

Introducing Microsoft Windows Server 2003 x64 Editions for the Intel EM64T Platform

The launch of Microsoft® Windows Server™ 2003 x64 Editions marks a milestone toward the acceptance of 64-bit technology in mainstream computing. This 64-bit platform offers several enhanced features and advantages, including the opportunity for IT environments to investigate 64-bit technology without giving up 32-bit applications. This article provides an overview of Windows Server 2003 x64 Editions and their distinguishing features, and compares them with 32-bit Microsoft Windows® operating systems.

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Microsoft Windows Server 2003 x64 Editions—also referred to as x64—are designed for servers based on 64-bit extended architecture. This article addresses key features of the Intel® Extended Memory 64 Technology (EM64T)¹ architecture to help provide a better understanding of the behavior of Windows Server 2003 x64 Editions on this platform. Note that this OS does not support 64-bit Intel Itanium® processors; the Windows Server 2003 for 64-Bit Itanium-based Systems OS is designed for the Itanium platform. References in this article to 64-bit technology refer to EM64T and are not applicable to 64-bit Itanium-based hardware or Windows Server 2003 for 64-Bit Itanium-based Systems.

Compatibility with 32-bit applications

A key feature of the 64-bit extended architecture is the capability to run both 32-bit and 64-bit applications. Dell™

PowerEdge™ servers with Intel EM64T-capable processors² support this capability by using the different operating modes and sub-modes within the Intel EM64T architecture. Figure 1 shows the different operating modes of the 64-bit extended processor.

Long mode is the 64-bit mode of the 64-bit extended processor, and this mode supports x64. Legacy mode supports 32-bit x86-based operating systems such as 32-bit Windows Server 2003. When a Windows Server 2003 x64 Editions OS is booting up, the OS automatically³ switches from Legacy mode, which is the processor's initial mode, to Long mode.⁴ A 32-bit x86-based OS such as 32-bit Windows Server 2003 cannot switch the processor mode to Long mode—the processor will always be in Legacy mode for these operating systems.

Long mode has two sub-modes: Compatibility and 64-bit. Compatibility mode allows Windows Server 2003

¹ For more information about the hardware capabilities and features of Intel EM64T, visit www.intel.com/technology/64bitextensions.

² For more information about installing Windows Server 2003 x64 Editions on supported Dell PowerEdge servers, see "Deploying Microsoft Windows Server 2003 x64 Editions on Dell PowerEdge Servers" by Ranjith Purush and Sandhya Senapathi in *Dell Power Solutions*, May 2005.

³ NT Loader (Ntldr) performs the switching function. No special switches are required in the boot.ini file to accomplish this process. Unlike the Windows Server 2003 for 64-Bit Itanium-based Systems OS, Windows Server 2003 x64 Editions do not require a separate partition to store boot code.

⁴ Windows Server 2003 x64 Editions enable Long mode of an EM64T-capable processor by setting the Long Mode Active (LMA) control bit, which is bit 10 of the extended feature enable register (IA32_EFER).

x64 Editions to run existing 32-bit applications natively⁵ on a 64-bit processor without recompilation. The capability to run 32-bit applications natively on the 64-bit processor is a distinguishing feature of x64, and is possible because the x64 instruction set is an extension of the industry-standard x86 architecture. Applications running in

Processor operating modes and sub-modes		Required OS	Application recompilation required?	Default address size	Default data size	Register extensions allowed?
Long mode	64-bit mode	x64 OS	Yes	64-bit	32-bit	Yes (64-bit GPR*** width)
	Compatibility mode*		No**	32-bit	32-bit	No (32-bit GPR width)
Legacy mode		32-bit x86-based OS	No	32-bit	32-bit	No (32-bit GPR width)

*The EM64T-capable processors support 16-bit applications in Compatibility mode. However, Windows Server 2003 x64 Editions do not support 16-bit applications.
 **The 32-bit applications that are not recompiled to 64-bit will run on x64 in Compatibility mode.
 ***The 32-bit x86 architecture offers only eight 32-bit general-purpose registers (GPRs). Intel EM64T increases the number of GPRs to 16, and all GPRs in EM64T-capable processors are 64-bit.

