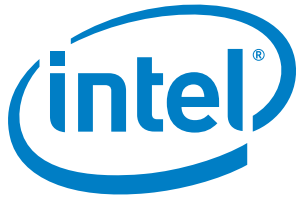

Leading Virtualization 2.0

How Intel is driving virtualization beyond consolidation into a solution for maximizing business agility within the enterprise

White Paper

Intel® Virtualization Technology (Intel® VT)

Introduction

Virtualization is one of the hottest technologies in IT infrastructure today. According to Gartner, "Virtualization is the highest impact trend changing infrastructure and operations through 2012. It will change how you manage, how and what you buy, how you deploy, how you plan, and how you charge."[1] Several studies by the research firm IDC support this claim. The firm reports 22 percent of servers today as being virtualized and expects that number to grow to 45 percent over the next 12 to 18 months.[2] Another IDC study predicts the number of logical servers generated on virtualized servers will surpass the number of non-virtualized physical server units by 2010.[3]

Historically limited to mainframe environments, virtualization's rapid adoption on Intel® architecture-based platforms is being enabled by virtualization software and Intel's advances in both multi-core processing and a suite of virtualization technologies known as Intel® Virtualization Technology (Intel® VT). The first virtualization implementations on Intel platforms primarily focused on server consolidation (utilizing multiple virtual machines to run multiple applications on one physical server). This consolidation has greatly benefited data centers by increasing server utilization and easing deployment of systems in data center environments.

Today Intel is helping enable the next generation of virtualization usage efficiently. Virtualization 2.0 focuses on increasing service efficiency through flexible resource management. In the near future, this usage model will become absolutely critical to data centers, allowing IT managers to use virtualization to deliver high availability solutions with the agility to address disaster recovery and real-time workload balancing so they can respond to the expected and the unexpected.

