Intel® Cloud Builders Guide
Intel® Xeon® Processor-based Servers
Joyent Smart Computing

Intel® Cloud Builders Guide: Cloud Design and Deployment on Intel® Platforms

Joyent SmartDataCenter*

Intel® Xeon® Processor 5600 Series

AUDIENCE AND PURPOSE

The cloud computing market is growing rapidly as companies of all sizes see real benefits in deploying new or legacy applications on cloud computing services and migrating their entire data centers to computing and storage clouds. If properly architected, these new cloud infrastructure, platform, and software services can help significantly reduce the time to market for new products, and the capital and operating expenses for IT resources.

The Intel® Cloud Builders program provides reference architectures in the form of basic hardware blueprints with Intel® Xeon® processor-based servers running cloud computing software such as Joyent's Smart Computing cloud infrastructure. This paper describes a basic hardware architecture reference point from which to build a cloud solution using Joyent's SmartDataCenter,* SmartPlatform,* SmartMachines,* and SmartOS.* The use cases in this paper can reduce the learning curve for provisioning, administering, operating, and maintaining your first cloud and should be used as a baseline to build more complex, scalable, and resilient cloud computing architectures adapted to your specific needs.

The audience for this Intel Cloud Builders Guide includes enterprise IT organizations, service providers, and systems integrators looking to transform the cost structures and agility of IT organizations and accelerate the revenue potential of providing public, private, or hybrid cloud computing solutions.

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Executive Summary

In an increasingly connected global environment marked by rapid change, the acceleration of real-time communications and the deluge of sensor- or user-generated content are forcing organizations to abandon traditional IT paradigms and to adopt a range of cloud computing services. Highly available and secure clouds help speed the delivery of innovative products and optimize financial performance in entities of all sizes, from individuals and entrepreneurial startups, to multinational enterprises, public sector institutions, and governments.

These cloud computing services are characterized by on-demand self-service for provisioning computing resources, rapid elasticity to scale out or scale in, measured service for optimal resource use, resource pooling for dynamically serving multiple tenants, and network access via standard protocols. Implementing real-world cloud computing solutions can be fraught with many challenges and trade-offs. Companies and IT architects have to make decisions concerning capability, performance, capacity, deployment models (private, public, hybrid, or community clouds), and service models (Software-, Platform- or Infrastructure-as-a-Service).

Joyent and Intel worked together to build a simple private cloud computing testbed using Intel® Xeon® processor 5600 series-based servers and Joyent's SmartDataCenter and SmartOS software. The hardware selected for this Intel Cloud Builders reference architecture consists of three Intel® Xeon® processor X5667-based servers. These servers ran Joyent SmartOS on bare metal for high-performance operating-system-level virtualization zones and dynamic trace performance introspection capabilities. An additional server was configured to run Joyent SmartDataCenter software for cloud control and automation. One of the most common bottlenecks in modern data centers is network throughput. This testbed uses an Arista 7124S* 10GB Ethernet [1] switch to help meet the growing bandwidth needs of a dense cloud computing environment while also providing redundant power, cooling, and a flexible rack-top server deployment configuration.

Using the administration portal, cloud-service providers can create accounts that allow customers to provision SmartMachines based on pre-configured templates. These services can be scaled horizontally and vertically to meet higher demand. Providers can improve uptime and design for graceful failover by utilizing Zeus Load Balancer* software [2] that allows service continuity when physical servers fail. The administration portal also allows IT to shut down and delete SmartMachines as demand for services tapers.

This guide presents the reference architecture and explores several provisioning and administration use cases to demonstrate the ease of use, scalable computing, and fault tolerance characteristics of the Joyent cloud computing infrastructure service.

Introduction

This testbed incorporates Joyent's SmartDataCenter and SmartOS software components, ideal for deploying and administering a cloud infrastructure:

- Scalable platform with dynamic allocation of CPU and memory cache that accommodates real-world traffic bursts with no intervention
- Highly secure and responsive SmartOS, a UNIX* variant
- Adaptable design that allows components to integrate with multiple systems and applications, such as Oracle, MySQL, load balancers, legacy operating systems, or other third-party virtualization software, such as Xen*

Joyent SmartDataCenter and SmartOS cloud computing infrastructure software allows for flexible deployment of public, private, or hybrid clouds in globally distributed data centers.

Joyent Smart Computing Overview

Rather than evolving from a generic virtual machine environment, Joyent engineered Smart Computing technologies from the ground up to provide greater flexibility, resilience, and performance for cloud customers and their applications. This application-centric focus helps customers realize greater value with cloud-based computing. The Joyent Smart Computing solution is purpose-built to eliminate complexity and simplify making dynamic adjustments in a cloud environment. The Joyent software technology stack consists of three layers shown in Figure 1: SmartPlatform, SmartMachines, and SmartDataCenter.

Joyent SmartPlatform

The SmartPlatform is an open-source, server-side JavaScript platform, providing developers with the simplicity and freedom of Platform-as-a-Service, without sacrificing performance. SmartPlatform eliminates all the details of managing virtual hardware, with built-in scalability. This version of the Intel Cloud Builders reference architecture does not include use cases for the Joyent SmartPlatform.

Joyent SmartMachines

The SmartMachine's lightweight virtualization lets developers enable horizontal scaling by simply managing the application logic. This is simpler than traditional hardware or virtual machine-based architectures, where the developer must also create and manage multiple abstractions of physical servers with operating systems and other software. Pooled hardware also allows for easy and dynamic vertical scaling. Developers can concentrate on application production rather than abstraction layers, operating system management, or virtual machine resources.

