Combating Malware in the age of APT

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Jason Garman

CTO, Kyrus Technology

New directions for malware

- Malicious code used in APT attacks are usually:
  - Not “sexy” – the simple techniques work well!
  - To some extent, custom
    - Not widely disseminated = not picked up by AV
    - Not necessarily custom code but custom “packaging”
  - Highly targeted
    - Mostly a factor of the delivery mechanism, spear-phishing email, web link, etc.
  - Modular
    - Monolithic binary is risky; reveals too much about the MO, capabilities of the attacker

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Modular?

- Historically your neighborhood script kiddie had one of two choices for his exploitation tools:
  - The Unix way: a lot of tools, each one does a certain function very, very well
  - The Microsoft Word way: one tool to rule them all, contains all the functionality plus the kitchen sink

- However both of these techniques have drawbacks
  - The Unix way inevitably leads to tools that have vastly different interfaces, difficult learning curve
  - The Word way helps ensure a consistent interface but exposes all of your capabilities at once to the malware analyst

Modular Implants vs. Memory Analysis

- These modular implants pose a significant challenge to the incident responder
  - No longer is the entire binary (or binaries) available for viewing and analysis from the disk
  - Now we must fuse together the results of traditional malware analysis with the volatile data acquisition

- Malware authors will continue to improve in this arena
  - Freeing unused memory as soon as it is no longer necessary
  - Zeroing out sensitive memory areas after use

- Will need more research and development to keep pace with the malicious code authors!