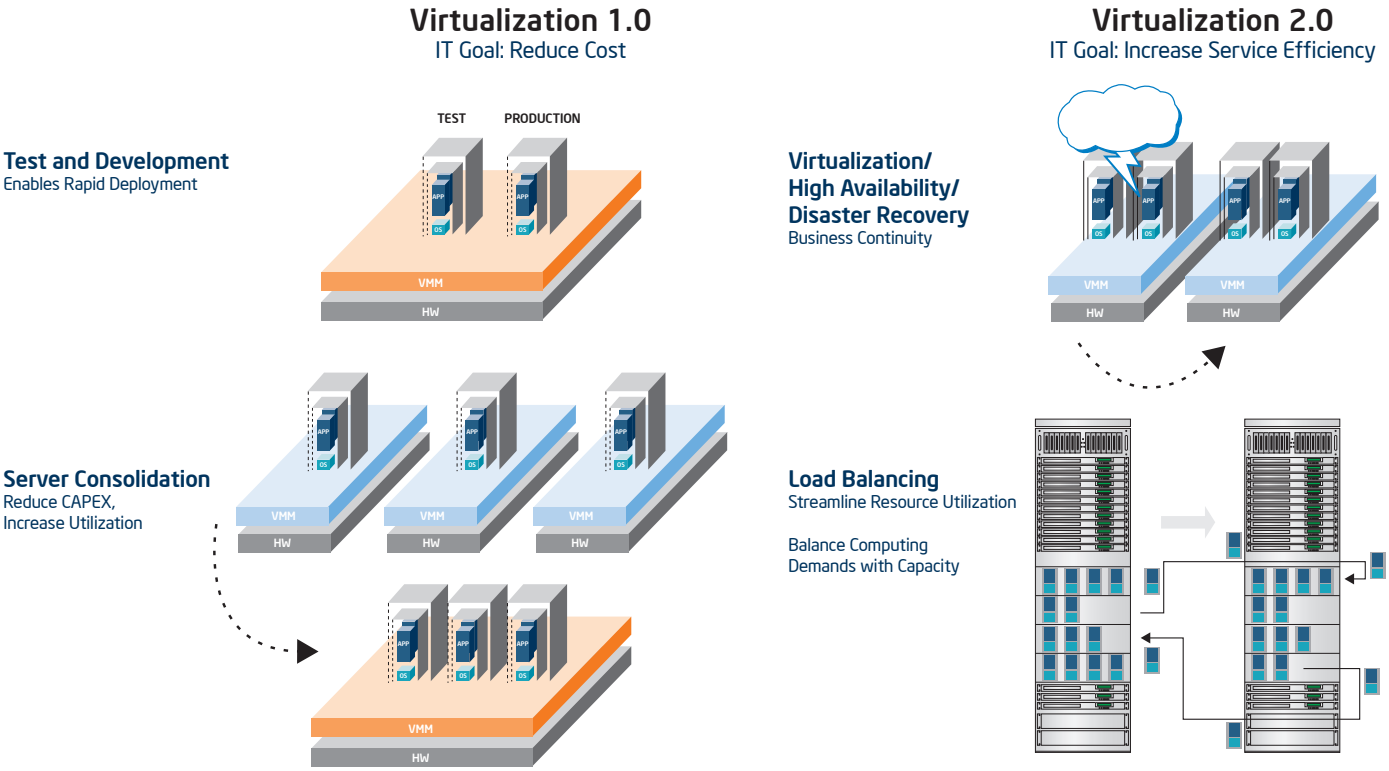

Figure 1. Intel is enabling new usage models for virtualization in the data center by making continual advances in its virtualization platform.

Consolidation will continue

Consolidation, the usage model labeled in Figure 2 as Virtualization 1.0 and the earliest driver for virtualization in traditional IT deployments, came as a result of data center managers looking for ways to improve server utilization and lessen the impact of rising energy costs. This continues to be a primary and valuable usage model for small and large businesses alike. Consolidation using virtualization has proven to be a real cost saver. A recent IDC study found 88 percent of U.S.-based organizations using virtualization for consolidation saved at least 20 percent of capital expenditures (CAPEX) by adopting virtualization technologies.[4] Overall x86 utilization rose from 35 percent before virtualization to 52 percent with virtualization.[5] IT organizations around the world still have much more to gain through further utilization improvements through consolidation. Intel predicts this will continue to be true as Intel®-based hardware virtualization continues to increase in performance capability in years to come.

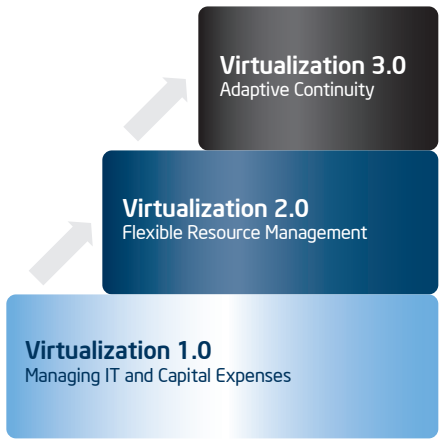

Figure 2. Intel is providing the technology leadership to enable an evolution of usage models for virtualization.

Driving existing and future virtualization usage models

Intel's technology direction has laid and continues to lay the foundation for current and emerging virtualization usage models. For Virtualization 1.0 where the desired outcome is primarily consolidation, IT needs servers with performance tuned for virtualization. Anticipating these needs, Intel delivered the following technologies:

- **Virtualization hardware-assist in server processors.** Intel introduced this technology in 2005 in both Intel® Itanium® processors for mission critical servers and Intel® Xeon® processors.
- **Unparalleled power-efficient performance.** Intel Xeon processors based on Intel® Core™ microarchitecture (introduced in second quarter 2006) and the Intel® hafnium-based 45nm Hi-k silicon process technology (introduced in second half 2007) have set new standards in power-efficient performance for server processors. Current Intel Core Microarchitecture-based Intel® Xeon® processor-based servers achieve the top industry-standard power efficiency benchmark results[6] (July 2008). By rapidly ramping up processor capacity and performance over the last few years, Intel has been able to fulfill IT needs for servers capable of improving performance while hosting many guests. Today's Intel Xeon processors deliver up to 6.36 times better performance/watt than single core.[7] Quad-core processors also provide twice the performance of dual-core processors[8] for better TCO.
- **Reliability.** Intel® Xeon® processor-based platforms include the best-in-class RAS capabilities that increase data availability and reliability – this is essential for deploying more VMs per server with confidence. These processors provide features designed to improve reliability and recovery speed. Examples include improved Error Correcting Code (ECC) coverage for system bus and cache, new memory mirroring, fully buffered DIMM technology, and hot pluggable component support. Intel's X8 Single Device Data Correction (X8 SDDC), for instance, allows IT to fix the failure of an entire DRAM device on-the-fly by removing a single DRAM from the memory map and recovering its data into a new device.

