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Mobile Terminals' Energy: A Survey of Battery Technologies and Energy Management Techniques

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ABSTRACT

In the last few years of the past decade, advancements in electronics technology have increasingly made electronic devices offer high performance with corresponding decrease in size of the electronic devices. However with this increase in performance and decrease in size of electronics devices there is an increase in demand for mobile devices' battery to keep the device up for longer period in operation and standby times. Research has however shown that advancements in battery technology have not being in tandem with advancements in other fields of electronics. Therefore wherever battery technology fails, it is complemented by electronics and communication technologies. In this work; a survey of mobile terminal energy management techniques and battery technologies was carried out and Dynamic power control algorithm (DPCA) was proposed. Results from simulation showed that DPCA increased battery performance when compared with another power control technique in literature.

Keywords: *Battery, Dynamic Control, Power control, Step-wise, Base Station*

1. INTRODUCTION

With recent advancements in Electronics, Mechatronics and Communication engineering, human life has become more meaningful and living more comfortable as these technologies are now shaping our lives for the better. Now robots are more sophisticated, satellites are more intelligent, homes are now smart and cell phones are not just "telephones" anymore. These devices now function at the highest level of precision, accuracy and performance. They also perform multiple tasks or functions; other than the traditional functions they have been known to perform. However, in most cases, these devices are operated or are deployed far away from power supply and they have to draw power from small energy-limited battery.

Therefore, these supercomputing electronics devices invite a complex problem; which is keeping these products running on very small batteries for longer periods of operation and standby time [1]. Manufacturers of these electronics devices are continually designing low-energy consuming components [2] and implementing dynamic power-consumption-management procedures and policies that help conserve the power of the electronics device [4]. Although, there have been impressive technological advancements in battery technology over the years, it definitely has not kept up with the advances in other technological fields [5, 6, 11].

Therefore, Communication engineers have taken advantage of advancements in Wireless Network technologies and have implemented procedures which effectively involve the networks in energy management. One of such procedures that is now being used to increase the performance of battery and increase battery life is Power control. Power control regulates transmit power of a transmitting electronics device; so that the device does not transmit at unnecessary high transmit power. By this process, the device draws less power from stored energy in the battery, thereby reducing the number of times in between discharge/charge cycle prior to battery disposal, consequently increasing the battery life.

1.1 Battery Technologies

To achieve the light weight and the small size of electronic devices as we see them today, the battery powering these devices had to be considerably light and thin and still possess the required quality and power output that the device needs. Some parameters of battery that are important to the designers and manufactures of electronics devices and especially mobile electronics devices are (i) weight (ii) cost (iii) cycle life performance, and (iv) volume [12].

Battery technologies that have been used over the years and still evolving include;

1.1.1 Nickel Cadmium Battery (NiCd)

This battery technology has been in used for several decades to develop rechargeable batteries for portable electronic devices such as low cost portable radios, emergency medical equipment and portable CD players [13]. The advantages of this battery technology include; low cost, fast and simple charge even after prolonged storage [11]. High number of charge/discharge cycles, if properly maintained. The NiCd provides over 1000 charge/discharge cycles. However, NiCd is losing its relevance to newer battery technologies with higher energy density and less toxic metals [12].

1.1.2 Nickel Metal-Hydride Battery (NiMH)

Research in this battery technology started in the 1970s, and it is now being used in areas such as mobile computing, satellite and wireless communications [12]. Its advantages include high energy density, 30% to 40% more than NiCd [13]; and it uses environmentally friendly metals. However, they have shorter cycle life, about 50% self-discharge compared to NiCd, are 20% more expensive, and are inefficient at high rates of discharge [11].

1.1.3 Lithium Ion Battery (Li-ion)

Today, the Li-ion is the fastest growing and most promising battery Technology [12]. The energy density of the Li-ion is typically twice that of the standard NiCd [11], and its cycle life about twice that of Ni-MH batteries. It also has relatively low self-discharge, less than 50% of that of NiCd and NiMH. These characteristics of Li-ion, in addition to longer lifetimes have made it first choice battery for PDAs, laptops and Mobile phones. Li –ion is however more expensive than Ni-MH batteries [11].

1.1.4 Lithium Polymer battery (Li-polymer)

These are very slim, extremely light weight batteries based on the new Polymer Lithium Ion Technology. These are the highest energy density batteries currently in production [12]. Each cell outputs a nominal 3.7V at 1000mAh and is expected to suit the needs of light-weight next-generation portable computing and communication devices [13].

