An Empirical Study on Managing Energy and Accuracy Requirements of Location Based Android Applications

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Abstract

The improper use of GPS and location-related APIs may result in abnormal battery drain in Android applications. Over the last few years, the developers' discussions on improving energy efficiency have been increased. In this paper, we mine StackOverflow to analyze and summarize the characteristics of developers' discussions of managing energy and accuracy-related requirements of location-based Android applications. We extracted 11,911 questions from StackOverflow and filtered 320 relevant questions to answer four research questions. We conducted a manual thematic analysis on relevant questions. Our study shows that the developers are concerned about energy consumption, but are unclear about their preferences as energy and accuracy evolved as conflicting requirements.

1 Introduction

In Location Based Applications (LBAs), the improper use of location-related APIs may result in abnormal battery drain [1]. There has been an increasing amount of research efforts [2, 3] made by researchers to reduce the energy consumption of location sensing in Android smartphones. These studies have less information on the programming knowledge required to manage the energy and accuracy-related issues of LBAs. In recent years, mining StackOverflow [4, 5] to summarize the knowledge on energy consumption of Android applications proved to be a successful technique. However, these studies are not specifically focusing on location-based Android applications. Hence, in this paper, we aim to summarize the characteristics of developers' discussion of managing energy and accuracy-related requirements of location-based Android applications. More specifically, this paper aims to explore and answer the following questions:

- **RQ1:** Do developers ask questions to improve energy and accuracy requirements?
- **RQ2:** Which developer goal yield more successful answers?
- **RQ3:** Which developer goal is popular among the developer community?
- **RQ4:** How have the developers' goals changed over time?

We followed the methodology suggested by Braun et al. [6] to conduct a thematic analysis of the selected questions. We extracted 11, 911 questions from StackOverflow and through semi-automated filtering and manual validation process, we identified 320 relevant questions for further analysis. We identify 3 main categorizations, namely: Status of question (*successful, unsuccessful, ordinary*), Goals of developers (*energy saving, improving accuracy, balancing both*) and Type of question (*implicit, explicit, fundamental*). The important finding of this study is that the developers are facing problem in balancing energy and accuracy-related requirements. In addition to this, the study found that several developers are unclear about their preference for selecting energy saving or improving accuracy as their primary goal.

The rest of the paper is structured as follows: Section 2 presents related works, Section 3 describes the empirical study methodology, Section 4 presents the answers to the research questions, Section 5 briefs the validity threats and Section 6 concludes the paper with possible future works.

2 Related Works

In recent years, there has been an increasing amount of empirical studies on the energy consumption of Android applications [7, 8, 4, 5]. The first empirical study on categorizing the energy-related issues of smartphones was published by Pathak et al. [8] by mining four online forums and presented a comprehensive study of energy-related issues in smartphones. Pinto et al. [4] mined StackOverflow for software energy consumption-related questions and answers and identified seven causes for energy consumption problems. Malik et al. [5] explored the quantitative and qualitative aspects of energy-related questions specific to the Android platform on StackOverflow. The authors have summarized energy-related issues into four main categories and explore the APIs that are significantly discussed in the energy-related posts. Though there have been several studies on energy consumption in Android applications, none of the studies have explicitly focused on location-based Android applications. In this paper, we aim at summarizing the developers' discussion on energy and accuracy-related issues of location-based Android applications.

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3 Study Methodology

We collected the energy and accuracy-related questions of location-based Android applications using suitable SQL Queries on StackExchange Data Explorer[1]. We used the keywords $android, location, gps$ on the tag field of StackOverflow questions. The SQL query returned a total of 11,911 questions in the form of $.csv$ file. This file was our raw data set which was used for the further filtering process. The dataset contains information about *Title, Body, Accepted Answer, Score, Views Count, Favorites Count, Created Date* and other relevant information. The second step is a semi-automated method to filter the questions that are specific to energy and accuracy-related issues of location-based Android applications. During this filtering process, we used keyword matching on the $Body$ field of the questions and obtained 651 relevant questions[2]. We further categorized the questions under three different categories: *successful, ordinary and unsuccessful*. The questions with negative and zero scores were removed from successful and ordinary categories as they were insignificant to our study. This reduced the dataset to 399 relevant questions. We manually read the title and body fields of the questions to verify its relevance to energy and accuracy-related requirements during which 79 false positives were found and removed resulting in 320 questions being considered for thematic analysis. We followed the guidelines given by Braun et al. [6], to conduct the thematic analysis. We defined three major themes based on the codes that we created during our reading. The first category of theme is about the type of questions asked (*Implicit, Explicit and Fundamental*), the second category of theme is based on the developers' goal (*Energy Saving, Improving Accuracy and Balancing Both*), and the third category of theme is based on the status of the question (*Successful, Ordinary, Unsuccessful*). Each question's title and body field was read and marked by the first author and verified by the second and third author. During the discussion sessions, we resolved the conflicts in the coding process. Due to space restriction, more details on the data analysis have been discussed in Section 4.

4 Answers and Discussions

In this section, we describe the analysis method and answers to the mentioned research questions.

