# Using Hardware-Assisted Virtualization to Protect Application Address Space Inside Untrusted Environment

**Denis Silakov**
Institute for System Programming, RAS
silakov@ispras.ru

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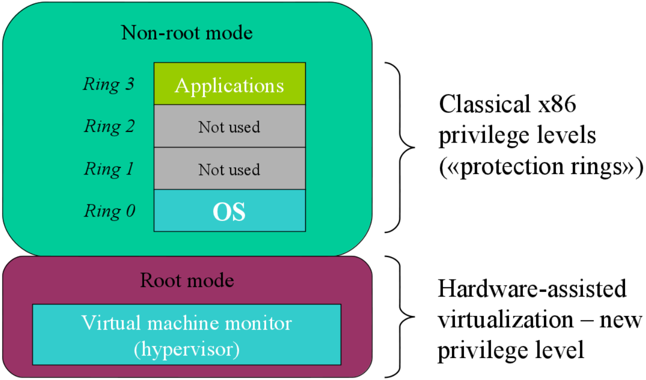
# Hardware-Assisted Virtualization



# Virtualization and Security

Hypervisor is just a program. It can perform different tasks, not only virtual machine management.

Hypervisor has higher privileges than OS.

Hypervisor can be made much more smaller than OS ⇒ (potentially) less vulnerable.

⇒ **Some security functions can be delegated to hypervisor.**

# Hypervisor-Based Protection Systems

- Encrypt process memory (*Overshadow*)
- Launch different processes in different VMs (*Qubes OS*, *Terra*)
- Provide additional services for Malware detection software like antivirus, IDS, etc. (*VMware VMsafe*)

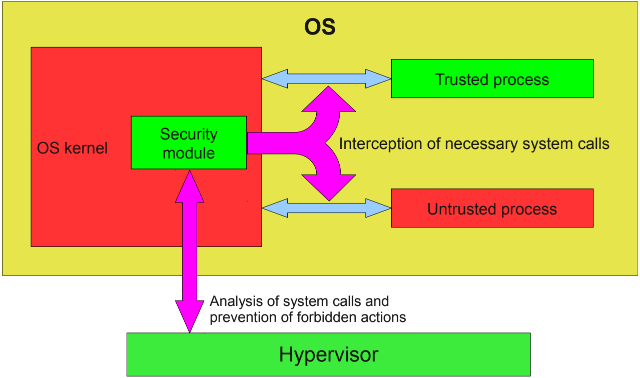
# Our Goal

Develop a protection system with the following properties:

- No modifications of applications or OS are required
- Memory and files of trusted process are protected from unallowed **modifications** attempts only. The process should still be able to interact with other programs

OS is considered to be (potentially) compromised, so the system should protect processes from the OS itself.

# System Architecture



# Controlling Consistency of a Trusted Process

- Protect files on storage media
- Protect address space of a running process

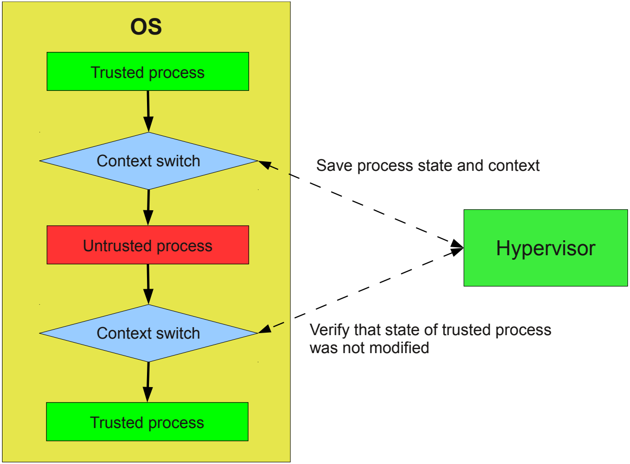
# Checking Consistency of Application Files

Checksum-based algorithm

- Calculate checksum (SHA-1) for every memory page of application file inside trusted environment
- At startup, hypervisor checks the sums to ensure consistency of loaded/launched files

# Protecting Control Flow

Single-core CPU $\Rightarrow$ only one process is running at any moment of time



# Protecting Address Space

Based on *Nested Page Tables* (used to translate memory addresses inside VM to physical ones). A separate set of NPT for every process is maintained by hypervisor.

For every process, hypervisor sets corresponding access permissions for different physical pages

- for pages used by a trusted process, only that process is granted with write permissions
- if a page is not used by any trusted process, hypervisor doesn't perform any specific actions
- OS is allowed to read all pages, but cannot modify memory of trusted processes

# Types of Protected Applications

- Statically linked programs
- Dynamically linked applications and programs loading libraries at runtime (using *dlopen*() functionality); pre-loaded libraries are also handled
- Multithread applications

# Assumptions

- System dynamic loader is trusted
- All libraries loaded by trusted process are also trusted *(work in progress – allow to load untrusted libraries)*
- Applications don't use *lazy binding (can be achieved by setting LD_BIND_NOW variable)*

# Implementation

- Hypervisor based on KVM (Kernel Virtual Machine)
- Supported hardware – AMD processors with hardware-assisted virtualization
- Supported OSes – 32bit Linux with kernel 2.6.31 or higher

# Attack Detection Power

*Trusted process – SSH (network connection with remote host)*

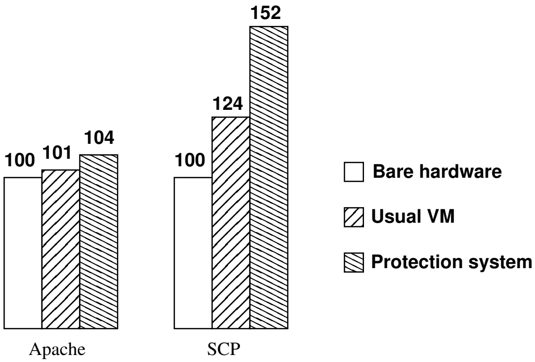
Emulated attacks:

- Modification of application executables and libraries (including those loaded using *dlopen*())
- Injection of malicious code in the process address space:
  - load a library using LD_PRELOAD
  - modify process memory using *ptrace*()-based techniques (**gdb** debugger, **PreZ** code injector)

All attack attempts were successfully detected by the protection system.

# Performance

- Apache – Flood load test (∼10 requests per second)
- SCP – copy large file (4GB) using SSH



# Questions?

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