Low Cost Solution for Location Determination of Mobile Nodes in a Wireless Local Area Network

Dr. M.A. Ansari
Federal Urdu University of Arts, Science and Technology, Islamabad
Ph: +(92) 321 5285504, drmaansari@fuuast.edu.pk

Sherjeel Farooqui
Foundation University Institute of Management and Computer Sciences, Rawalpindi
Ph: +(92) 321 5204804, sherjeelfa@yahoo.com

Ansar-Ul-Haque Yasar
Air University, Islamabad
Ph: +(92) 321 5109498, ahyasar@gmail.com

2005

Abstract

In this research paper we undertook the problem of Location Determination of Mobile nodes in a Wireless Local area network, as finding out the location in a wireless environment is to-date not very easy, cheap and accurate using 802.11b technology. We used the classical method of Triangulation with a little alteration which is later on described in the paper. Another method we used is the methods of calibration by research to produce more accurate results and also to cross verify the results of the method of Triangulation. The work in this paper attempts to illustrate the different aspects of the problem of location determination in WiFi networks. We started with an investigation of the influence that network characteristics have on the ability of middleware location determination protocols to accurately estimate position of mobile nodes. We presented an implementation based study that demonstrated the strong relationship between the two of the location determination methods and their performance. The main objective of this paper is to provide method in which no dedication hardware is required. Only Wireless Lan card is required and can be placed in any suitable location. The significance of this result lies in allowing a network designer to make a suitable tradeoff between QoS of location determination and other application protocols while choosing a network topology. The combination of two methods reduced the error rate of locating a mobile node to a great extent. The results were being plotted on a given map using both the algorithms.

Keywords: Location estimation, location determination, signal attenuation, Wi-Fi.

1. Introduction

Global Positioning Systems (GPS) make use of 24 satellites orbiting the earth in geosynchronous orbit that transmit their position and time of day to any device on the Earth's surface that happen to be listening. A GPS device, through triangulation of multiple signals received and determination of propagation (how long it took the signal to go from the satellite to the GPS device), is able to accurately determine a users location to within a meter. The problem with GPS is that the device must have a clear line of sight between itself and the satellite. This means the technology is unusable in heavily forested areas, urban environments with tall buildings and indoor environments. The popularity of wireless 802.11 networks over the past few years has grown significantly and provides an excellent opportunity to include location based services in indoor environments, where GPS fails. With the wireless networks in place, a user with a laptop or PDA and an 802.11 network card needs no further hardware. The mobile users with PDA or Labtop with 802.11 card donot need addition software to be installed.

There has been a great deal of research done on this topic and most of the research specify the entire area instead of the pin point location at the map means other technique shows that the client is in conference room but in which part? Therefore our aim of this paper is not to illustrate any totally new technique in location determination. Rather, the intent is to demonstrate how one technique can be improved by pin pointing the location of the user at the map and cheaply implemented as we do not use any AP's only simple Wireless Lan Card Is used. Since most of the research really deals with Linux environments due to easily hardware access. We provide location determination solution that is implemented in Windows machine using 802.11b technology. As Windows continues to be the dominating operating system for laptops and most of the PDAs, most users would benefit from a having location determination system designed for windows platform. For this purpose classical method of triangulation is modified a little to obtain better results and also calibration is being done to improve and cross verify the results obtained. We can use three systems which are least requirement for location determination.

The method of triangulation uses formulas for the finding of the angle of a client in the WLAN(described in sec 2.1) but the second method of calibration uses hard and fast rule to fine user location as described in sec 2.2

2. Description

There are four servers used in the implementation. One is the central server in which all the results i.e. signal strengths of all the three servers with respect to the client(s) are stored and the location of the client is determined with the help of these signal strengths.

The other three servers are connected to the client and send the results to the central server. The central server is not connected to the clients (mobile nodes) but is connected to all the three other servers.

Three servers which are basic requirement for our system are use to obtain RSSI value of the mobile node

which will vary depending upon the wireless LAN card used at servers. The we have proposed fourth system so that any of the three servers could not over whelmed by the extensive calculating and output displaying overhead. Our objective is to get the approximate location of the client. We have implemented two methods one is triangulation and other is calibration.

