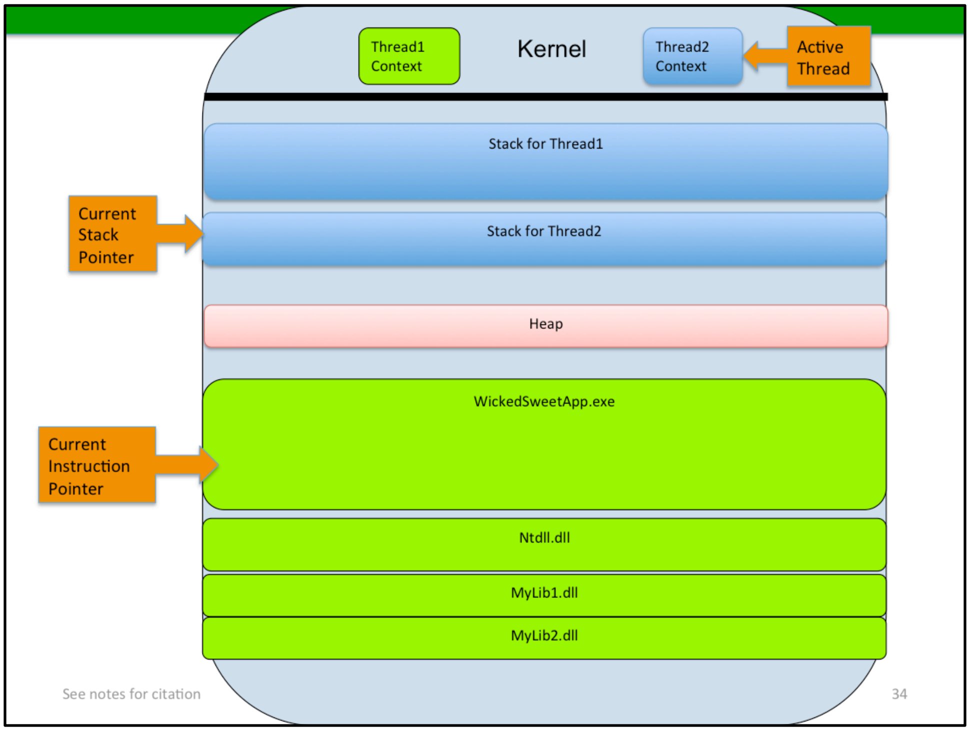
MyLib2.dll
See notes for citation
33


Thread1 Context
Kernel
Thread2 Context
Active Thread
Stack for Thread1
Current Stack Pointer
Stack for Thread2
Heap
WickedSweetApp.exe
Current Instruction Pointer
Ntdll.dll
MyLib1.dll
MyLib2.dll
See notes for citation
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DLL Injection Methods (3a)

- SetWindowsHookEX Windows API
  - Monitor certain types of events (e.g. key strokes)
  - HHOOK WINAPI SetWindowsHookEx(

```
  _In_  int idHook,
  _In_  HOOKPROC lpfn,
  _In_  HINSTANCE hMod,
  _In_  DWORD dwThreadId
);
```

See notes for citation

[References]

- Michael Sikorski et al., Chapter 12. Covert Malware Launching, Practical Malware Analysis
- SetWindowsHookEx function, http://msdn.microsoft.com/en-us/library/windows/desktop/ms644990(v=vs.85).aspx

DLL Injection Methods (3b)

- If dwThreadId is zero, it injects DLL into memory space of every process in the same Windows “desktop” (which is a memory organization term, not the desktop you see when looking at your computer)
- If dwThreadId belongs to another process, it injects DLL into the process
- For the sake of simple DLL injection, use uncommon message type (e.g. WH_CBT)

See notes for citation

DLL Injection Methods (4)

- Codecave (*a redirection of program execution to another location and then returning back to the area where program execution had previously left.*)
  - Inject a snippet of code, which calls LoadLibrary, to a victim process
  - Suspend a thread in the victim process and restart the thread with the injected code
  - API call pattern
    - OpenProcess → VirtualAllocEx → WriteProcessMemory → SuspendThread → GetThreadContext → SetThreadContext → ResumeThread

