Dublin Green Watch

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in partial fulfillment of the requirements for the degree of
Master of Science in Computer Science

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Declaration

I declare that the work described in this dissertation is, except where otherwise stated, entirely my own work and has not been submitted as an exercise for a degree at this or any other university.

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Dublin Green Watch

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Urbanisation, as a global phenomenon and likely to be a continuing trend over next few decades due to high proportion of world's population in cities. The rapid pace of urbanisation is having many adverse affects on the urban environmental sustainability and resilience. The various core global challenges and issues are emerging related to scarcity of resources and energy, negative effects of urban environment caused by different pollution, public transport and more. Therefore, "Smart City" as a popular topic, has been introduced and discussed in recent years and the purpose of it is to provide a smart and sustainable urban environment for citizens to dwell by taking advantage of digital technologies, especially information and communications technology (ICT).

Participatory sensing, as a subtype of people-centric sensing framework, enables the participators to collect and share data by using devices, especially mobile devices. According to the research, the existing works lack practice of security measurements and implementation of trust model which has ability to classify relevant sensing data as trusted or not and present specific user contribution to the system. Consequently, a sensing-based Android application is developed associated with several security considerations and REST is used as web service on server side to complete a participatory sensing system which intends to utilize citizen-power by participating and reporting relevant green-related information to discover the current status of urban environment and promote green initiatives so as to enhance public awareness of the urban environment in this dissertation. The evaluation based on real participants is to illustrate the availability of this urban-scale system and the feasibility and accuracy of trust model based on rating as well.

Table of contents

List of Figures

List of Figures

Chapter 1: Introduction

1.1 Background

According to the latest statics estimated and reported by United Nation [1], the results demonstrate that over half of the world's population have settled and dwelled on urban areas on almost developed countries and there will be a continuous trend of leading urbanization at an incredible pace over next four decades that are especially under pressure. For instance, in Figure 1, in Ireland recently, over sixty percentage of total population dwell on cities, towns or conurbations [2].

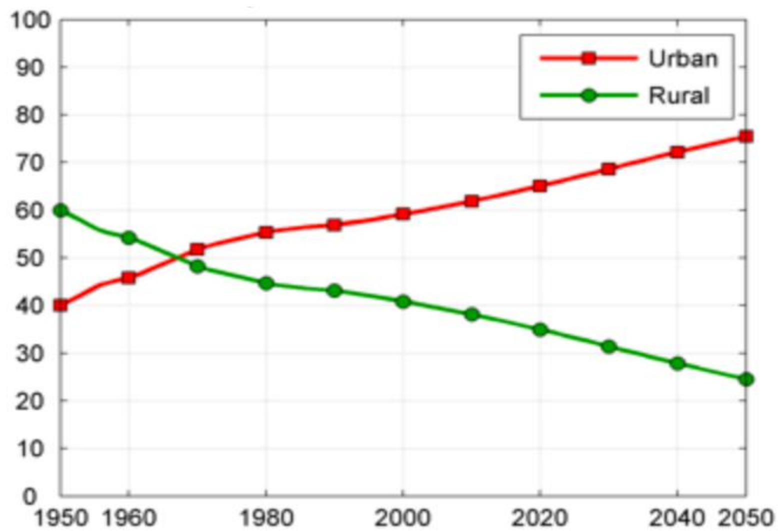


Figure 1: Forecast percentage of urban and rural population from 1950 to 2050

The various core global challenges and issues arising from rapid urbanization for cities based on scarcity of resources, energy (consumption, conservation and shortage), environment (e.g. air, water), public transport (e.g. traffic congestion) and other [3, 4] required to overcome and tangle in order to provide a sustainable and liveable place for citizens to settle on. Therefore, to establish more intelligent urban environment using smart technologies is considered as a practical and potential approach that generate a new term "smart city". The definition of smart city is wide and still a ongoing topic, however, the major task of smart city is to utilize digital technologies, such as hardware, software, and network, so as to delivery high quality of services to the public in an efficient manner [5] and reflect smarter determination to several needs, including environmental protection, public safety, daily livelihood and so on [6]. To summarize the characteristic for smart city, the study conducted by [7] to identify six main dimensions of a smart city, seen as Figure 2.

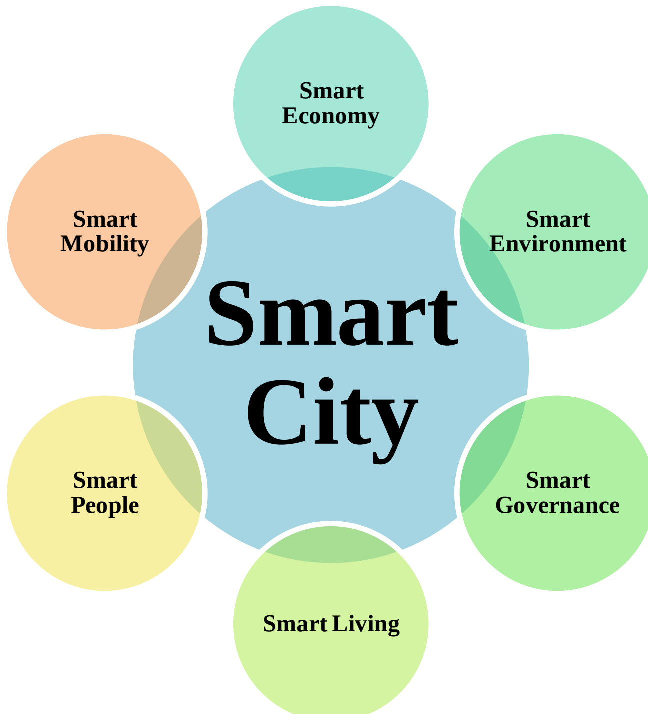


Figure 2: Six dimension of a smart city

Moreover, there are not only existing cities, like London, Amsterdam, but also other newer cities [5] with heterogeneous project of smart city to spread this concern globally. According to the news [8], Dublin, as the capital of Republic of Ireland, has joined a series of collaborative programmes with Intel Labs Europe to explore and test the citizen-centric services and solutions to ameliorate and sharpen Dublin being a more sustainable state in future. The authors state [9] that core concept of smart city is to utilize technologies to better manage urban environment. The smart environment mentioned by [10] is to describe how to spend efforts towards detection of pollution, environmental protection and effective resource management which also is regarded as major part of construction of smart city. Notwithstanding, "*a rising quality of life, and high rates of resource consumption patterns have had a unintended and negative impact on the urban environment - generation of wastes far beyond the handling capacities of urban governments and agencies*" [80]. Cities are now grappling with the problems of high volumes of waste as well. On the governments' side, they carry out several solutions, including enhancement of solid waste management, effective process of waste recycling and reuse. The report [11] from WorldBank said that, due to higher rate of waste generation in urban, citizens will also require to take more responsibility for it. As a result, citizens should empower and participate into improving urban environment and play significant roles [12], data collectors and information recipients.

1.2 Motivation

“Dublin Green Watch”, which intends to utilize involvement and participant from citizens as “citizen-power”, advancements in information and communication technology in order to discover urban environment problems (i.e. energy wasteful behaviors, pollution) and promote green initiatives so that the public awareness of urban environment will be enhanced and change their patterns in the positive direction.

1.3 Outline

This dissertation is organised as follows

Chapter 2 explores a state-of-the-art in existing academic people-centric sensing applications/systems and trust model.

Chapter 3 lists the requirements and technical options for "Dublin Green Watch" application, initial idea of design trust model and the relevant decisions made in the end of this chapter.

Chapter 4 demonstrates the actual work for completed application in details, implementation of trust model and architecture of this application.

Chapter 5 details the evaluation methodology, the results based on trust model and summary of feedback from online survey.

Chapter 6 makes the relevant conclusion and discuss the future work.

Chapter 2: State-of-the-art

2.1 People-centric sensing: Opportunistic sensing & Participatory sensing

With the rapid development of communication technology and digital electronics over decades, wireless sensor network contains nodes which applied by low-cost and less power-constraint sensor devices widely used in various areas or applications, such as environment, military and health [14]. The current trend is the consumer devices like mobile devices instead of traditional sensor in static network to generate a new opportunity to deal with a urban-scale problem for wireless sensor network [15]. The author [16] proposed a brand-new concept based on people-centric sensing paradigm at urban scale which consider the human-carried devices as fundamental node using in the sensing network. In a people-centric sensing network, citizens or individuals become the core point and play significant role of determining how they involve and participate to meet application requirements. There are two subtypes based on custodian awareness and involvement, opportunistic sensing and participatory sensing [15] in Figure 3.

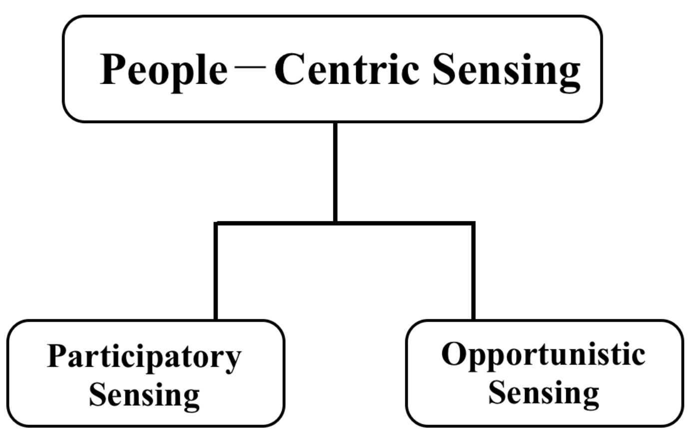


Figure 3: Diagram of people-centric sensing

2.1.1 Opportunistic sensing

To identify it, where the stage of data collection is fully automated when devices can be utilized to meet application requests without custodians' awareness. In short, opportunistic sensing is relevantly passive. There is a merit for it that helps to release the burden, endures a high population of users if the application has no common interests for each users and be propitious for community sensing [17]. However, there are several challenges and concerns [15] [17] to be considered due to low-priority sensing operation.

- More decision-making responsibility
- More complex
- More usage of resource
- Privacy of personal sensitive information
- Determination of sensing context

The motivation of opportunistic sensing [35] is to ascend the scalability and scope of applications which may be not suit or support. Difference between opportunistic sensing and participatory sensing is that the front one concentrates on whether privacy and transparency match the requirements of the application needs; the latter one focus on the tools and mechanisms to make decision during the sensing.

2.1.2 Participatory sensing

In comparison with opportunistic sensing, participatory sensing is a more active form of mass data collection which enables individual, community/group or public to gather, analyze and share local knowledge and explore interesting aspects from various fields through interactive participatory sensor networks using mobile device, such as smart phone [18]. One of merits [17] of it is to address the sensing context issue by the participators manually actions rather than automation in opportunistic sensing. The involvement of citizen as key element in this paradigm and the contribution and participation from citizens benefits not only for individuals, also for your friends, neighbours and even to citizen science. The citizen science [19] can be defined as a method to particular science research, project, work based on involvement of volunteers who might be professional or non-professional but must pair common interest.

Nonetheless, participatory sensing is also regarded as an innovative citizen-powered approach for people to observe the whole world in a new angle.

2.2 Criteria of people-centric sensing applications/systems

- PEIR, the Personal Environmental Impact Report [20]

  PEIR, is a completely participatory sensing system, seen the screenshot in Figure 4, which utilizes the daily collection data from mobile phones to estimate personalized four major types of environmental impact (carbon, sensitive site) and exposure (smog, fast food) through time-location traces (GPS) and support two kind of phone clients (Symbian and Windows Phone) so far. Meanwhile, they proposed a enhanced map-matching solution to determine the user's behavior and improve accuracy of positioning by using GSM to eliminate the potential poor performance caused by GPS in particular condition (indoor, near tall buildings). To overview, the system consist of two part, client (mobile handsets) and server side (web). The approach of user engagement is to use graphical user interface, provide sharing function to social network (Facebook) which allow users to compare own results with friends and a ranking mechanism. The size of user group is relatively small and many were system designers and work with PEIR. In conclusion, the author states that PEIR has capability to meet the small community needs. The privacy regulation and concerns about management and protection of location data were applied in the system by selective hiding, selective deletion and retention.

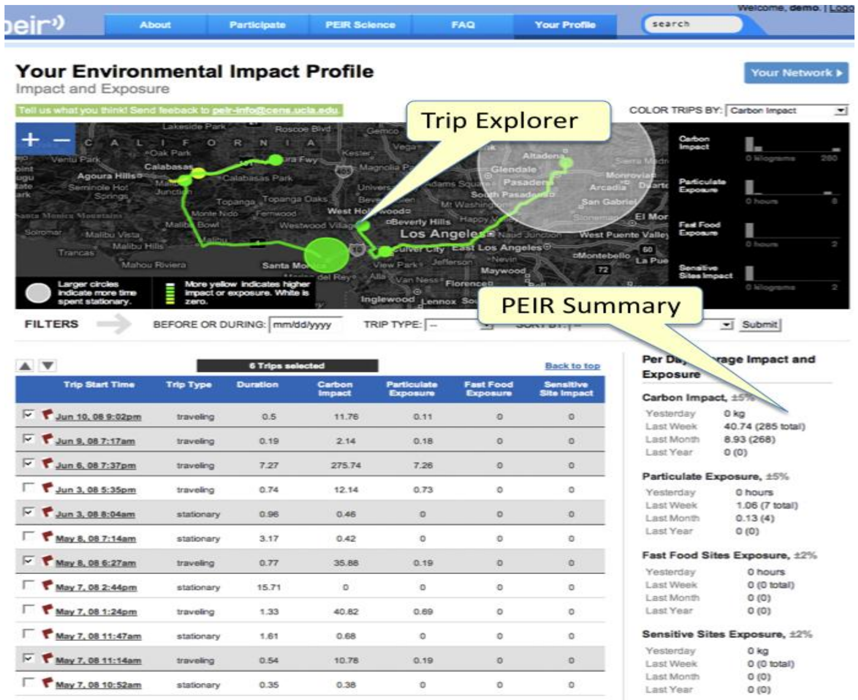


Figure 4: Screenshot - PEIR

- PetrolWatch [21]

  A participatory sensing architecture to collect and share fuel images taken from camera, as a sensor, on mobile phone. When the image capture, through the cellular network (3G/GSM), the information will deliver to central data server which can be queried by other application user. The purpose of this paper is to propose a image pre-selection approach using accelerometer embedded in the mobile phone to eliminating blurred image rather than cover on other details (e.g. user group, privacy concerns ...)

- GreenGPS [22]

  A navigation service based on participatory sensing data to map fuel consumption in urban area by using particular physical sensors (scanner and OBD-II equipment) which has functions to data collection and transport. And the result demonstrates on a map as virtualization. The potential user group focus on drivers who can discover the most fuel-efficient routine. This service developed based on a PoolView [23], which is a stream-privacy participatory sensing framework using data perturbation before sharing.

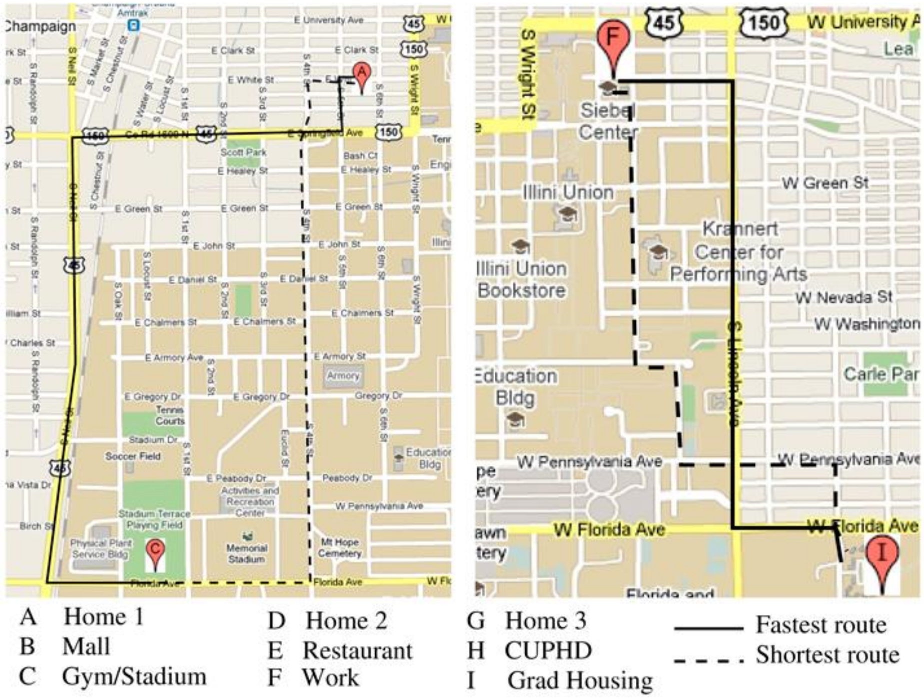


Figure 5: Screenshot - GreenGPS

- NoiseTube [24]

  The authors [24] present a fantastic, open-source and multi-platform mobile application associated with web-based map as virtualization, that used to monitor the noise pollution in urban environments. In this case, the mobile phone as an environmental sensor through embedded microphone to calculate the level of loudness, and usage of tagging (environment and geo) as well is vital to make data more meaningful. The user group is obviously citizen and it also provides web API to access public data in order to engage and recruit more potential participators. Quality of information, especially, credibility are considered during the development. The approach of dealing with privacy and data ownership for this application is that the decision-marking depends on users' own willingness and selection.

