

Chapter 1: Introduction

1.1 Orientation of the proposed study

Mobile phones have undergone a tremendous breakthrough over the past two decades, starting from the simple voice service to the “smartphone”, offering services such as mobile internet, geographical locations and maps, media service, high data connectivity and so much more [1]. To allow a high degree of freedom to the user, the smartphone power is driven by battery and the battery must empower all the features that come with it. Today most smartphones are powered by a single lithium-ion battery [1]. As the smartphone continues to evolve against the clock, it also becomes more and more power demanding. This paper takes direction based on this phenomenon and aims at scrutinizing the smartphone lithium-ion battery in terms of its battery capacity.

Battery capacity represents the maximum amount of energy that can be extracted from a battery under certain specified parameters and conditions [2]. Temperature, amperage and charging pattern can have significant effects on the level of battery capacity of a lithium-ion battery [3]. For smartphone users, it is important to have a high level of battery capacity for their lithium-ion batteries because it is directly proportional to the smartphones active time. Analyzing the battery capacity of the lithium-ion battery through varying these parameters and conditions can help evaluate several instances and deduce the optimal sets that would ensure that the lithium-ion battery retains its desired charge capacity level giving users enough active time before the device can fully discharge.

This research can answer the questions of why some lithium batteries depreciate in terms of capacity faster than others. It can also help device reliable guide line on how to keep smartphone lithium-ion batteries efficient.

1.2 Statement of the Problem

Smartphones have become very important and useful in almost all sectors of life. However power is still a persisting problem. While brand new smartphones may run conveniently, as they age, the full-battery to Empty-battery time seem to reduce - for some, faster than others. This in theory is brought about by the reduction in the charge capacity level in the lithium-ion battery [1] and hence brings about the need to frequently recharge these smartphones. The problem is that the smartphone soon becomes disagreeably dependent on the charger pack supply. Users become restricted from enjoying the full experience of the smartphone for fear of draining the device to dead battery and so the smartphone becomes underutilized.

1.3 Objectives of the Study

- Measure the battery capacity of a lithium ion batteries at different temperatures and varying current rate.
- Plot the results obtained for each experiment iteration.
- Compare the results obtained for each experiment to all the other results of the battery.
- Deduce the best range of temperatures that keep the lithium ion battery at highest charge capacity.
- Make a conclusion and recommendation that can serve as a guide for battery systems design.

1.4 Justification of the Study

This study will contribute largely aid on improving the efficiency of the lithium ion battery capacity, it will aid the design of improved battery circuits that can control and regulate temperature, and it will help electronics designers that use the lithium ion battery to design battery circuits that regulate temperature to the optimum and in return guaranteeing great efficiency. This study can as well provoke further studies on the lithium ion battery considering the other factors that affect both capacity and battery life such as Voltage, Charging Patten, Chemical and physical materials of the battery.

1.5 Limitation of the Study

This study is conducted in Namibia and is focused on the effect of temperature on lithium ion battery capacity. Due to the uniqueness in both environmental and geographical conditions of Namibia and more specifically Ongwediva, the study may not be consistent to other similar studies done outside these geometrics. Capacity however, maybe affected by so many other factors which this study does not consider.

CHAPTER 2: Literature Review

A battery is an energy storage that is particularly useful for powering small portable devices like phones, laptop and many other entertainment devices [4].

There are various types of batteries, but this study focuses entirely on the rechargeable lithium ion battery. The lithium ion battery is known to be a high energy battery and very desirable for portable electronics like smartphones.

The number of smartphones as well as the traffic generated by them are increasing dramatically [5]. However, short battery life has been a major limiting factor for the utility of smartphones as battery technology could not keep pace. A lot of research effort has been put into designing energy efficient protocols and networks to make best use of the available battery capacity [6]. My research will, however shifts the research focus onto the battery itself, how the capacity can be utilized to the maximum.

There is need to study the performance of the lithium ion battery to aid in its efficient use. According to [4], battery performance parameters include voltage, capacity and c-rate.

The Amp-hour capacity of a battery (or cell) is its most important figure of merit: it is defined as the amount of current that a battery can deliver for 1 hour before the battery voltage reaches the end-of-life point [4].

The battery capacity in A-hr is calculated as follows:

$$C_{dis} = T_{dis} \cdot (I_{dis})^k$$

Where C_{dis} is the capacity of the battery, T_{dis} is the time of discharge expressed in seconds (s) and I_{dis} is the discharge current expressed in amperes (A). The parameter k is the Peukert constant. This parameter is strongly dependent on the battery technology. For the lithium ion battery technology, the Peukert constant is between 1.00 and 1.28 [8]. In this study the peukert constant shall be kept at 1.00 should there be lack of specifications for the sample battery used.