2.1 Triangulation Method

1. Get the RSSI value of the client (mobile nodes) from each server which will be in the form of dbm. Since 802.11b is highly effective by the multipath propagation, where several waves arrive at the receiver via different paths and with different phases, different variations of the actual signal. This phenomenon is described in [11]. So to over come this problem we at each server, which is connected to the mobile node (client), multiple readings of signal strength is taken and then these signal strengths are converted into an average signal strength by using simple averaging formula described below

$$RSSI = (RSSI_1+RSSI_2+RSSI_3+\ldots\ldots+RSSI_n)) / n$$

Where

RSSI = Average signal strength value (dbm)

$RSSI_1$ = Signal strength at first interval

$RSSI_2$ = Signal strength at second interval

$RSSI_n$ = Signal strength at n^{th} interval

n = No. of intervals

As we increases the n values the error also get minimized it only depend how much load you want to put on servers that is connecting to wireless node. The actual values of signal strength in different environment are given below. This fading effect is detailed study in [12] figures are given below.

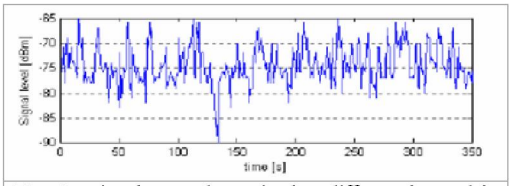


Fig. 1 - signal strength received at different interval in presence of people

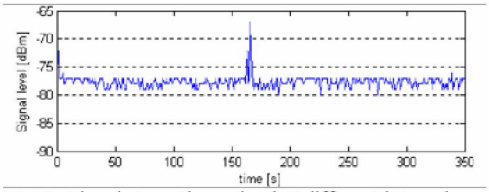


Fig. 2- Signal strength received at different interval without disruption by moving people

2. Once the signal strength of the client is obtained with respect to each server, we use to calculated distance to determine the approximate location of the client (mobile node) in the area covered by the Wireless Local Area Network (WLAN).

Following are the formulae used for calculating distance.

*S = (RS-BS) * k (ignoring the negative sign of the signal strength)*

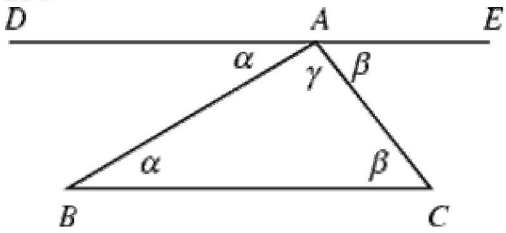
Where RS = Received Signal Strength

BS = Basic Signal Strength (which in the hardware we used is -45dbm)

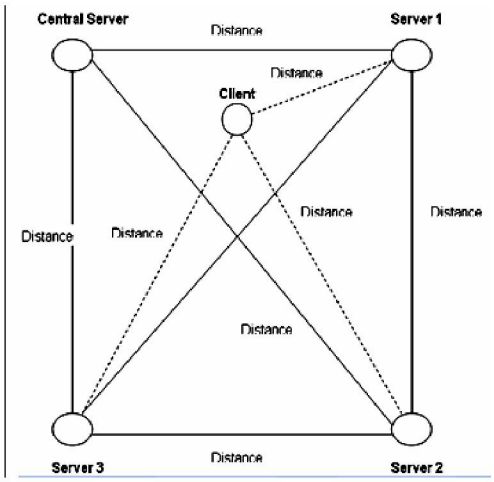
k = distance covered in 1dbm (which is calculated using calibration)

3. Then we have to calculate angle using the Trigonometric functions i.e.

$$Cos\ \alpha = (b^2+c^2-a^2) / 2bc$$



The calculated Distance and the Angle is then stored back into the central repository at the central server where the results are used to find the approximate location of the client. The software we developed is known as the *Wireless Explorer*.



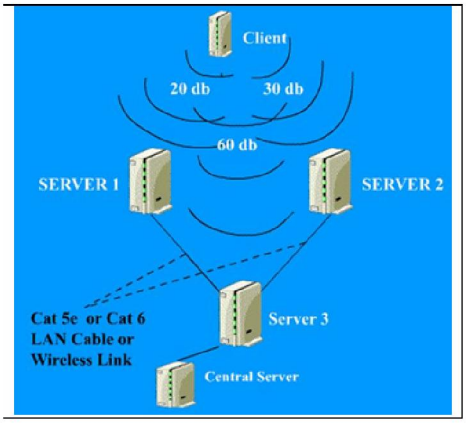


Figure 3: General Diagram of Wireless Explorer's working and methodology

It is important to note that the central server is only connected to the three other servers. Its function is only to get the average distance of the client from each of the three servers connected to the client (mobile node) and store the results into a database and then use these results to find the approximate location of the client and show it on the graphical map. We also developed a method to find the right plane for the client on the map corresponding to the angle. For this we manually calculated the coordinates of the servers and then gave an increment or decrement according to the angle calculated for a client with respect to any of the server.