[References]

- Darawk, DLL Injection, http://www.blizzhackers.cc/viewtopic.php?p=2483118

Maneuvering

- DLL injection
- Direct code injection
- DLL search order hijacking
- Asynchronous Procedure Call (APC) injection
- IAT/EAT hooking
- Inline hooking

See notes for citation

DLL Search Order Hijacking (1)

- (default) DLL search order in Windows XP SP3
  1. KnownDLLs and its dependent DLLs HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet \Control\Session Manager\KnownDLLs
  2. Directory from which the application loaded
  3. System directory (e.g. c:\WINDOWS\system32)
  4. 16-bit System Directory (e.g. c:\WINDOWS\system)
  5. Windows Directory
  6. Current working directory
  7. Directories in %Path%

[References]

- Dynamic-Link Library Search Order (Windows), http://msdn.microsoft.com/en-us/library/windows/desktop/ms682586(v=vs.85).aspx

DLL Search Order Hijacking (2)

- Also an obfuscated method to be persistent
- A malware can make a legitimate looking DLL
  - Loaded by an application
  - In the directory where the application is located or the current working directory
  - Which is not listed in KnownDLLs and its dependent DLLs
  - Identically named dll as the one in system32 directory

See notes for citation

[References]

- Nick Harbour, Malware Persistence without the Windows Registry, https://www.mandiant.com/blog/malware-persistence-windows-registry/

Checking KnownDLLs

- Use Regedit
  1) Start →Run.. →regedit
  2) Search for the following registry key HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet \Control\Session Manager\KnownDLLs
- Use Winobj.exe to see all dependent DLLs of KnownDLL
  – On desktop, SysinternalSuite\Winobj.exe
  – Check \KnownDlls

See notes for citation

Observing Nitol's Maneuvering

- For this lab, we will use Process Monitor to analyze nitol/malware.exe

Q1. Which DLL is used for maneuvering?

Q2. Where is it maneuvering to?

Q3. Open question: Any theories why it’s maneuvering to there?

Q4. Bonus question: How does it persist?

See notes for citation

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[References]

- Microsoft Digital Crimes Unit, Operation b70, http://blogs.technet.com/cfs-file.ashx/__key/communityserver-blogs-components-weblogfiles/00-00-00-80-54/3755.Microsoft-Study-into-b70.pdf
- Rex Plantado, MSRT October '12 - Nitol: Counterfeit code isn't such a great deal after all, http://blogs.technet.com/b/mmpc/archive/2012/10/15/msrt-october-12-nitol-counterfeit-code-isn-t-such-a-great-deal-after-all.aspx

Answers for Nitol Lab

A1. lpk.dll was written to multiple directories where executable files exist

- C:\Program Files\Internet Explorer\lpk.dll
  C:\Program Files\Messenger\lpk.dll etc.
- Check where lpk.dll is loaded from with iexplorer.exe

A2. All executable which has lpk.dll in the same directory and uses lpk.dll

Just for fun, 基础类应用程序 means “Foundation Classes application” according to Google Translate

Maneuvering

- DLL injection
- Direct code injection
- DLL search order hijacking
- Asynchronous Procedure Call (APC) injection
- IAT/EAT hooking
- Inline hooking

See notes for citation

Asynchronous Procedure Call (APC) Injection

- A function executed asynchronously when a thread is in an alertable state
- A thread enters to alertable states when it calls some functions such as SleepEx, WaitForSingleObjectEx, WaitForMultipleObjectEx
- Each thread has a queue of APCs
- Kernel-mode APC is generated by the system
- User-mode APC is generated by an application
- API call pattern
  - OpenThread→QueueUserAPC
  - From kernel-space to run user-mode code: KeInitializeAPC→KeInsertQueueApc

See notes for citation

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[References]

- Michael Sikorski et al., Chapter 12. Covert Malware Launching, Practical Malware Analysis

