WHITE PAPER

IDEAS INTERNATIONAL

custom consulting services

PRIVATE CLOUDS FLOAT WITH IBM SYSTEMS AND SOFTWARE

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PREPARED FOR

IBM

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Executive Summary

Successful deployment of private clouds has some basic technical requirements, such as robust virtualization platforms with good management tools. Private clouds also depend on the adoption of certain operational practices for managing virtualized systems, including standardizing virtualized images; managing the lifecycle of the images; monitoring the behavior of virtualized workloads and tracking the internal consumption of resources by user or workload; and automating provisioning tasks. Once these practices are in place, it becomes possible to implement self-service driven catalogs that allow users to rapidly deploy their own computing environments with a minimal knowledge about the underlying computing infrastructure. By eliminating much of the administrative overhead required to deploy services in this manner, private clouds can introduce significant cost savings. The primary challenge for most users is to stage the gradual adoption of private clouds in a way that allows the benefits of cloud computing to be accrued as quickly as possible.

With proven virtualization capabilities on its each of its server platforms, IBM is in a strong position to facilitate the deployment of private clouds. IBM offers its customers multiple pathways for deploying private clouds, and integrated service management is a core added value in all of them. Depending on how quickly customers want to achieve a return on investment (ROI), they can deploy IBM's solution in several ways: as part of an integrated system solution with IBM CloudBurst; as an integrated software solution called IBM Service Delivery Manager (ISDM); or as a custom solution leveraging Tivoli Service Automation Manager (TSAM) and virtualized IBM systems. For customers who deploy private clouds on IBM's server hardware, IBM Systems Director provides even more precise control of the virtualized resources underlying the services in a private cloud. For customers needing to support a multivendor infrastructure, ISDM and TSAM support a number of server vendor choices. IBM's solution can thus be applied at every stage of a customer's transition to a private cloud, culminating in a complete platform that can manage the entire chain of events from a user self-selecting a service to activating the underlying physical compute resources that drive that service.

Introduction

Cloud computing continues to dominate the discourse at every level of the IT industry, and the cloud concept is gaining increased visibility with mainstream business leaders and even consumers. In datacenters, dramatic improvements in performance and packaging of server hardware, along with the rise of virtualization technology, have made computing capacity more easily accessible, and at more attractive costs, than ever before. At the same time, the rise of ubiquitous broadband has increased end-user expectations for anywhere access to applications and computing activities. The confluence of these trends makes it clear that the emergence of

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IDEAS RECOMMENDATIONS FOR USERS

Ideas International (IDEAS) offers the following recommendations for users who are considering the deployment of private clouds:

» Carefully consider the hardware platform and identify key differentiators for hosting virtual infrastructure and private clouds (i.e., memory management and systems management capabilities).

» After applying virtualization to perform consolidation, standardize on a relatively small number of software images in libraries based on standard, open formats that can be browsed in a service catalog.

» Implement disciplined processes for managing the lifecycle of virtual software images, with clearly defined stages for developing, testing, updating and patching, and retiring the software underlying virtualized services.

» Develop processes for monitoring the behavior of virtualized workloads and tracking the internal consumption of resources by user or workload. Determine the need for chargeback procedures to make sure users and departments receive their fair share of virtualized resources in a private cloud.

» Evaluate tradeoffs in time to ROI between installing separate software packages to manage services in private clouds, versus installing integrated solutions such as ISDM or IBM Cloudburst.

cloud computing will represent a major transition for IT in general, with a far-reaching effect on the way that computing is installed and used.

After some period of debate about cloud terminology and categorization, the concept of cloud computing is now becoming better defined, as users come to terms with its practical application and benefits in real-world environments. Despite long-term interest in the prospect of tapping into third-party computing infrastructures, the priority for most organizations at present is to virtualize as much as of their internal infrastructure as possible. Indeed, for many users (especially in large organizations) the term “cloud” largely implies converging virtualized server, storage, and network resources into a single pool that workloads can draw upon as needed, while also affording some degree of self-service and better accounting of the resources consumed by users and workloads.

Eventually, as private clouds mature, they could evolve into “hybrid” clouds that have the ability to send some workloads to public clouds where appropriate, ideally with the same frameworks and controls used to allocate on-premise resources. Third-party clouds may first be embraced for “cloud bursting,” – in which workload spikes are absorbed by temporarily taking on third-party computing resources – and then for selective re-hosting of non-critical workloads with third-parties. In the meantime, though, the primary challenge for most users is to stage the gradual adoption of private clouds in a way that allows the benefits of cloud computing to be accrued as quickly as possible.

