Location-based Service with GPS-WLAN Positioning Technique Using Signal Strength

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Abstract

The Global Positioning System, GPS, is the fully-functional satellite navigation system. At least three GPS satellites are required for broadcasting precise timing signals by radio to GPS receiving stations on the earth to accurately determine a location. However, the system is not very effective when used in city areas with crowded high-rise buildings. Therefore, this research proposes a technique using a hybrid scheme with GPS satellites and WLAN access points to provide a location-based service using signal strength measurement technique. The signal strength acquired is used for calculating a distance between the sending station and the receiving station and later be used with Triangulation technique to find a requested location.

Keywords: Positioning system, Hybrid Positioning System, Location-based Service, GPS

1. Introduction

Location-based services are useful in many applications. For example, they are needed especially for finding a missing person at a disaster time or locating a stolen item, etc. [1]

GPS uses Triangulation technique to calculation a location. In a big crowded area with high-rise building, the accuracy of the calculated result is deteriorated because it must acquire the data from at least three GPS satellites to find a location on our two dimensional earth surface. If a person requesting for a service is inside a building where GPS signal having troubled reaching, it is difficult to obtain such a service.

A number of researches proposed techniques using GPS together with the Global System for Mobile Communications (GSM) [1], GPS and the wireless LAN IEEE 802.11 [2], etc.

2. Free-Space Propagation

The attenuation undergone by an electromagnetic wave in transit between a transmitter and a receiver in a telecommunication system or the loss in signal strength that would result if all absorbing, diffracting, obstructing, refracting, scattering, and reflecting influences were sufficiently removed so as to have no effect on its propagation.is called *free-space path loss*, L_f, can be defined as:

$$L_f = \frac{P_t}{P_r} \tag{1}$$

$$L_f = \frac{1}{G_r G_t}(\frac{4\pi d}{\lambda})^2 \tag{2}$$

where

L_f - Free space path loss (Watts)

P_t - transmitted power

P_r - received power

G_t - Transmitter Gain

G_r - Receiver Gain

d - the distance or radius of the signal from the transmitter

λ - the signal wavelength

When $G_t = G_r = 1$, free-space path loss equation can be derived in dB as:

$$L_f = 20\log(\frac{4\pi d}{\lambda}) \tag{3}$$

where L_f - free space path loss (dB)

λ - the signal wavelength

3. Land Propagation

In wireless telecommunications, the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths is called multipath. Its causes include atmospheric ducting, ionospheric reflection and refraction, and reflection from terrestrial objects, such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal[8].

The environment which the signal propagates through contributing to the signal transmission as the following equation[3].

$$P_r = \frac{G_t G_r P_t}{L} \qquad (4)$$

where

L - free-space path loss can be subdivided into three parts.

$$L = L_P L_S L_F \qquad (5)$$

L_P - path loss

L_S - slow fading loss
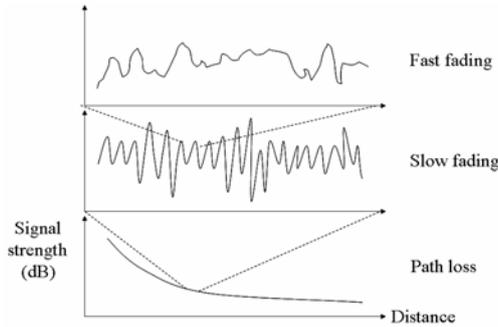
L_F - fast fading loss

Fig.1: Schematic diagram of propagation loss

3.1 Slow Fading

Slow Fading is the result of shadowing by building, moiuntains, hills and other objects. The average within individual small areas also varies from one small area to the next in a random manner. The variation of the average is frequently described in the terms of average power in dB

3.2 Fast fading

Fast fading occurs if the channel impulse response rapidly within the symbol duration. It is due to reflections of local objects and the motion of the objects relative to those objects. The receive signal is the sum of a number of signals reflected from local surfaces and these signals sum in a constructive or destructive manner – relative phase shift. In case which the receiving device is close to the signal originator, the probability distribution of the signal amplitude of all multi-path is Gaussian distribution , Phase distribution which is a uniform distribution on the range of $(0, 2\pi)$ radian and Probability distribution of the sum of a number of signals is Rayleigh distribution having Probability density function as:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \qquad (13)$$

where r - numbers of the reflected signal,
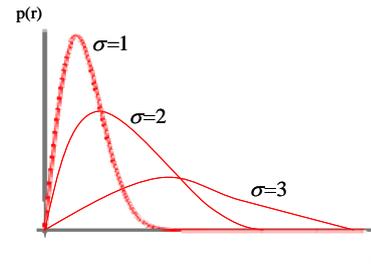
σ - a standard deviation

Fig.3: Probability density function of Rayleigh distribution

In case which the receiving device is far from the signal originator the probability distribution of the signal amplitude of all multi-path is Gaussian distribution, Phase distribution -- Uniform distribution in the range of $(0, 2\pi)$ radian. The probability distribution of the sum of a number of signals is Rician distribution having probability density function as:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{(r^2 + \alpha^2)}{2\sigma^2}} I_0(\frac{\alpha r}{\sigma}) \qquad (14)$$

where I_0 - Zero-order modified Bessel function and I_0 is defined by:

$$I_0(x) = \frac{1}{2\pi} \int_0^{2\pi} e^{x\cos\theta} d\theta \qquad (15)$$

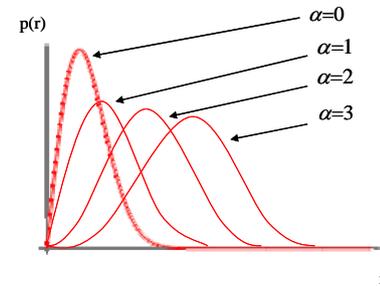$$I_0(x) \approx \frac{e^x}{\sqrt{2\pi\theta}} \qquad (16)$$

Fig.4: Probability density function of envelope of composite signals according to Rician distribution

4. Triangulation Technique

GPS uses Triangulation Technique for calculating a location which requires at least three satellites. See the algorithms and the derivation in [2].

