Controlling the Speed of Virtual Time for Malware Deactivation

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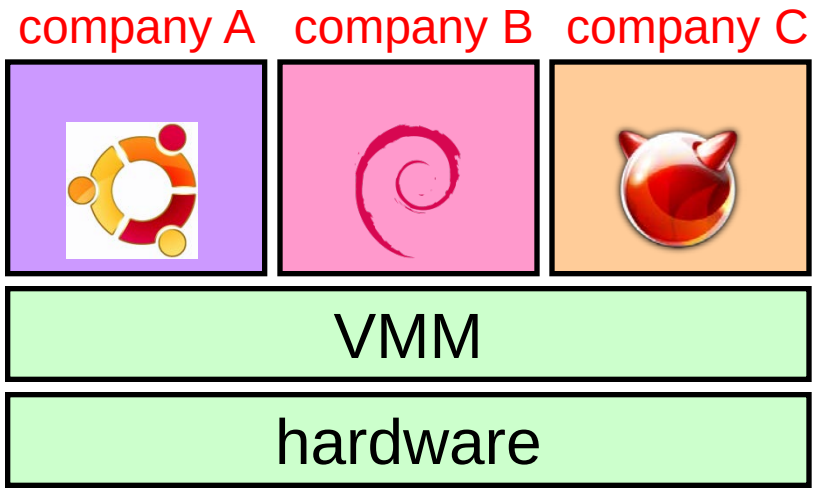
Background

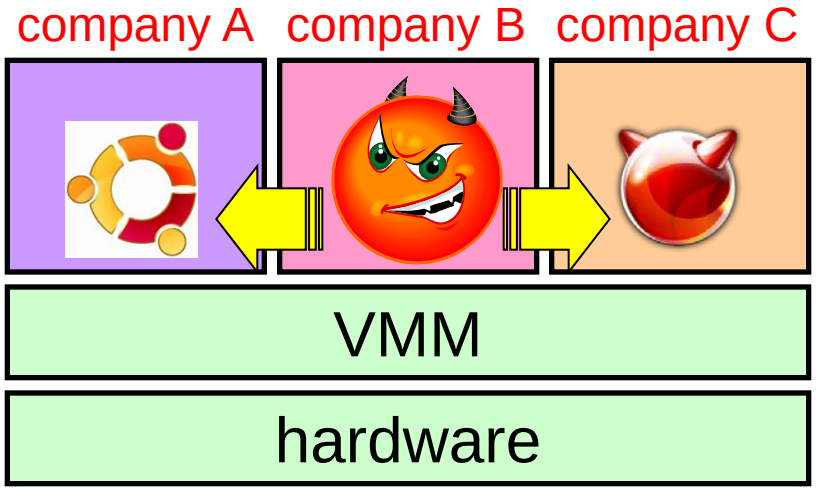
- IaaS (Infrastructure as a Service)
  - Ex.: Amazon EC2, Rackspace Cloud
  - IaaS provider lends VMs to customers
  - Customers freely use their own VMs



administrator of VMM ≠
administrator of guest OS

Malware Infection

- One guest OS is infected with malware that consumes resource
  - Wastes CPU, memory, …
  - May have bad effect on other guest OSes



- Much literature showed that some malware could be detected from the VMM layer
  - VMwatcher [Jiang et al. ’10], Lares [Brian et al. ’08], Lycosid [Jones et al. ’08]

Problem

- VMM administrator cannot modify the data managed by the guest OS
  - Ethically: Customer possesses the guest OS
  - Technically: Kind and version of the guest OS is unknown --- Windows? Linux? What version?
- Unfortunately, existing countermeasures are limited to coarse-grain ones
  - Ex.1: Stop whole VM
  - Ex.2: Drop all network packets from/to the VM
  - They affect even good processes running in the guest OS!

