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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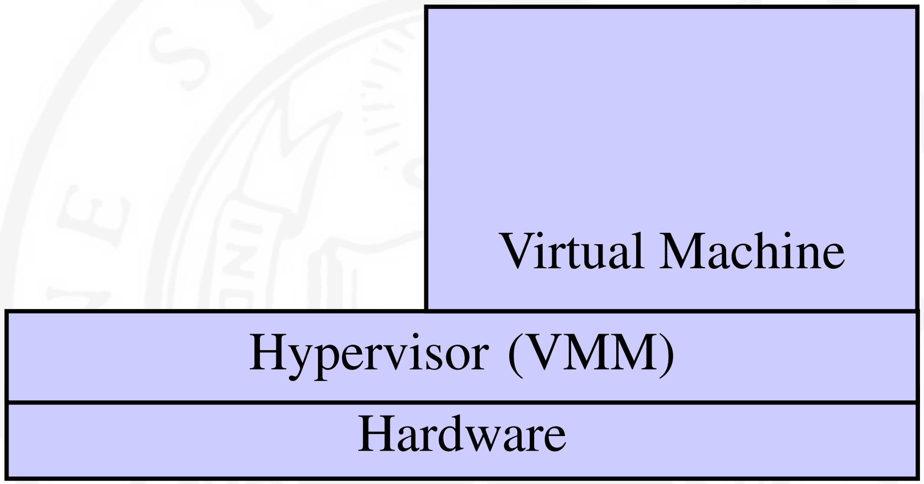
Motivation

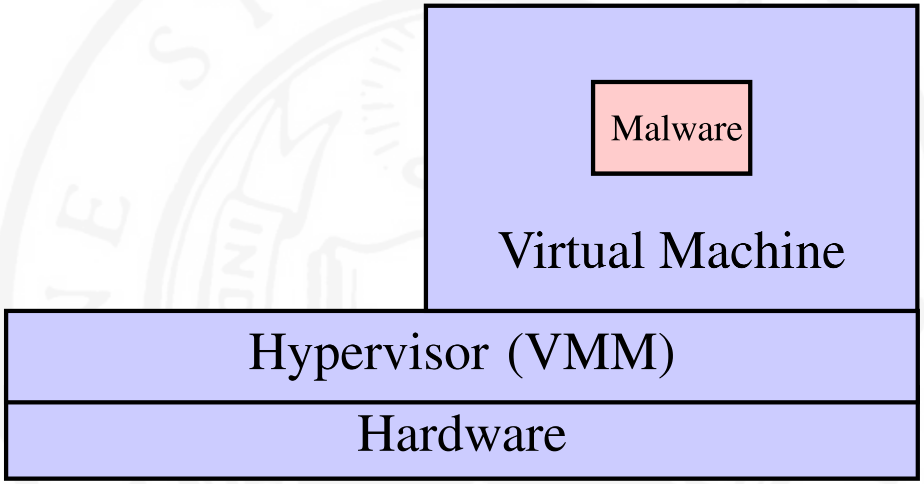
- Malware attacks statistics
  - Symantec blocked an average of 247,000 attacks per day [1]
  - McAfee (Intel Security) reported 8,000,000 new malware samples in the first quarter in 2014 [2]
  - Kaspersky reported malware threats have grown 34% with over 200,000 new threats per day last year [3]
- Computer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