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Case Study: Poison Ivy

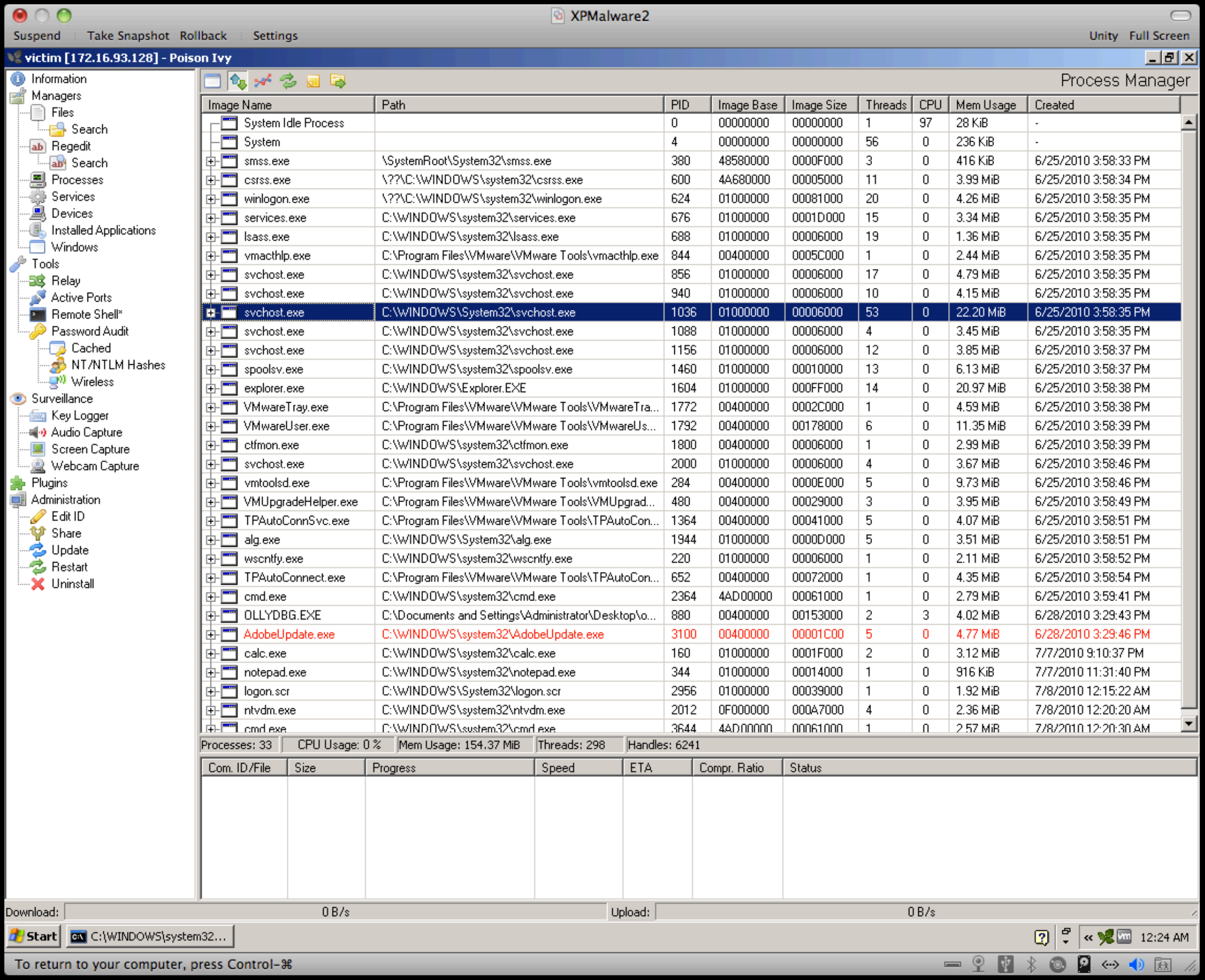
