Lares: An Architecture for Secure Active Monitoring Using Virtualization

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Motivation

- Host-based security tools are not adequately protected.
  - Antivirus
  - IDS
- We need *active* monitoring for *prevention*
- **Lares** - Applies VM techniques for active monitoring
- Presents an architecture and sample implementation

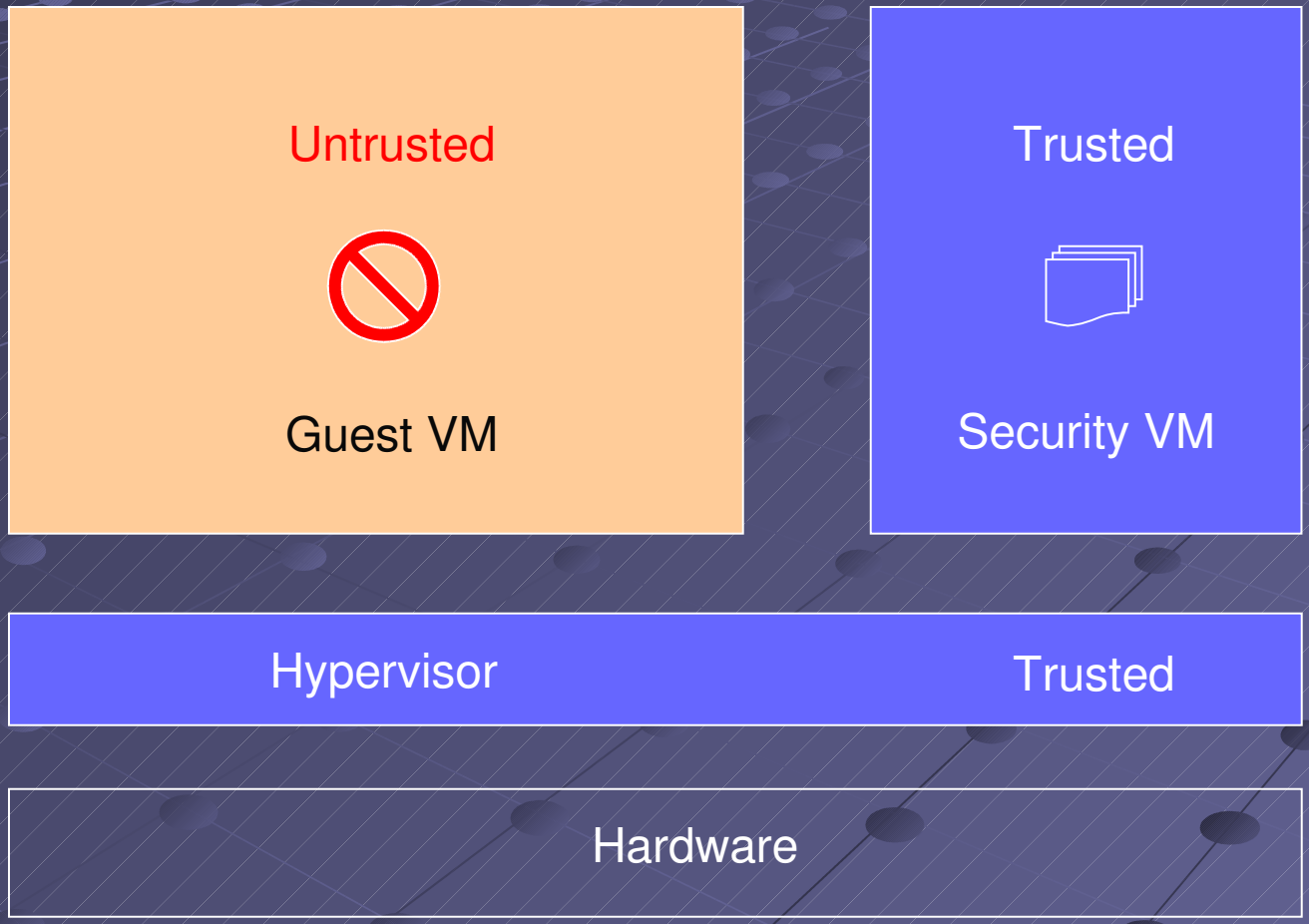
Active vs. Passive Monitoring

- Passive Monitoring
  - Run external scanning or polling
  - Detect a malicious access (e.g. memory corruption) and Correct
  - Example: VM Introspection
- Active Monitoring
  - Trigger a handler when an event happens
  - Prevent a malicious access
  - Example: Antivirus, IDS

