Using Hardware Features for Increased Debugging Transparency

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Overview

- Motivation
- Background: System Management Mode (SMM)
- System Architecture
- Evaluation: Transparency and Performance
- Conclusions and Future Directions

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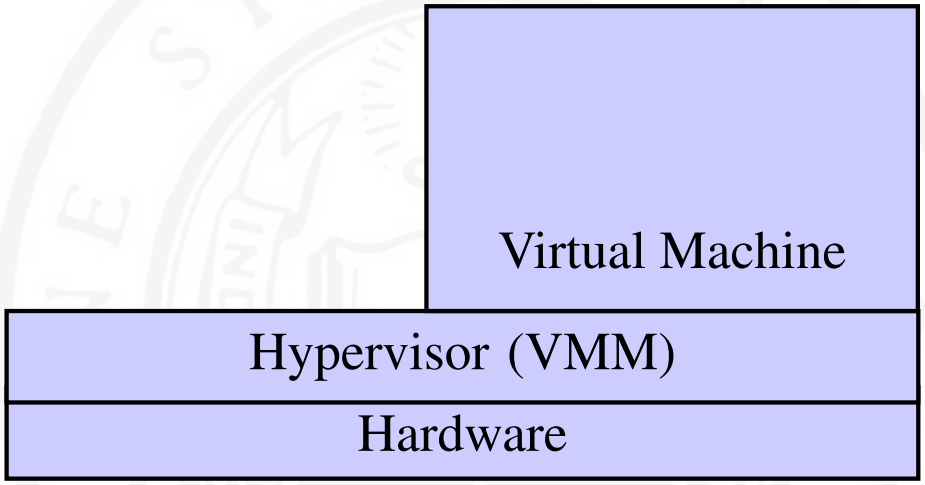
Motivation

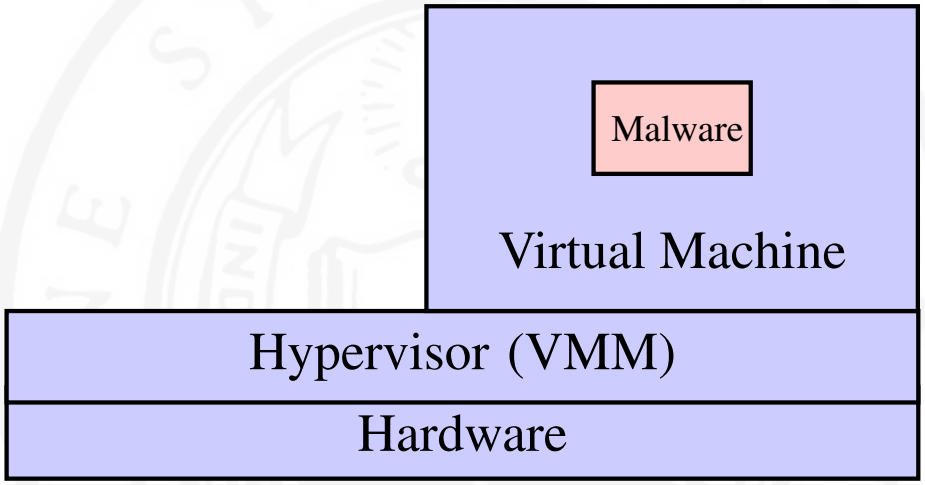
- Malware attacks statistics
  - Symantec blocked an average of 247,000 attacks per day [1]
  - McAfee (Intel Security) reported 8,000,000 new malware samples in the first quarter in 2014 [2]
  - Kaspersky reported malware threats have grown 34% with over 200,000 new threats per day last year [3]
- Computer systems have vulnerable applications that could be exploited by attackers.