Traditional Malware Analysis



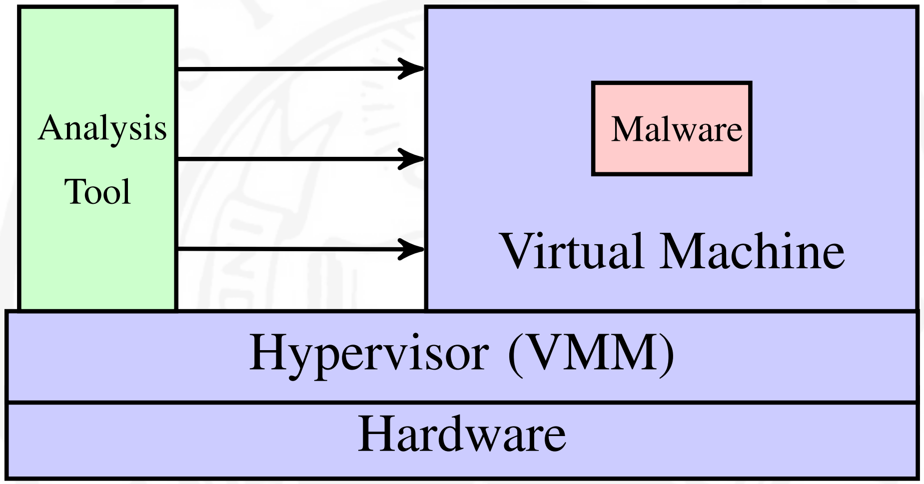
- Using virtualization technology to create an isolated execution environment for malware debugging

Traditional Malware Analysis



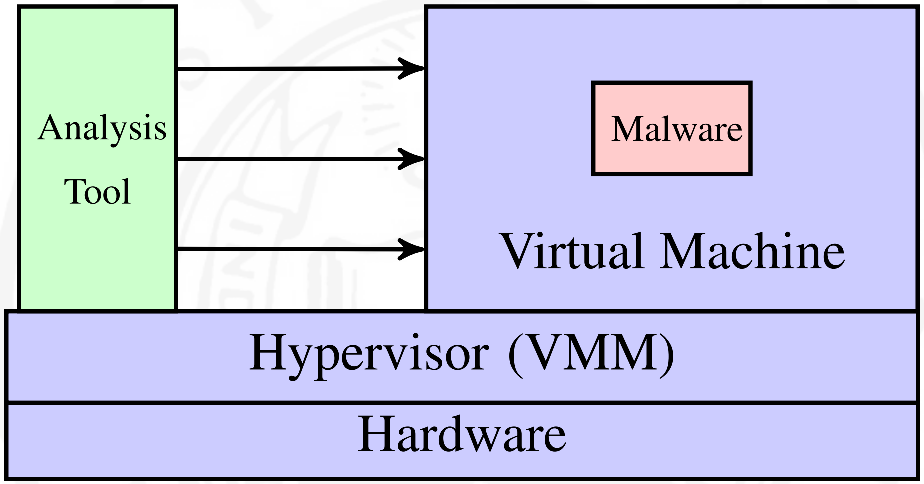
- Using virtualization technology to create an isolated execution environment for malware debugging
- Running malware inside a VM

