Indoor Localization Algorithm using Virtual Access Points in Wi-Fi Environment

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Abstract

In recent years, indoor localization in Wi-Fi environment has been researched for its location determining capability. The fingerprint and RF propagation models has been the main approach in determining indoor positioning. With the use of fingerprint, a low-cost, versatile localization system can be achieved without the use of external hardware. However, only a few research have been made on virtual access points (VAPs) among indoor localization models. In this paper, the idea of indoor localization system using fingerprint with the addition of VAP in Wi-Fi environment is discussed. The idea is to virtually add APs in the existing indoor Wi-Fi system, this would mean additional virtually APs in the network. The experiments of the proposed algorithm shows the positive results when 2VAPs are used compared with only APs. A combination of 3APs and 2VAPs had the lowest average error in all 4 scenarios with 3.99 meters.

I. INTRODUCTION

Recently, the location based services (LBS) have been a great impact in our daily lives. It also progresses with the innovation of internet of things (IoT), which refers to a network of internet enabled devices such as everyday objects with ubiquitous intelligence. As the localization system based on the wireless signal strength as discussed in [1], it is important to propose the indoor positioning system under the low-cost and low-complexity using Wi-Fi technology.

The Wi-Fi is popularly used to most of indoor buildings or large scale markets to provide mobile services to the customers by connecting Internet. Researchers has utilized the Wi-Fi to acquire positioning services in closed indoor environment because of its availability and capability of smart phones and tablets on the Wi-Fi. In addition to this, many schemes in the Wi-Fi have been developed to acquire a much accurate, precise and low-cost indoor positioning based on fingerprint scheme or RF propagation method.

Because the layout of the indoor environment may be often changed, it is necessary to move the location of access point (AP) for the proper connection in the Wi-Fi. Therefore, the determination of the exact location of APs in creating the fingerprint map and application of VAPs is also seen as an alternative in this paper.

Localization systems based on measuring of signal strength in Wi-Fi environment was firstly proposed in [2]. The functions of this system are divided into the training phase (offline phase) and the fingerprint based localization phase (online phase). A radio map is constructed based on the received signal strength (RSS) of existing APs in the indoor environment in the training phase, and the location is estimated by K-nearest neighbors (KNN) algorithm to find the nearest Euclidean distance of the radio map from the observed RSS vector in the localization phase, respectively.

The other topic in this paper is the virtual access point (VAP). VAP is defined as a virtual machine running on a single physical AP with different service set identifier (SSID). It can be virtually constructed to the AP on a certain location in the indoor environment through statistical models. Because the VAP can be constructed with relation to the current existing APs in the structure by linear correlation regression, this proves the advantage of VAP in fixed WLAN infrastructure since there will no longer be a need in deployment of actual APs [3].

In the fingerprint based localization phase, the data collection phase is a very important and time consuming process, especially with the addition of VAPs. But since VAPs are created by statistical analysis, no additional hardware will be needed in the study. This has motivated the research to create a VAP in the current existing Wi-Fi environment, creating an algorithm that will make use of VAP and fingerprint scheme to achieve a better performance compared to the conventional fingerprint scheme.

This paper is organized as follows. Chapter II reviews indoor localizations based on fingerprint scheme and VAP studies. Chapter III proposes the indoor localization algorithm using VAPs in Wi-Fi environment. Chapter IV discusses and analyzes the experimental results. Chapter V finally concludes this paper.

II. RELATED STUDIES

1. Wi-Fi Fingerprint Scheme

The indoor positioning techniques using Wi-Fi has seen many approaches with low-cost, high accuracy, low-complexity and robustness. In [4], the information of the physical layer in the scheme can be easily obtained in the Wi-Fi fingerprint scheme. The measured and obtained RSS reflects the distance information of the transmitter and the receiver. Because each location in an indoor environment receives a unique signal strength due to multi-path effect, the signal property, especially the signal strength, has its own fingerprint. A fingerprint map is built up actually using this property.

Wi-Fi fingerprint scheme has been a popular localization technique since the idea of RADAR [2] and has since been improved with different approaches and ideas added to its concept. A study on the properties of Wi-Fi signals in finding the user location [6], was done, and it provided results that the certain factors may affect the properties of Wi-Fi signals that can affect the location estimation. The accuracy of the location estimation varies on the orientation of user or mobile unit, the temporal and spatial variations of Wi-Fi signals, the time dependency, the device hardware and a number of samples.

