MULTICORE PROCESSOR TECHNOLOGY- ADVANTAGES AND CHALLENGES

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Abstract

Until recent times, we have worked with processors having a single computing/processing unit (CPU), also called a core. The clock frequency of the processor, which determines the speed of it, cannot be exceeded beyond a certain limit as with the increasing frequency, the power dissipation increases and therefore the amount of heating. So manufacturers came up with a new design of processors, called Multicore processors. A multicore processor has two or more independent computing/processing units (cores) on the same chip. Multiple cores have advantage that they run on lower frequency as compared to the single processing unit, which reduces the power dissipation or temperature. These multiple cores work together to increase the multitasking capability or performance of the system by operating on multiple instructions simultaneously in an efficient manner. This also means that with multithreaded applications, the amount of parallel computing or parallelism is increased. The applications or algorithms must be designed in such a way that their subroutines take full advantage of the multicore technology. Each core or computing unit has its own independent interface with the system bus.. But along with all these advantages, there are certain issues or challenges that must be addressed carefully when we add more cores. In this paper, we discuss about multicore processor technology. In addition to this, we also discuss various challenges faced such as power and temperature (thermal issue), interconnect issue etc. when more cores are added.

Key Words: *CMP (Chip Multiprocessor), Clock, Core, ILP (Instructions Level parallelism), TLP (Thread level Parallelism).*

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1. INTRODUCTION

The multicore processor comprises of two or more cores or computational/processing units that operate in parallel to read and execute instructions. These multiple processing units or cores are fabricated on a single die. So, its also called a Chip Multiprocessor (CMP). The key factor about multicore processor is that it gives the same performance of a single faster processor at lower power dissipation and at a lower clock frequency by handling more tasks or instructions in parallel. [1] This enhances the ILP (Instructions Level Parallelism). The performance of a processor is a function of three major factors, which includes IPC (instructions per cycle), CPI (clock cycles per instruction) and clock cycle (or clock frequency). The IPC can be increased by increasing ILP and TLP (thread level parallelism). The CPI can be improved by the techniques of pipelining. But there is a limiting factor towards increasing the clock frequency. [2]

The dynamic power dissipation is given by-

$$P = QCV^2f \quad (1.1)$$

- Q- Number of Transistors
- C- Load Capacitance
- V- Supply Voltage
- f- Clock Frequency

So, if we increase the clock frequency, the power dissipation increases which in turn causes overheating. So, the idea of multicore technology is to use multiple cores instead of one (like single processor) at a comparatively lower frequency, but an overall improvement in the performance is delivered through multiple cores operating simultaneously on multiple instructions.[1] Multicore processors work on multiple instructions and multiple data. Multiple cores execute multiple threads (multiple processes/instructions) while using different parts of memory (multiple data). This enhances TLP. The main memory is shared by all cores. Each core is associated with its own cache and they all share the system bus.[3]

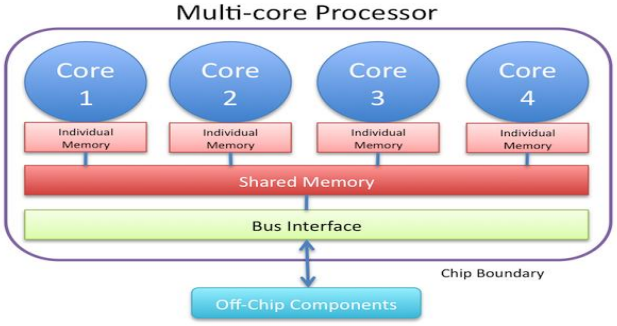

Fig.1. Quad cores sharing memory and bus interface

Intel came up with its first dual core processor in 2005. A dual core processor contains two cores- (Intel Core Duo, AMD Phenom II X2), a quad core processor has four cores (Intel core i5 and i7 processors, AMD Phenom II X4), a hexa core processor has six cores(AMD Phenom II X6, Intel Core i7 Extreme Edition 980X), a Octa core processor has eight cores (AMD FX-8350, Intel Xeon E7-2820), a deca core has ten cores (Intel Xeon E7 2850) or more. There are various topologies to interconnect cores such as Ring topology, Bus topology, Two-dimensional mesh and crossbar. The choice of a particular topology is a crucial factor as it affects performance parameters like speed, latency etc. The type of topology also affects area consumed on a chip and power dissipation.

In addition to this, multicore technology uses homogeneous and heterogeneous cores. In homogeneous configuration, all the cores are identical and each core has same hardware. These cores use divide and rule approach for improving the performance by dividing a more complex application into less complex applications and execute them simultaneously. There are many other benefits of this approach such as reusability, simpler design etc.[1]

In heterogeneous cores, there are dedicated application specific cores that work on specialized applications. For example a system comprising of a DSP core that handles a multimedia application requiring intensive mathematical computations, while other cores handle some other applications simultaneously. Heterogeneous core is more complex, but has its own benefits also. Multicore Processors sometimes take advantage of both homogeneous and heterogeneous configurations to improve performance. The IBM multicore processor, CELL uses this approach. [1] Various applications that benefit from multicore technology are multimedia applications, DSP , servers, graphics, compilers etc. and also applications which exhibit thread level parallelism. The efficient use of multicore technology requires high level of parallelism.[3] Some multicore processors allow one or more cores which are not required at times to turn off to save power.

