Demo Abstract: Enabling Energy Efficient Continuous Sensing on Mobile Phones with LittleRock

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ABSTRACT

Although mobile phones are ideal platforms for continuous human centric sensing, the state of the art phone architectures today have not been designed to support continuous sensing applications. Currently, sampling and processing sensor data on the phone requires the main processor and associated components to be continuously on, creating a large energy overhead that can severely impact the battery lifetime of the phone. We will demonstrate Little Rock, a novel sensing architecture for mobile phones, where sampling and, when possible, processing of sensor data is offloaded to a dedicated low-power processor. This approach enables the phone to perform continuous sensing three orders of magnitude more energy efficiently compared to the normal approaches.

Categories and Subject Descriptors

C.3 [**SPECIAL-PURPOSE AND APPLICATION-BASED SYSTEMS**]: [Real-time and embedded systems]

General Terms

Design, Measurement, Performance

Keywords

continuous sensing, mobile phones, offload sensing

1. INTRODUCTION

The ubiquity, mobility, and connectivity of cell phones make them an ideal platform for human-centered sensing applications. Phones today have a rich set of built-in sensors and a powerful processor for information processing. This allows phones to *continuously sense* their users and the environment they interact with, *understand* this environment and use this understanding to *provide meaningful services*. Several recent research projects have already used cell phones as the key sensing components in their systems [2, 3, 1].

However, continuous sensing, required by many phone-based applications, is challenging under the current phone architecture. Designed mainly for *bursty* user interaction, current smart phones use the main processor to control the sensors directly. Continuous sensing implies that the main processor has to stay on all the time. These processors typically consume hundreds of mW when they are active even when the screen and radios are not on. As a result, continuous sensing applications drastically reduce battery lifetime into a few hours, jeopardizing the usability of the phone.

In this work, we demonstrate a new mobile phone architecture (called *Little Rock*, Figure 1) that uses an energy efficient co-processor to offload continuous sensing tasks. All the available sensors on the phone are connected to the co-processor enabling the phone to transition to sleep mode while the co-processor is continuously acquiring and processing sensor data at a low power overhead. Since the two processors are tightly integrated, data between them can be exchanged fast and on demand because the co-processor can wake up the main processor at any time and the main processor can request access to sensor data acquired by the co-processor whenever it needs to.

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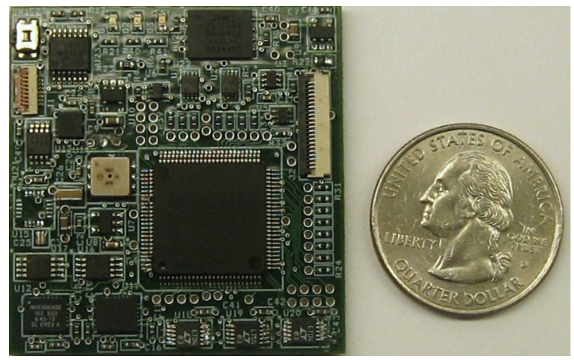

Figure 1: The *Little Rock* sensing platform.

2. DESIGN

Little rock is built around an MSP430F5438 processor and a number of sensors including accelerometer, gyroscope, compass, pressure and temperature sensors. Our sensing platform consumes 12.9 mW when active, approximately 60 times less energy compared to the main processor on a typical smartphone. When the phone is in the sleep mode the combined power consumption of the phone and the *Little Rock* is only 7.87mW.

Figure 2 provides an overview of the *Little Rock* architecture. A low power processor is directly interfaced to a set of digital and analog sensors over the I2C and SPI serial interfaces. The sensor data acquired by the processor can be either stored immediately on the on-board flash memory or first filtered and processed by the main processor.

