WiFi Location Information System for both Indoors and Outdoors

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Abstract. We introduce a location information system for both indoors and outdoors which utilize WiFi location technology. The system is composed of a mobile terminal with a WiFi device and a communication server. We have developed seven location aware applications for the mobile terminal. Each of the application helps the user with current location information. We have performed a demonstration experiment in the subway of Nagoya City with 35 subjects and got a positive acceptance of the system.

1 Introduction

Any object in the real world has its location. So, "location information" plays an important role in the field of Ubiquitous Computing. However, it is not easy to tag a location with the object because the technology for localizing the object is not matured. Fig.1 shows a various localization technologies and its estimation accuracy.

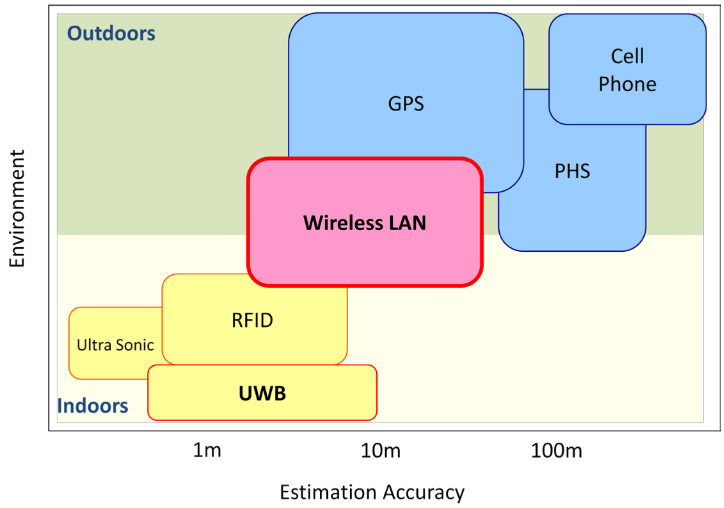

Fig.1: Estimation accuracy for various localization technologies and its effective environment.

GPS (Global Positioning System) plays a main role in the field of localization systems. However, GPS mostly works well in outdoors, but not for indoors. Ultra Sonic, UWB (Ultra Wide Band) and RFID are accurate positioning systems but they require some sort of large infrastructure deployments.

Recently, WiFi location technologies become popular by the research papers[1,2,3] and several working services. Skyhook Wireless provides a service named "Loki"[4] and also serves for iPhone/iPod Touch WiFi location services. Koozyt also provides a WiFi Location Web services in Japan named "PlaceEngine"[5]. We have been also managing a portal Web site named "Locky.jp"[6,7,8,9] and gathered more than half million of AP location information for outdoor WiFi positioning. However, current working technologies are mostly for outdoors, because it is easy to gather the location of WiFi APs for outdoors using GPS and it is not easy to gather the indoor location of APs.

In this paper, we introduce a WiFi location information system for both indoors and outdoors. For outdoors, we utilize our AP location information and propose a compact format for mobile devices. For indoors, we have developed seven mobile applications to support users of the Nagoya City subway system.

In the following section, we first introduce the current status of WiFi location technologies and several features. Then introduce "Locky.jp" and indoor positioning system.

2 WiFi Location Technologies

Recent advancement of wireless technology enables easy and cheap usage of WiFi devices. Now we have a lot of WiFi APs in our home, office, school, airport, etc. By using these WiFi APs, we can estimate our position. Location estimation performed by WiFi is based on the following facts.

1. All WiFi AP have a unique ID called BSSID (a.k.a. MAC address)
2. Each WiFi AP broadcasts its BSSID periodically.
3. Any WiFi client can receive broadcasted BSSID from the WiFi APs.

So, if a WiFi client has a database of WiFi AP location (We named it as "WLDB: WiFi Location Database"), the client can estimate its position. If the client does not have WLDB, but it can record BSSID and utilize it afterwards or use network service to estimate its position from BSSID.