Batteries are acutely sensitive to operating temperature with respect to their charging characteristics and A-hr capacity [7] with this knowledge this study gains the much need motivation to take off.

[8] Investigated a lithium nickel manganese cobalt battery at various working temperatures (-18°C , 0°C , 25°C and 40°C) and at different current rates ($0.3 I_t$, $1 I_t$, $2 I_t$, $5 I_t$ and $10 I_t$). The observation was that the battery has particularly good performance in terms of delivered capacity in the envelope current rates $0.33 I_t$ and $2 I_t$ and in the temperature range of 25°C to 40°C . The figure below show his findings.

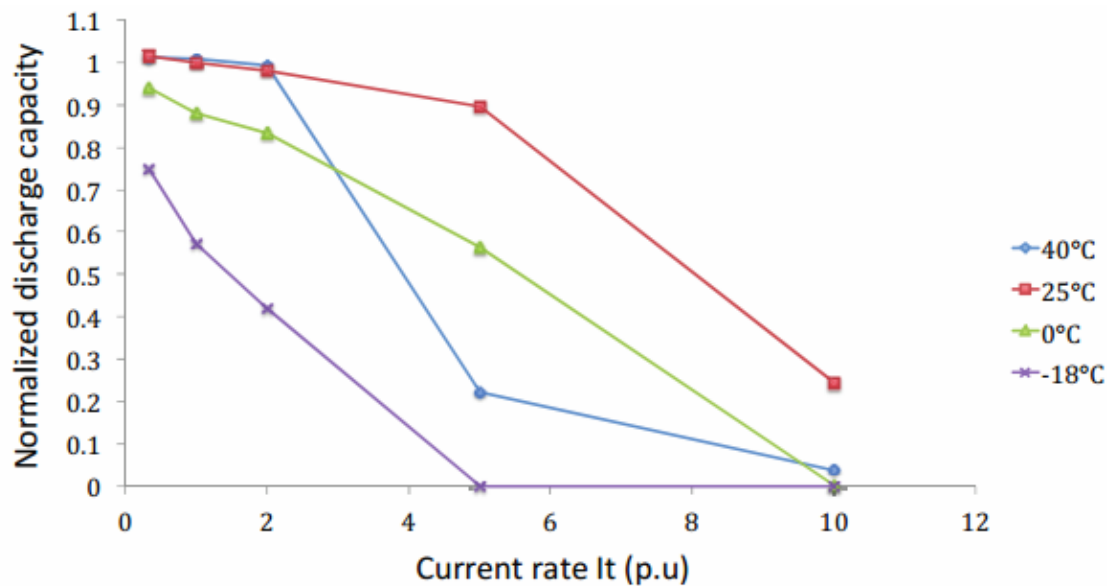


Figure 1. The graph of normalized discharge capacity vs current at different temperatures of lithium nickel manganese cobalt battery [8]

Between 0.33 and 2 for the temperatures 40° and 25° , show the highest normalized discharge capacity. Now a system can be designed to keep the battery conditions such that the capacity is maximum. This research encourage more research to be done on batteries because of its enlightening quality, this study is just one of the many.

CHAPTER 3: Methodology

3.1 Research Design

There are two main parameters to be measure during this study, these are temperature and capacity. Like [8], a series of experiments will be done with changing currents between $0.1I_t$ to $10I_t$. The likely range of temperatures that will be used is between 0° to 30° , because they are much easier to access and are the temperatures under which most devices that use the lithium ion battery operate. Capacity A-hr in these experiment will be measured using an ordinary multi-meter and a stopwatch. The two instruments will measure discharge current and duration to formulate the capacity respectively. To quicken the process, a load will be used to facilitate the discharge process for the batteries.

A lithium ion battery will be charged to full battery capacity will be discharged by a load of a current sample set $0.1I_t$ to $10.0I_t$ [0.1, 2, 4, 6, 8, 10] at different temperatures. The discharge current will be read for an interval T and plotted, this plot will help derive the different temperatures discharge capacity of the battery for the specified sample current and temperature. The experiment is repeated for all the sample currents at the different sample temperature 0° to 30° [$X < 0^{\circ}$, $0^{\circ} < X < 10^{\circ}$, $10^{\circ} < X < 20^{\circ}$, $20^{\circ} < X < 30^{\circ}$, $X > 30^{\circ}$] where X is the set temperature during the experiment.

