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.

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...

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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 natively in 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 64-bit 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. In Windows Server 2003 x64 Editions, a 32-bit application 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 much larger virtual address space.
A list of supported 16-bit installer switches 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 that a 32-bit process can use more than 2 GB of virtual address space.

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. 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):

- **Wwow64.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.

- **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.**

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. All 32-bit kernel-mode drivers must be ported to 64-bit. 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.

32-bit Windows OS on Dell PowerEdge server

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<th>64-bit applications</th>
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<td>Processor in Virtual mode</td>
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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. 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.

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**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. 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.

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**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 calls 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 System 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. 

To facilitate backward compatibility, the following

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3 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/khtml/hh439555.xml.

14 For more information about the file system redirector, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/win32/win32/file_system_redirector.aspx. 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/psinfo/base/wow64enablewow64fss redirection.aspx.
subdirectories in %SystemRoot%\System32 are excluded from automatic redirection by the file system redirector:

- %windir%\system32\drivers\etc
- %windir%\system32\spool
- %windir%\system32\catroot2
- %windir%\system32\logfiles

To accommodate 32-bit and 64-bit applications, the x64 registry layout also has been designed to ensure that hard-coded DLL paths, application settings, and other parameter values are not overwritten. The 32-bit and 64-bit processes in an x64 OS use different registry sections: native 64-bit processes use HKLM\Software, while 32-bit processes running in WOW64 mode access HKLM\Software, WOW6432Node. This process of automatically directing applications to the appropriate registry keys, which depends on whether the application is 32-bit or 64-bit, is implemented by WOW64 and is known as registry redirection.15

While 32-bit applications running on an x64 OS may experience nominal performance benefits because of the architectural differences in the 64-bit OS and x64-capable hardware, 32-bit applications should be upgraded to 64-bit versions to take full advantage of x64-capable hardware and OS capabilities. Figure 9 provides a list of Microsoft applications and their support status on Windows Server 2003 x64 Editions at press time. Please visit www.microsoft.com for the latest support information.

15 For more information about the registry redirector and other features such as registry reflection, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/win64/win64/registry_redirector.asp. By default, WTM64 registry reflection is turned on. Programmers may override this feature by using certain registry APIs. For more information, visit msdn.microsoft.com/library/default.asp?url=/library/en-us/win64/win64/accessing_an_alternate_registry_view.asp.

Figure 9. Microsoft applications that currently support Windows Server 2003 x64 Editions

### Applications supported in Compatibility mode (via WoW64)

- .NET Framework 1.1
- Visual Studio® .NET 2003
- SQL Server 2000 SP4

### Applications that are already 64-bit

- Internet Information Services on Windows Server 2003 x64 Editions
- Microsoft Cluster Service (MSCS) for Windows Server 2003 x64 Editions
- Windows System Resource Manager (WSRM) shipping with Windows Server 2003 x64 Editions

### Applications not supported on Windows Server 2003 x64 Editions

- Exchange Server 2003 and Exchange Server 2003 SP1
- SQL Server 2000 SP3a or earlier
- Virtual Server 2005 with x64 as the host OS

An initial step in migrating to 64-bit technology

Even though Windows Server 2003 x64 Editions do not have “SP1” in their product names, these operating systems are built from the Windows Server 2003 SP1 code-tree. For that reason, they include most updates, features, and security enhancements introduced in Windows Server 2003 SP1—including data execution prevention, the Security Configuration Wizard, Windows Firewall enhancements, and Server Balanced Processor Power and Performance. By supporting both 32-bit and 64-bit applications, Windows Server 2003 x64 Editions on Intel EM64T architecture can enable organizations to integrate 64-bit technology into their data centers and gradually migrate to this emerging platform without requiring a major overhaul of their IT infrastructure.

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