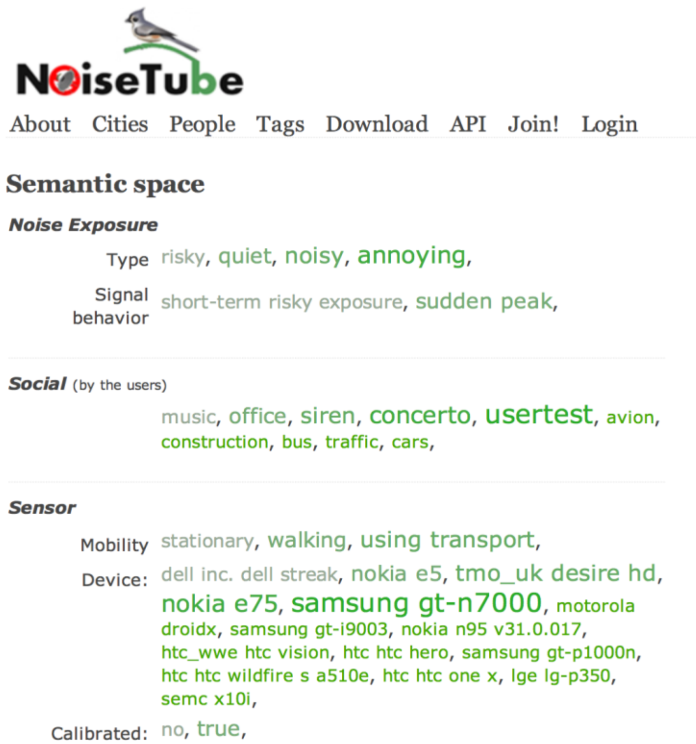


Figure 6: Screenshot - web site of NoiseTube

- WithSense [25]

  The similar idea on monitoring noise pollution applied into the WithSense application based on JME technology. The aim of this tool is to cope with the usability issue for users to use it rather than other applications (e.g. NoiseTube [24]). 20 users joined the test on validation among three participatory sensing applications and the result illustrated that WithSense is most preferred due to better usability and automatic data collection. No privacy consideration and quality of information mentioned and covered in this project.

- NoiseMap [26]

  Another Android-based application on monitoring noise pollution released. The users still can access the noise map and public data at da-sense website, which is a open urban platform of smart city. It provides several functions like control over collected data, incentive through information and open data access. The measurement on privacy is to visualize the private data for users after login. The ranking system as an incentive algorithm have been utilized in the da-sense already as well. The size of user group could match a larger.

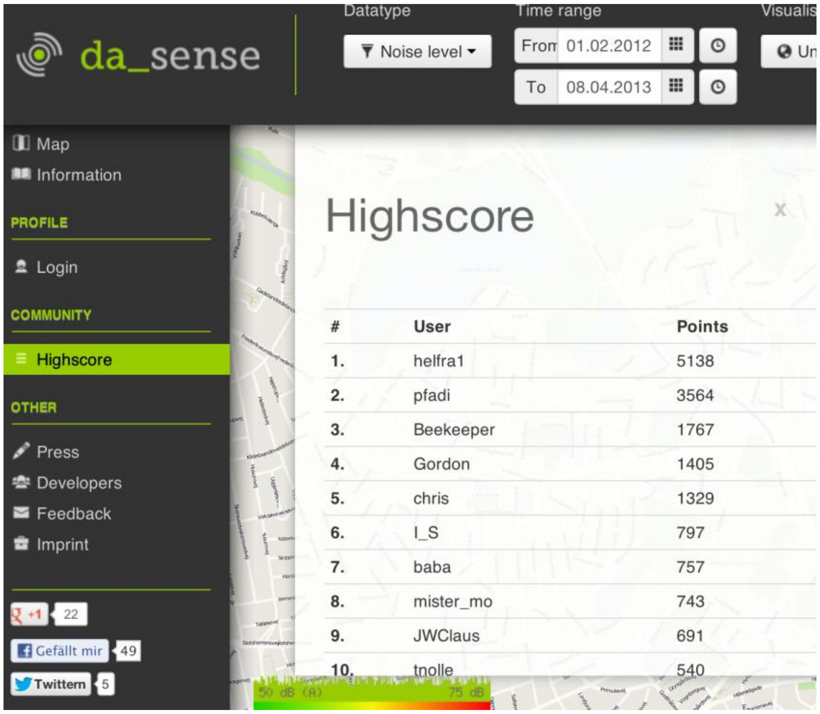


Figure 7: Screenshot - web site of NoiseMap

- EnviObserver [27]

  An environmental monitoring (air quality, water quality and plant diseases) tool based on Android and JME is produced to gather subjective people's observations mainly, unlike other participatory sensing applications that manipulate typical sensors (sensors embedded on mobile phones or external sensors), and demonstrate the data on a map. The users' location information (GPS) is required to be determined automatically. The input text through mobile phone is considered as a sensor or context of sensor sampling. To recruit potential observers, at initial stage, they did some promotion activities (advertisements) on website. However, the result didn't meet the expectation. Thus, they published the recruitment invitation on national, local news services and used social network (Facebook) as well so that it improves the number of users. The incentive mechanism is recommended strongly to motivate users to make contribution. The privacy and reliability concerns are suggested by the authors as well.

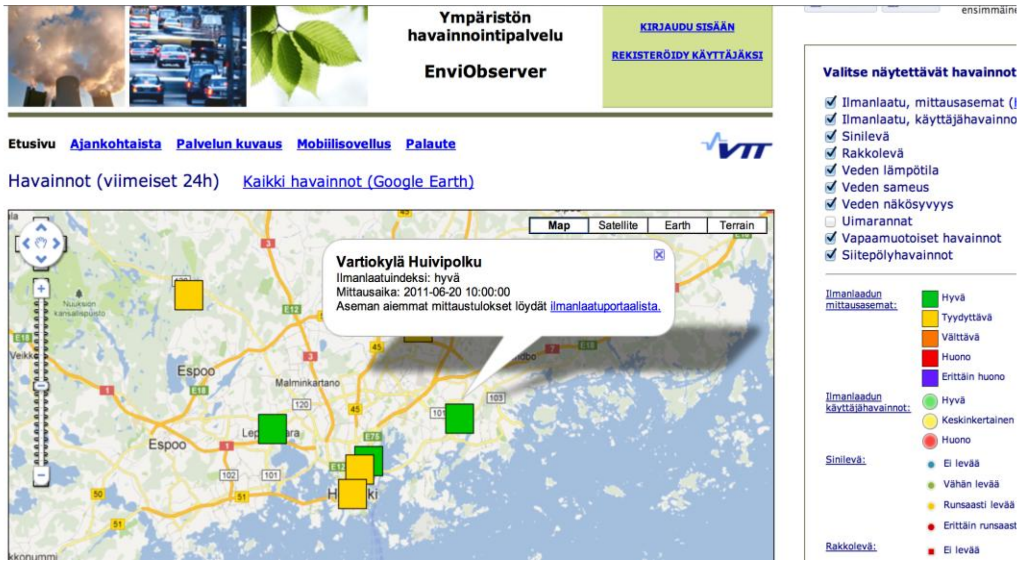


Figure 8: Screenshot - web site of EnviObserver

- MobGeoSen [28]

  One robust system which allows individuals to supervise and investigate local environment and private spaces daily by utilizing mobile phones and ameliorate internal integrated sensor of mobile phone and external physical sensors. The collection of data displays on a Google Earth 3D map and benefits for further aggregation and analyze. Sixty pupils involved the process of evaluation. The privacy issue was considered due to personal location information (record of date and time stamp on GPS positioning) however lack solutions to mention or discuss.

- CenceMe [29]

  One J2M-based opportunistic sensing application is to share personal sensing presence (activity, disposition, habits and surroundings) associated with social network (Facebook, MySpace). It establishes a new communication way with your friends and benefits yourself to observe your life pattern. On privacy concerns, the system drops off the raw data after the performance and provides privacy setting GUI for users.

- Biketastic [30]

  By using a variety of sensors (GPS, camera, microphone and accelerometer) of smartphone, Biketastic, is an Android application to provide the feature of recording, querying and sharing the effective route between bikers. The user group could be a larger bike community. No privacy concerns is considered.

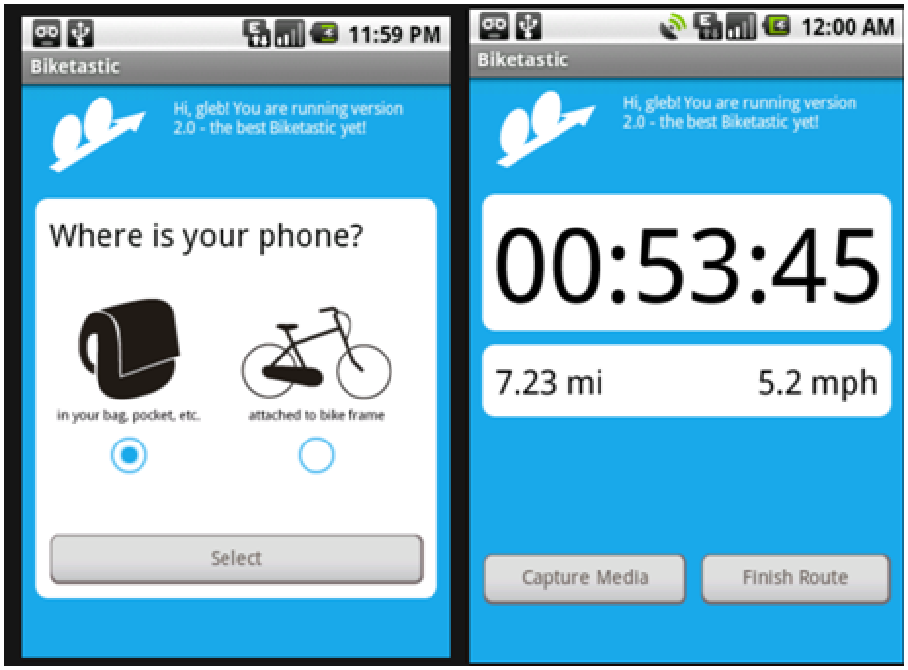


Figure 9: Screenshot - application of Bikeastic

- BikeNet [36]

  An opportunistic sensing based system proposed by authors associated with usage of different type sensors (mobile phones and other physical sensors) to present an cyclist experience map which related to the impact on environment from aspects of cyclists' sensing data (air quality, braking, noise, coasting, car density, distance ...) and also share real-time data with others (bike-to-bike or indirectly third-party entities) and through social networks in cycling community. The BikeView, as web server side, is to display data and query submission. However, in the practice, the system was not integrated privacy protection and some possible approaches were considered (virtual walls, light-weight encryption) for future work.

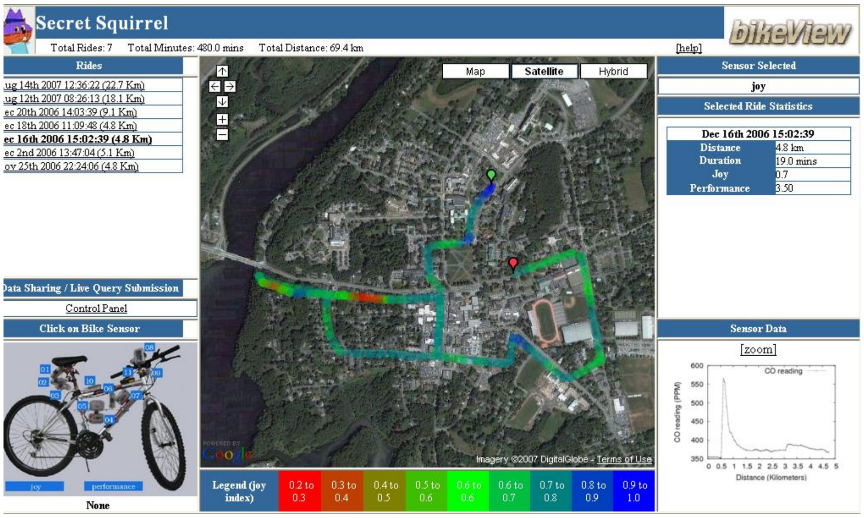


Figure 10: Screenshot - web site of BikeNet

There are seven criteria to be outlined according to the analysis of 11 existing academic project based on people-centric sensing as following:

1. User Group - Who

   According to the relevant search, there are three major segments, individual, group/community and general public, existing in people-centric sensing applications. Almost applications only cover one part.

2. Data collection - How

   Generally, how to collect data was related to different custodian awareness. The passive approach presents the opportunistic sensing which utilizes users' devices to sample data for sensing automatically when meet particular requirements (privacy and transparency). The active method is related to the participatory sensing which requires people to take actions or make decision for sensing process. Some cases might associate with two approaches together.

3. Sensors - What

   Sensors used during the activities of sensing will be considered as two types: sensors embedded in the mobile and a variety of external physical sensors. The sensors which are supported by smartphone [17] [37] contain microphone, camera, text editor, GPS, WiFi, Bluetooth, accelerometer, proximity, light, compass. The external physical sensors could be a GPS receiver unit or other professional environmental detectors (CO2 meter, magnetometer, speedometer, humidity sensor, air quality sensor ...) applied in some people-centric sensing systems as well [36] [22] [25] [28].

4. Coverage of mobile platforms

   According to the report [38], Android, iOS and Symbian are top three mobile operating systems which have dominated most of proportion of market share in Figure 11. The sensing applications opt at least one of them as mobile platform to implement and develop based on their particular sensing framework to meet the needs according to essential requirements.

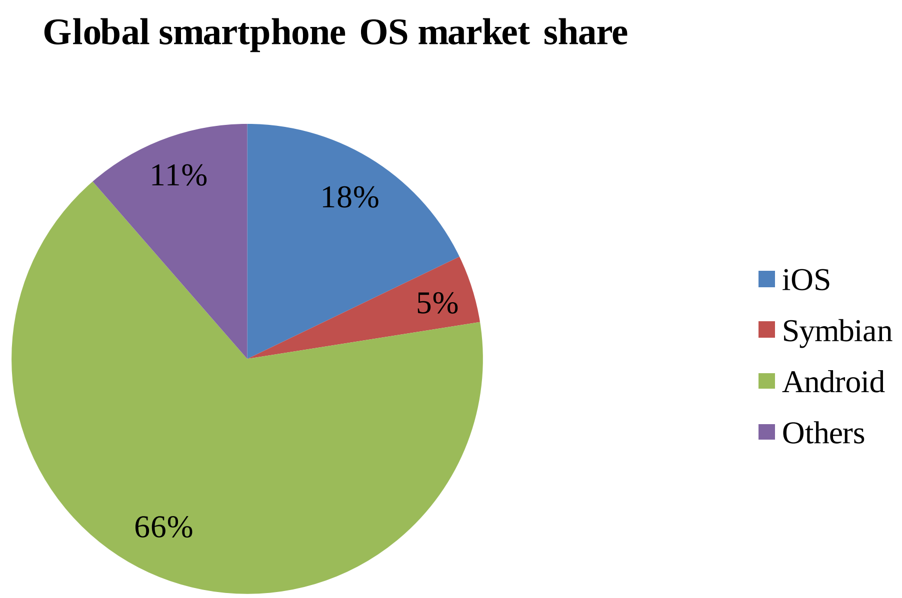


Figure 11: Pie chart - global smartphone OS market share

5. Security considerations

   Relative to the field of application of the traditional WSN, some security challenges were raised for . Firstly, a mass of sensed data not only describes the environment of each sensor nodes, but also the node itself - the participators' information which may be relevant sensitive or correlate to matter of personal privacy. In addition, the heterogeneous of network nodes, mobility, and highly dynamic network topology requires applications to apply different multi-level dynamic adaptive security mechanisms. In the paper [39], the authors, from three security concerns (privacy, data integrity, availability) to consider the security of people-centric sensing, summarized nine challenges based on the following lists.

   ✓ Context privacy, anonymous tasking and anonymous data reporting

- ✓ Reliable data readings, data authenticity and system integrity
- ✓ Preventing data suppression, participation and fairness

From the side of server providers, they concentrate on the data integrity, availability which also relate to trustworthiness of sensor. In the paper [40], the specific case to threat security is data pollution caused by malicious users was a issue for people-centric sensing application and the possible solution will be to require participants to use a trusted sensor by two designs. The first one is to depend on Trusted Platform Module (TPM) and offer trusted sensor reading on a virtualized environment. The similar idea was mentioned on [41] as well. The second is without cooperating trusted primitives and directly to sensors. The reputation system was a other possible solution provided in [42]. This solution based on Gompertz function to calculate the reputation score of each sensors (devices) to detect the trustworthiness of the sensed data. On other side of device owners, the privacy with revealing personal information (location, time) was the key issue. The authors [43] designed a hybrid-MDAV which utilize and mix the tessellation and micro aggregation privacy-preserving concepts, for preserving location privacy in participatory sensing. Other possible solutions for addressing privacy issue was to implement and apply particular cryptographic techniques or algorithms, like PEPSI: Privacy-Enhanced Participatory Sensing Infrastructure [44]. The Paillier cryptosystem used in the paper [45] to present a new privacy-preserving architecture that on no personal data items are disclosed and the distribution computation is performed on encrypted data. Moreover, AnonySense [46], a system in opportunistic sensing which utilizes a new Lisp-like syntax based task language rather than implementation of cryptographic algorithm due to insufficient cryptographic unlinkability. Additive data perturbation [47] [48], in short, to add noise on raw sensor data, was the common approach to alter data for privacy as well.

6. Engagement mechanism/algorithm

How to recruit participators get involved into sensing process is crucial for the framework, especially participatory sensing. A monetary-based incentive mechanism can help to address issues of quantity and quality at same time [49] [50] [27]as well as non-monetary incentive approaches like competition, ranking, reward, share through social networks, visualizations, free API to access to database [50] [20] [24] [26] [28] [29] [36], which engage and motivate the users in order to improve trustworthiness, fidelity and credibility of data.

7. Quality of service /Quality of information

   There are few papers to consider the quality of services or information provided in sensing framework or network.

2.3 Trust and trust/reputation model

Due to the voluntary and randomness as unique characteristics of participatory sensing, the inherent openness of the system can be a double-edged sword and leads to some potential vulnerabilities caused by malicious users. For instance, the malicious users intend to counterfeit data deliberately and report to the system. If the system lack particular components to evaluate the information from those users to share with other users, the information and system present the lower confidence on quality of information and data integrity so as to disenchant users' attention and lose continuous common interest for other users.

