FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

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A Mobile Solution for Location-Based Crowdsourcing

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ABSTRACT

This thesis introduces a location-aware application, which can be used as a task distribution platform in a variety of mobile crowdsourcing research scenarios. First, the thesis presents the most closely related research on crowdsourcing and, in particular, mobile crowdsourcing. Second, the thesis presents the relevant architectural and functional features of the developed application using higher-level graphs and application screenshots. The key contribution of the thesis is a fully functional, partially dynamic platform that is already being used in a research case study by the Center for Ubiquitous Computing at the University of Oulu.

Keywords: crowdsourcing, location-aware crowdsourcing, mobile crowdsourcing, situated crowdsourcing, spatial crowdsourcing, mobile application, Android, Firebase, OneSignal

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TIIVISTELMÄ

Tämä kandidaatintyö esittelee paikkatietoisen mobiilisovelluksen, jota voi käyttää joukkouttamiseen monissa eri tutkimusasetelmissa. Ensin työ esittelee aiheeseen liittyvää tutkimusta, keskittyen mobiiliin joukkouttamiseen. Seuraavaksi työ esittelee kehitetyn sovelluksen arkkitehtuurin ja toiminnot käyttäen kaavioita ja ruutukaappauksia. Työn tärkein lopputulos on täysin toimiva, osittain etäkonfiguroitava työkalu, joka on jo otettu käyttöön Oulun yliopistolla toimivassa jokapaikan tietotekniikan tutkimuskeskuksessa.

Avainsanat: joukkoistaminen, paikkasidonnainen joukkoistaminen, mobiili joukkoistaminen, spatiaalinen joukkoistaminen, mobiilisovellus, Android, Firebase, OneSignal

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FOREWORD

The introduced application was created for the University of Oulu, faculty of Information Technology and Electrical Engineering. The application can be used for mobile crowdsourcing and other associated research. The implementation of the application was created solely by the author of this thesis, with the supervision of Ph.D. Simo Hosio. It uses well-known methods which are shared by the Android developer community.

Oulu, 27.11.2018

Niko Leinonen

1. INTRODUCTION

The term crowdsourcing has various definitions, depending on the context it is used in. Wired Magazine journalist Jeff Howe has defined crowdsourcing as a *"business practice that means literally to outsource an activity to the crowd"* [1]. Crowdsourcing can also be defined as a 'tool to gather collective intelligence for certain task' [2]. As a general concept, crowdsourcing is used both in academic and industrial research. With the current infrastructure of the internet and increased popularity of mobile devices, using crowdsourcing as a research tool has become an effective way to reach more people than what has been traditionally feasible.

This thesis introduces a mobile application developed for Android devices. The purpose of the developed application is to connect users and distribute crowdsourcing tasks for location-aware crowdsourcing research. The application aims to be flexible for various types of tasks, utilises GPS location information, implemented map feature showing other user locations, and notification messaging. The architecture is shown in a high-level graph, visualising the connectivity and data-flow of different components of the application. Basic features, third-party platforms used in data processing and other operations are demonstrated with descriptions and application screenshots.

Besides the application presentation, this thesis also describes different crowdsourcing methods and reflects the current related research regarding crowdsourcing. It compares the issues and benefits found by researchers in the traditional web-based crowdsourcing and focuses on the modern mobile crowdsourcing. The current existing commercial platforms are also shortly introduced. The possible ethical and security issues are put forward and the thesis also discusses the possible future trend of this field of study. The thesis starts with an introduction to the most common crowdsourcing methods and other key themes of this topic.

2. RELATED WORK

2.1. Crowdsourcing Models

There are several different ways to crowdsource tasks, differentiated by the device, platform, and purpose of use. Here are described examples of different types of crowdsourcing models.

2.1.1. Web-based Crowdsourcing

Today, many websites are based on the idea of crowdsourcing. Using the website as a crowdsourcing platform is a classical way of gathering data and practicing crowdsourcing, reaching a suitable number of users. Platforms which gathers workforce for employers to hire are called labour markets. A more prominent web-based labour market is Amazon's *Mechanical Turk*, which has been the main-focus for the labour crowdsourcing studies [3]. Despite Amazon's Mechanical Turk being the main focus among the researchers, with the popularity of the crowdsourcing concept, there are several other platforms with different workflow models and features. For example, *Prolific Academic*, which among other things, offers academic consultation services for researchers in various fields of study.