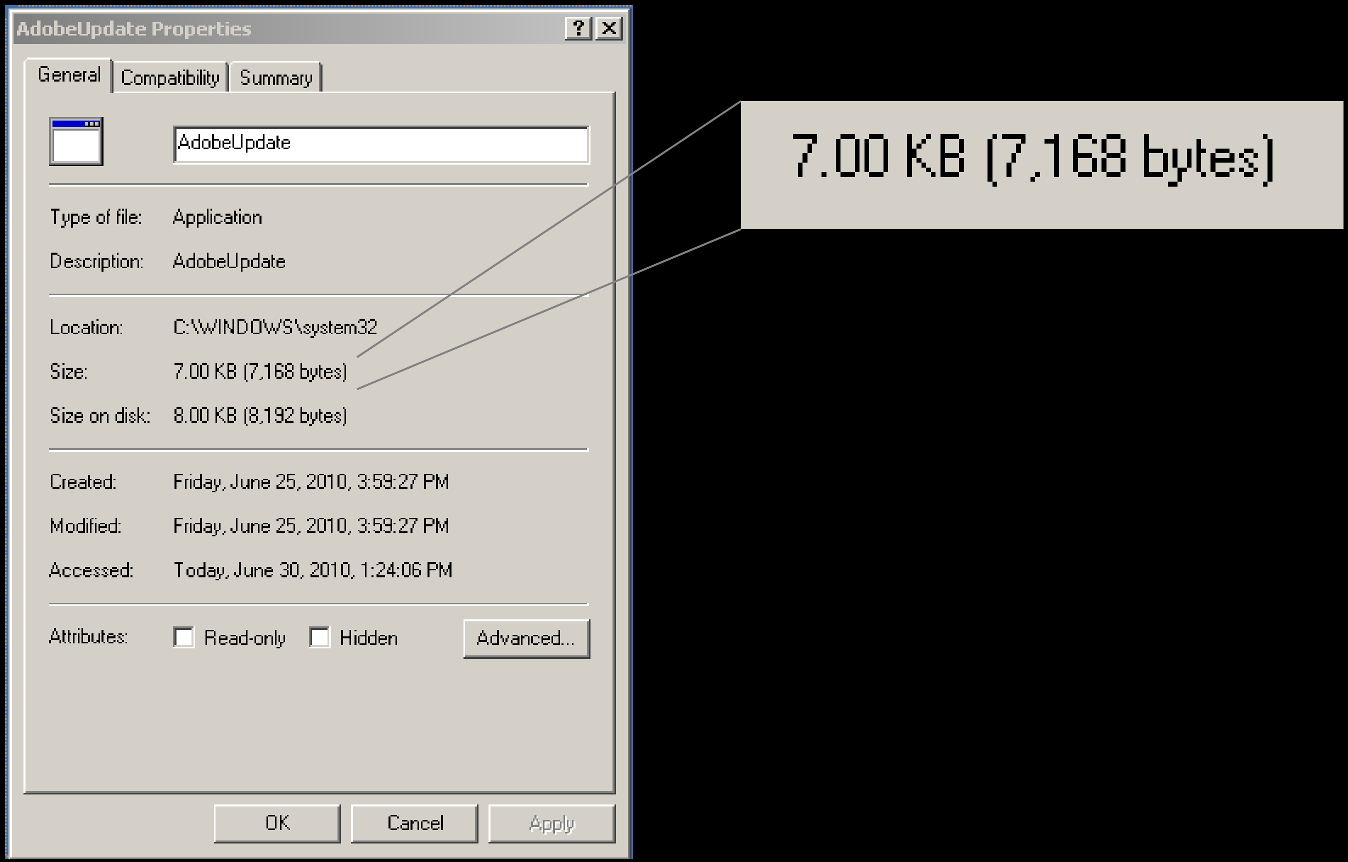
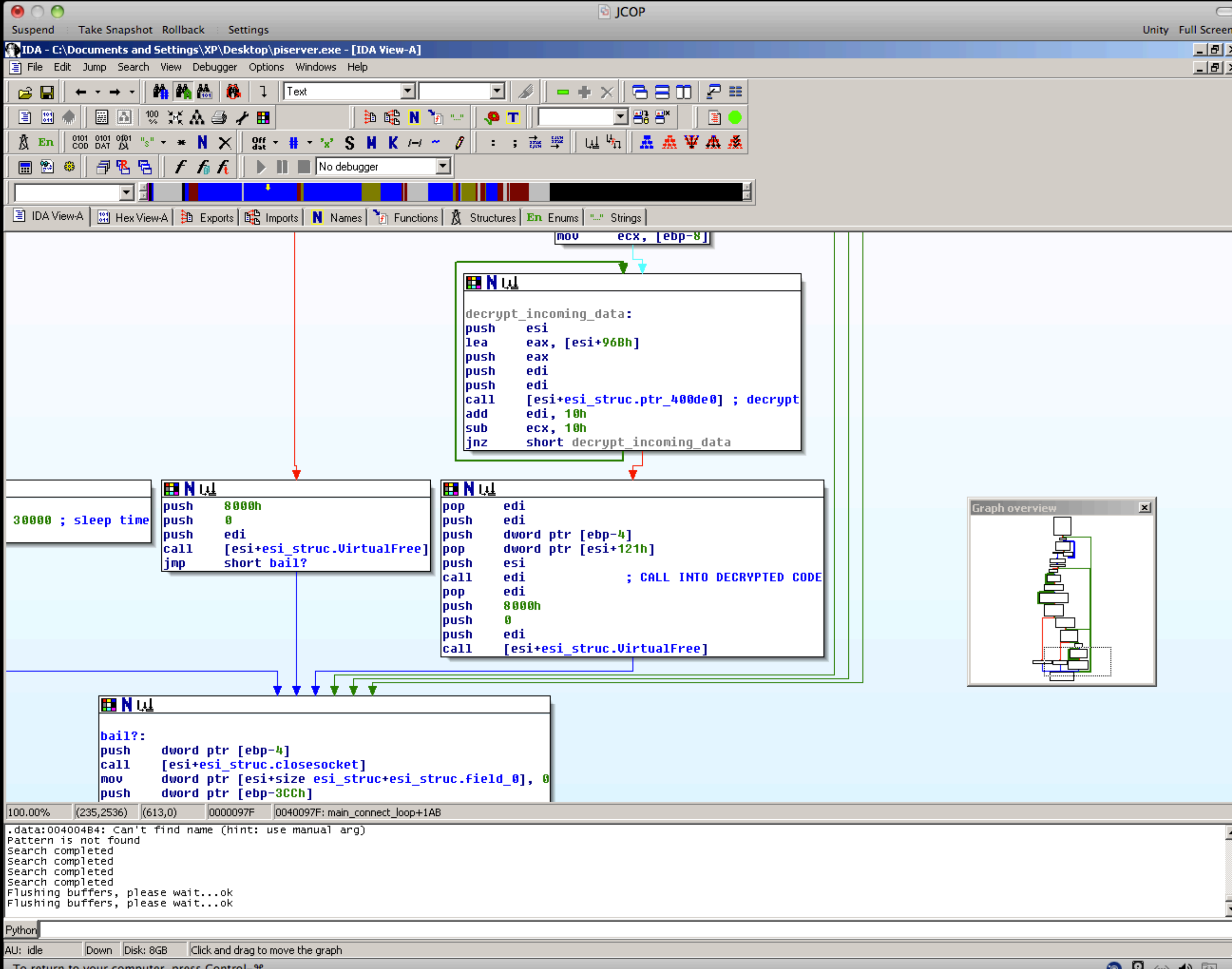


