

Survey on the Indoor Localization Technique of Wi-Fi Access Points

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ABSTRACT

This article describes how indoor localization of Wi-Fi AP (access point) plays an important role in the discovery of illegal indoor Wi-Fi and for the safety inspection of confidential places. There have been many related research results in recent years. In this article, a review is presented on the indoor localization technique of Wi-Fi AP. First, indoor localization methods of Wi-Fi AP can be divided into three categories: localization based on signal strength; fingerprint feature; and distance measurement. Then, the basic principles of the three methods are described respectively, and an evaluation of the typical methods are provided. Finally, the authors point out some research tendency of the indoor localization techniques of Wi-Fi AP.

KEYWORDS

Distance Measurement, Fingerprint Feature, Indoor Localization, Signal Strength, Wi-Fi Access Points

1. INTRODUCTION

In recent years, the popularity of Wi-Fi continues to improve, which has brought great convenience to people's daily life, but also provides the possibility for hackers to set up illegal AP and trick users into accessing. Besides, Wi-Fi signals are prone to privacy leaks. For example, lawless people can set a Wi-Fi without a password. In this case, all computers equipped with a wireless card are likely to be automatically connected. This can lead to lots of safety problems, such as information interception of PIN numbers or bank account. In addition, in many special departments that prohibit the coverage of wireless signals there still have private Wi-Fi. The study of indoor localization techniques of Wi-Fi AP is of great significance for safety inspectors to discover illegal Wi-Fi AP in security work.

There are two kinds of researches of indoor equipment localization related to Wi-Fi access point. One is to locate wireless terminal based on the Wi-Fi signal, and the other is to locate the indoor Wi-Fi AP. In the former aspect, the earlier proposed localization algorithms are mainly based on AOA (Angle of Arrival) (Gu, 2009; Niculescu et al., 2003; Brida, 2009), TOA (Time of Arrival) (Patwari et al., 2003; Thomas, 2000), TDOA (Time Difference of Arrival) (Reza, 2000; Gezici et al., 2005; Ma, 2003), RSSI (Received Signal Strength Indication) distance measurement (Madhan, 2014; Ash et al., 2004; Bshara et al., 2010; Park et al., 2011), etc. Later some scholars improve the above methods. Bahl et al. (2000) present RADAR (radio-frequency based system) algorithm to combine signal strength with the signal propagation model. The experimental results show that the localization accuracy is about 3 to 5 meters. Roberto Battiti et al. (2005, 2002) put forward a localization method based on Wi-Fi fingerprint, and the neural network model is used to locate the target. The localization

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accuracy is about 3 meters. The RTLS (Real Time Locate System) (Veen et al., 1988; Yong et al., 2010) of Ekahau periodically collects signal strength information by positioning tags, and uses the signal attenuation formula to locate target AP on the accuracy of 1 meters. In the latter aspect, there are two ways to detect Wi-Fi signal - outdoor and indoor. The main flow of detecting indoor Wi-Fi signal from outdoor is to set detectors around the building where the Wi-Fi AP is erected. Then, the coordinates of the detectors and the corresponding Wi-Fi signal is simultaneously collected to locate the location of Wi-Fi AP. Le T M et al. (2012) presents a distance-based localization algorithm to obtain the location of the AP utilizing the location of the detectors and the measured angles. Subramanian A P et al. (2008) exploit a DrivebyLoc algorithm regarding the angle of the strongest signal as the direction of the target AP, whose average error is about 50 meters. Chen et al. (2015) proposed the PDAPL (Probability Density algorithm for Access Point Localization) based on probability density, which obtains an increase (30 meters) in localization accuracy and reduces the number of required detectors to half of the DrivebyLoc algorithm.