Stages to Private Cloud Adoption

Cloud computing is generally associated with virtualization. Most definitions of cloud computing also cover approaches such as Software as a Service (SaaS) and Platform as a Service (PaaS), which do not necessarily depend on virtualization. However, virtualization provides a powerful means to adapt existing infrastructure and applications for achieving the benefits of cloud computing in the form of Infrastructure as a Service (IaaS). There are a variety of ways to implement private clouds, which usually involve coupling virtualization with management frameworks that are optimized for pooling virtual resources. Private clouds typically also provide some form of self-service provisioning, whereby users select the services they need, after which the virtualized back-end resources needed to host the services are automatically assembled.

Even before the emergence of cloud computing, virtualization was having a major impact across the IT industry. After being used on mainframes for decades, virtualization technology has matured on all of the major server platforms in use today, including those based on x86 and RISC architectures. Virtualization has already proven its ability in a variety of real-world environments to deliver some key business benefits, including consolidation and improved resource utilization; simplified resource provisioning; simplified High Availability (HA) / Disaster Recovery (DR); legacy application support; and improved test and development processes. Consolidation is perhaps the most widely applied use case for virtualization, which enables administrators to reduce the number of physical machines that they have to acquire and manage. The improved resource utilization reduces the server and storage hardware footprint, which results in lower acquisition costs, and can also reduce some operational costs related to maintenance, cooling, and power consumption.

Virtualization dramatically reduces the time required to provision new systems, compared with physical servers. While the end-to-end time required to bring up a new physical server can span weeks or months from planning to actual deployment, virtual machines can be launched in minutes or seconds. Virtualization also makes it easier to reconfigure systems in response to fluctuating workloads. Live migration of virtual machines between hosts provides flexibility for assigning computing resources to workloads. Storage virtualization allows storage resources to be expanded or migrated online, and it may enable virtual machines that are migrated to be accompanied by the storage Logical Units (LUNs) they need to ensure continued access to

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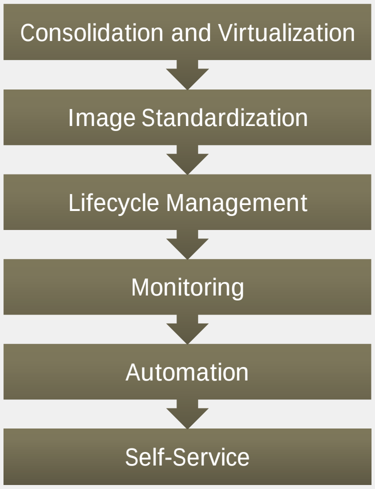
FIGURE 1

Staging the Adoption of Operational Processes for Managing Private Clouds



data. These capabilities enable computing resources to be treated collectively as virtual infrastructure that can be reallocated to different workloads on demand without having to reconfigure physical resources.

Management tools integrated with such virtual infrastructure make it possible to convert entire application stacks into services that can be activated on demand – a key requirement for achieving the benefits of cloud computing. By shielding end users from most of the administrative overhead associated with bringing up computing resources for a new application, virtualized applications can be treated as standardized services, in which all of the dependencies on computing resources are managed transparently in the background. Allowing end users to take control of deploying such services with minimal administrator intervention is critical to lowering operational costs – a central promise of private clouds.

The effective deployment of private clouds has some distinct technical requirements, including robust virtualization platforms and management tools, and these will be discussed below. However, success with private clouds will also depend on adopting certain operational practices for managing virtualized systems (see Figure 1, left).