Figure 1. Different operating modes of Intel EM64T-capable processors

	Legacy mode	Long mode	
		Compatibility mode	64-bit mode
Applications	32-bit	32-bit	64-bit
Drivers	32-bit	64-bit	64-bit
OS	32-bit	64-bit	64-bit
Flat address space	4 GB	4 GB	16 TB
General-purpose registers	32-bit	32-bit	64-bit

Figure 2. Applications, drivers, and operating systems supported in the different modes of Intel EM64T-capable processors

Windows OS edition*	32-bit		x64	
	Supported physical memory	Supported physical processors	Supported physical memory	Supported physical processors
Windows XP Professional**	4 GB	1–2	128 GB	1–2
Windows Server 2003, Standard Edition	4 GB	1–4	32 GB	1–4
Windows Server 2003, Enterprise Edition	32 GB/64 GB***	1–8	1 TB	1–8

* Microsoft offers four x64 editions: Windows XP Professional x64 Edition and the Standard, Enterprise, and Datacenter editions of Windows Server 2003 x64. At press time, Dell did not support Windows Server 2003, Datacenter x64 Edition.
 ** This article focuses on server operating systems and thus does not include Windows XP Professional. For more information about Windows XP Professional x64 Edition, visit www.microsoft.com/windowsxp/64bit/default.mspx.
 *** Memory support increased to 64 GB in 32-bit Windows Server 2003, Enterprise Edition, with Service Pack 1 (SP1).

Figure 3. Comparison of processor and memory support for 32-bit and x64 Windows operating systems

Compatibility mode use 32-bit data operands and 32-bit addressing that allow access only to the first 4 GB of virtual address space. However, as true 64-bit operating systems, Windows Server 2003 x64 Editions are designed to use 64 bits for all work—even while a 32-bit application is using only 32 bits. The 64-bit mode supports 64-bit applications.

The determination of whether the processor is in 64-bit mode or Compatibility mode is based on the currently executing code segment.⁶ In Windows Server 2003 x64 Editions, a 32-bit application⁷ will always be in Compatibility mode and a 64-bit application will always be in 64-bit mode. The x64 architecture and components are discussed in further detail later in this article.

Figure 2 shows the types of applications, drivers, and operating systems that are supported in the different modes of the x64-capable processor. Legacy mode preserves the binary compatibility with 32-bit applications and supports only the Legacy Protected mode, which is equivalent to an x86 32-bit protected-mode environment.

Extended memory support

The 64-bit OS significantly extends physical memory and memory allocation limits. Figures 3 and 4 summarize the memory support in Windows Server 2003 x64 Editions and compare it to 32-bit Windows operating systems. Note that x64 enables increased physical memory support—up to 32 GB for Standard x64 Edition and up to 1 TB for Enterprise x64 Edition.

Virtual memory comprises a large address space used by processes and applications. Some parts of the virtual memory space may be located in physical memory, while other parts of virtual memory may be located on storage media such as hard drives. Windows Server 2003 x64 Editions allow 64-bit processes and applications to use a

Memory limits	32-bit Windows Server	Windows Server 2003 x64 Editions
Total virtual address space	4 GB	16 TB
Virtual address space per 32-bit process	2 GB (3 GB with /3GB switch)	2 GB/4 GB
Virtual address space per 64-bit process	Not applicable	8 TB
Paged pool	470 MB (650 MB in Windows Server 2003 SP1)	128 GB
Non-paged pool	256 MB	128 GB
System cache	1 GB	1 TB

Figure 4. Comparison of memory allocation limits for 32-bit and x64 Windows operating systems

⁵ The 64-bit Itanium processors do not run 32-bit applications natively. Limited support for 32-bit applications on Itanium processors is made possible by the Windows Server 2003 for 64-Bit Itanium-based Systems OS—the processor has an x86 emulation mode through which Windows can execute x86 programs, albeit with a substantial performance penalty.

⁶ The processor switches modes based on the values of two bits (L and D) in the segment descriptor specified by the selector in the Code Segment (CS) register. The code segment of a 32-bit process is set to have L=0 and D=1, while a 64-bit process will set L=1 and D=0.

⁷ More specifically, a process cannot switch from 64-bit mode to Compatibility mode and vice versa. However, a process in one mode can launch a process in the other mode.

32-bit Windows OS on Dell PowerEdge server		Windows Server 2003 x64 Editions on Dell PowerEdge server	
DOS/16-bit applications (WOW32)	32-bit applications	32-bit applications (WOW64)	64-bit applications
Processor in Virtual mode	Processor in Protected mode	Processor in Compatibility mode	Processor in 64-bit mode
32-bit Windows OS and 32-bit drivers		Windows Server 2003 x64 Editions OS and 64-bit drivers	
Dell system BIOS		Dell system BIOS	
Legacy 32-bit Dell PowerEdge server or EM64T-based Dell PowerEdge server		EM64T-based Dell PowerEdge server	

Figure 5. Comparison of requirements for drivers and applications in 32-bit and x64 Windows operating systems

single contiguous memory space and access locations anywhere in the linear 64-bit address range.⁸ This capability allows the 64-bit OS to run memory-intensive applications, such as Microsoft SQL Server, more efficiently than the 32-bit OS. The 32-bit processes running on x64 may be allocated up to 2 GB of virtual address space, and administrators can increase this limit to 4 GB by compiling the 32-bit applications with the `/LARGEADDRESSAWARE` switch. Windows Server 2003 x64 Editions do not support the `/3GB` switch.⁹

