A VIRTUALIZED ARCHITECTURE FOR MOODLEROOMS SCALABILITY

HIGH SERVICE LEVELS WITH COST-EFFECTIVE DELL SYSTEMS

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Contents

Chapter 1

Introduction

A growing population of students and their high demand for online content is making online learning a mission-critical application. Growth in the number of online students stems both from an increase in the need for continuing education in today's workforce and the fact that distance learning provides access for students who might not otherwise be able to participate in on campus courses.

The success of an online learning initiative is dependent upon achieving predictable high service levels even during peak demand periods. Yet most institutions cannot afford to spend a lot of money on their Learning Management System (LMS) software nor its implementation. The cost of deploying and maintaining a proprietary LMS solution is causing many educational institutions to look for new ways address their needs. Many are considering open source software and hosted offerings that can help reduce cost and complexity.

Moodle is emerging as the leading open source LMS solution with more than 45,000 registered sites. Moodlerooms is making it easy for institutions to get up and running quickly with their Moodle LMS implementation through hosted offerings, value-added software and services, and a full spectrum of additional support options that can help increase instructor participation.

Moodlerooms can help institutions get started quickly with no capital expenditure and no long-term commitment. The hosted services provide high service levels without requiring a big team of internal developers or administrators.

Dell and Moodlerooms have partnered to design and test a high performance hosted environment that offers massive scalability for the Moodlerooms implementation. This not only yields improved service levels for Moodlerooms users, but also results in lower costs that are passed on to users in the form of lower subscription rates.

Characterization tests were performed in Dell's labs to define a recommended architecture and to measure scalability for a multi-tenancy hosted solution. This white paper offers an overview of the hosted architecture from Dell and Moodlerooms and describes the benefits of the combined offering.

Chapter 2

The Dell and Moodlerooms Solution

Moodlerooms combines the benefits of the open source Moodle software platform with enterprise-level security, reliability and scalability, enabling institutions to confidently focus on high-quality teaching and learning.

The Moodle software platform was designed using sound pedagogical principles and has been embraced by a broad community of more than 30 millions users in over 200 countries. 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 600,000 students. The open source Moodle software platform can be downloaded for free and thus offers a low cost LMS that makes online learning practical.

Choosing open source software for a mission-critical application such as eLearning, however, often brings up concerns about being able to properly design, build, and support an IT environment that can deliver consistently high service levels for users.

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. Moodlerooms also devotes ongoing development efforts to the open source Moodle software platform to help the platform continue to grow and evolve. All code contributed by Moodlerooms is tested for quality assurance to verify its functionality, security and scalability.

Services offered by Moodlerooms include:

- **Hosting solutions** — Moodlerooms provides a wide range of hosting and bandwidth packages. From individual users to institutions with tens of thousands of users, Moodlerooms offers secure hosting of Moodle software to simplify deployment and ongoing support.

- **Help-desk services** — To help support onsite implementations and users of hosted services, Moodlerooms offers first-line help to users and administrators as well as context-sensitive help features. These extra help and support features make Moodle even easier to use in a real classroom setting.

- **Implementation/integration services** — Moodlerooms can write the customization code that will integrate the Moodle platform into a Student Information System (SIS) or other existing applications within the 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.

The combined offering from Dell and Moodlerooms can provide the following key benefits to institutions:

- **Reduced cost** – Open source software deployed on a cost-effective hardware architecture that offers extreme performance and scalability and utilizes virtualization technology to enable high resource utilization.

- **High service levels** – The architecture has been proven to support 2,500 concurrent users and 150 page requests/second with a single database server. This demonstrates very good scalability for the Moodle application itself while the Moodlerooms hosting service provides another dimension of scalability. The hosting service can scale to support virtually any number of Moodlerooms customers and Moodle application instances. No known upper limit has been identified and the architecture is expected to support many times the number of users supported by a single database server.

- **Reduced risk** – Pre-validated hardware and software stack greatly reduces the risk of unforeseen problems in a production implementation.

- **Agility** – Hosted offering can be up and running almost immediately and can be easily and quickly expanded as needed.

Chapter 3

Scalable Multi-tenancy Architecture

Dell, Moodlerooms and Intel have come together to design and test a virtualized architecture that takes advantage of today's latest technologies to deliver a highly scalable solution for the multi-tenancy hosting environment at Moodlerooms.

