Intel IT Center

August 2013

Planning Guide

Virtualization and Cloud Computing

Steps in the Evolution from Virtualization to Private Cloud Infrastructure as a Service

Why You Should Read This Document

This guide summarizes valuable information and practical steps for IT managers who want to plan and implement private cloud infrastructure as a service (IaaS) as the first step toward cloud services delivery, including:

- How building a cloud service delivery model will help your organization take full advantage of the agility and efficiency benefits of cloud computing
- The key technologies and capabilities that you need to move from an IT virtualization practice to a private cloud computing practice
- A framework for approaching your private cloud project that lays the groundwork for moving to a hybrid model when you are ready
- A quick review of the five leading cloud management platforms (CMPs): Apache* CloudStack*, Eucalyptus* Cloud platform, Microsoft* cloud software, OpenStack* cloud software, and VMware* vCloud Director*

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The Path to Simplified Delivery of Cloud Services

Today the cloud is a proven delivery model, with a growing number of enterprises realizing impressive agility and efficiency benefits. As the technology matures, the trend is for organizations to extend cloud deployments to even more flexible private, hybrid, and public cloud models that promise exciting new ways to expand the scope of value-added business services, address top priorities like big data and Bring Your Own Device initiatives, and deliver enterprise applications as services.

Many organizations no longer question the value proposition associated with cloud computing. But the conversation has changed—from "Should we do it?" to "How should we do it to get the most value?" Intel wants to help you simplify delivery of your cloud services so that your business can realize the full benefits of cloud computing now, while laying the groundwork to move to a more elastic hybrid model at the same time. The purpose of this guide is to help you take the first step—building a private cloud on a highly virtualized foundation.

Why Private Cloud?

Many companies are already virtualizing their IT environment and have been doing so for years. Initially, virtualization was deployed for compute resources, primarily as a cost-saving technology. Organizations soon recognized that virtualization provided additional cost-savings benefits as well as enhanced speed and flexibility.

Most clouds are built on virtualized infrastructure technology. Cloud computing originated as a new way to deliver IT services by providing a customer interface to automated, self-service catalogs of standard services, and by using autoscaling to respond to increasing or decreasing user demand. From an IT perspective, a private cloud offers the key advantages of speed, agility, and efficiency while maintaining control of sensitive workloads.

Best Practices and Insights from Intel IT

Intel IT solves some of today's most demanding and complex technology challenges—right here at home. Our computing environment supports 95,200 employees globally and includes 68 data centers and 147,000 devices. To create as much business value for Intel as possible, we proactively invest in and implement innovative IT strategies and capabilities, including cloud computing, consumerization of IT, and big data analytics.

Intel has realized significant benefits from deploying its own private cloud, from increased agility—server provisioning dropped from 90 days to 45 minutes—and reduced operational costs—$21 million in savings since 2009. Throughout this planning guide, we'll share best practices from Intel's cloud journey to reinforce our recommendations, help you reduce organizational risk, and simplify your path to the cloud.

Find additional insights and best practices from Intel IT leaders about strategic planning, creating business value, improving productivity, managing growth, and more at Intel IT.

Private clouds also enable IT to be more responsive to the business and to work more effectively with its constituencies—business users, suppliers, partners, employees, and others. Without private clouds, line-of-business (LOB) requests to IT for provisioning server or storage capacity for key business initiatives can take weeks—or even longer. With a private, self-provisioning cloud, users can be up and running in hours or even minutes, with no or minimal interaction with IT. Projects don't languish, and users can gain access to the capacity they need on demand. IT can provide better service, monitor demand, and maintain control of sensitive workloads and resources. Users benefit with increased speed to market and the ability to go after short-term opportunities.

Offering a private cloud also provides these benefits, important for the evolution of services:

- Establishes a foundation for new services, such as platform as a service (Paas),[1] to accelerate customer application deployment and promote cloud-aware application design principles.
- Enables extension to public service providers as needed to manage spikes in demand.
- Positions IT as the broker of cloud services across the enterprise. In this role, IT can offer perspectives and skills to help users find the best internal or external solution for their needs, as well as better utilize existing private cloud resources. Also, IT can reduce the risk of working with public providers by helping to meet LOB expectations on price, capacity, and provisioning speed, while ensuring that organizational requirements for security and data governance are in place.

BMW's Private Cloud Strategy

One example of a company successful in deploying a private cloud is BMW. The BMW Group is pursuing a long-term cloud strategy in two phases with short development cycles and specific short-term objectives. The first phase focuses on delivering private cloud services; phase two extends the private cloud to a hybrid model. The decision to start with a private cloud infrastructure was designed to avoid data and infrastructure security issues, provider dependencies, and integration deficiencies that are often encountered with public cloud infrastructures.

For its private cloud environment, BMW uses modularized open architecture based on industry standards and usage models from the Open Data Center Alliance to create secure platform and infrastructure layers, business orchestration, and technical automation.

Find out more about BMW's cloud strategy in *Open Data Center Alliance*: The Private Cloud Strategy at BMW*.

High-Performance Cloud Capabilities

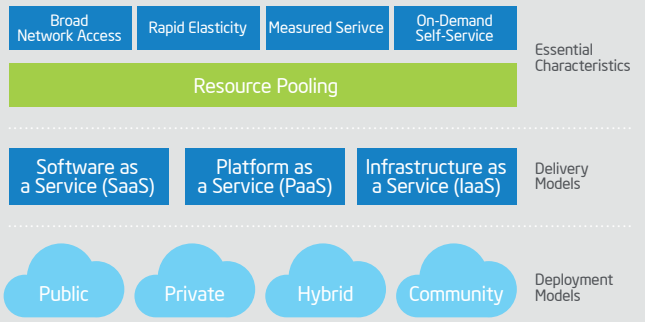
The U.S. National Institute of Standards and Technology (NIST) identifies several essential characteristics of a high-performing private cloud.[2]

- **On-demand self-service –** Users can automatically provision their own computing resources as needed and without requiring human intervention, typically through an interactive portal that enables them to configure and manage these services themselves.
- **Broad network access –** Resources are available via the network and can be accessed by multiple devices, including smart phones, tablets, laptops, and desktops.
- **Rapid elasticity –** Resources can be quickly and transparently expanded or contracted depending on demand. Scaling is automatic to users, and provisioning what they need is transparent.
- **Measured service –** Usage is measured and can be monitored, controlled, and reported for transparency.
- **Location-transparent resource pooling for multiple tenants –** Compute, storage, and networking resources are pooled to serve multiple user groups (tenants) with different physical and virtual resources that can be dynamically assigned and reassigned according to user demand. Because users generally have no control of the exact location of the resources, there is a sense of location independence, although location may be specified at a higher level abstraction (country, state, data center).

