Virtual Iron™

WHITE PAPER JANUARY 2007

The New Economics of Virtualization

The Impact of Open Source, Hardware-Assist and Native Virtualization

TABLE OF CONTENTS

Introduction 3

The State of Virtualization Today 4

Native Virtualization — A New, More Efficient Approach 6

Applying Virtualization for Greater ROI — Common Use Cases 9

Management — The Real Value in Virtualization 13

Conclusion 15

INTRODUCTION

Companies are finding it increasingly difficult to manage their enterprise data centers today. They're highly complex, expensive to build out and difficult to reconfigure as needs change. The net result is a very high cost of ownership for a resource that is poorly positioned to meet the needs of the business. Virtualization delivers capabilities that address many data center shortcomings and companies are making significant investments in the technology. Unfortunately, until recently, the alternatives (i.e. VMware) were few, proprietary, expensive and slow to respond to industry innovation and standards.

A new wave of virtualization-related technologies has emerged that address these challenges and improve upon the efficiency and value of virtualization.

A new wave of virtualization-related technologies has emerged that address these challenges and improve upon the efficiency and value of virtualization. Native virtualization is a new approach that improves performance, reliability and total cost of ownership. New virtualization solutions that leverage open source hypervisors derived from the Xen™ open source project offer users choice and minimize the risk of proprietary lock up. Additionally, hardware-assisted virtualization, now available in new processors from AMD and Intel, enable high performance virtualization without modification to operating systems.

With these new capabilities, a truly dynamic IT infrastructure is emerging — transforming the static, hard-wired data center into a software-based, dynamic pool of shared computing resources. These new solutions provide simplified management of industry standard hardware and enable today's business applications to run on virtual infrastructure without modification. Using centralized policy-based management to automate resource and workload management, they deliver "capacity on demand" with high availability built in.

All these advancements are changing the economics of virtualization and IT organizations are embracing them to expand the breadth and ROI of their virtualization initiatives.

THE STATE OF VIRTUALIZATION TODAY

Virtualization may be one of the hottest areas in technology today, but many IT professionals are still having difficulty grasping the terminology and comprehending the many choices of hypervisors and hardware that make up the complicated virtualization landscape.

Originally part of mainframe technology, virtualization is not a new concept. It has been applied to various technology problems throughout computing history and is now receiving renewed interest as an approach for managing standardized (x86) servers, racks and blade systems.

Virtualization decouples applications and data from the functional details of the physical systems, increasing the flexibility with which workloads can be matched to physical resources.

Virtualization lets administrators focus on service delivery by abstracting hardware and removing physical resource management. It decouples applications and data from the functional details of the physical systems, increasing the flexibility with which the workloads and data can be matched with physical resources. This enables administrators to develop business-driven policies for delivering resources based on priority, cost and service-level requirements. It also enables them to upgrade underlying hardware without having to reinstall and reconfigure the virtual servers, making environments more resilient to failures.

At the core of most virtualization software solutions is a "virtual machine monitor" or "hypervisor" as it is sometimes called. A hypervisor is a very low-level virtualization program that allows multiple operating systems — either different operating systems or multiple instances of the same operating system — to share a single hardware processor. A hypervisor is designed for a particular processor architecture, such as an x86 processor. Each operating system appears to have the processor, memory and other resources all to itself. However, the hypervisor actually controls the real processor and its resources, allocating what is needed to each operating system in turn. Because an operating system is often used to run a particular application or set of applications in a dedicated hardware server, the use of a hypervisor can make it possible to run multiple operating systems (and their applications) in a single server, reducing overall hardware costs.

What about Open Source?

The open source hypervisor has received considerable attention in the last year. On its own, the open source hypervisor doesn't do much, but it has a broad ecosystem that includes all the major processor manufacturers, server companies and operating system providers. These companies, including Virtual Iron, have been working together to deliver enterprise-class virtualization functionality on top of the open source hypervisor. In addition to driving innovation and building new solutions around this standard, this ecosystem has also formed an extended testing team, further driving quality improvements.

