Poster: The Accuracy of Android Energy Measurements for Offloading Computational Expensive Tasks

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ABSTRACT

Computational offloading from smartphones into the cloud has proved to be one of useful approaches for improving energy efficiency. To assess the benefit of offloading and decide the most suitable offloading strategies, it is essential to account the energy consumption of smartphones. In this paper, we investigate the accuracy and capabilities of the Android smart battery interface. For comparison, we measure the energy consumption using an oscilloscope. We experimentally investigate the energy consumption of different applications on a modern smartphones including local computation and network communication over WiFi. Our results show that both of methods bring high accuracy. Our work builds the basis for next generation offloading algorithms.

CCS Concepts

- **Information systems → Retrieval on mobile devices;**
- **Hardware → Energy metering;**

Keywords

Smartphone; Energy measurement; Offloading

1. INTRODUCTION

The number of smartphones has increased rapidly over the last ten years. Along with the great technological improvement, modern smartphones have higher capability and enable more advanced applications and services. However, current battery technologies have difficulties to keep up with the rapid innovations of mobile device functionalities, which require heavy computation and energy consumption. One possible solution to reduce the pressure on battery capability is to use offloading of computational tasks to the cloud [1,2]. The main idea of this approach is to migrate expensive computations on smartphones to more resourceful computers instead of executing them locally. In this context, the smartphones could potentially reduce the energy consumption for computing local tasks if less energy is used to send the processing data to the cloud and to download the result. One of the first approaches towards offloading of communication-related tasks has been investigated in [3]. In [5], this has been further explored to understand the break-even point for offloading using different communication technologies. Both works relied on external measurements for the decision process. Obviously, to improve the energy efficiency of smartphones through offloading, it is important to understand how much energy is used by each application and network operation. Therefore, a reliable way to measure the energy consumption of the phones is required. In this paper, we first discuss the general methodology of energy measurements. In particular, we investigate the accuracy of the Android smart battery system. We experimentally evaluated this system and compared to results using an oscilloscope.

MobiHoc'16 July 04-08, 2016, Paderborn, Germany

ACM ISBN 978-1-4503-4184-4/16/07.
DOI: http://dx.doi.org/10.1145/2942358.2942412

2. ENERGY MEASUREMENT

In theory, the energy consumption relies on the equations: $E = PT$ and $P = UI$ where E, P, U, and I represent energy, power, voltage, and current in the period of time T. In practice, we measure a time-discrete, sampled versions of voltage $U(t)$ and current $I(t)$. Then we can approximate the energy consumption over the time T by applying numerical integration of their product. There have been several different approaches to achieve the sampling of voltage and current. Hardware-based measurement utilizes physical devices that connected to hardware and/or battery of smartphones. Software-based measurement runs as a program that logs the readings of a built-in smart battery interface.

In hardware-based measurement, the most common way to measure the power consumption of the phone is to insert a high-precision sensing resistor in series between a battery terminal and connector on the phone. Several existing tools are suggested to measure the voltage across the phone bat-

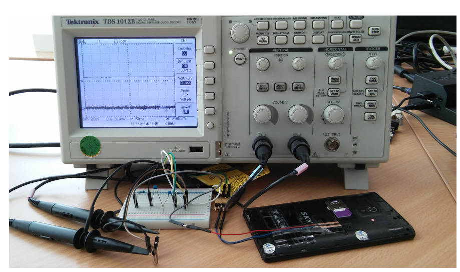

Figure 1: Photograph of the measurement setup.

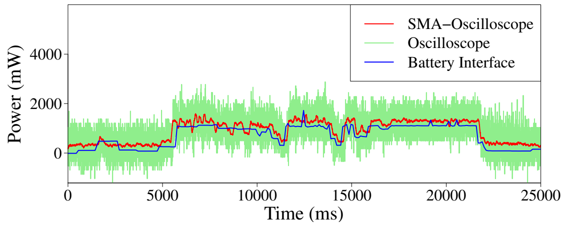

Figure 2: Power trace over time.

tery and also the voltage drop across the sensing resistors, including Monsoon's PowerMonitor[1] and BattOr [4].

In this paper, we use a Tektronix TDS1012B oscilloscope for sampling the voltage signal of the phone. A photograph of the measurement setup is depicted in Figure 1. In order to sample the voltage, we put the oscilloscope in the scan mode in which the sampling rate can reach 2500 Hz. In addition, the minimum vertical scale factors is 20 mV, which allows to deal with very low voltage signals without the amplifiers. We connect the TDS1001B to a PC using USB Device port. Typically, there are short quite high spikes in voltage signal that can affect the precision of our reading. We use a RC low pass filter that prevent the instantaneously change in voltage and make the signal smoothed. We use two cooper tape intervened by a printing paper to intercept the connection between the phone and the battery.

Most modern smart phones now relay on a smart battery system to enable applications to become energy-aware. The smart battery interface, however, is platform-specific. Only Android devices that include a battery fuel gauge, such as Summit SMB347 or Maxim MAX17050, can provide voltage and current readings that we can use for calculating the power consumption.

The update rate of the battery status can vary from hundreds of milliseconds to as long as 40 s. Normally, the battery status can be easily read from Android file system at /sys/class/power_supply/battery/. Android supports all of the following properties: current_now, current_average, energy_counter, charge_counter, voltage_now. The actually properties that can be read, however depend on the device.

3. EXPERIMENTAL SETUP

We conducted our experiments on a PANTECH VEGA S5 smart phone running Android v4.1.2. We run three different applications on the phone and estimate the energy consumption using both the oscilloscope and battery interface at the same time: (1) perform matrix multiplication locally on the phone, (2) upload data to a server, and (3) download data from a server.

The upload and download processes are performed using WiFi. All of applications require a wake lock to prevent the phone from switching to standby mode. Moreover, to avoid noise in measurement, we disable the power management and background services. The power consumption of the phone in idle state is calculated in advance and is subtracted from the experimental results. We read the battery status every 100 ms. The sampling rate of oscilloscope is 1 kHz.

[1]https://www.msoon.com/LabEquipment/PowerMonitor/

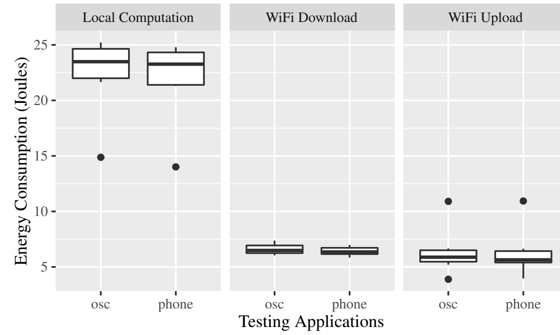

Figure 3: Energy consumption for each application.

Table 1: Measurement accuracy of Android.

Application	Error Rate (avg.)
Matrix multiplication	2.353 %
WiFi upload	4.259 %
WiFi download	3.161 %

4. RESULTS AND DISCUSSION

As shown in Figure 2, the battery interface can provide a highly accuracy power trace, especially with long-time running applications. This particularly holds if an averaging technique is used (indicated as Simple Moving Average (SMA) oscilloscope). In order to verify the reliability of both methods, we repeat each application for 10 times for statistical evaluation. Figure 3 shows the distribution of the measurements. Finally, the error distribution shown in Table 1 is stable within 5 % compared to the measurement from oscilloscope. One noticeable aspect is how much energy the phone consumes for each application. Figure 3 also reveals some quantitative insights. The phone uses much more energy for local computation compared to data transfer over the network. Therefore, the phone could save much energy if expensive tasks are offloaded to more powerful server.

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