In Fig.2, we show the WiFi AP map in the city center of Nagoya. We have gathered the WiFi AP information by using WiFi client with GPS and walked through all roads in the area. BSSID of each AP and its signal strength (RSSI: Received Signal Strength Indicator) is recorded with its received position (longitude and latitude from GPS). We plot the AP with the highest RSSI. The map shows 1km square area and it contains 878 unique WiFi APs. The map shows that we can receive several WiFi APs signal at every point in the area and we can estimate our position with WLDB. We also performed same acquisition in the center of Tokyo and Osaka and got almost same results.

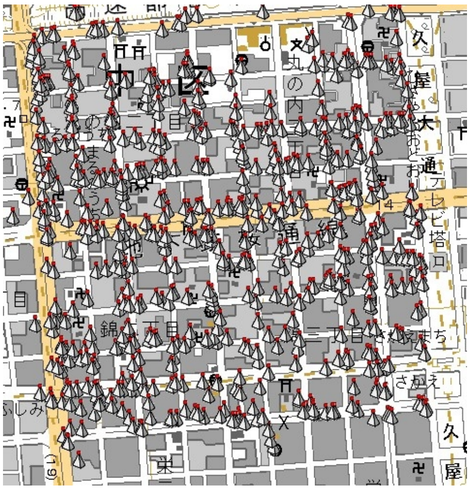

Fig.2: WiFi AP map in the center of Nagoya City (878 APs in 1km x 1km area).

The density of the WiFi APs is also high in the residential area in Nagoya (273 APs in 1km square). So this results shows that the feasibility of the WiFi localization system.

There are several technologies for WiFi location estimations. Most of them can be classified into 3 as follows.

1. Proximity
   Most simple method. Just use the most powerful WiFi AP's location as a estimated position.
2. Triangulation
   Utilize several WiFi APs signals and estimate the position with the weight of signal strength.
3. Scene Analysis (Fingerprinting)
   Required to perform a pre-acquisition of wireless signal environment at the estimation site to find the most similar place.

Each of these methods has pros and cons, so it depends on what kind of estimation is required to select the methods. If the estimation site is not broad, the scene analysis method is the best for accuracy. But if you want to develop a wide-area location estimation system, the scene analysis method is not suitable because it requires long time pre-acquisition of wireless environment. It also requires a huge data for modeling the environment. Triangulation is rather simple than scene analysis, but still have a problem if there are wireless reflection or fading. Proximity is the simplest method and if you have enough density of WiFi APs, it also results better accuracy. However, if there is not enough number of APs, proximity is not suitable. So, we need some kind of hybrid methods from these technologies. Also, we are trying to create a simple model of wireless signal strengths. By the signal model, we might be possible to estimate the position more accurate with less data.

3 Outdoor WiFi Localization and Locky WLDB

For outdoor environment, it is required to gather a huge database for location of WiFi APs. So, we have built a tool named “Locky Stumbler” to gather WiFi AP information with GPS. Fig.3 shows a screen shot of Locky Stumbler. By using Locky Stumbler, one can easily collect the WiFi AP data with connected GPS information. We have got more than 300 volunteers who are working for Locky.jp to gather the WiFi AP data mostly for Japan. We also have Stumbler tools for other platforms such as MacOS, Linux, and FreeBSD built by volunteers.

Currently (March 2008), we have collected more than 585 thousand AP locations through the Locky.jp. Each AP has BSSID (6byte), SSID (32 byte string for identify the AP by human), longitude and latitude. If we distribute the raw database, the whole data results 54bytes (6+32+8+8) x 585 x 10^3 APs = 31 M bytes. For current PC, there is no problem to handle more than 30M bytes data. But for embedded devices, it is better for small sized database. So we compact the database using ID hashing and location compaction. For ID hashing, we merge BSSID with SSID and take MD5 hash and utilize front 8bytes. By using hash function, the database also becomes anonymous. Without right pair of BSSID and SSID, one cannot retrieve its position. For location compaction, we employ matrix coding and degrade the precision into around 3m. This compaction enables to denote longitude and latitude with height in 8bytes. Finally, we got 8Mbytes encoded database. From Locky.jp, registered user can download the nightly updated WLDB at anytime.

In Locky.jp, we also provide Locky Toolkit, a java based middleware for WiFi localization. By using Locky Toolkit and WLDB, one can easily create outdoor WiFi location system with a few line of java code.

