Battery Life Optimization in Mobile Devices with Internet Usage

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***Abstract*—The developing ubiquity of smart phones and tablets has highlighted a few exploration issues. In this paper we focus on optimizing energy usage of mobile devices and show results of power and energy consumption measurements conducted on mobile devices from Internet usage. Mobile devices turned out to be increasingly energy- hungry decreasing the operational time for the user. An application "Power Monitor" is created to comprehend the usage pattern of smart devices. We have displayed three usage patterns and have demonstrated that how higher power consumption can be evaluated from such patterns. The paper then gives satisfactory guide to create such applications having less effect on battery life. Several rules for the end users are likewise given to prolong the battery life. At last the paper finishes up with some future research headings on minimizing energy use in mobile devices.**

Index Terms-Battery life, power consumption, android applications, usage patterns

I. Problem Area

A most frequently occurring problem among handheld devices such as tablets, smartphones and laptops is the energy consumption which is at high rate and battery capacity which is limited to a certain range. The high energy-consuming parts of hardware in mobile devices are Central processing units, display resolution and network adapters. Not only hardware parts even the usage of software applications reduce the battery life of device. If large amounts of data is to be processed by the software application then the usage of CPU will be high as it has to be remained active for more hours and in this case there will be high effect on battery life as more energy is consumed. The battery life is also affected if a program has pictures which need bright displays and this keeps the screen to be switched on continuously which gives a negative effect. There are many platforms for mobile devices such as Android, Windows, Apple IOS and Blackberry which share the common problems and effects although released by different companies.

II. Introduction

The most dominant devices in the present market are the mobile phones, tablets and IPads. The smart mobile phones provide various other functions by using internet, i.e. either by using Wi-Fi or 2G or 3G networks, the various activities performed by the smart phone are sharing the photos on the social media, playing games online etc. Sensors are also used by the smart mobile devices for services like GPS, digital compass etc. The hardware of the smart phones has high power CPU, bright displays and RAM. These hardware components use lot of power, the energy consumption is more and if the device is active continuously for longer hours by different internet applications it sucks lot of battery and the battery will be down very soon, the battery capacity is limited and is different from one device to that of other. The battery capacity for HTC dream device is 1150mAh and that of Samsung GT19100 is 1630mAh. The tablets have higher battery compared to that of mobile devices but even they too face problems from less life of the battery. Several research activities are going on how to improve the efficiency of battery but still we couldnt found a reliable solution for that. Lithium batteries are preferred by most of the smart mobile devices because it provides more energy than any other battery can provide. The amount of energy generated by a battery must be increased but that is not possible for the chemists at this point of time. Power saving is the significant issue among the various mobile devices now-a-days. The hardware components are power hungry and the battery consumption would be high by the hardware devices.The smart phones have features like GPS, graphics and high MP camera. They have Bluetooth, Wi-Fi, 2G and 3G mobile data connectivity. Various other applications are developed for the smart phones like browser applications, weather forecast apps etc. Due to this there is a heavy flow of network traffic.

In this paper, we briefly explained how power is spent in the devices forms the crux of proposing solutions in increased battery life .The objective of the paper is twofold. Firstly, it reports energy expenditure in smart devices. We have developed Power Monitor to understand the usage pattern of smart devices and estimate power consumption from the pattern. We have deployed the application to several individuals and collected usage logs. It is seen that usage patterns can explain high power consumption of smart devices. The second part germinates from these observations and we attempt to answer how to develop power optimized Android applications while engaging user experience. At the same time, we put forward a collaborative method for detecting and diagnosing energy problems by looking for deviation from typical battery use and an implementation as an application called Carat. We also presented a usage pattern analysis of smartphones. We define possible smartphone states based on their basic functions, e.g., voice call and data communication. Second, we define log metrics to measure time and battery spent in each operational state.

The remaining of the paper is organized as follows. Section II describes previous work for predicting battery lifetime and mobile applications for battery management. Section III describes in detail energy expenditure in smart devices and estimates power consumption through Usage pattern in mobile devices. Section IV provides several guidelines for the Android software developers to produce applications that are battery-aware which optimize accordingly and control some features of their devices to increase the battery life. Finally, we draw conclusion by presenting our analysis results minimizing battery consumption.

