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Comparison of WLAN and Geomagnetic Fields for Indoor Positioning

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***Abstract*— For positioning technology based on wireless local area networks (WLAN) in an area of high density of access points (AP), when a change in the conditions of the APs comprising the localization infrastructure occurs, a change in the pattern of signal strength occurs, and consequently,so the signal strength map should be updated. Owing to limitations arising from dependence on the existing radio waves, it is necessary to introduce other new resources guaranteeing constancy and other properties in indoor settings. The geomagnetic field can be used with a method to determine position that has constancy and property even without the establishment of indoor access points. Fingerprint localization is most suitable for indoor applications among stochastic models that estimate position by means of the value of signal strength, whereas in the case of geomagnetism, the strength of the geomagnetic field is used for database building. In this paper, we compare a method using the signal strength received from the WLAN and a method using magnetic- field-based real-time location systems from various perspectives, such as system complexity, accuracy, and stability. To evaluate the performance of these systems, we built several test fields with different types of environments. We will compare both approaches side-by-side and address issues such as optimal calibration step (measurement interval), location accuracy, effects of minor and major environment changes to the fingerprint database, and the overall system accuracy.**

Keywords-component; geomagnetic; RSSI; WLAN; indoor position;

I. INTRODUCTION

Location determination technology utilizing geographic location-based services that has become important with the growth of smart devices is the subject of this paper. In 2007, the commercialization of vehicle navigation by LBS has made rapid progress. Since the late 2009, the prevalence of smart phones outdoors and the growth of the indoor location-based services sector have increased sharply. Domestic and international service providers and mobile device providers have been researching and developing improvements in the accuracy of indoor positioning. LBS systems are the most popular way to estimate the user's location and include using satellite communications systems, mobile networks, and short-range wireless communication systems based on image recognition. Currently, location determination based on satellite communications and mobile communication networks is the most popular approach. However, limited technology is available at the terminal, and its error range varies depending on the environment[1].

Recently, the most popular and inexpensive technology has been positioning based on wireless local area networks (WLAN). This approach uses the fingerprint method to measure relative signal strength from nearby access points (AP) when the positions of the APs are unknown. This method relies on a map of fingerprints (received signal strengths (RSSI) distributions) of corresponding locations in order to infer locations. The overall location accuracy depends on WLAN infrastructure complexity (more APs provide more unique RSSI fingerprints) and environment stability (RSSI values are sensitive to large-scale environment changes).

Another interesting aspect that is being studied is the utilization of magnetic field information inside buildings for localization and navigation purposes. This approach also relies on a fingerprint database (DB), but rather than collecting RSSI values, unique features of the indoor magnetic field are used to create a map. Magnetic field variations inside the buildings are found in iron, cobalt, or nickel and also occur from man-made sources such as steel structures, electric power systems, and electronic appliances [4].

In this paper, we compare both WLAN RSSI and magnetic field real-time location systems (RTLS) from various perspectives, such as system complexity, accuracy, and stability.

II. METHOD

The strength of the received power from a signal can be used to estimate distance because all electromagnetic waves have an inverse-square relationship between received power and distance. WLAN infrastructure with several access points provides a unique combination of RSSI values from different APs at a particular point. This combination is used to pinpoint the user location in the future.

Magnetic field variations indoors arise from both natural and man-made sources, such as steel and reinforced concrete structures, electric power systems, electric and electronic appliances, and industrial devices. Assuming that the anomalies of the magnetic field inside a building are nearly static and they have sufficient local variability, these anomalies provide a unique magnetic fingerprint that can be utilized in self-localization. For instance, a specific room could be characterized by its magnetic field intensity profile, or an office can be profiled to help in the future by identifying in whose office one is presently located [5]. As RSSI-based locating systems uses Wi-Fi access points as location signal sources, geomagnetic systems utilize pillars and other structures that show high magnetic field values inside a building. Both, WLAN and magnetic, approaches work in two steps: calibration and tracking. The calibration process builds a fingerprint DB (RSSI or magnetic) of a target site by moving around and taking samples [2], [6]. Tracking is a scanning process for a mobile device to estimate its location. Both approaches use a map- matching location algorithm, which is a correlating technology between the field reference (magnetic or RSSI) map and the tracking measurements

A. Calibration

During calibration, a site survey should be performed in the target environment. In the case of a WLAN- based method locating two systems, RSSI values of the radio signals transmitted by APs are collected at certain calibration points for certain periods of time and then stored in the fingerprint DB [3]. Varying combinations of APs with different RSSI values result in a unique fingerprint for each calibration point. As for the magnetic localization technique, the magnetic field of the target site is measured, producing a three-dimensional vector (m = [mx; my; mz]) consisting of three components [4], in units of magnetic flux density (uT) in x, y, and z directions, respectively [6].