A final enabling ingredient for this first stage of virtualization was Intel's collaboration and continued support in the development of a strong ecosystem. An important part of that support was Intel VT – the suite of virtualization technologies that make it easier for software providers to develop a robust hypervisor and bring solutions to market faster. This has enabled a wealth of virtualization software that takes advantage of these platform-centric capabilities and solutions to better help IT meet their needs.

The transition to Virtualization 2.0

The success of consolidation deployments, combined with software evolution and Intel's continued advancements in processor performance, energy efficiency, and virtualization technologies, are now enabling many IT organizations to take the next step: using virtualization to improve their operational efficiencies. The time has come to ask more of virtualization and give virtualized data centers the opportunity to increase service levels and deliver major business agility advancements. Virtualization 2.0 focuses precisely on that by enabling flexible resource management.

Organizations worldwide are already beginning to take advantage of this model. The 2007 IDC study, for example, showed that 50 percent of all VMware ESX users had adopted VMotion* capability. This technology enables live migration—moving guests from one physical server to another with no impact to end users' experience.[4] By giving IT managers the ability to move guests on the fly, live migrations make it easier to balance workloads and manage planned and unplanned downtimes more efficiently.

This next phase, focused on flexible resource management, will require an infrastructure that supports:

- Flexible workload management for easier load balancing across different generations of Intel® Xeon® processor-based servers
- I/O tuned for virtualization to enable more efficient migration and greater I/O throughput capacity.
- Hardware and software compatibility that enables the new usage models and provides the confidence that 'it just works'.

Intel is providing the key enabling ingredients in its hardware to support all three of these needs and working with leading ecosystem providers to deliver best-in-class solutions for the data center.

Flexible workload management

Dynamic load balancing requires the ability to easily move workloads across multiple generations of processors without disrupting services. Performing live migrations from a newer generation processor with a newer instruction set to an older generation processor with an older instruction set carries the risk of unexpected behaviors in the guest. In 2007 Intel helped solve this problem by developing Intel® Virtualization Technology (Intel® VT) FlexMigration. By allowing virtual machine monitor (VMM) software to report a consistent set of available instructions to guest software running within a hypervisor, this technology broadens the live migration compatibility pool across multiple generations of Intel Xeon processors in the data center. This also reduces the challenges to IT in deploying new generations of hardware, enabling faster utilization of servers with new performance capabilities as they become available.

Accelerating I/O performance and enabling more efficient migration

Virtualization solutions are inherently challenged in the area of network I/O because the guests on a host server all end up sharing the same I/O resources. Moreover, many I/O resources are emulated in software for consistency and decision-making (e.g., network packet routing from the shared I/O resource is often done in software).

Intel improves availability through a number of technologies that accelerate I/O performance. This enhances the ability to deploy I/O intensive workloads (beyond simple consolidation) and increases efficiency in Virtualization 2.0 usage models such as load balancing, high availability, and disaster recovery (all of which extensively rely on data transfer over the network).

Intel's I/O technologies for improving data transfer include:

- **Intel® Virtualization Technology (Intel® VT) for Connectivity (Intel® VT-c)** provides unique I/O innovations like Virtual Machine Device Queues (VMDq) that offloads routine I/O tasks to network silicon to free up more CPU cycles for applications and delivers over 2x throughput gains on 10 GbE.[9]
- **Intel® Virtualization Technology (Intel® VT) for Directed I/O (Intel® VT-d)** delivers scalable I/O performance through direct assignment (e.g., assigning a network interface card to a guest) and enables single root input/output virtualization (IOV) for sharing devices natively with multiple guest systems.

Centralized storage is a key aspect of Virtualization 2.0 usage models. Usage models like load balancing, high availability, and disaster recovery rely on a VM's ability to efficiently migrate from one physical system to another while having constant access to data storage for continued operation. Thus, simplifying the fabric and providing a cost-effective means to deploy storage area networks (SAN) and LANs are key requirements for Virtualization 2.0. Intel products address this need for more cost-effective SAN and LAN fabric through support of Fibre Channel over Ethernet (FCoE).

