IBM

To Blade or Not to Blade . . .
That is the IT Question

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Executive Overview

Blade servers are selling like hotcakes these days, and with good reason. They can offer a level of rack density and network/infrastructure integration previously unknown. A key reason for the interest in blade servers is the attractiveness of physical consolidation of IT resources for better management and control, combined with lower costs.

Blade servers do offer superior density, but just as a *uniprocessor 1U* server may not be appropriate for enterprise database applications, and an *8-way 7U* server isn't ideal as a file/printer server, so too are blade servers better suited for some uses than others. Don't forget that as hot as the blade server segment is today, it's still only a small piece of the overall rack server market. According to IDC[1], in 2002 blade servers constituted less than **1%** of overall server market share. Even by 2007, IDC expects blade servers to account for less than **25%** of shipments of all servers. *Other rack-optimized* servers are expected to command **40.7%** of the market in 2007, with *non-rack-optimized* (tower) servers claiming the remaining **34.6%**. This means that there is still a tremendous market for non-blade servers.

There is an old saying that to a man with a hammer, everything looks like a nail. Don't be so blinded by the bright future of blade servers that every IT need looks like a blade server opportunity. Traditional rack servers may be a better fit for some customers, while a combination of blade and traditional rack servers may be best for others.

This paper compares IBM @server BladeCenter with other IBM rack-optimized servers, and shows which may work best in various environments.

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[1] IDC March 2003 Forecast.

Contents

Overview of IBM Rack-Optimized Intel-Compatible @server Systems

IBM offers a comprehensive portfolio of rack-optimized servers. Ranging from the "pizza box" size uniprocessor and 2-way SMP servers to a performance-leading 16-way server, selection and choice allows maximum customer flexibility. Current Intel or AMD processor-based IBM servers include the @server xSeries® 305, x335, x345, x360, x382, x445, x450 and the @server 325 and BladeCenter™. Because one size *doesn't* fit all needs, IBM offers a range of 32- and 64-bit systems, from rack-dense 1U edge servers to 2U application and high-performance computing (HPC) servers to 4U ultra-expandable enterprise servers to 7U blade servers. Each is built with Enterprise X-Architecture™ technology, in support of the IBM e-business on demand™ computing initiative and to enable autonomic computing[2].

Autonomic computing is an IBM initiative to advance the goal of enabling self-managing systems. It does so by incorporating multiple layers of proactive and reactive tools designed to allow the server to continue operating, despite system errors or failures. These tools include features that offer self-configuring, self-healing, self-optimizing and self-protecting capabilities to servers. To maintain high-performance, there are intelligent technologies to help allocate system resources to high-priority applications for extra support and to prevent bottlenecks in critical system resources, such as memory and network traffic.

Due to their relative newness, some of these servers may not be familiar to all readers and thus are briefly described here:

1U Uniprocessor 32-bit Server — x305

The x305 is a highly affordable, rack-dense, uniprocessor server for Web and network infrastructure. It's ideal for telecom infrastructures, Web caching, firewalls, load-balancing and encryption. The x305 is a **1U** server, offering **one** Intel® **Pentium**® **4** processor, up to **512K** of **L2** cache, a **533MHz** front side bus (FSB), up to **4GB**[3] of **PC2100** double data rate (**DDR**) **ECC** memory, **two PCI-X** adapter slots[4] and integrated **dual Gigabit Ethernet** controllers. Up to **240GB**[5] of **IDE** or **146.8GB** of **Ultra160 SCSI** storage is supported in **two** drive bays. Rack-specific features include toolless slides for one-person installation and servicing, a reduced-depth (**16.75"/42.5cm**) chassis for easy cable management and efficient cooling, **2-post** or **4-post** mounting and the optional IBM Advanced Connectivity Technology (**ACT**) Category 5 (CAT5)-based KVM cabling feature. A **-48V DC** power supply-based model is available for telecom customers. One 42U rack full of x305 servers would provide **42** processors and **84** internal I/O slots.

1U 2-Way 32-bit Server — x335

The x335 is a highly manageable, rack-dense 2-way server for performance computing in space-constrained environments. It's ideal for Web content servers, firewalls, gateways, replicated data servers and scientific/technical computing. The **1U** x335 offers up to **two** 32-bit Intel **Xeon**™ processors, a **400MHz** or **533MHz** front side bus (FSB), up to **8GB** of **PC2100** double data rate (**DDR**) **Chipkill**™ ECC memory, **C2T Interconnect**™ KVM cabling, integrated **dual Gigabit Ethernet** controllers, an Integrated Systems Management Processor (ISMP), **two PCI-X** slots and **two** hard disk drives: up to either **293.6GB** of **Ultra320** SCSI *hot-swap* hard disk

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[2] For more information about On Demand computing and autonomic computing, visit http://**ibm.com**/ondemand and http://**ibm.com**/autonomic.

[3] Maximum memory and disk capacity may require the replacement of standard components with the largest supported component available.

[4] One slot is occupied in SCSI models.

[5] GB equals 1,000,000,000 bytes when referring to hard disk drive capacity. Accessible capacity may be less.

drives with **integrated RAID 1** mirroring *or* **240GB** of *non*-hot-swap **IDE** storage. **Light path diagnostics** and **Real Time Diagnostics** are standard features that simplify management and improve uptime. Rack-specific features include toolless rails, a reduced-depth (**26"/66cm**) chassis, the integrated **C2T Interconnect** cabling feature and interoperability with other IBM servers using the optional **ACT** cabling system. Predictive Failure Analysis® (**PFA**) support is provided for hard disk drives, processors, memory, voltage regulator modules (VRMs) and power supply. (An optional **Remote Supervisor Adapter I** adds PFA support for fans.) A model equipped with a **-48V DC** power supply for telecom customers is available as well. Up to **42** x335 servers can be installed in a **42U** rack, providing up to **84** processors and **84** internal I/O slots.

1U 2-Way 64-bit Server — e325

The e325 is a highly manageable, rack-dense 2-way server for 32-bit and 64-bit HPC and cluster environments. It's ideal for customers wanting outstanding 32-bit performance today and a simple, inexpensive upgrade path to 64-bit computing with exceptional price/performance. The **1U** e325 ships with one **AMD™ Opteron™ 64-bit** processor with **1MB** of L2 cache, upgradable to 2-way. Replacing the front side bus (FSB) used by other processor architectures with a full processor-clock-rate **HyperTransport™ Tunnel**, and incorporating an **integrated memory controller**, produces outstanding performance, for both 32-bit and 64-bit software (even concurrently). The e325 offers up to **12GB** of **PC2700** (**333MHz**) double data rate (**DDR**) **Chipkill** ECC memory, integrated **dual Gigabit Ethernet** controllers, an integrated systems management controller, **two PCI-X** slots and **two** hard disk drives: up to either **293.6GB** using **two Ultra320** SCSI *hot-swap* hard disk drives with **integrated RAID 1** mirroring *or* **240GB** using **two** *non*-hot-swap **IDE** drives. Rack-specific features include toolless rails and chassis, a reduced-depth (**26"/66cm**) chassis and interoperability with other IBM servers using the optional **ACT** cabling system. **PFA** support is provided for hard disk drives. (An optional **Remote Supervisor Adapter II**[6] adds PFA support for fans.) Up to **42** e325 servers can be installed in a **42U** rack, providing up to **84** processors and **84** internal I/O slots.

2U 2-Way 32-bit Server — x345

*The x345 is a highly available and expandable rack-dense **2U** 2-way server for space-constrained data centers and application serving in Web environments. It's ideal for e-commerce, departmental infrastructure, mission critical e-mail/collaboration serving and high-availability clustering.* The **2U** x345 supports up to **two Xeon** processors, up to **8GB** of **PC2100 DDR Chipkill** memory, **1MB** of **L3** processor cache (per processor), a **400MHz** or **533MHz** FSB, **five** adapter slots (**four PCI-X** and **one PCI**), an integrated **dual-port Gigabit Ethernet** controller and an Integrated Systems Management Processor (ISMP). Up to **six Ultra320** SCSI hot-swap hard disk drives (**880.8GB** total) are supported, with **integrated RAID-1** mirroring. The x345 offers *optional* **redundant power and cooling**. **Light path diagnostics** and **Real Time Diagnostics** are standard. Rack-specific features include toolless slides, a cable-management arm, a reduced-depth (**27.5"/70cm**) chassis and optional **ACT** cabling. **PFA** support is provided for hard disk drives, processors, memory, voltage regulator modules (VRMs) and power supplies. (An optional **Remote Supervisor Adapter I** adds PFA support for fans.) Up to **21** x345 servers can be installed in a **42U** rack, providing up to **42** processors and **105** I/O slots.

