Optimizing Power Consumption in Smartphones: A Comprehensive Survey

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Abstract- Smartphones are being used extensively these days and they are capable of replacing conventional computers and laptops to some extent. The main reason is that smartphones are smaller in size and lighter compared to bigger and heavier computers or laptops. The battery powering a smartphone also has a size constraint and hence the capacity. Though new generation communication systems such as 3rd Generation (3G), 4th Generation (4G) and 5th Generation (5G) can provide the best services to users, they draw considerably more power in smartphones. This limits the battery backup of smartphones and hence the battery life. This survey presents various ideas and proposals published for reducing the power consumption in smartphones which support new generation communication standards.

Keywords – Smartphones, communication, generation, power consumption

I. INTRODUCTION

Most of the electronic devices are powered from batteries. The power consumption analysis in various components of the device is crucial for the designer or engineer to produce the best device in the market with improved battery backup. Smartphone is a very good example among the electronic devices and is attracting many engineers and researchers in this field. The new generation communication standards like 3G, 4G and 5G require more power for their operation. They are causing battery backup problems in smartphones. This stems from the fact that these communication systems provide rich data rate services like video/audio conference, video on demand, faster internet and many others along with the basic audio call service.

The mobile phone manufacturers are competing with each other to produce smartphones with improved battery life. It is essential to optimize and manage energy usage efficiently in network components. The hardware components of a typical smartphone are processor/CPU, RAM (Random Access Memory), LCD screen, modem (2G/3G/4G/all of it), GPS, WiFi, Bluetooth etc. The power consumption in these components vary depending on the usage and application that is running on the smartphone.

The new generation communication technologies offer high data rate services. This is due to higher bandwidth allocated to these technologies. Hence power drain will be more compared to 2G. In order to improve battery life, it is necessary to optimize power consumption in every possible use case scenario. With such optimization technique one also should make sure that the performance of the overall system is not affected. This means throughput and quality of service (QoS) should remain unaffected.

The rest of this paper is organized as follows. Section II presents the related work in power optimization techniques in smartphones. Section III discusses the methodology along with the background study. Section IV discusses power consumption analysis in smartphones and Section V presents a detailed study of investigated power consumption optimization in smartphones. Section VI concludes the paper.

II. RELATED WORK

An analysis of power consumption in a smartphone under various usage scenarios is described for a mobile phone ‘Openmoko Neo Freerunner’ for 2G (GSM) connection by developing a power model [1]. The experiment identifies many components during various states of the phone where the power consumption will be more and critical.

An analysis and comparison of power consumption measurements in mobile phones for 2G and 3G networks is presented for the services-text messaging, voice and data [2]. The paper reports larger energy consumption in 3G networks for text messaging and voice services than energy consumption in 2G networks.

In [3], authors analyse the end-to-end communication activities of a modern mobile phone, Nokia N95, to understand how much energy different communication alternatives consume. In particular, they investigated the interactions when multiple connections are used in parallel.

In [4] authors show that the energy can be saved and hence the capacity of the cellular networks can be increased by guiding users indirectly to optimize their UE (User Equipment) location. The results show that a path loss (PL) improvement of up to 10–25 dB can be achieved.

The architectural design-space and methodologies for reducing the dynamic power dissipation in the Direct Sequence Code Division Multiple Access (DS-CDMA) downlink RAKE receiver is presented in [5]. At the algorithm level, authors investigate the tradeoffs of reduced precision and arithmetic complexity on the receiver performance.

An architecture for receive diversity which significantly reduces the power consumption in Long Term Evolution (LTE) compared to conventional approaches is proposed in [6]. Depending on the environment it has a similar performance as maximum ratio combining while delivering a power saving of 30% in the radio frontend.

A power management scheme while downloading webpages in 3G network is proposed in [7]. Authors identified some special characteristics in WCDMA and address power consumption issues through two novel techniques.

Adaptive power control algorithms has been widely studied for interference reduction, base station radiation decrease and terminal battery saving in 3G cellular systems. In [8] authors propose an evolution of these algorithms in the forward link.