Image Name	Path	PID	Image Base	Image Size	Threads	CPU	Mem Usage	Created
System Idle Process		0	00000000	00000000	1	97	28 KiB	-
System		4	00000000	00000000	56	0	236 KiB	-
smss.exe	\SystemRoot\System32\smss.exe	380	48580000	0000F000	3	0	416 KiB	6/25/2010 3:58:33 PM
csrss.exe	\??\C:\WINDOWS\system32\csrss.exe	600	4A680000	00005000	11	0	3.99 MiB	6/25/2010 3:58:34 PM
winlogon.exe	\??\C:\WINDOWS\system32\winlogon.exe	624	01000000	00081000	20	0	4.26 MiB	6/25/2010 3:58:35 PM
services.exe	C:\WINDOWS\system32\services.exe	676	01000000	0001D000	15	0	3.34 MiB	6/25/2010 3:58:35 PM
lsass.exe	C:\WINDOWS\system32\lsass.exe	688	01000000	00006000	19	0	1.36 MiB	6/25/2010 3:58:35 PM
vmacthlp.exe	C:\Program Files\VMware\VMware Tools\vmacthlp.exe	844	00400000	0005C000	1	0	2.44 MiB	6/25/2010 3:58:35 PM
svchost.exe	C:\WINDOWS\system32\svchost.exe	856	01000000	00006000	17	0	4.79 MiB	6/25/2010 3:58:35 PM
svchost.exe	C:\WINDOWS\system32\svchost.exe	940	01000000	00006000	10	0	4.15 MiB	6/25/2010 3:58:35 PM
svchost.exe	C:\WINDOWS\System32\svchost.exe	1036	01000000	00006000	53	0	22.20 MiB	6/25/2010 3:58:35 PM
svchost.exe	C:\WINDOWS\system32\svchost.exe	1088	01000000	00006000	4	0	3.45 MiB	6/25/2010 3:58:35 PM
svchost.exe	C:\WINDOWS\system32\svchost.exe	1156	01000000	00006000	12	0	3.85 MiB	6/25/2010 3:58:37 PM
spoolsv.exe	C:\WINDOWS\system32\spoolsv.exe	1460	01000000	00010000	13	0	6.13 MiB	6/25/2010 3:58:37 PM
explorer.exe	C:\WINDOWS\Explorer.EXE	1604	01000000	000FF000	14	0	20.97 MiB	6/25/2010 3:58:38 PM
VMwareTray.exe	C:\Program Files\VMware\VMware Tools\VMwareTra...	1772	00400000	0002C000	1	0	4.59 MiB	6/25/2010 3:58:38 PM
VMwareUser.exe	C:\Program Files\VMware\VMware Tools\VMwareUs...	1792	00400000	00178000	6	0	11.35 MiB	6/25/2010 3:58:39 PM
ctfmon.exe	C:\WINDOWS\system32\ctfmon.exe	1800	00400000	00006000	1	0	2.99 MiB	6/25/2010 3:58:39 PM
svchost.exe	C:\WINDOWS\system32\svchost.exe	2000	01000000	00006000	4	0	3.67 MiB	6/25/2010 3:58:46 PM
vmtoolsd.exe	C:\Program Files\VMware\VMware Tools\vmtoolsd.exe	284	00400000	0000E000	5	0	9.73 MiB	6/25/2010 3:58:46 PM
VMUpgradeHelper.exe	C:\Program Files\VMware\VMware Tools\VMUpgrad...	480	00400000	00029000	3	0	3.95 MiB	6/25/2010 3:58:49 PM
TPAutoConnSvc.exe	C:\Program Files\VMware\VMware Tools\TPAutoCon...	1364	00400000	00041000	5	0	4.07 MiB	6/25/2010 3:58:51 PM
alg.exe	C:\WINDOWS\System32\alg.exe	1944	01000000	0000D000	5	0	3.51 MiB	6/25/2010 3:58:51 PM
wscntfy.exe	C:\WINDOWS\system32\wscntfy.exe	220	01000000	00006000	1	0	2.11 MiB	6/25/2010 3:58:52 PM
TPAutoConnect.exe	C:\Program Files\VMware\VMware Tools\TPAutoCon...	652	00400000	00072000	1	0	4.35 MiB	6/25/2010 3:58:54 PM
cmd.exe	C:\WINDOWS\system32\cmd.exe	2364	4AD00000	00061000	1	0	2.79 MiB	6/25/2010 3:59:41 PM
OLLYDBG.EXE	C:\Documents and Settings\Administrator\Desktop\o...	880	00400000	00153000	2	3	4.02 MiB	6/28/2010 3:29:43 PM
AdobeUpdate.exe	C:\WINDOWS\system32\AdobeUpdate.exe	3100	00400000	00001C00	5	0	4.77 MiB	6/28/2010 3:29:46 PM
calc.exe	C:\WINDOWS\system32\calc.exe	160	01000000	0001F000	2	0	3.12 MiB	7/7/2010 9:10:37 PM
notepad.exe	C:\WINDOWS\system32\notepad.exe	344	01000000	00014000	1	0	916 KiB	7/7/2010 11:31:40 PM
logon.scr	C:\WINDOWS\System32\logon.scr	2956	01000000	00039000	1	0	1.92 MiB	7/8/2010 12:15:22 AM
ntvdm.exe	C:\WINDOWS\system32\ntvdm.exe	2012	0F000000	000A7000	4	0	2.36 MiB	7/8/2010 12:20:20 AM
cmd.exe	C:\WINDOWS\system32\cmd.exe	3644	4AD00000	00061000	1	0	2.57 MiB	7/8/2010 12:20:30 AM