The solution architecture was designed by a team of engineers from Dell and Moodlerooms. The team took advantage of testing resources at the Dell testing facility in Round Rock, Texas to validate and fine-tune the architecture and to profile its capacity. The rigorous testing included performance benchmarks, which affirmed that the architecture was capable of supporting in excess of 2,500 concurrent user sessions when using a small, cost-effective footprint of Dell servers and storage systems. The following chapter provides additional details about the results of the performance tests. Due to the modular nature of the architecture, it can be scaled to support virtually any number of Moodlerooms customers.

Figure 1 shows a logical representation of the architecture with different tiers for the application, database, and storage components of the architecture. Each tier can be expanded independently as needed to support increased load, enabling Moodlerooms to easily adapt the architecture as their customer base and user loads evolve over time. The architecture includes a unique database instance for each customer, providing enhanced security and enabling easy expandability of the database tier. The solution also takes advantage of VMware virtualization technologies at the database tier, enabling higher utilization of the Intel 5500 series processors in the database servers.

The subsections that follow provide additional details about the design of the architecture.
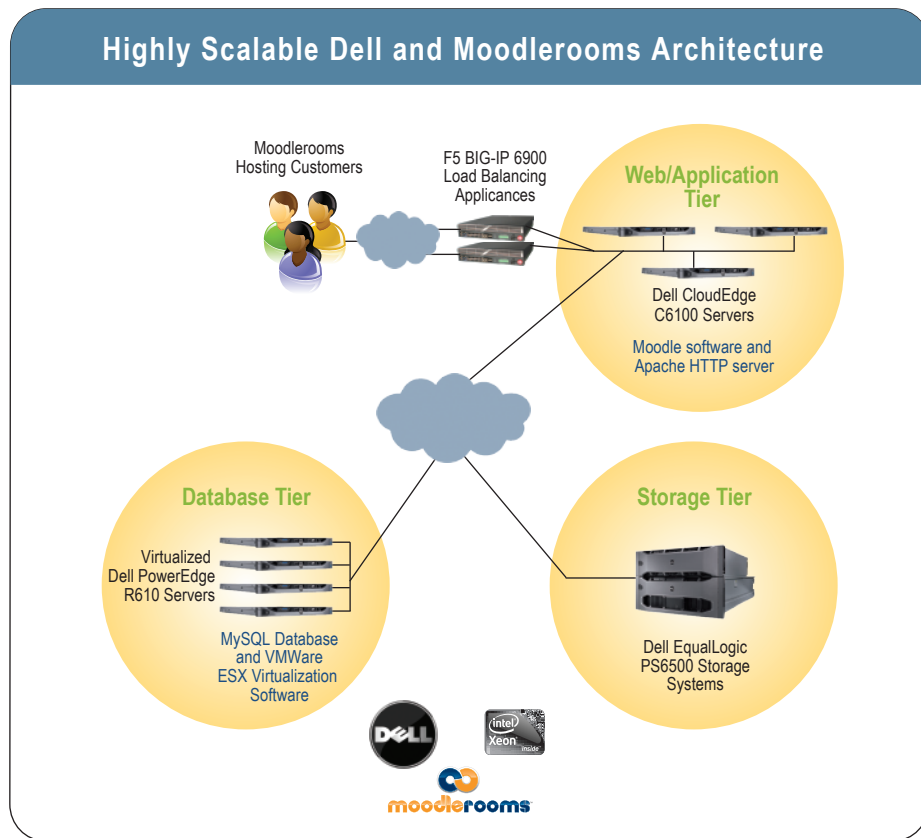
Figure 1: Logical Diagram of Dell and Moodlerooms Architecture

Flexible Web/Application Tier

The horizontally scaled Web/application tier uses load balancing across a pool of servers to support a high volume of user requests. Load balancing is achieved by using an application delivery switch such as the F5 Networks BIG-IP® 6900 platform to distribute user requests across the available server resources. Transactions are dynamically assigned to physical servers to distribute workloads and to enable fast recovery from a hardware failure.