In addition to these capabilities, NIST also defines service delivery layers and deployment models. Deployment models include private, public, community, and hybrid clouds. Service layers for each of these delivery models include:

- **Infrastructure as a service (IaaS) –** Cloud infrastructure is the collection of hardware and software that enables the essential characteristics of the cloud. IaaS enables users to self-provision these resources in order to run platforms and applications.
- **Platform as a service (PaaS) –** PaaS enables users to adapt legacy applications to a cloud environment or develop cloud-aware applications using programming languages, services, libraries, and other developer tools.[3]
- **Software as a service (SaaS) –** Users can run applications via multiple devices on cloud infrastructure.

National Institute of Standards and Technology (NIST) Cloud Computing Model



Based on *The NIST Definition of Cloud Computing.* U.S. National Institute of Standards and Technology Special Publication 800-145 (September 2011). http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

About Cloud Delivery Models

- **Private –** Cloud infrastructure is provisioned for use by a single organization that comprises multiple tenants. Private clouds may be operated on- or off-premises and are behind the company firewall.
- **Public –** A cloud service provider offers services to multiple businesses, academic institutions, government agencies, and other organizations with access via the Internet.
- **Hybrid –** Hybrid clouds combine two cloud delivery models (for example, private and public) that remain unique as entities but are bound together by technology that enables data and application portability. Cloudbursting is an example of one way enterprises use hybrid clouds to balance loads during peak demand periods.
- **Community –** Cloud infrastructure is provisioned for the exclusive use of a specific community of user organizations with shared computing requirements such as security, policy, and compliance.

Virtualization as an Enabling Technology

The underpinning for the majority of high-performing clouds is a virtualized infrastructure. Virtualization has been in data centers for several years as a successful IT strategy for consolidating servers. Used more broadly to pool infrastructure resources, virtualization can also provide the basic building blocks for your cloud environment to enhance agility and flexibility.

Today, the primary focus for virtualization continues to be on servers. However, virtualizing storage and networks is emerging as a general strategy. Results from a Gartner survey of 505 data center managers worldwide reports that planned or in-process virtualization of infrastructure workloads will increase from approximately 60 percent in 2012 to almost 90 percent in 2014.[4] This continuing growth makes cloud computing an obvious next step for many organizations.

Virtualization Is Not Cloud Computing

Here's the difference: Virtualization abstracts compute resources—typically as virtual machines (VMs)—with associated storage and networking connectivity. The cloud determines how those virtualized resources are allocated, delivered, and presented. Virtualization is not necessary to create a cloud environment, but it enables rapid scaling of resources in a way that nonvirtualized environments find hard to achieve.

From Virtualization to Private Cloud Services: Five High-Level Steps

The path from virtualization to a self-service cloud poses technical as well as organizational challenges related to management and operational processes, culture, and politics. The following five high-level actions serve as a framework to help you understand and successfully address the organizational and technology issues you will face. Many of the specific activities involved will take place simultaneously. Neglecting any one of these can trip you up and cause your project to fail.

The framework:

- **Step 1: Develop a cloud strategy –** Establish where you want to go.
- **Step 2: Manage organizational and business process change –** Get the business on board.
- **Step 3: Organize IT around services delivery –** IT shifts its role to a broker of cloud services.
- **Step 4: Put the right technology in place –** Set short-, medium-, and long-term goals.
- **Step 5: Manage and monitor your cloud and manage with data –** Use analytics to improve operations.

Step 1: Develop a Cloud Strategy

A cloud strategy clearly articulates the benefits, approach, and expected outcomes for your technology investment across your organization. Tied to line-of-business goals, it helps you get senior management buy-in and manage expectations—both keys to your success. Your cloud strategy should include:

- **The high-level business case –** Describe the benefits to both IT and the business and the expected return on investment.
- **Implementation phases –** Define short-term, mid-term, and long-term goals for delivering services with related benefits. For example: Intel IT implemented IaaS first to enable broader enterprise use cases.
- **Workloads –** Identify the workloads you plan to move to the cloud and the associated user groups.
- **Cloud architecture –** Define cloud architecture, including the components of IaaS, PaaS, and SaaS, as well as security and related systems such as backup and disaster recovery.
- **Client devices –** Define how users will access the cloud and integrate with your enterprisewide mobile strategy.
- **Monitoring and management –** Determine how you will manage your cloud, monitor health and performance, and define success.
- **IT-business relationships –** Define how IT will partner effectively with the business to specify business process requirements and request services.

With a cloud strategy, you now have an overarching approach to cloud computing across the organization. It gives you the tools to deepen relationships with line-of-business managers, generate some excitement for your project, and manage expectations for each phase of implementation. Plus, it's a roadmap for where you want to go, helping to direct virtualization efforts so you can fully achieve the value on your private cloud investment and lay the groundwork for a more elastic hybrid model. A cloud strategy will also help you avoid the potential for shadow IT created by business units who may go to a public cloud provider in the absence of private cloud services in the enterprise.

About Intel's Cloud Strategy

In 2009, Intel IT began work on a core business strategy to build an enterprise private cloud. The complex, multiyear approach was designed to increase agility, boost infrastructure efficiency, and provide high availability, as well as host highly demanding, mission-critical business applications.