We highlight four features in this design:

Transparency: In the case where the phone needs direct access to one of the sensors on *Little Rock*, the main processor will act as

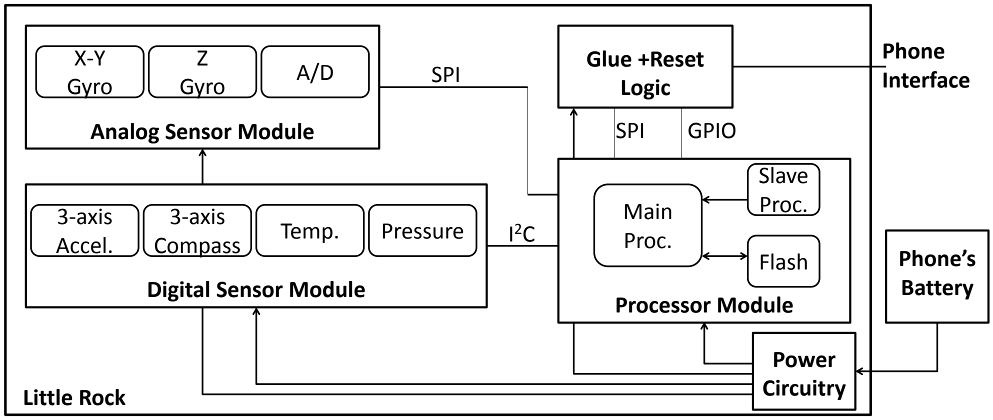

Figure 2: Overview of the *Little Rock* architecture

a bridge between phone's processor and the actual sensor, enabling phone's processor to directly access any sensor through the SPI bus.

Power independence: *Little Rock* is powered directly from the battery and not from the internal power electronics of the phone. Thus, the majority of the main power circuitry can be turned off when the phone is in the sleep mode, and *Little Rock* can continue to be functioning, a key requirement for continuous sensing.

Interrupt: There might be cases where the sensing data collected by *Little Rock* requires that a specific service or action on the phone be triggered. In order to achieve this, *Little Rock's* main processor is able to interrupt and wake up the phone using a GPIO pin. The phone is then able to recognize the source of the interrupt and query *Little Rock* to identify the exact reason of the wake up event.

Re-purposing: *Little Rock* has two processors, a main and a slave. The secondary slave processor can be used by the phone to re-program the *Little Rock*'s main processor. This functionality can be particularly useful when the user installs a new sensing application on her phone, that requires a very specific "device driver" or types of processing on the sensor data.

3. DEMONSTRATION

We use a step counting application as our example continuous sensing application. This application samples the 3-axis accelerometer at a fixed frequency, and after collecting a batch of samples, it executes a routine that computes the number of steps taken by the user carrying the phone. We will demonstrate this pedometer application while running on the phone, on *Little Rock* as well as in a hybrid mode. In the hybrid mode, *Little Rock* is responsible for sampling the accelerometer but whenever processing of the data is required, it will wake up the processor, transfer the data and let the phone do the processing.

Figure 3 shows the average power consumption for all three different hardware configurations. The phone only configuration consumes on average 700mW. On the other hand, *Little Rock* consumes on average 0.7mW. This corresponds to 3 orders of magnitude improvement in the power consumption of the phone. We also observe that, with small processing batch sizes, the power consumption of the hybrid approach is similar to that of the phone because the phone has to wake up frequently. However, when the processing batch size increases, the power consumption of the hybrid approach becomes 70 times lower than that of the phone only approach because the phone can spend more time in the sleep mode.

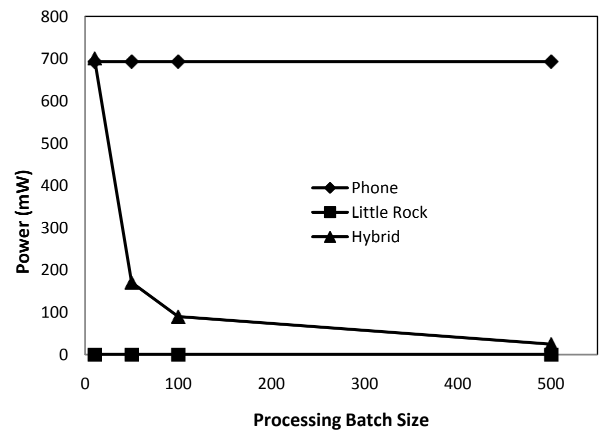

Figure 3: Average power consumption of the pedometer application under different processing batch sizes.

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