Looking into Heterogeneity: When Simple is Faster

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***Abstract*—Cores based on a complex architecture are generally much faster than those based on a simple architecture. On the other hand, cores are more energy-efficient when based on simple architecture. Since the recent mobile environments require both the high performance and low power consumption, HMP (heterogeneous multi-processing) architecture with both the complex cores and the simple cores in a chip has been introduced. In the HMP architecture, complex cores are used to enhance the performance, and the simple cores are used to save energy. However, in contrary to the conventional belief, complex cores do not enhance the performance for all applications, neither do the simple cores save energy for all applications. Consequently, the running application should be carefully considered to fully benefit from the HMP architecture.**

I. Introduction

Enduring battery life of a mobile device has become one of the most critical problem in the mobile industry. Since an AP (application processor) is one of the most power consuming component of a mobile device, researchers and vendors have focused on power reduction of the AP. In general, an easy way to reduce the power consumption of CPU is using a simple architecture with less number of functional units, but it also results in lower performance. Unfortunately, most consumers are conservative in lowering the performance of their mobile devices for a longer battery life. As a solution to reduce the power consumption without degrading the performance, HMP architecture consisting both the complex high-performance cores and the simple energy-efficient cores has been introduced. The vendors of HMP processors suggest that the mobile devices utilize the complex cores when the performance demand is high, and the simple cores when the performance demand is low.

In order to fully benefit from the HMP architecture, there have been several studies that introduce the performance modeling for the architecture [1][2]. When an application is running on one type of core, those models predict the performance on the other type of core, to determine whether migration should be done or not. However, none of the studies point out that simple cores are faster than complex cores for some applications, nor that complex cores are more energy-efficient than simple cores for some applications. In this paper, we explain and present such cases based on real measurements.

II. Performance and Energy Consumption of the HMP Processors

In this section, we investigate the characteristics of HMP processors throguh an off-the-shelf HMP architecture introduced by ARM (big.LITTLE processor). ARM big.LITTLE processor consists of 4 complex cores (big cores) and 4 simple cores (LITTLE cores).

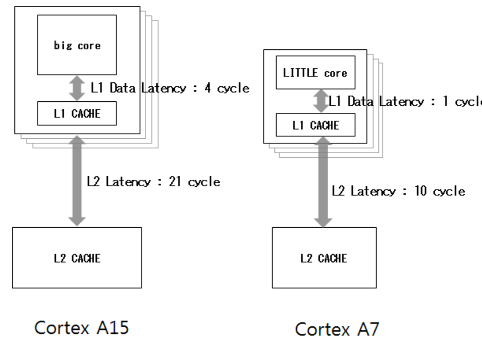

Fig. 1. Cache access latency of the ARM big.LITTLE cores

A. Performance: when LITTLE is faster

Although the big cores generally show much higher performance compared to the LITTLE cores, cache access latency is much shorter in LITTLE cores as shown in Fig. 1. Thus, big cores tend to hide the cache access latency by applying techniques such as out-of-order execution. However, when big cores fail to hide the delay caused by cache access, LITTLE core may show better performance. Therefore, performance of big and LITTLE cores should be carefully predicted based on various application statistics such as memory access pattern or instruction-level parallelism.

B. Energy: when big saves energy

Although the LITTLE cores consume much lower power compared to the big cores, power consumed by the other parts of the system remains similar. Thus, when the execution time is greatly increased by using the LITTLE cores, the system-wide energy consumption may increase. In the example shown in Fig. 2, the energy consumed by the CPU is decreased when

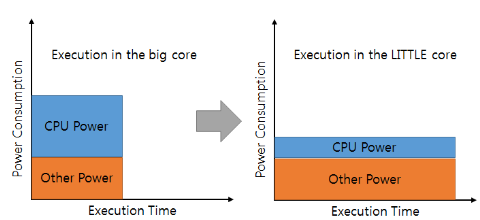

Fig. 2. An example where the energy consumption increases in the LITTLE core

using the LITTLE cores, since the power consumption is only one-third compared to the big cores, while the execution time is doubled. However, when considering the power consumed by the other components, the system-wide energy consumption is increased, despite the energy saving in the CPU.

III. Evaluation

In this section, we present the real measurement results from the Exynos 5410 [3] based mobile device, Odroid-XU [4]. Exynos 5410 adopts the same architecture that we explained in the previous section. We execute the EEMBC benchmarks to evaluate the performance and energy consumption of big and LITTLE cores.

A. Performance

In general, big cores are considered to be at least 1.5 times faster than the LITTLE cores, at the same frequency. Therefore, Odroid-XU is configured to migrate the applications from the LITTLE cores running at 1200 MHz to the big cores running at 800 MHz for higher performance, assuming that the big cores are faster even at the lower frequency. However, Fig. 3 shows that this is only true for six cases (out of thirteen). In other seven cases, LITTLE running at 1200 MHz is faster or same compared to the big running in 800 MHz. In case of routelookup, LITTLE running at 1200 MHz is 30% faster even compared to the big core running at the same frequency. Therefore, migration of the applications should be done only after careful consideration of running applications.

