

Cloud Based Application Architectures using Smart Computing

Potential Strategies and Configurations

How to Use this Guide

Joyent Smart Technology represents a sophisticated evolution in cloud computing infrastructure. Most cloud computing products remain wedded to the concept of simple virtual machine rental—if more capacity, computing cycles, or greater I/O is needed, the prevalent solution is to add more and more virtual machines to potentially address the problem. The result, however, is often wasted resources and an inadequate solution. On the other hand, Joyent's Smart Computing architecture is a comprehensive and integrated system that spans from dynamic CPU and memory usage through complete data center management and resource allocation. The result is that Joyent Smart Computing can provide small to large companies flexible, high performance cloud-based application architectures that are responsive to business needs and budgets with options and performance not easily implemented on more traditional platforms.

This paper provides a broad framework for companies to examine typical Joyent cloud computing application architectures and compare these example configurations to their own potential or current cloud computing strategies. Companies should at least read the Joyent Smart Computing Overview for a better understanding of how Joyent Smart Computing conceptually differs with common virtual machine implementations, then move on to configuration examples and scenarios that best describe potential strategies for addressing their own business computing requirements.

Finally, the section titled The Importance of Database Scaling and High Availability provides a more detailed explanation of configuration options for companies that rely heavily on database applications for their business.

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Joyent Smart Computing Overview

Joyent's Smart Computing architecture incorporates innovations in networking, virtualization, application development, and the operating system kernel. The entire smart computing system represents an evolutionary advancement in the core concepts of cloud computing by improving performance, scalability, and reliability of Internet-based resources. Each Smart Computing enhancement to the cloud removes operational and structural barriers, allowing companies to focus on business innovation rather than their computing infrastructure. As a result, Joyent customers use Smart Computing as a competitive advantage in the marketplace while simultaneously improving productivity.

Among the chief components of Joyent's Smart Computing architecture is its Smart Technology suite of components, which include SmartMachine, SmartOS, and SmartDataCenter. These components work together to provide a more resilient, responsive, and better performing cloud-based data center.

SmartMachine and SmartOS

The Joyent SmartMachine differs from traditional and virtual machine architectures primarily in that it goes further in abstraction of the hardware by presenting the hosted application with access to a pool of resources rather than control of a fixed resource. The SmartMachine has been designed to be very transparent to the underlying operating system, Joyent SmartOS, a modified and enhanced version of OpenSolaris Unix. SmartOS uses this visibility into the SmartMachine to provide all SmartMachines with as-needed access to a large pool of available resources while still providing each SmartMachine with minimum guaranteed access to resources based on a pre-established fair share schedule. This transparency also allows the underlying operating system, Joyent SmartOS, to identify underutilized resources and use them to provide enhanced performance. In normal operating conditions, all RAM and CPU resources are either directly used by applications, or are being used by the operating system to optimize disk I/O and provide other performance enhancements to the SmartMachines.

Furthermore, the lightweight virtualization of the SmartMachine means that a highly tuned operating system (Joyent SmartOS) is available within the SmartMachine,

reducing the need for the developer to manage multiple operating system images. Developers can then concentrate on application production rather than abstraction layers, operating system management, or virtual machine resources.

The SmartMachine incorporates the following core features:

Resource bursting—SmartMachines have the ability to tap the expanded pool of CPU and network bandwidth through the Joyent SmartOS, providing needed capacity during bursts of activity or usage. Joyent SmartOS also supports more CPU cores and a larger memory footprint than other virtualization operating systems, so the resource pools will grow larger as underlying hardware is improved.

Flexible configuration— SmartMachines come preloaded with a variety of popular software environments including a vanilla Unix installation (SmartOS), development platforms (PHP, Java, Ruby, 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.

Enhanced application performance —Joyent SmartMachine provides a system-wide RAM cache for all disk I/O that significantly improves read and write performance for applications. Within a resource pool, any memory and CPU not directly utilized for application business logic is dedicated to providing improved performance. This approach of drawing on idle resources and providing them directly to applications is unique to Joyent's Smart Technology.

Integrated security— The SmartOS also adds additional security and stability to the SmartMachine application environment. Per-machine administration is performed as root user with no ability to manipulate the operating system kernel. SmartOS isolates memory, network, and processor to block network reconfiguration and traffic sniffing. This strategy also keeps public cloud applications completely segregated from one another. [Please see our white paper on cloud security.]

SmartDataCenter

In a multiple machine and application environment, the Joyent SmartDataCenter provides an abstraction layer for the entire data center – including compute, storage, and network resources across multiple physical and virtual locations. In addition to providing centralized management of these resources by cloud operators, SmartDataCenter provides APIs that allow applications to manage resource allocation and configuration.

SmartDataCenter comprehensive APIs allow applications to automate horizontal scaling by adding or removing assets, detect network issues and reconfigure network topology, and perform many other complex infrastructure-related tasks that would normally require manual management.

At the network layer, the SmartDataCenter supports complete virtualization of complex, multi-device architectures, including VLANs, load balancing, VPN, and routing. SmartDataCenter also provides for the creation, provisioning, running, and termination of SmartMachines on any hardware within the SmartDataCenter. It is possible, for example, to decide to stop a process at one physical location and start it within seconds in another physical location to enhance load balancing or provide redundancy.

SmartDataCenter was designed to support a multi-tenant model for application deployment, where each tenant is provided with a complement of SmartMachines and network resources that are isolated from any other tenant. This multi-tenant model can be used for public hosting, as Joyent has done for its hosting service, or it can be used to support federated, private deployment within large enterprises. Some enterprises have chosen to employ a virtual private data center configuration, reserving a dedicated set of hardware within a larger public SmartDataCenter.

SmartDataCenter can scale to millions of potential devices using a reliable message bus for management of all hardware and software in the SmartDataCenter. This message bus uses open, extensible protocols such as AMQP and XMPP that drive the largest volume communication systems currently deployed in the world.

The administration of the SmartDataCenter can be automated in software or managed through a web based administrative console. The management console can be used to monitor and manage network assets, and provides hierarchical management where individual customers have more limited functionality.

The SmartDataCenter also incorporates the following features:

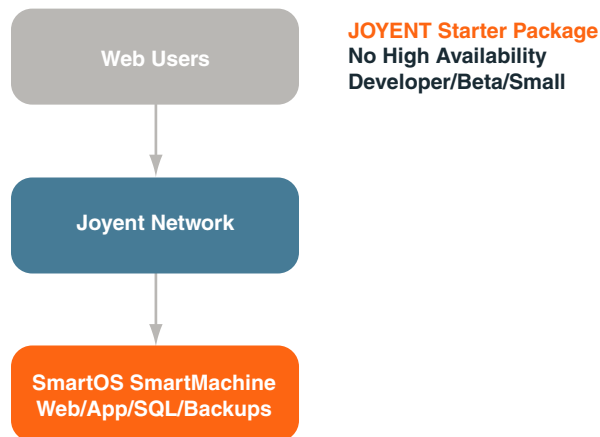
Flexible deployment—Licensing is available for private, public, or virtual private installations, and also through Joyent reseller partners, including Dell.

