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Wi-Fi Location Tracker System

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Abstract: The purpose of this paper is to create a platform independent, software-only, indoor geolocation solution. System utilizes the existing 802.11b Wireless Local Area Network infrastructure without using the GPS or proprietary tags. System is design using object-oriented techniques and implemented in Java with platform independent modules clearly abstracted. The project illustrates a simple path and location tracking system within an organization based on its available infrastructure of Wi-Fi networks. The location tracking algorithm compares runtime signal strength values of mobile device to pre-recorded calibration values that provide an approximate determination of the location in the service area and by using the histories of access points used by mobile device system provide moved path of the mobile device, and is also able to track multiple objects simultaneously. In our work we use web services for location services to enable queries and manage the path and location of the mobile node.

Index Terms: Indoor Positioning, WiFi Network, Mobile Node, Location Based Services, Tracking Systems, Wireless LANs, Signal Attenuation.

1 Introduction

Wireless networks have become a critical component of the networking infrastructure and are available in most corporate environments (universities, airports, train stations, hospitals, company Buildings etc) and in various commercial buildings (cafes, restaurants, cinemas, shopping centres, etc) [1, 2]. Path and location tracking are one of the main interesting and fast growing applications in wireless communications. The developments of such systems have interested many research, industrial and government bodies with solutions that range in scale and accuracy. Wi-Fi location tracker systems use the popular 802.11b network infrastructure to determine the user location without using any extra hardware. This makes these systems attractive in indoor environments where traditional techniques, such as Global Positioning System (GPS) fail. In order to estimate the user location, wireless Ethernet devices measure signal strength of received packets. This signal strength is a function of the distance and obstacles between wireless nodes and the access points. Moreover, the system needs one or more reference points (Access Points) to measure the distance from. Unfortunately, in indoor environments, the wireless channel is very noisy and the radio frequency (RF) signal can suffer from reflection, diffraction and multipath effect, which makes the signal strength a complex function of distance.

During the training phase, the system constructs the wireless-map. In the estimation phase, the vector of samples received from each access point is compared to the wireless-map and the "nearest" match is returned as the estimated user location [3].

2 Background

In this section first, we describe several location sensing systems and then we describe needs of developing new system.

2.1 Global Positioning Systems

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 is able to accurately determine a user's location to within a meter. The problem with GPS is that the device must have an obvious line of sight among itself and the satellite. This means the technology is unusable in heavily forested areas, urban environments with tall buildings and indoor environments [4, 5].

2.2 Cellular Network

Cellular networks use location management techniques to track mobile node. Location Management essentially involves two processes, location update and paging. But cellular systems are not hold through organizations and only work with mobile phones and have greate uses charge [6, 7].

2.3 Infrared Based Systems

An active badge location system uses infrared technology (IR) to transmit data. Associatea of staff wear badges that transmit signals given that information about their location to a centralized location service, through a network of sensors. Active badge approach is to 'tag' a person and try to locate the tag. Active Badges have difficulty in locations with fluorescent lightning or direct sunlight because of the spurious infrared emissions these light sources generate and it does not work in closed room [8, 9].

2.4 Ultrasonic Sensors and Actuator Systems

Active bat use ultrasound technology to transmit signals to the receivers that are installed at some intervals on the ceiling. Three receivers take the time of propagation of the ultrasound from the bat. Then by triangulation the position of the bat can be determined in three dimensions. Scalability, ease of deployment, and cost are disadvantages of this approach [10].

2.5 Computer Vision Systems

Computer vision is concerned with the theory for building artificial systems that obtain information from images.This is a

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feature-based tracking system for detecting vehicles under the challenging conditions. Instead of tracking entire vehicles, vehicle features are tracked to make the system robust [11].

Easy living uses two sets of color stereo cameras for tracking multiple people during live demonstrations in a living room. The stereo images are used for locating people, and the color images are used for maintaining their identities [12].

2.6 Physical Contact Based Actuator Systems

Smart Floor system is used for biometric user identification based on footstep profiles. These uses a floor tile with force measuring sensors and are using the data gathered as users walk over the tile to identify them [13].

