WIRELESS LAN BASED VEHICULAR LOCATION INFORMATION PROCESSING

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ABSTRACT

This paper focused on environmental signal like wireless signal which can observe from outside of vehicle. These signals are mostly used for localization of terminal in mobile system. Particularly, we examine wireless LAN based localization in vehicle. Additional to this, we explore the possibility of orientation estimation in vehicle using wireless LAN. Vehicles itself interrupts wireless signal and work like big obstacle. It causes difference of signal strength distribution according to installation location of wireless LAN antenna. By using these differences we estimate vehicles' orientation. Finally, we introduce our metropolitan scale localization project named locky.jp.

1. INTRODUCTION

For the research and development of driver support system, many types of data have been collected in vehicle, for example, driving signal (ex. gas pedal, brake pedal), car state signal (ex. speed), car location (ex. inter-vehicular distance), video signal, and sound signal. In addition to these signal, we focused on environmental signal like wireless signal which emitted from outside vehicles. When we drive vehicles we can observe various wireless signals, for example, GSM (Global System for Mobile Communications) cell towers signals, FM-AM radio signals, GPS (Global Positioning System), and wireless LAN signals. It is possible to consider these infrastructures as a type of lighthouse. These environmental signals are very useful for various usages. The most major usage is localization. As another usage of these signals, for example, Krumm proposed destination estimation method [1] named predestination, by using vehicles trajectories along with data about driving behaviors. Sohn proposed mobility detection method [2] using every day GSM signals. This method estimates user's mobility by comparing difference of signal strength distribution among some mobility. Our results show that environmental wireless signals can be used for various purposes.

Especially, we focused on wireless LAN signals. Because, according to wide spread of wireless LAN in these days, we can observe wireless LAN signal everywhere. And almost all laptops and PDA has wireless LAN adapter. It is easy to collect data with existence vehicular system.

This paper is presented in main three parts. First, we introduce and examine wireless LAN based signal processing for localization. Second, we explore possibility wireless LAN based signal processing for orientation estimation. Finally, we introduce our metropolitan-scale localization project named locky.jp and present conclusions.

2. LOCALIZATION

2.1. Wireless LAN Based Localization

Preparation for explaining of wireless LAN based localization, we introduce scheme of wireless LAN based localization. In wireless LAN, many access points emit beacons periodically. Wireless terminals can obtain various information from these beacons, such as SSID, MAC address of AP (BSSID), and signal strength, etc. If a vehicle enters in wireless LAN available area, the vehicle can get these beacons information. Then, if the access point's position is known, the vehicle can estimate its position relationship with access point. This is basic scheme of wireless LAN based localization.

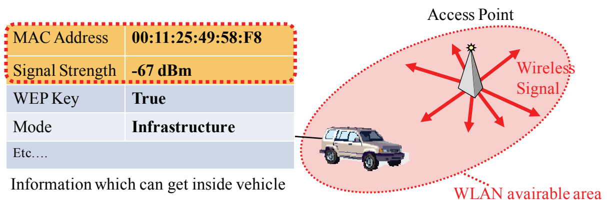

Fig. 1. Scheme of WLAN Localization

Wireless LAN based localization can be mainly classified into proximity approach [3], triangulation approach [4][5] and scene analysis approach[6][7][8].

2.2. Proximity Approach

The proximity approach is most easiest way for localization. This method considers nearest access point position as terminal position. When a terminal has position list of access point, the terminal can estimate its position by proximity easily. However, accuracy of this method is low.

2.3. Triangulation Approach

The triangulation approach uses reference points which position is known (ex. access point). One type of this approach is also used by GPS. When systems use relative distance from reference point, it is called Lateration. Fig.3. shows overview of lateration. When a terminal observed signal strength *(ss_1 ... ss_n)* from known access points *[(x_1,y_1) .... (x_n,y_n)]*, the system calculates the terminal's position *(x_t,y_t)* as follows (n is the number of access points which the user observed).

$$(x_t, y_t) = \left(\frac{\sum_{i=1}^{n} \frac{x_i}{10^{-32-ss_i/25}}}{\sum_{i=1}^{n} \frac{1}{10^{-32-ss_i/25}}}, \frac{\sum_{i=1}^{n} \frac{y_i}{10^{-32-ss_i/25}}}{\sum_{i=1}^{n} \frac{1}{10^{-32-ss_i/25}}} \right)$$

2.4. Scene Analysis Approach

This approach uses prior knowledge of environment like radio map. This approach has high accuracy. However, to get high accuracy, this approach needs fine-grained pre-sampling in environment. For example, if a system need 1 feet accuracy, approximate equivalent interval's pre-sampling are required. Therefore, it is not suitable for vehicular localization. Our previous work [6] using scene analysis shows 64% of localization requests are within 2m in indoors environment.

