An examination of the dual-core capability of the new HP xw4300 Workstation

By employing single- and dual-core Intel Pentium processor technology, users have a choice of processing power options in a compact, state-of-the art personal workstation.

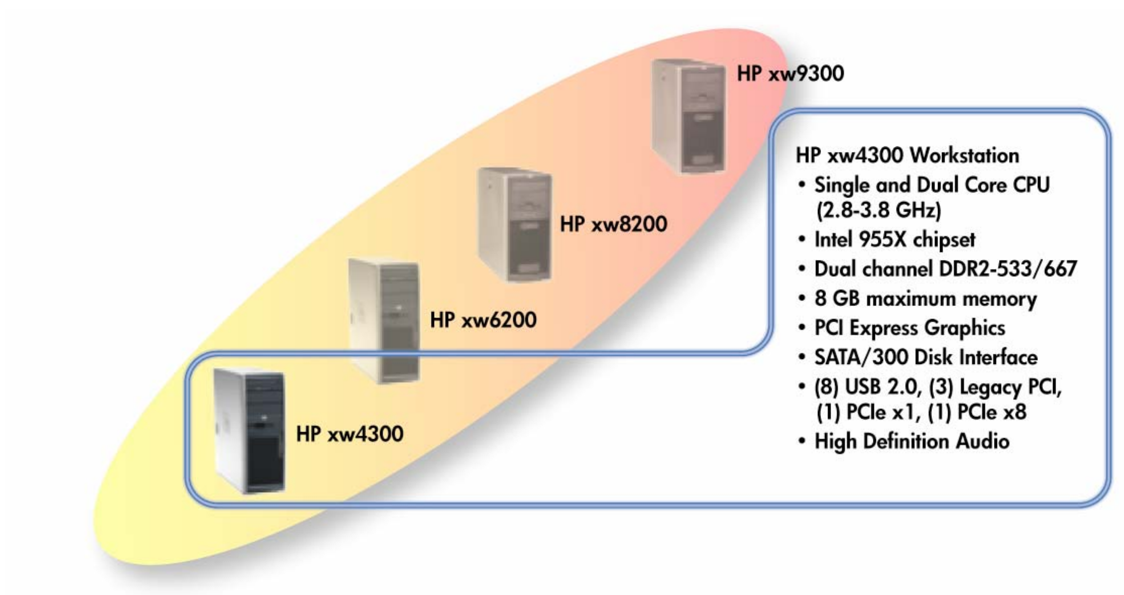
Introduction

Performance requirements for applications in the major market segments for personal workstations continue to grow. In fact, there is a "leapfrog" phenomenon at work—the more powerful the hardware becomes, the larger the problems that can be solved, and the more functionality software vendors add to applications. As users employ these larger problem sizes and increased amounts of functionality, workstation technology scrambles to increase performance, and the cycle repeats itself.

The two most common methods of increasing performance are: (a) increase the clock speed of the system's processor(s), and/or (b) increasing the number of processors. (Note that for the moment, we are discussing raw, aggregate performance, without regard to actual application performance.) Given that these two ways of increasing performance are mutually exclusive (for reasons discussed below), the best situation is to provide customers an easy way to choose which is best for their particular situation.

The latest evolution of the entry-level personal workstation from HP, the model HP xw4300 (Figure 1), allows users to choose which of these mechanisms they will employ to increase performance. The choice is largely based on the application characteristics and mix that will be run on the workstation. This paper will discuss these options, and offers information to help customers select the appropriate processor configuration.

Figure 1. The current line of HP personal workstations and the position of the HP xw4300.



Single vs. Multicore Comparison

Introduction

The current dual-core processor used in the HP xw4300 Workstation is socket-compatible with the single-core processor[1]. This situation is enabled by the use of the dual-core enabled chipset, the Intel 955X. The advantage is that it is relatively easy for HP to deliver single- or dual-core technology as different configuration options.

Applications Environment

A critical criterion in deciding what processor architecture to purchase is its performance with a user's key applications. In fact, users are strongly encouraged to ask the vendor of their software applications about performance on dual-core systems, as it could be that there is marginal performance improvement. Figure 2 below provides an overview of three different market segments for which the HP xw4300 is primarily suited[2], and an indication of the applicability of a dual-core processor to that segment.

