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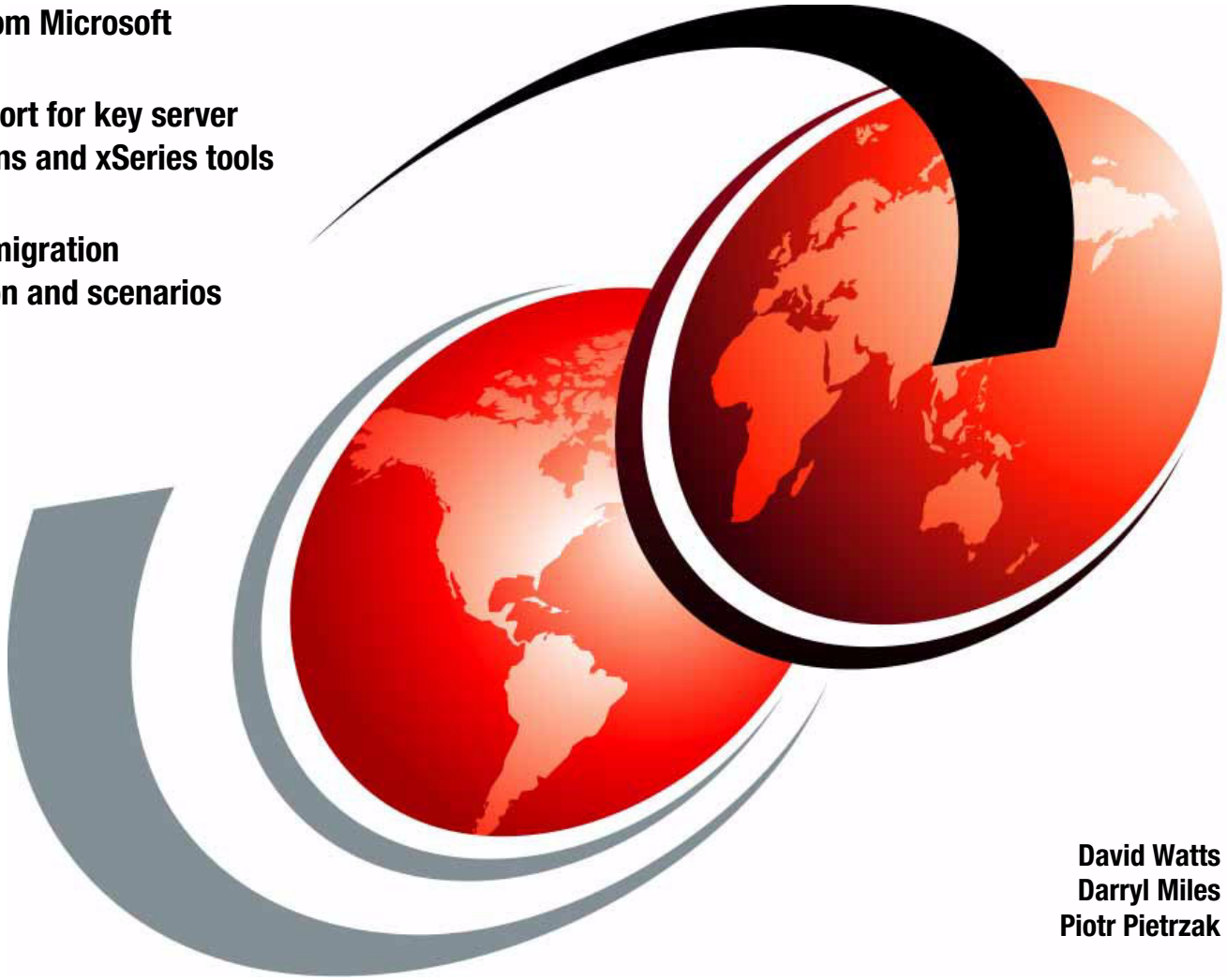
Introducing Windows Server x64 on IBM @server xSeries Servers

- Describes the new 64-bit operating system from Microsoft
- Lists support for key server applications and xSeries tools
- Provides migration information and scenarios



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Redpaper

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International Technical Support Organization

Introducing Windows Server x64 on IBM @server xSeries Servers

June 2005

Note: Before using this information and the product it supports, read the information in “Notices” on page v.

First Edition (June 2005)

This edition applies to Windows Server 2003, x64 Edition.

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Contents

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Preface

Until now, the Intel®-processor server marketplace has been largely a 32-bit arena. Certainly systems with Intel Itanium 2 and AMD Opteron™ processors running Windows® (Itanium) or Linux® offer 64-bit processing, but mainstream computing has remained 32-bit. With the release of Windows Server 2003, x64 Edition, the domination of 32-bit systems is likely to begin to change. The new operating system from Microsoft® allows for a smooth migration from 32-bit systems and provides benefits in terms of performance and scalability. This new operating system is especially beneficial to enterprise customers, where the current 4 GB direct memory addressability limitation of 32-bit is already having an impact.

This Redpaper introduces Windows Server 2003, x64 Edition, the 64-bit processors from Intel and AMD that support it, and the xSeries® servers on which the operating system runs. It describes the concepts of 64-bit computing and the technology behind the processors. This paper introduces the xSeries product line that includes the Intel EM64T processor. It also describes how the new Windows operating system is different from its 32-bit counterpart and discusses the migration options that are available to customers and developers.

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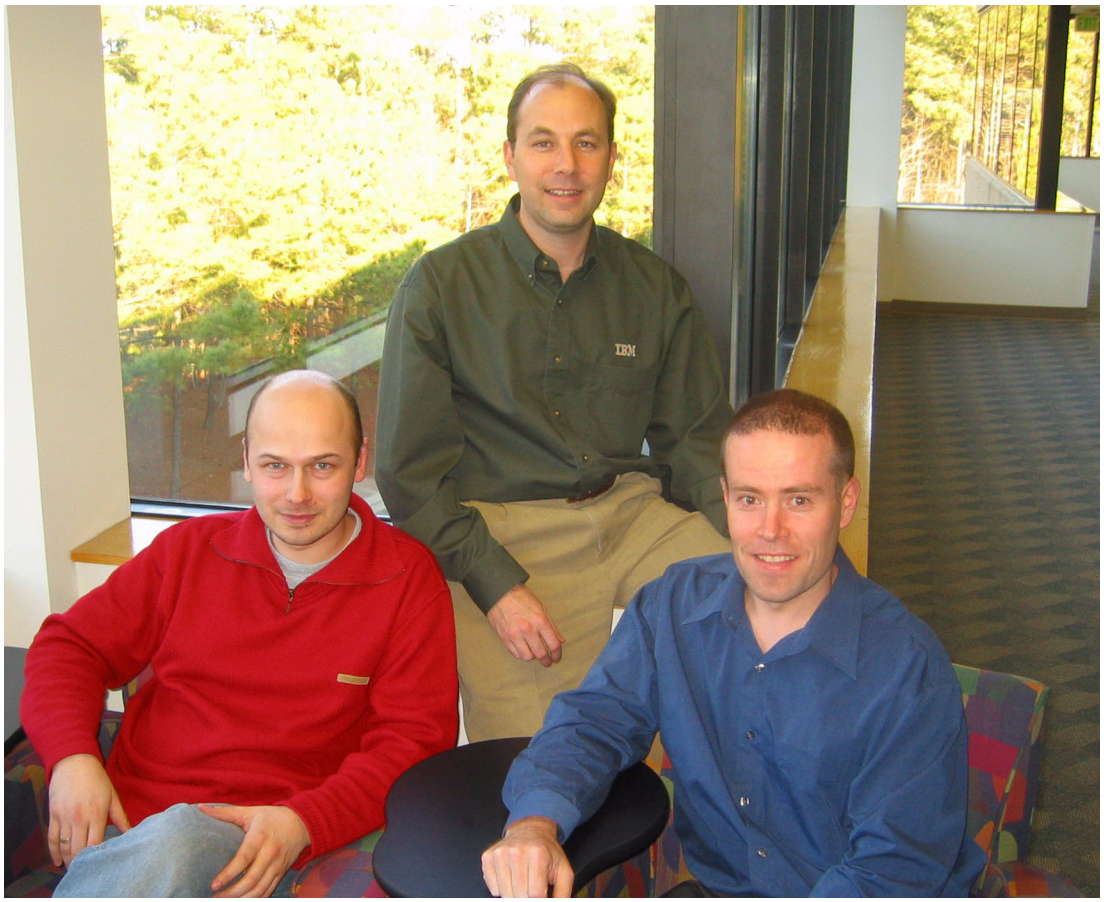

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Introduction to this paper

The Intel compatible microprocessor has evolved from the first 4004 4-bit processor, produced in 1971, to the current line of Xeon processors. The addressable memory in the original 4004 was 640 bytes, a large amount of memory at the time, but minute by today's standards. Current 32-bit processors can address 4 GB of memory and even larger amounts through memory address extensions.

Windows operating systems have also changed significantly from the early 32-bit versions such as Windows 95 through to the latest server release of Windows Server™ 2003. The memory requirements of these new operating systems and applications, once considered un-imaginable over 30 years ago, are now stretching the limits of current 32-bit technology. By moving to a fully 64-bit platform, existing memory scalability limits are significantly increased, allowing developers the flexibility to create more powerful applications with greater features and functionality.

64-bit processors also support a greater range of integer values, which can provide performance improvements for scientific computing, cryptography, and simulations applications that calculate larger integer results. 64-bit servers have been around for many years in the form of UNIX® (IBM pSeries®) and IBM Mainframes (zSeries®). However, in the Intel-processor marketplace, 64-bit is a relatively new phenomenon, introduced with the Itanium processor in 2000. AMD, and more recently Intel, have produced 64-bit processors, which are backward compatible and support 32-bit operating systems and applications. Over the next few years, almost all computers will include 64-bit processors.

Windows Server 2003, x64 Edition is the latest member of the Windows Server System™ family to support the 64-bit processors from Intel and AMD. This operating system allows organizations to migrate their infrastructure to 64-bit computing as their application requirements demand it. For more information about Windows Server 2003, x64 Edition, see:

http://www.microsoft.com/windowsserver2003/64bit/x64

1.1 Benefits of Windows Server 2003, x64 Edition

Windows Server 2003, x64 Edition provides organizations with the smoothest path to 64-bit computing. It provides a number of scalability and performance improvements without sacrificing 32-bit backward compatibility. For business executives, the move to 64-bit computing using Windows Server 2003, x64 Edition enables further server consolidation, which ultimately reduces the total cost of ownership. Windows Server 2003, x64 Edition provides the same familiar Windows environment, which leverages existing IT skills in your organization.

Windows Server 2003, x64 Edition offers a number of key business and technical benefits as described in the following sections.

1.1.1 Technical benefits

Windows Server 2003, x64 Edition provides the following technical benefits:

- Increased performance and scalability

  Windows Server 2003, x64 Edition fully uses the underlying 64-bit hardware which enables an incredibly larger virtual memory model for the operating system and applications. Directly addressable memory is currently as much as 64 GB and this increases as DIMM and chipset technology improves. Directly addressable memory improves application scalability by allowing large parts of an applications data to be stored in the server's memory, which is significantly faster than being accessed from disk storage.

  Applications which perform large number calculations and encryption might also benefit by 64-bit computing by increasing the range of numbers a servers processor can manipulate.

- Runs both 32-bit and 64-bit applications natively

  The Windows Server 2003, x64 Edition platform provides excellent 32-bit application compatibility and performance. Windows 32-bit applications can run side-by-side with Windows 64-bit applications on the same server.

- The same Windows experience

  Windows Server 2003, x64 Edition has the same user interface, commands, configuration tools and core applications as it's equivalent 32-bit product. So, it won't take you long to become familiar with this 64-bit operating system and install it in your organization.

- Improved security

  Windows Server 2003, x64 Edition includes not only the latest set of operating system fixes but new security features such as Security Configuration Wizard (SCW), firewall startup/shutdown protection, and Post-Setup Security Updates (PSSU).

1.1.2 Business benefits

What do all of these technical benefits mean for your business? Essentially, Windows Server 2003, x64 Edition provides a more powerful application platform for today's enterprise applications and more advanced applications in the future. Some of the key benefits of Windows Server 2003, x64 Edition are outlined below:

- Upgrade your business to 64-bit incrementally

  Your business can move components of your IT infrastructure today to 64-bit computing where it makes sense. You can buy 64-bit capable hardware today to run all of your 32-bit software, and when you're ready for the switch to 64-bit computing, you can simply re-install the server with Windows Server 2003, x64 Edition. You can still run your 32-bit

applications with equivalent performance as it would on a 32-bit operating system. Then when your ready for the final step you can upgrade your applications to 64-bit versions as well, to take full advantage of the 64-bit platform.

- Leverages existing IT skills

  The new operating system has the same look and feel as equivalent 32-bit operating systems, so little if any, retraining by your IT staff is required.

- Can reduce the number of systems you manage

  Using 64-bit technology, businesses can consider scenarios such as consolidating many smaller database servers to a single 64-bit database cluster, or consolidating the number of Windows Terminal Servers in their environment.

- Reduces your total cost of ownership

  All these benefits equate to greater value and lower total cost of ownership of a business computing infrastructure.

1.2 Why now?

To meet the increasing demands of business, both server operating systems and applications have become increasingly powerful and provide greater functionality. This requires increasingly faster processors and greater amounts of memory and storage. Even today, the architectural limits of the Windows 32-bit server is becoming increasingly tested by these larger server applications.

A number of factors will drive the migration to 64-bit computing into the mainstream over the next few years:

- Within the next year, it is expected that almost all server and workstation hardware will ship with 64-bit processors from either AMD or Intel. These processors can support today's popular 32-bit operating systems without any loss in performance or compatibility issues.
- The release by Microsoft of 64-bit versions of the server and desktop operating systems, called Windows Server 2003, x64 Edition and Windows XP x64 respectively. Both operating systems will have feature parity with existing 32-bit versions.
- Windows Server 2003, x64 Edition can run seamlessly almost all existing 32-bit applications available today with similar performance to a 32-bit platform. In some cases enterprise 32-bit applications can gain some increase in performance.
- For many customers, the memory architectural limits of 32-bit Windows Server are limiting what they can do with their servers. These restrictions are effectively removed with 64-bit operating systems.
- Application vendors acknowledge the benefits of the new 64-bit platform. The majority of enterprise server applications have either plans for x64 versions or beta products already available.

1.3 64-bit misconceptions

The broad choice of 64-bit processors offers organizations greater flexibility, yet at the same time introduces confusion into the marketplace. Some of these industry misconceptions are discussed in the following sections.

1.3.1 Processor performance

A common misconception is that by migrating to 64-bit (2 x 32-bits), a server will be twice as fast, or the server's performance doubles an equivalent 32-bit system. A 64-bit processor can represent a much larger range of integer numbers than a 32-bit processor. However, only applications that *require* and use 64-bit integers will see a performance increase on 64-bit hardware. Many believe that a processor is the most important part of the server and can be the single measure when comparing system performance. Unfortunately, in practice, this is often not the case.

These days, processors are so fast that their power far exceeds the rest of the server components, especially when the server is improperly configured. Servers are often over-configured with processor and under-configured with disks, memory, and network components (see the IBM Redbook *Tuning IBM@server xSeries Servers for Performance*, SG24-5827). Thus, many factors contribute to a servers overall performance. It is important to remember that performance benchmarks, such as SPECcpu2000, are in no way related to whether the server has 32-bit or 64-bit processors.

1.3.2 Not all 64-bit Windows are the same

With the release of Windows Server 2003, x64 Edition, Microsoft has two 64-bit operating systems. Windows Server 2003, x64 Edition support the AMD64 and the Intel Extended Memory 64 Technology (Intel EM64T) while Windows Server 2003 for 64-bit for Itanium supports Itanium and Itanium 2 processor-based servers only.

These two versions have the same Windows look and feel. However, they are incompatible in the following areas:

- Only Windows Server 2003, x64 Edition can be installed on EM64T/AMD64-based servers. Likewise only Windows Server 2003 for 64-Bit Itanium-based Systems is suitable for Itanium 64-bit servers.
- 64-bit applications for Windows Server 2003, x64 Edition are incompatible with the Itanium version and vice-versa. Most application vendors are now developing x64 versions.
- 64-bit device drivers are required for Windows Server 2003, x64 Edition. Again, 64-bit device drivers for x64 are incompatible with the Itanium version and vice-versa.
- Windows Server 2003, x64 Edition runs 32-bit applications at the processors full clock speed. By comparison, the Itanium version of Windows runs 32-bit applications via an emulation layer. This results in 32-bit applications running slower on Itanium than running on a native 32-bit server.
- Windows Server 2003, Datacenter x64 Edition can support up to 1 TB of physical RAM and 64 processors where as the Itanium equivalent can support 512 GB of physical RAM and 64 processors. These limits exceed what can be practically installed in current Intel based server hardware.
- There are a number of features that will be available in the x64 versions that are not available in the Itanium versions. These differences are expanded in 4.2, "Changes in Windows Server 2003, x64 Edition" on page 45.

1.3.3 Application performance

As discussed, 64-bit applications running on Windows Server 2003, x64 Edition have access to an incredibly larger virtual memory model and additional registers. Not all applications benefit by migrating to a 64-bit platform. Applications which benefit the most are large database and application servers, Terminal Server environments and very large Active Directory/Exchange implementations.

With a new 64-bit EM64T/AMD64 processor, the number of SSE/SSE2 registers is doubled from 8 to 16, which provides extra space for temporary variables rather than accessing this data from main memory. This provides some performance improvement for most 64-bit applications but particularly those which perform compute-intensive tasks.

It is important to remember that there is no uniform performance improvement by migrating to Windows Server 2003, x64 Edition. However, almost all enterprise applications benefit to some extent by migrating to 64-bit versions. Over time, as applications use larger amounts of server memory, the capacity and performance increases even further.

2

Hardware technology

This chapter describes the new 64-bit processor architectures from Intel (IA32e or EM64T) and AMD (AMD64). It covers the main differences between these architectures and the extensions that they provide to the 32-bit space, which is an evolutionary step forward to 64-bit computing. This chapter also describes the memory limitations and other related subjects.

2.1 What makes a 64-bit processor

When talking about what makes a 64-bit processor, there are several factors that are often discussed and sometimes confused:

- Operand size (integer or floating point)
- Register sizes
- Internal or external bus widths
- Physical or virtual address sizes

These factors are used at times to distinguish between processors size. For example, the 8086 and 8088 processors are identical, with the exception that the 8086 uses a 16-bit data bus while the 8088 uses an 8-bit data bus. The 8086 is considered a 16-bit computer, while the 8088 is considered an 8-bit computer.

The Xeon (Prestonia or Gallatin, not EM64T) is considered a 32-bit processor because it has 32-bit general purpose registers (GPRs) and a 32-bit virtual address space. Note, however, that the 32-bit Xeon also supports both 64-bit integer and floating-point operands, 128-bit internal data paths, 64-bit external data paths, and 36-bit physical addressing.

Itanium 2 supports 64-bit GP registers, 82-bit floating-point registers, 64-bit virtual addresses, and 128-bit external data paths. So, why is it a 64-bit architecture? The operands or Prestonia/Gallatin Xeon would not be considered 64-bit. In addition, it can't be the data paths, because none of those are 64-bit. Physical addresses are 50 bits, not 64. The one thing of significance here is that 64 bits are the virtual addresses.

Definition of 64-bit: A 64-bit processor is a processor that is able to address 64 bits of virtual address space. A 64-bit processor can store data in 64-bit format and calculate arithmetic operations on 64-bit operands. In addition, a 64-bit processor has GPRs and arithmetic logical units (ALUs) that are 64 bits wide.

