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Multi-Core Processors in Smart Phones

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***Abstract*— Nowadays, Personal Computers with many cores are common because of high performance demand and increased power consumption. People want to use mobile phones like they use their personal computers. They want a high performance, less battery consuming Smartphone. There are many manufacturers of multi-core processors for mobile devices. We will see how manufacturers get better performance by increasing number of cores in mobile devices. Vendors used either symmetric multi-core processors or asymmetric multi core processors. We have done comparative analysis of various multi core processors on the basis of their benchmark scores.**

Index Terms — multicore processor, core count, multicore architectures, many-core architecture, symmetric multicore, asymmetric multicore, benchmarking performance models

I. INTRODUCTION

Modern computing machines are more efficient than those of the 90's only possible because of many innovations in the field of microprocessors. Nowadays, having Many Cores in Personal Computers is a new trend. In a market, mostly PCs come with a multicore processor. It came into the picture that frequency of single core cannot be further increased [1]. Increasing its frequency demands more power consumption and can result in laggy performance [2]. Multicore Processors in PC solved this problem by adding more cores whilst maintaining the frequency producing efficient results at low power consumption [2].

Nowadays, people are migrating from PC to the smartphones for their usual tasks. Smartphone is a cellular telephonic device which performs many tasks of computer having internet access and an interactive operating system [3]. Therefore, mobile phones are becoming prominent gadget for everyone. Usual tasks include playback of high-definition 4K videos, graphic-rich gaming, photo and video editing and real-time video conferencing [4]. To ensure the quality of experience smartphone should have a good processor.

In the modern era, mobile phones are getting more and more advanced by making use of the latest technologies available. To manage such powerful hardware user requires a powerful processor and a good battery. But there are many constraints on the size of the battery as its size can't increase much if the smartphone manufacturers increase battery size the smartphone will not be as handy. The clock frequency of a processor can't exceed beyond a certain limit as on increasing frequency the power dissipation will increase and so the heating issues [2].

To depreciate the utilization of the battery we can increase the cores of the CPU which will use less power as compared to the single core processors [4]. For example, Xiaomi Redmi Note 3 which has a Hexa-core processor has processing power equivalent to six Galaxy Y Duos having single core processors together.

II. MULTICORE PROCESSORS IN MOBILE PHONE

In 2010, first dual core was given by NVIDIA used in LG Optimus phone featuring 1GHz ARM CORTEX A9[5].

A multi-core processor is a prominent component of mobile phone which is composed of two or more units which read and execute instructions known as cores [6]. The cores are integrated onto a single IC die on single chip package. Instructions used are ordinary but multiple cores can run multiple instructions at a time which increases the speed of the application [6].

The use of multiple cores on the die allows cache coherency circuitry to function at the higher clock rate [7]. Fabricating homogeneous and heterogeneous CPUs on a single die improves Bus Snooping performance which actually means that time taken by signals between different CPUs will be shorter which allows more data can be sent in same time via high-quality signals [8].

Multiple core CPU gives higher performance at a lower energy which is useful in mobile devices and parallel code can be implemented in these devices. This is very useful for the devices that use batteries as each core in multi-core uses less percentage of battery as compared to an individual large single cored CPU [6].

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Significant improvement in response time has been noticed whilst performing many shared and consecutive tasks.

I. TYPES OF MULTICORE PROCESSORS IN MOBILE PHONE

a) Homogeneous Multi-Core Processor (Symmetric Multicore):Homogeneous multi core processor consists of identical CPU that possesses same architecture. Each Core shares a single Operating System. Symmetric CPUs share the physical memory available among all the cores. In market various vendors like Samsung, Snapdragon, Intel manufactures SMP based processors. For example, Samsung Exynos 5 Dual. *Reference Fig. 1.*

b) Heterogeneous Multi-Core Processor (Asymmetric Multicore):Asymmetric multicore processor consists of multiple CPUs with same or different architecture. "Different CPUs can have same clock speed but same CPU should have different clock speed to be asymmetric". Each core has its own address space. Each core can have a different operating system or can share same operating system [9]. Symmetric Multiprocessing is needed when more CPU power is needed by an embedded application to manage its workload. Asymmetric architecture based CPUs are manufactured by Snapdragon, Mediatek, Samsung. For example, Snapdragon 808 features a octa-core processor having Quad-Core Cortex-A72 and quad-core Cortex-A53.Refer Fig. 2.