Figure 2. General applicability of different application segments to dual-core processor technology.

Application Segment	General Characteristics	Applicability to dual-core processors
Mechanical Computer-Aided Design (MCAD)	Most MCAD applications are not multi-threaded and depend heavily on graphics performance. Individual application runs require the highest processor performance possible. In some MCAD environments, it is beneficial to run multiple simulations concurrently. In this case, while the application is not multithreaded, the overall job mix benefits from multiple processors by providing higher throughput.	Moderate
Mechanical Computer-Aided Engineering (MCAE)	MCAE applications require high processor performance, and are generally designed to run on a multiprocessor system. Note that some MCAE applications tend to rely heavily on the memory subsystem, and may be limited by the FSB performance when multiple processors are used.	High
Digital Content Creation (DCC)	The DCC applications that demand the most of a workstation processor are generally complex animations, rendering, and physics systems as well as video effects. Most DCC applications are multithreaded. Rendering is a highly parallelizable operation and benefits from multiple processors.	High
Power Office	Many "Power Office" applications (e.g., some components of Microsoft Office) are multi-threaded, and benefit directly from a multiprocessor environment.	High

An additional performance consideration is that of response time to the workstation user. All of the popular operating systems today are multi-threaded to some degree. The result is that multiple tasks (e.g., file system access, window management, printing functions) can be carried out simultaneously, and will generally result in better response time to the workstation user.

[1] Note, though, that the processor is not socket-compatible with previous workstation models (e.g., the HP xw4200).
[2] The xw4300 workstation is well suited for wide variety of applications; for brevity, we present the most common.

Performance Comparison

Many benchmarks are available that attempt to predict the performance of an application on a specific platform. The sections below compare synthetic benchmarks (SPEC) as well as some application benchmarks. The SPEC benchmarks are specifically used to compare single- vs. multi-processor performance (see the section on "performance," below).

SPEC benchmark performance

One of the more widely used is that of the SPEC CPU2000 benchmarks[3]. While users are strongly advised to test individual applications on different architectures, the SPEC benchmarks provide a common measurement for comparing architectures.

Figure 3. Comparison of performance using the SPECfp2000 (single-CPU) benchmark.