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

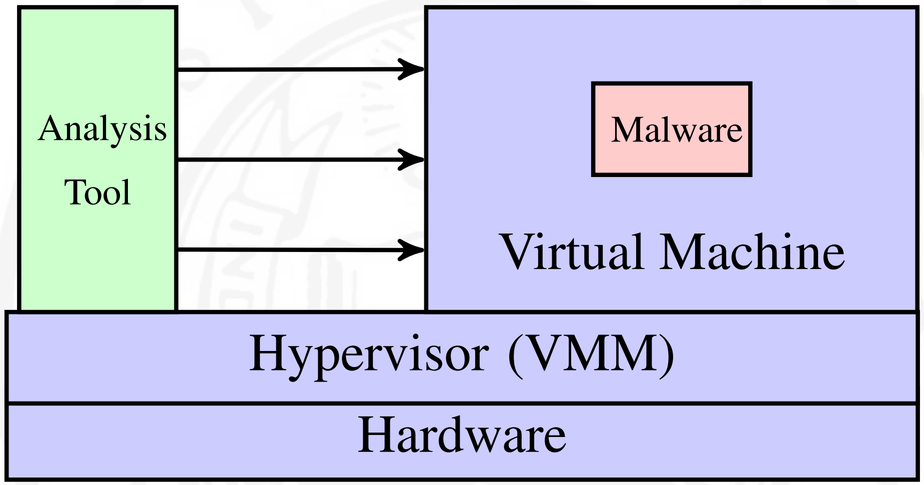
Traditional Malware Analysis



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

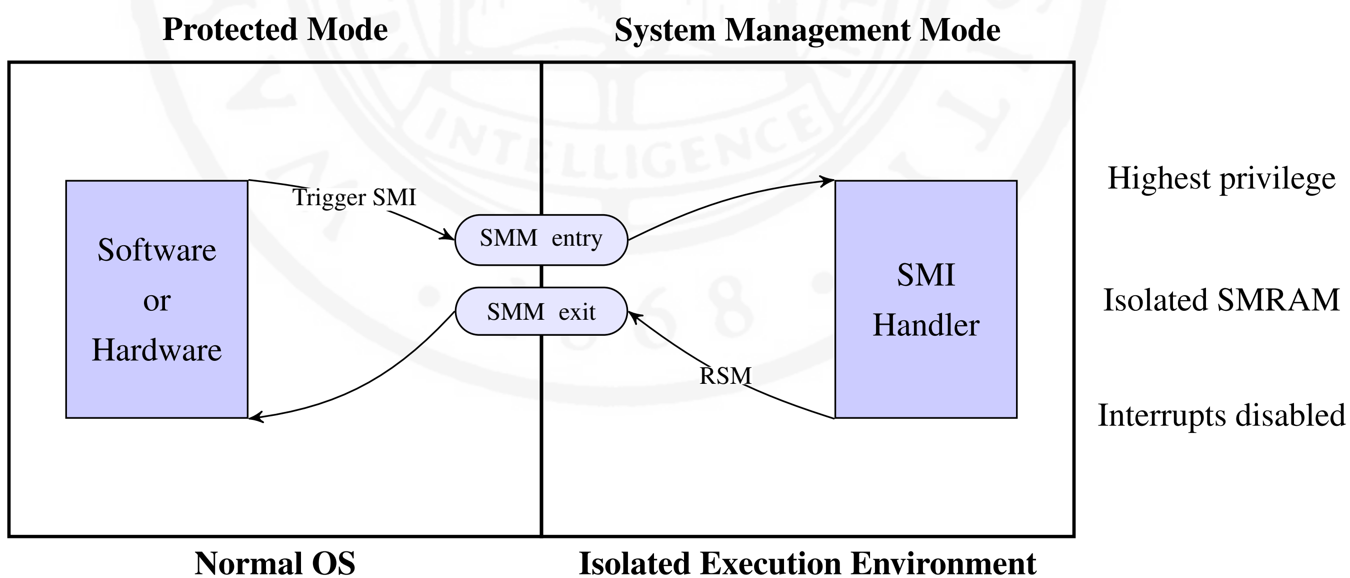
System Management Mode (SMM) is special CPU mode existing in x86 architecture, and it can be used as a hardware isolated execution environment.

- 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)