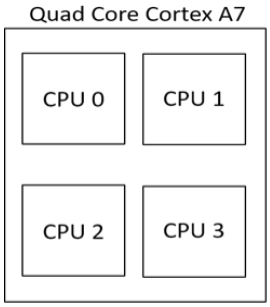

Fig. 1. Quad Core Cortex A7 having 4 symmetric CPU cores

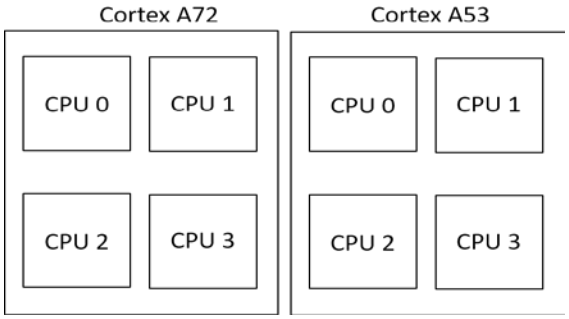

Fig. 2. Quad-Core Cortex A72 and Quad-Core Cortex A53 having different architectures forms an asymmetric processor.

TABLE I. LITERATURE REVIEW OF VARIOUS PROCESSORS IN MOBILE

Vendor	CPU	ARM	Cores	Frequency	Fabrication	Smartphones
Samsung [10]	Exynos 3 Single	Cortex-A8	1	1.2GHz	45nm	Samsung Galaxy S, Nexus S,
	Exynos 4 Dual 4212	Cortex-A9	2	1.5GHz	45nm	Samsung Galaxy SII, Note (International)
	Exynos 4 Quad	Cortex-A9	4	1.6 GHz	32nm	Samsung Galaxy SIII
	Exynos 5 Dual 5250	Cortex-A15	2	1.7 GHZ	32nm	Samsung Nexus 10
	Exynos 5 hexa	Cortex A15+ Cortex A7	2+4=6	1.7 and 1.3	28nm	Samsung Note 3 Neo
	Exynos 5410	Cortex-A15 + Cortex A7	4+4=8	1.6 and 1.2	28 nm	Samsung Galaxy S 4
	Exynos 7420	Cortex A57+ Cortex A53	4+4=8	2.1 and 1.5	14 nm	Samsung Galaxy S6,S6 edge+, Note 5

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	Exynos 8 Octa 8890	Cortex-A53 and Mongoose	4+4=8	2.3 and 1.6	14 nm	Samsung Galaxy S7, Note 7
Apple[11]	Apple A5	Cortex A9	2	800MHZ	32nm	ipad 2,iphone 4s
	Apple A6	Swift(ARMv7-A)	2	1.3 GHZ	32nm	iphone 5 and 5c
	Apple A7	Cyclone (ARMv8-A)	2	1.3-1.4 GHZ	28 nm	iPhone 5s,iPad Air,iPad mini 2
	Apple A8	Typhoon (ARMv8-A)	2	1.1-1.5 GHZ	20 nm	iPhone 6,6 Plus
	Apple A9	Twister(ARMv 8-A)	2	1.85 GHZ	16nm	iPhone6s, 6S Plus
	Apple A10 Fusion	2 x Hurricane + 2 "Low Power"	4	2.34GHZ	16 nm	iphone 7,7Plus
Qualcomm Snapdragon[12]	Snapdragon s1	ARM Cortex A5	1	1GHz	45 nm	Coolpad, LG optimus, Galaxy Ace, Sony Xperia
	Snapdragon 4	dual-core Krait	2	1.7GHz	28nm	HTC One, Blackberry, Motorola, Nokia Lumia, Samsung Galaxy S3, SonyXperia Z
	Snapdragon 400	ARM Cortex-A7	4	1.2 GHz	28nm	Galaxy S4 Duos
	Snapdragon 430	8x ARM Cortex A53	8	1.4 GHz	28nm	Redmi 3s
	Snapdragon 600	4x Qualcomm® Krait™ 300 CPU	4	1.7 GHz	28nm	Samsung S4 deluxe
	Snapdragon 615	8x ARM Cortex A53	8	1.5 GHz + 1.0 GHz A53	28nm	Desire 820
	Snapdragon 650	2xA72 + 4xA53	6	1.7GHz +1.4 GHz	28nm	Redmi note3
	Snapdragon 800	4x Qualcomm® Krait™ 400 CPU	4	2.26 GHz	28nm	Lg G2
	Snapdragon 808	2xA57 + 4xA53	6	1.82GHz + 1.44 GHz	20nm	Moto X Style
	Snapdragon 810	4xA57 + 4xA53	8	2.0GHz + 1.55 GHz	20nm	Xperia z5

	Snapdragon 820	4x Qualcomm® Kryo™ CPU	4	2.15 GHz + 1.6 GHz Kryo	14nm	One Plus 3

III. Comparison of Multicore CPUs

We studied various symmetric as well as asymmetric multicore CPU used in mobile phones provided by various vendors. Further, we have done comparative analysis of CPU cores and their performance on the basis of benchmarks.

