Increasing Location Based Service Performance with Hybrid GPS-WLAN Positioning Technique

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Abstract

Currently, the location base service can be performed using either purely Global Positioning System (GPS). Using the method in locating a user's position has a limitation on the coverage area for Location Based Service. There are a few research attempting the use of GPS and GSM [1,2]. However, the technique has proven to be costly due to high cell site installation price. This paper presents an alternative less expensive method using a hybrid of GPS satellite and Wireless LAN access points with Triangulation technique. The widespread deployment of Wireless LANs enables us to make use of the access points together with GPS's satellite in order to find the position. The technique also improves performance of location base service compared with that by using GSM only.

Keywords -- Location Based Services, Hybrid Positioning System, GPS

1. Introduction

Traditionally, people have been using GPS in locating his actual position on our globe.
The GPS technique requires information from at least three satellites to obtain an accurate position in two dimensions. The accuracy of the calculated position depends on the satellite signals. Therefore, locating a person's position using GPS has a limitation especially when the person is inside a building. That is because satellite signal cannot pass through the constructions such as buildings. Therefore, in city areas it is not feasible to find a correct position using GPS.

The rapidly growing adoption of WLANs enables us to make use of the access points together with GPS's satellite in order to locate the position. Using Hybrid Positioning Technique can solves the problem that a receiver device cannot receive the signals from three satellites because access points are installed in various places inside the buildings. An access point would function like a virtual satellite. This paper hereby presents a hybrid GPS-WLAN positioning system with triangulation technique.

2. Hybrid Technique using two GPS satellites and an access point

Our proposed hybrid positioning technique uses a hybrid of GPS or WLAN. At start, a receiver device tries to connect with the GPS satellites. If it cannot connect to all three of them, it will connect to one

or two WLAN access points in order to find the receiver's position. An access point then connects to a Location Measurement Unit (LMU) which, in turn, will connect to the GPS satellite(s) so as to synchronize the time between the satellites and the access point(s).

3. Triangulation Technique

Locating a user's position using GPS with Triangulation technique using three satellites (see figure. 1)

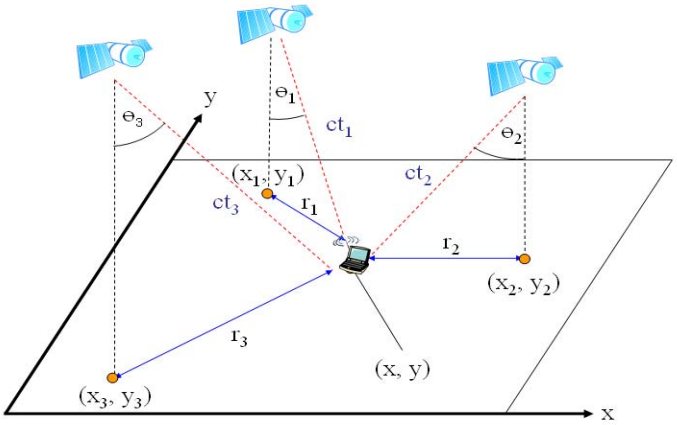

Figure 1 Locating position by GPS satellite.

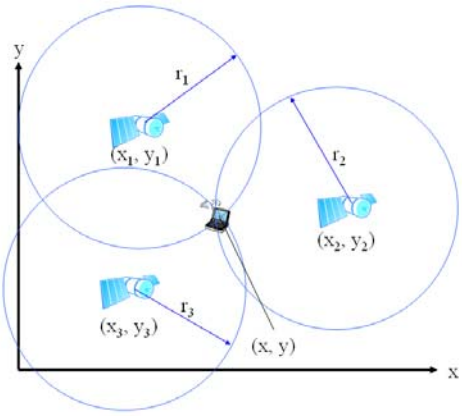

Figure 2 Locating position by GPS satellite.

Let θ_i be the angle between normal line of a satellite *i* and line from satellite *i* to receiver device, r_i be the distance between satellite *i* and receiver device on earth surface, (x_i, y_i) be a position of satellite *i* on earth surface when looks from the above to below and (x, y) be the position of a receiver device.

