Windows Server Virtualization & The Windows Hypervisor

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Agenda - Windows Server Virtualization (WSV)

- Why a hypervisor?
- Quick Background & Architecture
  - For more details, see presentation on conference CD
- Security Characteristics
- Deployment Considerations
- Future Directions

Why a hypervisor?

- Thin, low level microkernel
- Eliminates ring compression
- Runs guest operating systems w/o modification
- Adds defense in depth
- Leverage current & future hardware
- Scalability

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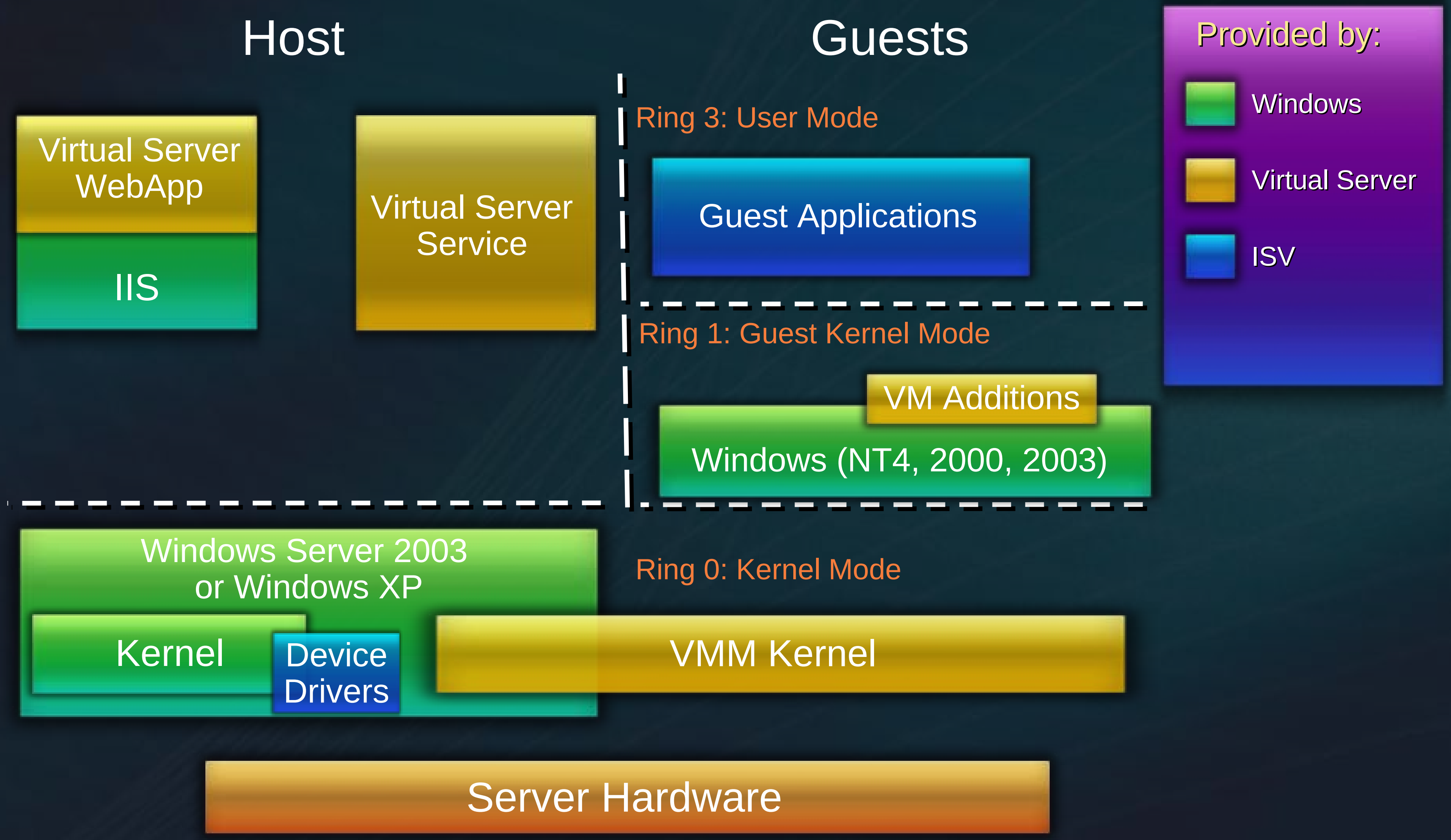
Windows Server Virtualization Background

