The 64-bit Tipping Point

Optimizing Performance, Flexibility, and Value with Intel® Itanium® Architecture and Intel® Extended Memory 64 Technology (Intel® EM64T)

With the launch of the new Intel Xeon™ processor with Intel Extended Memory 64 Technology (Intel EM64T), the industry is poised for a large-scale migration to 64-bit computing. Intel EM64T delivers dramatic benefits for some applications, while others are better suited for 32-bit computing, and still others for the more robust 64-bit capabilities of Intel Itanium architecture. With leading support for all three options, Intel processor-based platforms offer unparalleled flexibility for optimizing capacity, performance, and business value across the full range of enterprise and technical computing environments.

September 2004

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Executive Summary

"… New system shipments based on 32-bit x86 processors will be swept away, over time, by refreshed designs built around x86-64 processors as these are released into the marketplace. Meanwhile, IDC's Server group forecasts that the Itanium-based server market will grow from less than $1 billion in 2003 to more than $8 billion in 2008."

– *What Impact Will 64-Bit Computing Have on the x86 Software World?,* Al Gillen and Jean S. Bozman, IDC Analysts, June 2004.

For more than a decade, 64-bit architectures have played an important role at the high-end of enterprise and technical computing. Intel Itanium architecture shifted the market dynamics in that space, lowering the cost of entry and challenging high-end RISC-based systems in scalability, capacity, performance, and RAS (reliability, availability, serviceability). The new Intel Xeon processor with Intel Extended Memory Technology (Intel EM64T) will trigger a broader shift toward 64-bit solutions. Servers and workstations based on this new processor offer reliable and exceptionally cost-effective 64-bit support, while simultaneously providing leading performance for existing 32-bit applications. They deliver a valuable addition to the high-end capabilities of Itanium architecture, and will help reduce 64-bit migration costs for a wide variety of general-purpose enterprise and technical applications.

The move toward 64-bit computing for mainstream applications, will initially focus on applications that are already constrained by 32-bit memory limitations. The challenge for IT organizations is to determine the best architecture for specific solutions, while taking into account total cost and value within the broader IT and business environments. Itanium architecture remains the platform of choice for the most demanding, business-critical data tier applications, such as high-end database and business intelligence solutions. Platforms based on the Intel Xeon processor with Intel EM64T are preferable for general purpose applications, such as Web and mail infrastructure, digital content creation, mechanical computer-aided design, and electronic design automation; and for mixed environments in which optimized 32-bit performance remains critical. For some mid-tier enterprise applications, the best choice may not be obvious, and will require a close look at software availability, business drivers, and workloads.

This paper explores the increasing importance of 64-bit capable platforms, and offers guidelines for planning a cost-effective transition. It also discusses the importance of platform and software synergy, and describes Intel's industry-wide efforts to assist software developers in tuning their software for best performance on Intel architecture. These efforts will be increasingly important as Intel EM64T and future architectural innovations (such as multi-core processors) become prominent in the marketplace, providing IT organizations with additional options for increasing the business value of their IT investments.

Test Drive Your 64-bit Solutions

Find out how your software performs in a 64-bit environment, by test driving it for 30 days on Intel architecture based enterprise platforms. For details, visit the Intel Web site at: http://www.intel.com/cd/ids/developer/asmo-na/eng/microprocessors/itanium/171236.htm

Advantages of 64-bit Solutions

There are two key advantages to platforms with 64-bit capabilities. First, a 64-bit processor transcends the 4GB memory limit encountered with 32-bit processors, and can directly access virtually unlimited physical memory.[1] This allows an application to store vast amounts of data in main memory, which is several orders of magnitude faster than today's fastest mass-storage subsystems. Large, memory-intensive applications that can take advantage of this extra capacity can see dramatic performance increases. Secondly, a 64-bit processor can manipulate data and execute instructions in chunks that are twice as large (64-bits versus 32-bits). This can be a key advantage for complex calculations that require a high-level of precision.

Although most existing 32-bit applications have no immediate need for additional memory, many scientific, engineering, and design applications will benefit. So will an increasing percentage of enterprise business solutions, such as security applications and real-time transactional systems that rely on large data sets. The availability of highly affordable 64-bit platforms will simplify migration for many of these applications, and fuel the development of additional 64-bit software solutions.

Over the next few years, a variety of additional factors will accelerate the move toward 64-bit computing. The most important is the ongoing explosion in data storage and access requirements, along with the growing need for near-real-time processes to improve customer service, productivity, regulatory compliance, and business transparency. The rise of Web Services and Service Oriented Architecture (SOA) is accelerating these developments, by simplifying integration across businesses and supply chains. High-volume business transactions are increasingly taking place interactively and in real-time, requiring both high security and fast server response times.

The impact of these trends is magnified by the ongoing proliferation of high-performance client devices, including smart phones, wireless-enabled notebooks, and PDAs. Non-user end-points, such as radio frequency identification (RFID) tags and point of sale devices, are causing a quantum leap in processing, capacity, and data requirements that may ultimately dwarf the end-user-related workloads we know today.[2] As these trends converge, 64-bit computing capabilities will become increasingly important for a growing number of mainstream enterprise applications.

The Value of Choice for 64-bit Migration

All 64-bit applications and workloads are not the same. Data, processing, and RAS requirements can vary dramatically. For example, a complex engineering application may access terabytes of data and consume vast processing resources. Yet response times are typically not critical and an isolated system failure may not be catastrophic. An enterprise resource planning (ERP) application, on the other hand, may require less total compute and data resources, yet failure or slow response times may impact thousands of users and cost millions of dollars per minute. In any implementation, it is therefore vital to clearly determine workload and business needs, and to craft a best-fit solution that balances reliability, cost, and performance.

Intel offers two complementary architectural choices that cover the full range of 64-bit requirements. One is Intel Itanium architecture, which is designed for the most demanding and business-critical enterprise and technical applications. The other is the family of Intel Xeon processor-based systems with Intel EM64T. Though not equivalent to Itanium architecture in terms of capacity, performance, and RAS, these platforms enable a more gradual migration to 64-bit solutions, since they provide native support for existing, legacy 32-bit applications.[3] In most enterprise computing environments, both platforms will be needed.

[1] The maximum physical memory supported by an Intel architecture-based platform depends on the processor: Intel Xeon processor (64 gigabyte); Intel Xeon processor MP (1 terabyte); Intel Itanium 2 processor (1 petabyte).

