IBIMA Publishing
Communications of the IBIMA
http://www.ibimapublishing.com/journals/CIBIMA/cibima.html
Vol. 2010 (2010), Article ID 566928, 7 pages
DOI: 10.5171/2010.566928

Mobile Phone Location Tracking by the Combination of GPS, Wi-Fi and Cell Location Technology

Pornpen Ratsameethammawong and M.L.Kulthon Kasemsan

Faculty of Information Technology, Rangsit University, Thailand

---

Abstract

This research introduced the latest method of tracking and locating of client-based mobile phone which will eliminate the limitation of the build-in GPS phone. It has been known that GPS usage is limited in buildings and places unreachable by satellite signal. In order to find better and more accurate results, the method of integrating Wi-Fi signal, cell locations and vector calculation to track and locate mobile phone whereabouts are introduced. Furthermore, it would also be beneficial to develop this method to be applied with other utility programs e.g. delivery truck tracking system or personal locating system via mobile phone.

Keywords: Mobile Tracking, Tracking, Mobile Location

Introduction

Mobile technology has been continuously and rapidly developed over the past years. Not only the cellular network that has been improved but the cellular phone unit or mobile phone itself has also been greatly improved with state-of-the-art technology and numeral enhanced features. Mobile phones are built to be faster with better and higher CPU speed and larger memory storage. They are designed to be more modern and more fashionable looking with additional features like bigger screen, touch screen and built-in high resolution camera. They are equipped with various means of connection such as Bluetooth and Wi-Fi, and navigation system such as GPS. The mobile phone operating system are also more capable of handling faster, larger and more tasks with variety of choices from many famous software developers to choose from, for example, Symbian by Nokia, Windows Mobile by Microsoft, iPhone by Apple and Android by Google. Nowadays, Wi-Fi is considered a standard feature for most mobile phones, and so is GPS.

Even though, GPS, as an almost standard feature for many mobile phones, is considered very convenient but it has some limitation. GPS works by triangulating the signals from satellites orbiting around the earth. GPS usage will be impossible once the satellite signals cannot be received, for example, inside buildings, tunnels or undergrounds, places where the signals from the satellites are not reachable. Hence, tracking mobile phone position by GPS alone is not sufficient. Other technologies are then combined to enhance GPS.

 Contact author: Pornpen Ratsameethammawong e–mail: pornpen.rath@gmail.com

Research Framework

GPS (Global Positioning System)

GPS is a system that pinpoints 24 hours the position of user on earth by triangulating signals from 24 satellites orbiting around the globe. In the past, it was designed for military purposed to be used by the U.S. Ministry of Defense only. Now, it is available to public and is widely used by anyone with a suitable device. Its usages are numerous namely giving directions, tracking of persons and vehicles, etc. Nowadays, GPS is combined with many handheld devices such as mobile phone. Mobile phones with built-in GPS were used in this research.

Wi-Fi (Wireless Fidelity)

The term Wi-Fi was created by an organization called the Wi-Fi Alliance to certify products that belong to a class of wireless local area network (WLAN) devices based on the IEEE 802.11 standards. A product that passes the alliance tests is given the label "Wi-Fi certified". Any Wi-Fi certified devices are able to connect and communicate with one another through Wi-Fi.

Wi-Fi network is based on Wi-Fi signal types and Wi-Fi signal coverage. Opened or closed area, building with walls and furniture, external antenna, etc, all of these can affect the quality of Wi-Fi signal since it is a low frequency radio signal that cannot penetrate metal, water and other materials easily. Generally, Wi-Fi network range is around 75-150 feet. Many mobile phones today are equipped with Wi-Fi to enable them to connect to the internet conveniently.

In this research, in the case where GPS signal is blocked, the researcher would identify the closest wireless access point with the strongest signal shown on researcher's Wi-Fi equipped mobile phone. The data obtained will be used to calculate the position of the mobile phone later on.

