

Mobile Crowd Sensing: A Comprehensive Review of Challenges and Solutions

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Abstract:

Now a days, Mobile Crowd Sensing (MCS) is a most lucrative model for sensing data as smart devices has become a crucial component of IoT. Now a days, smart devices are equipped with many sensing gadgets like accelerometer, digital compass, gyroscope, GPS, microphone and camera. These embedded sensors can take photo, recording sound, sensing environmental parameters such as temperature, humidity, pollution and noise. In this paper, we have done an exclusive survey on MCS by considering its diverse parameters. Here, we have not only studied overall impact of MCS in urban civilization but considered specific application domain of MCS. We have done the survey by concentrating on 2 primary issues of MCS such as object tracking and participant/user selection strategies used in MCS. As this survey is parameterized according to application domain of MCS, thus it will be very beneficial for a diverse group of researchers. We have provided our detailed findings in tabular format.

Keywords: MCS, object tracking, user selection, privacy, incentive, proficient Prediction based User Recruitment (PURE), Pay As You Go (PAYG), piggyback MCS (PMCS).

INTRODUCTION

Now-a-days, Inter of Things(IoT) has become the core technology behind the deployment of smart city, IoT based health care, IoT based agriculture, home automation and traffic control etc. Data sensing from the environment and data analysis are two fundamental tasks of any IoT application. The repeat growth of IoT has

become possible because of extensive development of cheap computer chips and network infrastructure. From last few decades, to sense the data from the environment uses Wireless Sensor Network (WSN) as a primary protocol. The implementation of domain specific sensor as well as the installation of dedicated sensors to include the entire area of interest is not a feasible solution. Recently, smart devices (mobile phones, smart watches, wearables and vehicular electronics) has many sensors like accelerometer, digital compass, gyroscope, GPS, microphone and camera. These embedded sensors, can take photo, recording sound, sensing environmental factors like temperature, humidity, pollution and noise. A new paradigm has emerged known as Mobile Crowd Sensing (MCS) by considering the adequate amount of computing power and communication capabilities of the mobile devices. Instead of using, application specific sensors a many mobile participants are selected to perform the crowdsensing. The samples of the phenomena of interest are spread throughout the entire area under observation. It was found that the data quality reduces when the samples are concentrated in a cluster of area but quality of data is upgrade if the data collectors are distributed throughout the area. The characteristic of MCS is Budget Constraint where an optimal number of user involvement is required for appropriate implementation of MCS. To encourage the users to contribute in sensing task MCS platform must provide incentives to the users. However, platform must expect a high quality of sensed data. In this budget constraint situation, a trade-off must be maintained to maximize the quality of data with optimal reward.

- **Data Quality:** The standard of data depends on the amount of high-quality data sample collected from the entire area of coverage. The quality of data depends on selection of enough number user and also the past reputation of the user [1]
- **Area of Coverage:** The data samples must be collected from entire city under consideration. There are some issues while collecting the data from different place. In some places there exists adequate number of participants (low sample price) or in other places lack of users (high sample price)
- **Participation of users:** A constant participation of optimal number of users are needed to ensure data quality along with coverage area. A mobile user consumes its own resource such as battery, processing power and time to sense data for MCS application. To compensate the users cost system must provide incentive in terms of reward.

The MCS applications are used in every sphere of life. Apart from academics, it is used in industries to provide online services such as Facebook, Twitter, OLA etc. By understanding the potential in mobile devices to do a complex task collectively researchers have developed many application such as Ear-Phone [2] and NoiseTude [3] to develop urban noise map, P-Sense [2] to observe air pollution, Nericell to sense road traffic conditions, and Zee [2] to construct internal fingerprint database, City-Explorer [4], and Sensory

[5] for creating cellular/Wi-Fi network coverage map, VTrack

[6] for collecting traffic data and PIER [7] for estimating personalized environmental impact. Based on the participating nature of users in MCS, it is divided into two categories such as participatory sensing and opportunistic sensing. In the Participatory sensing users are dynamically take part in the sensing task through taking photos reporting weather condition. In this type of sensing users demands sufficient amount of incentive as they expend their own resource to participate in the joining task. However, in opportunistic sensing users passively participate in the sensing task. To find poisonous flower in the society, the user participates willingly without caring about the reward. Moreover, to implement in real world, we need to face many challenges. We will discuss some of this implementation related issues here.

