IntroLib: Efficient and Transparent Library Call Introspection for Malware Forensics

By

Zhui Deng, Dongyan Xu, Xiangyu Zhang and Xuxian Jiang

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IntroLib: Efficient and Transparent Library Call Introspection for Malware Forensics

Zhui Deng[†], Dongyan Xu[†], Xiangyu Zhang[†], Xuxian Jiang[*]

[†]Purdue University
[*]North Carolina State University

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Motivation

- Malware Analysis
  - Reveal goals and detailed behavior of malware
- Dynamic Analysis
  - Complement static analysis to capture and analyze runtime behavior
- Tamper Resistance
  - Higher privilege over malware in virtualization environment
- Anti-analysis Methods
  - Thwart dynamic analysis

Existing Approach:

- Ether (Dinaburg et al., 2008), MAVMM (Nguyen et al., 2009)
  - Leverage hardware virtualization
    - Avoid problem of instruction semantic discrepancies in emulators
  - Suffer from significant performance overhead when performing fine-grained live malware analysis
    - Single-stepping triggers transitions between guest and hypervisor

Existing Approach:

- Kang et al. (2009)
  - Guide the execution of malware in emulators using transparent reference systems
  - High performance penalty when obtaining execution traces
- V2E (Yan et al., 2012)
  - Selectively emulating instructions to boost performance
  - enumerate all such instructions remains a challenge