Built on the Joyent SmartOS, the SmartMachine incorporates:

- **Resource bursting:** SmartMachines use the Joyent SmartOS to tap the expanded pool of CPU, RAM, and network bandwidth, providing needed capacity during usage spikes. Joyent SmartOS also supports more CPU cores and a larger memory footprint than other virtualization operating systems, so the resource pools will expand as underlying hardware is improved.
- **Flexible configuration:** SmartMachines come preloaded with a variety of popular software environments, including a generic UNIX installation (SmartOS), development platforms (PHP, Java, Ruby on Rails), databases (MySQL, Oracle), load balancers (Zeus), and more. Customers can require variable hardware configurations, and the Joyent SmartOS can run Xen virtual machines to accommodate any legacy operating system in addition to its native SmartMachine.

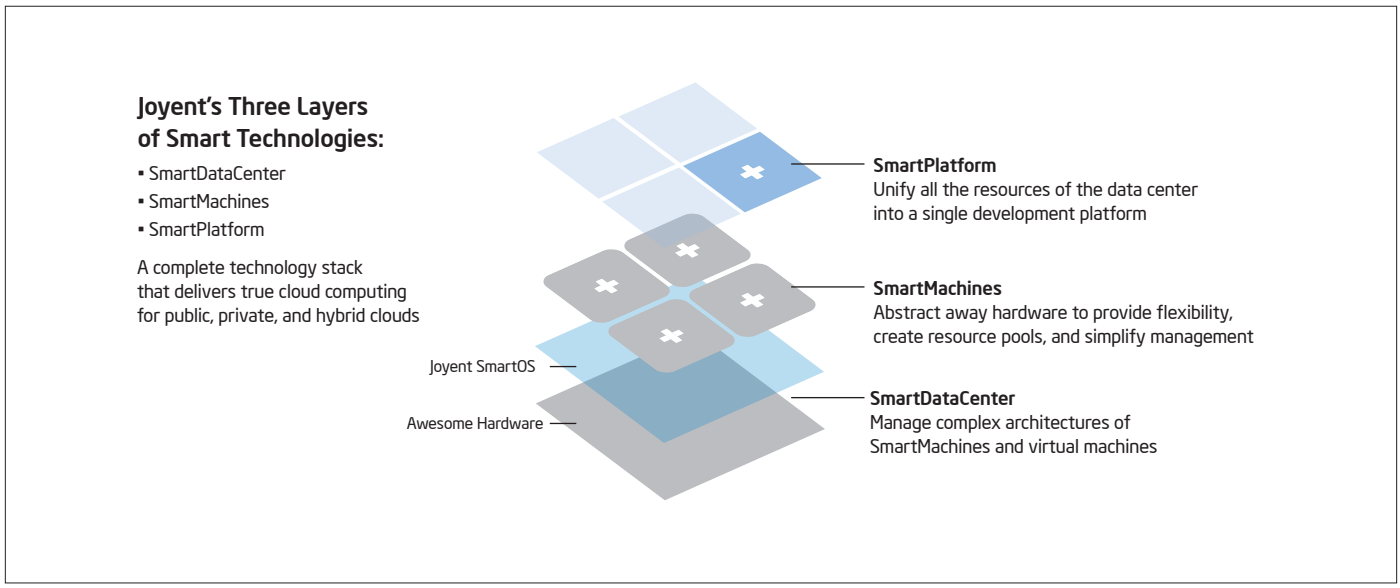

Figure 1. Layers of Joyent Smart Technologies.

- **Enhanced application performance:** Joyent SmartOS provides a system-wide ARC cache for high-frequency disk I/O that significantly improves read and write performance for applications. Within a resource pool, any memory and CPU not used for application business logic is dedicated to improving performance. Re-directing idle resources to boost application performance is unique to Joyent Smart Technologies.
- **Integrated security:** The SmartOS also adds additional security and stability to the SmartMachine application environment. Per-machine administration is performed as a root user, with no ability to manipulate the operating system kernel. SmartOS isolates memory, network, and processor isolation and blocks network reconfiguration and traffic sniffing to keep even public cloud applications completely segregated.
- **Cloud Management and Administration Portal:** To facilitate cloud management, Joyent SmartDataCenter provides administrative and user control with a combination of scripts and a web-based administration portal.

Joyent SmartDataCenter

The Joyent SmartDataCenter provides the following features:

- Reporting, including capacity, utilization, and health monitoring
- User access control and account administration
- Resource management controls for compute, storage, network, and vLAN and SmartMachine security
- Delivery of virtual appliances
- Automation for deploying and reclaiming resources in the cloud
- A RESTful API for integration with third-party services

Additionally, the SmartDataCenter administration portal helps manage the provisioning, operation and administration of all network elements, including servers, switches, SmartMachines and other hardware and software components, the associations of these components, and customer provisioning and billing data (see Figure 2).

