Tracking Smartphone Users using Activity Recognition and Location based Services

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ABSTRACT
The numbers of smartphone users is expected to be 2 billion around the globe by 2016 according to new figure e-Marketer, there is a great need of efficient location tracking system. At the same time the privacy of the users is a prime concern for security. The traditional global positioning system is not able to efficiently track the indoor location of users. This paper is comprehensive survey of various localization techniques and proposes a combined approach of GPS, cellular tower triangulation, Activity recognition, Wi-Fi and Harversine Formula to track the user's location.

Keywords
Activity Recognition, Cellular tower triangulation, mobile sensors

1. INTRODUCTION
With the continuous development of mobile technology in recent years and the worldwide adaptation of smartphones, mobile technology and mobile computing technique has tremendously increased. Humans have become dependent on their smartphones for their daily needs such as e-banking, shopping etc. results in the importance of user's location for industries to expand their business.

The recent propagation of GPS enabled mobile phones has allowed the people to share their locations with other users. However access of actual location concerns security and privacy issues for users. Sometimes the third party applications access the location information of users from service provider which is prone to easy spoofing. Wightman et al. introduces the Private Information Retrieval algorithm that allows the creation of a map, understood by both users and service provider, which offers only required information to service request in order to hide the actual location of the user or its area of interest and also save the location information of the user in the query logs [12].Hasan et al. proposed a same approach and ready to deploy application for generating and verifying users location witness oriented asserted location provenance for mobile devices [1].Self reporting location presence using GPS co-ordinates, cellular tower triangulation etc. are all susceptible to manipulation and false location information [3].The untrustworthy reporting of location information have implications ranging from game cheating [4] and national security [5]. LBS give the information of user on the basis of geographical position of their smartphones or mobile devices only. It gives the related or specific area where the mobile phone is present but it fails to give the indoor locations.Pornpenet al. proposed the indoor mobile phone users location by combining Wi-Fi GPS and cellular tower triangulation [6] but fails to provide actual indoor location.

Many smartphones are equipped with various sensors like accelerometer; gyroscope, barometer etc. are used to activity recognition takes input from these sensors and tracks the user's motion activities like walking, jogging etc. [2]. Finding the indoor location of smartphone users can be achieved by monitoring the users motion activity, Activity recognition takes the raw input data from sensors and give the information about user's motion activity but activity model build from one subject's data has lower accuracy in recognizing another's subject's activity and sensor's orientation and position on the body, if different from how the model is build will decrease the accuracy [7] [8]. Table 1 in [2] summarizes the set of sensors that are provided smartphone. Please refer to android document for detailed knowledge of all the supported sensors and their definition on Android Smartphone [9]. Song et al proposed a floor localization system to find 9-1-1 caller in the building by inferring current floor level using activity recognition [10].

Cellular tower triangulation is another approach for finding the mobile in a relative area. In this it finds the user's mobile location by finding that user is present in which cellular tower region. But it has some drawbacks alone it does not gives the accurate position. It requires 2-3 towers for give the accurate position.

2. RELATED WORK
There have been many surveys on activity recognition and GPS in smartphones. Earlier work done by scientists provides a rough approach on various techniques to find human activity recognition. These surveys include all wearable sensors platforms for activity recognition in contrast this survey focuses on specific wearable sensor platform (smartphone).

However most research works on activity recognition, GPS, cellular tower triangulation, vector calculation are done on individual domain. Research work done by Pornpen et al. focuses on combination of GPS Wi-Fi and cellular tower triangulation to locate smartphone users. In distinction this survey is based on combining activity recognition, GPS, cellular tower triangulation, vector calculation to efficiently track user's indoor location.

3. MOBILE PHONE SENSING TECHNOLOGIES
This section is the reviewed of various technologies used in tracking smartphone user's location like GPS, Cell location, activity recognition, vector calculation etc.

3.1 Global Positioning System (GPS)
GPS work by triangulating the signals from satellite revolving around the earth. GPS give us the information about the user's location [6]. But the GPS is limited to the areas where the

satellite signals are unreachable like inside building, underground bases, and tunnel. Moreover power consumption of GPS is much higher than other sensors.

