An Indoor Location Scheme Based on Wireless Local Area Networks

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Abstract—**This paper presents an indoor location scheme based on wireless local area networks, where the position of a mobile terminal is estimated according to the measured signal-to-noise ratio (SNR) information from multiple access points. With the antenna pattern-measurement method for measuring the SNRs, pretty good location estimates can be obtained. Our experimental results show that more than 85 percent of the estimated locations have error distances less than two meters.**

Keywords-antenna pattern-measurement method; location scheme; signal-to-noise ratio; wireless local area network

I. Introduction

Location-aware services have received great attention in wireless networks [1], [2]. There have been a number of location techniques using the Global Positioning System (GPS) or cellular networks proposed in the literature. The GPS is based on a well-known concept called the triangulation technique [3], which can work accurately outdoors but fails indoors due to the blocking of buildings between satellites and the GPS receiver. In a cellular network, each mobile terminal (MT) can measure the time of arrival, the time difference of arrivals, or the angle of arrival to derive the location information [4], [5]. Although such approaches have been shown to be effective in outdoor environments, their location capabilities are limited in indoor environments due to multiple reflections and refractions of the signal.

Several approaches have been adopted for estimating the location of an MT indoors [6]. Among them, the existing structure of wireless local area networks (LANs) offers an inexpensive solution to the indoor location estimation problem. The first location system based on such an approach is called RADAR [7], which operates by measuring and recording the signal strength (SS) information of a number of sampled locations during the off-line phase and then inferring the location of an MT based on the recorded SS database information in the real-time phase. There are two approaches of RADAR to determine the location of an MT in the real-time phase; one is the empirical method that compares the observed SS with the recorded SS database and picks the best-matched one as the location estimate; the other is the signal propagation modeling method that estimates the location of an MT based on a radio propagation model constructed in the off-line phase based on the recorded SS database information. In general, the latter approach reduces the computational complexity of the real-time phase with degraded location accuracy, as compared to the former one.

A location system based on wireless LAN can adopt an infrastructure-based or client-based deployment [8]; for an infrastructure-based deployment, a group of access points (APs) collect the signal measurements from an MT and send them to a central server for location estimation; for a client-based deployment, an MT reports the signal measurements from different APs to a central server for location estimation. Basically, a client-based system may provide better location accuracy than an infrastructure-based system, but the management issues (including provisioning, security, deployment, and maintenance) are easier to handle for the latter than for the former.

In this paper, we propose a client-based location scheme using wireless LANs for indoor applications, where each MT gathers signal-to-noise ratios (SNR) from multiple APs for location estimation. In the proposed scheme, the SNR information is obtained from a simple antenna pattern-measurement technique. Experimental results demonstrate that more than 85 percent of the locations estimated using the proposed SNR-based scheme have error distances less than two meters. Such location accuracy is better than that achieved by the SS-based RADAR system in [7].

II. Research Methodology

A. Experimental Environment

Our experimental testbed was located on the sixth floor of a building, where the floor layout is shown in Fig. 1. We placed four access points, AP1, AP2, AP3, and AP4, at the corners of a rectangle region. Each AP was a laptop computer with an IEEE 802.11b wireless adapter using a directional patch antenna. The sampled locations for SNR information measurement during the off-line phase are along the four hallways as illustrated in Fig. 1, with 2 m separation between adjacent points. The wireless LAN adopted can provide a data rate of 1, 2, 5.5, or 11 Mbps, from channels 1 to 11, and the transmitted power can be 1, 5, 20, 30, 50, or 100 mW. The four APs were assigned with four different channels for data transmission.

B. Data Collection and Processing

During the off-line phase, the transmitted power of each AP was set to be the maximum level (100 mW). We used the

This work was supported by the National Science Council of the Republic of China under Grant NSC 93-2752-E-007-003-PAE.

Aironet Client Utility [9] as the measuring tool to gather the SNR information of the radio signal, where the diversity antenna and the ad hoc mode were chosen. Since each AP makes use of a directional patch antenna for signal transmission, it will provide more energy in one direction and less energy in the other directions. In order to measure the SNR information more accurately, the simple antenna pattern-measurement method described in [10] was adopted. With this technique, the receiver antenna of an MT was placed on a turntable, which was rotated such that the antenna was directed to the north, south, east, and west directions consecutively. We measured the SNRs and noise levels from each AP in the four directions and then averaged all of the results to form the database, where some of the results are shown in Fig. 2. This means that we have the advantages of space-time average in measuring the SNR information. According to SNR information from the four APs, we can determine the location of an MT by picking the one from the recorded database that best matches the observed SNR information during the real-time phase. Note that the noise level of the real-time phase may be different from that of the off-line phase. To compensate this difference, we need to calibrate the measured SNRs stored in the database before the matching process is performed. Let SNR_i^o and N_i^o denote the measured SNR and noise level form APi in the off-line phase, respectively. Also, let SNR_i^r and N_i^r denote the corresponding information in the real-time phase. Then the calibrated SNR (denoted by $CSNR_i^o$) for APi used for the matching process can be expresses by

$$CSNR^o = SNR_i^o + N_i^o - N_i^r \qquad \text{[dB]} \qquad (1)$$

With the calibrated SNRs, the matching process will need to compute the following Euclidean distance for each sampled point or location in the database:

$$\text{Euclidean Distance} = (\sqrt{\sum_{i=1}^{4} (SNR_i^r - CSNR_i^o)^2} \qquad (2)$$

III. Emperimental Results and Discussion

In our experiments, we used time average (60 seconds to get stable data) and space average (4 directions via the MT rotation) to measure the SNR information. This means that it will take 16 minutes to collect the SNR information of one sampled location.