Firstly, we need to use the following definition by McKnight & Chervany [63] to express the general concept of trust.

"Trust is the extent to which one party is willing to depend on something or somebody in a given situation with a feeling of relative security, even though negative consequences are possible."

The trusted platform module (TPM) proposed in [40], concentrates on trusted hardware platform in order to improve content integrity based on participatory sensing. In the paper [], the authors described two types of approach on how to generate and derive a trust, widely used in online website. A reputation system which collect the user actions calculates relevant reputation score. The other one is considered as more subjective and centralized that express the trust between users. Related to reality, the reputation can be computed by simple sum of the number of rating or advanced average of rating [32] which has been applied into some commercial websites. There is other schema proposed in [32] that presents reputation in discrete labels without mathematical tractability. And the beta distribution related to Bayesian systems, widely used in peer-to-peer network [64], is used to express uncertain probability [65]based on two binary outcome (i.e. positive rating and negative rating). The user's reputation can be conducted by expectation value using Beta distribution. For instance, a user reported 2 trusted data and 3 distrusted data.

$$f(p|\alpha,\beta) = \frac{\Gamma(\alpha+\ \beta)}{\Gamma(\alpha)\Gamma(\beta)} p^{\alpha-1}(1-p)^{\beta-1}\ \ (p \in [0,1], \alpha, \beta > 0)$$

p is probability value. α and β is two parameters as outcome. In this case, α is 2 as number of trusted data and β is 3 as number of distrusted data. The probability expectation value can be calculated as the following formula.

$$E(p) = \frac{\alpha}{\alpha+\beta}\ \ (\alpha = \alpha+1, \beta = \beta+1)$$

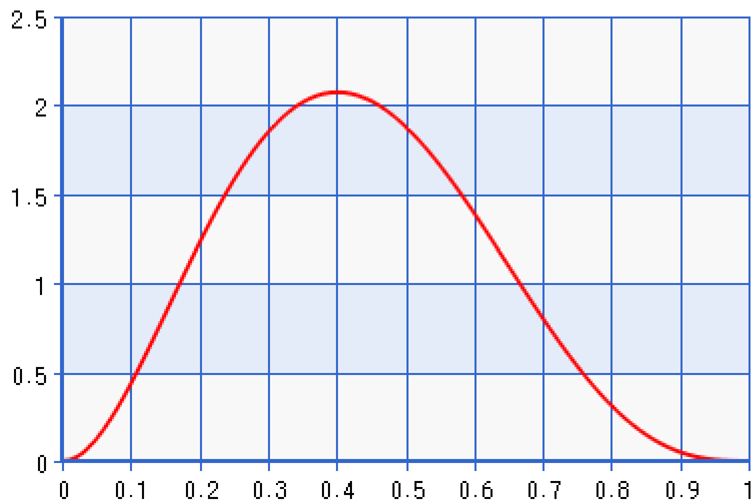


Figure 12: Sample graph of Beta distribution

The Figure 12 demonstrates the curve to express the uncertain probability that the relative frequency of trusted data this user reported is unknown in future, however the most likely value of E(p) is approx. 0.43. This beta distribution can be used to compute the reputation of a user and detect the performance of users. [32]

2.4 Summary & Research questions

According to the analysis of several academic participatory sensing application/systems, there are seven criteria summarized applied into the systems. As a result, there is a lack of system that can involve citizens to collect and share real-time urban environmental information and help trigger a change in their behaviors. The participatory sensing that enables citizens to collect and share urban environmental data using smartphone can be helpful to collect and share relevant information. As a successful participatory sensing application, it should be clearly defined by the criteria summarized above. Notwithstanding, the existing participatory sensing applications/systems are in the absence of concentrating on whether the data collected from participants can be trusted to share and demonstrate and the contribution on the participants to the system. The unique characteristics of "Dublin Green Watch" system that are different with other existing participatory sensing application/system are as follows:

- Real-time data collection on participatory sensing based on smartphone
- Share real-time data on a map as visulization based on application rather than web site
- A implementation of trust model to evaluate relevant trustworthiness of data and contribution of participants
- Basic security consideration covered

Based on the criteria, the table in Appendix A demonstrates the average of evaluation score for all projects is 10.55. The aim of "Dublin Green Watch" is to meet the criteria of success and achieve the evaluation score which at least is over than average. The expectation of evaluation score for "Dublin Green Watch" participatory sensing system will be 19.

Consequently, two research question that this dissertation aims to answer is as follows:

- *How can we classify a green-related incident report shared with citizens as trusted or not trusted?*
- *How can we classify that participatory sensing participants collecting urban environmental data is sharing correct information?*

Chapter 3: Design/Methodology

3.1 Requirements

According to the result of evaluation, the insight of “Dublin Green Watch” is to generate a high effective, multi-functional, scalable and motivated participatory sensing framework based an mobile application. The options based on Appendix A:

- User group
- Data collection
- Sensors used
- Smartphone OS selected
- Security concerns
- Engagement algorithms (incentive mechanisms)
- Quality of service /Quality of information

3.1.1 Client side

- Smartphone platform and programming language for developing an application

  According to the summary from state-of-the-art, there are three major mobile smartphone OS as options, iOS, Android and Symbian.

  The Table 1 demonstrates the different prime programming language used on those three mobile OS.

Mobile Platforms	**Programming language**
iOS	Objective-C
Android	Java & XML
Symbian	C++

Table 1: Summary of programming language on iOS, Android and Symbian

- Image storage

  The application as a real-time sensing mobile application which enables users to report a green-related incident associated with a real-time image captured by camera. The initial idea is to encode the image into binary data using Base64, convert binary data to be string value and store into the database on backend via connection between application and server. The approach is proposed to enhance the security for data (image) and avoid using third party APIs to store the image.

- Visulization as a map

  The map as visulization to display the data to the users is significant and will be implemented into the application. According to the research, there are three possible alternatives which suit for mobile application development.

  - Google Maps for mobile

    It is provided by Google as a popular map-based service and can be applied into multiple mobile platforms.

  - OpenStreetMap [81]

    The open-source map can be contributed by other users.

  - Leaflet [82]

    It supplies the open-source web mapping library based on JavaScript.

- Security concerns

  - CAPTCHA

    To avoid the potential malicious behaviors by computer programs so as to improve and empower security on robot detection and anti-spam [66], the application also proposes a local feasible CAPTCHA (Completely Automated Public Turing Test to tell Computers and Human Apart) program [67], which is considered as a standard security technology applied in most websites and login system.

    The text-based CAPTCHA [68] is the most common approach used widely over Internet. nevertheless, it also has several vulnerabilities and weakness on reversing or guessing by particular anti-CAPTCHA program, object recognition techniques [69] due to simplicity sometime. The paper [70] discussed about the usability and robustness of CAPTCHA so that the aim of this application intend to originate a flexible, effective and dynamical approach of advanced text-based CAPTCHA without relying on any third party CAPTCHA libraries. The initiate idea is to draw a canvas containing random basic fundamental arithmetic operation with random numbers in a dynamic range and background colour, then after it generates, the application will transfer it to a bitmap to demonstrate.

The Figure 13 is to demonstrate the initial idea to design a CAPTCHA program.

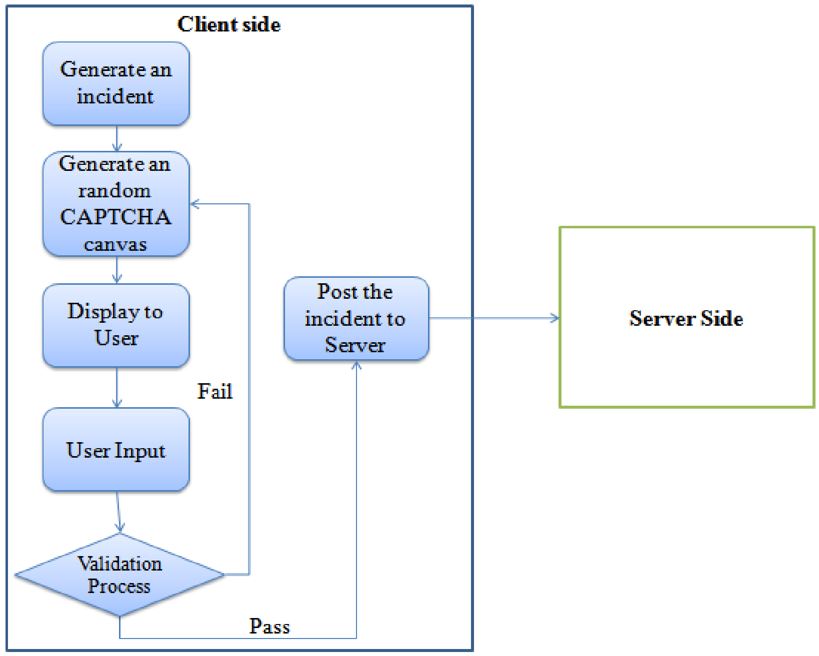


Figure 13: Flowchart - initial design for CAPTCHA

- Authentication

  The reason to use particular authentication is that the application has ability to verify and identify of a user who intends to use. General information used to identify the users can be based on the user account and password. Therefore, the login function will be implemented into this application in order to identify the user and be capable of limitation of the access when the user behaves in malicious way.

3.1.2 Server side: Web services

To achieve the distribution and scalability, the application need to choose a suitable web service, connected to data storage, that meet the needs for mobile device rather than traditional website. There are basic two popular web service framework currently, REST and SOAP.

- REST – Representational State Transfer

REST[51], "an architectural style for building networked applications", which specifies a series of network architecture constraints and principles so as to transmit resources, data or information from one site or application to another. Unlike SOAP or RPC (Remote Procedure Calls), REST uses simple HTTP/HTTPS requests on CRUD (CREATE, READ, UPDATE, DELETE) operations, to establish communication between client and server. The lightweight requests and responses lead to a better performance than others. Using REST, a dedicated web page that may contains an XML file is created that describes and includes the desired content. However, other formats can also be accepted to utilize, like JSON. No standard data representation means that different data formats meet the different needs and match different performance requirements for the client. To access this information or operations, the content subscribers need to know only the web page's URL (Uniform Resource Locator) to call relevant API method.

1. Be suitable when bandwidth and resource is limited [56] [60]

   The return structure is really in any format, and it can use the XMLHttpRequest object.

2. Totally stateless operations [61]

   If an operation needs to be continued, then REST is not the best approach and SOAP may fit it better. However, you need stateless CRUD(Create, Read, Update and Delete) operations, then REST is it. Each REST request contains all the information the server needs to perform the requested action. The server doesn't rely on information from previous requests to answer a new one. [57]

3. Caching situations

   The resources must be cacheable in order to reduce server load time and also for fault tolerance and scalability.

- SOAP - Service Oriented Access Protocol

SOAP [52] is considered to be a more complicated standard for APIs, but is popular nonetheless. SOAP is an XML-based protocol [54] [55] that consists of three parts: an envelope that defines a framework for describing what is in a message and how to process it, a set of encoding rules for expressing instances of application-defined data types, and a convention for representing remote procedure calls and responses. SOAP allows programs on different operating systems to communicate, using HTTP (Hypertext Transfer Protocol) or other protocols like TCP. WSDL is used along with SOAP to make the messages available over the Web via web services. The envelope element indicates the starting and ending of the message. The header element contains optional data helpful for processing messages. The body element consists of the main XML data. In comparison with SOAP and REST, the main advantages of SOAP are that supported by more tool, has been standardized and type-safety XML requests. Due to the security performance, SOAP has been widely used and more suits for business area like finance industries [62].

The following Table 2 illustrates that the pros and cons between SOAP and REST according to some research papers [51] [52] [53] [56] [57] [58] [59] [61].

SOAP	REST
Advantages:	**Advantages:**
✓ Good degree of QoS (security/reliability: attachment element with SOAP message) [56] [59] ✓ Standardized protocol [52] ✓ Use other Transport rather than just HTTP [53] ✓ Can be tested and debugged before deployment [56]	✓ Simplicity (use HTTP directly) [51] [56] ✓ Statelessness (trade-off i.e. performance) [57] ✓ Scalability [56] ✓ Efficiency (lightweight without extra request/response headers) - better for mobile device [51] [53] [58] [61]
Disadvantages:	**Disadvantages**
✓ Complexity [59]	✓ Lack QoS coverage (reliability, security)

Table 2: The summary of pro and con between REST and SOAP

To sum up, selection between REST and SOAP literally depends on specific requirements, like concentrating on more accessing named resources or operations, for a mobile application. The following concerns list will be common scopes covered in "Dublin Green Watch" application.

- ✓ Robustness (fault tolerance)
- ✓ Bandwidth efficiency usage (concerns on battery limitation of mobile device)
- ✓ Security (easy to accomplish rather than implementing cryptography algorithm)
- ✓ Performance (not heavy network traffic requested due to memory/cost used on mobile device)

3.1.3 Cloud hosting & Database schema

The cloud computing [71] is the production that integrate with traditional computer technology and development of network technology, such as Grid Computing, Parallel Computing, Network Storage Technologies. The core idea of it is to utilize the network to connect a large number of computing resources in a unified management and scheduling in order to constitute on-demand services to users.

Google App Engine (GAE), Amazon Web Services and Microsoft Azure Service Platform, as top three of cloud computing platforms [72], allow the clients to host and develop particular application.

"Dublin Green Watch" application requires to achieve the distribution and scalability. Thus, one of cloud hosting will be selected to deploy as server side to establish real-time communication via cloud technology.

There are two kind of database will be utilized in this application.

- On native application side, it depends on which mobile OS is chosen. The initial idea is to use relevant API provided by specific mobile OS API to carry out some basic and minor operations, like validation of login.
- On server side, SQL or non-SQL depends on the availability of cloud hosting. The major task is to store the incidents information in an efficient manner.

3.2 Design of trust model

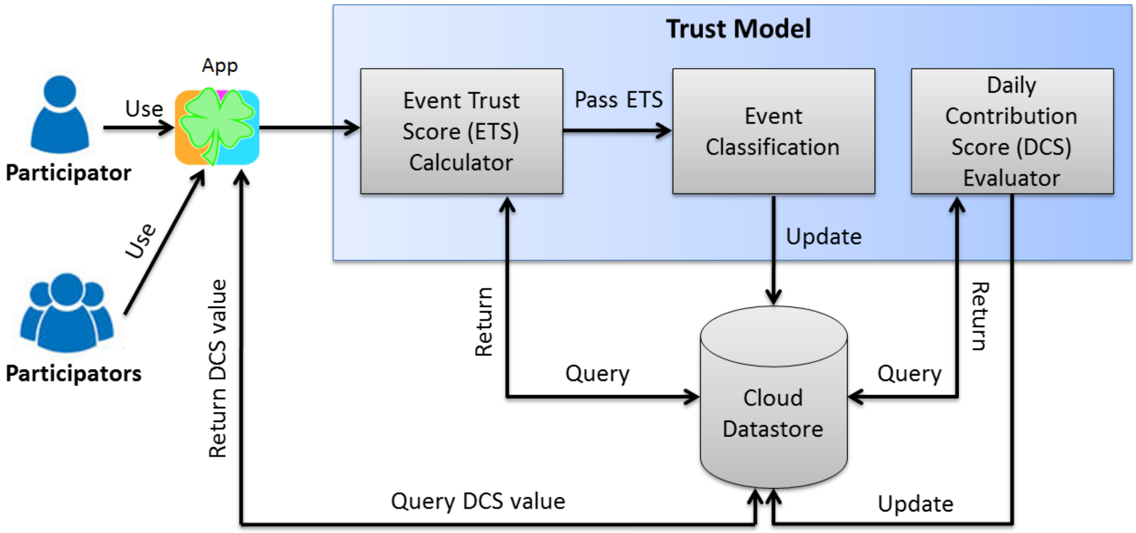


Figure 14: Initial design for trust model

In order to classify the incidents as trusted or distrusted, the initial design for this trust model will implement an "Event Trust Score (ETS) Calculator" component which enables the computation of value of trustworthiness based on other participators information (feedbacks/comments/rating). After that, the value of trustworthiness for the incident will transfer to the "Event Classification" component to classify the incident as trusted or not trusted based on some general if-then logic rules. The similar principle has been applied into Amazon rating system [73]. The rating system used for EBay.com, one popular online auction site, is classified as a centralized approach [74] that might raise some significant issues like falsifying information, unfairness. Thus, in this project, the computation of trustworthiness of the incident will be conducted on advanced scheme on average of all ratings rather than a simple centralized approach based on sum of rating. The Figure 14 demonstrates the process of trust model.

The trustworthiness and reputation is generally among participants and the participatory sensing system/application. However, to answer other research question on classification of participants contribution, the relationship between incidents is independent and the relationship between incidents and participators is dependent. Therefore, one component called "Daily Contribution Score Evaluator" is utilized to calculate based on average of ETS of all the incidents contributed by a specific participator on a specific day.

3.3 Design decisions

According to the requirements of this application. The following design decisions are made.

- Mobile platform

  Android, is the biggest smartphone OS and open-source without any charges to develop a sensing Android application.

- Programming language

  The use of Java and XML related to Android SDK API is to develop a native application.

- Visulization as a map

  Google Maps for Android provides a better map services to satisfy the basic requirement of this application.

- Cloud hosting

  Due to the selection of Android as mobile application OS, the Google App Engine has the advantage of association with Android and opted as the cloud hosting in this project.

- Web service:

  This application is selected to implement REST (Google Cloud Endpoints REST API) as mobile web service architecture on server side using corresponding CRUD operations (Create, Read, Update, Delete) rather than SOAP without heavily considering about security. In this project, we use HTTPS protocol as easy-to-use secure approach.

- Database

  On client side, the Android SDK API supplies the SQLite that has ability to be embedded into each Android application in order to achieve basic database operations asynchronously.