Intel IT made the decision to build the cloud from the inside out in three phases:

- Phase 1: We created hosting platforms, implementing infrastructure as a service (IaaS) to enable broader enterprise usage models.
- Phase 2: Then we built on our success by offering platform as a service (PaaS) to encourage cloud-aware application development for specific use cases.
- Phase 3: Currently, we are laying the foundation for hybrid clouds to maximize agility and provide bursting capability.

Source: *Best Practices for Building an Enterprise Private Cloud*, Intel IT (December 2011).

Step 2: Manage Business Process Change

Business process changes are pervasive in a cloud implementation. For your cloud project to succeed, you must collaborate with process owners to accurately document the processes and tasks affected and determine how to minimize the number of required human control points. Plus, you need management cooperation to implement any changes to existing processes that might benefit from the automation; and you will be developing new processes, such as how users access and specify the cloud resources they need. By drawing on cross-domain expertise, you ensure that your technical considerations benefit from business knowledge of the activities and tasks to be automated and avoid the potential of user and management apathy—or worse, hostility.

Cloud obviously affects IT-specific processes as well. Capacity management, for instance, becomes radically different in a cloud environment. In the cloud, rather than IT assigning physical resources with unused overhead to handle peak conditions, capacity is governed by predefined limits based on demand for individual applications and provisioned by users.

You also need to implement other processes to better manage your cloud, such as system-related business intelligence and costing information. For example, with manageability and business intelligence tools, you can keep operational costs at a minimum by maintaining a thin overhead of unused capacity and making investments in new infrastructure on a just-in-time basis. Business intelligence capabilities also provide insights into consumption, performance, utilization trends, and security-related events.

Costing Information: User Chargeback?

Intel IT provides users of the company's private cloud with the cost of capacity. This is a reporting detail rather than a chargeback, but it helps people understand how they are using shared assets. The information also can be figured into new project planning or other decisions, such as finding ways to reduce costs.

Find out more about metering and chargeback in *An Enterprise Private Cloud Architecture and Implementation Roadmap*.

Step 3: Organize IT around Service Delivery

Many users in large companies are already familiar with the concept of consuming IT services. Organizing your IT workforce around cloud service delivery enables you to serve the business more effectively as a cloud services broker.

As a cloud services broker, your role is to weigh user needs against the available delivery options for your organization. From the IT perspective, this reduces organization risk, improves resource utilization, and monitors demand. From the perspective of users, they get the right solution to meet their needs—made easy with self-provisioning and automation. Ultimately you gain experience delivering cloud services that can be extended later to brokering public services in a hybrid cloud model. You also eliminate the need for business users to stand up their own individual cloud silos.

New IT Skills for Cloud Computing

Delivering cloud services requires a shift in IT skills to include abilities in planning, modeling, financial management, building architecture for evolving needs, and performance measurement for efficiency, service analysis, and continuous improvement. While legacy and cloud resources may be managed separately now, the trend is toward a single management structure for both. IT groups are using a combination of tactics to make sure they have the right mix of skills, including hiring new talent and training existing staff.

Step 4: Put the Right Technology in Place

Your cloud won't succeed without the right technology. Set your technology priorities based on the implementation phases and milestones described in your cloud strategy. For example, short-term priorities would typically include implementing pervasive virtualization to integrate compute, storage, network, and physical resources, and then offering IaaS by implementing end-to-end, on-demand, self-service capabilities; automation; orchestration; and security. Longer term, you might plan to integrate public services into a hybrid model.

Reference architectures and out-of-the box workflow templates or building blocks can significantly simplify implementation as well as reduce project time. You'll need your business process documentation to use these tools efficiently, especially for provisioning, scheduling, and automation. Proofs of concept will help increase confidence and point to areas of improvement.

Step 5: Manage a Data-Driven Cloud

End-to-end health and performance monitoring of the environment is essential for cloud management. Without data collection and analytics, you won't have the information you need to benefit from system efficiencies or measure success. A dashboard with integrated operational analytics that encompass facilities, network, storage, compute, and applications can help you assess whether you are meeting availability and performance goals, inform decisions to add capacity, troubleshoot problems, and comply with security and privacy regulations. Plus, at the point where you want to offer externally hosted cloud services, you must have a way to measure overall service availability in place to monitor third-party service-level agreements.

About Intel® Cloud Builder Reference Architecture Solutions

Intel can help simplify your path to the cloud with reference architectures and more from Intel® Cloud Builders, a cross-industry initiative aimed at making it easier to build, enhance, and operate cloud infrastructure.
Resources include:

- Reference architectures, or recipes, on how to deploy ecosystem solutions built on commercially available offerings from leading systems and solutions providers based on Intel technologies
- Reference implementations describing real-world customer deployments of a reference architecture
- Webcasts providing in-depth presentations on solutions and architectures
- Weekly podcasts on cloud computing topics
- An ecosystem of more than 60 leading cloud computing companies that can provide cloud solutions based on Intel Xeon®-based servers

Find more at intelcloudbuilders.com.