Fig. 3 illustrates how the measured SNR from each of the four APs varies as the MT walks along the upper hallway in Fig. 1 from left to right. It is clear that the measured SNR is getting stronger when the MT is moving close to the corresponding AP, and is getting weaker when the MT is moving far away from the AP. Moreover, measured SNRs from an AP in line-of-sight paths with respect to the MT are generally much higher than those from an AP in non-line-of-sight paths. These properties support that the use of SNR information to estimate the MT location is a promising approach.

Fig. 4 shows the cumulative distribution function (CDF) of the error distance for the proposed SNR-based location scheme. It is obvious that increasing the total number of APs from 1 to 2 or more can provide a significant improvement in location accuracy. However, the performance improvement is saturated when the total number of APs is increased from 3 to 4. This means that three APs can provide enough SNR information for locating an MT in our experimental environment. It is worth noting from the experimental results that more than 85 percent of the estimated locations have error distances less than 2 m. Fig. 5 presents the CDF of the error distance for the SS-based location scheme in [7]. It is apparent the experimental results are rather similar to those shown in Fig. 4.

A comparison of the proposed SNR-based location scheme and the SS-based location scheme in terms of the CDF of the error distance are given in Fig. 6. It should be noted that the latter outperforms the former when only one AP is considered. This may be due to the fact that the SNR-based mechanism is more sensitive to the noise level than the SS-based mechanism (without using the noise information) for the case of one AP. When the total number of APs is equal to 2 or more, the location accuracy of the SNR-based scheme is better than the SS-based scheme. This can be explained as follows. Assume that there are two candidate locations with the same signal strength but different noise levels to be chosen by a location scheme. In this case, the SS-based cannot tell these two points apart and may select a worse candidate as the location estimate; on the contrary, the SNR-based scheme can distinguish these two points and make a better decision for the location estimate.

IV. Conclusion

In this paper, we have proposed an SNR-based mechanism for locating MTs in wireless LANs for indoor applications, where an antenna pattern-measurement method is used for measuring the SNR information. For the proposed scheme, SNRs and noise levels from multiple APs are measured at some sampled locations of an MT to form a database during the off-line phase. The noise levels measured in the off-line and real-time phases are used to calibrate the SNRs stored in the database. The MT location is then determined by picking the one from the calibrated database that best matches the measured SNR information in the real-time phase. As compared to the RADAR location system that makes use of SS information gathered from multiple APs to estimate the MT location inside buildings, the proposed SNR-based location scheme provides better performance.

References

[1] C. A. Patterson, R. R. Muntz, and C. M. Pancake, "Challenges in location-aware computing," *Pervasive Computing*, vol. 2, pp. 80-89, April/June 2003.

[2] J. N. K. Synnes and P. Parnes, "An architecture for location aware applications," in *Proc. 35th Annual HICSS*, Jan. 2002, pp. 3805-3810.

[3] D. P. Agrawal and Q. A. Zeng, *Introduction to Wireless and Mobile Systems*. Thomson Learning, 2003.

[4] D. Niculescu and B. Nath, "Ad hoc positioning system (APS) using AOA," in *Proc. IEEE INFOCOM 2003*, vol. 3, March 2003, pp. 1734-1743.

[5] I. K. Adusei, K. Kyamakya, and K. Jobmann, "Mobile positioning technologies in cellular networks: an evaluation of their performance metrics," in *Proc. MILCOM 2002*, vol. 2, Oct. 2002, pp.1239-1244.

[6] K. Pahlavan, X. Li, and J. P. Makela, "Indoor geolocation science and technology," *IEEE Commun. Mag.*, vol. 40, pp. 112-118, Feb. 2002.

[7] P. Bahl and V. N. Padmanabhan, "RADAR: An in-building RF-based user location and tracking system," in *Proc. IEEE INFOCOM 2000*, vol. 2, May 2000, pp. 775-784.

[8] P. Krishnan, A. S. Krishnakumar, W. H. Ju, C. Mallows, and S. Ganu, "A system for LEASE: Location estimation assisted by stationary emitters for indoor RF wireless networks," in *Proc. IEEE INFOCOM 2004*, March 2004.

[9] http://www.cisco.com.

[10] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*. New York: John Wiely & Sons, 1998.