Open source technologies have a history of providing improved functionality, better performance and lower total cost of ownership than proprietary technologies. The open source hypervisor is quickly making its way into commercial offerings and end-user solutions. And as virtualization solution costs come down, it becomes feasible to deploy virtualization to every server throughout an enterprise's IT infrastructure. History also shows open source offerings, when generally accepted, tend to quickly catch up to their proprietary counterparts. Not since the Linux and Apache open source projects have such a large open source community and ecosystem formed so quickly. Although current proprietary offerings like VMware have a few years head start, the gap is closing quickly and the open source hypervisor is emerging as a de facto standard.

Choosing the Right Path

With the emergence of new virtualization technologies, the challenge for users is making sense of what is available in the virtual world and creating an environment that will deliver the promise of improved performance, reliability and total cost of ownership, while preserving investments in their existing software stack

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The benefits of standards-based products are well known and well understood. Customers benefit from "vendor choice" which reduces upfront and ongoing capital expenditures. With standards in place, IT managers are also able to tap a large pool of available professionals with required skill sets (e.g. Linux, J2EE, etc.) This reduces personnel costs and improves productivity. Other benefits include increased agility, flexibility and interoperability. Industry standard solutions promote common approaches and architectures for business applications, making it easier to integrate new applications and functionality into core business processes and architectures. This interoperability promotes application agility and allows for rapid response to changing business conditions.

It is difficult and rare to find an off-the-shelf product that delivers a total solution or precisely matches the features and requirements the business needs. It is usually necessary to integrate different software products and system management tools from different vendors. And integration is made easier by standard interfaces and protocols. A standards-based infrastructure also leads to a more stable environment because industry standards are typically backed by an ecosystem of vendors who support the standard and evolve it conservatively as to not cause major disruption. The standardized environment increases the reliability of infrastructure and reduces the time to repair because support staff has fewer products to master and start from well-known and documented capabilities.

NATIVE VIRTUALIZATION® — A NEW APPROACH TO SERVER VIRTUALIZATION

Native virtualization is a new approach to virtualizing the x86 processor architecture. It leverages new hardware-assisted capabilities available in the latest processors from AMD and Intel and provides near-native performance.

Native virtualization is just becoming available on the market and it offers considerable benefit to users in both performance and ease of implementation.

Prior to these new processors, the x86 architecture did not meet some fundamental requirements for virtualization making it very difficult to implement a virtual machine monitor (VMM) or hypervisor for this type of processor. These requirements* include:

- **Equivalence:** a program running under the virtual machine should exhibit a behavior essentially identical to the original physical machine.
- **Resource control:** the virtual machine must be in complete control of the virtualized resources.
- **Efficiency:** the virtual machine should not significantly degrade workload performance.

Historically the virtualization of the x86 architecture has been accomplished in two ways:

- **Full virtualization** — the virtual machine simulates the complete hardware, allowing an unmodified OS for the same type of CPU to execute within the virtual machine container.
- **Paravirtualization** — the virtual machine does not simulate complete hardware, instead offering an interface to virtual machines that differs from that of the actual hardware. Operating systems are then ported to this new interface, which does not use the sensitive, hard-to-virtualize instructions of the x86 instruction set.