Due to the existence of GPS (Global Positioning System) error and a variety of environmental factors, the accuracy of indoor AP localization from outdoor is low, which cannot meet the actual requirements. In contrast to outdoor detecting, the indoor detecting method cannot acquire GPS signals, but can get more accurate localization results. The existing Wi-Fi AP indoor localization methods can be divided into three categories: The localization method based on the signal strength, fingerprint feature and distance measurement. This paper focuses on the localization techniques of Wi-Fi AP in the indoor environment, and aims to summarize the research progress of the indoor localization techniques of Wi-Fi AP. Then the performance of the three typical methods mentioned above is analyzed, and the problems in current indoor localization techniques of Wi-Fi AP are pointed out to provide a reference for the researchers and engineers engaged in this domain.

2. LOCALIZATION METHOD BASED ON SIGNAL STRENGTH

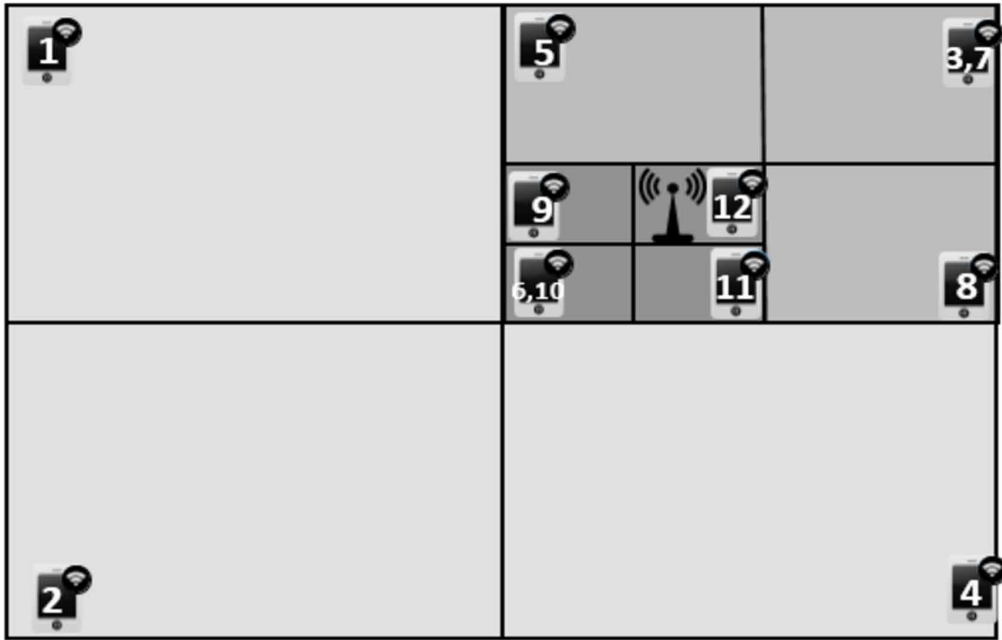
When locating Wi-Fi AP based on signal strength, the locator is required to move with the handheld wireless detection equipment in the area to be located. The search range is gradually narrowed according to the Wi-Fi signal strength trend until the Wi-Fi AP is located. At first, select the Wi-Fi that you want to locate according to the detection results and associate the NIC (Network Interface Card) with the target Wi-Fi. Then, the real-time signal strength of the target Wi-Fi in different locations or different directions is acquired by the signal strength detector. Next, the signal strength is converted to the distance between current location and the target Wi-Fi AP, and the next search area is determined according to the comparison result. Finally, approach the target Wi-Fi AP gradually until its specific location is determined.

According to the different antennas used, the algorithms used for reducing the search range to approach the target AP mainly include the convergence-based localization and the vector-based localization (Satoh et al., 2015).

2.1. Convergence-Based Localization

The principle of the convergence-based localization is shown in Figure 1. It requires a signal strength detector and a wireless network card with an omni-directional antenna, which has the same effect of transmitting and receiving in all directions. The main steps are as follows: Firstly, the search area is regarded as a large rectangle and is divided into four quadrants. Secondly, the signal strength is measured in the four corners of the large rectangle and the mean values are recorded. Thirdly, the recorded signal strength is compared to determine the quadrant owning the target AP. The quadrant with strongest signal strength is regarded as the next search area. Finally, the new search area is divided into four quadrants again, and the above operation is repeated to narrow the search range until the actual location of the Wi-Fi AP is determined.