The x86-64/EM64T processors have 64-bit GP registers, and they support 64-bit integer and floating-point operations. So, from that perspective, they are true 64-bit. Data buses are all 64 bits wide or greater. So, from that stand point, they too are true 64-bit. In addition, 64-bit virtual addresses are supported. (Actually, 64-bit addresses are allowed, but only the least significant 48 bits are used. The top 16 bits are required to be zero. It is a distinction that could be raised, but one that is unimportant for all practical purposes because 48-bit addresses are 256 TB.)

Instructions involving 64-bit addresses are given full support. The processor can operate in either 32-bit or 64-bit modes, and there are sufficient resources within the processor to support either mode. Both modes are supported for the sake of backwards compatibility, not because of any inherent restriction on 64-bit operation. EM64T is basically a 64-bit processor, but it is a processor that retains its compatibility with earlier generations of hardware.

This is one of the principle sources of confusion. The issue of *extensions*, a term that Intel uses, is all about the instruction set. In other words, how compatible it is with existing software. The 32-bit instruction set is extended to provide greater flexibility while maintaining compatibility with existing software. It is the implementation of that instruction set that makes the difference in trying to give any sensible definition to what constitutes a true 64-bit architecture, and the x86 cores were beefed up where necessary to make sure it has full 64-bit support. So, in effect it is more accurate to describe them as 64-bit architectures that support backwards compatibility modes.

A key difference between EM64T and Itanium is that the Itanium EPIC architecture doesn't support both 32-bit and 64-bit modes. In fact, it is less flexible than EM64T. The key to a successful and high performing Itanium solution is ensuring that the application is written and compiled to take advantage of the highly parallel architecture, which typically requires a complete rewrite of the application.

Remember: AMD64 and EM64T architectures are not compatible with IA-64 (Itanium 2). This compatibility also means that application code is different for other 64-bit platforms and must be completely changed (either rewritten, ported, or recompiled) before running on any x86-64 machines.

Benefits of 64-bit computing on x86-64 platform are tied mainly to the integer and memory addressing components of an application or OS. 64-bit computing does not speed up floating point workloads, logical workloads, and integer math unless most of calculations in your application use greater numbers (for example, indexes in the large data base or mail systems). In 64-bit processors, default integer calculation mode is 32 bit, not 64 (because, when adding 1+1, there is no need to enter 64-bit).

2.2 AMD and Intel processors

The current 64-bit processors in the xSeries market are:

- From Intel
  - Xeon DP/Xeon MP without EM64T (Gallatin/Prestonia)
  - Xeon DP with EM64T extensions (starting with Nacona)
  - Xeon MP with EM64T extensions (starting with Cranford)
  - Itanium 2
- From AMD
  - AMD Opteron processor

For the new Windows Server 2003, x64 Edition, the processors that are supported are the EM64T processors from Intel and the AMD Opteron processor from AMD.

These two processor types (EM64T and AMD64) support almost identical CISC instruction sets and as a result are both supported by Windows Server 2003, x64 Edition. The biggest advantage of these processors is that they can run existing 32-bit and new EM64T/AMD64 64-bit code natively and with no performance degradation. This is in contrast to the Itanium 2 processor, where the instruction set is based on an EPIC architecture and is not compatible with existing 32-bit applications except via a slower software-based Execution Layer conversion routine.

The implementation of 64-bit computing as offered by the EM64T and AMD64 processors is considered to be an evolutionary step, rather than a revolutionary step, because the chip design has merely been extended to support 64-bit as opposed to replacing the design.

Note: This publication covers the Intel Xeon EM64T and AMD Opteron (AMD64) processors. It does not discuss the Itanium 2 and any other 64-bit processors because they do not run on Windows Server 2003, x64 Edition.

2.3 Intel Xeon with Extended Memory 64 Technology

The Xeon processor is the server version of the Pentium® 4 (P4) family. There are two versions of the Xeon that are available currently. The Xeon DP supports natively 2-way SMP, and the Xeon MP natively supports 4-way SMP. The term *natively* means without additional logic. The IBM XA-32 and XA-64e chipsets provides additional logic that supports up to 32-way Xeon MP configurations.

The Pentium 4 introduced the first significant micro-architecture change for the processor since the introduction of the Pentium Pro (P6) core in 1995. P6 core was used in the Pentium Pro through to the Pentium III Xeon processor. This new P4 architecture used in the Xeon DP and Xeon MP processors is called NetBurst.

In response to the AMD Opteron processor, Intel created a version of the Xeon that offers 64-bit extensions, the “Extended Memory 64 Technology” (EM64T). It offers advantages similar to the AMD Opteron processor in terms of 32-bit x86 software compatibility, improved performance over the older 32-bit Xeon processors, and large memory addressing.

The new 64-bit Xeon processor has double the registers of its predecessors, resulting in improved performance — the more registers there are, the less often the processor has to retrieve data from cache. This enhancement alone can help increase performance, depending on the application.

Intel processors support additional features such as the SSE3 instruction set which offers accelerated processing of video decoding and complex arithmetic. The are now eight additional 128-bit SSE registers (for multimedia support) and eight additional 64-bit general-purpose registers. The Xeon EM64T processors also support Hyper-Threading Technology (which the AMD Opteron processor does not support).

The high clock frequencies of the Xeon EM64T processors helps with certain types of applications, and the integer performance is now on par with the Itanium 2. In addition, Xeon EM64T supports DDR2 memory and PCI Express. It’s offers an 800 MHz front-side bus. In case of 64-bit wide registers, Intel’s doubles the integer precision that is supported. Figure 2-1 shows an overview of the Intel architecture.

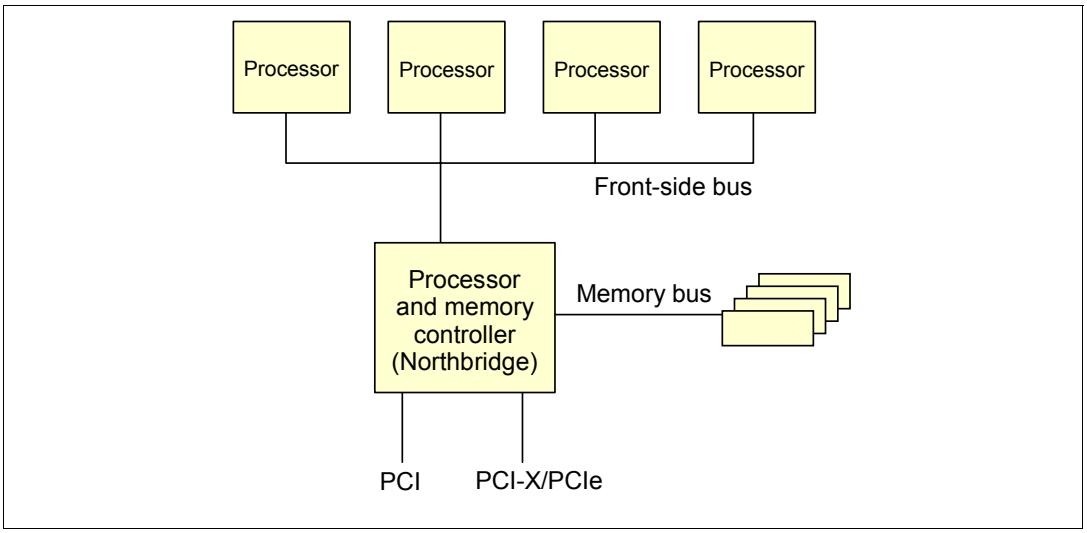

Figure 2-1 Overview of Intel architecture

Intel Xeon DP EM64T

The current version of the Xeon DP is codenamed Nocona. It is being built using 90 nm process technology and includes Intel's EM64T instruction set. Nocona supports a 36-bit physical address space. With 36-bit physical addressing, the Nocona processor is capable of addressing up to 64 GB of physical memory.

The major differences of the Nocona when compared to the earlier Xeon DP processor are:

- EM64T support with 36-bit physical addressing
- Greater clock frequency of up to 3.60 GHz
- 90 nm process technology
- Rapid Execution Engine: Arithmetic Logic Units (ALUs) run at twice the processor core frequency
- Hyper-Threading Technology support
- Front-side bus speed of 800 MHz
- 16 KB L1 cache
- 1 MB of advance transfer L2 cache
- 144 Streaming SIMD Extensions 2 (SSE2) instructions
- 13 new SSE3 instructions
- Additional GPRs and additional floating-point registers

Intel Xeon MP EM64T

The current versions of the Xeon MP are Cranford and Potomac. Potomac supports a 40-bit physical address space and Cranford supports 36-bit. With 40-bit physical addressing, processor is capable of addressing up to 1 TB of real memory and 36-bit corresponds to 64 GB.

The major differences of the Potomac and Cranford when compared to the first Xeon MP processor are:

- EM64T support with 36 or 40-bit physical addressing
- Greater clock frequency: Cranford up to 3.66 GHz, Potomac up to 3.33 GHz
- 90 nm process technology
- Rapid Execution Engine: Arithmetic Logic Units (ALUs) run at twice the processor core frequency
- Hyper-Threading support
- Front side bus speed of 667 MHz
- Includes 16 KB L1cache
- 1 MB of advance transfer L2 cache
- 4 MB or 8 MB of L3 cache (Potomac only)
- 144 Streaming SIMD Extensions 2 (SSE2) instructions
- 13 new SSE3 instructions
- Additional GPRs and additional floating-point registers

The primary difference between Potomac and Cranford is the addition of L3 cache (4 MB or 8 MB) with Potomac.

Hyper-Threading Technology

Hyper-Threading Technology effectively enables a single physical processor to execute two separate code streams (threads) concurrently. To the operating system, a processor with Hyper-Threading appears as two *logical* processors, each of which has its own architectural state, that is, its own data, segment and control registers and its own advanced programmable interrupt controller (APIC).

Each logical processor can be individually halted, interrupted, or directed to execute a specified thread, independently of the other logical processor on the chip. However, unlike a traditional 2-way SMP configuration that uses two separate physical processors, the logical processors share the execution resources of the processor core, which include the execution engine, the caches, the system bus interface, and firmware. The basic layout of a Hyper-Threading-enabled processor is outlined in Figure 2-2, which shows that only the components for the architectural state of the processor have doubled.

Hyper-Threading Technology is designed to improve server performance by exploiting the multi-threading capability of operating systems, such as Windows Server 2003 and Linux, and server applications, in such a way as to increase the use of the on-chip execution resources available on these processors.

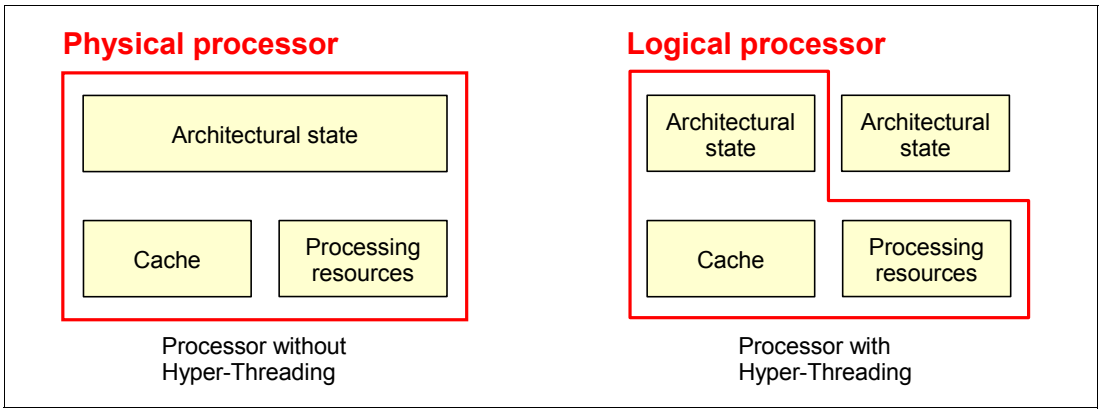

Figure 2-2 The architectural changes of adding Hyper-Threading

Having fewer or slower processors usually yields the best gains in performance when comparing Hyper-Threading Technology on versus off because, with fewer processors, there is a greater likelihood that the software can spawn sufficient numbers of threads to keep both paths busy. The performance gains from Hyper-Threading Technology running on slower speed processors are usually greater than the gains obtained when running on high-speed processors because on the slower processors, there are longer periods of time between serialization points that nearly every software must use. Whenever two threads must serialize, performance is reduced.

The performance gains obtained when enabling Hyper-Threading Technology are approximately as follows:

- Two physical processors: up to about 25% performance gain
- Four physical processors: up to about 15% gain
- Eight physical processors: up to about 10% gain

Over time, these gains in performance change because software developers introduce improved threading which makes more efficient use of Hyper-Threading Technology. Although, much of the currently available software often limits SMP scalability, you can expect improved results as software matures.

Best-case multi-threaded applications today are:

- Databases
- Java™
- Web servers
- E-mail

The increase in instruction processing throughput that Hyper-Threading Technology provides results from a combination of:

- Intel NetBurst architecture
- The mix of IA-32 instructions typically found in multi-threaded code

NetBurst architecture

Under the name NetBurst, Intel introduced the first significant architectural change since the P6 architecture introduced by the Pentium Pro. The NetBurst architecture is primarily aimed at very high clock rates and explains Intel's leadership in processor clock rates. It also has been designed to provide optimum performance when executing a single instruction stream.

The main features of the NetBurst architecture are:

- New cache architecture

  Compared to the Pentium III class of processors, the Xeon line of processors features a drastically increased level one (L1) cache. The first Xeon processor, codenamed Foster, feature a L1 data cache of 8 KB and an instruction cache (Execution Trace Cache) able to store 12 000 decoded before micro-operations. However, this large L1 cache is required because the longer pipeline architecture that are used in the new P4 processors can experience longer stall times during cache miss operations. So, the larger caches are needed to keep the very long pipeline of the NetBurst architecture from stalling.

- Double-clock arithmetic

  Double-clock arithmetic is also referred to as Rapid Execution Engine, meaning that simple integer operations are processed at twice the actual processor clock speed. Within the processor, the two ALUs can execute most operations within half of a clock cycle (this is why integer operations are processed at twice the processor clock). However, this feature does not lead to twice the integer performance because instructions cannot go through the pipeline faster than the actual processor clock. The purpose of this feature, just as with the new cache architecture, is to keep the very long pipeline from stalling. That said, you should not underestimate the significant integer performance of a Xeon processor.

- Compact floating-point

  Basic floating-point operations are processed faster thanks to this feature of the NetBurst architecture. Also, the registers for floating-point operations are expanded to a width of double precision 80 bits plus additional registers for the status of data movement.

- Streaming 128-bit arithmetic

  SSE2 or Streaming SIMD Execution 2 gives the Xeon processor the ability to perform multiple integer or floating-point operations at a time. SIMD refers to Single Instruction Multiple Data; this effectively gives the processor the ability to perform an operation like ADD to multiple data sets. Of course, the basic requirement for SIMD to work is having enough data sets at hand that can be processed using the very same operation. SIMD or SSE is especially handy when it comes to multimedia applications such as graphics processing or MPEG rendering, but scientific problems like matrix multiplications may also benefit from the SSE2 engine.

- Accelerated system bus

  The Pentium III Xeon processor in older servers had a 100 MHz front-side bus that equates a burst throughput of 800 MBps. With protocols such as TCP/IP, this has been shown to be a bottleneck in high-throughput situations.

  The Cranford Xeon MP improves on this by using two 133 MHz clocks, out of phase with each other by 90°, and using both edges of each clock to transmit data. Figure 2-3 on page 14 shows this configuration, which results in a front-side bus of 533 MHz. Nocona uses two 200 MHz clocks in the same way to achieve an 800 MHz front-side bus.

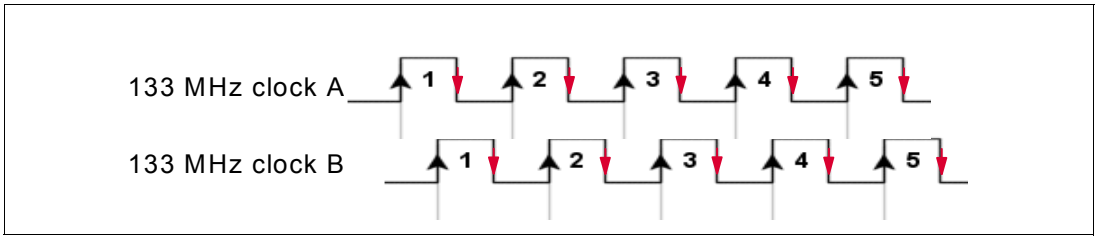

Figure 2-3 Quad-pumped front-side bus

For more information about the NetBurst architecture, see:

- Recent History of Intel Architecture — a refresher

  http://www.intel.com/cd/ids/developer/asmo-na/eng/44015.htm?page=5

- The Micro architecture of the Intel Pentium 4 Processor on 90nm Technology — NetBurst Micro architecture Overview

  http://www.intel.com/technology/itj/2004/volume08issue01/art01_microarchitecture/p03_netburst.htm

- Intel NetBurst Architecture Innovations

  http://www.intel.com/cd/ids/developer/asmo-na/eng/microprocessors/19933.htm?page=2

2.4 AMD Opteron™ processor

In a server with an AMD Opteron processor, memory has its own high-speed path to the processor, rather than having to share the front-side bus with other devices. Not only that, but because each AMD Opteron processor contains its own integrated memory controller, installing a second processor means having two high-speed data paths to memory, effectively providing up to double the throughput. The memory controller is clocked at the same rate as the processor - increasing processor speed also increases memory controller speed, which reduces memory latency for faster memory access (memory-to-processor latency is the delay between data request and data availability).

The AMD Opteron processor has a physical address limit of 40-bit addressing (meaning that up to 1 TB of memory can be addressed) and the ability to be configured in up to 8-way multi-processor configurations.