Fixed Temperature with iterating currents

For every iteration of the experiment, a sample temperature will be picked and kept constant, for this specified temperature, the capacities of the battery are plotted then derived and tabulated for every one of the sample currents 0.1 to 10. The air conditioner of the laboratory is likely to be used to set the room temperature for most experiment iterations. For the lower experiment, a laboratory refrigerator is more likely to be used.

This experiment is repeated for all the temperatures and there results tabulated and plotted. The Plot or graph obtained will be that of capacity (calculated by the integral of the curve of discharge current and time for different iterations) and the current rate I_t . A sample graph of such result should be similar to the graph obtained by [8].

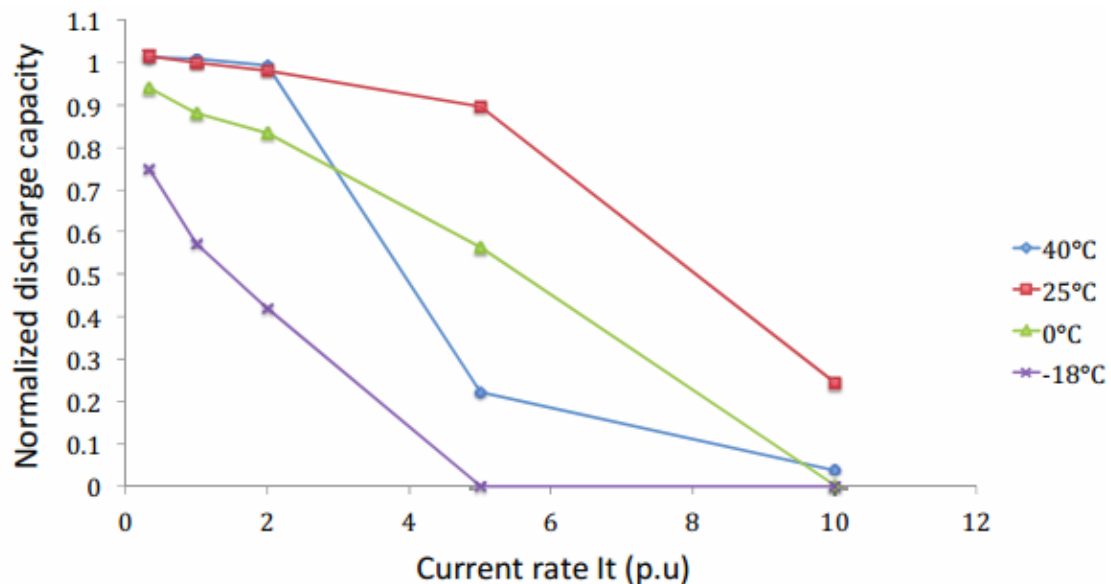


Figure 2 Sample expected results of graph between discharge capacity and current rate of Lithium ion battery by [8]

These different graphs will be used to deduce the optimum temperature for the highest capacity of the battery.

3.2 Research Instruments

The following instrument will be used in carrying out this study.

- Multi-meter: The multi-meter will be used to measure the current drop of the battering during discharging period.
- Stopwatch: the stop watch will be used to measure the discharge period T.
- Computer software for graph development.
- Refrigerator and/or air conditioner: For temperature regulation and varying.
- A Load with variable current: For discharging the battery
- Lithium battery charger: For changing the Lithium battery
- Lithium ion battery: The sample specimen

3.3 Procedure

First the lithium ion battery is charged with the battery charger to its full capacity. The battery will be connected to power the load. During this discharge, the multi-meter will be used to monitor the discharge current drop of the battery. The stopwatch will be used to keep the time between every interval T during the discharge. The refrigerator/ air-conditioner will be used to set the experiment at different temperatures. After every iteration, the curve of current and time are plotted in computer software and the integral calculated to obtain the capacity for that iteration. Finally all

the capacities obtained are plotted against the varied current of the load to come up with the final graph for data analysis.

3.4 Data Analysis

The graph between discharge capacity and load current rate will be obtained to give a clear representation of their relationship for different temperature. This will help to constructively make clear conclusion and recommendations as stated in the objectives.

