Adaptive-Weighting Schemes for Location-based Services over Heterogeneous Wireless Networks

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Abstract—**Global positioning systems, widely known as GPSs, provide timing, navigation, and positioning signals to military and civilian users. When a GPS receiver receives satellite signals, the distance between the satellite and the user is first calculated, and then the user's current position is located using the triangulation method. However, there is a possibility that atmospheric conditions, multipath fading, and shadowing effects could have an impact on the satellite signal. As wireless technology has progressed, different user locations and locating systems have been invented, such as the WiFi locating system, which mainly uses received signal strength indication (RSSI) to set up radio maps that provide locations, and RF models to estimate the locations of a moving user. The Zigbee locating system tracks the position of blind nodes, using RF signal strength calculation and known coordinates to estimate the distance between reference points. Using the triangulation method, Zigbee searches for blind node coordinates. This research proposes an adaptive-weighting locating mechanism within wireless heterogeneous networks, which enhances GPS's ability to receive signals in buildings and precision in estimating locations.**

Keywords-GPS; WiFi; Zigbee; Location-based service (LBS)

I. INTRODUCTION

In recent years, with the rapid growing of wireless communications technology, location-based services (LBS) have received great attention in commercial, public safety, and military applications [1]. Also, because of the proliferation of GPS and increased interest in location-aware systems and services, combining wireless technology with locating systems has become a popular proposal [2]. Thus LBS can provide users with appropriate information at different locations. Understanding how to detect a user's position and enhancing precision have become important factors for such services and technology.

GPS is the most commonly utilized outdoor technology. GPS receivers receive signals from GPS satellites, and calculate the distances between GPS receivers and satellites with time difference, and the triangulation method calculates a client's location (the longitude and latitude) [3]. However, if a client simply uses a GPS locating system, a huge estimation error will occur at places that cannot receive satellite signals (due to the atmospheric conditions, multipath fading, and shadowing effects). This paper combines GPS, WiFI and Zigbee methods of positioning and proposes an adaptive-weighting locating mechanism to enhance estimation precision and allow LBS to be applied both indoors and outdoors.

II. RELATED WORK

To date, few studies have investigated related research on wireless heterogeneous networks. In 2003, when GPS was unreliable, Hyung Chul Son and his team proposed to combine GPS and mobile phones to form a locating system with fewer estimation errors [4]. This research is suitable for larger areas of positioning. Another related research project was conducted at India's C-DAC (Centre for Development of Advanced Computing, C-DAC) in 2007 combined the Ultra Wide Band with the WiFi locating system, which uses WiFi's characteristic signal strength attenuation with distance to back step a user's distance from AP and estimate user's location with the triangulation method [5]. The Ultra Wide Band and WiFi combination also uses UWB's high frequency signals, which are not easily hindered or reduced by moving objects in the environment, to calculate a user's precise location. This research combines two different wireless internet technologies and enhances estimation precision. However, precision is relatively proportional to calculation complexity. Increasing number of users utilizing this system will also affect real-time positioning.

A. Global Positioning System

The global positioning system (GPS) is a United States government invention, which has gradually become ubiquitous. The basic concept (triangulation method) of GPS is to constantly send signals to Earth from twenty-four satellites in six orbits around the Earth. As a user's GPS receives signals from more than three GPS satellites, satellites refer to the GPS as the center. Using TOA to calculate the radius from the GPS to the satellites, the GPS then draws from three Earth surfaces, and the point of intersection of the three surfaces is where the GPS receiver is located as shown in Figure 1[2][3].

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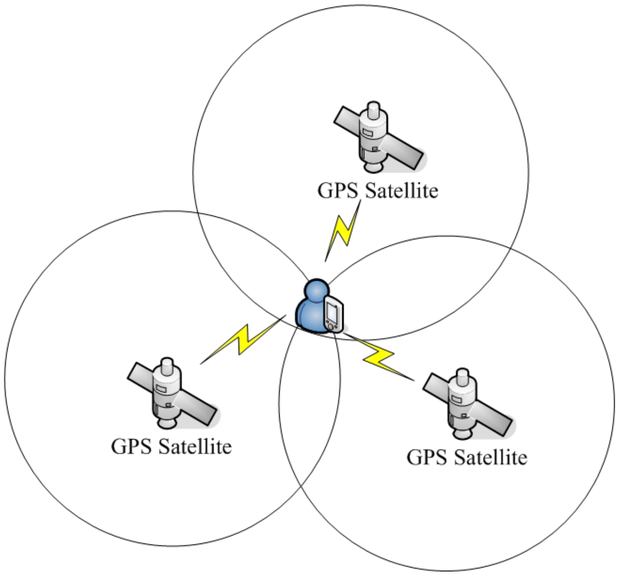

Fig. 1. A GPS receiver calculates a client's location by using the triangulation method.