For the intersection position of three circles as shown in figure 2, each circle results from the signal propagation by a satellite to a receiver device. Using but three of them may not intersect into a single point because of delay error on GPS such as delay error from Ionosphere[5,6], non-synchronize clock between GPS satellite and receiver device[7], delay from Troposphere[8], Signal multipath[9], Orbit error of GPS satellite[10], GPS satellite geometry/shading[10] which is the result of overlapping space of three signal propagation circles. In order to make the three circles intersect at the exact same point (the desired position), we need to adjust the signal propagation time which is the delay error by a constant. Two equations: $f(x,y)$ and $g(x,y)$ are used to locate the position (x, y) as follows.

$$f(x,y) = \sin\theta_2\sqrt{(x-x_1)^2+(y-y_1)^2} - \sin\theta_1\sqrt{(x-x_2)^2+(y-y_2)^2} - c^2\sin\theta_1\sin\theta_2(t_1-t_2) \quad \text{.....(1)}$$

$$g(x,y) = \sin\theta_3\sqrt{(x-x_2)^2+(y-y_2)^2} - \sin\theta_2\sqrt{(x-x_3)^2+(y-y_3)^2} - c^2\sin\theta_2\sin\theta_3(t_2-t_3) \quad \text{.....(2)}$$

Solve equation (1) and (2) in order to find value (x, y) using Newton method.

$$f_x(x,y) = -\frac{(x-x_2)\sin\theta_1}{\sqrt{(x-x_2)^2+(y-y_2)^2}} + \frac{(x-x_1)\sin\theta_2}{\sqrt{(x-x_1)^2+(y-y_1)^2}} \quad \text{.....(3)}$$

$$f_y(x,y) = -\frac{(y-y_2)\sin\theta_1}{\sqrt{(x-x_2)^2+(y-y_2)^2}} + \frac{(y-y_1)\sin\theta_2}{\sqrt{(x-x_1)^2+(y-y_1)^2}} \quad \text{.....(4)}$$

$$g_x(x,y) = -\frac{(x-x_3)\sin\theta_2}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{(x-x_2)\sin\theta_3}{\sqrt{(x-x_2)^2+(y-y_2)^2}} \quad \text{.....(5)}$$

$$g_y(x,y) = -\frac{(y-y_3)\sin\theta_2}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{(y-y_2)\sin\theta_3}{\sqrt{(x-x_2)^2+(y-y_2)^2}} \quad \text{.....(6)}$$

Thus, value of x_{n+1} and y_{n+1} are:

$$x_{n+1} = x_n - \frac{g_y(x_n,y_n)f(x_n,y_n) - f_y(x_n,y_n)g(x_n,y_n)}{f_x(x_n,y_n)g_y(x_n,y_n) - f_y(x_n,y_n)g_x(x_n,y_n)} \quad \text{.....(7)}$$

$$y_{n+1} = y_n - \frac{-g_x(x_n,y_n)f(x_n,y_n) + f_x(x_n,y_n)g(x_n,y_n)}{f_x(x_n,y_n)g_y(x_n,y_n) - f_y(x_n,y_n)g_x(x_n,y_n)} \quad \text{.....(8)}$$

4. Improving triangulation technique

Triangulation technique used in GPS only has to account for a signal propagation deviation which is a constant value. However, such delay position error values measured of a satellite and that of an access point are unequal. When we use the same delay position error constant in triangulation technique to find a receiver's position using our hybrid GPS-WLAN approach, it results in a big discrepancy of the calculated position. Figure 2 shows that *(x', y')* is real position of receiver device but the *(x, y)* position is a position calculated from triangulation technique.

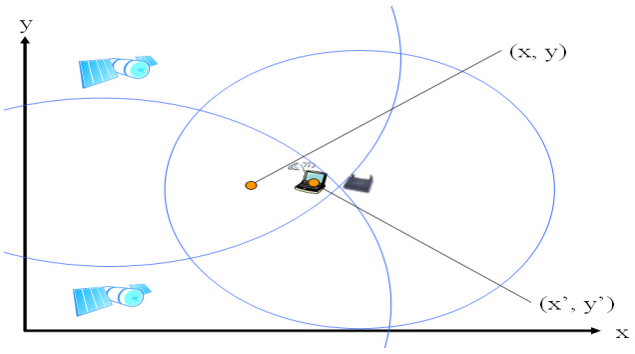

Figure 3 Show errors positioning between GPS and WLAN by using original triangulation technique.

To solve the above problem when using our hybrid GPS-WLAN approach, the improvement on the triangulation technique based on an assumption that the delay causing position error varies proportionately to the average delay position error.