The AMD Opteron processor exists in various models that differ in their ability to scale up:

- AMD Opteron 100 series: uni-processor support
- AMD Opteron 200 series: up to 2-way processor support
- AMD Opteron 800 series: up to 8-way processor support

The common features of these processors are:

- Processor clocks up to 2.4 GHz
- 64-bit integer registers, 48-bit virtual addresses, 40-bit physical addresses
- 16 64-bit wide GPRs
- 16 64-bit wide SSE/SSE2 registers
- Three HyperTransport™ links at 800 MHz with a 16-bit width
  - On the 100 series processors, HT links can only connect to I/O devices
  - On the 200 series processors, HT links can connect to I/O and one link can connect to another processor (but only one link — the processor is limited to 2-way processing).
  - On the 800 series processors, all HT links can connect either to I/O or to another processor
- 64 KB of L1 data cache, 2-way associative with ECC protection
- 64 KB of L1 instruction cache, 2-way associative with parity protection
- 1 MB of L2 cache, 16-way associative with ECC protection
- Integrated memory controller
  - Low-latency, high-bandwidth
  - 144-bit DDR SDRAM at 100, 133, 166 and 200 MHz
- HyperTransport Technology to I/O devices

  Three links, 16-bits in each direction, that each supports up to 3.2 GB per second bandwidth in each direction (leads to peak full-duplex capacity of 6.4 GB per second). Each link can connect to an I/O device or another processor

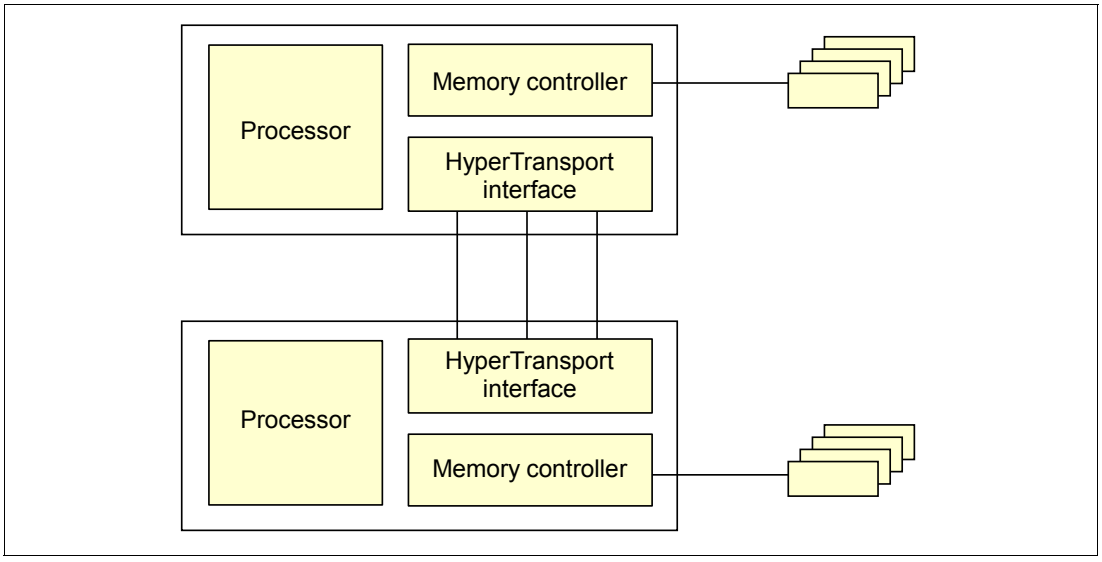

Figure 2-4 Schema of AMD Opteron processor architecture

HyperTransport™

The HyperTransport architecture was initially developed by AMD but is now managed by an open consortium of several IT companies including AMD, Apple, Cisco, Broadcom, ATI, and IBM. HyperTransport is an open standard for a high-speed, point-to-point link system that can be used for connecting a variety of chips.

The HyperTransport technology is used in devices such as network devices, graphics cards or, as in the case of the AMD Opteron processor, as a high-speed interconnect for processors. The HyperTransport technology used for interconnecting AMD Opteron processors is currently implemented at a speed of 800 MHz with a bidirectional bandwidth of 3.2 GB per second each way that leads to a peak full-duplex capacity of 6.4 GB per second.

You can find more information about the HyperTransport at:

http://www.hypertransport.org/

2.5 Memory addressing

This section describes the memory issues with 32-bit addressing, including memory paging and the ways to give 32-bit applications access to memory beyond 2 MB, such PAE and AWE switches.

2.5.1 The 4 GB memory limit with 32-bit operating systems

32-bit processors such as the Pentium 4 have an architectural limit of only being able to directly address 4 GB of memory with only 2 GB available to applications and the rest for the operating system kernel. With many enterprise server applications requiring more and more memory, Intel and the operating system vendors came up with methods to give applications access to more memory.

The first method was implemented by Microsoft and its Windows NT® 4.0 Enterprise Edition operating system. Prior to Enterprise Edition, the 4 GB memory space in Windows was divided into 2 GB for the operating system kernel and 2 GB for applications. Enterprise Edition offer the option to allocate 3 GB to applications and 1 GB to the operating system using the /3GB parameter in the BOOT.INI file. This modification provided a performance improvement of about 20% as measured by TPC-C benchmarks.

For some large enterprise applications, more than 3 GB of memory will add performance benefits. To address more than 4 GB of memory, three addressing schemes were created to access this upper memory: PSE (Page Size Extension), PAE (Physical Address Extension) and, for Windows, AWE (Address Windowing Extensions). PSE is no longer used.

On a server with between 4 GB and 16 GB of RAM hosting applications that have been compiled or written with AWE to use more than 2 GB of RAM per process or hosting many applications (processes) each contending for limited physical memory, it would be desirable to use both the /3GB and /PAE switches.

Servers with more than 16 GB of physical memory should not use both the /3GB switch and the /PAE switch. The /PAE switch is obviously required to make use of all physical memory above 4 GB. Remember that PAE uses the kernel addressable memory to manage the physical memory above 4 GB. When physical memory exceeds 16 GB, the 1 GB of memory allocated to the kernel when the /3GB switch is used is not sufficient to manage all the additional physical memory above 4 GB. Thus, only the /PAE switch should be used in such a case to avoid the system running out of kernel memory.

Note: The following Windows versions support PAE:

- Windows 2000 Advanced Server
- Windows 2000 Datacenter Server
- Windows Server 2003, Enterprise Edition (32 GB maximum)
- Windows Server 2003, Datacenter Edition (64 GB maximum)

2.5.2 64-bit memory addressing

The width of a memory address dictates how much memory the processor can address. As shown in Table 2-1 on page 17, a 32-bit processor can address up to 2^{32} bytes or 4 GB. A 64-bit processor can theoretically address up to 2^{64} bytes or 16 Exabytes (or 16777216 Terabytes).

Table 2-1 Relation between address space and number of address bits

Bits (Notation)	Address space
8 (2^8)	256 bytes
16 (2^{16})	65 KB
32 (2^{32})	4 GB
64 (2^{64})	18 Exabytes (EB)

Current implementation limits are related to memory technology and economics. As a result, physical addressing limits for processors are less, as shown in Table 2-2.

Table 2-2 Memory addressability by current processors

Processor	Physical addressing
Intel Xeon MP Gallatin (32-bit)	4 GB (32-bit)
Intel EM64T Nocona (64-bit)	64 GB (36-bit)
Intel EM64T Cranford (64-bit)	1 TB (40-bit)
Intel EM64T Potomac (64-bit)	1 TB (40-bit)
Intel Itanium 2 (64-bit)	1 Petabyte (50-bit)
AMD Opteron processor (64-bit)	1 TB (40-bit)

These values are the limits imposed by the processors. Memory addressing can be limited further by the chipset or supporting hardware in the server. For example, the x460 Potomac-based server addresses up to 512 GB of memory in a 32-way configuration when using 4 GB DIMMs — a technology and physical space limitation.

A memory address is a unique identifier for a memory location at which a processor or other device can store a piece of data for later retrieval. Each address identifies a single byte of storage.

All applications use *virtual* addresses, not physical. The operating system maps any (virtual) memory requests from applications into physical locations in RAM. When the total amount of virtual memory used by all applications combined exceed the physical RAM installed, the difference is stored in the page file also managed by the operating system.

2.6 Comparing AMD64 and EM64T

There are some differences between AMD64 and EM64T. However, the operating system makes these differences transparent to applications. The net result is that the two architectures are almost completely compatible.

The main technical difference between these architectures is bus structure to memory. A front-side bus and separate memory controller with EM64T as opposed to an integrated memory controller with AMD64.

As far as what is presented to the operating system, the key difference is the slight variation in the instruction set, which includes:

- NX (AMD) versus XD (Intel) — No Execute Bit

  The bit to each instruction is meant to prevent treating data as executable code, thereby preventing corruption (and virus/trojan horse infections) due to buffer overflows. This will require developers to explicitly mark the specific code pages as executable.

  AMD implements this as an additional NX (No Execute) bit. With this set, execution of the code from memory pages is prevented. Intel will also implement this in future, referring to it as the XD (execute disable) bit.

- LAHF and SAHF

  These instructions are used for reading (loading - LAHF) and storing (SAHF) AH register from/into flags. This is not implemented in EM64T.

- CPUID

  The type of processor and its specific features is identified by OS with CPUID. When the OS issues the CPUID request to determinate the type of processor, AMD returns all bytes with information about processor and additional bytes describing 64-bit availability. Intel returns only a subset of this information.

- MSR — Machine Specific Registers

  Each processor has their own specific set of registers describing its hardware functionality using Extended Feature Enable (EFER). AMD64 and EM64T implement this set of registers differently. For example: if 10th byte of EFER is set to 1 it means that both IA-32e mode and paging have been enabled (this is read only byte set by processor).

- 3DNow versus SSE-3

  These instructions prefetch data which can help speed up blocks operations such as copying memory pages. These are not only used for speed up graphics operations (as name suggests).

  AMD implements the 3DNow instruction set and Intel implements the SSE-3 set of instructions. Windows x64 uses both.

- Others such as I/O address translations, cmpxchg16b, syscall, sysret, swapgs, bsf, bsr, calls with prefix 66h, sysenter, sysexit, saving FPU state

Figure 2-5 on page 19 shows the changes made to the registers with the addition of the EM64T extensions. The AMD Opteron processor changes are similar.

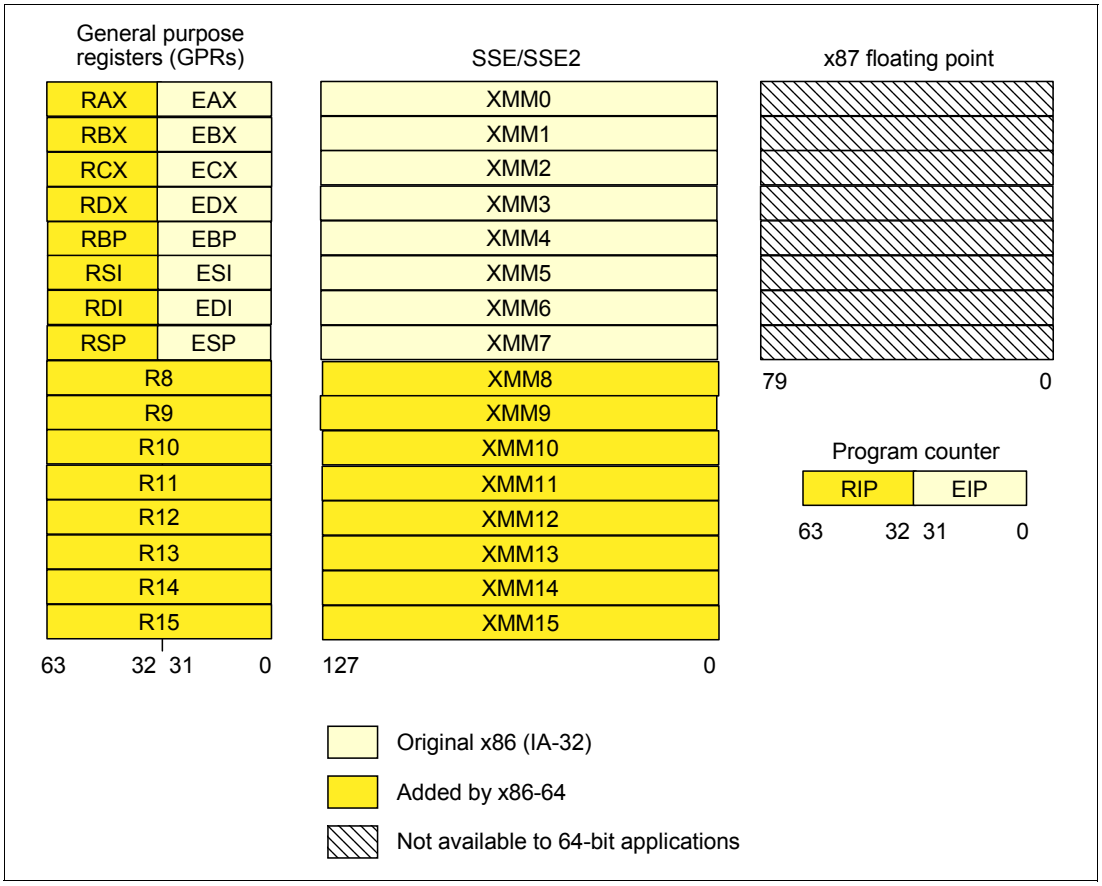

Figure 2-5 Comparison between old and new set of registers

The x87 registers should not be used by 64-bit applications. For more information, see “Can x87 instructions still be used by 64-bit applications?” on page 11 of the following document:

http://www.amd.com/us-en/assets/content_type/DownloadableAssets/AMD64_Porting_FAQ.pdf

Intel Xeon versus AMD Opteron™ processor performance summary

Processor performance is a complex topic because the effective processor performance is affected by system architecture, operating system, application, workload and many other factors. In this section we are not trying to directly compare processors but only list the most important variables which can potentially impact performance.

- Intel Xeon processors offer more raw processing power
  - Higher frequency with greater execution performance
  - Larger processor caches (2-8 MB versus 1 MB). Workloads which run out of cache are expected to yield greater performance on Xeon compared to AMD Opteron processor
  - However shared front-side bus limits processor to memory bandwidth
- AMD Opteron processors employ integrated memory controller
  - Directly attached main memory reduces memory latency
  - Dedicated path to memory for each processor yields greater processor to memory bandwidth
  - Higher performance is expected only when the workload requires frequent accesses to memory (low processor cache-hit rates)

2.7 Three operational modes

Both processors can operate in three different modes, as shown in Figure 2-3. Modes are changed automatically without any user interaction. The new enhancements described in this chapter are only available in compatibility and 64-bit mode.

Table 2-3 Processor modes

	32-bit legacy mode	Compatibility mode	64-bit mode
Operating system	32-bit	64-bit	64-bit
Applications	32-bit	32-bit	64-bit
Drivers	32-bit	64-bit	64-bit
Address space	4 GB total	4 GB per process	64-bit virtual
GPRs	32-bit	32-bit	64-bit

Remember: Ensure that you have 64-bit device drivers versions before changing your system. The 64-bit operating system will not boot with 32-bit drivers.

For more details on the operation modes that are supported, see 4.2.5, “32-bit and 64-bit application support” on page 49.

3

IBM products

This chapter provides an introduction to the IBM@server products family and an overview of the xSeries brand. It also describes advantages of Intel-based servers that are offered from IBM. This chapter discusses the unique features of xSeries servers and specifies which of these servers are 64-bit aware. In addition, this chapter include a description of IBM tools and drivers that are related to those servers with support plans for the new Windows Server 2003, x64 Edition operating system.

3.1 The IBM @server product line

IBM offers servers for small and medium applications, such as file or print server, database, e-mail, and collaboration, as well as machine suites for huge corporations, in one complete product line, IBM @server.

In October 2000, IBM launched its IBM @server initiative to unite the four server platforms under a common server brand umbrella. This plan has transformed every sector within the IBM server group, including its technology, manufacturing, marketing, and sales organizations. IBM @server solutions combine the foundation of IBM hardware, software, and middleware with the strengths of applications from our solution developer IBM Business Partners. This successful combination, coupled with flexible financing and packaging options, help businesses meet and overcome the challenges of doing business in the on demand world.

The new IBM @server family of servers reflects more than just a name change. It is an entirely new single-integrated server strategy, with different servers for different workloads, client requirements, and industry-specific needs. All IBM @server products are self-managing systems, Linux-ready, and modular in design.

IBM @server products offer application flexibility, solution choice, and innovative technology for extreme performance, outstanding scalability, reliability and security. The IBM @server products offer the tools that are needed to help transform an organization into an on demand business.

The IBM @server family of servers consists of a large variety of products and product lines. The main products lines are:

- zSeries
- iSeries™
- pSeries
- xSeries
- BladeCenter

Each brand within the IBM @server family provides different strengths, capabilities, and architectures.

3.1.1 zSeries

IBM @server zSeries systems are directed toward enterprise accounts. They provide high security and efficient use of resources and can virtualize large numbers of UNIX, Microsoft Windows, and Linux workloads.

IBM announced the new IBM @server z890 and z990. The IBM @server z890 offers the flexibility to manage numerous operating systems on a single server, including z/OS®, OS/390®, z/VM®, VM/ESA®, VSE/ESA™, TPF, as well as Linux for zSeries and Linux for S/390®.

The IBM @server z990 is designed to provide a balanced system and improved price and performance. From processor storage to the system's I/O and network channels, end-to-end bandwidth is designed to deliver data where and when it is needed. With a choice of four models, the largest IBM @server z990 can be configured with up to three times the processing power, four times the memory, four times the HiperSockets™, up

to four times the number of ESCON® channels, up to 25% more Fiber Connection (FICON®), and up to twice the number external coupling links of an IBM @server z900 Model 216 server.

3.1.2 iSeries

The mid-range iSeries servers are directed toward mid-market accounts. They allow integration of multiple operating systems, such as OS/400®, Linux and Windows, with storage management capabilities and key middleware, such as WebSphere®. Their manageability and reliability, coupled with an integrated attachment to the xSeries and the new On/Off Capacity on Demand, positions the iSeries to adjust dynamically to the changing demands of the on demand environment.

IBM announced the IBM @server i5 520 and IBM @server i5 570. The IBM @server i5 servers are the industry's first servers that are based on IBM POWER5™ technology. The IBM @server i5 server supports multiple operating systems, dynamic — even automatic — distribution of processing resources, and dynamic logical partitioning that is part of the IBM Virtualization Engine™ platform technologies.

3.1.3 pSeries

The IBM @server pSeries servers offer UNIX (IBM AIX®) and Linux-based servers combined with the POWER4™ technology and autonomic computing features. Through high-performance and flexibility between AIX 5L™ and Linux operating environments, IBM @server pSeries servers deliver reliable, cost-effective solutions for commercial and technical computing applications in the entry, mid-range, and high-end UNIX segments.

IBM announced the IBM @server pSeries mid-range p655 and high-end p690 servers. The pSeries 655 server uses a 64-bit POWER4 processor and has a maximum internal storage of 14.6 TB. The pSeries 655 server is used for building high-performance clusters. The pSeries 690 server also uses the 64-bit POWER4 processor and has a maximum internal storage of 18.7 TB. The pSeries 690 server has the power to handle demanding scientific and technical workloads.

3.1.4 xSeries

The IBM @server xSeries are Intel processor-based servers featuring Intel Xeon processors provide outstanding availability and price and performance capabilities that help better manage and provision your IT environment. The xSeries servers family can be determined in the following groups of servers:

- Universal servers
- Rack servers
- Blades

xSeries server are covered in detail in 3.2, “xSeries servers” on page 24.

3.1.5 BladeCenter

The IBM @server BladeCenter units are individual, single-board servers that are installed into a rack-mounted chassis that share power, cooling, and networking functions. These units increase the physical density of servers, improve the overall management of large numbers of servers, and provide new application opportunities that are based on specialized blade functions.

In November 2003, IBM introduced the IBM @server BladeCenter JS20 server, the industry's first blade server based on 64-bit POWER™ architecture. The JS20 server supports both SUSE LINUX and Turbolinux and uses the POWERPS 970 processor.

IBM announced the BladeCenter T system which delivers telecommunication features and functionality. The BladeCenter T systems are unique among blade servers in that they are both Network Equipment Building Systems 3 (NEBS 3) and European Telecommunications Standard Industry (ETSI) compliant. They can withstand high temperature, violent shaking, lightning strikes, airborne contaminants, fires, and electrostatic discharge and are used for wireless and telecommunications applications that require continuous uptime.

The BladeCenter T supports the HS20 and HS40 server models. The HS20 is an ultra-thin modular design. Up to 84 HS20 servers can be placed in an industry-standard rack. Up to 42 HS40 servers can be placed in an industry-standard rack. Both are hot swappable without disrupting other chassis operations.

3.2 xSeries servers

The xSeries servers are based on Intel processor technology including IA-32, IA-32e, IA-64 architectures. In addition, the IBM @server 326 is based on AMD64 technology. The xSeries family can scale-up to 32-way. This line of servers is based on X-Architecture™, where IBM industry-standard technology is linked with the advanced technology from years of enterprise server development.