3.5 Research Validation Reliability and Ethics

This study may be prone to error, however this error will be reduced by the repetition of the experiments' reading iterations, picking a range of readings and tabulating the average result of the reading as the final. This method of iteration will reduce human error and improve consistency of the results should the experiment or study be repeated. Other errors will be eliminated by careful calibration of instruments

CHAPTER 4: Project Plan

The study time line is as shown in figure 3 below, with an overall duration of 100 days, the highlighted part on the graphs shows the starting part of the research and till the final part of the research.

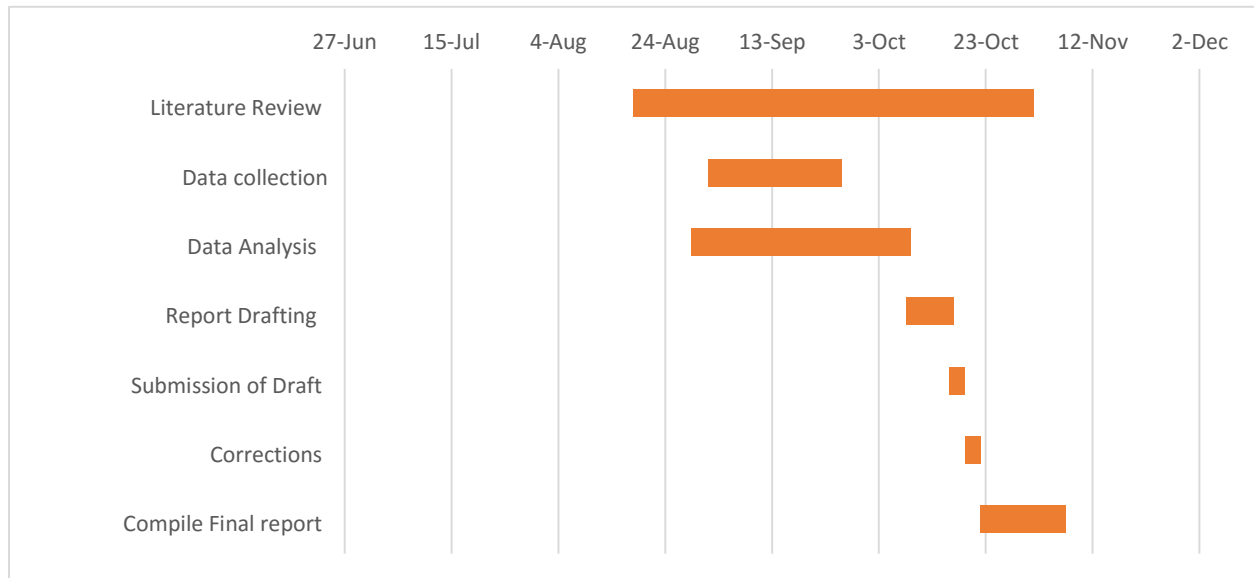


Figure 3: Project Plan

References

1. Perrucci, G.P.; Fitzek, F.H.P.; Widmer, J., "Survey on Energy Consumption Entities on the Smartphone Platform," in *Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd* , vol., no., pp.1-6, 15-18 May 2011
doi: 10.1109/VETECS.2011.5956528
2. A. Singh, "Gadget Tech," 13 june 2014. [Online]. Available:
<http://gadgetstouse.com/gadget-tech/overcharging-kill-battery-smartphone/21380>.
3. Kim, B.G.; Tredeau, F.P.; Salameh, Z.M., "Performance evaluation of lithium polymer batteries for use in electric vehicles," in *Vehicle Power and Propulsion Conference, 2008. VPPC '08. IEEE* , vol., no., pp.1-5, 3-5 Sept. 2008
4. Gears Educational System LLC, *Battery Basics Research, test, measure, analyze and select optimal battery*, Massachusetts: Gears Educational System LLC, 2009.
5. Cisco, "Global Mobile Data Traffic Forecast Update, 2012-2017," Feb. 2013. [Online]. Available:http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.htm
6. J. S. B. C. Z. Tuan Ta, "Improving Smartphone Battery Life Utilizing Device-to-device Cooperative Relays Underlying LTE Networks," *Institute for Systems Research*, vol. I, no. 1, p. 1, 2010.

7. C. Simpson, *Characteristics of Rechargeable batteries*, Dallas: Texas Instruments Incorporated, 2011.
8. P. V. d. B. T. C. a. J. V. M. Noshin Omar *, "Peukert Revisited—Critical Appraisal and Need for Modification for Lithium-Ion Batteries," *Mobility, Logistics and Automotive Technology Research Centre (MOBI)*, vol. 6, no. 1, pp. 3-5, 2013. \