UNIVERSITI PUTRA MALAYSIA

EARLY ANALYSIS OF SOFTWARE ARCHITECTURE TO ESTIMATE ENERGY CONSUMPTION IN ANDROID PLATFORM

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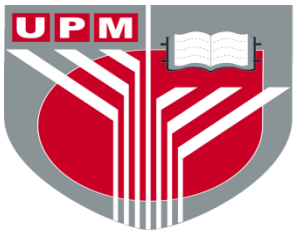

UNIVERSITI PUTRA MALAYSIA

BERILMU BERBAKTI

EARLY ANALYSIS OF SOFTWARE ARCHITECTURE TO ESTIMATE ENERGY CONSUMPTION IN ANDROID PLATFORM

By

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APPROVAL

This thesis report is submitted to the Department of Software Engineering and Information System, Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, and has been accepted as partial fulfillment of the requirements for the Master's degree of computer science/software engineering. The members of the Examination Committee are as follows:

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DEDICATION

To my Parents, Family and my Prospective Wife

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In the name of Allah the most Beneficent and the most Merciful, first and foremost, I would like to express gratitude to Allah Almighty, for endowing me the opportunity, patience and guidance to complete this thesis successfully.

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ABSTRACT

Resource consumption of mobile applications (e.g. battery and data traffic) are still the primary concerns of mobile manufactures. It has been noted earlier that the consumption of a particular mobile application depends heavily on its software architecture. Therefore, mobile developers can make proper design decisions based on the comparative study performed on different software architectures. The idea of this research started through trying to find the evidence from literature on the consumption patterns of mobile applications. Consequently, we formulated the first objective which was to investigate the evidence related to the effectiveness of CP in android platform mobile applications**.** The results of this objective clarified the research importance which motivates us to move forward to the next objective which was to evaluate which approach, either SC architecture or MC architecture, is less energy-consuming in android mobile applications (DRCICS). This work presents three main approaches that are used in this research: Critical data analysis was performed using Systematic Literature Review (SLR); through the revision of the literature related to our research, quantitative data collection using mobile phone application was utilized for this purpose, and quantitative evaluating was done using SPSS: this approach was used in order to evaluate which approach, either SC architecture or MC architecture, is less energy-consuming in android mobile applications. The result of evaluation shows that MC architecture is less energy-consuming in android mobile applications in term of retrieval of data from the applied database, especially when the focus was on DRCICS. Such a fact discovered in the design phase is quite crucial for developers to be able to reduce resource consumption and hence increase the likelihood of success of their apps. These results provide useful guidelines for the developers in terms of energy consumption for the development of mobile applications needed to connect to remote or relational databases.

ABSTRAK

Penggunaan sumber oleh aplikasi bergerak (seperti bateri dan data trafik) masih menjadi kebimbangan utama pengeluar alat bergerak. Telah diperhatikan sebelum ini bahawa penggunaan oleh sesuatu aplikasi bergerak sangat bergantung kepada seni bina perisiannya. Oleh itu, pemaju alat bergerak boleh membuat keputusan reka bentuk yang betul berdasarkan kajian perbandingan yang dilakukan ke atas seni bina perisian yang berbeza. Idea penyelidikan ini bermula melalui percubaan untuk mencari bukti daripada kepustakaan mengenai corak penggunaan aplikasi bergerak. Hasil dari itu, kami rumuskan objektif pertama iaitu untuk menyiasat bukti yang berkaitan dengan keberkesanan CP di dalam aplikasi bergerak platform android. Keputusan objektif ini menjelaskan kepentingan penyelidikan yang mendorong kami untuk bergerak ke hadapan kepada matlamat seterusnya iaitu untuk menilai pendekatan yang mana, sama ada seni bina SC atau seni bina MC, yang kurang mengguna tenaga di dalam aplikasi bergerak android (DRCICS). Kajian ini membentangkan tiga pendekatan utama yang digunakan di dalam penyelidikan ini: analisis data kritikal dilakukan dengan menggunakan Ulasan Kepustakaan Sistematik (SLR); melalui semakan kepustakaan yang berkaitan dengan kajian kami, pengumpulan data kuantitatif dengan menggunakan aplikasi telefon bimbit telah digunakan untuk tujuan ini, dan penilaian kuantitatif telah dilakukan dengan menggunakan SPSS: pendekatan ini digunakan untuk menilai pendekatan yang mana, sama ada seni bina SC atau seni bina MC, kurang mengguna tenaga dalam aplikasi bergerak android. Hasil penilaian menunjukkan bahawa seni bina MC kurang mengguna tenaga dalam aplikasi bergerak android dari segi mendapatkan semula data dari pangkalan data yang digunakan, terutama apabila tumpuan adalah pada DRCICS. Fakta sebegini yang ditemui di fasa reka bentuk adalah terpenting untuk pemaju dari segi penggunaan sumber dan dengan itu meningkatkan kemungkinan kejayaan aplikasi mereka. Keputusan-keputusan ini menyediakan garis panduan yang berguna untuk pemaju dari segi penggunaan tenaga untuk pembangunan aplikasi bergerak yang diperlukan untuk menyambung kepada pangkalan data jarak jauh atau relasional.