Each physical server in the Web/application tier runs a single instance of the Moodle application and one instance of the Apache HTTP server. Dell™ PowerEdge™ C6100 servers were chosen for the Web/application tier because of their small footprint and the price/performance advantages of Intel 5500 series processors. It is recommended that each PowerEdge C6100 server be configured with 24 GB of memory and two quad-core Intel 5500 series processors, providing eight CPU cores or 16 threads within each server. The Web/application tier could also be built using other Dell servers such as Dell™ PowerEdge™ R610 rack mountable servers or Dell™ PowerEdge™ M610 or M710 blade servers, all of which feature the latest Intel 5500 series processors.

The Web/application tier can be easily scaled by simply deploying additional Dell PowerEdge C6100 servers to meet the increased user load. Each additional server also adds to the availability of the Web/application tier by providing

resilience in the event that a different server goes down. Upscaling to add more capacity is a seamless process for Moodlerooms and its clients.

Customized Presentation Layer

Moodlerooms supports a unique customized view for each Moodlerooms customer. Using its proprietary SaaS Configurator, Moodlerooms presents a virtual dedicated version of the Moodle application to each customer. All users within the same organization thus view the same uniquely branded version of the application, including a tailored feature set and unparalleled security.

Database Tier

The Moodlerooms database is based on MySQL and holds the index for course offerings, student profiles, and student data such as homework and test results. The database tier uses VMware vSphere 4 virtualization technology to enable the platform to scale well for multiple Moodlerooms customers. There is one database instance for each Moodlerooms customer and each database instance is run in its own virtual machine to maximize security. The use of multiple virtual machines also enables Moodlerooms to more fully utilize the Dell PowerEdge R610 server.

The Dell PowerEdge R610 server was chosen because of its small footprint, low cost, and powerful performance in virtualized environments. The virtualized database tier allows Moodlerooms to take full advantage of the powerful Intel 5500 series processors on the Dell PowerEdge R610 servers.

Higher Utilization Through Virtualization

VMware vSphere 4.0 virtualization technology enables each physical server in the database tier to run multiple instances of the Red Hat Enterprise Linux operating system and multiple MySQL databases. VMware vSphere 4.0 abstracts server processor, memory, storage and networking resources so that each operating system instance can have direct control over specific system resources. Applications are then installed and can operate on these virtual machines (VMs) in much the same way that they run on separate physical servers. VMware is the market-leading provider of hypervisor technology with production-proven installations at thousands of customers of all sizes.

An important reason for implementing virtualization in the database tier is that modern CPUs such as the Intel 5500 series processors are so powerful that a single instance of the operating system and one database typically cannot fully utilize the CPU. Thus, it's more cost-effective to add more memory to a server and divide its resources into multiple virtual machines than it is to deploy multiple physical servers where each server is only partially utilized.

As shown in Figure 2, each physical server can support up to 15 virtual machines and from 15 to 150 separate customer databases in this Dell and Moodlerooms architecture.

To optimize performance and database server resource utilization, it is recommended that each virtual machine in the database tier be sized with two virtual CPUs and approximately 4 GB of memory. The tests that were run in the Dell lab utilized 4 GB of memory for each virtual machine and the team found this to be plenty of memory for the workload that was tested. Other workloads may require more or less virtual memory depending on the number and size of databases deployed and the level of user activity.

As noted in the figure, it is possible in the Dell and Moodlerooms architecture to run up to 10 MySQL instances within a single virtual machine while still providing complete data isolation and security. Security is maintained through the inherent security features in the MySQL database.