Users may phase in these practices gradually as they progress toward complete deployment of private clouds, and at each step, incremental benefits accrue:

- Consolidation and virtualization are the first steps. At this stage, workloads are rehosted as system images in virtual machines, which are deployed on servers equipped with robust virtualization capabilities. These virtual machines can be securely stacked on physical hardware, allowing computing resources to be assigned to workloads with far greater precision, which leads to better utilization of servers.
- Standardization of the system images in which cloud-based services will be hosted is the next step. The relative ease of creating virtual machines significantly increases the challenge of provisioning those virtual machines with software that makes them useful for production workloads. At the same time, with virtualization, users have more variables than ever to consider for matching an application workload with the resources needed to host it. Within virtual machines, a particular application or its users will dictate the installation of specific operating systems, all of which may draw on a steady stream of updates and patches. Administrators targeting private clouds therefore should exercise discipline in maintaining a relatively small number of system images in libraries based on standard, open formats that can be browsed in a service catalog. Ideally, the number of these images should be limited to dozens or hundreds, rather than the thousands of images that administrators might contend with in the traditional physical infrastructure found in enterprise environments
- Lifecycle management is a critical part of the provisioning process in virtualized environments. Tracking and properly installing software updates represents a significant share of administrative overhead, and this burden can be magnified as the number of virtual machines increases or fluctuates in private cloud environments. Without disciplined lifecycle management, private clouds will simply become virtual replicas of traditional unwieldy physical infrastructure, making it difficult to achieve the economic promises of cloud computing.
- Monitoring internal consumption of resources by user or workload will also be important to achieving the economic benefits of private clouds. By adopting disciplined measurement of resource consumption, administrators can implement internal chargeback processes, which may be coupled with self-service interfaces so that users can make informed decisions about the costs of instantiating services. Deeper accounting of computing resources will also help managers prepare for the eventual adoption of third-party cloud services, since it will allow managers to more precisely compare the costs of external versus internal resources.
- Automation is the final step toward achieving the full benefits of private clouds. Provisioning, lifecycle management, and monitoring should be accomplished behind the scenes, with as

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little operator intervention as possible, so that users can have the flexibility to initiate and terminate services at will. Of course, the most critical aspect of automation is trust – i.e., building confidence with users and administrators that automated actions will perform as expected. The key to building this trust is the ability to activate automation gradually, and with detailed monitoring to verify the results of automated actions.

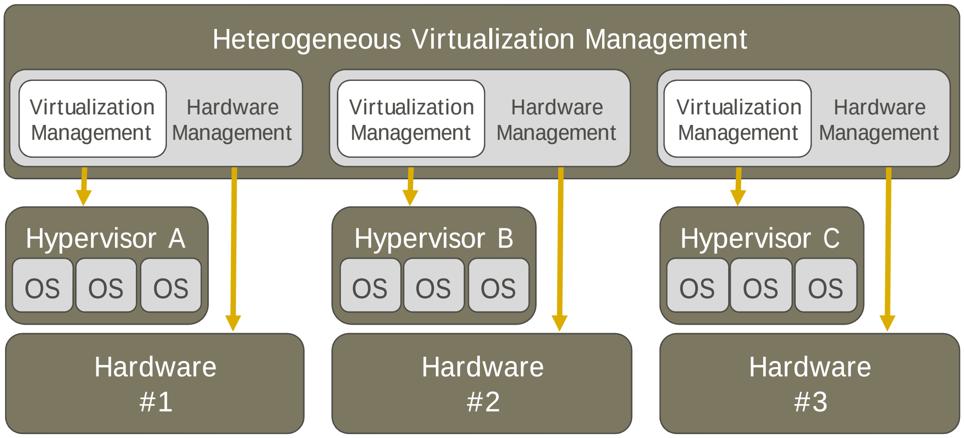
Once these practices are put into place, it becomes possible to implement service catalogs that can be reliably invoked by users. Along the way, the deployment of certain software packages will be required in order to implement the technical capabilities needed to support these practices.

Management Requirements for the Private Cloud

The rise of virtualization, potentially followed by an industry shift toward cloud computing, clearly introduces new management requirements at multiple layers of IT infrastructure. The addition of a virtualization layer into systems potentially introduces uncertainty – and complexity – because the relationship between workloads and computing resources inherently becomes indirect. As a result, administrators require new management tools that can provide visibility over both the physical and virtual layers of infrastructure from a single interface. If possible, administrators should also have consistent visibility and control over other layers of infrastructure, such as storage and networks. The closer the relationship between the management of all these components, the easier it will be for administrators to achieve the operational benefits that virtualization promises.