Let $f_x(x,y)$ be the differentiation of $f(x,y)$ compared with x, $f_y(x,y)$ be differentiation of $f(x,y)$ compared with y, $g_x(x,y)$ be differentiation of $g(x,y)$ compared with x and $g_y(x,y)$ be differentiation of $g(x,y)$ compare with y. We can derive the following equations.

$$f(x,y) = d_3 \sin\theta_3\sqrt{(x-x_1)^2+(y-y_1)^2} - d_1 \sin\theta_1\sqrt{(x-x_3)^2+(y-y_3)^2} + c^2 \sin\theta_1 \sin\theta_3(d_1t_3 - d_3t_1) \quad \ldots (11)$$

$$g(x,y) = d_3 \sin\theta_3\sqrt{(x-x_2)^2+(y-y_2)^2} - d_2 \sin\theta_2\sqrt{(x-x_3)^2+(y-y_3)^2} + c^2 \sin\theta_2 \sin\theta_3(d_2t_3 - d_3t_2) \quad \ldots (12)$$

$$f_x(x,y) = -\frac{d_1(x-x_3)\sin\theta_1}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{d_3(x-x_1)\sin\theta_3}{\sqrt{(x-x_1)^2+(y-y_1)^2}} \quad \ldots (13)$$

$$f_y(x,y) = -\frac{d_1(y-y_3)\sin\theta_1}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{d_3(y-y_1)\sin\theta_3}{\sqrt{(x-x_1)^2+(y-y_1)^2}} \quad \ldots (14)$$

$$g_x(x,y) = -\frac{d_2(x-x_3)\sin\theta_2}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{d_3(x-x_2)\sin\theta_3}{\sqrt{(x-x_2)^2+(y-y_2)^2}} \quad \ldots (15)$$

$$g_y(x,y) = -\frac{d_2(y-y_3)\sin\theta_2}{\sqrt{(x-x_3)^2+(y-y_3)^2}} + \frac{d_3(y-y_2)\sin\theta_3}{\sqrt{(x-x_2)^2+(y-y_2)^2}} \quad \ldots (16)$$

Therefore, the value of x_{n+1} and y_{n+1} taken from the calculation in (11), (12), (13), (14), (15) and (16) will be used in the equation (7) and (8).

5. Results

First of all, an experiment is done to find a delay causing position error on WLAN. A ping-pong program was run sending a short message from a laptop to another laptop repeatedly for 1,000,000 times. The average delay of 1,040,326 nanoseconds and standard deviation of 40,722.98 nanoseconds were measured from the experiment and the numbers are used in our later experiments. Next, the experiments for locating a position using GPS only, WLAN only and hybrid of GPS and WLAN are done as shown in table 1. Each approach was experimented 1,000 times and the average position discrepancies and the standard deviations are recorded. The cause of the high standard deviation when using two access points and a satellite with triangulation technique improvement was from the access points' high delay discrepancy. The experiment results can be concluded in table 1.

Table 1 Experimental results

Technique	Positioning Method	Average error (meters)	Standard deviation
Original triangulation technique	• GPS	1.67	31.14
	• WLAN	31,706.89	47,666.09
	• 2 GPS satellites 1 access point	279,611.30	897,803.20
	• 1 GPS satellite 2 access points	195,682.60	69,308.42
Improved triangulation technique	• 2 GPS satellites 1 access point	28.36	553.55
	• 1 GPS satellite 2 access points	21,847.77	41,560.46

6. Conclusion

Locating a position using GPS alone has proven to obtain the most accurate result because delay error is only 17 nanoseconds. However, locating a position using WLAN alone results in a much larger error than using GPS because delay error is as large as 1 millisecond. Evidently, delay error on WLAN depends on several factors such as application software, operating system and hardware. Using a hybrid approach between GPS and WLAN with the original triangulation technique does not work well because it does not consider the effect of having different types of signal sources which induce a large position error. Taking the effect into account by adjusting the delay from GPS and WLAN can improve the triangulation technique and thus makes the acceptable position result. In the case of using two GPS satellites and an access point the position discrepancy is within 28.356 meters, but with one GPS satellite and two access points the position discrepancy grows to 22 kilometers due to the greater delay error from the use of access point. Therefore, in the city area where a receiver device may not receive signals from all three satellites, it is reasonable and acceptable to adopt our technique of using two GPS satellite and an access point in order to find a desired position.

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