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GLOSSARY of TERMS

SC	Server-centric
MC	Mobile-centric
DRS	Data Retrieval System
SLR	Systematic Literature Review
CP	Consumption Patterns
DRCICS	Data Retrieval of Criminal Information Checker System
CICS	Criminal Information Checker System
DTMC	Discrete Time Markov Chain
MCDM	Multi-Criteria Decision Making
DR	Direct Read
ILP	Integer Linear Programming
TDM	Ternary Decision Maker
MADM	Multi Attribute Decision Making
μAh	Microampere-hours

CHAPTER 1

INTRODUCTION

1.1 Background

The popularities of smartphones and mobile apps have been increasing since the beginning of this century. According to B. Sanou (2015), the number of mobile-cellular subscriptions increases from 738 million to about 7 billion currently [1]. Mobile apps and cloud services are consumed massively nowadays [2]. As reported by The Zettabyte Era (2016),the traffic of global mobile data is expected to exceed that of wired devices in 2016 [3]. For example, the data provided in the second quarter report of Facebook shows that about 88% of the active users log on to Facebook from a mobile device [4]. The widespread of mobile application is mainly due to the sustainability of those functionalities in terms of the devices' resources. On the other hand, the popularity of a mobile application relies heavily on its resource consumption such as battery use [5,6] and network technology [7]. Mobile applications that require huge resources are not recommended[8,9]; therefore, the development of a mobile application should include analysis of energy consumption patterns. Energy consumption patterns are determined primarily by software architecture[10].

The most established architecture for mobile apps is the Server-centric (SC) approach [11], whereby mobile devices are acting as simple clients and tasks such as information storage, processing, and communication tasks are delegated in the cloud. This approach is popular because it is able to delegate the processing workloads to the servers. Also, task such as aggregation of data coming from individual users is possible, thus facilitating the implementation and maintenance processes in different platforms.

Nowadays, emerging mobile-centric architectures inspired by distributed processing are available [12,13]. The choice of architectural approach (Server-center (SC) architecture or Mobile-centric (MC) architecture) would determine the energy consumption of a mobile application especially in Data Retrieval System (DRS).

To support extensive applications in mobile phones that require retrieval of data from the phone or from remote data sources, there are many relational database systems like IBM's DB2 Everywhere 1.0, Oracle Lite, and Sybase's SQL etc. that work on hand held devices and can provide local data storage for relational data acquired from enterprise relational databases [14]. Most of the existing systems that offer applications work based on the previous applied database that contains the personal information's, this information can be provided to the user for more progress. Unfortunately, the users are usually away from energy sources. So, sustainable and effective phone energy is quite essential to the functionality of the applications to keep it in running. It is quite apparent that resources consumption particularly battery[5,6] and network technology [7] such as Wi-Fi are the determining factors in the success of any mobile application[8]. The energy consumption in network technology is intimately related to the characteristics of the workload and not just the total transfer size, e.g., a few hundred bytes transferred intermittently on 3G or Wi-Fi can consume more energy than transferring a megabyte in one shot. In a nutshell, any application that drains battery's energy soon will be cast off by users [9], and will eventually lead to a decrease in companies' revenue.

This work presents the energy consumption analysis of DRS. An effective application designed to be used in Android smartphones to execute primitives operations especially:

retrieving data from applied database, storing and measuring the energy consumption. This application builds by two different architectures (Server and Mobile-centric) in order to identify the least energy-consuming architecture for this kind of applications.