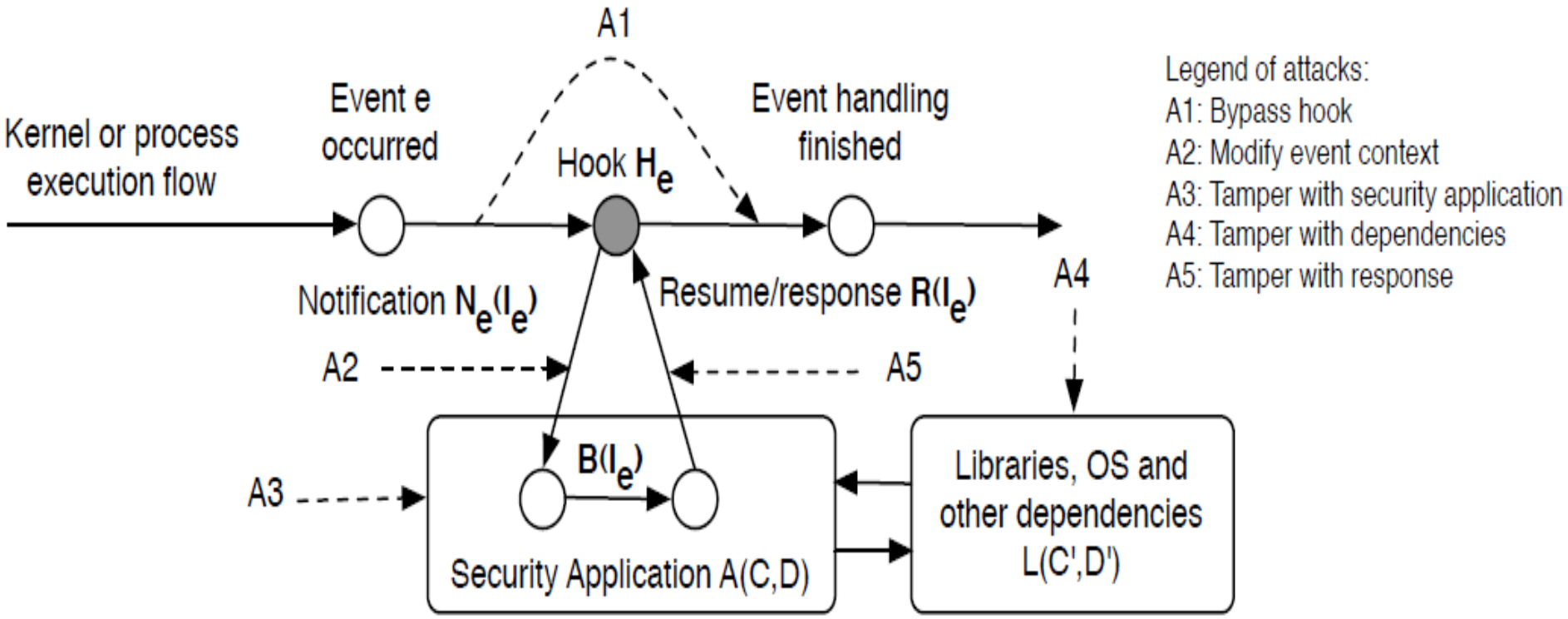
Major Challenges

- Malware monitoring requires
  - The analyzer and monitor must be hidden from malware
- Critical requirements:
  - For active monitoring we need to place hooks on the running system
  - Hooks are in the untrusted OS
  - How to protect the hooks and its comm. to VM?

System Layout



Adversary Model



- N_e is triggered if and only if *e* occurs legitimately
- I_e is not modifiable between occurrences of *e* and N_e

3. $B(I_e)$ of the security application is not altered maliciously
4. The effects of $R(I_e)$ on the system are enforced

Design Goals

- Protect Monitoring Components
  - Meet formal requirements
- Flexible Hook Placement
  - Difficult since adversary controls the host system
- Acceptable Performance Overhead