2.1.2. Mobile Crowdsourcing

Crowdsourcing done with mobile devices, also known as mobile crowdsourcing, is possible due to the powerful input technologies available on smartphones, such as touchscreens and keyboards. Further, in mobile crowdsourcing settings, the various built-in sensors in modern mobile devices can be leveraged. These sensors enable the features such as location information tracking with GPS (Geo Positioning System), instant message communication and data exchange and synchronization. Mobile applications, which serves as an interface between the researcher and the task performer, can be customized to function in a flexible way for the specific research. Wide connection network between mobile users enables the tasks to be performed without the need for physical presence of the users [4]. Outsourcing data computation tasks to a crowd of user's mobile devices are called *mobile crowd computing*. Collecting sensory data from the user's using crowdsourcing methods is called *crowdsensing* [5].

2.1.3. Situated Crowdsourcing

Situated technologies, such as public displays, can be used as a crowdsourcing user interface. These displays can be deployed in an area with lots of population and have the benefit of being distinguishable and compelling to passer-by users. The crowdsourcing application is usable all the time (excluding possible downtimes) and does not require any application installation from the user. Since the crowdsourcing platform is limited to its fixed location, it usually reaches a lesser number of users than mobile or web-based crowdsourcing platforms [6].

2.1.4. Knowledge-intensive Crowdsourcing

Information, knowledge or other content can be created through crowdsourcing. Different professionals from different field collaborate and contribute their own competence in a platform. With more experts reviewing the content, the quality of the content will increase over time. A well-known example of this is Wikipedia or different news articles [7].

2.1.5. Location-aware Crowdsourcing

Derived from mobile crowdsourcing, if the task requires the users to be physically in the same location, this can be achieved with the mobile application implementing a real-time map feature, using location information to guide the users to the same desired area. Mobile crowdsourcing with the use of location information is also known as location-aware crowdsourcing, or spatial crowdsourcing [8].

There are several research papers published related to different crowdsourcing methods. The development of ubiquitous computing technologies and network infrastructure has allowed crowdsourcing to be implemented in various fields of industries. As mentioned before, the cost-effective nature of crowdsourcing can benefit many organizations and companies to find the best solution they need. Crowdsourcing is a very effective tool to gather a great amount of feedback information from the users, and if implemented properly, it can reduce the operational costs of a business [9]. For both non-profit companies and for-profit enterprises, crowdsourcing can also provide quicker task completion time and create a network of experts which can expand outside the company [10]. Connected expert communities make sharing competency for tasks more proficient, increase the quality of work through broad participation of professionals, and ensures more innovative solutions for the task [11].

2.2. General Considerations in Designing Crowdsourcing Systems

Legal and Ethical Issues of Crowdsourcing, a paper published in *International Journal of Computer Applications* [12], states that besides previously mentioned benefits, there are some common problems revolving around crowdsourcing research, such as legal, privacy, ethical, and information accuracy issues. These problems are not specific to crowdsourcing, but common when coping with modern mobile devices with access to sensitive user data. While designing an application with location-aware elements, it is ethical to inform the user what data is the user giving away and when. This can increase trust and positive subjective feeling towards the application [13], which is important when the research participant is required to use a third-party application for their personal device.

It is also important to realize that implementing crowdsourcing system to an existing company infrastructure without using any existing prototypes or crowdsourcing models can require a significant amount of integration process for the business [10]. Another challenge is that if the distributed task is complex or interdependent (such as a software development project), communication,

coordination, task scheduling, and planning issues might arise while completing the task. Complex tasks also might need decomposition (to create smaller, more feasible tasks) which can lead to previously mentioned management issues as well [11].

Ethical issues are well researched in the *Understanding the Crowd: Ethical and Practical Matters in the Academic Use of Crowdsourcing* [14], a study conducted together with various universities. The study states that "*on a number of occasions, crowdsourcing currently operates in a legal grey area – i.e. pre-existing laws do not clearly map onto the territory it occupies, and therefore, which legal principles should apply and how they should be applied are still open questions.*"

2.3. Work Compensation

It is common for a crowdsourcing platform to offer some sort of compensation or a reward system for the completed tasks. One way of rewarding the users is monetary payment, or "physical goods" reward, for example, movie or coffee tickets. Popular platform with monetary compensation is Amazon's crowdsourcing platform Mechanical Turk that rewards workers with low amounts of money for every completed task. There are also other ways to motivate users to complete tasks. Immaterial rewards could be learning a certain skill or social recognition. The desire for users to complete given tasks because of some sort of direct compensation or social benefit is called extrinsic motivation and have a significant effect on the time users spend on the crowdsourcing platforms [15].