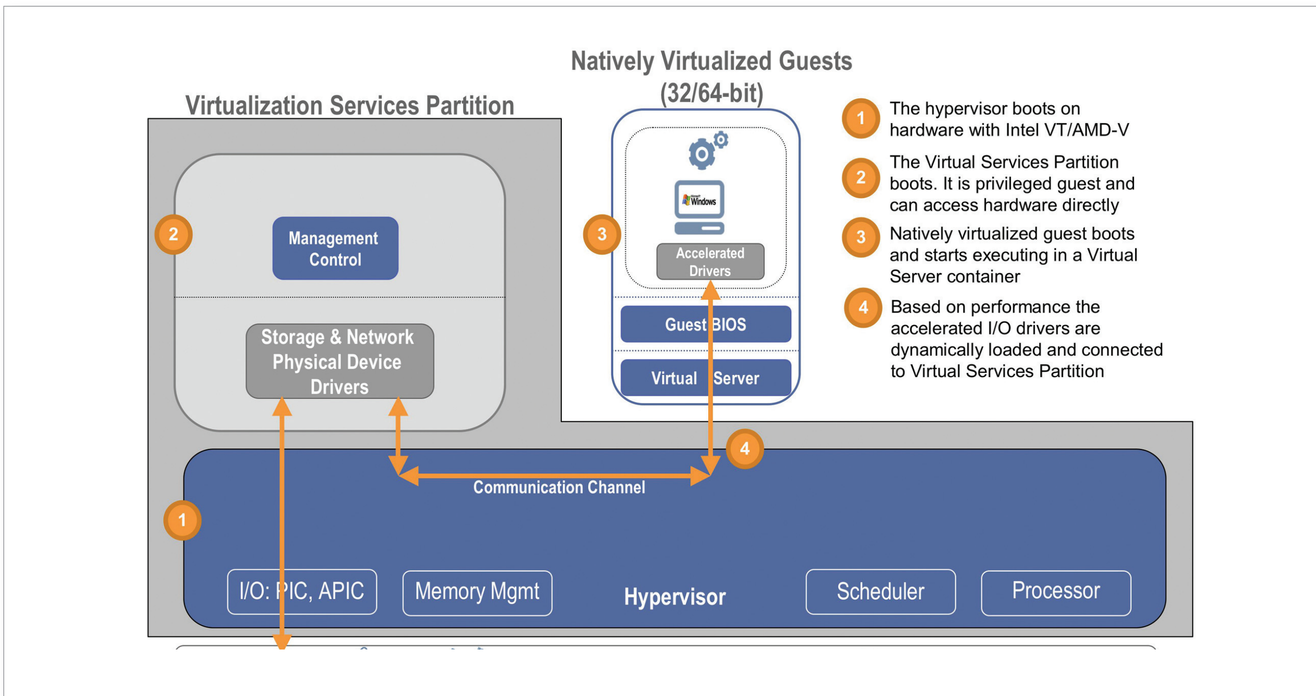
Paravirtualization, as a technique for virtualizing Intel x86 architecture, has primarily been used within the confines of university research. The research projects Denali, L4, and most recently Xen, employ this technique to run modified versions of operating systems, for which source code is readily available (Linux, FreeBSD, etc). Paravirtualization requires radical modifications of the operating system and therefore is not capable of supporting deployed operating systems. As a result, this approach cannot be seriously considered within a commercial environment. We will leave any discussion of this approach and its potential applicability to the university researchers and academics.

Full Virtualization is a technique implemented in first generation Virtual Machine Monitors (VMMs). It relies on sophisticated, but fragile, software techniques to trap and virtualize the execution of certain sensitive, "non-virtualizable" instructions in software via binary patching. With this approach critical instructions are discovered at run-time and replaced with a trap into the VMM to be emulated in software. While fully functional, these techniques incur large performance overhead as compared to a virtual machine running on natively virtualized architectures such as the IBM System/370. Where this really becomes a problem is in the area of system calls, interrupt virtualization, and frequent access to the privileged resources. As a result, the first-generation VMMs have been relegated to non-mission critical and non performance taxing applications.

Recently both AMD and Intel released processors with hardware-assisted virtualization support built in. With these new processor capabilities, the x86 architecture now meets the virtualization requirements stated above, making native virtualization a reality. With Native Virtualization the VMM simulates the complete hardware, allowing an unmodified OS for the same type of CPU to execute within the virtual machine container. With Native Virtualization, the VMM can efficiently virtualize the x86 instruction set by handling the sensitive, "non-virtualizable" instructions using a classic trap and emulate model in hardware versus software. It also uses performance analysis to selectively employ acceleration techniques for memory and I/O operations.

Native virtualization is just becoming available on the market. While it is a new approach, it offers considerable benefit to users in both performance and ease of implementation. It's worthy of consideration for those planning their next steps in server virtualization.