[2] As reported by Giga Research, "RFID has the potential to explode data volumes and message traffic." *IT Trends 2004: Application Architecture and Design*, Randy Heffner, Giga Research, a wholly owned subsidiary of Forrester Research, Inc., November 25, 2003.

[3] Itanium 2 processor-based platforms are also capable of simultaneously running 32-bit and 64-bit applications. However, they do not run 32-bit applications natively, so there is some degradation of performance in comparison with leading Intel Xeon processor-based platforms. In many 64-bit environments this is not an issue. Either all components are available in 64-bit versions, or some 32-bit components are required, but are not performance-critical to the core application.

Matching the Platform to the Workload: BEA WebLogic* on Intel® Architecture

"Then we worked with BEA and Intel to optimize our code for BEA WebLogic Server on the Intel Itanium 2 processor…It blew away anything else we looked at."

– Hans Cobben, Managing Partner, Omicronn, discussing internal benchmark results for BEA WebLogic Server on Intel Itanium 2 processor-based platforms.

At the time this paper was published, the leading SpecjAppServer2002 benchmark results for both absolute performance and price/performance were all achieved using Intel architecture, and the majority using Intel Itanium® 2 processors. A key reason for this result is BEA JRockit Java Virtual Machine* (JVM), which was co-developed by Intel and BEA and is optimized for both IA-32 and Itanium architectures. This does not mean Itanium architecture should be used for all BEA WebLogic deployments. Front-end Web applications and medium-size or smaller mid-tier applications may run better on Intel Xeon™ processor-based platforms. However, Itanium architecture is the clear choice for server-side Java applications that have complex business logic or require large memory resources.

A case in point is Omicronn's Trax* software suite, a platform used by financial organizations that need to process millions of complex transactions per hour. The company turned to BEA WEbLogic on Intel Itanium 2 processor-based platforms when it could not achieve desired performance levels on RISC-based systems. In internal benchmark tests, the platform performed 5 million messages per hour, at only 50-60 percent utilization, leaving extra capacity for fail-over of another WebLogic instance—all on a platform that is far more cost-effective than RISC-based alternatives.[a]

[a] For detailed information, see the full Omicronn case study at: http://www.intel.com/products/services/intelsolutionservices/success/casestudies/omicronn.pdf

Intel Itanium Architecture

"Itanium stands out as a processor technology that firms want…"

Firms Stay The Course On Server Technologies, Brad Day and Frank E. Gillett, Forrester Research, Inc., July 14, 2004.

Itanium architecture was built from the ground up for high-end 64-bit computing in business-critical environments. It is based on Explicitly Parallel Instruction Computing (EPIC) technology, which incorporates highly parallel processing and innovative, compiler-based optimization that greatly improves performance for compute-intensive applications. With these capabilities, Itanium 2 processor-based systems are delivering outstanding performance for some of today's largest and most demanding workloads, and for technical and scientific applications requiring high-performance floating-point calculations. According to analysts at Aberdeen, they "consistently outperform 64-bit applications running on 64-bit RISC-based servers,"[4] and do so at substantially lower costs.

Itanium architecture is also designed to support the highest levels of reliability, availability, and serviceability for business-critical environments. The RAS features of Intel Itanium 2 processor-based systems are comparable, and in some cases superior, to those found in leading, proprietary platforms. Because of its enhanced parallelism, large cache configurations, and massive execution resources, Itanium architecture-based systems also tend to scale exceptionally well in large SMP configurations.

This combination of features makes Itanium architecture an attractive, standards-based alternative to high-end RISC and mainframe systems. According to the Aberdeen Group, "Intel-based platforms are typically better performing per processor, more scalable, more cost-effective, and more flexible (standards-based, open, and able to adapt to new technologies and integrate with other platforms). They also are more programmer-productive and feature a smaller footprint."[5] In other words, they are comparable or superior to high-end, proprietary architectures on virtually all levels, and provide extremely powerful and cost-effective alternatives to aging RISC-based systems for business-critical, data tier applications.

Businesses are responding to these capabilities, and to the wide and growing choice of compatible operating systems (5) and applications (more than 2,000). As reported by Forrester Research, Inc., "94% of current Itanium-installed firms plan to buy more over the next three years, and 50% of those that haven't yet bought 10 or more Itanium-based servers list it in their future spend plans."[6]

[4] *Itanium 2-Based Servers: Perspective*, Gartner Technology Overview, June 8, 2004.
[5] *Intel's Itanium: Ready and Desirable for Mainframe-Class Workloads*, Peter Kastner, Aberdeen Group, May 14, 2004.
[6] *Firms Stay The Course On Server Technologies*, Brad Day and Frank E. Gillett, Forrester Research, Inc., July 14, 2004.