When a user desires to complete the task for other than external rewards, it is called intrinsic motivation. For instance, the task itself could be interesting or satisfying to complete. A task could give community-based satisfaction, for example, help to build a network of friends, or any other social human interaction [15,16].

2.4. Task Distribution

Task distribution can be divided into two different techniques: Tasks are selected by the workers or tasks are assigned by the server. If the tasks are selected by the workers, the server acts as a public publishing platform for the tasks. From that platform, workers can choose the task they are most interested to complete. It is not a necessity for workers to share their personal information for the platform to function and this decreases the chance for a potential security risk. However, there are some downsides in this technique. Since the task assignment process is not controlled by the server, there might be optimization issues. Some popular tasks might get completed more times than other and some of the tasks might not get completed at all. With the other technique, the server distributes the task to a certain group of users, segmented by a common feature, such as location, or expertise. The advantage of this is that unlike in the previous technique, the system has a full picture of the current situation, being able to optimize the task assignment process. This requires the users to share their personal information with the system, which increases the chance for security risks [17].

2.5. Academic Research on Mobile Crowdsourcing

With the continuing development of technology, the research has branched out from the web-platform and desktop-focused crowdsourcing to the next generation crowdsourcing, such as crowdsensing, situated crowdsourcing, and location-aware crowdsourcing [18]. It expands the field of research and although crowdsourcing has been studied by various scientific institutions and many different approaches has been created [19], it still needs to be researched even further to understand thoroughly this phenomenon.

Constantly developing and flexible nature of mobile applications and devices also makes crowdsourcing methods to be in a constant state of development. Every time a new mobile device feature is developed, that feature can be used for crowdsourcing research. These mobile device features can also be used in situated crowdsourcing. Using display hardware with fixed locations, various tasks can be sent to a specific area with a certain demographic or expertise. When distributing tasks via mobile devices such as tablets or touchscreen devices, the physical presence of the platform attracts more populous labour with higher work quality comparing to the online crowdsourcing platforms [20]. One of the strengths of mobile crowdsourcing is the fact that mobile crowdsourcing can be *opportunistic* in nature, meaning that data can be sent automatically without the user's input. These tasks include computational tasks such as trajectory matching and positional triangulation and other tasks which utilizes the data collected from the surrounding environment. Traditional web-based crowdsourcing solutions have always been *participatory*, requiring the user's input for data to be sent [21]. As mobile devices develop, complex and data-intensive tasks can be performed in a more efficient manner. Mobile crowdsourcing has been studied to be useful in emergency situations, where people need to acquire information quickly [22].

There are also general challenges discovered solely in mobile crowdsourcing applications and platforms. Mobile devices use different methods to transfer data to a server, or to a mobile device. Commonly used methods to transfer sensory and other data are WiFi, mobile wireless technologies (2G/3G/4G), GPS location tracking, and Bluetooth. Since all these technologies differ in energy consumption, data transfer rate and connection reliability, different level of speed and reliability might cause data synchronization issues. Connection reliability is a particularly common issue if the system uses GPS or WiFi connection to synchronize location information with other users. The connection could be lost due to a weak, disrupted or blocked signal.

Today, massive numbers of mobile devices are sold for the everyday consumer. These devices can have a different operating system, computing power, sensor, and connection feature capability, and application interface level (API). In the software development side, these differences must be factored in when implementing features to a new crowdsourcing application. If too modern features are used in the application, older, usually more commonly used devices are unable to use the application correctly. However, cross-platform solutions offer potential help in this regard, as many modern developer platforms allow for creating applications, that, at least in theory, operate similarly on all mobile platforms. These are particularly useful in research, where development resources are often scarce.

2.6. Academic Research on Location-aware Crowdsourcing

As previously defined, crowdsourcing which utilizes the location information of the users is called location-aware, or spatial crowdsourcing. Location-aware crowdsourcing is enabled by modern mobile devices with location tracking capabilities, such as GPS transmission, or using a WiFi connection. The tasks distributed with location-aware crowdsourcing system are usually spatial in nature. Task itself is related to some predetermined location and the current location of the user. For example, tasks can involve activities such as taking a picture of a place or visiting a certain restaurant and give a review of it.

Referring to the *Spatial Crowdsourcing: Current State and Future Directions* [8], there are some unique challenges concerning location-aware crowdsourcing, due to the requirement of physical presence of the workers. In some tasks, user movement plays an essential role, and location-aware crowdsourcing systems must factor in location verification features, viable routes to the task location and data synchronization with the relocating users. If there is a form of compensation involved, users usually prioritize the maximization of the reward value and spending a minimal amount of time doing so. On the other hand, the task distributor aims to maximize the amounts of tasks done, minimizing the costs at the same time. If there is a deadline for a given task, the task distributor must develop a strategy to minimize the amounts of tasks with a missed deadline. Scheduling the tasks and proposing the optimal route for the user is essential to solve this problem.