  On server side, due to the billing, the application can only utilize the datastore service on the backend provided by Google App Engine. The backend database in this case, the application utilizes Google App Engine Datastore [75] API to store all information. Compared with traditional database, the Datastore provides a more robust, scalable approach which suits for metadata so as to maintain high performance when the application is under the heavy data-loading traffic and hold one entity with various properties containing different types of value.

- Trust model

Trust model will be implemented and deployed into the server side using REST to achieve.

- Authentication

  To implement the OAuth 2.0 associated with a user's Google Account as login information.

- Security concerns

  An advanced, robust and adjustable Android-based CAPTCHA is required to implement into this application so as to improve the security of this application.

Chapter 4: Implementation

4.1 Implementation of "Dublin Green Watch" application

There are four major functions to be implemented based on a 2*2 dashboard style layout in Figure 15, as one of five user interface design patterns recommended by Google [77], that containing large and clear symbols of main functionality to provide a good first impression for the participators to understand major features and capabilities of this application.

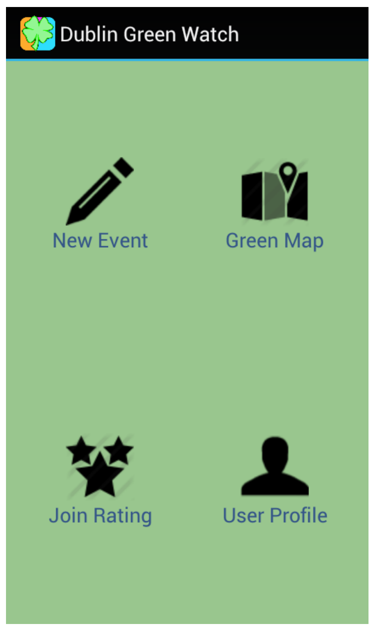


Figure 15: Screenshot - main activity of "Dublin Green Watch" application

1. "New Event" functionality

   To report one of type of incident from the Table 3 which must contain one image, captured by the user using camera on the device, need to submit to a public Flickr photo stream, relevant limited length description, an unique automatically generated event title and the current location information recorded from the GPS sensor for this user.

Number	Types
1	Waste Case
2	Environment Pollution Incident

3	Dog Fouling
4	Plants Protection
5	Road Problem
6	Public Lightning
7	Others

Table 3: Types of green-related incidents

When users complete the incident and are ready to upload to the server via cloud, the Figure 16 display a CAPTCHA field for users to enter the correct answer to complete the upload operation.

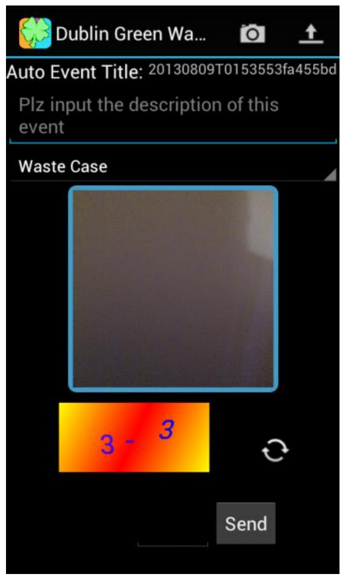


Figure 16: Screenshot - CAPTCHA in "New Event" functionality

The following procedures to implement a CAPTCHA into this application:

- To draw a background canvas using random selected colour that range from 1 to 10.
- To draw a front field which includes two random numbers and one random mathematic operation symbol in random selected colour as well.
- The application called the classes to generate a CAPTCHA object and set it to an ImageView field which display the relevant random CAPTCHA bitmap.
- The CAPTCHA random bitmap will be automatically regenerated when the user input incorrect answer.
- The CAPTCHA random bitmap can also be manually refreshed by a button when the bitmap is clearly visible due to a clash of random colours for background and front

word.

2. "Green Map" functionality

The purpose for green map will display all incidents which are used relevant icon as markers to present on Dublin area only in order to be aware of surrounding environment and raise interests for each participators. And the users are able to click the icon of each markers which has been drawn on the map to observe the details about this "Event" and whether this "Event" can be trusted based on the trust model that implemented into this application. When the user click the information window that pop up from the icon, the application will make a notification to remind the participator that this "Event" title has been copied into clipboard so that it is convenient for the user to do the search and vote in "Join Rating" functionality.

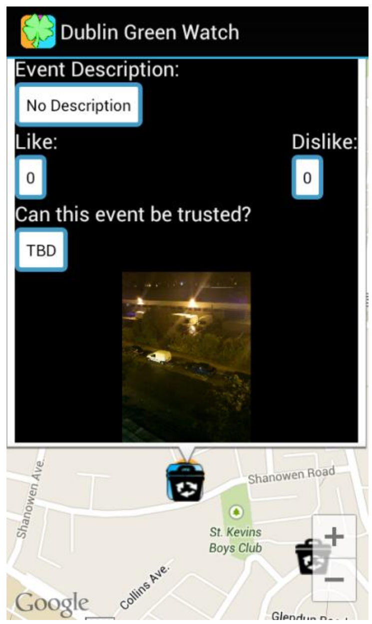


Figure 17: Screenshot - "Green Map" functionality

3. "Join Rating" functionality

As part of incentive mechanism and trust model, this section will encourage the users to rate the incidents which might be interested in. By searching particular "Event" title that can be pasted from the "Green Map" by a long click gesture, there are "Like" or "DisLike" two options to show negative and positive effect for this "Event". And "Trust", "Don't Know" and "Distrust" options will decide the correctness of this "Event" according to the details and image which is significant and related to the basic trust model implementation. In order to achieve fairness, all incidents can be only voted once by each participators the same day and other incidents reported on previous days can be only observed without rating function.

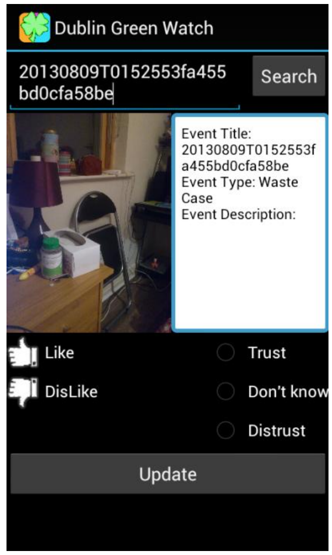


Figure 18: Screenshot - "Join Rating" functionality

4. "User Profile" functionality

To display current user records about incidents reported by himself at that day via a shake gesture and user daily contribution score, which relate to the basic trust model implementation in this application.

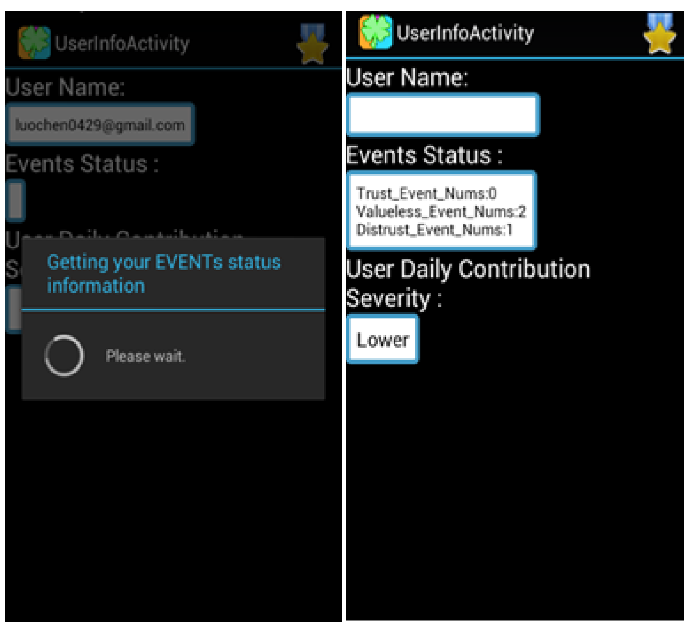


Figure 19: Screenshot - "User Profile" functionality

4.2 Implementation of REST and backend datastore

The "Mobile Backend Starter" provides a rapid approach to establish flexible and stable connection using REST web service between client and server side. The clients upload the incident, called "Event" as one cloud entity which to convert into GSON format rather than Extensible Markup Language (XML) into the backend's Google Cloud Datastore. The results of experiments in the paper [78] indicated that the JSON has a better performance on encoding and parsing than XML and both of them are human readable. The GSON [76] was designed originally by Google which is a open source project which provides the Java library that enables transform Java Objects into JSON [79] representation.

The below screenshot Figure 20 illustrates the sample of GSON format used in this application which is human readable and well-defined as well.


```
{
    "createdAt": " ",
    "createdBy": "XX@gmail.com",
    "id":" ",
    "kindName":" ",
    "owner":" ",
    "properties":
    {
        "Event_Location_Lat": ,
        "Event_Title":" ",
        "Event_Type":" ",
        "Event_Trust_Score":" ",
        "Event_Trust":" ",
        "Event_Distrust":" ",
        "Event_Description":" ",
        "Event_Skip":" ",
        "Event_Dislike":" ",
        "Event_Location_Lon": ,
        "Event_Image_URL":"http://fXXXX_b.jpg",
        "Event_Like":" "
    },
    "updatedAt":" ",
    "updatedBy":" "
}
```


Figure 20: Screenshot - "EventList" entity in GSON

There are five major REST API methods generated on server side as the following table.

REST API Methods	Http Method
get (Finds the CloudEntity	GET

specified by its Id)	
insert (Inserts a CloudEntity on the backend)	POST
update (Updates a CloudEntity on the backend)	POST
delete (Deletes the CloudEntity specified by its Id)	DELETE
list (Execute a query)	POST

Table 4: REST API methods implemented into the server

The principle is that the application call the relevant unique REST API URL, looks like "https:// [PROJECT_ID].appspot.com/_ah/api/CloudEntities/[operations]/..." to carry out particular operations (get, insert, update ,delete, list).

4.3 Implementation of trust model

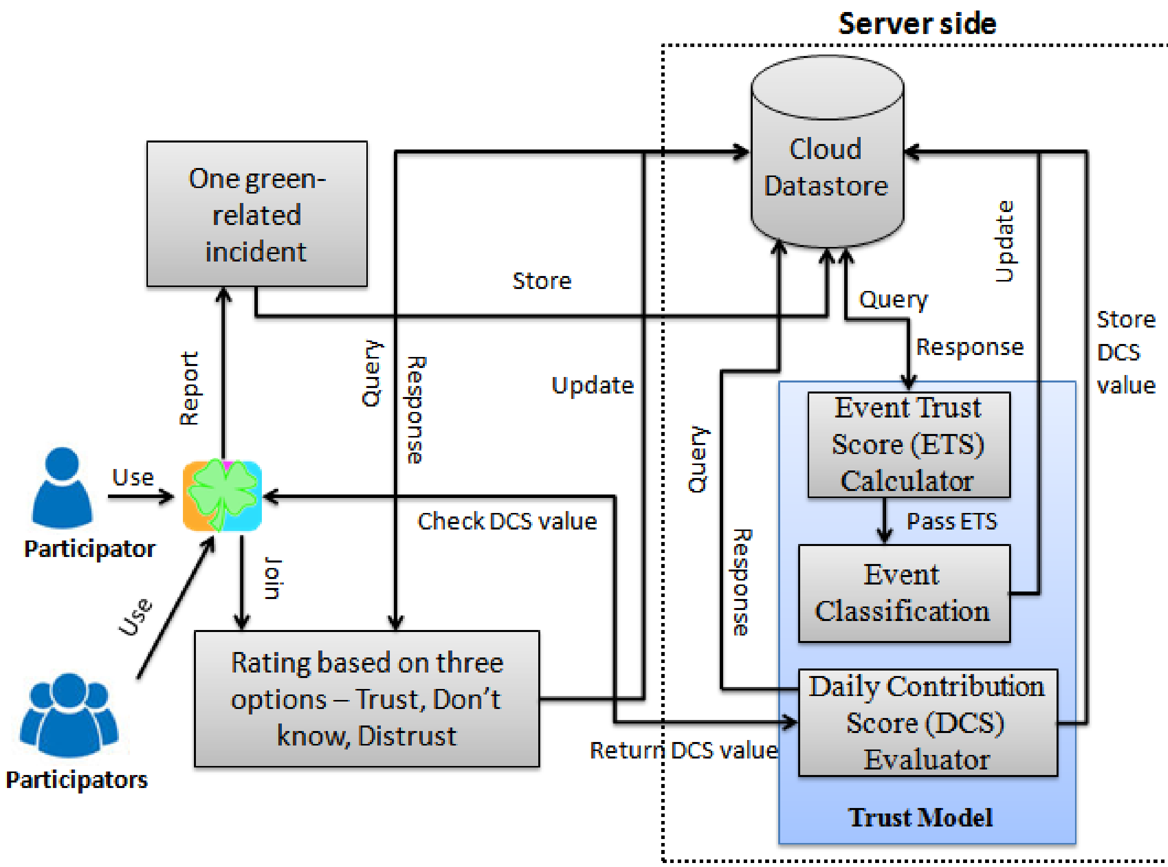


Figure 21: Diagram - Implementation of trust model

The following points to illustrate the process of "Event Trust Score Calculator" and "Event Classification" components of the trust model in Figure 21

1. When a participator use this app to report one green-related incident, called "Event", the "Event" is stored into backend datastore via cloud.
2. The other participators use this app and observe this incident on the "Green Map" who have common interest in it. Then, they rate this incident with relevant options based on "Trust", "Don't Know" and "Distrust". The rating results are stored automatically into backend database.
3. On server side, when the application called API method "list" to query the particular entity of incident, the backend programme will calculate the "Event_Trust_Score" (ETS) on "Event Trust Score (ETS) Calculator" component of trust model , was based on the subjective rating statistics (Total number of trust [TNT], Total number of distrust [TND],

Total number of skip [TNS]). The option value for those three is one for "Trust", zero for "Don't know" and minus one for "Distrust".

4. The ETS is computed based on the following formula.

$$\boldsymbol{ETS} = \frac{\boldsymbol{TNT} * \mathbf{1} + \boldsymbol{TND} * -\mathbf{1} + \boldsymbol{TNS} * \mathbf{0}}{\boldsymbol{TNT} + \boldsymbol{TND} + \boldsymbol{TNS}} \quad (\boldsymbol{ETS} \in [-\mathbf{1}, \mathbf{1}])$$

5. The result of ETS is passed to the "Event Classification" which classify the incident followed by the logic rules:
   - If the result via rating after calculation is greater than 0.0, that means this "Event" can be trusted,
     Then "Event" is marked as "Trust Event" and set 1 value to ETS.
   - If the result via rating after calculation is less than 0.0, that means this "Event" can't be trusted,
     Then "Event" is marked as "Distrust Event" and set -1 value to ETS.
   - If the result via rating after calculation equals 0.0, that means this "Event" can't be judged properly,
     Then "Event" is marked as "Valueless Event" and set 0 value to ETS.
   - If no one vote the "Event",
     Then "Event" is marked as "Valueless Event" and set 0 value to ETS
6. In the distrusted application, the fairness is also considered to achieve. In the ETS Calculator, there is a validation process to detect whether the incident lack enough rating. The application set a particular value as minimum value that the total number of rating must be over minimum value to illustrate that the incident has been rated by enough participators.
   - If the total number of rating on this "Event" is less than minimum value, that means that it lacks enough rating from other participators and can't be judged properly,
     Then "Event" is marked as "Valueless Event" and set 0 value to ETS.

   The expire time for "Event" rating is limited, in this case, will set up to 24 hours in order to achieve the fairness. However, the length of expire time can be modified dynamically according to the application requirement.
7. "Event Classification" will update relevant incident to datastore, seen as Figure 22.

Event_Trust_Score	Event_Type
0	Waste Case
0	Environment Pollution Incident
1	Dog Fouling
-1	Waste Case
0	Waste Case
-1	Others

Figure 22: Screenshot - datastore for "EventList" Entities

The following points to illustrate the process of "Daily Contribution Score (DCS) Evaluator" component of the trust model

1. When a participator desires to get to know how good of his contribution on "User Profile" functionality, the particular API method called on server side related to "Daily Contribution Score (DCS) Evaluator " component.
2. The component will query all incidents in current date for this user and calculate according to this formula.

$$\boldsymbol{DCS} = \frac{\boldsymbol{NTE} * \mathbf{1} + \boldsymbol{NVE} * \mathbf{0.5} + \boldsymbol{NDE} * \mathbf{0}}{\boldsymbol{NTE} + \boldsymbol{NVE} + \boldsymbol{NDE}} \quad (\boldsymbol{DCS} \in [\mathbf{0}, \mathbf{1}])$$

   NTE is total number of "Trust Events", NVE is total number of "Valueless Events" and NDE is total number of "Distrust Events".

   - For each "Trust Events" , the model will assign 1 contribution value.
   - For each "Valueless Events", the model will assign 0.5 contribution value.
   - For each "Distrust Events", the model will assign 0 as none, contribution value.

   After the calculation and presentation to the participator, the DCS will be stored as well into the datastore.
3. If the DCS value directly present, like Figure 23, to the participator, it must lead confusion and misunderstand. To solve this problem, the DCS will be represented in linguistic variables which is defined by the particular if-then logic in Table 5.