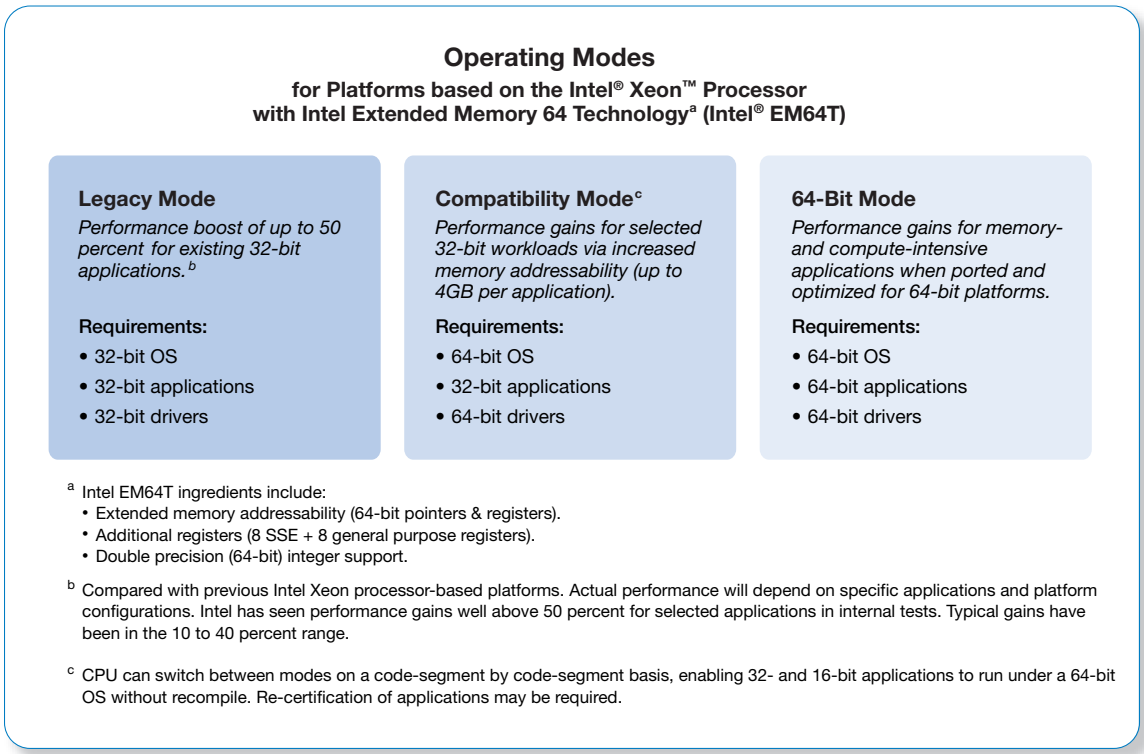


Figure 1. With a performance boost of up to 50 percent or more for existing 32-bit applications, and multiple options for extending memory addressability[7], these platforms deliver exceptional flexibility for cost-effective performance scaling.

Intel Extended Memory 64 Technology (Intel EM64T)

> *"This change opens up a viable path for customers to begin their move from 32-bit computing to 64-bit computing in earnest—and across the board."*
>
> – *What Impact Will 64-Bit Computing Have on the x86 Software World?,* Al Gillen and Jean S. Bozman, IDC Analysts, June, 2004.

Intel EM64T is a natural migration of Intel's 32-bit server architecture to 64-bits, with additional architectural features (including instructions and registers) that enable Intel Xeon processor-based platforms to expand memory addressability and to run both 32-bit and 64-bit operating systems and applications. These new platforms deliver leading performance for existing 32-bit workloads, while eliminating many of the barriers organizations face in moving one or more critical applications to 64-bit platforms.

Intel is currently integrating Intel EM64T into all of its IA-32 processor lines. This will allow businesses to establish an extremely flexible 32/64-bit infrastructure at very little cost, so they can migrate operating systems and applications as needed without new hardware purchases. According to IDC, this strategy provides "Excellent investment protection and additional headroom, all with few or no drawbacks."[8] It is likely to initiate a broad move toward 64-bit capable platforms as companies strive to future proof their infrastructure against unpredictable business requirements.

Three operating modes are possible, and platforms can switch modes on a code-segment by code-segment basis (Figure 1).

- **Legacy Mode for Traditional IA-32 Deployments (32-bit OS/32-bit Applications)**—This is the traditional IA-32 mode of operation and requires no changes to existing 32-bit applications. The processor supports a maximum of 4GB of virtual memory, which is shared among the OS and all applications.[9] In most cases, the OS allocates approximately 2GB of memory to itself, leaving 2GB to the application stack. Since the Intel Xeon processor

[7] Actual performance will depend on specific applications and platform configurations. Intel has seen performance gains well above 50 percent for selected applications in internal tests. Typical gains have been in the 10 to 40 percent range.

[8] *What Impact Will 64-Bit Computing Have on the x86 Software World*, Al Gillen, Jean S. Bozman, IDC Analysts, June, 2004.

[9] IA-32 supports Physical Address Extensions (PAE), which enables virtual memory of up to 64GB in a 32-bit system (with appropriate OS support). However, this approach is subject to performance penalties that do not exist with Intel EM64T.

The Intel® Xeon™ Processor with Intel EM64T—More Than Just Extended Memory

"With its host of new memory and I/O technologies, Intel's latest server platform…has the potential to help us continue to meet rapidly growing trading demands."

– Steve Randich, CIO and Executive Vice President, NASDAQ Stock Market.

Intel EM64T is one of many new features introduced in the latest Intel Xeon processor, which is not only 64-bit capable, but has been shown to deliver performance boosts of up to 50 percent or more for existing 32-bit applications.[a] These performance gains are enabled by a wide variety of processor and platform advances, including higher clock frequency, enhanced multi-threading capabilities, dramatically improved I/O bandwidth, a faster system bus and a faster memory subsystem.

Platforms based on this new processor also benefit from Intel's extensive work with leading server manufacturers and software vendors to develop balanced systems that not only boost performance, but also help to drive down total cost of ownership. For example, with this processor and related chipsets, Intel has introduced new memory and manageability features that can improve total platform availability and reduce operating costs. Demanded Based Switching with Intel SpeedStep® Technology is also supported, and can reduce platform power consumption by as much as 25%. In addition, platforms are available with an integrated Intel IOP332 Storage I/O Processor that improves RAID storage performance. By working with industry leaders to advance the entire platform, Intel helps to ensure that its processor innovations deliver better value in a wider range of real-world implementations.

[a] Actual performance will depend on specific applications and platform configurations. Intel has seen performance gains well above 50 percent for selected applications in internal tests. Typical gains have been in the 10 to 40 percent range.

with Intel EM64T is the most recent IA-32 processor, it includes a variety of innovations that can improve performance for existing 32-bit workloads by as much as 50 percent or more, even in Legacy Mode[10] (see Sidebar p. 6, *The Intel Xeon Processor with Intel EM64T—More Than Just Extended Memory*).

- **Compatibility Mode for Running 32-bit Applications in 64-bit Environments (64-bit OS/32-bit Applications)**—In this mode, a 64 bit operating system manages system resources for a 32-bit application. Depending on the particular OS, each application can be allocated up to 4GB of memory. No code changes are needed for the application itself, but 64-bit device drivers are required. Migration flexibility is the key advantage of this mode. It enables 32- and 64-bit applications to run concurrently on the same platform. Migrations to 64-bits can therefore be performed incrementally, component by component, based on performance and cost.[11]
- **Full 64-bit Mode for Running 64-bit Applications (64-bit OS/64-bit applications)**—This mode delivers the full memory advantages of a 64-bit solution, but existing 32-bit applications must be ported to 64-bits and optimized to achieve full benefits. For those applications that will ultimately require more robust 64-bit support, this can be seen as an interim stage in moving toward the higher-performance, scalability, and RAS of an Itanium architecture-based solution. As reported by IDC, "Software revised and recompiled for 64-bit Xeon processors will be an important step closer to running on platforms using Itanium processors."[12] Once an application is ported to 64-bits, it is relatively easy to port between the two architectures.

