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QUERY TYPES AND ENERGY CONSUMPTION IN MOBILE APPLICATIONS: AN EXPERIMENTAL STUDY

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Mobile devices and applications have been very popular in people's daily life. However, the energy issue in mobile platform, or in other words, the quick use-out of battery, has been rather a bottle-neck for the further development of mobile applications, as modern mobile applications usually cost a lot of power in mobile devices. Thus, it has been an urgent need to develop energy-friendly techniques for mobile applications. The most important thing is to identify the major factors that cause the rapid decreasing of power in mobile applications. In this paper, we make a preliminary study on this issue, and conduct experiments on mobile platform to analyse the connection between query types and energy consumption. On this basis, we can identify the most energy-consuming queries in mobile applications. In detail, we choose the TPC_H benchmark as the basic workload and select different types of queries to see the relationship between query type and energy consumption in mobile applications. The results show that the energy consumption in mobile applications is sensitive to high-cost queries. This indicates that there should be query-dependant methods to improve the energy efficiency in mobile applications.

Key words: Mobile application, energy consumption, query type, measurement

1 Introduction

Nowadays, smart phones have been very popular in people's daily life. As Fig.1 shows, the global shipments of smart phones are extremely increasing in recent years [1]. At the same time, smart phones are facing the serious problem of power supply, which refers that modern mobile applications usually cause the fast use-out of the battery in smart phones [2,3]. This problem has been a bottle-neck for the further development of smart phones and applications [4].

There has been some works for energy saving, such as the energy saving research for the mobile multimedia [5], the energy saving research for the mobile location technology [6], the energy saving research for the network technology [7, 8], and so on. Besides, there are also some approaches for energy efficient, such as offloading [9, 10] and latency communication [11]. Some researchers have found that I/O is one of the most energy-consuming operations [12], but there has not been clear understanding to the relationship between the performance and energy consumption in mobile applications. As the I/O property is much connected with the query types in mobile applications, it is very useful to identify the influence of query types on the energy consumption in mobile applications.

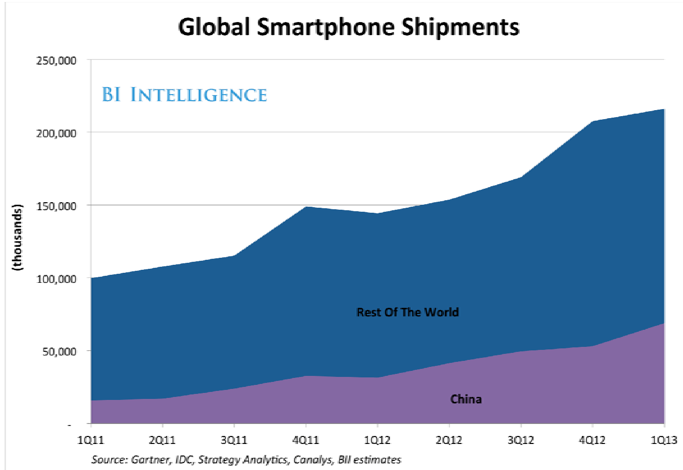

Figure 1. Global Shipments of smart phones

In this paper, we aim at making an experimental study on the performance-energy connections for different query types in mobile applications. Our study is based on the popular Android operation system and the embedded database system SQLite. The contributions of the paper can be summarized as follows:

(a) We designed a benchmark system called TPCdroid to measure the energy consumption and performance metrics for mobile applications, which is based on the popular Andriod system and SQLite. And we use the standard TPC-H benchmark as the workload [13].

(b) We measured the influence of different query types over energy consumption in mobile applications. We select different types of queries in TPCdroid to see the relationship between query type and energy consumption. The results show that the energy consumption in mobile applications is sensitive to high-cost queries. This indicates that there should be query-dependant methods to improve the energy efficiency in mobile applications.

(c) Based on the experimental result, we propose some suggestions on the energy consumption and performance in mobile applications. Firstly, there is a dynamic relationship between energy and performance in mobile applications. If a technique for query optimization can highly improve the query performance, it can also reduce energy consumption. Secondly, only the applications involving high-cost queries will have positive meaning for the energy efficiency in mobile applications.

The rest of this paper is organized as follows. Section 2 shows the general design of the energy measurement system. Section 2 discusses the impact of query types on the energy and performance in mobile applications. In Section 4, we propose some formal analysis and suggestions on the energy-performance tradeoffs in mobile applications, and the conclusions are in Section 5.

