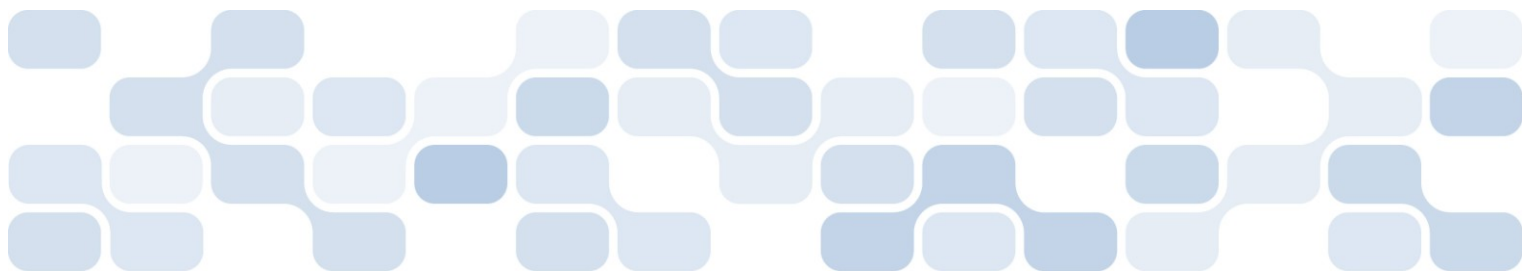


The Manycore Shift

Microsoft Parallel Computing Initiative Ushers Computing into the Next Era

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Abstract

When major qualitative shifts such as the emergence of the graphical user interface (GUI), the Internet, mobile devices, and software services transformed the computing industry, Microsoft has successfully adapted the company, products, and business models to enable the next generation of computing experiences. Each previous shift has made computing more personal, social, and mobile. The recent advances in microelectronic technology and the advent of multi-core and manycore processors are a signal that another large industry change is on the horizon. The computational power of manycore processors, new programming models and platform, and advanced research in usability promises to change the way people interact with computers. This paper describes how Microsoft and industry partners are working together to enable businesses, software and hardware vendors, and individuals to take advantage of the “manycore shift”.

The Manycore Shift: Background

In 1965, Gordon Moore famously predicted what is now known as Moore’s Law, an observation predicting that the number of transistors placed on an integrated circuit would double every 18 to 24 months, which roughly translates to increases in clock speed and microprocessor power in the same time period. This growth in processing power and in commodity hardware, along with emergence of the GUI, the Internet, mobile devices, and software services, has transformed information management and personal productivity. Each wave of new technologies has made computing more personal, social, and mobile. Personal computing has fundamentally changed the way we work, the way we learn, and the way companies conduct business.

Future improvements in hardware processing power are proceeding on a new model. Instead of deriving processing power from scaling clock speed, which eventually increases power usage and heat emission to unmanageable levels, chip manufacturers have begun to increase overall processing power by adding additional CPUs, or “cores” to the microprocessor package.