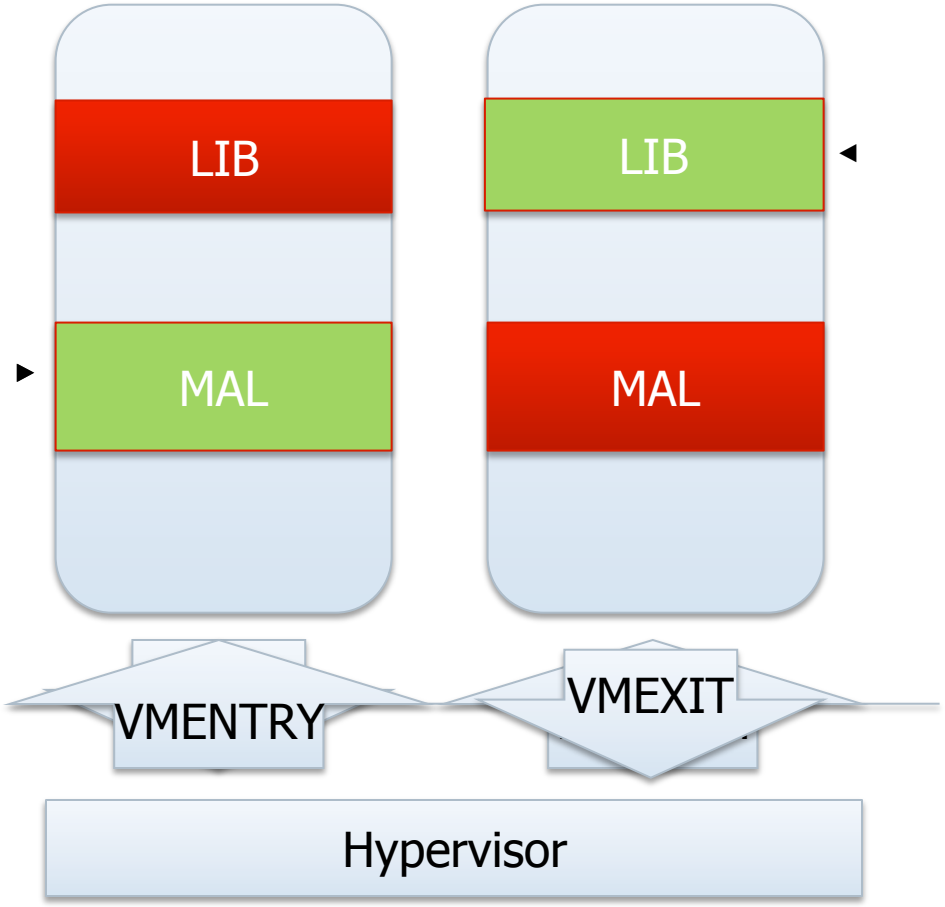
Our Approach

- IntroLib
  - Track and log the sequence of user-level library calls made by the malware
  - More informative and provides more insights into malware
    - Compare with system call based introspection
  - More lightweight and suitable for live malware forensics
    - Compare with instruction-level dynamic analysis
  - More immune to malware's emulation detection logic
    - Compare with emulation-based tools
  - Cover all kinds of user-mode library calls
    - such as Windows API library functions and C library functions.

Goals

- Trustworthiness
  - Cover all user-mode library calls
- High transparency to malware
  - Difficult to detect by advanced anti-analysis malware
- Efficiency
  - The performance overhead should be low for live forensic analysis

Design: Intercept Control flow Transitions



Lib!Fn:
  push ebp
  …
  ret

Mal:
  call Lib!Fn
  cmp eax, 1

Design: Identify Memory Layout

- Categorize user-mode pages into three types:
  - malware code, library code and data pages
- Malware program might generate new code and load additional libraries at runtime
  - Data pages => malware code | library code pages
- Lazy Identification
  - Code pages are not identified until there is an instruction fetched
  - Hypervisor leverages VMI to determine the type of memory area

Design: Logging

- Read the source/destination addresses of the transition from the Last Branch Record (LBR) stack
- Parse library function names/addresses from library files
  - Copy-on-write disk to prevent tampering
- Read function arguments from stack according to function prototype
- Match function return by recording return address
- Extract return value from EAX register

Design: Improving Transparency

- Avoid timing attack
  - Modify execution time queried from guest
- Shadow LBR Stack
  - Conceal utilization of LBR from guest

Evaluation

- Evaluate in three aspects
  - Functionality
  - Transparency
  - Performance
- Hardware configuration
  - Host CPU: Intel(R) Core(TM) i5-2410M 2.30GHz
  - Host memory: 4GB
  - Host OS: Ubuntu Linux 11.04 64bit with kernel version 2.6.38
  - Guest memory: 1GB
  - Guest disk: 10GB
  - Guest OS: windows xp with no service pack