2U 2-Way 64-bit Server — x382

*The x382 is a highly available rack-dense **2U** 2-way server for 64-bit HPC environments. It's ideal for floating-point-intensive 64-bit applications and high-availability clustering.* The **2U** x382 supports up to **two** 64-bit Intel **Itanium™ 2** processors, a **400MHz** front side bus (FSB), up to **16GB** of **PC2100** double data rate (**DDR**) ECC memory, integrated **dual Gigabit Ethernet**

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[6] e325 support for the Remote Supervisor Adapter II is planned for Q4/03.

controllers, an integrated systems management controller, **three PCI-X** slots, a DVD/CDRW combo drive and **two** hard disk drives: up to either **293.6GB** of **Ultra320** SCSI *hot-swap* hard disk drives with **integrated RAID 1** mirroring *or* **240GB** of *non*-hot-swap **IDE** storage. Rack-specific features include toolless rails and interoperability with other IBM servers using the optional **ACT** cabling system. **PFA** support is provided for hard disk drives, processors, memory, voltage regulator modules (VRMs) and power supplies. The x382 offers **hot-swap redundant cooling, dual hot-swap power supplies** and *optional* **redundant power** (available by special bid). Up to **21** x382 servers can be installed in a **42U** rack, providing up to **42** processors and **63** internal I/O slots.

3U 4-Way 32-bit Server — x360

The x360 is a space-efficient, expandable, rack-dense server for demanding enterprise applications. It's ideal for space-constrained data centers, for ISPs and ASPs and as a departmental infrastructure server. The first server to incorporate **Enterprise X-Architecture** technology, the x360 supports up to **four** Intel **Xeon MP** processors, up to **16GB** of **DDR Chipkill** memory, **1MB** of **L3** processor cache (per processor), a **400MHz** FSB, integrated **10/100** Ethernet controller, **Remote Supervisor Adapter I** (installed in a dedicated slot) and **six hot-add/hot-swap Active™ PCI-X** slots. SAN-optimized and designed for external storage, it includes **three** disk drive bays, making it ideal for mirroring your OS and having a hot-spare, or for a RAID 5 array containing up to **220.2GB** of **Ultra160** SCSI hot-swap hard disk drive storage. Rack-specific features include toolless slides and optional **ACT** cabling. **PFA** support is provided for hard disk drives, processors, memory, VRMs, fans and power supplies. **Light path diagnostics** and **Real Time Diagnostics** are standard. Up to **14** x360 servers can fit in a **42U** rack, providing up to **56** processors and **84** internal I/O slots.

One optional **3U RXE-100 Remote Expansion Enclosure** is supported, adding **6** or **12** more PCI-X slots, thereby doubling or tripling the number of PCI-X slots available to the x360. This is perfect for configuring high availability solutions and clusters with redundant Fibre Channel host bus adapters, RAID adapters, NICs, etc. The x360 also supports the IBM Integrated xSeries Adapter (**IXA**), which enables a direct high-speed link to an iSeries™ server.

4U 2-Way to 32-Way 32-bit Modular/Scalable Server — x445

The x445 combines outstanding scalability, performance and manageability with a revolutionary economic model for optimized 32-bit IT resources. It's ideal for space-constrained data centers, for server consolidation, for high-performance computing and for customers seeking extreme scalability of processors, memory and I/O. This scalable XpandOnDemand™ **Enterprise X-Architecture** server offers a choice of scalability configurations. The x445 supports either:

- Up to **16 (32** planned[7]**) Xeon MP** processors with up to **256GB** of DDR Chipkill ECC memory (by interconnecting up to four 8-way chassis); up to **eight Xeon MP** processors and **64GB** of DDR Chipkill ECC memory per individual *chassis* (**1MB** or **2MB** of **L3** cache per *processor*)

- **Two or four Xeon** (not MP) processors and **32 or 64GB** of DDR Chipkill ECC memory per stand-alone *chassis* (no multichassis configurations are available)

Either configuration offers **Chipkill** *and* **Memory ProteXion™** capabilities with memory mirroring, hot-swap and hot-add memory support[8], a **400MHz** front-side bus and up to **64MB** of **400MHz L4** XceL4™ Server Accelerator Cache per *SMP Expansion Module* (**4-way Xeon MP**, or **2-way Xeon**). Each *chassis* contains **six hot-add/hot-swap Active™ PCI-X** slots, a **dual-channel Ultra320** SCSI controller, up to **two Ultra320** SCSI hot-swap hard disk drives (**293.6GB** max.), dual **Gigabit Ethernet** and a **Remote Supervisor Adapter I** or **II** (included standard in a dedicated slot). *Four 8-way Xeon MP-based x445 chassis can be linked together via high-speed*

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[7] 32-way support is planned for Q4/2003. Until then, the maximum is 16-way, using two 8-way chassis.

[8] Hot-add support currently requires Windows Server 2003 Enterprise Edition or Datacenter Edition.

*SMP Expansion Cables to form one **multichassis 32-way** SMP server.* Rack-specific features include the optional ACT feature. **PFA** support is provided for hard disk drives, processors, memory, L4 cache, fans and power supplies. **Hot-swap support** is provided for hard disk drives, PCI-X adapters, memory, fans and power supplies. **Light path diagnostics, Copper Diagnostics™**, **Real Time Diagnostics** and scalability cable failover are standard features that simplify management and improve uptime. Up to **ten** x445 servers can fit[9] in a **42U** rack, providing up to **80** processors and **60** internal I/O slots.

One RXE-100 remote I/O expansion unit (providing up to **12** external PCI-X adapter slots in addition to the **six** slots inside the x445) is supported per x445 *configuration* of up to **four** interconnected chassis. Optionally, **two** independent x445 4-way, 8-way or 16-way configurations can *share* one RXE-100 (providing **six** extra slots per configuration).

4U 1-Way to 4-Way Server — x450

The x450 is a highly available and expandable leadership 64-bit Itanium 2-based solution. It leverages the proven Enterprise X-Architecture chipset to deliver new levels of scalability and flexibility to 64-bit industry-standard servers. It's ideal for server consolidation, for floating-point intensive 64-bit applications and high-availability clustering, and for customers seeking scalability of processors, memory and I/O. This scalable **Enterprise X-Architecture** server supports up to **four** 64-bit Intel **Itanium 2** processors with **3MB**, **4MB** or **6MB** of **L3** cache. The x450 includes a **400MHz** front side bus (FSB) and up to **40GB** of **PC2100** double data rate (**DDR**) memory.

Like the x445, the x450 offers **Chipkill** *and* **Memory ProteXion** capabilities with memory mirroring, hot-swap memory support, and up to **64MB** of **400MHz L4** XceL4 Server Accelerator Cache per **4-way** chassis. Each system contains **six hot-add/hot-swap Active PCI-X** slots, a **dual-channel Ultra320** SCSI controller, up to **two Ultra320** SCSI hot-swap hard disk drives (**146.8GB** max.), dual **Gigabit Ethernet** and a **Remote Supervisor Adapter I** (in a dedicated slot). Rack-specific features include toolless rails and interoperability with other IBM servers using the optional **ACT** cabling system. **PFA** support is provided for hard disk drives, processors, memory, voltage regulator modules (VRMs), L4 cache and power supplies. The x450 offers **hot-swap redundant fans** and **power supplies**. Up to **10** x450 servers can be installed in a **42U** rack, providing up to **40** processors and **60** internal I/O slots.

One RXE-100 remote I/O expansion unit (providing up to **12** external PCI-X adapter slots in addition to the **six** slots inside the x450) is supported per x450 chassis. (In other words, a **12-slot** RXE-100 units can be connected to a **6-slot** chassis, for a total of **18** PCI-X slots in the configuration.)

7U BladeCenter Chassis

BladeCenter *is a cost-effective, highly dense, highly scalable server chassis for application workloads. It's ideal for Citrix, IBM WebSphere™, Lotus® Notes™, Microsoft® Exchange and Linux® cluster usage.* BladeCenter uses hot-swap blade servers with the individual blades arranged in the chassis much like books on a bookshelf, to offer up to **168** processors in one **42U** rack (**28** processors on **14** 2-way blades per **7U** chassis)—**twice** the density of the x335 and e325 and **four** times the density of the x305 and x345. The chassis supports **hot swap and redundant fans, power supplies, I/O switches** and **management modules**, along with a midplane with redundant components and a hot-swap media tray. Independently powered **Light path diagnostics** simplifies and speeds up maintenance. BladeCenter also integrates functionality that traditionally exists outside the server, decreasing complexity and increasing manageability. For example, it includes a **management module** and supports the addition of option modules,

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[9] Although ten x445 chassis will fit in a 42U rack, for power distribution and heat dissipation reasons it is recommended that a maximum of eight chassis be installed. The remaining 10U can be used for other server models, RXE-100 I/O expansion units, disk or tape storage units and other devices.

such as **Gigabit Ethernet** and **Fibre Channel** switches that would normally take additional rack space, and a *second* management module. BladeCenter includes **four** switch bays that support various combinations of Gigabit Ethernet switches, Fibre Channel switches and Optical Pass-thru Modules (OPMs).

The modular design of BladeCenter makes upgrading server capacity a simple matter of plugging in a new blade server—or swapping one out for service. It also greatly simplifies cable management and lowers cabling costs, because each blade doesn't need its own cables. By eliminating all the duplicate cabinets, power supplies, fans, KVM cabling, Ethernet cabling and other components normally included with a server and sharing them in one blade server chassis, an organization can achieve significant cost savings in these areas for a full rack of servers. The BladeCenter chassis can connect to the same optional ACT cabling system as the other xSeries rack-mounted servers.