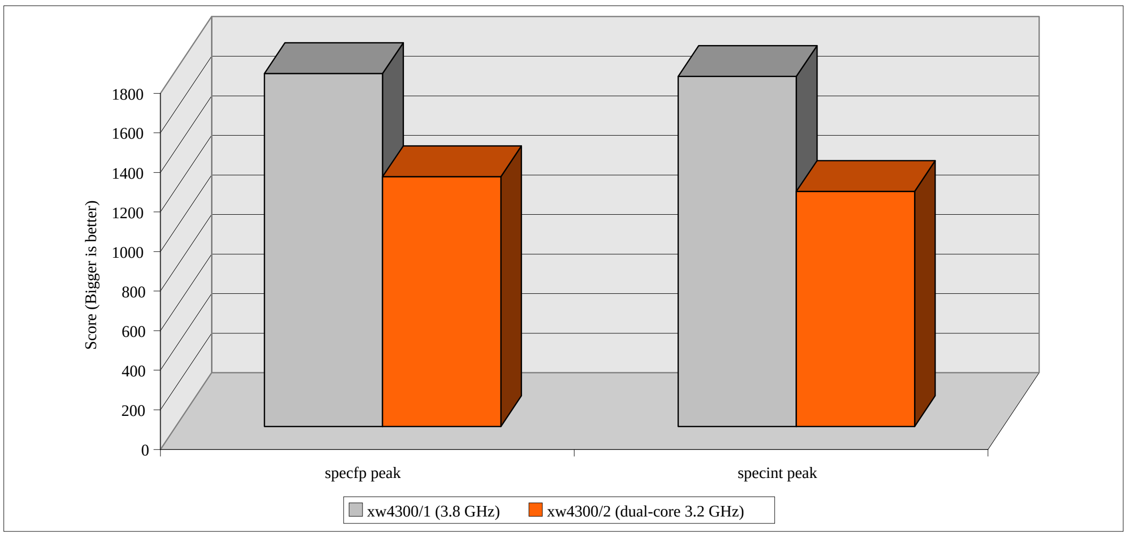


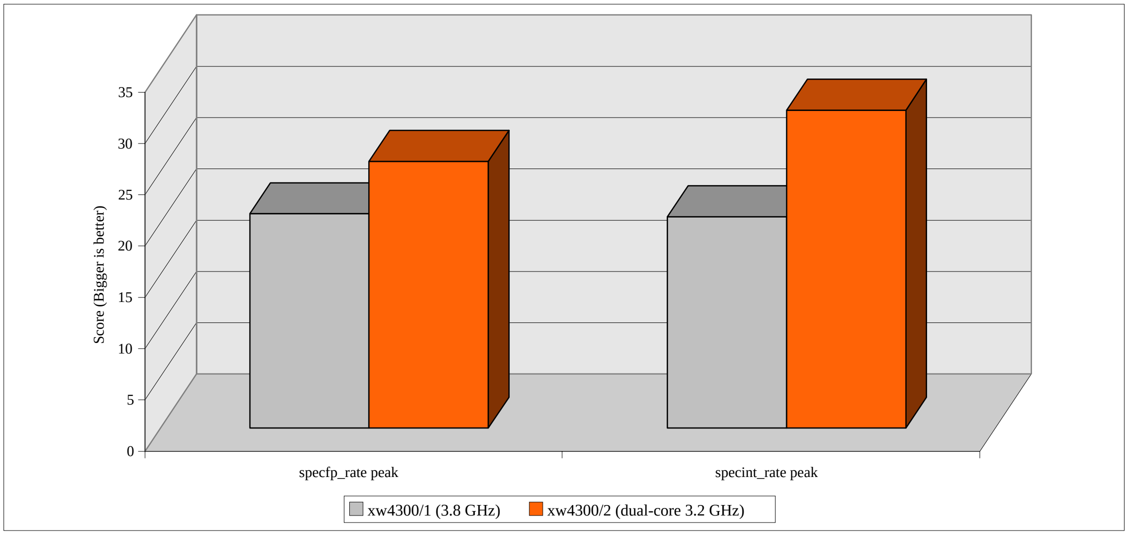
Figure 3 illustrates the performance of two different processor configurations that are available on the HP xw4300 Workstation: 3.8 GHz Pentium single-processor, and dual-core 3.2 GHz Pentium processors. As expected, the additional processor in the dual-core configuration provides no contribution to performance with this benchmark, because the benchmark only uses a single processor.

Figure 4 shows the same processor configurations using the SPECfp_rate benchmark, a benchmark that benefits from multiple processors and measures the amount of work that can be accomplished in a given amount of time. Here, the multiprocessing capabilities of the dual-core processor technology are clearly an advantage.

In "real world" applications and uses, performance requirements will generally be somewhere in between absolute single-processor performance and true multiprocessing.

[3] See http://www.spec.org/cpu2000/

Figure 4. Comparison of performance using the SPECfp_rate2000 (multiple CPU) benchmark.