The consumer portal enables customers to perform self-service tasks, including the ability to:

- Rapidly create SmartMachines up to assigned quotas (see Figure 3)
- Reboot, halt, or decommission SmartMachines
- Add capacity up to assigned quotas
- Access invoices and charges
- Deploy resources during times of increased traffic

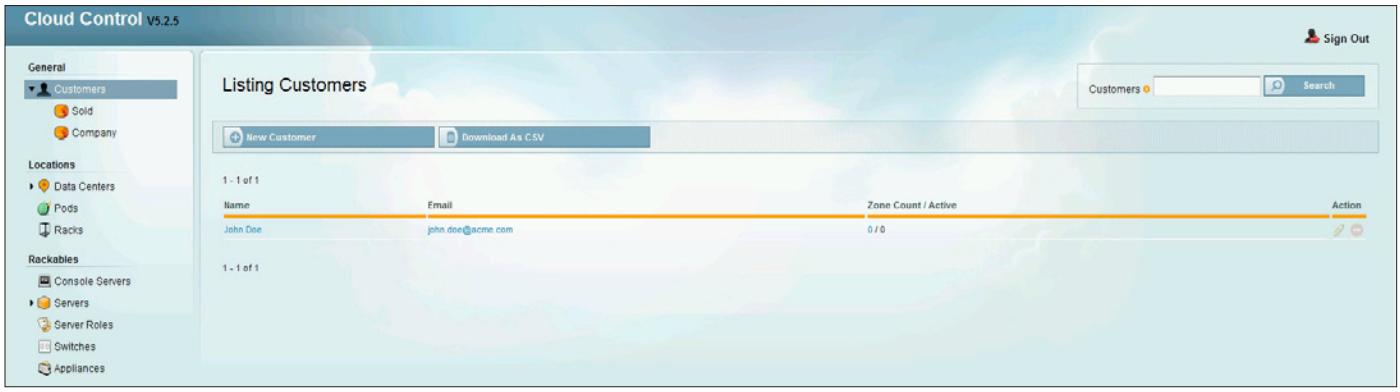

Figure 2. Joyent SmartDataCenter* Administration Portal Screen.

Implementation Overview

This testbed was implemented using homogenous hardware and software components across the cloud infrastructure, including identical network infrastructures to reduce management and performance complexities. This consistency makes overall cloud maintenance and scalability more reliable—especially important as application workloads increase. The testbed components were deployed in a redundant configuration, providing resilience in case of failure of any infrastructure components.

Testbed Blueprint Overview

Hardware Description

This testbed uses Intel Xeon processor 5600 series-based servers. Built on Intel's new 32nm Nehalem microarchitecture, the Intel Xeon processor 5600 series brings new levels of performance to the cloud with:

- **Intelligent performance** that automatically varies the processor frequency to meet business and application performance requirements.
- **Automated energy efficiency** that scales energy usage to the workload to achieve optimal performance/watt and reduce operating costs.
- **Intel® Virtualization Technology (Intel VT)◊ and Intel® VT FlexMigration** offer best-in-class performance and manageability in virtualized environments to strengthen the infrastructure and reduce costs [3].

The hardware includes:

- Three Intel Xeon processor X5667-based systems running Joyent SmartOS 5.2.2
- A 1 GB management network using a Cisco Layer 2 switch and Intel® Intelligent Power Node Manager software
- A 10 GB data network using an Arista 7124S* 24-port switch
- Local disk storage on all compute nodes including Intel® Solid-State Drives (Intel® SSDs) with persistent ZFS zones, which offer copy-on-write, transactional data integrity, and high performance

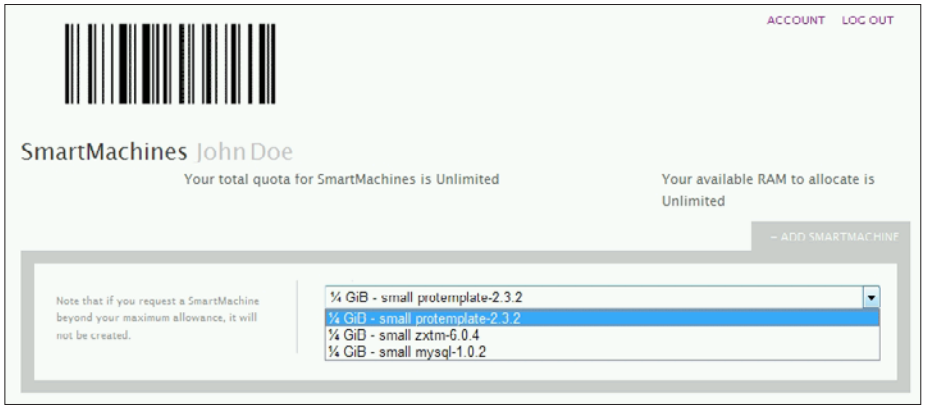

Figure 3. Consumer Portal for Creating and Configuring SmartMachines.*

Network Configuration

Figure 4 shows the basic architecture of the testbed network connections. Each compute node has three network interfaces. The administrative connection provides cloud control, portal, and provisioning functions for the solution. The private network connection provides connectivity between the infrastructure servers and the nodes, and the public connection provides access to IP-addressable customer applications, data, etc.

This logical network configuration relies heavily on vLAN technologies to separate the different networks. There are three networks configured by default for all configurations:

External vLANs are typically addressed with Internet-routable addresses and are used to connect to devices that are external to the cloud infrastructure, including load balancers and web servers. There can be one or many of these networks depending on the need to segregate traffic among groups of SmartMachines.

Internal vLANs are typically addressed with private addresses and are used for communications between SmartMachines. SmartMachines which perform front-end and back-end functions should be configured to communicate via these vLANs. There can be one or many of these networks depending on the need to segregate traffic among groups of SmartMachines.

The Administrative vLAN is used for management purposes, such as SmartDataCenter provisioning, operating and troubleshooting functions, console-level access, broadcast/multicast control, system logs and backups. SmartMachines do not have access to this network; there is only one vLAN set up for this function, and it spans the entire rack. Figure 5 is a diagram of the physical architecture used in the testbed.