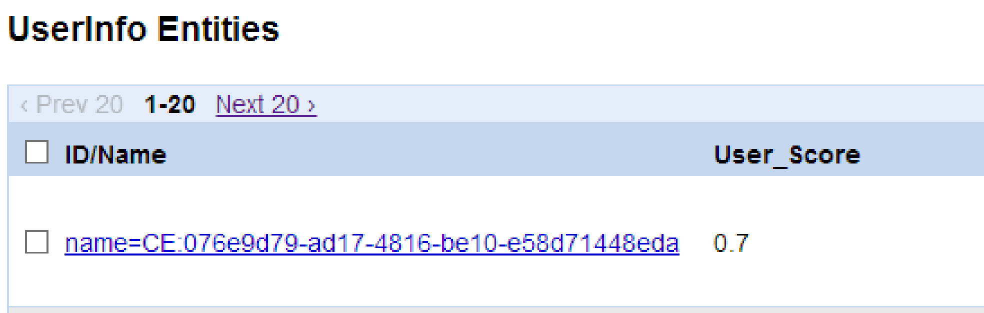


Figure 23: Screenshot - DCS stored on datastore

if-then logic	DCS
IF DCS IS 0.0 THEN mark the DCS as	**"Lowest"**
IF DCS IS GEATER THAN 0.0 AND LESS THAN 0.5 THEN mark the DCS as	**"Lower"**
IF DCS IS 0.5 THEN mark the DCS as	**"Low"**
IF DCS IS GEATER THAN 0.5 AND LESS THAN 1.0 THEN mark the DCS as	**"Medium"**
IF DCS IS 1.0 THEN mark the DCS as	**"High"**

Table 5: if-then logic for DCS

The linguistic variables of DCS is similar with the principle proposed in the paper [76], to demonstrate trust degree and their meaning.

4.4 Application architecture overview

1. Application technical architecture

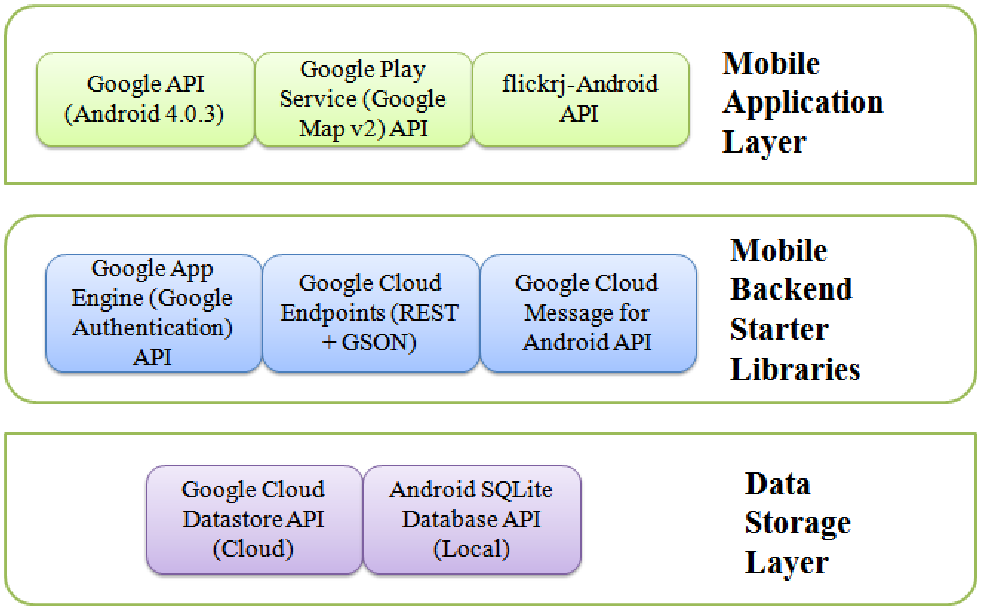


Figure 24: Application technical architecture

- Google APIs [Android 4.0.3]

  Which provides plenty of advanced features, such as user interface widgets, layout on Android for developers to use and the programming language is Java and basic XML for handling and managing user interface layout and several string variables used. In this case, the following sensor features we implement were slightly different with original plan claimed in the state of art according to the actual demand:

  - ✓ Camera (Photo)
  - ✓ Text editor (Editor Text)
  - ✓ Location services (GPS/Google's location service)
  - ✓ WiFi/Cellular (3G)
  - ✓ Accelerometer (optional)

  According to the initial idea, we also need to use microphone, however, there are plenty of successful noise map based participator sensing projects and applications already deployed and developed. Thus, the "Dublin Green Watch" application will concentrate on the text-based information with the image at this stage to keep it unique character. And Bluetooth sensor has been removed because of no such function required in this application.

- "Mobile Backend Starter" libraries

  Which proposes a basic ready-to-use and flexible cloud backend for Android client which enable interact with the backend. And also it reduces the time spending on writing and managing server code for developers.

- Google Cloud Messaging (GCM) for Android API

  The application supports continuous queries which notifies the clients via GCM established on the Google App Engine API wherever the query results modify on the server. In this case, when a new "Event" raise, the Google Map will display it dynamically.

- Google Maps Android v2 API

  The application is required to display the all incidents as a custom marker with relevant icon and details of those incidents using map as better visualization to demonstrate the environment around Dublin area. Therefore, the latest version of Google Maps Android is selected to implement associated with Google Play services. Because the API has been already distrusted as the component of Google Play services.

- Google Authentication (OAuth 2.0)

  In the participant sensing, privacy concerns need to be considered when you develop a relevant application. Because, in this case, we require to store information which might be personal and sensitive into the cloud data storage so that the application has the function to detect and limit the access for the users. Unlike general authentication approach, asking user to enter username and password to sign in , used in most website or various systems, the application uses Google Authentication which is regarded as an easy-to-use way which requires users' Gmail account only without passwords typing. On the server side, we need to limit access to the REST API to only our own Android user to setup the Android Client ID.

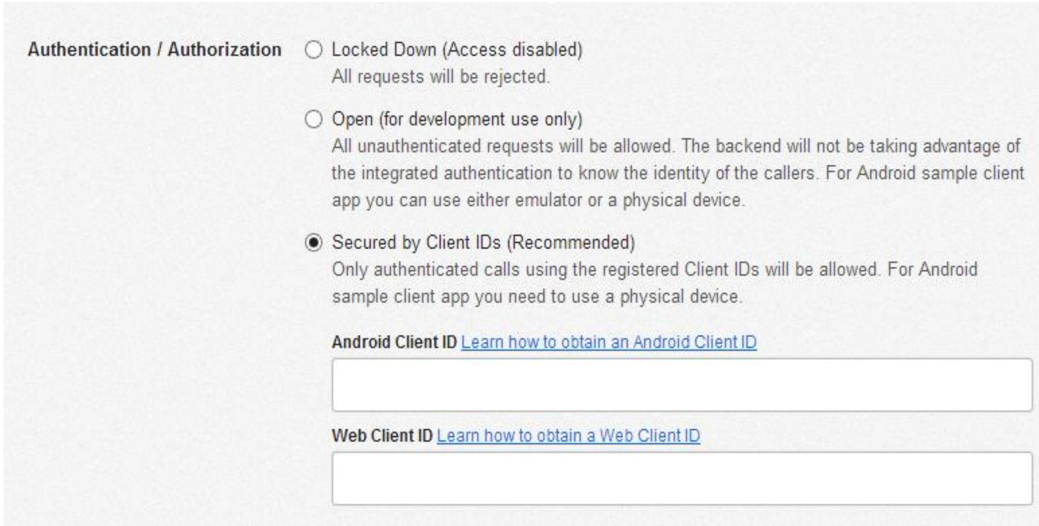


Figure 25: Screenshot - auth setting

And also we need to register the application on Google Cloud Console entering SHA1 hash and the unique application package name. When completed those steps, the Mobile Backend Starter provides all existing code to enable auth using OAuth 2.0 in Figure 26.

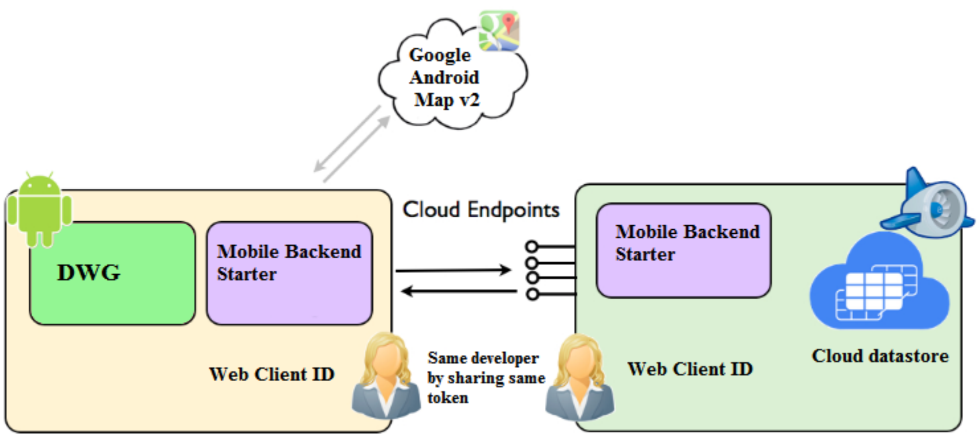


Figure 26: Implementation of OAuth 2.0 in the project

When you launch the "Dublin Green Watch" application, it will not ask users to type password and only need to select an account once if the user has one.

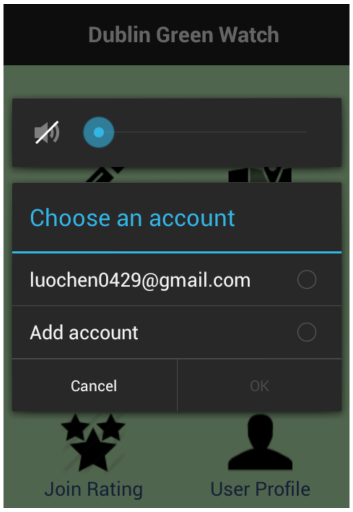


Figure 27: Screenshot - Google Auth in the application

- flickrj-android API

  Due to the limitation of length of string stored on the datastore, the image captured by the user using the camera on the device will be stored via a third party photo stream platform. The flickrj-android API was the available option and applied into this application successfully. To ensure security, the Flickr also enables the application to authenticate users using OAuth throughout three steps:

  1. Gain a Request Token
  2. Get the User's Authorization
  3. Exchange the Request Token for an Access Token

  After the successful authentication process, the application has ability to upload the photos when confirming the authentication. And the result will return a photo id from Flickr. The application intends to use this photo id to retrieve the static photo URL as request via a Flickr Java object and relevant method called.

2. Application overall architecture

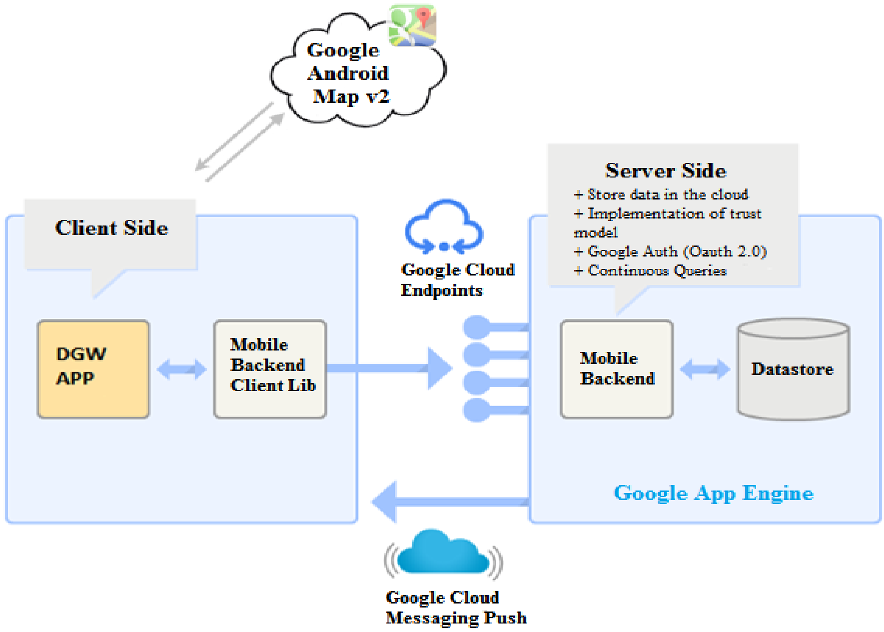


Figure 28: Application Overall Architecture

The above diagram of Figure 28 demonstrates the overall architecture of "Dublin Green Watch" including the application on client side and backend with datastore on server side.

3. Database structure

On local side, using Android SQLiteDatabase API, the two tables demonstrate the details about structure of database. The "event_image" table used in "New Event" functionality and "event_rating" used in "Join Rating" functionality.

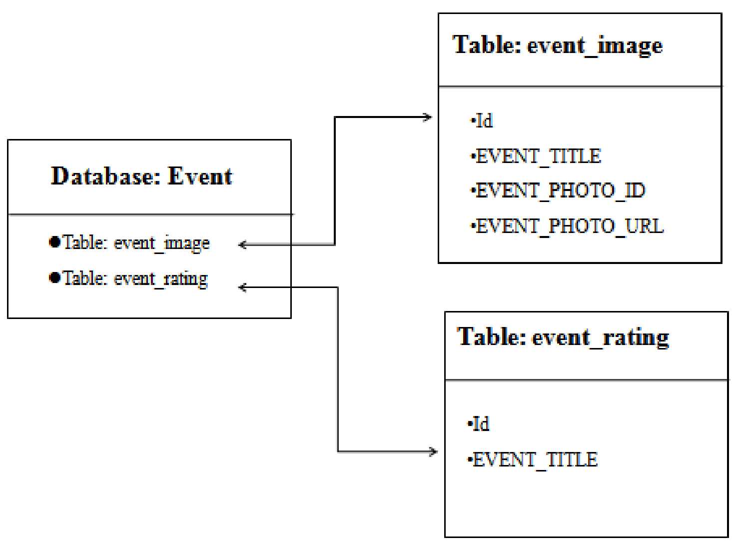


Figure 29: Database structure

On the backend's datastore, unlike traditional database containing particular relationship among tables, the diagram illustrates three major independent entities ("_Users" , "UsersInfo", "EventsList") which contain numerous properties.

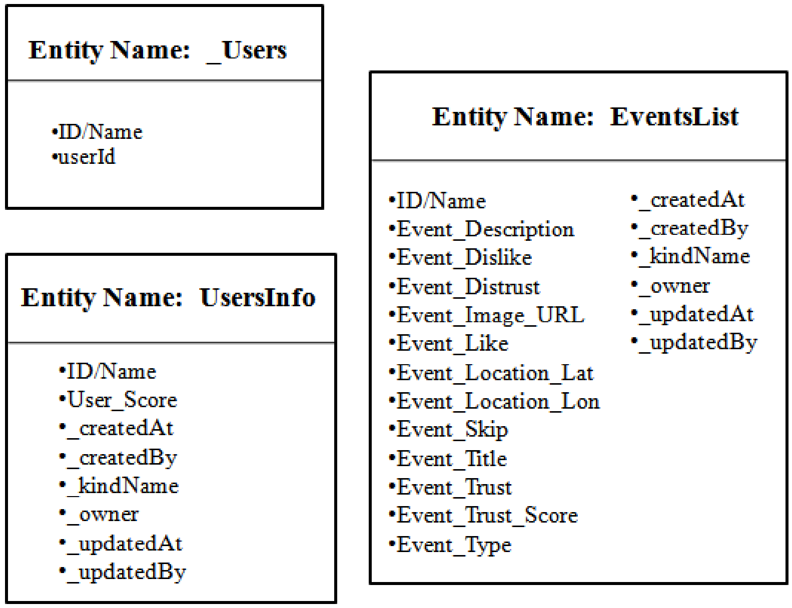


Figure 30: Three major entities in the datastore

4.5 Implementation issues

- For the image storage, the initial idea is to avoid using third parity libraries to store the image, and convert the image into string variable using Base64 recorded on the database directly. Due to the limited length of one string variable, 500 characters on Google datastore, the solution is to deal with this major issue that opts particular third party image storage as an alternative to achieve. According to the research, the Flickr as the popular freely photo stream is selected and it also requires the OAuth to access from third parties application.
- The Google Map for Android v2 is the latest version of map as part of Google Play Services which means the minimum targeted Android OS is Android 4.0.0 plus. The OS on device is lower than this requirement cannot launch the "Green Map" functionality successfully.
- The accuracy of obtaining the real-time location information must be reduced by the limitation of different GPS chips installed on Android mobile devices and the location when users are inside building.

Chapter 5: Evaluation & Results

5.1 Key research objective

In order to evaluate the "Dublin Green Watch" application to reach the average score which summarized in the state of art, based on several criteria of participatory sensing and prove the feasibility and practicability of trust model implemented into this project, the evaluation concentrated on the following key objectives:

- Testing the success of reporting a green-related incident, called "Event" associated with real-time image using different sensors to the server side
- Testing the success of visualization as "Green Map" to display all incidents reported from the participants
- Evaluation and testing the accuracy, feasibility and practicability of trust model
- Analyze the feedback and user experience from the online survey

5.2 Evaluation requirements and methodology

Due to the technologies implemented into this project, there are some requirements and inclusive criteria to recruit the participants.

- The participants must own an smartphone based on at least Android 4. 0.3 operation system
- The smartphone must contain Google Play Service in order to use Google Map Service
- The participants must be adults (over 18 years of age)

In accordance with Trinity College Dublin's research procedures, each participants received the ethics committee before testing and required to sign on a consent form which contains brief background of this project, a list of declaration and tasks had to complete during the testing. The method of participant recruitment is based on the invitation via email and social network.

The participants required to follow the steps on the guide of installation document in

Appendix to install the application on the device and comprehend all functions of this application according to the guide of application document. The evaluation was designed to take one and half hour daily during three days totally. The following tasks for participants to complete:

- Login with a Gmail account
- Report at least one "Event" per day
- Observe the "Green Map" at least one time per day
- Rate at least one "Event" per day
- Check own "Event" status and obtain the contribution score per day

Once the participants completed the tasks, they were asked to fill out a online survey with 17 questions in Appendix which was created and hosted on SurveyMonkey.

The following points covered in this survey:

- User group? / User basic range of age?
- Basic status of using this application
- More expected functions for future work
- User experience of using this application

5.3 Results

5.3.1 Evaluation of classification of incidents

The evaluation period was 3 days long and total number of participants joined the evaluation stage and completed the task of data collection is 7. The Figure demonstrates the status of all "Event"s after 3 days. According to the records on backend datastore, there were 39 "Event"s entities stored successfully over 3 days. The reason of occurrence of error for trust model to evaluate the relevant "Event"s is that the time for several "Event"s report is between previous date and current date.. The REST API method for trust model will only carry out the operation only between the time for using this application ranges from 8:00 am to 22:00 pm. But overall, the percentage of accuracy for the trust model deployed into this application is 92% according the Figure 31. And also it illustrates that the basic success of implementation of trust model to classify the "Event"s as trusted or not trusted is to meet the requirements based on design.