Centralized management—One GUI console manages the entire collection of system-wide SmartMachines, including resource allocation and OS provisioning and kernel patch management.

Extensible, resource-oriented architecture—Customers can add, remove, or introduce new capabilities and resources without disrupting the existing SmartDataCenter.

As a part of the Joyent hosting service, the SmartDataCenter has currently scaled to thousands of SmartMachines across five data centers. These applications, in turn, service millions of end user requests every day. The Joyent SmartDataCenter has run without system-wide service interruption (100 percent uptime) over six years with hardware utilization rates consistently above 70 percent.

Starter package



The basic Joyent package includes all network infrastructure and application support for a basic cloud-based data center or Web-based business application. Included is access to the Joyent network, a standard Joyent SmartMachine with a configurable amount of RAM and disk storage space, as well as a MySQL database for integration with applications. Joyent SmartDataCenters

complete regular backup of all data, including database files and logs.

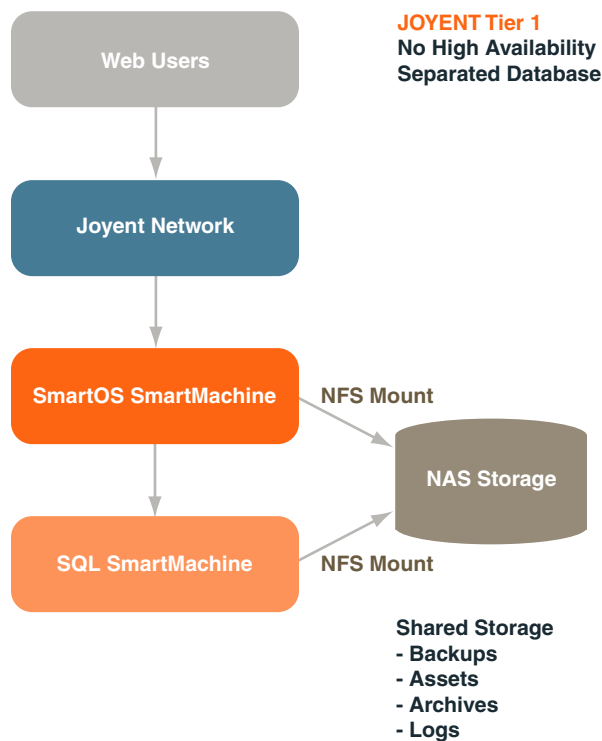
Uses and benefits

This basic Smart Computing configuration is ideal for a developer or development team that needs online space for simple application and database testing. After preliminary development and testing, engineers can extend the scope and complexity of their applications by easily expanding the Smart Computing environment on an incremental basis with additional SmartMachines, more sophisticated database architectures, load balancing, and many more enterprise features as the application itself grows.

For many small to medium-sized companies, the basic Smart Computing package contains all the features, functions, and capabilities they need to host online applications, media rich Web sites, or a basic online business data center available 24X7.

With Joyent's dynamic CPU bursting and RAM caching of Disk IO, spikes in demand that would slow normal virtual machine implementations or require immediate upgrades, customer sites essentially receive extra CPU cycles for free as the Joyent SmartMachine and SmartDataCenter spread traffic surges across cached memory and shared CPUs. Dedicated IP addressing of Joyent customer installations allows for persistent connections to storage and no management overhead for allocating and tracking IP address ranges.

Tier 1: SQL storage



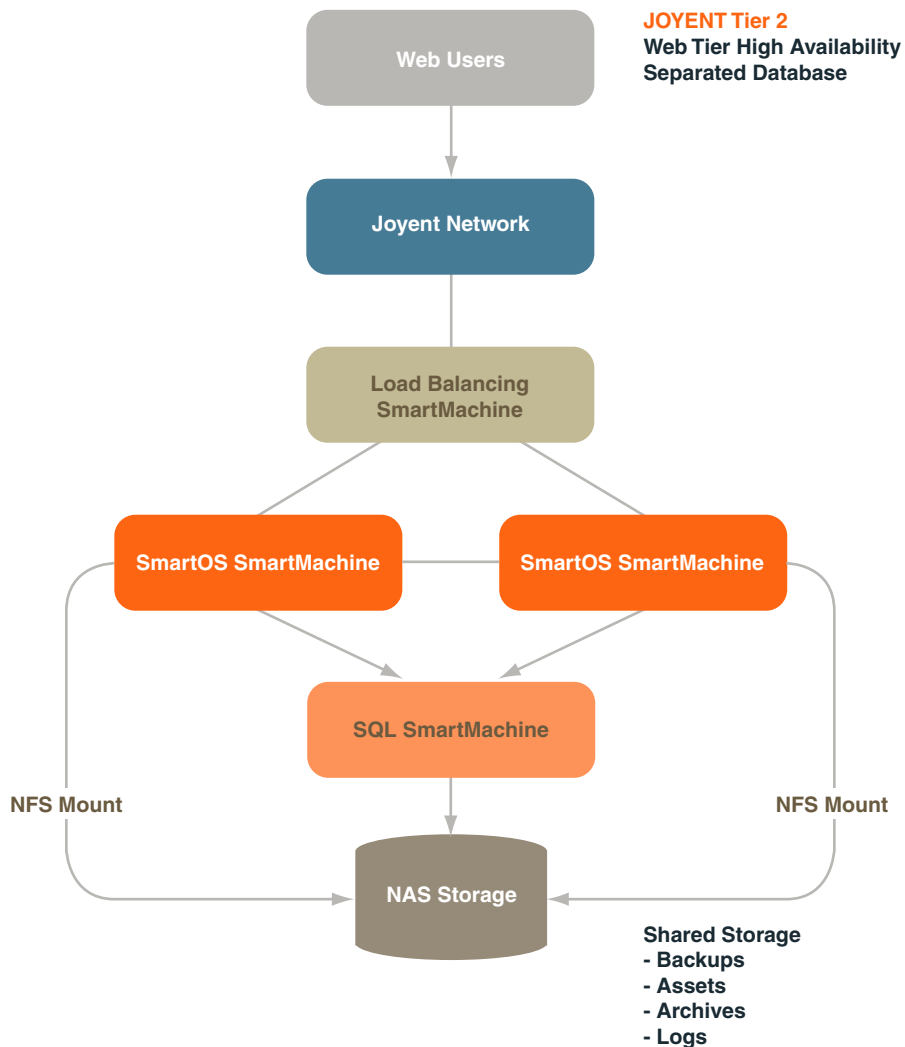
In a tier 1 scenario, companies can move toward separating their database applications from the main site and also house data on yet another system. Under this scenario the SQL database application runs on its own SmartMachine while its data, logs, and archives are stored on a network attached storage device. In parallel, the site's main applications are hosted on a separate SmartMachine, and its data is stored on the NFS volume as well. The Joyent SmartDataCenter then backs up the NAS volume on a regular basis.

Uses and benefits

This configuration has a number of benefits. First and foremost, by segregating main applications and access from database applications, the database performance can be greatly increased. In all likelihood the database may need significantly more resources—both RAM and storage—than the main system applications. By maintaining the database application on its own SmartMachine, the company can provision it for optimum performance. In addition, as the company and applications grow, the segregation of database applications serves as a foundation for highly efficient scalability. As demand grows, additional SQL SmartMachines can easily be added and tied to the main system and NAS storage.