In addition Chon el at stated that in comparison with other sensors, GPS the power usage of is higher than others sensors [11]. GPS location cannot be obtain if the there is no line of transmission between GPS device and Satellite. GPS require communication with external location providers to get the users location but even if the users don't want to give his/her location, their location related information is provided to location providers.

The experiments were conducted to measure the power consumption of mobile phone on continuous sensing. The results were taken using Micromaxx A106 the different readings were shows in Fig 1 (Loc: location of users using GPS, Acc : Accelerometer Sensors power Consumption, MIC :Sound Sensors power consumption, Wi-Fi :Power consumption by Wi-Fi sensing, Acc+MIC+WiFi : Sensing through Accelerometer, Sound Sensors And Wi-Fi.),the figure shows that the power consumption of tracking users through the GPS is the most followed by accelerometer, Sound sensor and Wi-Fi. Considering the power consumption by the GPS it is not recommended to use during the low battery level of mobile phone.

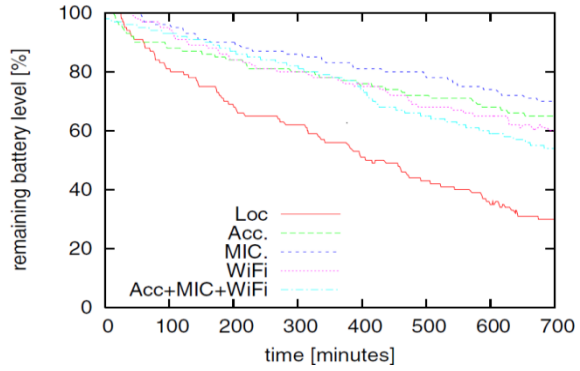

Fig 1: Mobile Phone power consumption during continuous sensing.

Most of the smartphone uses Google maps as the API to navigate to the user's location using latitude and longitude coordinates. But this information is not sufficient to track the user as GPS can only give an approximate area of uses location if the smartphone users are in remote location. In terms of horizontal and vertical accuracy, high accuracy represents a requirement for results correct to within 100m. Low accuracy Providers are correct to more than 500m, whereas medium accuracy Providers represent accuracy between 100 and 500 meters. GPS has some source of error in location information like(1) Incorrect datum error and typographic errors when putting coordinates into GPS receiver can result in error up to kilometers.(2)Unknowingly relying on less than four satellites for determine position coordinates can also result in unreliable position fixes that can be easily be off by distance in excess of a mile,(3) Human body can cause signal interference Holding GPS device close to the body can block satellite signals and hinder accurate position.

3.2 Cellular Tower Triangulation

Cellular tower triangular is also a way of tracking mobile phone users location if the GPS is not working .It gives the information about the users location based on the signal of cell tower nearest to it. However it is not very efficient in tracking users location as it require at least three cell tower signal to form a triangulation and then it predict the users location by calculating the union of region of range under these towers. The Fig [2] illustrates the cellular tower triangulation working.

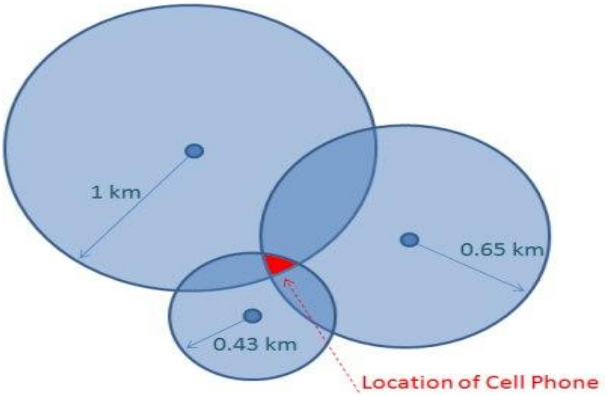

Fig 2: Cell phone detection by cell towers forming a triangulation

In this the estimated distance between the users and the tower are estimated by calculating time taken by signal to reach cell and return back to cell towers. If signal quality of one tower is poor it switches to another tower in the vicinity for better signal. If GPS failed triangulation provide the location of user.