Database Server Virtualization
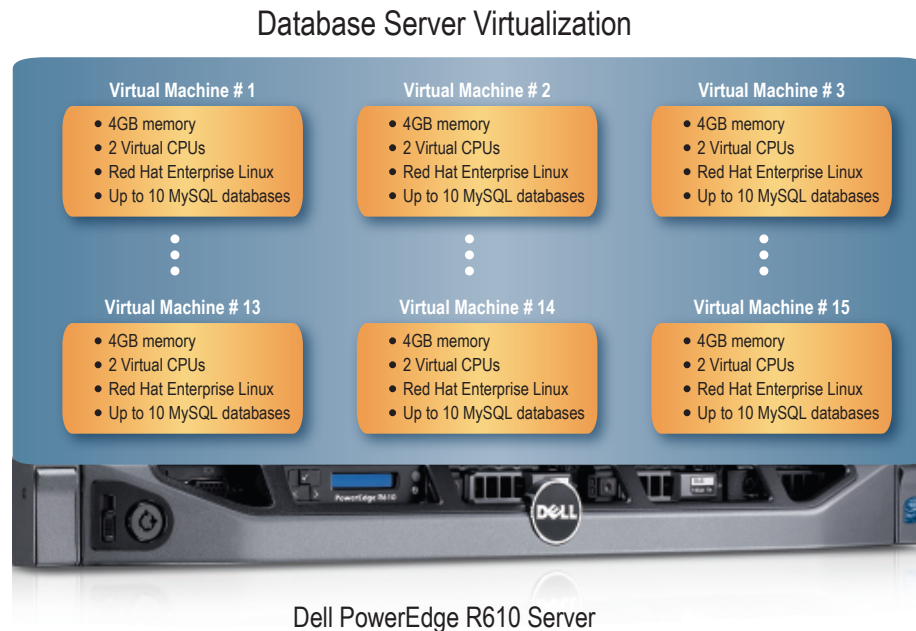
Figure 2: Database server virtualization enables high utilization.

Increased Availability Through Virtualization

A second key reason for virtualizing the database tier is to increase application availability. The VMware High Availability (HA) feature allows all of the VMs on a server to be automatically restarted from another server should that server fail unexpectedly. VMware VMotion also eliminates the need to schedule application downtime due to planned server maintenance. It enables live migration of virtual machines across servers with no disruption to users or loss of service.

While not required at this time, database server redundancy could also be implemented using a clustered database farm and automated HA failover.

Benefits of Virtualization

With its virtualized database tier, the architecture can help customers achieve:

Lower costs – Increased utilization of servers enables good performance on a low-cost consolidated infrastructure, enabling savings to be passed on to Moodlerooms customers.

Increased flexibility – Virtual machines can be easily moved to other physical servers to redistribute resources or to recover quickly from a hardware failure.

Increased service levels – High availability and service level control features in VMware can help increase availability while also helping to achieve response time objectives.

Storage with Reduced Complexity

The storage tier utilizes Dell EqualLogic PS Series storage systems, which were chosen because they provide affordable enterprise-class storage and the flexibility to support the NFS storage needs of the Moodlerooms application environment. An NFS mount point is created by assigning a machine within the Web/application tier to act as an NFS gateway to the storage arrays.

Dell EqualLogic PS Series arrays simplify storage deployment by offering seamless access to a single pool of storage that can be easily allocated to specific components of the architecture. The arrays also include intelligent automation of storage management. They offer single console management and ease of storage provisioning to increase the power and flexibility of the storage infrastructure. Additional arrays can be seamlessly added into an existing SAN to automatically increase storage pool resources without disruption of the Moodlerooms application or the availability of its data.

The Moodlerooms storage environment utilizes Dell EqualLogic PS6500X storage systems for the primary storage area network and EqualLogic PS6500E storage systems for backup and second tier storage.

Web/application servers use the NFS protocol to store and retrieve data such as course syllabi, assignments, assessments and other learning content. This data is accessed via an NFS gateway in the Web/application tier, which then connects to the Dell EqualLogic storage area network to store or retrieve data to/from the Dell EqualLogic storage arrays using the iSCSI protocol. Database content residing on the EqualLogic storage systems is accessed directly through a 1 GB Ethernet network switch connected to the Dell EqualLogic storage arrays.

Benefits of the Storage Tier Design

The storage infrastructure based on Dell EqualLogic PS Series storage systems brings the following benefits to Moodlerooms and its customers:

- **Optimized utilization** – Storage utilization is optimized by balancing loads dynamically among multiple storage arrays as usage patterns change.

- **Reduced deployment time and effort** – The EqualLogic PS Series Group Manager enables administrators to easily create new volumes and assign them to server hosts.

- **Reduced management complexity** – EqualLogic PS Series SANs simplify storage management by consolidating physical storage and providing a single-pane management view of the entire virtualized storage pool.

- **High scalability** – Adding more PS Series array members to a PS Series group allows storage capacity to scale along with performance and does not disrupt application or data availability.

- **Increased flexibility** – The net result of all these features and capabilities is to enable IT administrators to respond quickly and flexibly to enterprise demands and initiatives.

