The Nigerian Society of Engineers
ILARO BRANCH

1ST NATIONAL CONFERENCE

BOOK OF PROCEEDINGS

The Nigerian Society of Engineers
Ilaro Branch

1st National Engineering Conference, Ilaro - VIRTUAL

Theme: **RESEARCH AND INNOVATION THROUGH ACADEMIAINDUSTRY SYNERGY: PANACEA FOR TECHNOLOGICAL AND NATIONAL DEVELOPMENT IN POST COVID-19 ERA**

Date: 2 – 3 November, 2020

BOOK OF PROCEEDINGS

Compiled by Zacheus Adesakin Adetona, MNSE

Proceedings of the 2020 Ilaro Branch Engineering Conference of the Nigerian Society of Engineers

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ISSN: 2782-8441

Publication by:
Nigerian Society of Engineers
Ilaro Branch

A Review of the Efficiency of Smartphone Battery and Energy Usage in Technological Application for Sustainable Development

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ABSTRACT
Advancement in smartphones such as intensification in the raw computing power, efficient operating systems (OSs), or supporting feature-rich application-based functionalities, can be attributed to the key enablers of utilizing smartphone. To attain energy efficiency, it is very crucial to have a good understanding of how energy is used and how to efficiently use smartphone battery. The objective of the paper is to review the efficiency of smartphone battery and energy usage in technological application for sustainable development. Smartphones have become indispensable for many people around the world as they continue to evolve and introduce newer functions and operations. Battery capacity has however failed to keep up with the rate at which smartphones have evolved in recent years, which has led to rapid battery drain and the need for users to discard and replace them very frequently. The result showed that most common factors responsible for energy consumption and battery drain in smartphones are identified as the network, the device specifications, the applications on the device, and the common practices by the user.

Keywords: Battery, Efficiency, Operating System, Smartphone, Sustainability.

1. INTRODUCTION

More than two decades ago, smartphones have changed the way we live our lives. From checking the weather to running a business, we often rely on these small powerful devices to complete our daily tasks with ease. Since their first introduction, smartphones have consistently evolved to meet our growing needs in the form of faster wireless connections, sharper images, and greater memory storage, just to name a few. Today, we salute the ever-changing smartphone and feature highlights to understand its transformation to this day.

With the advancement in miniaturized hardware, the size of computers gradually became smaller, ultimately bringing a new computing paradigm called mobile computing (also referred as nomadic computing). Over the years, the mobile computing scenario also has changed drastically, and with the emergence of smartphones, mobile devices have become our new computers in a true sense (Tamimi, et.al. 2018).Today's mobile phones provide countless features for their users, users have become spoiled with the speed of their everyday electronic devices. Unfortunately, this variety of functionalities has its price. The battery life has become the main trade-off and is therefore a large marketing strategy. Smartphone batteries cannot keep up with power demands, even though battery technologies were improved in terms of performance and capacity (Schuss & Rahkonen, 2013).

Smartphones have also become a crucial enabler for smart homes and smart cities, supporting context-awareness for the IoT (Internet of Things), and this have increase the power consumption of this device. The battery accumulates energy when it is being charged, stores the energy for a duration and that is discharged when the device is on or/and in operation. Due to this continuous discharging, and the fact that the batteries of mobile devices are limited in capacity, the battery needs to be recharged periodically and most often in quick succession maybe several times in a day, depending on several parameters being used on the smartphone.

2. EVOLUTION OF SMARTPHONES

Ahmad, *et al.* (2017), presented a survey on energy estimation and power modelling schemes for smartphone applications. They considered studying energy estimation and modelling schemes for smartphone apps only, but not the hardware. The hardware-based mobile application energy estimation suffers from a few drawbacks, such as time-consuming and resources expensive, on the contrary, code-based energy estimation provides a wide range of options to the developer. Energy estimation against a smartphone application provides an opportunity to the developer for

remodelling the design with the objective of lowering the battery consumption. In a nutshell, the authors described existing smartphone energy estimation applications, qualitative and quantitative analysis of energy estimation schemes and some of the future research issues related to optimization of smartphone energy estimation to improve battery lifetime. In this context, a lightweight energy estimation framework design for mobile application is projected to be one of the future challenges to the research community.