2.7 Radio Frequency (RF) Based Systems

Radar is a system that uses electromagnetic waves to identify the range, altitude, direction, or speed of both moving and fixed objects. Generalizing RADAR to multi-floored buildings or three dimensions presents a nontrivial problem [14, 15, 16]. Also sensor networks [17, 18] can be installed as a small RF device to generated signals to be interrupted by applications or user carried devices.

All the system described above, either requires extra hardware or it does not work inside of building. So address this problem, we have developed a software based location tracker system.

3 Signal Strength Preprocessing

Relationship of physical position and received signal strength at different distances away from access points or hotspots is a key criterion for computing user's position in WLAN. The most basic radio wave propagation is called the free space loss, as with any signal loss it is due to absorbing, diffracting, obstructing or refracting. The formula used for free space loss calculation is

$$free\ space\ loss = FSL = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi d}{c}\right)^2$$

$$\text{free space loss} = \mathbf{FSL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi df}{c}\right)^2;$$

…….1

Where λ is the signal wavelength, f is the signal frequency, d is the distance or radius of the signal from the transmitter, and c is the speed of light in the signal transmission medium the units used should be consistent, e.g., and R in meters, and c in meters per second [19].

The more useful representation of this formula is in terms of dB that is based on Hz and meters

$$\begin{aligned}\mathrm{FSL(dB)} &= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) - 120,\\ &\approx 20\log_{10}(d) + 20\log_{10}(f) - 147.55;\end{aligned}$$

……2

If the indoor propagation of the 2.4 GHz signal follows an approximate 1/(range^3.5) power rule instead of the 1/(range^2) in the free space loss formula then the propagation loses can be predicted with the following relationship

$$\text{Path Loss (dB)} = 40 + 35 * \log(D)$$

……3

D – is the distance in meters and 40 is a constant that includes both the output power and the static cumulative gains and losses. (802.11 tracking quote) Because this the value 40 may not be the same for all situations, it is substituted by a constant variable "V".

$$\boldsymbol{Path\ Loss\ (dB) = V + 35 * \log(D)}$$

……4

When a signal propagation model is introduced to describe the attenuation process, different building layouts should be taken into consideration as well as large-scale path loss [20].

$$\boldsymbol{P(d)[dBm] = P(d)[dBm] - 10\log\left(\frac{d}{d_0}\right)^n - \sum_{p=1}^{P} WAF(p) - \sum_{q=1}^{Q} FAF(q)}$$

……5

Where P (d) is the signal strength in decibels at a distance d from the transmitter. d_0 is a reference distance introduced to normalize the path loss. The parameter n is the mean path loss exponent, which indicates how fast path loss increases with distance. P and Q are number of walls and floors between the transmitter and receiver, while WAF (p) and FAF (q) are termed wall attenuation factor and floor attenuation factor respectively.

Received signal = (transmit power) - (loss between transmitter and antenna) + (transmit antenna gain) - (path loss)-(multi path and obstruction loss) + (receive antenna gain)-(loss between antenna and receiver)

……6

4 Architecture Of Location Tracker System

The concept of Wi-Fi LTS is inspired by the usage of access points installed within an organization to provide wide area network access to mobile users. Apart from providing a connection access point for mobile devices, access points also have their added value of identification, since every access point has a unique id presented in its MAC address of the port that connects it to the infrastructure. The collected information of access points signal coverage, resulting from mobile nodes association inquiries enable the implementation of location and path tracking concepts.

Our system uses architecture that provide three different solution i.e. Where Am I? (WAI), Where Are You? (WAY), Where Are They? (WAT)

WAI: this approach allows the mobile node to determine its own location.

WAY: this approach allows two mobile nodes that implement WAI to query each other for their location. WAT: this approach allows an administrator to monitor the location of mul-

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tiple mobile nodes.