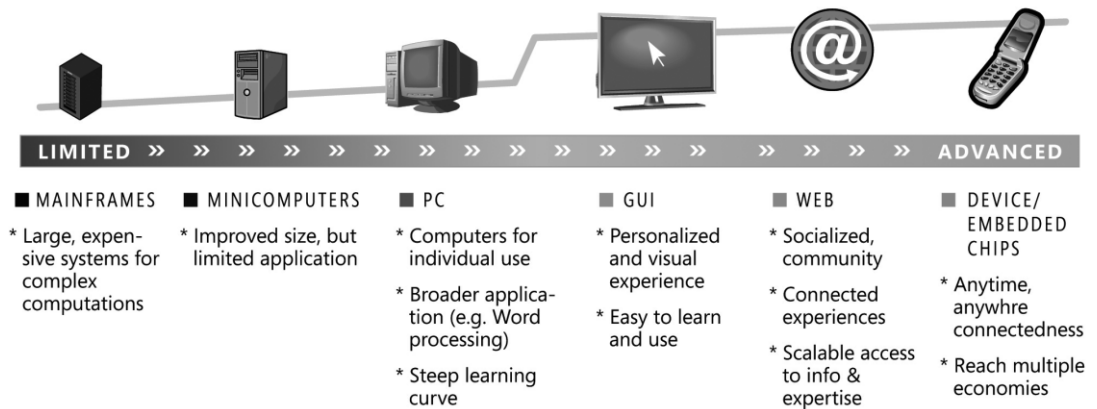


Figure 1. Computing industry shifts and their effects on user experience

Microsoft devotes significant resources into research on how to bring the benefits and opportunities made available by new microprocessor technology to the mainstream. As a result of this effort, and in response to this shift in hardware evolution, Microsoft established the **Parallel Computing Initiative**, which encompasses the vision, strategy, and innovative developments for delivering natural and immersive personal computing experiences, harnessing the compute power of manycore architecture.

Developments in Hardware

Most mainstream desktop and laptop systems now ship with dual-core microprocessors (a single processor package that contains two separate CPUs). The additional core is the beginning of a new trend, as evidenced by quad-core processors that are now entering the market. New processors will eventually come in heterogeneous configurations such as combinations of high- and low-power cores,

Multi-core and manycore systems

In general, a “multi-core” chip refers to eight or less homogeneous cores in one microprocessor package, whereas a “manycore” chip has more than eight possibly heterogeneous cores in one microprocessor package. In a manycore system, all cores share the resources and services, including memory and disk access, provided by the operating system. Microsoft and industry partners anticipate the advent of affordable general-purpose “manycore” systems in a few years.

graphical processors, cache blocks, and on-chip interconnect. By bundling many CPUs into one processor, creating what is known as a “manycore processor,” the computing industry can continue to provide dramatic increases in computing power.

Progress in Parallel Computing

Manycore systems hold the promise of delivering 10 to 100 times the processing power in the next few years. Developing applications that harness the full power of manycore systems is difficult and requires software developers to transition from writing serial programs to writing parallel programs. Applications must scale up or down according to the capabilities of the system and must adapt to changing resources and power availability. There are new pitfalls to creating robust and efficient parallel applications. Microsoft and its partners are working to deliver software architecture, tools, and applications designed to solve these problems and unlock the performance and potential offered by manycore hardware.

In addition to providing tools to enable developers to write parallel applications, Microsoft is enabling better coordination of system resources and services when executing applications.

The combination of manycore hardware with parallel computing enabled by system, platform, and tools will result in compelling new experiences: natural language, computer vision, sophisticated image analysis and manipulation, semantic analysis of data, and rendering and simulation with movie-style realism. While today’s users interact with applications on the computer’s terms, future users will benefit from applications that adapt to the user by observing and learning the user’s work behaviors, that anticipate future needs, and that apply appropriate changes to the application’s resource usage.

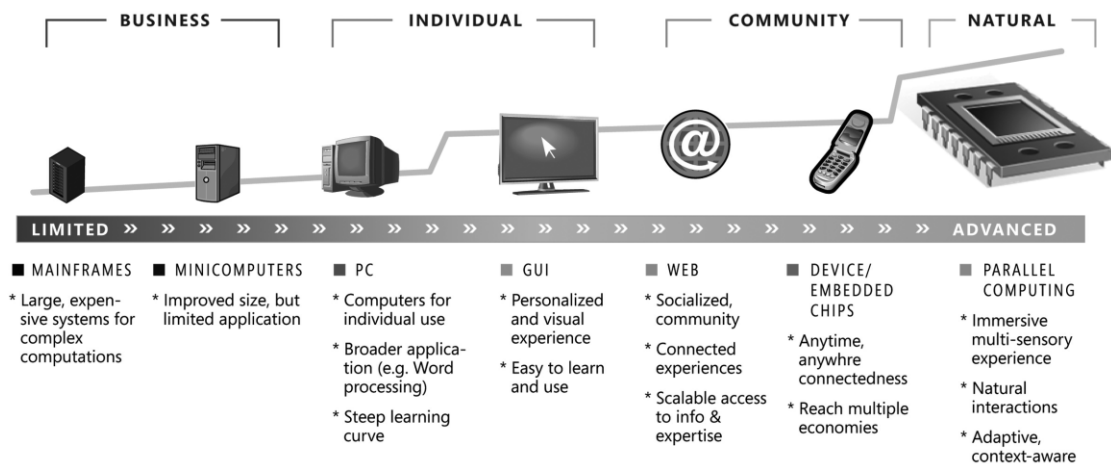


Figure 2. Parallel computing and the next generation of user experiences.