According to Zaman & Almusalli. (2017) in a survey on smartphone power consumption and energy-saving techniques been conducted discussed the importance of power-efficient software design to make the device more useable. It has highlighted the role of no sleep bugs whose presence causes unexpected energy drainage from the smartphone battery during the idle period. In the default condition, all the components should either remain in off status or in idle condition except intentional coding by the developer to keep the component on. Such leakage of energy may occur due to mishandling power control Application Programming Interface (API) The availability of automatic detection of such no sleep bug and their ability to reduce the power consumption up to 32% have been described in the paper. The authors also discussed the role of energy profiling by the developer to analyse power consumption.

According to Degu (2019), who presented a systematic literature review where he categorizesd the reviewed works by different aspects of the performance of android-based smartphones. A total of thirty-one papers were studied and mapped into categories such as performance testing, resource leaks, memory utilization, and energy utilization. The presentation approaches of the studied papers were also identified, i.e., whether the paper presents a method, tool, evaluation, or a framework. Also, different research issues on these aspects are identified and discussed.

In a survey on energy consumption in mobile phones, Javed, *et al.* (2017), considered different factors which consume energy in a smartphone, such as OS, hardware, applications (e.g., browsers, social media, games, etc.) and user interaction with them including wireless (e.g., Wi-Fi, Bluetooth, 3G, etc.) and sensor networks.

Jofri, Fudzee & Ismail (2015) presented a survey on energy-aware profiler for energy management in mobile devices, whereby the authors classified the elements of energy profilers and reviewed related papers for each category. An energy-aware profiler collects data from the OS, hardware, applications, services and the usage pattern of a mobile device for analysing energy consumption. Also, Oliver & Keshav (2010) highlighted the importance of using real user data collected from the world and how it can influence application developmentby introducing the Energy Emulation Toolkit (EET) that allows developers to evaluate the energy consumption requirements of their applications against the collected data. As a result, by classifying smartphone users based on their charging characteristics, the energy level can be predicted with 72% accuracy a full day in advance.

3. SMARTPHONE POWER CONSUMPTION

For effective and efficient management of energy in a smartphone, it is very important to understand the power consumption details of each entity within a smartphone. A smartphone is a complex system and is composed of various hardware components and software applications. Both the hardware and the software components are responsible for the power consumption of a smartphone. If the hardware is efficient and the software is not able to carry out that efficiency, then the power consumption will be higher, and the same holds true for inefficient hardware with optimised software. Therefore, it should be noted that both the hardware and the software components must be equally efficient in order to provide maximum performance with less power consumption in a smartphone. Therefore, according to (Pramanik, et.al., 2019) understanding the power consumption in a smartphone requires the following knowledge

- A good understanding of each component of a smartphone
- The hardware and software relationship and coordination
- Where, how, how much, and in which condition the energy is used
- Energy consumption of each individual hardware
- Energy consumption of the OS and other system software
- Energy consumption of the applications
- Energy consumption due to usage
- The external factors responsible for power consumption

Identification of all possible power consumption sources in a smartphone as basis for the understanding of energy requirement and consumption in smartphones are essential. Several research works, (Elliot, Kor, & Omotosho (2017), Carroll & Heiser (2010), Xia et. al. (2015))1 have attempted to find out the key factors that are responsible for major energy consumption in mobile devices. But along with identifying the power consumption sources and estimating the approximate amount of consumption, the possible solutions to minimize the power expense of each component also have been suggested.

A smartphone is a complex system; exact analysis and estimation of power consumption of different components individually are not straightforward. It is further complexed due to the fact that besides the users and the manufacturers, many other external entities are directly or indirectly involved with smartphone ecosystem and they play a crucial role in its overall power consumption. Efficient energy management in a smartphone is all about maximising its battery life. For that, a rigorous understanding of the energy requirement and consumption of each component of a smartphone is required (Pramanik, et.al., 2019). Fig. 1 showed the stakeholders in smartphone power consumption and their roles.

Fig. 1: Stakeholders in smartphone power consumption and their role
Source: Pramanik, et.al., (2019)

According to Pramanik, et.al. (2019) the most important components that may lead to higher power consumption in a smartphone include CPU, GPU (GPU is a special type of processor that is responsible for processing graphical tasks like rendering 3D objects and playing games), memory, storage, display and sensors. Nevertheless, the networking modules together consume the most power than any other categories, as can be seen in Fig 2, which presents a suggestive power consumption share of different components in a smartphone.

