OS Security

Virtualization

Radboud University, Nijmegen, The Netherlands

Winter 2016/2017

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  - (i) signature-based detection, (ii) anomaly-based detection and (iii) protocol state analysis detection

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  - Crucial
  - Very important
  - Important

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  - 2-level protection: kernel and user mode
  - Multilevel protection: Ring 0-3

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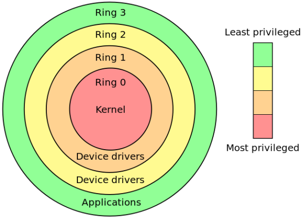
  - Manipulate memory management: set up page tables, load/flush the CPU cache, etc
  - Call halt instruction: put CPU into low-power or idle state until next interrupt

Multilevel Protection: Ring 0-3



- **Ring 0**: kernel
- **Rings 1-2**: third-party drivers (less privileged OS code)
- **Ring 3**: application code

More on Protection Rings - I

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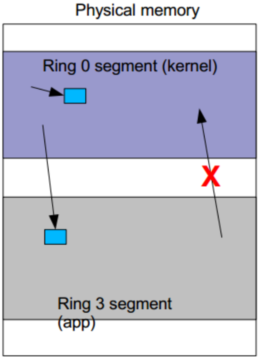
- The CPU has a Current Protection Level (CPL)
    -> Usually the privilege level of the segment where the program's instructions are being read from



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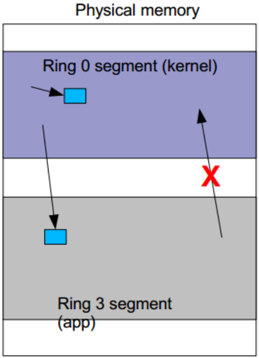

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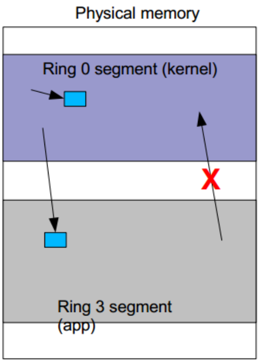
  -> e.g. Kernel can read/write user memory
  -> But user cannot read/write kernel memory.... Why?



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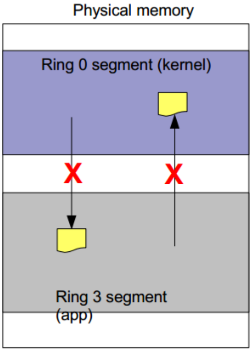

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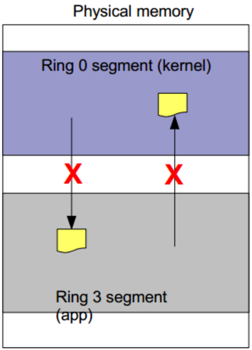


Types of Virtualization

1. OS-level virtualization
2. Application level virtualization
3. Full/native virtualization
4. Paravirtualization
5. Emulation

1. OS-level virtualization

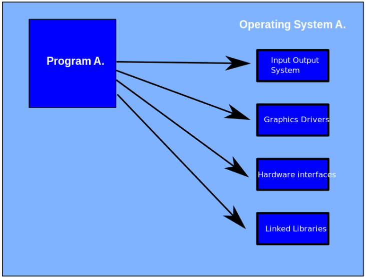
- OS allows multiple secure virtual servers to be run
- Makes the subsystem thinks it is running in its own operating system
- Abstracts the services and kernel from an application
- Guest OS is the same as the host OS, but appears isolated; apps see an isolated OS
- For example: Solaris Containers, FreeBSD Jails, Linux Vserver

2. Application level virtualization

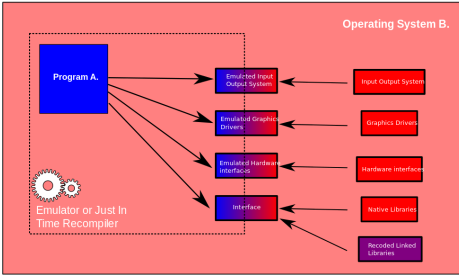
- Application behaves at runtime in a similar way when directly interfacing with the original OS
- Application gives its own copy of components that are not shared
- For instance: own registry files, global objects
- Application virtualization layer replaces part of the runtime environment normally provided by the OS
- Example: Java Virtual Machine (JVM)

2. Application level virtualization

1. Application in Native Environment



2. Application in Non-Native Environment



3. Full/native virtualization

- VM simulates "enough" hardware to allow an unmodified guest OS to be run in isolation
- Any software capable of execution on the hardware can be run in the virtual machine
- Example: VMWare Workstation/Server, Mac-on-Linux etc.

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- Example: VMWare Workstation/Server, Mac-on-Linux etc.
- Challenge: Interception and simulation of privileged operations (I/O operations)
- Every operation performed within a given virtual machine must be kept within that virtual machine; virtual operations cannot be allowed to alter the state of any other virtual machine, control program or hardware.