In effect, these three modes of operation establish a pathway for migrating incrementally and very cost-effectively toward 64-bit solutions. As noted by Forrester Research, Inc., "…the impact is compelling. Now they [businesses] can deploy 32/64-bit systems at almost no cost penalty, which will allow them to gradually migrate to 64-bit through a three-stage process involving a progression from pure 32-bit software, to 32-bit applications under 64-bit operating systems, and ending with pure 64-bit environments with minimal disruption and risk."[13] Given the flexibility of this approach, the industry migration to 64-bits is likely to be a gradual and selective process. Most software developers will begin by validating their existing 32-bit applications for 64-bit operating environments. They will then migrate their code if and when it makes sense based on workload requirements and market demand.

[10] Actual performance will depend on specific applications and platform configurations. Intel has seen performance gains well above 50 percent for selected applications in internal tests. Typical gains have been in the 10 to 40 percent range.

[11] Most existing 32-bit workloads are optimized for 32-bit operating systems, and are likely to show little or no performance gain in Compatibility Mode. Performance may even decrease slightly for some (typically less than 5%), because of the increased overhead of the 64-bit operating system.

[12] *Intel's Enterprise Processor Plans: Positioning the Xeon Processor and the Itanium Processor*, by Vernon Turner, IDC, April 2004.

[13] *Strategic Platforms—The Shift Continues*, Richard Fichera, Forrester Research, Inc., June 22, 2004.

Table 1. Understanding the Tradeoffs between Intel's 64-bit Solutions[a]

	Intel® Xeon™ Processor with Intel® EM64T-based Platforms	Intel Itanium® 2 Processor-based Platforms	Advantages of Itanium Versus IA-32 Architecture
Performance	• Outstanding price/performance for 32-bit applications • Ideal for gradual, pay-as-you-go migrations to 64-bits	• Exceptional performance for high-end 64-bit applications • Compatible with 32-bit applications	• Itanium architecture typically delivers 30-50 percent better performance.[b] The advantage tends to be greatest for floating-point-intensive and business-critical data tier workloads
Scalability	• Scales to 16-way	• Scales to 512-way, with larger platforms on the way	The performance advantage of Itanium architecture increases substantially in large, SMP configurations: • 4-way servers: ~ 35% better • 32-way servers: ~140% better
Memory Addressability	• Up to 1TB	• Up to 1PB (1,000TB)	• Itanium architecture scales to support the largest platforms and enterprise data sets
RAS	• High reliability, with on-chip features such as memory spares, Chipkill* memory, and error correction (ECC)	• Additional on-chip reliability features, such as Enhanced Machine Check Architecture (MCA); Pellston technology will be supported in next-generation processors	• Itanium architecture delivers high-end RAS for core, business-critical applications, making it ideal for mainframe and high-end RISC replacement
Platforms	• Balanced bandwidth and high performance for a wide variety of workloads	• Greater bus bandwidths and enhanced support for large symmetric multiprocessing (SMP) configurations	• Platform manufacturers tend to offer more advanced platform options for Itanium architecture-based systems, targeting high-end, business-critical data tier environments

[a] This table is based, in part, on information reported in *Intel's Enterprise Processor Plans: Positioning the Xeon Processor and the Itanium Processor*, by Vernon Turner, IDC, April 2004; available on the Intel Web site at: http://www.intel.com/technology/64bitextensions/4071_intel_xeon_rev3.pdf

[b] Though this is generally true, actual performance will depend on specific workloads and configurations, and Intel Xeon processor-based systems may deliver better performance in select cases.

Understanding the Tradeoffs

> *"Key differences in performance, scalability, and reliability lead to different optimal workloads for workstations and servers built with Xeon versus Itanium processors."*
>
> – *Intel's Enterprise Processor Plans: Positioning the Xeon Processor and the Itanium Processor,* Vernon Turner, IDC, April 2004.

In simple terms, Itanium architecture offers better performance, scalability, and RAS for high-end environments (Table 1). As described by IDC, "Scaling advantages for SMP servers using the Itanium processor versus the new Xeon processor increase sharply when moving to 8-way and higher SMP configurations."[14] It can therefore be useful to think of Itanium architecture as best for "scaling up" on large, high-RAS, multiprocessor platforms for the business-critical data tier; and to think of Intel Xeon processor-based platforms as best for "scaling out" on clustered server architectures. Of course, specific business or technical considerations may take precedence in a particular implementation, and both architectures can be used successfully to scale up and out.

The availability of compatible applications should also be monitored. Multiple operating systems and thousands of applications are now available for Itanium architecture. The Linux* environment currently includes a 64-bit operating system for Intel Xeon processor-based platforms with Intel EM64T, and Microsoft expects to deliver a compatible operating system in the first half of 2005.[15] Application availability is also beginning to ramp up, and Intel is working extensively with leading ISVs to accelerate delivery and optimize performance.

[14] *Intel's Enterprise Processor Plans: Positioning the Xeon Processor and the Itanium Processor*, by Vernon Turner, IDC, April 2004.

[15] Microsoft has announced plans to release two 64-bit operating systems in the first half of 2005, both of which will be compatible with Intel Xeon processors with Intel EM64T. Windows Server 2003, Standard x64 Edition, will support servers with up to 4 processors and up to 32 GB of RAM. Windows Server 2003, Enterprise x64 Edition, will support servers with up to 8 processors and 64 GB of RAM. For more information, including application recommendations, see the Microsoft Web site at: http://www.microsoft.com/windowsserver2003/64bit/extended/standard.mspx and http://www.microsoft.com/windowsserver2003/64bit/extended/enterprise.mspx