UMTS (Universal Mobile Communication Systems) is a 3rd generation (3G) telecommunication network based on the existing GSM (2nd generation, 2G) core network employing a totally new radio access technology WCDMA (Wideband Code Division Multiple Access). 3G was developed mainly to provide high data rate (up to 2 Mbps) services such as internet, video telephony, multimedia and audio/video streaming which 2G could not support due to bandwidth limitations [9].

III. Methodology

WCDMA is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system. User information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits (called chips). The chip rate of 3.84 Mcps (Million chips per second) leads to a carrier bandwidth of approximately 5 MHz. It supports highly variable user data rates, in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. It supports two basic modes of operation- Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, separate 5 MHz carrier frequencies are used for the uplink and downlink respectively, whereas in TDD only one 5 MHz is timeshared between the uplink and downlink. Uplink is the connection from the mobile to the base station, and downlink is that from the base station to the mobile.

The radio interface protocols are needed to set up, reconfigure and release the Radio Bearer services. The protocol architecture [9] is shown in Figure 1. The protocol layers above the physical layer are called the data link layer (Layer 2) and the network layer (Layer 3). In the UTRA FDD radio interface, Layer 2 is split into sublayers. In the control plane, Layer 2 contains two sub-layers – Medium Access Control (MAC) protocol and Radio Link Control (RLC) protocol. In the user plane, in addition to MAC and RLC, two additional service-dependent protocols exist - Packet Data Convergence Protocol (PDCP) and Broadcast/Multicast Control Protocol (BMC). Layer 3 consists of one protocol, called Radio Resource Control (RRC), which belongs to the control plane.

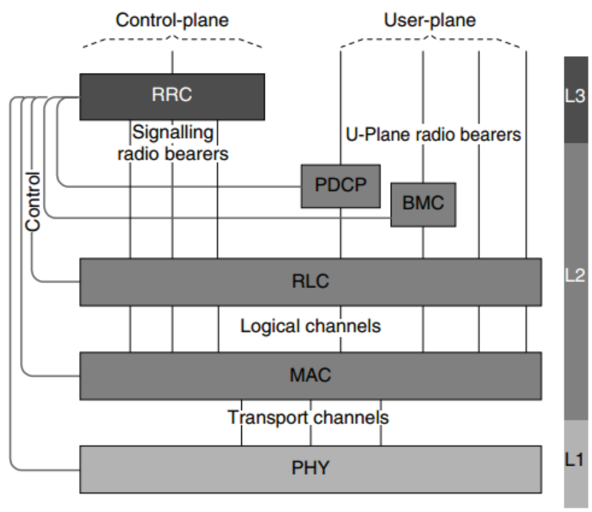

Figure 1. UTRA FDD Radio Interface protocol architecture

IV. Power Consumption Analysis

Power consumed for sending an SMS is dominated by the display components and is as shown in Figure. 2 [1]. The GSM radio shows an average power of 66.3 ± 20.9 mW, only 7.9 mW greater than idle over the full length of the benchmark, and accounting for 22 % of the aggregate power (excluding backlight). All other components showed an RSD of below 3 %.

Figure. 3. shows the power consumption when making a GSM phone call of 57 second duration [1]. GSM power clearly dominates in this case at an average power of 832.4 ± 99.0 mW. The power breakdown for emailing between the GPRS and WiFi benchmarks is comparable, except for the GSM and WiFi radios. Despite presenting identical workloads to the radios, GSM consumes more than three times the power of WiFi. For web browsing application, GPRS consumes more power than WiFi by a factor of 2.5. In case of a next generation technology 3G, this factor may increase even more because of the higher bandwidths supported by 3G. The results in this study show that the majority of power consumption can be attributed to the GSM module and the display, including the LCD panel and touchscreen, the graphics accelerator/driver, and the backlight.