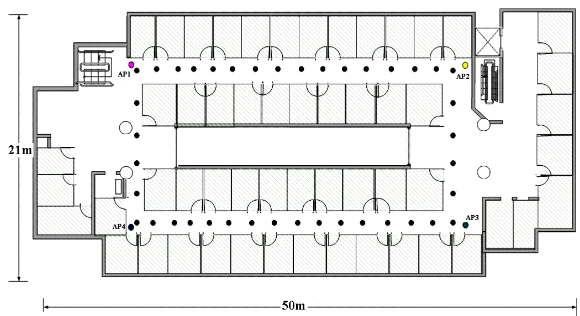

Figure 1. The floor layout of our experimental environment.

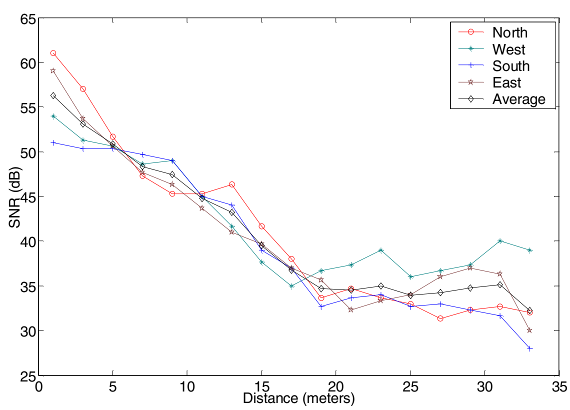

Figure 2. Measured SNRs from an AP in the four directions and their average result.

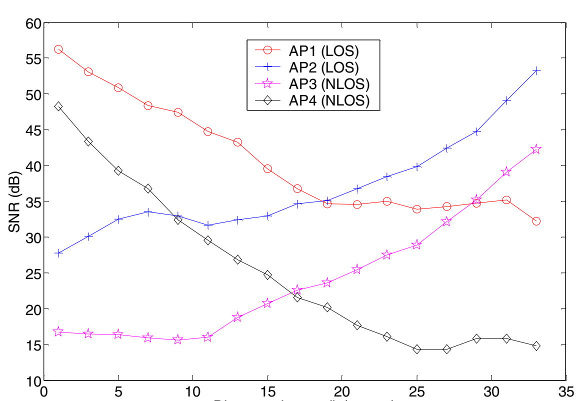

Figure 3. Measured SNRs from the four APs as the MT walks along the upper hallway in Fig. 1 from left to right. AP1 and AP2 to MT: LOS (line-of-sight); AP3 and AP4 to MT: NLOS (non-line-of-sight).

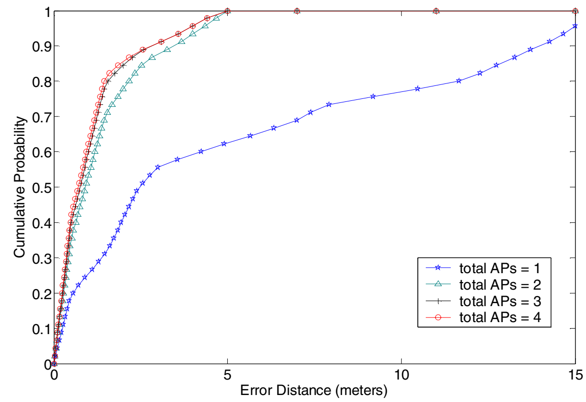

Figure 4. Cumulative distribution function of the error distance for the proposed SNR-based location scheme.

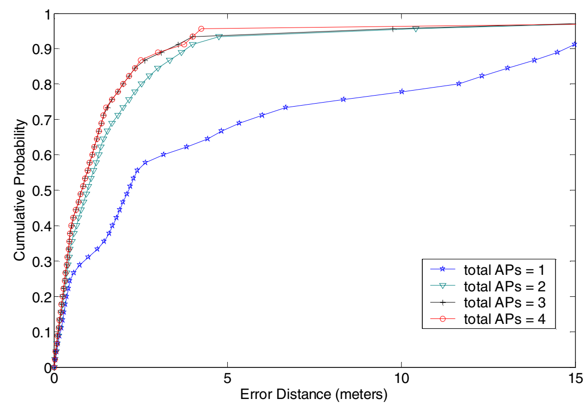

Figure 5. Cumulative distribution function of the error distance for the SS-based location scheme in [7].

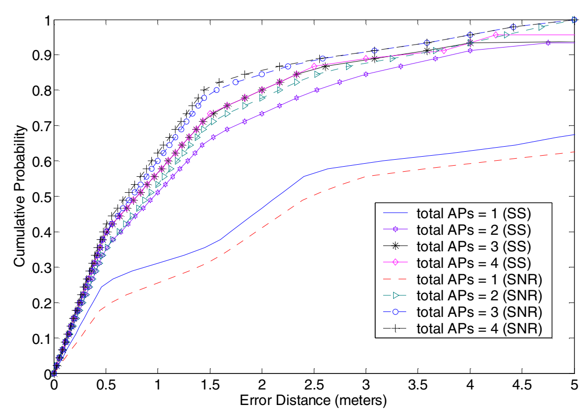

Figure 6. Comparison of the proposed SNR-based location scheme and the SS-based location scheme in [7] in terms of the cumulative distribution function of the error distance.