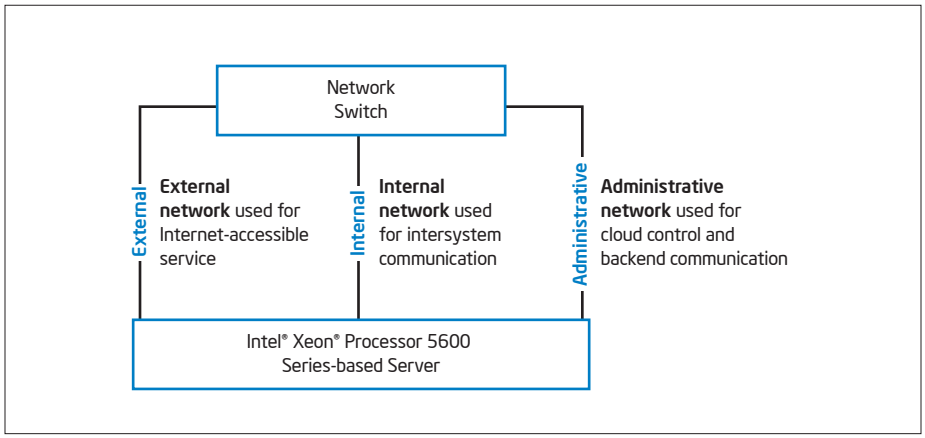

Figure 4. Network Topology of Compute Nodes in the Testbed.

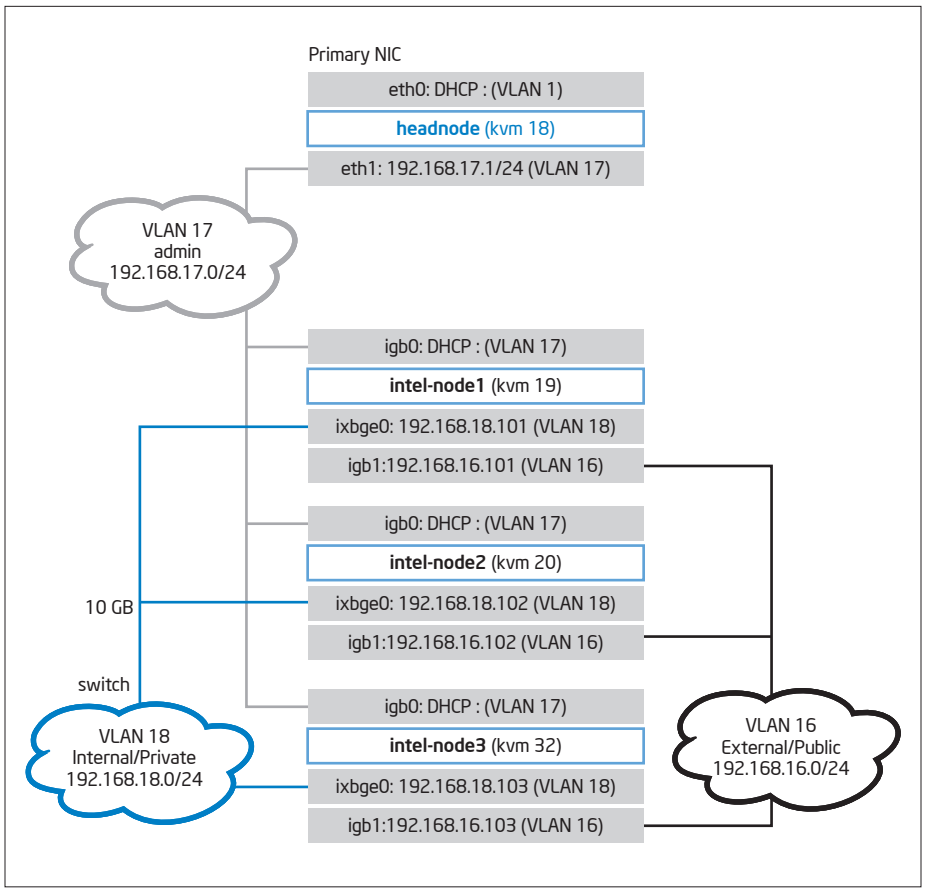

Figure 5. Diagram of the Joyent SmartDataCenter* Testbed Hardware.

Use Case – Execution Methodology

The following outlines the steps used to deploy the cloud platform for the use case:

1. Create a service provider administrator on the platform once the appropriate vLAN connections were established.
2. Next, using SmartDataCenter and Administration Portal interfaces, configure two cloud-service consumers.
3. Create multiple Joyent SmartMachines through each service's consumer-management interface, including persistent IP addresses and links to storage.
4. Test each service consumer for the following:
   - Dynamically add new bare-metal server capacity without disruption
   - Terminate and remove SmartMachine-based applications from the virtual machines and load balancers
   - Monitor service from each consumer
   - Verify utilization reporting by consumers and service provider
   - Maintain operations using failover during server failure
   - Monitor the installation of benchmark applications for MySQL, Ruby, and other applications and services

The following sections describe the step-by-step implementations and results of these tests.

Use Case – Context

This reference architecture includes six typical use cases for a hypothetical company with a cloud administrator, Tim, and John Doe, a cloud customer.

