Evolution of Multi-core Processors

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Abstract— *one constant in* computing is that the world's desire for faster performance is never satisfied. Every new performance advance in processor leads to another level of better performance demands from businesses and consumers. This is one of the reasons that lead to the evolving of many core and multi-core processors. This fruition has not come in a short time, it takes decades. During this epoch there is a concern for cost, eco friendly nature, size of the processor along with speed and also the scope of the computing increases in a wide range. Multi-core processors empower the development of new usage models that will enable wide range advances in everything from medicine to IT, as well as revolutionize the digital home, digital office and computer gaming.

Without performance improvement, the application developers will no longer be able to introduce new features and better interface to their applications. In this paper we are going to expose the multi-core processor characteristics, types and reasons behind their evolution.

***Keywords*— processor, many core, performance, multicore, evolution**

I. INTRODUCTION

A processor or microprocessor is a small chip that resides in computer and other electronic devices. It is considered as the intellect of a computer. Its basic job is to receive the input and provide the appropriate output. While this may seems like to be a simple task, modern processors can handle trillions of calculations per second.

Modern CPUs often include multiple processing cores, which work together to process instructions. While these cores are contained in one physical unit, they are actually individual processors. In fact, if you view your computer's performance with a system monitoring utility like Windows Task Manager (Windows) or Activity Monitor (Mac OS X), you will see separate graphs for each core of the processor.

Processors which include two cores are called dual-core processors and those with four cores are called quad-core processors. Some high-end workstations contain multiple CPUs with multiple cores, allowing a single machine to have eight, twelve, sixteen or even more processing cores.

In addition to general purpose cores, multi-core processors will eventually comprise specialized cores for processing communication protocols, speech recognition algorithms, graphics and more. The improvement in the performance gained by the multi-core processor depends on the software algorithms used and their implementation.

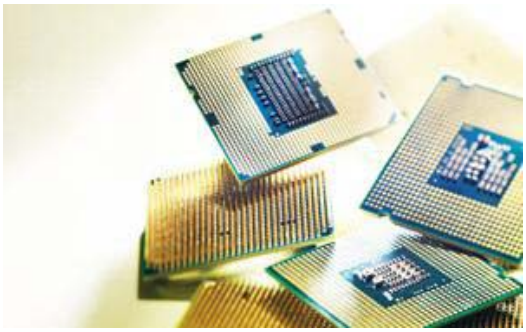

Fig 1: multicore processors

II. TYPES

Modern processors are typically designed by two distinct companies Intel and AMD (Advanced Micro Devices). They hold the major share of the market of processors manufacturing. Intel processors are most commonly used in prefabricated computer systems, such as those from Dell, ASUS, HCL and HP etc. The company focuses on two different lines of processors: the Pentium and the Celeron. Pentium processors are the

larger microchip style that works on most desktops and some laptops. They can handle high-demand processing, such as that found in 3D gaming, video editing and other multimedia-intense applications. Celeron processors are other multimedia-intense applications. Celeron processors are more compact models with the ability to run a basic computer more efficiently and cost-effectively.
AMD's line of computer processors can be found in prefabricated models and are most usual with home-built systems or specially designed machines. AMD was the first to build a 64-bit processor, capable of high-end applications use with graphic intensive operations. The previous industry standard was 32-bit processing. Some AMD processors offer built-in virus protection.

A. Characteristics to differentiate a processor

By using the following basic characteristics we can differentiate microprocessors:

1) *Instruction set (ISA)*: The set of instructions that the microprocessor can execute.

2) *Bandwidth*: The number of bits processed in a single instruction.

3) *Cores*: number of cores varies depend on the type of processor, dual core contains 2 cores and quad core contains 4
cores, octa core contains 8 cores etc.

B. Architecture

While considering the architecture of a computer processor, there are only a few key factors to think about. Whether the processor has a 32-bit or 64-bit core determines the capability of the processor that run your software suitably or not. The size of cache memory on die processor is also of importance, as this integrated memory space is used to hold the processor instructions before execution. Finally, is the system a single, dual, quad or octa core processor? While multi-core processors do have their advantages, there is still a lack of software able to utilize multi-core processors.

C. Clock Speed

The clock speed of a computer processor determines the rate at which a processor executes instructions on data. Today this rate of execution is expressed in billions of instructions per second. Though having a computer processor with a high clock speed is gainful, it alone is not the only factor that dictates overall system performance. If we consider processors run at different clock speeds, a faster dual-core processor can perform better than a slower quad-core processor.