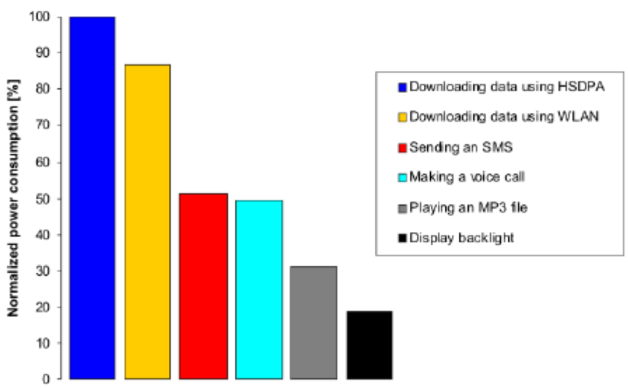

Fig. 1. Normalized Power Consumption

III. Related Work

Energy consumption brought about by wireless information transmission on mobile devices is expanding quickly with the development of web applications, which requires network connectivity. Battery life is declined due to this, several innovations are taking place to increase the battery life of the mobile phones but they are not up to the mark, the energy consumption of internet applications are more and the existing batteries are not able to meet the demand of applications.Existing network management techniques have concentrated on execution and performance of network itself. The power models that use traffic characteristics to evaluate the consumption of energy at the time of transmission of data using Wi-Fi are generated and this is used as a solution for this problem by the authors [11]. In [12], the authors addressed the previously stated test by building up a device called ARO (mobile Application Resource Optimizer). The cross-layer connection for layers extending from higher layers, for example, user input and applications performance down to the lower protocol layers, for example, HTTP, transport, and essentially radio resources is exposed by the ARO (Application Resource Optimizer) which is the principle tool. Specifically, so far less focus has been set on the collaboration amongst applications and the radio access network (RAN) in the community of the research. The authors in [13] recognized the most well-known NRAs and configurable parameters which can affect the consumption of energy while running these NRAs. They advanced and proposed a method to calculate the consumption of energy in mobile phones while doing a practical set of observations. A measurement bench has been created to measure the consumption of energy in the smart mobile devices is presented by the authors. To support the methodology selected experiments are done on the latest mobile devices. A detailed study on the consumption of energy by the smart phones concentrating on various communication interfaces such as Bluetooth, 3G, and Wi-Fi in various situations such as scanning, transferring and standby is given by the authors in [14]. Various other aspects that impact the energy consumptions and performance of mobile devices hardware components such as CPU, Screen and Networking. The energy consumption is in direct relationship with the measure of light transmitted. A user can choose the screen brightness level, the screen is more clear and readable if the brightness is high but it increases the consumption level of energy [15]. A user generally wouldnt increase the brightness level in most cases. The authors [16] say that 30

The most energy consuming things of hardware in mobile devices are CPU and Screen. It can be reduced and avoided is by using various other schemes i.e. by reducing the screen brightness that have proven successful [16]. The DFS is combined with such schemes and the results show that the battery consumption has been lowered to 10

IV. Result and Discussion

A few researches have been undertaken to figure out how energy is spent in mobile devices. In the paper [1, 2], the authors have displayed a breakdown of power utilization by different hardware segments. The outcomes are summarized as beneath.

A. *Power consumption in hardware segments*

It states that higher the brightness of the touchscreen, higher is the power utilization of display hardware. Along these lines decreasing the brightness in mobile devices would bring down the wastage of energy.

- Network compounds: The network interfaces expand high amount of static and dynamic power. Figure 2 illustrates that even when the EDGE, Wi-Fi or 3G are unmoving, they utilize lot of power. Likewise when these advance technologies are being utilized by applications for information exchange, the power consumption is higher [2].
- CPU and RAM: The authors report that CPU working with higher frequency draws more power. But also argues that dynamic scaling of frequency may not be successful arrangement for this situation as it will expand the execution time of uses and different tasks. It is demonstrated that RAM, audio and flash subsystems consume less

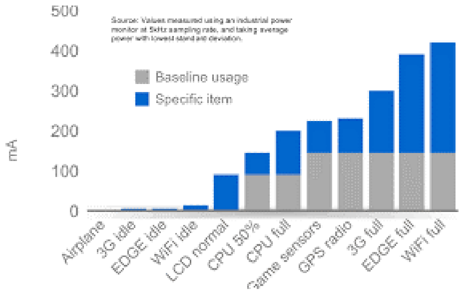

Fig. 2. Power consumption by various hardware components

power. Even for video playback utilization of energy will be lower, the power drawn by SD cards is underneath 1

B. power utilization by from android applications

Clearly if Android applications don't utilize the hardware reasonably, the battery life will diminish significantly. In this subsection we show how the applications expand the power utilization.