Using NAS storage for consolidating data in this configuration increases the reliability and efficiency of data backup, as the system has only one location to back up. Expanding storage and storage availability is also easier using NAS-based systems rather than direct-attached server storage. Moving from basic NAS to high availability and highly redundant storage is only an incremental addition to the existing architecture rather than a complete overhaul of the system.

Tier 2: Web High Availability



An important upgrade to basic cloud computing data centers is the addition of load balancers. In the above scenario, a Zeus Load Balancer is placed at the head of the site access point, serving as a traffic manager for all incoming access to the site. Load balancers perform two functions: 1) to evenly distribute traffic among network connections to avoid overloading any one network path, and 2) to reroute traffic from a failed network path to a viable network path, insuring that the site remains up and running despite a segment failure.

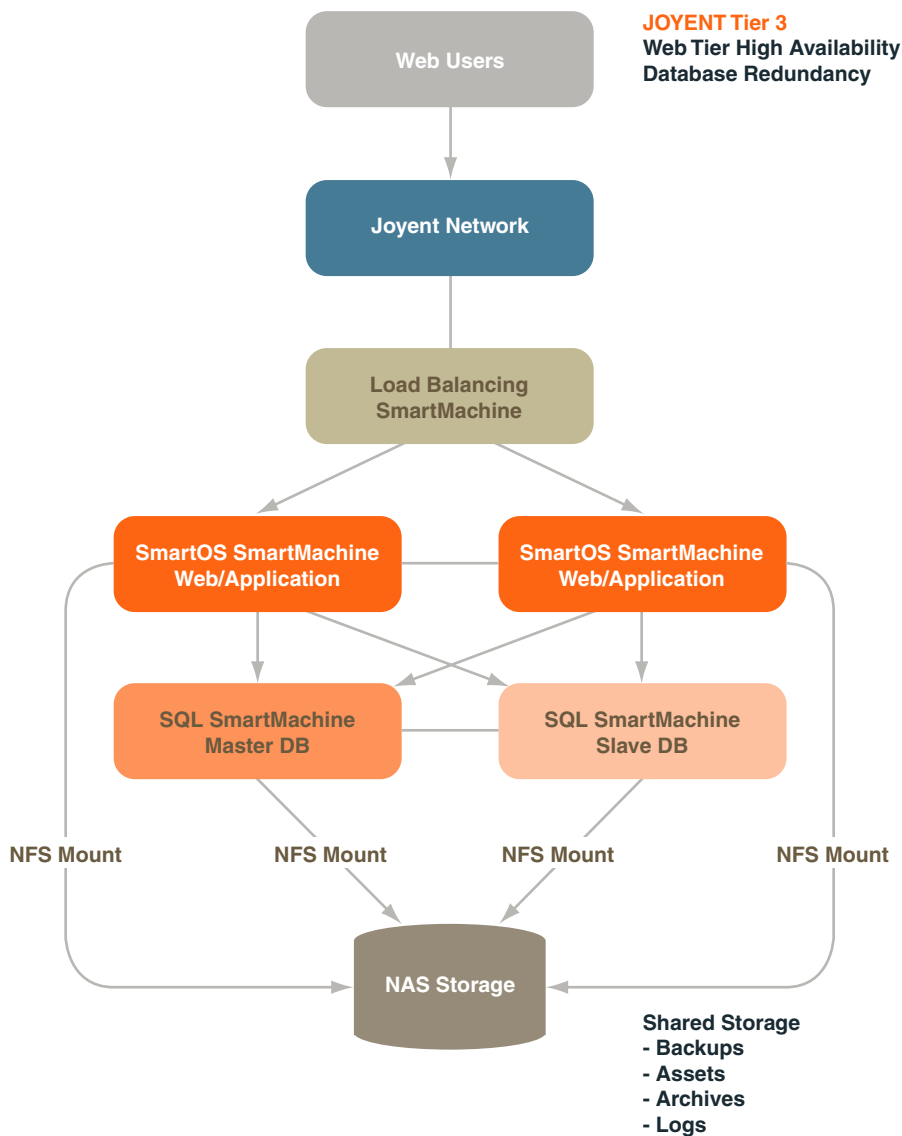
Uses and benefits

As illustrated in tier 2, Web availability is assured as the failure of any Web access SmartMachine is immediately rerouted to another SmartMachine. No management intervention is required.

In addition, because of the basic dynamically scalable features of Joyent SmartMachines, the increased load and associated burst in activity from the failed machine is covered using Joyent's shared CPU and RAM caching capabilities. Again, the increase in RAM and burstable CPU to accommodate the rerouted traffic requires no administrator intervention – the Web site remains available with little or no degradation in performance.

In routine operations with no failures, the load balancer evenly routes traffic among network paths, ensuring that no one path is overburdened. This increases performance throughout the site. Finally, the addition of load balancing lays the foundation for further performance enhancements and high availability features as a company's data center grows.

Tier 3: Web HA and database master/slave



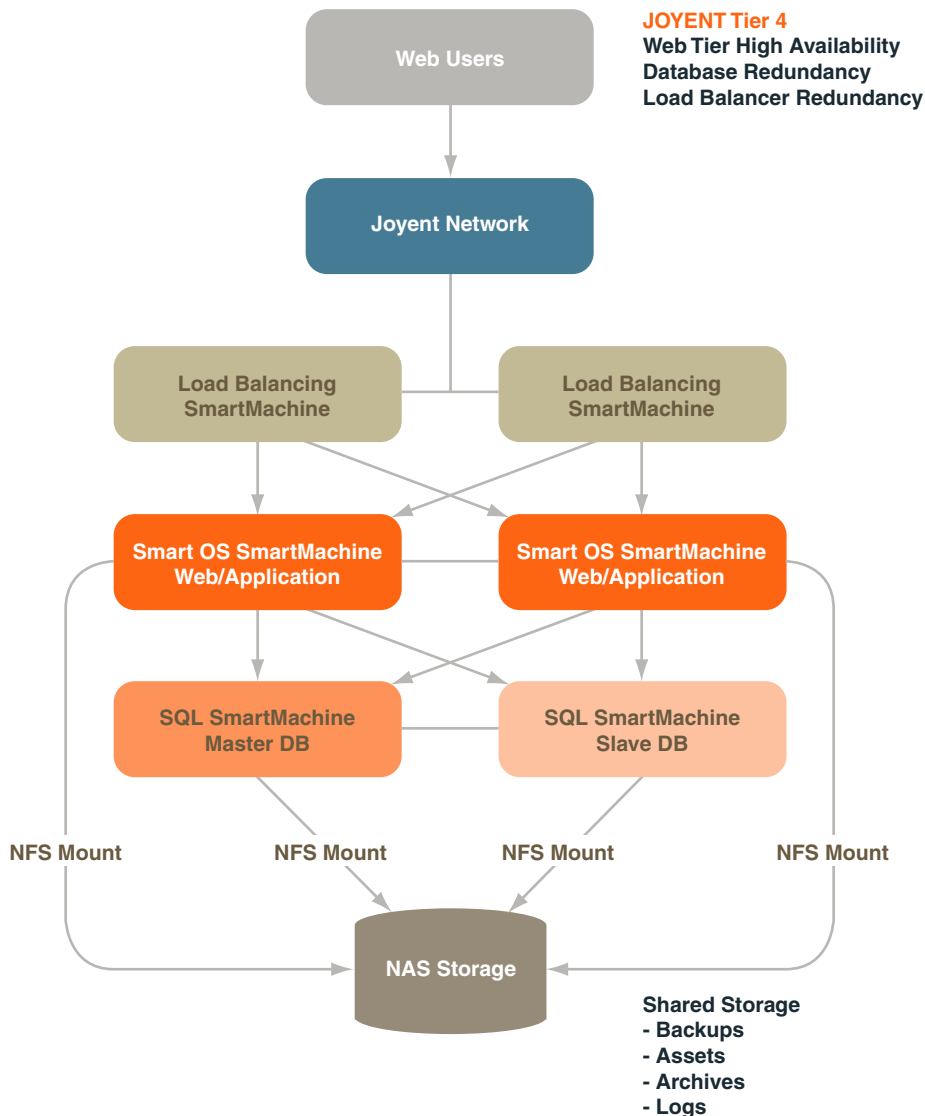
In an effort to add greater reliability to core applications, companies can add a redundant, Slave MySQL database to their configuration. As illustrated above, in this scenario all data coming through either SmartMachine-hosted application are sent to both the Master and the Slave databases. In addition, the Master database continually pings the Slave database to check that its contents match. The Slave database, on the other hand, continually checks the Master database to make sure it is up and running. In the event that the Master goes down, the Slave database takes on all database functions.