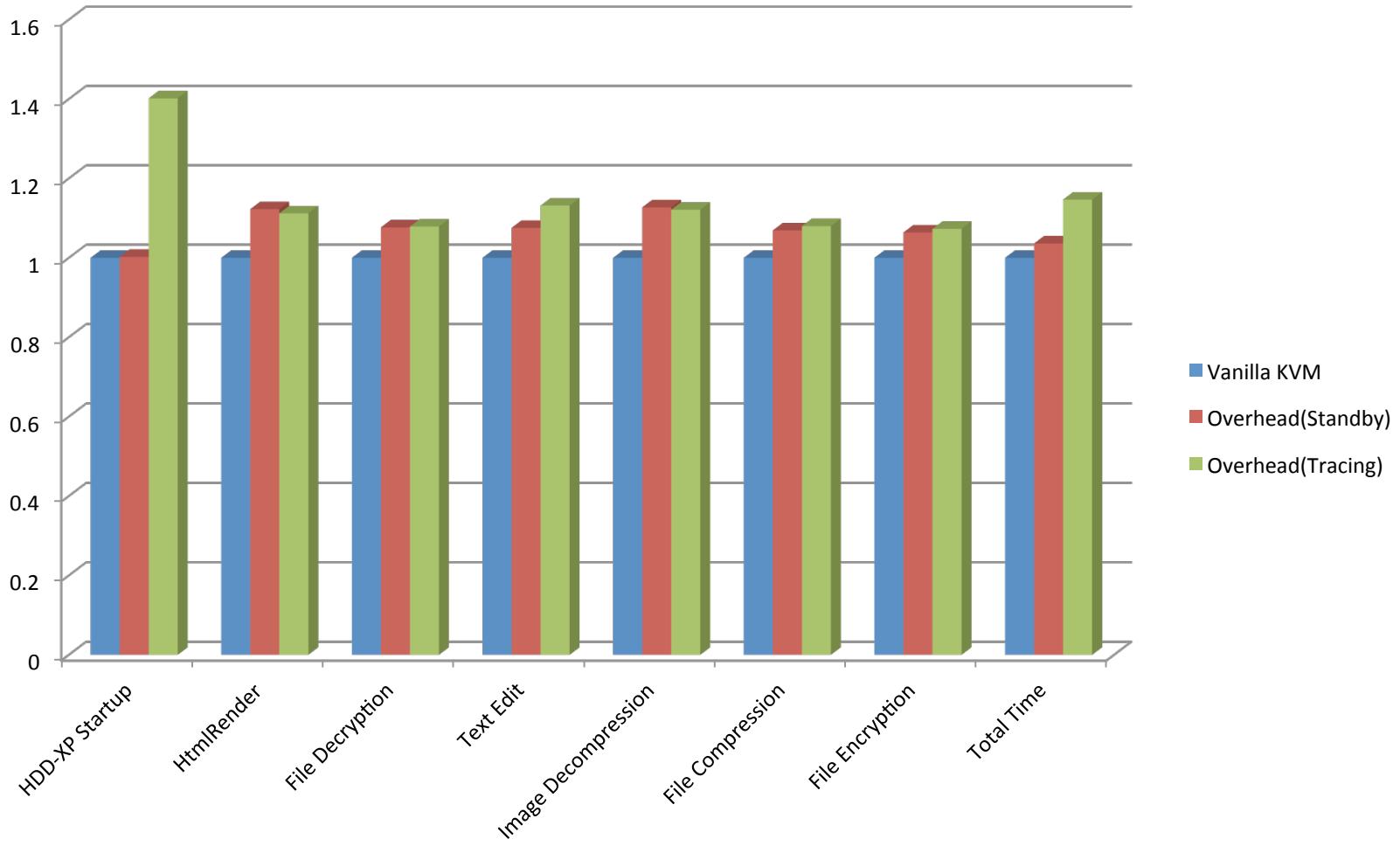
Evaluation: Functionality

- Evaluate with a pool of 93 real-world, Windows-based malware samples
- Case study 1
  - Win32/FakeRean
  - Disguised as a rogue anti-virus tool
- Case study 2
  - Win32/Dorkbot.AJ
  - multiple levels of packing and encryption/decryption to prevent static analysis
  - several anti-debugging and anti-VM tricks to thwart dynamic analysis.
- Fine-grained library call tracing logs is more helpful than system call logs for understanding malware

Evaluation: Transparency

- Crafted synthetic anti-emulation samples using detection code in previous work
  - None of these samples were able to detect our system
- 93 real-world malware samples
  - 3 of them crashed before showing any behavior
    - Crashed on Anubis and CWSandbox
    - Crashed when being executed in an unmodified KVM
    - The crashes were not due to detection of IntroLib
  - Obtain library call logs of all the remaining 90 samples
- IntroLib could maintain transparency to all similar attacks which detect the presence of analysis system in memory

Evaluation: Performance



Discussion

- IntroLib is not completely undetectable
  - TLB flush
  - TLB-based detection incurs high false positive rate
- IntroLib conceals itself but not the underlying virtualization platform
  - Virtualization has become a universal platform
- IntroLib relies on page level protection, so intra-page transitions could not be intercepted
  - Co-location of malware code and library code in the same page is rare and difficult
- IntroLib relies on some in-guest data when performing memory layout identification and library call logging
  - Possible solution: content-based identification of library code area and functions

Conclusion

- Perform efficient library calls tracing for malware forensics
- Utilize hardware virtualization to elevate its transparency
- Page table-based mechanism
- Uncover richer information than system call tracing-based approaches
- Incur low overhead

Thank You

{deng14,dxu,xyzhang}@cs.purdue.edu
jiang@cs.ncsu.edu