MOODLEROOMS AND SUN REFERENCE ARCHITECTURE
THE NEXT GENERATION OF LEARNING MANAGEMENT

White Paper
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Chapter 1

Executive Summary

Today's students have the ability to access educational resources and content from anywhere, with a high degree of sharing, collaboration and participation. The Web has enabled people from diverse cultures and backgrounds to participate in each other's learning, enriching the experience for both students and teachers.

With online learning, students from remote locations around the world can join and participate — students who might otherwise not enroll in courses. The rising number of students is further magnified by the fact that children of the Baby Boomer generation are now reaching college age or are already in the workforce and continuing their education. Addressing this increased student population by simply building more brick and mortar infrastructure for education would be very expensive, ecologically unfriendly, and would retard the pace of growth. Instead, competitive market forces have driven more institutions around the world to build online learning environments that can serve the needs of a new population of learners.

Today’s population of learners includes a new generation of students who have grown up using the latest digital technology. Sometimes called, “digital natives,” these students use technology in ways that previous generations of students have not. They tend to do many things at the same time and can function well with multiple simultaneous modes of interaction. They expect to have digital content and want their online learning experience to be multimedia, self-directed, and entertaining.

They also require flexibility to access learning materials both synchronously (live) and asynchronously (on demand). Having become accustomed to high service levels with well known consumer Web services such as Google, Amazon, and iTunes, these students expect similar levels of service from their online learning environment. Digital natives expect 24 X 7 availability whether using a desktop system on campus or accessing the environment remotely via a laptop, mobile phone, or other device.

Together these trends have raised eLearning to a mission-critical campus application. Learning Management Systems (LMS) are one of the most highly utilized applications on campus, often second only to email in terms of the level of user activity and the IT system resources required.

The success of an eLearning initiative is dependent upon achieving predictable high performance and reliability for the LMS. Yet many educational institutions are operating with an LMS that is neither architected for scalability and performance, nor managed with the kinds of enterprise datacenter disciplines that have proven successful with other mission-critical applications.

With limited IT budget and staff resources, most institutions cannot afford to spend a lot of money on their LMS software nor its implementation. They must be able to get the system up and running quickly and then maintain high service levels without assigning a big team of developers or administrators to the project. Since datacenter space, power, and cooling resources are already constrained, it is also important to find solutions that can help ease these datacenter constraints through consolidation and virtualization or a hosted offering. Institutions are looking for LMS solutions that are easy to deploy and manage and can achieve high service levels without overspending on hardware resources that are then poorly utilized.

Many institutions are also turning to open source software for eLearning as a means to help reduce costs and improve flexibility. Open source solutions help address a key challenge that the digital world brings to today's educational institutions. Institutions must constantly adapt to keep pace with rapidly evolving tools and content so that they can effectively serve digital natives and the diverse multi-cultural backgrounds of their student populations.

With an open source LMS, institutions can more easily build and share interoperable educational content. They can also quickly adapt their LMS to support the latest teaching tools that are created and shared in the education community. An open source environment can therefore give institutions greater flexibility to choose content and teaching tools that will meet the needs of their students.

In summary, institutions must achieve the following objectives for their eLearning initiatives:

- *High service levels* — Systems must operate 24X7 with little downtime, planned or unplanned, and must be able handle spikes in user demand without degrading response time.
- *Low TCO* — Systems must be cost-effective to procure and manage when considering everything from hardware and software license costs to the system's impact on datacenter power and cooling costs and the operational costs of maintaining the hardware and software infrastructure.
- *Scalability* — With a growing population of students and an ever-growing demand for online delivery, the eLearning infrastructure must be easy to scale in support of higher levels of throughput, more users, and more online courses.
- *Open sharing* — The use of open content, open source software, and open standards can help promote greater interoperability of content, thus lowering the cost of education and providing increased flexibility and choice for teachers and students.
- *Simplified manageability* — With limited IT staff to assign to the project, the LMS must be easy to deploy and manage so that service levels can be met without an extensive IT staff.

The Sun and Moodlerooms offering

While in the past the perception may have been that using open source software for eLearning would mean sacrificing other requirements such as reliability and scalability, this is no longer the case today. Sun Microsystems and Moodlerooms have teamed together to deliver a cost-effective implementation of the hugely popular open source Moodle software platform that meets all of the requirements for a mission-critical eLearning application for large institutions.

Sun and Moodlerooms have defined a reference architecture that can help customers reduce the time, cost, and complexity of deploying and optimizing the Moodle software platform and which reduces the risk of unforeseen problems. The architecture utilizes proven components that offer maximum performance and scalability, making it much easier for customers to achieve consistently high service levels in a cost-effective consolidated environment.

Sun and Moodlerooms have validated the performance of specific configurations of the architecture for small, medium and large campus environments. The validated configurations have also been proven to offer low total cost of ownership because they support virtualization using Solaris™ Containers, enabling very high utilization of the Sun servers.

Sun Fire™ X4600 servers provide the foundation for the scalable architecture and are deployed in a horizontally scaled application tier that offers extremely high throughput.

Cost-effective and reliable hosting services

For customers who want to combine the flexibility of open source with the ease and speed of a fully supported turnkey solution, Moodlerooms also offers hosting services for Moodle software running on proven Sun systems. Many institutions are now turning to the software-as-a-service model to achieve high service levels without the capital costs or the time and expense of staffing an IT team dedicated to building and supporting another internal system. Moodlerooms can help institutions get up and running quickly while reducing the cost and risk of deploying the Moodle platform. With experience running the world's largest Moodle software implementation on Sun, Moodlerooms brings outstanding reliability and delivers excellent customer service and support.