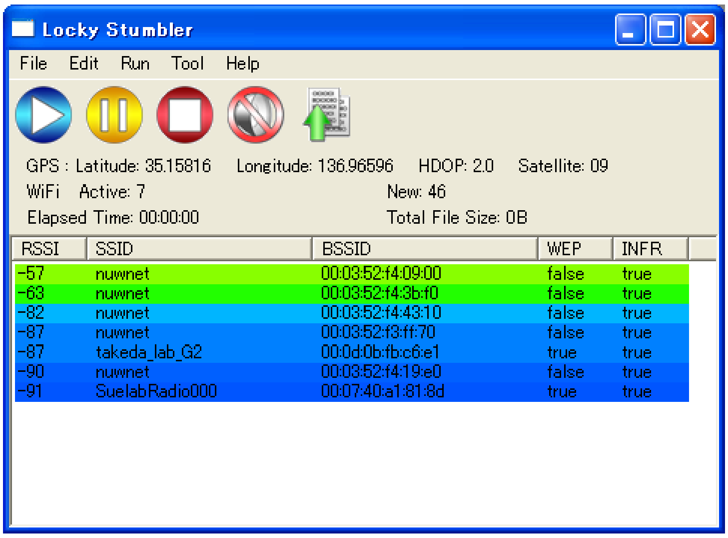

Fig.3: Screen shot of Locky Stumbler (WiFi AP information acquisition tool).

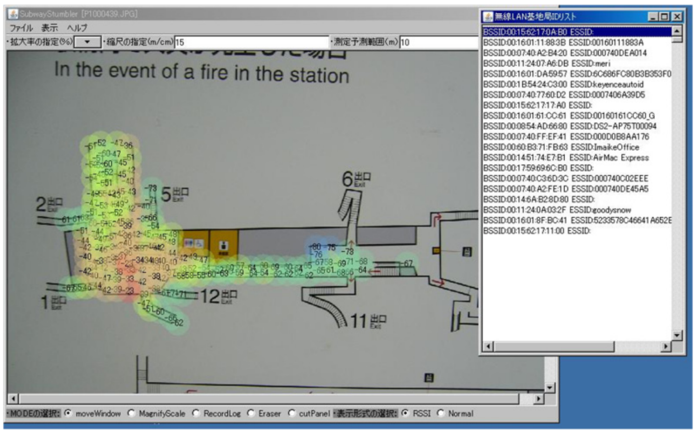

Fig.4: Screen shot of Subway Stumbler.

4 Indoor WiFi Localization Tools and Data Acquisition

For outdoors, it is easy to collect the AP information using Locky Stumbler with GPS. However, there is no easy way to gather WiFi AP information for indoors because we have no mean to locate ourselves. So we have developed software named “Subway Stumbler” and include a feature to locate ourselves and to record WiFi environment. We utilize a digital photo of a floor map. In the most of the public places, we have a floor map sign board. But it is not easy to obtain the digital version of the map. So we decided to use just a photo of the board. By this decision, one can easily gather the location information using a PDA or PC which has a digital camera and a touch screen. Fig.4 shows a screen shot of Subway Stumbler. User can import a photo and zoom/unzoom for locating himself.

By using Subway Stumbler, we decide to gather the information of the WiFi in the stations of Nagoya Subway System because the subway just placed WiFi APs in 2007. Nagoya city is a large size city with two million citizens and have 6 subway lines with 83 stations. We map and gather the all floors of the all stations in Nagoya. Finally, we found APs shown in Table 1. We also transform the location of each APs from the relative position in the photo image into the absolute position in the WGS83 lon-lat. We put the all WiFi AP location on the Google Earth.(Fig. 5).

Table 1. Gathered WiFi AP Locations in Nagoya Underground

Number of Stations	83 stations
Number of Floors	356 floors
Number of APs	1,777 APs
Collected Points	28,620 points
Cost for gathering	30 man month

Fig.5: Gathered WiFi AP location database for all 83 Nagoya subway stations.