Goal

- Develop a VMM-based method for deactivating malware
  - Pinpointing the malware process
  - Mostly guest-OS-independent
  - Specifically, the method slows a malware process significantly
- Implement a system based on the method, HyperSlow, and demonstrate the effectiveness

HyperSlow

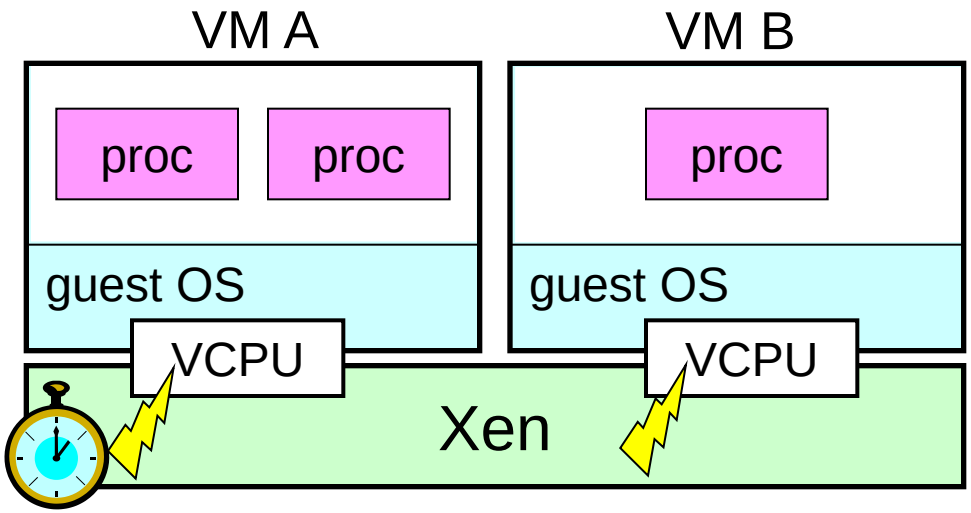
- Increases the speed of virtual time only while a malware process is running
  - It changes the rate of virtual timer interrupts and system time (elapsed time from boot)
- Is not a malware detection system, but a prevention system
  - It must cooperate with other detectors
- Xen-based

Process Scheduling Basics

- OS kernels (incl. Linux and Windows) use timer interrupts and/or system time for process scheduling
- Linux case:
  - When kernel receives a timer interrupt, it calculates the time consumed by the current process
    - Consumed time is calculated using system time
    - System time is calculated from hardware clock such as TSC
  - If the process has consumed all of the assigned time slice, it is preempted

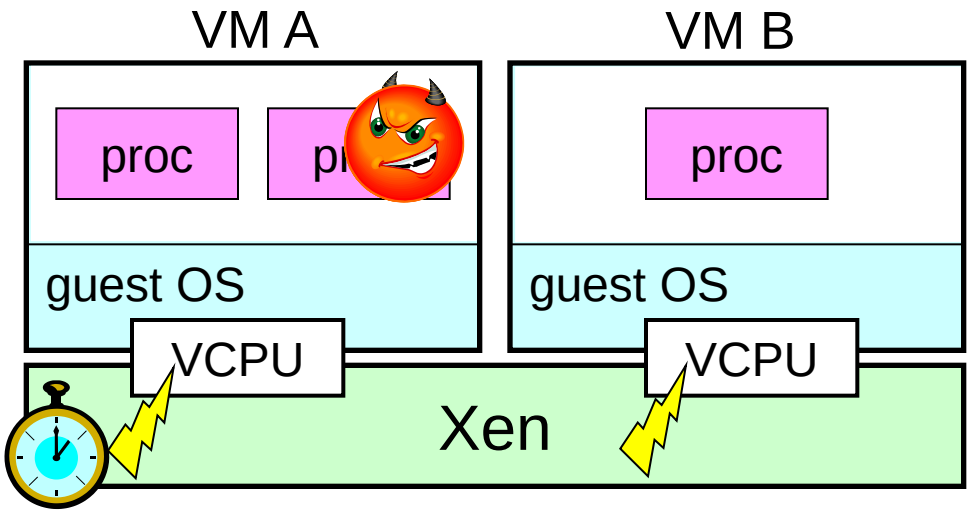
Virtual Timer Interrupts in Xen

- Xen periodically injects virtual timer interrupts to virtual CPUs
  - Based on them, guest OS schedules processes and performs timekeeping