Cloud computing is by its nature heterogeneous. Workloads routinely span multiple departments or business units, some of which may be deploying different virtualization technologies. As the use of virtualization becomes a part of standard operating procedure on all systems, administrators will increasingly be confronted with the need to manage virtualization on multiple platforms. Each platform will have its own characteristics, both at the server hardware level (which may have unique functionality to support virtualization, or require coordination with hypervisor operation) and the hypervisor level. Even on the same hardware platforms, different hypervisors typically have their own interface for controlling virtualization functions. As a result, administrators will require a heterogeneous management framework that has the capability to control multiple classes of virtualization functions, on multiple server platforms, from a single interface (see Figure 2). Such a framework would provide a consistent interface for administrators to perform canonical virtualization functions, such as creating, moving, and destroying virtual machines; provisioning workloads on virtual machines; and managing libraries of preconfigured virtual machine images.

Figure 2. Framework for Heterogeneous Virtualization Management



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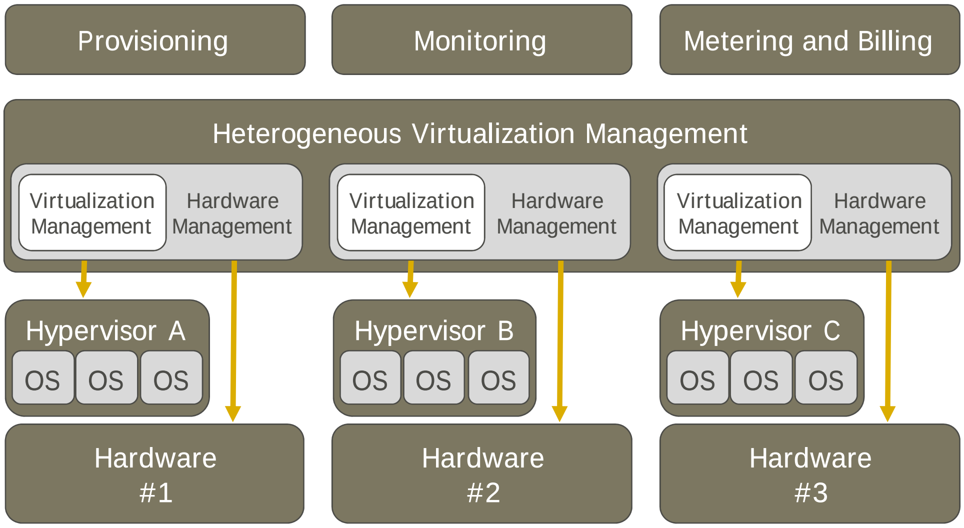
IBM's private cloud offerings are designed to deliver their value most quickly in integrated solutions such as IBM CloudBurst or IBM Service Delivery Manager (ISDM). For customers who want to maintain heterogeneity at various tiers of their infrastructure, IBM also enables the deployment of custom solutions for private clouds.

A heterogeneous virtualization management framework can serve as the foundation for higher-level services that are deployed on top of virtual machines, and managed with some degree of automation. To meet the needs of private clouds, some additional classes of management functions will be required (see Figure 3):

- Provisioning and image management tools for installing, maintaining, and patching the software on virtual machines as their number increases. One management challenge that arises quickly with broad virtualization deployments is provisioning virtual machines (i.e., installing and maintaining the necessary software on virtual machines so that they can perform a particular workload). The software needed for a workload typically includes an operating system, middleware, application software, and virtual infrastructure, all of which have to be patched on occasion. The burden of maintaining software in virtual machines increases significantly as the number of VMs grows. Such growth sometimes results from "virtual machine sprawl," which arises as a result of the relative ease with which VMs can be created. To meet the challenge of provisioning systems in virtualized environments, administrators require the ability to create "master images" of virtual machines using class-based templates that describe generically what software is needed on a particular VM. Once the template is defined, administrators can rapidly instantiate a virtual machine based on that class, which automatically installs all of the software itemized in the template. As a result, administrators can rapidly set up large numbers of VMs with relatively few commands.
- Monitoring functions that can be used to observe operational conditions at every level of the stack, starting with the underlying hardware and hypervisor functions, through the generic control parameters that apply across multiple virtualization platforms, and up to the applications and services that are layered on top of virtual infrastructure. When sufficiently integrated with provisioning tools, these monitoring functions will be essential for enabling automation, by allowing provisioning operations to be performed automatically in response to changing workload conditions.
- Metering and billing functions for tracking consumption of shared virtual computing resources and, where appropriate, allocating costs to users on a chargeback basis. The deployment of virtualization often results in infrastructure that is shared by different business units or departments, and users may demand accounting of resource consumption for chargeback purposes to make sure they are getting their "fair share" of virtualized resources.