IAT/EAT Hooking

- Import Address Table (IAT) holds addresses of dynamically linked library functions
- Export Address Table (EAT) holds addresses of functions a DLL allows other code to call
- Overwrite one or more IAT/EAT entries to redirect a function call to the attacker controlled code
- IAT hooking only affects a module
- EAT hooking affects all modules loaded after EAT hooking takes place
- IAT & EAT hooking only affect one process memory space

See notes for citation

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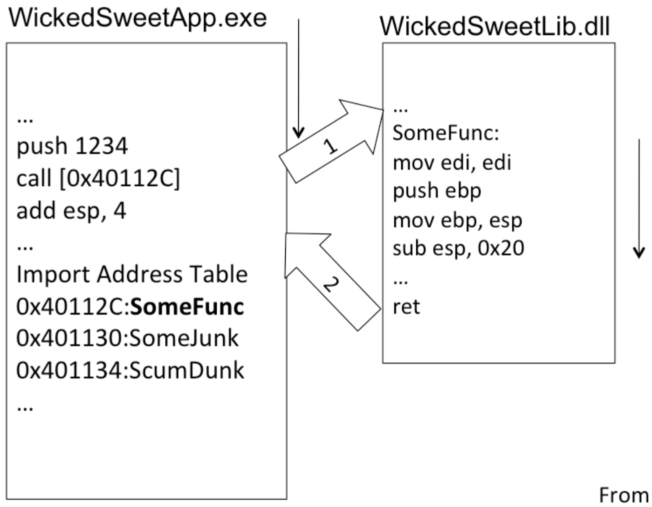
[References]

- Xeno Kovah, Rookits: What they are, and how to find them, http://opensecuritytraining.info/Rootkits.html

Normal Inter-Module Function Call



From the Rootkits class

See notes for citation

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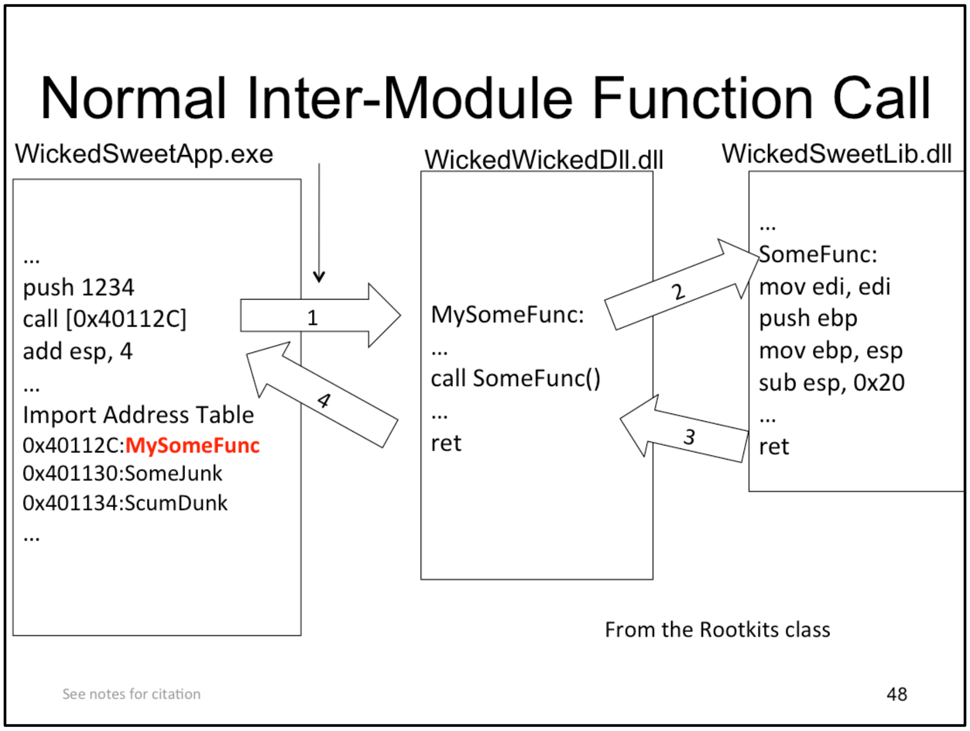
Normal Inter-Module Function Call
WickedSweetApp.exe
...
push 1234
call [0x40112C]
add esp, 4
...
Import Address Table
0x40112C:MySomeFunc
0x401130:SomeJunk
0x401134:ScumDunk
...
1
4
WickedWickedDll.dll
MySomeFunc:
...
call SomeFunc()
...
ret
2
3
WickedSweetLib.dll
...
SomeFunc:
mov edi, edi
push ebp
mov ebp, esp
sub esp, 0x20
...
ret
From the Rootkits class
See notes for citation
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Inline Hooking