5. Experiments

We started our experiment by measuring Rayleigh and Rician fading values on the Glomosim simulator. We measured the value on each round for 10,000 times. Our assumptions are that:

1. the simulated two-dimensional area has the width and length of 200 meters
2. there is no node movement in the system
3. the minimum signal strength that a node can still picked up the signal is -81.0 dBm
4. there exists noise interference
5. the signal strength at the transmitting node is 15 dBm
6. there is no signal at both transmitting node and receiving node

We did our experiments on four scenarios: all GPS, all WLAN access points, 2 GPS and 1 WLAN access point, 1 GPS and 2 WLAN access points with following assumptions.

1. GPS satellite is 20,200 km orthogonal to the earth surface.
2. The location requesting device is immobile.
3. The angle between the device and the GPS satellite less than 55 degrees.
4. Average delay error is 17 nanoseconds and standard deviation is 1 [7].
5. The distance between location device and a WLAN access point is not farther than 100 meters.
6. The angle between the device and the access point is between 0 to 720 degrees.
7. Error of device location from calculating position not more than 0.001 meter.

6. RESULTS

Using GPS alone results in an average positioning error of 0.508612 meter with a standard deviation of 2.792299 meters.

When using pure wireless LAN and Rayleigh distribution fading, the best case (sd=0.6) yields an average positioning error of 13.53194 meters and a standard deviation of 25.416 meters, while the worst case (sd=2.0) yields an average positioning error of 23.31718 meters and a standard deviation of 37.38275 meters. With Rician distribution fading, the best case (k=4) of an average positioning error of 11.09718 meters and a standard deviation of 24.71701 meters, while the worst case (k=1) yields an average positioning error of 11.51309 meters and a standard deviation of 18.78252 meters.

When using two GPS satellites and one WLAN access point, with Rayleigh distribution fading, the best case yields an average positioning error of 9.937714 meters and a standard deviation of 9.102256 meters, while the worse case yields an average positioning error of 24.07428 meters and a standard deviation of 27.96546 meters. With Rician distribution fading, the best case yields an average positioning of 3.020781 meters and a standard deviation of 4.885848 meters, while the worst case yields an average positioning error of 7.807562 meters and a standard deviation of 13.49027 meters.

When using one GPS satellites and two access points, with Rayleigh distribution fading, the best case yields an average positioning error of 17.93405 meters and a standard deviation of 39.2767 meters, The worst case

yields an average positioning error of 31.52143 meters and a standard deviation of 76.34837 meters. With Rician distribution fading, the best case yields an average positioning error of 18.16296 meters and a standard deviation of 50.24907 meters, while the worst case yields an average positioning error of 15.59062 meters and a standard deviation is 42.78029 meters.

Table 1: Results of Position

Signal source	Fading	Average error	SD error
GPS	-	0.508612	2.792299
Wireless LAN	Rayleigh (B)	13.53194	25.416
	Rayleigh (W)	23.31718	37.38275
	Rician (B)	11.09718	24.71701
	Rician (W)	11.51309	18.78252
2 SATs 1 AP	Rayleigh (B)	9.937714	9.102256
	Rayleigh (W)	24.07428	27.96546
	Rician (B)	3.020781	4.885848
	Rician (W)	7.807562	13.49027
1 SAT 2 APs	Rayleigh (B)	17.93405	39.2767
	Rayleigh (W)	31.52143	76.34837
	Rician (B)	18.16296	50.24907
	Rician (W)	15.59062	42.78029

Comment: B – Best case
W – Worst case

7. CONCLUSIONS

Locating a position using GPS alone has proven to obtain the most accurate result because delay error is only 17 nanoseconds. In case of using pure wireless LAN position error is between 11 to 24 meters. When using two GPS satellites and one access point position error is between 3 to 25 meters. However, in this case using time/delay for distance measurement proves to be better than using signal strength [2]. In case of positioning with one GPS satellite and two access points position error is between 17 to 32 meters. Therefore, when receiver device can receive signal from three or more GPS satellites we suggest finding a position using pure GPS. But if a device can receive signal from only two GPS satellites, we suggest finding a position by using two GPS satellites and one access point with time measurement and using modified triangulation technique. But in case that a device can receive signal from only one GPS satellite, we suggest finding a position using pure wireless LAN with signal strength measurement.

8. Future Work

There is a chance that any of location results calculated from Triangulation technique can unusually deviated from the actual location. Hence, to avoid that to happen, for each location request the calculation must be done several times and then choose the one with closer proximity to other result or a centroid of the group regardless of the error result as a returning result. For example, if the calculation is done four times and the

distance deviations are 1.5, 1.76, 3 and 390 meters. The 390 results can be thrown away as it deviates too much.

9. Acknowledgement

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