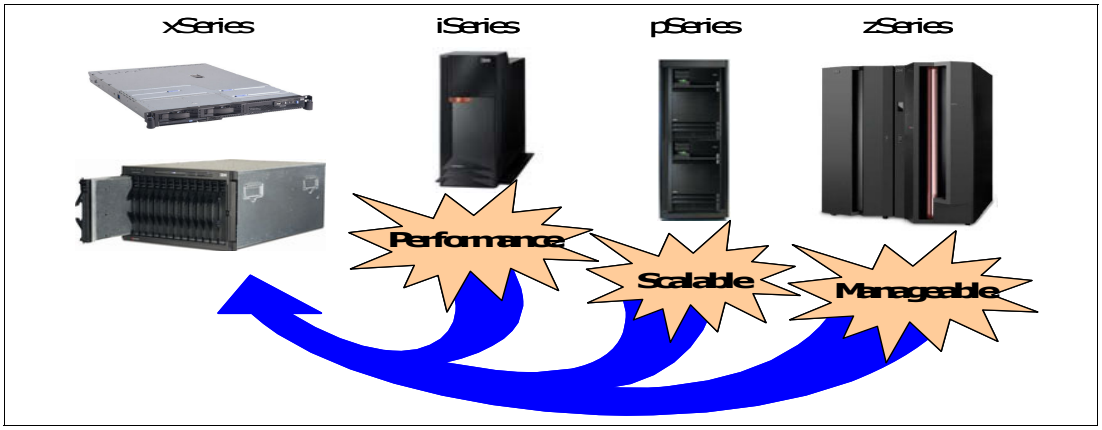

Figure 3-1 The concept of xSeries: Learning the best from all IBM@server product lines

3.2.1 IBM Enterprise X-Architecture

While the xSeries server delivers advanced technology to customers at a low price, many applications and services with industry standards are also usable. In 2001, IBM announced the Enterprise X-Architecture. IBM offers Enterprise X-Architecture through core logic developed by IBM and implemented through the IBM XA-32 and XA-64 chipsets corresponding to the IA-32 and IA-64 processors.

IBM X-Architecture technology is a blueprint for extending the benefits of advanced availability technologies to IBM Intel processor-based servers. These benefits are in the areas of availability, scalability, systems management, service, and support. IBM has been delivering on the promise of the X-Architecture model since 1998. It has included such innovative technologies as Active PCI, C2T Interconnect cabling, Chipkill™ memory, Predictive Failure Analysis®, Light Path Diagnostics, and IBM Director Software Rejuvenation.

IBM continues to build on the X-Architecture blueprint with Enterprise X-Architecture technologies. These technologies produce advances in the I/O, memory, and performance of xSeries servers. The results are systems that can be scaled quickly, easily, and inexpensively.

3.2.2 IBM eServer X3 Architecture

In 2005, IBM introduced the IBM @server X3 Architecture, the culmination of a three year, $100 million development effort, to bring mainframe-inspired capabilities and sophisticated high-end technology to the company's next-generation 64-bit Intel Xeon processor-based xSeries servers. The new X3 Architecture provides up to 38% higher 4-way performance than the previous generation of Intel Xeon processor-based systems. It enables businesses to run 32-bit and 64-bit applications simultaneously and to process massive amounts of data more rapidly.

The third generation of Enterprise X-Architecture design, X3 Architecture, is optimized for superior server consolidation and enterprise application software, and uses the IBM high-end Virtualization Engine technology to enhance virtualization capabilities. The X3 Architecture offers investment protection for IBM customers with its family of pay-as-you-grow Intel-based servers by supporting both 32-bit and 64-bit applications on the same platform so clients can migrate to 64-bit as needed.

XA-64e, the third-generation Enterprise X-Architecture chipset (codename Hurricane), is the heart of the X3 Architecture, providing an integrated processor and memory controller that significantly reduces memory latency, improving response times and overall system performance. The XA-64e chipset was specifically designed for xSeries by a cross-platform architectural team.

Key advantages available from the XA-64e chipset include:

- Up to 100% higher performance than EXA 2G (x365, x445)
- XceL4v cache with integrated snoop filter reduces latency. An integrated snoop filter that frees up front side bus traffic by storing a local cache directory, reducing latency, and increasing transaction processing.
- Higher performance than Itanium 2 and AMD Opteron processor
- Grow up to 32-way in 4 processor increments
- 64-bit memory addressability supporting up to 512 GB
- Optimized for high-end virtualization for server consolidation
- Next-generation Active Memory with DDR2 Performance
- Hot-swap and Memory Mirroring with all DIMMs accessible
- Supports 32-bit and 64-bit applications on the same platform
- Migrate to 64-bit as needed or as supported by commercial applications
- Support for future dual-core processors

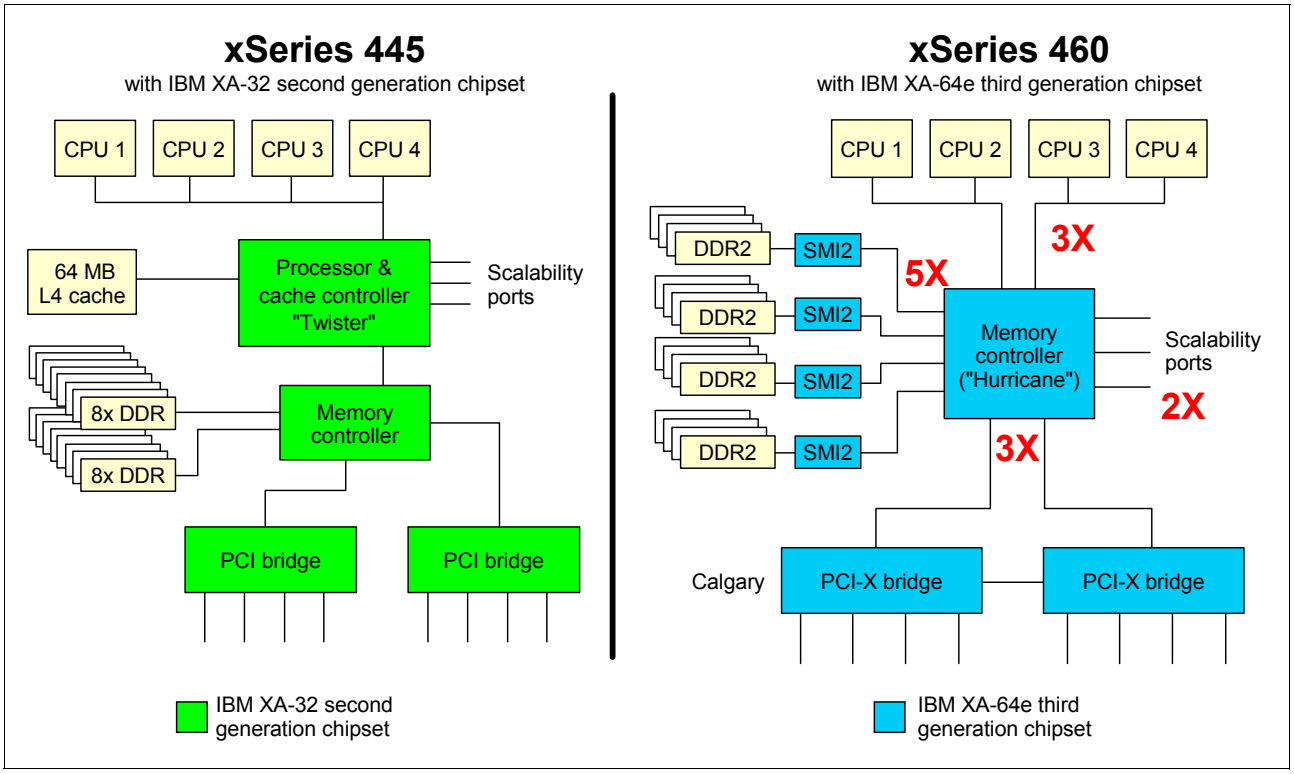

Figure 3-2 EXA2 versus EXA3: Faster pipes and lower latencies

3.2.3 IBM xSeries product portfolio

The xSeries servers family is divided into the following groups of servers:

- Universal servers
- Rack servers
- Blade servers

Universal server means a tower server with possibility to convert to rack based on an optional tower-to-rack conversion kit. Rack servers are rack cabinet optimized and cannot be converted to tower standalone servers. Other ways to groups servers are by:

- Functionality
- Number of processors
- Application or business oriented
- Scalability

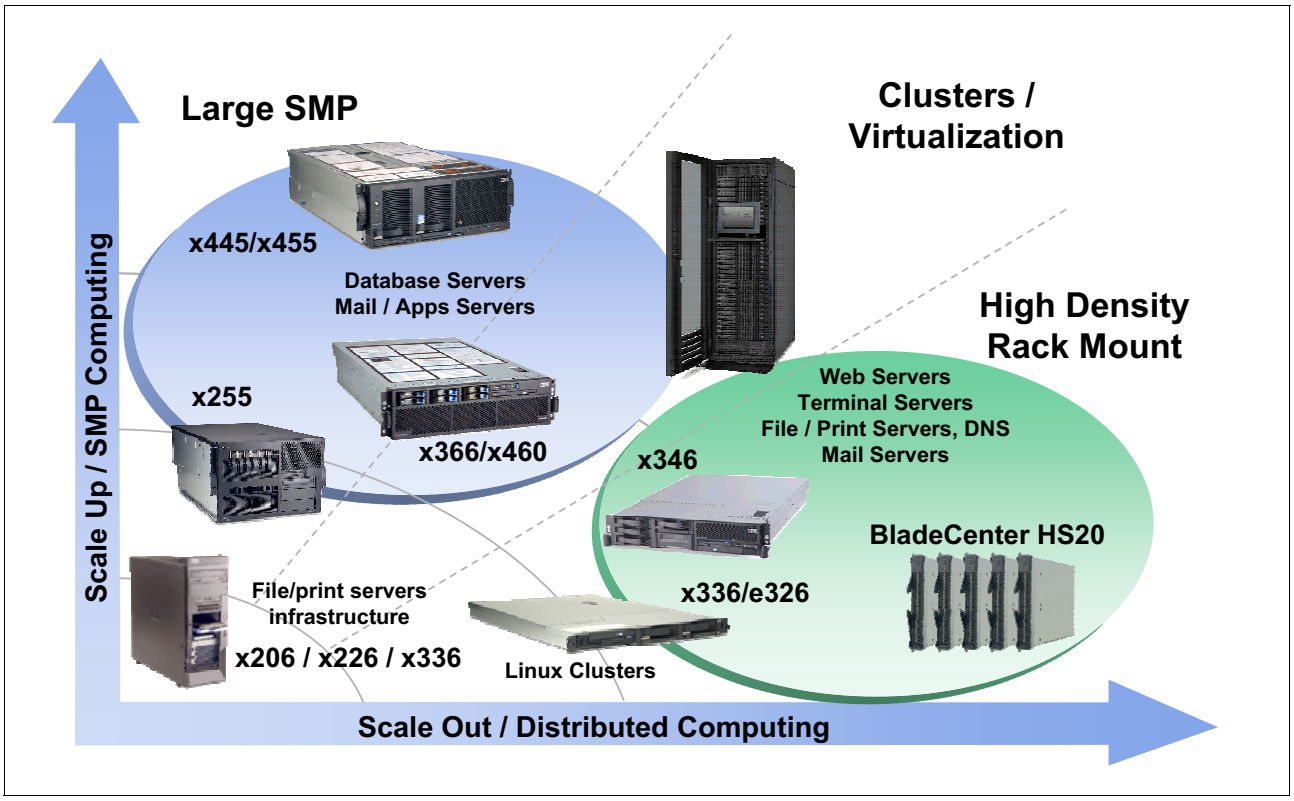

Figure 3-3 IBM@server xSeries servers portfolio

xSeries systems are designed to match nearly any application workload environment, from entry-level, uni-processor systems to 32-way enterprise-class configurations. For more information visit:

http://www.ibm.com/eserver/xseries

Table 3-1 lists the servers in the current product line that support Windows Server 2003, x64 Edition.

Table 3-1 xSeries servers that support Windows Server 2003, x64 Edition

Server	Supports Windows Server 2003, x64 Edition
x206	Yes
x226	Yes
x236	Yes
x255	Not supported
x306	Yes
x336	Yes
x346	Yes
x366	Yes
e326	Yes
x445	Not supported
x455	Not supported
x460	Yes
HS20	Yes
HS40	Planned
JS20	Not supported

Operating system support for xSeries changes periodically. Current information is available at the IBM ServerProven® site at:

http://www.pc.ibm.com/us/compat/nos/matrix.shtml

3.2.4 xSeries 206

Table 3-2 lists the specifications for the xSeries 206.

Table 3-2 xSeries 206 specifications

Form Factor	Tower, rack/4U
Processor	Intel Pentium 4 Processor up to 3.4 GHz/800 MHz front-side bus (select models include Intel EM64T)
Number of processor (std/max)	1/1
Cache (max)	1 MB L2
Memory (std/max)	256 MB/4 GB PC2700/PC3200 DDR standard via 4 DIMM slots (model dependent)
Expansion Slots	2 PCI-X, 3 PCI
Disk bays (total/hot-swap)	4 non-hot-swap SCSI3 hot-swap SCSI2 simple-swap SATA (optional 4)
Maximum internal storage	587.2 GB SCSI, 500 GB SATA, 1 TB SATA optional
Network	Integrated 10/100/1000 Ethernet
System Management processor	Supports optional Remote Supervisor Adapter II
Power supply (std/max)	340W 1/1
Hot-swap components	Hard disk drives (select models)
Light path diagnostics	Limited
RAID support	Integrated IBM ServeRAID™-7E (RAID-0, -1) optional RAID-5 with adapter
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows, Novell NetWare, OS 4690

For more detailed information about the xSeries 206, see:

http://www.ibm.com/eserver/xseries/x206.html

Figure 3-4 The xSeries 206

3.2.5 xSeries 226

Table 3-3 lists the specification for xSeries 226.

Table 3-3 xSeries 226 specifications

Form Factor	Tower, rack/4U
Processor	Intel Xeon Processor up to 3.4 GHz/800 MHz front side bus supports Intel EM64T
Number of processor (std/max)	1/2
Cache (max)	Up to 2 MB L2
Memory (std/max)	512 MB/16 GB 3 PC2-3200 DDR2
Expansion Slots	6 total (3 PCI-X, 2 PCI, 1 PCI-Express)
Disk bays (total/hot-swap)	9/6 — up to 6 hot-swap SCSI up to four simple-swap Serial ATA (with adapter)
Maximum internal storage	1.8 TB Ultra320 hot-swap, 1 TB SATA
Network	Integrated 10/100/1000 Ethernet
System Management processor	Supports optional Remote Supervisor Adapter II
Power supply (std/max)	530W or (2) 514W hot-swap
Hot-swap components	Power supply, hard disk drives (select models)
Light path diagnostics	Limited
RAID support	IBM ServeRAID-7e (integrated RAID-0 or RAID-1), optional RAID-5
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows, Novell NetWare, OS/2®

For more detailed information about the xSeries 226, see:

http://www.ibm.com/eserver/xseries/x226.html

Figure 3-5 The xSeries 226

3.2.6 xSeries 236

Table 3-4 lists the specifications for the xSeries 236.

Table 3-4 xSeries 236 specifications

Form Factor	Tower, rack/5U
Processor	Intel Xeon Processor up to 3.60 GHz/800 MHz front-side bus supports Intel EM64T
Number of processor (std/max)	1/2
Cache (max)	2 MB L2
Memory (std/max)	512 MB or 1 GB/16 GB PC2-3200 DDR2 via 8 DIMM slots
Expansion Slots	6 available (1x PCI-X 133 MHz Active PCI-X, 2x PCI-X 100 MHz, 2x PCI-Express, 1x 32-bit/33 MHz
Disk bays (total/hot-swap)	6/6 (9 bays via 3-pack option)
Maximum internal storage	2.7 TB Ultra320 SCSI
Network	Dual integrated 10/100/1000 Ethernet
System Management processor	Integrated Systems Management Processor (supports optional Remote Supervisor Adapter II SlimLine)
Power supply (std/max)	670W 1/2
Hot-swap components	Drives, power supply, fans and 1 Active PCI slot
Light path diagnostics	Yes
RAID support	Integrated RAID-0, -1, -10, optional RAID-5
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows, Novell NetWare

For more detailed information about the xSeries 236, see:

http://www.ibm.com/eserver/xseries/x236.html

Figure 3-6 The xSeries 236

3.2.7 xSeries 306

Table 3-5 lists the specifications for the xSeries 306.

Table 3-5 xSeries 306 specifications

Form Factor	Rack/1U
Processor	Intel Pentium 4 Processor up to 3.2 GHz/800 MHz front-side bus (select models support Intel EM64T)
Number of processor (std/max)	1/1
Cache (max)	1 MB L2
Memory (std/max)	512 MB/4 GB PC2700/PC3200 DDR standard (model dependent)
Expansion Slots	2 PCI-X (66 MHz)
Disk bays (total/hot-swap)	2 non-hot-swap SCSI2 simple-swap SATA
Maximum internal storage	500 GB SATA or 293.6 GB SCSI
Network	Dual integrated 10/100/1000 Ethernet
System Management processor	Supports optional Remote Supervisor Adapter II
Power supply (std/max)	300W 1/1
Hot-swap components	Simple-swap SATA drives
Light path diagnostics	N/A
RAID support	Integrated IBM ServeRAID-7e (RAID-0,-1)
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows

For more detailed information about the xSeries 306, see:

http://www.ibm.com/eserver/xseries/x306.html

Figure 3-7 The xSeries 306

3.2.8 xSeries 336

Table 3-6 lists the specifications for the xSeries 336.

Table 3-6 xSeries 336 specifications

Form Factor	Rack/1U
Processor	Intel Xeon Processor up to 3.60 GHz/800 MHz front-side bus supports Intel EM64T
Number of processor (std/max)	1/2
Cache (max)	Up to 2 MB L2
Memory (std/max)	512 MB or 1 GB/16 GB PC2-3200 DDR2
Expansion Slots	1 PCI-X (64-bit 100 MHz) and 1 PCI-X (64-bit 133 MHz) or 1 PCI-Express x8
Disk bays (total/hot-swap)	2/2 or 4/4
Maximum internal storage	600 GB Ultra320 SCSI or 500 GB simple-swap SATA
Network	Dual integrated 10/100/1000 Ethernet
System Management processor	Integrated Systems Management Processor (supports optional Remote Supervisor Adapter II SlimLine)
Power supply (std/max)	585W 1/2
Hot-swap components	Power supply, hard disk drives (select models)
Light path diagnostics	Yes
RAID support	Integrated RAID-1, -1E, optional RAID-5
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows, Novell NetWare, VMware ESX Server

For more detailed information about the xSeries 336, see:

http://www.ibm.com/eserver/xseries/x336.html

Figure 3-8 The xSeries 336

3.2.9 xSeries 346

Table 3-7 lists the specifications for the xSeries 346.

Table 3-7 xSeries 346 specifications

Form Factor	Rack/2U
Processor	Intel Xeon Processor up to 3.60 GHz/800 MHz front-side bus supports Intel EM64T
Number of processor (std/max)	1/2
Cache (max)	Up to 2MB L2
Memory (std/max)	512MB or 1GB/16GB PC2-3200 DDR2 via 8 DIMM slots
Expansion Slots	4 PCI-X or 2 PCI-X and 2 PCI-Express
Disk bays (total/hot-swap)	6/6
Maximum internal storage	1.8TB Ultra320 SCSI
Network	Dual integrated 10/100/1000 Ethernet
System Management processor	Integrated Systems Management Processor (supports optional Remote Supervisor Adapter II)
Power supply (std/max)	625W 1/2
Hot-swap components	Power supply, fans and hard disk drives
Light path diagnostics	Yes
RAID support	Integrated RAID-0/-1, optional RAID-5
OS compatibilities support	Red Hat, SUSE LINUX, Microsoft Windows, Novell NetWare, VMware ESX Server

For more detailed information about the xSeries 346, see:

http://www.ibm.com/eserver/xseries/x346.html

Figure 3-9 The xSeries 346

3.2.10 xSeries 366

Table 3-8 lists the specifications for the xSeries 366.