A Benchmark is a hardware and software performance test. We have used Geekbench scores as performance scores for various multicore CPU used in mobile phones. Geekbench 4 scores are calibrated against intel i7 6600U which has baseline score of 4000[13].

A. Comparison of Symmetric Processors in mobile phones

In Fig.3, we have studied comparison of performance of smartphones based on multicore architecture various manufacturers. A single Core, Dual Core and Quad core chip from every manufacturer have been studied and benchmarked. From Snapdragon we picked Snapdragon S4 for dual core category and Snapdragon 400 for Quad Core category. in Samsung, for single core, we picked Exynos 3110, Exynos 4212 for dual core and Exynos 4 Quad for QuadCore. In Mediatek we took MT6572 for the dual-core CPU category and MT6852 for the quad-core CPU category. All the above mentioned SoC's follows Symmetric CPU architecture.

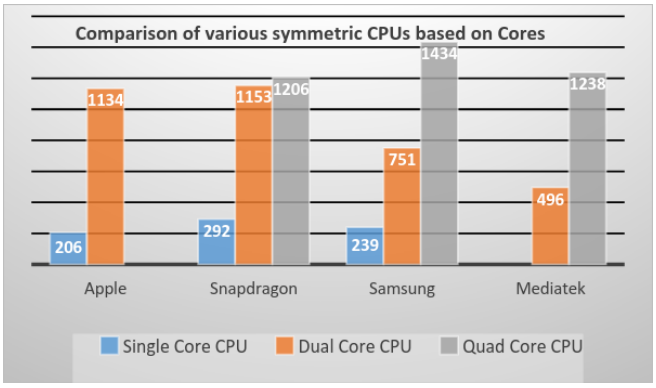

Fig. 3. .

Apple A4 consists of ARM Cortex A8 CPU operating at 800MHz clock rate with 32 KB L1 cache can be found in iPhone 4. Apple A6 consists of ARM-v7-A compatible CPU operating at 1.3GHz clock rate with 32 KB L1 cache can be found in iPhone 5 and iPhone 5c. The performance of Dual core variant is much greater than the single core variant and emphasizes power efficiency [11].

Snapdragon S4 consists of a dual core ARM v7 CPU instruction set operating at 1.7 GHz clock rate can be found in HTC Desire 520 while Snapdragon 400 consists of quad-core ARM-v7 compatible CPU operating at 1.5GHz clock rate found in Galaxy S4 Duos [12].

Exynos 3110 consists of single core ARM-v7 compatible Cortex A8 CPU architecture operating at 1.1 GHz clock rate can be found in Samsung Galaxy S and Google Nexus S while Exynos 4212 consists of dual-core ARM-v7 compatible Cortex A9 CPU architecture operating at 1.5GHz clock rate found in Galaxy Note and Exynos 4412 consists of quad-core ARM-v7 compatible Cortex A9 CPU architecture operating at 1.4 GHz clock rate and 64-bit memory technology can be found in Samsung Galaxy S3[12].

It has been observed from the above figure that the performance and the power efficiency of the CPU increases with increasing number of cores in the CPU and it also improves multi-tasking.

B. Asymmetric Processors in mobile phones

In fig 1.4, Snapdragon 808 in Moto X Style features a hexa-core SoC clocked at 2GHz with the 64-bit data bus and both Harvard and ARM Big-LITTLE CPU Architecture. It supports ARMv8-A ISA and RISC CPU Structure. In Snapdragon 808, hexa-core is essentially the combination of dual 64-bit Cortex A57 MP Core and quad 64-bit Cortex A-53 MP Core. Octa-Core Snapdragon 810 features four Cortex A57 MP Core and four Cortex A53 MP Core clocked at 2.5 GHz. It supports 64-bit data bus. Both SD810 and SD808 uses 20nm Semiconductor process.

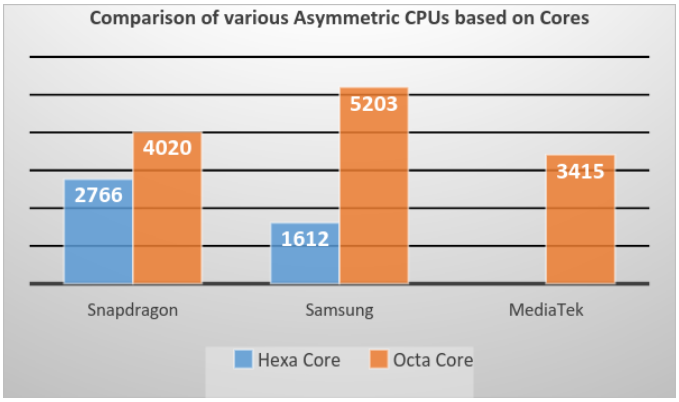

Fig. 4. .