Perhaps the most compelling part of the offering is that hosting services from Moodlerooms are offered at the price of $1 per student per year for up to one million students.

The Sun and Moodlerooms advantage

The Moodlerooms and Sun Reference Architecture takes advantage of Sun technologies that can help customers more easily optimize their IT infrastructure and reduce risk. Institutions can gain the following benefits by deploying the Moodle software platform on Sun systems and utilizing the expertise and/or hosting services of Moodlerooms:

- Reduced risk with hosting solutions and validated configurations that offer proven reliability and scalability as well as extremely high levels of availability using failover cluster configurations
- Lower TCO with hosting services priced at $1 per student per year and a consolidated hardware environment that offers outstanding price/performance, high levels of system utilization, and dramatic savings in space, power and cooling
- Investment protection with an IT infrastructure that can easily scale to support future needs and by using standards-based systems that offer a choice of CPU architectures and OS environments
- Faster time to market and greater flexibility with hosted solutions that can be up and running quickly and can be easily transitioned to an in-house implementation if and when desired

Scope of this white paper

This white paper provides an overview of the Moodlerooms and Sun Reference Architecture and its benefits as well as best practices to help institutions make wise choices to optimize their eLearning environment.

Chapter 2
Introduction

Learning Management Systems (LMS) have become an important application in today's education infrastructure and more and more institutions are turning to the free open source Moodle software as an alternative to costly proprietary LMS solutions.

The Moodle software platform was designed using sound pedagogical principles and has been embraced by a broad community of users. More than six millions users in over 160 countries are using the Moodle software platform for online learning. Moodle also has an extensive list of contributing developers who help maintain the code base to keep up with the needs of today's LMS environments. The software has been proven to scale well with implementations that currently serve as many as 50,000 students. As an open source solution, the Moodle software platform can be downloaded for free and thus offers a low cost LMS that makes online learning practical.

There are many advantages of an open source LMS solution:

- *Easier to procure* — Open source solutions offer a streamlined procurement process that involves some basic homework about the available options and then downloading the software to begin implementation. If commercial support is needed, it can be purchased once the project is started to avoid delays.
- *Greater reliability* — Open source solutions have a much greater level of peer review for specifications and feature implementations. They also can have faster bug fixes due to wide participation from developers who support the software and have incentive to keep it running well.
- *No vendor lock-in* — Access to the source code prevents a vendor from locking in customers.
- *Community sharing* — Open source solutions often bring together ideas and best practices from many customers who want to share their results to help the rest of the community benefit.
- *Reduce the risk of obsolescence* — Vendor consolidation in the technology market can sometimes leave institutions stranded with a product that would require a major upgrade to continue its support. With access to the source code of an open source software solution, customers can have greater choice about whether to migrate to a new platform in such a situation.
- *Reduced costs* — Elimination of license fees and a competitive market for follow on service and support helps keep costs low.

In the past, many institutions have had concerns about using open source software for a mission-critical application such as eLearning. Open source application environments were thought to be lacking sufficient reliability and scalability for a large enterprise installation and most institutions want service and support for their mission-critical

applications. Indeed, with eLearning, the success of the project is often dependent upon achieving predictable high performance and reliability for the LMS.

LMS deployments must also coexist with and support broader IT agenda's such as Green computing, server consolidation, and virtualization. In other words, the LMS must support the same kind of technologies that are being used help improve efficiency and eco-responsibility in today's datacenters.

Moodlerooms works closely with the global Moodle community to provide access to proven and tested implementations of Moodle as well as a full spectrum of support options including hosting solutions that accelerate implementation time. Sun and Moodlerooms have invested in testing and characterization of the Moodle software platform on Sun systems to offer proven configurations that greatly reduce the risk of unforeseen problems in enterprise implementations. These solutions leverage Sun technologies for datacenter efficiency, including Solaris Containers and energy-efficient Sun Fire X4600 servers based on Next Generation AMD Opteron™ processors.

Moodlerooms offerings

As an official Moodle Partner, Moodlerooms provides the support, hosting, customization, instruction, training and other services that today's institutions need to tap the full potential of the Moodle software platform. Whether for a single class, a school or a 50,000 student university, Moodlerooms can help institutions accelerate deployment, reduce risk, and gain greater benefits from their Moodle platform implementation.

Services offered by Moodlerooms include:

- *Hosting solutions* — Moodlerooms provides a wide range of hosting and bandwidth packages powered by systems from Sun Microsystems. From individual users to institutions with tens of thousands of users, Moodlerooms offers secure hosting of Moodle software to simplify deployment and ongoing support.
- *Implementation/integration services* — Moodlerooms can write the customization code that will integrate the Moodle platform into an existing campus IT infrastructure.
- *Instruction/training services* — Moodlerooms offers online and onsite training for Moodle instructors. A blend of instruction will give instructors the skills and deliverables they need to run their own Moodle courses.
- *Moodle mentor services* — Seasoned Moodle experts guide clients through pedagogical and technical questions concerning Moodle. The Moodle Mentor subscription is one year of support couched in a community of Moodle instructors.
- *Customization services* — With open-source code and a development team, Moodlerooms can shape Moodle to better match the needs and vision of individual institutions.