NATIVE VIRTUALIZATION; HOW IT WORKS



The Role of Hardware-Assisted Virtualization

It's a common misperception that hardware-assisted virtualization minimizes the role and value of virtualization software. It's actually just the opposite. The new processors from Intel and AMD add additional capabilities that simplify and improve virtualization performance. Without virtualization software — such as the hypervisor, and other virtualization services and virtualization management capabilities — you have only a standard server that can run one operating system.

Native virtualization leverages these hardware-assisted virtualization extensions that have been added to the latest processors from AMD and Intel to support virtualization software in an integrated and seamless fashion improving the efficiency, performance and security of virtual servers. By providing a new privilege layer for virtual machines, and supporting key virtualization functions in hardware, this technology simplifies virtual server development and maintenance, improves interoperability with legacy operating systems, enhances security and reliability, and reduces the cost and risk of implementation. These extensions to the chip architectures are already helping commercial vendors deliver products that reduce the cost and risk of implementing server virtualization solutions and increase the reliability, availability, and security of applications running in virtual partitions.

Virtualization technology built into processors from both AMD and Intel are addressing the past limitations of the x86 architecture and instruction set. In a typical platform environment, there is a single operating system that controls platform resources, and arbitrates requests from one or more applications. In a virtualized platform environment, there may be many guest OSs running on top of the virtualization layer. To avoid conflicts, the virtualization layer must maintain control of critical platform resources, and hand off limited control to each guest OS, as appropriate. The efficiency and integrity of these hand-offs are critical for optimal performance and reliability.

APPLYING VIRTUALIZATION FOR GREATER ROI — COMMON USE CASES

Virtualization is being applied to a variety of data center initiatives to reduce both cost and complexity. To date, the most common applications have centered on server consolidation and the rapid provisioning of development and test environments. Looking forward, new enterprise-class capabilities are targeting higher ROI opportunities including capacity management and high availability/disaster recovery. Below we briefly discuss some of these applications and how they benefit from new virtualization technologies.

Server Consolidation

The unimpeded growth of data centers over the last decade along with the popularity of distributed applications has resulted in a proliferation of servers, storage systems, and operating systems. Most of these applications are on isolated, single-function physical servers that are over-sized and under-utilized. The result:

- Single function servers and application silos are wasting capacity.
- Administration costs are exorbitant due to the increased complexity and lack of manageability of the data center environment.
- Managing, patching, and securing servers is cumbersome, error-prone and time consuming.

New virtualization technologies allow a physical server of any size (from a single CPU to a 32-way multi-processor) to be partitioned into multiple virtual servers that work identically to a physical server. Each virtual server can expand as demand dictates by allocating capacity that is available on the physical server. With this capability, enterprises gain:

- A virtual computing platform that supports multiple virtual servers running concurrently, and multiple workloads per physical server; and adapts in real-time by delivering capacity based on the resource demands of the applications.
- Efficient server virtualization with minimal performance overhead; optimized to take full advantage of hardware-assisted virtualization built into today's processors from AMD and Intel.
- Support for running unmodified Linux and Windows 32- and 64-bit x86 guest operating systems.
- Comprehensive policy-based management of virtual infrastructure capable of handling a wide range of applications and workloads.
- Reduced risk of performance drag due to automated capacity management.
- Up to 10X improvement in resource utilization.

TARGETING HIGH ROI APPLICATIONS FOR VIRTUALIZATION

	Consolidation	Rapid Provisioning	HA & DR	Capacity Management
Capital Expense	Reduce HW & SW Costs • Server • Storage • Network		Reduce HW & SW Costs • Server • Storage • Network	
Operational Expense	Reduce Energy Costs • Cooling • Power Reduce Space Costs Reduce Labor Costs • IT Admin	Save Time • Provision • Deploy • Upgrade	Reduce Energy Costs • Cooling • Power Reduce Space Costs Reduce Labor Costs • IT Admin	Reduce Labor Costs • IT Admin
Enhanced Business Agility		Fast App Deployment	Minimal Downtime Reduce Failure Risk	Optimal Apps Response