2.7. Examples of Commercial Crowdsourcing Work

When different enterprises learned about the financial benefits of crowdsourcing methods, many commercially successful applications and platforms were created over the years. The following does not include every crowdsourcing platform but instead describes only some of the more prominent ones that are still active and practicing business.

Amazon's *Mechanical Turk* [23] is a marketplace built upon web-based crowdsourcing platform. In this site, company (or any task requester) can request workers to perform tasks which computers are unable to perform. Today, Mechanical Turk's workers are mainly located in the United States.

Threadless.com [24] is a clothing shop website which uses crowdsourcing to generate ideas for clothing designs. Users contribute with their own idea of a clothing design and votes for the best design of the week. After a week, top designs are sold, and the designers are rewarded with royalties of the sold clothing.

Topcoder [25] is a crowdsourcing company focusing on a software design, data science, and programming related tasks. Community members of Topcoder are paid for their programming work and the company sells the services of the community members for other companies. Topcoder was founded by Jack Hughes in the year 2001.

Duolingo [26] is a language learning platform developed by Luis von Ahn (the developer of reCAPTCHA) with his associates. It uses voluntary work to generate courses for different languages and translate words and sentences.

Uber [27] is a peer-to-peer transportation platform, which can be used for various delivery or transportation services. It was founded by Travis Kalanick and

Garret Camp in the year 2009. Uber platform uses spatial crowdsourcing to operate [26].

Most of the popular commercial crowdsourcing platforms are web-based platforms, but applications such as Uber or Duolingo are used with mobile devices. In the next section, we introduce a mobile application with crowdsourcing capabilities, more specifically a location-aware crowdsourcing platform.

3. APPLICATION

3.1. Background

This application was developed with the purpose of receiving different tasks for the users, which can complete the tasks by visiting a given task web address or reading the given description shown by the application. The task can have a pinpointed location shown on a map, and with this map, users can also locate each other and co-operate to complete the given task.

The application is developed with Android Studio 3.1.4 for Android devices with API (Application Programming Interface) higher than 21, or operating system 'Lollipop' or newer. The application uses fine-location permission and shares the GPS location information between the users, when map feature, provided by Google Maps, is activated. Users do not need registration or any pre-existing accounts to log in to the application. Authentication is done only using the user's device ID token. A new unique token is created every time user logs in the first time or logs in after signing out from the application.

Google Firebase [28] is used for backend database support. Location data, device id token, current task information, and working status are constantly updated in a single database. Task information is acquired from notification messages, created and sent with OneSignal [29].

3.2. Architecture

Google Firebase connects every user together, sharing all necessary information between active devices (Figure 1. "Firebase Database"). OneSignal is used to send notifications simultaneously, containing information such as task title, task description, task web address and task location coordinates as a metadata (Figure 1. "OneSignal push notification"). The application itself has a map feature (based on google maps), showing the location of other users, and the location of the current task. The location information is updated only when the map feature is active in the application screen.

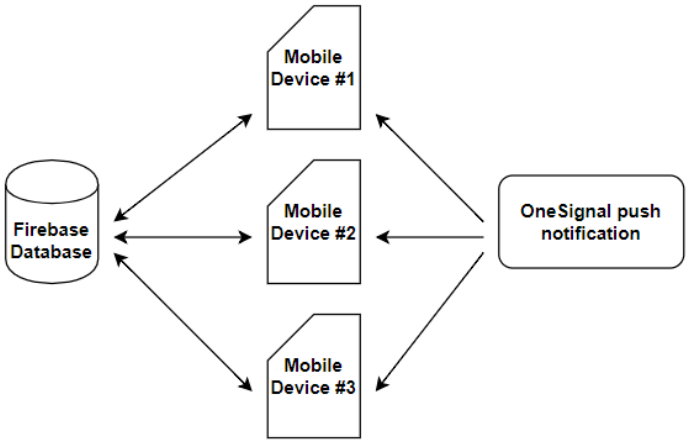

Figure 1. High-level architecture.

3.3. Operation

In this section, the basic features of the application are demonstrated. Users must ensure the Android device they are using supports the application, with operating system Lollipop (API level 21) or newer. After the installation, the user starts with the starting screen.

