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Studying the Energy Consumption in Mobile Devices

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Abstract

In the last few years, it is noticed that mobile smart devices are becoming very essential component of our daily life. The smart phones can do a variety of very useful jobs. In addition to make calls, they can be used to create and share multimedia files, run very useful applications and do data processing. But those devices suffer from some limitations including limited storage and processing capacity and short battery life time due to energy drain which is noticed to be increased when running applications that require intensive computations on the mobile devices. In this paper, the literature is searched for related work, and the power consumption is measured experimentally for different components of two common brands of smart phones, namely, Galaxy Note3 and Sony Xperia Z2. The measurements are done using applications that measures the power consumed in each component of the phone. The obtained results are presented to get more accurate understanding of how these components participate to the overall power consumption of the smart phone. Also, this work can be used in the future to propose better techniques to reduce the energy consumption by the smart phones.

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1. Introduction

Nowadays, many people around the globe are using smartphones for various tasks other than just making calls. The smart phones are used to create and edit multimedia files (audio and video), access the social communication websites, navigate for the destination using GPS, and run more complex and useful applications. Charging these devices might not take a considerable amount of power, but those devices are energy hungry when they are used. The mobile devices are very popular nowadays because they offer for the user computation environment and useful tools and facilities anywhere and anytime. This ‘mobility’ is the significant feature of those devices were the user can continue his/her work simply regardless of the location, at home, at office, or travelling.

Among the main limitations of these smart phones is the energy consumption. This problem will become more serious in the next few years due to the tremendous usage trends of these smart phones. In addition to that, the usage of these device to access the Internet, imposes extra traffic on the networked servers and resources and increases the power consumption. So, there is a need for major improvements in resources management to increase the efficiency and reduce the energy consumption.

There are different components that consumes different amounts of energy in mobile devices and in the smart phones. There are the traditional components such as the Central Processing Unit (CPU), Light Emitting Diode (LED) and Operating System (OS). Adding to that, the new components embedded in the smart phone such as GPS, 3G and Wi-Fi technologies that are integrated in the smart phones and consume a considerable amount of power.

In this paper, we will measure and analyze the power consumption of many components of two smart phones brands to obtain better understanding based on real measurements on how these components contribute to the overall consumed power by those smart phones. The remaining of this paper begins by literature review in Section 2. In Section 3, energy saving techniques in Mobile Computing are explored. The experimental results are shown in Section 4, and Section 5 concludes this paper.

2. Literature Review

Considering the impact of the applications workload on the energy consumption in smart phone, an energy-aware scheduling algorithms for different application workload was developed. Another research studied the relation between the consumed energy while transferring data and the strength of the wireless signal. They suggested a new power model for WiFi and 3G that takes in consideration the impact of strong/poor signal on the power consumed by the wireless components embedded in the smart phone.

The authors measured the power consumption of connection and data transmission over 802.11 wireless networks. They reached to the conclusion that handset, the devices context, and the OS are among the many factors affecting the optimal choice of data transmission strategy.

Since Mobile devices are used widely with cloud computing to form what is called mobile cloud computing, the research in and 9 presented techniques for energy optimization in mobile cloud computing. In the same context, a detailed study about resilience and efficient mobile cloud computing was made in 10. In 11, the authors proposed a model that allocates jobs of certain applications to be executed in the smart device and sends other jobs to be executed at the cloud.

3. Energy saving techniques in mobile computing

There are many energy saving techniques for mobile devices. One of the main techniques is the offloading. Executing complex applications in mobile devices increases the energy consumption. Offloading mechanisms have been proposed to transfer offloaded tasks execution from a mobile device to a computational infrastructure (cloud for example) to reduce the energy consumption and the local execution time at the mobile device. To determine the effect of offloading, the authors in 14 proposed a middleware called MACS “Mobile Augmentation.
Cloud Services”. This middleware handles the processing power and battery lifetime limitations of Android mobile phones. It augments the Android mobile device resource by offload two Android applications. For evaluation purposes, they used Motorola Milestone mobile phone based on Android platform 2.2, and desktop computer as a cloud provider. The results showed that the computation energy was saved by around 95% after offloading, and the execution speed is up to 20 times faster. Computation offloading is carried out by exploiting the virtualization of smart phone in the cloud, and task parallelization feature. A ThinkAir tool is presented for developers to migrate their smart phone applications to the cloud. The two special characteristics in this framework are performing on-demand resource allocation, and exploiting parallelism. Moreover, bandwidth, CPU workload, input size, and delay tolerance threshold, will affect the energy consumption and execution time of the applications. The results show that the tool reduces effectively the energy consumption in smart phones, and reduces the application’s execution time by determining the better execution region for each application.

Authors in proposed a theoretical framework for energy-optimal application execution under stochastic wireless channel. They consider two application factors, input size and deadline to complete the application. The numerical results of this theoretical framework determine where is the energy-optimal execution place for each mobile application. So, based on the related literature, we can say that offloading mechanism can be used to reduce the energy-consumption in a mobile device, but there are many factors affecting the efficiency of this technique such as the type of applications, data size, and network connection

4. Experimental results

To conduct the experiments and measurements, the first step is selecting two Android smart phones from known brands: the first one is Samsung Galaxy Note3 and the second one is Sony Xperia Z2. The next step, is to use the PowerTutor and AMobiSense tools to measure the power consumed by the following major components of these smart phones: CPU, OLED, WiFi Interface, GPS Unit, Video playback, and both operation modes: normal and airplane. Figure 1.a shows the interface of the first tool to be use: PowerTutor. In addition to the previous mentioned features of this tool that made me decide to use it in this project, it has an interesting feature that measures the average consumed power during last day, minute, or hour, and Figure 1.b shows the interface of the AMobiSense application to measure the consumed power in Android devices.