Next-Generation Personal Computing Experiences

For consumers and information workers, Microsoft's Parallel Computing Initiative will advance a new generation of experiences that expand the scope and efficiency of what users can accomplish in their digital lifestyles and work place. These experiences include more natural, immersive, and increasingly multisensory interactions that offer multi-dimensional richness and context awareness. Users will be able to accomplish complex tasks with more confidence in their decision-making. As the user's needs and environment continually change, the system will be able to compose new experiences at any given moment to support the user's goals. For example, users may experience possible scenarios including:

- **Personal modeling:** A homeowner can use powerful remodeling applications to “walk-through” 3-dimensional, photo-realistic renderings of a home renovation. The application will gather information about the home's structural, electrical, heating, and plumbing systems, providing an immersive experience of sophisticated simulation that shows precisely how choices in finish material, interior design, lighting, and space organization will appear.
- **Personalized learning:** In some developing countries, qualified teachers are in huge demand, and the teacher-to-student ratio is usually very low. Technology can bridge this gap and increase “personal” attention for students. Imagine a manycore system capable of processing a large amount of data coupled with a learning application running in the background. This system can analyze the students' learning patterns, assess their progress, and create a personalized, context-aware curriculum for them in real-time.
- **Public safety:** First responders in emergencies can use simulations to safely assess disaster areas by stitching together emergency scenes in detailed 2- or 3-dimensional renderings nearly instantaneously and with movie-like realism. These applications can use object recognition and enhanced interaction to fill in missing information. Personnel in remote locations can view real-time renderings of structural damage in a burning building or assess the predicted path of a fast-traveling wildfire. These tools will help responders to make well-informed decisions critical to rescue tactics, evacuations, and emergency response.

Business Opportunities

While parallel computing requires architects and developers to rethink the way systems are built, the manycore shift also brings significant business opportunities for organizations and hardware and software vendors.

Organizations will gain a new generation of experiences and performance that will accelerate product and service delivery, resulting in potential new business opportunities. Information workers within these organizations will be more effective in performing the vital aspects of their job: synthesizing information, visualizing complex information to make better decisions, and accelerating or re-engineering workflow. For example, organizations may see opportunities including:

- **Financial modeling:** Investment companies can provide more value to their customers by offering a powerful, personal investment modeling tool, enabling detailed 3-dimensional views and rich analytics of complex financial scenarios nearly instantaneously—all viewed from the customer's own manycore personal computer.

- Product design simulation: Manufacturing companies can enhance time to market by improving their product lifecycle management (PLM) process through 3-dimensional, integrated, and rapid simulation.

By using new tools, programming models, and infrastructure from Microsoft, developers, independent software vendors, system integrators, and value-added resellers will be able to fully unleash the power of parallel computing and create more powerful solutions faster and more cost-effectively. The ecosystem can spawn new revenue streams and, as a result, invigorate the personal computer industry. The following examples describe how software partners make enterprises, information workers, and consumers more productive in what they do:

- Create and integrate applications for vertical markets that are already in need of high compute power (capital market, manufacturing, life sciences, and so on) to help these markets achieve breakthroughs in product development.
- Deliver better productivity, training, and analysis software that aggregates and filters data for information workers, helping them to better visualize and interact with the information and increase their productivity.
- Drive consumer demand for applications with natural user interfaces, better accessibility, and immersive experiences for learning, entertainment, and modeling. These experiences enable users to expand the enjoyment, imagination, and efficiency of what they can accomplish in their digital lifestyles.

Helping mainstream users to realize the opportunities offered by manycore systems requires a radical shift in how software is developed. Currently, only a small group of the most highly skilled developers has expertise in parallel programming. Software developers need new programming models, tools, and abstraction by the operating system to handle concurrency and complexity of numerous processors.