Network Environment

Due to the high volume of data that flows between servers and storage systems in the Dell and Moodlerooms architecture, a high-performance Ethernet network is utilized. The network includes a storage area network (SAN) to help improve

I/O throughput and increase reliability. Sub-networks with the greatest traffic volume are implemented with 10 GB Ethernet while other parts of the network utilize 1 GB Ethernet.

For load balancing at the Web/application tier, the BIG-IP 6900 application delivery controller from F5 Networks is used to enhance performance and throughput. The BIG-IP 6900 system delivers high performance for SSL encryption of Web forms by using hardware to encrypt and decrypt both the keys and data. With two dual-core processors, it can process up to 6 Gbps and has the performance needed to operate as an integrated platform for application delivery.

Chapter 4

Proven Performance

To validate the design of the architecture and to identify server resource requirements, a team of engineers from Dell and Moodlerooms conducted a Proof of Concept project that included a series of performance benchmark tests. The tests were performed at a Dell testing facility in Round Rock, Texas using servers and storage systems based on the latest Intel processors. Multiple configurations were tested to determine the most effective way to use virtualization to maximize performance and availability with a cost-effective infrastructure.

This chapter describes the benchmark process and interprets the performance results in terms of what it means for the large hosting environment at Moodlerooms.

Benchmark Process

The first series of tests utilized a Jmeter script from Moodlerooms that simulated users logging in to the Moodlerooms hosting service and performing a few simple operations such as retrieving a course listing and selecting an activity within a course. The goal of the performance testing effort was to determine the maximum number of concurrent users sessions that could be running against a single virtualized database server. The database server would be tested in multiple configurations using virtualization to allocate server resources to specific databases. More and more users would be added until the database became saturated. When the average response time for page requests reached the threshold limit of two seconds, the database server was considered saturated.

Some preliminary tests were performed to measure the Web/application tier and determine how many Web/application tier servers would be needed to match the throughput capacity of a single database server. It was quickly determined that four Dell PowerEdge C6100 servers in the Web/application tier would provide enough power to avoid a bottleneck in this tier and thus allow the tests to focus on the performance of the database tier.

A second series of tests were conducted using the same scripts running against existing Sun servers in the Moodlerooms environment. The purpose of these tests was to compare the results of the Dell environment versus the existing Sun server environment to see how much performance gain could be achieved by migrating to Dell servers based on the Intel 5500 series processors.

Benchmark Server Configurations

The tests performed at the Dell lab in Round Rock utilized four Dell PowerEdge R610 servers in the Web/application tier and a single Dell PowerEdge R710 server in the database tier. Because the Dell PowerEdge C6100 server and the Dell PowerEdge R610 and R710 servers are all two-socket servers using the same Intel CPUs, these systems are essentially interchangeable in terms of performance throughput. Thus the PowerEdge R610 servers tested in the Web/application tier can provide an accurate representation of the performance

that Moodlerooms and its customers can expect from the PowerEdge C6100 servers that Moodlerooms will be deploying for its hosting environment. Similarly, Moodlerooms has chosen to use the 1RU PowerEdge R610 servers in its database tier rather than the 2RU PowerEdge R710 servers and can expect performance to be equivalent.

Table 1 provides the configurations of the systems that were tested in Dell's labs.

	System Model	CPU	Memory
Web/application server	Dell PowerEdge R610 server	8 cores (2 x quad-core Intel 5570 processors)	24 GB
Database server	Dell PowerEdge R710 server	8 cores (2 x quad-core Intel 5570 processors)	48 GB

Table 1: Configurations of servers used in the test environment

Performance Results

Tests showed that a database server configuration with 15 virtual machines could support 150 separate databases (10 in each virtual machine) and up to 2,500 concurrent users and 150 page requests per second. Using 15 virtual machines also resulted in significantly lower CPU utilization than when running the same 150 databases on the server without the use of virtual machines.

The nature of the Dell and Moodlerooms architecture is such that additional database servers can be easily added to the hosting environment to support additional customers or a greater volume of transactions. Thus the most important criteria of the environment is the cost per simultaneous user. The second round of tests compared this ratio to that of the Sun servers that had already been deployed by Moodlerooms.