HS20 32-bit Blade Servers for BladeCenter

xSeries HS20 blade servers contain one or two **Xeon** processors, up to **8GB** of high-speed **DDR ECC** memory, up to **80GB of IDE storage**, **dual Gigabit Ethernet** controllers and an **ISMP**. An optional **SCSI storage expansion option** is available that supports up to **146.8GB of hot-swap Ultra320** SCSI storage, however adding the option doubles the size of the blade server. **PFA** is available for processors, memory, power supplies, fans and hard disk drives.

Processor Density vs. Adapter I/O and Storage Density

Blade servers offer very high density of processors and memory, but they do so by optimizing the system for external storage through network-attached storage (NAS) or a storage area network (SAN). BladeCenter offers up to two IDE (or optionally, SCSI) drive bays. (An optional *I/O Expansion Card* feature allows the use of one compatible PCI[10] card, but limits the number of *IDE* drives to one.) For additional storage, customers can choose between external NAS and SAN solutions. By comparison, the **2U** xSeries 345 (**x345**) can hold up to **six** internal hot-swap Ultra320 SCSI drives containing up to **880.8GB** of storage and offers five adapter slots. A rack full of **21** x345 servers can support nearly **18.5TB** of disk storage internally. Those same servers will also contain **105** adapter slots.

On the other hand, one **7U** BladeCenter chassis can support up to **14** 2-way blade servers, for a total of **168** processors per rack (6 chassis x 14 blades x 2 processors), to only **42** processors using a rack full of x305 or x345 servers.

For comparison, *Table 1* shows the number of processors, adapter slots and hard disk drives, and the amount of memory that one rack could hold for various rack-optimized servers. Overall, the **x335** and **e325** show the best *balance* between processor, memory, adapter and internal storage density, the **x360** offers the greatest *adapter* density (at the expense of processors), the **x345** gives the greatest internal *disk storage* density (with a large number of adapter slots as well), and **BladeCenter** provides by far the greatest *processor* and *memory* density, but limits the number of available adapter slots. Although it isn't revealed in the table, the **x305** can be the least expensive solution for uniprocessor needs. At present, HS20 blade servers support up to **2-way** configurations; **4-way** configurations are planned, but they will require two blade slots, so the processor density won't increase. If you need **4-way** or larger servers consider the **x360** and **x445**.

Each of these xSeries offerings can fill some specific needs better than the other servers. In *Table 1*, results highlighted in **bold green** indicate the *highe*r numbers in that column, while **bold**

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[10] The I/O Expansion Card option allows the use of PCI cards that are designed specifically for BladeCenter, not legacy PCI or PCI-X adapters.

red numbers show the *lower* totals. The *very* best and worst results in each color are identified by a larger font. *Note that no server has the highest or lowest totals in all areas.*

Processor / Memory / Adapter / HDD Rack Density by Server					
Server	**Processors (Max.)**	**Memory (Max.)**	**Adapter Slots**	**Internal Hard Disk Drives (Max.)**	**Total Internal HDD Capacity**
x305	**42**	**168GB**	42	84	6.17TB (SCSI)
x305	**42**	**168GB**	84	84	10.08TB (IDE)
e325	84	**504GB**	84	84	**12.33TB (SCSI)** 10.08TB (IDE)
x335	84	336GB	84	84	**12.33TB (SCSI)** 10.08TB (IDE)
x345	**42**	**168GB**	**105**	**126**	**18.5TB**
x360	56	224GB	84	42	3.08TB
x360 (Note 1)	**28**	**112GB**	**126**	**21**	**1.54TB**
x382	**42**	336GB	63	42	6.17TB
x445 (Notes 2, 3)	64	**512GB**	84	**16**	**2.35TB**
x445 (Note 4)	48	384GB	**108**	**12**	**1.76TB**
x450 (Notes 2, 3)	32	320GB	84	**16**	**1.17TB**
x450 (Note 4)	**24**	240GB	**108**	**12**	**880.8GB**
BladeCenter / HS20 Blade servers (IDE) (Note 5)	**168**	**672GB**	**0**	**168**	6.72TB
BladeCenter / HS20 Blade servers (IDE) (Note 6)	**168**	**672GB**	84	84	3.36TB
BladeCenter / HS20 Blade servers (SCSI) (Notes 5, 7)	84	336GB	**0**	84	6.17TB
BladeCenter / HS20 Blade servers (SCSI) (Notes 6, 7)	84	336GB	84	84	6.17TB

Table 1. *Comparison of processor, memory, adapter slot and HDD rack density.*

Notes for Table 1

1. Using **seven** x360 servers and **seven** 12-slot RXE-100 expansion units.
2. Although **ten** x445/x450 chassis will fit in a 42U rack, for power distribution reasons it is recommended that a maximum of **eight** chassis be installed. The remaining 10U can be used for other server models, RXE-100 I/O expansion units, disk or tape storage units and other devices.
3. Using **eight** x445/x450 servers and **three** 12-slot RXE-100 expansion units.

4. Using **six** x445/x450 servers and **six** 12-slot RXE-100 expansion units.
5. Without the optional I/O Expansion Card.
6. Using the I/O Expansion Card option. It offers one PCI slot per blade, but limits the blade to one IDE drive.
7. The use of SCSI HDDs requires an optional SCSI kit, which *doubles* the width of the blade and therefore reduces the number of blades that can be used per chassis. The *default* number of PCI slots provided is zero, however the optional I/O Expansion Card option offers one PCI slot per blade without limiting the number of SCSI drives.
8. Maximum capacity may require replacing preinstalled memory/hard disk drive with higher-capacity components.

A Solution View of Hardware/Software Costs and Environmental Factors

When evaluating the relative costs associated with server purchases many factors must be considered. In addition to the obvious costs of the servers and racks themselves, as well as other components such as KVM cables and power distribution units (PDUs), there are other, perhaps less obvious, costs that must enter into the equation. For example how many operating system licenses are required for each solution? (168 *uniprocessor* servers will require 168 OS licenses, while 84 *2-way* servers will need only 84 licenses.) And what are the relative differences in power draw and cooling requirements? Can your infrastructure handle it? Naturally, the more racks that are required, the larger the data center floor space footprint is.

To illustrate, the following three configurations show the differences in the hardware and software that are required for solutions providing **equivalent processing power**, as measured by the SPECfp_rate2000 and SPECweb99_SSL benchmarks. *For the sake of simplicity, the comparisons don't consider the costs of rack space used by management consoles or SAN storage, the cost of application software licenses or the potential difference in personnel costs for administering varying numbers of servers. It strictly looks at the cost of the servers, basic rack infrastructure and OS licenses, as well as floor space, electrical draw and cooling costs. Feel free to plug in your own known costs for anything omitted here. Only **BladeCenter**, **x335** and **x305** were used for the **Web serving** comparison, and **BladeCenter**, **x335** and **e325** for the **HPC clustering** comparison.*

In **Solution #1**, using **six BladeCenter** chassis and **84 IBM HS20** 2-way blade servers, one rack can hold 168 processors. In addition, using IBM Advanced Connectivity Technology[11] (ACT) interconnect cabling to tie everything together from a management standpoint, the rack requires **one** Local Console Manager (LCM), **six** KVM Conversion Options (KCOs), **four** 60 amp front-end PDUs and **12** rack PDUs. The footprint for one 42U IBM NetBAY42™ Enterprise Rack is **1.75** square meters or **18.7** square feet (including room for the door to open, airflow, etc.). The six BladeCenter chassis, 84 blades and all the LCMs and PDUs require **15 kilowatts** of power and generate **51,180 BTUs**[12] of heat per hour. This solution requires **84** OS licenses, one per *2-way* blade server.

Solution #2, consisting of **66 x335** 2-way servers, uses *two* racks. It requires only minimal optional ACT cabling, because the x335 ships with IBM C2T Interconnect cable-chaining technology. The racks require **two** LCMs and **two** C2T Conversion Options (CCOs), **four** 60 amp front-end PDUs and **10** rack PDUs. The 66 x335 servers require **16.1 kW** of power and produce **54,933 BTUs** of heat. The footprint of *two* IBM NetBAY42 Enterprise Racks (**3.5** sq. m or **37.4** sq. ft), of course, is twice that of the one rack used in Solution #1. This solution requires **66** OS licenses, one per *2-way* server.

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[11] For more information about the IBM ACT and IBM C2T Interconnect cabling solutions, please refer to the *IBM Rack Solutions* white paper.

[12] Electrical usage and heat output are directly related to the application running and the load it places on the server. These numbers are based on estimates using the maximum output of the servers under full load. Actual results may vary and could be significantly lower than the numbers listed in this paper.

Solution #3, comprises **42 e325** servers in the HPC example. The servers themselves are individually a bit more expensive than the x335 systems are, however fewer servers are needed to produce the equivalent processing power. The HPC configuration requires *two* racks, **three** LCMs, **42** USB Connectivity Options (UCOs), **two** 60 amp front-end PDUs and **six** rack PDUs. The **42** servers consume **16.8 kW** of power and produce **57,322 BTUs**. Like Solution #1, the footprint of one IBM NetBAY42 Enterprise Rack is **1.75** sq. m or **18.7** sq. ft. Unlike the first two solutions, Solution #3 requires **42** OS licenses, one per *2-way* server.