- Project code name Viridian
- Full machine virtualization for guest operating systems
- Component of Windows Server 2008
- Final version available within 180 days of Windows Server 2008 RTM
- Installs as a role on Server Core

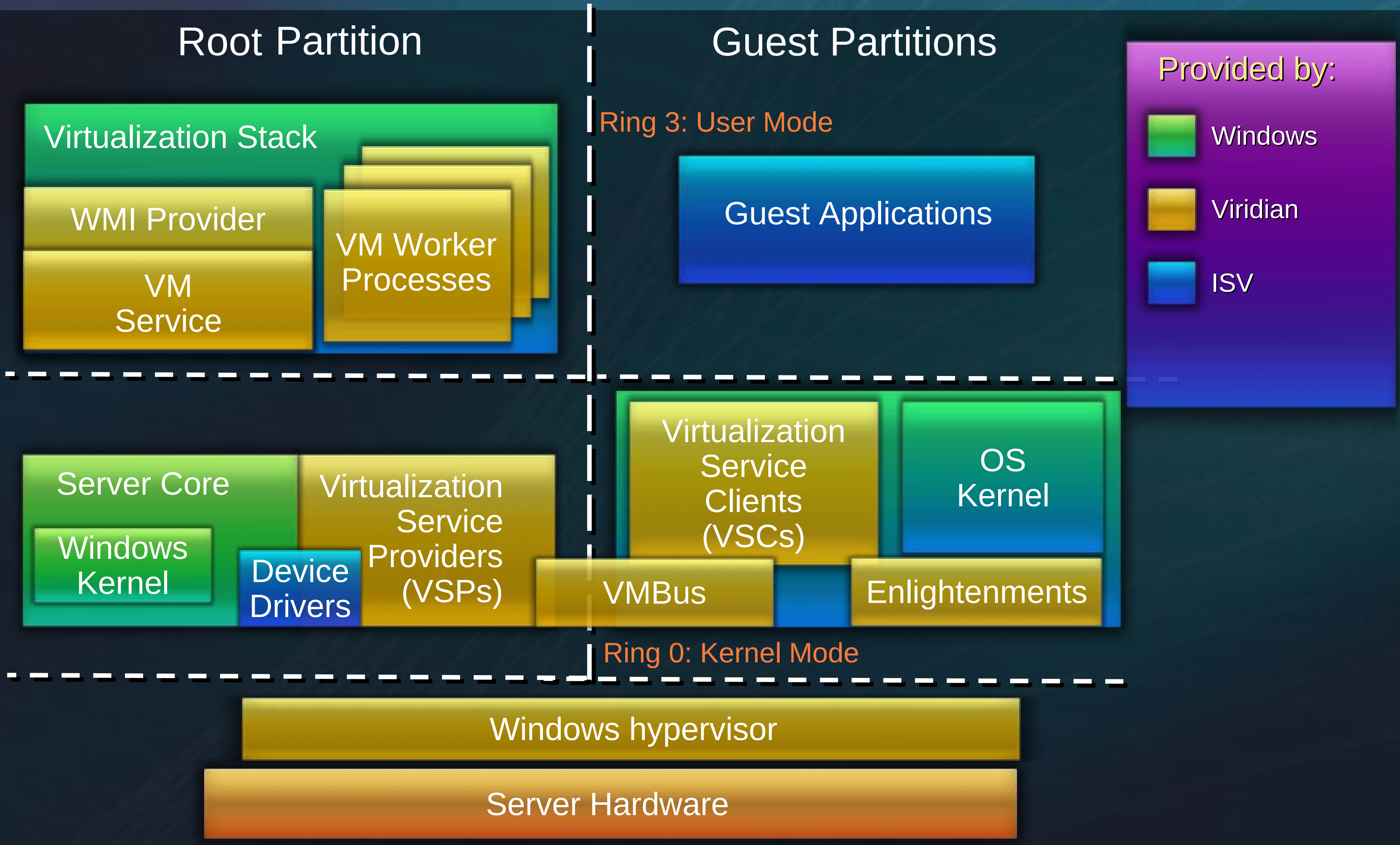
Windows Server Virtualization Background

- Has three major components:
  - Hypervisor
  - Virtualization Stack
  - Virtual Devices
- Hypervisor Based
  - Takes advantage of (and requires) processor virtualization extensions
  - Supported on x64 hardware only, 32/64bit guest support