2 Energy Measurement for Mobile Applications

2.1 System Architecture

We first design a tool to measure the energy consumption as well as the performance metrics for mobile applications. The tool is named TPCdroid, because it is designed for the Android platform and the TPC-H benchmark [13].

Figure 2 shows the general architecture of TPCdroid. It consists of five parts: (1) SQL and database loading module. (2) SQL pre-processing module. (3) Query execution module. (4) Hardware management module. (5) Database power and performance monitoring module. We select the queries in TPC-H which contain multiple-table join operations as our test queries. As a consequence, the following queries in TPC-H, Q3, Q5, Q7, Q8, Q9, Q18, Q1, Q6, and Q14, are chosen as the test workload in TPCdroid. They are numbered from Query 1 to Query 9 in this paper, where Query 1 refers to Q3, Query 2 is Q5, and Query 9 equals Q14.

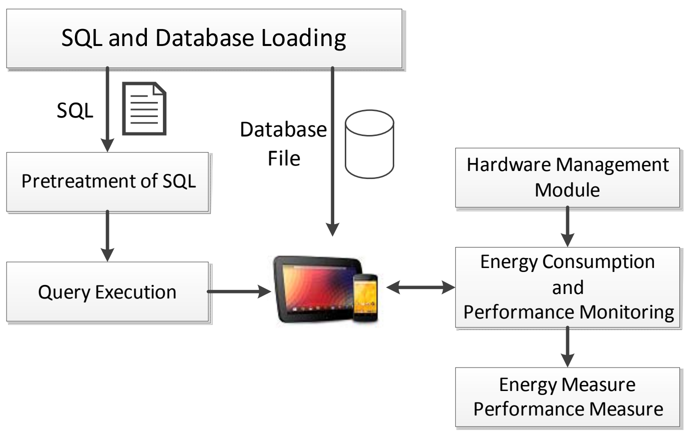

Figure 2. The architecture of TPCdroid.

2.2 Database Design

Before executing the test, we first design the test database according to the TPC-H benchmark, as shown in Fig.3. There are eight tables in the test database and the arrows represent the foreign key relationship. As the creation of the test database will cost much power in the targeted mobile device, we first create the database in PC and load it into SQLite on android. The selected TPC-H queries are prepared into an SQL script, which is also loaded into TPCdroid before the test. The parameters used in the SQL queries are randomly generated during the loading procedure. TPCdroid invokes the android API to access SQLite and the queries are actually executed in SQLite.

