OPTIMIZING BLACKBOARD ACADEMIC SUITE ON DELL SERVERS AND STORAGE

TAKING ADVANTAGE OF VIRTUALIZED RESOURCES

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Section 1

Introduction

As organizations continue to expand their eLearning initiatives, many are looking to upgrade their IT infrastructure to support greater numbers of students and a broader mix of course content. Many Blackboard® customers initially implemented the Blackboard Academic Suite™ as an online environment that was simply intended to augment the in-classroom experience. These initial implementations were often small in scale and were deployed using Microsoft® Windows Server® and Microsoft® SQL Server®. Due to the popularity of Blackboard platform and the many available applications, many of these pilot eLearning programs have since expanded to stretch the capacity limits of their initial system architecture.

As organizations consider an upgrade to their Blackboard system infrastructure, most would like to preserve their investments in their Microsoft SQL Server infrastructure as this helps contain costs and avoids the need to retrain IT staff. With this in mind, Dell, Blackboard, and Quest Software recently embarked on a project to optimize Blackboard Academic Suite software for Windows and SQL Server. The joint efforts have resulted in significantly greater scalability as well as simplified management, enabling customers to run large campus implementations on a cost-effective infrastructure. The project not only involved optimization of the software, but also defined a reference architecture that would take advantage of server virtualization and the latest management tools for optimizing the Blackboard production environment.

These efforts to increase scalability and optimize the management environment have been largely driven by customer demand. Many Blackboard customers have expressed interest in server virtualization as an opportunity to improve utilization of hardware resources and increase the adaptability of their IT environment. Blackboard also observed that customers who were making use of leading-edge management tools and applying good datacenter disciplines were also achieving greater uptime and better performance with their Blackboard systems. Since this topic was of high interest throughout the Blackboard customer base, collaboration with Quest Software was initiated to define a management environment that could help customers achieve high service levels with their Blackboard Academic Suite implementations.

Addressing All Aspects of Enterprise eLearning

The collaboration between Dell, Blackboard and Quest encompassed every aspect of an enterprise eLearning implementation. The Dell reference architecture for Blackboard software, which resulted from the collaboration, is based on the following technical investments by the three vendors:

- Optimizing Blackboard Academic Suite to improve overall throughput when many active users are simultaneously accessing the system.
- Tuning SQL database access within Blackboard Academic Suite and defining best practices for deploying SQL Server with Blackboard Academic Suite.

- Characterization testing to define an optimized configuration for implementing server virtualization to deliver maximum throughput when using multiple VMs with VMware ESX server.
- Designing a robust hardware server and storage architecture based on virtualized Dell PowerEdge™ servers and Dell EqualLogic™ iSCSI storage systems.
- Creating an end-to-end management infrastructure based on monitoring and management tools from Quest Software.

Business Benefits of the Reference Architecture

The performance and scalability achieved with this architecture goes far beyond what was previously possible. Customers can deploy a horizontally scaled solution that supports up to 30,000 active users on a cost-effective infrastructure of virtualized Dell servers and storage systems. The entire infrastructure, which includes a simplified enterprise management environment, is designed to help customers achieve:

- Reduced risk through proven reliability, scalability, and performance.
- Lower TCO due to outstanding price/performance and simplified management.
- Investment protection in Microsoft Windows and Microsoft SQL Server technologies and related staff expertise.
- High service levels due to the high-performance architecture and simplified management environment that helps reduce downtime.

The remainder of this paper provides an overview of the reference architecture and the advantages of the technology components within it.

Section 2

Dell Reference Architecture for Blackboard Academic Suite

The Dell reference architecture for Blackboard software is a blueprint for successfully optimizing the deployment and management of Blackboard software on Dell servers and storage. It identifies key system components and management processes that are required to achieve high service levels and scalability along with efficient IT operations.