The company is configuring a private cloud based on a cluster of Intel Xeon processor 5600 series-based servers and the Joyent SmartDataCenter and SmartOS. This cloud is to be used for internal IT deployments. John represents a group within the company who will deploy end-user workloads in the cloud. Note that users of these workloads (the end users) are not aware that their services exist in the cloud.

Use Case – Overview

1. Tim adds a new customer (John Doe) to the Joyent SmartDataCenter infrastructure and gives him permissions to provision new services using SmartMachines.
2. John provisions and deploys a new SmartMachine using the Joyent administration portal.
3. Tim monitors the newly provisioned SmartMachine.
4. John scales up his service vertically by adding system resources to his existing SmartMachine.
5. When there's heavy customer demand, John horizontally scales out his service.
6. John terminates a SmartMachine.

Use Case 1: Adding a Customer to the Cloud

Tim adds a new customer to the Joyent SmartDataCenter infrastructure and gives him permissions to provision new services using SmartMachines.

1. The administration portal makes it easy to configure private clouds. Once the private cloud is set up, the cloud administrator can add new customers. Here, the administrator adds a new customer named John Doe by using the **New Customer** option in the Joyent DataSmartCenter Cloud Control Administration portal (see Figure 6).
2. The new customer (John Doe) appears in the **Listing Customers** screen. John has not been assigned any SmartMachines yet.

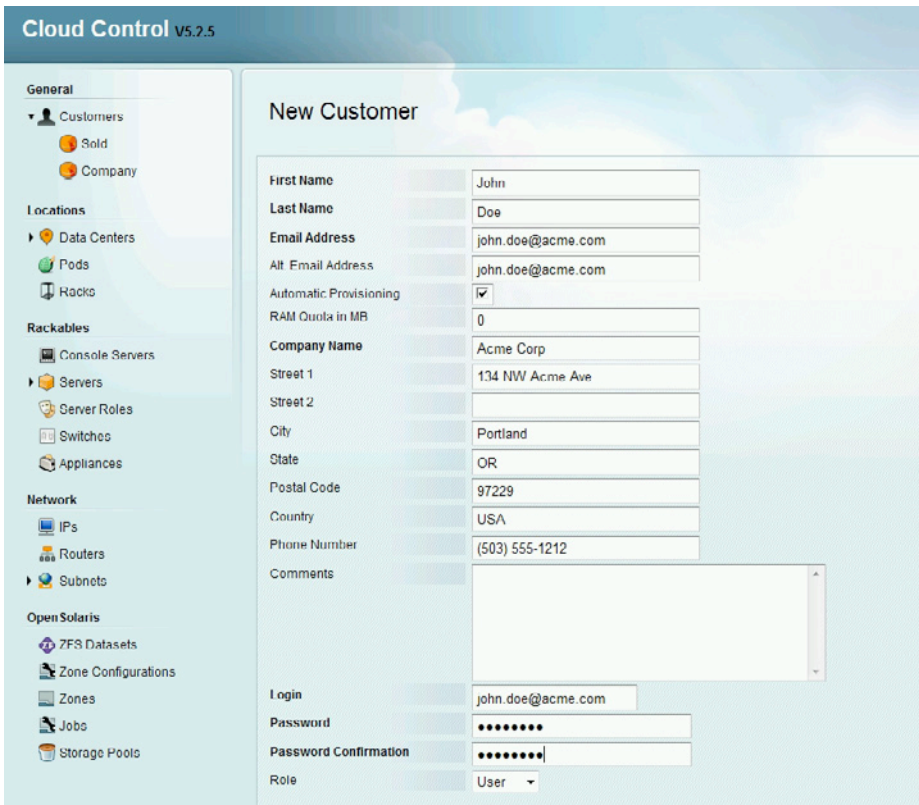

Figure 6. Tim adds a new customer (John Doe).

Use Case 2: Customer Provisioning of a SmartMachine

1. Using the ID and password assigned to him when his account was created, John Doe logs into his consumer portal. Once logged in, he can view his account page, where he uses the **Add SmartMachine** option to provision a new zone.
2. John can choose from three default SmartMachine templates for his new zone. In this case, he chooses the **small_protemplate-2.3.2** template, which is a basic zone template (see Figure 3 on page 6).
3. Once John has added the SmartMachine, the administration portal begins the provisioning process. John is taken to a provisioning page that auto-updates to show the current status of the newly provisioned SmartMachine.

Use Case 3: Monitoring Newly Provisioned SmartMachines

1. At this point, the cloud administrator can get a detailed status of the provisioned SmartMachine that John submitted. Figure 7 shows that John's SmartMachine (marked in red) has a successful running status.
2. The cloud administrator can also view the detailed configuration of John's SmartMachine, including the two IP addresses assigned by Joyent SmartDataCenter—a public IP address, and an internal, private IP address.

Figure 7. Tim views the status of the SmartMachine* that John provisioned.

Use Case 4: Vertically Scaling a Service

1. Using Joyent SmartDataCenter, John can vertically scale his newly created service by adding more CPU resources and memory. This allows his service to support more end users while maintaining his service levels. To do this, Tim, the cloud administrator, needs to edit John's specific SmartMachine zone and modify the existing CPU cap, which in turn directs the Joyent SmartOS running on the compute node to reserve more CPU cores for the service (see Figure 8).
2. Tim now changes the SmartMachine Zone Configuration to one with a higher amount of memory (the smart 1 GB template in this case).
3. Using his account page, John verifies that his SmartMachine now has more CPU resources and memory.