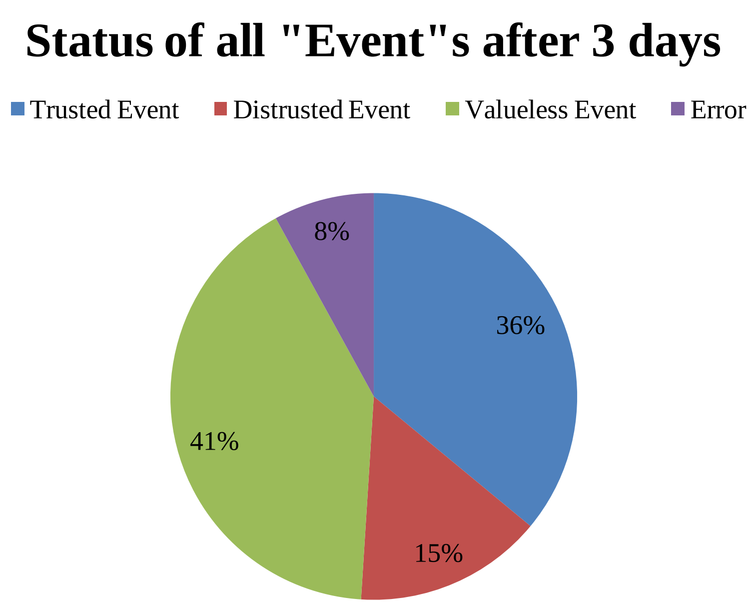


Figure 31: Pie chart - status of all "Event"s after 3 day

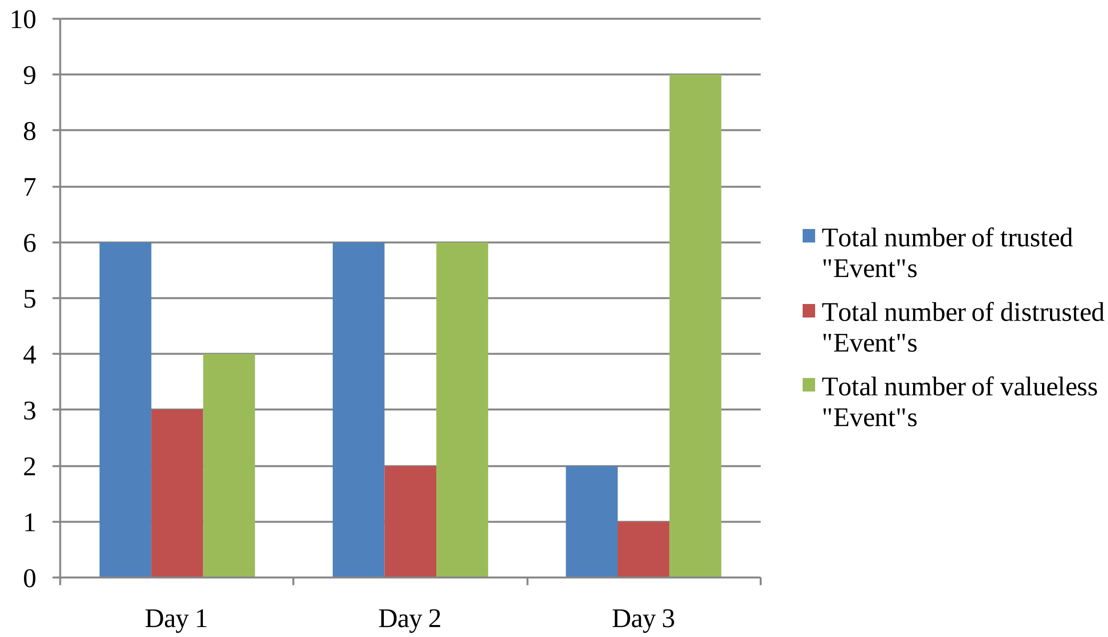


Figure 32: Line chart - status of number of different "Event"s over 3 days

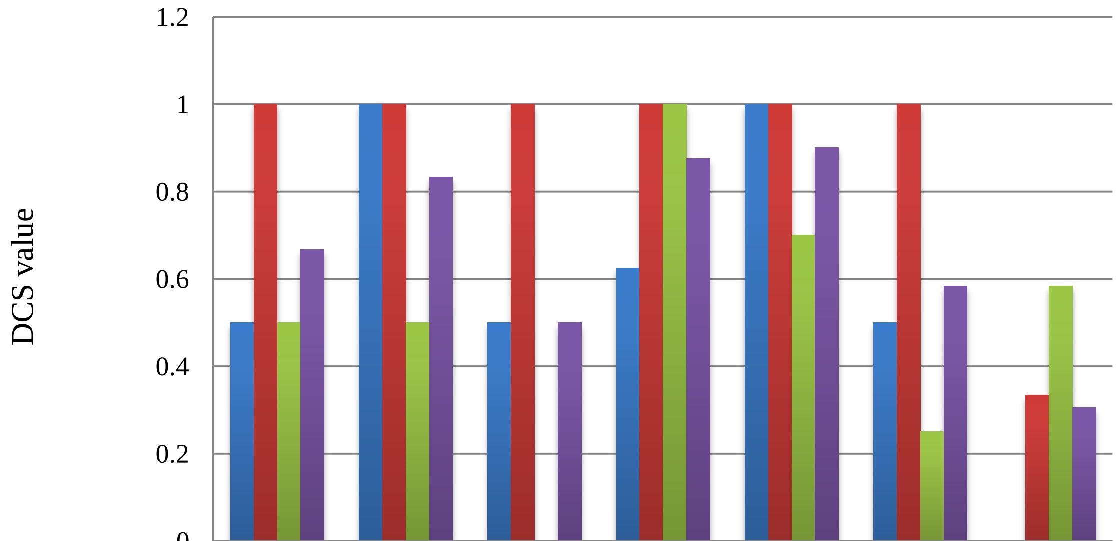
The Figure 32 illustrates that there was a downward trend of distrusted "Event"s report. It means that after the familiarity and understood of using this application day by day, the participants' sensing behavior has been changed into a positive direction. The results also illustrates one phenomena that the number of "Valueless Event" occupied the biggest proportion of all "Event"s, which was greater than the number of "Trust Model" that is without expectation. To analyze the reasons for it, due to lack of implementation of an efficiency incentive mechanism and a higher minimum value (MV) as threshold, setting for identifying the situation of being short of enough vote for particular "Event", thus, if the system adjust this value to 2 instead of initial setting value 3 (one of third of total number of users), the following table illustrates the change of total number of "Valueless Event"s.

When *MV = 3*			**When *MV = 2***
No Valueless Event	**Total rating results**	**Is a Valueless Event?**	**Is a Valueless Event?**
Event 1	3	Yes	No
Event 2	0	Yes	Yes
Event 3	3	Yes	No
Event 4	0	Yes	Yes
Event 5	3	Yes	No
Event 6	3	Yes	No
Event 7	2	Yes	Yes
Event 8	3	Yes	No
Event 9	0	Yes	Yes
Event 10	2	Yes	Yes
Event 11	3	Yes	No
Event 12	2	Yes	Yes
Event 13	3	Yes	No
Event 14	2	Yes	Yes
Event 15	3	Yes	No
Event 16	3	Yes	No
Total number of "Valueless Event"s:		**16**	**7**

Table 6: Change of VM values

After adjusting the *MV* to 2, the total number of "Valueless Event"s reduced by 56%. Therefore, the *MV* of this trust model can be modified dynamically according to different level of requirement.

5.3.2 Evaluation of daily contribution score by a specific user



	User 1	User 2	User 3	User 4	User 5	User 6	User 7
DCS for Day 1	0.5	1	0.5	0.625	1	0.5	0
DCS for Day 2	1	1	1	1	1	1	0.333
DCS for Day 3	0.5	0.5	0	1	0.7	0.25	0.583
Average of DCS	0.6667	0.8333	0.5	0.875	0.9	0.5833	0.3053

Figure 33: Line chart - daily contribution score after 3 days

The Figure 33 demonstrates the relevant user's daily contribution score (DCS) value which present their sensing performance over 3 days. The user 5 is clearly to be considered as a well-suited and trusted participant who has the highest DCS value. The user 7 can be marked as the potential malicious participant who has lowest contribution score in this case. The DCS value is only used to present the current contribution by a specific participator in period of time. The limitation of DCS is that usage of DCS can't classify clearly the specific participants' sensing behavior as positive or negative as follows.

- When a participant like User 5 has higher DCS value, his sensing behavior changed from positive to negative.
- When a participant like User 7 has lower DCS value at the beginning, however, there was a upward trend of his sensing behavior to illustrate the positive direction rather than negative direction.

5.3.3 Probability of "Trust Event" by a specific user

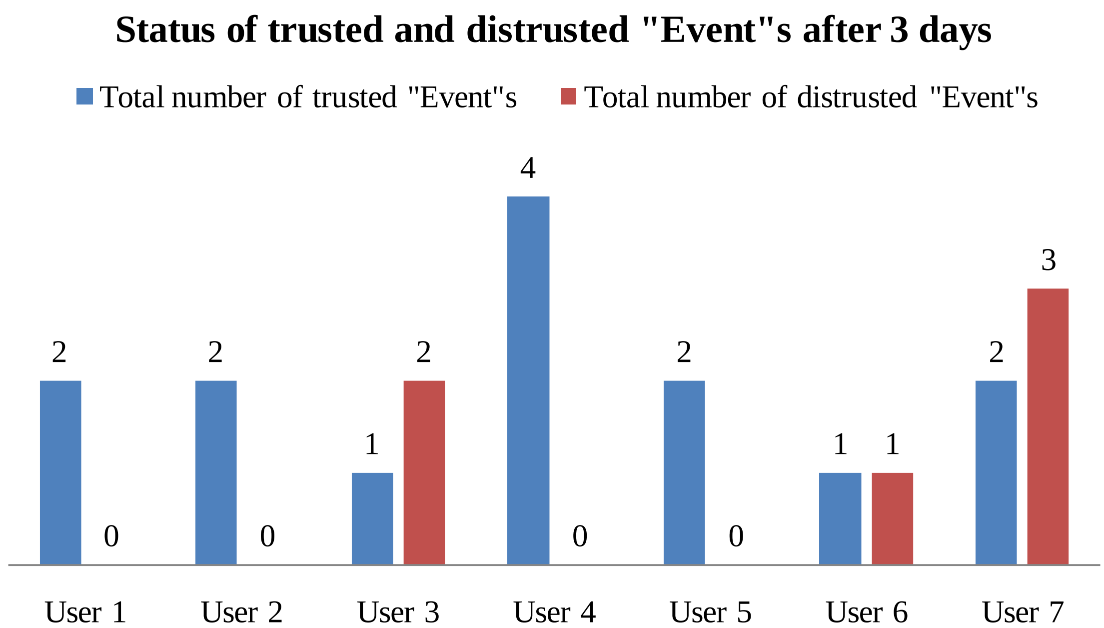


Figure 34: Line chart - status of trusted and distrusted "Event"s after 3 days

Although, according to DCS, the system can't classify the participants' sensing behaviors. The figures in Figure 34 could be applied into Beta distribution what we have discussed about it on state-of-the-art of trust model to predict the probability of trusted "Event" will be reported by a specific user in the future.

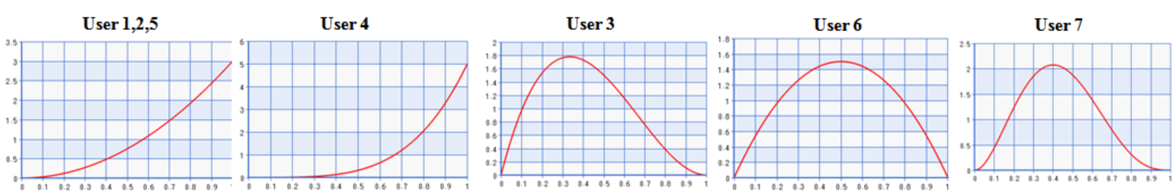


Figure 35: Beta distribution of 7 users based on trusted "Event" and distrusted "Event"

The user 1,2 and 5 have similar graph due to same parameters as outcome α and β, nonetheless, the confidence on those 3 users is lower due to small number of trusted and distrusted "Event"s reported, compared with user 4. The User 3,6 and 7 generated those curves that expressed the uncertain probability and the probability of expectation value for User 3,6 and 7 were 0.4, 0.5 and 0.43. In comparison of expectation value for User 3, 6 and 7, we can say that User 6 can be trusted more to report the trust "Event" based on his current performance and most likely frequent value is 0.5.

5.3.4 Summary of responses from the online survey

According to the responses for the online survey in Appendix C, the following points are covered to be confirmed for this application:

- User Group: general public (citizens) are selected in 100%
- Total number of "Event"s have been reported after 3 days per users is 0 to 3 according to the Question 4 in the survey. The reason is that this application without the implementation of an effective incentive algorithm so as to encourage participants to join this activity. This is also related to the Question 10 and 12 about necessary of adding particular incentive mechanism and association with social network in the future work. The results demonstrates that all participants desire this application to add encouragement algorithms such as monetary (i.e. vouchers for top 10 contribution users) or non-monetary incentive (i.e. competition based on ranking) in the future work. One useful comment from the participating who votes "No" for adding social network share function. The reason is that connection with social network might cause the disturbance for users with metadata to decrease the usability and quality of user experience.

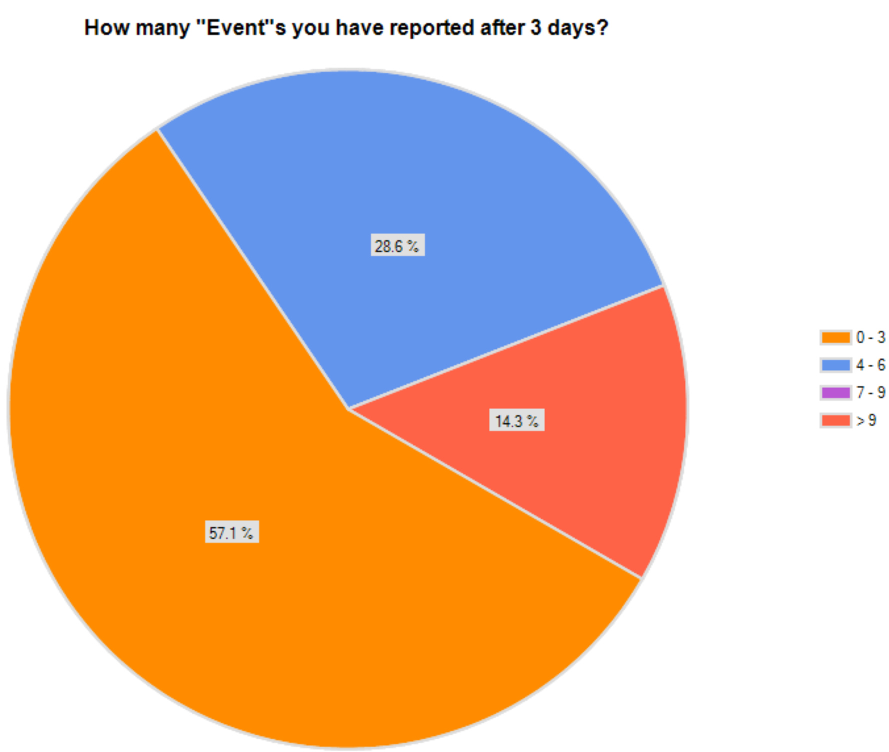


Figure 36: Pie chart - how many "Event"s you have reported after 3 days?