In addition, the Master and Slave databases can create separate NFS storage pools on the NAS device, capable of being interchangeably mounted in event of a failure.

Uses and benefits

In this configuration, companies receive a high level of redundancy and availability with a minimum of hardware and software. With two Web head SmartMachines, they are covered for failure or overload of Web access, and with Master/Slave databases they are protected in the event that the main database fails or is compromised. Multiple data pools on the NAS also provide some level of redundancy for database assets. Short of full-scale redundancy, this is the most protection available. It also serves as a foundation for continued growth and scalability—as the system (and business) grows, components can be added and reconfigured, rather than requiring a complete system re-engineering.

Tier 4: High availability up to storage

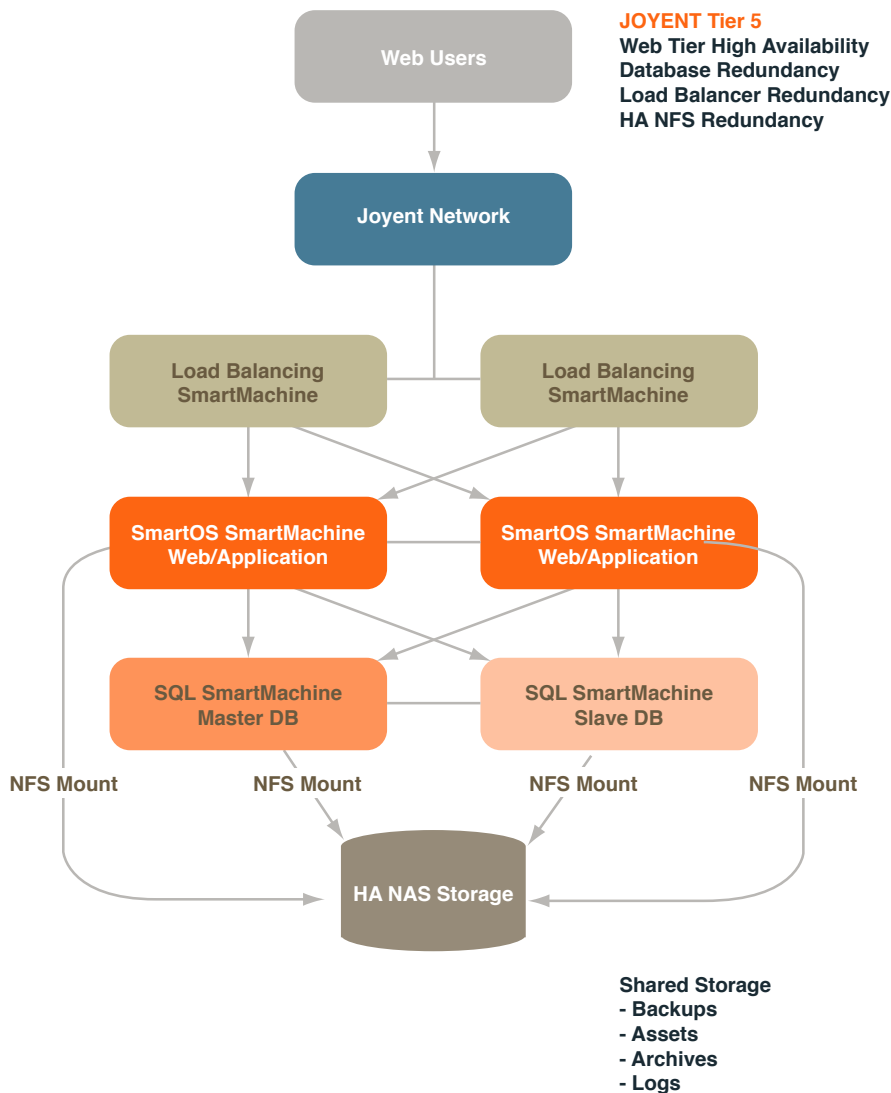


In a tier 4 implementation, a second Zeus Load Balancer has been added to the system architecture. This provides even greater traffic management, but more importantly, it provides a redundant load balancer in the event that one fails. Now all critical elements of the data center have redundant backup units, from Web head to database applications.

Uses and benefits

A second load balancer adds greater performance benefits but also provides another layer of high availability to the system. This second balancer enables a broader, horizontal scale of SmartMachines as well. Higher capacity and greater computing capabilities are achieved by adding more and more SmartMachines as needed.

Tier 5: Full high availability including storage



The addition of multiple NetApp Network Attached Storage (NAS) head-ends provides the final layer of redundancy and high availability to the system architecture. All system data and applications are backed up continuously and redundantly—if one storage unit fails, the backup storage unit immediately takes over. The system is now fully redundant with high availability capabilities from the Web applications down to data storage and backup.