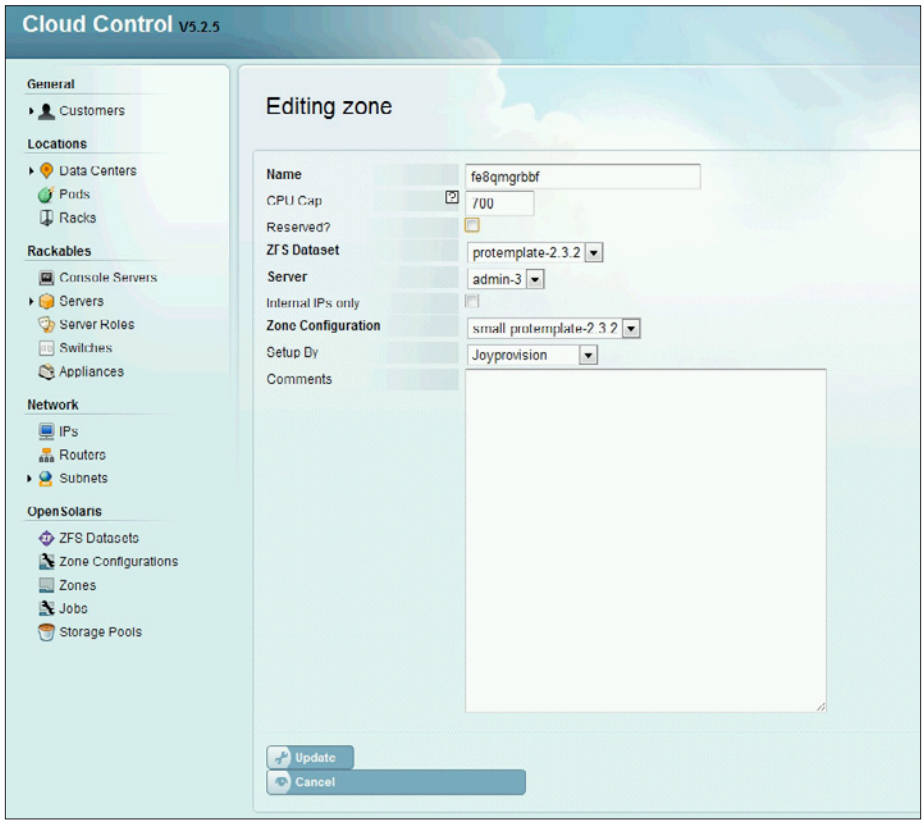

Figure 8. Editing the zone through Joyent SmartDataCenter.*

Use Case 5: Horizontally Scaling a Service

Using Joyent SmartDataCenter, John can horizontally scale his newly created service by adding new SmartMachines and configuring them to run behind a Zeus Load Balancer. This will ensure requests are spread across both SmartMachines, effectively doubling the overall request rate.

1. John adds a second SmartMachine following the steps in Use Case 2 (see Figure 9).
2. John adds a third SmartMachine using the **1 GB – zxtm** large template. This is a Zeus Load Balancer template that comes pre-packaged with Joyent SmartDataCenter.
3. At this point, John has three SmartMachines—two application servers and a load balancer (see Figure 9).
4. John then logs on to the Zeus Extensible Traffic Manager* (ZXTM) configuration portal on his SmartMachine and adds a virtual server that will act as his application's web front-end (see Figure 10). This virtual server load balances incoming traffic across both his SmartMachines. The ZXTM configuration portal IP address and log-in information are available in the details section of the SmartMachine that corresponds to the ZXTM.
5. John then starts his new virtual service using the ZXTM administration portal (see Figure 11). The IP address shown in Figure 10 (192.168.16.26:80) now acts as a virtual IP address that resolves to one of the two SmartMachines that are configured behind it.

Figure 9. The three SmartMachines* that make up John's service.

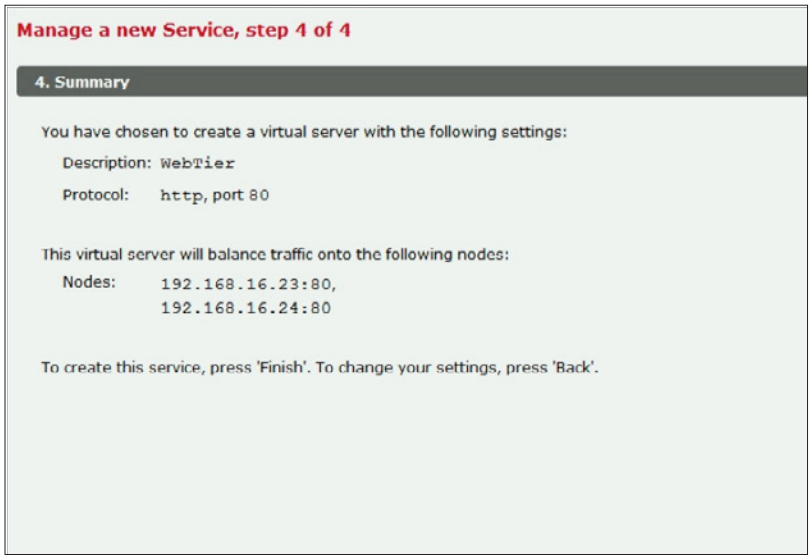

Figure 10. John configures a new virtual server that provides load balancing across his two SmartMachines.*