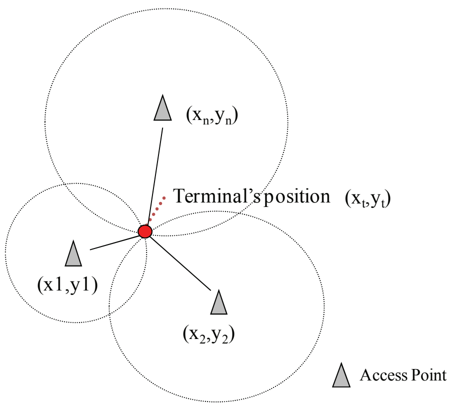

Fig. 2. The triangulation approach (lateration)

2.5. Accuracy in outdoors

To examine wireless LAN based localization accuracy in outdoors, we collected information of access point (Fig.3). Collectors of access point information carried laptop, wireless LAN adapter, wireless survey software, and GPS in a backpack. By using this backpack they acquired the access point's position. After collecting access point's position, we examined accuracy of wireless LAN based localization.

We considered GPS position as correct position and calculated wireless LAN based positioning accuracy. We conducted experiment with 3 types of vehicles, a bicycle, a motorbike and a car. Table 1 shows the result, accuracy average, standard deviation, and coverage. The coverage means ratio which vehicles estimates its position using only wireless LAN. There was a little difference of coverage among three vehicles. As for the reason for difference of coverage, there are differences of speed to each vehicle. We empirically observed according to increasing of vehicles speed, the number of access point which vehicles can observe is decreasing. Therefore, it is considered the bicycle has high coverage and the car has low coverage in this area.

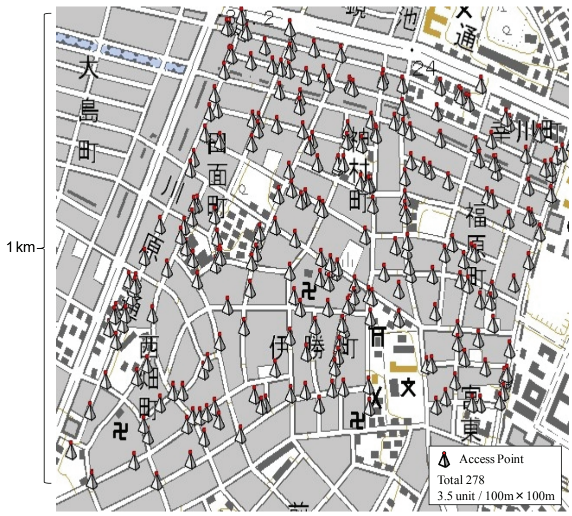

Fig. 3. Access Point Map (Residential Area)

Table. 1. Accuracy of WLAN localization in outdoors

Vehicle	Average	SD	Coverage
Bicycle	25.4m	21.2m	98.3%
Motorbike	27.7m	18.8m	97.2%
Car	27.4m	23.8m	96.7%

3. ORIENTATION ESTIMATION

3.1. Difference of Signal Strength

In the previous section, we introduced localization of wireless LAN. But, it is empirically known that received signal strength varies according to the relative angles between terminals and access points.

For the purpose of survey, we observed received signal strength distributions for each orientation at same positions (Figure 3). Figure 4 shows the average value of received signal strength for each orientation. In figure 4, the distance from the middle of a circle shows the average received signal strength, and each axis shows the relative angle between the terminal and the access point. We obviously see the difference of received signal strength for each orientation. For example, in wireless LAN adapter A, the terminal observed the highest average at relative angle 0 when the user is facing the access point. Even in the same location, received strength signal varies according to the wireless LAN adapter.