The Microsoft Parallel Computing Initiative

Microsoft is in a unique position to support the industry to take advantage of the opportunities that the manycore shift will provide. Not only does Microsoft have established collaborative relationships with hardware and software vendors, it also has extensive experience in building tools and applications that scale from devices to desktops to datacenters with high-performance computing needs. With the reach and ability to deliver programming models, tools, and system software, Microsoft is committed to supporting its ecosystem partners so that the best solutions and value are available to customers.

Microsoft established the Parallel Computing Initiative that encompasses the vision, strategy, and innovative developments for delivering natural and immersive personal computing experiences, harnessing the compute power of manycore architecture. This initiative supports a holistic, solution-stack approach that delivers the user experiences described above. The solution stack includes the following:

- **Applications.** Applications that enable the next generation of experiences, improve productivity, and open new business opportunities are at the heart of the Parallel Computing Initiative vision.
- **Domain libraries.** A key to manycore application availability is the delivery of a broad range of system building blocks, such as math library and image-processing libraries, which decrease the time for developers to deliver rich solutions.

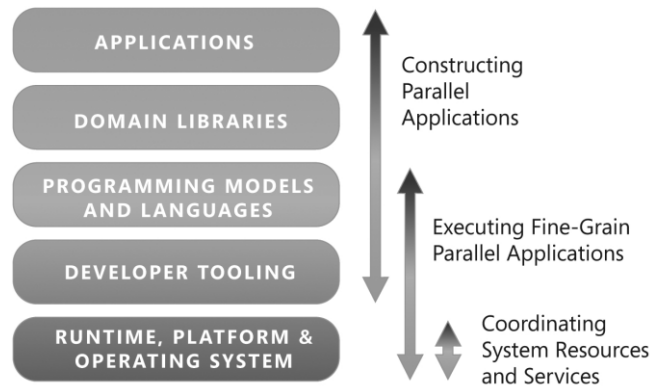


Figure 3. Solution-stack approach to deliver next generation of personal computing experiences.

- **Programming models and languages.** In the past, only expert developers would venture into building parallel applications. Microsoft will deliver programming models and languages that will enable developers of differing levels and work styles to successfully design, develop, debug, and deliver parallel software.
- **Developer tooling.** Microsoft’s philosophy of development has consistently focused on delivering a seamless, integrated development experience—combining programming models, languages, compilers, editors, and diagnostic systems to help enhance developer productivity. The Parallel Computing Initiative will build on this philosophy, helping to reduce complexity and enable developers to build efficient and correct parallel algorithms.
- **Runtime, platform, and operating systems.** Microsoft will evolve the operating system (OS) to more effectively budget and arbitrate among competing requests for available resources in the face of parallelism and quality-of-service demands. Additionally, Microsoft will continue to improve the reliability and security of the platform.

Manycore and High Performance Computing systems

High Performance Computing (HPC) uses a composition of servers (clusters) that are connected over a high-bandwidth interconnect. HPC is used in organizations to meet high performance and productivity needs, and many HPC configurations consist of thousands of nodes. HPC is a distributed and complex environment that requires sophisticated tools.

In the past, each node in an HPC cluster had a single or multi-core package. Moving into the future, Microsoft expects to see nodes evolve into a manycore system. When multi-core or manycore systems are used in a HPC cluster, customers receive the following benefits:

- Significant increase in node compute power
- Significant increase in compute power/watts consumed
- Reduction in total cost of ownership (TCO)
- Increases in density and reduction in cooling requirements

The OpenMP and MPI programming models are broadly used in the HPC environment and are supported in the Microsoft suite of developer tools. In addition, Microsoft's Parallel Computing Initiative outlines a vision for new programming models, support tools, and enhanced platform capabilities that will increase developer productivity and improve the correctness and maintenance of parallel code for developers of all skill levels. Microsoft will deliver and support new programming models, including Parallel Extensions to the .NET Framework and Parallel Extensions for C++, to enhance developer productivity and efficiency.

Microsoft's goal is to support shared programming models on both HPC systems and manycore systems for some scenarios. Developers for the HPC systems can use these programming models. The benefits to the HPC developers include the following:

- Developer skills will be transferable between both environments.
- Each multi-core or manycore node in an HPC system can use the same programming model as in a manycore client.