Traditional Malware Analysis



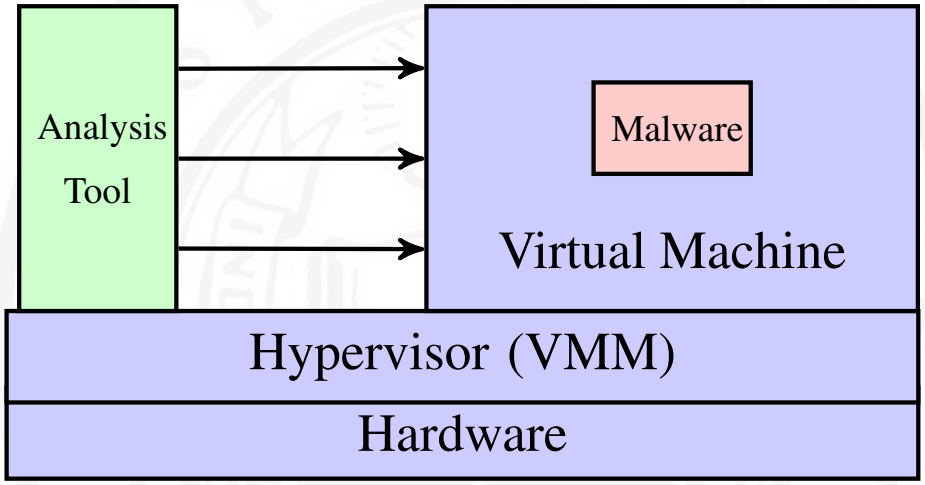
- Using virtualization technology to create an isolated execution environment for malware debugging

Traditional Malware Analysis



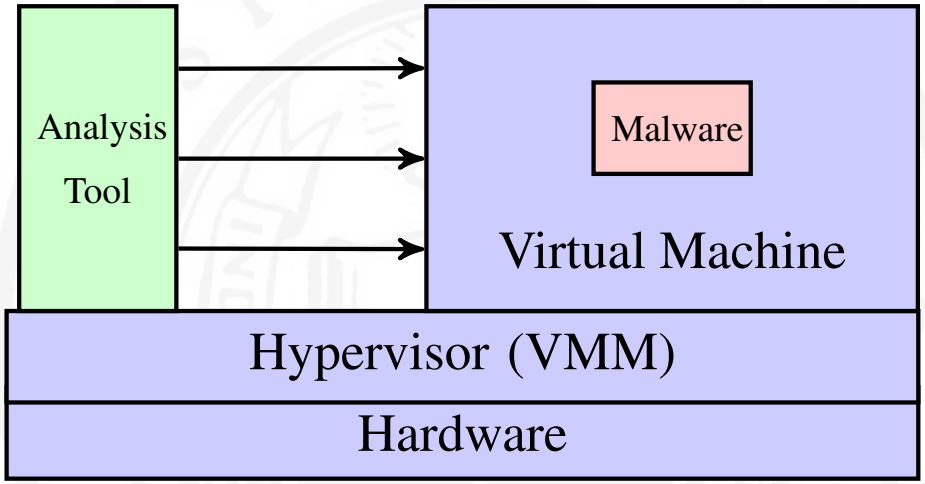
- Using virtualization technology to create an isolated execution environment for malware debugging
- Running malware inside a VM

Traditional Malware Analysis



- Using virtualization technology to create an isolated execution environment for malware debugging
- Running malware inside a VM
- Running analysis tools outside a VM

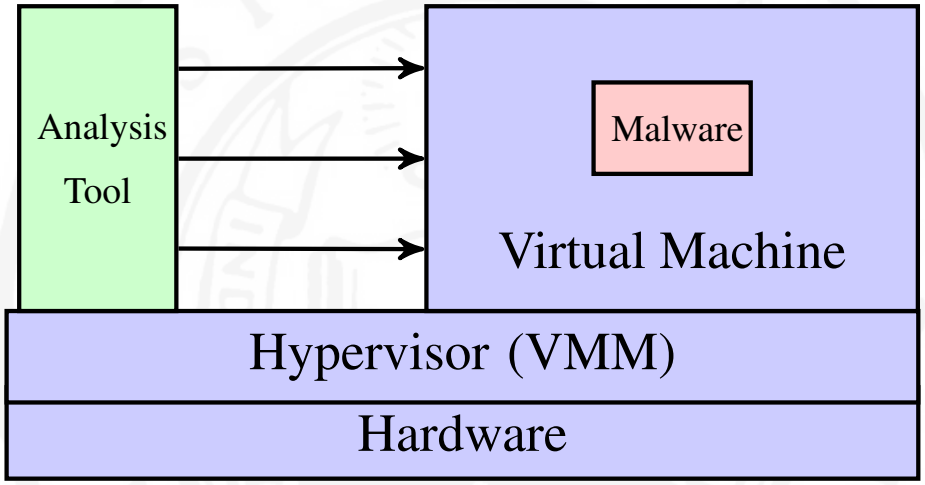
Traditional Malware Analysis



Limitations:

- Depending on hypervisors that have a large TCB (e.g., Xen has 500K SLOC and 245 vulnerabilities in NVD)
- Incapable of analyzing rootkits with the same or higher privilege level (e.g., hypervisor and firmware rootkits)
- Unable to analyze armored malware with anti-virtualization or anti-emulation techniques

Our Approach



We present a bare-metal debugging system called MalT that leverages System Management Mode for malware analysis

- Uses System Management Mode as a hardware isolated execution environment to run analysis tools and can debug hypervisors
- Moves analysis tools from hypervisor-layer to hardware-layer that achieves a high level of transparency

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Background: System Management Mode

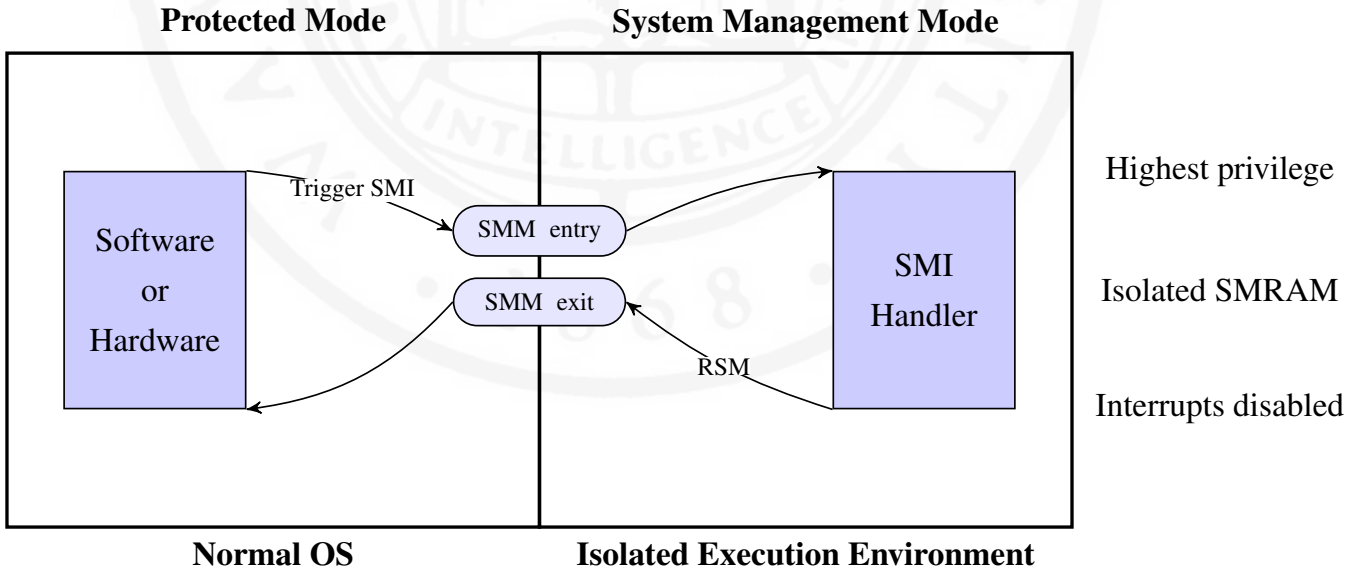
System Management Mode (SMM) is special CPU mode existing in x86 architecture, and it can be used as a hardware isolated execution environment.

- Originally designed for implementing system functions (e.g., power management)
- Isolated System Management RAM (SMRAM) that is inaccessible from OS
- Only way to enter SMM is to trigger a System Management Interrupt (SMI)
- Executing RSM instruction to resume OS (Protected Mode)