4. REDUCING POWER CONSUMPTION IN SMARTPHONE

Like OS, it is difficult to minimize the power consumption of today's complex and feature-rich mobile applications. However, the following tips might help in reducing the power consumption of smartphone:

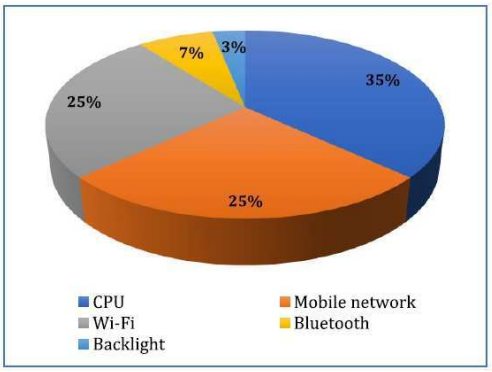

Fig. 2: Power consumption percentage share of different components in a smartphone
Pramanik, et.al., (2019)

- Install reliable applications: Installing verified and popular applications developed by well-known power handling of the application.
- Remove power-hungry applications: Removing any application that seems to be consuming more power is also a good option to reduce power usage.
- Remove unwanted applications: Some applications are not at all required by the user and hence can be uninstalled. Further, an accidentally installed adware must be removed in order to save the device from using excessive power due to usage of the unwanted resource.
- Manage permissions: Giving proper attention after starting an application in order to provide only the required permissions to the application is preferred. The permission should be restricted to only the required services to perform its operation and not anything else.
- Stop auto start-up: Some applications tend to use the automatic start-up option; to reduce energy consumption, only system specified applications should be allowed to auto-start, and the rest of the apps need not have that permission.

Background apps	•Apps like memory booster, file cleaning, Facebook, email, etc., run in the background continually, causing faster battery drainage. Also, continuous auto refreshing of the apps for social media, email, news, etc. discharge battery.
Regular updating of software	•Updating software involves connecting to the internet and downloading significant amount of data. This contributes to battery usage. Therefore, unnecessary updation should be avoided.
Music and video streaming	•Continuous streaming of music and videos is one of the major sources of power consumption.
Automatic data backup and apps synching	•The automatic backup of the data (e.g., photos, videos, or documents) and automatic synchronization of apps cause battery loss significantly.
Receiving notifications frequently	•Lighting, ringing, and vibration due to frequent notifications causes significant battery loss. •Notifications make the transceiver antenna busy, which also consumes battery.
Using lots of widgets	•Using a huge number of widgets, especially the health trackers (step counters, calorie burn calculators, etc.) definitely juice more battery power.
Bright & live wallpapers	•Live wallpapers or bright wallpapers with sharp contrast and vivid coloured on AMOLED display are quite notorious as battery burners.

Fig 3: Some of the reasons for battery drain in smartphone [Pramanik, et.al., 2019]

The following might help in reducing the power consumption of applications:

- **Install reliable applications:** Installing verified and popular applications developed by well-known developers will ensure proper optimization and efficient power handling of the application.
- **Remove power-hungry applications:** Removing any application that seems to be consuming more power is also a good option to reduce power usage.

- **Remove unwanted applications:** Some applications are not at all required by the user and hence can be uninstalled. Further, an accidentally installed adware must be removed in order to save the device from using excessive power due to usage of the unwanted resource.
- **Manage permissions:** Giving proper attention after starting an application in order to provide only the required permissions to the application is preferred. The permission should be restricted to only the required services to perform its operation and not anything else.
- **Stop auto start-up:** Some applications tend to use the automatic start-up option; to reduce energy consumption, only system specified applications should be allowed to auto-start, and the rest of the apps need not have that permission.

5. CONCLUSION

Smartphones are increasingly useful for so many applications. Many innovative and new applications of smartphones are being developed and still developing, such as location detector, monitoring of environmental conditions, sensing of traffic on the road, monitoring health conditions of people, gaming, and so on. All these applications work on real-time and consume a lot of energy. The battery within the smartphone supplies the required power to it all. But there is a limitation of the battery capacity, which is determined by its chemical properties and cannot be increased beyond a certain limit. This has been a constraint in unleashing the true power of smartphones. Therefore, it is suggested that energy limitations should be used cautiously, whereby efficient energy management in a smartphone is all about maximising its battery life. Nevertheless, all the stakeholders in the smartphone energy ecosystem should be responsible for realizing their roles in minimising energy consumption and have a methodological approach and planning to attain that.

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