High-Performance IaaS Technology Requirements: Five Steps

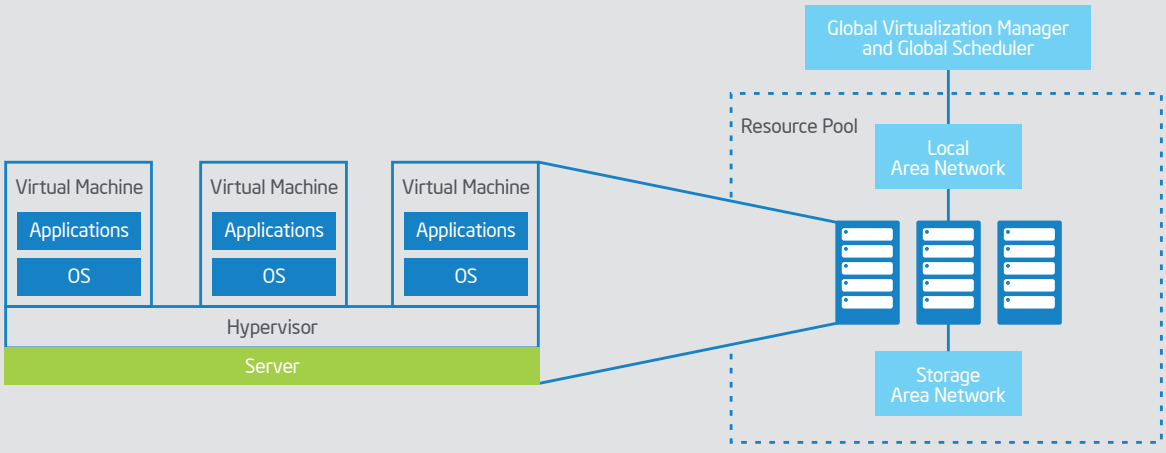
IaaS is the virtualized, multitenant infrastructure that underpins your private cloud and enables multiple applications for business groups across the enterprise to share. IaaS is built and delivered using a set of technologies that start with virtualization as the basic building block. A cloud management platform enables you to run a multitenant environment using the resources from the virtual infrastructure and security technologies at every level. Although clouds are built with IaaS, PaaS, and SaaS service layers, infrastructure services are the most typical private cloud services offered today.

Step 1: Implement Pervasive Virtualization

Virtualization is the foundation for an agile, scalable cloud—and the first practical step—for building cloud infrastructure. Virtualization abstracts and isolates the underlying hardware as virtual machines (VMs) in their own runtime environment and with multiple VMs for computing, storage, and networking resources in a single hosting environment. These virtualized resources are critical for managing data, moving it into and out of the cloud, and running applications with high utilization and high availability.

Virtualization is managed by a host server running a hypervisor—software, firmware, or hardware that creates and runs VMs. The VMs are referred to as guest machines. The hypervisor serves as a virtual operating platform that executes the guest operating system for an application. Host servers are designed to run multiple VMs sharing multiple instances of guest operating systems.

Virtualization also provides several key capabilities for cloud computing, including resource sharing, VM isolation, and load balancing. In a cloud environment, these capabilities enable scalability, high utilization of pooled resources, rapid provisioning, workload isolation, and increased uptime.



Infrastructure as a service is built on pooled resources for computing, storage, and networking. (From *An Enterprise Private Cloud Architecture and Implementation Roadmap*. Intel IT [June 2010].)

Today, the trend in virtualization has moved from reducing costs by consolidating data centers to increasing flexibility and agility through the pervasive use of virtualization for faster service deployment and dynamic placement of workloads. Pervasive virtualization is a strategic approach that provides a method for judiciously bringing legacy applications into your cloud to meet your strategic goals or as time and budget allow. Its benefits include better quality of service, improved availability and business continuity, faster resource deployment, and lower energy consumption.

About Virtualization Best Practices

Intel IT implemented pervasive virtualization as part of the plan for the company's private cloud, with a goal of virtualizing 75 percent of servers. Virtualization best practices that lay the groundwork for building Intel's cloud services included:

- Establishing a standardized, repeatable process for identifying, virtualizing, and managing the life cycle for virtualized servers
- Creating demand from business groups by explaining plans, promoting private cloud benefits, and proving that virtualization would not impact their production environments
- Resolution of technical limiters, such as security, storage replication, backup and recovery, very large virtual machines (VMs), and Sarbanes-Oxley compliance, in order to virtualize mission-critical applications

Learn more about pervasive virtualization from *Best Practices for Building an Enterprise Private Cloud* and *Technical Limiters for Pervasive Virtualization*.

Step 2: Select Your Cloud Management Platform

With increased virtualization infrastructure, you also need greater management capabilities, a technical challenge that can be achieved in parallel to your transition to a cloud environment. At this juncture you can decide to:

- Use a virtualization management platform that can also be used or extended easily for the cloud.
- Augment existing tools with an expanded set of cloud management capabilities on top of your existing virtualization management platform.
- Add a new cloud management platform (CMP) that can run the cloud and your existing virtualization environment.

A cloud management platform is integrated software that delivers service quality, security, and availability for workloads running in cloud environments. CMP offerings vary widely in terms of platform maturity, architecture complexity, and capabilities. At minimum, it should provide:

- Direct user access to the system
- Self-service capabilities and interfaces
- Workflow engine
- Automated provisioning
- Metering and chargeback functionality

More advanced capabilities might include performance and capacity management, interoperability between private and public IaaS offerings, connectivity to and management of external clouds, application life-cycle support, back-end service catalogs, and integration with external enterprise management systems.

The cloud management platform you choose should be based on organization size and complexity, the degree of heterogeneity in your virtualized infrastructure, and the cloud functionality you require. With heterogeneous infrastructure, you are more likely to benefit from using IT operations management architectures to manage both legacy and cloud environments. For data centers with homogeneous infrastructure, evaluating the vendor as your supplier is a good place to start.

About Open Data Center Alliance* Cloud Usage Models

The Open Data Center Alliance (ODCA) is an independent IT consortium comprised of global IT leaders who work on a unified customer vision for long-term data center requirements, including critical cloud infrastructure needs. ODCA membership includes more than 300 companies representing more than USD 100 billion in annual IT spend. ODCA began releasing a roadmap of IT requirements in 2011, including master usage models for compute infrastructure as a service and service orchestration, as well as security, management, governance, and monitoring. Intel is the nonvoting technical advisor to ODCA.
Learn more at opendatacenteralliance.org.

Step 3: Automate Workflows and Other System Capabilities

Automation is a key capability of elastic, high-performing cloud environments. By eliminating or minimizing manual processes and requiring minimal human control points, you can optimize and manage resources faster, deliver services, manage service life cycle, and respond to changing conditions.