These services combined with the Sun and Moodlerooms reference architecture can result in the following primary benefits to educational institutions:

- *Simple migration* — Moodlerooms offers support options for easily transitioning courses from other LMS environments to Moodle.
- *Accelerated adoption* — Get up and running quickly using pre-configured software solutions or a hosted solution that can be available in a matter of days.
- *Reduced risk* — Take the guesswork or trial and error out of deploying the Moodle platform using validated configurations that reduce the risk of unforeseen problems.
- *High value* — Cost-effective support offerings and hosting services offered at the attractive rate of $1/student/year with unlimited courses. Enjoy a full range of support options from Moodlerooms while still saving significant costs as compared to a proprietary LMS deployment.

Moodlerooms and Sun Reference Architecture

The Moodlerooms and Sun Reference Architecture is a blueprint for optimizing the implementation of the Moodle software platform on Sun systems. It delivers extreme levels of availability and offers proven enterprise-class scalability. The reference architecture includes specific recommendations for hardware and software components that can help improve operational performance and efficiency. It also provides user load characterization to enable accurate sizing and configuration of Moodle implementations on Sun systems. And best of all, the reference architecture configurations are fully supported by Moodlerooms so that customers can get the service they need for their mission-critical LMS deployments.

Reference architecture components

The Moodlerooms and Sun Reference Architecture consists of the following key components:

- *Moodle software platform* — Moodle is a free, open source learning management system designed to help educators who want to create quality online courses. The software is used all over the world by universities, schools, companies and independent teachers. It offers 12 standard learning activities as well as a variety of additional resources.
- *Sun Fire X4600 M2 server* — The Sun Fire X4600 M2 server with AMD Opteron processors provides up to eight CPU cores in a single compact 4 RU, energy-efficient system. The system's modular design also makes upgrading to future quad-core processor technologies simple and nondisruptive. Virtualization capabilities in the Sun Fire X4600 server enable many instances of distributed Moodle software components to be deployed and managed in a single server. This simplifies overall management and enables very high utilization of system resources.
- *Sun Fire X4100 M2 server* — The Sun Fire X4100 M2 server is a fast, reliable, and energy-efficient one- to four-way x64 server in a 1 RU form factor. Powered by one or two dual-core or single-core AMD Opteron 2000 series processors, this compact

power-saver saves up to 56 percent on power and cooling costs compared to servers based on Intel Xeon processors[1].

- *Sun Fire X4200 M2 server* —The Sun Fire X4200 M2 server is a fast, reliable, and expandable one-way to four-way server in a 2 RU form factor x64 server. Like the Sun Fire X4100 M2 server, the Sun Fire X4200 M2 server can be purchased with one or two dual-core or single-core AMD Opteron 2000 series processors. Sun Fire X4200 servers provide virtually unmatched flexibility in their class with twice the storage capacity and more I/O ports compared to the Sun Fire X4100 server.
- *Sun StorageTek™ 2540 array* — The affordable Sun StorageTek 2540 array is ideal for primary workgroup and enterprise-class tier 2 storage. The array delivers reliable RAID functionality and the highest availability in its class. The flexible, high-density array is easy to deploy with Fibre Channel and optimized for rack-intensive environments.
- *Sun StorageTek QFS software* — Sun StorageTek QFS software provides a high-performance storage solution that enables customers to consolidate, share, and protect their business information. It improves time to results for collaborative environments by offering highly scalable file distribution in a LAN environment and exceptional performance for accessing data.
- *Solaris 10 Operating System* — One of the most advanced operating systems available, the Solaris 10 OS is the latest version of Sun's industry-leading operating system. Interoperable with Linux and Windows, the Solaris OS also offers binary compatibility within each Sun server line, whether based on UltraSPARC®, AMD Opteron, or Intel Xeon processors. As a result, all Sun servers running the Solaris 10 OS provide powerful features that can help reduce cost, complexity, and risk.
- *MySQL database server* — The MySQL database server is the world's most popular open source database environment and according to Evans Data Corporation, it has achieved 25 percent market share in overall database usage by developers in the last two years[2]. It offers one of the most powerful transactional database engines on the market and provides rock-solid reliability and availability.
- *Cool Stack* — Cool Stack is a variant of the commonly used Open Source Apache, MySQL and PHP (AMP) platform that has been compiled with performance settings specifically for the Solaris 10 operating system. Cool Stack binaries are compiled and optimized with Sun Studio 12 compilers, resulting in a 30- to 200-percent performance improvement over standard binaries compiled with GCC. Cool Stack binaries can be deployed on both x64 and SPARC® systems running the Solaris OS.
- *Tsung Open Source load framework* — Sizing tests for the reference architecture utilize the Tsung Open Source load framework written in the high performance Erlang computing language.

1. One Rack of Sun Fire X4100 Servers populated with AMD Dual-Core Processors can take as much as 56 percent less power on average than the Intel Xeon MP processor based solution required to provide a similar amount of CPU cores.

2. Market share statistics are available at www.mysql.com/why-mysql/marketshare/.

Key benefits

The reference architecture identifies key system components and processes that are required to achieve high service levels and scalability. It provides the following major benefits to educational institutions:

- *Higher service levels* — The architecture is designed to optimize service levels with redundant components and automated failover using cluster technologies.
- *Reduced cost* — Virtualization technologies enable consolidated solutions with higher resource utilization and configuration sizing information helps customers avoid overprovisioning or underprovisioning their systems. Best practices for management can also reduce the cost of maintaining the solution environment.
- *Faster time to delivery* — Accelerates deployment by providing proven and tested configurations with simplified installation and a complete hosted solution that can be up and running almost immediately.
- *Reduced risk* — Validated hardware and software configurations are combined with pretested installation scripts to greatly reduce the risk of unforeseen problems in a production implementation of the Moodle software platform.