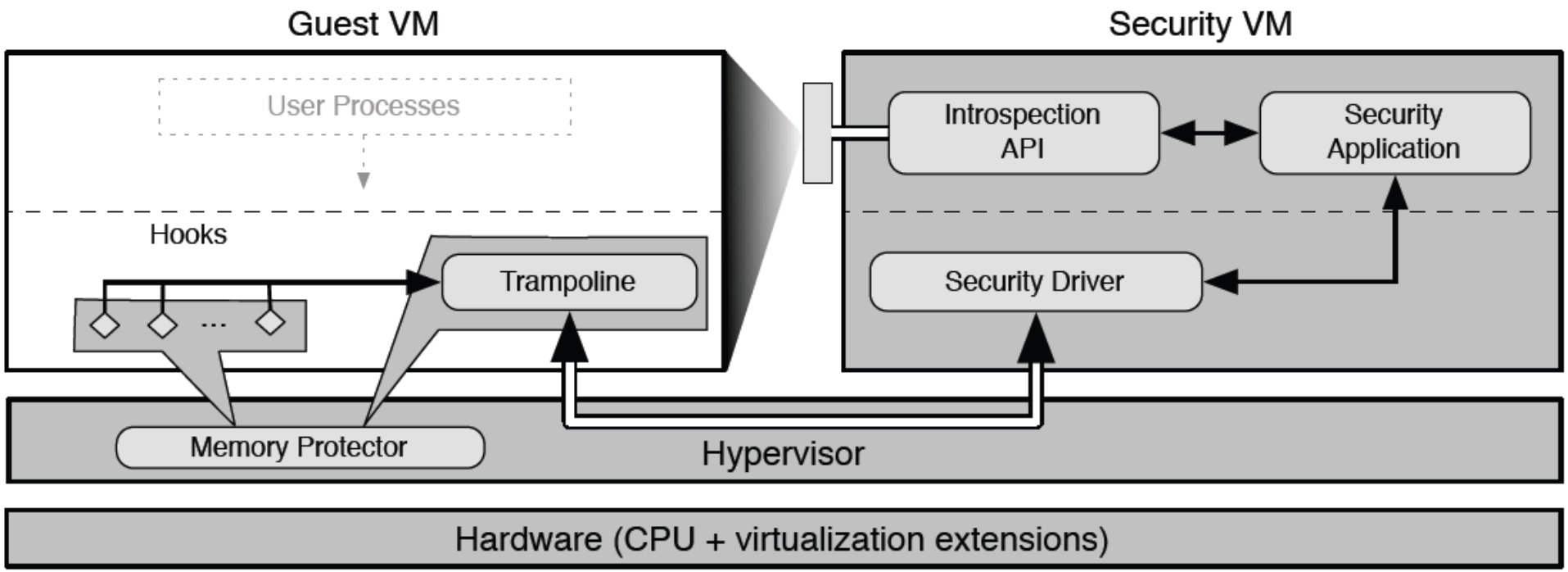
Solution Approach

- Split security solution over two VMs
- Guest VM
  - VM running the host OS
  - Controlled by adversary
  - Contains hooks
- Security VM
  - Contain security application (antivirus, IDS)
  - Trusted
  - Runs at same privilege level as hypervisor
- Use hypervisor-based memory protection to secure the hooks

Assumptions

- The hypervisor and Security VM form a trusted code base (TCB)
- The machine can undergo *secure boot*
- Guest VM undergoes an *initialization* after boot
  - Start the security components
  - Protect them
  - Add other security configurations

Architecture Overview



Guest VM Components

- Hooks
  - JUMP in program code
  - Redirection in jump tables
  - Any other technique to transfer control
- Trampoline
  - Bridge between the hooks and security drivers in security VM
  - Passes arguments to the security driver

- Requirements for designing trampoline
  - Should be completely self-contained
  - Execute atomically at each round
  - Usage of data elements must be completely non-persistent

Security VM Components

- Security application
- Introspection API
- Security driver

Hypervisor Components

- Guest OS component protection
  - Mark the memory location of hooks and trampoline as read-only
- Inter-VM communication
  - Delay returning to Guest OS until security VM gives a response

Implementation

- Uses hook on Windows syscall `NtCreateSection`
- Wrote a driver to install hook and trampoline
  - Inited during Guest OS initialization
  - Never swapped to disk
  - Hypervisor activate memory protection
  - 324 SLOC