Matching the Platform to the Workload: SAS* on Intel® Architecture

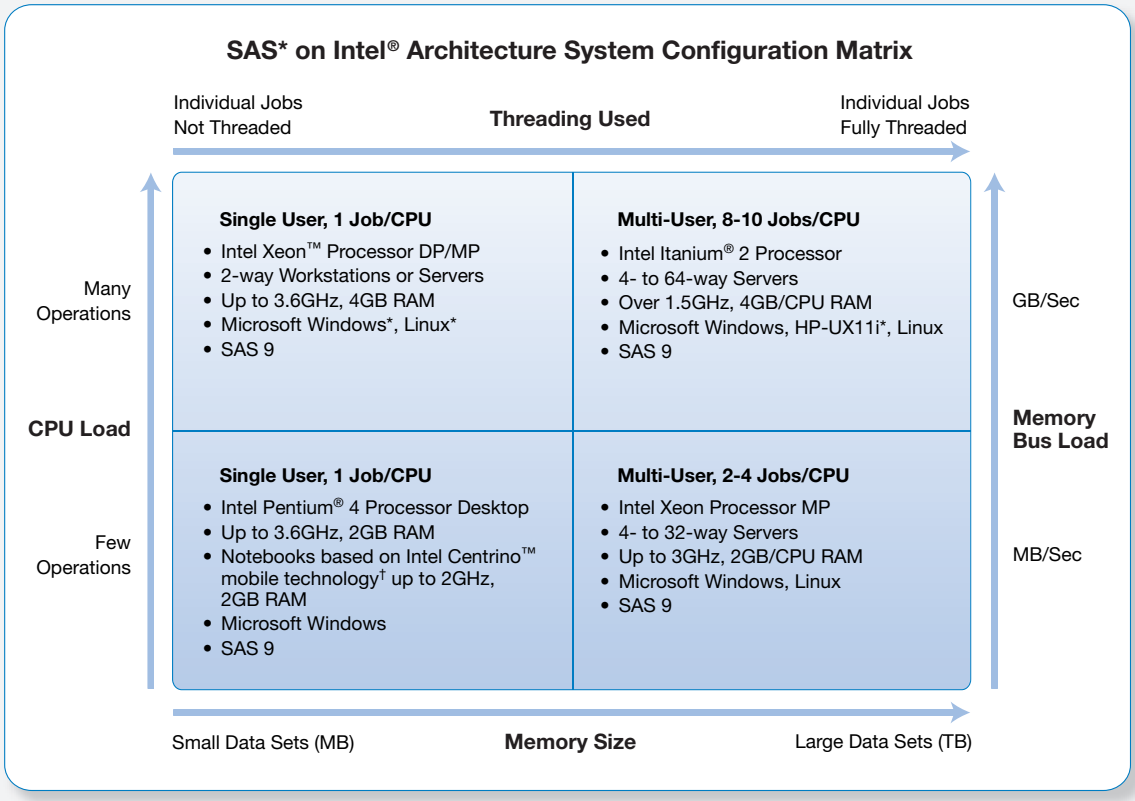
"We continue to view Itanium as our strategic platform for providing high-end enterprise computing on Intel architecture. The Xeon processor is a viable platform for many SAS solutions, with Itanium offering the growth path for advanced Analytic Intelligence."

– Keith Collins, CTO, SAS

Intel and SAS have been working together for nearly a decade to optimize performance for SAS solutions on both Intel Itanium® 2 and Intel Xeon™ processor based platforms, and continue to do so at the SAS and Intel Advanced Research Center (SIARC). With the release of SAS 9, these efforts are delivering increasingly dramatic gains for customers, such as the U.S. Census Bureau. The bureau is now moving from legacy, RISC-based systems to Itanium architecture, after tests showed they could reduce their processing time for two years' workload—48 million records—from an average of 5 days to just over 7 hours.

SAS is a global leader in business intelligence solutions. SAS workloads can vary dramatically between and within customer implementations, response times can be critical, and solutions may have to support anywhere from a single user to thousands of mobile users in distributed locations. IA-32 solutions may deliver better performance for simpler workloads with fewer users, especially if individual jobs are not threaded. As processing and memory requirements increase, larger platforms and Intel Itanium 2 processors can deliver essential benefits.

- For a detailed discussion of workload and platform considerations for SAS solutions, see *Sizing and Performance Considerations for Intel® Architecture-Based SAS® Solutions*, available at: http://www.intel.com/business/bss/solutions/alliances/sas/sizing_guide.pdf
- For more information about the U.S. Census Bureau's SAS implementation, see *SAS® Performance Exceeds the U.S. Census Bureau's Expectations*, available at: http://www.intel.com/business/bss/solutions/alliances/sas/census.pdf



High-end SAS implementations will typically run substantially better on Itanium architecture, but a close look at workload characteristics can be important in making the best platform choices for any given implementation.

It will also be important to monitor platform evolution. Intel is moving toward a common platform architecture for IA-32 and Itanium 2 processor-based systems by 2007. At that time, it is expected that Intel Itanium 2 processors will be delivering approximately 1.5 to 2 times the performance of Intel Xeon processors and platform prices should be roughly equivalent. With these developments, customers will have even greater flexibility for customizing 64-bit solutions to match their specific workload and business requirements.

General Recommendations for Platform Selection

> *"Know your applications well, know what resources are required, and identify where the 'bottlenecks' occur."*
>
> – *64-Bit Extensions Complicate Server Selection*, J. Encjk, A. Butler, G. Weiss, Gartner Research Note, March 19, 2004.

Enterprise computing solutions are complex, and there will always be exceptions to general recommendations. With that caveat, the following rules of thumb provide a useful starting point for planning migrations and selecting platforms. When in doubt about the need for 64-bits, consider deploying 64-bit capable platforms to lay the foundation for migrating if and when needed.

- **Front-end Workloads and General Purpose Infrastructure Applications**—Many front-end applications do not require 64-bit capabilities and scale very well across multiple servers. This tends to be true for Web, email, customer relationship management, and some supply chain management solutions. Depending on processing loads and data sets, it may also be true for more demanding applications, such as digital content creation, mechanical computer-aided design, and electronic design automation. In general, unless there are specific workload considerations, Intel Xeon processor-based systems are likely to provide the most cost-effective solution in these categories.
- **Mid-Tier Workloads**—These applications are more varied in their requirements. Many will benefit from both 64-bit capabilities and from the migration flexibility of Intel Xeon processor-based platforms with Intel EM64T. Some will require the greater capacity and compute power of Itanium architecture. Software availability and vendor optimizations will likely be deciding factors for packaged applications. For custom code, it will be especially important to look closely at transaction loads, data requirements, growth expectations, and migration costs. Be aware that the performance of application infrastructure solutions, such as BEA WebLogic* Platform, IBM WebSphere*, and Oracle Application Server*, will impact a wide assortment of applications, and may see substantial performance gains on 64-bit platforms.
- **Data Tier Workloads**—Large data sets and heavy processing loads are more usual for these types of applications. Examples include enterprise databases, enterprise resource planning (ERP), supply chain management (planning), computer assisted engineering, and business intelligence. In general, these applications will perform and scale more effectively on Intel Itanium 2 processor-based systems and will also benefit from the enhanced set of RAS features. Applications currently running on mainframes and RISC-based systems should be considered prime candidates for migration to Itanium architecture.