Chapter 3

Moodlerooms and Sun Reference Architecture

The Moodlerooms and Sun Reference Architecture is an implementation of the open source Moodle software platform utilizing free virtualization technologies from Sun to help optimize the performance and efficiency. By taking advantage of Solaris Containers and high performance, energy-efficient Sun servers, the architecture enables institutions to deliver higher service levels while reducing costs. And because the architecture's modular design, it offers the flexibility to start with a cost-effective small implementation and then scale to a large enterprise installation.

Figure 1 shows a logical representation of the architecture with hardware and software components defined across the application, database, storage and management tiers.

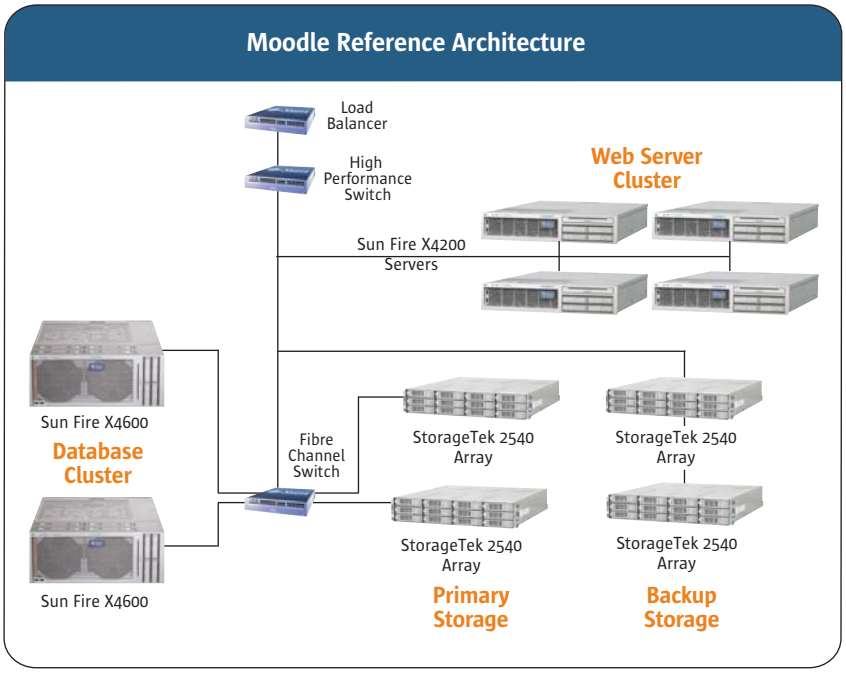

Figure 1. The reference architecture defines an optimized configuration that takes advantage of Sun technologies

Delivering high availability

The architecture is designed to deliver "five nines" availability when deployed using advanced clustering technologies as with the "Large" configuration. Redundancy is built-in on multiple levels including:

- Horizontally scaled application tier with load balancing across redundant servers
- Multiple instances of Moodle software components running on the Sun Cool Stack, an optimized open source software stack

- Optional clustered database
- Storage solutions with RAID availability and/or redundant connectivity

Moodlerooms uses the Solaris virtualization technology called Solaris Containers, sometimes referred to as Solaris Zones, to deploy all instances of software throughout both the Web tier and the database tier. Solaris Containers not only isolate separate instances of Moodle software from a security point of view, but they also enable fine-grained resource management.

Solaris Containers can be dynamically reconfigured to add or subtract memory and processing power. This enables much greater flexibility when managing the operational characteristics of the Moodle software implementation. By using this capability, administrators can proactively avert major performance problems by quickly assigning additional resources to specific instances of the Moodle software when faced with a sudden increase in user loads.

The sections that follow provide further information on the specific software components that are deployed across each tier of the architecture and the options that customers have for scalability and availability. Customers can decide the level of scalability and availability required for their environment and then choose the configuration options that best suit their needs.

Across all of the tires described below, network traffic is handled using Virtual Private Networks (VPN) for increased security and efficiency and to help ensure that security issues do not become causes for system downtime.

Web tier

The Web tier contains the Moodle software platform running on one or more Sun Fire X4100 M2 or X4200 M2 servers. The Sun Fire servers are deployed using a horizontally distributed architecture in which the servers are partitioned into multiple Solaris Containers, each acting as a virtual system. Each Solaris Container runs an independent instance of Moodle software that is securely isolated from other instances running on the same server and using the same instance of the Solaris OS. The architecture utilizes load balancing to distribute the user workload evenly across the separate Moodle software instances within their respective Solaris Containers.

For small campus environments where there is a need to control costs by consolidating the entire Moodle platform onto a single low cost server, the X4100 M2 server is recommended. It must contain at least two separate containers so that the database tier can be isolated from the Web tier. If multiple instances of Moodle software are required for the Web tier, additional Solaris Containers must be created so that each Moodle software instance can run in its own Solaris Container.

For medium and large configurations, the Sun Fire X4200 M2 server with four AMD Opteron cores and 16 GB of memory is recommended. The architecture utilizes load balancing to distribute the workload across the Moodle software instances deployed in the Web tier (each in their own Solaris Container). The load balancing software can distribute the load across multiple Solaris Containers within a single server or across multiple servers when redundant Sun Fire X4200 servers are deployed.