3.3.1. User Interface

After the user has pressed the “Start here” button (Figure 2) and “Anonymous login button” after that, (Figure 3) a new device ID token is created, serving as an anonymous user account until the user signs out.

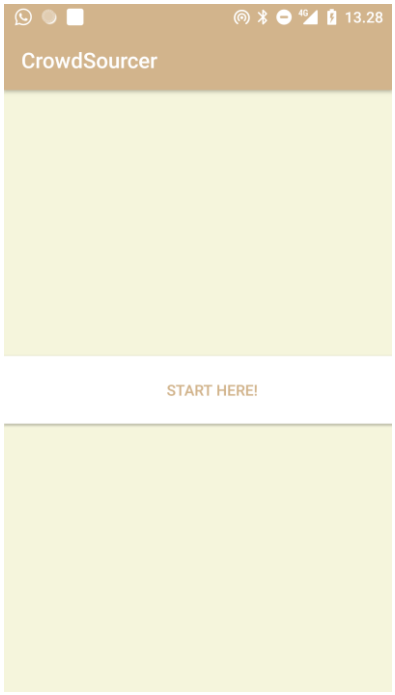

Figure 2. Starting Screen

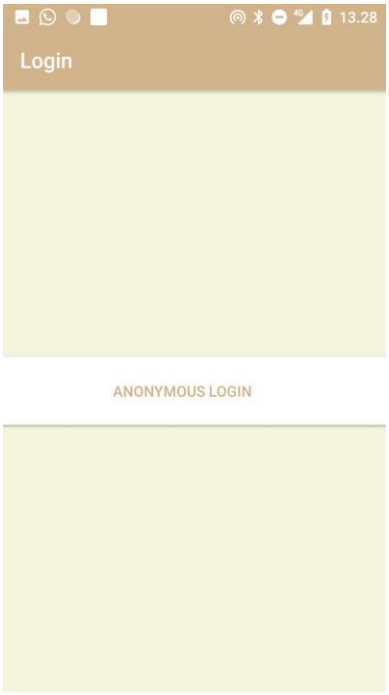

Figure 3. Login Screen

In the menu screen (Figure 4), current tasks can be seen by pressing the “Current Task” button, which opens a separate view for the available task information (Figure 5). The user can observe other users by using the “Worker map” button, first accepting the permission for GPS location feature. Green and red circles on the map are the other users, green indicating that the user is willing to complete tasks, and red indicating the opposite. You can change your own status from the “Ready to work” switch in the Menu screen. By default, the switch is in the right position, showing you as a green dot for other users in the worker map (Figure 6). If you change this switch to the left position, you do not receive any tasks or notifications. Task location coordinates are shown as a separate marker in the worker map (Figure 7).

