A Predictive Power Management System for Mobile Processors based on Long Short-Term Memory

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Abstract

Recently, since smartphone specification is continuously upgraded, various researches have been conducted on software-based power-saving techniques for mobile processors. The existing frequency/voltage control system in Android smartphone is based on the current processor usage, but it allocates resources more than necessary and consumes power frequently. In this paper, we propose a new machine learning based processor power control system that more accurately predicts the processor frequency that an application requires.

Keywords-DVFS; Android; Governor; Power Management System; Load Prediction;

I. Introduction

Smartphone manufacturers use a range of strategies to gain competitive advantages from various aspects such as enhancing overall performance, extending the time between charges, and increasing user convenience. As a result, high clock speeds and multi-core processors are now part of the basic configuration. Processor performance enhancement entails an increase in power consumption, and the hardware-based approach has reached its limits. Operating systems are now adopting software-based techniques to reduce the power consumption of processors.

Most smartphones on the market have embedded power-saving systems, such as dynamic voltage and frequency scaling (DVFS) techniques that reduce power consumption by adjusting the frequency and voltage to the level of power usage [1] and hotplug methods that control the activation status of individual processor cores [2] controlled by the operating system. Software-based power-saving methods work under the scheduling method of the fair processor resource allocation to all apps. Processor resources are allocated to an app as required by it, then the operating frequency and the number of cores are controlled accordingly.

Adjusting operating frequency properly is important for preventing the slowdown of the application processing time. In conventional smartphones, it was difficult for the processor power management system to achieve both good responsiveness and power efficiency, which are important features in a mobile environment, because it simply took account of the processor usage rate sampled at the given point of time. In this paper, a system for prediction-based allocation of the required processor resources to apps is designed.

The rest of this paper is organized as follows: Chapter II gives an overview of the existing smartphone power management techniques. Chapter III describes the architecture of a processor power management system capable of predicting the processor resource requirement of an app. In Chapter IV, we conclude with our work with some future research directions.

II. Related Work

The power consumption of mobile processors can be reduced by controlling operating frequency or deactivating cores. Fig. 1 describes the processor power management of the Linux kernel used in Android. It shows how the kernel

![Fig. 1. Android’s processor power management architecture](image-url)
measures the load of the processor, controls the operating frequency, or activates the processor cores. The DVFS technique applied to the governor aims to reduce power consumption by lowering the operating frequency, based on the fact that power consumption in the processor is proportional to the square of the operating frequency and the input voltage. In DVFS, precise adjustment of operating frequency is important due to performance degradation on a lowered operating frequency, resulting in prolonged processing time and increased energy consumption.

Governors available on the Linux kernel include Performance Governor, Powersave Governor, Conservative Governor, Ondemand Governor, and Interactive Governor [3][4][5]. The Performance Governor sets the processor frequency to the highest available value, whereas the Conservative Governor increases the frequency step by step based on processor utilization. The Ondemand and Interactive governors are set by default in most Android smartphones; they set the frequency to the highest available value at the moment of processor load exceeding its upper threshold and lower it stepwise when the processor utilization falls below the lower threshold. The Ondemand and Interactive governors have the advantage of responsiveness because the frequency is set to the maximum whenever the processor utilization tends to increase. One of a disadvantage of those methods is a considerable waste of processor resources.

This paper proposes a system architecture for accurate prediction of processor resource allocation based on the resource usage history.

### III. A Predictive Power Management System for Mobile Processors

Fig. 2 presents the design of the Predictive Power Management System in this paper. It shows the architecture for the training of the processor usage history, in addition to the prediction and allocation of processor resources as required by the applications. This system consists of three modules: Trainer, Prediction, and Power Control modules. The Trainer Module generates and learns the long short-term memory (LSTM) [6] model, and transfers them to the Prediction Module, which predicts the processor load based on the LSTM model learned. The Power Control Module sets the target frequency value and the number of active cores of the Processor Power Management based on the prediction of the processor load.

#### A. Trainer Module

Trainer Module stores the information on processor load. Once an adequate amount of data is collected, training of LSTM model begins. Upon completion of training, the LSTM model is transferred to the Prediction Module for processor load prediction. Given the considerable amount of system resource consumption necessary for training LSTM, the Training Module is activated while the smartphone is being charged or the user is sleeping.

#### B. Prediction Module

The Prediction Module begins to run after the first renewal of the LSTM model. It collects the processor load information and inputs it into the already learned LSTM model, and the upcoming processor load is predicted based on it. The predicted information is then transferred to the Power Control Module.

#### C. Power Control Module

In the Power Control module, the processor status is controlled based on the processor load predicted in the Prediction Module, whereby the processor frequency and the number of active cores are set using Governor and Core Controller, respectively. This information is transferred to the Processor Power Management.

### IV. Conclusion

In this paper, we designed a system for accurate prediction and allocation of processor resource in order to reduce resource waste in the existing mobile systems. The proposed LSTM-based processor load prediction and control mechanism are expected to greatly contribute to minimizing the process resource waste and extend the smartphone usage time.

Within the near future, we plan to design an LSTM model to maximize the processor load prediction accuracy, evaluate the prediction performance, and quantify the power consumption. Also planned is a study on reducing computation overhead for LSTM-based prediction.

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### References