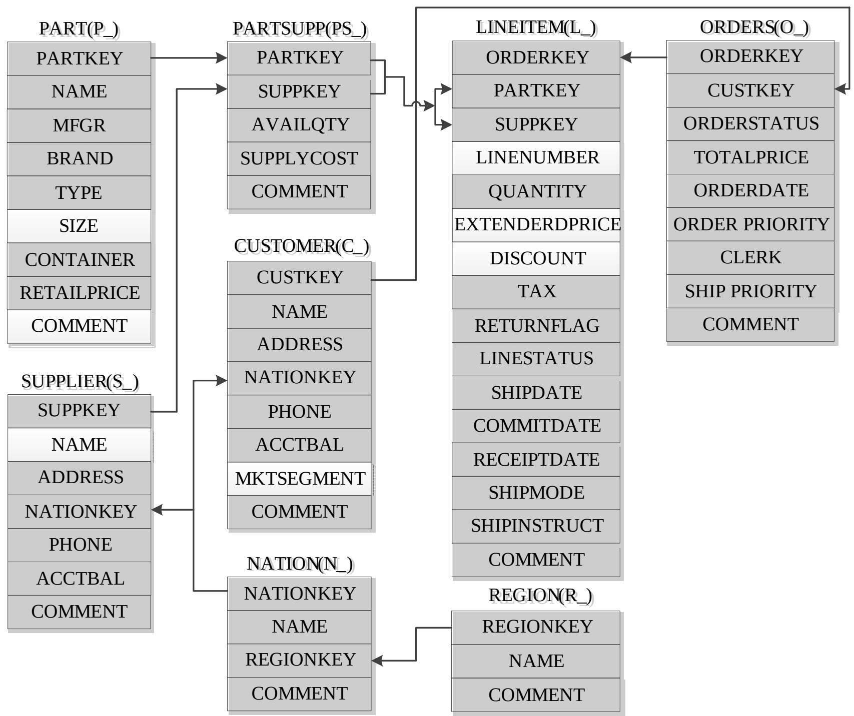

Figure 3. Test database design

2.3 Measurement Setup

Before the queries are transformed into SQLite, TPCdroid allows users to first set up the parameters reflecting the states of the hardware. Those parameters are used as the beacons of the energy consumption and performance of the hardware. As a mobile device usually include many components such as processor, external storage device, screen, and network, in TPCdrioid we simply disable the network module and set the screen in the lowest brightness so as to eliminate the influence from those components. After the queries are transformed into SQLite, TPCdroid starts to monitor the battery information of the device, such as the energy consumption, the voltage peak, the temperature of the device, and so on. The main test information is shown in Table 1.

The test data shown in Table 1 are all collected through the module “Energy consumption and Performance Monitoring” shown in Fig.2. The energy consumption is computed by listening the battery broadcasting in the android system. Whenever the battery is changed, we record the battery data according to the broadcasting information.

Table 1. Test data for TPCdroid

Test Information	Description
Run Time	second
Number of Tuples Returned	
Battery	%
Running Peak Temperature	℃
Temperature Before Execution	℃
Running Peak Voltage	mV
Voltage Before Execution	mV

3 Query Types vs. Energy Consumption

3.1 Influence of Query Types on Energy Consumption and Performance

The run time of all 9 queries is shown in Fig.4. The workload of query 7~9 is smaller than other 6 queries. The run time of query 1~6 which have heavier cost grows about 1/5~1/4 times at 800MHz more than that at 1GHz. The run time of query 7~9 grows about only 1/8 times at 800MHz more than that at 1GHz. The test data suggests changing processor frequency has great influence on the requests with more workload.

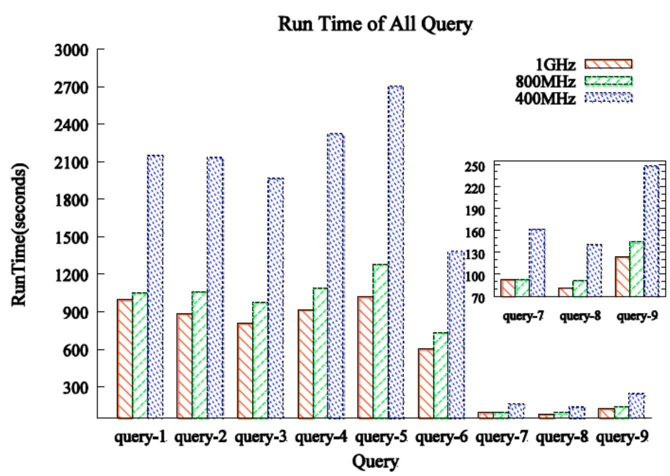

Figure 4. Run time of all queries

The energy consumption of all the 9 queries is shown in Fig.5. The energy consumption, of query 7~9 with smaller workload, is smaller than that of query 1~6. There is no the relationship like Fig.3 for query 7~9. For query 7~9, the gap between energy consumptions at three frequencies is very small, which indicates that improving performance and reducing run time is an effective method to put down the energy consumption.

For the requests with small workload, the mobile database shows a feature that performance and energy consumption have a negative relationship. The energy consumption is getting smaller with the performance getting higher, which is new to the traditional viewpoint.

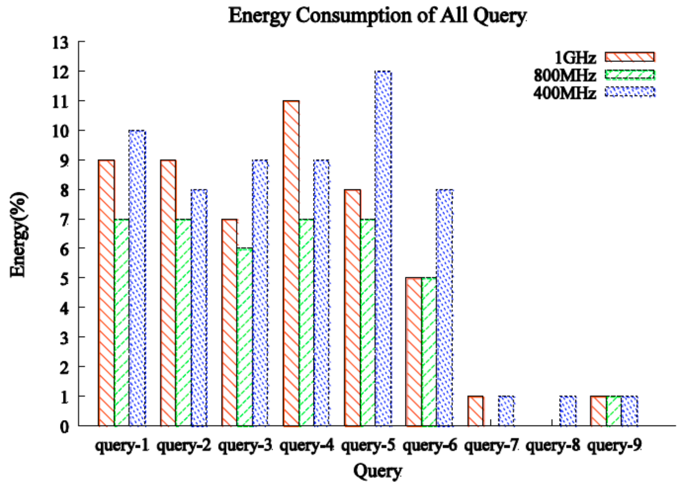

Figure 5. Energy consumption of all queries

3.2 Influence of Query Types on Energy efficiency

After discussing the query 1~6, it is found that the energy efficiency of query 7~9 is very different. Because the energy consumption spent by the query 7 at 800MHz and the query 8 at 800MHz, 1GHz is less than 1% that it cannot be measured. We ignore the 3 test data to discuss the energy efficiency of query 7~9 as shown in Fig.6. The test data in Fig.6 shows that the energy efficiency is positively related to the performance and the energy efficiency gets greater with the performance getting higher.

