Monitoring & Controlling Kernel-mode Events by HyperPlatform

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Takeaway

- If you want to have more ability to monitor and control Windows system activities in a lightweight manner, HyperPlatfrom is for you.
- HyperPlatfrom is the hypervisor designed as a VM-exit filtering platform to utilize virtualization technology (VT) and write new types of tools on Windows quicker and easier.
About Us

• Satoshi Tanda (@standa_t)
  - Reverse engineer interested in the Windows kernel
  - Implemented HyperPlatform
  - Threat Researcher at Sophos specializing in behaviour based detection on Windows

• Igor Korkin (@Igorkorkin)
  - An independent researcher focusing on cyber security science: memory forensics, rootkit detection & spy technologies
  - Co-researcher, focused on application of HyperPlatform
Background

- Issue: Lack of tools for kernel mode code analysis on Windows
  - Debugger and IDA are time consuming
  - Existing tools were not efficient
- Solution: Virtualization Technology (VT)
  - Plenty of analysis systems, and academic papers
  - VT is more than just sandbox
Challenges

• No suitable hypervisor to take advantage of VT only for system monitoring on Windows

• Existing lightweight hypervisors for Windows?
  – lacked modern platform support

• More comprehensive hypervisors?
  – Too large to understand and extend
  – Not straightforward to compile and run
  – Very slow (i.e., Bochs)
Challenges: Summary

- Lack of tools to monitor kernel activities
- Commercial and proprietary
- Insufficient modern platform support
- Large to use VT just for system monitoring
- Not Windows researchers friendly
- Too slow
Answer: HyperPlatform

- Allows you to monitor system activities incl. kernel-mode
- Open source under the relaxed license (MIT License)
- Supports Windows 7-10 on x86/x64
- Small (7KLOC)
- Can be compiled on Visual Studio w/o any 3rd party libraries, and debugged just like ordinary Windows drivers
- Fast (about 10% of overhead)
How It Works: Overview

User Mode

Kernel Mode

Applications

Kernel

Drivers

HyperPlatform.sys

Enables VMX operation mode

Processors
How It Works: Overview

User Mode

Kernel Mode

Applications

CPUID

VM-exit handler is executed upon occurrence of certain events (VM-exit)

Kernel

Drivers

MOV CR3, RAX

Exception

HyperPlatform.sys

VMExitHandler()

VM-exit

Processors VMX enabled
How It Works: Implementation

```c
void VMExitHandler(
    GuestRegisters* context,
    int exit_reason)
{
    switch (exit_reason)
    {
        case VMEXIT_CPUID:
            CpuidHandler(context); break;
        case VMEXIT_EXCEPTION:
            ExceptionHandler(context); break;
        //...
    }
}
```

- Invoked on VM-exit
- Context of the system and VM-exit reason are given
- Handle an event accordingly
As a VM-exit Filtering Platform

Windows

HyperPlatform

YourDriver.sys

Your extended logic for “move-to-cr3” event

MOV CR3, RAX

Exception

PROCESSORS VMX enabled

MOV CR3, RAX

CPUID

VM-exit

Your extended logic for “move-to-cr3” event
Advantage

• You can do what you cannot do without VT
• VM-exit is a new class of events
  – access to system registers
  – occurrence of exceptions and interruptions
  – execution of certain instructions
  – access to memory using extended page tables (EPT)
• VM-exit handler is flexible
  – returning different register values and/or memory contents
• None of them is easy to achieve without VT
Application (part 1)

- Kernel mode code analysis
  - Detection of dodgy instruction execution (e.g., modification of CR0.WP)
    - GuardMon – PatchGuard monitor
  - Detection of pool memory execution
    - MemoryMon – Memory execution monitor
  - Invisible API hook
    - DdiMon – kernel-mode API monitor
Demo (part 1)

- MemoryMon against Turla (Uroburos)
  - getting unpacked code from memory
Application (part 2)

- Hypervisor based protection
  - Instead of monitoring, terminate a process upon dodgy events
  - Checking certain conditions on task switching
    - EopMon – elevation of privilege exploit (token stealing) monitor

```
Time
Running
Process A
MOV CR3, RAX
Running
Process B
Check
MOV CR3, RAX
Running
Process C
Check
VM-exit
EopMon
VM-exit
```

```
Demo (part 2)

- EopMon against Gozi (Ursnif)
  - Detecting and killing elevated malware (stole a system token)
Limitations

• Cannot run inside VirtualBox by design
• No AMD processors support (#2, won't fix)
• Cannot run with other hypervisors simultaneously (#14)
Future

- Looking for more ideas on what we can do
  - Kernel code coverage with Intel Processor Trace for effective fuzzing
  - Memory access visualization and authorization
  - Race condition (TOCTOU) bug discovery with memory access monitoring
Conclusion

- Virtualization technology (VT) is powerful but underutilized in reverse engineering
- HyperPlatform is the hypervisor designed as a VM-exit filtering platform to utilize VT and write new types of tools on Windows quickly and easily
- Check out GitHub pages, develop your own unique ideas and solutions
  - github.com/tandasat/HyperPlatform
Thank You

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Appendix 1: Performance Metrics

Performance Comparison

- Base
- EopMon
- MemoryMon

PCMark8 Home
Novabench RAM Speed
Novabench CPU Tests
Novabench Graphics Tests
Novabench Drive Write Speed
References 1

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  - https://www.vmray.com/features/
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- SecVisor: A Tiny Hypervisor to Provide Lifetime Kernel Code Integrity for Commodity OSes
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  - http://drakvuf.com/
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- BluePill
  - http://invisiblethingslab.com/resources/bh07/nbp-0.32-public.zip
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  - https://github.com/ainfosec/MoRE
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