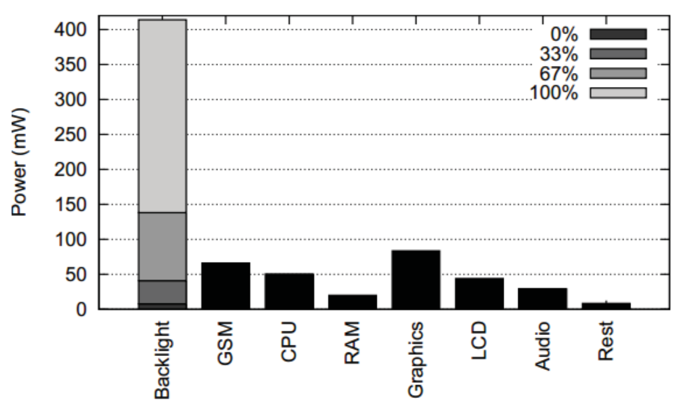

Figure 2. Power breakdown for sending an SMS

In Figure. 4. power consumption for different mobile services normalized to the power consumption during downloading data using High Speed Downlink Packet Access (HSDPA) is shown [2]. Downloading data using Wireless Local Area Network (WLAN) comparatively drains lesser power. For sending an SMS and making a voice call, the power consumption is almost comparable but significantly less than that of HSDPA and WLAN. It is clear from the plot that all the capabilities that imply the use of a wireless air interfaces are power-hungry, thus significantly reducing the battery life of the phone.

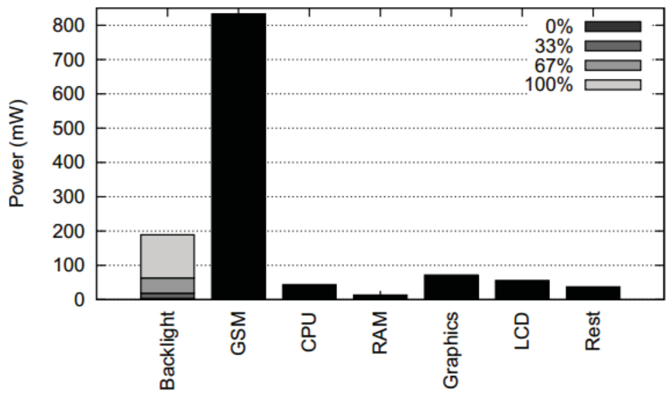

Figure 3. GSM phone call average power

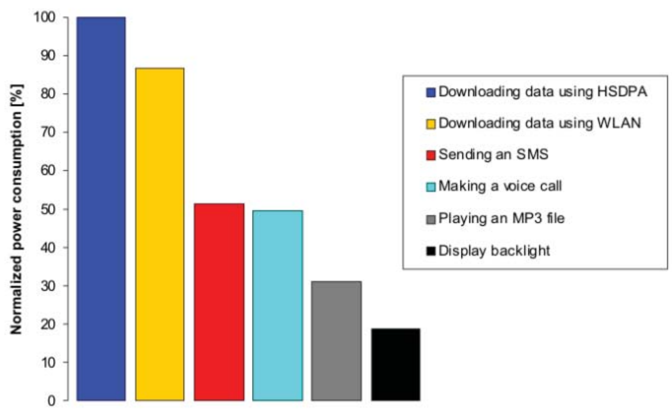

Figure 4. Power consumption for different services

The paper reports larger energy consumption in 3G networks for text messaging and voice services than energy consumption in 2G networks. On the other side the 3G networks become more energy friendly when large volumes of data have to be downloaded.

Table 1 shows the values for power consumption on a Nokia N95 for both GSM and UMTS using the voice service [2]. The power values for the calls have been obtained by making and receiving a phone call of five minutes duration and calculating the average of the power levels. The results show that making a call using GSM costs 46% less energy and receiving a call costs 50% less energy than using UMTS. Being idle while connected to a GSM network costs 41% less than UMTS.

Table 2 shows a comparison of energy consumption using 2G alone, 3G alone and intelligent switching [2] between these networks (Handover). It is clear from the observation that, 3G consumes more power than 2G for the applications text messaging, downloading data and voice call.

Table -1 Power consumption for voice service

Scenario	**GSM**	**UMTS**
Receiving a voice call	612.7 mW	1224.3 mW
Making a voice call	683.6 mW	1265.7 mW
Idle mode	15.1 mW	25.3 mW

Table -2 . Energy comparison using 2G, 3G and handover

Service	2G	3G	Switching
50 SMS of 100 bytes	90 J	110 J	90 J
100 Mbytes downloading	10006.2 J	3512.1 J	3512.1 J
5 hours of voice calls	12304.8 J	22782.6 J	12304.8 J
50 handoffs			245 J
TOTAL	**22401.0 J**	**26404.7 J**	**16151.9 J**

Parallel connections save energy but the gains vary depending on the technology. TCP downloads during 3G voice calls result into 75%-90% energy savings, TCP downloads during VoIP calls result into 30%-40% savings, and TCP downloads when other TCP streams are active at the same interface result into 0%- 20% savings. The results indicate that there is a significant potential to save energy if applications are engineered to take advantage of this phenomenon.