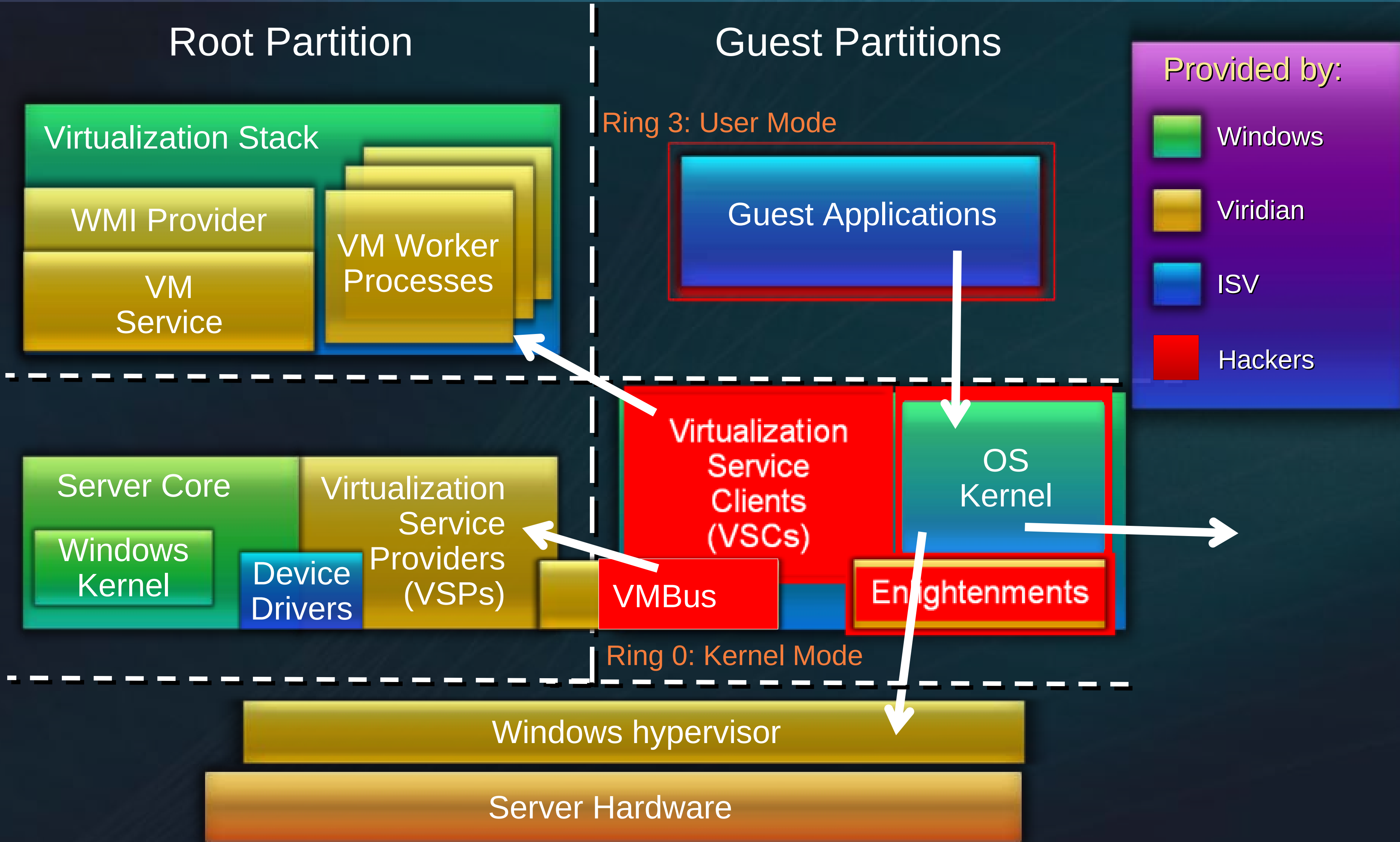
The Old Way
Virtual Server Architecture



The New Way
WSV Architecture



Virtualization Attacks



Hypervisor

- Partitioning Kernel
  - Partition is isolation boundary
  - Few virtualization functions; relies on virtualization stack
- Very thin layer of software
  - Microkernel
  - Highly reliable
- No device drivers
  - Two versions, one for Intel and one for AMD
  - Drivers run in the root
  - Leverage the large base of Windows drivers
- Well-defined interface
  - Allow others to create support for their OSes as guests

Virtualization Stack

- Runs within the root partition
- Portion of traditional hypervisor that has been pushed up and out to make a micro-hypervisor
- Manages guest partitions
- Handles intercepts
- Emulates devices