The method of triangulation is altered in our research project. We formed triangles of client with servers and then calculated the distance and angles using the formulas mentioned above rather then finding the triangulation region as used in the classical method of triangulation.

In the fig 3, we have described the General System working using the proposed methodology. We see that all servers are connected with each other and one client is in the range of the Wireless LAN. The client (mobile node) is connected to the three servers except the central server. There are three triangles forming in this diagram with respect to the client and three servers. Each server is found in every triangle and hence there are three signal strengths coming to each server for a respective client. At each server the average signal strength is calculated and sends to the central server where the location of the client is determined with the help of the signal strengths calculated by the three servers and shown on the map of the

area covered by the Wireless Local Area Network.

2.1 Calibration Method

Calibration method is an and hard and fast rule method in which we have divided our area into number of specific regions and reading of that regions are noted. It has two stages.

i. **Offline stage** which is also known as the training phase in which the location coordinates and distances are noted and stored in central database.

ii. **Online stage** which is also known as the run time stage where in the real time the signal strength of the mobile user is noted and then search the databse made in offline stage which give the region value and then the location of mobile user is ploted on the map.

The problem in this method is the reading obtained during the offline stage for a particular point may vary in the online stage due to any environment change like number of people , electrical equipments etc. To overcome this problem we thought of providing a range for all the particular points and whenever a client falls in between the range it is being plotted on the map (fig 4). This method is less effective as compare to the method of triangulation.

The map of Foundation University Institute of Management and Computer Sciences, Rawalpindi is as under on which the location of a mobile client was displayed graphically. This map is to the scale and exact.

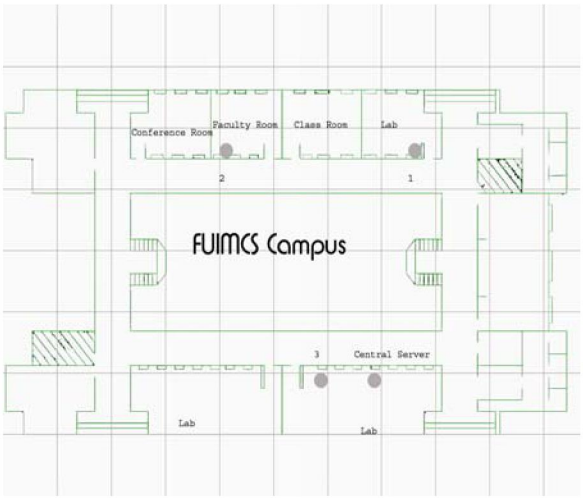


Figure 4: Testing environment of wireless explorer

3. Development Environment

We used the Microsoft Visual Studio .NET platform and implementing the code using C#. For database storage we are using Microsoft SQL 7.0 Desktop Edition. We are using Microsoft Windows XP with Service Pack 2 as the required operating system.

The basic programming language used is C# which is one of the programming tools provided by Microsoft Visual Studio .NET 2005. It is used for implementing the project because it has many built-in functions and support for many APIs. Also it is very convenient to establish connections with the databases on the local system and with the remote systems with which the connection is established. For user interface, forms and main menu, we are using Microsoft Visual Basic 6.0 from the Microsoft Visual Studio 2000. After having contacted Thomas F. Divine, the creator of RawEther, at PCAUSA; he was kind enough to grant us the usage of the

source code of RawEther for academic use. RawEther is API used to support the wireless devices.

4. Tests and Proofs

We implemented this research at Foundation University Institute of Management and Computer Sciences, Rawalpindi. We used 802.11 b Planet Wireless Cards. The softwares used to implement are already mentioned above. The results obtained using both the methods proved to improve the estimation of the location of a client in a WLAN. There was a error rate of ±5m. Which can also be reduced using 802.11 a+g technology based cards operating on 5 GHz as 802.11b is operating at 2.4 Ghz which is disturbed by any object like concrete walls, high power electronic equipment, etc.