Driver requirements for x64

Figure 5 summarizes the application and driver support requirements for Windows Server 2003 x64 Editions and shows the difference between an x64 OS and a 32-bit OS. A key distinction is that Windows Server 2003 x64 Editions require all drivers—including all device drivers—to be 64-bit drivers.¹⁰ All 32-bit kernel-mode drivers must be ported to 64-bit.¹¹ Because Windows Server 2003 x64 Editions are new, Microsoft has transformed certain best-practices recommendations for 32-bit operating systems into mandatory requirements for x64, as follows:

- **x64 device drivers:** All x64 device drivers should have x64-specific decorators in the driver `.inf` files. For more information, visit www.microsoft.com/whdc/device/storage/F6dirs.mspx and www.microsoft.com/whdc/driver/install/64INF_reqs.mspx.
- **Kernel-mode drivers:** Kernel-mode drivers cannot patch (extend or replace) kernel services by modifying system

service tables, modifying the Interrupt Descriptor Table (IDT) and Global Descriptor Table (GDT), and so forth. For more information on this requirement, visit www.microsoft.com/whdc/driver/kernel/64bitpatching.mspx.

The WOW64 subsystem: The replacement for WOW32

Another important distinction in Windows Server 2003 x64 Editions is the removal of the Virtual mode (Windows On Windows 32, or WOW32) that allows 16-bit application support on 32-bit systems. Because of this change, 16-bit applications or applications that have 16-bit components are not supported on x64. Attempting to run a 16-bit application on an x64 OS will generate an informational message that informs the user of the incompatibility. Because many mainstream 32-bit applications have 16-bit installer components, Microsoft has provided a work-around that allows x64 to support such 32-bit applications.¹² Windows Server 2003 x64 Editions recognize these supported 16-bit programs and automatically substitute them with their 32-bit versions. Windows Server 2003 x64 Editions support the use of 32-bit Windows installers for 32-bit applications; however, 64-bit applications must have 64-bit installers to properly access the 64-bit folders and native 64-bit registry hives.

The WOW32 subsystem has been replaced with the WOW64 (Windows On Windows 64) subsystem in x64 (see Figure 5). The WOW64 subsystem, which is a component in Windows Server 2003 x64 Editions, is the 32-bit Windows emulation layer that ensures binary compatibility with 32-bit Windows applications and allows 32-bit x86-based applications to run on 64-bit Windows Server 2003 x64 Editions.

The core of WOW64 consists of the following three dynamic-link libraries (DLLs):

- **Wow64.dll:** Manages process and thread initialization as well as exception dispatching to 32-bit code; intercepts base system calls (exported by `Ntoskrnl.exe`); and implements file system and registry redirection (discussed later in this section) and registry reflection

Features of the WOW64 subsystem such as the file system redirector and the registry redirector allow 32-bit applications to run on an x64 system with complete transparency.

⁸ Current Windows Server 2003 x64 Editions implementations use 46-bit virtual addresses. Future implementations are expected to increase this limit as PC hardware evolves.

⁹ The 32-bit Windows operating systems allow the use of the `/3GB` switch in the `boot.ini` file to increase the virtual address space for a 32-bit process from 2 GB to 3 GB. Because this effectively restricts the address space available to the kernel to 1 GB, there may be a negative performance impact from using the `/3GB` switch. Only applications compiled with the `/LARGEADDRESSAWARE` switch can use more than 2 GB of virtual address space.

¹⁰ Note that the binary versions of 64-bit drivers and 64-bit applications for Windows Server 2003 x64 Editions are very different from those for the Windows Server 2003 for 64-Bit Itanium-based Systems OS.

¹¹ For more information about porting drivers to 64-bit, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/kmarch/hh/kmarch/Other_394c38ae-a3e6-45fb-87f2-c3e227cb6b7c.xml.asp.

¹² A list of supported 16-bit installer programs is available in the registry at the following location on an x64 system: `HKLM\Software\Microsoft\Windows NT\CurrentVersion\NtVdm64`.