Solution #4, consisting of **84 x335** 2-way servers, requires *two* racks. It requires only minimal optional ACT cabling, because the x335 ships with IBM C2T Interconnect cable-chaining technology. The racks require **two** LCMs and **two** C2T Conversion Options (CCOs), **five** 60 amp front-end PDUs and **12** rack PDUs. The 84 x335 servers require **20.5 kW** of power and produce **69,946 BTUs** of heat. The footprint of *two* IBM NetBAY42 Enterprise Racks (**3.5** sq. m or **37.4** sq. ft), of course, is twice that of the one rack used in Solution #1. This solution requires **84** OS licenses, one per *2-way* server.

Solution #5, includes **149 x305** uniprocessor servers in the Web Serving example. The servers themselves are much less expensive than the x335 systems are, but there are many more of them. In the Web configuration they require **four** racks, **four** LCMs, **149** KVM Connectivity Options (KCOs), **eight** 30 amp front-end PDUs and **22** rack PDUs. The **149** servers require **20.3 kW** of power and generate **69,264** BTUs. The footprint of *four* IBM NetBAY42 Enterprise Racks is *quadruple* **(7.0** sq. m or **74.8** sq. ft) that of the one rack used in Solution #1. Unlike the first two solutions, Solution #3 requires **149** OS licenses, one per *uniprocessor* server.

The relative costs of these solutions in different environments are summarized in *Tables 2* and *3*. *Table 2* shows the costs involved in an **HPC Linux cluster** using Red Hat Linux 9.0, for applications such as particle physics, weather modeling or computational fluid dynamics. *Table 3* illustrates the costs involved in a **Web serving environment**, using the same infrastructure and operating system, with appropriate Web serving software. The number of processors used in each configuration produce equivalent benchmark results for the entire configuration.

In *Table 2*, the three configurations (**84 2-way 2.8GHz Xeon**-based HS20 blade servers, **66 2-way 3.06GHz Xeon**-based x335 servers and **42 2-way 2.0GHz Opteron**-based e325 servers) produced an equivalent SPECfp_rate2000 benchmark result of approximately **1109**. (Source: Extrapolated from individual server scores as of May 2003). Each server was equipped with the fastest processor of its type available at that time for that server.

Relative Costs of Selected IBM Rack-Optimized Servers for HPC Linux Cluster			
Attributes	**Solution #1**	**Solution #2**	**Solution #3**
Server hardware description	**6 BladeCenter** chassis containing **84 HS20** blade servers (2 x **2.8GHz Xeon** processors with **533MHz** FSB, 2GB Chipkill ECC RAM, 2 x **40GB** IDE drives), in **1** rack	**66 x335** servers (2 x **3.06GHz Xeon** processors with **533MHz** FSB, 2GB Chipkill ECC RAM, 2 x **40GB** IDE drives), in **2** racks	**42 e325** servers (2 x **2.0GHz Opteron 246** processors with **2.0GHz** HyperTransport Tunnel, 2GB Chipkill ECC RAM, 2 x **80GB** IDE drives), in **1** rack

Relative Costs of Selected IBM Rack-Optimized Servers for HPC Linux Cluster			
Attributes	Solution #1	Solution #2	Solution #3
Hardware cost for servers and equivalent processor, memory and storage options	$514,386 (includes integrated switches)	$346,179	$258,762
Infrastructure cost (including racks, switches, KVM cables, PDUs, etc.)	$8,632 (Note 1)	$11,320 (Note 1)	$18,069 (Note 1)
Cost of Linux licenses	84 x $150.00 = $12,600 (32-bit RHEL AS 2.1)	66 x $150.00 = $9,900 (32-bit RHEL AS 2.1)	42 x $749.00 = $31,458 (64-bit SLES 8.0)
Combined cost of hardware, infrastructure, and software licenses	$535,618	$367,399	$308,289
Rack footprint — Three-year data center floor space cost —	1.7 sq. m / 18.7 sq. ft $201,960	3.5 sq. m / 37.4 sq. ft $403,920	1.7 sq. m / 18.7 sq. ft $201,960
Electrical usage — Three-year power cost —	15.0 kW/hr $35,478	16.1 kW/hr $38,097	16.8 kW/hr $39,735
Heat produced — Three-year cooling cost —	51,180 BTUs/hr $11,708	54,933 BTUs/hr $12,572	57,322 BTUs/hr $13,113
Combined cost for data center floor space, electricity and cooling	$249,146 (Note 3)	$454,589 (Note 3)	$254,808 (Note 3)
Total cost for hardware, software and facilities	784,764	821,988	563,097

Table 2. *Cost comparison of BladeCenter with x305 and x335 for HPC Linux clustering.*

As you can see, due to the enhanced performance of the Opteron-based e325, many fewer servers are required to produce the same output. This allows the combined hardware, software and infrastructure costs to be far lower than for BladeCenter or the x335. Once the facilities costs are added in (requiring a second rack for the x335, the overall cost of the x335 jumps relative to the others. In this configuration, only one rack is required for BladeCenter and the e325.

Table 3 shows the costs for equivalent performance of **(84) 2-way 2.8GHz Xeon**-based HS20 blade servers, **(84) 2-way 2.8GHz Xeon**-based x335 servers and **(149) 2.8GHz Pentium 4**-equipped x305 servers in a **Web server** environment, using Red Hat Enterprise Linux AS 8.0 and Web Server software. In *Table 3*, the configurations achieved an equivalent SPECweb99_SSL benchmark result of **144,480**. (Source: IBM Performance Team, May 2003). Because performance isn't the paramount consideration in the Web Serving environment, in this example, all servers are equipped with 2.8GHz processors (Xeon or Pentium 4).

(**Note:** An HS20 blade server equipped with a **3.06GHz** Xeon processor was announced on September 9, 2003, too late to be used in these comparisons. It produced a SPECweb99_SSL score of **1,304** simultaneous connections, which was nearly **18%** better than the **2.8GHz** HS20 blade used in the comparison and **5%** better than the HP BL20p G2's score of **1,242**[13].)

[13] The BladeCenter HS20 score is available at: *http://www.spec.org/web99ssl/results/res2003q3/web99ssl-20030721-00075.html*.
The HP BL20p score is available from: *http://www.spec.org/web99ssl/results/res2003q2/web99ssl-20030414-00054.html*.
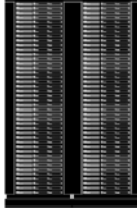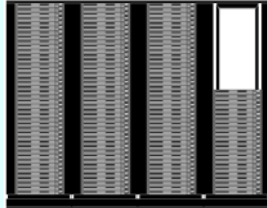
Relative Costs of Selected IBM Rack-Optimized Servers for Linux Web Server			
Attributes	**Solution #1**	**Solution #4**	**Solution #5**
Server hardware description	**6 BladeCenter** chassis containing **84 HS20** blade servers (**2 x 2.8GHz Xeon** processors with 533MHz FSB, **2GB** Chipkill ECC RAM, 2 x 40GB IDE drives), in **1** rack	**84 x335** servers (**2 x 2.8GHz Xeon** processors with 533MHz FSB, **2GB** Chipkill ECC RAM, 2 x 40GB IDE drives), in **2** racks	**149 x305** servers (**1 x 2.8GHz Pentium 4** processors with 533MHz FSB, **1GB** std. ECC RAM, 2 x 40GB IDE drives), in **4** racks
Hardware cost for servers and equivalent processor, memory and storage options	**$514,386** (includes integrated switches)	**$406,984**	**$489,018**
Infrastructure cost (including racks, switches, KVM cables, PDUs, etc.)	**$8,632** (Note 2)	**$12,643** (Note 2)	**$56,534** (Note 2)
Cost of Linux licenses	84 x $150.00 = **$12,600** (32-bit RHEL AS 8)	84 x $150.00 = **$12,600** (32-bit RHEL AS 8)	149 x $150.00 = **$22,350** (32-bit RHEL AS 8)
Total cost of hardware plus software licenses	**$535,618**	**$432,227**	**$567,902**
Rack footprint — Three-year data center floor space cost —	**1.7** sq. m / **18.7** sq. ft **$201,960**	**3.5** sq. m / **37.4** sq. ft **$403,920**	**7.0** sq. m / **74.8** sq. ft **$807,840**
Electrical usage — Three-year power cost —	**15.0** kW/hr **$35,478**	**20.5** kW/hr **$48,486**	**20.3** kW/hr **$48,036**
Heat produced — Three-year cooling cost —	**51,180** BTUs/hr **$11,708**	**69,946** BTUs/hr **$16,000**	**69,264** BTUs/hr **$15,852**
Combined cost for data center floor space, electricity and cooling	**$249,146** (Note 3)	**$468,406** (Note 3)	**$871,728** (Note 3)
Total cost for hardware, software and facilities	**$784,764**	**$900,633**	**$1,439,630**

Table 3. *Cost comparison of BladeCenter with x305 and x335 for Windows Web serving*

Notes for Tables 2 and 3

1. Solutions #1 and #3 use **one** NetBAY42 Enterprise rack. Solution #2 uses **one** NetBAY42 Enterprise rack and **one** NetBAY42 Enterprise Expansion rack.