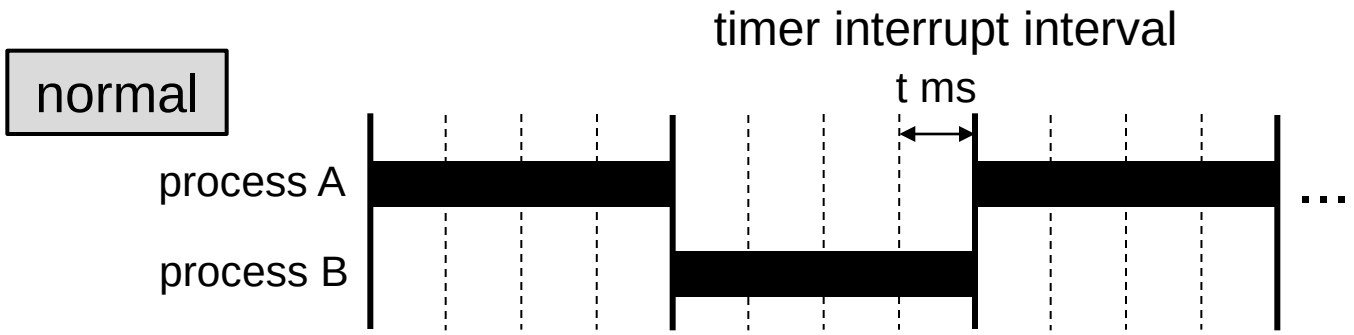


Basic Idea

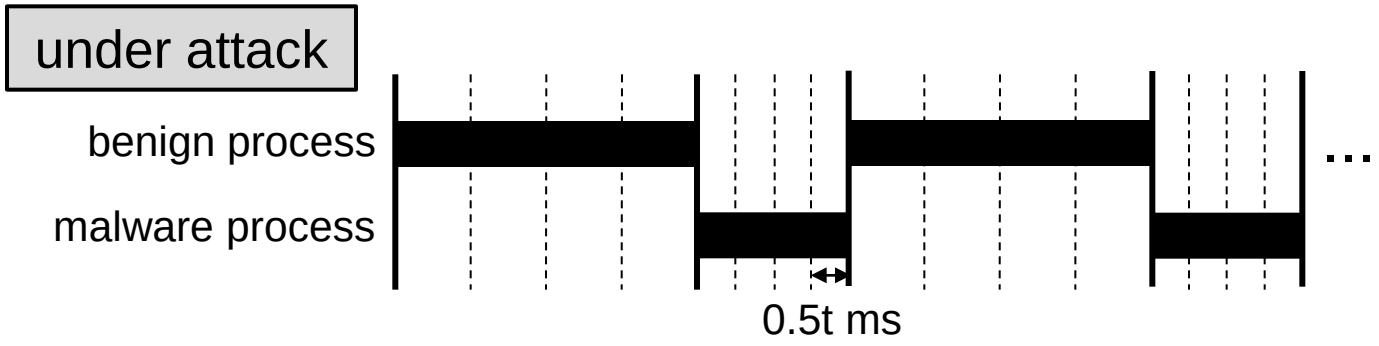
- HyperSlow extremely shortens the interval between virtual timer interrupts, only while a malware process is scheduled
  - Promotes context switch by having guest OS kernel misunderstand the elapsed time
  - Uses CR3 register as a pseudo PID [Jones et al. ’06]



Example



While the malware is running, HyperSlow sets
- Timer interrupt interval: ½
- Speed of system time: twice