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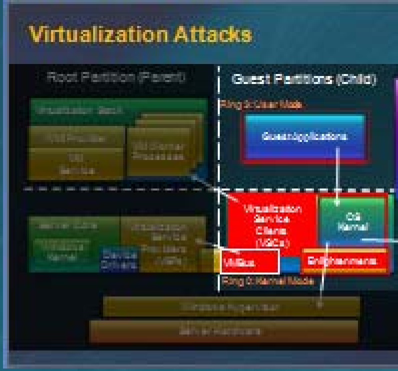
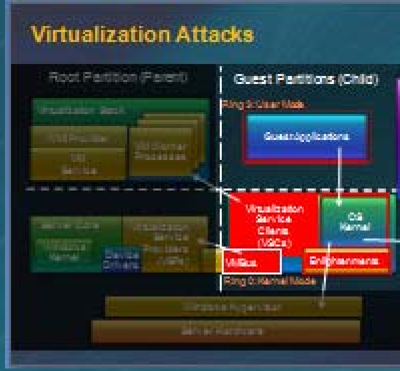
Security Assumptions



- Guests are untrusted
- Root must be trusted by hypervisor; parent must be trusted by children.
- Code will run in all available processor modes, rings, and segments
- Hypercall interface will be well documented and widely available to attackers.
- All hypercalls can be attempted by guests
- Can detect you are running on a hypervisor
- We'll even give you the version
- The internal design of the hypervisor will be well understood

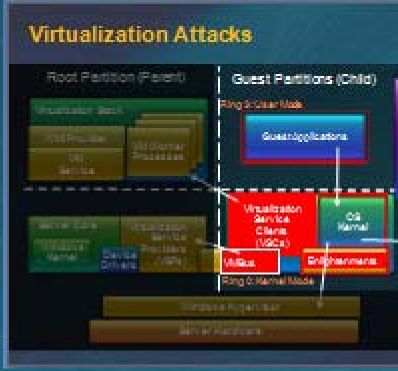
Security Goals



- Strong isolation between partitions
- Protect confidentiality and integrity of guest data

- Separation
  - Unique hypervisor resource pools per guest
  - Separate worker processes per guest
  - Guest-to-parent communications over unique channels
- Non-interference
  - Guests cannot affect the contents of other guests, parent, hypervisor
  - Guest computations protected from other guests
  - Guest-to-guest communications not allowed through VM interfaces

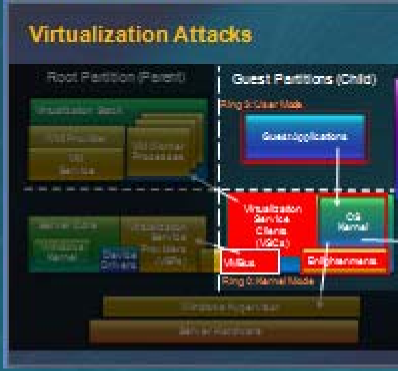
Security Non-Goals



- Things we don't do in Windows Server Virtualization*
  - Mitigate hardware bleed-through (inference attacks)
  - Mitigate covert channels
  - Guarantee availability
  - Protect guests from the root
  - Protect the hypervisor from the root
  - Utilize trusted hardware
    - TPM, Device Assignment, DMA protection, Secure Launch

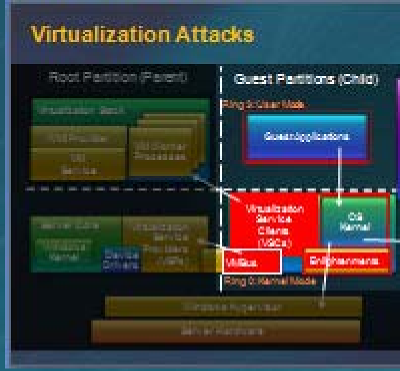
*at least, not yet

WSV Security Hardening (1/2)



- Hypervisor has separate address space
  - Guest addresses != Hypervisor addresses
- No 3rd party code in the Hypervisor
- Limited number of channels from guests to hypervisor
  - No "IOCTL"-like things
- Guest to guest communication through hypervisor is prohibited
- No shared memory mapped between guests
- Guests never touch real hardware i/o

WSV Security Hardening (2/2)



- Hypervisor built with
  - Stack guard cookies (/GS)
  - Hardware No eXecute (NX)
  - Code pages marked read only
  - Memory guard pages
  - Limited exception handling
  - Hypervisor binary is signed
- Hypervisor and Root going through SDL
  - Threat modeling
  - Static Analysis
  - Fuzz testing
  - Penetration testing