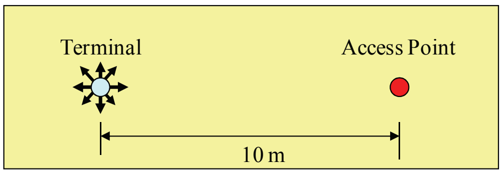

Fig. 4. Observation Setting

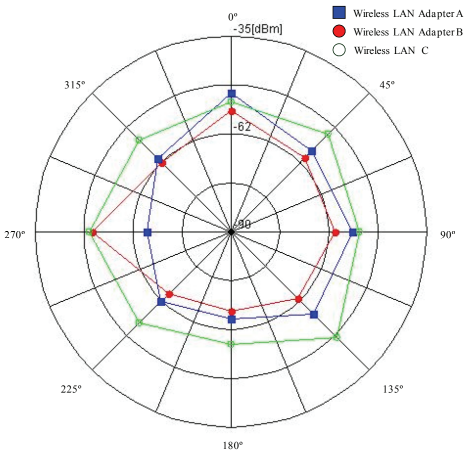

Fig. 5. Average signal strength for each orientation

By using these differences of received signal strength, we proposed wireless LAN based orientation estimation method [10]. Our method compares signal strength distribution and use KL-divergence [11], and estimates orientation. With our method, users can determine orientation only using a wireless LAN adapter. The accuracy of 2-way estimation is 92% and 4-way estimation is 83% under six seconds observation of four access points.

3.2. Orientation Estimation in Vehicle

When we collect wireless signal as environmental signal in vehicle, we must consider difference of signal strength distribution according to antenna's location. Because vehicle itself interrupts wireless signal and works like a big obstacle. If it thinks upside down, there is a possibility of orientation estimation according to antennas location. We examine differences of received signal strength distribution for each antenna's location.

Figure 6 shows a setting of the each wireless LAN antennas. We set wireless LAN antennas in three places front side, inside vehicle and backside of vehicle. The antenna is omnidirectional antenna BUFFALO WLE-NDR. The vehicle is TOYOTA Hybrid ESTIMA. Observations were conducted in two minutes to each location and the car was stopped.

Figure 5 shows the result of probability density of received signal strength from an access point at each antenna. X-axis shows the received signal strength and Y-axis shows probability density. At backside and inside vehicle, averages were -48 dBm and -50 dBm. In contrast, the average at front side was -39 dBm. These difference of received signal strength distribution are enough to applying our orientation estimation method [10] described section 3.1.

If we use wireless LAN for easy orientation sensor, there are various usage scenario. For example, if car stopped, a system can't estimate cars orientation only GPS. However, if the system equipped wireless LAN adapter, it is easy to estimate cars orientation.

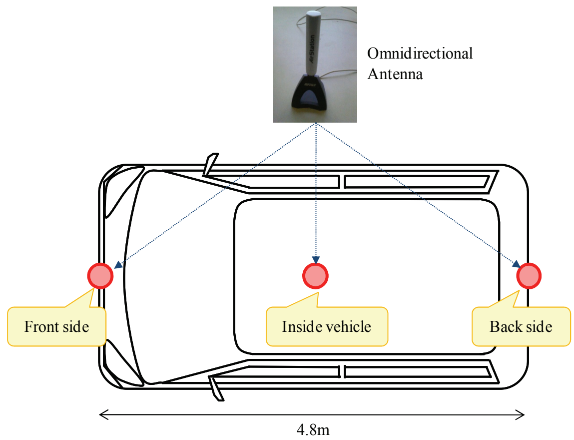

Fig. 6. Antenna's Location

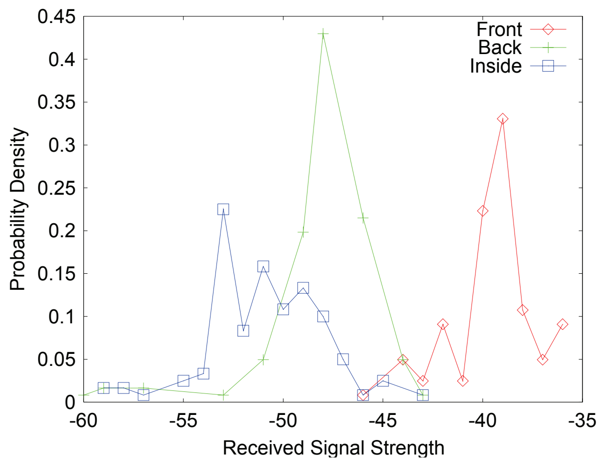

Fig. 7. Difference of Signal Strength

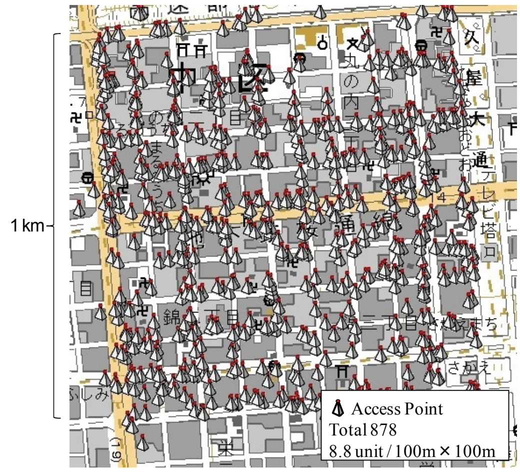

Fig. 9. AP Map in Nagoya (Commercial Area)