At present these batteries are expensive to manufacture, however, once these batteries can be mass-produced, the Li-ion polymer has the potential for lower cost. Higher manufacturing costs will be offset by reduced control circuit. Having taken an overview of battery technologies for today and the future, an overview of power management techniques is presented in the following session.

1.2 Energy Management Techniques

1.2.1 Dynamic Power Management

Dynamic power management (DPM) is one of the most popular and successful low power design techniques in commercial electronic devices [6]. It is a power management techniques greatly explored by manufacturer of electronic devices, and mobile devices in particular. The principle of DPM is to selectively shutdown or depresses voltage/frequency of some components which are idle, thereby conserving battery energy for the device whose energy is being managed by DPM [3]. In a power-managed system it is possible to set components into different power states. Some weakness of the DPM is that based on its stochastic and predictive nature, policies are implemented on prediction of future events based on past history and or events resulting sometimes in over predictions and under predictions; consequently, a policy is likely to issue more shutdown commands and degrade performance. On the other hand, a policy can be conservative in power saving and issue fewer shutdown commands. While performance and accuracy improve, these policies consume more power.

1.2.2 Discontinuous Transmission

Discontinuous transmission (DTX) is another technique that has been employed in system power optimization, especially in wireless network, where it has been used to preserve and prolong mobile terminal battery [8], much research work have also been done in this area. Discontinuous transmission is a method for optimizing the efficiency of wireless voice communications systems by momentarily powering-down or muting a mobile or portable telephone in the absence of voice input [10]. Each party in a typical 2-way conversation speaks slightly less than half the time, so if a transmitter is on during voice input only, the phone's duty cycle can be cut to less than 50%. That condition conserves battery power, eases the workload of transmitter components, and frees the channel, allowing the system to take advantage of available bandwidth by sharing the channel with other signals.

DTX circuits operate with voice activity detection (VAD), which in wireless transmitters is sometimes called voice-operated transmission (VOX) DTX when activated in a mobile device or system have been found to conserve substantial amount of battery energy, however, some of the problems with is the need for a DTX circuits which consumes additional power when this feature is turn on, and at times when the Voice Activity Detector mistakes background noise for voice and noise is transmitted, stored battery energy is wasted in transmission of this noise component.

1.2.3 Discontinuous Reception

Another method used to conserve power at the mobile station is discontinuous reception, and it is very similar to discontinuous transmission already discussed. In discontinuous reception however, the paging channel, used by the base station to signal an incoming call, is structured into sub-channels. Each mobile station needs to listen only to its own sub-channel. In the time between successive paging sub-channels, the mobile can go into sleep mode, when almost no power is used, thereby conserving battery energy [9]. Transmission timing is another method in these categories; however it is very similar to both discontinuous transmission and reception discussed in the preceding sessions.

2. MATERIALS AND METHODS

2.1 Dynamic Power Control

The dynamic power control algorithm (DPCA) being proposed in this work evaluates and adjusts the transmitted power to the desired signal strength and quality by a power regulation process that regulates the transmitted power directly to the required optimum transmitted power so that the mobile device draws less power from the energy stored in the battery and consequently prolong the battery life of the mobile device. The DPCA is however related to the stepwise control algorithm but has a faster response to transmit power control than the stepwise power control. In the Step-wise Power Control a Table of GSM power levels is defined, and the base station controls the power of the mobile terminal by sending a GSM "power level" number to it. The mobile terminal then adjusts its power accordingly. In all cases the increment/decrement between the different power level numbers is 2dB. A typical view of the OPNET simulator's process domain in the DPCA design is shown in Figure 2.0. The OPNET simulator basically operates in a hierarchical manner; namely the network domain, the node domain, and the process domain.

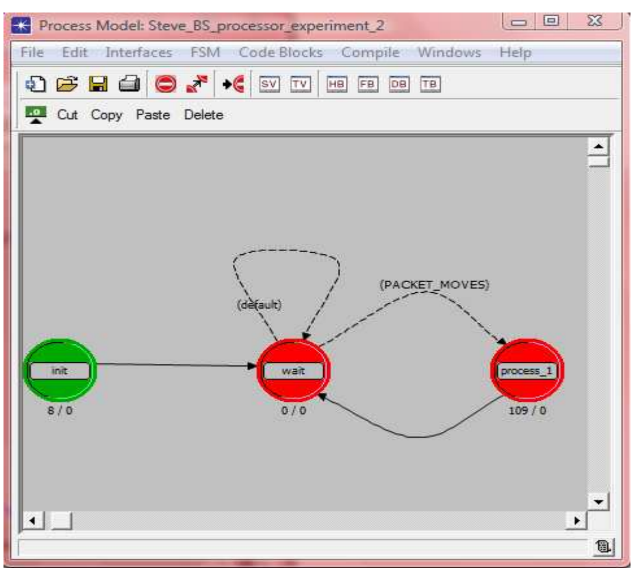

Figure 2.0 Process Model of DPCA design

The process domain describes the behaviour of processes (algorithms, protocols, applications) specified using Finite State Machines (FSM) and extended high-level language. The FSMs run on sets of programming codes referred to as PROTO-C. This programming language is a variant of C++. It is in this domain that all calculations and the proposed DPCA algorithm were coded into the simulator.