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

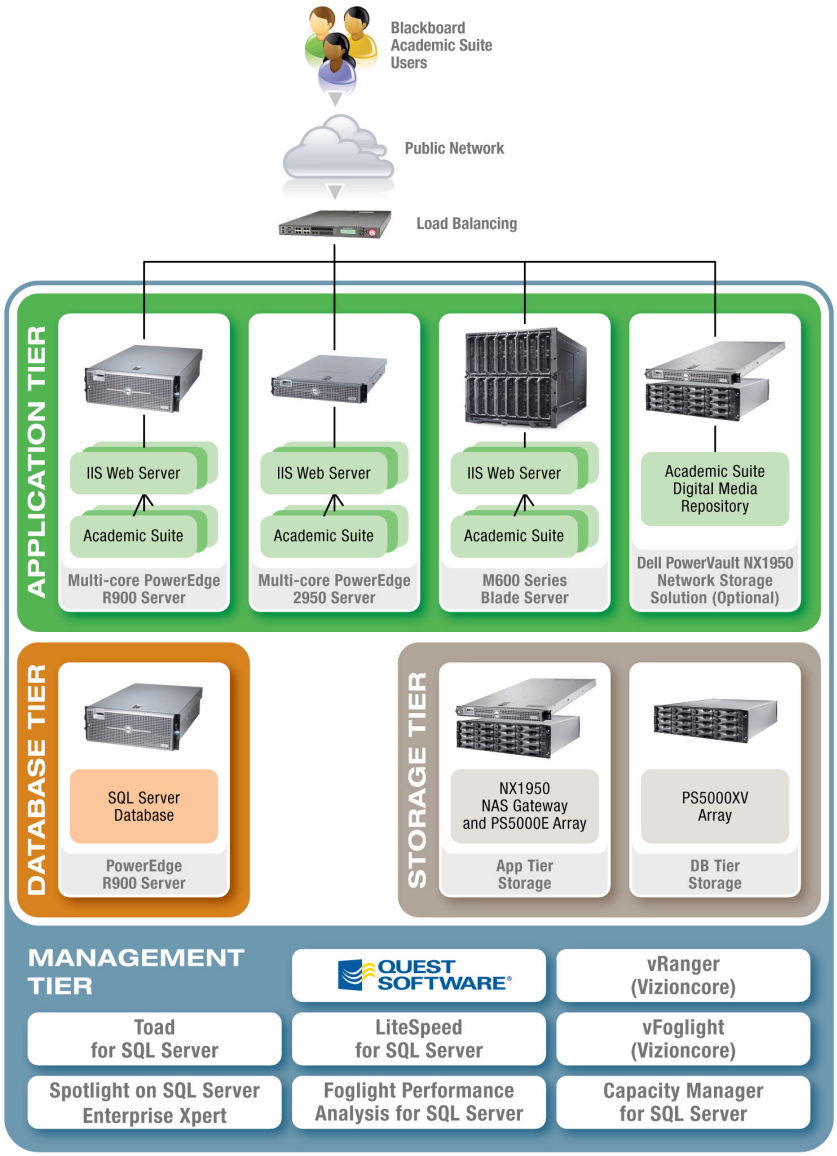

Figure 1: Logical Diagram of Dell Reference Architecture for Blackboard software

Designed for scalability

The architecture is designed to support maximum scalability and high service levels through virtualization and an optimized management environment. To achieve a high volume of concurrent user sessions, the horizontally scaled architecture uses load balancing across virtualized servers in the application tier. Each application server runs multiple instances of the Blackboard Academic Suite software as well as multiple instances of the Microsoft IIS Web Server.

Characterization tests have enabled Dell and Blackboard to define sample configurations for different customer load scenarios so that customers can choose a configuration that best suits their expected number of concurrent user sessions. The sizing table in a later section of this document provides recommended sizing guidelines.

Virtualized Application Tier

Application tier scalability is achieved by running multiple instances of the Blackboard Academic Suite and the Microsoft IIS Web server on virtualized servers. As shown in Figure 1, these instances can be deployed on rackmountable servers such as the Dell™ PowerEdge™ R900 or PowerEdge 2950 servers. They can also be deployed on blade servers such as the Dell PowerEdge M600 series.

In either case, the virtualized environment is achieved by using hypervisor technology from VMware to run multiple instances of the Microsoft Windows operating system on each physical server. VMware ESX Server 3.0 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 ESX is the market leading hypervisor and is production-proven at thousands of customers of all sizes.

In the virtualized environment of the Dell reference architecture for Blackboard software, each virtual machine runs an instance of the Blackboard Academic Suite and an instance of the Microsoft IIS Web server. An application delivery switch such as the BIG-IP® 3600 platform is used to balance the load of the traffic across all Web server instances in all servers. Each Web server then communicates with its corresponding instance of Blackboard Academic Suite

Benefits of Virtualization

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

- Lower costs – Increased utilization of servers enables good performance on a low-cost consolidated infrastructure.
- Increased flexibility – Virtual machines can be easily moved to other physical servers to redistribute workloads or recover quickly from a hardware failure.
- Faster Deployment – With fewer physical systems to setup and configure, less time is required for deployment.

Components of the Reference Architecture

The backbone of the reference architecture is Dell PowerEdge servers and Dell EqualLogic and PowerVault™ storage solutions. Characterization tests for these systems were performed in Dell's labs using a virtualized environment running VMware ESX server. The results show dramatic scalability and specific configurations were validated to offer specific levels of throughput, thus greatly reducing the risk of unforeseen problems in enterprise implementations.

Tables 1 and 2 list the hardware and software components of the reference architecture.