- Frequent awakening in background: Consider an application that performs some tasks in backend [9]. If the task performs some features and updates by waking up the monitor, it draws huge amount of battery. By taking GPS traffic apps (Google Maps and Waze) into consideration, offer highly-targeted and dynamic driving directions and traffic estimates, but with their powerful capabilities, comes great resource drainage. Figure 3 states that Waze Android background battery drain rate exceeds the Google Maps app battery drain rate by 285

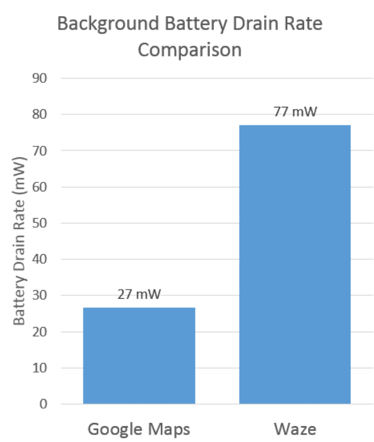

Fig. 3. Background battery drain rate comparision

- Power consumption for 3G usage: Almost all the cell phones contain the equipment for 3G connections in recent times. The applications that rely upon web to get information from server(s) or run updates will drain battery quickly. Typically 3G requires 225 mA when performing any tasks or browsing in web [1, 2].
- Bulk information exchange: Several applications (e.g. Facebook, YouTube, and Dropbox) exchange mass information or stream audio/video over web and thus account for high power usage. As far as battery utilization, 3G takes 225mA, Edge 300mA and Wi- Fi around 330mA. Even if the cell phone is idle and connected to network utilizing Wi-Fi, Edge or 3G, it consumes power to get access from the network. Edge expands around 5mA even in idle state [1, 2].

C. Detecting bug behavior of android applications

Energy Bugs which present in Android applications, consumes energy by performing tasks not intrinsic to application functions in mobile devices. The research [2, 3] presents a collaborative way to deal with such bugs. The paper classifies the applications as Bugs and Hogs. Bugs are characterized as applications that utilize huge energy on small devices and drain the battery much faster when compared to other instances of same app whereas Hogs utilize high energy in smart devices and drain battery much faster than the average app. In Figure 4, the rates when an application is running on a client with a specific OS version (subject distribution) might be higher than when running on clients with another OS version (reference distribution).

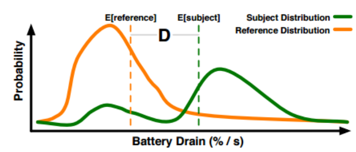

Fig. 4. values of conditional energy drain rate distributions to classify apps as hogs, bugs.

This paper also depicts a strategy and execution, called Carat, for performing such analysis on mobile devices. Carat is created to accumulate data about running applications, operating systems and device model. The Carat architecture consists of an app, a central server, and an analysis. Figure 5 shows an overview of our implementation.

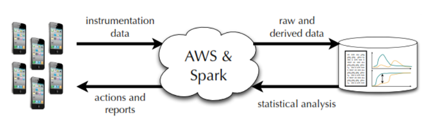

Fig. 5. The Carat architecture, showing the crowd-based front end, the central server with the analysis running in the cloud, and the stored samples and results.

Carat keeps running as a user- level application on stock devices. This platform specify limitations on what data can be accessible and when our application is permitted CPU time to measure it. The Carat server collects samples from users running the Carat app and stores them for later use by the backend analysis. The backend analysis converts samples to rate distributions and loads them into Spark RDDs, a distributed data structure that provides caching.

D. Power saving profile through Usage pattern in mobile devices

Few explorations [4, 5] has concentrated on applying the usage patterns of smart devices which reveal much data about energy consumption by individual devices. In this paper, we determine and show power saving profiles by analyzing them in mobile device usage patterns. The whole architecture is developed as an Android application ”Power Monitor and is deployed to the mobile devices. In Figure 6, a monitoring module of the application monitor the battery power information by periodically collecting several data from the devices and stores them locally [6]. A learning engine then operates on the raw data to generate multiple usage patterns over time and space, which characterizes the user contexts by recording the information about power of battery and its applications. The engine then processes the patterns by analyzing the information and generate power saving profiles dynamically within the devices. The profiles contain a few framework modules namely Application monitor, Battery monitor, Context monitor, CPU monitor, Display monitor, Network monitor as mentioned below , deploys into smart devices and wisely optimize power consumption.