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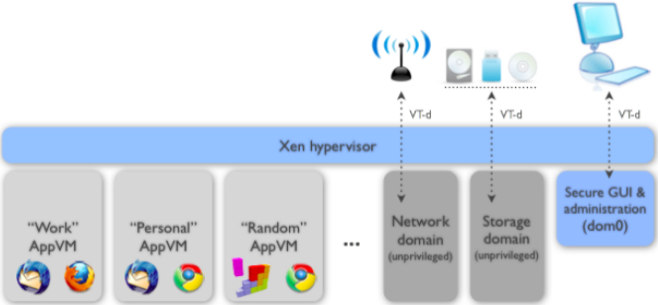
- Hypercalls trapped by the Hypervisor and serviced
- Provides specially defined ‘hooks’ to allow the guest(s) and host to request and acknowledge operations, which would otherwise be executed in the virtual domain
- Hence, reduces the portion of the guest’s execution time spent performing operations which are substantially more difficult to run in a virtual environment compared to a non-virtualized environment
- For example: Xen, VMWare ESX Server

5. Emulation

- VM emulates complete hardware and software
- Emulator is a hardware/software enabling a system (i.e. host) to behave like another system (i.e. guest)
- Unmodified guest OS for a different system can be run
- Useful for reverse engineering, malware analysis, forensics (taint tracking)
- For example: QEMU, VirtualPC for Mac, Android

Qubes OS



- Based on a secure bare-metal hypervisor (Xen)
- Networking code sandboxed in an unprivileged VM (using IOMMU/VT-d)
- USB stacks and drivers sandboxed in an unprivileged VM
- No networking code in the privileged domain (dom0)

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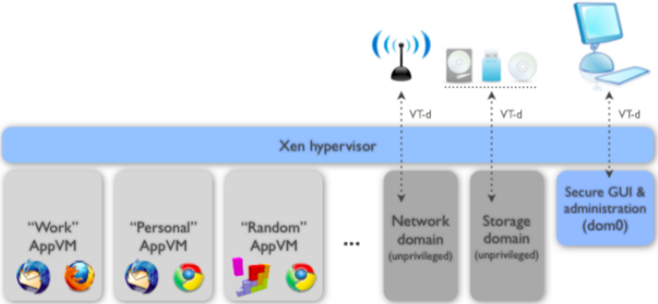
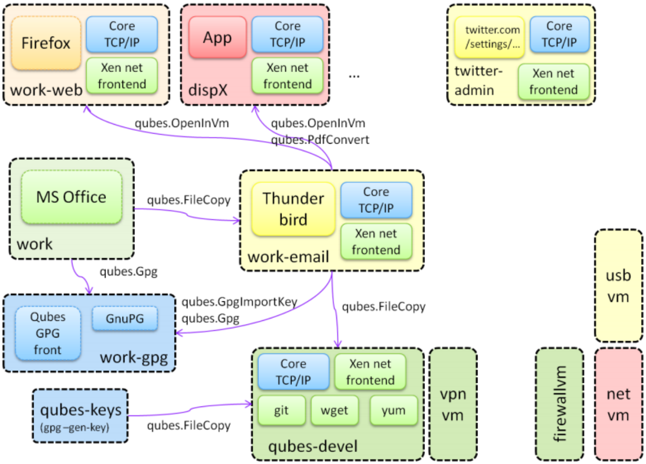
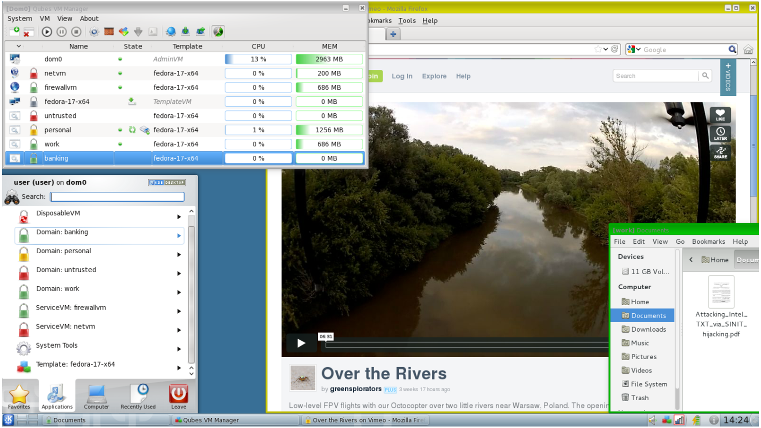


- All user applications run in "AppVMs," lightweight VMs based on Linux
- Centralized updates of all AppVMs based on the same template
- Qubes GUI virtualization presents applications as if they were running locally
- Qubes GUI provides isolation between apps sharing the same desktop
- Secure system boot

Compartmentalization in Qubes OS



Qubes OS Live



TUDOS - TU Dresden OS

- Demo
- Can be downloaded from:
  http://demo.tudos.org/eng_download.html

VM Vulnerabilities

- Hardware-oriented attacks
- Management interface exploits
- Break out of jail attacks (VM escape)
- Virtual-machine based rootkits (Blue Pill)
- Application privilege escalation
- Just-In-Time (JIT) spraying - circumvents the protection of ASLR by exploiting the behaviour of JIT compilation. Has been used to exploit PDF format and Adobe Flash
- Untrusted native code execution