3.3 Harversine Formula

This formula is for calculating shortest distance between two points on a sphere from their latitude and longitude. This holds much importance in navigation. However Earth is not a sphere but still this formula can be used for finding distance between two points.

$a = \sin^2(\Delta \text{ latitude}/2) + \cos(\text{latitude1}) \times \cos(\text{latitude2}) \times \sin^2(\Delta \text{ longitude}/2)$.

$c = 2 \times \arctan(\sqrt{a}\sqrt{(1-a)})$

$d = R*c$

Where,

R = radius of the earth

Δ latitude = |lat2- lat1|

Δ longitude = |long2- long1|

d = distance in kilometre

Distance calculated by using these formulas is compared by GPS co-ordinates for accuracy.

3.4 Activity Recognition

Activity recognition is the process of recognizing the actions done by one entity by the use of external or wearable sensors. In recent advancement in mobile technology enabling smartphones to have most of the sensors required for activity recognition it has received the most attention of scientific research. Activity recognition uses raw data from sensors to predict the user's motion. But taking all the data from the smartphone sensor is meaningless and a costly process, so the data from these sensors are pre-processed and then converted into useful result give the prediction after specified time defined in the data mining algorithm used.Table 1 in [2] summarize a set of sensors that are provided in current mainstream smartphone devices. This subsection contains the

survey done on mainly two sensors namely accelerometer and gyroscope since these two are mainly used for activity recognition of the users.

3.4.1 Accelerometer

Accelerometer senses the accelerating reading of the smartphone to predict the user's motion activity. It is very helpful for finding the motion of smartphone like if the users change its activity from jogging to walking. The raw data of the accelerometer is acceleration of each axis in unit of g-force. Accelerometer measures the acceleration that means it means the rate of change of speed of the device in a given direction.It's interesting to know that those accelerometers do not measure speed of device at particular direction, so you can't measure speed directly based on a single accelerometer raw data. Instead, you need to integrate the acceleration over time to find the velocity. You can then integrate the velocity over time to determine the distance travelled. Since accelerometer can measure the device acceleration therefore it can also be used in combining with magnetometer to calculate the device orientation.

Accelerometer can measure the acceleration of device along three direction axes, (1) x-axis **(**lateral)-Sideways acceleration, for which positive values represent movement toward the right, and negative values represents movement to the left.(2) y-axis (longitudinal) Forward or backward acceleration, for which forward acceleration, such as the device being pushed in the direction of the device, is represented by a positive value and acceleration backwards represented by negative values,(3)z-axis (vertical)— Upward or downward acceleration, for which positive represents upward movement. While at rest at the device's natural orientation, the vertical accelerometer will register –9.8m/s2 as a result of gravity. The Fig 3 show the three directional acceleration axes in relation to the device at rest in its natural orientation. Many sensors are used to reduce the effect of gravity on the accelerometer readings and convert its reading from body co-ordinates to earth co-ordinates system [14].The accelerometer is also used to measure the changes in the environment conditions of the mobile. Motions like shaking, tilting, gestures are recorded through the accelerometer.

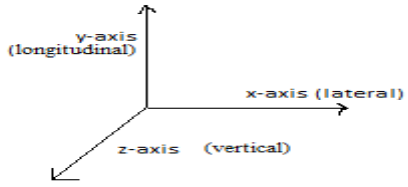

Fig 3: the mapping of the three directional acceleration axes in relation to the device at rest in its natural orientation.

3.4.2 Gyroscope Sensor

In addition to the traditional accelerometer and magnetic field sensors smartphone device are nowadays equipped with gyroscope sensors. It is mainly used to calculate the angular velocity of the device in a particular direction in radian per second using the same coordinate system as described for the acceleration sensor.Because gyroscopes measure speed rather than direction, their results must be integrated over time in order to determine the current orientation. Smartphone gyroscopes return the rate of rotation around three axes, where their sensitivity and high update rates provide extremely smooth and correct updates. It's worth noting that orientation values derived solely from a gyroscope can become increasingly inaccurate due to calibration errors and noise.