The Power of Parallelism

"Essentially, the design paradigm has shifted at Intel, and all the resources we have are dedicated to multi-core [processors]."

– Paul Otellini, President and Chief Operating Officer, Intel Corporation[a]

64-bit computing is not the only way to increase application performance. The simultaneous processing of multiple instructions, otherwise known as parallelism, is another strategy that is also gaining importance in both 32-bit and 64-bit environments. There are many ways to increase parallelism, from Intel® Hyper-Threading Technology‡, to Explicitly Parallel Instruction Computing (the foundation of Itanium architecture), to symmetric multiprocessing (SMP) servers, to clustered architectures and grid computing.

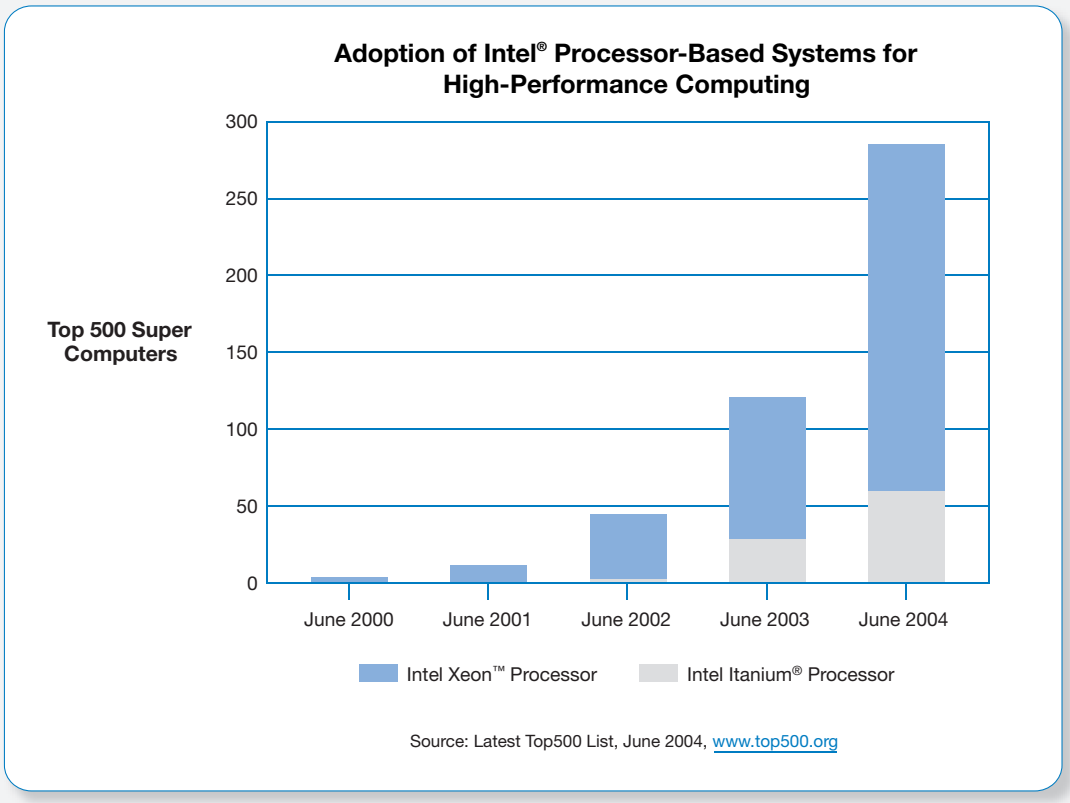
Intel will soon add to these options by delivering multi-core processors that will take per-processor parallelism to a new level. It will be important to consider these options as part of the broader picture when evaluating 32-bit versus 64-bit solutions. Here again, software optimization will be critical, and it will be essential to understand workloads to determine the best solution for any given application.

[a] *Intel Shoots for Dual Cores, Wireless Profits*, John G. Spooner, CNET News.com, May 13, 2004.

Matching the Platform to the Workload: High-Performance Computing on Intel® Architecture

In recent years, the growing price and performance advantages of COTS (common-off-the-shelf) systems and components have fueled a shift away from purpose-built high performance computing (HPC) platforms. In fact, Intel processors are now used in more than 50% of the world's 500 most powerful systems, including a 20 teraflop supercomputer based on Intel Itanium processors that went from concept to deployment in just 5 months at the Lawrence Livermore National Laboratory.[a]

The new Intel Xeon processor with Intel EM64T introduces additional options for price-sensitive HPC deployments that can benefit from a 64-bit address space. For example, Amber (Assisted Model Building with Energy Refinement) is a suite about 50 applications that are used to explore molecular structures and energies. In recent internal tests, Intel engineers compared the performance of 7 key Amber applications using the legacy (32-bit) and 64-bit modes of a platform based on pre-production versions of the Intel Xeon processor with Intel EM64T. The performance benefits in 64-bit mode were dramatic, ranging from 20% to 73%, with an average gain of 64%.[b] Given the low cost of Intel Xeon processor-based platforms, these results highlight their value for scaling the performance of many real-world HPC applications.



Driven by rapid performance increases, Intel processor-based systems have become the leading choice for high-performance computing, and now account for more than 50% of the world's 500 most powerful systems.

[a] See "Thunder – N. America's Fastest Linux Supercomputer, May 13, 2004. Available on the LinuxWorld Web site at: http://www.linuxworld.com/story/44799.htm

[b] Intel performed internal benchmarking tests on Intel Xeon processor-based systems with Intel EM64T, in a 3.6GHz single cpu configuration, running AMBER molecular modeling code v.8 distributed as source code (under license) from the University of California. The operating system used was 64-bit Linux. Application code was compiled with Intel Fortran compilers (LinuxCompiler 8.0 for 32 bit testing; 8.1 for 64 bit testing). Performance was measured on 7 workloads that utilized serial processes.