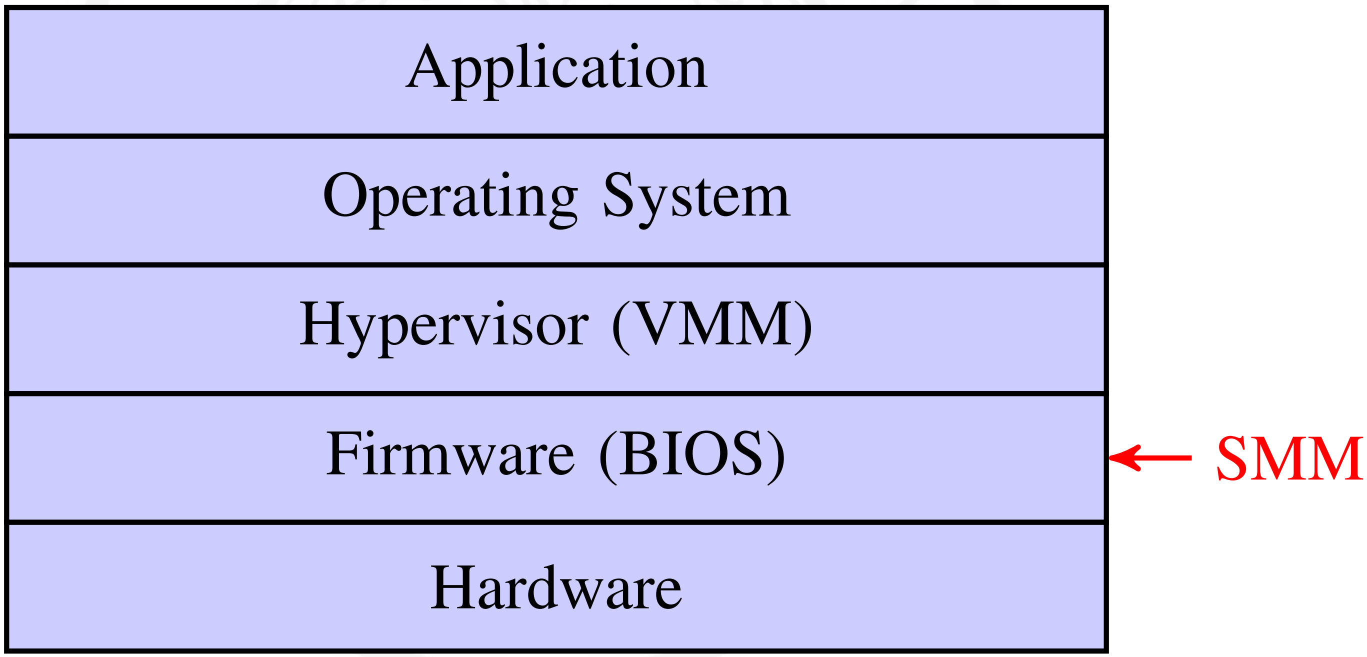
Background: System Management Mode

Approaches for Triggering a System Management Interrupt (SMI)

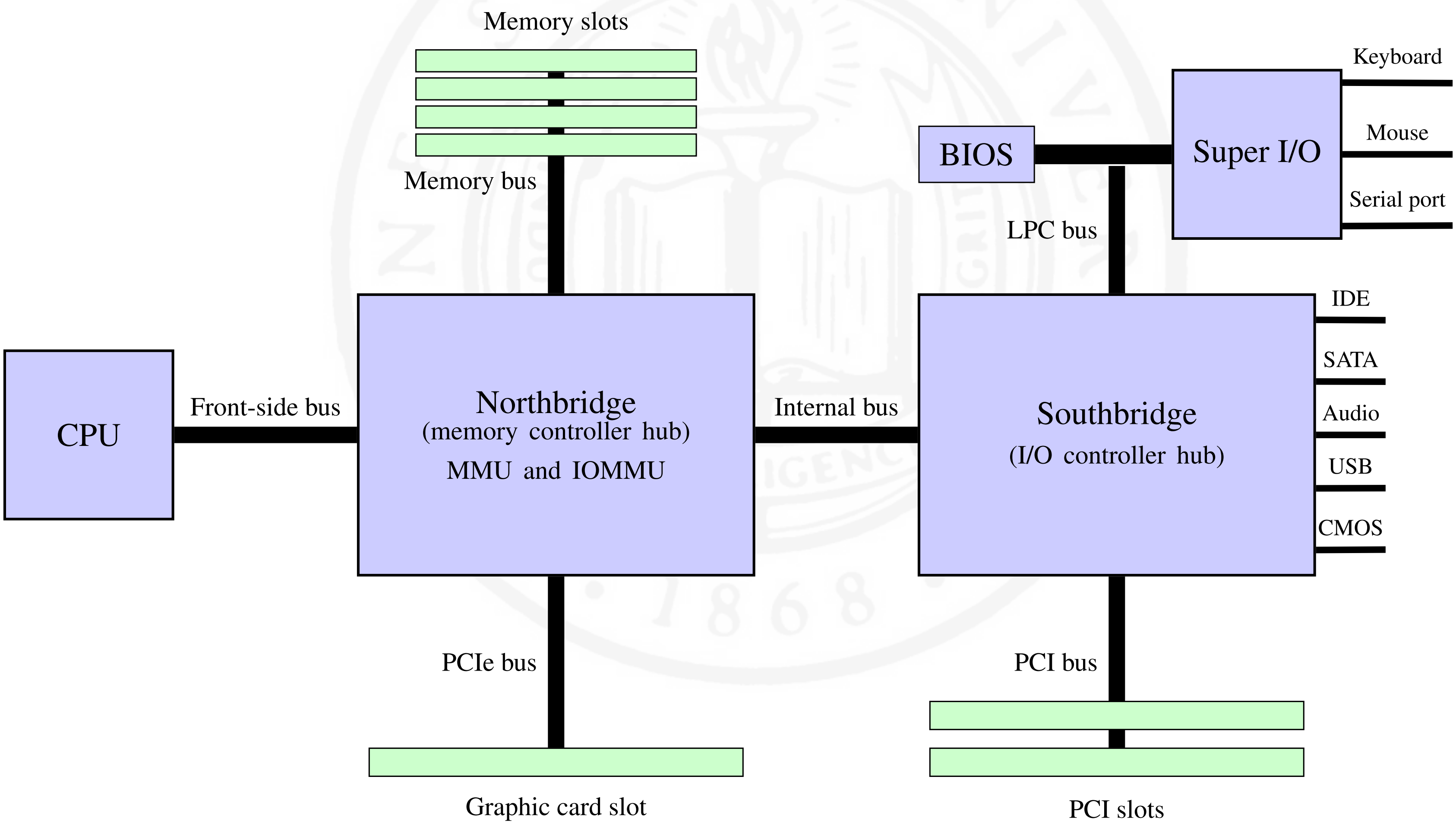
- Software-based: Write to an I/O port specified by Southbridge datasheet (e.g., 0x2B for Intel)
- Hardware-based: Network card, keyboard, hardware timers