2.2 Design Calculations

The following parameters obtained from standard GSM network and Nokia mobile phone were used for calculation

1. Maximum power transmitted for the mobile is set at 39 dB as specified by GSM 900. Note that GSM 900 specifies 5 classes of power.

2. Maximum battery capacity is set at 700 mAH, a typical value for Nokia mobile phone battery. Note that one Ampere-hour (1AH) is equal to a current of one ampere flowing for one hour. This means that if you have a two Ampere-hour battery, then it has the capacity to push a current of two Ampere for one hour or a current of one Ampere for two hours.

3. A maximum voltage of 3.7 V was set, which is also typical of the model of the Nokia phone battery.

4. 700 mAH × 3.7 V = 2.59 WH. Approx. 3 WH

5. 3W × 60s = 180 Ws, this is the value of available battery power at the start of transmission.

6. Available bat. Power = Max. Capacity – Power Drain value

7. The algorithm takes into consideration both received signal quality and received signal strength 8. When both received signal strength and quality are low, the algorithm steps up transmit power

8. However, in the case where both received signal strength and quality are greater than the set threshold, algorithm steps down transmit power.

9. Where both received signal strength and quality are within the optimum, no power regulation is done.

3. RESULTS

Figure 2.1 is the graph of energy density of the different battery technologies; the graph shows that practically Li-ion battery has the highest energy density, while NiCd has the lowest. However, Li-ion polymer has the potential of having the highest energy density when produced.
NiCd has the lowest fast charge time when compared with other batteries technologies as depicted in Figure 2.2.

Lion-ion and Lion-ion Polymer have the highest cell voltage, while NiCd and NiMH have the lowest cell voltage value.

Li-ion polymer has the lowest self discharge with NiMH having the highest self discharge, this fact is supported by Figure 2.6.

However, Li-ion and Li-ion Polymer battery are the most expensive batteries in production as of now. Results from simulation show that DPCA responded to transmit power control faster than the stepwise power control thereby saving battery power by 24% more than the stepwise power control for a transmitting mobile electronics device; this fact is supported by Figure 2.6 and Figure 2.7.

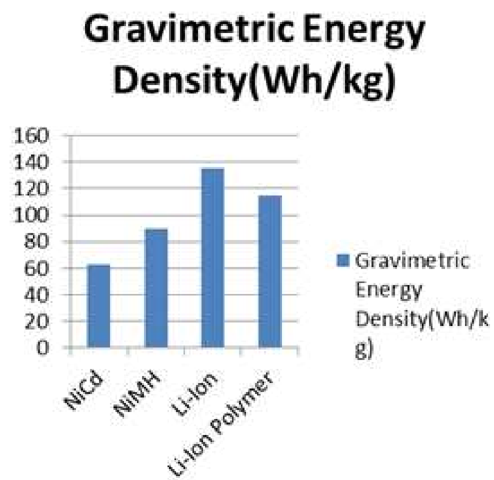

Figure 2.1 Energy density of the different battery technologies.(SI unit, wh/kg)

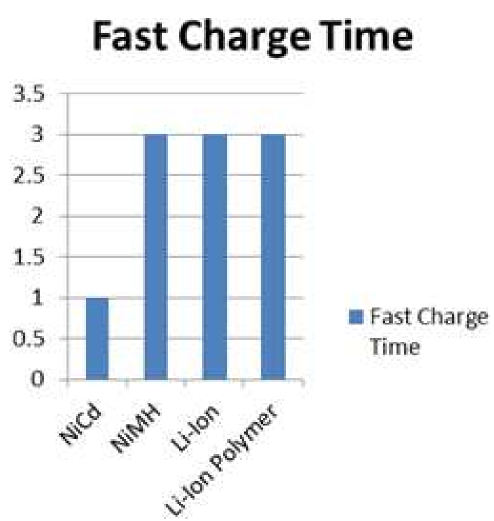

Figure 2.2 Fast charge time of the different battery technologies (SI unit, seconds)