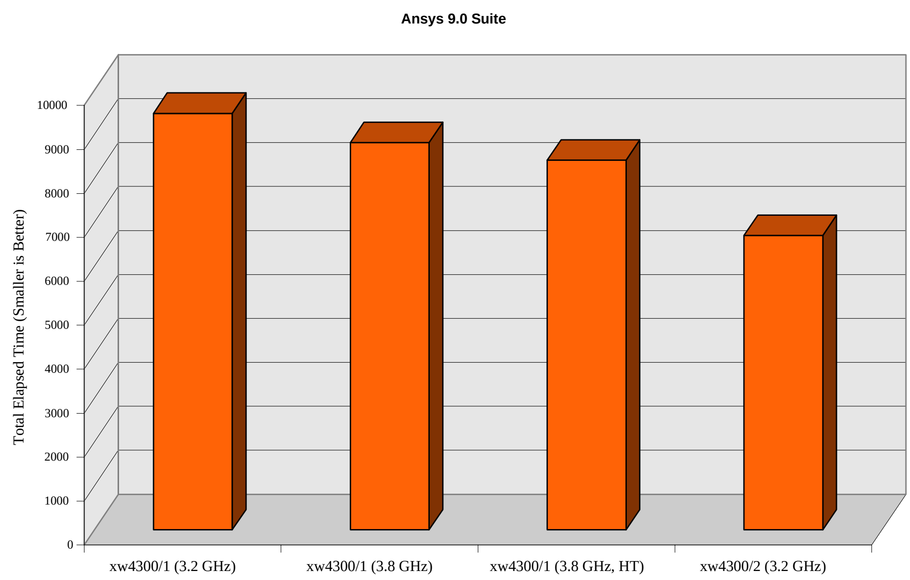


Application benchmarks

Several application benchmarks are shown below. The first, Figure 5, illustrates performance on a suite of twenty-six engineering simulation programs using the Ansys 9.0 application[4]. For each processor configuration, the total runtime of all twenty-six benchmarks is shown (thus, the smaller the result the better the performance). As can be expected, the slowest runtime is a single 3.2 GHz processor, followed by a single 3.8 GHz processor. Note that with Hyper-Threading turned on (see “Performance Through Processor Technology,” below), there is a marginal performance improvement (about five percent). The best performance, by a substantial margin, is that of a dual processors at 3.2 GHz.

[4] Please see http://www.ansys.com

Figure 5. Comparison of performance using Ansys 9.0 standard benchmark suite.



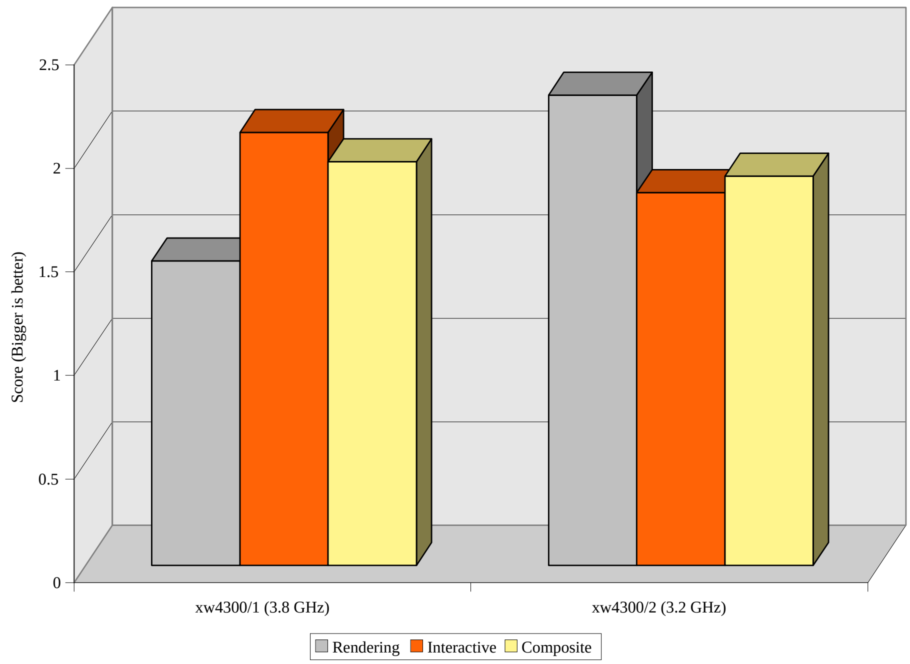
The second application benchmark, Figure 6, is based on the SPECapc (Application Performance Characterization) suite[5] and measures performance based on the workload of a typical workstation user using the application 3D Studio Max (v6)[6]. The 3D Studio Max benchmark includes functions such as wireframe modeling, shading, texturing, lighting, blending, inverse kinematics, object creation and manipulation, editing, scene creation, particle tracing, animation and rendering.

The total number of seconds to run each test is normalized based on a reference machine, and a composite score is computed. Composite scores are reported for both rendering and interactive tests. An overall composite score is also reported.

As shown in Figure 6, the rendering activity benefits greatly from the dual-core implementation on the xw4300—this is because the rendering algorithms are quite parallelizable and the 3D Studio Max application implements them in a multi-threaded environment. The interactive component, dominated by graphics and single-threaded portions of the application, do not benefit as much from two processors.

[5] Please see http://www.spec.org/gpc/apc.static/max6info.html
[6] Please see http://www4.discreet.com/3dsmax/

Figure 6. Comparison of performance for different workloads using the 3D Studio Max application.