3.5 Wi-Fi (Wireless Fidelity)

This is used for establish or maintain connection between two device wirelessly. Wi-Fi connectivity is based upon its signal and signal coverage. Since it is low frequency radio signal various externals media such as buildings, closed area, antennas can affect its quality because it cannot penetrate walls, water and various other media. Its network coverage is around 75-1100ft. Every smartphones are equipped with Wi-Fi capability.

Region where there is no GPS signal Wi-Fi is capable of tracking users location. Even if there is no W-Fi or location service data initially gathered from W-Fi signal is capable of tracking user's location. Wi-Fi positioning system is well suitable for indoor location. When user connects through any Wi-Fi network it leaves its location fingerprints.

4. Challenges

This section describe the various challenges in tracking the smartphone users location using GPS, Cellular tower triangulation, Activity Recognition and Wi-Fi.

4.1 Availability

Availability of the technology used to track the user location is a big challenge in smartphone sensors. There will be huge problem in tracking the location of user if there is non-availability of required resources. For tracking the users using GPS user must have an internet connection without which GPS will not be able to work, in some remote area where there is very low internet speed the tracking of smartphone using GPS becomes difficult. On the hand using cellular tower triangulation technique in international border where the there is no service of cellular operator and very weak internet connect lead to complete failure in tracking the users using both GPS and Cellular tower triangulation. So the availability of technology is big concern for tracking user's location.

4.2 Accuracy

The accuracy of various localization techniques such as GPS, cellular triangulation, activity recognition, Wi-Fi varies in various conditions. The accuracy of GPS is highest and is most preferred technology but in case of bad weather or non-availability of line of sight the position of smartphone users cannot be predicted accurately. Hence there is a need of other localization techniques to achieve the aim such as cellular tower triangulation, activity recognition, Wi-Fi etc. Although none of the above techniques can accurately predicts the user's positions. A combine approach of all these technologies is proposed to be used for localization of smartphone users.Gabber et al. [15] utilized multi-channel records from GPS, satellite technology, cellular tower triangulation and Caller-ID, in a combined approach to find the position and activity of user devices but this can be bypassed easily as GPS signatures [16] are not very helpful since they are prone to spoofing attacks [17].

4.3 Power consumption

Since the power of the mobile is very limited, power consumption of various technologies used to track the user's locations is a great challenge. The technology like GPS which takes very huge amount of energy to track the user's location is not always preferred if the battery level of the mobile is not good. In contrast the batter consumption in tracking the users by cellular tower triangulation is very low. The alternative

technique such as activity recognition and Wi-Fi can be used to detect user's location also. The Experimental results of the power consumption by different mobile sensors for Micromaxx A106 are taken under the outdoor condition and in continuous motion. The results show the power consumption by the IEEE 802.11 is higher than the GPS.

Table 1 Average Power Consumption by mobile sensors for Micromaxx A106

Sensor	Approx. Battery life(in hours)	Average Power Consumption(in mW)
IEEE 802.11	6.24	875
GPS	7.5	725
Accelerometer	48.7	72

In this regard there is need to effectively switching between the methods of tracking users based on their battery level. For example if the users phone battery is below 15 per cent then instead of using GPS a combine approach of Activity recognition, Wi-Fi and Cellular tower triangulation could be used to track the users location. Liang et al. [13] developed the activity recognition algorithm with a lower sampling frequency to reduce the power usage of mobile devices during activity recognition.

5. CONCLUSION AND FUTURE WORK

The increase in the numbers of smartphones together with their ever-growing sensing and computing powers have been changing the way of people's daily life. With the huge increase in smartphone users the localization techniques of tracking the smartphone users has become the topic of prime importance for research. This paper presents a comprehensive survey of various localization techniques. And reported the various challenges regarding the retrieval of user's location information and proposed a combine approach of GPS, Activity recognition, cellular tower triangulation, Wi-Fi and the Harversine Formula for obtaining pin point location of smartphone users taking into consideration of parameter such as availability, accuracy, power consumption.