Optimized Sun Cool Stack

Moodle software instances run on an optimized version of the Sun Cool Stack, a variant of the commonly used open source Apache, MySQL and PHP (AMP) platform. The Moodle PHP codebase is deployed on the Apache2 Web server as part of the Cool Stack. The PHP execution environment is also part of the Cool Stack. Cool Stack has been compiled with performance settings specifically for the Solaris 10 operating system and Moodlerooms has optimized the PHP engine with the Sun Studio 12 compiler to take best advantage of the Sun x64 servers.

Record performance in industry benchmark

The Sun Fire X4200 M2 server is an ideal platform for the Web and application tiers due to its low TCO, energy efficiency, and high throughput for multi-threaded applications such as Web servers and application servers. As of May 17, 2006, the Sun Fire X4200 server running the Solaris 10 Operating System showed record performance for 2-socket, 2-way systems[3].

Database tier

The database tier contains the MySQL database, which is used to maintain user records and indexes to application specific data such as course offerings, student profiles, test results, etc. The database server requires vertical scalability because there is a single large database instance used by all application tier servers. The reference architecture recommends different size systems for the database tier depending on the expected volume of user transactions.

For hosted solutions, Moodlerooms runs MySQL 5 enterprise with a Platinum support contract from MySQL. Each database is a trusted build from MySQL optimized for Solaris 10 and is deployed into zones for independent management and fail-over.

High availability in the database tier is supported through an optional cluster configuration with a fully redundant database server. Customers can use Sun Cluster software and multiple instances of the MySQL database to provide redundancy. The

3. Results as of May 17, 2006. The Sun Fire X4200 server, powered by single-core AMD Opteron Model 256 processors, delivered a new high score of 38,090 SPECjbb2005 bops for throughput and a new high score of 32,018 SPECjbb2005 bops/JVM for JVM scaling. More information is available at sun.com/servers/entry/x4200/benchmarks.jsp#13. For the latest results, visit www.spec.org.

database server can thus be configured to support automatic failover in the event of a critical fault.

Recommended configuration for large campus environments

For large campus configurations, the Sun Fire X4600 M2 server with four cores and 32 GB of memory is the recommended database server configuration. This server can be expanded to up to eight cores if the volume of database transactions increases beyond the recommended capacity for the four core configuration.

Application consolidation using Solaris Containers on the Sun Fire X4600 server is a promising way to lower costs and complexity, increase flexibility and scalability, and reduce datacenter space and energy requirements by enabling multiple virtual servers to run efficiently and without conflict on the same physical platform.

Based on several industry standard benchmarks, the Sun Fire X4600 M2 server is the world's fastest system of its kind. The combined capabilities of the Sun Fire X4600 server and Solaris Containers technology produced record breaking single node performance in the industry-standard SPECjAppServer2004 benchmark. With a result of 1000.86 SPECjAppServer2004 JOPS@Standard, the Sun Fire X4600 server surpassed many competing solutions that used multiple physical servers even though the Sun Fire X4600 test ran everything in a single physical system.

Recommended configuration for medium campus environments

For medium campus configurations, the recommended server configuration is a Sun Fire X4200 M2 server with 4 cores and 16 GB of memory. Its record setting database price/performance, low TCO, and high energy efficiency make the Sun Fire X4200 M2 server an ideal platform for medium size database workloads. It delivers world-record performance on variety of compute intensive and enterprise-class industry-standard benchmarks.

The fast, reliable, and expandable Sun Fire X4200 M2 server demonstrated the best price-performance on the industry standard TCP-H benchmark among all 2-socket/4-core TPC-H results at the 100GB scale factor. The TPC-H benchmark demonstrates the performance of Business Intelligence/Data Warehousing (BIDW) and Decision Support Systems (DSS), allowing customers to evaluate the performance of various DSS systems in conjunction with a standard database size, referred to as the scale factor (SF)[4].

4. Results as of May 25, 2007. The Sun Fire X4200 M2 server achieved the result of 8587QphH@100GB on the TCP-H benchmark. The tests utilized SybaseIQ database manager and used RAID-protected database storage to emulate real-world enterprise datacenter requirements. More information is available at sun.com/servers/entry/x4200/benchmarks.jsp#19. For the latest results, visit www.spec.org.

Storage tier

The Moodle software platform is used to store large artifacts such as multimedia course delivery materials, student reports and assignments, and any other content that is submitted for sharing between students and teachers. In addition to educational content, the storage environment also maintains a primary and backup copy of the MySQL database index (in all cases except the small campus configuration). As the number of users increases as in the large campus configuration, storage requirements can become quite substantial.

To meet the demanding storage requirements of the large campus configuration, storage is implemented on external Sun StorageTek 2540 arrays using a storage area network (SAN) with dual connections via a fibre channel switch for redundancy.

The total storage requirement will vary for each institution based on the size of the user population and total number of courses being managed in the system. The best way to estimate the total storage required is to start with an amount of storage that was required for an initial implementation with a small set of users and courses. The storage requirement for the larger configuration can then be calculated by using the same ratio of storage per user (based on population size as opposed to concurrent users) and storage per courses.

In the absence of known storage requirements for a subset of the system, a rough approximation of storage requirements can be achieved by using the estimate of 100 MB per course plus 20 MB per user. As the system grows, an estimate that more closely matches the unique usage patterns of the institution can be substituted.