Figure 1. Schematic diagram of the convergence-based localization



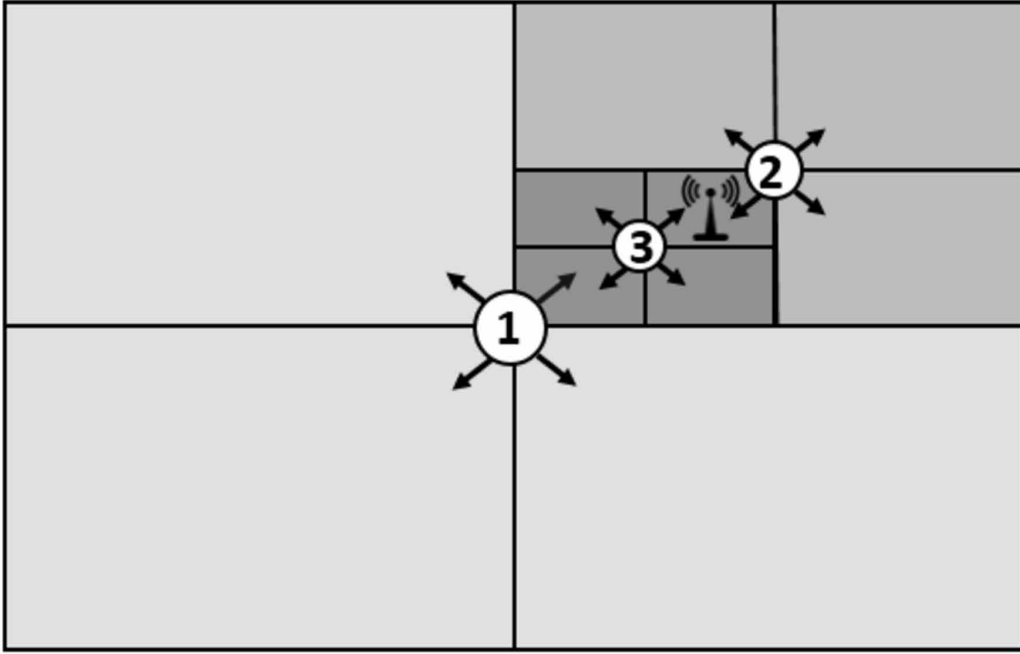
2.2. Vector-Based Localization

The principle of the vector-based localization is shown in Figure 2. It requires a signal strength detector and a wireless network card with a unidirectional antenna, which will reinforce signals from one direction and suppress signals in other directions. The main steps include: Firstly, the search area is regarded as a large rectangle and is divided into four quadrants. Secondly, the antenna is directed to the first quadrant at the center of the rectangle and rotated 90 degrees counterclockwise, pointing to the other three quadrants. It is required to measure multiple sets of signal strength respectively and record their mean values. Thirdly, the recorded signal strength is compared to determine the quadrant of the target AP. The quadrant with strongest signal strength is used as the next search area. Finally, the new search area is divided into four quadrants again, and the above operation is repeated to narrow the search range until the actual location of the Wi-Fi AP is determined.

Apel et al. (2010) use a variety of signal strength detectors to test the convergence-based localization and the vector-based localization. Test results show that the location of the Wi-Fi AP can be determined in a normal office via Aircheck after 12 measurements. We tested 15 Wi-Fi APs in a normal office of 18×15 square meters. The experiments show that all the localization error is within 1.5 meters and the minimum reaches 1 meter below. In addition, the average time of locating a Wi-Fi AP using vector-based Localization is shorter than the convergence-based Localization.