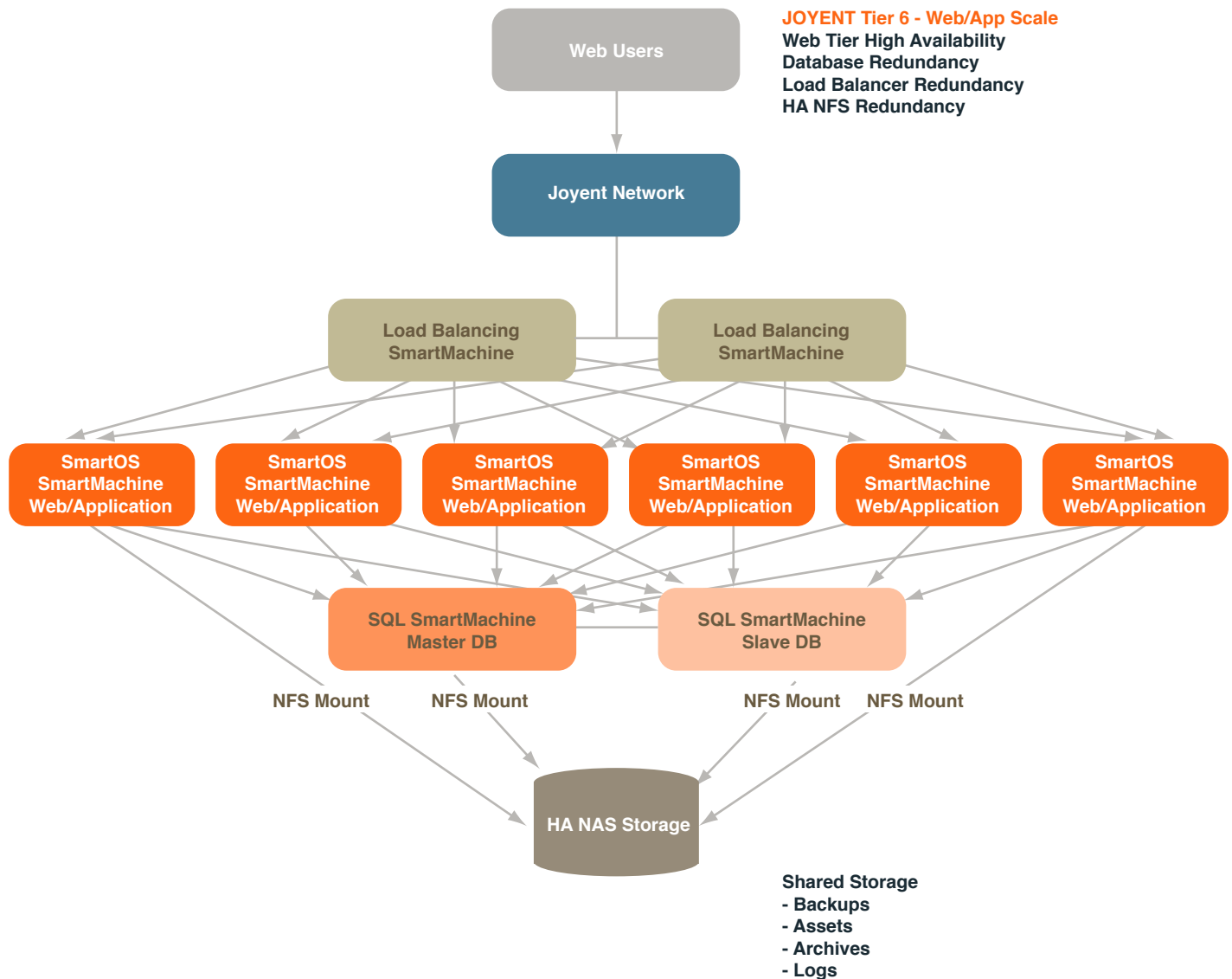
Uses and benefits

Regardless of component failure, the system has redundant capabilities to continue operation until repairs or can be made. Some companies add further redundancies, particularly for critically important aspects of the network such as database files and logs. In most situations, however, dual redundancy covers the vast majority of network failures with a minimum impact on 24X7

operations. Network users will notice little or no degradation in performance or experience any data or application losses.

In redundant NAS device deployments, disk I/O is also significantly improved. Multiple copies of the file system can be hosted across storage devices, relieving storage read/write bottlenecks and increasing application performance, particularly database applications that require significant read/write access.

Tier 6: Scaling horizontally



The most significant system stress that most companies experience is the growth of user traffic and increased application access. As more and more users log onto applications, the system needs to expand to accommodate the additional demands. With Joyent SmartMachine implementations, each virtual node resides on a separate physical node providing greater performance and availability. In addition, Joyent's Smart Technology more efficiently shares these CPU nodes, unlike standard virtual machines that lock CPU cycles to each machine; with

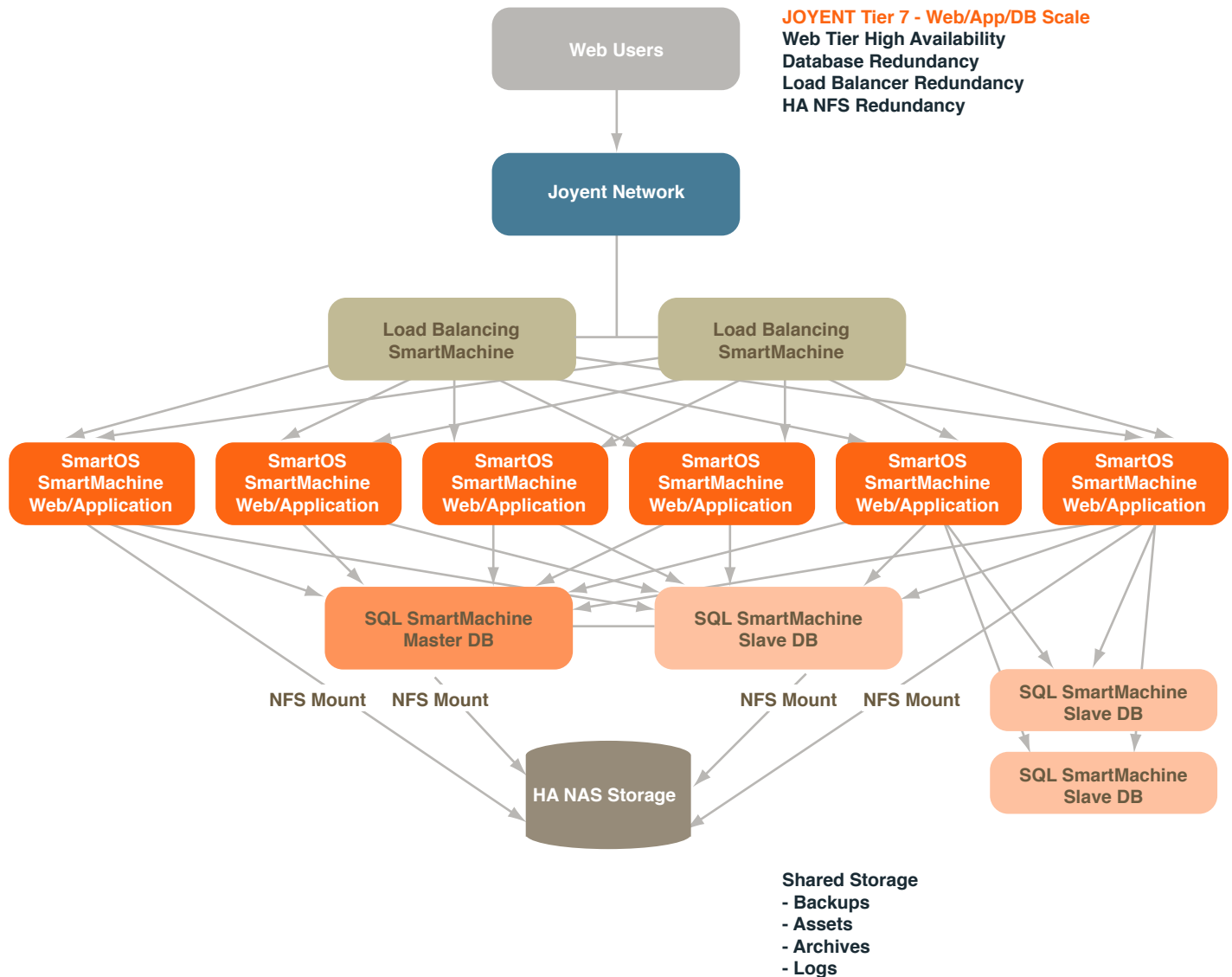
SmartMachines, the result is more efficient and cost-effective horizontal scalability. Therefore, Joyent systems experience up to 60% utilization, as opposed to less than 20% utilization on most standard virtual machines.