5 Location Aware Applications for Indoor environment

We selected Apple's iPod Touch as the platform of the indoor location system because it has a WiFi, touch screen, large memory and good development environment. We have developed seven applications for Subway Information System on the iPod Touch such that:

- Launcher
- Nagoya Subway Rail Map
- NextTrain (Real time timeable)
- Friend Map
- iNavi (Location aware database system)
- Underground Map
- Station Map

Fig.6: Launcher (Left) and Nagoya Subway Rail Map(Right) Application.

Each application can start from the "Launcher" by using URL scheme with location information. Rail Map shows a real time status of trains from timetables (Fig.6). NextTrain count down a time to next train and FriendMap shows a location of your friend using location server (Fig.7). FriendMap has a function to chat with other friends. iNavi contains 40 thousand location related shop information. Station Map and Underground Map contains digital map of each places(Fig.8).

Fig.7: NextTrain(Real time timetable), and FriendMap (Right).

Fig.8: iNavi(Left), Station Map(Center) , UndergroundMap (Right).

6 Demonstration Experiment

By using these applications and iPod Touch, we have performed a demonstration experiment with 35 subjects. We made a group of a few subjects and give a different "task" for each. The task includes to find a shop, restaurant and to meet each other in

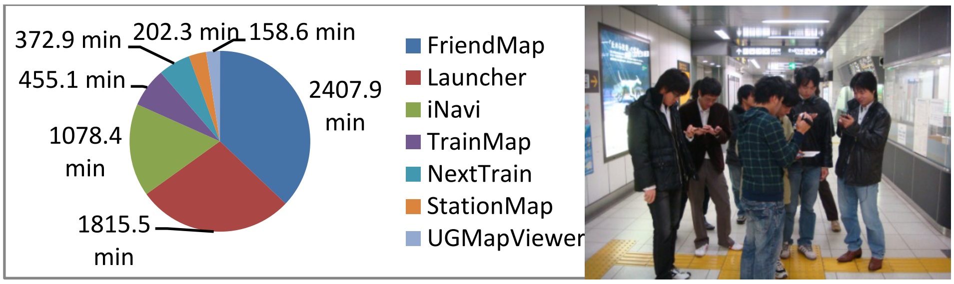

Fig.9: Application Usage Statistics of the Subjects in the Demo. Experiment (Total over 100h)

the subway by using Friend Map. After the experiment, we collected questionnaires from each subject about what they feel in the experiment. We got positive responses from most of subjects while there are future improving points. Logs from the experiment are collected and analyzed thorough the location and type of the application (Fig. 9).

7 Conclusion

In this paper, we introduce our implementation of WiFi based Location Information System both for indoors and outdoors. In the demonstration Experiment, we have recorded all user logs of each subject. We can extract the intent of each subject with the location. So we will analyze the log to make a better recommendation of the service.

References

[1] Paramvir Bahl, and Venkata N. Padmanabhan: RADAR: An In-Building RF-based User Location and Tracking System, IEEE Infocom 2000, pp. 775-784 (2000) .
[2] Seigo Ito, Nobuo Kawaguchi, Bayesian Based Location Estimation System Using Wireless LAN, Proceedings of Third IEEE International Conference on Pervasive Computing and Communications Workshops, pp.273-278(2003).
[3] Anthony LaMarca, et.al, Place Lab: Device Positioning Using Radio Beacons in the Wild, Proc. of Pervasive2005, LNCS3468, pp.116-133(2005).
[4] Loki : http://loki.com
[5] PlaceEngine: http://placeengine.com
[6] Locky.jp : http://locky.jp
[7] Hirokazu Satoh, Seigo Ito and Nobuo Kawaguchi, Position Estimation of Wireless Access Point using Directional Antennas, International Workshop on Location- and Context-Awareness (LoCA 2005), LNCS 3479, pp.144-156(2005).
[8] Hiroshi Yoshida, Seigo Ito, Nobuo Kawaguchi, Evaluation of Pre-Acquisition Methods for Position Estimation System using Wireless LAN, The Third International Conference on Mobile Computing and Ubiquitous Networking (ICMU 2006), pp.148-155(2006).
[9] Seigo Ito, Nobuo Kawaguchi, Orientation Estimation Method using Divergence of Signal Strength Distribution, Proceedings of Third International Conference on Networked Sensing Systems (INSS2006), pp.180-187(2006).