- Performance of MCS depends on user participation in the sensing task. If the user uploaded huge amount of good quality data then the QoS of system increases. So, selection of proper sub set of participants is a very important issue in MCS.
- When a user loads the sensed collected data to the central server along with the data user reveals its own identity with location information. Many privacies preserving

[8] approaches have been developed to anonymized the sensed data. We have to maintain a trade-off between the security and the trust worthiness of the data.

- To sense and reporting them mobile users spent its own battery, processing power and data plan. Thus, to attract the users for participating in sensing task MCS platform have to provide them reward. So, developing a appropriate incentive mechanism for the system is a crucial issue.
- For reporting large amount of data, it incurs a huge load on communication infrastructure.
- The central server is overwhelmed to store, process and analysis the sensed data. The fundamental components of Mobile Crowd Sensing are Task Requester: Task requester publishes the MCS task to the platform. MCS Platform: It accepts the task request and recruit users (data contributor) depending upon the requirement of published task by considering budget and quality of data. The data Contributor/user: Data contributor consists of various type of sensors such as acetometers, gyroscope, microscope and in-vehicle sensors. This units sense the raw data from the Point of Interest (PoI), create report based on the sensed data and delivered them to the platform.

Through the literature study we have found the proper defini- tion MCS [9] with its current position in research and open research challenges. There is a very good survey [10] on MCS that defines the layered architecture of Mobile Crowd Sensing. But we didn't find any work that addresses both factors together like user selection and object tracking strategies. In this paper we have done an exclusive study on all the aforesaid factors. In the section II we will discuss related literature survey in this area of interest. To increase the performance of MCS different modified version of MCS is discussed in section

I. In section III and section IV. We have done review object tracking in MCS and user selection strategies respectively. Finally in section VI we have summarised our finding in a tabular format. At last we have concluded the paper in section VII.

RELATED WORK

The fundamental framework along with its characteristics has been presented by [9]. In this paper the application of MCS has been divided in category (a)Environmental (b) Infrastruc- ture (c) Social. Along with the application, the characteristics and resource limitation and privacy issues are studied very neatly. A survey paper has been presented by [11] on MCS that includes the research challenges, solutions and future opportunities.

There must be adequate number of users to sense data for the accuracy of the service and on the other hand to recruit too much participant will increase the overall cost of the MCS application. To solve the problem a modified version of MCS termed as Sparse MCS has been represented by [12]. In this technique instead of collecting data samples from entire area of interest, data samples are collected from some particular sub areas then using various data inference algorithm the un- sensed data of remaining sub areas are calculated.

To collect data from the surroundings and send the report to the central server consume the resource of the user. But without user participation the real time implementation of the MCS is not possible. To motivate the user towards data sensing data requester must provide user proper incentive [5] [13] [14] as reward. A review on incentive mechanism is done where the incentive is represented as entertainment, service and money. In entertainment as incentive BARKHUS [15] design a game known as Treasure where each participant must have a Wi- Fi and GPS enabled smart phone. The players of the game need to collect virtual points which are spread throughout the gaming area and send them to the server for earning game point. In Service as an incentive [16] proposed TruCentive a technique for parking information where the data contributor and data consumer both are drivers of the car. In money

as incentive Rivest and Shamir initially have measured web content utilization through users by giving them a good amount of reward based on page visit to a site.

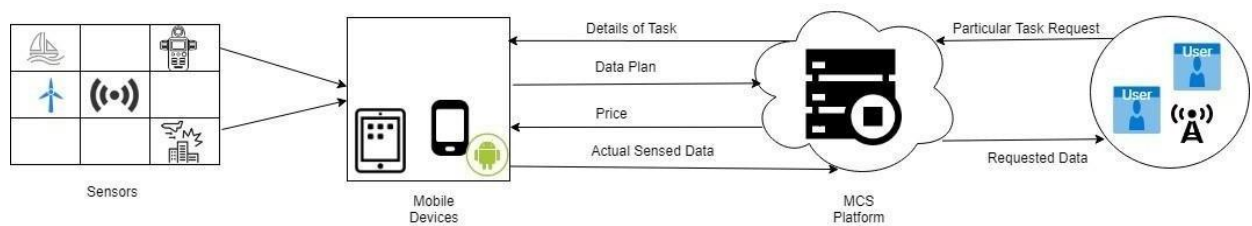


Fig. 1: . The Basic Structure of MCS

MOBILE CROWDSENSING

With the enormous growth in computing hardware like smart phone, tablets and wearable that has many sensors such as camera makes them prominent participants for MCS. It has become lucrative technology in industry as well as academic. The online service provided by many companies such as Facebook, amazon and OLA utilizes MCS as a core technology for sensing data in cost effective manner.