4.1 RQ1: Do developers ask questions to improve energy and accuracy requirements?

The purpose of this research question is to know how clear the developers are with energy and accuracy-related requirements. We conducted a manual thematic analysis on the title and body field of the relevant questions. We identified the following themes:

- **Explicit**: We categorized the questions under this category, if the developers can clearly specify their requirements in terms of energy, or accuracy, or balancing both. Ex: "*Battery dies quickly when GPS or Wi-Fi is used. How can I save battery life? Is it right to request location updates every 5 seconds in the code?*" (PostID: 28407944).
- **Implicit**: We categorized questions under this category if the developers are unsure about the solutions and mentioned only the issue they are facing rather than their specific requirements or goals. Ex: "*How to keep an application running in the background? Keep collecting data?*" (PostID: 6291729)
- **Fundamental**: We categorize the questions under this category if the developer wants to gain knowledge about the topic. Ex: "*Does anyone know whether the Android addProximityAlert on the LocationManager is battery intensive*" (PostID: 1113606).

As a result of quantitative analysis, we found 35% questions under *Explicit* category, 16% questions under *Implicit* category, and 49% questions under *fundamental* category. From the results, we can infer that the developers do ask questions to improve energy and accuracy requirements. To be more specific, 51% of the developers that ask questions about location-based Android applications strive to improve energy and accuracy requirements. Among this 51% of questions, 35% are explicit about their requirements, whereas, the rest 16% are implicit or indirect. We also infer that 49% of the developers asking fundamental questions are unaware of the best practices related to energy consumption and increasing accuracy.

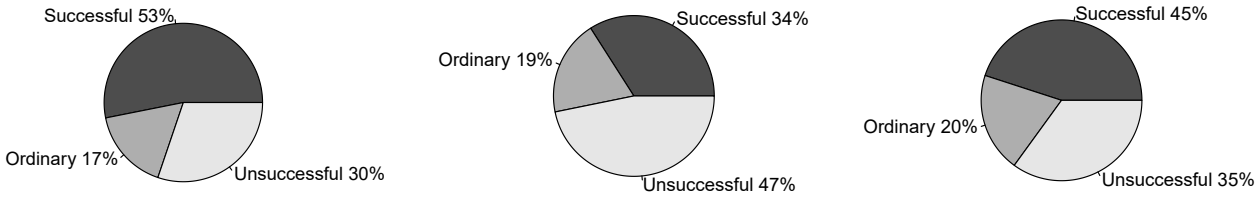
4.2 RQ2: Which developer goal yield more successful answers?

The purpose of this question is to summarize which developers goals get more preference and consequently get more accepted answers. The fundamental questions (157) which were identified from the previous thematic analysis were removed as they were not contributing to either improving energy-efficiency or accuracy. The remaining 163 questions related to developers goals category were considered for thematic analysis. We identified the following themes: *Energy saving, Improving accuracy and Balancing both*. Table 1, describes the identified themes and few examples from StackOverflow. Further, we classified these 163 questions based on their status. Under the status category, we found the following themes: *successful, ordinary and unsuccessful*. The questions are classified under *successful* category if there is an *accepted* answer. The ordinary questions are categorized so if they have been answered, but none of the answers were *accepted* by the developer who posted the question. The questions with no

[1] https://data.stackexchange.com/
[2] https://bit.ly/2E1kbID

Table 1: Identified themes under developers' goals category and examples

Goal	Description	Percentage	Example
Energy Saving	Questions were categorized under this category, if they are about reducing the battery usage by ignoring accuracy	58.89%	"*How to receive driving start and stop activity with Android in an energy efficient manner which works even offline?*" (PostID:45739938).
Improving Accuracy	Questions were categorized under this category, if they are about increasing the accuracy by ignoring battery draining behaviour	28.83%	"*How to get location updates while device is powered?*" (PostID:45204188).
Balancing Both	Questions were categorized under this category, if they are about balancing energy and accuracy related requirements	12.26%	"*Android best way to get location repeatedly in background considering battery as well?*" (PostID:27313684).



(a) Energy Saving (b) Improving Accuracy (c) Balancing Both

Figure 1: Developer goal versus Status of questions

answers are categorized as *unsuccessful*. The categorized questions were grouped based on the status of the question and the developer's goal.

The result of thematic analysis is represented in Figure 1 where we observe that *energy saving* related questions yield the most successful answers, closely followed by questions related to *balancing both*. This shows that the developers are more interested in either energy saving or balancing both conflicting requirements (energy and accuracy). On the other hand, *improving accuracy* alone has not been given much preference as it yields 47% *unsuccessful* questions. This shows that improving accuracy by ignoring energy issues may not be feasible or not a best practice while developing location based Android applications. Therefore, to build a successful application we believe that balancing between both the conflicting requirements is the essential factor.