Comparison to Existing Sun Servers at Moodlerooms

The second series of tests were executed using the same scripts and the same Web/application tier environment as the first test. However, the database tier hardware platforms were changed for different tests in order to make a comparison. Moodlerooms tested Sun servers with AMD processors as well as Intel processor-based Sun servers. Since these servers did not come equipped with as much memory as the Dell servers tested in the Dell labs, Moodlerooms also tested some Dell servers configured with the same amount of memory to make a better comparison.

Table 2 shows the configurations of the Sun systems that were tested by Moodlerooms at their data center.

	System Model	CPU	Memory
Sun 4-core AMD processor-based server	Sun Fire X4100 server	4 cores (2 x dual-core AMD Opteron 2220 SE processors)	16 GB
Dell 4-core Intel processor-based server	Dell PowerEdge R610 server	4 cores (1 x quad-core Intel Xeon 5570 processor)	16 GB
Sun 8-core Intel processor-based server	Sun Fire X4150 server	8 cores (2 x quad-core Intel Xeon 5400 processors)	16 GB
Dell 8-core Intel processor-based server	Dell PowerEdge R610 server	8 cores (2 x quad-core Intel Xeon 5570 processor)	16 GB

Table 2: Configurations of existing Moodlerooms servers tested

Figure 3 shows the total number of concurrent users supported by each of the servers listed in Table 2. Note that the Dell PowerEdge R610 server with four cores supports almost as many users as the Sun Fire X4150 server with eight cores.

Maximum Concurrent Users

- Sun Fire X4100 (Four cores): 209
- Dell PowerEdge R610 (Four cores): 362
- Sun Fire X4150 (Eight cores): 381
- Dell PowerEdge R610 (Eight cores): 514
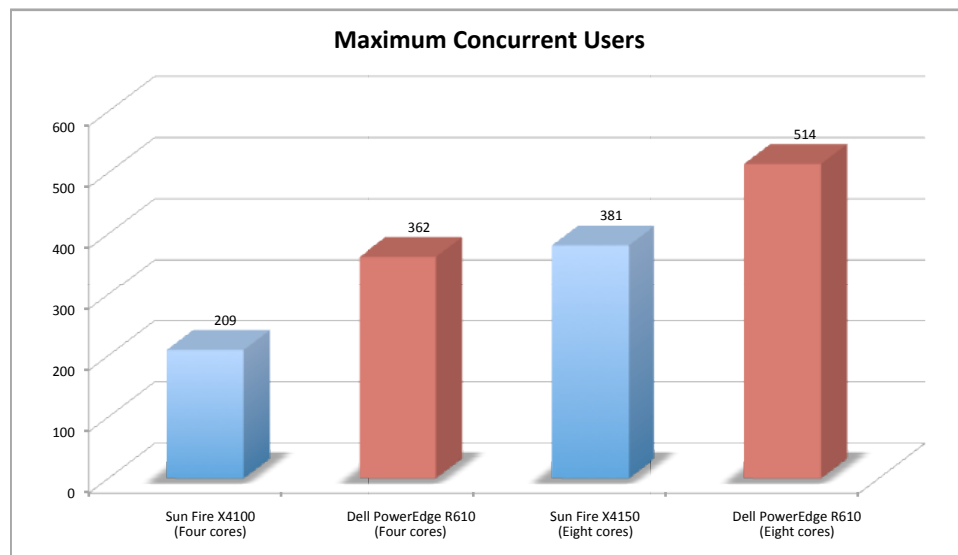
Figure 3: Comparison of concurrent users supported on different platforms

What's most important in a large hosting environment, however, is not the overall scalability of a server, but how cost-effective the server is in delivering its results. Moodlerooms compared its purchase costs for the four different servers shown

and calculated a cost per concurrent user by dividing the purchase cost by the number of concurrent users each machine would support. These results are highlighted in Figure 4. Note that the Dell servers offer much better price/performance than the Sun servers, and the Sun AMD processor-based four-core server offers only about half of the price/performance of the comparable four-core server from Dell with Intel Xeon 5570 processors.