Hardware Component	Description
Dell PowerEdge R900 server	The PowerEdge R900 server is Dell's most powerful Intel® server, offering up to 24 Intel® Xeon® processor cores. It is designed and optimized to provide outstanding virtualization performance.
Dell PowerEdge 2950 server	The high-performance, PowerEdge 2950 delivers excellent security, manageability, and energy efficiency in a 2U, rack dense chassis for customers seeking a balance between expandability and rack density.
Dell EqualLogic PS5000E iSCSI Array	The PS5000E array is an intelligent virtualized iSCSI storage array that is designed to provide rapid installation, simple management, and seamless expansion. Its SATA disk drives provide cost-effective high capacity storage for the application tier.
Dell EqualLogic PS5000XV iSCSI Array	The Dell EqualLogic PS5000XV array is a virtualized iSCSI SAN solution that combines intelligence and automation with fault tolerance to provide simplified administration, rapid deployment, enterprise performance and reliability, and seamless scalability. With 15,000 RPM SAS disk drives, the PS5000XV array provides high transactional performance, making it an ideal SAN platform for the database server in this reference architecture.
Dell PowerVault NX1950 unified network storage solution	The Dell PowerVault NX1950 is a unified network storage solution that simultaneously stores both file and application data. It can be used as an integrated storage solution or a NAS gateway and is deployed in the reference architecture as a NAS gateway connecting to the Dell PS5000E storage system for application tier storage.
F5 Networks BIG-IP 3600 application switch	The BIG-IP 3600 application network delivery platform provides eight Gigabit Ethernet ports and is rated to deliver 1.5 Gbps in traffic throughput.

Table 1: Reference Architecture Hardware Components

Software Component	Description	Version
Blackboard Academic Suite software	The Blackboard Academic Suite includes Blackboard's flagship Course Management System (CMS), the Blackboard Learning System™ as well as four other core applications, the Blackboard Community System™, the Blackboard Portfolio System™, the Blackboard Content System™ and the Blackboard Outcomes System™.	Release 8, SP4
Quest Management tools for SQL Server	The reference architecture utilizes a number of monitoring and management tools from Quest Software as defined in the chapter titled, “Enabling Management Efficiency.”	n/a
Solutions for managing the VMware virtual environment	The reference architecture utilizes solutions from Vizioncore, a subsidiary of Quest Software, to manage the VMware virtual environment.	n/a
Microsoft Windows Server 2003	Windows Server 2003 R2 offers a platform for cost-effective server virtualization and rich Web services. It can help simplify server management, improve identity and access management, and reduce storage management costs. Note that the application tier of this reference architecture uses the 32-bit version of Windows Server while the database tier uses Windows Server x64 Edition to take full advantage of the scalability of 64-bit Dell systems.	R2 Enterprise Edition
Microsoft Internet Information Services (IIS) Web Server	Microsoft IIS 6.0 is a powerful Web server available in all versions of Microsoft Windows Server 2003. It provides a highly reliable, manageable, scalable, and secure Web application infrastructure that can help reduce total cost of ownership through server consolidation and simplified server management.	6.0
Microsoft SQL Server 2005	SQL Server 2005 (64-bit) is an award-winning data management and analysis platform that is optimized to run on x64 systems. Service Pack 2 supports excellent scalability for Blackboard Academic Suite on Dell PowerEdge servers.	SP2, 64-bit
VMware ESX	VMware ESX is a “bare-metal” hypervisor that partitions physical servers into multiple virtual machines. Each virtual machine represents a complete system, with processors, memory, networking, storage and BIOS.	v3.5 update 1

Table 2: Reference Architecture Software Components

Key Benefits of the Reference Architecture

The reference architecture combines the above mentioned system components with the management processes described later in this white paper to deliver the following major benefits to educational institutions:

- Higher service levels – The architecture is designed to help optimize service levels and provide a path to more mature operation of the datacenter.
- Reduced cost – Virtualization technologies enable a consolidated solution with higher resource utilization. Configuration and sizing information defined with the reference architecture can help customers avoid overprovisioning. Best practices for management can also reduce the cost of maintaining the production environment.
- Faster time to delivery – The reference architecture saves institutions time by greatly reducing the need for research or trial and error discovery when building and optimizing a course management environment.
- Reduced risk – Validated hardware configurations and software partners are combined with best practices for operational performance to greatly reduce the risk of unforeseen problems in a production implementation of Blackboard Academic Suite.
- Simplified management – Tools and best practices for maintaining high service levels can save time and simplify the management process.

Section 3

Sizing Considerations

This chapter describes key considerations when sizing a system for Blackboard Academic Suite and provides capacity guidelines as well as recommended platforms for the various components of the architecture.

Active Sessions Defined

The sizing guidelines for Blackboard Academic Suite are based on the concept of an active session, which can be defined as an authenticated user who is currently logged into the system. While each user may not be actively using Blackboard Academic Suite during their entire login time, a session is still considered active as long as the user is logged in.