4. METOROPOLITAN SCALE LOCALIZATION

We have been studied basic localization method and orientation method. However for practical purpose, it is required to collect access point information widely and to expand service available area. Therefore, we surveyed major city and evaluate feasibility of metropolitan-scale localization based on wireless LAN. Additional to this, we introduce metropolitan-scale localization project Locky.jp which use environmental signal as reference point for localization.

4.1. Feasibility of metropolitan scale localization

For the purpose of feasibility examination for metropolitan scale localization, we conducted survey and accuracy evaluation in major cities. We surveyed 1km square of commercial area in Tokyo, Osaka, and Nagoya. In this survey, we used wireless survey backpack described in section 2.5.

As a result of survey, we found 2746 (Tokyo:928, Osaka:940, Nagoya:878) access points in these area, and there are full coverage of wireless LAN. Figure 3 shows the result of survey in Nagoya. By using these surveyed data, we examined estimation accuracy to each city. We used the localization method described in section 2.3.

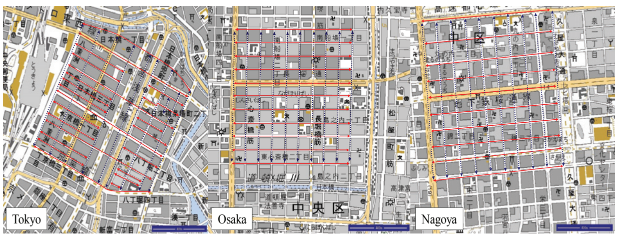

Fig. 8. Survey Area

Table 2 shows the result of accuracy, average, and coverage in three cities. It should be noted that all city has more than 97% coverage of wireless LAN based localization. Even when a terminal can't receive signal from access point, only a few meters move enables terminal to observe wireless LAN signal. In other words, wireless LAN based metropolitan-scale localization is available everywhere and has great possibility.

Table. 2. Accuracy and Coverage in Principal City

Vehicle	Average	SD	Coverage
Tokyo	40.3m	28.8m	97.6%
Osaka	34.7m	25.8m	98.1%
Nagoya	48.7m	33.5m	98.8%

4.2. Locky.jp

In previous section, we pointed out the feasibility of metropolitan scale wireless LAN based localization and conclude metropolitan scale wireless LAN based localization has a great deal of potential. Therefore, we launched the project Locky.jp to make wide area wireless LAN based localization come true.

Locky.jp [12] is metropolitan-scale localization project designed to collect reference trace sets covering major cities in Japan among users collaboration. Reference trace set (RTS) consist of BSSID (Basic Service Set Identifier), signal strength (SS) and position of access point (latitude and longitude).

$$RTS = \{BSSID, ss, latitude, longitude\}$$

Locky.jp has the following 3 main goals.

- Collection of metropolitan-scale reference trace set in Japan (and also abroad). The realization of a metropolitan-scale positioning system needs at least a prior survey of the wireless LAN environment. Locky.jp aim to construct this system among users collaboration.
- Provision of a client program for the positioning system based on 802.11. We provide the "Locky client" that can estimate the device location based on reference trace set from a large number of users.
- Development and provision of location-aware application. The "Locky client" provides different type of information according to the location. Locky.jp is also aiming for the development of different location-aware application.

Figure 6 shows the overview of locky.jp. Volunteer users collect wireless LAN reference trace set. By using reference trace set and localization method we introduced in section 2, the system estimates terminals position. Then, reference traces set are uploaded to locky.jp server, and construct a database. Finally, the database is released to users with some applications. To construct a wide-area positioning system, it is important to collect the reference trace set effectively and widely.

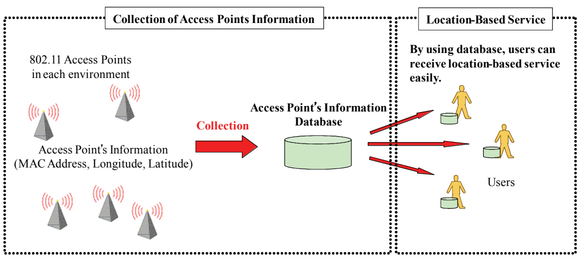

Fig. 10. Locky.jp overview

4.3. Current status

Figure 7 shows all reference trace set in May 11, 2007. We collected 308607 reference trace set (the number of access points) with 185 collaborators. These collaborators consist of universities, companies, and many other peoples. We provide wireless LAN survey software named Locky Stumbler. Collaborators survey reference trace set using Locky Stumbler.