High-performance file system

The file system that maintains the digital content stored in the Moodle software utilizes Sun StorageTek QFS software to enhance the performance of shared access to the storage pool. Files can be stored across multiple hardware systems to improve scalability while isolating the Moodle software application from the details of the physical storage infrastructure. Up to 128 systems can have shared access to the same data while maintaining file integrity and storage volumes can scale up to four petabytes in size.

StorageTek QFS technology delivers performance that virtually matches that of direct access to raw devices and scales linearly as hardware is added. The software allows multiple I/O streams to write in parallel across multiple disk systems for increased bandwidth. It also stores metadata (information about files) separately from the data, thus improving high performance RAID cache utilization, reducing access latency, and enabling cost-effective mirroring of metadata.

Optional digital media server

For institutions that have a requirement for a significant volume of multimedia storage and playback, the storage tier can be augmented with the Sun Fire X4500 server can be deployed as a digital media server that supports the Web tier. With up to 48 TB of storage in a 4-way AMD Opteron server, the Sun Fire X4500 server is an ideal platform for the high capacity and demanding I/O throughput requirements of streaming video. This powerful digital media server can be NFS mounted for transparent access and high performance digital media storage and delivery by any Moodle software instance in the configuration.

Management tier

The reference architecture is based on open systems solutions with standard interfaces that make it easier to provision and manage the IT infrastructure.

The management environment includes an open source tool for managing the resources assigned to specific Solaris Containers (and thus specific instances of Moodle software). A central configuration management utility enables the administrator to both create and manage Moodle software instances by managing and provisioning the Solaris Containers in which the Moodle software instances reside.

When deploying new instances of Moodle software, an administrator can quickly provision them along with a new Solaris Container — all as a single operation. Administrators can then redistribute system resources between existing Solaris Containers to adjust the performance of Moodle software instances. Whenever additional resources are added to the hardware environment, they can then be assigned to existing Solaris Containers as desired.

The entire environment can also be integrated into a higher level management framework that encompasses management of the broader heterogeneous environment throughout the datacenter. Third party enterprise management solutions can interact with Sun server and storage components using simple network management protocol (SNMP) to manage the components within this broader management framework.

Administrators can also take advantage of Sun management tools such as the following for managing the datacenter infrastructure:

- *Sun™ xVM Ops Center* — Sun xVM Ops Center provides a single unified interface to simplify the discovery, provisioning, updating, monitoring, and reporting of datacenters assets in Linux and Solaris environments. It uniquely integrates virtualization and management to help customers better manage both physical and virtualized assets across heterogeneous environments. Sun xVM Ops Center is specifically designed to work in existing datacenters and can easily integrate with other toolsets. Customers can use the unified Sun xVM Ops Center tool to manage

multi-platform x64 and SPARC systems distributed throughout their global datacenter.

- *Sun™ Management Center* software — Sun Management Center software provides in-depth monitoring and management capabilities for the entire line of Sun servers. Customers can utilize in-depth diagnostic information as well as analysis and reporting to improve system performance and availability. Sun Management Center software also provides support for advanced Solaris 10 features, including Solaris Containers and the Solaris Dynamic Tracing (DTrace) facility.
- *Sun℠ Connection* — Sun Connection simplifies the process of tracking, provisioning, updating and managing Solaris and Linux operating system configurations. OS updates can be delivered and automatically provisioned to registered servers at the customer location and administrators can elect to update entire groups of servers based on user-defined rules.

Validated configurations

Sun and Moodlerooms have invested in performance testing and characterization of Moodle software on Sun servers to help institutions properly configure and size their systems, reducing the risk of unforeseen problems. The results of these tests have been used to define specific configurations that are known to offer sustained throughput similar to what is expected for small, medium and large campus scenarios as defined below.

Table 1. Configuration information for small, medium and large campus configurations

Description	Small Campus Configuration	Medium Campus Configuration	Large Campus Configuration
Concurrent Users	• Up to 100	• Up to 1,500	• Up to 25,000
Application Tier	Sun Fire X4100 server • 2 X AMD Opteron dual-core processors • 8 GB memory	2 X Sun Fire X4200 servers • 2 X AMD Opteron dual-core processors • 16 GB memory	2 X Sun Fire X4200 servers • 2 X AMD Opteron dual-core processors • 16 GB memory
Database Tier	MySQL running in a separate zone in the same Sun Fire X4100 server that runs the application tier	2 X Sun Fire X4200 servers • 2 X AMD Opteron dual-core processors • 16 GB memory	2 X Sun Fire X4600 servers • 4 X AMD Opteron dual-core processors • 32 GB memory
Storage Tier	• Total raw capacity of 146 GB • Dual 73 GB drives in the Sun Fire X4100 server • RAID 5	• Total raw capacity of 146 GB • Dual 73 GB drives in the Sun Fire X4200 servers in the database tier • RAID 5	• Total raw capacity of 8 TB in primary storage • 2 X Sun StorageTek 2540 arrays • SAN infrastructure • RAID 6

Small Campus Configuration

Figure 2 shows a representation of the small campus configuration that is designed to support a user community of up to 100 concurrent users in a single system configuration that utilizes Solaris Containers (Solaris Zones) to isolate the application tier from the database tier.