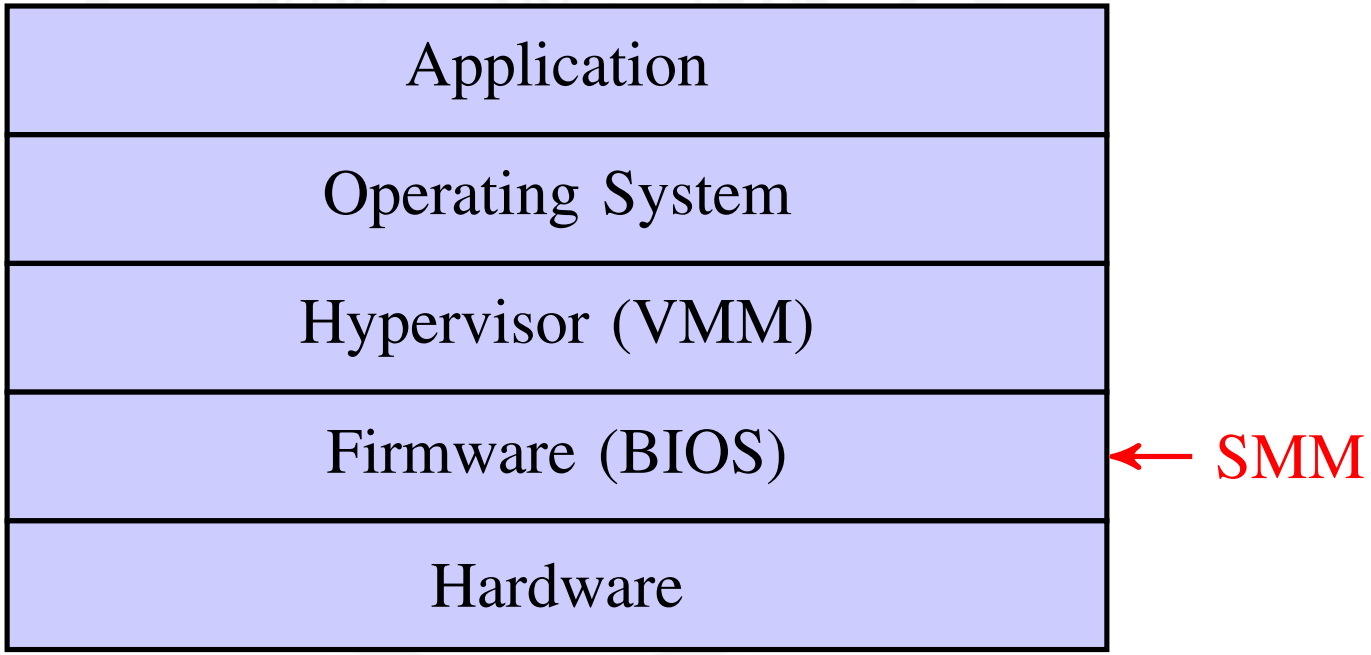
Background: System Management Mode

Approaches for Triggering a System Management Interrupt (SMI)

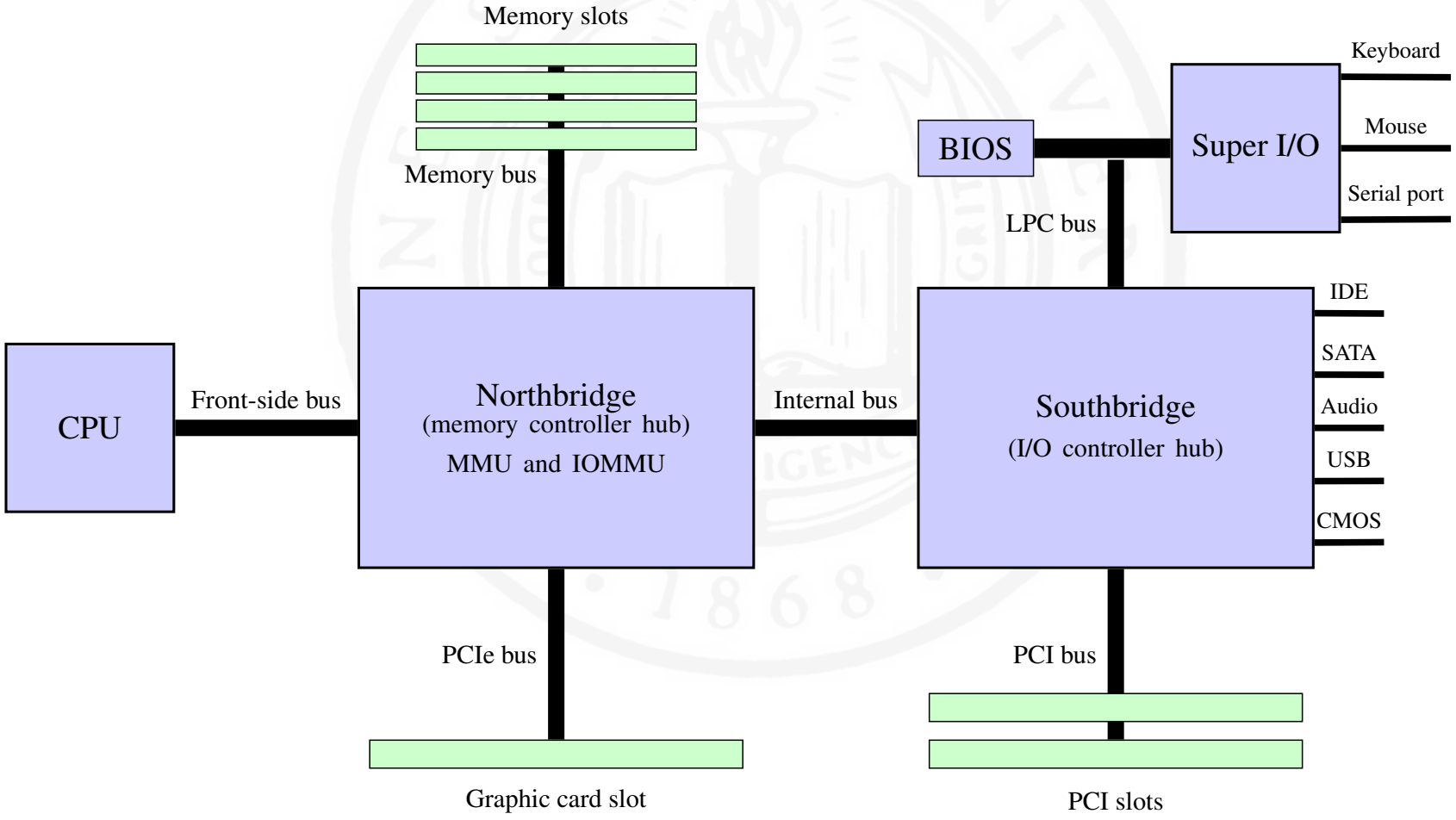
- Software-based: Write to an I/O port specified by Southbridge datasheet (e.g., 0x2B for Intel)
- Hardware-based: Network card, keyboard, hardware timers