2. Solution #1 uses **one** NetBAY42 Enterprise rack. Solution #2 uses **one** NetBAY42 Enterprise rack and **one** NetBAY42 Enterprise Expansion rack. Solution #4 uses **one** NetBAY42 Enterprise rack and **three** NetBAY42 Enterprise Expansion racks.

3. Using electrical costs of $.09 per hour and floor space costs of $300 per sq. ft./$3,300 per sq. m. per month. These costs can differ widely from customer to customer, region to region, country to country. By using actual costs per square meter or foot of data center space, and the per kilowatt hour cost of electricity for power and cooling, customers can create customized results that are appropriate for their locations.

As the preceding tables show, the pricing differences between Solutions #1, #2, #3 and #4—which compare configurations offering equivalent performance—can be dramatic in large quantities. However, in many environments, cost and density are higher priorities than performance. *Figure 1* takes a different look at the servers, comparing *identical quantities* of x335, e325 and BladeCenter HS20 servers (rather than looking at equivalent processing power).
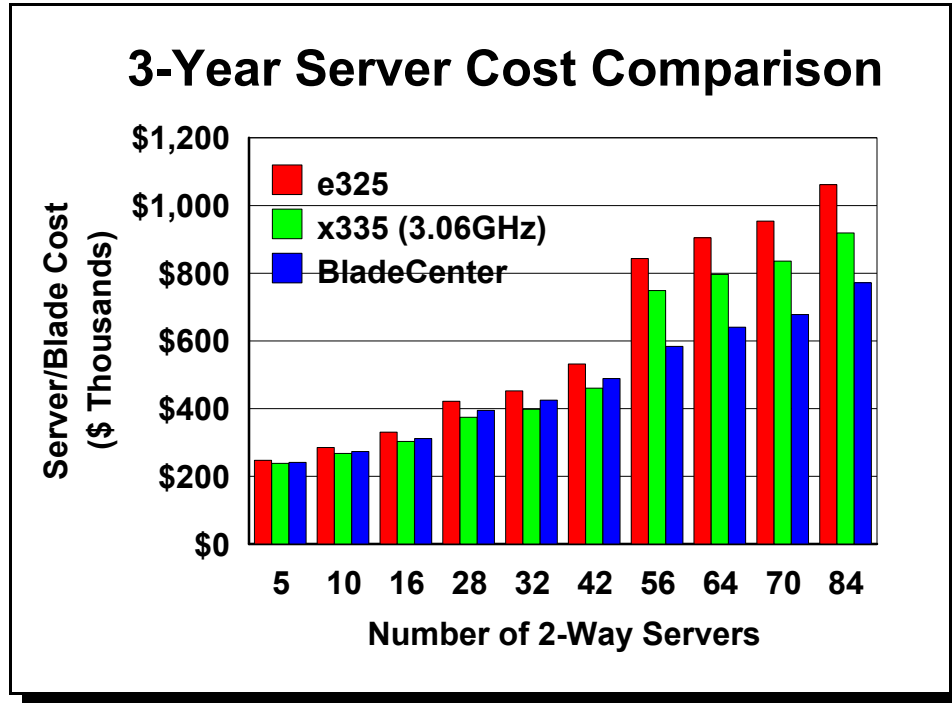
Figure 1. *Cost comparisons at various server quantities*

In this view, which server is the most cost-effective depends entirely on the number of servers you intend to use. (In other words, rather than equating **84** BladeCenter HS20 and **66** x335 servers to **42** e325 processors for equivalent performance, the comparison is between the costs of **5**, **10**, etc., up to **84** of *each type* of server.) This cost comparison[14] is also different from the ones in *Tables 2* and *3* in that it excludes software (because the same number of licenses are required for every comparison).

In quantities up to **42** servers (one full rack), the x335 (using the **2.8GHz** Xeon processor, from *Table 2*) was the least expensive server, falling between **1.92%** and **9.6%** less than BladeCenter, with the e325 trailing BladeCenter by another **2.5%** to **8%**. However, once the numbers of e325 and x335 servers required a second rack, at quantities beyond **42** servers**,** BladeCenter became **13.5%** to **20.1%** *less* expensive to operate than the x335 (and as much as **30.8%** less than the

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[14] The cost comparison uses IBM web prices as of September 8, 2003 for x335 models 8676-12X and 8676-22X, and an e325 model 8835-52X. The prices for BladeCenter are for model 8677-1XX, and for HS20 blades model 8832-21X. The x335 servers model 8676-12X and the HS20 blades are configured with two **2.8GHz** Xeon processors, 533MHz FSB, 2GB of memory and two **40GB** IDE drives. e325 servers are configured with two 2.0GHz Opteron 246 processors, 2GB of memory and two **80GB** IDE drives. The e325 includes one IBM Remote Supervisor Adapter II per server; while the x335 includes one IBM Remote Supervisor Adapter I for each **24** servers, to provide similar function. Each BladeCenter chassis includes one Ethernet switch module, one systems management module, and one breakout cable. The e325 and x335 configurations includes one Myrinet 32-port Ethernet switch per 32 servers and two breakout cables per server. The configurations include the appropriate number of PDUs, KCOs, CCOs, UCOs, console switches and LCMs.

e325), due in large part to the monthly data center floor space costs of the additional racks required for the e325 and x335. For configuration details, see *Appendix A*.

> ***Note 1:*** In these examples, x335 was less expensive than BladeCenter in all configurations up through **42** servers, using per-square-foot costs of $135 per month or more. When the monthly cost dropped below $100 per month, the x335 also became less expensive in most or all processor configurations of **112** or more.)
> ***Note 2:*** Although the e325 server had the highest cost in all quantities tested, it should be noted that the e325 is a 64-bit server, offering greater potential longevity than the 32-bit Xeon-based BladeCenter HS20 and x335 servers.

Application Workload Scalability

As mentioned previously, no one server is perfect for all customer uses and application types. *Figure 1* suggests which servers are best suited for certain types of environments:

SMP	File/Print	Web Serving	HPC Cluster Node	E-mail / Collaboration (MS Exchange, Lotus Notes)	Business Logic (SAP, PS/JDE, ERP, CRM, etc.)	Database (MS SQL, IBM DB2, Oracle 9i)	Server Consolid'n (File/Print Custom, E-mail, Database)
8 way+						✔ x445	✔ x445 with VMware
4 way				✔ x360 x445	✔ x445 x450	✔ x360 x445	✔ x445 with VMware
2 way	✔ x335 x345	✔ x335 BladeCenter	✔ e325 x335 x382 BladeCenter	✔ x345 BladeCenter	✔ x345 x382 BladeCenter	✔ x345 BladeCenter	✔ BladeCenter
1 way	✔ x305	✔ x305	✔ x305	✔ x305			

Figure 1. *Application workload scalability.*

Note that of the 28 boxes in the table, describing 28 different environments, the **x445** and **BladeCenter** each "play" in six of them, the **x305** and **x345** are best suited for four, the **x335** is right for three of them, the **x360** and **x382** for two, and the **e325** and **x450** are most appropriate for one each. In nine of the environments, more than one type of server could be the right choice, depending on the specific customer needs.

Advantages and Inhibitors

Each type of server has features and capabilities that make it better suited for use in certain types of customer environments than other servers, and each has some aspects that make it less suitable for other uses. The following topics describe those for BladeCenter, x305, x335, x382 and e325. It is crucial that you carefully evaluate your requirements to determine whether a blade server will truly serve your needs better than a conventional rack-optimized server.

Key BladeCenter Advantages

The following are some of the key advantages of BladeCenter as compared to other IBM rack-optimized servers:

- **Lower cost in certain configurations.** Due to efficiencies in power usage, heat emissions, and data center floor space utilization, once a configuration of other servers exceeds one rack, it is often less expensive over a multiyear period to use a single rack of BladeCenter chassis and HS20 blade servers instead. (See *Figure 1*, above.)

- **Physical server consolidation.** BladeCenter is an ideal way to replace many uniprocessor or 2-way servers to save space, even compared to a 1U x335 or x305. 14U of rack space for 14 1U servers can be replaced with one 7U BladeCenter chassis. Additional rack space that would normally be taken for Ethernet, Fibre Channel and other switches would also be eliminated by the integrated switches in the BladeCenter chassis.

- **High availability.** The BladeCenter chassis offers redundant and/or hot-swap components that can prevent failure of the chassis or blade servers when one of those components fail. The chassis has redundant, hot-swap cooling, power, midplane features, management, and I/O switches. It also has a hot-swap media tray, with CD-ROM and floppy drive, that can be removed and serviced while all blade servers are operating.

- **Integrated switch technology.** All service is from the front and rear of BladeCenter. There is no need to slide the chassis out of the rack and remove the top cover for service. Also, numerous cables are eliminated, reducing both cabling cost and servicer/administrator time.

- **More integrated systems management features.** The BladeCenter chassis includes a management module, which eliminates the need for individual management adapters (such as the Remote Supervisor Adapter I or II) in each blade server for remote control. It also eliminates the need for RS485 interconnect cabling between the blade servers.

- **SAN optimization.** A Fibre Channel switch module installed in a BladeCenter chassis provides SAN access to all blade servers in the chassis without internal cabling.