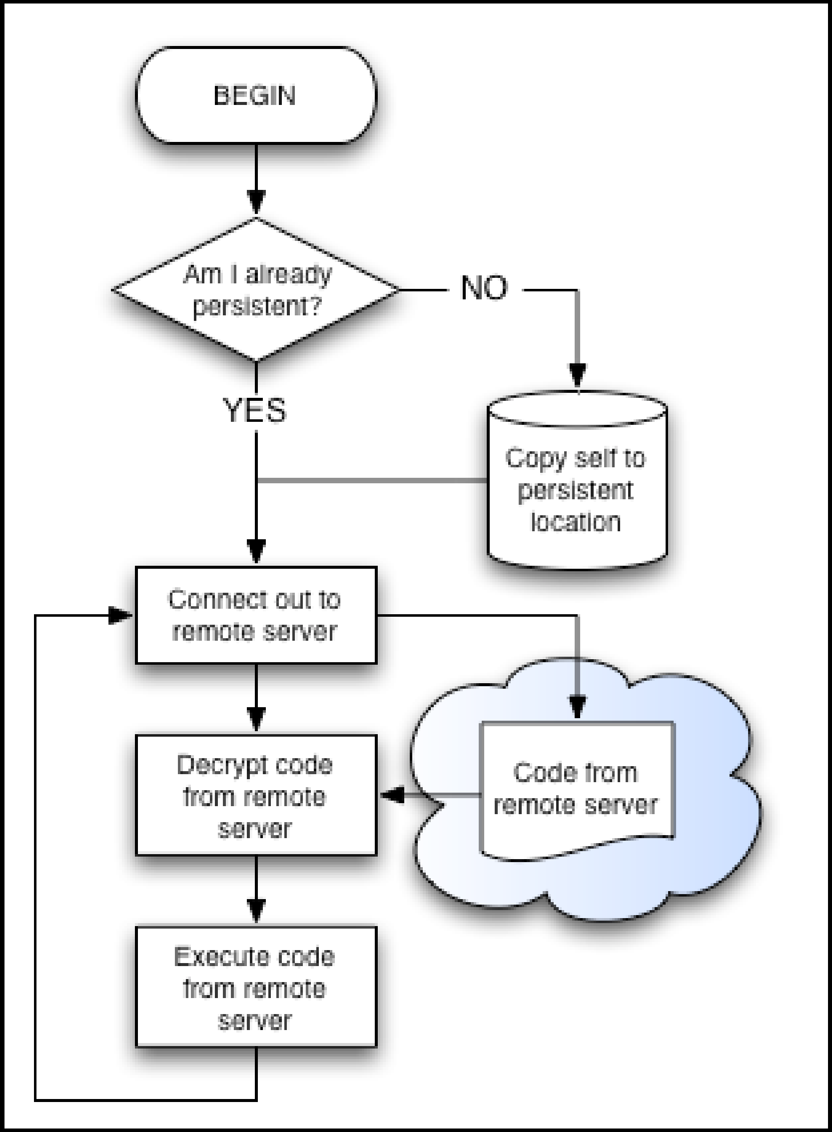
The Challenge



- A 7kb file? Probably not much in there… but let’s try anyway.


JCOP
Suspend Take Snapshot Rollback Settings
Unity Full Screen
IDA - C:\Documents and Settings\XP\Desktop\piserver.exe - [IDA View-A]
File Edit Jump Search View Debugger Options Windows Help
Text
No debugger
IDA View-A Hex View-A Exports Imports Names Functions Structures Enums Strings
mov ecx, [ebp-8]
decrypt_incoming_data:
push esi
lea eax, [esi+96Bh]
push eax
push edi
push edi
call [esi+esi_struc.ptr_400de0] ; decrypt
add edi, 10h
sub ecx, 10h
jnz short decrypt_incoming_data
30000 ; sleep time
push 8000h
push 0
push edi
call [esi+esi_struc.VirtualFree]
jmp short bail?
pop edi
push edi
push dword ptr [ebp-4]
pop dword ptr [esi+121h]
push esi
call edi ; CALL INTO DECRYPTED CODE
pop edi
push 8000h
push 0
push edi
call [esi+esi_struc.VirtualFree]
Graph overview
bail?:
push dword ptr [ebp-4]
call [esi+esi_struc.closesocket]
mov dword ptr [esi+size esi_struc+esi_struc.field_0], 0
push dword ptr [ebp-3CCh]
100.00% (235,2536) (613,0) 0000097F 0040097F: main_connect_loop+1AB
.data:004004B4: Can't find name (hint: use manual arg)
Pattern is not found
Search completed
Search completed
Search completed
Search completed
Flushing buffers, please wait...ok
Flushing buffers, please wait...ok
Python
AU: idle Down Disk: 8GB Click and drag to move the graph
To return to your computer, press Control-⌘

The 10,000 foot view



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What do we have?

- We know that it pulls in several useful imports:
  - Socket creation/connection
  - Registry set/query (RegSetValue, etc.)
  - File manipulation (CreateFile/WriteFile, etc.)
  - Process listing (CreateToolHelp32Snapshot…)
  - Memory manipulation (VirtualAlloc/Free)

- Also, some framework for future “modules”:
  - Most notably, a custom import resolver (to avoid using GetProcAddress)
  - Also, decryption code (Camellia block cipher)

But… not much else

- The application code as it exists on disk is limited to placing itself in the run key (for persistence) and using the network functions to “call out” to a server

- No indication of “command” functionality… but instead:
  - It validates that the server has the correct key
  - Decrypts the incoming data
  - Allocates some memory, copying the decrypted data to the new memory area
  - … and jumps to it (blindly)

So now what?

- We can use the memory image of the target machine to (hopefully) reconstruct some of the capabilities loaded at run time by the attacker

- Wouldn't it be nice to have some record of the commands invoked by the attacker as well?

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Some questions we can answer

- What dlls were loaded into this process?
  - Use dlllist from volatility

- Are there executable code segments outside of the mapped executable image?
  - If so, can we disassemble them?
  - Use the VAD tree to find these memory mappings and dump using vaddump from volatility

- What strings exist that might indicate malicious activity?
  - Possibly including command lines, etc.

- More importantly, we want to exclude 7kb image from these analyses, so we can “diff” against a baseline

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Volatile “Diffing”

- Take a “baseline” of the VAD tree/DLL list/file list/etc when the binary has started up (without network connection)
- Compare with the corresponding analysis on the memory image from your incident
- This is especially useful if the original binary was packed
  - For example, the memory regions used to unpack the binary
- For example…

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Example

- Collect the DLL listing for the baseline and incident images:
  - `volatility dlllist –p [PID] -f [Baseline Memory Image] > dlllist_base.txt`
  - `volatility vadinfo –p [PID] -f [Incident Memory Image] > dlllist_incident.txt`

- Diff the two to determine what new DLLs were loaded once Poison Ivy was able to call out to the C&C server:
  - `diff –u dlllist_base.txt dlllist_incident.txt`