Table 3-8 xSeries 366 specifications

Form Factor	Rack / 3U
Processor	64-bit Intel Xeon Processor MP at up to 3.66 MHz/supports Intel Extended Memory 64 Technology
Number of processor (std/max)	1/4
Cache (max)	1 MB L2 per processor plus Integrated XceL4v Dynamic Server Cache
Memory (std/max)	2 GB/64 GB PC2-3200 DDR2 SDRAM
Expansion Slots	6 PCI-X
Disk bays (total/hot-swap)	6/6 2.5" Serial Attached SCSI (SAS)
Maximum internal storage	440.4 GB SAS (supports 36.4 GB and 72.8 GB hard disk drives)
Network	Integrated dual 10/100/1000 Ethernet
System Management processor	Alert on LAN™, Automatic Server Restart, IBM Director, IBM ServerGuide™, Remote Supervisor Adapter II SlimLine optional, light path diagnostics (independently powered), Predictive Failure Analysis on hard disk drives, processors, VRMs, fans and memory, Wake on LAN®
Power supply (std/max)	1300W 1/2 hot-swap
Hot-swap components	Power supplies, fans, memory, hard disk drives and PCI-X adapters
Light path diagnostics	Yes
RAID support	Optional with ServeRAID-8i
OS compatibilities support	Microsoft Windows Server 2003 (Standard and Enterprise editions 32-bit and x64), Red Hat Linux, SUSE LINUX, Microsoft Windows 2000 (Server and Advanced Server), VMware ESX Server

For more detailed information about the xSeries 366, see:

http://www.ibm.com/eserver/xseries/x366/

Figure 3-10 The xSeries 366

3.2.11 xSeries 460 and MXE-460

Table 3-9 lists the specifications for the xSeries 460 and MXE-460.

Table 3-9 xSeries 460 and MXE-460 specifications

Form Factor	Rack / 3U
Processor	64-bit Intel Xeon Processor MP at up to 3.66 MHz/supports Intel Extended Memory 64 Technology
Number of processor (std/max)	1/4 per node
Multi-node configurations	Yes (8 nodes maximum for a total of 32-way and 512 GB memory). Nodes are either x460 or MXE-460 servers. MXE-460 is for expansion only.
Cache (max)	1 MB L2 per processor 4 to 8 MB L3 cache per processor (model dependent) 32 MB per 4-way XceL4v Dynamic Server Cache per node
Memory (std/max)	2GB/64GB PC2-3200 DDR2 SDRAM (512 GB in eight nodes)
Expansion Slots	6 PCI-X
Disk bays (total/hot-swap)	6/6 2.5" Serial Attached SCSI (SAS)
Maximum internal storage	440.4 GB SAS (supports 36.4 GB and 72.8 GB hard disk drives)
Network	Integrated dual 10/100/1000 Ethernet
System Management processor	Alert on LAN, Automatic Server Restart, IBM Director, IBM ServerGuide, Remote Supervisor Adapter II SlimLine, light path diagnostics (independently powered), Predictive Failure Analysis on hard disk drives, processors, VRMs, fans and memory, Wake on LAN
Power supply (std/max)	1300W hot-swap (2/2)
Hot-swap components	Power supplies, fans, memory, hard disk drives and PCI-X adapters
Light path diagnostics	Yes
RAID support	Optional with ServeRAID-8i
OS compatibilities support	Microsoft Windows Server 2003 (Standard and Enterprise editions 32-bit and x64), Red Hat Linux, SUSE LINUX, Microsoft Windows 2000 (Server and Advanced Server), VMware ESX Server

For more detailed information about the xSeries 460 and MXE-460, see:

http://www.ibm.com/eserver/xseries/460/

Figure 3-11 The xSeries 460 and MXE-460

3.2.12 IBM@server 326

Table 3-10 lists the specifications for the IBM@server 326.

Table 3-10 IBM@server326 specifications

Form Factor	Rack / 1U
Processor	AMD Opteron processor up to 2.4 GHz
Number of processor (std/max)	1/2
Cache (max)	1 MB L2
Memory (std/max)	1 GB / 16 GB PC2700 or PC3200 DDR-SDRAM
Expansion Slots	2x 63-bit 133/100 MHz PCI-X
Disk bays (total/hot-swap)	2/2
Maximum internal storage	292 GB Ultra320 SCSI or 320GB simple-swap SATA
Network	Integrated dual 10/100/1000 Ethernet
System Management processor	BMC module
Power supply (std/max)	411W 1/1
Hot-swap components	hard disk drives (select models)
Light path diagnostics	Limited
RAID support	Integrated RAID-1
OS compatibilities support	Microsoft Windows Server 2003 (Standard and Enterprise editions 32-bit and x64), Red Hat Linux, SUSE LINUX

For more detailed information about the IBM@server 326, see:

http://www.ibm.com/eserver/opteron/325

Figure 3-12 The IBM@server 326

3.2.13 BladeCenter - HS20 server

Blade servers are a relatively new technology that reduce cost with a more efficient use of valuable floor space and simplified management. BladeCenter's modular design gathers computing resources into cost-effective, high-density enclosures that support hot-swappable, high-performance 2-way Intel processor-based (HS20) and new 2-way POWER processor-based (JS20) blade servers. Also, the 4-way Intel Xeon MP based Blade servers called HS40 can be a whole back-office infrastructure inside the 7U box.

Figure 3-13 IBM BladeCenter fitted with 14 HS20 servers

Table 3-11 lists the specifications for the BladeCenter servers.

Table 3-11 IBM BladeCenter at a glance (HS20, HS40 and JS20 chassis)

Form factor	Rack/7U, high-availability midplane
Blade bays	Up to 14 2-way, and up to 7 4-way
Standard media	DVD-ROM and diskette drive available from each server blade
Switch modules	4 switch module bays
Power supply module	Up to 4 (hot-swap and redundant 2000W with load balancing and failover capabilities)
Cooling modules	2 hot-swap and redundant blowers standard
Systems management hardware	1 management module standard, add an optional second module for redundancy
I/O ports	Keyboard, video, mouse, Ethernet, USB

BladeCenter HS20 blade servers are revolutionizing the economics of application server deployment with power, scalability, control, and serviceability. These servers features include:

- Up to 3.6 GHz/800 MHz models, with 1 MB L2 cache Intel Xeon processors with Extended Memory 64 Technology (EM64T)
- 2-way SMP processing with 800 MHz front-side bus (FSB)
- Up to 8 MB of DDR2-SDRAM memory
- Dual Broadcom 5704S Gigabit Ethernet connections with failover support
- Support for Fibre Channel (FC)
- Support for HS20 Ethernet or Fibre Channel expansion card
- Integrated systems-management processor
- Integrated SCSI controller and connectors for two 2.5-inch small form factor SCSI HDDs
- Connector for adding optional BladeCenter Storage Expansion Unit supporting up to two hot-swap 3.5 inch U320 HDDs and two additional HS20 Ethernet or Fibre Channel expansion cards
- LV models offer lower power usage and NEBS support in BladeCenter with full blade configurations

For more detailed information about BladeCenter servers, see:

http://www.ibm.com/eserver/bladecenter

3.2.14 Useful links

The following are useful links to learn information about the xSeries servers:

- Main web-page about xSeries servers:

  http://www.ibm.com/eserver/xseries
- IBM@server xSeries Literature

  http://www.ibm.com/servers/eserver/xseries/literature
- xREF: one-page technical specifications on the xSeries servers

  http://www.ibm.com/servers/eserver/education/cust/xseries/xref.html
- Configuration and Option Guide for xSeries servers

  http://www.pc.ibm.com/us/eserver/xseries/library/configtools.html
- Sales Configuration Aid - spreadsheet tool (Excel) for creating xSeries configurations

  http://www.pc.ibm.com/support?page=MIGR-41411
- Rack configuration

  http://www.pc.ibm.com/support?page=BBOD-3MDQFF

3.3 Support for Windows Server 2003, x64 Edition from IBM

In support of the Microsoft Windows Server 2003, x64 Edition, IBM@server xSeries provides the following relevant information and downloads:

- Tips for Windows Server 2003, x64 Edition:

  http://www.pc.ibm.com/support?page=SERV-X64TIP

- Beta device drivers for Windows Server 2003, x64 Edition:

  http://www.pc.ibm.com/support?page=MIGR-57377

3.3.1 ServerGuide

ServerGuide is an IBM server installation assistant that simplifies the process of installing and configuring IBM@server xSeries and Netfinity® servers. ServerGuide goes beyond hardware configuration by assisting with the installation of your operating system, the latest system device drivers and other system components with minimal user intervention. There are plans to support Windows Server 2003, x64 Edition in 3Q/2005 with Version 7.4. You can access the latest ServerGuide at:

http://www.pc.ibm.com/support?page=MIGR-4ZKPPT

3.3.2 ServeRAID

ServeRAID is a set of device drivers which support following RAID controllers under different OS platforms. ServeRAID includes also additional software helping with everyday RAID administration. The ServeRAID CD is bootable and with it you can configure RAID arrays before OS installation. Supported RAID adapters are:

- ServeRAID
- ServeRAID II
- ServeRAID-3L and ServeRAID-3L II
- ServeRAID-3H
- ServeRAID-3HB
- ServeRAID-4L
- ServeRAID-4Lx
- ServeRAID-4M
- ServeRAID-4Mx
- ServeRAID-4H
- ServeRAID-5i
- ServeRAID-6M
- ServeRAID-6i and ServeRAID-6i+
- ServeRAID 7t
- ServeRAID 7e
- ServeRAID 7k
- ServeRAID 8i

ServeRAID version 7.12 is expected in mid-2005. This version will include drivers for Windows Server 2003, x64 Edition edition for the following adapters:

- ServeRAID 6i+
- ServeRAID 6M
- ServeRAID 7k
- ServeRAID 7t

Support for the ServeRAID 8i will be separate from the v7.12 CD. SCSI ServeRAID driver (nfrd960) is native in the x86-64 version of Windows.

Fore more information and to download ServeRAID drivers, see:

http://www.pc.ibm.com/support?page=MIGR-495PES

3.3.3 UpdateXpress

UpdateXpress is an effective and simple way to update server firmware and firmware of supported options contained within the server on most of your xSeries products. If you have purchased an IBM xSeries server, UpdateXpress is available for download at no additional charge.

When the drivers and online BIOS, firmware, and diagnostics updates are made available, it will take a further three months to incorporate those into UpdateXpress. UpdateXpress is released three times a year: May, August, and December.

UpdateXpress is available at:

http://www.pc.ibm.com/support?page=MIGR-53046

3.3.4 IBM Director

IBM Director is the industry leading client/server workgroup manager. With IBM Director, IT administrators can view and track the hardware configuration of remote systems in detail and monitor the usage and performance of critical components, such as processors, disks, and memory. Extensions to IBM Director are available for customers who want advanced capabilities. These extensions include:

- Server Plus Pack
- Software Distribution Premium Edition
- Remote Deployment Manager
- Application Workload Manager

IBM Director features include:

- Self-managing, smart tools — automated, proactive capabilities that reduce IT costs and maximize uptime.
- Support for non-IBM hardware — Innovative use of industry standards from CIM to SNMP enables heterogeneous hardware management, protecting your existing IT investment.
- Seamless Integration — IBM Director protects your investments in other management packages, complementing them with more extensive hardware manageability.
- Single-click management GUI — a convenient user interface delivers the ability to drag and drop tasks to specific systems or groups of systems.
- Integrated, centralized SQL database — an internal database makes system-related data available, even when the specific system is not directly available.
- Multiple operating system support — IBM Director smoothly handles a variety of popular operating systems.
- Comprehensive BladeCenter support — an easy, single point of deployment and management of new blade server architectures.
- Provides a consistent framework that can be extended with plug-ins for advanced management.
- Command Line Interface support for many IBM Director management tasks.

IBM Director 5.1, scheduled for release in June 2005, will support Windows Server x64 agents.

3.3.5 RDM

Remote Deployment Manager (RDM) facilitates remote deployment of both IBM and non-IBM systems. RDM allows for remote unattended installation of new and existing systems. RDM helps automate deployment tasks such as initial operating system installation, BIOS updates, and disposal of retired systems. All of these tasks can be done without visiting the remote system.

Seamless integration into IBM Director means that only one console is required to both remotely manage and deploy supported systems. The combination of IBM Director, RDM, and Software Distribution Premium Edition provides a potent set of tools for both management and deployment.

Features for RDM include:

- Support for deploying Windows and Linux operating systems.
- Ability to capture and deploy images from / to systems.
- Interview wizards for Windows and Linux makes it easy to create unattended install scripts.
- Integration into IBM Director provides a consistent, single point of management and deployment via a drag-and-drop interface and allows use of IBM Director's task scheduler and group management capability.
- Support for IBM and non-IBM hardware that adhere to industry standards including PXE (preboot execution) and WOL (Wake on LAN).
- Fast system restoration and deployment with Power Restore feature.
- Secure Data Disposal utility for securely eliminating confidential data from systems being retired.
- Scripting capability to run multiple RDM tasks in a single step.
- Provides an easy, single point of deployment and management for IBM xSeries BladeCenter servers.
- Wide Area Network and multicast support for worldwide deployment.

Initial RDM 4.2 support for Windows Server x64 is due for release in 3Q/2005.

For more information about systems management, see:

http://www.ibm.com/servers/eserver/xseries/systems_management/xseries_sm.html

4

Windows Server 2003, x64 Edition

Windows Server 2003, x64 Edition is the latest member of the Windows Server System family, and supports the AMD AMD64 and the Intel Extended Memory 64 Technology (EM64T) processors. To simplify the various x86 naming schemes, Microsoft has used the nomenclature *x64* to group its operating system compatibility with these Intel and AMD processor architectures. The AMD64/EM64T is based on 64-bit extensions to the x86 instruction set and is incompatible with 64-bit Itanium systems.

This chapter describes the Windows Server 2003 products that are available for both 32-bit and 64-bit platforms and the changes between Windows Server 2003, x64 Edition and 32-bit editions. It also looks at a selection of Windows server applications, how they benefit from 64-bit computing, and the 64-bit products that are available at the time of the writing of this Redpaper.

4.1 Windows products for 32-bit and 64-bit platforms

The Microsoft Windows Server System is a suite of server operating systems and applications. With the availability of Windows Server 2003, x64 Edition, Windows will support three architectures: x86, EM64T/AMD, and Itanium. The Windows Server 2003, x64 Edition supports both the AMD64 and Intel's EM64T architectures. Table 4-1 shows the availability of products for the corresponding 32-bit or 64-bit platforms.

Table 4-1 Microsoft Server operating system by 32-bit or 64-bit platform

Windows Server 2003 edition	32-bit	Intel EM64T AMD AMD64	Itanium 2
Windows Server 2003, Web Edition	Yes		
Windows Server 2003, Standard Edition	Yes		
Windows Server 2003, Enterprise Edition	Yes		
Windows Server 2003, Datacenter Edition	Yes		
Windows Server 2003, Standard x64 Edition		Yes	
Windows Server 2003, Enterprise x64 Edition		Yes	
Windows Server 2003, Datacenter x64 Edition		Yes	
Windows Server 2003, Enterprise 64-Bit Edition (Itanium)			Yes
Windows Server 2003, Datacenter 64-Bit Edition (Itanium)			Yes

Previous versions of 64-bit Windows products, such as Windows XP 64-Bit Edition released in 2001, contained only a subset of features that are found in the Windows XP Professional Edition (32-bit). For example, features such as Windows Media® Player, Infrared, and Windows Installer were not available in the 64-bit edition. For a detailed feature list, see the following:

http://www.microsoft.com/resources/documentation/Windows/XP/all/reskit/en-us/prka_fea_tfiu.asp

With the release of Windows XP Professional x64 and Windows Server 2003, x64 Edition, Microsoft is positioning these new products as an extension of the existing 32-bit product families. Therefore, the operating system features are essentially equivalent across all products where it is possible via the underling hardware architecture.

Microsoft achieves this feature parity by developing Windows Server 2003 from a single source base, which is then used to create binary versions for either x86, EM64T/AMD or Itanium architectures. This allows Microsoft to release features and critical updates at the same time for each operating system platform.

4.2 Changes in Windows Server 2003, x64 Edition

Windows Server 2003, x64 Edition is the latest operating system from Microsoft that supports 64-bit computing on Intel and AMD 64-bit processors. The key differences in this operating system compared to 32-bit version are:

- Compatible with Intel's Xeon processor with Intel Extended Memory 64 Technology (Intel EM64T) and AMD Opteron processors and cannot be installed on 32-bit servers.
- Support for more than 4 GB of virtual memory.
- Support for a greater amount of physical memory (or RAM).
- The ability to run both 32-bit and 64-bit applications on the same operating system. In most cases 32-bit applications will run the same or faster than on an equivalent 32-bit processor.
- 64-bit drivers are required for all hardware devices such as disk controllers, network cards, and video adapters.

The following sections discuss these changes in detail.

4.2.1 Intel EM64T and AMD Opteron™ processor support

All three versions of Windows Server 2003, x64 Edition (Standard, Enterprise and Datacenter) provide support for Intel's Xeon processor with Intel Extended Memory 64 Technology (Intel EM64T) and the AMD Opteron processors. This version of the operating system can only be installed on these 64-bit processor based servers and cannot be installed on 32-bit or the Itanium 64-bit servers as detailed in Table 4-2.

Table 4-2 Where each operating system can run

Windows Server 2003 edition	32-bit	Intel EM64T AMD AMD64	Itanium 2
Windows Server 2003, Web Edition	Supported	Supported	No
Windows Server 2003, Standard Edition	Supported	Supported	No
Windows Server 2003, Enterprise Edition	Supported	Supported	No
Windows Server 2003, Datacenter Edition	Supported	Supported	No
Windows Server 2003, Standard x64 Edition	No	Supported	No
Windows Server 2003, Enterprise x64 Edition	No	Supported	No
Windows Server 2003, Datacenter x64 Edition	No	Supported	No
Windows Server 2003, Enterprise 64-Bit Edition (Itanium)	No	No	Supported
Windows Server 2003, Datacenter 64-Bit Edition (Itanium)	No	No	Supported

4.2.2 Increased processor and memory scalability

Windows Server 2003 implements a virtual memory system to extend the available physical RAM in server. There are several benefits of a virtual address space such as isolating applications and making it easier for programmers. The logical address space is divided into a number of pages which are mapped to physical memory pages. Frequently used pages are kept in memory while others are saved to a page file on the servers hard disk.

Windows 32-bit virtual addressing

All processes running on Windows Server 2003 operate under a virtual address space from 0 to 4,294,967,295 (2^{32}-1 = 4 GB). This is regardless of how much physical RAM is installed in the server. This virtual address space is then shared by the operating system's kernel which uses 2GB of RAM. All other applications are each allocated 2 GB of private virtual address space per process, as illustrated in Figure 4-1.