Authors [17] have proposed a crowdsensing methodology using a combination of deep learning with edge computing. The edge computing utilizes the resource of data contributor to reduce the load on the cloud infrastructure. Multiple layers of nodes have been introduced in this computing paradigm. The edge nodes in the lowest layer such as mobile phone and tablets do some computing and send the extracted values to the next upper layer above it.

The intermediate layers consist of cellular base station, gate- way and routers manipulate the data again and forward it to the central server. The central server does the higher layer processing and analysis.

OBJECT TRACKING IN MCS

In [18], authors want to formulate and solve the object tracking problem under MCS. In this process the user captures the photo of the person as it meets the target person. Then upload the data along with time and place of the activity. The platform verifies the person identified is a right person. A history list is prepared based on the data due to the delay of the user for uploading the data, a location prediction method is proposed to track the next location of the target.

For location prediction, they have use different parameters such as, friendship information, place attribute (school, office and cinema). A person perhaps similar mobility pattern like his friend and visit same places as his friend do.

Alike from stationary cameras in [19] paper authors have proposed Crowd Tracking an MCS based system to monitor moving vehicle on the roads by instantaneously taking photo of the vehicle using the mobile cameras of the people with smart phones. To gather data for tracking the vehicle, there exist many issues. First issue is "How to track the vehicle". The data collection through GPS is not sufficient, we need more precise localized mechanism to get more accurate data. Secondly, how to do the task with minimum number of participants.

To monitor the vehicle and approximate its moving pattern authors proposed a photographic based approach. To make the process energy efficient they have used orientation sensor and GPS sensors for tracking the vehicle. An algorithm has proposed to select a proper subset of user whose trajectory lies with the vehicle.

USER SELECTION

With the growth of digital world, Mobile Crowd Sensing has become very promising method for many urban applications such as environment monitoring etc. The achievement of MCS is solely depended on the sensing capability of the mobile users. That's why user (mobile device) selection is the primary task of Mobile

Authors in the paper concentrated on the data uploading expense of the user rather than the recruitment cost because the latter one is less than the former and paid once at the time of recruitment. They have proposed PURE for mobile crowdsensing to reduce data uploading expense by engaging users with higher contact possibility to destination. According to PURE users are classified into two categories

- **PAYG:** The data upload rate of the user is depended on the amount of data transferred.
- **Pay Monthly (PAYM):** In this case the data transfer rate of the user doesn't depended on the amount of data transferred. A user is able to upload enormous amount of data during a month.

Authors of [20] have discussed about two problems.

1) To achieve minimal data uploading cost the recruiter has to decide which user has been selected for sensing task from each of the PoI (Point of Interest). To solve this problem authors has designed a user selection approach using semi Markov model. Using this scheme authors are able to predict which PAYG users have the highest contact probability with PAYM users so that recruit them for each PoI. To find a trade-off between data delivery rate and user recruitment authors have proposed PURE-DF according to delegation forwarding.

In any crowd sensing application participant (user) selection is a primary matter to be consider. Authors design an adoptive participant selection scheme for non-homogeneous sensing tasks for a large-scale PMCS system. In PMCS system the data sensed by the user are returned back to the MCS system. Authors defined some terminology here [21].

- **Mobile Participants:** A large number of users who are willing to do sensing tasks allotted to them.
- **Crowd Sensing Applications:** Many applications are nonstop creating crowd sensing tasks and searching for sensing data from allotted users.
- **Participant Recruitment Component:** This module dynamically selects specific participants for each sensing task.
- **Prediction Probability $p(u_i, l_j, t)$:** It is the probability of user u_i to make a phone call (or sensing data) at location l_j at time instance t .
- **Coverage ratio $C(i,j,t)$:** Coverage ratio of the task S_j by the user u_i who is selected at time t .