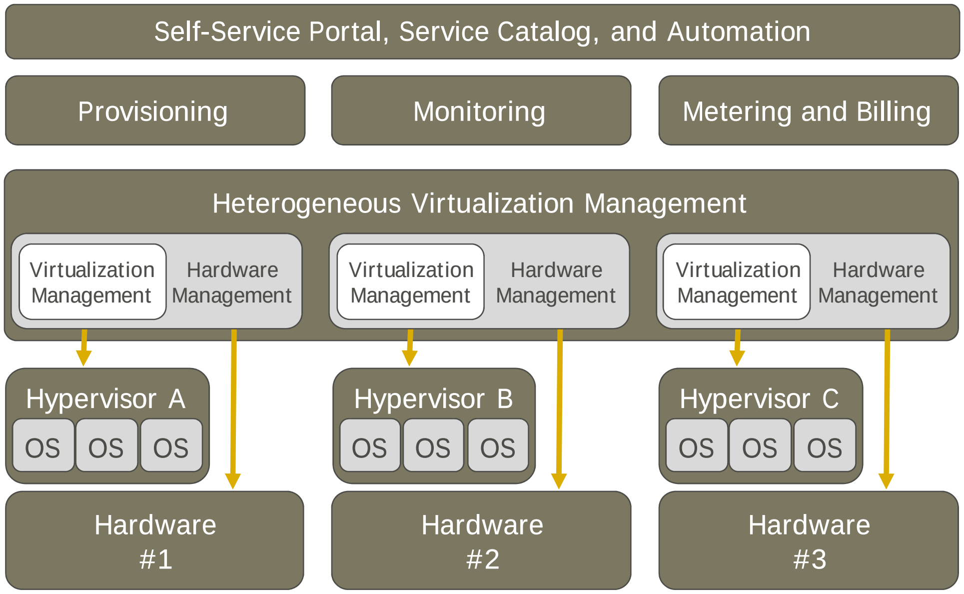
Figure 3. Private Cloud Support Functions



When integrated in ISDM, the Tivoli service management software offers the greatest value. For example, ISDM tightly links TPM provisioning functions with ITM monitoring, so that whenever a service is deployed, it will automatically be enabled for monitoring.

Finally, once robust implementations of the necessary private cloud support functions are in place, a self-service provisioning portal can be deployed. Such a portal gives end users the ability to initiate their own deployments of services, whereby the services are implemented through underlying virtual resources (see Figure 4). The portal should implement a catalog of available services, and then automatically and transparently trigger the necessary provisioning operations when a particular service is selected.

Figure 4. Complete Infrastructure for Private Cloud Management



All of these functions should work together in an integrated fashion. For example, if monitoring functions detect that a service's performance is beginning to dip below acceptable bounds, it should be able to correct the problem by triggering a virtualization management operation. Similarly, metering should be integrated with provisioning functions as well as lower-level virtualization functions, and they should automatically be activated when a service is activated from the self-service portal. The self-service portal should also be able to represent relevant parameters in the billing functions (i.e., the cost of initiating a particular service).

IBM and the Deployment of Private Clouds

With proven virtualization capabilities on each of its server platforms, IBM is in a strong position to facilitate the deployment of private clouds. IBM has strategically embraced cloud computing as a new way of thinking about delivering IT services to users. IBM views cloud computing as a new model for consumption and delivery of IT. Its approaches are inspired by consumer Internet services such as Amazon EC2, and its cloud efforts are therefore optimized for the needs of end-users. IBM sees cloud enabling the delivery of IT as services that can be directly accessed on demand by end users themselves, while opening up new sourcing options at better economies of scale through private, public, and hybrid models. IBM believes that its clients are currently more comfortable with private clouds than public or hybrid clouds, and that many are ready to deploy fundamental business applications in private clouds.