- There are a few first meaningless bytes at the beginning of a function for hooking if it is compiled with /hotpatch option
- Overwrite the first 5 or so bytes of a function with jump to the attacker's code
- This redirect the program control from the called function to the malicious code
- Execute any instructions overwritten in the first 5 bytes as the last part of the malicious code before jumping back to wherever it came from

See notes for citation

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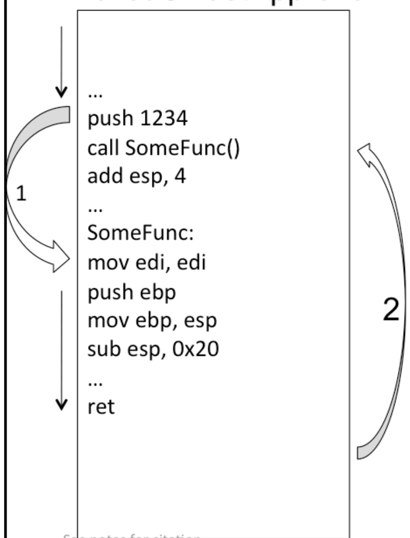
[References]

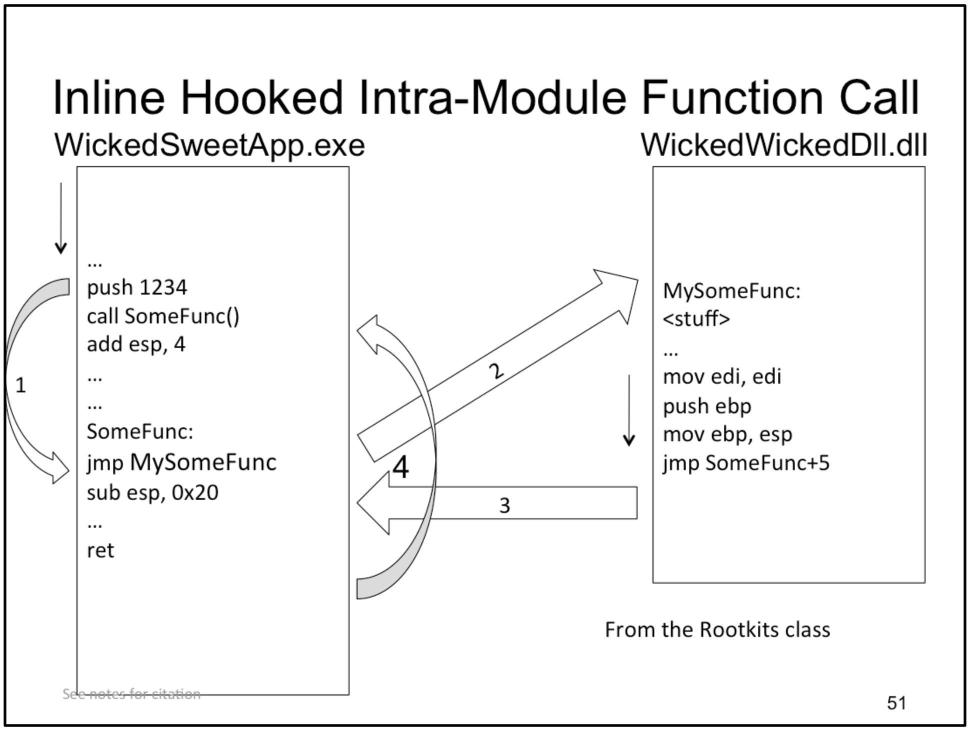
- /hotpatch (Create Hotpatchable Image), http://msdn.microsoft.com/en-us/library/ms173507.aspx
- Greg Hoglund et al., Chapter 4. The Age-Old Art of Hooking, Rootkits

