# Power Consumption in Smartphones (Hardware Behaviourism)

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*Abstract* — Power consumption is a critical concern for battery driven mobile devices such as Smartphone, batteries are limited in size and therefore capacity. This implies that managing energy well is paramount in such devices. Significant work has been devoted to improving it through better software and Hardware. **In this paper, we cover studies that measured power in the energy consuming entities of a Smartphones such as wireless air interfaces, display, CPU and others.**

Keywords: Power, Smartphone, mobile phone's network technologies.

## I. INTRODUCTION

The smartphone market is a popular and growing market in technology nowadays. With 488 million smartphones sold in 2011[10], the market has grown larger than the PC market, which sold 412 million computers. The market is also still growing, with a growth in 2011 of 63%. Keeping in mind these numbers, and multiplying them with the power consumption of one phone, we can see that smartphone power consumption is consuming quite some power, constantly.

In fact, mobile phones present significant differences in terms of power consumption signatures depending on the manufacturer, operating system and other contextual factors such as network coverage. Understanding how energy is being consumed by the hardware components is essential in order to design energy-aware systems.

The paper is organized as follow: In Section II we present energy consumed by several smartphones hardware components, Section III outlines important points and discusses limitations. Finally, Section IV concludes the paper.

## II. RESOURCES UNDER STUDY

It is of great importance to protect rapidly-spreading and widely-used small mobile devices like smartphones from energy-depletion by monitoring software and hardware components. Here we will focus on power consumed by specific hardware components.

### A. Power consumption for CPU AND MEMORY

Modern smartphones use heterogeneous multi-core SoC which includes CPU, GPU, DSP and various application specific accelerators. It provides opportunities to realize compute-intensive applications on a battery-powered and resource-limited mobile device by assigning each sub-task to the most suitable computing core.

Perrucci *et al.* in [9] loading the CPU from 0% to 100% with various tasks and measured the power levels. During the measurements, the displays as well as all air interfaces are off. Table1 shows results. (Nokia N95 is used, which is running Symbian OS 9.2 as an operating system)

Table 1: Power consumption for CPU and Memory

| Technology | Action | Power[mW] |
|---|---|---|
| CPU usage | 2% | 55 |
| | 25% | 310 |
| | 50% | 462 |
| | 75% | 561 |
| | 100% | 612 |
| Memory | Saving 1Mb on drive C | 587.7 |
| | Saving 1Mb on drive E | 612.8 |
| | Saving 1Mb on drive D | 560.0 |

Saving power in CPU is very hard, there are not many ways of managing power consumption on a software level in this component because it's usually consume a specific amount of power, in which you can hardly put any nuance.

Running fewer applications can save power (this is not considered a design aspect to be managed in software but is dependent on the user's preferences), the same goes for graphics, audio.

Memory components like RAM and SD, unless moving a file or streaming video, they usually consume so little power, Perrucci *et al.* in [9] measured consumption of memory access by saving a file of one MB on different drives of the phone:

- **D**: temporary files Drive.
- **E**: Memory card (micro SD).
- **C**: flash memory (phone memory) drive.

Table 1 shows the values of power and data rate for saving the file. As expected time, and

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therefore energy, is smaller when using the "D" drive.

B. Power consumption for LCD

Running fewer applications also can save power when using LCD, Carroll and Heiser in [1] shows that the most energy intense component are the display (400mW including LCD panel, touch-screen, backlight and graphics accelerator). They also demonstrated that the content displayed in the screen can affect the energy consumption in the LCD panel: 33.1mW with white screen and 74.2mW for a black screen.

C. Power consumption for networking technologies.

One of the major consumers of a mobile phone's energy is a networking technology such as 3G, GSM and WiFi. These technologies are used to transfer data from and to mobile phones, making it able to browse the internet, send and receive e-mails, Voice over IP, and so on. The only downside of these technologies is that they drain quite a lot of battery power. Studies show that this power consumption is proportional to the workload caused by the transfer, rather than the total transfer size itself.

3G and GSM can be situated in the "cellular technology" category, being designed to enable mobile devices to establish data connections from all over the world. WiFi does not really belong in that category, since the use of this technology is much more widespread (PC's, laptops, phones, printers, etc.).

To compare the energy cost of transfer through cellular technologies or WiFi, [10] provide following graph:

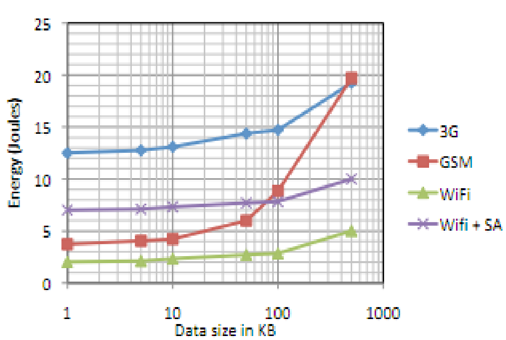


Figure 1: energy consumption to data size in KB

Fitzek *et al.* analysed the energy impact of 2G and 3G network usage for Nokia N95's [2]. Specifically, they analysed the energy consumption of three common services like text messaging, voice and data using an application called *Nokia Energy Profiler*3 and an external power meter for correctness. Their experimental results report a larger energy consumption in 3G networks for text messaging (SMS) and voice services compared to 2G networks. The energy consumption of sending text messages increases linearly with the length of the message while the signal strength clearly affects the time required to transmit the message in both types of networks. In the case of voice services, using GSM requires around 46% less energy than UMTS networks. However, 3G+ technologies become more energy efficient to transmit large volumes of data. The work by Balasubramanian *et al.* in [3] goes a bit deeper in the analysis of IEEE 802.11 standards and cellular networks (using exclusively Nokia Energy Profiler as measurement tool). They found that cellular networks present high tail energy overhead by staying in high energy-states after completing a transfer. This effect is much lower in GSM than in 3G networks. On the other hand, IEEE 802.11 networks do not present any tail energy and they are more efficient than cellular networks. However, they have an energy overhead caused by associating to the access point procedures. The authors modelled the energy consumption required by the wireless interfaces in the devices they studied.

The work by Rice and Hay [4] is probably the more accurate energy measurement of WiFi interfaces in smartphones. In this paper, the authors present a platform to run automatic measurements in mobile phones using high-resolution power meters. Their platform synchronises the device and the measurement tool which is sampling at 250 KHz with minimal error, using short screen pulses for synchronisation. The paper also incorporates a detailed analysis of the cost of sending messages over a IEEE 802.11 links. Their results reveal that the energy cost per KB transmitted varies with the buffer size and interesting effects during transmissions and idle power states. Another interesting power model for wireless interfaces in Symbian devices has been done by Xiao *et al.* in [5]. In this case, the authors aim to model the energy impact of data transmission over IEEE 802.11g as a function of the traffic burstiness and an off-line measurement of the power consumed by the devices at a specific power state. Their model, validated using both an external multimeter and Nokia Energy Profiler, can be used to estimate the energy consumption of IEEE 802.11g interfaces in runtime but it is not clear the power overhead that this technique

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will have in the system due to the computation requirements.

## III. IMPORTANT POINTS AND LIMITATIONS

In this work we gave detailed information on the energy consumption of smartphones. This work should give the reader a feeling where energy is used and help to design energy aware protocols to reduce the overall power consumption, However Here is some important points:

1- Studies show that the most energy hungry parts of a mobile phone are the wireless technologies and not the display or the CPU.
2- Studies show that power consumption is proportional to the workload caused by the transfer, rather than the total transfer size itself.
3- For the short range communication Bluetooth should be used in case only a few data needs to be exchanged.
4- If more data needs to be transmitted, WiFi should be used.

Due to the space limitation not all works have been presented here, however presented works has a number of limitations which need to be described:

1- The last part of the paper in [1] is a coarse-grained estimation of the potential energy consumption of different usage patterns. They modeled five usage profiles but the paper does not include any justification of the values used to model each profile**.**
2- Xiao *et al.* [8], Despite that it is probably the most complete model, it does not consider resources like accelerometer and camera, and it does not take into account the impact of signal strength and burstiness on wireless interfaces.

Comparison of the different energy measurements and power models can be found in Table 2 (the table highlights the mobile platforms and the resources under study).

TABLE 2
COMPARISON OF THE DIFFERENT ENERGY MEASUREMENTS AND POWER MODEL

| Cite | Platform | CPU | Display | GPS | Bluetooth | WiFi | GSM | 3G | Description |
|---|---|---|---|---|---|---|---|---|---|
| [1] | Openmoko | * | * | * | * | * | * | | Power measurements |
| [2] | Symbian | | | | | | * | * | Energy impact of 2G and 3G cellular networks. |
| [3] | Symbian | | | | | * | * | * | Energy costs of wireless interfaces. |
| [4] | Android | | | | | * | | | High resolution analysis of 802.11 interfaces. |
| [5] | Symbian | * | | | | * | | | Energy model for data transmissions on WiFi as a function of the traffic burstiness. |
| [6] | Android | * | * | * | | * | * | | PowerTutor: online Power Model based on the voltage curve and linear regression techniques |
| [7] | Android | * | * | | | * | * | | Power Model for Android using application benchmarks. |
| [8] | Symbian | * | * | | | | | * | Power Model using linear regression. |
| [9] | Symbian | * | * | | * | * | | * | Power measurements |

## IV. CONCLUSION

Although tremendous efforts done by hardware manufacturers and operating system vendors but Mobile handsets are still power-hungry devices because they incorporate power-hungry hardware resources such as touchscreen displays and location sensors, and they support Internet data services so they are always connected to the network. Now researchers have been emphasizing the need of considering energy as a fundamental system resource in mobile devices.

To this end we present a detailed analysis of the power consumption of a recent mobile phones and covered studies that measured power in the energy consuming entities of a Smartphones.

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