Memory Forensics with Hyper-V Virtual Machines

By: @wyattroersma
Who Am I? – Wyatt Roersma

• NVINT – Senior Security Engineer
• Mad Security – DFIR challenge creator
• The Hacker Academy – Content Dev
• I research for fun
• Lots of Debug testing for Volatility
Motivation for this Research

• Better understanding of Hyper-V virtual machines
• Preform in depth host analysis
• I work with lots of Hyper-V servers
• Need for better documentation for Hyper-V forensic analysis
• Hyper-V accounts for %28 of the hypervisor market share [4]
Agenda

• Hyper-V Architecture Overview
• Overview of the Hyper-V Virtual Machine
• Acquisition tools 2008 – 2012 R2
• Hyper-V Host Memory Analysis
• Conclusions/Q&A
• APIC – Advanced Programmable Interrupt Controller – A device which allows priority levels to be assigned to its interrupt outputs.

• Child Partition – Partition that hosts a guest operating system - All access to physical memory and devices by a child partition is provided via the Virtual Machine Bus (VMBus) or the hypervisor.

• Hypercall – Interface for communication with the hypervisor - The hypercall interface accommodates access to the optimizations provided by the hypervisor.

• Hypervisor – A layer of software that sits between the hardware and one or more operating systems. Its primary job is to provide isolated execution environments called partitions. The hypervisor controls and arbitrates access to the underlying hardware.

• IC – Integration component – Component that allows child partitions to communication with other partitions and the hypervisor.

• I/O stack – Input/output stack

• MSR – Memory Service Routine

• Root Partition – Manages machine-level functions such as device drivers, power management, and device hot addition/removal. The root (or parent) partition is the only partition that has direct access to physical memory and devices.
VID – Virtualization Infrastructure Driver – Provides partition management services, virtual processor management services, and memory management services for partitions.

VMBus – Channel-based communication mechanism used for inter-partition communication and device enumeration on systems with multiple active virtualized partitions. The VMBus is installed with Hyper-V Integration Services.

VMMS – Virtual Machine Management Service – Responsible for managing the state of all virtual machines in child partitions.

VMWP – Virtual Machine Worker Process – A user mode component of the virtualization stack. The worker process provides virtual machine management services from the Windows Server 2008 instance in the parent partition to the guest operating systems in the child partitions. The Virtual Machine Management Service spawns a separate worker process for each running virtual machine.

VSC – Virtualization Service Client – A synthetic device instance that resides in a child partition. VSCs utilize hardware resources that are provided by Virtualization Service Providers (VSPs) in the parent partition. They communicate with the corresponding VSPs in the parent partition over the VMBus to satisfy a child partitions device I/O requests.

VSP – Virtualization Service Provider – Resides in the root partition and provide synthetic device support to child partitions over the Virtual Machine Bus (VMBus).

WinHv – Windows Hypervisor Interface Library - WinHv is essentially a bridge between a partitioned operating system’s drivers and the hypervisor which allows drivers to call the hypervisor using standard Windows calling conventions.

WMI – The Virtual Machine Management Service exposes a set of Windows Management Instrumentation (WMI)-based APIs for managing and controlling virtual machines.
Windows Hyper-V Virtual Machine Basics

- .bin - Physical Memory Chunks
- .vsv - Memory Metadata
- .xml – Virtual Machine Config
.xml – Hyper-V Virtual Machine Configuration
.bin - Physical Memory Chunks
.vsv - Memory Metadata
Acquisition Tools: Windows Server 2008 -2008R2

Vm2dmp.exe
• archive.msdn.microsoft.com/vm2dmp - no longer works
• Used to convert saved state files (.vsv .bin) into a crashdump

Requirements:
• Windows Debugging tools

Problems:
• 4GB RAM or more will cause the VM2DMP “ERROR: Failed to map guest block 4096 to any saved state block! ERROR: Element not found.” Doesn't support saved Linux virtual machines
Examples:

• Create a dump file using virtual machine state files:

  > vm2dmp.exe -bin C:\dir\ VM-Instance-ID.bin -vsv C:\VM\ VM-Instance-ID.vsv -dmp C:\dir\crashdump.dmp

• Create a dump file from virtual machine and snapshot name:

  > vm2dmp.exe –vm VMName -dmp C:\VM\crashdump.dmp

  > vm2dmp.exe –vm VMName –snap “vm VMName -snap-SP1” -dmp C:\VM\crashdump.dmp

• Note: If you have a downloaded path of the debugging symbols then you can specify –sym and then the directory of the symbols path.
Acquisition Tools: Windows Server 2012 - 2012R2

Livekd.exe
- Converts live, saved, and snapshot files to Windows crash dump format

Cons:
- No Linux System Support
- Windows API

LiveDump.exe
- crashdmp.wordpress.com/2014/08/04/livedump-1-0-is-available/
Examples:

• If you want to list the virtual machines on the server just use the –hvl options and it will list GUIDs and names of running Hyper-V VM’s.