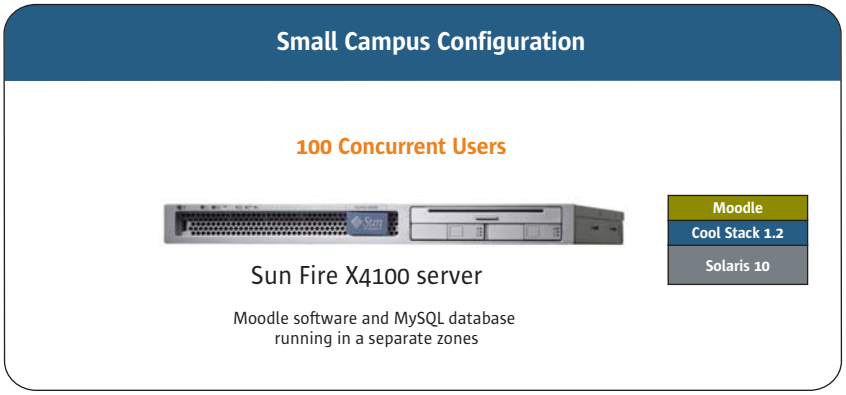

Figure 2. Small Campus Configuration

Medium Campus Configuration

Figure 3 shows a logical representation of the medium campus configuration that is designed to support a user community of up to 1,500 concurrent users.

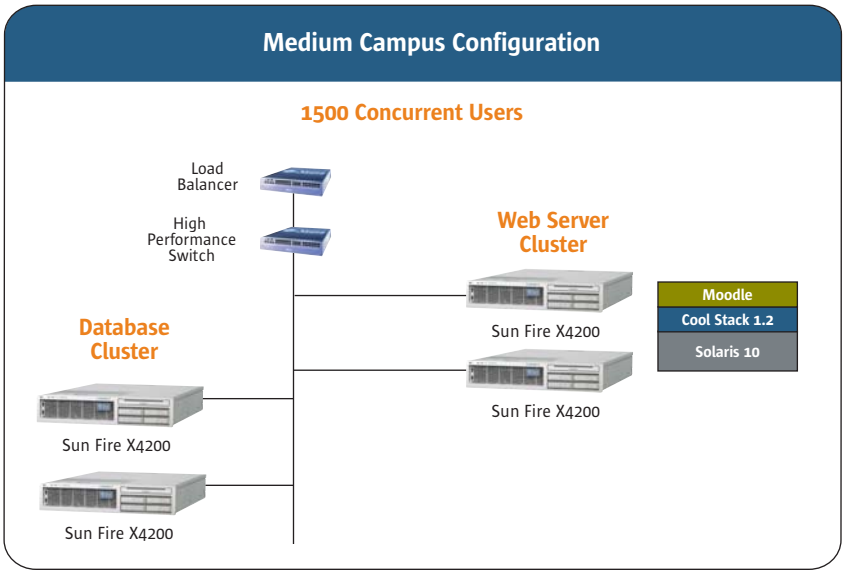

Figure 3. Medium Campus Configuration

Large Campus Configuration

Figure 4 shows a logical representation of the large campus configuration that is designed to support a user community of up to 3,000 concurrent users.

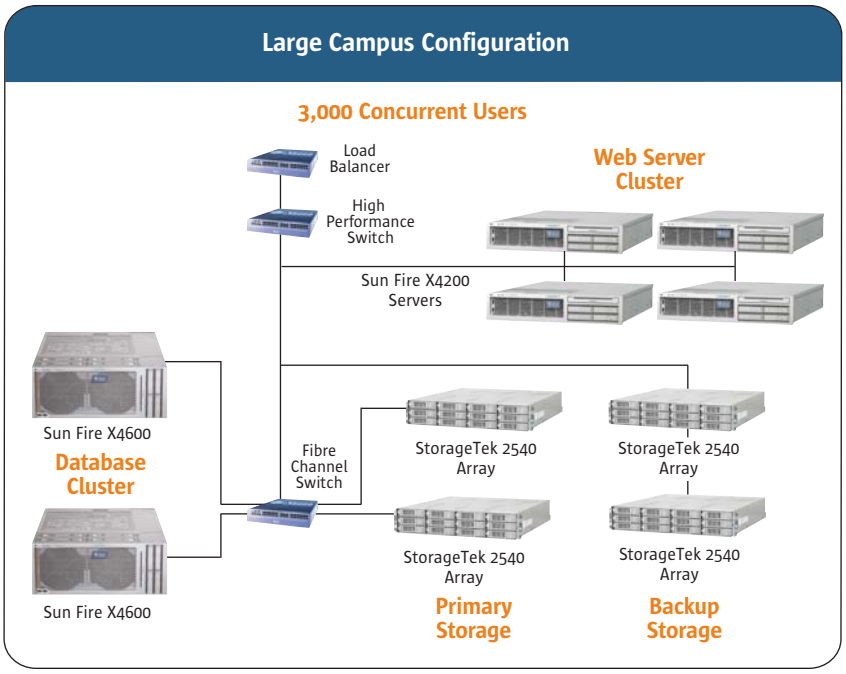

Figure 4. Large Campus Configuration

Chapter 4

Conclusion

With tight budgets and limited IT staff resources, educational institutions are always looking for ways to improve their IT services in the most efficient manner possible. The Moodlerooms and Sun Reference Architecture enables institutions to combine the flexibility and low cost of open source with a fully supported turnkey solution based on highly efficient Sun systems. The reference architecture takes advantage of many innovative Sun technologies that can help institutions do more with less.

Specific advantages of the combined solution include:

- *Reduced risk*
  The Moodle platform has been proven to run well on Sun systems and the Solaris OS. The specific configurations described in this white paper have also been validated to meet the performance requirements of specific campus scenarios. The enterprise-class RAS features in Sun CoolThreads servers and their cooler operating temperatures help these systems deliver mission-critical reliability that far surpasses that of similarly priced PC-based servers. This reliability is further enhanced by the predictive self-healing capabilities in the Solaris 10 OS, providing maximum protection for Moodlerooms customers whether deploying an in-house solution or a hosted solution that is deployed and maintained by Moodlerooms.