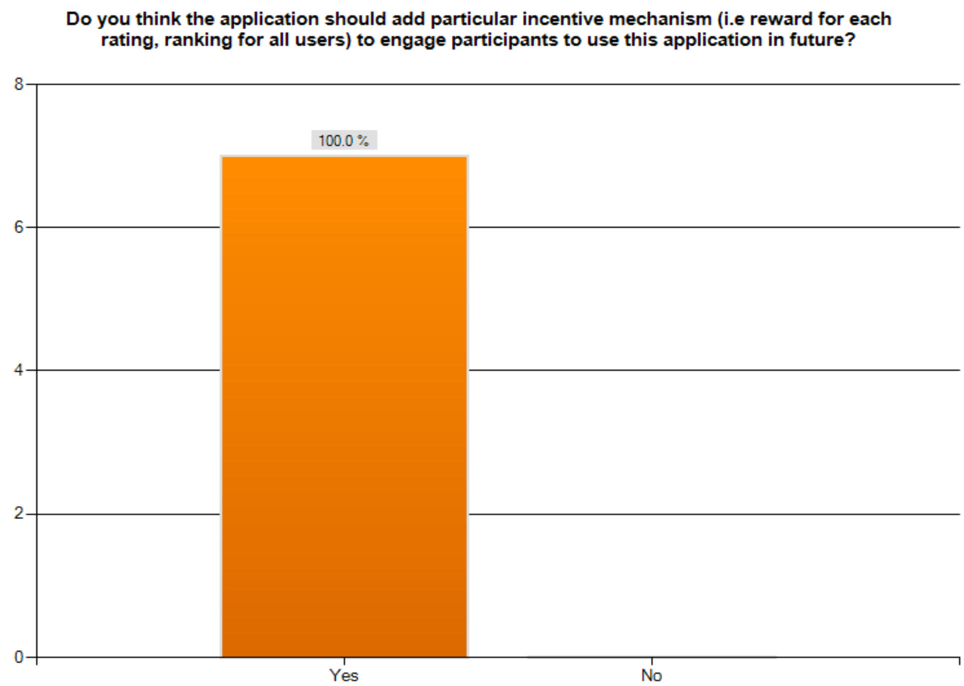


Figure 37: Line chart - question about necessary of implementation of incentive mechanism

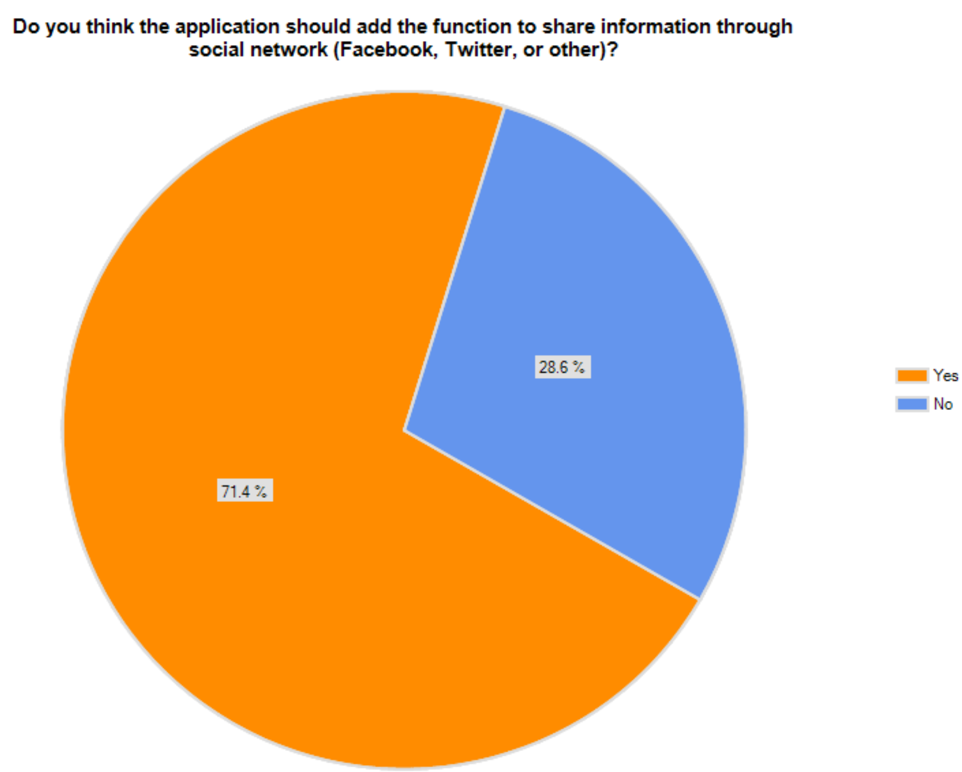


Figure 38: Pie chart - question about share information through social network

- The Figure 39 and 40 of when and how long the participants will use this application are also collected and analyzed related to Question 5 and 14. According to the analysis of the chart, commuting time was selected as the most option. The average of time users will spent on this application ranges from 0 to 1 hour daily. The results illustrate that the participants will spend less one hour on this application only at their commuting time or spare time.

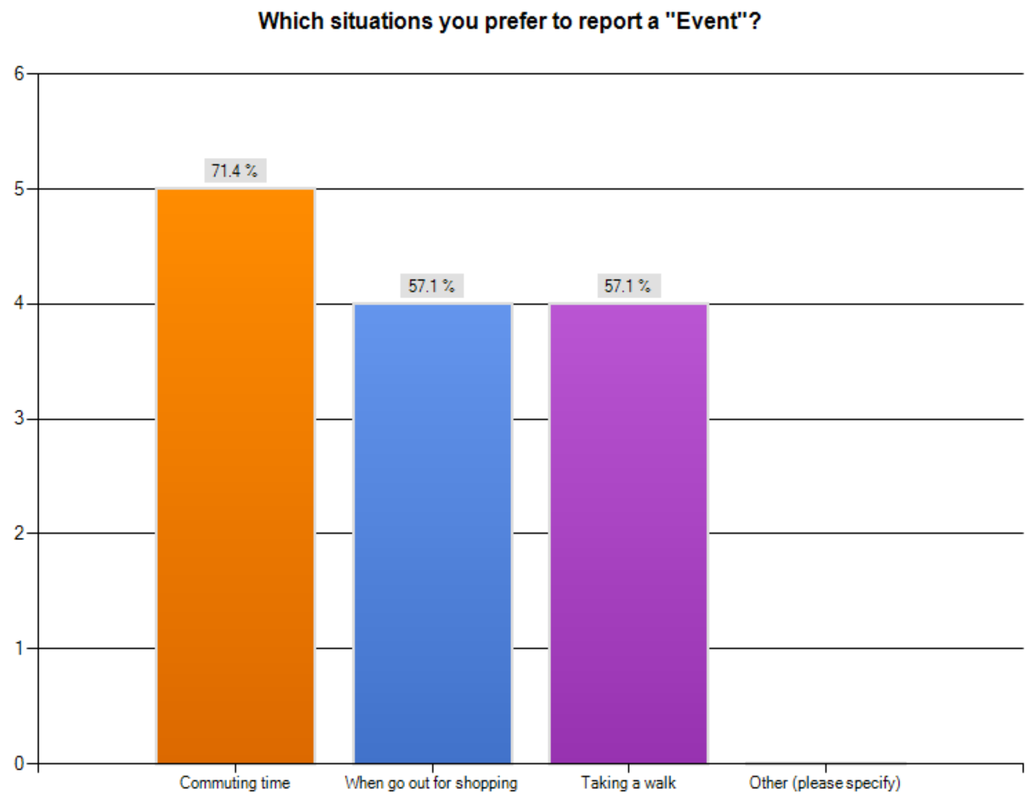


Figure 39: Line chart - which situation users prefer to report an "Event"?

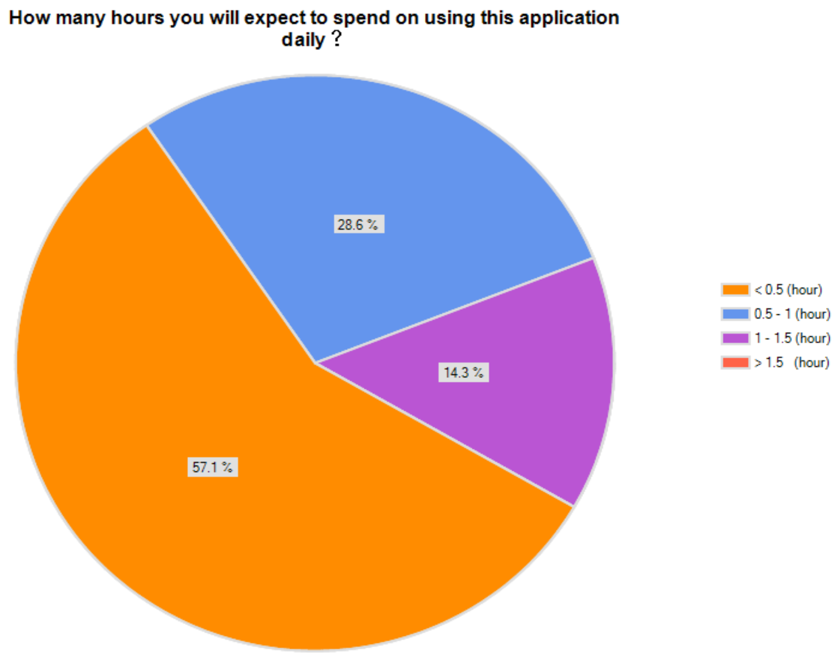


Figure 40: Pie chart - How many hours users will spend on using this application daily

- The percentage of acceptability and usability of implementation of CAPTCHA is high by all participants related to Question 7 in Figure 41. As a result, the original advanced text-based CAPTCHA is accomplished to achieve the usability and feasibility in the system.

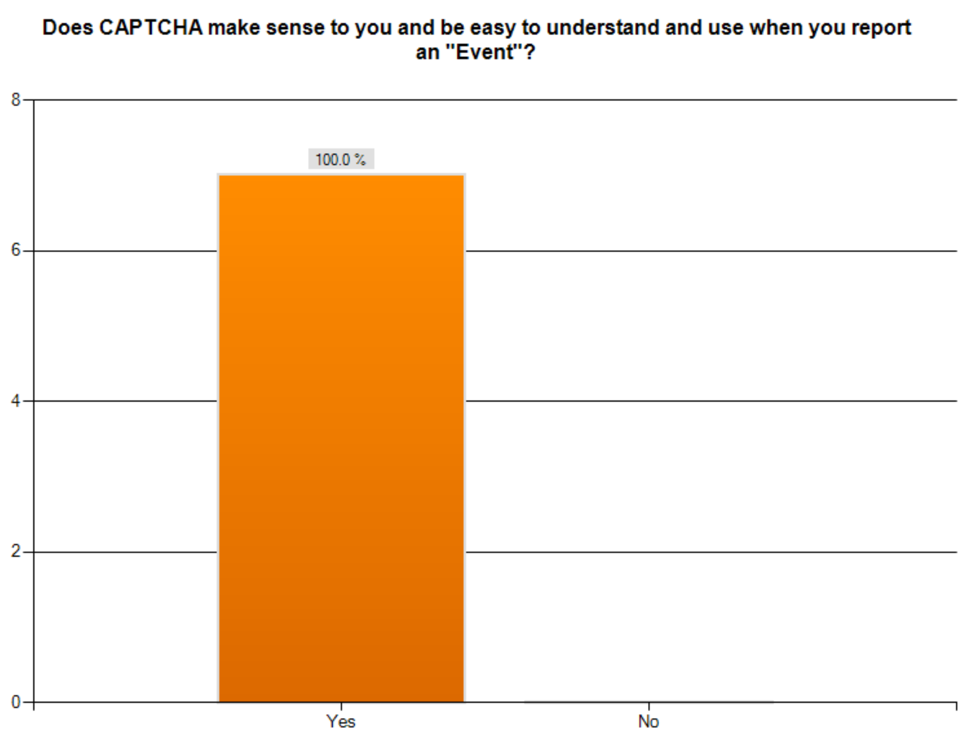


Figure 41: Line chart - usability of CAPTCHA

- The result, related to Question 8 in Figure 42, illustrates that the "Green Map" as visualization do help the participants efficiently to observe the green-related incidents and comprehend urban environment in order to enhance their awareness of environment.

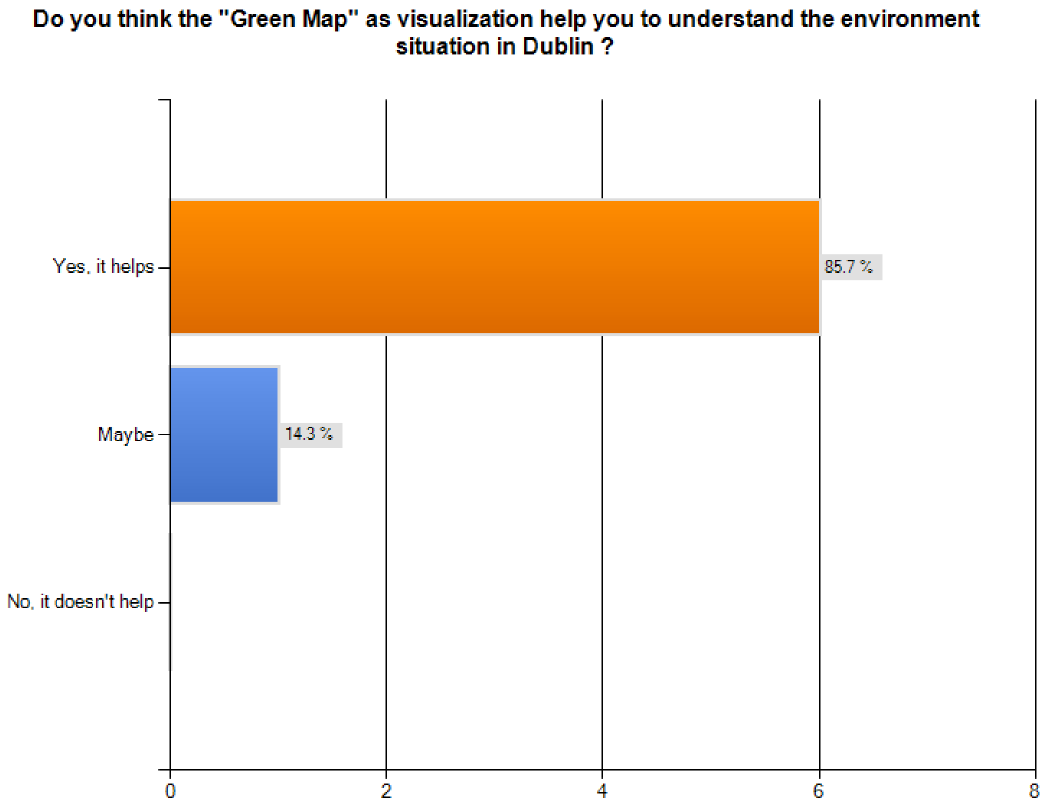


Figure 42: Line chart - map as visualization for users

- In Question 11, the participants selected the options about the factors that have an impact on rating an incident as "Distrust" which refers to the quality of information. The result indicates that the most factor is when the image attached can't match with particular type or content of the incident. The second most option is when an incident reported without an image or relevant description, the user will vote the incident as distrusted.

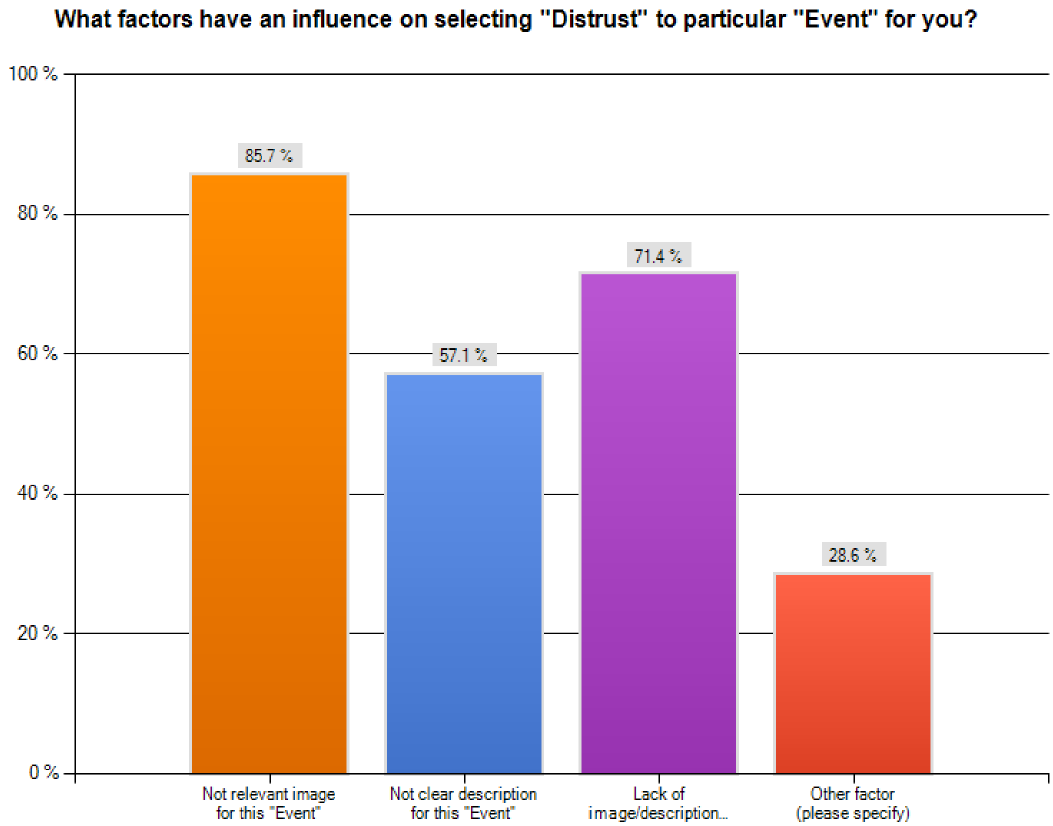


Figure 43: Line chart - factors of selecting "Distrust" option for users

- Related to privacy concerns on participator sensing, in this case, the Question 13 was to ask for participants whether they prefer to share the data at own risk for the further public research in the future work. The result illustrates that over half of participants admit and are willing to share the data.

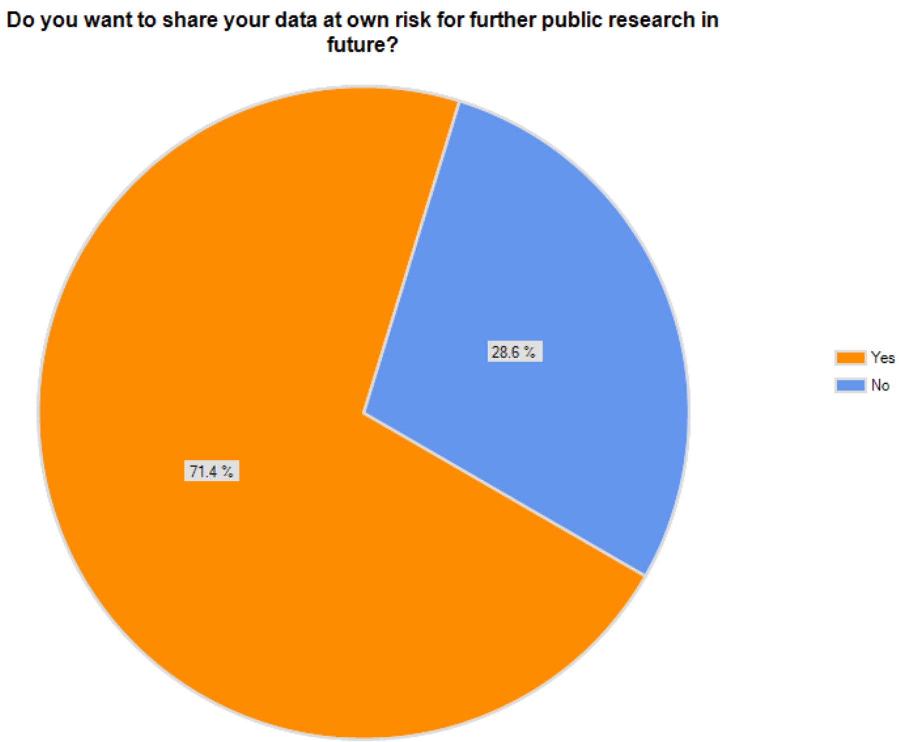


Figure 44: Pie chart - privacy decision

- Whether via using this app by citizens, the participants will be aware of environmental issues around Dublin area in order to help to enhance Dublin city in a sustainable and smart direction. The result demonstrates that all participants believe that this application did certain contribution on participatory sensing.