Performance Summary

As would be expected, applications that are able to take advantage of executing multiple threads or process simultaneously benefit from the dual-core configuration; those that are not so structured will not. Further, the benefits of dual-core technology may even vary from one data set to another within the same application. It is prudent for users to check with their software vendor to determine the benefit of dual-core technology for a specific application.

Parallelizing Applications

The software development environment available today under modern operating systems (Microsoft Windows XP, Linux) has many features designed to provide multithreaded applications. The result is that new applications being designed are nearly always designed with multithreading in mind (provided the underlying algorithms permit). For example, HP is the first computer vendor to release a product version of UPC, the Unified Parallel C compiler (available for the Linux operating environment). UPC allows automatic parallelization of standard C code on various multiprocessor systems. Other compilers from HP that perform automatic parallelization are FORTRAN, ANSI C, and C++. The amount of code that is parallelized by these compilers varies considerably, depending upon coding styles, compiler directives, and underlying algorithms being employed.

Runtime Libraries

HP provides several runtime libraries to developers that facilitate parallelization of applications. Of most importance are HP-MPI and HP MLIB.

The HP-MPI (Message Passing Interface) is an implementation of the industry-standard MPI libraries used to implement parallelization on multiple systems (as in a cluster). Importantly, HP-MPI has been extended to accelerate applications that use MPI on shared-memory systems (such as a multicore workstation). HP-MPI will automatically recognize that the application is running with multiple processors available, and parallelize the execution of the application appropriately. HP-MPI is only available under the Linux operating system.

HP MLIB is another set of libraries specifically designed for technical applications. The HP MLIB libraries provide the functionality of many commonly used algorithms in scientific applications. HP-MLIB will automatically detect a system that has multiple processors, and execute the library routines in parallel if possible. HP MLIB is only available under the Linux operating system.

Applications Licensing

Another important issue when comparing single- to multicore processor technology is that of applications licensing. Some software vendors license applications by the computer system, some by the processor and some by the core. It is prudent to check with your independent software vendor (ISV) before making a decision, since customers who use software from vendors that license by individual core may face increased software costs when upgrading to multicore processor systems.

One important data point in applications licensing is the decision by Microsoft to license by the processor *chip*, regardless of the number of *cores* on the chip[7]. In October 2004, Microsoft announced that its server software that is currently licensed on a per-processor model will continue to be licensed on a per-processor, and not on a per-core, model.

[7] See http://www.microsoft.com/licensing/highlights/multicore.mspx

Performance Through Processor Technology

Given the background on applications and uses of dual-core technology, it is useful to describe what is meant by "performance," as different applications require different types of performance.

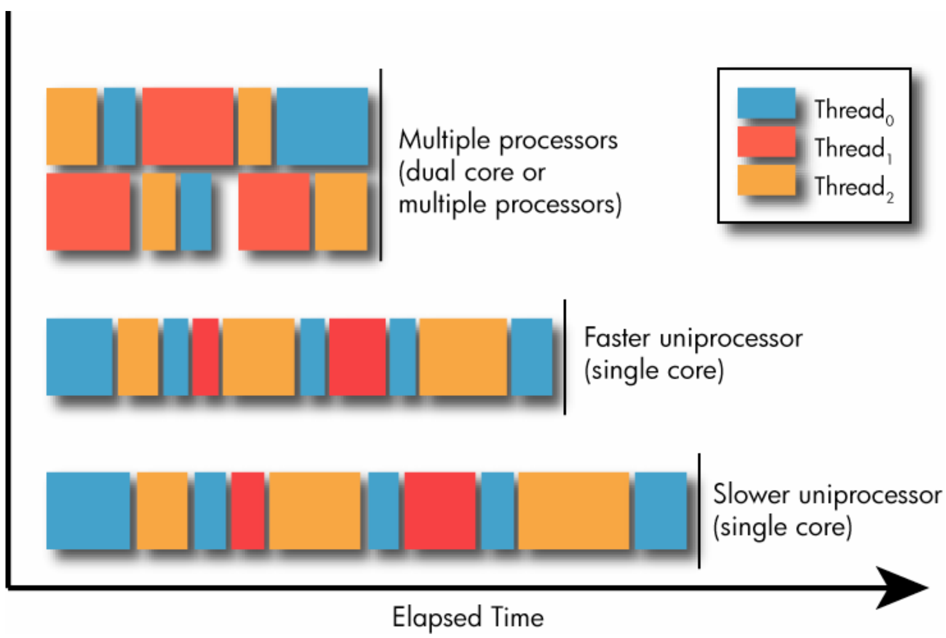
What is Performance?