Uses and benefits

Joyent SmartMachines enable companies to quickly grow their businesses without investing in significant physical assets. Because Joyent SmartMachines handle bursts in traffic far better than static virtual machine implementations, Joyent customers can add significantly more bursting capacity at a lower cost than with competing architectures. This extra bursting capacity maintains performance during spikes in usage. Because Joyent data centers are staffed 24X7 and available online or by phone, additional resources can be allocated in many cases in a matter of minutes.

With system redundancy from Web access through the network file system, and the ability to easily add additional computing power, this Joyent configuration is a truly enterprise-ready platform that can scale to nearly any size very quickly.

Tier 7: Scaling databases



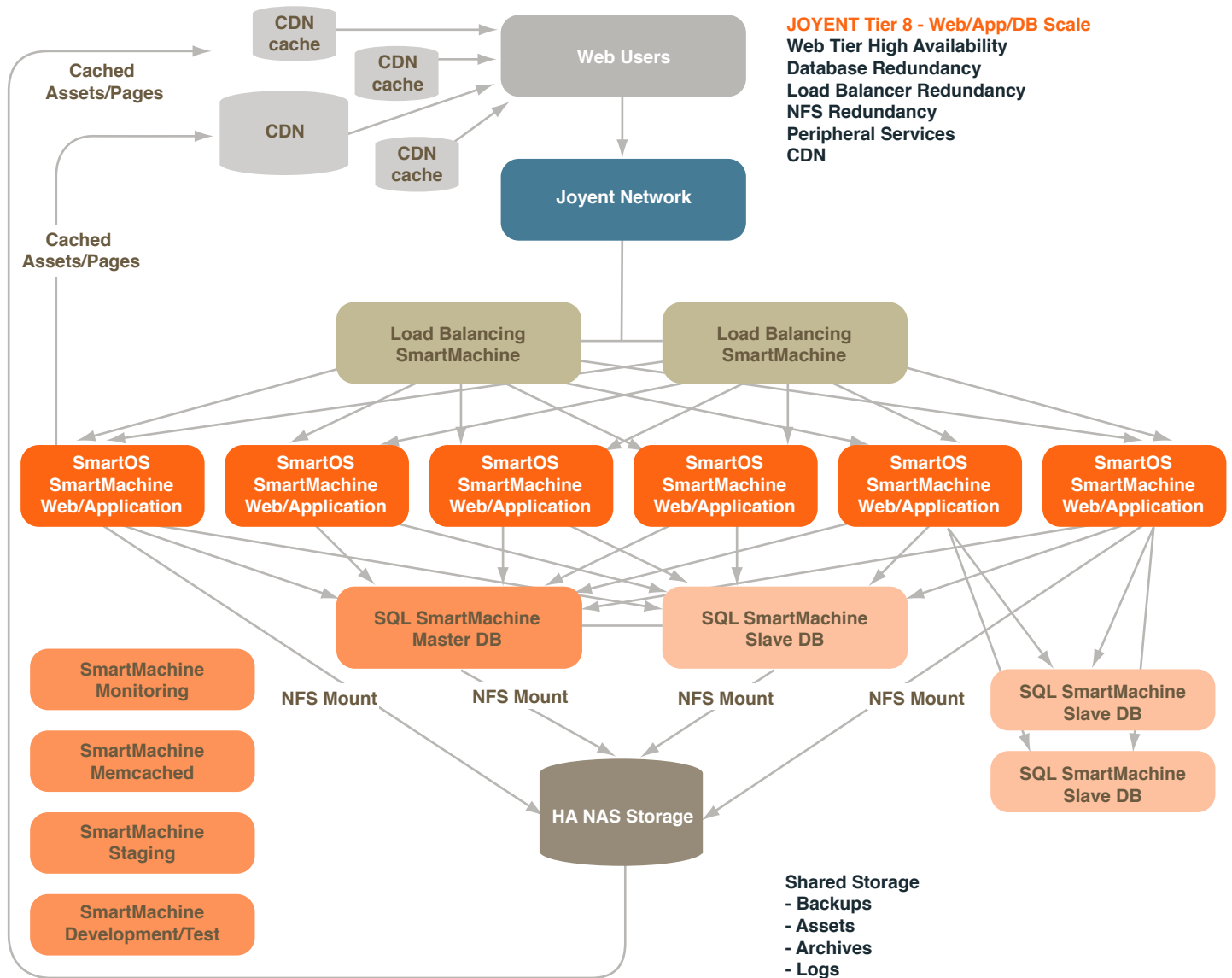
In many environments, database access can be a key bottleneck to system performance. As more and more users access databases for information, both network paths and database read/write processes become congested, reducing productivity, and in some cases, even crashing applications that rely on back-end database functions. A solid solution for increasing responsiveness and reliability is to add additional, replicated datasets to the network with multiple paths to the data. In this scenario, multiple SmartMachines can route application database requests to

any of a number of replicated Slave databases. Since multiple paths access multiple data sets, system performance is restored. Another key differentiator for Joyent Smart Computing is the ability to allocate additional RAM for any machine, on the fly, with no need to reboot. This is especially important as spikes in user access and database parsing require sudden and unexpected demands on system memory. If such a spike occurs, resources can be allocated real-time, with no system penalty or disruption of the live environment. In most virtual machine environments, the system would need to go off-line for reconfiguration or be rebooted for additional memory allocation to become available.

Uses and benefits

Companies with database intensive applications know that performance is key to productivity. If the database is used for order entry or transaction processing, it is the life blood of the company. Using multiple Slave databases with multiple paths to data guarantees that productivity does not suffer during peak use. Avoiding database crashes or system slow-downs is essential. Joyent Smart Computing enables easy implementation of multiple replicated databases and network paths, and also covers extreme bursts in traffic dynamically, with no intervention. To further boost performance, load balancers can be configured to split application read/write requests. The basic framework of this configuration allows for easy, on-the-fly expansion when needed. The redundant components, including NAS storage, also provide high availability in the event of a component or segment failure.