There are three fundamental entities in Mobile Crowd Sensing

- 1) **Data Provider:** The smart devices (user) that sense the raw data from environment.
- 2) **Service Provider:** Accumulate the sensed data from the user and process it to serve particular application.
- 3) **Data Consumer:** The entity that consume the service through mobile application.

The main difficulty of SP is to choose efficient Data Provider which can effectively sense the data along with transferring the data to the server. As per literature most of the sensing devices transfer data through mobile network. There are some difficulties to use mobile network as a data transfer medium. The overall cost of crowdsensing increases because the charges due to the battery and data plan consumption is included in the user recruitment fees. The cellular network become over loaded depending upon the type of the sense data such as quality of photo. The Opportunistic networking is the alternative to reduce the impact of the issues related to transferring the sensor data. In [22] authors proposed user selection method using opportunistic networking. Depending upon the mobility pattern of an user they may take the role of either sensor or relay. An user can sense data from the target area but may not have the capacity to transfer them to the service provider. Then this user transfers the data to the relays (user), they transfer the data to the service provider. The step by step contribution of the authors.

1) They have constructed the problem by considering both deterministic and stochastic user motion as an instance of the minimum cost set cover problem with sub-modular objective functions.

2) They have discussed a method for calculating the probability with that various space-time paths are designed across the opportunistic network out of data about the nodes' mobility patterns in the past.

3) Since the problem is NP-hard, they propose practical greedy heuristics and derive the approximation ratios they achieve.

Now a day's smart mobile phones are furnished with different types of sensors which are able to perform complex sensing task in collaboration. Thus, MCS is a correct alternate of traditional sensor network. With the immense advantage of crowd sensing over traditional sensor network there are some challenges to consider such as the expenditure and valuation of data and anonymity of personal information. In participatory sensing users are dynamically engaged in the sensing process by taking a picture, manually activating a sensor, manually accepting or rejecting a request for samples. To ensure data quality, cost effectiveness and privacy issues require a huge repository of sensed data. So, it is a big deal to select a huge number of members to gather data for ensuring QoS of the system. The problem of high quality with low payment is modelled as a multi-objective Knapsack problem [23] with a weight constraint and two objectives.

1) Authors combine scheme of EGDE3 [24] and UDMA

[25] to solve the modelled Knapsack problem based on the criteria like non-domination and crowding distance.

2) Authors enrich selection step of EGDE3 to choose the best individual as root for solution of the succeeding generation.

3) To generate a new population authors [26] have used UDMA, for reducing take-over time. At the end, their paper introduces two strategies built on the non-domination and crowding distance to increase the number of the solutions in every generation.

At the initial stage of MCS, the task publisher distributes its sensing task that contains the type and coordinates of the event of interest, the minimum QoS requirement for the task, the maximum amount of reward and time frame to complete the request into a location consisting of a group of participants. To select a group of participants that satisfy all of the above parameter is a vital task. The collaboration of the mobility and uncertain nature of participants with the location aware and time constrain manners of sensing task make user selection a really complex job.

From the Data consumer's side, to ensure reliability and quality of data the factors under considerations are factors like the concentration of population in a specific AoI, number of participating users with required sensors, or the expense of uploading collected data by the sensors, the previous behaviour and reputation of participants.

On the other hand, from the point of data contributor to ensure data types and standard of the sensory data, time and budget restrictions, the user can upload the data periodically or in a continuous manner.

Authors have proposed in [26] a mathematical model to represent the user selection process of MCS by considering many parameters that improves the quality and reliability of the system. The proposed system has three entities data consumer, data contributor and the platform as agent between data consumers and data collectors. To supply proper information to the data consumer the agent stores status information such as updated location and sensors' availability from data collectors at a regular interval. The data consumers send their requests to the agents, then the agent uses the request requisite and the existing data collectors' status information to get the suitable set of collectors/participants who can provide the response of the request. The sensing request send by data consumer to the agent must have the type and position of the event of interest. Every MCS system is consists mobile users i.e, the smart phones, data consumers and a platform through which the entities interact with each other. The platform is the in charge for allocating task to the mobile devices, determination of incentive and user recruitment. An event recognition in a large urban zone is an vital application of MCS. To accomplish a high recognition accuracy with mobile users and resource constrained situation needs a huge amount sensory data. The collection of adequate amounts of data requires recruitment of large number of participants. There are several issues we discuss here that has direct impact on high event detection accuracy.