Rapid Provisioning of Development & Test Environments

IT organizations are under immense pressure to reduce testing costs and shorten the cycle from development to deployment. The number of test scenarios, use cases and supported software environments has exploded due to all the permutations of hardware, app servers, firewalls, browsers, and databases that need to be supported. Development organizations need to work closely with their quality assurance and production/operation counterparts to orchestrate these complex development, test, staging, and production environments. The issues that must be overcome include:

- Scarce hardware resources to support all the test configurations.
- Development and test environments that cannot match the expensive and massive multi-tiered, multi-server production environments, making it riskier to deploy new applications.
- Configuration idiosyncrasies between development, test and production.
- Off-shore or distributed development/test teams that require their own test environments.
- Managing patches consistently across all environments.
- Installations that are complicated, error-prone and arduous — often taking days to get just right.
- Environments that are difficult to administer, support and reconfigure.
- New equipment constantly arriving that needs to be provisioned immediately.

New virtualization technologies enable IT organizations to quickly and economically set up development, test, staging and production environments. Users can partition a single physical server into dozens of isolated development environments, reducing hardware requirements and capital expenditures while improving operational efficiency.

Using rapid provisioning and image management capabilities, software reference stacks can be used to create standardized environments. These can be deployed in minutes, eliminating repetitive configuration tasks and enabling users to:

- Move virtual servers around live with their operating systems.
- Coordinate configurations and footprints between the development, test, staging and production environments using "golden images" (software reference stacks), eliminating repetitive configurations and improving time to market.
- Clone and copy exact production environments into virtual servers for troubleshooting and testing.
- Roll back to previous known environments using captured images (snapshots).
- Automate QA server updates with new engineering drops via snapshots and simulate complex networked applications on a single server.
- Remove hardware restrictions by allowing teams to use physical hardware that does not need to be identical across development, QA and production.

Today's organizations require fail-proof solutions for high availability when localized software or equipment fails and disaster recovery when a data center is faced with catastrophic events.

Business Continuity — High Availability (HA) and Disaster Recovery (DR)

The need for new business continuity strategies has been made abundantly clear — from man-made accidents such as power failures to natural disasters such as hurricanes and earthquakes. Given these inherent risks, enterprises are making large investments in infrastructure to ensure that applications are always available for their business users and customers. Today's organizations require fail-proof solutions for high availability when localized software or equipment fails and disaster recovery when a data center is faced with catastrophic events.

Existing approaches like high-availability clustering and failover software are meeting the need for business continuity, but major challenges remain:

- The significant cost of idle hardware and software.
- Extremely expensive specialized disaster recovery software and services.
- Complex management environments.
- Running out of weekends to perform system maintenance.
- Inefficient use of idle resources that are primarily in place for redundancy.

New virtualization technologies enable users to deliver business continuity in a more efficient, cost-effective manner by:

- Increasing business-critical application uptime.
- Building a flexible and inexpensive high availability and disaster recovery solutions with less hardware.
- Increasing data center hardware utilization.
- Reducing scheduled downtime.
- Streamlining and automating recovery processes.
- Using reliable and repeatable processes for implementing high availability and disaster recovery solutions.
- Gaining more than 10X productivity improvements.

Capacity Management

Organizations continue to struggle to align computing resources with their business initiatives to deliver the response and agility required for success. This requires a dynamic infrastructure that allows technology to dynamically adapt by matching IT supply with business application demand. Specific issues and challenges include:

- Computing resources "trapped" in over-provisioned application silos.
- Poor service levels because of workloads that can not tap additional capacity when needed.
- Major revenue losses as a result of application outages due to capacity constraints or system failures.
- High administration costs of reconfiguring capacity due to complex data center environments.

New virtualization technologies optimally match available capacity of computing resources to workload demands.