Today, you can deploy multi-core HPC systems to increase scale and ease of use, expanding beyond computing with Web services and high-speed networking and clustered storage support. Microsoft's Parallel Computing Initiative includes the vision for common productivity and development tools between manycore systems and HPC systems to further scale the utility of HPC.

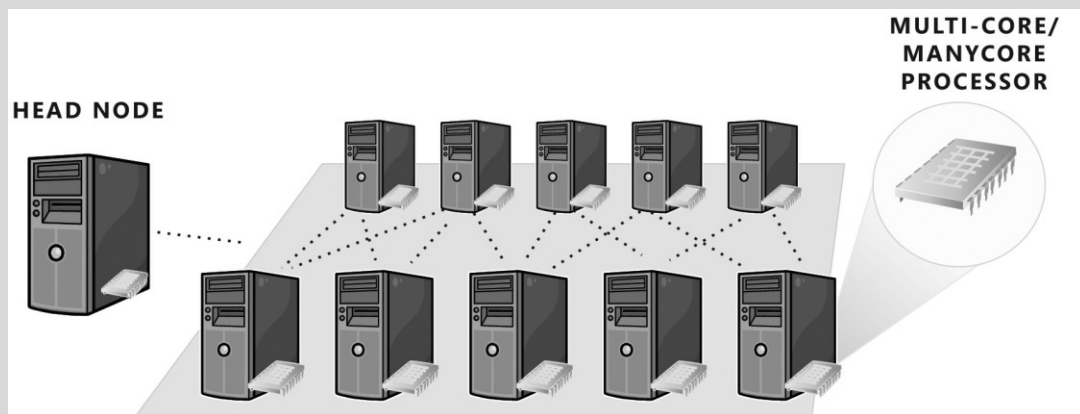


Figure 4. Multi-core HPC cluster

Initial Steps toward Realizing the Potential

Over the next several years, Microsoft will develop and release a number of ground-breaking technologies to simplify writing parallel code and to reduce the associated overhead. These technologies will allow system, component, and application developers to expend minimal effort to gain the benefits of parallelism. In the first of many steps, Microsoft will deliver prototype technologies to the public for an early preview with the goal of collecting valuable industry feedback.

The first of these technology previews will be the Parallel Extensions to the .NET Framework. Parallel Extensions will provide benefits to developers including:

- Enable developers to express parallelism easily and focus on the problem to be solved
- Improve the efficiency and scalability of parallel applications
- Simplify the process of debugging parallel applications

In the future, Microsoft will extend Parallel Extensions to languages and runtime of native code.

Summary

The manycore shift is the next significant step in how people will interact with their personal computers. It opens up the potential for the next generation of personal computer applications and experiences, and Microsoft is excited about the opportunities that manycore systems will bring.

To realize these opportunities for the personal computer user, the processes of developing software for machines with manycore processors must evolve. Microsoft established the Parallel Computing Initiative that encompasses the vision, strategy, and innovative developments to support parallel computing, and Microsoft is committed to enabling its ecosystem partners to be successful on its platforms, whether they are mobile phones, laptops, desktops, servers, or clusters. The first step is to make it easier for managed code developers to write applications that will run well on the multi-core system. In the next few months, Microsoft will start to deliver a prototype technology for preview, Parallel Extensions, to help developers begin to fully leverage the parallel platform. As developers are seeking a powerful computing platform, Microsoft's HPC Compute Cluster Server continues to deliver high productivity in a distributed cluster environment. In the future, Parallel Extensions will be available to developers for the HPC platform as well.

Through the Microsoft vision and proven ability to enable the industry, personal computer users will reap the advantages of manycore and parallel computing. They will realize the next generation—and endless possibilities—of personal computing opportunities.

Resources

For more information on the Microsoft Parallel Computing Initiative and the manycore shift, see the following:

- MSDN: "Running Queries on Multi-core Processors"
<http://msdn.microsoft.com/msdnmag/issues/07/10/PLINQ/default.aspx>

- MSDN: “Optimize Managed Code for Multi-core Machines”
<http://msdn.microsoft.com/msdnmag/issues/07/10/Futures/default.aspx>

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