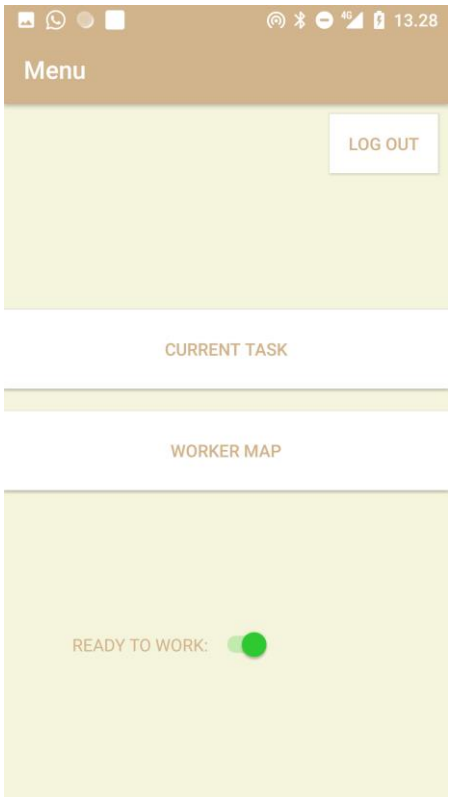

Figure 4. Menu Screen

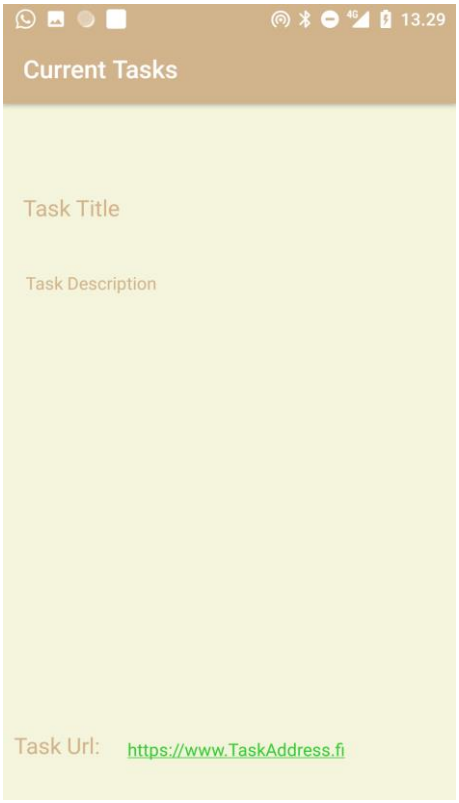

Figure 5. Task Screen

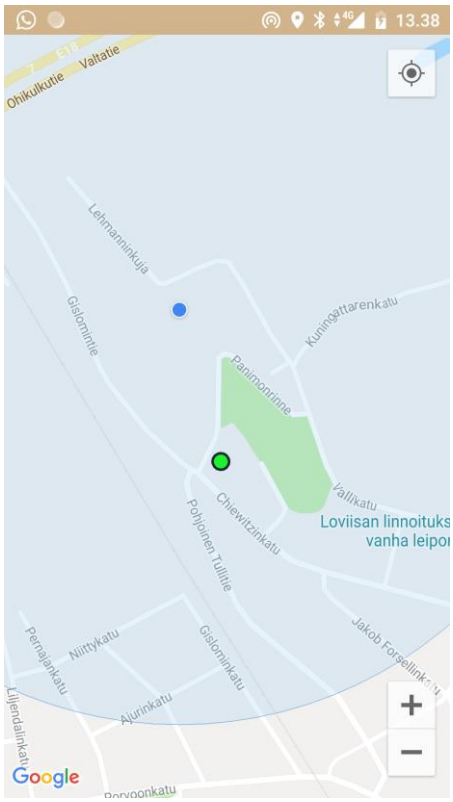

Figure 6. Another user on the map

Figure 7. Task location on the map

3.3.2. Using OneSignal

OneSignal mobile push notification service is used to send notifications with all necessary task information. Task title and body will appear as a text in the Current Task screen of the application, as well as in the notifications of the device. Title and description of the task are created with OneSignal's built-in "Messages" feature (Figure 8). Task location information must be in the format of "latitude, longitude", and the key value must be "Location". Task URL address is inserted with the key value "Url" (Figure 8). This information is inserted in the "Messages" feature as the title and description.

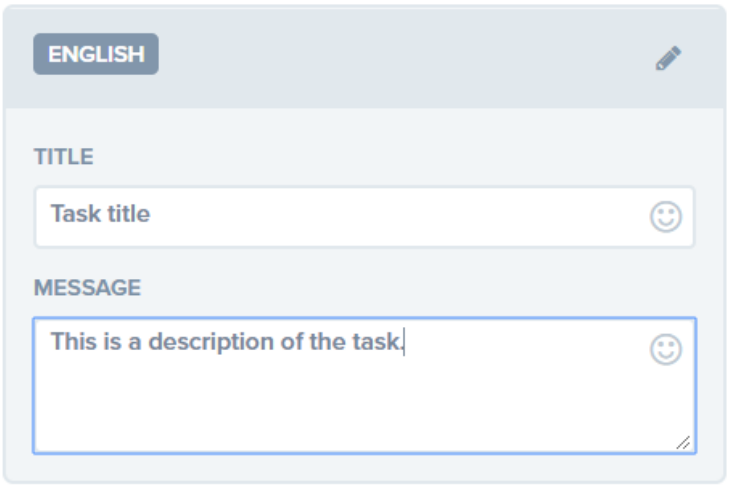

Figure 8. Title and description input box.

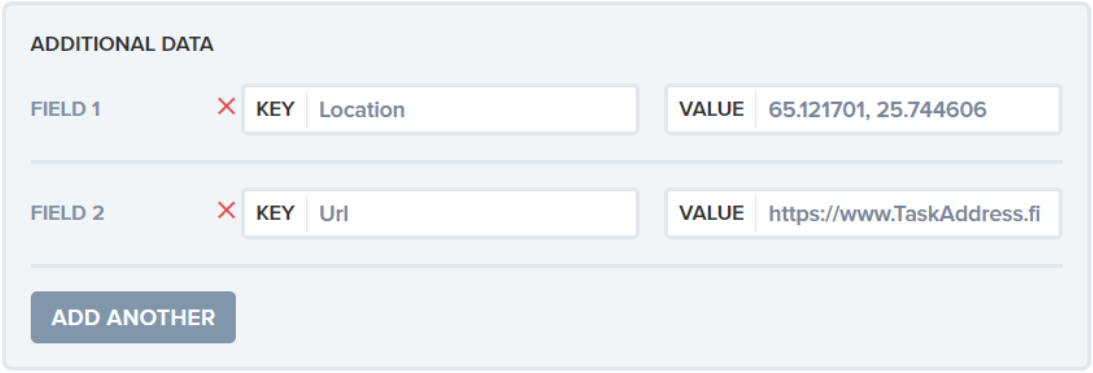

Figure 9. Correct notification metadata format.