Samsung Exynos 5 Hexa features a 6 core CPU with two Cortex-A15 with clock speed 1.7 GHz and four Cortex-A7 MP Core withclock speed 1.3 GHz.It supports ARMv7 ISA and RISC CPU architecture with a 32-bit data bus can be found in Samsung Galaxy Note 3 Neo. While the octa-core variant Samsung Exynos 8890 features quad Cortex A53 at 2.5 GHz and quad Mongoose at 1. 6GHz.It uses 14nm fabrication process and supports DDR4 memory. It supports ARMv8-A ISA and follows both ARM big. LITTLE and Harvard CPU architecture.It can be found in Samsung Galaxy S7.

MediaTek MT6595 features an octa-core processor with 2.2-GHz quad-core Cortex-A17 and 1.7 GHz quad-core Cortex- A7 CPU with ARM big.LITTLE has ARMv7 ISA and RISC CPU architecture .MT6595 can be found in Lenovo Vibe X2[15].

C. C. Snapdragon vs Exynos in same Mobile Phone

In Fig. 5, we have conducted the comparative analysis of the performance of Snapdragon and Exynos Processors in the same smartphone. Samsung supports both the processors in their Galaxy Series for example Samsung Galaxy S5, S7.

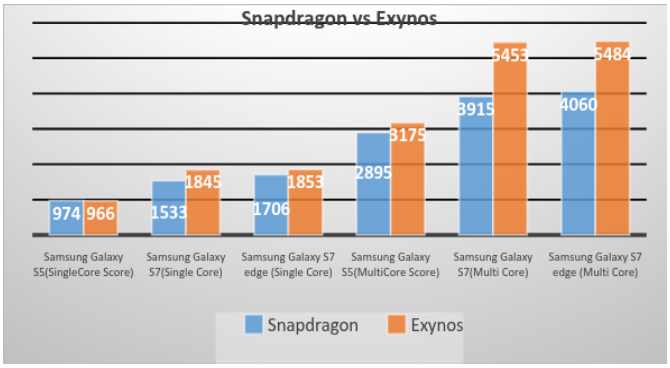

Fig. 5. .

Benchmarking is the innate way of calculating or comparing the performances of various devices. [16] The Single Core performance of the two chips are very much comparable in most cases, a huge increase in the score is noticed in the processor whilst comparing their multi-core scores. Exynos performs better in multi-core applications while the snapdragon lags behind [17] [18].

This can be best explained as Exynos variant in S7 and S7 edge has more core count as that of Snapdragon variant. Also, Exynos chipset is more efficient in managing RAM than Snapdragon variant [19]. Finally, it's worth mentioning that both devices returned very consistent scores in Geekbench test.

IV. Conclusion and Future Scope

From the table 1 and the figures 1.1 ,1.2, 1.3 it has been pretty clear that there is an increasing shift in the performance as the number of cores increases in the SoC.Single core Snapdragon processor has a Geekbench score of 292 while a hexacore processor scores 2766 and an octa-core processor scores 4020 in the benchmarking test. From this data, an increasing performance can be clearly noticed with increasing the core count. Apart from the core count and the clock speed the fabrication technique Also plays an important role in the performance and power efficiency of the CPU.

It has also been observed that it can be a case that a dual-core can perform comparable to a quad core.This shift has been observed when we compared Apple A10 (quad core ,GeekBench SingleCore:3306 MultiCore:5344)and Exynos 8 Octa(octa-core ,GeekBench SingleCore:1789 MultiCore:5203).It can be clearly noticed that the quad core performance of Apple A10 in iPhone 7 is much better than the performance of Exynos octa-core in Samsung Galaxy S7 .This is because the IPC and memory bandwidth of Apple SoC are more as compared to other SoC in the market[20].

So from this, we can conclude that clock speed, a number of cores and fabrication technique can be used to increase the performance of the multi-core SoC but it is not limited to this only we can also increase the IPC (Instruction Per Cycle) which offers a higher per-thread performance instead of expanding the core count.

Think of a processor's performance featuring an octa-core processor with good clock speed and high memory bandwidth. The performance could be incredible.

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