One of the first difficulties we encounter in comparing performance technologies is determining what is really meant by "performance." For example, the popular standard benchmark SPECfp2000 from the SPEC Corporation is often used to determine the relative floating-point performance of a system. Assuming the benchmark has not been parallelized (see below), a multiprocessor system would record the same results on the CFP2000 benchmark regardless of whether it had one, or one hundred, processors.

Another standard benchmark, the SPECfp_rate2000, runs multiple copies of the SPECfp2000 benchmark, and provides results based on the total throughput (number of jobs) that a system is capable of executing in a fixed amount of time. In this case, the more processors the better the result. Therefore, "performance" can depend on both how fast a single job completes as well as how quickly many jobs complete.

In the past decade, much progress has been made in utilizing multiple processors to increase the performance of a single job, generally referred to as parallelization. Parallelization involves taking the compute-intensive kernel of an application and splitting it up such that it has multiple threads of execution, and will execute on multiple processors. (For example, the SPECfp2000 benchmark allows parallelization—run as such, it *would* matter if it ran on one or one hundred processors.) Further, modern operating systems (Linux, HP-UX, Windows XP) are multi-threaded, meaning they, too, will utilize multiple processors if they are available. Therefore, multiprocessor performance is often more important than would initially be thought (Figure 7).

Figure 7. Different levels of performance based on processor technology.



More will be discussed about performance in the "Applications" section below. For now, keep in mind that performance is nearly always a combination of multiprocessor throughput and single application performance. For this discussion, we will characterize performance as primarily multiprocessor throughput performance (i.e., aggregate system performance).

Power vs. Performance

As discussed, one of the most common methods of increasing workstation performance involves increasing the clock rate of the processor(s). However, there is a limit: processor power consumption, and therefore heat dissipated, grows with the processor clock rate[8]. Thus, at some point it becomes impractical to continue to increase the processor speed. Unless other variables change (e.g., the semiconductor technology employed), increasing the number of processors is the only viable method of increasing performance.

As semiconductor technology marches forward, it presents designers with the ability to put more transistors on a die. Designers are using these transistors to put more processors, called *cores*, on a single chip, rather than just putting more single-core processors into a workstation. The advantage is compactness, manufacturing efficiencies and reduced power consumption.

However, there are tradeoffs. Given that there is a practical limit to the amount of power (heat) that can be dissipated from an object the size of a processor chip, the clock speed of each core in a multicore processor will necessarily be less than that of a single core processor. Thus, the tradeoff: two or more cooler processors (with lower clock rates) can be packaged to dissipate roughly the same heat as a single, hotter processor (with a higher clock rate). Note that we are effectively ignoring the sophisticated heat management techniques employed by modern processors—such as varying frequency and voltage on the fly as determined by the workload on the CPU and the ambient thermal environment.