2. Virtual Access Points

Another study [5] points out the importance of the proposing of the new Wi-Fi fingerprint scheme to improve the accuracy of the localization. It had been identified that the certain factors such as the weather conditions, building layout and frequency bandwidth significantly affects the accuracy of localization. The study also proposed the encouraging results on the use of VAPs as it has higher accuracy compared to using only APs. The addition of VAPs had indeed a positive impact to the study with minimal effort in preparation.

In [3], VAP is created in an open spaced indoor environment without any obstacles. Two VAPs were added to the existing 3 APs, whereas one VAP was placed in the exact opposite of one existing AP and the other VAP was placed in the middle of the indoor environment. Though the experiments cause the best results, it was done with a series of trials and simulations in order to determine the VAP location. This was done during the data collection phase for the fingerprint map and takes more time than conventional data collection where RSSIs of the existing APs are collected. In the same manner, the creation of the VAP also requires much time as in the case of VAP location.

III. PROPOSED MODEL AND ALGORITHM

Even though the increasing of APs has been one of popular idea in order to improve the Wi-Fi fingerprint scheme, the VAP can be used to solve this problem for cost-effective solution. The VAP can be realized by a statistical model with correlation. However, because the creation of VAP requires a great amount of time, the indoor localization algorithm for decreasing the amount of time to make VAP is proposed to overcome this problem in this paper.

1. Design Considerations

The VAP model will be dependent on the indoor floor plan and structure. The optimal VAP placement will be in accordance with how the floor structure is laid out while the path loss of signal varies on indoor environment.

Knowing the number and locations of existing APs should be also considered in making the suggested model because the VAP placement depends on the locations of the existing APs. The received signal strength indicator (RSSI) values of VAPs will be generated based on its correlation to existing APs. It is very important that the floor plan of the experimental testbed, known as the VAP placement, is dependent to the existing APs locations. Several attempts for seizing the VAP placement was made and some locations has low correlation to existing APs causing low placement accuracy. It is confirmed that the VAP correlation with at least 1 or 2 APs is should be greater than 70% in order to achieve the desired placement accuracy.

2. System Architecture of Proposed Model

The overall system architecture for the suggested model is showed in Fig. 1, where the processing steps are follows: 1) Acquiring of the floor plan to determine the placement of the VAP; 2) Correlation creation with added VAPs by calculating the number of existing APs in the indoor environment; 3) Data collection phase; 4) Fingerprint based localization phase.

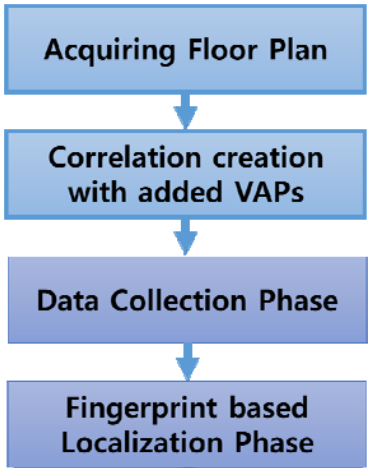

Fig 1. Overall system architecture of proposed model.

In order to make the VAP model, a statistical method will be used. The VAP related data added in the fingerprint map is the collected data during the data collection phase making one AP plus some VAPs matrix. From the collected RSS data, the regression coefficient of VAPs with respect to APs can be calculated.

However, on the FLP, the RSS data for VAPs is dependent on the RSS values of the collected APs. The RSS data for VAPs is equal to the sum of all existing APs with respect to their corresponding regression coefficient. These collected RSS data for APs and VAPs is compared with the fingerprint map database matrix for APs + VAPs collected during the data collection phase. Finally, the user location can be estimated by executing the fingerprint based localization phase using the collected RSS obtained in the data collected phase.

2.1 Data collection phase

In the proposed model, it is required to collect labeled data (fingerprints) to create a fingerprint map. The fingerprints are the measured received signal strengths (RSSs) at certain coordinates. The RSS data can be obtained by war walking using smart phones with pre-installed application capable of detecting RSS.

On the data collection phase, any devices capable of emitting Wi-Fi signals will act as VAP placed in strategic locations. That is to say, these devices will act as if actual APs but will only be used temporarily. RSS data will be collected from existing APs and the device acting as AP or VAP.