1.2 Problem Statement

The resource consumption of mobile devices and their applications is a topic that has garnered significant attention recently [11]. Resources managing an important role in estimating energy consumption and are also regarded as one of the critical factors in determining application successful. Most researches have focused on optimizing the consumption of applications after they have been developed. There has been no work assisting developers in choosing the most suitable software architecture for their applications in terms of resource consumption except (Berrocal. 2016), and their work still limited to a number of case studies, architectures, and real applications [15]. So, the core of this process is the software architecture and its behavior. Hence, applications developers should have the skills and knowledge of how to make the life of the battery more sustainable in order to support extensive applications in mobile phones that require retrieval of data from mobile relational databases or remote data sources. To do so, they have to be aware of the early analysis of consumption patterns (especially software architecture) in order to avoid this crucial issue: energy-inefficient applications in Data Retrieval System (DRS).

1.3 Research Objectives

1. To investigate the evidence related to the effectiveness of consumption pattern (CP) in android platform mobile application.
2. To implement an effective mobile application with two different architectures, server and mobile-centric architecture, by executing primitive operations for Data Retrieval System (DRS) in order to evaluating which approach; Server-centric architecture or Mobile-centric architecture, is less energy-consuming in android mobile applications.

1.4 Research Approaches

Table 1.1: shows the link between the research problems, research objectives, and research approaches. There are three main approaches that are used in this research as the following:

- Critical data analysis using Systematic Literature Review (SLR): through the revision of the literature related to our research, the main idea is the Mobile Application Energy Consumption Pattern in Android Platform. Also, the most suitable methods and specifications of energy consumption based on the mobile application architecture could be analyzed in order to make the phone battery life more sustainable.
- Quantitative data collection using mobile phone application: via this approach, we will collect the primary data and analyze the energy consumption of mobile application architecture. The aim of this approach is to analyze the consumption of server centric architecture and mobile-centric architecture. The quantitative data will be collected from two mobile application designed for this purpose.

- Quantitative evaluating using SPSS: this approach will be used in order to evaluating which approach; server centric architecture or mobile-centric architecture, is less energy-consuming in android mobile applications.

Table 1.1: Linking between research directions

Research Problem	Research Objectives	Objectives Activities	Approach
There has been no work assisting developers in choosing the most suitable software architecture for their applications in terms of resource consumption.	To evaluate which approach; server centric architecture or mobile-centric architecture, is less energy-consuming in android mobile applications.	Phase 1: To investigate the evidence related to the effectiveness of consumption pattern (CP) in android platform mobile application.	Systematic Literature Review
		Phase 2: To implement an effective mobile application with two different architectures, i.e. server and mobile-centric architecture executing primitive operations for Data Retrieval System (DRS).	Implementation and Collect the Data
		Phase 3: To evaluate which approach; server centric architecture or mobile-centric architecture, is less energy-consuming in android mobile applications.	Quantitative Evaluation

1.5 Scope of the Research

The current focuses on analyses of two architectures (Server and Mobile-centric architecture) and which of the two approaches (Server or Mobile-centric) architecture is less demanding for energy consumption in mobile devices. Specially, we focus on Data Retrieval of Criminal Information Checker System (DRCICS) as a case for this study.

1.6 Expected Results

At the end of the study we aim to achieve the following:

1. Reveal the effort of software developer, utilizing systematic literature review, in delivering energy conservation in android platform mobile application in term of software architecture.
2. Evaluate which approach; server centric architecture or mobile-centric architecture, is less energy-consuming in android mobile applications as such a fact of the design phase is quite crucial for developers to be able to reduce resource consumption and hence increase the likelihood of success of their apps.
3. The results of this research provide useful guidelines for the developers in terms of energy consumption for the development of mobile applications needing to connect to remote databases or data sources.

1.7 Thesis Structure

There are five chapters in this thesis inclusive of chapter**:**

- This section (chapter 1) gives a brief overview of what is contained in the other five chapters (chapter two to chapter six) below.
- In chapter 2, A Systematic Literature Review is done in other to acquire more knowledge on the various technologies which has been used to show the evidence relative to the effectiveness of consumption pattern (CP) in android platform mobile application.
- In chapter 3, the methodology is done, detail up two different architecture Server-centric architecture and Mobile-centric architecture for android mobile applications DRCICS. The experimental setup, method, process, way and how the apps was designed to estimate the energy consumption.

- In chapter 4, the primary data and measurements of two architectures, i.e. server-centric and mobile-centric, collected and compared by using descriptive analysis.
- Chapter 5 gives a conclusion and summery of the chapters (chapter 1-4) discussed in this thesis, results of the research, and it also describes the future works.

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