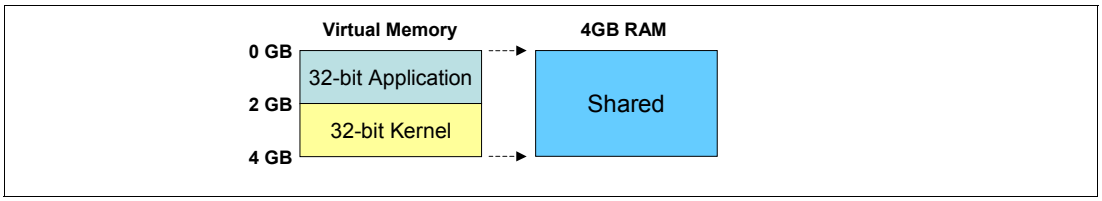

Figure 4-1 Windows 32-bit virtual address space

Virtual addressing

The major advantage of Windows Server 2003, x64 Edition is its ability to support more than 4 GB of virtual memory. Both the kernel and each 64-bit process can address substantially more memory. As the operating system uses a virtual address space outside of the range of 32-bits, each 32-bit application has exclusive use to 4 GB of virtual RAM. The kernel and 64-bit applications can each use up to 8 TB of virtual memory. An example Windows 64-bit virtual memory address space is shown in Figure 4-2.

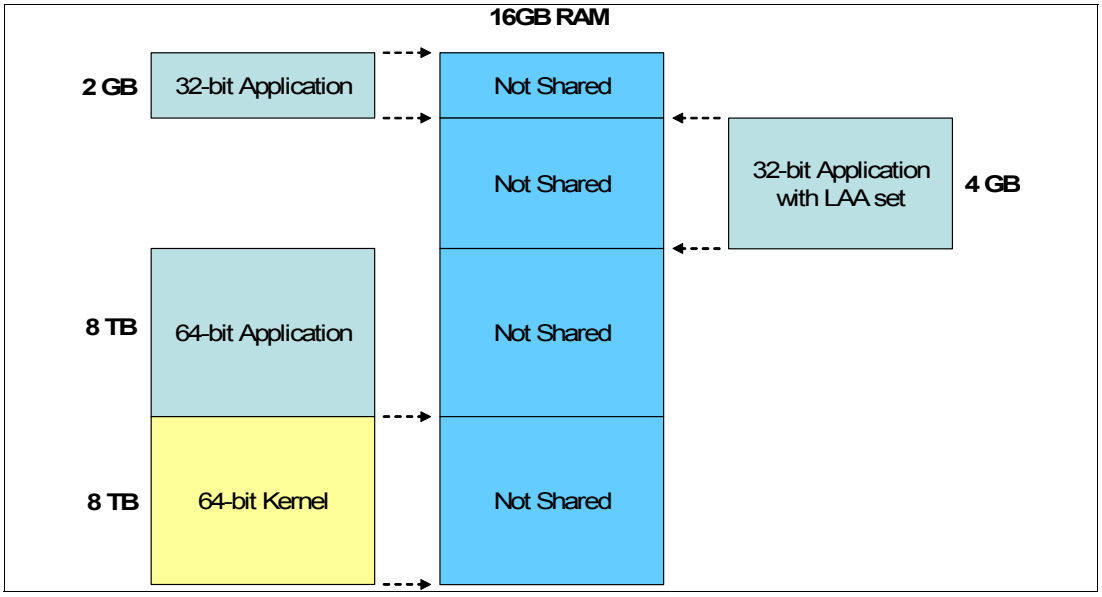

Figure 4-2 Windows 64-bit virtual address space

Large address aware 32-bit applications

32-bit applications need to be Large Address Aware (LAA) to use 4GB of virtual memory instead of the usual 2 GB on a 64-bit operating system. Large Address Aware applications include Microsoft Exchange, SQL Server and Oracle. This flag is set in the program's executable and indicates to the operating system to allocate more than 2 GB of RAM for that process.

You can use a program such as dumpbin.exe, which is included in Microsoft Visual Studio®, to test whether a program can use the additional virtual address space using the following example:

```
dumpbin /headers testprogram.exe
```

If an application can support more than 2 GB of virtual memory, dumpbin.exe displays:

```
Application can handle large (2>GB) addresses
```

You can use programs such as editbit.exe (also included in Visual Studio) to change the LAA flag so that it can access more than 2 GB of virtual RAM on your 64-bit server. You need to test the application in this mode, however, to ensure it is functioning correctly. For more information about LAA, see:

http://www.amd.com/us-en/assets/content_type/DownloadableAssets/Expand_Memory_of_32-bit_App_-_Microsoft_4GT-_6204.pdf

The end of older memory tuning techniques

The increased flat memory model of Windows Server 2003, x64 Edition allows means that older memory turning options such as /4GT (equivalent is /3GB in Windows 2000) and Physical Address Extensions (/PAE) are not longer required.

Note: For more information about the BOOT.INI switches (/PAE and /3GB) that are used in Windows 32-bit operating systems, refer to the IBM Redbook, *Tuning IBM@server xSeries Servers for Performance*, SG24-5827

4.2.3 Processor and memory limits

Windows Server 2003, x64 Edition supports a significant amount of physical RAM. The numbers of processors that are supported has also increased in the Windows Server 2003, Datacenter Edition. The amount of physical RAM that is supported for the Enterprise and Datacenter additions is substantially greater than the amount of RAM that can be installed in servers today. Table 4-3 illustrates the differences between the 32-bit and 64-bit operating systems.

Table 4-3 Physical memory and processor limits

Operating system	32-bit	64-bit (x64)
Windows Server 2003, Standard Edition	4 GB / 4-way	32 GB / 4-way
Windows Server 2003, Enterprise Edition	32 GB / 8-way	1 TB / 8-way
Windows Server 2003, Datacenter Edition	64 GB / 32-way	1 TB / 64-way

Windows also supports dual-core processors that have two physical processor cores on a single chip. Microsoft's licensing policy is based on the number of processors (that is, the number of sockets) and not the number of cores.

Intel's Hyper-Threading Technology allows a single physical processor to execute multiple threads (instruction streams), making it appear to the operating system as two processors for each physical processor installed. Microsoft's licensing is based on physical processors.

Therefore, if an IBM x366 is fitted with four dual core Xeon processors and Hyper-Threading Technology enabled, a license of Windows Server 2003, Standard Edition is sufficient even though the system contains eight processor cores and the Windows operating system sees 16 logical processors.

4.2.4 Virtual memory limits

More importantly for developers and application vendors, the *virtual* memory limits are increased significantly in all versions of Windows Server 2003, x64 Edition. Table 4-4 illustrates the differences between the 32-bit and 64-bit operating systems.

Table 4-4 Virtual memory limits

Description	32-bit	64-bit (x64)
Total virtual address space	4 GB	16 TB
Virtual address space per 32-bit application	2 GB (Note 1)	2 GB (Note 2)
Virtual address space per 64-bit process	Not applicable	8 TB
Virtual address space for the operating system kernel	2 GB (Note 1)	8 TB
Paged pool	470 MB	128 GB
Non-paged pool	256 MB	128 GB
System cache	1 GB	1 TB
Notes: 1. 3 GB for the application and 1 GB for the kernel if system booted with `/3GB` switch 2. 4 GB if the 32-bit application has the LARGEADDRESSAWARE flag set (LAA). See "Large address aware 32-bit applications" on page 47 for details.		

4.2.5 32-bit and 64-bit application support

Windows Server 2003, x64 Edition provides an easy path to 64-bit computing by allowing both 32-bit and 64-bit applications to run in parallel on the same operating system. This parallelism is achieved by the server operating in one of three modes, as outlined in Figure 4-3.

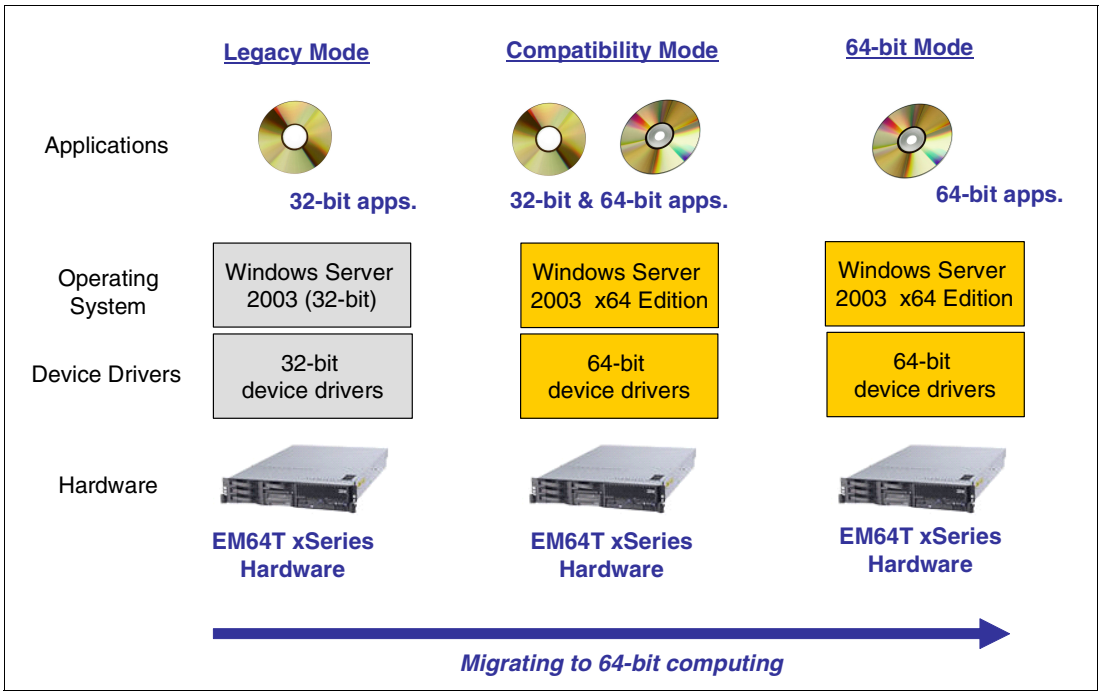

Figure 4-3 Processor operating modes

Legacy mode

The first mode is where existing 32-bit server operating systems such as Windows Server 2003 are installed on the new Intel EM64T or AMD64 server hardware. As far as the operating system and applications are concerned, they are operating on a standard 32-bit processor. The operating system allocates 2 GB of virtual memory for the kernel and 2 GB for applications. Even in this mode, Intel tests have determine performance improvements between 10% to 40% by only replacing the underlying hardware infrastructure with new to Xeon EM64T systems.

Compatibility mode

The second mode supported by the AMD64 and EM64T is compatibility mode, which is an intermediate mode of the full 64-bit mode described below. In compatibility mode, the server is running Windows Server 2003, x64 Edition. (As previously discussed, Windows Server 2003 for 64-bit Itanium-based systems is not compatible with an EM64T/AMD64 processor architecture and therefore cannot be installed.) 64-bit drivers are required for all peripherals and is discussed in 4.2.6, “64-bit drivers” on page 51.

Both 32-bit and 64-bit applications run side-by-side on the same operating system. 32-bit application support is provided by the Windows on Windows64 (WOW64) emulator as shown in Figure 4-4.

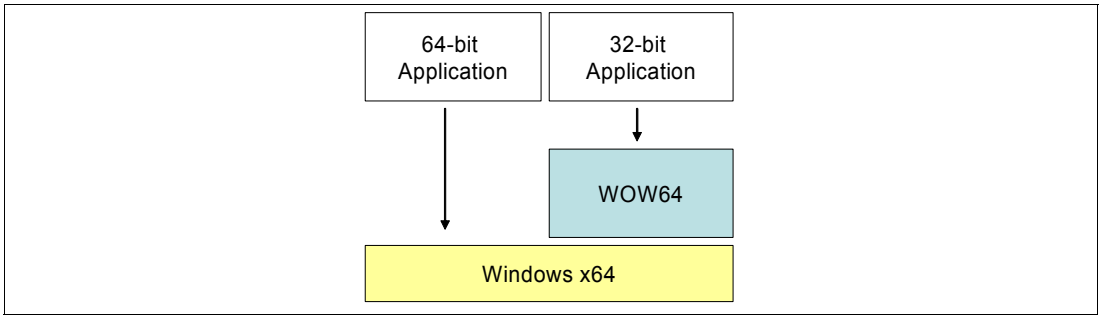

Figure 4-4 WOW64 architecture on Windows Server 2003, x64 Edition

WOW64 consists of three user mode DLLs, two of which are used on the x64 platform to execute x86-32 instructions at full processor clock speed. Microsoft advises that execution performance under WOW64 is similar to a 32-bit system. By comparison, on the Itanium platform, a third DLL, wow64cpu.dll, provides x86 instruction emulation which is results in 32-bit applications running slower than an equivalent 32-bit/EM64T/AMD platforms.

WOW64 transparently redirects 32-bit requests for the System32 directory to the %systemroot%\SysWOW64 directory, where 32-bit DLLs are stored. Although confusing, Windows 64-bit DLLs and system files are stored in %systemroot%\System32 directory.

Almost all 32-bit applications can be installed easily without modification and can run on Windows Server 2003, x64 Edition. This experience was reflected in industry reviews and the beta testing program of Windows XP Professional x64 and Windows Server 2003, x64 Edition. Application migration is discussed in further detail in Chapter 5, “Migration” on page 61.

You can identify easily in the Windows Task Manager which applications are 32-bit. These are designated with the **32* after the process name, as shown in Figure 4-5 on page 51, for the Microsoft Word 2003 executable, WINWORD.EXE.

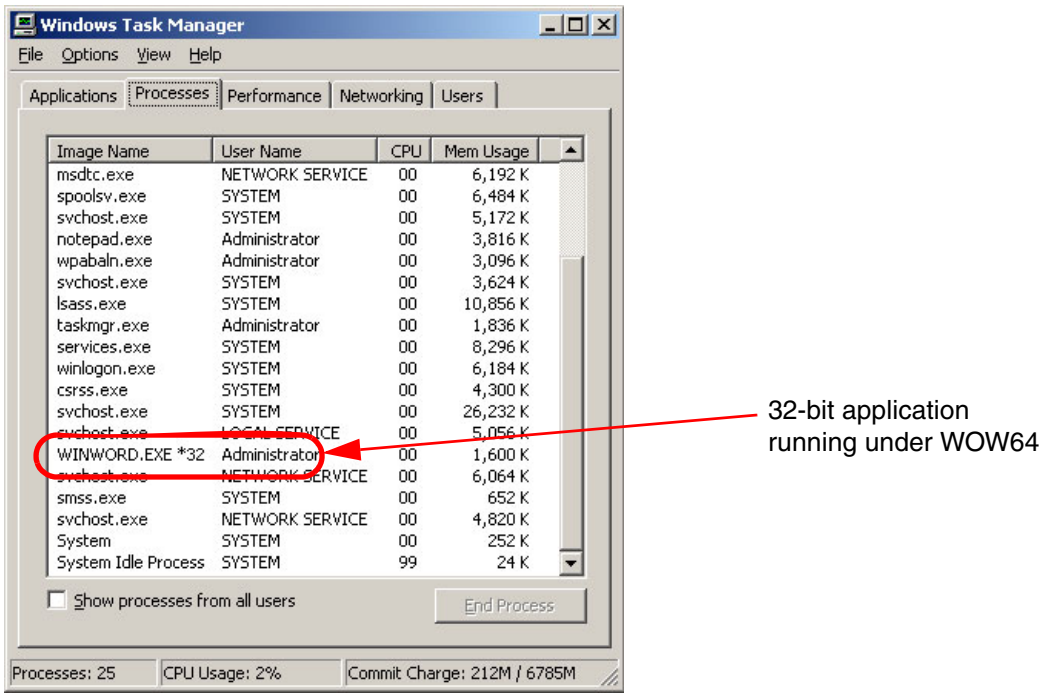

Figure 4-5 Task Manager showing 32-bit applications

64-bit mode

The final mode is the full 64-bit mode. AMD refer to this as *long mode* and Intel refer to it as *IA-32e mode*. This mode is when a 64-bit operating system and 64-bit application are used. In the full 64-bit operating mode, an application can have a virtual address space of up to 8 TB of addressable memory. The amount of physical memory is determined by how many DIMM slots the server has and the maximum DIMM capacity supported and available at the time. This mode is essentially the same as compatibility mode except that WOW64 is not invoked by any 32-bit applications.

64-bit applications also get access to the new general purpose registers (GPRs) as well as to the expanded GPRs. However it is important to understand that this mode of operation requires not only a 64-bit operating system (and of course 64-bit drivers) but also requires a 64-bit application that has been recompiled to take full advantage of the various enhancements of the 64-bit addressing architecture.

4.2.6 64-bit drivers

To install any version of Windows Server 2003, x64 Edition requires 64-bit drivers which are compatible with the operating system. 64-bit drivers available for the Itanium version of Windows are not compatible and cannot be installed. Likewise, 32-bit device drivers are also incompatible and cannot be installed. Windows Server 2003, x64 Edition comes included with a comprehensive list of 64-bit device drivers. If you are installing an xSeries server, you can download any additional 64-bit drivers as required from the following:

`http://www.pc.ibm.com/support`

For additional third-party 64-bit device drivers, review independent Web sites, such as:

`http://planetamd64.com`

To assist clients with installing the appropriate driver for the correct platform, Microsoft has changed the requirements for driver installation for Windows Server 2003, Service Pack 1 (SP1). When a driver is installed, Windows reads the INF file that is supplied with the driver binary for entries such in the Manufacturer and Models section names with .ntamd64 (for EM64T and AMD) or .ntia64 (for Itanium). The operating system can now provide a more informative message as to whether the driver is suitable for the operating system as shown in Figure 4-6.

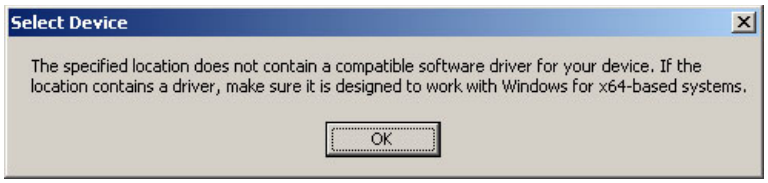

Figure 4-6 Installation error when trying to install a 64-bit driver for the wrong hardware platform

For more information about changes to INF requirements in Windows Server 2003, SP1, see:

`http://www.microsoft.com/whdc/driver/install/64INF_reqs.mspx`

4.2.7 Machine Check Architecture Support

Machine Check Architecture (MCA) is an open standard first developed by Intel for it's Pentium and Pentium Pro processors. It provides a mechanism for detecting and reporting hardware faults such as memory and bus errors. In previous versions of Windows, the operating system might simply halt (a blue screen error) if a critical MCA error is detected. Windows Server 2003, x64 Edition now provides improved reporting of these errors to the operating systems event log. In the future, MCA will allow the operating system to take action on specific events which would otherwise cause system downtime.

4.2.8 Features not supported

As discussed, all Windows Server operating systems are compiled from a single code base. However, the following features available in Windows Server 2003 32-bit version are not supported in Windows Server 2003, x64 Edition:

- Microsoft DOS
- 16-bit applications
- OS/2 subsystem
- Portable Operating System for UNIX (POSIX)
- A number of older transport protocols, such as AppleTalk and NETBEUI

Figure 4-7 shows an error that you get when trying to run a 16-bit application on Windows Server 2003, x64 Edition.

Figure 4-7 16-bit application run error on the x64 platform

Refer to Chapter 5, "Migration" on page 61 for a discussion on how this error can effect your application migration to a Windows Server 2003, x64 Edition platform.

4.3 Applications

Windows Server 2003, x64 Edition benefits enterprise applications which require large amounts of memory or perform intensive numeric calculations. As disk operations are typically thousands of times slower than memory accesses, by loading larger amounts of data into RAM overall system performance will increase.

This section reviews a selection of operating system applications and third-party applications and discusses how each can benefit from a 64-bit operating system. It also provides details about which applications have 64-bit versions available for the Windows Server 2003, x64 Edition platform.