B. RADAR Locating System

In 2000, Microsoft presented RADAR locating technology, at IEEE INFOCOM, which uses signal indication strength to locate users. RADAR technology has two stages: off-line and on-line. The off-line stage notices every training point, and collects signal indication strength and signal strength and noise ratios (SNR) of different Access Points (AP); when on-line and after the signal strength is measured, the Euclidean Distance formula is used to calculate the difference, and even the tiniest difference can determine user position. This is also known as the signal pattern matching method [6].

C. Zigbee Locating System

The Zigbee network is based on IEEE 802.15.4. Zigbee has characteristics such as low transfer rate, low power, low cost, and it supports a large number of network nodes. Zigbee uses AODV (Ad hoc On-Demand Distance Vector Routing) between nodes to establish and maintain routing, and also exchanges information during the route maintenance process. Zigbee locating systems include three main models: coordinator, reference node, and blind node. The coordinator is directly connected to computers, and the information collected by the coordinator is then processed by client positioning systems while reference nodes have a set position. After blind node joined the Zigbee network, broadcast messages were requested to be stationary, so reference nodes would send device IDs and coordinates to blind nodes when receiving broadcast messages. Thus, when blind node receives signals from neighboring reference nodes, the distance between reference nodes can be calculated through the converting signal strength and distance. Blind node coordinates can also be discovered using the triangulation method. Finally, blind nodes send coordinates, which are shown on the locating system to the coordinator through Zigbee [7].

III. SYSTEM STRUCTURE AND LOCATING SCHEME

The most popular outdoor tracking system, GPS, mainly receives signals from outer space satellites. GPS calculates the distance between the GPS receiver and satellites, and then locates the longitude and latitude of users by using the Triangulation method. However, when the GPS receiver is sheltered, there will be errors in location estimation [8]. Thus, this research combines different locating system over heterogeneous wireless network when less than eight GPS satellites send out signals, WiFi and Zigbee locating methods are included. Eventually, this research proposes an adaptive weighting locating mechanism.

A. System Structure

The LBS system used in this research can be split into two stages: off-line stage and on-line stage. When offline, the GPS collects the longitude and latitude information of training points in the experimental environment, and then establishes a radio map of WiFi network's AP signal strength indication. PDA user interface is shown in Figure 2. Finally, a coordinate database of reference nodes and training points of the Zigbee tracking system is established.

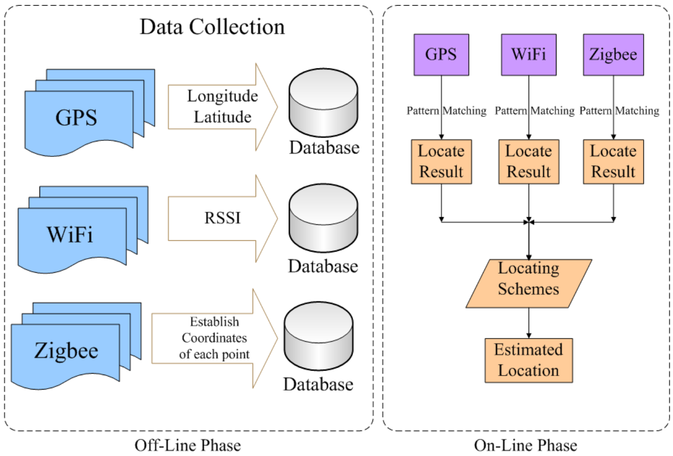

Fig. 2. The system structure divides two phases over heterogeneous wireless networks.

Using longitude and latitude results that GPS collected in its on-line stage and GPS information established when offline, GPS sets the smallest value as the positioning result after being compared with the Euclidean Distance formula. The WiFi network collecting signal strength is also compared to the information library to find the WiFi positioning result [8].

The Zigbee locating system uses the received signal strength to back step the distances between difference reference nodes, and calculates the blind spot coordinates using the triangulation method. The coordinates are compared with all established coordinates in the library to find the Zigbee positioning result.

Finally, using the three different positioning results and utilizing the adaptive weighting mechanism to find the user's location enhances estimation precision.