Key BladeCenter Inhibitors

While BladeCenter is an ideal solution for certain uses and in certain environments, there are some environments where another IBM rack server would be a better fit:

- **Small numbers of servers are needed.** Because a BladeCenter chassis is required for even one blade, to be cost-effective versus some stand-alone servers a chassis should be full or nearly so.

- **Legacy PCI adapters are needed.** BladeCenter includes no adapter slots as shipped. An optional I/O Expansion Card feature offers one PCI slot per blade, but it limits the blade to one IDE drive and the expansion feature supports only PCI cards designed for BladeCenter. Here, a *mix* of BladeCenter and traditional rack-optimized servers may be appropriate. (**One x360** with an attached **RXE-100** Remote Expansion Enclosure, for example, would provide up to **18** full-size high-performance PCI-X slots in only **6U** of space. Alternatively, **three x345** servers offer **15** adapter slots in **6U**.)

- **Large internal storage, or external SCSI storage is needed.** BladeCenter is limited to 80GB of IDE or 146.8GB of SCSI storage internally, with no provision for external SCSI storage. (There is, however, an external *Fibre Channel SAN* storage option.) Also, using the optional internal SCSI storage feature doubles the space requirement of the blade, cutting the number of blade servers that can be installed in a chassis in half. If you need large internal storage, the **x345**, capable of holding up to **880.8GB** of hot-swap SCSI storage, would be a better solution. All rack-mounted *xSeries* servers are capable, either natively or via an optional ServeRAID adapter, of supporting external SCSI arrays.

- **Redeployment/repurposing at end of original need is a concern.** Stand-alone uniprocessor and 2-way servers, once they fall behind the technology curve, can be

distributed individually for use as departmental file/print servers and other low-horsepower uses. Because blade servers can't be used without a chassis, the entire chassis-and-blades combo generally would need to stay together. (***Note:*** The original chassis may continue to be useful if older blade servers are discarded and newer/faster ones take their places in the chassis.)

- **No upgradability to 64-bit computing.** The **Xeon** processor used in the HS20 blade server is limited to 32-bit operating systems and applications. 64-bit Intel-compatible blade servers *may* be offered in the future, but for now consider the **e325** or the **x382** for 64-bit computing needs.

- **The data center is wired for 110-120V power.** BladeCenter requires **220-240V** power.

Key x305 Advantages

The following are some of the key advantages of the x305 as compared to other IBM rack servers:

- **Low cost in certain configurations.** The base x305 is very inexpensive compared to the x335 and BladeCenter. If the same degree of systems management capability is *not* required, costs can be kept down by using only one *Remote Supervisor Adapter I* per **24** x305 servers in an ACT cabling configuration, rather than one per server, as used in the preceding cost comparisons.

- **Shallow depth.** The extremely shallow depth of the x305 (**425.5mm/16.75"**) allows some devices—such as a 1U flat-panel monitor console—to be used *behind* the server, saving valuable rack space.

- **High-speed PCI-X slots.** The x305 provides support for **one 133MHz, 64-bit PCI-X** adapter for present and future high-performance needs, such as **10 Gigabit** Ethernet and **10X InfiniBand**™ cards. BladeCenter HS20 blade servers and x335 servers are limited to **100MHz** PCI-X speeds.

Key x305 Inhibitors

Situations where another IBM rack-optimized server might be a better fit than the x305 include:

- **Higher cost in certain configurations.** If the same degree of systems management capability and operating system redundancy as **x335** or **BladeCenter** *are* required, adding one Remote Supervisor Adapter I *per server* and a *second* IDE HDD can increase the cost of the x305 considerably relative to either the x335 or BladeCenter. To produce equivalent aggregate performance would require twice as many x305 servers as 2-way servers. In quantities of *more* than 42 x305 servers (which would then require two or more racks), the floor-space costs alone could make the x305 more expensive to operate over time than a lower number of 2-way servers.

- **Redundant/highly-available components.** The x305 does not offer redundant power, unlike BladeCenter. Also, it provides *standard* ECC error correction, not the more advanced Chipkill ECC memory protection that other IBM servers feature.

- **External Ultra320/large SCSI support.** The x305 supports one ServeRAID-**4Lx** adapter, which provides **one** external **Ultra160** SCSI port. By comparison, the **x335** (along with other IBM servers) supports the high-performance ServeRAID-**4H**, containing **four Ultra160** SCSI channels, as well as the ServeRAID-**6M**, with **two Ultra320** SCSI channels.

- **Large memory requirement.** The x305 is limited to **4GB** of RAM, compared with **8GB** per **BladeCenter HS20** blade or **x335** and **12GB** in the **e325**.

- **Limited number of full-length adapter slots.** Only one full-length slot is available (along with a short slot). If two or more full-length slots are required, consider the x345, which provides five PCI-X slots.

- **No upgradability to 64-bit computing.** The **Pentium 4** processor used in the x305 is limited to 32-bit operating systems and applications. For 64-bit computing on a budget, consider the **e325**.

Key x335 Advantages

The following are some of the key advantages of the x335 as compared to other IBM rack-optimized servers:

- **Low cost in certain configurations.** Given similar configurations, the x335 is often less expensive to buy than an equal number of **x305**, **e325** or **HS20** blade servers and their associated BladeCenter chassis.

- **Larger internal disk capacity/external SCSI storage.** The x335 supports at least triple the internal IDE disk capacity of BladeCenter, at **240GB**; and double the internal Ultra320 SCSI capacity of the x305 (**293.6GB**). Unlike BladeCenter it also supports terabytes of external **Ultra160** or **Ultra320** SCSI storage via an IBM ServeRAID™ SCSI adapter.

- **Extremely simple cable management.** In quantities of up to 42 servers, the C2T Interconnect cabling makes cable management a non-issue on the x335; merely connect the "out" port of one server to the "in" port of the next. (Beyond 42 servers, the C2T chain connects into a larger ACT cabling system, the same as e325, BladeCenter and the other xSeries servers, do.)

Key x335 Inhibitors

Like BladeCenter, there are some environments where another IBM rack-optimized server would be a better fit than the x335:

- **Higher cost in certain configurations.** In quantities of *more* than 42 x335 servers (which would require two or more racks), the floor-space costs alone can make the x335 more expensive to operate over time than the same number of BladeCenter **HS20** blade servers, depending on how high the cost per square foot/meter is in a particular data center.

- **Limited number of full-length adapter slots.** Like the x305 and e325, only one full-length slot is available (along with a short slot). If two or more full-length slots are required, consider the **x345**, which provides five PCI-X slots, or the **x382** (especially in an HPC environment) with three slots.

- **No upgradability to 64-bit computing.** The **Xeon** processor used in the x335 is limited to 32-bit operating systems and applications. For 64-bit computing, consider the **e325** or the **x382**.

Key x382 Advantages

The following are some of the key advantages of the x382 as compared to other IBM rack servers:

- **Outstanding 64-bit performance.** The Itanium 2-based x382 server offers significantly *better* floating point performance (according to the **SPECfp_rate2000** benchmark), than the Opteron-based e325 server. If leading-edge floating-point performance is your primary consideration, then this is the @server model for you.

- **More memory.** The x382 offers up to **16GB** of RAM for application use, compared to **12GB** for the e325, and **8GB** for the x335 and BladeCenter.

- **Large memory addressing.** Unlike the 4GB-per-process limitation of 32-bit processors, the 64-bit Itanium 2 allows software to directly address the full **16GB** of RAM provided by the x382. This offers superior performance to software that can take advantage of this feature.

- **Offers high-availability features. Hot-swap/redundant cooling** is standard, as is **hot-swap power**. (Redundant power is optionally available via special bid.)

Key x382 Inhibitors

Situations where another IBM rack-optimized server might be a better fit than the x382 include:

- **Price sensitivity.** Although the 64-bit floating-point performance of x382 is significantly better than for the e325 server, if cost is a higher priority than performance, the **e325** might be a better option.

- **32-bit performance.** 32-bit software runs in *32-bit emulation mode* on the Itanium 2 processor, rather than in the native 64-bit mode of 64-bit software. This considerably inhibits the performance of 32-bit software on the x382. If you have a need to run performance-sensitive 32-bit software, or a mix of 32-bit and 64-bit software, **x335** or **e325** might be a better solution.

- **Rack density.** The x382 is a **2U** 2-way rack server, and therefore only half as rack-dense as **1U** 2-way servers, such as the **x335** and **e325**.

Key e325 Advantages

The following are some of the key advantages of the e325 as compared to other IBM rack servers:

- **Simple, cost-effective migration to 64-bit computing.** The 64-bit hardware is ready to go. All you need is to upgrade to a 64-bit operating system. 32-bit applications will continue to run as before, perhaps faster, until you are ready to upgrade to 64-bit applications.

- **Outstanding 32-bit and 64-bit price/performance.** The Opteron-based e325 server offers terrific 64-bit integer performance, and **63%** of the floating point performance[15] of the Itanium 2-based rx2600 server from HP (according to the **SPECfp_rate2000** benchmark), at **1/7th** the cost for a similar configuration! The same e325 SPECfp_rate2000 score was also **41% better** than the Xeon-based HP DL360 G3 server.