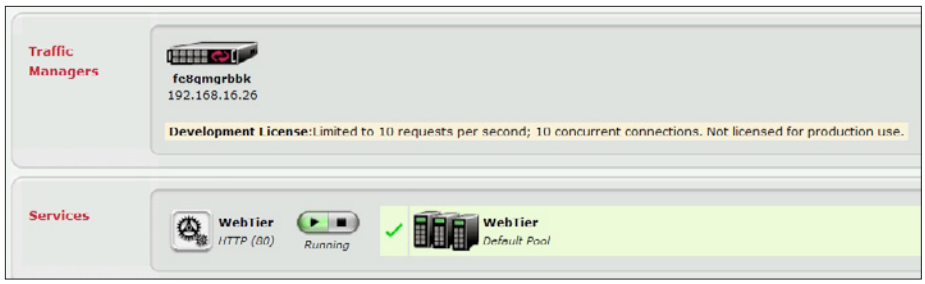

Figure 11. John starts his virtual service using the ZXTM* administration portal.

Use Case 6: Shutting Down a SmartMachine

1. John uses his account page to shut down one of his SmartMachines (see Figure 12).
2. The SmartMachine status changes to "installed" once it has been cleanly shut down (see Figure 13). Since this SmartMachine was one of the two being serviced by Zeus Load Balancer, shutting it down also seamlessly scales down the service, one of the most attractive features of a private cloud.

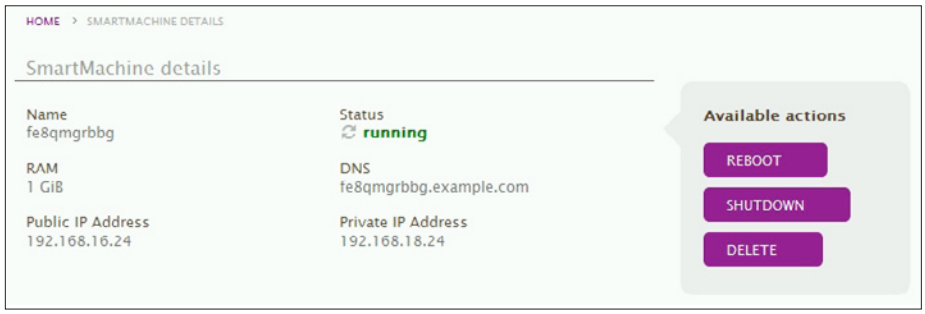

Figure 12. John shuts down a SmartMachine.*

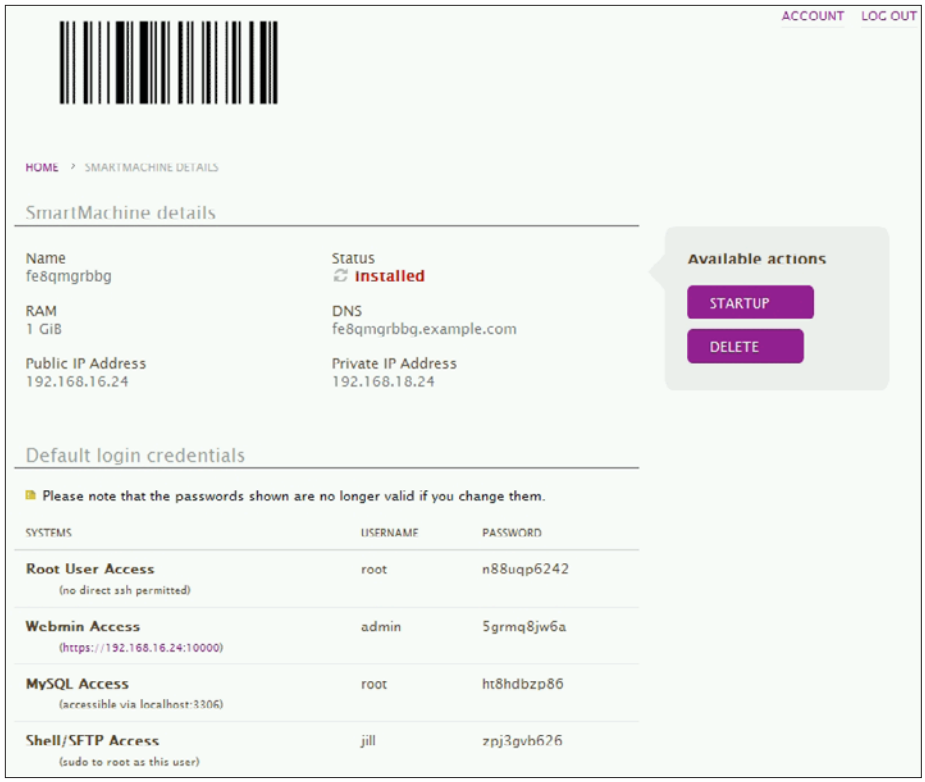

Figure 13. John's SmartMachine* is now turned off and in the "installed" state.

Things to Consider

Successfully deploying a cloud platform requires careful planning and consideration of several key factors—security, scalability, application development environment, and hardware and storage requirements.

Security is a major concern for most cloud service providers. Following established best practices for security in a conventional physical host context (e.g., password management, patch management, server hardening, anti-malware, etc.) should be applied to virtual hosts operating on any IaaS platform. Hardware-assisted virtualization, as implemented in Intel Xeon processor 5600 series, provides full isolation between individual virtual servers, providing an additional layer of security.