GSM (Global System for Mobile Communications)

GSM is the most popular standard for mobile phone systems in the world. It is a standard under the supervision of 3GPP; a collaboration between groups of telecommunications associations originated in Europe. GSM network consists of 2 types of channels to link the mobile phone unit and the base stations.

- Traffic Channel carries speech and data traffic.
- Control Channel carries network information e.g. location area, perform call set up while dialing out and page mobile phone when receive a call.

When turned on and left as standby, the mobile phone will link or connect itself to the base station using Control Channel and remind connected at all time in that particular base station range or cell location. The mobile phone will continuously send and receive signals from the cell location. Once the signal quality is poor it will switch to a new control channel with a better signal from other cell locations in the area and will link to the cell location with the best signal quality.

The research used the GSM network cell location to calculate the mobile phone position. Should the GPS signal failed, the cell location with the best signal quality would be selected as reference point to calculate and pinpoint the location of the mobile phone.

Finding the center between two points

Finding the center between 2 points in this method of tracking and locating the mobile phone is essential. We can do that by applying Pythagoras' equation.

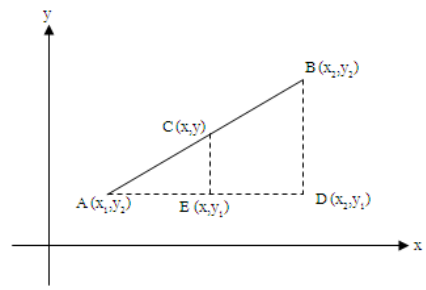

Fig 1. Finding the center between 2 points using Pythagoras' theorem

From the Pythagoras' theorem, to find the center point between point A and point B, line AD is drawn parallel to axis x, and line CE and BD is drawn parallel to axis y. Co-ordinations of point D (x_2, y_1) and point E (x, y_1) will be obtained. From fig 1, ACE and ABD are similar triangles. Hence, center point between A (x_1, y_1) and B (x_2, y_2) is C $\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$.

The researcher would calculate the point of lost signal by assuming that the point of lost signal was in the center between the two points i.e. a pre- point of lost signal and a post- point of lost signal.

Haversine Formula

The haversine formula can be used to calculate the great-circle distances or the shortest distance between the two points on a sphere from their longitudes and latitudes. It is a very important equation in navigation. Although, earth, itself is ellipsoid, not an exact sphere. Harversine formula can still be applied.

R = radius of the earth

$\Delta lat = |lat2 - lat1|$

$\Delta long = |long2 - long1|$

$a = \sin^2(\Delta lat/2)$
$+\cos(lat1) \times \cos(lat2) \times \sin^2(\Delta long/2)$

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

$d = R \times c$
d = distance in kilometers

The researcher used Haversine formula to calculate the distance between two points measured in longitude and latitude. The calculated distance would, then, be compared with between the actual GPS co-ordinate and the calculated co-ordinate.

Research Experimental

Design steps to find the point of lost signal using vector calculation

This method would calculate the point of signal lost by assuming that it was the center point between pre- lost signal point and post- lost signal point.

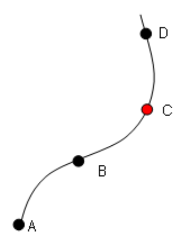

Fig 2. Model of test route

An application would transfer the data of the locations to a server as shown in fig 2, that is, location A, B, C and D consecutively. Assuming that C was the spot where GPS signal was lost. We can calculate the latitude and longitude of C by finding the center point between B and D.

Whereas, C was the point of lost signal or the latitude and longitude obtained from the result of the vector calculation as shown in fig 3.

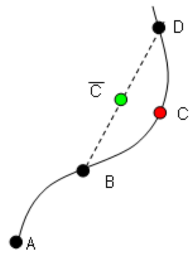

Fig 3. point C obtained from vector calculation

Step 1 Find the assumed point of lost signal, that is, the center point between the pre- and post- point of lost signal using simple calculation method. Co-ordinates of point C (shown in fig 2) were obtained.