After sending the notification, users can navigate to the given task location, finding other willing users to complete the given task using the URL or task description. Current task will be removed if the user signs out (deleting the device ID token).

4. DISCUSSION

Mobile crowdsourcing is increasingly becoming more popular with the development of ubiquitous technology in the urban environment. In the modern world, almost every mobile device is capable of some sort of crowdsourcing activity and location-aware applications can be used by increasing amount of people. Since the rise of the concept of IoT (Internet of Things), many common household devices and personal gadgets are interconnected together, opening a wide variety of possibilities for crowdsourcing to be implemented. Additionally, cross-platforming technologies can remove some of the compatibility problems regarding different devices with a different operating system. Constantly developing mobile wireless technologies with increasing data transfer rate and processing power makes crowdsourcing devices more capable of processing more complex and bigger data formats, enabling the use of more sophisticated tasks for crowdsourcing. After the year 2008, the concept of crowdsourcing has also gained more popularity among published scientific literature (Figure 10).

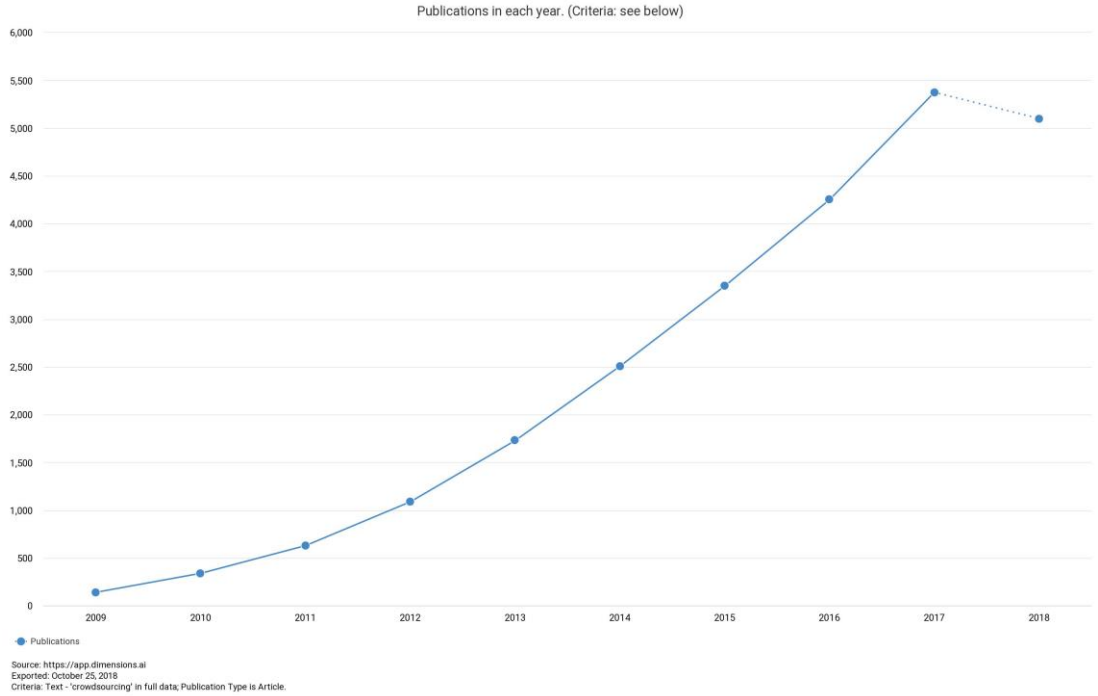

Figure 10. The number of publications from various scientific journals with the term "crowdsourcing" until the year 2017 [30].