New virtualization technologies offer capacity management capabilities developed specifically to combat the inefficiencies and inflexibilities of today's data centers. The software optimally matches available capacity of computing resources to workload demands. Leveraging these new technologies, IT organizations are able to:

- Combine the resources of many servers into a single, seamless, sharable, infrastructure-wide pool.
- Make data center resources rapidly available to any application without incurring provisioning costs and without disruption.
- Deliver on Service Level Agreements (SLAs) more consistently and cost effectively.
- Use new **LiveMigrate**™ and **LiveCapacity**™ capabilities to move workloads and add resources "on the fly" without any downtime.
- Share resources across applications, using computing resources where they are needed most and avoid the risk of running out of capacity.
- Build virtual servers of virtually any size — to scale up or down on an incremental basis as required — utilizing anywhere from a fraction of a processor to 32 processors.
- Optimize equipment for efficiency and avoid overbuying capacity (CPU, memory, I/O) for peak workloads.
- Provision any server in seconds, without downtime. With a few clicks of a mouse increase any virtual server's processors, memory, I/O, storage — or simply move an application from one virtual server to another.
- Automate provisioning and reconfiguration by setting policies to automatically manage performance and availability based on certain times, workloads or events.

MANAGEMENT — THE REAL VALUE IN VIRTUALIZATION

More advanced management tools allow you to centrally manage a shared pool of virtual and physical servers using a sophisticated GUI console.

Virtualization enables the consolidation of data center resources and eliminates physical server sprawl, but without the right management tools, organizations are left to deal with a whole new set of challenges created by virtual server sprawl. These include:

- Inefficiencies in managing and orchestrating a large number of virtual servers.
- Lack of management tools for matching capacity with business demands.
- Lack of tools for automating the management of service levels.
- Operational overhead required to administer and reconfigure virtual infrastructure.

Some of the latest virtualization technologies provide a comprehensive management environment and policy-engine to automate the management of shared processing, storage and networking resources. Resources can be allocated and de-allocated on the fly to applications when needed based on business rules. Unique policy-driven automation capabilities enable rapid reconfiguration, capacity on demand, failover and recovery without increased administrative overhead. The most comprehensive management tools enable users to:

- Use policies to automatically apply resources when and where needed, so that performance is maintained regardless of usage spikes.
- Respond more quickly to changes in capacity demand with automated reconfiguration.
- Create policies for real-time resource allocation and failover using a graphical policy-builder wizard.
- Automatically maintain application availability and service levels using policies.
- Reduce human labor, errors and operational costs by automating operations.
- Trigger reconfigurations based on rules that detect exceeded user-set performance thresholds, e.g. add more CPU capacity to a virtual server when CPU utilization is greater than 90 percent.
- Migrate servers and adjust resource allocations "on-the-fly" without impacting running applications.

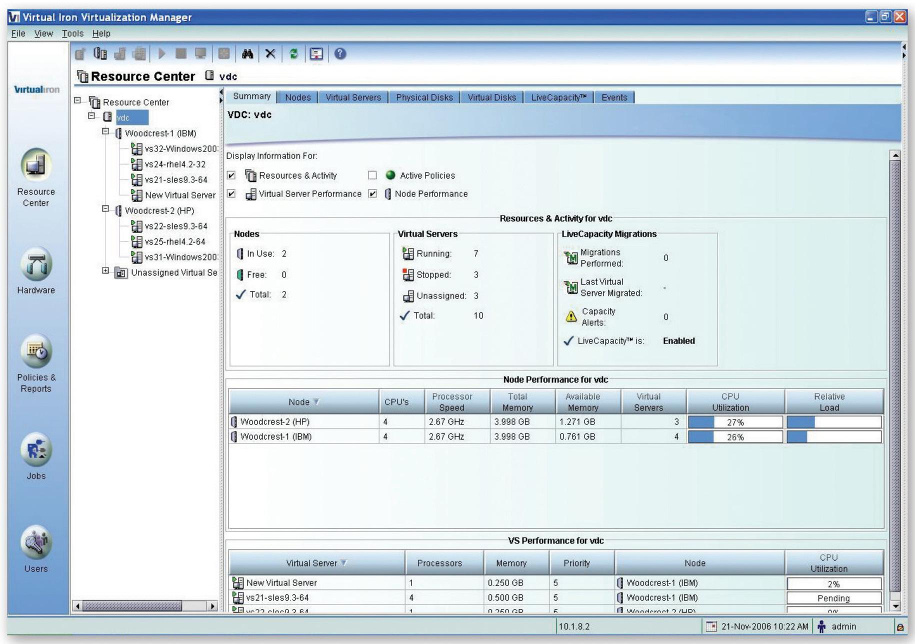
The depth of available tools varies greatly. Most allow users to create virtual servers, assign physical resources and allocate capacity. More advanced tools allow you to centrally manage a shared pool of virtual and physical servers using a sophisticated GUI console. Most allow administrators to snapshot system images and use these reference software stacks to support rapid provisioning of environments. Only a few include a comprehensive policy engine to automate changes in resource allocation and to reconfigure servers on-the-fly.