D. Performance

The largest boost in performance will likely be noticed in enhanced response time while running CPU-intensive processes like antivirus scans, ripping/burning media (requiring file conversion), or searching for files/folders. For example if the automatic virus scan initiates while the movie is being watched, the application running the movie is far less likely to be starved of processor power, as the antivirus program will be assigned to different processor core than the one running the movie playback.

Additionally, the processor's performance is dependent on hardware and software (program) limitations. A dual-core processor will not be twice as fast as a single-core that has the same clock speed; the two cores work on one task, as opposed to one core that does a task twice as fast. Additionally, software needs to be programmed to take advantage of the multiple cores, otherwise only one core will handle the task. Video-editing software, 3-D-rendering software, and games can get a significant performance boost from multi-core processors when they are programmed to take advantage of the hardware.

III.MULTITASKING

Because the cores act independently in a multi-core processor, they are better outfitted to perform multiple tasks at the same time when compared to single-core processors. The variation between dual-core processors and other multi-core processors is most noticeable when multitasking. Multi-
core processors can perform multiple tasks at the same time better than single core processors. For example, if you are browsing the web, checking email constantly and calculating the 30,000 cells in your latest spread sheet all at the same time, having multiple cores means that core 1 can be working on the email, core 2 on the flash webpage you are viewing and

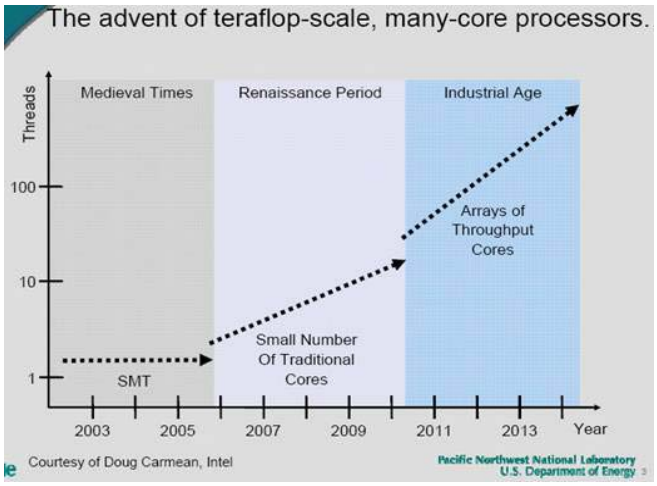

Fig 2: The above graph shows the increasing the number of threads in the evolution of many-core processors [2].

cores 3 and 4 on the spreadsheet. When you have a single task that needs to be done right away, multiple cores can help you by breaking the task into smaller chunks, working on each chunk in parallel, and thus you'll get your work done faster. An example of this is the 3D interpretation of a still image. Most modern rendering programs can split the task into blocks, then pack those blocks to each core as needed, and then the final image is put together at the end.

IV.FRUITION OF MULTI-CORE

Up to the starting of 21st century, single core processors performance was increased due to the result of increasing of transistor density on the die. However as the speed of the transistor increases, their power consumption is also increased. Most of this power is dissipated as heat which results in increasing the capacity of cooling fans and it was expensive. Processor manufacturers started research to find out the alternative for additional processing.

In the search for additional processing power for personal computers, the improvement in super computer raises a very good question: rather than solely looking to increase the performance of a single processing core, why not put more than one in a personal computer? In this way, personal computers could continue improve in performance without the need for continuing increase in processor clock speed. In 2005, due to increasingly competitive marketplace and few alternatives, leading CPU manufacturers began offering processors with two computing cores instead of one. Over the following years, they followed this development with the release of three, four, six and eight-core central processor units. Sometimes referred to as multi-core revolution, this trend has marked a huge shift in the evolution of the consumer computing market.

Today, it will be relatively challenging to purchase a desktop computer with a CPU containing but a single computing core. Even low-end, low-power central processors are having with two or more cores per die. In the year 2008, intel released two quad core green processors (L5420, L5410) for servers and work stations which runs faster than previous quad core processors without consuming any more power [3]. These types of processors are highly recommendable for the sustainable development.

V. HOMOGENEOUS VS HETEROGENEOUS CORES

Architects have debated whether the cores in the multi-core environment should be homogeneous or heterogeneous, and yet there is no definite answer. In homogeneous cores, all the cores are having exactly the same cache sizes, equivalent frequencies, functions etc. However in heterogeneous cores, each core may have a different memory model, frequency, functions etc. Homogeneous cores are easier to produce since each core contains same hardware and same instruction set is used across all the cores. But are they the most efficient use of multi-core technology?

