Programming Techniques for Energy-efficient Software

Prof. Dr. em. Vesselin Iossifov
School of Energy and Information technology
University for Applied Sciences (HTW) Berlin, Germany
Vesselin.Iossifov@htw-berlin.de | http://www.f1.HTW-Berlin.de
Member of Board
VDE/ETV e.V. Berlin-Brandenburg, Germany
https://www.vde-berlin-brandenburg.de/de/ueber-uns/vorstand

Software is becoming a central issue in decreasing the power consumption in low-power programmable computer systems. In such systems the amount of energy consumption caused by software has several impact of the systems costs. Minimizing power consumption is one of the primary challenges that applications developers faces due to lack of the running cost (x86 based server or HPC) or the instrumentation functionality (Embedded Applications) of the system. This lecture will cover different prospect of energy usage and energy aware software design in computer systems ranging from Embedded Systems to x86 based server or HPC. This lecture will present some examples of the role of programming techniques to rise the system energy efficiency, quantify the impact and fix the issues in applications to minimize the power consumption.

Keywords: Energy aware computing, software design for power optimization, Embedded Applications, IoT, x86 based server and HPC.

I. INTRODUCTION

Power consumption is a key element for different form factors of computer systems. The lecture will focus on the important role of application software for x86 servers an HPC and Embedded Systems. Such systems are placed on both ends of computer's performance range.

Applications can extend or remove advantages of low power designed hardware. As the hardware becomes more sensitive for several energy states in the last 20 years, algorithms and resulting codes must be well behaved to use the opportunity of many energy states [1] to [3] to exploit hardware components to have minimal power impact during active processor workload state.

This lecture describes several case studies that show how application algorithms can be codded with low-power techniques to implement the opportunities of low power designed hardware. Several methodologies for both x86 and Embedded processors to optimize the applications for power are described. Possible power savings by implementing the optimization on Parallel Assembly Level (x86) and the use of Interrupt techniques (Embedded) for typical applications will be presented.

II. OVERIVEW OF POWER METRICS

Power Metrics gives the behavior of the system and how we quantify an application if it is sub optimal or optimal written for the power profile. Power metrics which are presented in this lecture are number of processor clocks and programmed processor power states and interrupts to become one optimal mixture of it to minimize the system power consumed for given application. Power management is categorized into following important goals [1] to [3]:

A. Minimize number of CPU Clocks

Consumed power by a running code in a digital system is described by the formula:

$$P = \Delta T \times F \times U \times I$$

where **F** is the frequency clocking the digital components, **ΔT** the code run time and **U** and **I** are voltage value and current rating. Minimizing the average **F** is discussed at point **B**. Minimizing **ΔT** means to cut the number of clocks at the average **F** using programming techniques on the HLL or use Parallel Assembly instructions for integer or float data types **(x86)**.

B. Use Processor power management technologies [2], [3]

*** Processor idle sleep states (x86)**

CPU supports several levels of core and package idle states. Idle states are also known at C-states. Deeper the C-states and more time spent in deep C-states by an application, more power is saved. C-state transitions have direct impact on power consumption and response time.

*** Power performance states (x86)**

P-States is an operational state, also can be called as part of C0-State. P-States provide a way to scale the frequency and voltage at which the processor runs to reduce power consumption. Processor in active P-states consumes maximum power called in Thermal Design Power (TDP) specs.

Embedded CPUs (**MSP430FR5969**, Texas Instruments, [3]) use as x86 as well also four power states – **Low Power Management States** (LPM)1 to 4.

C. Application specific use of Interrupts to minimize power consumed [3]

Using Interrupts in Embedded Systems waiting on process responds gives the possibility to bring CPU and other components in to the idle mode (LPM 1 to 4) and to rise down the clock frequency for them. This and other programming techniques in HLL, assembly language and Fixed Point Math Libraries instead of float data types and functions will be presented and measured for **MSP430** code.

III. SUMMARY AND CONCLUSION

Software power optimization makes a huge impact on overall CPU platforms. Power awareness is a critical step in minimizing power costs for x86 servers and HPC or to make Embedded applications (IoT, Wireless Sensor networks) in a energy harvesting environment possible. There are many steps that developers can follow to reduce their application power consumption. This lecture gives overview on how to analyze, use handful of tools and optimize applications to create energy aware applications (x86 and Embedded).

IV. REFERENCES

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