The sizing recommendations in this white paper define configurations that support a given number of concurrent active sessions based on some assumptions about user activity. To get an accurate assessment of user activity, it is recommended that institutions spend some time analyzing the number of successful login attempts made to their systems in order to identify peak requirements. Monitoring the number of logins per day and per hour over an entire semester, for example, will make it easier to identify trends and peak login periods. A system can then be configured to handle the peak loads that have been observed. If user activity levels cannot be known when purchasing Blackboard Academic Suite, it is a good idea to make a conservative estimate of user activity and then resize the system after more data can be obtained.

It is worth noting that some functional areas such as exams and quizzes require more system resources than others. Therefore, it is also important for customers to identify the breakdown of how their users tend to utilize Blackboard Academic Suite. In the benchmark tests that were conducted, the break down of activity among the user sessions was simulated as follows:

- 32% reading or submitting content.
- 24% engaged in Discussion Boards.
- 16% taking exams or quizzes.
- 8% submitting assignments.
- 20% working in other areas such as Announcements, Calendar, Tasks, Gradebook, and System Administration activities.

If this does not match the expected usage patterns in a customer environment, configuration recommendations may need to be modified.

Application Tier

The application tier contains the Blackboard Academic Suite software and Microsoft IIS Web server running on one or more Dell PowerEdge servers in a virtualized environment. As described in Chapter 2, the virtualized application tier

utilizes load balancing to distribute the user workload evenly across multiple virtual machines.

Due to the virtualized nature of the application tier, the sizing recommendations are based on the number of active sessions that can be managed by a single virtual machine. The number of required VMs, and the required CPU and memory capacity for the application tier is calculated based on the expected number of active sessions.

Minimum and Optimal VM Configurations

In addition to the *optimal configuration* that is recommended, by Blackboard and Dell, a *minimum configuration* has also been defined to provide some guidelines for customers that may need to operate on more limited resources while absorbing additional risk. The minimum configuration is more aggressive in terms of minimizing cost per user while the optimal configuration provides more potential for growth as well as greater buffer for unexpected peak usage. Table 3 shows a comparison of the recommended guidelines for a minimum versus optimal configuration.

	Minimum Configuration	**Optimal Configuration**
CPUs per VM	1	2
Memory per VM	3 GB	4 GB
Operating System	Microsoft Windows Server 2003 R2 Enterprise Edition (32-bit)	Microsoft Windows Server 2003 R2 Enterprise Edition (32-bit)
Number of VMs supported on a 16-core server	16 VMs	8 VMs
Memory required to support max VMs on a 16-core server	48 GB	32 GB

Table 3: Configuring VMs in the Application Tier

Capacity of Minimum and Optimal VM Configurations

Benchmark tests revealed that optimum performance could be achieved on a 16-core Dell PowerEdge R900 server when 8 VMs were deployed. This resulted in the definition of an optimal configuration as one that provides 2 CPU cores per VM. This optimal configuration has been calibrated to support 750 to 1,000 active sessions[1]. If users are performing demanding operations such as concurrent exams or quizzes, this number can certainly vary.

[1] Benchmark tests indicated that the recommended configuration was able scale to 1,800 active sessions per VM in a lab setting. Results will vary from institution to institution, but sizing for 750 to 1,000 active sessions per VM is considered a good general guideline for most institutions.

The sizing guidelines in the remainder of this paper focus on the capacity of the optimal configuration for each VM in the application tier. In general, the minimum configuration should be expected to achieve something in the range of 50 to 75% of the anticipated peak capacity of the optimal configuration. The minimum configuration may also be able to achieve 750 to 1,000 active sessions, if, for example, exams and quizzes are not being utilized.

By following the guidelines for memory and CPU resource requirements within a VM, customers can mix and match different Dell servers within their architecture to include any combination of blade servers or rack-mounted servers as long as the CPU speed is comparable to that of the 2.93 GHz Xeon X7350 Quad Core Processor used in the PowerEdge R900 servers in the benchmark tests.

Horizontal Scaling for Availability and Demand

Using the optimal sizing guideline of 1,000 active sessions per VM, it is easy to size the application tier by simply dividing the expected number of concurrent active sessions by 1,000 (use 750 if user workflows are more demanding). This will provide the required number of VMs to yield the expected throughput. The optimal number of CPU cores is simply twice the number of VMs and the number of GBs of memory required is four times the number of VMs.

If a minimum configuration is desired, the number of CPU cores can be defined as equal to the number of VMs. The number of GBs of memory required in the minimum configuration is three times the number of VMs.

If 10,000 active sessions were expected at peak usage, the application tier optimal configuration would consist of ten VMs deployed across a total of 20 CPU cores with 40 GB of total memory. These 20 cores could be spread across any number of physical application servers or blades as long as each server or blade were to include sufficient memory to allocate 4 GB of memory per VM.

Sample configurations for small, medium, and large campuses are shown in the sizing summary section below.

Database Tier

The Microsoft SQL Server database is used to maintain user records and indexes to application specific data such as course offerings, student profiles, test results, etc. While the application tier uses a virtualized horizontally scaled architecture, the database tier is not virtualized. In fact, the database itself requires significant vertical scalability because a single large database instance is used by all application tier components.