- **Large memory addressing.** Like the 64-bit addressing of the Itanium 2, the 64-bit Opteron allows software to directly address the full **12GB** of RAM provided by the e325. This offers superior performance to software that can take advantage of this feature.

Key e325 Inhibitors

Environments where another IBM rack-optimized server might be a better fit than the e325 include:

- **Price sensitivity.** Although the price/performance of e325 is better than for xSeries servers, if cost is a higher priority than performance—and 64-bit operation is not a requirement—the **x305** or **x335** might be a better option.

- **Limited number of full-length adapter slots.** Like the **x305** and **x335**, only one full-length slot is available (along with a short slot). If two or more full-length slots are required, consider the 32-bit **x345**, which provides five PCI-X slots, or the 64-bit **x382** (three slots) or **x450** (six slots).

- **Ultimate 64-bit floating-point performance needed.** If your operation requires the highest possible floating point performance, consider the Itanium 2-based **x382** or **x450** instead.

- **More total RAM needed.** If 12GB isn't enough memory for your 64-bit computing needs, consider the **x382** (16GB) or the **x450** (40GB).

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[15] HP rx2600 results are available at: *http://www.spec.org/cpu2000/results/res2003q3/cpu2000-20030630-02322.html*; HP DL360 G3 results: *http://www.spec.org/cpu2000/results/res2003q3/cpu2000-20030630-02353.html*; IBM @server 325 results: *http://www.spec.org/cpu2000/results/res2003q3/cpu2000-20030728-02418.html*. Price comparisons are using public web pricing as of September 12, 2003.

Commonality of Hardware and Software

So far, this paper has focused on the *differences* between BladeCenter and other IBM rack servers, but it is important to know that they have a number of points in common. As mentioned earlier, for some customers it makes sense to use a mix of blade servers and traditional servers. For those customers, the following topics are crucial:

Interchangeable Components

There is much commonality of components and options among IBM rack-optimized servers, including BladeCenter: They all can fit in the same IBM racks, use the same flat-panel monitors, uninterruptible power supplies and PDUs, and they share the same SAN offerings. They all can use ACT interconnect cabling, and many of the servers share the same memory DIMMs, hard disk drives and adapters. This means that a heterogeneous combination of IBM servers doesn't require multiple unique combinations of components and infrastructure, which helps to simplify the administration of your data center.

Also, as mentioned briefly earlier, IBM offers two cable management alternatives to traditional KVM switching that can help dramatically reduce the cost and complexity of KVM cabling, reduce setup time, and simplify the administration of rack servers. *C2T Interconnect* cabling is a standard feature on x335 servers, while *IBM Advanced Connectivity Technology* (ACT) is an optional feature available for *all* xSeries servers, including C2T chains of x335 servers, as well as e325, BladeCenter and legacy Netfinity servers. Both cabling systems use a "daisy chain" approach to interconnecting servers that allows servers to be added or removed *without* significant recabling, unlike traditional KVM cabling methods. For example, to remove a server, merely unplug one server from the chain and plug the next "downstream" server to the previous "upstream" server. Voila! The recabling is done. The intelligent cabling takes care of the rest.

Systems Management

Helping to tie together all elements of a data center are sophisticated systems management tools from IBM. These tools can be used to streamline the management and deployment of *all* xSeries servers, from stand-alone towers to rack-optimized to BladeCenter. There isn't room in this short paper for a detailed description of these tools, or even to list them all, but here is a brief synopsis of some of them:

Management

- **IBM Director** — IBM Director provides a comprehensive and extremely powerful set of workgroup systems management tools that are included with each xSeries system. The award-winning[16] IBM Director suite allows you to centrally configure and manage individual systems and groups of computers throughout the enterprise. IBM Director works equally well, and concurrently, with all IBM rack servers, including BladeCenter. Provided with IBM Director 4.1 are: *Management Processor Assistant, RAID Manager, Update Assistant, BladeCenter Deployment Wizard* and *Software Distribution Standard Edition*. In addition to the modules that ship with IBM Director, two other tools that *integrate* into IBM Director may be downloaded*: Real Time Diagnostics* and *Management Processor Command Line Interface*.

- **IBM Director Server Plus Pack** — IBM Director can be extended for more advanced server management with the optional *IBM Director Server Plus Pack*. The Plus Pack is a fee-based offering of five tools: *Rack Manager, Capacity Manager, Active PCI Manager, System Availability* and *Software Rejuvenation*. They integrate into IBM Director for a consistent look and feel and provide advanced systems management from a single console.

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[16] Most recently, *PC Magazine* bestowed upon IBM Director 3.1 its Editors' Choice award for mid-tier systems management suites, saying "IBM Director, the best proprietary product we reviewed, earns our Editors' Choice. We are most impressed by how easy it is to manage this suite. .... In short, IBM strikes the best balance by offering capabilities native to IBM products along with compatibility with non-IBM equipment." (*PC Magazine*, October 1, 2002.)

- **Application Workload Manager** — Developed for IBM by Aurema, Application Workload Manager (AWM) for IBM Director 4.1 is an optional enterprise-class resource management tool for advanced workload management on xSeries servers, e325 and BladeCenter. AWM integrates tightly with IBM Director 4.1 to extend the systems management capabilities of Microsoft Windows 2000 by providing a comprehensive, proven solution for allocation, management and control of system resources such as CPU, real memory and virtual memory that allows the administrator to specify how multiple applications use server resources. It autonomously manages server workloads to help protect against unexpected resource contention, and it does all this with little or no impact to application performance.

- **Cluster Systems Management** — Cluster Systems Management (CSM), which integrates with IBM Director, can help to reduce the total cost of ownership for Linux cluster environments by streamlining and simplifying the management of large numbers of servers from a single point of control.

- **Remote Supervisor Adapters** — These adapters, standard in some servers and optional in others, offer enhanced systems management and control over servers. Features including system alerts sent via LAN, pager, serial port or e-mail; remote keyboard, mouse and video control of servers, including observing POST and Windows "blue screen" errors; the ability to control up to 24 servers *per adapter*; and much more.

- **VMware ESX Server** — "Virtual machine" software that sits between the server hardware and the operating system to provide logical (versus physical) server consolidation. Each server partition functions as an independent entity, complete with a unique OS and application image. ESX Server from VMware can be tuned dynamically to increase or decrease the number of virtual servers available, and to adjust the processor, memory and other resource allocations.

Deployment

- **Remote Deployment Manager** — Remote Deployment Manager (RDM) 4.1, which integrates into IBM Director, supports the deployment, update and retirement of servers across the computing environment. RDM offers high-performance cloning, recovery, and reprovisioning solutions, and provides administrators with the ability to download an entire system image or a firmware update remotely to any node in the network. RDM also provides scripting capabilities to simplify the configuration of systems with unique requirements.

- **Software Distribution Premium Edition** — Unlike RDM, which allows an administrator to deploy system images in an *offline* environment, the optional Software Distribution Premium Edition allows the creation, packaging and distribution of software applications and updates to individual systems or groups that are *up and running* with the IBM Director Agent for Windows or Linux. It provides wizards to simplify the creation of packages using Microsoft Windows Installer, InstallShield and Linux RPM Package Manager files.

- **UpdateXpress** — UpdateXpress can help reduce your cost of computing by providing a simple yet effective way to update server firmware and the firmware of supported options within most xSeries servers. With UpdateXpress, administrators no longer have to spend hours visiting each individual server that they want to update. Now they can update the server or client system firmware from virtually anywhere on the network.

Configuration

- **IBM @server xSeries and Netfinity Rack Configurator** — Configuring a full rack of servers and ensuring that you have all the cables, PDUs, KVM switches and other components you need, as well as the proper airflow clearances, electrical circuits and other environmental conditions, is not the easiest task in the world. To help simplify this chore, IBM offers a downloadable rack configurator. The *IBM @server xSeries and Netfinity® Rack Configurator* program helps you check, correct and report the following:
  - Components by product number and position

- Width and depth; front, rear and side clearances; total weight and top clearance
- Infrastructure specifications, including weight, power, volt-amps (VA), heat (BTUs/hr), bays, EIA, outlets and console ports
- Cables and connectors by component position

Go to http://**ibm.com**/servers/eserver/xseries/systems_management/xseries_sm.html for more information about xSeries systems management products, or download the *Systems Management for IBM @server xSeries Servers* white paper from http://**ibm.com**/pc/ww/me.nsf.

Conclusion

As you have seen, no one type or size of server fits all customer needs. Whether your primary concern is cost, configuration flexibility, processor and memory density, adapter or storage density, investment protection, high availability, or a combination of the above, there is no one server that can do it all. For this reason, IBM offers an array of rack-optimized servers to choose from, including x305, x335, x345, x360, x382, x445, x450, e325 and BladeCenter. Each option has its own set of advantages.

BladeCenter advantages:

- Extremely high processor and memory density.
- The flexibility to mix and match processor blade servers in one chassis (different processor types and speeds). This provides investment protection (customers can add blades with faster/newer processors as they become available, and/or add pSeries blades to the same chassis).
- High chassis-level availability when configured with hot-swap redundant components.
- Extremely cost-effective in large numbers; ideal for medium and large centralized enterprises.
- Integration of rack infrastructure, such as Fibre Channel and Ethernet switches, that typically require separate rack space and additional cabling.
- Simpler rack management via fewer cables and connections, and many front- and rear-accessible hot-swap components.
- *Physical* server consolidation (one 2-way blade server for one 2-way stand-alone server, for example).