Tier 8: Enterprise example, including CDN cache and app servers



To further increase performance, reliability, and productivity, customers can add components outside the main data path. For example, many customers connect content delivery network (CDN) clusters—either hosted internally or externally at a vendor site—to serve frequent downloads and read-only files to customers. These CDNs fall outside the main system data path, providing data quickly without stressing the main system. Similarly, companies can construct special purpose SmartMachines outside the main data path for application development and testing,

system monitoring, memory cache, or other uses. The specialized machines add extra functionality to the system with little impact.

Uses and benefits

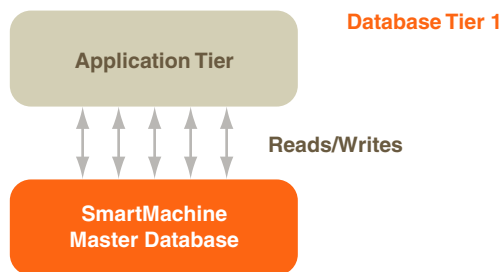
Because Joyent Smart Technology is not exclusively focused on virtual machine rental, adding performance-enhancing components at the edge of the network can deliver tremendous benefits. CDN at the edge can increase real network throughput by a factor of 100, given properly cached materials, such as multimedia files, Flash files, and other large, frequently accessed data. The ability to selectively roll out application testing on SmartMachines—and decommission them when work is completed—is a more cost-effective approach to engineering. Similarly, the introduction of memory cache and network monitoring applications on SmartMachines can also provide increased performance and reliability with no disruption to the live network or any other applications.

The Importance of Database Scaling and High Availability

Most companies rely on some form of database application to conduct their daily business. Customer records, customer orders, and customer bill processing are familiar uses for business databases. In other companies, the database *is* their business: consider the searchable catalogs of online retailers, or multimedia content served up by YouTube and Hulu. Traditionally, database applications have two major problems, however. The first problem is reliability. Although databases are no more likely to fail than any other file or application, they are often at the critical core of business, and any loss can be catastrophic. The second problem is scalability. Many company databases start out small and continue to grow, sometimes exponentially. The architecture or platform that was perfectly serviceable for a smaller database becomes too unwieldy, unreliable, or slow when the business grows. Crashed systems, massive re-engineering of the applications, and lost productivity are often the result. Therefore, companies need to engineer their database applications from the beginning to allow for greater scale and higher availability.

While Joyent's Smart Computing infrastructure incorporates features and functions that dynamically improve database performance, such as shared CPU cycles and system memory cache, the Joyent architecture also provides an ideal platform for engineering database application that are easier to grow and protect.

Tier 1: Simple DB

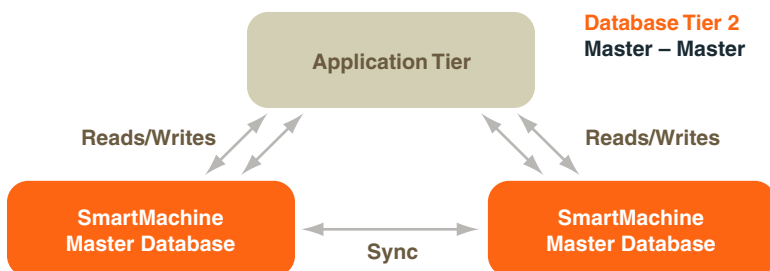


The separation of the database from its application is the first step in building a foundation for better scalability and high availability. Since the database is separated, there is no reason for system downtime when Web tiers are cloned or when databases are replicated. The

system can scale with no down time. In addition, the ability to clone data with no disruption allows for far more comprehensive disaster recovery and business continuity solutions.

Even in the simplest implementation, Joyent SmartMachine hosting of databases provides more dynamic and adaptable response to read and write traffic than other strategies. During bursts in activity, the SmartMachine can call on pooled CPU resources and system memory cache to handle the sudden demands with no performance penalty.

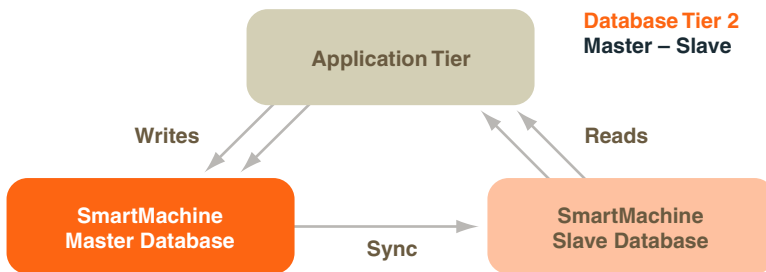
Tier 2: Master – Master



With the separation of the database from its application, performance enhancements for reading and writing data are more easily implemented. In this simple Master-Master database configuration, two synchronized, Master databases serve the application tier,

which could include a number of SmartMachines. With multiple Master databases and multiple data paths, far more read/write requests can be serviced simultaneously. In addition, if one database goes down, the remaining Master database is available. This configuration is suited for environments that have unpredictable spikes in traffic and roughly the same amount of both read and write requests. Expanding beyond two or three synchronized Master databases can be problematic, however, and does not provide proportional benefits over other database configurations, such as Master-Slave or split datasets.

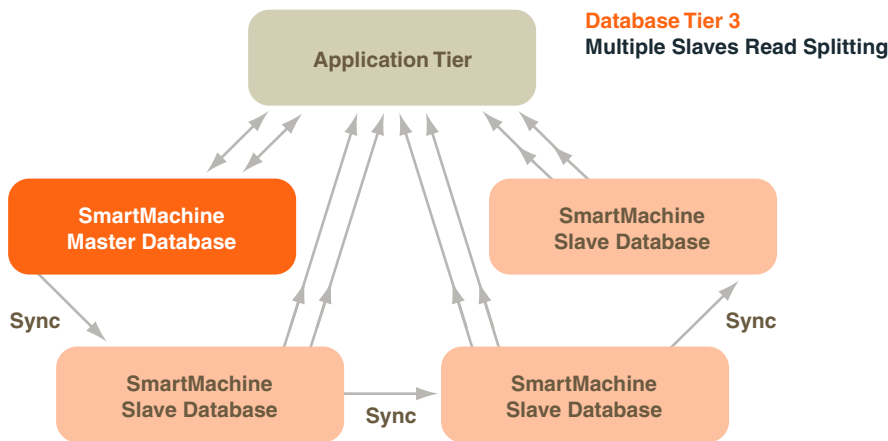
Tier 2: Master – Slave



In a Master-Slave database configuration, the Master database receives all incoming write traffic and then synchronizes it with the Slave database. In turn, the Slave database services all read requests from the application tier. Failover scripts can be

written that enable the Slave database to take over both read and write functions in the event that the Master database is unavailable. This architecture is very scalable and can serve as the foundation for expanding read-intensive applications and providing multiple redundancies for higher data availability.