Background: Software Layers



Background: Hardware Layout



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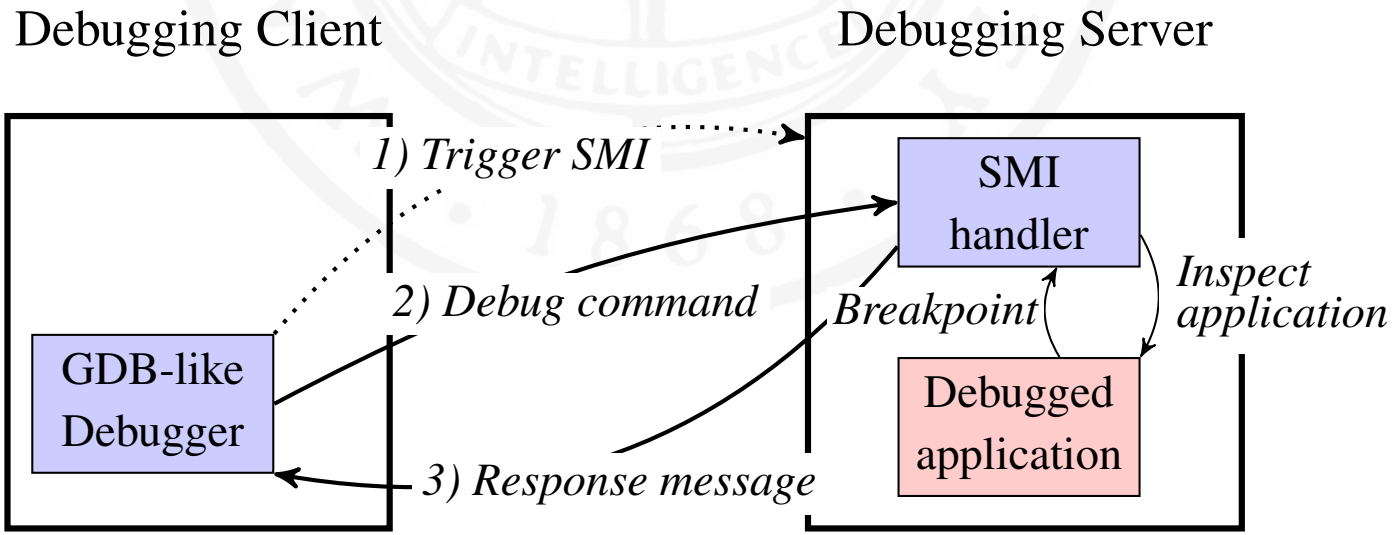
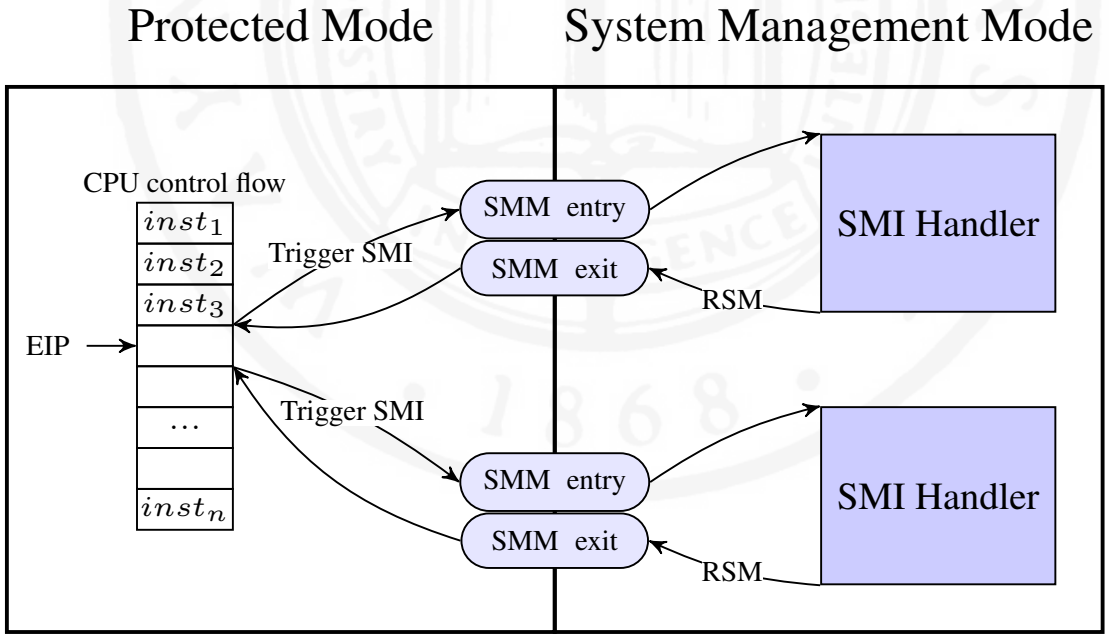
System Architecture