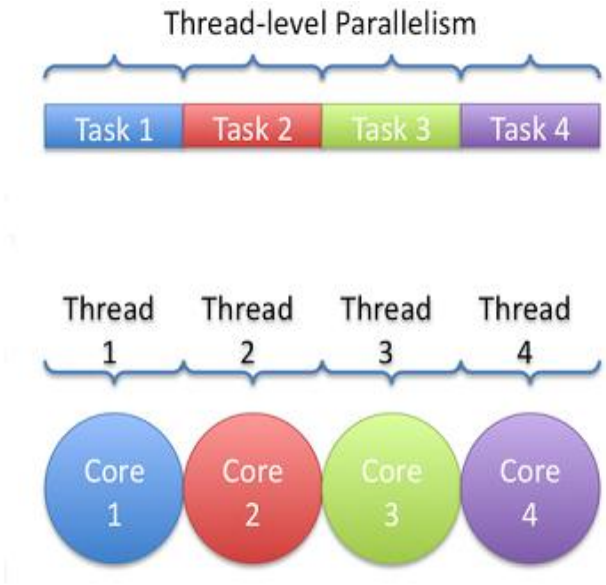

Fig.2. Multiple threads in different Cores[3]

The performance of a multicore processor strongly depends on the design of algorithm or application which is governed by Amdahl's Law. This law was given by Geve Amdahl, a computer architect. This law is used to compute the theoretical maximum speed with multiple processors in parallel computing. This law states that the speed of a process in parallel computing is limited by the time needed for the sequential part of the process. For example , if a process requires X hours to complete on a single core, and a portion of the process that takes Y hours to execute which can not be parallelized, while remaining (X-Y) hours can be parallelized, then regardless of the number of processors, the minimum time required for the execution can not be less then (X-Y) hours.[4]

2. MULTICORE ADVANTAGES

The good processing speed of the multicore processors is due to the multiple cores which operate simultaneously on instructions, at lower frequency than the single core. At the same clock frequency, the multicore processor will process more data than the single core processor. In addition to this, multicore processors deliver high performance and handle complex tasks at a comparatively lower energy or lower power as compared with a single core, which is crucial factor in appliances such as mobile phones, laptop etc. which operate on batteries. Also, since the cores are fabricated close to each other on the same chip, the signals travel shorter distance between them due to which there is less attenuation of signals. Since the signals don't attenuate much, more data is transferred in a given time and there is no need of repeating the signals

3. CHALLENGES OF MULTICORE PROCESSOR

So far, we have seen the benefits of multicore technology but there are some problems that arise when more cores are added. The various challenges that are faced with the addition of new cores are power and temperature issues, the level of parallelism in the application or algorithms, interconnect issues etc. Now we discuss the challenges in detail:-

3.1 Thermal Issues (Power and temperature):

- To reduce the unnecessary power consumption, the multicore design also has to make use of a separate power management unit that can manage or control unnecessary wastage of power. For this to happen, the power management unit has to turn off or shut down the cores which don't operate at times or the cores that are not required at times. Also, the cores run at a comparatively lower frequency than a single processor to reduce the power dissipation.
- The architecture of the core must be such that the amount of heat generated in the chip is well distributed across the chip. The power consumption is also a function of number of transistors on a chip. When more cores are added, the transistor density also increases which contributes to the power consumption.

The core which overheats in a multicore configuration is called a hot-spot.

- There are various ways to tackle the issue of power dissipation and temperature such as thread migration, DVFS (Dynamic Voltage and Frequency Scaling) etc. In the thread migration technique, a high power consuming process or thread is moved to a different core and a low power consuming process or thread is moved to an overheated core. Also, in order to cool an overheated core, the work which is being handled by the overheated core is divided among other cores.
- In DVFS (Dynamic Voltage and Frequency Scaling) technique, voltage and frequency of the hot core is reduced since the power dissipation or heating is a function of both voltage and frequency. This slightly affects the overall performance also.[2]

3.2 Level of Parallelism:

One of the biggest factors affecting the performance of a multicore processor is the level of parallelism of the process/ application.

- The lesser the time required to complete a process, better will be the performance. Performance is directly related to the amount of parallelism because more the number of processes that can be executed simultaneously more will be the parallelism. Parallelism can be considered at two levels ILP and TLP.
- TLP increases overall parallelism by breaking a program into many threads (Small Processes) and execute them simultaneously.
- To achieve a high level of parallelism and an overall high performance, software developers must write such algorithms that can take full advantage of multicore design. In other words, all the cores should be used in the most efficient manner. If the algorithms written are not compatible with the multicore design, then it may happen that one or more cores starve for data. In such a case, the process will run on one of the cores, while other cores will sit idle. So, in a nutshell, the success of multicore technology strongly depends on the way the algorithms are written. Also, companies like Microsoft and Apple have designed their operating systems which can run efficiently on multicore configuration.

3.3 Interconnect Issues:

Since there are so many components on chip in a multicore processor like cores, caches, network controllers etc., the interaction between them can affect the performance if the interconnection issues are not resolved properly. In the initial processors, bus was used for communication between the components. In order to reduce the latency, crossbar and mesh topologies are used for interconnection of components. Also, as the parallelism increases at the thread level, communication also increases off-chip for memory access, I/O etc. For issues like this, packet based interconnection is actively used. This packet based interconnection has been used by Intel (Quick path interconnect) and is also being used by AMD.[1][2]

4. CONCLUSIONS

In this paper, we reviewed the basic concepts of the multicore technology. We studied that it is possible to increase the performance of a processor without increasing the clock frequency, by simply adding more cores. The limitation of a single core processor at a high clock frequency has opened the gates for multicore technology and has become the trend of the industries today. However, adding more cores also gives rise to certain issues or challenges that must be carefully addressed in order to get the most out of multicore technology. We also studied various challenges associated with increasing the number of cores like power and temperature (thermal issues), level of parallelism, interconnect issues etc. The applications/ algorithms which run on multicore environment must be compatible with it. Research is constantly going on in the areas like developing more efficient applications/ algorithms for multicore environment and also in other areas in order to get the maximum performance throughput from multicore processors. Industries are constantly working towards achieving better and better performance from multicore processors.

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