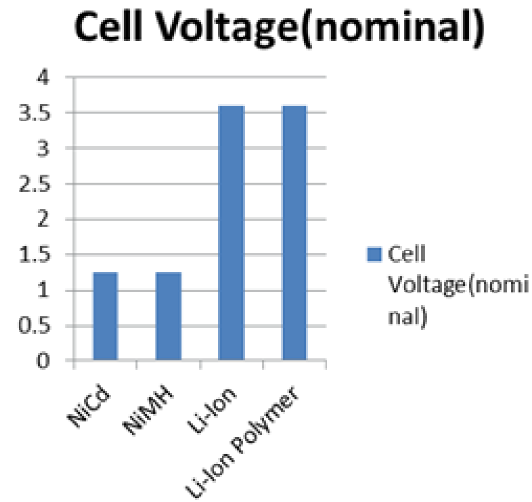

Figure 2.4 Cell voltage of the different battery technologies.(SI unit,Volts

Figure 2.5 Cost of the different battery technologies (SI unit US dollar)

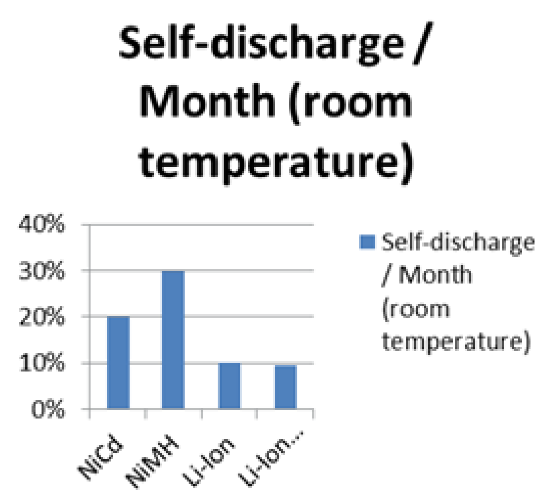

Figure 2.6 Self-discharge of different battery technologies (SI unit, Percentage)

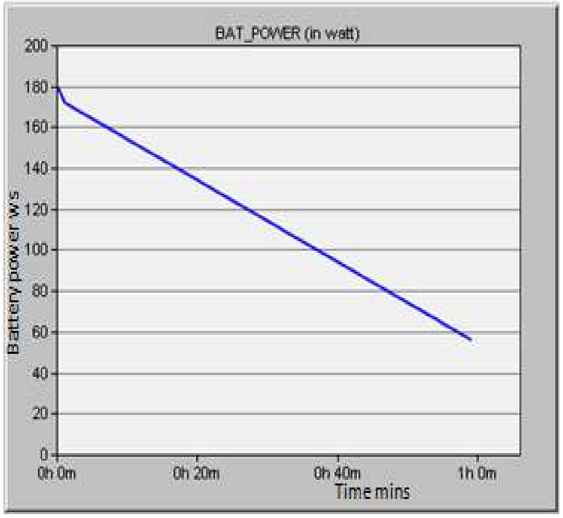

Figure 2.7.Available battery power for stepwise transmission after 1 hour transmission

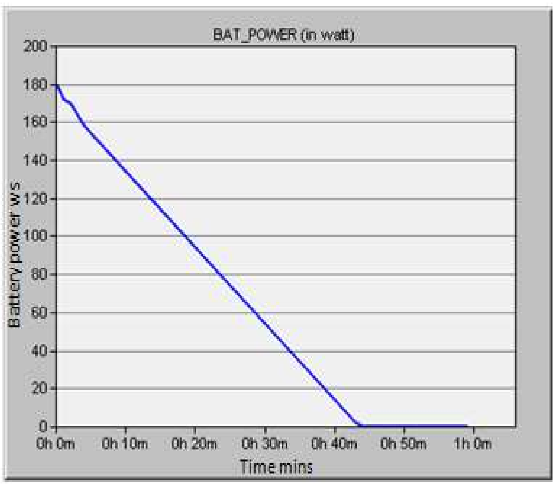

Figure 2.8 Available battery power for DPCA after 1 hour transmission

4. CONCLUSION

In this paper, we present an overview of battery technologies as applied to mobile terminal operation. Classification was made and individual advantages were highlighted. We further provide results of a Dynamic Power Control Algorithm (DPCA) that manages the mobile transmit power in a linear fashion rather than the stepwise approach adopted in literature. Results of the performance of this management technique was also presented.

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