It's also important to consider the virtual environment on which you will be deploying a service. For instance, Joyent's SmartMachine virtual resources are a part of the Joyent SmartOS rather than a virtual machine running on top of a hypervisor. This inclusive virtualization eliminates potential application operating system vulnerabilities at the outset, reducing the risk of hyperjacking and reducing overall attack surface within the virtual machine. Each of the SmartMachine resource containers (storage, memory, network, I/O) is isolated from the rest.

The Joyent SmartDataCenter supports dynamic vLANs, enabling cloud administrators to effectively segment multi-tenant customers from one another at any time. In addition, customers can request multiple layers of security within their own secure LAN segment, providing even greater security flexibility.

Hardware-based security: Hardware-assisted virtualization, as implemented in the Intel Xeon processor 5600 series, provides full isolation between individual virtual servers—an additional layer of security for a cloud computing platform.

In addition, Intel® Trusted Execution Technology† (Intel® TXT) [4] uses capabilities in the Intel Xeon processor 5600 series, chipset, and BIOS, in conjunction with a Trusted Platform Module (TPM) to provide a mechanism for enabling a very small atomic level of "assumed trust" while allowing a robust basis for verification of platform components such as BIOS, option ROMs, etc. to a hypervisor or operating system. With Intel TXT, the assumed trust (root of trust) is pushed down into the processor itself—perhaps the best-protected component of any platform.

Finally, Intel® Advanced Encryption Standard (AES) New Instructions (AES-NI) [5], a new set of instructions available on the Intel Xeon processor 5600 series, enables fast and robust encryption without additional appliances and increased performance overhead. This technology can improve performance of AES operations by 3 to 10X over software implementations [6], allowing more secure Internet transactions and broader use of encryption throughout the data center.

Efficient scalability: For a cloud computing platform to effectively host business data and applications, it must provide dynamic scalability, a difficult task when multiple resources, such as storage, CPU, memory, and network bandwidth must be available on demand. Most systems will scale with more resources, but if the point of cloud computing is to maximize resources and minimize hardware purchases, the cloud provider should guarantee that it is using resources economically when adding capacity.

Joyent's Smart Technology architecture has the following key advantages to deliver efficient scalability:

- **SmartMachine lightweight virtualization:** Joyent SmartMachines have been designed to provide the best possible performance with limited overhead. The SmartOS operating system maximizes available RAM for applications. Joyent makes use of all of the unused memory in the cloud by providing a large ARC cache pool, delivering unparalleled disk I/O. Both reads and writes are greatly improved as content that would traditionally be served from the disk is cached in high-speed memory without any customer interaction.
- **CPU Bursting:** The Joyent implementation of its CPU engine allows on-demand processing cycles from a resource pool of available CPUs, enabling instantaneous vertical scaling to meet bursts of application demand without costly and time-consuming manual provisioning of resources.

Application development environment: Cloud development platforms should mirror their target deployment environments as much as possible. If there are multiple deployments, developers should choose platforms that can be reconfigured to resemble each target environment in which the application will ultimately reside. This can become complicated in environments where actual control over virtual machine resources is required. Consider an environment, such as Joyent's open-source SmartPlatform, that enables developers to write to one interface, reducing programming complexity.

Hardware requirements: Processor architecture can impact the performance of virtual machines in a cloud computing environment. Specific features, available on the Intel Xeon processor 5600 series-based servers, including Intel Virtualization Technology (Intel VT) and Intel® Virtualization Technology for Directed I/O (Intel® VT-d) can help improve the performance of virtual machines. Other features, like Intel Intelligent Power Node Manager [7] and Intel® Data Center Manager [8] can be used for policy-based power management and optimization.

Storage requirements: Using SSDs may improve the performance of storage nodes (and compute nodes when local storage is utilized), as well as reduce the overall power consumption of the cloud. While not specifically tested in this reference architecture, you may want to consider using SSDs when implementing a large-scale cloud. Also not tested in this reference architecture is persistent storage using Storage Area Networks (SANs) which can help meet storage requirements.

Glossary

Compute node: A single physical server that can host multiple operating systems and hypervisors.

Infrastructure-as-a-Service (IaaS): The delivery mechanism of the use of computing resources (such as network, storage, and CPU cycles) as a service, typically through virtualization.

Platform-as-a-Service (PaaS): The delivery of a computing platform solution stack as a service.

SmartMachine: Lightweight virtual machines that allow multiple virtual environments to run on a single piece of hardware.

SmartOS: The operating environment for running SmartMachines.

SmartPlatform: An open-source, hardware and software agnostic-application development environment that helps manage data centers.

SmartDataCenter: A collection of tools that help deploy, administer, and scale a cloud.

Software-as-a-Service: The delivery of a software application as a service.

VM: A virtual machine is a software implementation of a computer that executes programs like a physical machine.

Endnotes

1. Arista Networks 7124S Switch: **www.aristanetworks.com/en/products/7100series**
2. Zeus Load Balancer software: **www.zeus.com**
3. Intel Virtualization Technology (Intel VT): **www.intel.com/technology/virtualization**
4. Intel Trusted Execution Technology (Intel TXT): **www.intel.com/technology/security/downloads/TrustedExec_Overview.pdf**
5. Intel Advanced Encryption Standard – New Instructions (AES-NI): **software.intel.com/en-us/articles/intel-advanced-encryption-standard-instructions-aes-ni**
6. Breakthrough AES Performance with Intel AES New Instructions: **communities.intel.com/docs/DOC-5003**
7. Intel Intelligent Power Node Manager: **communities.intel.com/docs/DOC-4765**
8. Intel® Data Center Manager: **software.intel.com/sites/datacentermanager**

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