- Application monitor: The collected data will be retrieved by running the applications and their CPU load.
- Battery monitor: It records status (discharging/AC charging /USB charging) and remaining battery level.
- Context monitor: Context data like system date, time, location and luminosity module.
- CPU monitor: It registers the operating frequency and CPU load.
- Display monitor: It calculates the total interaction time of mobile devices and determines the brightness level and screen timeout.
- Network monitor: It records the status of Wi-Fi, GPS of mobile devices, mobile data and amount of network traffic used by the applications.

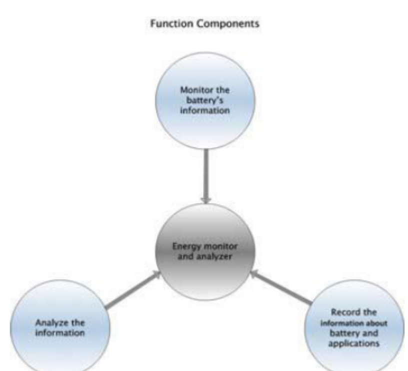

Fig. 6. Functional compounds of ”Power-monitor”

In order to evaluate the battery gain, three different usage patterns in this section are described to show the energy expenditure in the devices .Power Monitor is deployed to few Android mobile devices. The app calculates the initial battery life during the monitoring phase and after the power saving profiles are activated [4].

A real life usage pattern for Samsung GT-I9100 running Android 2.3.4 version.

- 32 percentage of battery capacity is being spent on networking operations and GPS when several applications (Facebook, Gmail, Google maps, snapchat) are running in backend.
- Battery level reduces from 75 percentage to 50 percentage when GPS is actively used for 30 minutes which dissipates 70mAh.if the GPS is turned off, total network usage is about 20 to 22MB when the device is connected using mobile data network.
- Brightness level is 65, screen timeout 60 seconds and interaction time is 87 - 110min if average CPU load and operating frequency are 54 and 800.
- If Battery capacity is 1650mAh then phone interaction time is 127 minutes/day on average and the brightness level is set to 30 which is the minimum for the phone.
- If 3G is actively used for 105 minutes and idle for 1335minutes resulting in 394mAh and 67mAh power consumption respectively when Wi-Fi and Bluetooth are not used.

E. USAGE PATTERN ANALYSIS

In this area, we summarize the theory of this study, a logger application, a collective method technique, and analysis result. First, we developed a mobile application based on the Android mobile platform in order to collect log data. This application monitors the previously defined data and records it to a log file periodically and transfers log file to data server [5].

By considering only five operation states which are a large influence on power consumption:

- Voice call.
- Data communication via Wi-Fi.
- Data communication via 3G.
- Waiting time.
- Other activity.

After collecting those data periodically, we calculate the time and battery spent in each state and compare usage patterns among smartphone users.
We present the results of our analysis of mobile device usage data.
1) Average usage: Average usage time and battery spent in each operation states where most users spent time in a waiting state (85-54)
2) Usage Pattern: Fig. 7 compares time and battery consumption for five operational states which described above. From the spent time comparison (Fig. 7a), each user spent a different amount of time in each state. Fig. 7b shows

how much battery is been utilized by each user and spent in each state and the differences from the time pattern shown in Fig. 7a. Many users have been using 3G as a major communication in recent times. We summarized some reasons for this situation. First, although Wi-Fi provides faster access and higher bandwidth, it is inconvenient because its coverage range is smaller than that of 3G. Second, this comparison is based on time spent in each state. Finally, Wi-Fi is less secure than 3G.From Fig. 7a, we can guess that User12 has a limited data plan and User14 has an unlimited data plan. In fact, User14 is the first client who is using an unlimited data plan. User12 is a friend of the first client who is using a limited data plan. Fig. 7b compares the battery consumption of the three main operational states. This figure shows that the battery consumption varies according to the type of networks [5].