V. POWER OPTIMIZATION TECHNIQUES

As evident from the survey done in section IV, 3G consumes more power than 2G in various use cases of smartphone. The technique of guiding users indirectly to optimize their UE (User Equipment) location results in lower power consumption by smartphones as well. The power levels of cellular network User Equipment (UE) may vary considerably in both the receiver and the transmitter side, especially in indoor locations. With an indirect guidance method, the users are self-optimizing their UE to a better location with the help of an application.

Thus, the user distribution is weighted more on high quality connection areas, which results in saving the UE batteries and reducing the overall radiation. This power reduction can also be understood as a capacity increase, especially in radio networks based on Code Division Multiple Access (CDMA), such as the Universal Mobile Telecommunications System (UMTS) technology. The results show that a path loss (PL) improvement of up to 10–25 dB can be achieved when the user locations are optimized and the signals are coming from the outdoor BSs.

Two architectures for implementing the reference and reduced complexity receivers are proposed and analyzed with respect to their dynamic power dissipation. Authors report that reduction in precision from a 16 bit to a 10 bit data-path is found to yield significant power savings of 25.6% in the reference RAKE receiver architecture, with a performance loss of less than 1 dB. Further, a power reduction of up to 24.65% is achieved in a 16 bit data-path for the reduced complexity RAKE receiver compared to the reference architecture, with a performance loss of less than 2 dB. The combined effect of reduced precision and complexity reduction leads to a 37.44% savings in baseband processing power.

Depending on the environment the optimized receive diversity has a similar performance as maximum ratio combining while delivering a power saving of 30% in the radio frontend and allowing even better power reduction on system level. Minor modifications have to be made at the radio frontend. The performance of the proposed architecture is evaluated in multipath fading channels in terms of bit error rates. This architecture uses either analog combining or MRC depending on the channel condition. A switching scheme tracks the channel condition and selects the best compromise between performance and power consumption.

In the full performance mode both receive branches are activated and MRC as well as spatial multiplexing can be used. In the analog combining mode, the power consumption is reduced by 30% while the performance in an urban micro channel at velocities up to 20 km/h is similar to those of MRC. Optimized switching between both combining schemes gains a longer usage time of the MS without compromising on receiver performance.

Two features are proposed for a power management scheme while downloading webpages in 3G network is proposed. First feature is to reorganize the computation sequence of the web browser when loading a webpage, so that the web browser can first run the computations that will generate new data transmissions and retrieve these data from the web server. Then, the web browser can put the 3G radio interface into low power state, release the radio resource, and then run the remaining computations.

Second feature is to introduce a practical data mining based method to predict the user reading time of webpages, based on which the smartphone can switch to low power state when the reading time is longer than a threshold. Experimental results show that the proposed approach can reduce the power consumption of smartphone by more than 30% during web browsing, and reduce the webpage loading time by 17%.

The proposed enhanced adaptive power control algorithm tries to maintain the inter-cell interference stable and to reduce intra-cell interference when it is possible. Therefore, the power control steps of mobiles requesting a power increase may be reduced to limit the total power increase if some constraints are verified. The proposed algorithm uses an adaptive step, which is updated using the instantaneous mobile power control command and the command history. Moreover, a stabilization zone above the SIR target is used to limit oscillations. The proposed algorithm has been compared to the 3rd Generation Partnership Project (3GPP) standardized power control and to a recently proposed adaptive power control. Simulation results has shown that the proposed algorithm decreases slightly the outage probability as the already proposed adaptive power control and reduces the power consumption.

VI. CONCLUSIONS

This survey presented the analysis of power consumption in smartphones in various use case scenarios such as sending an SMS, making a voice call, downloading data and many others. The outcome of this analysis is that the power consumption will be more and critical in phone's modem and hence can be considered as a good candidate for optimizing power consumption. The study also investigated several ideas and proposals for optimizing power consumption in smartphones supporting various communication standards.

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