We also provide collected data as locky.jp database with Java API. By using these database and API, developers can built-in function of wireless LAN based localization to their applications.

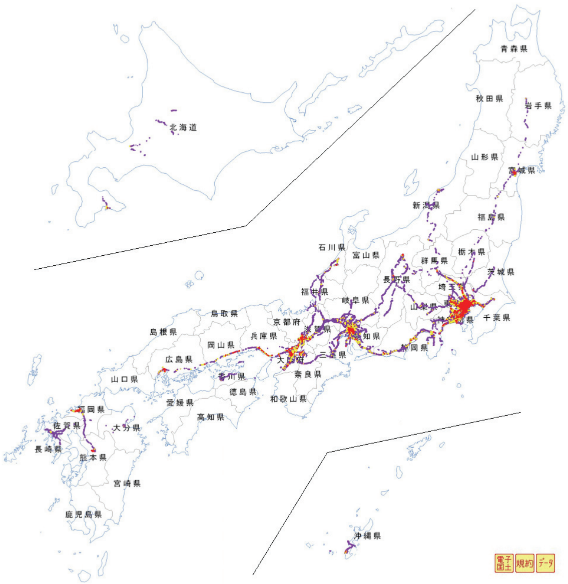

Fig. 11. Locky.jp Access Point Map (Japan)

4.4. Related Project

There are some projects that aim to construct metropolitan-scale wireless LAN based localization.

Place Engine [13] provides WEB API using wireless LAN based localization. When a user install Place Engine client to their terminal, the client collects wireless LAN information and send a positioning query to Place Engine server.

PlaceLab [14] is a project to support development of a location information system by providing a toolkit for position estimation and a database for wireless beacon (IEEE802.11, GSM, and Bluetooth) information. PlaceLab's toolkit also supports collection of the reference trace set.

4.5. Ongoing and Future Work

As a next step of locky.jp, we are considering construction of reference trace set in the basement and hybrid usage with GPS both indoors and outdoors. In the basement, like underground city and subway, GPS is not available. However, wireless LAN signal is available in such environment. We are discussing about construction of reference trace set in such environment.

As an issue of wireless LAN based metropolitan-scale positioning, there is refreshment of reference trace set. Position of access points may change, because of a crash, a move, and a destruction, etc. Therefore, we examined a existence transition of access points. We had collected access point's information for 316 days in same route. Figure 10 shows transitions of access point. X-axis shows elapsed days and Y-axis shows each access point. If an access point observed thorough the route, the day is plotted. On the first day, we observed 382 unique access points. However, on the last day, we observed 223 out of 382 access points. In other words, 41.6% access points were not observed. Further study will be necessary to refresh reference trace set, for example, self mapping method.

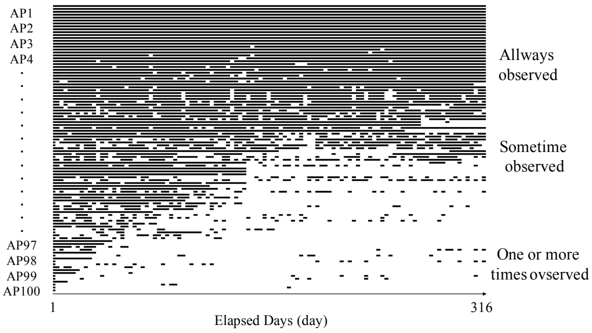

Fig. 12. Transition of Access Point Existence

5. CONCLUSION

In this paper, we focused on environmental signal and introduced wireless LAN based localization and orientation estimation with vehicle. Additional, we introduced metropolitan scale localization project locky.jp. As we described above, wireless LAN based localization and orientation estimation has a great deal of possibility. We continue to study improvement of accuracy and coverage.

Furthermore, wireless LAN can use with interesting application. For future application, we are discussing about some application with wireless LAN on vehicle. For example, we use wireless LAN as an easy inter-vehicular distance sensor, a multi hop car to car communication, a crash detection sensor, and a motion detection sensor, etc. At close range, wireless LAN signal is sensitive, therefore, it is possible to use wireless LAN as sensor in these scenario.

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