In a cloud environment, automated workflows integrate across heterogeneous and disparate systems that manage provisioning, scaling, VM configuration, identity and access controls, network resources, workflow monitoring, patching, and backup. More advanced automation capabilities can include release management, load balancing, firewalls, and management of more complex VMs.

About Intel IT's Automated Workflow

Intel IT created a workflow automation layer for the company's private cloud infrastructure through a modular, extensible framework that simplifies system integration and provides the prerequisites for fully functional, self-provisioned virtual machines (VMs) with compute, storage, and network resources. The modular design enables Intel IT to introduce additional automation capabilities as business and technical needs change.

Get more detail in *Best Practices for Building an Enterprise Private Cloud*.

Step 4: Orchestrate Services End to End

Orchestration software provides the automated intelligence that dynamically arranges, coordinates, and manages the elements of your cloud environment. Orchestration of end-to-end services enables the flexibility, economy of scale, and on-demand delivery for virtualized resources and provides the ease and convenience users expect when they access the cloud.

Orchestration has two main jobs: aligning service requests with available resources and monitoring the health of the physical and virtualized environment. These functions enable your cloud to scale up or down based on demand at specified performance levels. To accomplish this, orchestration manages across different systems to:

- Connect and automate workflows to deliver a specified service.
- Manage configuration, capacity, metering, and chargeback.
- Track and report on cloud performance and availability.
- Monitor and manage power, including energy consumption and cooling requirements.
- Monitor security threats and adherence to security policies, including access, authorization, and identity management.
- Take effective actions and make adjustments based on feedback from monitoring tools.
- Predict potential issues so they can be addressed before they become major issues.

Intel® Intelligent Power Technology and Your Cloud

Power is a significant cost for IT operations–for some companies, up to 25 percent of their operational costs. While the performance improvements of servers and other IT equipment have produced significant efficiency gains in the last several years, opportunities remain for IT managers to achieve even greater efficiencies as well as reduce costs.

Intel® Intelligent Power Technology is comprised of Intel Data Center Manager (Intel DCM) and Intel Data Node Manager (Intel NM) built into Intel Xeon®-based servers. Together they monitor and cap power in real time at server, rack, zone, and data center levels to manage aggregated power consumption and load migration on available power and cooling resources.

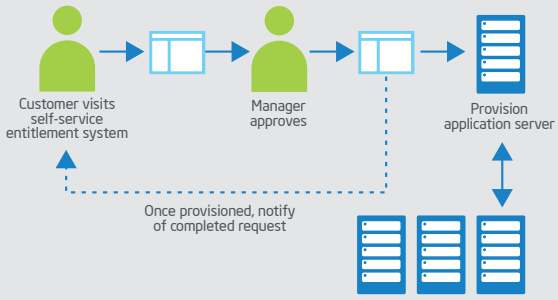
Case Study: Intel IT Offers Private IaaS

Intel IT began offering private on-demand, self-service cloud computing in 2009 to better realize the full business value of the cloud computing environment. The design goal was to enable Intel IT to provide capacity without getting in the way of business user demand by automating the business processes that handle the majority of IT workflow.

While virtualization had already reduced service provisioning from 90 to 14 days, self-service IaaS enables Intel IT to reduce that time to an average of 45 minutes. In addition, self-service capabilities enable Intel IT to implement more advanced services such as workload balancing and automated VM restart in conjunction with networked storage, disaster recovery, security, and quality-of-service monitoring.

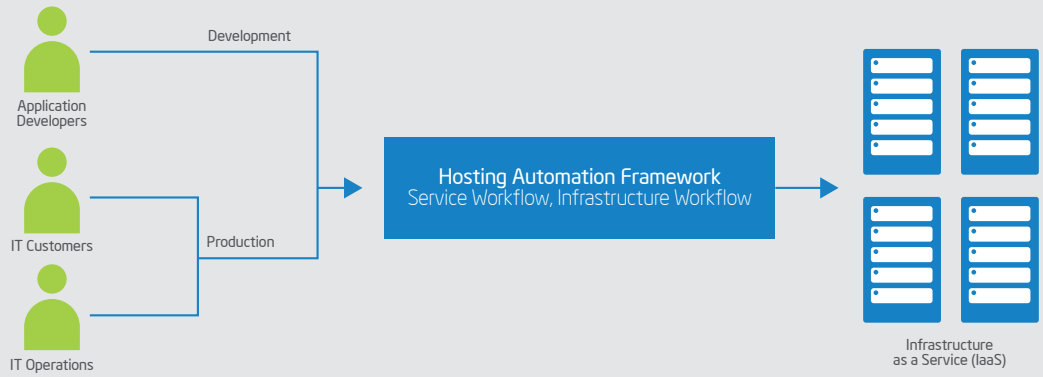
At the core of the self-service functionality is a hosting automation framework comprised of web services for receiving and responding to service requests, a database to track the status and progress of these requests, a scheduler to help ensure requests are being fulfilled, and an orchestration engine with a set of workflows to complete the tasks.

Self-service options are accessed via a consumer-focused portal for users and developers; a second portal is used by IT to manage and monitor measured services. Users can directly request, manage, track, and retire services and capacity to meet their business needs.



The self-service portal and automation capabilities have reduced database provisioning from 16 days, 38 process steps, and 8 human interventions to a 3-hour throughput with 13 steps and one human approval point.

Learn more about Intel's private, self-service IaaS in *Implementing On-Demand Services Inside the Intel IT Private Cloud.*



In this model of Intel IT's self-service framework, users request and consume services through a self-service portal, and IT manages and measures service consumption on a highly utilized resource pool of virtualized assets. The hosted automation framework includes entitlement criteria, quotas, transparent measured services, and data-driven business logic.