>livekd.exe –hvl

• If you want to create a full crash dump of a virtual machine running on the host system you would run

>livekd.exe –hv (System name or GUID) –p (to pause the system to create a more consistent image) –o (output-file)

>livekd.exe –hv AD –p –o AD.dmp
Hyper-V Host Memory Analysis

- Host Memory dumps >148GB
- Checking Host + VM’s for Artifacts
- Virtual Firewall Analysis
- All Traffic Live on the host
- Network Artifacts
<table>
<thead>
<tr>
<th>Filename</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>hvix64.exe / hvax64.exe</td>
<td>Core Hypervisor executables, for Intel and AMD. Includes all code that runs in VMX root mode after boot process is finished</td>
</tr>
<tr>
<td>vmwp.exe</td>
<td>Executable for VM worker processes. Includes code for device emulation, as well as several synthetic devices</td>
</tr>
<tr>
<td>vmswitch.sys</td>
<td>Windows Kernel driver that implements the Networking VSP</td>
</tr>
<tr>
<td>storvssp.sys / vhdmp.sys</td>
<td>Kernel driver for Storage VSP</td>
</tr>
</tbody>
</table>
Virtual Machine Worker Process

```
python vol.py -f HV2012R2.raw --profile=Win2012R2x64 psscan | grep vmwp.exe
```

Volatility Foundation Volatility Framework 2.4 (Beta)

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<th>Size</th>
<th>PID</th>
<th>Parent Address</th>
<th>Date/Time</th>
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<td>0x00000000cd7c100 vmwp.exe</td>
<td>3740</td>
<td>1504</td>
<td>0x00000000b73a5000</td>
<td>2014-08-03 21:42:06 UTC+0000</td>
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<td>0x00000001f80fc000</td>
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<td>19851536</td>
<td>3</td>
<td>192.42.116.161</td>
<td>10.0.0.103</td>
<td>6 9001</td>
</tr>
</tbody>
</table>
Pfsense FW

grep -i "pfsense" ps-strings.txt

snip...
2525873247 [FREE MEMORY] Jul 21 16:03:23 pfSense dnsmasq[19767]: reading /etc/resolv.conf
2525873312 [FREE MEMORY] Jul 21 16:03:23 pfSense dnsmasq[19767]: using nameserver 208.67.220.220#53
2525873387 [FREE MEMORY] Jul 21 16:03:23 pfSense dnsmasq[19767]: using nameserver 208.67.222.222#53
snip...
2468293174 [FREE MEMORY] Aug 3 20:42:47 pfSense kernel: root@pf2_1_1_amd64.pfsense.org:/usr/obj.amd64/usr/pfSensesrc/src/sys/pfSense_SMP.8 amd64
2468293295 [FREE MEMORY] Aug 3 20:42:47 pfSense kernel: Timecounter "i8254" frequency 1193182 Hz quality 0
2468293378 [FREE MEMORY] Aug 3 20:42:47 pfSense kernel: CPU: Intel(R) Xeon(R) CPU E5-2630 0 @ 2.30GHz (1653.76-MHz K8-class CPU)
2468293932 [FREE MEMORY] Aug 3 20:42:47 pfSense kernel: AMD Features2=0x1<LAHF>
2468294329 [FREE MEMORY] Aug 3 20:42:47 pfSense kernel: FreeBSD/SMP: 1 package(s) x 2 core(s)
Snip...
Conclusion/Q&A

• Firewall, Switch, and Router Memory Analysis?
• Hyper-V recap
• Watch my blog for more information wyattroersma.com
• Useful Plugin? Vmwp?
• Questions?
References:

- https://code.google.com/p/volatility/wiki/CommandReference22#imagecopy
- http://www.wyattroersma.com/?p=87
- http://www.wyattroersma.com/?p=77
- http://hypervking.info/hyper-v-tools/
- http://crashdump.wordpress.com/2014/08/04/livedump-1-0-is-available/