- Traditionally malware debugging uses virtualization or emulation
- MalT debugs malware on a bare-metal machine, and remains transparent in the presence of existing anti-debugging, anti-VM, and anti-emulation techniques.



Step-by-step Debugging in MalT

- Debugging program instruction-by-instruction
- Using performance counters to trigger an SMI for each instruction



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Evaluation: Transparency Analysis

- Two subjects: 1) running environment and 2) debugger itself
  - Running environments of a debugger
    - SMM v.s. virtualization/emulation
  - Side effects introduced by a debugger itself
    - CPU, cache, memory, I/O, BIOS, and timing
- Towards true transparency
  - MalT is not fully transparent (e.g., external timing attack) but increased
  - Draw attention to hardware-based approach for addressing debugging transparency

Evaluation: Performance Analysis

- Testbed Specification
  - Motherboard: ASUS M2V-MX SE
  - CPU: 2.2 GHz AMD LE-1250
  - Chipsets: AMD K8 Northbridge + VIA VT8237r Southbridge
  - BIOS: Coreboot + SeaBIOS

Table: SMM Switching and Resume (Time: μs)

Operations	**Mean**	**STD**	**95% CI**
SMM switching	3.29	0.08	[3.27,3.32]
SMM resume	4.58	0.10	[4.55,4.61]
Total	7.87		

Evaluation: Performance Analysis

Table: Stepping Overhead on Windows and Linux (Unit: Times of Slowdown)

Stepping Methods	**Windows**	**Linux**
	π	π
Far control transfer	2	2
Near return	30	26
Taken branch	565	192
Instruction	973	349