- *Investment protection*
  The Moodlerooms and Sun reference architecture offers extremely high scalability so that customers can start with a small pilot system and grow to a large enterprise installation using the same platform and architecture. By adhering to open standards, using open source software, and providing a choice of CPU architectures and OS environments, the architecture also gives customers complete freedom to change their implementation in the future or utilize new technology advances when they become available.

- *Low TCO and eco-responsibility*
  With hosting services priced at $1 per student per year, the Sun and Moodlerooms reference architecture offers a cost-effective way to implement and sustain an LMS infrastructure. For customers that deploy their solutions in-house, the architecture's use of open source software with no software license costs and the industry's fastest and most space and energy efficient systems, helps keep costs low while providing an eco-responsible infrastructure.

- *Fast time to market and increased flexibility*
  The hosted solution can be up and running quickly and can be easily transitioned to an in-house implementation if and when desired. Sun's broad line of binary compatible servers offers further flexibility with a cost-effective growth path to an enterprise implementation for customers that choose to deploy their environment in-house.

For more information

For additional information on how Sun and Moodlerooms can help educational institutions build cost-effective LMS solutions that are highly reliable and scalable, visit the Web sites below or contact a local Sun representative.

Table 2. Web links for additional information

Web Site URL	Description
sun.com/edu	Sun solutions for education and research
www.moodlerooms.com/	Moodlerooms home page
download.moodle.org/	Download site for the Moodle course management system
sun.com/solaris	Solaris Operating System
sun.com/x4600	Sun Fire X4600 servers
cooltools.sunsource.net/coolstack/	Sun’s optimized open source software stack (Cool Stack)
sun.com/storagetek/	Sun StorageTek storage solutions
sun.com/ldoms	Sun Logical Domains (LDoms)
sun.com/solaris/containers	Solaris Containers

Appendix A

Performance Characterization

The configurations recommended in this document are based on performance characterization tests that were performed by Moodlerooms and Sun. Tests indicated a specific number of transactions per second that could be achieved with each configuration. These numbers were then used to estimate maximum user loads in terms of concurrent users based on historically relevant usage patterns for Moodlerooms customers.

The test environment consisted of multiple Sun servers and storage systems configured in multiple tiers as shown in Figure 5. Users were simulated by generating HTTP requests on Sun Fire T2000 servers as shown in the left-hand side of the diagram. Testing scripts were written using the Tsung open-source distributed load testing tool (tsung.erlang-projects.org).

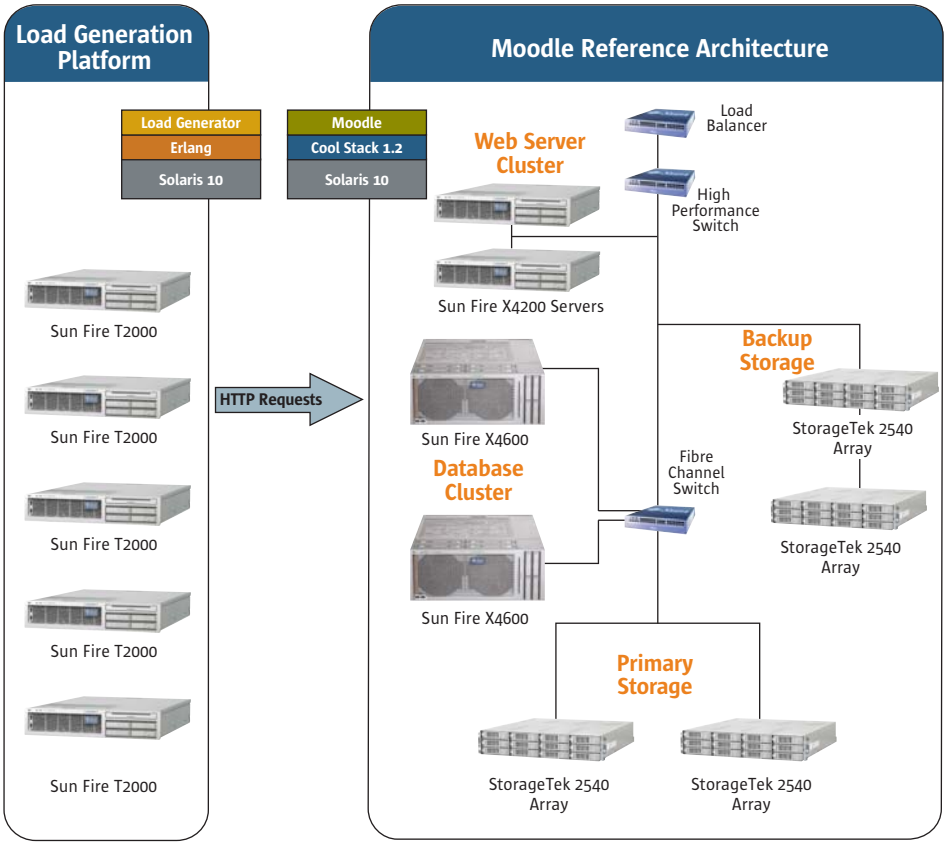

Figure 5. Test Configuration

For more information on performance characterization results or how to run similar scalability tests against another configuration, please contact a Moodlerooms or Sun representative.