Tests conducted by Dell and Blackboard offer evidence that Microsoft SQL Server can scale well beyond the needs of most Blackboard Academic Suite customers.

Recommended Database Server

Blackboard and Dell recommend the Dell PowerEdge 2950 or Dell's most powerful Intel server, the Dell PowerEdge R900 server, as the hardware platform for running Microsoft SQL Server in this architecture. These PowerEdge servers offer the following advantages:

- Proven application performance with the Blackboard Academic Suite.
- Excellent price/performance.
- Ability to optimize the need for expansion capacity versus rack density.

- Plenty of capacity for future growth with up to 24 CPU cores available in the PowerEdge R900 server.
- Enterprise-class reliability features to help protect against unwanted downtime.

Capacity Requirements for the Database Tier

The database server is optimized for 1,000 active sessions per CPU core. This means that a 16-core Dell PowerEdge R900 server could handle 16,000 active user sessions. Benchmark tests showed that the 16-core R900 server can actually handle a load of beyond 30,000 active Blackboard user sessions, so the recommendation of 1,000 active sessions per core leaves room for spikes in demand and some room for growth.

For the Blackboard Academic Suite database, the most important performance criterion is I/O throughput from the storage subsystem. The following section provides more details on storage performance.

Storage Tier

The reference architecture provides a very flexible storage environment that can utilize different types of storage solutions for different purposes. Blackboard and Dell recommend different types of disk drives to serve the differing requirements of the application tier and the database tier. Customers also have the option to implement a storage area network (SAN) with dual connections to all servers and storage devices for high availability.

The application tier uses the CIFS protocol to provide shared access to networked storage resources. A Network Attached Storage (NAS) device such as the Dell NX1950 (EqualLogic) gateway provides connectivity to the Dell/EqualLogic PS5000E storage system. This allows the Blackboard Academic Suite application to access the shared storage content regardless of which physical server Blackboard Academic Suite is running on. While storage capacity requirements for the application tier are significant, access speed is less important, so 7.2K RPM SATA drives are recommended as the most cost-effective way to meet the performance needs of the application tier.

The database tier requires high performance disk drives and a large number of spindles in order to handle the high volume of I/O read requests from the SQL Server database. Thus for database storage, it is recommended to use an iSCSI storage array with 10K or 15K RPM SAS drives. The reference architecture recommends the Dell/EqualLogic PS5000XV storage system, which offers both the high performance of iSCSI and the ability to increase availability with a SAN infrastructure. For the small and medium configurations, 10K RPM drives are recommended and the large configuration should utilize 15K RPM drives to deliver the high throughput required for that environment.

Storage Capacity

Storage at the application tier is primarily for the purpose of course and institutional content. Storage capacity will vary by institution based on factors such as data retention periods, user activity levels, and storage media types. These factors should be taken into consideration to come up with appropriate sizing recommendations for any institution. Based on historical client sampling, Blackboard recommends an average storage requirement of 1 to 2 GB per user. This accounts for personal and course-based multi-media content storage.

Database storage capacity can also vary widely, but is generally in the range of 50 to 100 MB per user. This can be used as an estimate until more accurate information about a customer's specific environment can be known.

Dell EqualLogic Storage Systems

Dell EqualLogic storage systems have been chosen because they offer affordable enterprise-class iSCSI storage that is ideal for virtualized environments such as the Dell reference architecture for Blackboard software.

Key advantages of Dell EqualLogic storage systems include:

- Fully virtualized SAN for fast deployment and simplified administration.
- Hypervisor-aware SAN-based snapshots and recovery simplifies data protection.
- Automatic load-balancing and online volume migration for improved IT responsiveness.
- Rapid deployment and provisioning.
- High performance with no tuning efforts.
- Seamless expandability as the Blackboard system implementation grows.
- Optimized storage utilization.

Section 4

Sizing Summary and Best Practices

Sizing Guidelines

The benchmark tests conducted in Dell's labs provided a good baseline for defining the conditions that result in optimal performance for Blackboard Academic Suite and for defining specific configurations that can serve as a baseline for meeting the performance and scalability needs of small, medium, and large institutions.

Tests showed that optimal performance in the reference architecture could be achieved when the following conditions are met:

- Application tier user sessions are load balanced across a number of virtual machines and each VM is expected to serve no more than 1,000 active sessions at a time.
- Each VM deployed in the application tier has two processor cores and 4GB of memory allocated to it. (Note that the minimal configuration for a VM is 1 processor core and 3GB of memory allocated, but optimal throughput may not be reached with the minimal configuration.)
- The database server has at least one processor core per 1,000 active sessions.

