SmartLocService: Place Identification Method Using Space Dependent Information for Indoor Location-Based Services

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Abstract—In this paper, we propose a location-based service (SmartLocService) using space dependent information. The space dependent information is defined as the unique information for a specific place such as set of service set identifier (SSID) from Wireless LAN (WLAN) access points (APs). Existing location-based services (LBSs) mainly use Global Positioning System (GPS) to identify a place. However, GPS cannot work well in an indoor environment. SmartLocService realizes exact place identifications in indoors by using space dependent information. SmartLocService can be applied to various sophisticated location-based services in indoor such as reminders, call bliss and geo-fencing. We implement SmartLocService on smartphones, and evaluate its performance about registration time and location accuracy. As a result, since the accuracy of location is within five meters, we show that SmartLocService is useful to realize location-based services even in indoors.

I. INTRODUCTION

One of the basic concepts of pervasive computing is providing a smart environment for users. In that system, environment adaptively changes for a user considering the user’s location or context. For example, when a user leaves an office, the system notifies the user what to do. As another example, when a user goes to a bedroom, the system automatically cancels a phone call from office workers. Many researches for realizing smart environment are presented such as location-based services (LBSs) [1][2] and context-aware services [3]. Among them, location-based services using mobile devices such as smartphones, tablets and laptop PCs are promising for pervasive computing. Reminder is a convenient application for iPhone [4]. Call Bliss automatically cancels a phone call from office workers while users are home [5]. Geo-fencing puts a virtual fence on the map and executes determined processes when someone goes out or goes in the virtual fence [6]. These services use GPS for place identifications. However, GPS cannot work well in indoor environments due to place acquisition accuracy. Therefore, some simple place identification methods for mobile devices which can use indoor environment are necessary.

In this paper, we propose a location-based service method (named SmartLocService) using space dependent information. Space dependent information is defined as the unique information for a specific place such as set of service set identifier (SSID) from Wireless LAN (WLAN) access points (APs). SmartLocService realizes exact place identifications in indoors by using space dependent information. SmartLocService can be applied to various sophisticated location-based services in indoor such as reminders, call bliss and geo-fencing. We implement SmartLocService on smartphones, and evaluate its performance of registration time and location accuracy. We show that SmartLocService is useful to realize location-based services even in indoors.

II. SMARTLOC SERVICE

SmartLocService is a place identification method using space dependent information.

A. Space Dependent Information

In SmartLocService, we use space dependent information for location identifications. The space dependent information is defined as a unique information for a specified place such as a set of received SSID beacons from neighbor WLAN APs. Another example is a beacon of Bluetooth. The radio from WLAN APs is within a limited area. In other words, detected SSIDs are different depending on location. Hereinafter, we explain the mechanism of the proposed place identification method by using the case where a set of received SSID beacons from WLAN APs.

B. Algorithm

SmartLocService has two processes to identify a place by using mobile device: Place Registration Process and Place Identification Process. SmartLocService uses Registration List and Comparison List to register neighbor SSIDs from WLAN APs and compare them. In Place Registration Process, a user registers a place. In Place Identification Process, the user checks whether the user is at the registered place or not. The detailed procedure in each process is as follows:

- Place Registration Process
  1) At a place where a user wants to register, the user’s mobile device detects SSIDs from WLAN APs around it for $T_a$ second.
  2) The device adds the detected SSIDs and their average received signal strength indicators (RSSIs) into the device’s Registration List.

- Place Identification Process
  1) At a place where a user wants to identify that the place is the same as the registered place,
Thus, the concordance rate $P$ is as follows:

$$P = \frac{P_{\text{num}}}{\text{Number of SSIDs in Comparison List}} \times 100$$

where $P_{\text{num}}$ is defined as follows:

$$P_{\text{num}} = \text{The number of SSIDs which are commonly included in both Registration List and Comparison List satisfying } R_{\text{ave}} - R_{\text{margin}} \leq R_{\text{auth}} \leq R_{\text{ave}} + R_{\text{margin}}$$

$R_{\text{margin}}$ is a pre-defined margin for absorbing received signal fluctuations. $R_{\text{ave}}$ is the average RSSI observed at the registration place. In addition, $R_{\text{auth}}$ is the detected RSSI at the place identification place.