Each core in a heterogeneous environment could run its own specialized instruction set and have a specific function. A heterogeneous model could have a large centralized core built for generic processing and running an OS, an audio core, a cryptographic core, a communications core, a core for graphics, a core for enhanced mathematics and the list goes on. [5]This model is more complex but may have power, efficiency and thermal benefits that outweigh its complexity. With major manufacturers on both sides of this issue, this debate will stretch on years to come.

VI. EXAMPLE

Let us take the example of squaring of numbers from 0 to 63. The output will 0,1,9,16.....etc. we know that squaring means multiplication of a number by itself. This operation involves 64 multiplications.
Let us assume each multiplication takes 2 nano seconds(ns).
On a single core total time taken for execution is 128 ns(64*2) as it contains single processor.

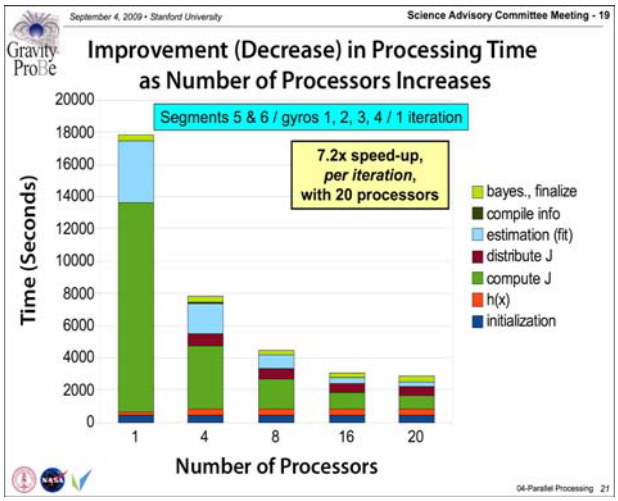

Fig 3: The above graph shows the improvement in processing time as number of processors increases [7].

For a multicore take example of quadcore. A quadcore contains 4 processors and 4 operations can be performed simultaneously. So, each processor can perform 16 multiplications. Here total time for execution is 32ns (16*2).

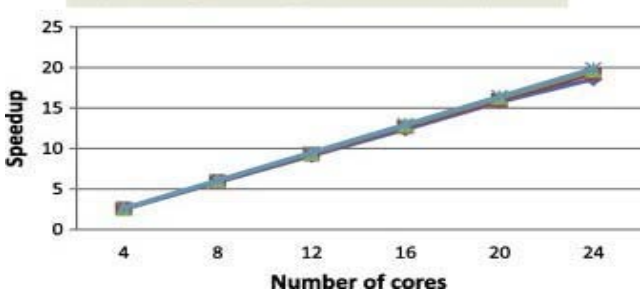

Fig 4: The above graph shows the increasing of speedup as the number of core increases [8].

VI. MULTI-CORE CHALLENGES

Regular software applications will run on a multi-core processor and in fact, they will run more proficiently, especially in multitasking scenarios. To exploit the power of a multi-core system, the operating system must be acquainted with multi-threading, and the software must be written using simultaneous multi-threading technology (SMT).

A multi-core processor must have the appropriate hardware to recognize and support it. Older computer systems may not be well-suited with newer multi-core technology and in these cases a new motherboard is necessary, one that is compatible with the multi-core processor. Purchase of a new motherboard may also involve purchase of other new hardware, depending on the motherboard's configuration.

VII. FUTURE TRENDS

In future, Computers will contain thousands of execution units per chip, either homogeneous or specialized for particular purposes. The parallelization of application workload is about to become the most significant strategy for speedup and scale up in every kind of application. The future research for multi-core enabled applications must be determined from two sides - a better expression of hardware, and a better design of software.
The increasing variety of multicore processor architectures must be abstracted in better models, in order to allow an appropriate software design. Software on the other side must be analysable and designable according to the

parallel workload it produces. This include the formulation of design patterns and algorithms equipped for parallel execution. Some applications will be scalable by default 3D graphics, scientific computing or high-throughput server computing.

VII.CONCLUSION

Multi-core processors are an important innovation in the microprocessor timeline. The future requires more and more high processing, optimization and differentiation in the design process for systems that contain different types of processor, while supporting the requirements of the software ecosystem. Energy efficiency and environment sustainability are the key differentiators in the world of processing and will be the key drivers for the future of computing. Anyone who ignores this evolution will simply get left behind. What we were enjoying the computing today is nothing but the result of processing power of multi-core processors.

As more applications are developed by taking the advantage of multi-core, the designs will continue to evolve to offer desire features of the application to the user. All of this makes extensively improved user experiences in both home and business environments.

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