For the current status of Windows software and their compatibility with different server operating systems, see the Windows Catalogue:

http://www.microsoft.com/windows/catalog/

AMD provides an excellent Web site with the status of products that are available for the Windows Server 2003, x64 Edition and other platforms. Select the appropriate software category on the right side of the browser window.

http://www.amd.com/us-en/Processors/ProductInformation/0,,30_118_8796_11869,00.html

Important: This section discusses the x64 status of products at the time of the writing of this Redpaper. Check the appropriate vendor to verify whether an x64 product has become available.

64-bit applications which are available on the Itanium platform, such as SQL Server 2000 (64-bit), are *not* compatible with the x64 platform. You must obtain Windows Server 2003, x64 Edition-compatible applications, which are typically called x64 versions.

4.3.1 Active Directory®

The Windows Server 2003, x64 Edition platform benefits large Active Directory databases. Because Active Directory is a database (Extensible Storage Engine that is based on the Jet database that is used by Exchange 5.5 and WINS), the 64-bit platform allows the database to run entirely in memory, particularly as the database grows beyond 3 GB. Microsoft testing during the beta program determined that throughput doubled for an Windows Server 2003, x64 Edition running Active Directory.

Microsoft uses 64-bit Domain Controllers (DC) and Global Catalogs (GC) primarily to improve directory access and to improve Exchange e-mail routing performance. At the time of the writing of this Redpaper, Microsoft's Active Directory contained approximately 110 000 computer accounts and 60 000 user accounts. The database was 9.5 GB in size. By migrating the DC function to a 64-bit platform, the number of 32-bit DCs can be consolidated to a few 64-bit servers. It is important that you keep two or more DCs at larger sites for disaster recovery purposes.

Microsoft suggests moving to a 64-bit Domain Controller when one or more of the following occurs:

- Scaling-out stops being effective
- You have Exchange 2000 or Exchange 2003 and e-mail queues are building up
- Your NTDS.DIT file on your DC is greater than 3 GB
- You need to deploy a DC for e-commerce purposes
- When you routinely perform a hardware upgrade which supports EM64T/AMD64

There is no functional level difference between a 32-bit DC or 64-bit DC. Both servers interact in the same way (such as forest/domain levels, replication, monitoring, and backup and restore). Therefore, an organization can easily introduce one or two 64-bit DCs into their Active Directory without any schema changes.

Table 4-5 Active Directory availability for Windows Server 2003, x64 Edition

Product	Windows x64 status	Other information
Active Directory	Available — included with operating system	http://www.microsoft.com/windowsserver2003/64bit/x64

4.3.2 Application servers

Applications servers vary greatly in their function and computing requirements. Large enterprise applications typically benefit by accessing significantly larger amounts of virtual memory. Microsoft testing during the beta program determined that Windows Server 2003, x64 Edition determined a 10% improvement in the SAP application server by migrating to the x64 platform. SAP are currently working on an x64 version at the time of writing. Over time, applications such as IBM WebSphere, BEA WebLogic, and Oracle Application Server are expected to see substantial performance gains on 64-bit platforms.

Table 4-6 Selected application server products for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
IBM WebSphere Application Server	Beta, available in Version 6.0.1	http://www.ibm.com/software/webservers/appserv/was/
SAP Web Application Server	Unknown at time of writing A Linux version is available	http://www.sap.com/ For SAP customers with appropriate access can check for the status of an SAP x64 version at: https://websmp205.sap-ag.de/pam
Microsoft .NET Framework	Beta	http://www.microsoft.com/net/
Oracle Application Server	No plans announced	http://www.oracle.com/appserver/

4.3.3 Database servers

Database servers such as IBM DB2®, Microsoft SQL and Oracle 10g also benefit significantly by moving to a 64-bit platform. Again, these applications take advantage of the 64-bit operating systems's increased virtual memory. Depending on the size, databases can be loaded entirely into memory to provide greater database scalability and performance.

Microsoft testing during the beta program determined that even 32-bit database performance improved by up to 17%. No 64-bit performance data was available at the time of the writing of this Redpaper.

Table 4-7 64-bit database products available for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
IBM DB2 UDB V8.2.2 (64-bit)	Beta	http://www.ibm.com/software/data/db2/udb/
Microsoft SQL Server 2005	Beta	http://www.microsoft.com/sql/2005
Oracle 10g	Beta	http://www.oracle.com/database

4.3.4 Developer applications

A variety of developer applications, such as compilers, debuggers, libraries, and Java applications, have products that are available for or are in beta for the Windows Server 2003, x64 Edition platform. These tools enable developers to develop and test existing applications and migrate them to a completely 64-bit code base. For more information about x64 developer tools, see the links under Development Tools on the right hand side of the following Web site:

http://www.amd.com/us-en/Processors/ProductInformation/0,,30_118_8796_11869,00.html

4.3.5 Electronic mail

Microsoft Exchange and Lotus Domino are key e-mail applications.

Microsoft Exchange

Exchange 2003 will not run on Windows Server 2003, x64 Edition because it installs 32-bit kernel mode drivers.

Microsoft Exchange benefits from as much RAM as possible. When Exchange starts the store process will reserve as much RAM as possible for itself. It returns this RAM to the operating system using an algorithm known as Dynamic Buffer Allocation. There are number of tuning options for Exchange when the server is installed with more than 1 GB of physical memory.

In 2006, Microsoft plans to ship the next major release of Exchange which will ship with a 32-bit and 64-bit (x64) version. The 64-bit version will be able to take advantage of the larger virtual memory provided with a 64-bit operating system. This is expected to improve the scalability Microsoft Exchange. No performance figures were available at the time of writing.

Lotus Domino

The memory model has been redesigned in Domino 6.5, and this has meant a 30% reduction in memory requirements per user over previous versions. Lotus Domino is reasonably frugal in memory use and requires approximately 200 KB of RAM for each active user session. A guideline to determine the minimum memory requirements for Lotus Domino are:

128 MB + (number of concurrent users/5) MB

This algorithm is appropriate for mail and application servers and mail hubs. However, it is not appropriate for replication hubs. Usually, replication hubs are heavily used but have few, if any, sessions open to active users.

Lotus Domino is a 32-bit application which is not Large Address Aware (LAA). It can therefore only access 2 GB of RAM, regardless of whether it is running on a Windows 32-bit or Windows Server 2003, x64 Edition. Domino has to be specifically modified by Lotus to use more than 2 GB of virtual RAM. Internal testing by Lotus has determined that increasing the amount of virtual memory for Domino does not provide any performance or scalability benefits.

Domino running on Windows Server 2003, x64 Edition may however benefit by scalability improvements in the underlying operating system itself. For example, the Kernel Page Pool allocates 1 KB for each file that is open on a server. Domino maintains a database cache to improve performance by keeping recently used files open for quicker access. Therefore, the more open databases, the larger the operating systems Page Pool size.

Page Pool limits have been dramatically increased in Windows Server 2003, x64 Edition. This increase, in theory, allows Domino to have a much large cache and thereby improves performance. At the time of the writing of this Redpaper, however, Domino was not supported on Windows Server 2003, x64 Edition and no performance figures were available.

If additional capacity is required, Lotus recommends you run additional Domino partitions on the one physical server. Each partition will each be allocated it's own separate 2 GB of virtual memory.

There are no immediate plans by Lotus to produce an x64 version of Lotus Domino.

Table 4-8 Exchange and Domino 64-bit version status for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
Microsoft Exchange	Planned 2006	http://www.microsoft.com/exchange
Lotus Domino	No plans announced	http://www.ibm.com/lotus/domino

4.3.6 File and print, and Web services

Windows Server 2003, x64 Edition provides a stable and easily manageable File and Print server. Improvements and optimizations in the operating system code base, flat memory model and the ability to cache larger numbers of files allows it to support a greater numbers of users than the 32-bit editions. Microsoft testing during the beta programme determined that Windows Server 2003, x64 Edition could support a 111% higher user capacity and a maximum network capacity of 7 GB per second. This increase capacity allows organizations to consolidate the numbers of File and Print servers without sacrificing performance.

The improved network capacity assists Web Services such as Internet Information Server (IIS), which is included in the server operating system.

Table 4-9 64-bit File and Print, Web Services availability for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
File and print, IIS 6.0	Available — included with operating system	http://www.microsoft.com/windowsserver2003/64bit/x64

4.3.7 Management tools

It is expected that the majority of Windows management and infrastructure tools can be successfully deployed as 32-bit applications on 64-bit Windows. In general, the capacity limits provided in the Windows Server 2003, x64 Edition are not as important for management products. Applications which include any kernel mode drivers will be the first to require x64 products to operate on Windows Server 2003, x64 Edition.

At the time of the writing of this Redpaper, only a handful of 64-bit management tools were available for Windows Server 2003, x64 Edition.

Table 4-10 Selected 64-bit management tools for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
IBM Tivoli® Enterprise™ Console	No plans announced	http://www.ibm.com/software/tivoli
Microsoft Systems Management Server (SMS)	Available to support x64 and IA64 hosts with SMS 2003 SP1	http://www.microsoft.com/smserver/
CA Unicenter	No plans announced	http://www.ca.com/unicenter
IBM Director	Agent planned for Director v5.1	See 3.3.4, “IBM Director” on page 41.

4.3.8 Network security

Network Security products operate reasonably efficiently on a 32-bit platform and will benefit less from a 64-bit operating system. However, new versions which are compatible with Windows Server 2003, x64 Edition are important to allow organizations to migrate to these new platforms. Applications which include kernel mode drivers will need to be upgraded to those applications which provide 64-bit drivers.

At the time of the writing of this Redpaper, some vendors, such as McAfee, had already produced a 64-bit version for Windows Server 2003, x64 Edition.

Table 4-11 Selected 64-bit antivirus products for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
McAfee VirusScan Enterprise	Available	http://nai.com/us/about/press/mcafee_enterprise/2003/20030923_105417.htm
Symantec (Norton) Antivirus	No plans announced	http://service1.symantec.com/SUPPORT/nav.nsf/pfdocs/2001051413133206
eTrust Antivirus 7.1	Beta	http://www.ca.com/antivirus

4.3.9 Terminal Services and Citrix MetaFrame

Windows Server 2003, Terminal Services provides organizations the ability to deploy applications using thin-client technology. Using Citrix MetaFrame Presentation Server, these Terminal Servers can be grouped together in what is typically called a *server farm*. Server farms can be used to deploy a single Windows desktop or applications to thousands of users. Increasing capacity in a Citrix MetaFrame farm is typically through a “scale out” methodology by simply installing extra additional servers. For very large thin-client environments, this may consist of hundreds of MetaFrame servers.

Significant changes were made to Windows Server 2003 to reduce the likelihood of kernel memory limits are reached. However, the scalability of Terminal Services in 32-bit systems can occur through a lack of kernel virtual memory rather than processor scalability. As all applications must share the same 2 GB kernel address space this resource can run out of resources such as Paged Pool and System Page Table Entries. Adding additional physical RAM does not make this available for the kernel, which is still limited to 2 GB of virtual RAM. While some memory tuning techniques such as /4GT can be used to provide additional RAM for applications, this actually reduces the amount of RAM for the kernel.

As outlined in 4.2.4, “Virtual memory limits” on page 48, Windows Server 2003, x64 Edition dramatically increases the various kernel limits. This removes any existing kernel restrictions, which allows a greater number of Terminal Server users. Microsoft testing during the beta program determined that Windows Server 2003, x64 Edition determined a 50% increase in the number of Terminal Server users.

By providing a greater scale up capacity with a 64-bit Terminal Services, customers can begin to consider using larger 4-way (such as the IBM HS40 Blade) and possibly larger 8-way processor servers. This allows organizations to reduce the number of Terminal Servers in the environment without having to rewrite the 32-bit client applications.

DOS, 16-bit and 32-bit applications

Infrastructure specialists need to be aware that DOS and 16-bit applications will not run on Windows Server 2003, x64 Edition. Therefore, if these applications are still required and are published via a Terminal Server, they need to remain on existing Windows Server 2003 (32-bit) Terminal Servers.

32-bit applications can operate on a Terminal Server in application mode via the WOW64. WOW64 adds significant virtual memory overhead if two or more instances of the same 32-bit application are run concurrently. Read-only memory pages are not shared between 32-bit processes as they are on a 32-bit platform. Therefore, this may adversely effect the scalability of many 32-bit applications on a 64-bit Terminal Server. Ensure that you perform adequate performance testing to determine if this is an issue in your environment.

Citrix MetaFrame Presentation Server x64

At the time of the writing of this Redpaper, Citrix was currently planning to release a version of MetaFrame Presentation Server to run on Windows Server 2003, x64 Edition shortly after the operating system release. Presentation Server supports both 32-bit and 64-bit applications.

Table 4-12 64-bit Terminal Services for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
Terminal Services	Available — included with operating system	http://www.microsoft.com/windowsserver2003/64bit/x64
Citrix MetaFrame Presentation Server	Beta	http://www.citrix.com/

4.3.10 Virtual computing

Virtual machine products such as VMware GSX Server, VMware Workstation, and Microsoft Virtual Server 2005 benefit from the increased virtual memory available in Windows Server 2003, x64 Edition. This is expected to allow physical servers to host greater numbers of virtual machines without the need for operating tuning techniques such as the /PAE option.

Microsoft expects that the final 64-bit version of Microsoft Virtual Server will provide clients the following benefits:

- Increased performance and scalability
- 64-bit host server support (x64)
- Support for Multi Processor Guest OS
- Better VM scaling across all host servers
- More than 3.6 GB of memory per VM

In the future, it is expected that products from VMware and Microsoft will support both 32-bit and 64-bit hosts running on the same physical server. This support allows organizations to continue to run existing 32-bit hosts on 64-bit hardware.

On users workstations, this capability can be particularly useful in running existing DOS/16-bit applications that are not supported in the new 64-bit operating systems. These applications can be run on a 32-bit virtual machine using products such as VMware Workstation.

Table 4-13 Virtual machine product status for Windows Server 2003, x64 Edition

Product	Windows x64 Status	Other information
VMware GSX Server	Version 3.1 in beta	http://www.vmware.com/news/releases/64bit_support.html http://www.vmware.com/products/server/gsx_features.html
VMware ESX Server (doesn't require Windows Server x64)	Support for x64 as a client planned late 2005	http://www.vmware.com/products/server/esx_features.html
Microsoft Virtual Server 2005	Due in Virtual Server 2005 SP1	http://www.microsoft.com/windowsserversystem/virtualserver

5

Migration

The combination of EM64T/AMD64-based xSeries servers and Windows Server 2003, x64 Edition provides organizations with the option of doing a three-step migration process to 64-bit computing from an all-32-bit installation:

1. Replace your existing server with an xSeries server with Xeon EM64T processors. Maintain all existing 32-bit applications and Windows operating system.
2. Replace the operating system with Windows Server 2003, x64 Edition, reinstalling the existing 32-bit applications. This operating system will run both 32-bit and 64-bit Windows applications running concurrently on the same server
3. Upgrade the applications as required to 64-bit versions, one at a time.

Even with this staged approach, it is perhaps more realistic that enterprise customers (who are most likely to perform this migration in the immediate future) will prefer to combine all three steps into one by creating a new all-64-bit installation and completely cutting over to it.

This chapter describes how to develop a 64-bit migration strategy for your organization. It looks at identifying 64-bit candidates, determining what hardware and software is required, and developing an appropriate migration strategy. It illustrates a number of migration scenarios to show how you can implement a 64-bit infrastructure in your organization. It also includes a 64-bit migration checklist.

5.1 When to upgrade to Windows Server 2003, x64 Edition

As technologies come and go, businesses continually need to assess how they can be applied in their organization. As with previous migrations to 32-bit computing, you need to determine what the benefit is to your organization by migrating your servers and applications to 64-bit. Start by answering questions such as “Will Windows Server 2003, x64 Edition provide your business the ability to support larger numbers of clients, reduce database server response times, or reduce operational costs by consolidating the number of terminal servers?” Then, you can plan and execute a migration to Windows Server 2003, x64 Edition.

5.2 Identifying 64-bit application candidates

Begin your 64-bit migration strategy by creating an inventory of your existing server applications. You might already have an existing inventory or technical architecture that you can use. From this inventory, determine which applications will benefit the most from a 64-bit platform. These are the applications that need to access large amounts of memory or to perform large number calculations. As discussed in 4.3, “Applications” on page 53, the applications which will benefit most from the 64-bit platform are:

- Large database servers
- Organizations with very large Active Directory or Exchange implementations
- Large Terminal Server environments
- Virtual computing systems that are running VMware products or Microsoft Virtual Server
- Application servers that are running SAP R/3, WebSphere, Microsoft .NET Framework and Oracle Application Server
- Large file and print environments

You might use tools such the Windows Server 2003 Performance console (or equivalents in earlier versions) to measure the load on existing Windows servers. The data from the Performance console can confirm whether existing systems have critical processor or memory bottlenecks. These bottlenecks might be resolved by tuning the existing operating system or application, or even upgrading the existing application, operating system or server. This can be the first step before ultimately upgrading these applications to 64-bit versions.

Tip: Even 32-bit applications can benefit from running on a 64-bit server and 64-bit Windows, depending on the application.

From the current server performance data, your application and infrastructure specialists can make a technical assessment as to whether an application will benefit from a 64-bit operating system.

5.3 Determining the hardware and software that is required

When you have identified suitable 64-bit application candidates, assess the existing hardware to determine if it supports Windows Server 2003, x64 Edition. In most cases, unless the server has been purchased recently, it will need to be replaced with servers which have either Intel's Xeon processor with Intel Extended Memory 64 Technology (Intel EM64T) or AMD Opteron processors. Table 3-1 on page 28 lists the IBM xSeries servers which are 64-bit capable.

The appropriate server operating system must also be determined. As outlined in 4.2.3, "Processor and memory limits" on page 47, there are three versions of Windows Server 2003, x64 Edition. Choose the appropriate version that will support your expected hardware capacity (both number of processors and RAM) and any specific operating system features you require.

As described in 4.2.6, "64-bit drivers" on page 51, all server peripherals also need 64-bit drivers which are compatible with Windows Server 2003, x64 Edition.

5.4 Migration strategies

Migrating to a 64-bit platform does not require a complete refresh of your entire infrastructure. Migrating to a completely 64-bit environment is expected to take several years for most organizations. When creating your 64-bit migration strategy consider not only of the technical components of the migration, but more importantly what people will execute the migration and what the migration schedule will be. The move to a 64-bit environment should not require a large retraining exercise. Windows Server 2003, x64 Edition has an identical user interface and operation to its 32-bit counterpart. The differences between the two have been outlined in this Redpaper.

The following sections discuss several Windows Server 2003, x64 Edition migration scenarios. Note that these are examples only. You should consider the specifics of your own environment when implementing Windows Server 2003, x64 Edition.

Active Directory and electronic mail

A worldwide organization with over 100 000 employees has standardized on Windows Server 2003 and Exchange Server 2003. To increase Active Directory capacity, their IT group has determined that as part of its 64-bit strategy, they will implement 64-bit Active Directory domain controllers (DCs). These DCs will be deployed at each of their data centers in New York, London, and Sydney. The DCs will also take on the role of Global Catalog (GC) servers in most cases.

By migrating the DCs to Windows Server 2003, x64 Edition, the entire organization's Active Directory can be loaded into each server's memory and, therefore, increase directory performance. As Exchange relies on Active Directory, directory performance assists Exchange's e-mail routing performance. Over time, the organization plans to also consolidate their Exchange environment to the Windows Server 2003, x64 Edition platform when the Exchange 64-bit version is released.

The organization is able to install the 64-bit DCs into their Active Directory without any schema changes. The migration schedule occurs on a site-by-site basis without any system downtime. Older domain controllers will be decommissioned after the new 64-bit DCs have become operational.