Firstly, for higher accuracy we need more data which in turn requires more user’s participation. The large number of participant recruitment increases the overall sensing cost of the sensing task. Secondly, before selection of an unreliable user, the quality of data collected is unknown to the platform. Finally, it is very complex to decide the contribution of the sensed data to the overall data precision that depends on the quality collected data as well as the data sensed by the other users.

To address these issues, authors propose an enhanced adaptive greedy user employment algorithm for a budgeted mobile crowdsensing scheme for fine-grained urban event recognition.

- 1) A probabilistic system to model the untrustworthiness of users.
- 2) Using Bayesian rule, for a given set of sensed data, a probability distribution of event occurrence in a specific area is estimated.
- 3) They have used Shannon entropy to evaluate existing uncertainty in the estimation.

User recruitment in a vital research problem in the area of Mobile Crowd sensing. More over while recruiting the users we have to consider which user will contribute more in sensing task among a group of users. While a user is recruited along with its performance in delivering data, we have to consider the cost for recruiting this user so that the overall expense of the system is maximized. When a data requester submits

TABLE I: Object Tracking Methodology in MCS.

Goal Achieved	Ref.	Approach
Object Tracking Methodology	Ref 15	Object is tracked using mobile phones, when the mobile phone meets the target takes the photo and send it to the plat- form.
	Ref 2	The vehicles on the roads are tracked through mobile devices. Besides locat- ing vehicles, they also considered the election of mobile devices.

TABLE II: User Selection Strategy in MCS.

Goal Achieved	Ref.	Approach
	Ref 1	The mobility of the user makes MCS more challenging than traditional crowd- sensing. Here, a group of selected par- ticipants collaboratively do the task.
	Ref 7	An alternative to reduce the overhead of data transfer from the cellular network, is opportunistic network. The role of the users(sensor/relay) are being differ- entiated depending upon their mobility pattern.
	Ref 12	A new dynamic user recruitment has been proposed for heterogeneous task. Various

User Selection Strategy		online and offline greedy algorithms are used for user selection
	Ref 20	There exists a trade-off between data quality and reward given to the participants. To achieve it, the problem is modelled as Multi Objective Knapsack problem.
	Ref 26	To minimize the overall sensing cost, it is very necessary to minimize the data uploading cost of the mobile user. In PURE, the contact users are selected for data sensing.
	Ref 27	Before recruiting a user the task requester compared his profit with the recruitment cost of the user.
	Ref 31	Event detection in affine grained urban area with mobile user is a very challenging job. An estimation of event occurrence has been done based on the probability distribution of the given data set.

its sensing task in a particular Point of Interest, the platform must choose a group of users from all the participants moving through that PoI to accomplish the task optimally. To increase the profit of the data requester authors proposed a suitable strategy for recruitment of the user.

The authors proposed [27] a User-Recruitment strategy for self-Organized mobile Crowdsensing (UROC), by considering recruitment cost and delivery accuracy to increase the requester’s profit. This strategy takes a decision whether to employee user or not by estimating the recruitment cost of that particular user. This estimation of cost is done based on their contact probability.

SUMMARY OF THE SURVEY

In this article, we have conducted an exclusive study on Mobile Crowd Sensing taking into account the object tracking methodology and user selection strategies. Today, mobile devices are equipped with good sensors that are capable enough to collect data to perform a task. Therefore, rather than using traditional wireless networks with preinstalled sensors, all of the above mentioned techniques use mobile devices to collect data to accomplish a task. In this section, we summarize all the literature that we have studied in this paper in a tabular form. We have created two tables for both of these topics. Table 1 contains key contributions of the papers related to object tracking methodology. In table 2 user selection strategies related research papers are summarized.

CONCLUSION

In this work a detailed overview of mobile crowd sensing (MCS) was provided, with an emphasis on object tracking and user/participant selection techniques. The increasing ubiquity and capabilities of smart devices are key factors supporting MCS’s development as a competitive alternative to conventional Wireless Sensor

Networks (WSNs). We investigated how mobile users contribute to sensing activities, incentive models that encourage participation, and privacy issues that need to be resolved through a thorough literature review. This work offers a systematic knowledge of the fundamental elements that support efficient and scalable MCS systems by categorizing and contrasting different methods for object tracking and participant recruitment.

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