Optimizing ROI for Selected Enterprise Workloads

"Intel is at the forefront of publishers providing quality software for cross platform development and performance enhancement."

– Jeff Largiader, Vice President of Marketing, Programmer's Paradise, Inc.

Optimized software can dramatically improve application performance on any platform, and is all the more important following a major platform transition, such as the introduction of Intel EM64T. For these reasons, Intel invests heavily in software-enabling initiatives that help to deliver the best possible performance on Intel architecture. Much of this work takes place in collaboration with leading independent software vendors (ISVs).

Intel works closely with ISVs to select meaningful and representative workloads, rather than artificial benchmarks, to ensure that optimization efforts deliver real value in production environments. Code performance is then profiled on test systems, bottlenecks are identified and resolved, and both software and platforms are optimized for best performance. The goal is a balanced system design in which processor, cache, bus, memory, and I/O resources are optimized to efficiently support a wide range of workloads at low cost.

Intel Software Tools and Developer Programs

"Intel's 32-bit compiler is the gold standard for optimizing compilers."[16]

— Nathan Brookwood, Insight64 Analyst

Intel has been involved in software optimization for decades, and now has over 2,000 software engineers supporting more than a thousand ISVs. In the course of these efforts, Intel has created a complete set of software optimization tools—compilers, performance primitives, tuning analyzers, threading, and clustering tools, etc. These tools are designed to deliver very deep code optimizations, while integrating seamlessly with leading development environments. They can dramatically improve application performance on Intel architecture. A variety of resources are also available for supporting and simplifying 64-bit migrations to Intel Itanium Architecture and Intel EM64T (see the additional resources listed at the end of this paper).

Intel® EM64T and High-Performance Workstations

"...the most demanding jobs ran best on the dual-[Intel] Xeon processor with its ability to run hyperthreading."[a]

From advanced computer-aided design (CAD), to digital content creation, to sophisticated manufacture and test modeling, to high-end visualization and analysis, today's engineers, scientists, and designers are dealing with more complex problems and rapidly growing data sets. In many cases, they habitually divide complex problems into smaller, more manageable parts, and then undertake the time consuming task of integrating the results. In other cases, they rely on expensive, proprietary 64-bit workstations, and then require a second PC for productivity applications.

Workstations based on the Intel Xeon™ processor with Intel EM64T offer an ideal solution to these challenges. With excellent performance and greatly enhanced memory addressability, they offer a far more cost-effective alternative to UNIX workstations for 64-bit applications. Since they also deliver leading performance for existing 32-bit applications, they can handle a wide variety of mixed workloads, including standard productivity applications.

Over the past decade, complex scientific, technical, and design applications have thrived on rapid increases in processor performance. By letting these applications store more data in main memory, workstations based on the Intel Xeon processor with Intel EM64T will help fuel the next decade of progress.

[a] *Workstation Showdown: Xeon vs. Opteron*, Wayne Rash, Randall C. Kennedy, InfoWorld.com, August 13, 2004.

[16] As quoted by Stephen Shankland, in his article, *Intel Earns Programmer Tool A Linux Foothold*, CNET News.com, August 4, 2004. The full article is available on the ZDNet Web site at: http://zdnet.com.com/2100-1104-5296761.html

Keeping the Focus on Business Value

"Find the right balance between the best choice of server for a given application and the number of supportable platforms maintained in the computing infrastructure."

– *64-Bit Extensions Complicate Server Selection*, J. Encjk, A. Butler, and G. Weiss, Gartner Research Note, March 19, 2004.

IT organizations continue to face intense scrutiny from business executives regarding new investments, so successful 64-bit migrations will require attention to business justification as well as technological considerations. Assessments should include issues of risk mitigation (including the risk of migrating to 64-bits as well as the risk inherent in retaining 32-bit solutions), change management, and transition planning to ensure good alignment with actual costs and potential impacts.

To be successful, it is best to take a consistent approach across the enterprise, by classifying your applications and workloads and developing appropriate criteria for migration based on business, as well as technical, variables. Understand vendor roadmaps and compare the cost impact of: 1) retaining 32-bit applications; 2) a single port to Itanium architecture; 3) a port to 64-bits on Intel Xeon processor-based platforms followed, potentially, by a second round of optimization for Itanium architecture. To fully understand the issues, implement pilot programs, with gated costs to evaluate and compare options. As always, work to standardize your infrastructure solutions, to simplify future migrations and reduce operating costs.

In evaluating your options, consider evolving platform costs and capabilities. Intel is committed to advancing both Itanium and IA-32 architectures, to provide customers with better choices and tools for managing escalating IT costs. This commitment includes ongoing advances in both processor families, including the integration of critical capabilities that will help to improve not only performance, but also power management, virtualization, security, and platform management. It also includes ongoing collaboration with industry leaders to deliver increasingly flexible platforms that are easier and less costly to deploy and manage. As one example, Intel Active Management Technology is being integrated into a wide variety of next-generation platforms, to provide enhanced asset management and remote troubleshooting for all business computing systems, from enterprise servers to PCs and cell phones.[17]

Moving Away from Expensive and Inflexible Proprietary Solutions

"... in the future, the balance will alter further and further in favor of Intel-based platforms for hardware, and choices for server OS will favor an increase in market share for Microsoft OS and Linux..."

– *Strategic Platforms—The Shift Continues*, R. Fichera, Forrester Research, Inc., June 22, 2004.

The value of industry-standard computing solutions continues to drive their wide acceptance as a powerful and cost-effective alternative to proprietary architectures (Figure 2). Itanium architecture has extended this value into high-end computing environments, and Intel EM64T is now filling in the gap, providing high-volume, cost-effective support for entry-level and mid-range 64-bit solutions.

This transition can be expected to continue, since the cumulative investment in industry-standard platforms and technologies is "at least an order of magnitude greater than investment in proprietary RISC technology, and the gap will probably widen over time."[18] The enormous ecosystem of hardware and software developers drives rapid innovation and competitive pricing, producing solutions that continue to displace expensive and limiting proprietary alternatives.

It takes a complete ecosystem to drive innovations that fully address business needs and opportunities. Intel is deeply involved in virtually all major developments, from processor and platform innovation, to standards development and evolving usage models. This broad participation is essential to continuously increase the business value of Intel architecture. As noted recently by an industry analyst, "Increasingly, 'Intel inside' means Intel software, as well as hardware, in a host of computing devices."[19] It also means a level of value and investment protection that is unparalleled in the computing industry.