Fig. 1. (a) PowerTutor Application Interface, (b) AmobiSense Application Interface
These tools were used to measure the total power consumed by the two smart phones (Galaxy Note3 and Sony Xperia Z2). Figure 2.a shows the total consumed power for Galaxy Note3, and Figure 2.b the total consumed power for Sony Xperia Z2.

![AMobiSense and PowerTutor](image)

**Fig. 2.** The total consumed power for: (a) Galaxy Note3; (b) Sony Xperia Z2

The measurements of the power consumed by each component of the smart phones under testing are shown in Figure 3. The figure shows the measured consumed power by LCD, CPU, 3G and WiFi for the two phones a) for Galaxy Note3, and b) for Sony Xperia Z2. The tools allow more than one way to present the measurements: it can be shown as chart view or pie view.

![Chart and Pie View](image)

**Fig. 3.** The measured consumed power by different components of the smart phones (a) For Galaxy Note 3; (b) For Sony Xperia Z2

Table 1 Shows all the consumed power measured using the two tools for different components of the two selected smart phones. Also, the total consumed power is shown as well.
Table 1. The consumed power measured using the two tools for different components of Galaxy Note3 and Sony Xperia Z2.

<table>
<thead>
<tr>
<th>Component</th>
<th>Sony Xperia Z2</th>
<th>Galaxy Note 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PowerTutor</td>
<td>AmobiSense</td>
</tr>
<tr>
<td>CPU</td>
<td>11.1</td>
<td>4.2</td>
</tr>
<tr>
<td>OLED</td>
<td>25.9</td>
<td>25.1</td>
</tr>
<tr>
<td>WiFi Interface</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>GPS Interface</td>
<td>9.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Video playback</td>
<td>16.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Normal mode</td>
<td>5.1</td>
<td>4.6</td>
</tr>
<tr>
<td>3G</td>
<td>29.2</td>
<td>20.3</td>
</tr>
<tr>
<td>Airplane mode</td>
<td>2.3</td>
<td>2.6</td>
</tr>
<tr>
<td>Total Power</td>
<td>470mW</td>
<td>476mW</td>
</tr>
</tbody>
</table>

It can be noticed from Table 1 that the 3G interface unit consumed the most amount of power in the two phones when using the PowerTutor tool, followed by the OLED. While using the Amobisense tool the OLED consumed little more power than the 3G unit. The WiFi unit in the Sony phone consumed about 20 mW while in the Galaxy phone it consumed about 24 mW. The least power dissipation occurred when both phones are operating in the airplane mode.

For more analysis and comparison, the power consumption by the components of each smart phone is drawn separately. Figure 4 shows the power measurements for Sony Xperia Z2 using PowerTutor tool.

![Power Consumption for Sony Xperia Z2 using PowerTutor](image)

Fig. 4. Power measurements for Sony Xperia Z2 using PowerTutor
Similarly, and using the PowerTutor, Figure 5 shows the power consumption for the Galaxy Note3.

![Power Consumption for Galaxy Note 3 using PowerTutor](image)

Fig. 5. Power measurements for Galaxy Note3 using PowerTutor.

It can be noticed that in both phones the 3G unit consumed approximately three times the power consumed by the GPS unit. Also, the 3G and the WiFi units are major components of power consumption in both smart phones. They consumed together 55 mW in Note3 which is about 45% when compared to the power consumed by all other components. Similarly, in Sony Xperia Z2, the GPS and WiFi units consumed about 50 mW which is also about 43% of the consumed power by all components.

It can be concluded that the smart phones has many useful applications that needs to be connected to the internet either through the 3G or the WiFi. Staying connected to the Internet will cost those devices approximately half of its battery life.

Finally, and as mentioned in the previous section, the decision of using two power measurement tools to confirm the obtained results is justified. It can be noticed from the Table 1 that the two power measurements applications gave very close results which gives more confidence to the obtained results. The total consumed power by the Sony phone was about 470 mW, while it was little bit more in the Galaxy phone (about 522 mW).

5. Conclusions

The advances in mobile communications technology put the smart phones on a daily use by millions of people worldwide to do a variety of very useful jobs. But those devices suffer from main limitation which is the short battery life time due to power consumption by different components of these smart phones. In this mini project, I searched the literature for related work, and I measured experimentally the power consumption of major components (including CPU, OLED, WiFi and GPS units) of two common brands of Andriod smart phones, namely, Galaxy Note3 and Sony Xperia Z2. The measurements were done using two applications: the PowerTutor and the AmobiSense that measure the power consumed in each component of the phone in addition to the total power consumed.

The obtained results showed that used measurements techniques gave close results, and the Galaxy Note3 consumes slightly more total power than the Sony Xperia Z2 phone. The major power consumption was by the 3G unit and the OLED. The WiFi unit also consumed a considerable amount of power in both phones. Together the 3G
and the WiFi units consumed about half of the total power consumed by all other components. In conclusion, this project addressed a very important issue that is related directly to the daily lives of many of us. Using the useful applications of these smart phones that need the connectivity to the Internet comes at high cost which is half of the battery life. This mini project gave more accurate understanding on the power consumption in the smart phones and could be used in the future to propose better techniques to reduce the energy consumption by the smart phones.

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References