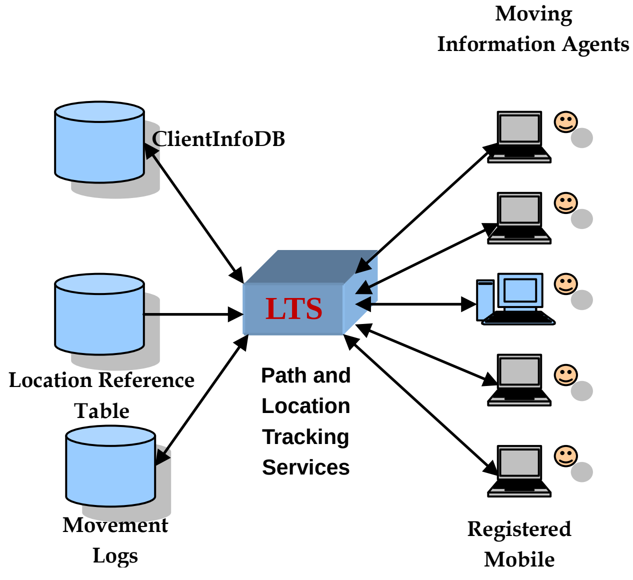

Figure 1. Architecture of LTS.

5 Implementation Of Location Tracker System

We implemented a location system that are based on structured components and are designed to keep the related information of the signal and location in order to determine the location of where a mobile device is located. The key design concept is to utilize the existing systems by not adding any new devices to the network but use what is already in existence within the organization network. To implement this system we use JSP technology for web service and swing to draw map. The main structure of our path and location tracking system is illustrated in Fig.1. It consists of:

5.1. Location References Table

This table stores the pre surveys data that will be used as references with the inquiry information for the path or location. This is done by saving the records of the separate divided areas of signal strength as received from the access points. We store signal strength of mobile node from access point and their latitude and longitude (X, Y) information. This information is also used as the display coordinate which shows the location and path of the node on the mobile device application. The accuracy of the location depends on the size of the grid that is kept in the table.

5.2. Client Information Table

This table stores mobile nodes related information such as name, login id, password, address, ip address, mac address, and phone no, email id etc that are used to uniquely identify the device.

5.3. Moving Information Agent

These agents are located in every participated mobile node. Their function is to get the movement related information from the node environment and send it to the system to keep as a movement log. The information is of which access point(s) the node is able to receive a signal and the signal strength of that access point. To get the signal strength of mobile node, we used a netstumbler. Netstumbler [21] store the signal strength of mobile node in to file, update file information at regular interval and MIA retrieve that information and sends back to path and location tracking service module at regular interval. The idea of using a moving information agent instead of getting the information from an access points itself is because we want to get all the access points signals that the mobile node gets from that location.

5.4. Client Location Services

These services work as a mobile node application that gets the information from the path and location tracking service and show the location information on the user's mobile device.

5.5. Movement Logs

This data is updated frequently from the mobile nodes when the new movement information is detected by the moving information agent. The information of this log is used to determine the movement paths of the mobile nodes. This information will be requested and used in the calculation process by the path and location tracking services module implemented in the location references table.

5.6. Path and Location Tracking Service

This service resides in the system and serves as a path and location tracking information agent for any queries from mobile nodes or any other application. This service also manages the movement log of each registered mobile node. We used triangulation algorithm to show the mobile node location in to map.

Triangulation Algorithm

Step 1: Get signal strengths and ssid of access points.
Step 2: If we get signal strength of mobile node from one or two access point then used strongest signal strength or closest access point method to determine the location. Get the position of access point from location reference table and draw the map.
Step 3: If we get signal strength of mobile node from three access point then we get these APs' coordinates by querying a location reference table with the AP's id. We can estimate the distances between the WiFi-mobile node and the APs with the signal strength information, and name the results with DS1, DS2, and DS3 respectively.