In addition to the above conditions for optimal performance, some guidelines were established for sizing storage capacity. As mentioned earlier, storage capacity requirements can vary widely between institutions because usage patterns can vary widely. Thus it is best if the institution can take the time to collect data about storage utilization of its own users. However, in the absence of such detail, the following guidelines can provide a temporary starting point for institutions:

- Application tier storage capacity can be estimated at 1TB per 5,000 users. Thus a community with a total user population of 25,000 would require 5TB of storage for the application tier.
- Database storage capacity can be estimated at 200GB per 5,000 users. Thus the same community of 25,000 users would require 1TB of storage for the database tier.

Sizing Summary

Table 4 shows recommended configurations three different sizes of institutions.

Description	Small Institution Configuration	Medium Institution Configuration	Large Institution Configuration
User Community Size (total users)	1,000 to 10,000	10,000 to 50,000	50,000 to 100,000
Sizing Assumptions	• 500 to 1,000 active courses • Optimized for 4,000 active (concurrent) sessions	• 1,000 to 5,000 active courses • Optimized for 8,000 active (concurrent) sessions	• 5,000 to 25,000 active courses • Optimized for 16,000 active (concurrent) sessions
Application Tier Platform Recommendations	Recommend either a bare metal architecture using Dell M600 series blade servers or a virtual architecture using a Dell PowerEdge 2950 or R900 server.	Recommend either a bare metal architecture using Dell M600 series blade servers or a virtual architecture using a Dell PowerEdge 2950 or R900 server.	Recommend either a bare metal architecture using Dell M600 series blade servers or a virtual architecture using the Dell PowerEdge R900 server.
Application Tier Optimal Configuration	• 4 VMs • 8 Intel Xeon processor cores • 16GB total memory (Each VM supports 750 to 1,000 active sessions and requires 2 CPU cores and 4 GB memory.)	• 8 VMs • 16 Intel Xeon processor cores • 32GB total memory (Each VM supports 750 to 1,000 active sessions and requires 2 CPU cores and 4 GB memory.)	• 24 VMs[2] • 48 Intel Xeon processor cores • 96 GB total memory (Each VM supports 750 to 1,000 active sessions and requires 2 CPU cores and 4 GB memory.)
Database Tier Configuration	Dell PowerEdge 2950 server • 2 Intel Xeon processor cores • 16 GB memory (Max capacity of 1,000 active sessions per CPU core)	Dell PowerEdge R900 server • 16 Intel Xeon processor cores • 32 GB memory (Max capacity of 1,000 active sessions per CPU core)	Dell PowerEdge R900 server • 24 Intel Xeon processor cores • GB memory (Max capacity of 1,000 active sessions per CPU core)
Storage Tier[3]	Dell EqualLogic PS5000XV system for database storage • 4.8TB raw capacity • 16 X 300GB 10K RPM SAS drives Dell EqualLogic PS 5000E systems for app tier storage • 2 TB total capacity • 8 X 250GB 7.2K RPM SATA drives • Dell EqualLogic NX1950 server for NAS gateway	Dell EqualLogic PS5000XV system for database storage • 4.8TB raw capacity • 16 X 300GB 10K RPM SAS drives Dell EqualLogic PS 5000E system for app tier storage • 12 TB total capacity • 16 X 750GB 7.2K RPM SATA drives Dell EqualLogic NX1950 server for NAS gateway	Dell EqualLogic PS5000XV system for database storage • 7.2TB raw capacity • 16 X 450GB 15K RPM SAS drives 2 X Dell EqualLogic PS 5000E systems for a total of 24 TB of app tier storage • 12 TB total capacity • 16 X 750GB 7.2K RPM SATA drives Dell EqualLogic NX1950 server for NAS gateway

Table 4: Sizing Guidelines for Blackboard Academic Suite

[2] The large configuration has been sized with extra VMs in case total throughput of each VM is closer to the low end of the expected range even though benchmark testing showed near linear scalability.

[3] Note that storage needs vary by institution and the storage capacities shown in this table are only a recommendation based on norms in the Blackboard user community.

Configuration Best Practices

Overall performance and management efficiency can also be significantly impacted by how the system is configured. Blackboard and Dell offer the following guidelines for optimizing Blackboard Academic Suite software to run on Dell servers and storage solutions:

- Blackboard content system files should be stored on a filer on the network rather than in the local machine. This makes it easier to move the Blackboard Academic Suite instances between servers in the application tier without having to remount the file systems. This approach saves time for administrators and can help avoid downtime.
- Database performance can be optimized by using separate drives for different types of data stored in the database. There should be separate drive(s) for the data files that comprise the database itself. Log files and tempdb files should then be stored on other drives to reduce contention, allowing these files to be read or written in parallel with database reads and writes. This can help reduce I/O wait time.

The following chapter provides additional information about improving performance and management efficiency through proper management of the Blackboard Academic Suite environment.