Normal Intra-Module Function Call

WickedSweetApp.exe



From the Rootkits class


Inline Hooked Intra-Module Function Call
WickedSweetApp.exe
WickedWickedDll.dll
...
push 1234
call SomeFunc()
add esp, 4
...
...
SomeFunc:
jmp MySomeFunc
sub esp, 0x20
...
ret
1
2
3
4
MySomeFunc:
<stuff>
...
mov edi, edi
push ebp
mov ebp, esp
jmp SomeFunc+5
From the Rootkits class
See notes for citation
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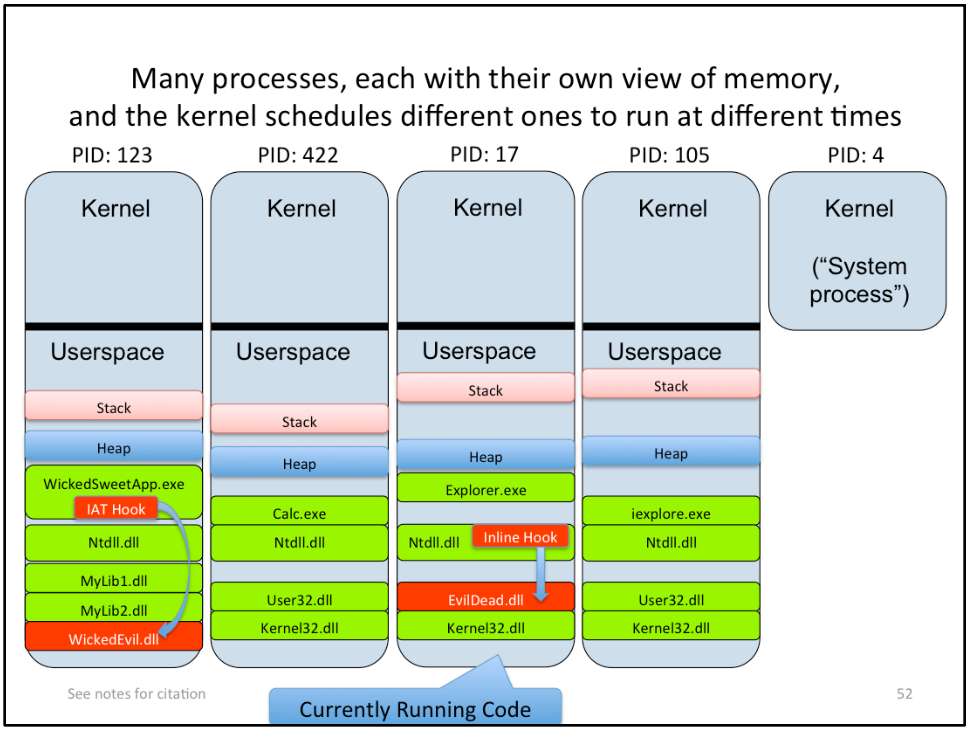
Many processes, each with their own view of memory,
and the kernel schedules different ones to run at different times
PID: 123
PID: 422
PID: 17
PID: 105
PID: 4
Kernel
Kernel
Kernel
Kernel
Kernel
("System process")
Userspace
Stack
Heap
WickedSweetApp.exe
IAT Hook
Ntdll.dll
MyLib1.dll
MyLib2.dll
WickedEvil.dll
Userspace
Stack
Heap
Calc.exe
Ntdll.dll
User32.dll
Kernel32.dll
Userspace
Stack
Heap
Explorer.exe
Ntdll.dll
Inline Hook
EvilDead.dll
Kernel32.dll
Userspace
Stack
Heap
iexplore.exe
Ntdll.dll
User32.dll
Kernel32.dll
See notes for citation
Currently Running Code
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