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Diffing the Loaded DLLs

- The code executed from the server loads several additional Windows DLLs:

```
\WINDOWS\WinSxS\x86_Microsoft.Windows.Common-
   Controls_6595b64144ccf1df_6.0.2600.5512_x-ww_35d4ce83\comctl32.dll
\WINDOWS\system32\atl.dll
\WINDOWS\system32\avicap32.dll
\WINDOWS\system32\comctl32.dll
\WINDOWS\system32\crypt32.dll
\WINDOWS\system32\iphlpapi.dll
\WINDOWS\system32\mpr.dll
\WINDOWS\system32\msasn1.dll
\WINDOWS\system32\msvfw32.dll
\WINDOWS\system32\pstorec.dll
\WINDOWS\system32\shell32.dll
\WINDOWS\system32\winmm.dll
```

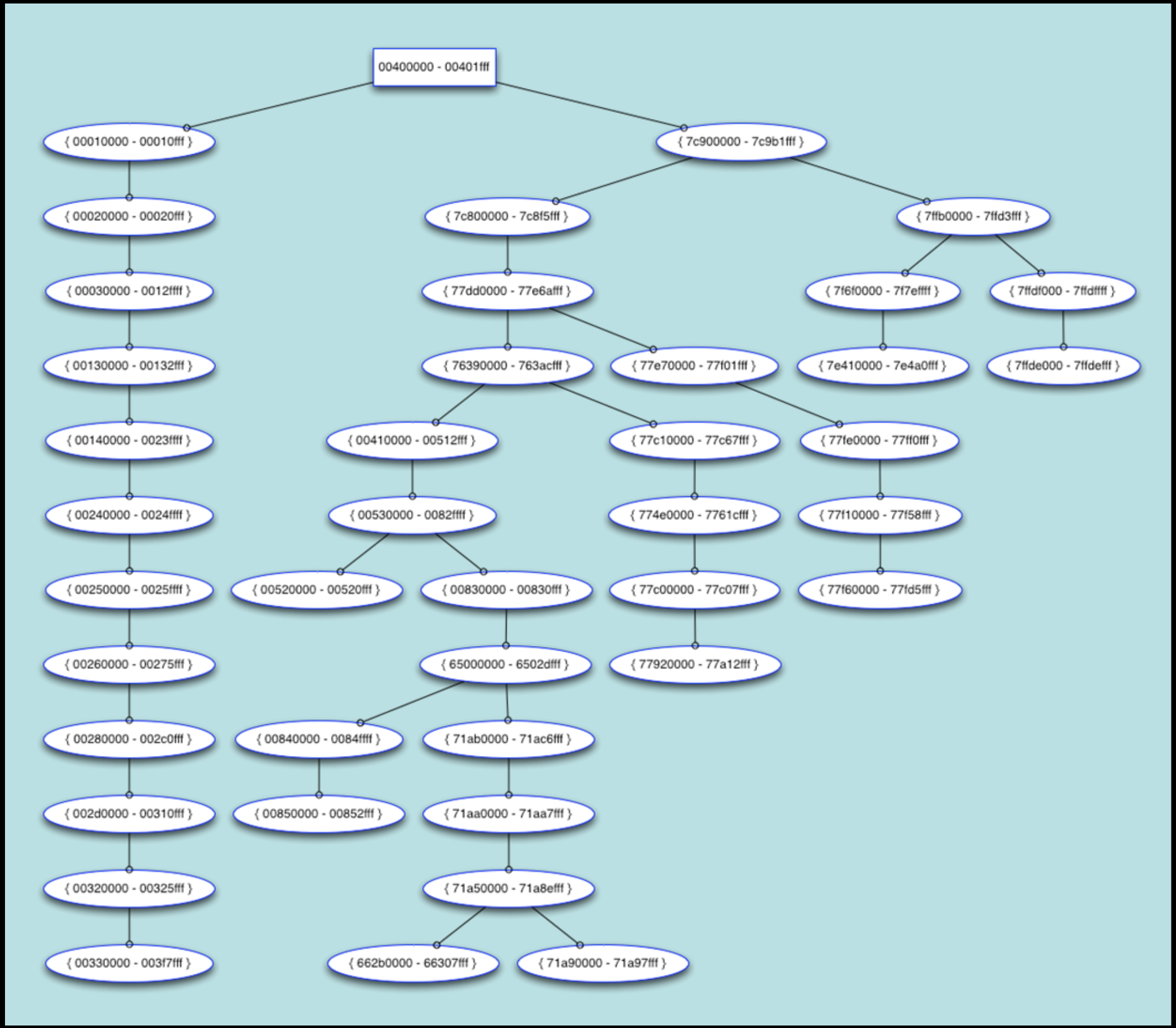
Getting to Executable Code…

- We could dump the entire process space, but that includes a lot of code & data we're not interested in (or have already analyzed)…

- So let's use "VAD Diffing" to narrow down to the new code downloaded by the tool from the network

- But first… what is the VAD?
  - Virtual Address Descriptor
  - Forensic application first discussed in a 2007 paper by Brendan Dolan-Gavitt
  - Essentially, metadata about allocated memory regions in a process
    - Is the region backed by disk?
    - What are the page protections?