In this paper, identification is successful means the device recognize that the registration place and the identification place is the same place. $P$ is defined as the following equation:

$$P = \frac{P_{\text{num}}}{\text{Number of SSIDs in Comparison List}} \times 100$$

We show an example of Place Registration Process of SmartLocService in Fig. 1. There are seven APs (A to G) around a device. In a Place Registration Process, we assume that the device detects six SSIDs (A to F) among seven APs. In this case, the device adds these six SSIDs and their average RSSI for $T_A$ second to its Registration List.

Fig. 2 shows an example of Place Identification Process of SmartLocService. We assume $R_{\text{margin}} = 5$ and $P_{\text{th}} = 80$. A device tries to check if the device is at the pre-registered place. The device detects SSIDs from WLAN APs around it. We assume the device detects five SSIDs (A, B, C, D and G). The device adds these detected SSIDs into its Comparison List. After that, the device compares its own Registration List and Comparison List. In this case, four APs (A, B, C and D) are included in both Registration List and Comparison List. In addition, the device checks if each SSID satisfies Eq. (1) or not. In this example, three SSIDs (A, B and C) satisfies this inequality. The SSID of D does not satisfy it because $-60 > -68.1 + 5$. Thus, the concordance rate $P$ is as follows:

$$P = \frac{6}{5} \times 100 = 60$$

In this example, since $P_{\text{th}} = 80$ as we defined, the device realizes that it is not at the registration place.

C. Application using SmartLocService

There are some location-based services using smartphones such as Reminders [4], Call Bliss [5] and Geo-Fencing [6]. Reminders is the application on iPhone that reminds us what to do. Reminder can remind something at a pre-defined time or at a pre-registered place. For example, Reminder notices a user what the user has to carry when goes out. In another case, it notices a user what the user should buy at the supermarket when he/she leaves the office. On the other hand, Call Bliss automatically cancels phone calls from office workers if the Call Bliss user is at home. Thus, the user can enjoy the private time without interference from colleagues. In addition, Geo-Fencing puts a virtual fence on a map and executes determined processes when someone goes out or goes in the virtual fence. For example, when customers enter the shopping mall, the system automatically sends a sales promotion message to them. Since these services use GPS, sophisticated services cannot be provided in indoor environment. SmartLocService can realize provide it thanks to a precise indoor place identification.
D. Sample Application using SmartLocService

We implement a sample application of SmartLocService, named SmartLocLock. SmartLocLock provides automatically locking or unlocking a mobile application according to the place identification method without any password or complicated processes even in indoor environment as shown in Fig. 3. We implement it on Galaxy Nexus (Android 4.0) and Nexus 4 (Android 4.2). Fig. 4 shows the screenshot of SmartLocLock. Users register a place to lock a smartphone using SmartLocLock as follows:

- **Place Registration Process**
  1) At a place where a user wants to register, the user launches SmartLocLock and selects which application to lock (Fig. 4a).
  2) SmartLocLock detects SSIDs of WLAN APs and their RSSIs around it (Fig. 4b).

- **Place Identification Process**
  1) We assume that the phone application is locked on SmartLocLock.
  2) A user tries to launch the phone application (Fig. 4c).
  3) SmartLocLock checks whether the user is at the pre-registered place or not.
     - If the user is at the pre-registered place, the phone application is unlocked. The user can use it (Fig. 4d).
     - If not, the phone application continues to be locked. The user cannot use it (Fig. 4e).