Step 5: Implement Cloud Security

As you move beyond virtualizing your data centers to building your private cloud, security must evolve to support both traditional and new vulnerabilities. Cloud environments require a new take on security with challenges around resource isolation, security event management, and data protection, including VM isolation, secure VM migration, virtual network isolation, and security event and access monitoring. Plus, with multiple business groups accessing cloud resources, visibility into secure data flow and compliance with business-specific security policies are critical.

Cloud security must be adaptive to an environment in which workloads are decoupled from the physical hardware and delivered from a fabric of pooled resources. At the same time, security must protect the physical boundaries of the network edge.

As you plan your security approach to your private cloud, you can also lay the groundwork for eventually moving certain workloads into a public cloud. One way to do this is to provide security as a set of on-demand, scalable services. In this approach, policies are tied to logical attributes that create adaptive trust zones to separate multiple tenants.[5] Workloads and the appropriate security policies can then be associated throughout the workload's life cycle. This approach involves virtualizing security controls throughout the environment, isolating applications, and building context awareness into applications that informs security decisions and delivers compound security policies independent of network topology.

About Security in Public Clouds

Security is one of the biggest barriers in cloud adoption. If you build a private cloud with strong security controls in place, you probably expect a public cloud provider to offer those same capabilities—especially if you have a hybrid cloud agenda in mind.

To better equip IT managers worldwide with the knowledge and answers they need to take full advantage of public cloud capabilities, Intel provides Intel® Cloud Finder. Users define required and desired features of their public cloud IaaS by answering a series of questions across several categories, including security, usability, quality, availability, technology, and business.

The tool matches user responses to the services available from a broad range of leading IaaS providers worldwide. Intel Cloud Finder can significantly shorten the time it takes to identify an appropriate public cloud provider.

Learn more at intelcloudfinder.com.

Intel IT and Secure Virtualization Host Architecture

Intel IT implemented secure virtualization by designing a virtualization host and networking architecture that provided private virtual LANs (PVLANs) and separated role-based administration for each host. This provides workload security by using network isolation to control traffic via PVLANs and deploying hosts into secure landing zones that protect applications from attacks originating from the Internet and the Intranet.

Learn more about cloud security in *Best Practices for Building an Enterprise Private Cloud*.

Intel recommends prioritizing five areas for combining physical and virtual controls:

1. Protect data by implementing pervasive encryption, using secure connections, and applying data loss prevention policies.
2. Establish and verify identities to control access from client devices and systems that you can trust, and manage API control points at the edge of the network.
3. Secure your data center platform, infrastructure, and client devices by establishing trusted compute pools.
4. Build higher assurance into compliance to streamline auditing and increase visibility into your cloud environment.
5. Enable secure migration from a private cloud environment to public cloud providers.

About Intel Cloud Security Technologies

Together, Intel and McAfee offer several data and infrastructure security technologies for cloud environments:

- Intel® Trusted Execution Technology[6] (Intel TXT), together with McAfee* Data Center Security Suites, helps detect server systems booting with unknown BIOS, firmware, and hypervisors and provides hardware-based verification for use in meeting compliance requirements.
- Intel Data Protection Technology with AES-NI[7] and Secure Key enables faster and stronger encryption and decryption of the McAfee Endpoint Encryption product.
- With Intel Expressway API Manager (Intel EAM), Intel packages a leading software as a service (SaaS) API sharing portal from Mashery with Intel's on-premises service gateway for API management. Intel EAM integrates and surfaces legacy data as APIs and then shares them with developers via the API sharing portal for enterprise and mobile development. At runtime, developers can apply mobile-friendly security, create real-time app mash-ups, and broker how apps are exposed across hybrid on-premises environments to cloud environments. The Intel Expressway product family is a core part of the Intel and McAfee cloud data center and comes integrated with several McAfee technologies, including McAfee ePolicy Orchestrator* (McAfee ePO*) for monitoring security events.

Leading Cloud Management Platforms

The CMP market is still evolving, and vendors offer solutions with varied feature sets. The following describes five CMP solutions, two commercial and three open-source offerings. The open-source solutions—Apache* CloudStack*, Eucalyptus* cloud computing software, and the OpenStack* platform—typically provide a low-cost point of entry for the software and the prospect of application portability, but require a significant amount of in-house development. Commercial vendors—Microsoft and VMware—offer commercial off-the-shelf capabilities, and are typically higher cost than open-source offerings.

Choosing the appropriate CMP for your cloud environment depends on your current virtualization environment, the scope of your cloud strategy, your business requirements, the availability of skilled resources, and your budget.

Apache* CloudStack*

Apache CloudStack software is a top-level project of the Apache Software Foundation and calls itself a turnkey solution. CloudStack software provides an open and flexible cloud orchestration platform for private and public clouds. It offers self-service IaaS capabilities and features:

- Compute orchestration
- Network as a service; user and account management
- Native API and Amazon* Web Services (AWS) API translator so that apps written for CloudStack can run in AWS
- Resource accounting of network, compute, and storage resources
- Multitenancy and account separation
- "First-class" user interface

CloudStack software is based on the Java* language and includes a management server and agents for hypervisor hosts. It currently supports hosts with the most prevalent hypervisors: VMware* ESXi with vSphere* technology, KVM software, XenServer* software, and the Xen* Cloud Platform (XCP).

CloudStack began as a project at the startup company Cloud.com and was bought by Citrix in 2011. The software became part of the Apache Software Foundation's open-source projects in April 2012. CloudStack boasts $1 billion worth of business transactions annually running across its clouds since Citrix first released the code.[8]

Eucalyptus Systems

Eucalyptus is an open-source provider of cloud management software with strong technical ties to Amazon Web Services. One of the advantages to deploying the Eucalyptus Cloud platform is the ability for a company to move seamlessly from a private cloud to a hybrid model by bursting into the Amazon public cloud as needed.

Eucalyptus software supports industry-standard AWS APIs, including Amazon Elastic Compute Cloud (Amazon EC2), Amazon Simple Storage Service (Amazon S3), Amazon Elastic Block Store (Amazon EBS), and Amazon Identity and Access Management (Amazon IAM). It supports three hypervisors: VMware ESXi with vSphere technology, KVM software, and the Xen Cloud Platform (XCP).