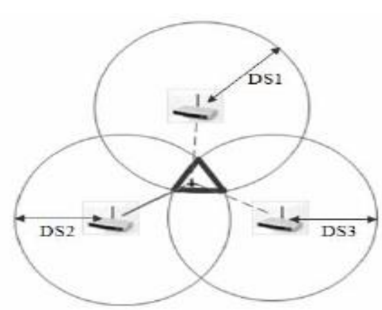

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Figure 2. Triangular positioning

Step 4: Draw three circles with the centers set as the AP's coordinates, and the radiuses set as DS1, DS2 and DS3 respectively.

Step 5: Taking any two of these three circles into account, there are two possible situations:

1. Two circles cut each other. Then we get two intersection points. Particularly, if two circles are tangential to each other, the tangent point should be taken into account twice.
2. Two circles stay apart from each other and do not cut. Then we connect the centers of these two circles with a straight line, which will cut these two circles respectively and generates two intersection points.
3.

Step 6: Perform the same process on every two of these three circles, and we will get six intersection points (p1-p6).

$$\overline{X} = \sum_{i=1}^{6} X_{Pi} \ , \qquad \overline{Y} = \sum_{i=1}^{6} Y_{Pi} \qquad \ldots\ldots 7$$

$(\overline{X}, \overline{Y})$ stands for the estimated coordinate of the Mobile node.

Step 7: The estimation error E_r is measured by absolute distance.

$$E_r = \sqrt{(X-\overline{X})^2 + (Y-\overline{Y})^2} \qquad \ldots\ldots 8$$

Where (X, Y) the actual is coordinate of the WiFi- Mobile node.

Step 8: Draw these x and y position in to map.

6 Experimental Results

We have tested this paper on test bed, where its shows the mobile node location in map. Figure 3 shows the mobile node location information in textual format.

SsId	IPAddress	Date	Hour::Minutes	Location
ssid_cs_sh	192.168.0.51	24 july 2008	5:58	Firstfloorlab1
ssid_mtl_sf	192.168.0.51	24 july 2008	5:38	Mtechseminarhal
ssid_mtl_sf	192.168.0.51	24 july 2008	4:56	Mtechseminarhal

Figure 3. Mobile node location information

Figure 4 shows the mobile node location and path information. Red circle indicate mobile node current position, green circle indicate second last position and dark blue circle indicate the third last position. By looking at table and map we can conclude the movement path of mobile node. Here path movement is from Mtech seminar hall to mtech seminar hall then move to its current position first floor lab 1.

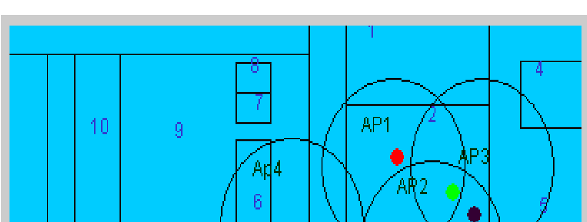

Figure 4. Location map of mobile node.

Number	Location
1	Electrical department
2	Computer department
3	MultiMedia Lab
4	Girls Hostel
5	FootBal Ground
6	Router Lab
7	Third Year Class Room
8	First Year Lab
9	Quartangle
10	Canteen
11	Director office

Figure 5. Reference table for location map.

7 Conclusion

This paper illustrated a simple path and location tracking system within an organization which is build, based on the already implemented Wi-Fi network infrastructure. This system uses the client server architecture and is also architecture neutral system. By using signal strength and histories of access points used by a mobile node and applying triangulation method, we can determine roughly the location in the services area and also the moved path of the mobile node. We uses web services for the provision of location based services that enable queries and manage the path and location of the mobile node. However the position of the mobile node that results from our system is not as accurate as those of GPS based systems. Nevertheless we enable a value added service to the existing Wi-Fi infrastructure. The accuracy of our proposed Path and Location Tracking System hugely depends on the precision of the signals detected, the size of the divided area, and the services area of one access point.

We plan to simplify the pre-surveys information process by using the map of the services area to help us generate Location References Table. We are still in the process of finding an efficient method of interpreting which locations are those that a mobile node is less likely to be located. We can also use wimax instead of wi-fi and locating mobile device in 3-D map instead of 2-D map.

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