B. Tracking

Magnetic map matching is similar to RSSI pattern matching and is a correlating technology between the field reference map and the on-site measurements to find the point at where the correlation values reach a maximum or the sum of the squared differences reaches a minimum. For further evaluation, we apply the nearest-neighbor (NN) indoor positioning algorithm. The NN algorithm is based on some context-dependent distance measure that assigns a non-negative distance value between any two observation vectors. Given a set of training data and a test observation vector, a location is estimated from the closest training sample whose observation vector has the minimum distance to the observation, assuming the use of Euclidean distance [2]. The observation vectors are the set of measured signal strength values of individual APs.

III. EXPERIMENTS

To evaluate our new algorithm, we built a test field at the Regional Innovation Center (RIC) building of Yeungnam University in Korea (Fig. 1). The test area represents a high-density office environment that is filled with a number of obstacles such as partitions, cubicles, electronic devices, and home appliances. The WLAN infrastructure consisted of 10 APs at fixed locations. During calibration and tracking, we used an HP dv4000 laptop that has a Cisco Aironet 802.11a/b/g wireless adapter. For magnetic measurements, we used a MicroMag3 integrated 3-axis magnetic field sensing module. To reduce any human errors during the measurement, we partitioned the test space into an equally spaced grid, whose side length is chosen to be one meter for a WLAN-based system and 20-100cm for a geomagnetic locating system. At every grid crossing point, we collected 100 observations. The final fingerprint value for every calibration point is then averaged over the one hundred observation data samples, and this value is then stored in the database.

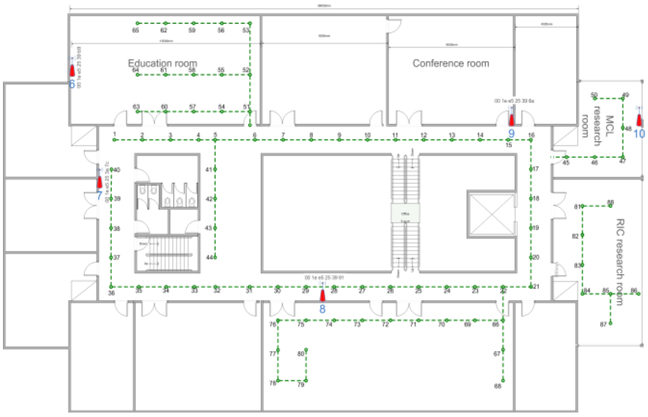

Figure 1. The plan of the building where the experiments were conducted

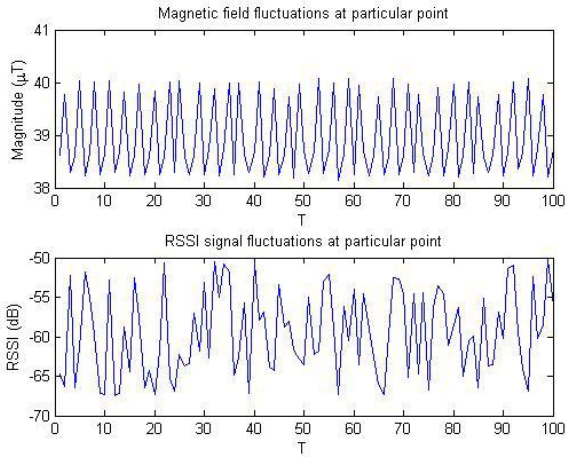

Figure 2. Magnetic and RSSI fluctuations

A. System complexity and stability

In order to provide a high level of accuracy, WLAN- based RTLS requires as many APs as possible to be installed in the target area, whereas a geomagnetic locating system uses natural anomalies of the magnetic field inside the building. However, Wi-Fi access points are currently installed almost everywhere people live and work [3]. Furthermore, an increasing number of manufacturers are integrating Wi-Fi chips with mobile handheld devices, such as smartphones, multimedia players, tablet PCs, and netbooks. This means that nearly any device can be used to make an RSSI fingerprint DB of the environment, whereas a geomagnetic locating system requires special hardware for both map building and location estimation.