Advantages of other specific IBM rack servers:

- x305 servers offer extremely shallow depth, allowing devices to be installed behind them.
- x305 and x335 are cost-effective in modest numbers and offer a relatively low entry cost.
- x305 and x335 offer DC-powered models.
- x305, x335 and e325 require only 1U of rack space.
- e325 offers exceptional price/performance for 64-bit computing.
- e325 offers the best upgrade path from 32-bit to 64-bit computing (requires only a software upgrade).
- e325 and x335[17] offer balanced processor, adapter slot, memory and HDD density.
- x345[18] offers high internal storage capacity.
- x345 offers high server-level availability via Chipkill memory, hot-swap HDDs, selectable internal RAID-1 arrays, and optional hot-swap redundant power and cooling.

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[17] A rack full of e325 or x335 servers can hold 84 processors, 84 adapter slots and 84 HDDs.
[18] x345 servers each offer up to 880.8GB of internal hot-swap Ultra320 SCSI storage.

- x360 and x445 offer high density of internal adapter I/O and optional[19] external adapter I/O.
- x382 and x450 offer outstanding 64-bit performance.
- x445 offers 4-way, 8-way, 12-way, 16-way and even 32-way configurations.
- x445 offers optional *virtualized* server consolidation[20] (a portion of the system resources are reserved for a specified application use).
- x450 offers a 4-way 64-bit configuration, and support for up to 40GB of RAM.

General advantages of the other IBM rack servers described here:

- Suitable for individual decentralized deployment.
- Capable of external SCSI storage solutions.
- Compatible with both 110-120V and 220-240V power.

Additional Information

For more information about blade server technology and benefits in general and BladeCenter specifically, go to http://**ibm.com**/pc/us/eserver/bladecenter/literature.html.

Visit http://**ibm.com**/servers/eserver/blades, http://**ibm.com**/pc/us/eserver/opteron, and http://**ibm.com**/eserver/xseries (or call **1-888-SHOPIBM**) for information about IBM @server products and services, including part numbers and prices for servers, racks, storage units and other options.

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[19] Optional external adapter I/O is available on the x360 and x445 via the RXE-100.
[20] Using x445 servers and optional VMware ESX Server software.

Appendix A.

The following figures were used in determining the relative facilities costs of the x305, x335, e325 and BladeCenter configurations:

- Cost of electricity per kilowatt hour: **$0.09**
- Cost of cooling BTUs/hour: **33%** of the electrical cost for powering the servers
- Cost of data center floor space *per month*: **$300.00 per sq. ft.** / **$3,300 per sq. m.** (Costs range across the country from under $100 per square foot to over $1,000, depending on location.)

Note: Your *actual* costs for these items will affect the facilities costs for these configurations.

Per item Web prices used in the following tables (as of September 8, 2003):

- BladeCenter chassis (8677-1XX; one per 14 blade servers) — $2,789.
- BladeCenter Power Module for chassis (one per chassis) — $999.
- BladeCenter Ethernet Switch Module (one per chassis) — $2,199.
- BladeCenter HS20 blade (model 8832-21X, 2.8GHz Xeon with 533MHz FSB) — $2,779.
- e325 server (8835-52X, 2.0GHz Opteron 246 with 2.0GHz HyperTransport Tunnel, 80GB IDE HDD) — $3,639.
- x335 server (8676-22X, 3.06GHz Xeon with 533MHz FSB, 40GB IDE HDD) — $2,579.
- x335 server (8676-12X, 2.8GHz Xeon with 533MHz FSB, 40GB IDE HDD) — $2,259.
- x305 server (8673-72X, 2.8GHz Pentium 4 with 533MHz FSB, 40GB IDE HDD) — $1,439.
- BladeCenter second processor option (one per server) — $1,099.
- x335 second 3.06GHz processor option (one per server) — $1,149.
- x335 second 2.8GHz processor option (one per server) — $1,099.
- e325 second processor option (one per server) — $1,399.
- Upgrade to 2GB RAM (BladeCenter and x335; 4 x 512MB) — $1,220.
- Upgrade to 2GB RAM (e325; 2 x 512MB) — $610.
- Upgrade to 1GB RAM (x305; 3 x 256MB) — $495.
- 40GB 2.5" IDE HDD options (BladeCenter; two per HS20 blade server) — $598.
- 40GB 3.5" IDE HDD option (x305, x335; one per server) — $129.
- 80GB 3.5" IDE HDD option (e325; one per server) — $189.
- Remote Supervisor Adapter I (x305, x335, e325; one per x305 or e325 server; one per 24 x335 servers) — $499.
- NetBAY42 Enterprise Rack (one per configuration) — $2,649.
- NetBAY42 Enterprise Expansion Rack (for additional racks beyond one) — $2,545.
- 60 amp front-end PDU (BladeCenter, x335; one per three rack PDUs) — $499.
- 30 amp front-end PDU (x305; one per three rack PDUs) — $299.
- Rack PDU (one per seven servers) — $179.
- Myrinet Ethernet Switch, 32 port (x305, x335; one per 32 servers) — $3,200.
- Local Console Manager (x305, x335, e325; one per 64 servers) — $759.
- KVM Connectivity Option (KCO) kits (x305; one per four servers) — $559.
- C2T Connectivity Option (CCO) kits (x335; one per 42 servers, when exceed 42) — $179.
- USB Connectivity Option (UCO) kits (e325; one per four servers) — $599.

- 2x8 Console Switch (BladeCenter; one per rack after the first chassis) — $1,359.
- 12-foot KVM Console Cable (one per BladeCenter chassis after the first) — $65.
- Breakout cables (x335; one per rack) — $34.
- Ethernet CAT5 cables (one per x305, x335 or e325 server, or BladeCenter chassis) — $3.
- 32-bit Red Hat Enterprise Linux AS license (one per x305, x335, or BladeCenter) — $150.
- 64-bit SuSE Linux Enterprise Server 8.0 (one per e325) — $750.

Note that the configurations used in *Tables 2* and *3* and in *Figure 1*, while as similar as possible, are not completely comparable with one another:

- BladeCenter has redundant components included in the price that aren't available on x335, x305 and e325. This increases the cost of BladeCenter relative to the other servers, but provides additional high-availability features.

- The x305 uses one Pentium 4 processor vs. the two Xeon processors in the BladeCenter and x335 configurations. Two x305 servers, each with one Pentium 4 processor, perform slightly faster than one server containing two Xeon processors of the same clock speed, front side bus speed and cache memory capacity, due to lower bus contention. In *Table 3*, the x305 configuration substitutes additional *uniprocessor* x305 servers for 2-way x335 or HS20 blade servers, to produce similar processing capabilities, using the full potential of all the servers. If your processing needs are modest, a comparison of uniprocessor x335 servers to *uni*processor x335 and HS20 blade servers would eliminate the cost gap in some configurations.

- The x335, e325 and BladeCenter servers use Chipkill ECC memory protection for higher memory availability than the standard ECC memory used in the x305 server.

- In *Table 2*, the x305 configuration includes two HDDs per *uni*processor system vs. two per *two-way* system in BladeCenter and x335, to offer the redundancy of a mirrored OS. This raises the cost of the x305 relative to the other servers. Eliminating the second HDD per server would result in the same total number of drives as the x335 and BladeCenter configurations, and reduce the cost of the x305 configuration by **$129** per server, but would eliminate the OS failover capability available in the other configurations.

- In *Tables 2* and *3*, each e325 and x305 included an IBM Remote Supervisor Adapter to provide equivalent systems management function to what the x335 offers with only one *Remote Supervisor Adapter I* per *24* servers and what BladeCenter offers with one built-in management module per chassis. This increases the cost of the e325 and x305 relative to the other server configurations. Configuring the e325 and x305 with fewer Remote Supervisor Adapters would reduce the configuration cost by **$499** (x305) or **$599** (e325) in 23 of every 24 servers, but with reduced function compared to the x335 and BladeCenter.

- In *Tables 2 and 3*, the x335, e325 and BladeCenter servers include **2GB** of memory (using four 512MB DIMMs)—**1GB** per *processor*. By contrast, the x305 has **1GB** per uniprocessor x305 server (using four 256MB DIMMs). The use of 512MB DIMM upgrades increases the memory cost of the x335, e325 and BladeCenter relative to the x305.

- In *Table 1*, the e325 uses two **80GB** drives, compared to two **40GB** drives for the x335 and BladeCenter, raising the cost of the e325 by **$60** relative to the other servers.

- The e325 uses a 64-bit Opteron processor and **333MHz PC2700** DDR memory, compared to a 32-bit Xeon processor and **266MHz PC2100** DDR memory used in the x335 and BladeCenter. The high-performance Opteron processor and memory add cost to the server, but provide considerably more performance in return.

- The e325 configuration in *Table 2* uses a **64-bit** OS, which is considerably more expensive than the 32-bit OS used on the other servers and makes the e325 more expensive relative to the BladeCenter, x305 and x335 configurations Using the same 32-bit OS would reduce the cost of the e325 configuration by about **$600** dollars per server.