VAD Tree for Poison Ivy



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The VAD info list

- Each loaded executable or DLL image will have its own entry in the VAD info list

```
VAD node @8221ec40 Start 65000000 End 6502dfff Tag Vad
Flags: ImageMap
Commit Charge: 15 Protection: 7
ControlArea @820db218 Segment e1835300
Dereference list: Flink 00000000, Blink 00000000
NumberOfSectionReferences:          0 NumberOfPfnReferences:          32
NumberOfMappedViews:                1 NumberOfSubsections:             5
FlushInProgressCount:               0 NumberOfUserReferences:          1
Flags: Accessed, HadUserReference, Image, File
FileObject @822c6028 (024c6028), Name: \WINDOWS\system32\advpack.dll
WaitingForDeletion Event: 00000000
ModifiedWriteCount:        0 NumberOfSystemCacheViews:        0
First prototype PTE: e1835340 Last contiguous PTE: fffffffc
Flags2: Inherit
File offset: 00000000
```

The VAD info list

- Dynamically allocated memory looks a bit different:

```
VAD node @81de8288 Start 00aa0000 End 00aa0fff Tag VadS
Flags: MemCommit, PrivateMemory
Commit Charge: 1 Protection: 6

VAD node @81d68330 Start 00ac0000 End 00ac0fff Tag VadS
Flags: MemCommit, PrivateMemory
Commit Charge: 1 Protection: 6
```

- We are most interested in these segments!

- As long as the system patchlevels match between the two machines and the program’s allocation pattern doesn’t change wildly between runs, you can get meaningful results from this (crude) method

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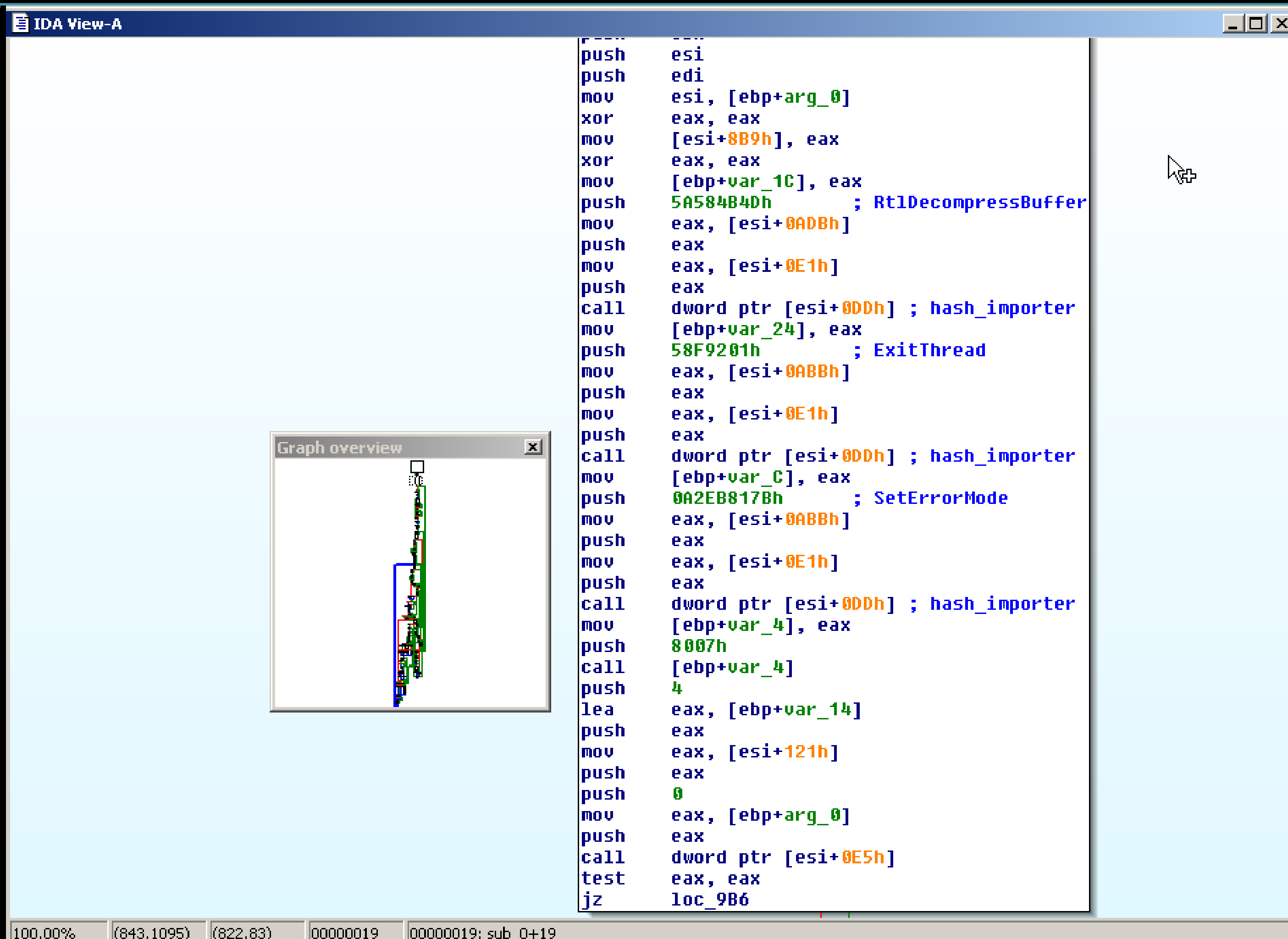
IDA Pro with Dynamically Loaded Modules