Continued …

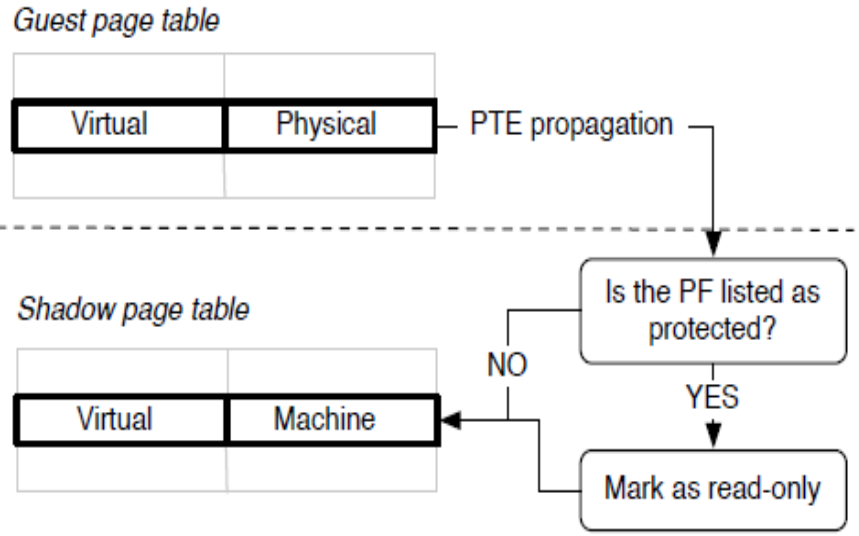
- Inter-VM Communication
  - Added a new hypercall
  - Uses a shared memory to send (receive) event request (response) to (from) hypervisor
  - 127 SLOC
- Security Driver
  - Imparts modularity/flexibility
  - Interfaces with security application
  - Built as Linux Kernel Module (LKM)
  - 182 SLOC

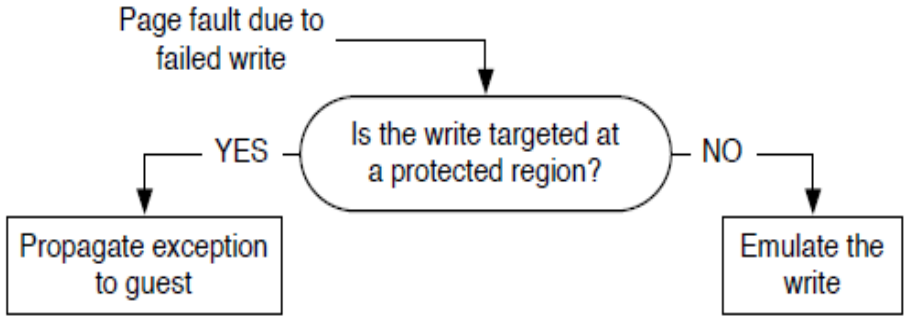
Continued …

- Security application
  - Checks the file handle that was passed to `NtCreateSection`
  - Allow execution if permitted
  - 298 SLOC

Memory Protection

- Takes advantage of shadow paging in Xen
- Modify Xen's page fault handler to enable byte-sized granularity
- 78 SLOC