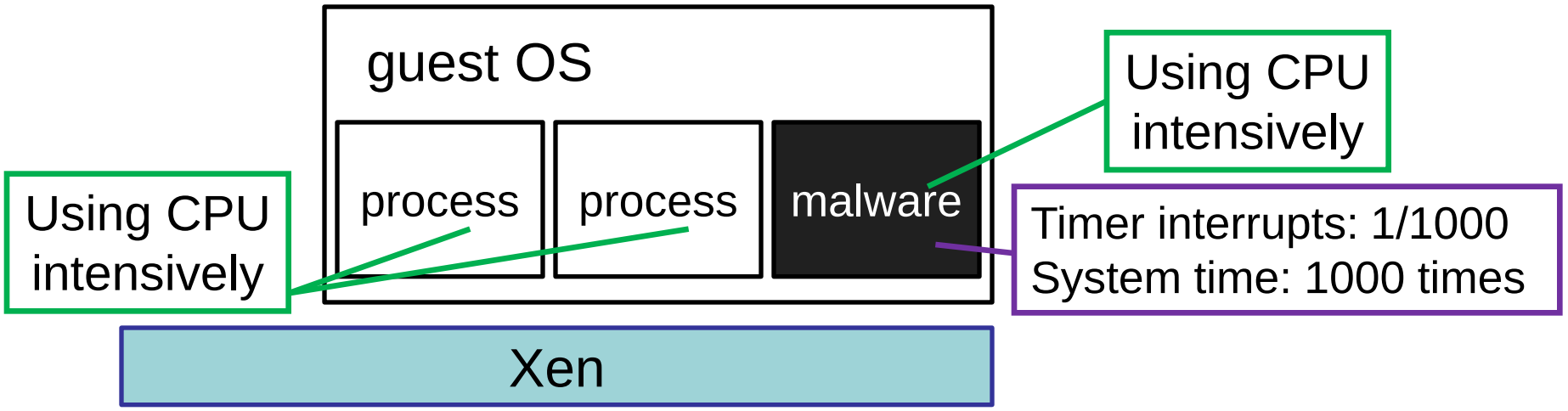


Malware obtains only half of the original time slice!

Experiments

- Platform
  - Intel Core 2 Duo 2.53 GHz, 2 GB memory
  - Xen 4.0.0
  - Guest OS:
    - Debian lenny (Linux 2.6.26), paravirtualized
    - Memory: 512 MB
    - Pinned to one physical CPU
- Three setting
  - Ideal setting
  - Web server and CPU-DoS malware
  - E-mailing malware