B. Energy consumption

In general, LITTLE cores are considered to be more energy-efficient than big cores. However, as we have already explained in Section 2, migrating an application to the LITTLE core may result in increased energy consumption when performance is significantly degraded. Fig. 4 shows that, LITTLE cores running at 1200 MHz consumes more energy compared to the big cores running at the same frequency in seven cases (out of thirteen). In the seven cases, LITTLE cores significantly lengthen the execution time (45% on average), as shown in Fig. 3, compared to big cores running at 1200 MHz. Consequently, system-wide energy consumption is increased when using the LITTLE cores. On the other hand, for the other six cases, LITTLE cores save energy (20% on average). In these cases, CPU power reduction of the LITTLE cores leads to system-wide energy reduction since the performance difference between LITTLE cores and big cores are only 10%, on average. Therefore, the execution time and power consumption of the other parts of the system should be fully considered in order to save energy, in the big.LITTLE architecture.

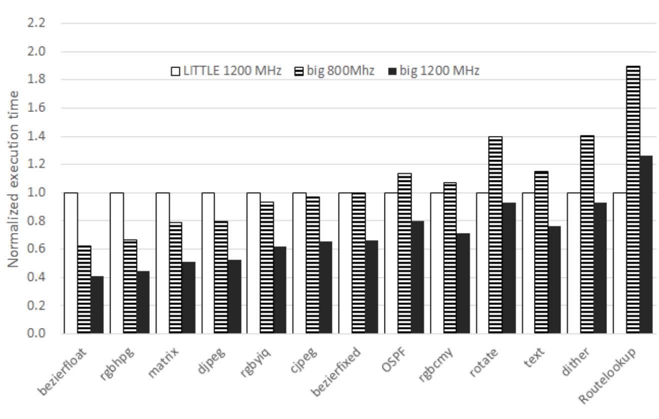

Fig. 3. Normalized execution time of the benchmark applications

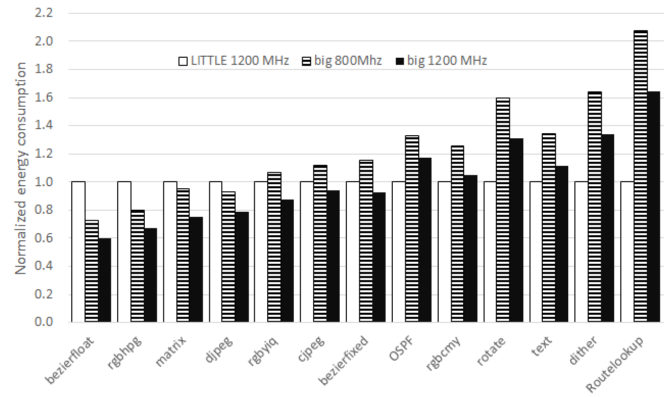

Fig. 4. Normalized energy consumption of the benchmark applications

IV. Conclusion

In our work, we introduce following two situations. First, simple cores sometimes show better performance compared to the complex cores, depending on the application. Second, complex cores somtimes save system-wide energy compared to the simple cores, when the execution time is significantly reduced. We approve our statements, based on the real experimental results on ARM big.LITTLE processor. Thus, determining the migration of the applications for either performance enhancement or energy saving must be done with careful consideration of the applications and the power consumption of other components.

Acknowledgment

Sung Woo Chung is the corresponding author of this paper. This research was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MEST) (NRF-2012-R1A2A2A01013816), and KSSRC program [Power and Thermal Management for Samsung big.LITTLE core-based AP].

References

[1] A. Lukefahr, S. Padmanabha, R. Das, F.M. Sleiman, R. Dreslinski, T.F. Wenisch, and Scott Mahlke, "Composite Cores: Pushing Heterogeneity Into a Core," In Proceedings of the IEEE/ACM International Symposium on Microarchitecture (MICRO-45), pp. 317-328. 2012. doi=10.1109/MICRO.2012.37

[2] M. Pricopi, T.S. Muthukaruppan, V. Venkataramani, T. Mitra, and S. Vishin, "Power-performance modeling on asymmetric multi-cores," In Proceedings of the International Conference on Compilers, Architecture and Synthesis for Embedded Systems (CASES), pp.1-10. 2013. doi: 10.1109/CASES.2013.6662519

[3] Exynos 5410 by Samsung Electronics. [online]. Available: http://system-on-a-chip.findthebest.com/l/328/Samsung-Exynos-5-Octa-5410, 2014.

[4] Odroid-XU by Hardkernel. [online]. Available: http://www.hardkernel.com, 2014.