5. Conclusion and Future Work

We are now planning on extending the available location determination methods for use with directional antennas. A set of three range estimation techniques using directional antennas was developed. Moreover, directional antenna based techniques exhibited less performance degradation under adverse conditions like low sensor density and error in power measurements.

A possible application for the Reduction of Deviation ROD algorithm is the task of optimal wireless access point (AP) placement. Given a pdf of the user's location distribution, the expected deviation of location error could be calculated. An optimal AP location, from the geo-location point of view, could be found by minimizing the expected location error deviation.

Other advances that could be made on this project, while not necessarily dealing with the location determination techniques, could include porting the application to a Pocket PC, including a graphical display of coordinates onto a live map, and updating the radio map file(averaging radio signals) after a search is performed and can be trusted to have provided accurate results. Also this research can be extended to CDMA and GSM based technologies which will be very useful and less effect by multi part due to its frequency range.

As part of future development of this work, we intend to extend the scheme using two anchors with aligned antennas for general deployment of nodes with possibly unaligned antennas. The proposed techniques in their current form use numerical methods for solving systems of non-linear equations. To avoid this computational expense we intend to explore possible ways of these equations to arrive at a closed form solution. Finally, we want to develop a location determination protocol to exploit the potential advantages of the proposed schemes like less message transmissions and more robustness to low sensor densities and high power measurement errors. We intend to implement such a protocol on a test-bed and experimentally verify the efficacy of the proposed schemes. This will also involve a study of the sensitivity of the schemes to the correlation in the error in power measurements at multiple receiving antennas on a sensor node.

We can also use this system with satellite system for location

determination which will be useful in such cases when the object to determine is not in the LOS of the satellite. In this case the object can be in between two buildings where its location can be determined by the Wireless LAN and then that location can be sent to the satellite through the server.

6. Acknowledgements

Authors would like to acknowledge the help provided by the SoftTek Systems Islamabad Pakistan team members for making this research successful. Authors would also like to acknowledge.

We would also like to express our special thanks and gratitude to Mr. Stanislav A. Selitskiy. Without his kind cooperation and basic research in this area it would have been difficult for us to complete the project. Last but not the least, our thanks to our family for their patience and cooperation in completing our work.

References

[1] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system", in Proceedings of IEEE INFOCOM 2000, pp. 775-784, Mar 2000.

[2] T. Roos, P. Myllymaki, H. Tirri, P. Misikangas, and J. Sievanen, "A probabilistic approach to wlan user location estimation", International Jornal of Wireless Information Networks, vol. 9, July 2002.

[3] J. Hightower, R. Want, and G. Borriello, "SpotON: An Indoor 3D Location Sensing Technology Based on RF Signal Strength," UW CSE 2000-02-02, University of Washington, Seattle, WA, Feb. 2000.

[4] M. A. Youssef, A. Agrawala, A. U. Shankar, and S. H. Noh, "Aprobabilistic clustering-based indoor location determination system", University of Maryland Computer Sciemce Department, Tech. Rep. CS-TR-4350, Mar. 2002.

[5] R. Battiti, M. Brunato, and A. Villani, "Statistical learning theory for location fingerprinting in wireless LANs", Dipartimento di Informatica e Telecomunicazioni, Universit`a di Trento, Tech. Rep. DIT-02-0086, Oct. 2002.

[6] R. Battiti, A. Villani, and T. Le Nhat, "Neural network models for intelligent networks: deriving the location from signal patterns", in Proceedings of AINS2002, (UCLA), May 2002.

[7] H. Hashemi, "The indoor radio propagation channel", Proceedings of the IEEE, vol. 81, no. 7, July 1993.

[8] M. Hassan-Ali and K. Pahlavan, "Statistical model for site-specific indoor radio propagation prediction", IEEE Transactions on wireless communications", vol. 1, no. 1, Jan. 2002.

[9] J. McKown and R.Hamilton, "Ray tracing as a design tool for radio networks", IEEE Network Mag., pp. 27-30, Nov. 1991.

[10] Eric W. Weisstein. "Normal Sum Distribution." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/NormalSumDistribution.html

[11] Saunders, S.R., 1999, "Antennas and Propagation for wireless Communication Systems", John Willey&Sons, London, UK.

[12] Stanislav ZVANOVEC, Pavel PECHAC, Martin KLEPAL "Wireless LAN Network Design"