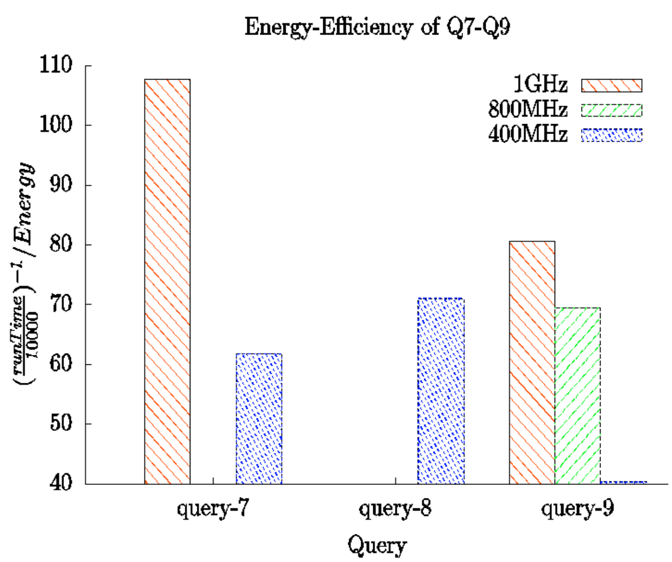

Figure 6. Energy efficiency of query 7~9

Both Fig.5 and Fig.6 show that the energy efficiency in mobile applications is positively related to the performance no matter the query workload is high or low. The relationship is not affected by the query type. Higher performance can bring better energy efficiency.

4 Discussions

4.1 Formal Description of Performance and Energy Consumption

As discussion above, for high-cost queries, there is a curvilinear relationship between the performance and energy consumption. Thus, the boundary of the high and low performance is a critical factor in the performance-energy tradeoffs for mobile applications. Supposing that the boundary of the high and low is W_0, and the upper bound is W_1, the relationship between the energy consumption and performance can be described by the formula (1).

$$E = f(W)\begin{cases} f^{'}(W) \le 0 \quad W \in (0, W_0] \quad with \quad high \quad workload \\ f^{'}(W) > 0 \quad W \in (W_0, W_1) \quad with \quad high \quad workload \\ f^{'}(W) < 0 \quad low \quad workload \end{cases} \tag{1}$$

E represents the energy consumption and *W* represents the performance. The derivative $f^{'}(x)$ in formula (1) represents the relationship which represents positive correlation being greater than 0 and negative correlation being less than 0. The formula suggests only when the W_1 can be increased greatly; the mobile database improving work is valuable.

4.2 Energy Efficiency for Mobile Applications

The relationship between energy efficiency and the performance can be described as formula (2). EE represents the energy efficiency and C_0 is a constant. The formula means when the performance is changing at a low level, the energy efficiency is positively related to the performance, but when the performance is changing at a high level, the energy efficiency has just a little change.

$$EE = \begin{cases} g(W) \quad g'(W) > 0 \quad W \in (0, W_0] \\ C \quad C \in [C_0, C_0 + \varepsilon] \quad W \in (W_0, W)_1 \end{cases} \tag{2}$$

Formula (2) suggests when the performance of mobile applications performance is close to the upper bound, the energy efficiency can get only little profit from the performance improvement. When the mobile database can be improved greatly, the energy efficiency can also be improved greatly.

Both the formula (1) and (2) suggest that the mobile database is very different from the traditional database, and not all improvement is perfect. Only the great improvement is right work for energy consumption.

5 Conclusions

In this paper, we studied the relationship between query types and energy consumption in mobile applications. We first designed a tool called TPCdroid to measure the performance and energy consumption for mobile applications, and then conducted experiments on the basis of the TPC-H benchmark to reveal the connections between energy and query types. Our results show that there is a curvilinear relationship between energy consumption and query types in mobile applications, and therefore we have to design different methods for different query types in order to achieve the energy efficiency in mobile applications.

Acknowledgements

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