Background: Software Layers



Background: Hardware Layout



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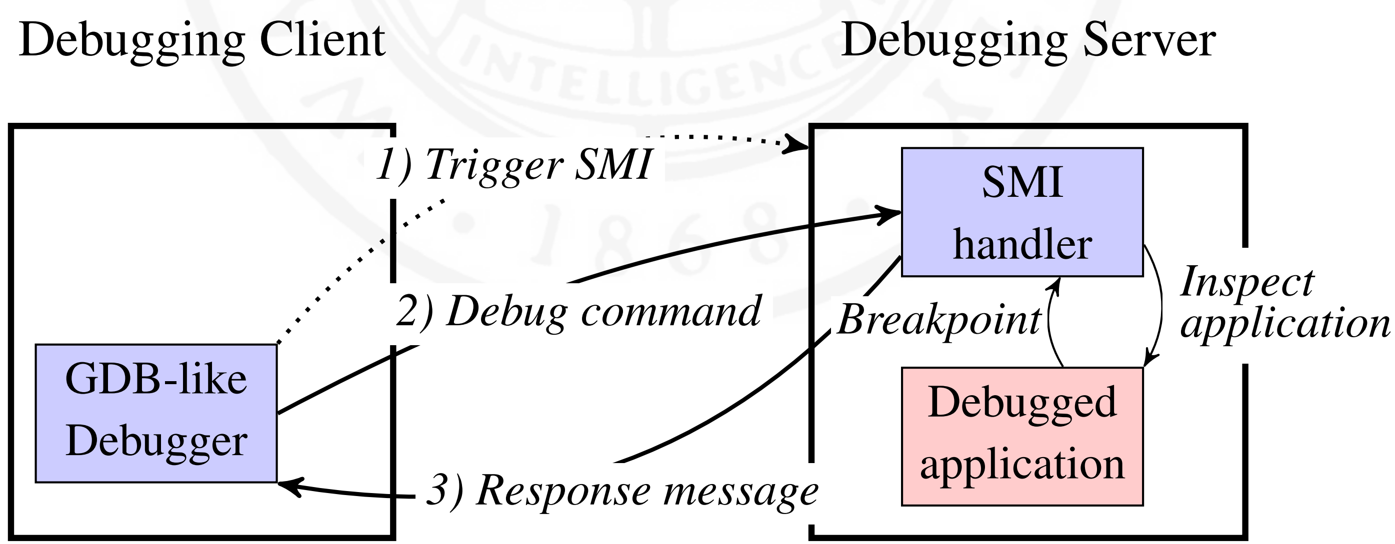
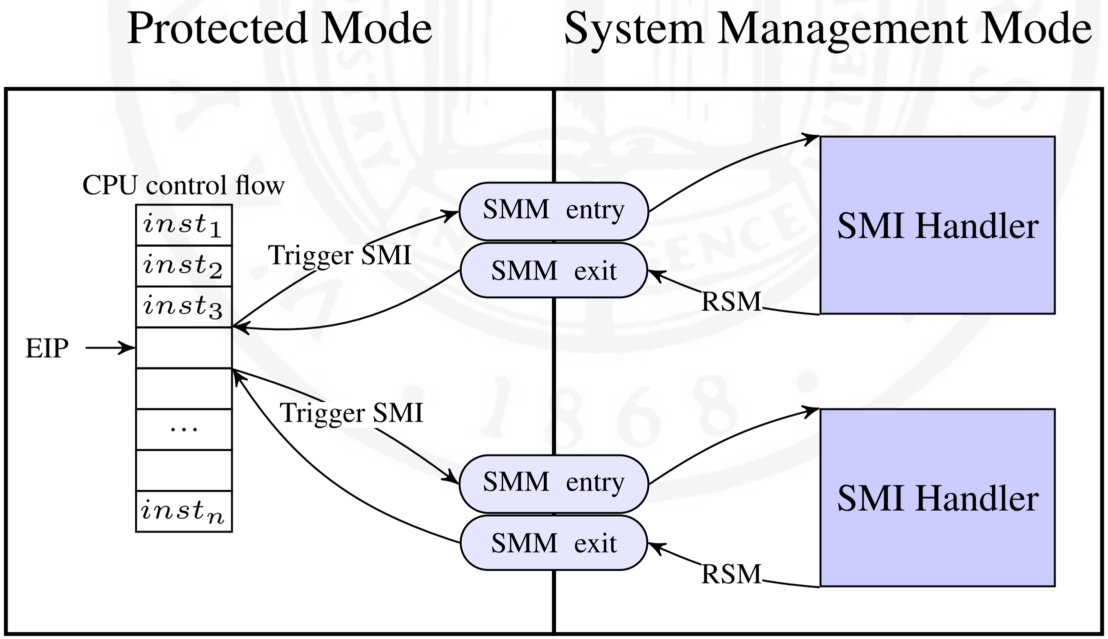
System Architecture