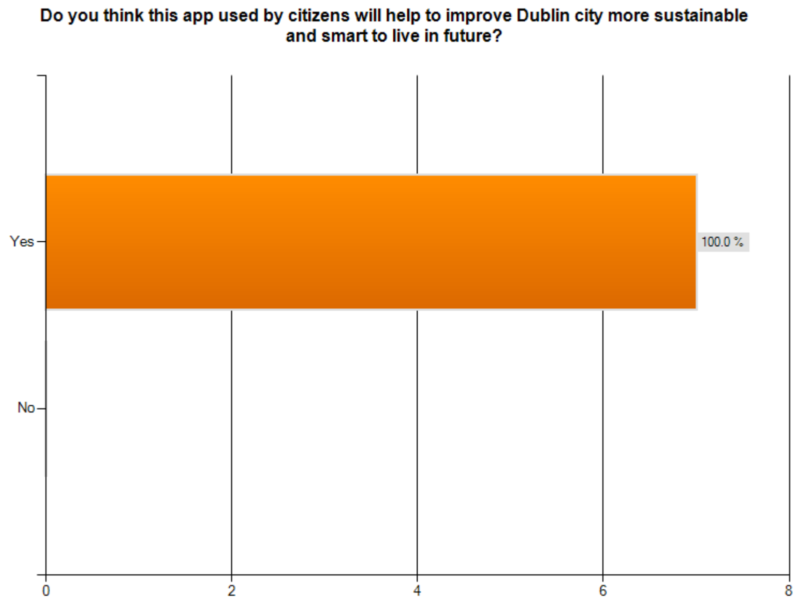


Figure 45: Line chart - usefulness of this application

- The last open-end question was based on usability and user experience through using this application during 3 days has been asked for providing major issues and opinions to summarize as following:
  - Combination of "Green Map" and "Join Rating" section to increase the application
  - Need a tutorial or clear explanation about contribution severity to all participants
  - The performance of "Green Map" is unstable under using cellular (3G)
  - In real world, sometime it's better to actually go into action (i.e. pick up the trashes in the street directly when you saw) rather than reporting an "Event" and waiting for rating. "Doer, not just a talker!"

Chapter 6: Conclusion and Future Work

6.1 Conclusion

The dissertation proposed an Android based sensing smartphone application, using participatory sensing framework to achieve data collection about reporting urban-scale green-related incident, that communicate with REST web service deployed on the Google App Engine via Google cloud technology. According to the criteria summarized from 11 existing academic projects, the success of one participatory sensing project require to comprehend several requirements related and then meet the criteria properly depending on those requirements. Nevertheless, the system does not achieve the expected evaluation score and see the table in Appendix B. The current evaluation score is 13 and accomplishment of this system lists as follows:

- Definition of user group:
  General citizens
- Data collection:
  Participatory sensing framework
- Sensors embedded on smartphone used:
  Text editor, camera, GPS, WiFi/Cellular
- Smartphone OS selected
  Android
- Security concerns
  Implementation of original CAPTCHA program and OAuth 2.0
- Engagement algorithms (incentive mechanisms)
  Google map as visualization and basic rating functionality
- Quality of service /Quality of information
  Implementation of trust model, distributed and scalable backend datastore and basic usability of application

The unique characteristics of "Dublin Green Watch" system are as follows:

- Real-time urban environmental information with image reported
- Real-time "Green" map as visulization on the application rather than website to the users
- Design and implementation of trust model based on user involvement to classify whether the data can be trusted and the daily contribution made by a specific user on a specific day can be used for recruitment well-suited participant for campaign
- Achievement of advanced, robust and adjustable text-based CAPTCHA and authentication based on security concerns to improve the quality of service

Correspondingly, to answer the research questions summarized from the state of art chapter.

- *How can we classify a green-related incident report shared with citizens as trusted or not trusted?*

  The results of evaluation illustrate that the implementation of trust model has ability to prove the feasibility and availability that enables classification of trustworthiness of data collected by a specific participant.
- *How can we classify that participatory sensing participants collecting urban environmental data is sharing correct information?*

  The DCS can be utilized as a metric to evaluate the contribution by a specific participant based their sensing behaviors to identify the relative correctness of information.

6.2 Future work

From user experience side, the performance of this mobile application need to be improved. The major reason is that the delay time increased when using cellular rather than WiFi to load mass data from backend. The possible solution will be implemented an efficient caching proxy server to store the information has been observed. The better usability of the mobile application is also as important as other functionalities because the time of spending on sensing mobile application is quite short period according to the results from the evaluation. On the other hand, to comprehend better and reduce the time of familiarity of using the application, a tutorial

For the participatory sensing project, the implementation of incentive and engagement mechanism is significant to attract the user interests. One of possible functionality in application enable the ability to share relevant data associated with social network like

Facebook and Twitter. And other suggestion is to supply a ranking system associated with reward algorithm. The ranking system might use momentary mechanism or non-momentary to reward the user who makes the better contribution which related to the trust model in this case. On the other hand, the privacy concerns need to be covered when linked to social network due to potential private and sensitive information leak. One of possible solution is that the personal sensitive information (i.e. location information) can be encoded by a customize hashmap on client side and the encoded string will be stored on server side to avoid the potential leak. Other critical question is raised on detection of potential user sensing behavior and it is complex to be addressed due to openness, uncertainty and randomness of participatory sensing.

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Appendix A: Participatory Sensing Applications/Systems Criteria 1

PARTICIPATORY SENSING APPLICATIONS/SYSTEMS CRITERIA

CRITERIA 1 [USER GROUP -WHO]	PEIR	PETROLWATCH	GREENGPS	NOISETUBE	WITHSENSE	NOISEMAP	ENVIOBSERVER	MOBGEOSEN	CENCEME	BIKETASTIC	BIKENET	DUBLIN GREEN WATCH (EXPECTED DEMO)
Group/Community	x		x				x			x	x	x
Individuals	x				x			x	x			
General public (citizens)				x		x						x
CRITERIA 2 [DATA COLLECTION - HOW]												
Passive (automatically) [opportunistic sensing]			x		x				x		x	
Active [participatory sensing]	x	x	x	x	x	x	x	x		x		x
CRITERIA 3 [Total Number types of Sensors used]	4	3	2	3	4	3	1	8	5	4	12	7
Mobile Sensors:												
microphone				x	x	x		x	x	x	x	x
camera		x			x			x	x	x	x	x
text editor				x	x	x	x					x
GPS	x	x		x	x	x		x	x	x		x
WiFi/Cellular	x											x
Bluetooth	x								x			x
accelerometer	x	x							x	x		x
compass												
proximity sensor												
light												
Non-mobile External Sensors (Number)	0	0	2	0	4	0	0	5	0	0	10	0
CRITERIA 4 [Number of Mobile Platforms]	2	1	0	3	1	2	2	1	1	1	1	1
Android				x		x	x			x		x
IOS				x		x						
Symbian (JME)	x	x		x	x		x	x	x		x	
WindowsPhone	x											
CRITERIA 5 [SECURITY CONSIDERATION LEVEL - (NONE-LOW-HIGH)]	HIGH	NONE	HIGH	HIGH	NONE	LOW	LOW	NONE	HIGH	NONE	NONE	LOW
Privacy/Security Concerns	x		x	x		x	x		x			x
Data Integrity	x		x	x					x			
CRITERIA 6 [ENGAGEMENT LEVEL - (NONE-LOW-HIGH)]	HIGH	NONE	LOW	LOW	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW	HIGH
Incentive algorithms/mechanisms:												
Monetary approach							x					
Non-monetary approaches:												
Reward mechanism												x
Ranking mechanism	x					x						x
Visualization (i.e. map)	x		x			x	x	x			x	x
Share (i.e. social networks)	x			x			x		x	x	x	x
Free access to database (Web API)				x		x						x
Usability / Friendly Use					x							x
CRITERIA 7 [QUALITY OF SERVICE/ QUALITY OF INFORMATION]				x								x
Total Score:	13	5	8	13	9	11	9	12	11	8	17	19
Average score (11 cases):	10.55											
Dublin Green Watch (EXPECTED DEMO) Score:	19											

Appendix B: Participatory Sensing Applications/Systems Criteria 2

PARTICIPATORY SENSING APPLICATIONS/SYSTEMS CRITERIA

CRITERIA 1 [USER GROUP -WHO]	PEIR	PETROLWATCH	GREENGPS	NOISETUBE	WITHSENSE	NOISEMAP	ENVIOBSERVER	MOBGEOSEN	CENCEME	BIKETASTIC	BIKENET	DUBLIN GREEN WATCH (COMPLETED DEMO)
Group/Community	x		x				x			x	x	
Individuals	x				x			x	x			
General public (citizens)				x		x						x
CRITERIA 2 [DATA COLLECTION - HOW]												
Passive (automatically) [opportunistic sensing]			x		x				x		x	
Active [participatory sensing]	x	x	x	x	x	x	x	x		x		x
CRITERIA 3 [Total Number types of Sensors used]	4	3	2	3	4	3	1	8	5	4	12	7
Mobile Sensors:												
microphone				x	x	x		x	x	x	x	
camera		x			x			x	x	x	x	x
text editor				x	x	x	x					x
GPS	x	x		x	x	x		x	x	x		x
WiFi/Cellular	x											x
Bluetooth	x								x			
accelerometer	x	x							x	x		x
compass												
proximity sensor												
light												
Non-mobile External Sensors (Number)	0	0	2	0	4	0	0	5	0	0	10	0
CRITERIA 4 [Number of Mobile Platforms]	2	1	0	3	1	2	2	1	1	1	1	1
Android				x		x	x			x		x
IOS				x		x						
Symbian (JME)	x	x		x	x		x	x	x		x	
WindowsPhone	x											
CRITERIA 5 [SECURITY CONSIDERATION LEVEL - (NONE-LOW-HIGH)]	HIGH	NONE	HIGH	HIGH	NONE	LOW	LOW	NONE	HIGH	NONE	NONE	LOW
Privacy/Security Concerns	x		x	x		x	x		x			x
Data Integrity	x		x	x					x			
CRITERIA 6 [ENGAGEMENT LEVEL - (NONE-LOW-HIGH)]	HIGH	NONE	LOW	LOW	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW	HIGH
Incentive algorithms/mechanisms:												
Monetary approach							x					
Non-monetary approaches:												
Reward mechanism												
Ranking mechanism	x					x						
Visualization (i.e. map)	x		x			x	x	x			x	x
Share (i.e. social networks)	x			x			x		x	x	x	
Free access to database (Web API)				x		x						x
Usability / Friendly Use					x							x
CRITERIA 7 [QUALITY OF SERVICE/ QUALITY OF INFORMATION]				x								x
Total Score:	13	5	8	13	9	11	9	12	11	8	17	13
Average score (11 cases):	10.55											
Dublin Green Watch (COMPLETED DEMO) Score:	13											

Appendix C: Survey Questions

Dublin Green Watch

***1. BACKGROUND OF RESEARCH:**

Due to several factors, such as the increasing population globally, especially urban population growth, sustained and rapid development of economy driven by industrial revolution, there is a existing trend of high demand for energy consumption. Unfortunately, although energy conservation became our priority and was aware by the public gradually in life, we still comprehend barely how to preserve energy efficiently. Nowadays, according to the scientists' report, our natural resources has starting to ruin and will run out if we fail to correct current consumption trends in future.

"Dublin Green Watch" is a mobile application based on participatory sensing which allow each participants to report several types of incidents called "Event" (i.e. wasting behavior, dog fouling, public light problem ...). Every participants will be encouraged to vote other "Event"s which will be evaluated by Trust Model to gain relevant trust score to demonstrate how much contribution for each participants.

The application is built on Android Operating System and associated with Flickr, Google App Engine and Google Cloud technologies. The application as client side is programmed based on Java using Android Development API. The Flickr provides a public storage of all images captured by each participators. The server side on Google App Engine provides a REST service using GSON and data storage to establish the communication between client and server using Google Cloud Endpoints, Google Cloud Message and Google App Engine Datastore.

PROCEDURES OF THIS STUDY:

1. Please download the document about guide of installation, APK file and the document about guide of application from the following URL : https://www.dropbox.com/sh/xk8mzicluf3tnjm/B-cAPCsCI3
2. Please install the APK file into your smartphone according to the document about guide of installation.
3. The application will not cause any harm to the smartphone which can be uninstalled freely after experiment.
4. Please use this application under the guide of application during 3 days (approx. 1.5 hour per day) .
5. Please fill in the online survey from the following URL: https://www.surveymonkey.com/s/879HQSR

Page 1

Dublin Green Watch

PUBLICATION:

All the research results will be used within the following venues, and will be presented without any personal identifier of participants. Individual results will be aggregated anonymously and research reported on aggregate results:

1. The researcher's thesis
2. Conference papers

DECLARATION:
• I am 18 years or older and am competent to provide consent.
• I have read, or had read to me, a document providing information about this research and this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction and understand the description of the research that is being provided to me.
• I agree that my data is used for scientific purposes and I have no objection that my data is published in scientific publications in a way that does not reveal my identity.
• I understand that if I make illicit activities known, these will be reported to appropriate authorities.
• I understand that if I or anyone in my family has a history of epilepsy then i am proceeding at my own risk
• I understand that, subject to the constraints above, no recordings will be replayed in any public forum or made available to any audience other than the current researchers/research team.
• I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights.
• I understand that I may refuse to answer any question and that I may withdraw at any time without penalty.
• I understand that my participation is fully anonymous and that no personal details about me will be recorded.
• I have received a copy of this agreement.

◯ Agree

◯ Disagree (end questionnaire. Thank you)

Page 2

Dublin Green Watch

2. What kind of user group you belong?

- ◯ Group/Community
- ◯ General public (Dublin citizen)

3. What's the age range for yourself?

- ◯ 18 - 24
- ◯ 24 - 30
- ◯ 30 +

4. How many "Event"s you have reported after 3 days?

- ◯ 0 - 3
- ◯ 4 - 6
- ◯ 7 - 9
- ◯ > 9

5. Which situations you prefer to report a "Event"?

- ☐ Commuting time
- ☐ When go out for shopping
- ☐ Taking a walk
- ☐ Other (please specify)

6. What most type of "Event" you have reported is most after 3 days?

- ◯ Waste Case
- ◯ Environment Pollution Incident
- ◯ Dog Fouling
- ◯ Plants Protection
- ◯ Road Problem
- ◯ Public Lighting
- ◯ Others (please specify)

7. Does CAPTCHA make sense to you and be easy to understand and use when you report an "Event"?

- ◯ Yes
- ◯ No

Page 3

8. Do you think the "Green Map" as visualization help you to understand the environment situation in Dublin ?

- ◯ Yes, it helps
- ◯ Maybe
- ◯ No, it doesn't help

If "No", Why? Please speficy

9. How many "Event"s you have rated after 3 days?

- ◯ 0 - 3
- ◯ 4 - 6
- ◯ 7 - 9
- ◯ > 9

10. Do you think the application should add particular incentive mechanism (i.e reward for each rating, ranking for all users) to engage participants to use this app in future?

- ◯ Yes
- ◯ No

If "No", Why? Please speficy

11. What factors have an influence on selecting "Distrust" to particular "Event" for you?

- ☐ Not relevant image for this "Event"
- ☐ Not clear description for this "Event"
- ☐ Lack of image/description for this "Event"
- ☐ Other factor (please specify)

12. Do you think the application should add the function to share information through social network (Facebook, Twitter, or other)?

- ◯ Yes
- ◯ No

If "No", Why? Please speficy

Dublin Green Watch

13. Do you want to share your data at own risk for further public research in future?

- ◯ Yes
- ◯ No

If "No", Why? Please speficy

14. How many hours you will expect to spend on using this application daily?

- ◯ < 0.5 (hour)
- ◯ 0.5 - 1 (hour)
- ◯ 1 - 1.5 (hour)
- ◯ > 1.5 (hour)

15. Do you think this app need to implement notification function to display the reminder message when a new "Event" report in the furture?

- ◯ Yes
- ◯ No

If "No", Why? Please speficy

16. Do you think this app used by citizens will help to improve Dublin city more sustainable and smart to live in future?

- ◯ Yes
- ◯ No

17. Any comments about user experience (ie. easy to use, hard to understand, performance improvement ...) for this application.
(Please do not name third parties in any open text filed of the questionnaire. Any such replies will be anonymised.)

Appendix D: Abbreviations

Short Term	Expanded Term
URL	Uniform resource locator
API	Application programming interface
SDK	Software development kit
HTTPS	Hypertext transfer protocol secure
WSDL	Web Service Description Language
HTTP	Hypertext transfer protocol
DCS	Daily contribution score
ETS	Event trust score
TNT	Total number of trust
TND	Total number of distrust
TNS	Total number of skip
NTE	Total number of trusted events
NDE	Total number of distrusted events
NVE	Total number of valueless events
XML	Extensible markup language
JSON	JavaScript object notation
REST	Representational state transfer
SOAP	Simple object access protocol
CAPTCHA	Completely automated public Turing test to tell computers and humans apart
MV	Minimum value
QoS	Quality of service
OS	Operating system
SQL	Structured query language