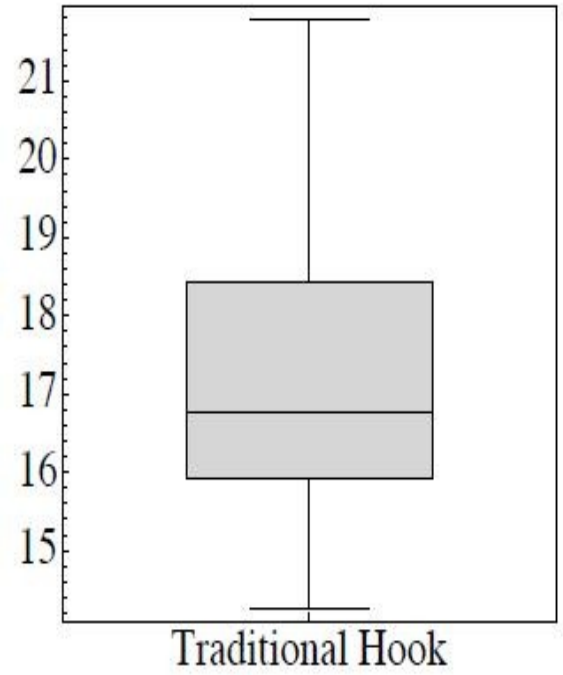




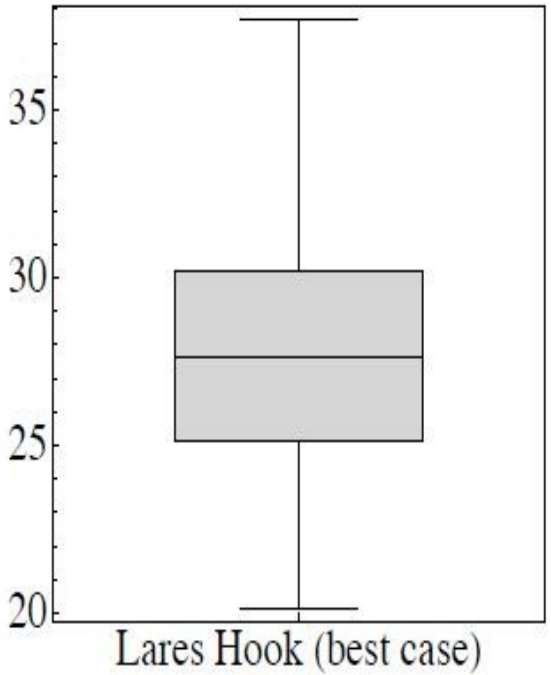
Performance

- Settings:
  - Intel Core Duo, 2GB RAM
  - Hypervisor: Xen
  - Guest VM: Windows XP, 384MB
  - Security VM: Fedora
- Hook processing time:
  - Traditional Hook (security application in same VM as host)
    - 17 micro-sec
  - Lares Hook (best case, minimal processing in security application)
    - 28 micro-sec
  - Lares Hook (with processing)
    - 150 micro-sec