IBM's private cloud offerings are designed to deliver their value most quickly in integrated solutions such as IBM CloudBurst or IBM Service Delivery Manager (ISDM). For customers who want to maintain heterogeneity at various tiers of their infrastructure, IBM also enables the deployment of custom solutions for private clouds. In all of these approaches, IBM's software

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When coupled with IBM's hardware, ISDM promises an ever-faster time to successful private cloud deployment. The components of ISDM were originally coupled with IBM's Cloudburst, an integrated package of hardware, software, and services for simplified cloud deployment. IBM now offers ISDM software separately from Cloud-Burst, giving customers the ability to deploy it on other hardware, either from IBM or other vendors.

plays a particularly strong role. The following packages from IBM Tivoli meet some of the key management requirements for private clouds, as described above:

- Tivoli Service Automation Manager (TSAM) is the heart of IBM's cloud software. TSAM maintains a catalog of available services and provides a self-service portal that can be used to request and reserve services from the catalog. TSAM masks the complexity of setting up and breaking down services from the end user, so that they don't need to know everything going on behind the scenes (i.e., what resources are needed, where they are located, and how the service will run on those resources presented). Users log into the portal, and are presented with a list of services, which may be provisioned into either virtual or physical infrastructure. Users simply have to select what class of software they want to provision (i.e., database or web server), enter a few parameters, and submit the request. TSAM will then automatically provision an entire operating environment based on the user's specification on the back-end infrastructure.
- Tivoli Provisioning Manager (TPM) automates lifecycle management for IT resources, supporting change and release management for physical and virtual system images. TPM provides an integrated solution for creating, provisioning, patching, and eventually de-provisioning these images.
- Tivoli Monitoring (ITM) can be used to monitor a variety of performance indicators and store them in a common warehouse for reporting and analysis. Administrators can mine the collected data for performance analysis as well as capacity analysis, and perform predictive trending to see when capacity will be exceeded.
- Tivoli Usage and Accounting Manager (TUAM) helps administrators track the usage of shared resources by user and accurately bill the users for their consumption of those resources. TUAM helps to alleviate the concerns of some users who link the cloud with lack of control (i.e., the risk of losing visibility over where an application is running, or who is using resources). TUAM helps these users understand in detail how resources are being allocated, and it can also be used for chargeback purposes.

These packages can be installed separately or as part of the integrated ISDM software solution. When integrated in ISDM, the Tivoli service management software offers the greatest value. For example, ISDM tightly links TPM provisioning functions with ITM monitoring, so that whenever a service is deployed, it will automatically be enabled for monitoring. As soon as a machine is provisioned, it becomes visible in the monitoring console.

When coupled with IBM's hardware, ISDM promises an ever-faster time to successful private cloud deployment. The components of ISDM were originally coupled with IBM's CloudBurst, an integrated package of hardware, software, and services for simplified cloud deployment. IBM now offers ISDM software separately from CloudBurst, giving customers the ability to deploy it on other hardware, either from IBM or other vendors. As a result, customers now have a range of options for installing IBM's cloud management software:

- The fastest return on investment can still be achieved from deploying IBM's complete, preconfigured, self-contained CloudBurst cloud infrastructure, in which ISDM software is integrated with IBM BladeCenter or IBM Power Systems hardware, networking, and storage. The CloudBurst package also includes IBM Global Technology Services (GTS) QuickStart Services for bringing the cloud system up, connecting the cloud system to the network, and providing training for users.
- Users who want the greatest flexibility for assembling their own cloud infrastructure with heterogeneous software and hardware can deploy the individual Tivoli software components on multiple server platforms from IBM and other vendors.
- Users who want to get the greatest leverage from just IBM's cloud management software can install the ISDM suite on hardware from IBM or other vendors.

IBM offers three strategic server platforms, each of which can play a role in private clouds. Each platform has unique optimizations at the systems level that can benefit particular work-loads . . .

To assist users who prefer to perform some of their own integration as they deploy private clouds, IBM has produced a Cloud Computing Reference Architecture, which describes a roadmap for structuring service management functions and services in the context of a cloud. The Cloud Computing Reference Architecture shows the relationships between Cloud Service Consumers, Cloud Service Providers, and Cloud Service Developers, and positions the roles and functions that may have to be fulfilled between these constituencies in detail. The architecture does not specifically depend on the deployment of IBM's hardware or software, but the structure of IBM's private cloud packages clearly reflects the company's goals. Moreover, private clouds deployed on IBM's server platforms will benefit from their unique capabilities, as well as from lower-level systems management software that is optimized for IBM hardware.