Based on the power consumption of the smart phone sensors this paper gives the hypothesis that in place of using the GPS for tracking the mobile phone user's location a combine Activity recognition, cellular tower triangulation and Wi-Fi techniques could be used as alternative. This paper also presents a hypothesis for tracking user's indoor location using combine approach of GPS, activity recognition and cellular tower triangulation. We are also developing some application to for tracking smart phone users location indoor like tracking emergency number dialler in a tall building and some others to support this hypothesis.

6. REFERENCES

[1] RagibHasan, Rasib Khan, Shams Zawoad, and MdMunirulHaque "A Witness Oriented Secure Location Provenance Framework for Mobile Devices," IEEE Transactions on Emerging Topics in Computing.2015.Volume 10.pp. 8-11.

[2] Xing Su, Hanghang Tong, and Ping Ji "Activity Recognition with Smartphone Sensors" TSINGHUA SCIENCE AND TECHNOLOGY. Volume 19, Number 3, June 2014 llpp235-249

[3] N. O. Tippenhauer, K. B. Rasmussen, C. Popper, and S. Capkun, "iPhone and iPod location spoofing" SysSec Tech. Rep., ETH Zurich, April, 2008.

[4] J. VanGrove, "Foursquare cracks down on cheaters." Online at http://mashable.com/2010/04/07/foursquare-cheaters/, April 2010

[5] Maduako, "Wanna hack a drone? possible with geo-location spoofing!", Online at http://geoawesomeness.com/?p=893,July 2012

[6] PornpenRatsameethammawong and M.L.KulthonKasemsan Faculty of Information Technology, Rangsit University, Thailand "Mobile Phone Location Tracking by the Combination of GPS, Wi-Fi and Cell Location Technology.2010 Volume 566928 pp. 3-7

[7] J. Lester, T. Choudhury, and G. Borriello, A practical approach to recognizing physical activities, in Pervasive

Computing, Springer, 2006, pp. 1-16.

[8] L. Bao and S. S. Intille," Activity recognition from user annotated acceleration data, in Pervasive Computing", Springer, 2004, pp. 1-17.

[9] Google Android, Sensors overview, http://developer.android.com/guide/topics/sensors/sensors overview.html,2014, Mar. 01.

[10] W. Song, J. Lee, H. G. Schulzrinne, and B. Lee, "Finding 9-1-1 callers in tall buildings", http://academiccommons.columbia.edu/item/ac:156057, 2014.

[11] Y. Chon, E. Talipov, H. Shin, and H. Cha, "Mobility prediction-based smartphone energy optimization for everyday location monitoring," in *SenSys 2011*, 2011, pp. 82–95.

[12] P. M. Wightman, M. Zurbaran, M. Rodríguez, M. A. Labrador, at 8th IEEE Workshop on Network Security. 2013.Volume 13 pp.964-967

[13] Y. Liang, X. Zhou, Z. Yu, and B. Guo, "Energy-efficient motion related activity recognition on mobile devices for pervasive healthcare, Mobile Networks and Applications," pp. 1-15, 2013.

[14] Y. E. Ustev, O. DurmazIncel, and C. Ersoy, "User, device and orientation independent human activity recognition on mobile phones: Challenges and a proposal," in Proc. 13th Int. Pervasive and Ubiquitous Computing Adjunct Publication Conf., Zurich, Switzerland, 2013, pp. 1427- 1436.

[15] E. Gabber and A. Wool, "How to prove where you are: tracking the location of customer equipment," in Proc. of CCS. ACM, 1998, pp. 142–149.

[16] D. E. Denning and P. F. MacDoran, "Location-based authentication: Grounding cyberspace for better security," Computer Fraud & Security, vol. 1996, no. 2, pp. 12–16, 1996.

[17] W. Luo and U. Hengartner, "Proving your location without giving up your privacy," in Proc. of HotMobile, 2010, pp. 7–12.