Another huge drawback of WLAN- based systems is that even minor changes in the environment may result in RSSI fluctuations. Since the RSSI system constructs site-specific parameters, a newly constructed database may no longer be valid if there are any major changes in the target site [3]. Consequently, large-scale deployments of indoor locations become nontrivial. Fig. 2 compares signal fluctuations of both systems at various points. It can be observed that RSSI fluctuations are much higher compared to magnetic field fluctuations. This is the main reason larger grid sizes (1 m) are used for WLAN-based systems, as the RSSI fingerprints with less-than-1-m intervals have less unique characteristics.

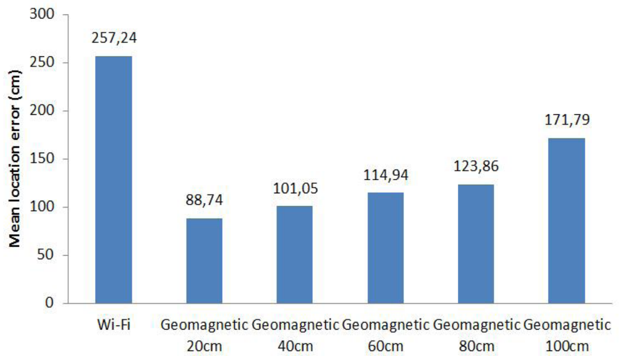

Figure 3. Wi-Fi vs. geomagnetic location accuracy

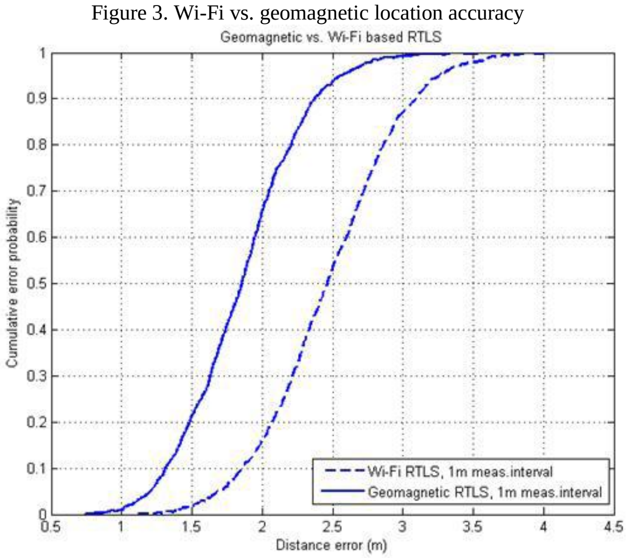

Figure 4. Wi-Fi vs. geomagnetic location accuracy

B. *Location accuracy*

Next, we evaluated the location accuracies of both systems. As mentioned above, we chose a 1m measurement interval for the WLAN-based system and an interval of 20-100 cm for the geomagnetic system. Fig. 3 compares the location accuracy of both systems. It is clear that even with a larger grid size, a magnetic locating system can provide quite accurate location estimation. Fig. 4 summarizes the location accuracy results with a cumulative distribution function. For this simulation, we consider a 1-m measurement interval. Again, it is clear that the geomagnetic RTLS provides much higher accuracy compared to the WLAN RTLS. In WLAN-based RTLS, location accuracy depends on the location estimation method used as well as on many other parameters, such as the number of APs and their allocation layout, the adapted locating algorithm, and the calibration accuracy. However, recent researches has shown that generally such systems provide a location accuracy of 1–3 m [2], whereas geomagnetic systems can achieve as low as cm-level accuracy [4].

IV. CONCLUSION AND FUTURE WORK

In this study, we compared WLAN RSSI and magnetic-field-based real-time location systems (RTLS) in terms of system complexity, accuracy, and stability. Both systems have their advantages and drawbacks. WLAN- based RTLS is easy to deploy since Wi-Fi access points are currently installed almost everywhere. However, geomagnetic systems provide a much higher level of location accuracy because the magnetic fields inside the building are nearly static and have sufficient local variability. In contrast, RSSI is sensitive to even small environmental changes and recalibration is required when there are major changes. Another advantage of a geomagnetic locating system is its low complexity, as it does not require special hardware to be installed in target environments.

The use of location-based services as a way to improve the quality of the construction of infrastructure that does not require using a geomagnetic field measurement system for the determination of location is expected.

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