Application servers

A manufacturing business located in North America uses SAP R/3 for production and materials management, quality management and plant maintenance. The company also uses WebSphere Commerce as their online store, allowing customers to place orders for their products via the Internet, provide online invoicing and delivery tracking. WebSphere InterChange Server from IBM is used to exchange data between WebSphere Commerce and SAP R/3. Both SAP R/3 and WebSphere commerce suite run on Microsoft Windows Server 2003.

To provide further capacity without scaling out the solution (that is, adding more servers), the business has decided to migrate the existing platform to 64-bit over time. The strategy consists of the following migration phases:

1. Upgrade components to 64-bit in the development and test environments using new xSeries hardware and Windows Server 2003, x64 Edition.
2. Upgrade the production hardware to latest xSeries servers which use EM64T processors, but use existing 32-bit operating systems and applications.
3. Upgrade selected components of the infrastructure to Windows Server 2003, x64 Edition. The applications will remain as 32-bit applications.
4. Upgrade selected applications to 64-bit versions when they become available in stages to minimize change and to ensure overall system availability.

Database servers

A division of a European-based chemical company uses Microsoft SQL Server 2000 as its database system. The database server is used for their own in-house developed stock management system. The IT department has deployed a SQL Server 2000 cluster on two xSeries 365 servers running Windows Server 2003, Enterprise Edition connected to an TotalStorage® DS4400 Storage Area Network. The current system has sufficient capacity for it's current user population, but is expected to require extra capacity within the next two years.

To meet this expected increase load, the IT department has chosen a 64-bit strategy for their SQL Server database servers by implementing a new Microsoft SQL Server cluster that runs on xSeries 366 hardware and Windows Server 2003, x64 Edition. This provides additional virtual memory for the existing 32-bit database server. The new infrastructure will be built in parallel to the existing production system, allowing sufficient time for installation, testing, and migration. Depending on the availability of the 64-bit edition of Microsoft SQL Server 2005, the new release of SQL Server might be used in place of the current 32-bit edition, which reduces the need for an additional upgrade and provides the full benefits of a 64-bit operating system and 64-bit application sooner.

Terminal Services

An organization would like to consolidate their large Citrix MetaFrame terminal server farm consisting of over 200 servers across five locations. The majority of terminal servers operate on dual processor servers using IBM HS20 blades and xSeries 335 servers.

Through the use of Windows Server 2003, x64 Edition and the x64 release of Citrix MetaFrame Presentation Server the organization plans to support greater numbers of users on the latest IBM HS20 blades which feature Xeon EM64T processors. In the future, further consolidation is expected by using 4-way processor blades with EM64T capability.

The migration to Windows Server 2003, x64 Edition with Terminal Services and Citrix MetaFrame will occur gradually as additional capacity is required and older equipment is retired. 64-bit servers will be members of the Citrix MetaFrame farm and coexist alongside equivalent 32-bit servers. Because the new 64-bit terminal servers cannot support 16-bit and

DOS applications, the organization plans to leave these applications on existing 32-bit terminal servers. These older applications will be migrated to 32-bit or 64-bit versions by the time the entire farm has been migrated to 64-bit.

Virtual computing

A banking organization has implemented VMware GSX Server to provide a virtual server development and testing platform. GSX Server provides the organization with a number of benefits:

- Minimizes the use of server hardware by running a number of virtual machines (VM) on one physical server.
- Rapidly creates new VM development and test servers.
- Uses VMs from the GSX server on developers workstations using VMware workstation.

The organization will use VMware technology to assist in its migration to a 64-bit platform. The next release of VMware GSX will support Windows Server 2003, x64 Edition hosts, allowing GSX to take advantage of the increased virtual memory that is available on these platforms. Future upgrades of GSX will allow both 32-bit and 64-bit virtual machines. The organization will then use GSX to test their migration procedures to the new 64-bit platform in a virtual environment.

5.5 Migration testing

Both 32-bit and 64-bit applications should be thoroughly tested on Windows Server 2003, x64 Edition to ensure they are operating efficiently and without error. At the time of the writing of this Redpaper, AMD expected that over 99% of 32-bit applications will work without any issue on Windows Server 2003, x64 Edition. The remaining 1% of issues are typically from installation failures due to 16-bit installation programs or incorrectly detecting the servers operating system version.

We recommend that you consider the use of a virtual development and testing environment using products such as GSX Server or ESX Server, or Microsoft Virtual Server when 64-bit versions become available. These virtual platforms will allow you to run both 32-bit and 64-bit virtual machines on the one 64-bit host. Alternatively, you could use BladeCenter technology which allows you to install a number of 2-way and 4-way servers in a single chassis. The BladeCenter HS20 server supports Windows Server 2003, x64 Edition.

5.6 Migration to Windows Server 2003, x64 Edition

Windows Server 2003, x64 Edition requires a fresh installation. Therefore, existing EM64T/AMD64 capable servers running Windows Server 32-bit versions cannot be upgraded in place. We recommend that you migrate your 32-bit applications to new server hardware to allow the new infrastructure to be installed and tested without any change to the existing production. If any critical issues are detected that cannot be resolved on the new server, the old server can be brought back online quickly.

The following is a migration checklist that you can use to assist with your migration to Windows Server 2003, x64 Edition:

- Which applications in your organization would benefit most from a 64-bit platform?
- Is there a capacity constraint with any of the existing 32-bit applications?
- Is any of your existing server hardware EM64T or AMD64 capable?

- If you are buying new hardware:
  - Is it EM64T or AMD64 capable?
  - What server model and components do you need (RAM, disk, and so forth)?
- For each server that is to be upgraded or purchased, do you have 64-bit device drivers for all server devices and peripherals (internal and external to the server)?
- (If required) Do you have 64-bit versions for all associated software such as anti-virus and remote access for your server?
- Is your application DOS or 16-bit? These are not supported on Windows Server 2003, x64 Edition and will need to be retired, ported, or upgraded to 32-bit or 64-bit versions or left in a 32-bit environment.
- Will the application run as a 32-bit application on x64? If so:
  - Have you undertaken any 32-bit application testing on the x64 platform?
  - Are their any incompatibilities with the application and the new Windows Server 2003, x64 Edition operating system?
- Is the application available as a 64-bit application?
  - Is it compatible with Windows Server 2003, x64 Edition and *not* Itanium?
  - Have you undertaken any 64-bit application testing on the x64 platform?
  - Are their any incompatibilities with the application and the new Windows Server 2003, x64 Edition operating system?

5.7 64-bit application migration for developers

Windows Server 2003, x64 Edition allows an organization to upgrade to 64-bit computing incrementally. The operating system can run both 32-bit and 64-bit applications on the same server, providing the flexibility to run both types of applications until they are eventually migrated to 64-bit versions. This section provides an introduction to application migration to 64-bit Windows, the issues that you might face, and the tools that you can use.

5.7.1 The Win32® API

In the past, when application developers began the migration of applications from 16-bit to 32-bit versions, the migration effort was complicated somewhat by the variations of the Win32 APIs at the time. Microsoft referred to the older 16-bit API as Win16. Win32 API had three main implementations: one for Windows NT (Win32), one called Win32s® (which was a subset of Win32 which could be used on Windows 3.1 systems), and one for Windows 95. Windows NT is the basis of what Windows Server 2003 is today.

The good news is that migrating your 32-bit applications to 64-bit is expected to require far less effort than migrating to Win32. The Win32 API in Windows Server 2003, x64 Edition remains the same as before. Only a few data types have been changed, to reflect certain items that grow to 64-bit data size.

Basic numeric data types, such `int` and `long`, remain 32-bit on a 64-bit Windows operating system. However, pointers become 64-bit long. New, 64-bit wide, numeric data types have been introduced to allow explicit use of 64-bit data types in calculations on 64-bit and on 32-bit.

5.7.2 Migrating your 32-bit applications to 64-bit

At the time of the writing of this Redpaper, a number of 64-bit developer tools are currently in beta. There is a wide variety of developer tools for the Windows platform. You can find a sample of 64-bit development tools and their 64-bit status at:

http://www.amd.com/us-en/Processors/ProductInformation/0,,30_118_8796_11869^11876,00.html

Development tools such as Microsoft Visual Studio 2005 simplify the developer's 64-bit migration effort. Compiler options, such as the /Wp64 switch can check existing 32-bit code for portability problems and warn about any code which cannot be used on a 64-bit platform. Most applications should re-compile without any issues into 64-bit executables.

Polymorphic data types have been introduced to allow for source code compatibility. The whole purpose of the polymorphic types is that code is flexible. It compiles correctly for both 32-bit and 64-bit platforms. In most cases developers can use the same untouched source code tree and compile them for different platforms with only modifications to the make file providing correct paths to different versions of components and compiler parameters.

On Windows Server 2003, x64 Edition, a 32-bit and a 64-bit application can run simultaneously, however one application cannot mix 32-bit and 64-bit code in the same process. Each application must be pure 32-bit or 64-bit code. If your application is using external components such as OCX, libraries or DLLs, these also need to be pure 64-bit versions.

When you have confirmed that your applications run correctly as 64-bit versions, Visual Studio 2005 provides a number of code optimizations switches. These optimizations can be enabled to further enhance the performance of most applications, particularly applications that perform a large number of floating point calculations.

5.7.3 Device driver migration

With Windows Server 2003, x64 Edition, some code must be migrated to 64-bit versions. This includes kernel mode drivers. No 32-bit device drivers will work on the 64-bit platform. You must also ensure that the device driver's associated INF file includes the appropriate platform information to install correctly on Windows Server 2003, x64 Edition. For more information see 4.2.6, "64-bit drivers" on page 51.

5.7.4 Further information

For further information about migration your applications to 64-bit versions, refer to:

- Getting Ready for 64-bit Windows

  http://msdn.microsoft.com/library/default.asp?url=/library/en-us/win64/win64/getting_ready_for_64_bit_windows.asp?frame=true

- 64-bit Platform

  http://www.microsoft.com/whdc/system/platform/64bit/default.mspx

- Porting IA-32 Applications to the Xeon Processor's with EM64T

  http://www.intel.com/cd/ids/developer/asmo-na/eng/171850.htm?page=1

- AMD64 Developer Resource Kit

  http://www.amd.com/us-en/Processors/DevelopWithAMD/0,,30_2252_9044,00.html

Abbreviations and acronyms

ALUs	arithmetic logical units
API	application programming interface
APIC	Advanced Programmable Interrupt Controller
AWE	Address Windowing Extensions
CCA	Citrix Certified Administrator
CCNA	Cisco Certified Network Associate
CIM	common information model
CISC	Complex Instruction Set Computing
CNE	Certified Novell Engineer
DC	domain controller
DDR	double data rate
DIMM	dual inline memory module
DLL	dynamic link library
ECC	error checking and correcting
EFER	Extended Feature Enable
EPIC	Explicitly Parallel Instruction Computing
ESCON	Enterprise Systems Connection
ESE	Extensible Storage Engine
ETSI	European Telecommunications Standard Industry
EXA	Enterprise X-Architecture
FC	Fibre Channel
FICON	Fibre Connection
FPU	floating point unit
FSB	front-side bus
GC	global catalog
GPRs	general purpose registers
GUI	graphical user interface
HDD	hard disk drive
HT	Hyper-Threading
LAA	Large Address Aware
LAHF	Load Register AH From Flags
LAN	local area network
LV	low voltage
MCA	Machine Check Architecture
MCDBA	Microsoft Certified Database Administrator
MCSA	Microsoft Certified Systems Administrator
MCSE	Microsoft Certified Systems Engineer
MPEG	Motion Picture Experts Group
MSR	Machine Specific Registers
NEBS	network equipment building system
NX	no execute
OS	operating system
PAE	Physical Address Extension
PCI	Peripheral Component Interconnect
PSE	Page Size Extension
PSSU	Post-Setup Security Updates
PXE	Pre-boot-execution
RAID	redundant array of independent disks
RDM	Remote Deployment Manager
SAHF	Store AH Register into Flags
SCSI	Small Systems Computer Interface
SCW	Security Configuration Wizard
SIMD	Single Instruction Multiple Data
SMP	symmetric multiprocessing
SNMP	Simple Network Management Protocol
SQL	structured query language
SSE	Streaming SIMD Execution
TPF	Transaction Processing Facility
URL	Uniform Resource Locator
WINS	Windows Internet Naming Service
WOL	Wake on LAN
XD	execute disable

Related publications

The publications listed in this section are considered particularly suitable for a more detailed discussion of the topics covered in this Redpaper.

IBM Redbooks

For information about ordering these publications, see “How to get IBM Redbooks” on page 74. Note that some of the documents referenced here may be available in softcopy only.

- *Tuning IBM@server xSeries Servers for Performance*, SG24-5827
- *IBM@server xSeries 366 Technical Introduction*, REDP-4006

Online resources

The Web sites and URLs that are listed in this section are also relevant as further information sources.

xSeries Web pages

- ServerProven operating system support matrix

  http://www.pc.ibm.com/us/compat/nos/matrix.shtml

- Tips for xSeries servers and Windows Server 2003, x64 Edition

  http://www.pc.ibm.com/support?page=SERV-X64TIP

- Device drivers for the beta program for Windows Server 2003, x64 Edition

  http://www.pc.ibm.com/support?page=MIGR-57377

- ServerGuide

  http://www.pc.ibm.com/support?page=MIGR-4ZKPPT

- ServeRAID and HostRAID software matrix

  http://www.pc.ibm.com/support?page=MIGR-495PES

- UpdateXpress

  http://www.pc.ibm.com/support?page=MIGR-53046

- IBM Rack Configurator

  http://www.pc.ibm.com/support?page=BBOD-3MDQFF

- xSeries and BladeCenter product pages

  http://www.ibm.com/eserver/xseries/x226.html
  http://www.ibm.com/eserver/xseries/x236.html
  http://www.ibm.com/eserver/xseries/x306.html
  http://www.ibm.com/eserver/xseries/x336.html
  http://www.ibm.com/eserver/xseries/x206.html
  http://www.ibm.com/eserver/xseries/x346.html
  http://www.ibm.com/eserver/xseries/x366
  http://www.ibm.com/eserver/opteron/325
  http://www.ibm.com/eserver/bladecenter

- xSeries literature - brochures, papers, datasheets, guides

  http://www.ibm.com/servers/eserver/xseries/literature
- xRef — one-page summaries of the technical specs of xSeries servers

  http://www.ibm.com/servers/eserver/education/cust/xseries/xref.html
- xSeries systems management

  http://www.ibm.com/servers/eserver/xseries/systems_management/xseries_sm.html
- xSeries configuration tools

  http://www.pc.ibm.com/us/eserver/xseries/library/configtools.html

IBM software

- DB2 Universal Database™

  http://www.ibm.com/software/data/db2/udb
- WebSphere Application Server

  http://www.ibm.com/software/webservers/appserv/was
- Lotus Domino

  http://www.ibm.com/lotus/domino
- Tivoli

  http://www.ibm.com/software/tivoli

Microsoft Web pages

- Windows Server 2003, x64 Edition home page

  http://www.microsoft.com/windowsserver2003/64bit/x64
- Features Not Supported in Windows XP 64-Bit Edition

  http://www.microsoft.com/resources/documentation/Windows/XP/all/reskit/en-us/prka_fea_tfiu.asp
- SQL Server 2005

  http://www.microsoft.com/sql/2005
- INF Requirements for 64-bit Systems

  http://www.microsoft.com/whdc/driver/install/64INF_reqs.mspx
- Windows Catalog

  http://www.microsoft.com/windows/catalog
- Microsoft Exchange

  http://www.microsoft.com/exchange
- Microsoft .NET

  http://www.microsoft.com/net
- Microsoft SMS

  http://www.microsoft.com/smserver
- Microsoft Virtual Server

  http://www.microsoft.com/windowsserversystem/virtualserver
- Platform design — 64-bit

  http://www.microsoft.com/whdc/system/platform/64bit

- Getting Ready for 64-bit Windows

  http://msdn.microsoft.com/library/default.asp?url=/library/en-us/win64/win64/getting_ready_for_64_bit_windows.asp?frame=true

AMD Web pages

- Porting to AMD64 — frequently asked questions

  http://www.amd.com/us-en/assets/content_type/DownloadableAssets/AMD64_Porting_FAQ.pdf

- Expand the memory of your 32-but application using Microsoft's 4GT

  http://www.amd.com/us-en/assets/content_type/DownloadableAssets/Expand_Memory_of_32-bit_App_-_Microsoft_4GT-_6204.pdf

- The AMD64 Ecosystem: Software solutions and their availability

  http://www.amd.com/us-en/Processors/ProductInformation/0,,30_118_8796_11869,00.html

- AMD64 Developer Resource Kit

  http://www.amd.com/us-en/Processors/DevelopWithAMD/0,,30_2252_9044,00.html

- Development Tools - Compilers

  http://www.amd.com/us-en/Processors/ProductInformation/0,,30_118_8796_11869^11876,00.html

Intel Web pages

- Recent History of Intel Architecture — a refresher

  http://www.intel.com/cd/ids/developer/asmo-na/eng/44015.htm?page=5

- The Microarchitecture of the Intel Pentium 4 Processor on 90nm Technology — NetBurst Microarchitecture Overview

  http://www.intel.com/technology/itj/2004/volume08issue01/art01_microarchitecture/p03_netburst.htm

- Intel NetBurst Architecture Innovations

  http://www.intel.com/cd/ids/developer/asmo-na/eng/microprocessors/19933.htm?page=2

- Porting IA-32 Apps to the Xeon Processor's with EM64T

  http://www.intel.com/cd/ids/developer/asmo-na/eng/171850.htm?page=1

Other Web pages

- HyperTransport Consortium

  http://www.hypertransport.org

- Planet AMD

  http://planetamd64.com

- Oracle database

  http://www.oracle.com/database

- SAP R/3

  http://www.sap.com

- Citrix

  http://www.citrix.com

- Network Associates press release on 64-bit support for Anti-Virus

  http://nai.com/us/about/press/mcafee_enterprise/2003/20030923_105417.htm
- Norton Antivirus support

  http://service1.symantec.com/SUPPORT/nav.nsf/pfdocs/2001051413133206
- CA eTrust Antivirus

  http://www.ca.com/antivirus
- CA Unicenter

  http://www.ca.com/unicenter
- Oracle Application Server

  http://www.oracle.com/appserver
- VMware press release on 64-bit support for GSX Server and Workstation

  http://www.vmware.com/news/releases/64bit_support.html
- VMware ESX Server

  http://www.vmware.com/products/server/esx_features.html
- VMware GSX Server

  http://www.vmware.com/products/server/gsx_features.html

How to get IBM Redbooks

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IBM Global Services

ibm.com/services

Introducing Windows Server x64 on IBM @server xSeries Servers

Redpaper

Describes the new 64-bit operating system from Microsoft

Lists support for key server applications and xSeries tools

Provides migration information and scenarios

Until now the Intel-processor server marketplace has been largely a 32-bit arena. Certainly systems with Intel Itanium 2 and AMD Opteron processors running Windows (Itanium) or Linux offer 64-bit processing, but mainstream computing has remained 32-bit. With the release of Windows Server 2003, x64 Edition, this is likely to begin to change. This new operating system from Microsoft has the opportunity to convince customers that a smooth migration from 32-bit to 64-bit is possible and will provide benefits in terms of performance and scalability. This is especially the case with enterprise customers, where the current 4 GB direct memory addressability limitation of 32-bit is already having an impact.

This redpaper introduces Windows Server 2003, x64 Edition, the 64-bit processors from Intel and AMD that support it, and the xSeries servers it will run on. We describe what 64-bit computing means, and the technology behind the processors. We also introduce the xSeries product line that include the Intel EM64T processor. We also describe how the new Windows operating system is different from its 32-bit counterpart. And finally, we discuss the migration options available to customers and developers.

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