Hypervisor Security Model

- Memory
  - Physical Address to Partition map maintained by Hv
  - Parent/Child ownership model on memory
  - Can supersede access rights in guest page tables (R, W, X)
- CPU
  - Hardware guarantees cache & register isolation, TLB flushing, instruction interception
- I/O
  - Hypervisor enforces Parent policy for all guest access to I/O ports
  - WSV v1 policy is guests have no access to real hardware
- Hypervisor Interface
  - Partition privilege model
  - Guests access to hypercalls, instructions, MSRs with security impact enforced based on Parent policy
  - WSV v1 policy is guests have no access to privileged instructions

WSV Security Model

- Uses Authorization Manager (AzMan)
  - Fine grained authorization and access control
  - Department and role based
  - Segregate who can manage groups of VMs
- Define specific functions for individuals or roles
  - Start, stop, create, add hardware, change drive image
- VM administrators don't have to be Server 2008 administrators
- Guest resources are controlled by per VM configuration files
- Shared resources are protected
  - Read-only (CD ISO file)
  - Copy on write (differencing disks)

Time Virtualization
Three types of time

- Calendar time
  - Affected by Daylight Savings changes
  - Source is parent-created virtual RTC device
- Machine time
  - Unaffected by Daylight Savings changes
    - 5 seconds in the future, etc.
  - Sources
    - Per-VP virtualized APIC timer (periodic or single-shot)
    - Four per-VP SynIC timers (periodic or single-shot)
    - Per-partition constant-rate monotonically-increasing reference counter
- Scheduling time
    - How long has this processor been scheduled

Time Virtualization
Design Choice

- How to handle RDTSC?
  - When a Virtual Processor (VP) is intercepted, a single instruction can appear to take a long time – namely, the time it takes to enter the hypervisor, perform actions, and return to a guest
- TSC is recorded and can be modified in guest control structure (VMCS/VMCB)

"Allow it to advance naturally"
•Just leave it alone
But…
•A VP can be rescheduled on a different LP, whose TSC could be smaller
•Can't allow TSCs to jump backwards in time

"Modify it to appear unchanged"
•On entry into the Hv, record guest TSC.
•On return to guest, reload original TSC value minus some amount
But…
•Never know how long the return instruction will take (caches!)
•Still observable at a certain granularity

Some software depends on knowing cycle counts between instruction blocks (video/audio codecs)

So, we allow it to advance naturally, with a guarantee that it will never appear to go backwards on a given VP

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Deployment Considerations (1/2)

- Patching the hypervisor
  - Windows Update
- Managing lots of virtual machines
  - System Center – Virtual Machine Manager
- Minimize risk to the Root Partition
  - Utilize Server Core
    - Don’t run arbitrary apps, no web surfing
    - Run your apps and services in guests
  - Connect to back-end management network
    - Only expose guests to internet traffic
- Enable NX and virtualization in BIOS

Deployment Considerations (2/2)

- Two virtual machines can't have the same degree of isolation as two physical machines:
  - Inference Attacks
  - Covert Channels
- Not recommended to host two VMs of vastly differing trust levels on the same system
  - e.g. a front-end web server and a certificate server

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Future Security Benefits

- Many types of virtualization (app, OS, machine) each with increasing levels of isolation (and overhead)
- Powerful tool for virus isolation and analysis
- Improved forensic capability for compromised operating systems
- Investments in OS hardening through hypervisor features
- Potential for greater intra-OS isolation (e.g. Ring 0 separation of drivers)
- VMs can be leveraged for hosting security appliances

Security Challenges

- VM to VM network monitoring
- Managing VM OS patch levels
- Leakage of information between partitions due to shared hardware
- Larger attack surface than air-gapped machines
- High availability – SLA attacks
- Threat of malicious, unauthorized hypervisors (hypervisor-mode rootkits)

Future Security Work

- Secure Launch
  - Intel TXT^tm (senter) and AMD SVM^tm (skinit)
  - Gives machine owner ability to control what code can use ring -1
  - Policy enforcement in hardware to block launch of unauthorized hypervisors
  - Allows hypervisor to protect itself against tampering

- DMA Remapping
  - Intel VT-d and AMD IOMMU
  - Gives guests gated access to real hardware
  - Allows hypervisor to protect self against DMA attack

Conclusion

- Hypervisors kick ass.
- Beta available with Server 2008 RTM
- We want your feedback

    http://blogs.technet.com/virtualization/

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