2.2 Fingerprinting based localization phase

In the fingerprint based localization phase, known as the online phase, the acquired RSSI is compared with the existing fingerprint map to estimate the user location. On this phase, the devices acting VAPs as temporary APs will leave only the existing APs emitting the Wi-Fi signals.

Fig. 2, shows the pseudo codes of the proposed indoor localization algorithm used to calculate the regression coefficient (*Creg*) and the VAP (*VAPtarget*) in order to obtain the error distance from the fingerprint map. These codes also utilize the measured RSS to create a statistical model of the VAP. The error distance is defined to the nearest distance from a reference point (RP) (*Der*).

Indoor Localization Algorithm using VAP
Offline Phase: Initialization **Scan RSS** (APs and temporary APs/VAPs) **Compute correlation** (APs and VAPs) **Compute regression coefficient** (*Creg)* **Create Fingerprint Map** End Online Phase: Initialization **Scan RSS** (APs) **Compute VAP** (using scanned AP and regression coefficient, *VAPtarget*) **Compare scanned RSS to Fingerprint Map** **Get nearest distance to reference point** (*Der)* End

Fig. 2. Indoor localization algorithm using VAPs.

IV. EXPERIMENTS AND RESULT ANALYSIS

1. Experimental Environment

The experiments are executed on the engineering building of Tongmyong University. The lobby of the first floor of the building is selected as the testbed for the experiments. 74 reference points (RPs) are used as the fingerprint map, and the area of each RP is defined to 1 * 1 m^2 space. The VAPs are strategically placed in the indoor environment to provide an optimal coverage together with the existing 3 APs.

During the data collection phase of the proposed algorithm, 2 devices acting as temporary APs are used as VAPs in the experiment. These two devices has a role of VAP are used together with the existing APs to create a 3APs + 2VAPs matrix for computing the correlation after power on. In this situation, the RSS data is collected from 3APs and 2VAPs in 74 RPs. In addition to this, the fingerprint map is also constructed together with the calculation of the regression coefficient in this phase.

During the fingerprinting based localization phase, 2VAPs will be powered off, leaving only the 3APs to provide the RSS for the mobile user. Once RSS is obtained by the user, the measured RSS of the 3 APs will also be used to calculate the VAP value with the help of the regression coefficient. Once the RSS of VAP is calculated, it will then be compared with the fingerprint map to determine the least Euclidian distance. The RP with the least Euclidean error distance is determined to the current location of the user.

2. Result Analysis

After obtaining the fingerprint map during the data collection phase, the correlation values in all 3APs and 2VAPs are shown in Table 1. In the Table 1, the high correlation of VAP#2 with AP#3 is measured, and it is regarded as a better result. The VAP#1, on the other hand, has a lower correlation with all other APs. This indicates that the VAP#1 position is not optimal.

Table 1. Correlation of APs and VAPs.

	AP#1	*VAP#2*	*AP#3*	*AP#2*	*VAP#1*
AP#1	1	0.349049	-0.48103	-0.15011	0.283031
VAP#2	0.349049	1	-0.70854	-0.31261	0.569292
AP#3	-0.48103	-0.70854	1	0.362526	-0.39199
AP#2	-0.15011	-0.31261	0.362526	1	-0.11113
VAP#1	0.283031	0.569292	-0.39199	-0.11113	1

The error distances are also measured in 4 scenarios (S1-S4). The placement types using 3APs and 2VAPs for producing the error distances are defined as follows: 1) only 3APs; 2) 3APs + VAP#1; 3) 3APs + VAP#2; 4) 3APs + 2VAPs as shown in Table 2. The error distance values for measuring the localization accuracy are measured in 4 scenarios of the experiment. It can be seen that the error distances of the proposed indoor localization algorithm in 4 scenarios such as 3APs, 3APs + VAP#1, 3APs + VAP#2 and 3APs + 2VAPs are measured to average 4.3484m, 5.2048m, 4.0716m and 3.9904m, respectively, as shown in Table 2. In this, the highest error distance in placement type of 3APs + VAP#1 proves that the lowest correlation affected the localization accuracy.

However, the placement type of 3APs + VAP#2 showed the low error distance compared with VAP#1 since VAP#2 has high correlation with AP#3 as shown in Table 1. With the high correlation of VAP#2 to AP#3, it compensated the low correlation of VAP#1 to all 3APs when both VAPs and 3APs were used in the scenario 4 resulting to the lowest error distance as indicated in Table 2.