Using results of longitude and latitude that GPS collected in its on-line stage and GPS information established when offline, GPS sets the smallest value as the positioning result after being compared with the Euclidean Distance formula; the WiFi network collecting signal strength is also compared to the fingerprinting database to locate the user's position.

B. Experiment Environment

This research chose the management building of Ming Chuan University in Taiwan as the experimental environment, which is shown in Figure 2. The environment is 31 meters long, 19 meters wide, and has a total of 96 training points, with 1 meter distanced between each training point.

GPS signals, which include WiFi signals of AP and Zigbee signals as reference nodes, can be received in the experimental environment. Users can use these references to discover longitude and latitude, WiFi signal strength, and coordinates of blind nodes.

This experimental environment has 4 Linksys WRT350N AP, which are responsible for broadcasting IEEE 802.11b's Beacon frame. Different SSID are used to indicate signal source, and related settings are shown in Figure 3; the Zigbee tracking system model utilizes CC2430/CC2431EM, which are Zigbee wireless chips, made by Texas Instruments. The eight reference nodes (RN) used in the environment chips are CC2431EM, while blind nodes used CC2430. On the other hand, Coordinator used CC2430EB (includes CC2430/CC2431EM), which collects blind node positioning results that are then transferred to a computer directly connected to CC2430E.

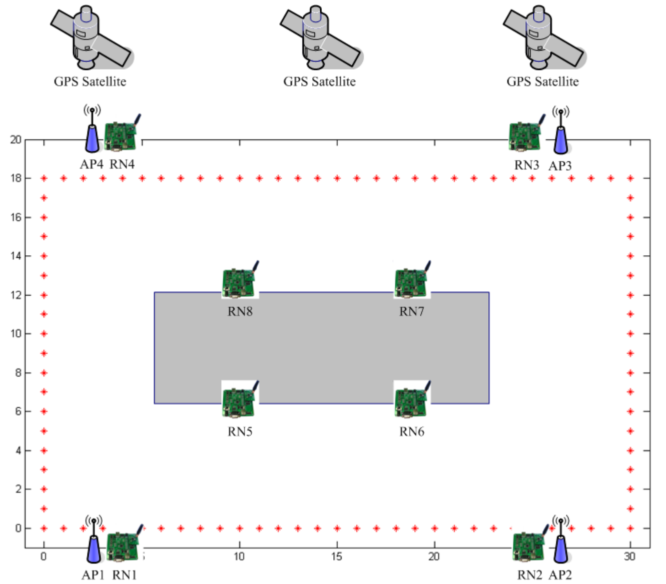

Fig. 3. The experiment environment includes GPS, WiFi, and Zigbee location systems.

C. Adaptive-Weighting Schemes

This paper proposes 2 schemes, and investigates the results of combining different positing systems, and uses adaptive weighting to evaluate effectiveness as listed in (1).

$$User(X,Y) = GPS(X,Y)*\alpha + Wifi(X,Y)*\beta + Zigbee(X,Y)*\gamma \qquad (1)$$

Scheme 1 mainly uses the Current Divider Rule for calculations [9], and views error distance (*ED*) as resistance, and adaptive-weighting as current; as the positioning distance error increases, the adaptive weighting decreases, and vice versa; the sum of reciprocals of distance error is used as the denominator to calculate three different adaptive weightings from (2) to (4). If adaptive weighting does not use a specific locating method, then the positioning distance error of that method is neglected. For example: If the Zigbee method is not used, then Zigbee's adaptive weighting and distance error is not put into the calculations.

$$Weight_{GPS} = \frac{\left(1/ED_{GPS}\right)}{\left(\left(1/ED_{GPS}\right)+\left(1/ED_{Wifi}\right)+\left(1/ED_{Zigbee}\right)\right)} = \alpha \qquad (2)$$

$$Weight_{Wifi} = \frac{\left(1/ED_{Wifi}\right)}{\left(\left(1/ED_{GPS}\right)+\left(1/ED_{Wifi}\right)+\left(1/ED_{Zigbee}\right)\right)} = \beta \qquad (3)$$

$$Weight_{Zigbee} = \frac{\left(1/ED_{Zigbee}\right)}{\left(\left(1/ED_{GPS}\right)+\left(1/ED_{Wifi}\right)+\left(1/ED_{Zigbee}\right)\right)} = \gamma \qquad (4)$$