III. PERFORMANCE EVALUATION

We implement SmartLocService on a smartphone (Galaxy Nexus, Android 4.0) and evaluate its performance in terms of registration time and identification success range. The experiments are performed at our laboratory.

Fig. 5. Identification success rate versus registration time.

A. Evaluation of Registration Time

We evaluate the identification success rate. The identification success rate $I$ is defined as follows:

$$I = \frac{\text{Number of Successful Identifications}}{\text{Number of Identification Trials}}$$

In this paper, the Number of Identification Trials is 5,000.

Fig. 5 shows registration time versus identification success rate. Identification success rate is increased for longer registration time. This is because some SSIDs are sometimes detected and sometimes not detected according to the state of radio wave, even if a device is at a same place. Therefore, if we set longer registration time, more SSIDs are detected. In that case, we can get high identification success rate even if $P_{th}$ is higher. On the other hand, if we set lower $P_{th}$, we can get high identification success rate with short registration time. According to Fig. 5, we can see that if $P_{th} = 60$, it takes only about five seconds to obtain 95 percent of identification success rate. In case of $P_{th} = 80$, 240 second is necessary for it. From these results, we should set $P_{th} = 60$ or 80 for practical use.
B. Evaluation of Identification Success Range

In general, place identification should be succeeded only near the pre-registered point (should be failed far from the pre-registered point). We evaluate the relationship between the distance from the registration place and identification success rate. Fig. 6 shows the identification success rate versus distance from the registration place. We set $T_A = 10$ and $R_{\text{margin}} = 10$. According to Fig. 6, $P_{th} = 50$ is the best choice because the identification success rate is 100 percent at the registration place, and the identification success rate is 0 percent at more than five meter away from the registration place. However, in the case of $P_{th} = 10$ to 40, identification success rate is not zero percent at less than nine meter away from the registration place. Thus, $P_{th} = 10$ to 40 does not limit the identification area adequately. On the other hand, in the case of $P_{th} = 60$ or more, the identification success rate is not 100 percent even at the registration place. As this result, from our implementation, the identification success rate can achieve 100 percent within four meter from the registration point.

We evaluate how $R_{\text{margin}}$ affects the identification success rate. Fig. 7 shows the identification success rate versus distance from registration point. We set $T_A = 10$ and $P_{th} = 50$. In addition, for reference, Fig. 7 also shows the model without considering RSSI ($R_{\text{margin}}$ is an enough large value). The identification success rate is not 100 percent in $R_{\text{margin}} \leq 6$, but it is 100 percent in $R_{\text{margin}} \geq 10$. Thus, we have to set $R_{\text{margin}}$ as more than or equal to 10. Next, we check identification success rate at six meter away from the registration place in Fig. 7. The identification success rate is 0 percent in $R_{\text{margin}} = 10$, but it is not 0 percent in $R_{\text{margin}} \geq 14$. Thus, $R_{\text{margin}} = 10$ is the best value.

From the above, there is a trade-off between registration time and identification success rate at registration place. Under these conditions, $T_A = 10$, $P_{th} = 50$, $R_{\text{margin}} = 10$ is the best setting to use SmartLocService.

IV. Conclusion

In this paper, we have proposed a location-based service (SmartLocService) using space dependent information. The space dependent information is defined as the unique information for a specific place such as set of SSIDs from WLAN APs. SmartLocService realizes exact place identifications in indoors and can be applied to various sophisticated location-based services. We have implemented SmartLocService on the smartphone (named SmartLocLock) and have evaluated registration time and accuracy of location. As a result, we can see that $T_A = 10$, $P_{th} = 50$, $R_{\text{margin}} = 10$ is the best setting to use SmartLocService. In this case, the identification success rate is 100 % at registration place and that is 0 % at more than 5 m away from registration place. Therefore, SmartLocService is practical as a location-based service even in indoors.

In this paper, we have implemented only SmartLocLock. In the future, we implement more applications that apply SmartLocService. Then, we evaluate whether these applications are practical.

REFERENCES