Matching IBM Server Platforms with Virtualized Workloads

IBM offers three strategic server platforms, each of which can play a role in private clouds. Each platform has unique optimizations at the systems level that can benefit particular workloads, such as database and transaction applications that have to support thousands of online users with 24x7 operation; business intelligence and analytics applications that draw data from multiple data sources; and business process management applications that have to orchestrate multiple services. All of these platforms support native virtualization capabilities that can become part of the foundation to a private cloud:

» IBM System x is IBM's line of industry-standard x86 and BladeCenter servers. IBM is one of the few vendors of x86 servers to perform its own engineering of the major system components. While most other x86 server suppliers use Intel's standard chipsets as the building blocks for complete server systems, IBM has differentiated its x86 servers with unique technology, including the eX5 architecture, Calibrated Vector Cooling, expansion blades, simple-swap drives, eXtended I/O, Predictive Failure Analysis, and Light-Path Diagnostics. System x supports several virtual machine platforms, including VMware, Microsoft Hyper-V, and the native virtualization management functions that are built into the leading Linux distributions (i.e., Xen and Kernel-based Virtual Machine [KVM]). IBM also supports the native management functions for these hypervisors on System x, including VMware vCenter and Microsoft SystemCenter. IBM's higher-level virtualization management tools "collaborate" with these native management systems in order to trigger specific actions at the level of virtual infrastructure.

» IBM Power Systems include a native virtualization platform called PowerVM, which offers a complete set of virtualization capabilities that are optimized for the POWER platform. The key components of Power VM include Micro-Partitions, which enable many distinct workloads to share a processor and memory simultaneously while running on different operating systems; Active Memory Sharing, which improves utilization of system memory by allowing physical memory in a machine to be assigned into a shared pool, and allocated to partitions on the fly; and Live Partition Mobility, which allows a virtual machine to migrate from one physical host to another without interrupting its processing.

» IBM System z has some of the most mature and efficient virtualization functions in the industry. The z/VM virtual machine platform for System z has proven its scalability with deployments of thousands of virtual machines running concurrently on a single host. With z/VM, Linux environments that need the highest qualities of service can be virtualized on the System z platform using standard Linux distributions from Red Hat and Novell. System z also has some of the most robust and efficient I/O virtualization capabilities of any server platform. With the z BladeCenter Extension and IBM's Unified Resource Manager, traditional mainframe governance can now be extended to heterogeneous workloads, allowing the leading reliability and security attributes of mainframe-based management to be applied to more modern workloads that are optimized for POWER and x86 processor architectures.

All of IBM's server platforms can be managed with the same interface, called IBM Systems Director, which is optimized to measure and control low-level functions in IBM's servers. IBM

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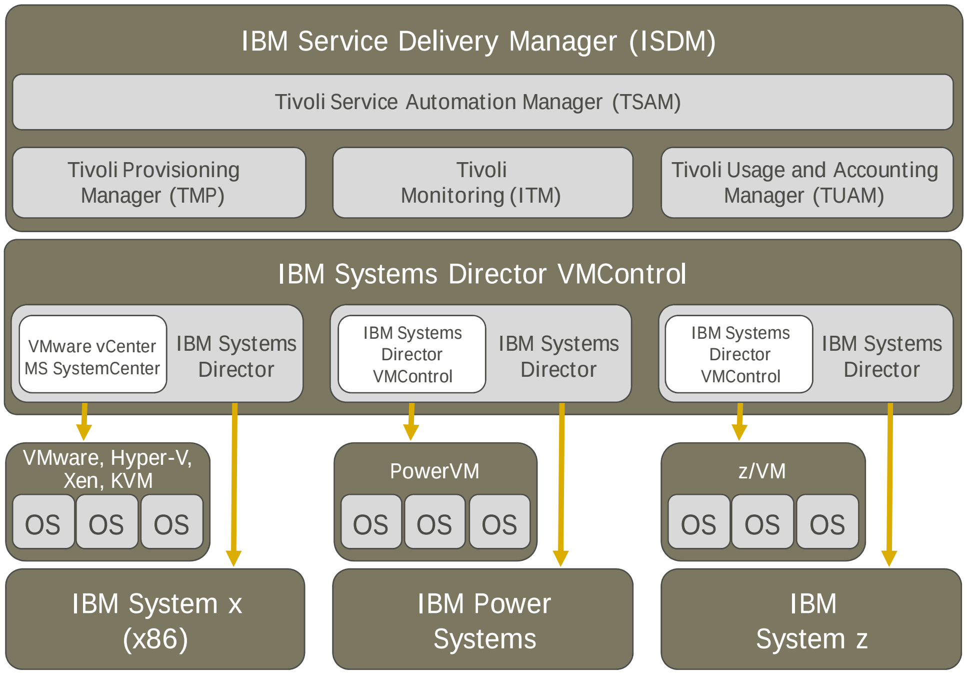
IBM offers its customers multiple pathways for deploying private clouds, ranging from high-touch service engagements, which will take on the entire task of bringing cloud computing to a customer based on their specific needs, to integrated "quick start" solutions such as CloudBurst hardware or ISDM.