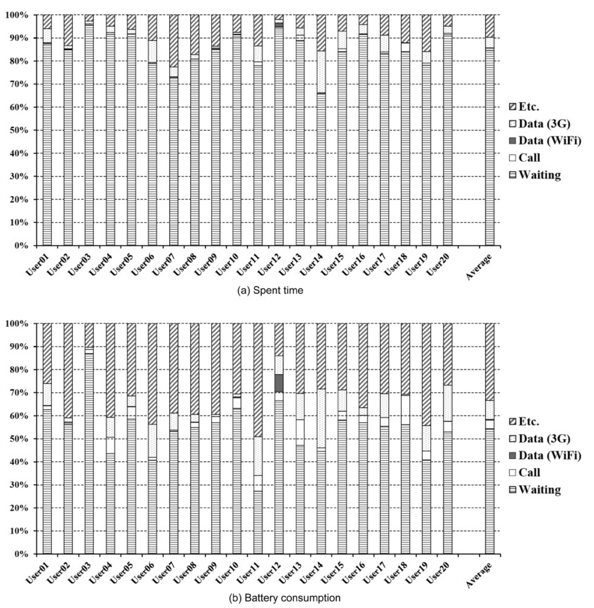

Fig. 7. comparison of time spent and battery consumption for five operational states.

V. Best practices for optimizing battery in mobile devices

A. Choosing network for downloading

For downloading high volume of data it is better to prefer Wi-Fi than to 3G because the speed is way higher to 3G but the download time will be significantly less even if it consumes more energy than 3G. Prefetching data: Too much download will increase in battery drain. So by avoiding increased network operations over Wi-Fi, EDGE or 3G, it will be a good sign to perfetch data and store them locally in mobile devices.

B. Turn down the brightness

It's probably obvious, but turning down the brightness manually and turning off automatic brightness will reduce the overall power spent in the Display hardware. Setting a shorter screen timeout: Set your display's screen timeout to as short a time as is practical for you. If your screen timeout is set to a minute, it'll use four times more power than if it were set to 15 seconds. Reducing it will help keep your battery running for longer [8].

C. Turning off wireless technologies

The wireless technologies spend energy to just maintain connection to the network. Thus if the smart device is not actively being used, Wi-Fi, 3G and Bluetooth must be switched off to conserve the battery.

D. Location

Use of GPS should be limited to cases where exceptionally fine-grained area data is required. Turning off location data, or changing your Location settings to use Wi-Fi or 3G data rather than GPS works perfectly well.

E. Trimming apps running in the background

It is possible that some applications are not visible to the user as they are running in background but consuming higher power. Such applications are barely use or a feature you never use, you will uninstall the app or turn off the feature to reclaim higher battery life.

F. Auto-sync trap

Applications using this feature open and maintain multiple network connections leading to more energy consumption at the networking interfaces .Turn off auto-sync for those apps you don't need constantly updated.

G. Sleep mode

Setting sleep mode or blocking mode to switch off Wi-Fi and mobile data when you don't need them.Likewise, you can set your phone to airplane mode when moving through areas with very poor signal, the smart devices emit signal at quite high power. In such cases airplane mode could be activated which disables all connectivity and saves battery where it consumes 1-2 mA [8].

H. Update applications

There is a reason developers constantly update apps, and most of the time it's memory or battery optimization. Keeping your apps updated also means you have the best optimizations available. Likewise, delete old apps you no longer use, because these may be running background processes that chew up RAM and battery life [8].

I. Using Power Tutor

This application provides how much energy is being consumed by the running applications in Android devices. It works like a task manager and keep on shows how much energy is being utilized by any applications for long period of time.

VI. Conclusion

Predicting the battery lifetime of mobile devices is important to minimize battery consumption at the application level. Where smart devices are one of the fastest growing types of devices in the current mobile networks. In a nutshell the paper describes how energy is being spent in today's smart devices. Power consumption in hardware and networking interfaces are reported to be the most power hungry components. Two other significant research studies are mentioned by detecting bug behavior out of which Carat classified and compared with applications like bug and hogs. The other work reports significant power saving profile through Usage pattern in mobile devices and also described three usage patterns using Power Monitor and estimated the power consumption of the respective devices and also presented a usage pattern analysis using log data collected from smartphones .Proposed a prediction model based on usage patterns, such as the battery consumption rate when making voice calls, using data communication, or waiting for calls and monitored smartphone usage and constructed usage patterns. We have presented our analysis results using real usage log data .Then the paper illustrates a survey of energy consumption caused by Wi-Fi data transmission. Further aimed to optimize the energy consumption by doing usage pattern analysis by creating usage profile of a user which will toggle the Wi-Fi connection of the smartphone to reduce the unnecessary battery power consumption. Incorporated power saving methods into Android development to create applications that are power optimized. Several useful tips are provided to minimize power drain by the display hardware, networking interfaces, keeping CPU frequency at the minimum and more. Moreover in detail end best practices for optimizing battery in mobile devices are also provided to further reduce energy expenditure. This analysis can help to optimize the battery and design the smartphones which consumes less power.

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