Intel also provides leadership in important I/O virtualization standards designed to improve I/O and fabric performance throughout the industry. Intel is working on T11 FCoE (through the T11 standard body of the American National Standards Institute, or ANSI), as well as playing important roles on the IEEE for Enhanced Ethernet and PCI-SIG* IOV specifications.

Hardware-software compatibility

Through its rich partnerships in the virtualization ecosystem, Intel is able to ensure that its products and those from virtualization providers are well suited to Virtualization 2.0 usage models. A recent example is a 2007 collaboration between Intel and VMware that enhanced how Intel VT FlexMigration and Enhanced VMotion worked together. Intel is also working with several virtualization software solution partners to enable platform capabilities that are important for Virtualization 2.0 usage models such as efficient power management. Usage models such as high availability require headroom build-out so that there are enough backup systems to run the workload in case the primary system or software fails. Efficient power management of this headroom is critical for data centers and Intel is working with its virtualization software partners to enable such power management capabilities as power monitoring and system power-capping through hardware technologies provided on the platform.

Furthering virtualization's role in the data center

On the horizon is Virtualization 3.0 where adaptive continuity takes flexible resource management to the next level. Hardware will provide more resilient infrastructure and instrumentation for enabling automation software to make the balancing decisions in real-time. Predictive decision-making will readjust loads automatically based on changing workload requirements and/or data center demands, such as power, server resource changes, software failures, or other factors.

Intel's virtualization vision is an action plan for enabling technologies in silicon across the platform that will deliver a truly service-based, policy-driven, flexible data center. For IT departments choosing Intel technology, this will be a path to an automated infrastructure where workloads can be dynamically moved and scaled across the data center depending on customer demand, resource requirements, and service-level assurance requirements including performance, I/O, and/or power. Virtualization 2.0 is the next step.

Learn more

To find out more about Intel VT and its features, see:
www.intel.com/technology/virtualization/

Functionality, performance or other benefits will vary depending on hardware and software configurations and may require a BIOS update. Software applications may not be compatible with all operating systems. Please check with your application vendor.

Intel® processor numbers are not a measure of performance. Processor numbers differentiate features within each processor series, not across different processor sequences. See www.intel.com/products/processor_number for details.

[1] "Virtualization Changes Virtually Everything," Gartner Special Report, March 28, 2008.
[2] "Virtualization Evolves into Disaster Recovery Tool," eWeek, May 7, 2008.
[3] Cayton, Ken, "Choosing the Right Hardware for Server Virtualization," IDC White Paper, April 2008.
[4] IDC Multiclient Study, "Server Virtualization on the Move 2007: Foundation for the Dynamic Data Center," July 2007.
[5] Source: IDC White Paper sponsored by Intel, Choosing the Right Hardware for Server Virtualization, document #211622, April 2008. http://www.intel.com/business/technologies/IDCchoosingvirthardware.pdf.
[6] See results for July 31, 2008: http://www.spec.org/power_ssj2008/results/power_ssj2008.html
[7] Intel Xeon processor (3.80GHz, 2MB L2 cache, 800MHz FSB) vs. Intel Xeon processor E5450 3.00GHz, 12MB L2 cache, 1333MHz FSB) – published/measured results on SPECjbb* 2005 – November 11, 2007. See: http://www.intel.com/performance/server/xeon/ppw.htm
[8] Intel Xeon processor 5160 (3.00GHz, 4MB L2 cache, 1333MHz FSB) vs. Intel Xeon processor E5450 3.00GHz, 12MB L2 cache, 1333MHz FSB) – published/measured results on SPECjbb* 2005 – November 11, 2007. See: http://www.intel.com/performance/server/xeon/ppw.htm
[9] Chinni, Shefali and Radhakrishna Hiremane, "Virtual Machine Device Queues," Intel White Paper, 2007.

Intel® Virtualization Technology requires a computer system with an enabled Intel® processor, BIOS, Hypervisor, or virtual machine monitor (VMM) and, for some uses, certain computer system software enabled for it. Functionality, performance or other benefits will vary depending on hardware and software configurations and may require a BIOS update. Software applications may not be compatible with all operating systems. Please check with your application vendor.

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