- 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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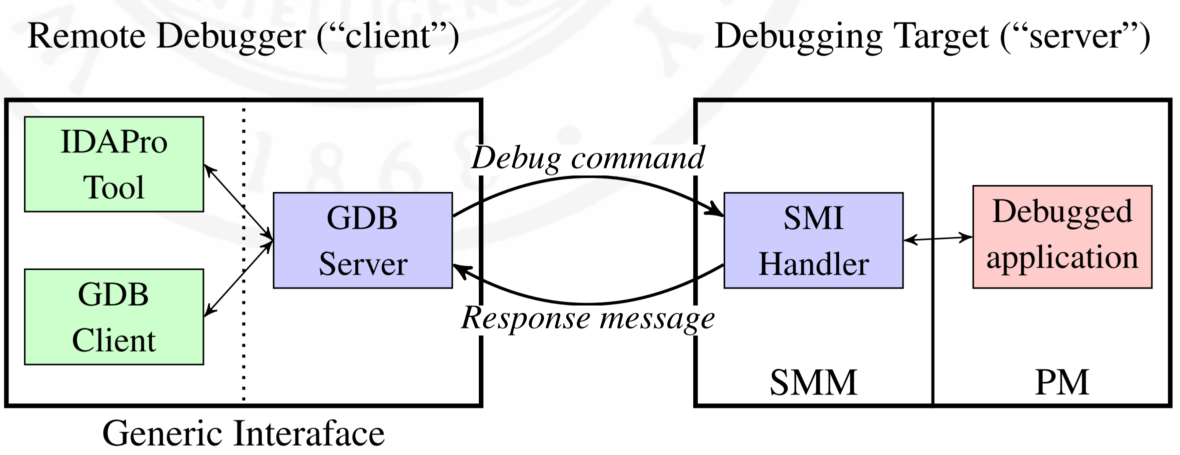
Conclusions and Future Work

- 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.