Systems Director VMControl is an extension to Systems Director that can be used to manage multiple virtualization platforms from the same interface. VMControl works with the virtualization functions on all of IBM's hardware platforms, including System x, Power Systems, and System z, and it is available in different versions.

The most basic version, VMControl Express Edition, can be used to create, modify, and delete virtual machines, or trigger the live migration of VMs from one host to another. A more advanced version, called VMControl Standard Edition, adds more powerful functions for performing virtual machine relocation; importing, editing, creating, and deleting virtual images; maintaining virtual images in a repository; and deploying virtual images. VMControl Enterprise Edition can be used to create pools of virtualized resources (both server and storage pools), which workloads can tap into on demand in response to changing workload conditions. Another extension for IBM Systems Director, the Storage Management plug-in, can be used to coordinate VM provisioning and mobility for server, storage, and network resources. The plug-in can be used to perform lifecycle management of storage systems, including discovery, health, status monitoring, configuration, updates, and management of storage virtualization functions.

When ISDM is deployed on one or more of IBM's server platforms, users gain transparent, end-to-end control over private cloud resources (see Figure 5). IBM Systems Director and VMControl can capture operational data and events at the level of hardware and specific virtualization platforms. Higher-level Tivoli service management software, including TPM, ITM, and TUAM can be used to implement standardized services that are built on the lower-level virtual infrastructure, spanning multiple server and virtualization platforms. TSAM then provides the necessary automation and control that allows end users to take over some of the responsibility for initiating and terminating services, delivering on one of the central promises of cloud computing.

Figure 5. IBM Private Cloud Infrastructure



The IDEAS Bottom Line

IT managers are currently preoccupied with responding to two global trends affecting the industry: adopting virtualization at multiple levels of infrastructure, including servers, network, and storage; and reducing costs of operations through improved processes and tools for managing higher-level services and workloads. The cloud computing concept is generating considerable interest in part because it touches on both concerns. Virtualization dramatically increases the flexibility of matching workloads with their necessary computing resources, helping to enable a new degree of automation for delivering and managing services. When virtualization is coupled with the appropriate higher-level mechanisms for cataloging these services, it becomes possible to deliver self-service tools to end users that allow them to rapidly deploy their own computing environments, with minimal knowledge about the underlying computing infrastructure. This efficiency yields much of the cost benefit of cloud computing.

For self-service provisioning to become a reality, some discipline is still required in the management of the underlying virtualized infrastructure. First, administrators must make an effort to standardize their virtual images as much as possible, both to reduce the scale of overhead for maintaining the various images, and to simplify the task for end users to select the appropriate image needed for a particular service. Second, administrators must institute rigorous processes for managing the lifecycle of virtual images (i.e., developing, testing, updating, patching, and eventually retiring the software underlying virtualized services). The tools to facilitate these processes become essential for successfully deploying clouds. Once robust processes for standardization and lifecycle management have been implemented, the opportunities follow for setting up comprehensive monitoring, automation, and self-service. IBM's Tivoli service management software can be applied at every stage of this transition, culminating in a complete platform that can manage the entire chain of events from a user self-selecting a service to activating the underlying physical resources that drive that service.

IBM offers its customers multiple pathways for deploying private clouds, ranging from high-touch service engagements, which will take on the entire task of bringing cloud computing to a customer based on their specific needs, to integrated "quick start" solutions such as CloudBurst or IBM Service Delivery Manager. For customers who prefer to perform their own integration of private clouds, IBM provides a choice of hardware and software building blocks, along with recommendations and a reference architecture that will help lead the way to a successful deployment. IBM's integrated service management is the key added value on all of these paths. By methodically addressing the operational requirements at every level of private cloud infrastructure, IBM provides the necessary foundation to fulfill much of the economic promise of cloud computing.

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