The Eucalyptus Cloud platform provides these additional capabilities and features:

- Self-service user console
- Dashboard for cloud management tasks
- Mixed hypervisor environments
- Storage area network (SAN) integration to take advantage of storage arrays
- Identity management with fine-grained role-based access control
- Accounting, chargeback, and quota management
- Usage reporting and pattern analysis
- Automated installation with guided configuration of cloud components

Microsoft* Hyper-V* Software and Microsoft System Center

Microsoft's vision for cloud is referred to as Microsoft* Cloud OS, a set of technologies, tools, and processes built on the Windows Server* operating system with Hyper-V* software, the Microsoft System Center, and the Windows Azure* platform. Together, these technologies provide a consistent platform for infrastructure, applications, and data.

Microsoft commands a great deal of credibility as a strategic enterprise vendor and offers a robust set of technologies with well-known, extensive capabilities. The Windows Server 2012 operating system was designed to run virtualization environments with the cloud in mind. Other Microsoft products can be added to your cloud mix, such as Microsoft SQL Server* and Microsoft Visual Studio*.

Microsoft cloud technologies also provide:

- Virtualization of servers, network, storage, and applications
- Automated self-service web portals and a provisioning engine
- Extensibility with third-party partner solutions
- Unified management view that can extend across private, hosted, and public clouds
- Single identity for secure user and device management
- A complete data platform that can handle petabytes of data with Microsoft SQL Server

OpenStack* Cloud Software

OpenStack, the third of the three open-source platforms in this guide, was cofounded by Rackspace and NASA in 2010 and is currently available under the Apache 2.0 license. Growth in the use of the OpenStack platform has been rapid, with dozens of companies, many of them well known, such as AT&T, HP, and IBM, signing on to use OpenStack as the base for their private cloud offerings. This gives IT departments two options for deploying OpenStack for private cloud—either as a free software download with in-house deployment or from a vendor.

The OpenStack platform has a modular design that enables integration with legacy and third-party technologies. It supports the Xen and KVM hypervisors. OpenStack also offers:

- Massively scalable redundant storage (OpenStack Swift* for object-based storage and OpenStack Cinder for block storage) for high availability
- Strong, token-based security and compute security groups for automated segmentation among tenants and VM roles within a single tenant
- Shared services for identity management, image management, and a web interface
- Native API and Amazon EC2–compatibility API
- A dashboard for administrators that provides an overview of the size and state of the cloud environment and user management for IT and provides self-provisioning for users
- Compatibility with software-defined networking (SDN) such as OpenFlow* technology
- Six-month release schedule for continuous code improvement

About Intel and the OpenStack* Platform

Intel IT uses OpenStack* as a platform for its private cloud to improve service delivery with increased interoperability. OpenStack provides an open-source-based, interoperable cloud platform that delivers consumable services across multiple users and devices and automates management across cloud components, such as compute, network, and storage. This enables rapid, on-demand provision of compute resources for Intel employees who must deliver projects in today's volatile marketplace.

The OpenStack-based Intel private cloud uses Swift* storage, Nova* compute, and the OpenStack dashboard. Intel IT's goal is to establish a federated, interoperable, and open cloud as the standard for providing services.

VMware* vCloud Director*

The VMware vCloud* Suite is a comprehensive, integrated cloud platform that includes all the elements to build cloud environments and operationalize VMware vSphere* virtualized environments. VMware vCenter* Server manages the compute, storage, and networking resources, and VMware vCloud Director* ties all the pieces of the cloud together so you can deploy a secure, multitenant cloud using the resources from VMware vSphere environments. VMware supports the VMware ESXi hypervisor.

VMware cloud technologies also offer:

- Rapid policy-controlled, self-service provisioning of virtual machines and applications
- Ability to enable trust-zone policies to protect and control traffic to IT-governed groups of virtual machines
- Comprehensive data center monitoring and management capabilities
- Compatibility with SDN
- Disaster protection and operational and regulatory compliance
- Self-service portal access
- High-performance service levels for disaster recovery, security, and compliance

Next Steps: A Checklist

By moving from virtualization to a private cloud with self-service and other attributes in place, you have taken the first major step toward brokering cloud services throughout your organization. As you become more familiar with the technology, new challenges will arise—opportunities, really. For example, you may cloud-enable an application with unpredictable demand or notice spikes or sudden drops in demand. These are opportunities that can prompt you to expand your service offerings, cloud-enable more legacy applications, or take the next step to a hybrid cloud model.

Here's a quick checklist summarizing how you can move from virtualization to a private cloud services model. When you're ready to go further, read Intel's upcoming Planning Guide Part 2: Move to Hybrid Cloud Computing. Look for it at intel.com/cloud.

Develop a Cloud Strategy

- ☐ Describe the anticipated business benefits and return on your investment.
- ☐ Set short-, mid-, and long-term goals.
- ☐ Identify the workloads and user groups you want to move with each project phase.
- ☐ Describe your cloud solution architecture and its components.
- ☐ Identify the client devices you will support.
- ☐ Describe how you will monitor and manage your cloud and define success.

Get the Business on Board and Create Strong Partnerships

- ☐ Communicate benefits and milestones to users.
- ☐ Develop a plan to manage expectations for each project phase.
- ☐ Engage business users to define and document new and existing business processes.

Organize IT around Service Delivery

- ☐ Determine how teams will work together.
- ☐ Hire or train for cloud-related skills.

Put the Right Technology in Place to Align with Your Strategy and Roadmap

- ☐ Implement pervasive virtualization.
- ☐ Select your cloud management platform.
- ☐ Implement cloud security.

Manage a Data-Driven Cloud

- ☐ Determine how you will monitor health and status.
- ☐ Determine how you will manage compliance.
- ☐ Determine what actions should be automated, and the associated triggers.