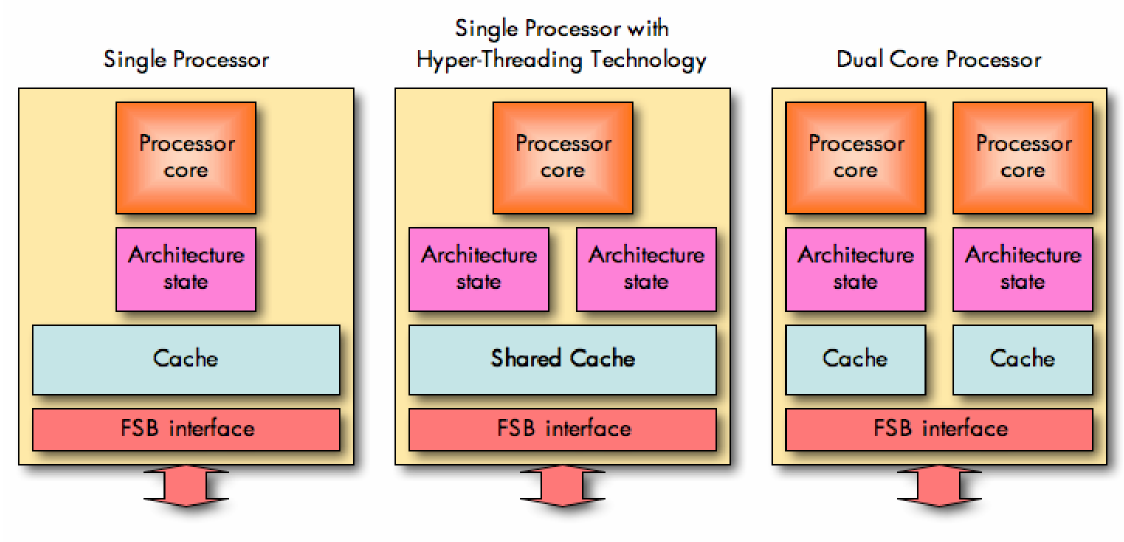
What about Hyper-Threading Technology‡?

Another way of increasing performance is to increase the efficiency of the processor. All processors have periods where they are waiting on something (usually data going to or from memory) and thus have wasted cycles. In 2003[9], Intel introduced an innovative way of increasing performance by adding logic to the processor that maintains two sets of processor states on-chip. The additional state allows one stream of instructions to work while another stream of instructions are waiting. The feature, called Hyper-Threading Technology‡ (HT Technology) is available on single-core Intel Xeon and Pentium processors; support for dual-core processors has not yet been announced.

A processor with HT Technology‡ has a physical processor core that has one set of processor execution resources (e.g., functional units such as add, multiply, etc.), and two sets of processor state information (e.g., program counter, registers, etc.)—please see Figure 8.

[8] "Dual Processors, Hyper-Threading Technology and Multi Core Systems," Intel. Also see "For More Information" section.
[9] http://www.intel.com/pressroom/archive/releases/20030623comp.htm

Figure 8. A comparison of processor technologies (on a single die) used to increase performance.



While Hyper-Threading‡ is an ingenious method of squeezing additional performance from a single die, it does have its limitations. For example, the shared processor core means that if the two threads of execution use the same resources (such as the same arithmetic functional units), performance can actually be degraded as they vie for the common resource. Indeed, performance will always be greater in a multiprocessor environment, because there are more processor execution resources available[10].

[10] See "http://www.intel.com/business/bss/products/hyperthreading/server/demo/#perf"

Conclusions

The introduction of multicore processors promises to bring higher levels of performance to workstation users. As more applications are designed for multiprocessor systems, users will benefit from reduced turn-around time on compute-intense applications, as well as better responsiveness to interactive tasks.

As an indication of the move toward multithreaded applications, note that Intel has publicly announced a strong commitment to multicore processor technology[11]. Intel forecasts that more than 85 percent of its server processors and more than 70 percent of its mobile and desktop Pentium family processors shipments will be dual-core-based exiting 2006[12].

The HP xw4300 Workstation provides users a choice of the highest performance single processor available, or a dual-core multiprocessor system with two slightly slower processors. Customers are urged to analyze their applications mix, and choose the configuration that best suits their needs.

[11] http://www.intel.com/pressroom/archive/releases/20050207corp.htm
[12] "Intel Multi-Core Processor Architecture Development Backgrounder," March 2005.

For more information

http://www.hp.com/workstations/
HP's personal workstations home page.

http://www.hp.com/workstations/pws/xw4300/index.html
The HP xw4300 personal workstation specifications.

http://www.intel.com/cd/ids/developer/asmo-na/eng/201969.htm
"Intel Multi-core Processor Architecture Development Backgrounder" white paper.

http://intel.com/cd/ids/developer/asmo-na/eng/technologies/threading/index.htm
The Intel Developer Services page on developing multithreaded applications.

http://www.microsoft.com/licensing/highlights/multicore.mspx
A statement from Microsoft on licensing issues related to multicore processors.

http://www.intel.com/info/hyperthreading/
Information including details on which processors support HT Technology.

www.intel.com/info/em64t
Information including details on which processors support Intel EM64T

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4AA0-0363ENW. May 2005