4.3 RQ3: Which developer goal is more popular among the developer community?

We followed the method suggested by Pinto et al. [4] to calculate the popularity of the questions. The formula for calculating the popularity of the questions is as follows:

$$P = S + A + C + F + V \quad (1)$$

Where, P is the calculated popularity of the question, S is the score of the question, A is the number of answers, C is the number of comments, F is the number of favoritizations, and V is the number of views. Here, we slightly deviated from the guidelines suggested by Pinto et al. [4] with respect to selecting StackOverflow views. Here, instead of selecting overall StackOverflow views, we used the average views of all questions related to location based android applications. Hence, the views of a question can be calculated as follows:

Table 2: Popularity of questions under each category

Developer Goal	Median (V)	Median (P)
Energy Saving	643.5	6.039
Improving Accuracy	373	5.047
Balancing Both	523	6.755

$$\frac{Views\ of\ question\ (Q)}{Avg.\ views\ of\ all\ LBAs\ related\ questions} \quad (2)$$

As shown in Table 2, it is clear that the theme of *balancing both* energy and accuracy has gained more popularity than the rest. Although the number of questions related to balancing both requirements is the least, this category has scored the most popularity, reflecting the importance of giving equal priority to both types of requirements. Further, *energy saving* is observed as the next most popular requirement. Activities such as continuous background location updates and improper use of location APIs result in more abnormal battery drain, making it a higher concern of the developers to extend users battery life.

4.4 RQ4: How have the developers' goals changed over time?

The purpose of this question is to observe the trend in developers preference towards *energy saving*, or *improving accuracy*, or *balancing both*. The obtained information related to questions were grouped by the year and the occurrences of each goals category were tabulated. The data were quantitatively analyzed and the trend over the years is depicted in Figure 2. As shown in Figure 2, we observe that energy saving has been given a higher priority from the beginning in 2010 with a ratio of 3:0:0 questions in each category (EnergySaving:ImprovingAccuracy:BalancingBoth). But as the years passed the priority of saving energy rela-

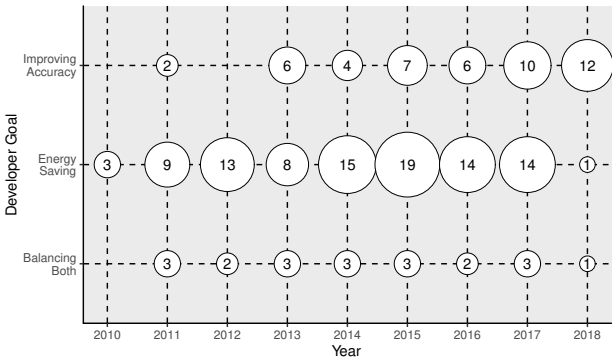


Figure 2: Developers goals over time.

tively decreased, changing the ratio to 1:12:1 in 2018. Till 2014, Android-native APIs were used, making it the task of the developers to configure everything by themselves resulting in major energy consumption issues. However, in 2015, the introduction of Google Location APIs had decreased the energy consumption related issues, hence, decreasing the requirement of the developers to find solutions for abnormal energy consumption. In the perspective of accuracy-related questions, developers have never shown much concern until 2016. However, in the years of 2017 and 2018, the interest in accuracy-related questions drastically rose due to the introduction of Doze mode in higher versions of Android. Doze mode, in short, kills the background location updates when a smartphone enters sleep mode. Users on StackOverflow have complained about not being able to decrease the time between consecutive background service updates and receiving the following message, "*In an effort to reduce power consumption, Android 8.0 (API level 26) limits how frequently background apps can retrieve the user's current location. Apps can receive location updates only a few times each hour*" (PostID: 47471600). This resulted in lesser accuracy as continuous location updates were not possible. Hence, developers were more interested in solving accuracy-related issues in recent years. As shown in Figure 2, we also observe that the questions related to *energy saving* decrease drastically to 1 in 2018 from a maximum of 19 in 2015 while there was an increase in accuracy-related questions. Hence, energy and accuracy evolve as two conflicting requirements, polarizing the interests of the developers.

5 Threats to Validity

This section presents the internal and external threats to validity.

Internal: As the scope of the study is narrowed down to location-based Android applications, we selected only 320 questions for thematic analysis. However, we believe that these manually selected questions may be a better candidate set for summarizing the characteristics of developers discussions. Second, the presence of false positives in the dataset. To reduce the number of false-positives, we conducted manual in-depth reading on all filtered questions and carefully removed the false positives.

External: First, our results are only limited to Questions and Answers on StackOverflow. Other online forums, online surveys, and physical interviews have not been used to obtain information. Second, the solutions and results presented cannot be generalized to other software, domains or type of developers. They are only applicable to location-based Android applications.

6 Conclusion and Future Works

In this paper, we present the results of an empirical study summarizing the characteristics of developers' discussions on StackOverflow about energy and accuracy requirements in location-based Android applications. We identify three main categorizations, namely: Status of the question, Goals of developers and Type of question. We applied quantitative and thematic analysis to answer four research questions based off 320 relevant StackOverflow questions. As a result of this study, we were able to infer that developers on StackOverflow are facing both energy and accuracy-related issues, however, are finding it difficult to balance both as energy and accuracy requirements have evolved as conflicting requirements. As future work, we aim to analyze the answers of relevant questions to provide more qualitative insights on balancing the energy and accuracy requirements of location-based Android applications.

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