With the rapid technological development in all the fields of technology, security of the platforms and connections should not be disregarded. Besides the benefits, interconnectivity of the environment causes potential security risks, and should always be considered when developing or using applications for any purposes. In mobile crowdsourcing, the constant stream of personal information generates cybersecurity risks for the user. Some users with malicious intent can also send incorrect sensory data to disrupt the crowdsourcing platform. This form of harassment is called *pollution attack.* Denial of service (DoS) attacks are also quite possible. These forms of security threats should be factored in while designing a robust and secure application [31]. Considering all the security issues in the design of

crowdsourcing application, one of the continuous concerns was how to implement and ask all the necessary permissions from the user without being intimidating. When sending user's personal information (GPS location information in this case), there should always be a proper communication link with the end user with suitable alerting messages when the information is sent. In software development in general, applications should be kept as clean and simple as possible. Coherent and simple user interface with descriptive messages and labels increases the positive user experience and the level of trust to the application itself. For example, below are screenshots taken from the presented application (Figures 11, 12 and 13).

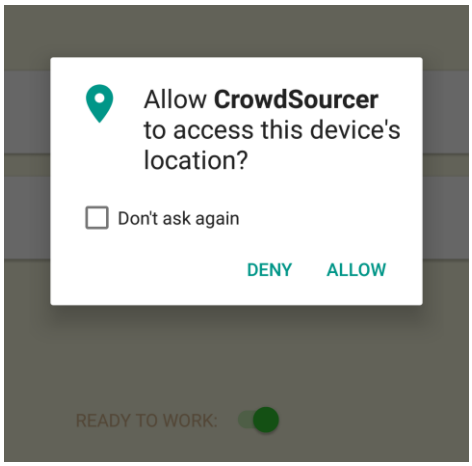

Figure 11. Default permission window.

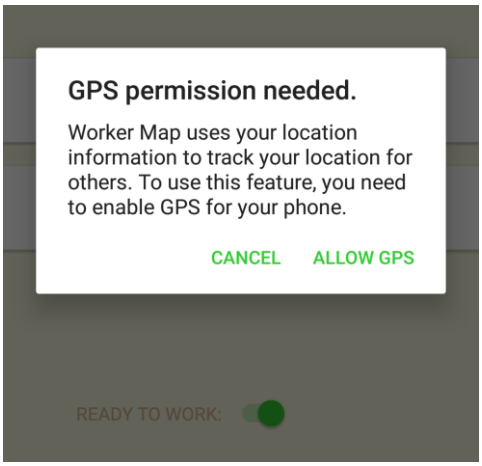

Figure 12. Customized window

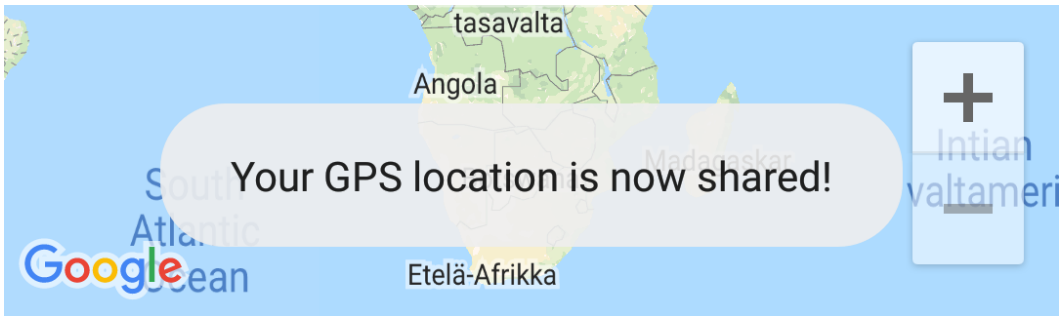

Figure 13. Notification pop-up for GPS sharing.

5. CONCLUSION

The presented application aims to be an interface or a “lobby” for crowdsourced tasks. For now, the simple architecture provides the possibility for further development and the application is flexible for various new features. The thesis itself does not conclude every aspect of crowdsourcing but only introduces the main themes of it, explaining why crowdsourcing is increasingly more popular topic in the industrial and academic world.

Since task creation, task content, or sending tasks to other users is not part of the application itself, future work should revolve around testing, user interface development, feature development, and user experience improvement. This work is already ongoing, as the application has been handed out to the “client” of this work, the Center for Ubiquitous Computing, where the application is going to serve as a host platform for a simple initial case study.

As for other hypothesised potential future feature development, navigating through different activities (screens) could be improved with shortcuts and other task functionality related features could be added if needed. Usability testing should be conducted with users to detect possible points of improvement in user experience and interface side. Stress testing with multiple users should be done to see if there is any need for optimization. Ultimately, we believe the goals of this thesis were well met, and the application will be useful for a set of local case studies or as part of other student works.

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