In general, these tools keep virtualization management time and costs down and allow IT organizations to rapidly provision and reconfigure servers. They support a more dynamic data center that is more flexible. These tools also produce more consistency between development, test, and production environments. Overall, with the right management tools, organizations virtualizing their infrastructure will reduce operational costs by decreasing complexity and streamlining the management of virtual servers.

Virtualization tools also need to evolve to deliver more advanced capacity planning and resource management capabilities — capabilities akin to those available today in system management tools used to manage the physical data center. These will help administrators determine how big a virtual machine should be and which virtual machine should run on which physical resource. They should also help load balance resources and identify resource issues.

Virtualization services will also incorporate capabilities found today in third party software, such as multi-path I/O, volume management, disk partitioning, security, and availability.

The figure shows a virtualization management user interface. A tree view on the left displays the virtual configuration consisting of virtual data centers and virtual servers. The dashboard on the right displays information such as most loaded virtual servers, running policies, and resource issues.



CONCLUSION

A new wave of virtualization-related technologies have emerged that address many data center challenges and dramatically improve the economics of virtualization.

- Native virtualization is a new approach to virtualization that improves upon the efficiency of previous approaches and delivers higher performance at a lower cost.
- New solutions based on a hypervisor derived from the Xen open source project increase customer choice and minimize the risk of proprietary lock up.
- Virtualization assistance, now available in hardware, specifically in the new processors from AMD and Intel, further improves efficiency and performance.
- Lastly, advances in virtual infrastructure management tools will improve the manageability of virtual environments and reduce operational costs related to maintaining them.

Virtual Iron is focused on delivering advanced virtualization and management capabilities that leverage these new technologies to dramatically change the economics of virtualization. Organizations are using Virtual Iron's software for consolidation, rapid provisioning, business continuity, capacity management and policy-based automation to deliver dramatic improvements in utilization, manageability and agility. The company works with IT organizations to transform the data center into a dynamic, efficient, pool of shared computing resources that are configured and managed via software. Virtual Iron delivers an open and economically attractive alternative to proprietary virtualization solutions by leveraging an open source hypervisor and supporting virtualization of enterprise-class applications without modification.

Now is the time to start creating a virtual data center and a "dynamic infrastructure" that will improve the operational efficiency, utilization and agility of the data center. IT organizations should look for solutions like Virtual Iron that leverage the advances and new technologies described in this paper to further improve upon the ROI of their virtualization initiatives.

ABOUT VIRTUAL IRON

Virtual Iron provides enterprise-class software solutions for creating and managing virtual infrastructure. Its software enables companies to dramatically reduce the complexity and cost of managing and operating their enterprise data center. Virtual Iron delivers advanced virtualization capabilities that exploit industry standards, open source economics and built-in hardware-assisted acceleration. Organizations use Virtual Iron's software for server consolidation, rapid provisioning, business continuity, capacity management and policy-based automation to deliver significant improvements in utilization, manageability and agility. Virtual Iron is privately held and based in Lowell, Massachusetts.

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