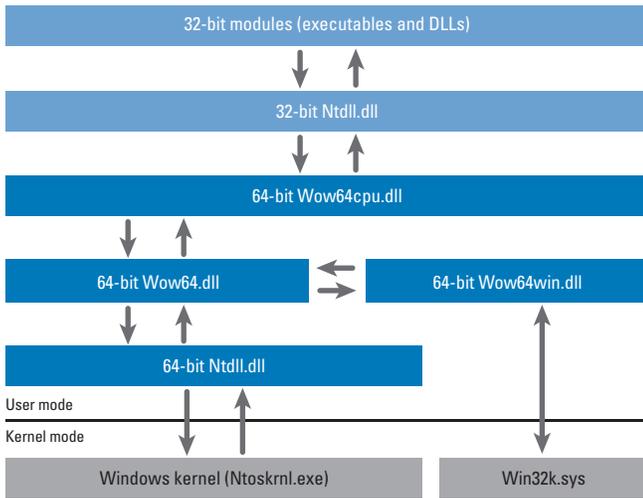


Figure 6. Interaction between 32-bit applications and the 64-bit kernel via WOW64

- **Wow64win.dll:** Intercepts graphical user interface (GUI) system calls (exported by Win32k.sys)
- **Wow64cpu.dll:** Manages the 32-bit CPU context of each running thread inside WOW64 and provides processor architecture-specific support for switching CPU modes from 32-bit to 64-bit and vice versa

Figure 6 shows the interaction between 32-bit applications and the 64-bit kernel via the WOW64 layer. The WOW64 subsystem intercepts system calls¹³ from the 32-bit application, transitions from Compatibility mode to 64-bit mode, converts all 32-bit data structures into 64-bit aligned data structures, issues the native 64-bit system call, writes back any output data from the 64-bit system call, and returns back to 32-bit Compatibility mode. This process of conversion performed by the WOW64 layer is commonly referred to as *thunking* and is transparent to the software developer in most cases.

Restrictions and limitations of the WOW64 layer include the following:

- WOW64 processes (32-bit processes) cannot load 64-bit DLLs (except for the core 64-bit Ntdll.dll and the 64-bit WOW64 binaries—Wow64.dll, Wow64win.dll, and Wow64cpu.dll); native 64-bit processes cannot load 32-bit DLLs.
- WOW64 does not support 16-bit applications, including the 16-bit WINNT.exe application.

- WOW64 cannot handle input buffer for the DeviceIoControl function.

The capability of Windows Server 2003 x64 Editions to support both 32-bit and 64-bit applications also introduces complexities in the coexistence of 32-bit and 64-bit versions of drivers, system files, and registry values. The x64 platform is designed to prevent issues relating to the coexistence of 32-bit and 64-bit applications through the implementation of the file system redirector, registry redirector, and registry reflection features.

Windows Server 2003 x64 Editions implement two Program Files directories, as shown in Figure 7. The Program Files folder hosts the 64-bit application program files and the Program Files (x86) folder hosts the 32-bit versions of the program files. These directories enable 32-bit and 64-bit applications to coexist without conflict on an x64 system. There are also two System folders, as shown in Figure 8. The System32 folder hosts the 64-bit system files, and the SysWOW64 folder contains the 32-bit files. The WOW64 subsystem can see only the Program Files (x86) and SysWOW64 folders.

File system redirector and registry redirector

Features of the WOW64 subsystem such as the file system redirector and the registry redirector allow 32-bit applications to run on an x64 system with complete transparency. Any 32-bit application that attempts to access the Program Files or System32 folder will automatically be resolved to the Program Files (x86) or SysWOW64 folder, respectively, by the WOW64 subsystem. This automatic path resolution, which depends on whether the application is 32-bit or 64-bit, is implemented by WOW64 and is known as file system redirection.¹⁴ To facilitate backward compatibility, the following

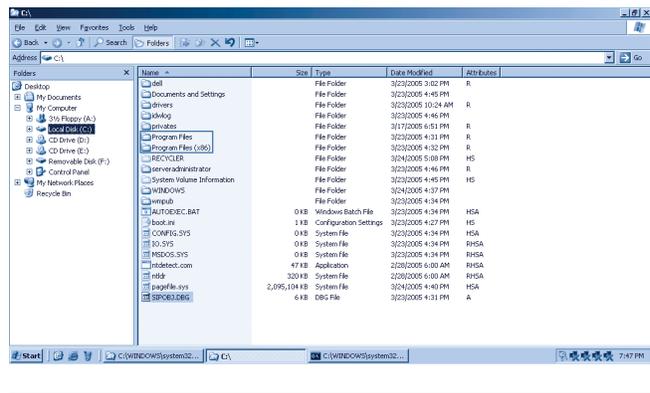


Figure 7. Windows Server 2003 x64 Editions Program Files folder for 64-bit program files and Program Files (x86) folder for 32-bit program files

¹³ An important exception is in the case of data buffers passed to device drivers (the DeviceIoControl function). For more information, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/kmarch/hh/kmarch/Other_6c9ff8b-fb41-4cb9-bbfd-b88e5fd17496.xml.asp.

¹⁴ For more information about the file system redirector, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/win64/win64/file_system_redirector.asp. By default, the WOW64 file system redirector is turned on. Programmers can enable or disable this feature by using the Wow64EnableWow64FsRedirection() application programming interface (API) that is available on x64. For more information, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/sysinfo/base/wow64enablewow64fsredirection.asp.