Conclusion

By providing 64-bit capabilities at little or no additional cost—and providing a bridge to the more robust capabilities of Itanium architecture—the Intel Xeon processor with Intel EM64T represents an inflection point for the computing industry. Within a relatively short time, 64-bit capability will likely be a baseline expectation for virtually all new platform purchases, and IT organizations will be able to migrate their applications as needed, while maintaining optimized performance for 32-bit workloads.

[17] Internal tests by Intel IT indicate this technology will reduce desk-side and depot repair costs in Intel's environment by 41.5 percent, while reducing the cost of maintenance contracts and improving employee productivity. Total benefits are conservatively estimated at more than $16M/year. For more information, see Intel® Active Management Technology Reduces IT Costs with Improved PC Manageability, available at http://www.intel.com/update/contents/it09042.htm.

[18] *Strategic Platforms—The Shift Continues*, R. Fichera, Forrester Research, Inc., June 22, 2004.

[19] *Hardware Kingpin Intel Beefs Up Software Business*, John G. Spooner, Staff Writer, CNET News.com, June 30, 2004.

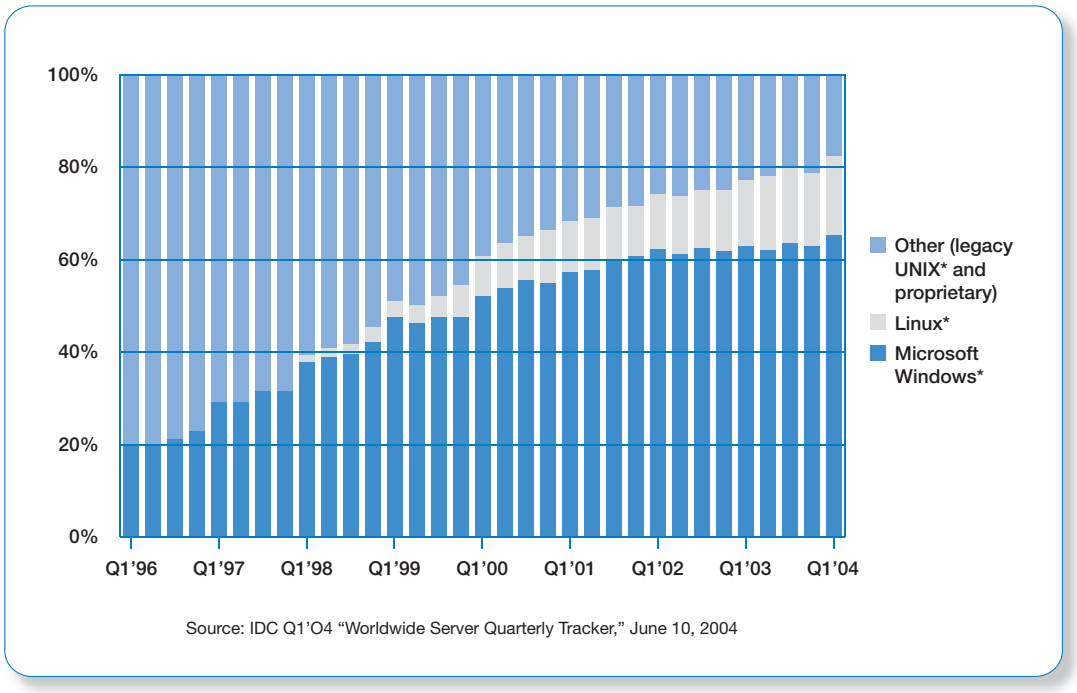


Figure 2. The move away from proprietary, RISC-based servers continues in both 32-bit and 64-bit environments, as Intel processor-based systems increasingly deliver comparable or better performance and RAS at a fraction of the cost.

The challenge for IT organizations will be to maximize the business value of these 64-bit capabilities, while minimizing the cost, risk, and disruption caused by software migration. To do this, they will need to understand current and future workload requirements for their key business applications, to ensure they neither miss critical 64-bit opportunities nor invest in upgrades for which the benefits do not justify the costs. They will also need to develop a consistent enterprise-wide migration strategy based on business and technical drivers, and contain operating costs by standardizing on a limited number of vendors and platform configurations. As a rule of thumb, Itanium architecture will remain the platform of choice for business-critical data tier applications, while Intel Xeon processor-based platforms will deliver better value for scaling out mid-tier and general purpose applications.

By making intelligent platform choices, IT organizations can increase the value of their IT investments. By relying on Intel architecture, they can be assured of staying in the vanguard of industry developments, reducing their risk, and taking advantage of affordable, high-volume platforms for even their most demanding applications.

Additional Resources

Intel Developer Services—Products, services, and recommendations for optimizing software performance on Intel architecture: http://www.intel.com/cd/ids/developer/asmo-na/eng/index.htm

- *Intel Itanium Architecture Resource Center:* http://www.intel.com/cd/ids/developer/asmo-na/eng/microprocessors/itanium/index.htm
- *Intel EM64T Resource Center:* http://www.intel.com/cd/ids/developer/asmo-na/eng/technologies/64bit/index.htm
- *Intel 64-bit Test Drive Web Site:* http://www.intel.com/cd/ids/developer/asmo-na/eng/microprocessors/itanium/171236.htm
- *Intel Software Tools:* http://www.intel.com/software/products/
- *Intel Early Access Program:* A variety of business, marketing, and technical resources that can help software vendors stay at the cutting edge of Intel architecture-based solutions: http://www.intel.com/ids/eap

Intel Solution Services—For more information about Intel Solution Services, visit our Web site at http://www.intel.com/go/intelsolutionservices, or contact us at www.intel.com/info/intelsolutionservices. To contact us by telephone, call toll free in the U.S. at 866-268-9812; Europe, Middle East, and Africa at +44 118 944 7931; Asia Pacific at +852 2844 4555; and Japan at +81 3 5208 5375.

‡Hyper-Threading Technology requires a computer system with an Intel® Xeon™ processor, a chipset and BIOS that utilize this technology, and an operating system that includes optimizations for this technology. Performance will vary depending on the specific hardware and software you use. See http://www.intel.com/info/hyperthreading/ for more information, including details on which processors support HT Technology.

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