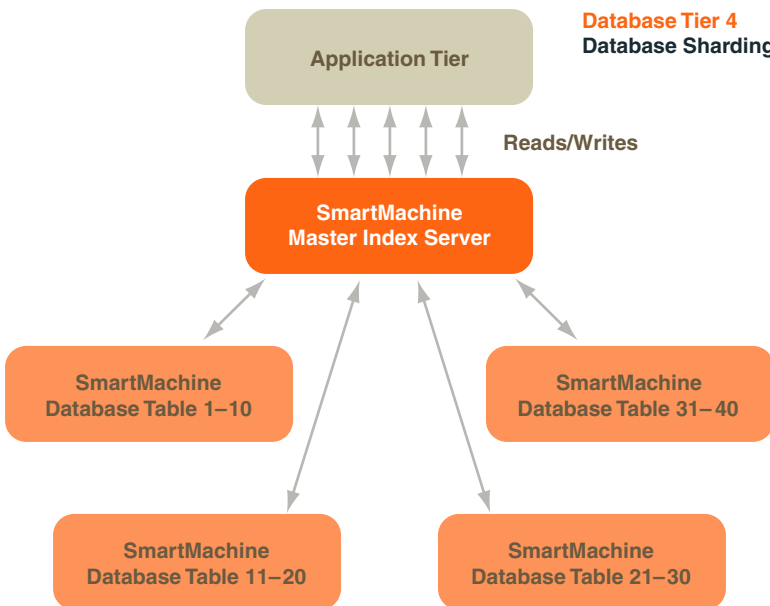
Tier 3: Multiple Slave – read splitting



In most businesses, applications generally perform more read functions than write. While splitting functions and synchronization with a Master-Slave database architecture is an improvement, if read traffic is extensive, one Slave database will quickly become overwhelmed. By adding additional Slave databases, reads can be split among a number of Slave databases

on SmartMachines, improving performance tremendously. Management of the read/write splitting is automatically handled by Zeus Load Balancers. This implementation is especially useful for applications that are Read-intensive and for databases that house a great deal of static data.

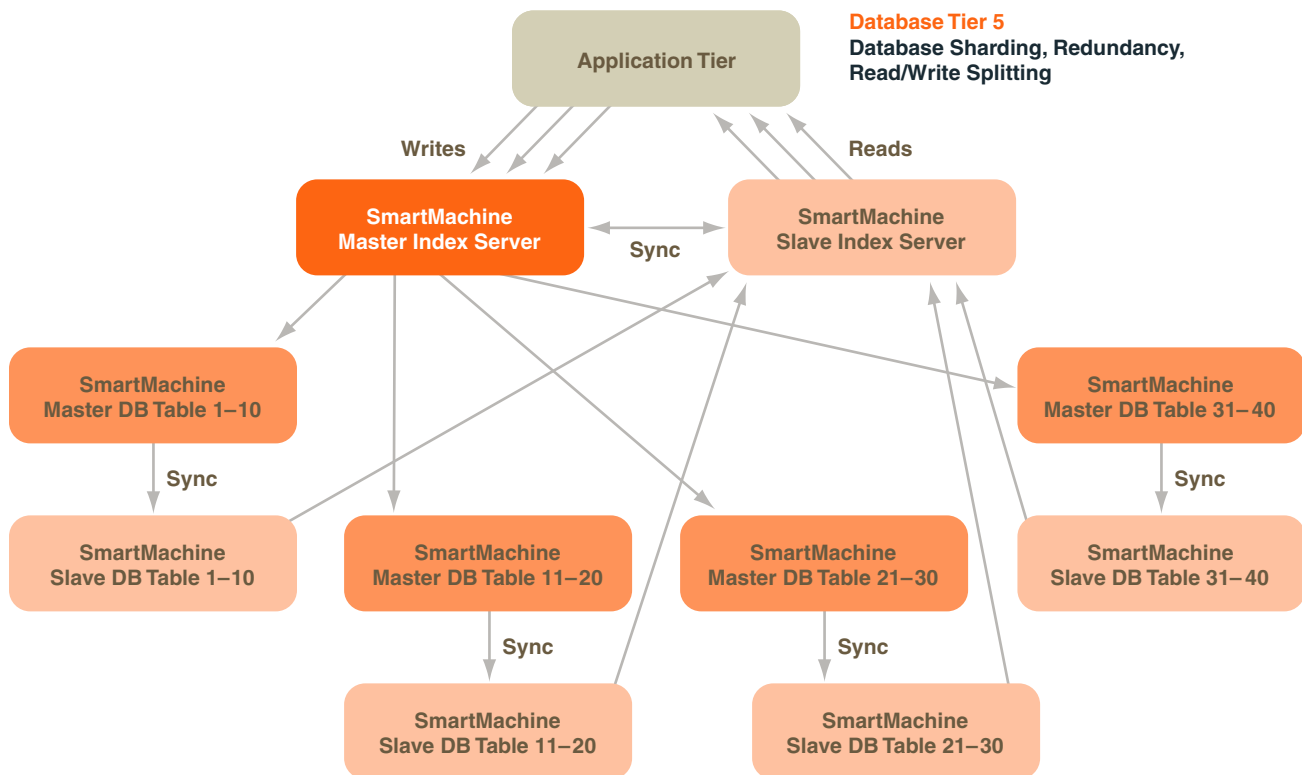
Tier 4: Database sharding



As databases continue to grow, the only way to preserve performance and reliability may be to split the database into multiple datasets. MySQL and the Joyent SmartDataCenter allow the use of database splitting called “sharding.” In this scenario, sequential sets of data are hosted on SmartMachines behind a Master SQL Index Server. As application tier requests come in to the database, the Index Server routes the read/write request to the appropriate “shard.” This implementation architecture is useful for extremely large databases and

databases that experience a high level of traffic.

Tier 5: Database sharding, redundancy, read/write splitting



As a natural extension of the previous Smart Computing configurations, each extension is built on the previous foundation. Ultimately, enterprise database applications can implement multiple SmartMachine datasets, replicated datasets, and load balancing traffic management. Under this scenario performance is optimized by multiple read/write paths across database shards, Slave databases provide reliable dataset backup and a resource for read-intensive queries. Traffic management using load balancers evenly distributes network traffic. This “ultimate” configuration is possible only by laying the architectural groundwork early in the network and application design phases, and it is emblematic of the extensible nature of the Joyent Smart Computing strategy.

Conclusion

Joyent's Smart Computing strategy and architecture provides a solid foundation for building out extremely scalable and high performance cloud data centers. Using Joyent Smart Technology components, companies can quickly build and grow online business and business applications without the serious technical barriers and inefficiencies of less sophisticated cloud computing platforms. Joyent is a cost-effective solution for small, medium, and enterprise businesses, and currently hosts hundreds of businesses in its five distributed data centers.

The following are some of the benefits unique to Joyent Smart Computing:

- 24X7 response and quick online provisioning
- Massively scalable
- Flexible upgrades and enhancements with no downtime or reboots
- Highly distributed and reliable
- Dynamic handling of traffic bursts
- Dedicated IPs and persistent storage
- Intelligent caching and CPU pooling

With an extensible architecture supported throughout, Joyent Smart Computing allows companies to start small and build large without re-engineering, reprogramming, or rebuilding. Because customers pay only for what they use, Joyent cloud computing is the most cost-effective means for building the right sized data center at an affordable cost. The configuration examples in this guide are just a few examples of the many possibilities available to Joyent customers when deploying their business on the Smart Computing platform. Joyent engineers and consultants can help businesses formulate a system that is right for any business.