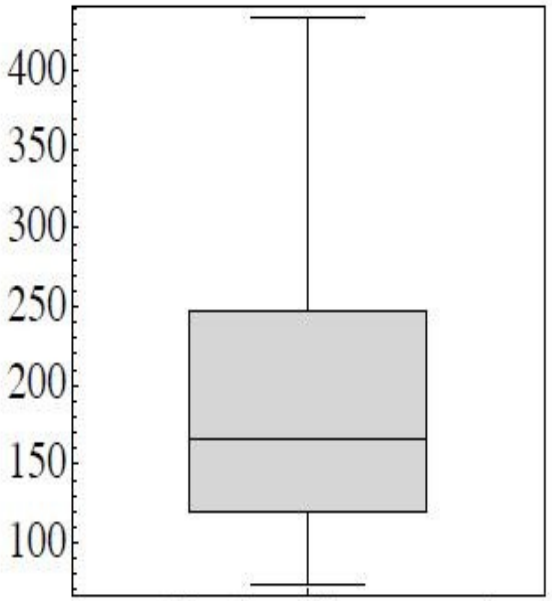
Results



Traditional Hook

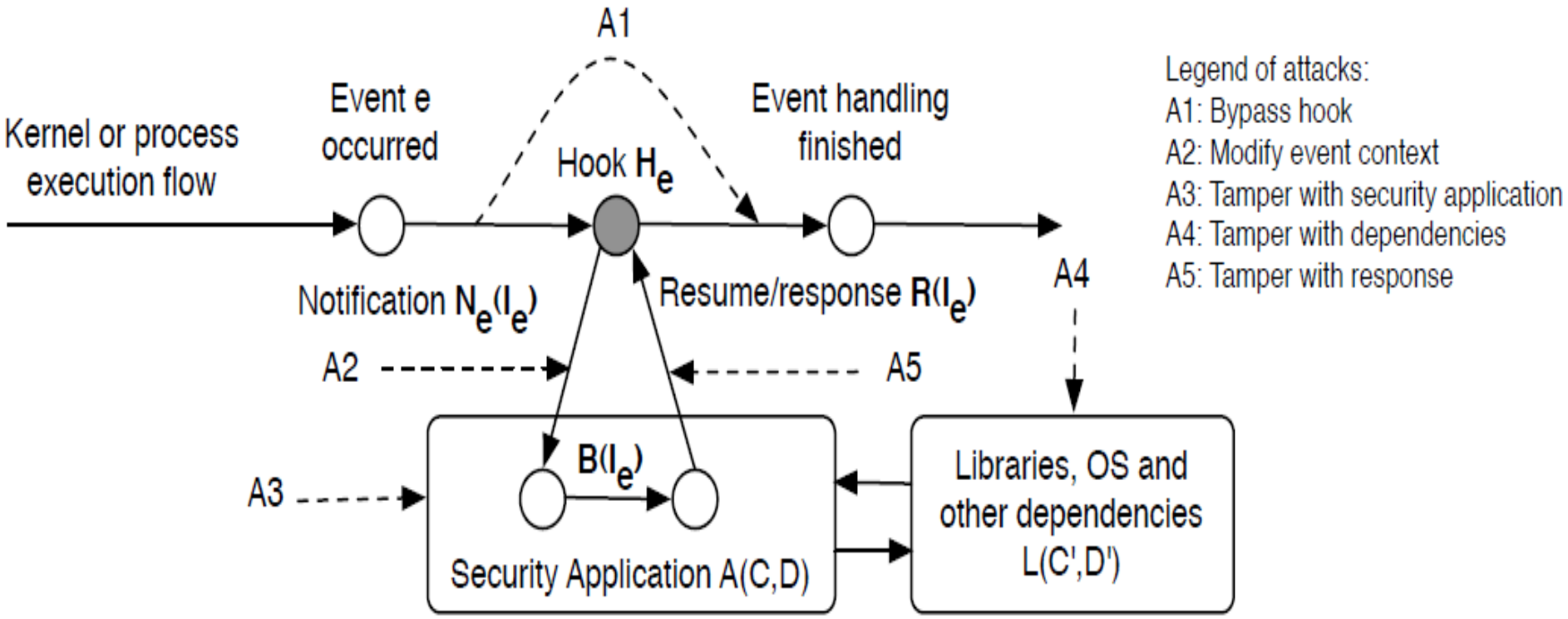


Lares Hook (best case)



Lares Hook (with processing)

Adversary Model



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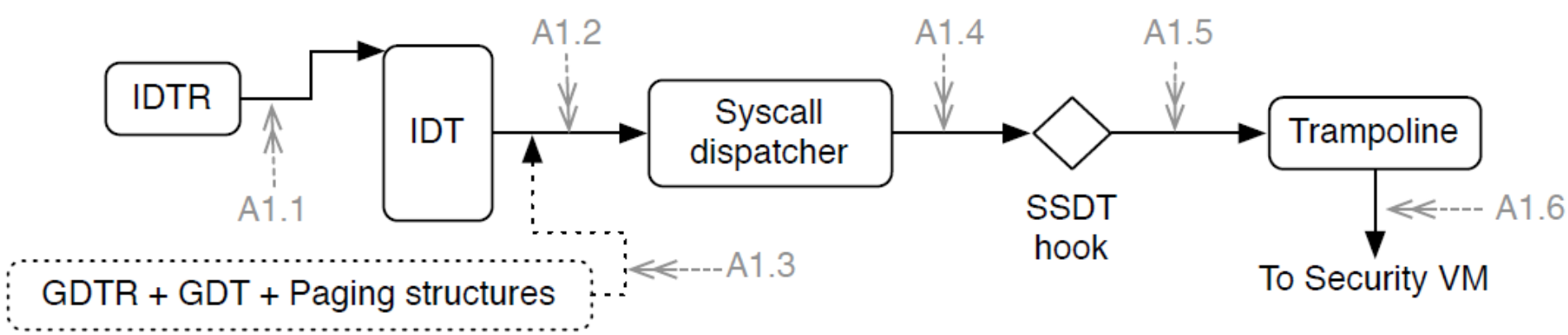
Security Analysis

- A3, A4 are met as per trusted VM assumptions
- A2, A5 are met by disabling interrupts by the trampoline
- A5 may be circumvented by non-maskable interrupts (NMI) [hardware fatal errors]
- But one VM uses a single core only
  - Malware cannot use the other core to send NMI

Handling Attacks of Type A1



- A1.5 and A1.6 handled by memory protection
- Write protect IDT to prevent A1.2 and A1.4
- A1.1 cannot be handled by Intel VT-x
- AMD SVM can trap changes to IDTR

Continued …

- A1.3 is more difficult to handle
  - Changes to GDTR, GDT, Page Tables
  - Memory Introspection has similar problems
  - Monitor shadow PT entries to check that they point to known good locations
- Preventing bogus event notification
  - Mark the trampoline memory region as non-executable (NX)
  - On fault, check origin of branch
    - If valid hook, proceed
    - Else attacker is making bogus call to trampoline

Conclusion

- Enable active monitoring with VM security
- Takes advantages of secure VM
- Can place hooks at arbitrary location in Kernel
- Low overhead
- Works on production systems
- Strong adversary model
- No special hardware needed