Scheme 2 adapts weighting using the variance (*Var*) of the distance error method [10]. The variance calculations are based on different point statistics and variances. Taking this research as an example, the variance calculation method divides the 96 training points into four sections and calculates each variance separately. Then the reciprocal of variance is substituted as the numerator in the shunt equation, and the variance reciprocal sums of three locating systems are substituted as the denominator from (5) to (7).

$$Weight_{GPS} = \frac{\left(1/(Var_{GPS})\right)}{\left(\left(1/(Var_{GPS})\right)+\left(1/(Var_{Wifi})\right)+\left(1/(Var_{Zigbee})\right)\right)} = \alpha \qquad (5)$$

$$Weight_{Wifi} = \frac{\left(1/(Var_{Wifi})\right)}{\left(\left(1/(Var_{GPS})\right)+\left(1/(Var_{Wifi})\right)+\left(1/(Var_{Zigbee})\right)\right)} = \beta \qquad (6)$$

$$Weight_{Zigbee} = \frac{\left(1/(Var_{Zigbee})\right)}{\left(\left(1/(Var_{GPS})\right)+\left(1/(Var_{Wifi})\right)+\left(1/(Var_{Zigbee})\right)\right)} = \gamma \qquad (7)$$

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The positioning results of this research combine and adapt WiFi and Zigbee positioning results when GPS positioning condition is poor. GPS, WiFi, Zigbee average positioning errors. The experiment result indicates that GPS has an error of 1m, which is within one node in this experiment, when there are more than eight satellites sending signals (without any shelter that hinders reception). When there are only three to eight satellites, GPS positioning error is 14m, which indicates the importance of the amount of satellites.

Figure 4 is a method that combines GPS, WiFi, Zigbee locating methods, basing on results of positioning calculated with the positioning algorithm and Variance Error distance Method (Scheme 2). Although not as accurate as results of GPS without shelter, its result is much better than the results of WiFi and Zigbee. Even though the average adaptive weighting results acquired with Scheme 1 are inferior to those obtained with the variance adaptive-weighting method, the results are close to WiFi's positioning results. In addition, if based on average adaptive-weighting results, the average error is 3.47 meters, and precision of positioning within the 3 meters error distance is 0.58; if based on variance adaptive-weighting results, the average error is 2.22 meters, and precision of positioning within the 3 meters error distance is 0.81, which shows that Scheme 2 is the better choice to enhance G+W+Z positioning precision.

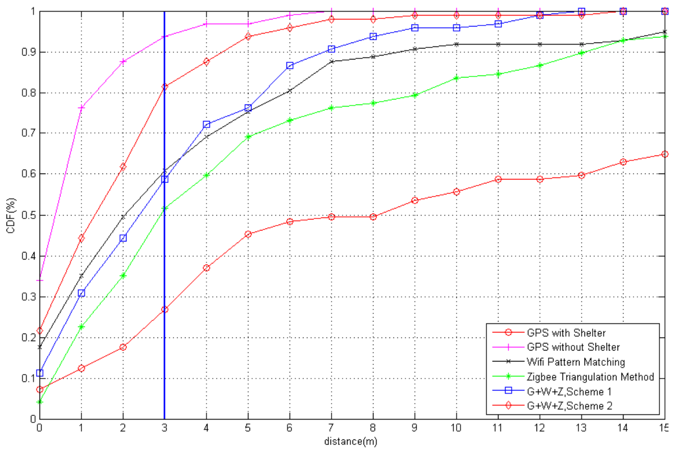

Fig. 4. The Cumulative Distribution Function (CDF) of error distance for different adaptive-weighting locating schemes.

V. Conclusion and Future Work

The paper discovered that combining different positioning methods enhances precision when there is a deficiency in the amount of satellites, and when precision is poor. This research further discovered that combining WiFi and Zigbee locating systems achieves precision almost as high as that of GPS without the shelters or atmospheric conditions.

If Scheme 2 of the paper is used for adaptive-weighting, this research hopes it can enhance positioning results. If the GPS receiver is sheltered, Scheme 2 provides the highest positioning precision because Scheme 2 works better when combining positioning methods that have low positioning precision.

This research adjusted adaptive weighting to previous errors on positioning errors, but the adjustment is still not big enough. Future experiments can add reference points into the environment, and when users reach those reference points, real-time adjustments can be made to positioning results and adaptive weighting. By combining different locating systems, this research enhanced positioning results and improved adaptive weighting efficiency.

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