Find the center point between pre- and the post- point of lost signal using vector calculation method. Co-ordinates of point C (shown in fig 3) would be obtained.

The pre- and post- point of lost signal could be acquired from GPS co-ordinates. In the case where GPS co-ordinates could not be found i.e. in a poor satellite signal area, the locations of the Wi-Fi hotspot that had the strongest signal should be applied. In the case where both GPS co-ordinates and Wi-Fi hotspot were not available, Cell Location must be considered.

Step 2 Calculate the co-ordinates of point C and point C from step 1 using Haversine formula to compare the results with actual co-ordinates.

Step 3 Conclude the findings of the co-ordinates obtained from vector calculation method to find out the deviated distance in meters from the actual co-ordinates.

Design steps to find the point of lost signal by calculating the locations of Wi-Fi hotspots and Cell Locations within 50 meters, 100 meters and 150 meters radius

By treating the co-ordinates of the point of lost signal from vector calculation as central location, we, then, find out the locations of Wi-Fi hotspots and cell locations within 50 meters, 100 meters and 150 meters radius. Next, use vector calculation method to find out Wi-Fi hotspots and Cell Locations that were closest to the point where the signal was lost.

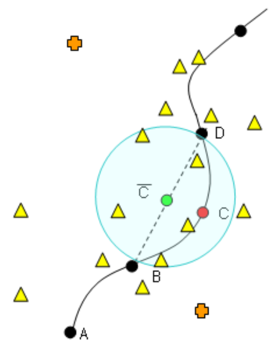

Fig 4. Wi-Fi hotspots and Cell Locations within the research area radius

From fig 4,

- The location points the application sent to the server
- The assumed point of lost signal
- The co-ordinates obtained by using vector calculation
- Wi-Fi hotspots
- Cell Locations

Step 1 The point of lost signal co-ordinates obtained from vector calculation would be used as center and to create 50 meter, 100 meter and 150 meter radius.

Step 2 Then, find out from the database the locations of Wi-Fi hotspots and Cell Locations within 50 meters, 100 meters and 150 meters radius using Haversine formula.

Step 3 Compare the distance between the point of lost signal co-ordinates calculated by vector method to the co-ordinates of the closest Wi-Fi hotspot and Cell Location within 50 meters, 100 meters and 150 meters.

<u>Step 4</u> Conclude whether which Wi-Fi hotspot or Cell Location was the closest to the point of lost signal. Compare the co-ordinates with the actual co-ordinates to find out the exact deviation distance in meters using vector calculation method.

Data collecting routes

Three routes were selected as data collection route. All of them were in business area where the usage of cell phones and Wi-Fi were high. Data were collected from all three methods, that is, from vector calculations, GPS signals and cell locations, and within every 5, 10 and 15 minutes. One of the routes was chosen as the route that received the data of Cell Location only to study the tracking accuracy in the case where there were neither GPS nor Wi-Fi signals available in the area.

The researcher would collect GPS, Wi-Fi hotspots and Cell locations data. Should the case be that there was neither of them; the tracking method would be made by using vector calculation method and the method of calculating of vector using the nearest Wi-Fi hotspot or Cell Location as reference point.

The routes selected must receive strong GPS signal in order to be able to compare the calculated co-ordinate results with the actual co-ordinate results obtained from GPS.

Findings

The researcher had installed an application that had developed by the researcher onto a mobile phone to collect data. Three routes were selected as data collecting routes. The data were collected every 5, 10 and 15 minutes. One of the routes was chosen as the route that received the data of Cell Location only.