Resources to Learn More

To learn more about cloud computing, visit these web sites:

- Cloud computing: intel.com/cloud
- Cloud security: intel.com/cloudsecurity
- Intel Cloud Builders: intelcloudbuilders.com
- Intel Cloud Finder: intelcloudfinder.com
- Intel IT Center: intel.com/ITCenter
- Open Data Center Alliance (ODCA): opendatacenteralliance.org/

About Cloud Computing

The NIST Definition of Cloud Computing

Developed to support U.S. government agency IT operations, this document from the U.S. National Institute of Standards and Technology describes standards and guidelines on cloud computing, including minimum requirements for security.

csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

Open Data Center Alliance: The Private Cloud Strategy at BMW*

This document describes how BMW's current cloud strategy focuses on the delivery of infrastructure services using industry-standard technology free of technical and vendor dependencies. This is the first part of a two-phase implementation strategy that starts with implementation of a private cloud. Phase 2 extends BMW's private cloud into a hybrid cloud.

opendatacenteralliance.org/docs/bmw_path_to_cloud_with_alliances_white_paper.pdf

Planning Guide: Cloud Security: Seven Steps for Building Security in the Cloud from the Ground Up

Practical information to help IT managers integrate security planning into cloud computing initiatives—from data center to endpoint devices.

intel.com/content/www/us/en/cloud-computing/cloud-security-checklist-planning-guide.html

Real-World Guide: Intel Security Technology for the Cloud

This guide provides an introduction to how Intel security technologies work together at key enforcement points throughout the cloud. It describes usage cases for how IT managers can protect data and infrastructure as well as meet compliance demands.

intel.com/content/www/us/en/cloud-computing/cloud-security-technology-real-world-guide.html

About Intel IT Virtualization and Cloud

Accelerating Deployment of Cloud Services Using Open Source Software

Intel IT shares how it used OpenStack open-source software in combination with Intel's own internal code and existing enterprise software to deploy a cloud infrastructure that serves as the foundation to transform data center solutions into quickly obtainable, consumable services and paves the way for hybrid cloud delivery.

intel.com/content/www/us/en/it-management/intel-it-best-practices/accelerating-deployment-of-open-source-cloud.html

Applying Factory Principles to Accelerate Enterprise Virtualization

Intel IT set a goal of virtualizing up to 75 percent of the company's Office and Enterprise computing environment to create the infrastructure for a broadly adopted enterprise private cloud.

intel.com/content/www/us/en/virtualization/virtualization-intel-it-applying-factory-principles-paper.html

Best Practices for Building an Enterprise Private Cloud

Intel IT shares best practices in several areas related to the design of the company's private cloud. The paper describes progress on and benefits from the company's enterprise private cloud, including cost savings of USD 9 million between 2009 and 2011, 80-percent-effective utilization of IT assets, and zero business impact from IT infrastructure failures.

intel.com/content/www/us/en/it-management/intel-it-best-practices/enterprise-private-cloud-paper.html

An Enterprise Private Cloud Architecture and Implementation Roadmap

Intel IT shares the company's architecture and implementation roadmap for building an enterprise private cloud. Critical business benefits include reduced provisioning times, higher resource utilization, high availability, and improved capacity management.

intel.com/content/www/us/en/cloud-computing/enterprise-cloud-computing/intel-it-enterprise-cloud-architecture-roadmap-paper.html

Implementing On-Demand Services Inside the Intel IT Private Cloud

This paper describes how Intel IT has moved from a traditional, static enterprise computing environment to a service-oriented environment as part of a core business strategy to build an enterprise private cloud. Providing an on-demand self-service delivery model provides improved infrastructure efficiency along with IT service-level agility, availability, and security.

intel.com/content/dam/doc/white-paper/intel-it-private-cloud-on-demand-services-paper.pdf

"Technical Limiters for Pervasive Virtualization" (blog)

This blog post describes Intel's approach to driving pervasive virtualization, including why Intel IT chose this path and how it fits into the company's overall cloud strategy.

communities.intel.com/community/itpeernetwork/blog/2010/10/07/technical-limiters-for-pervasive-virtualization

Endnotes

1. For more information about PaaS, read the white paper *Platform as a Service*. Intel (September 2013). intel.com/content/www/us/en/cloud-computing/cloud-computing-paas-cloud-demand-paper.html

2. *The NIST Definition of Cloud Computing*. U.S. Department of Commerce, National Institute of Standards and Technology Special Publication 800-145 (September 2011). http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

3. For more information about PaaS, read the white paper *Platform as a Service*. Intel (September 2013). intel.com/content/www/us/en/cloud-computing/cloud-computing-paas-cloud-demand-paper.html

4. "Will Private Cloud Adoption Increase by 2015? Gartner Research Note G00250893 (12 May 2013).

5. From Secure Virtualizaton to Secure Private Clouds. Gartner Research Note G00208057 (October 13, 2010).

6. No computer system can provide absolute security under all conditions. Intel Trusted Execution Technology (Intel TXT) requires a computer system with Intel Virtualization Technology, an Intel TXT–enabled processor and BIOS, a chipset, Authenticated Code Modules, and an Intel TXT–compatible measured launched environment (MLE). Intel TXT also requires the system to contain a TPM v1.s. For more information, visit intel.com/technology/security.

7. Intel AES-NI requires a computer system with an AES-NI–enabled processor, as well as non-Intel software to execute the instructions in the correct sequence. AES-NI is available on select Intel processors. For availability, consult your reseller or system manufacturer. For more information, see http://software.intel.com/en-us/articles/intel-advanced-encryption-standard-instructions-aes-ni/.

8. Burns, Christine. "Stack Wars: OpenStack v. CloudStack v. Eucalyptus." *Network World*. (June 3, 2013). networkworld.com/supp/2013/enterprise3/060313-ecs3-open-stack-269899.html?sourceWWNLE_nlt_cloud_security_2013-06-04

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