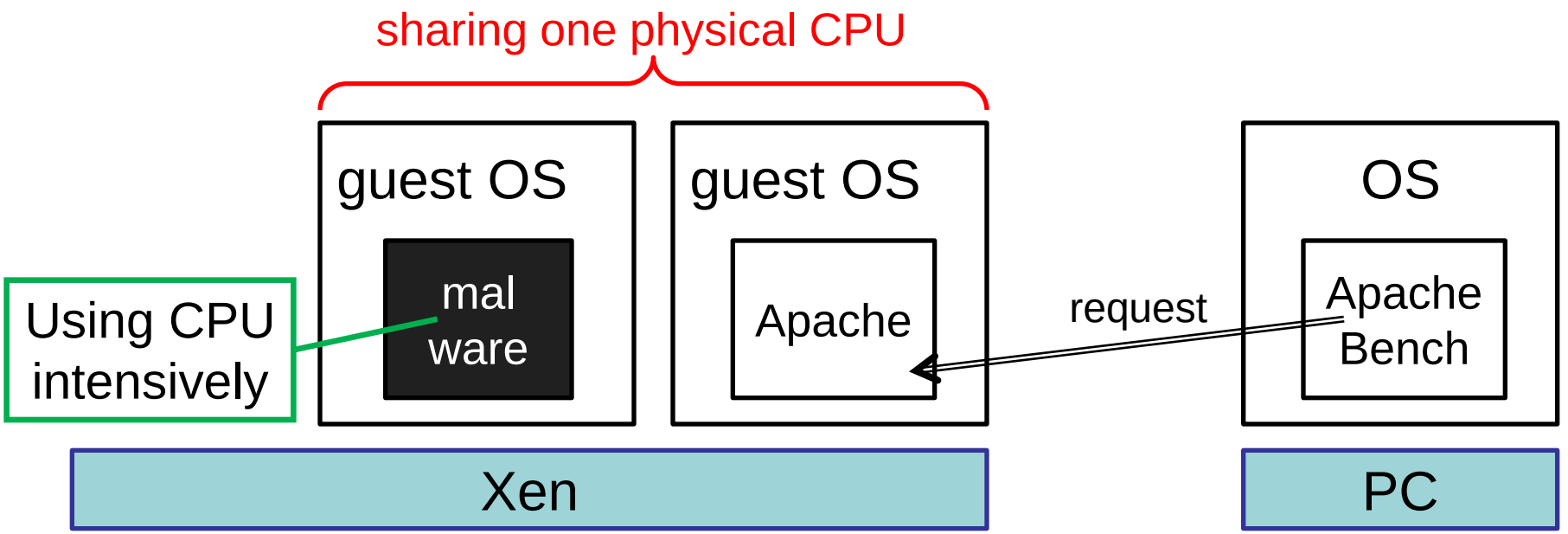
Ideal Setting



Speed of malware became 1/3869!
And, other processes were little affected!

- Why not 1/1000 but 1/3869?
  -> Due to OS noises such as context switch?
  Under investigation

Effect of CPU-DoS Malware on Web Server



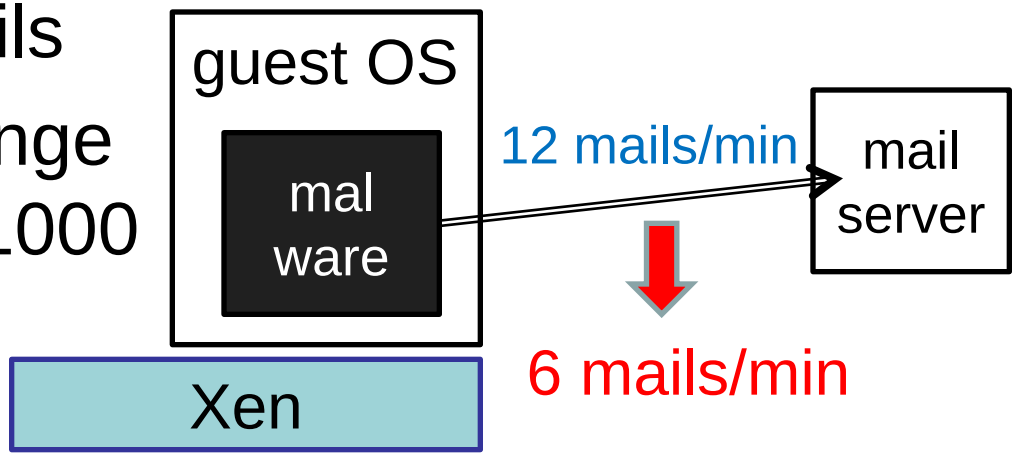
Effect of CPU-DoS Malware on Web Server

	average response time (ms)	worst response time (ms)
Original	8.52	3008
Malware added	76.63 (+799%)	46987 (+1462%)
HyperSlow added	11.92 (+39.8%)	9004 (+199%)

Greatly reduced negative effect on another guest OS

Slowing E-mailing Malware

- Malware sends e-mails
- We attempted to change malware speed to 1/1000



- Result:
  HyperSlow could change the speed to approximately the half of the original
  - Note that e-mailing software is I/O-intensive and/or sleeping most of time

Related Work

- FoxyTechnique [Yamada et al. VEE2007]
  - VMM-based system for changing resource management policy by OS kernel
  - No mention about slowing execution
- FoxyLargo [Yoshida et al. IWVT2008]
  - VMM-based system for slowing VCPU speed
  - Granularity is the whole OS, not a process
- Lycosid [Jones et al. VEE2008]
  - VMM increases CPU time consumed by a particular process
  - Focus on hidden process detection, not prevention

Conclusion and Future Work

- We proposed a malware deactivation method
  - Mostly OS-independent
    - Because it changes only the behavior of virtual hardware
  - Process granularity
  - It cannot completely stop malware, but will be useful for the first mild countermeasure in IaaS context
- Future work
  - Investigate side effects on timekeeping in guest OS
  - Combine with malware detection system
  - Do experiments on other platforms such as Windows, full-virtualized VMs, and other hypervisors