- Route 1

Fig 5. results from different methods in route 1

Approximate interval between actual GPS co-ordinates and co-ordinates obtained from vector calculation

Approximate interval between actual GPS co-ordinates and the closest Wi-Fi hotspot

Approximate interval between actual GPS co-ordinates and the closest Cell Location

The results of route 1 concluded that the method of finding the co-ordinates of the point of lost signal by locating the nearest Wi-Fi hotspot was the least inaccurate. If data collections were carried out more frequently the results would be more reliable.

- Route 2

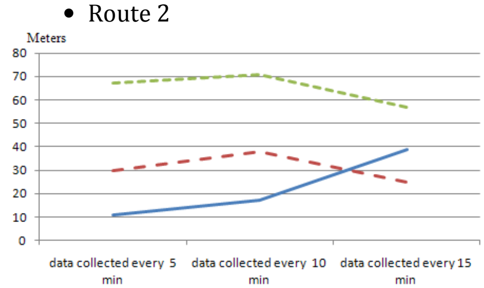

Fig 6. results from different methods in route 2

The results of route 2 concluded that the method of finding the co-ordinates of the point of lost signal by vector calculation was the most accurate. If data collections were carried out more frequently the results would be more reliable.

- Route 3

Fig 7. results from different methods in route 3

The results of route 3 concluded that the method of finding the co-ordinates of the lost signal point by locating the nearest Wi-Fi hotspot was the most accurate. If data collections were carried out more frequently the results would be more reliable.

- Route that received data of Cell Location only

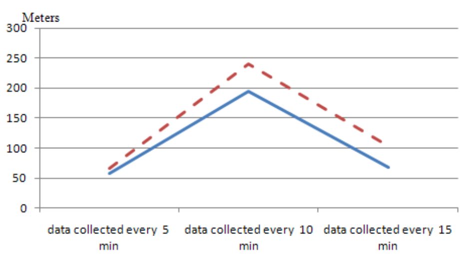

Fig 8. result from different methods assuming that one route received the data of Cell Location only

The results of the route that received the data from Cell Location only concluded that the method of finding the co-ordinates of the point of lost signal by using vector calculation was more accurate than by locating the nearest Cell Location. The frequent data collection times did not have effects on the results since the mobile phone would connect to the Cell Location with the available Control Channel that has the best signal quality which might not always be the nearest Cell Location.

Conclusion

Three routes were selected to perform 12 tests. The results of the 12 tests are as followed.

In the routes that went into business area with a lot of Wi-Fi hotspots and Cell Locations, it was found that the closest Wi-Fi hotspot calculated by vector method was the least deviated. However, if the routes were not in business area and Wi-Fi hotspot was not available, vector calculation method would give the best results. Nevertheless, more frequent data collection made the results more reliable and more accurate.

The combined methods suggested by this research would make the tracking and locating of moving mobile phone more accurate and more effective despite the fact that GPS signal was not available.

These combining methods could also be adapted to be applied vertically as well to cope with the growing numbers high rise buildings. Tracking and locating moving mobile phone floor by floor should be possible. Moreover, more efficient devices and applications to collect the data of GPS and Wi-Fi signals should also reduced the inaccuracy.

References

Behrouz,A. Forouzan. (2000) Data Communications and Networking, 3rd ed, Mcgraw-Hill College, New York.

Daniel,Zwillinger.(2002) CRC Standard Mathematical Tables and Formulae, 31st ed, Chapman and Hall, Florida.

Guochang,Xu.(2007) GPS Theory, Algorithm and Applications, 2nd ed, Springer, New York.

Ian,Poole.(2006) Cellular Communications Explained: From Basics to 3G, Newnes, Burlington.

Joel,McNamara.(2007) GPS For Dummies, Wiley Publishing, Inc, Hoboken.

Ross,John.(2003) The Book of Wi-Fi, No Starch Press, United States of America.

R.W, Sinnot. (1984) 'Virtues Of The Haversine,' *Sky and Telescope*, 68(2), 159.

Zegarelli, Mark. (2007) Basic Math and Pre-Algebra For Dummies, For Dummies, United States of America.