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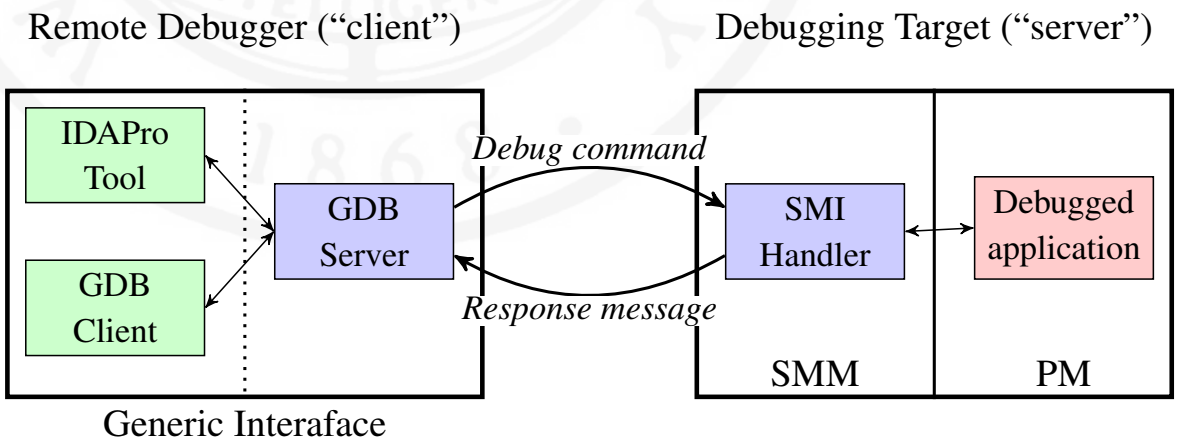
Conclusions and Future Work

- We developed MalT, a bare-matal debugging system that employs SMM to analyze malware
  - Hardware-assisted system; does not use virtualization or emulation technology
  - Providing a more transparent execution environment
  - Though testing existing anti-debugging, anti-VM, and anti-emulation techniques, MalT remains transparent
- Future work



References

[1] Symantec, "Internet Security Threat Report, Vol. 19 Main Report," http://www.symantec.com/content/en/us/enterprise/other_resources/b-istr_main_report_v19_21291018.en-us.pdf, 2014.

[2] McAfee, "Threats Report: First Quarter 2014," http://www.mcafee.com/us/resources/reports/rp-quarterly-threat-q1-2014-summary.pdf.

[3] Kaspersky Lab, "Kaspersky Security Bulletin 2013," http://media.kaspersky.com/pdf/KSB_2013_EN.pdf.

Paper Discussion

- Mikal Fourrier

- MALT is a framework for Windows and Linux designed to transparently detect malwares. It uses the System Management Mode on x86. Only the BIOS is trusted, bringing the KSLOC of trusted code down by two to four orders of magnitude compared to emulator-based techniques. The code executing in SMM acts as a debugging server and is controlled by a gdb-like userspace program. The standard operations like breakpoints and step-by-step execution are supported. Additionally, since the server is executed in ring -2, it can also be used to debug kernels and hypervisors. Since it's a new technique, none of the currents malwares detects it. Some side-effects introduced by SMM or techniques like timing attacks could be used by malwares in the future.

Paper Discussion

- Saeid Mofrad

- This paper is about Malt, a transparent debugger which leverages SMM mode in the x86 architecture. Malt is residing in SMM (ring -2) and can detect rootkits in the hypervisor (ring -1), OS kernel (ring 0) and also armored malware which can hide their payload and malicious activity in the event of the existence of the non-transparent malware detection systems. Malt is using client-server model for its implementation. The user connects remotely to the Malt by serial cable and constructs Malt to debug a particular program (putting a breakpoint, step into instructions or reading CPU registers value, etc.) into SMM and analyze it in a transparent manner. Also, Malt is susceptible to timing attacks. In example, malware may detect SMM based activity by measuring the time delay more effective by using encrypted external time measurement and hides its malicious activity.

Paper Discussion

- Sudeep Nanjappa Jayakumar

- This paper includes the usage of a framework called Malt, here the client-server architecture is used to debug and attain the transparency. Malt has the CPU mode in the architecture . This system management mode does not depend the virtualization or emulation which also makes this system not being affected much from most of the malware attacked environments. In this system there is a implementation of two types of machines to show that the transparency is maintained through out. SMM is a special purpose cpu mode used in here and it provides the strong protection for malware debugging. Here the malware is run on one of the physical machine and the SMM is implemented to communicate with client of the debugging machine. Further more SMM is usually considered as the (ring-2) which works with the hypervisor which is at (ring -1) and the OS kernel is at (ring -0).

Reminders

- Paper reviews
- Course Participation Confirmation
- Next class: Transparent Malware Analysis II