Cost per Concurrent User

Server	Cost
Sun Fire X4100 (Four cores)	$35.68
Sun Fire X4150 (Eight cores)	$20.54
Dell PowerEdge R610 (Four cores)	$17.70
Dell PowerEdge R610 (Eight cores)	$15.82
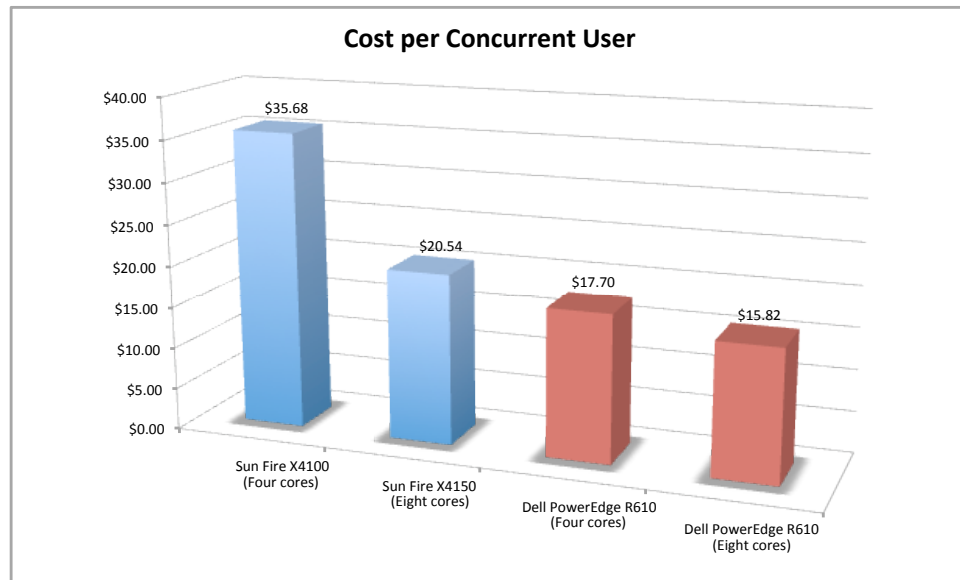
Figure 4: Dell servers with Intel 5570 processors provide the lowest cost per concurrent user

Implications of the Test Results

Since the Moodlerooms hosting environment supports many different customers, each with their own separate database, it is important that the architecture be easily scaled to support many separate database instances. These test results show that Moodlerooms can accommodate as many as 150 customers on a single PowerEdge R610 server. As the number of customers or the total transaction volume grows, Moodlerooms can accommodate by adding additional database servers along with four more Web/application servers for each additional database server.

Thus if Moodlerooms were to grow to 3,000 customers with 3,000 databases, they could deploy 20 PowerEdge R610 servers for the database and 80 PowerEdge C6100 servers in the Web/application tier and expect their IT infrastructure to be able to handle the load. Of course, actual customer loads may vary from the loads defined in these tests, resulting in variations in how many customers can be supported by a single server. The point, however, is that Moodlerooms can expect to scale the architecture to support several thousand customers with a cost-effective IT infrastructure.

The use of virtual machines also makes it easy for Moodlerooms to move customer databases from one physical server to another without disrupting the activity of the users. So, when adding a new database server, Moodlerooms can immediately migrate some of the existing customer databases to the new server to help balance the load.

Chapter 5

Summary

With growing demand for cost-effective learning management systems, more and more institutions will be considering hosted services as a means to achieve high service levels without high overhead costs. Moodlerooms is transitioning to Dell servers and storage systems as part of its plan to accommodate future growth while continuing to deliver a cost-effective offering.

The Dell and Moodlerooms architecture described in this white paper offers the following major benefits to Moodlerooms and its customers:

- Cost-effective hosting by leveraging Intel Xeon 5500 series processors and virtualization for maximum utilization
- Room for growth with a highly scalable solution architecture
- Proven open source software combined with a highly reliable server platform

For More Information

The Web links in Table 2 provide resources for additional information about the technologies and solutions from Dell, Moodlerooms, and Intel that are used this architecture.

URL	Description
www.dell.com/hied	Dell solutions for higher education
www.dell.com/poweredge	Dell PowerEdge servers
www.dell.com/poweredgec	Dell PowerEdge C servers
www.dell.com/equallogic	Dell EqualLogic PS Series iSCSI SAN arrays
www.moodlerooms.com	Moodlerooms home page
download.moodle.org	Download site for the Moodle learning management system
www.intel.com/p/en_US/products/server/processor	Intel server processors

Table 3: Web Links for Additional Information