Section 5

Enabling Management Efficiency

Maintaining performance and availability of the Blackboard environment without assigning a big IT staff requires having the right tools for efficient monitoring and management. Quest Software provides all of the tools needed to simplify administration, availability management, performance optimization, and capacity planning. Quest Software and its subsidiary company, Vizioncore, provide all the tools needed to simplify administration, availability management, performance optimization, and capacity planning for both the underlying database and the VMware ESX Server environment.

As illustrated in Figure 2, these Quest tools are integrated with VMware ESX server and provide a management infrastructure that provides visibility across all layers of the reference architecture.

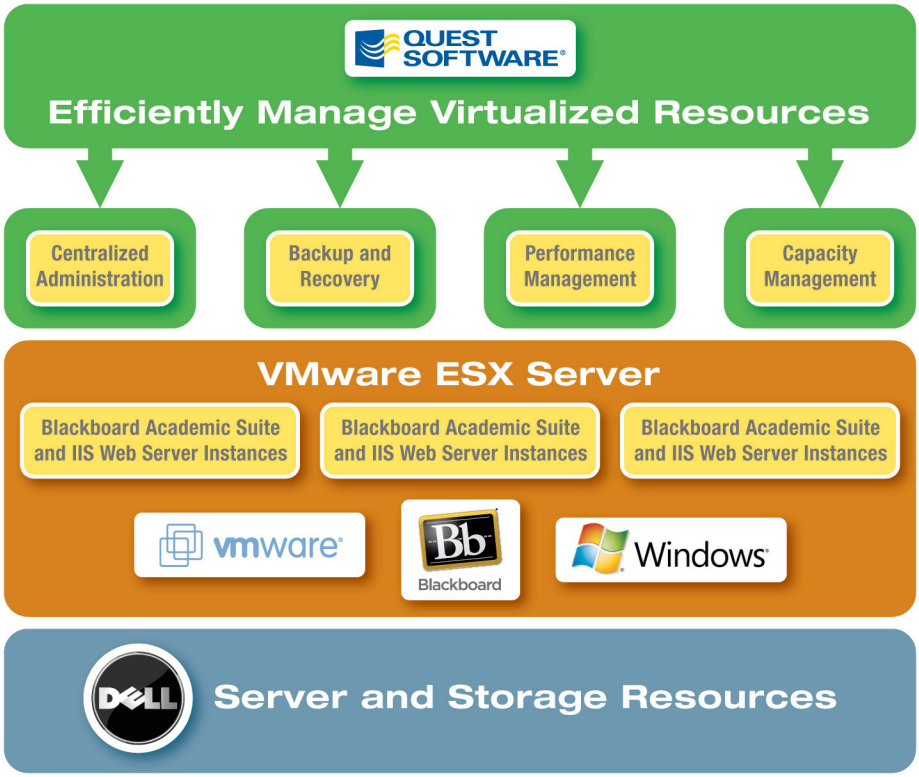

Figure 2: Quest and Vizioncore Management Infrastructure Across All Layers

Centralized Administration

Today's IT organizations need an efficient means to assess and manage SQL Server database instances and keep them performing well. SQL Server database administrators (DBAs) must perform a diverse range of functions, often using a

combination of tools such as SQL Server Management Studio and Visual Studio. Since the Blackboard Academic Suite database will likely be only one of many database instances that a single SQL Server DBA may be managing, it is important to have tools that can make DBAs more productive and help improve service levels.

Toad™ for SQL Server bridges the functionality gaps between Microsoft's SQL Server Management Studio and Visual Studio and it does it all within a single toolset that can be used to manage all critical aspects of the SQL Server environment. The software includes administration tools to improve application code quality and to help developers implement best practices and coding standards. It is also designed to shorten the learning curve for new SQL Server users. Users can access an online SQL Server knowledge base created and moderated by industry experts at www.sqlserverpedia.com.

Centralized administration of the Dell reference architecture for Blackboard software is also made easier with VMware Virtual Center, which is used for provisioning virtual machines in the application tier. VMware Virtual Center is used to create and deploy virtual machines as well as assign CPU and memory resources during the setup process and for ongoing maintenance. It allows administrators to quickly deploy virtual machines and easily move virtual machines between physical servers.

Backup and Recovery

SQL Server backups must be performed quickly and efficiently while minimizing the risk of data loss or lengthy downtimes during recovery. Quest offers two tools that can help optimize backup and recovery processes for the database as well as the virtualized infrastructure in the Blackboard application tier.

- LiteSpeed™ for SQL Server can help institutions reduce storage costs and deliver SQL Server backup and recovery times that are up to 70 percent faster than with native tools. This low-impact, high-performance compression tool gives administrators complete control over the backup and recovery process and creates backup files that have compression ratios of up to 95 percent.
- vRanger™ (Vizioncore) provides image-level hot backups while the virtual machine is still running. Unlike agent-based backup solutions, vRanger runs outside the guest OS and can be integrated with VMware VirtualCenter and VCB. Thus the host system can continue to operate without noticeable performance impact during backups. vRanger is also VMotion aware, allowing it to follow virtual machines when moved to new hosts so that changes to the environment do not affect system backups. vRanger also supports Microsoft Volume Shadow Copy (VSS) for database consistency.