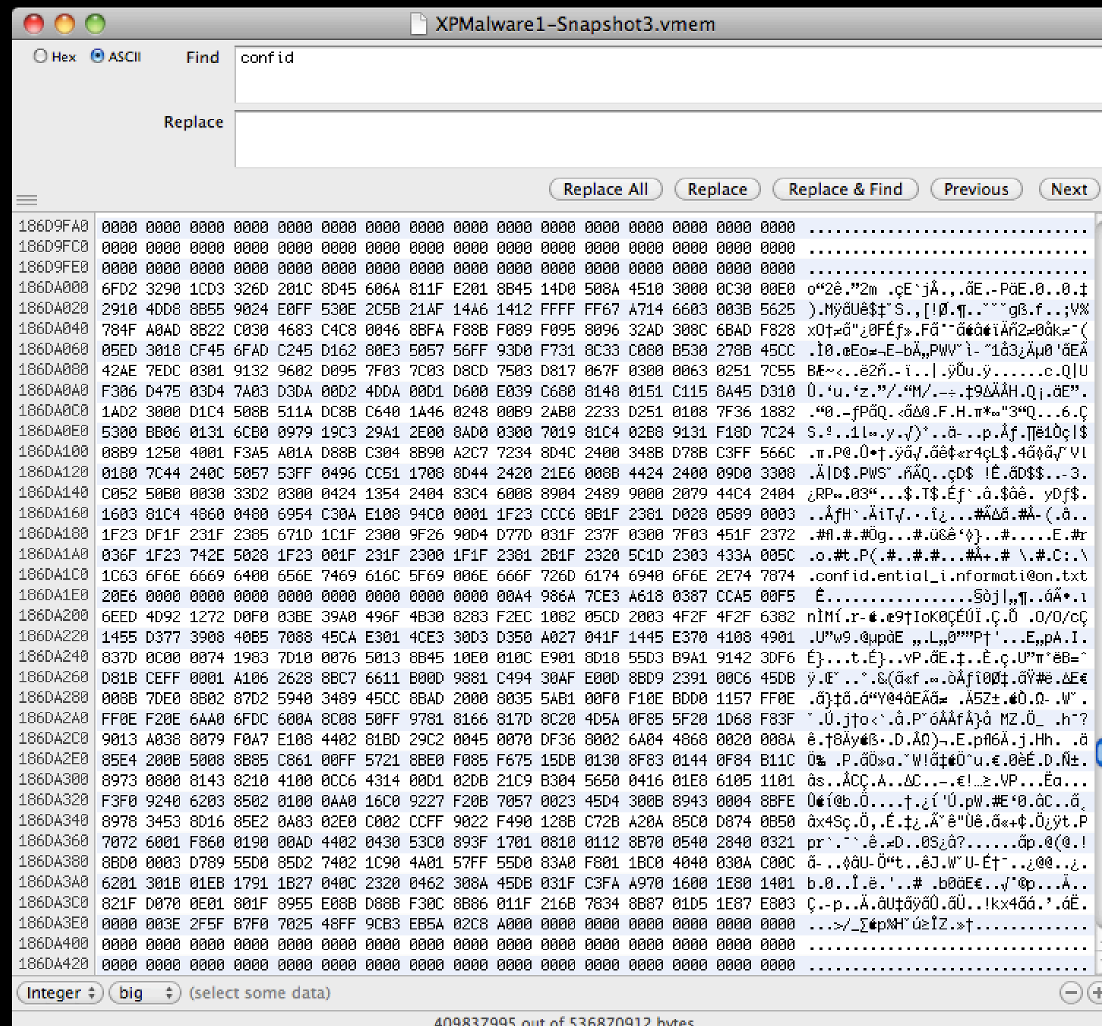


What are we missing?

- How do the pieces fit together? Not clear…
  - Perhaps with interpretation of the thread state and stack we could determine a code flow
  - Would need to be semi-automated to be useful
- Everything in Poison Ivy is PIC, so lots of tables of imports and local functions are used vftable-style
  - Requires some significant effort on the part of the reverse engineer, but can be automated
- Once a module is no longer needed, the memory is VirtualFree()'d
  - Unlinks the memory region from the VAD tree and makes it very difficult to find and associate back with the process
  - Means we lose not only modules but also the associated data (commands, search strings, etc.)

There be Nuggets

- Fragments of data before decompression:
  - "confidential information.txt"
  - Not reliable as it gets overwritten pretty quickly



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Which leaves us with…

- Some answers...
  - We can quickly focus in on code loaded/injected at runtime
  - That code can be analyzed just as if it were sitting on disk

- But in general, more questions …
  - How do we (or can we) get that list of commands we were promised?
  - What new tools & techniques are required (or even possible) against this class of malicious code?
  - How best to integrate more "context" available from the memory dump into the reverse engineering analysis?

the cake is a lie!

Questions?

Jason Garman
jason.garman@kyrus-tech.com