Table 2. Error distances comparison among 4 scenarios.

Items	S1	S2	S3	S4
Placement Types	3APs	3APs + VAP#1	3APs + VAP#2	3APs + 2VAPs
Error Distance(m)	4.3484	5.2048	4.0716	3.9904

The experimental results in 4 scenarios are presented to the form of cumulative frequency graph as shown in Fig. 3. The experiment was executed with 2VAPs placed in the testbed. VAP#1 had a lower correlation with the existing 3 APs while VAP#2 had a higher correlation with AP3. Fingerprint map data made is composed of RSS from 3 existing APs and 2 VAPs. Upon execution of the algorithm in real time, the RSSI of VAP#1 and VAP#2 is computed based on the RSSI received by the user from the 3 existing APs. This shows that due to the correlation of VAPs from the APs, higher correlation provides a higher accuracy than standard AP fingerprint localization. The differences of error distances are compared with the average of 4 scenarios in Fig. 4.

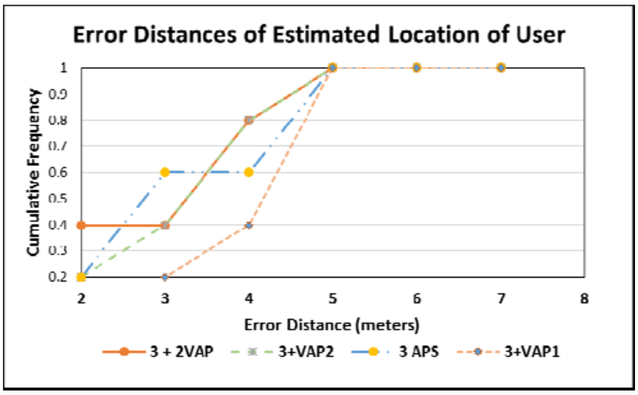

Figure 3. Error distances of estimated location of the user in 4 scenarios.

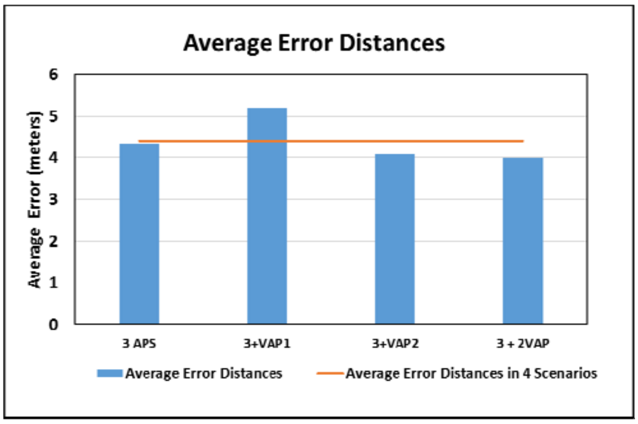

Figure 4. Comparison of average error distances in 4 scenarios.

V. CONCLUSION

Adding VAPs in an indoor environment with fixed APs results in an increased localization accuracy compared with only the fixed APs. In addition, creating VAPs only needs a temporary AP to be placed in a certain location thus not needing to have a fixed AP in that location. This reduces the cost of deployment of additional AP to be added in the system while increasing localization accuracy. Another improvement on this situation is to propose getting 4 direction data for the fixed APs during the data collection phase. This will help reducing the RSS fluctuations experienced due to different orientation of user's mobile devices. It is believed that reducing RSS fluctuations can also improve performance of localization.

Adding VAPs and collecting 4 direction data during the data collection phase will have greater performance compared with fingerprint based localization system using fixed APs and data using only a single direction in the data collection phase.

This study proves that increasing of the AP count during localization improves the localization accuracy. Furthermore, additional AP can be achieved using VAPs making it possible to increase AP counts in a system with already fixed APs. However our research also shows that the localization accuracy can be also decreased unlike the good correlation of VAP#2 to the 3APs due to poor correlation of VAP#1 to the 3APs. The poor performance of VAP#1 was compensated by VAP#2 still achieving a desired output when both VAPs are used in localization.

The correlation of VAPs to APs is a big factor when adding VAP to the system. Therefore, it can be concluded that adding more than 2VAPs will make localization accuracy higher, taking into consideration the placement of VAPs with high correlation to existing APs.

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