Performance Management

Consistent high service levels for Blackboard Academic Suite users can only be achieved when administrators can effectively monitor and manage all components and all layers of the system. Quest Software provides the following tools to enable comprehensive performance management of the SQL Server database and the virtualized environment of the application tier.

- Spotlight™ on SQL Server Enterprise Xpert is an easy-to-use performance monitoring solution that can help administrators quickly and

efficiently discover, diagnose, and resolve performance problems within an SQL Server environment. Deep diagnostics enable quick identification of the root cause of a performance bottleneck. SQL performance can be optimized through detection of problematic SQL, automated SQL tuning and benchmarking capabilities. Real-time alerts also allow administrators to respond more quickly to performance problems.

- Foglight™ Performance Analysis for SQL Server provides detailed historical and real-time analysis of performance issues. Its performance management digital dashboard can help DBAs efficiently identify performance issues and quickly isolate the root cause. Using Quest's proprietary StealthCollect™ technology, Foglight Performance Analysis enables administrators to quickly correlate application SQL performance with SQL Server and system resource consumption. The broad range of advanced diagnostic features in Foglight Performance Analysis gives DBAs comprehensive visibility as well as detailed granular views of performance issues.
- vFoglight™ (Vizioncore) can be used to monitor the end-to-end virtualized environment from the data center down to individual virtual machines. It provides visibility into critical applications and can help administrators reduce the mean-time-to-resolution for incidents and problems because it exposes the relationships and interaction between all components in the virtual environment.

Capacity Management

With fast growing application software such as Blackboard Academic Suite, it can be difficult for administrators to stay on top of capacity requirements for disk space and to fend off database performance issues.

Quest Capacity Manager for SQL Server provides an enterprise view of SQL Server resource and storage utilization, allowing administrators to effectively plan for future hardware requirements and ensure the most efficient use of existing assets. It enables DBAs to better forecast their database capacity requirements based on current growth rates of instances, databases, objects, CPU, memory, and I/O. Capacity Manager also helps improve database performance through intelligent defragmentation functionality. The index defragmentation process is automated to ensure that it takes place during maintenance windows, thus preventing this activity from competing for resources during peak hours.

Section 6

Summary

Together, Dell, Blackboard and Quest have created a scalable reference architecture that allows customers to achieve high service levels and predictable performance with a cost-effective infrastructure. The architecture contains multiple layers that contribute to the overall level of reliability and scalability. The application tier provides application level clustering and load balancing support across a virtualized infrastructure that enables very high system utilization. The SQL Server database in Blackboard Academic Suite has been optimized for higher performance and takes advantage of multi-core Dell servers and blades as well as high performance iSCSI storage for higher throughput. As a result, the database layer now scales to higher performance levels than were previously achievable with Blackboard Academic Suite and SQL Server.

The end-to-end management infrastructure based on monitoring and management tools from Quest Software can also help customers improve service levels as well as management efficiency. It provides administrators with effective tools that can simplify operational management and help improve the performance of the VMware virtualized infrastructure on which the reference architecture is based.

Institutions that utilize the reference architecture can benefit from:

- *Reduced risk through proven reliability, scalability and performance*

  Scalability and performance has been proven in characterization tests in Dell's labs and all of the reference architecture components have been proven to work together well. Management tools from Quest software can also help customers reduce the risk of downtime by optimizing performance and improving visibility throughout the system.

- *Lower TCO*

  Dell PowerEdge servers and blade servers such as the M600 series offer outstanding price/performance and allow customers to consolidate multiple instances of Blackboard Academic Suite onto virtualized servers for greater utilization of resources. The validated configurations described in this guide also help avoid overprovisioning, allowing customers to purchase the right size of system for their immediate needs while providing the scalability for future needs. Management tools from Quest also help keep administrative costs low by improving operational efficiency.

- *Investment protection*

  Because the reference architecture is based on Microsoft SQL Server and the Windows operating system, it enables customers to leverage their previous investments in their Microsoft infrastructure as well as their in-house Microsoft expertise.

For More Information

The Web links in Table 5 provide resources for additional information about the technologies and solutions from Dell, Blackboard, and Quest that comprise this reference architecture.

URL	Description
www.dell.com/hied	Dell solutions for higher education
www.dell.com/poweredge	Dell PowerEdge servers
www.dell.com/equallogic	Dell EqualLogic PS5000 Series iSCSI SAN array
www.blackboard.com	Blackboard Inc. home page
www.quest.com/sql-server	Quest Management tools for SQL Server
www.vizioncore.com	Server virtualization management solutions from Vizioncore, a fully-owned subsidiary of Quest Software
www.sqlserverpedia.com	Online community knowledge base for SQL Server

Table 5: Web Links for Additional Information