The localization method based on signal strength is widely used at present, which can not only locate on two-dimensional plane, but also determine the floor of the Wi-Fi AP in three-dimensional space. In addition to the simple principle and easy operation, the hardware cost of the localization is low, and the equipment is easy to hide. Also, it does not need a training phrase to collect data in practical applications. But the idea of the method is to narrow the search area via multiple detection, which makes the location efficiency very low. Besides, the efficiency depends on locators' experience, so it is still unable to meet the high localization efficiency requirements.

Figure 2. Schematic diagram of the vector-based localization



3. LOCALIZATION METHOD BASED ON FINGERPRINT FEATURE

The location fingerprint is a formal description of the environmental characteristics in the localization area. The fingerprint-based localization utilizes an easy-to-calculate physical quantity to characterize the indoor environment. The target Wi-Fi AP is located by collecting fingerprint information in advance and comparing the fingerprint in later period. The RSSI of Wi-Fi signal is usually used as the location fingerprint because it is different at different locations.

The fingerprint-based localization includes two phases: Offline training and online locating (Koo et al., 2012; Cho et al., 2012; Lemic et al., 2016; Jie et al., 2008). The basic principles are as follows (Figure 3):

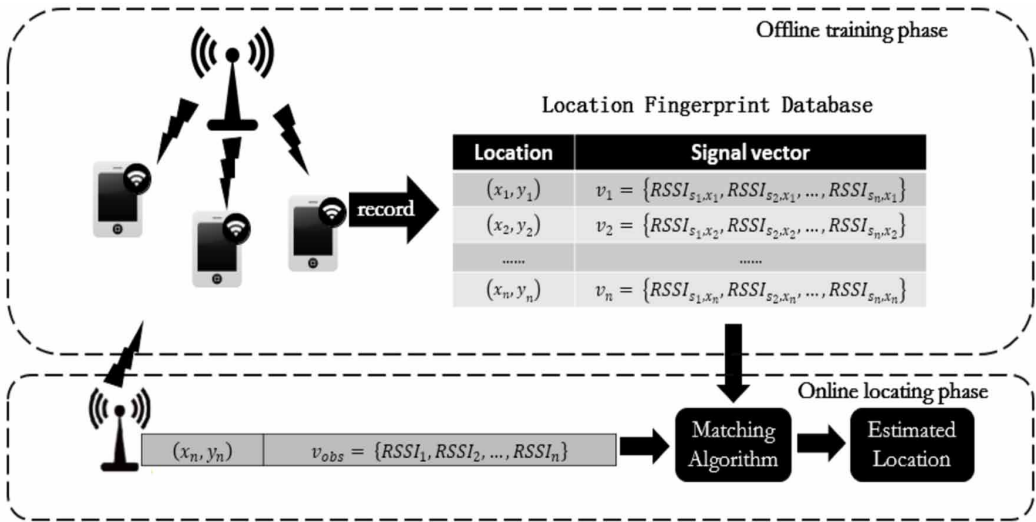
1. Offline Training Phase

The offline training phase collects a large amount of fingerprint information, and establishes a RSSI location fingerprint database. This needs to record RSSI data acquired from the detectors with Wi-Fi APs placed at several known locations.

Localization staff should place Wi-Fi APs at different locations covering the localization area, and record the RSSI values from n detectors corresponding to each location coordinates. The RSSI should be detected several times and represented as an average.

$X = \{(x_1, y_1), (x_2, y_2), \dots, (x_p, y_p)\}$ is the set of AP locations during the offline training phase. $S = \{s_1, s_2, \dots, s_n\}$ represents the n detectors. Each AP location $x_i \in X$ correspond to a signal vector $v_i \in V (1 \leq i \leq p)$. The signal vector $v_i = \{RSSI_{s_1 x_i}, RSSI_{s_2 x_i}, \dots, RSSI_{s_n x_i}\}$, where $RSSI_{s_j x_i}$ denotes the RSSI from the s_j when the Wi-Fi AP is at (x_i, y_i) .

Figure 3. Schematic diagram of the fingerprint-based localization



In the offline training phase, lots of data pairs (x_i, y_i) are collected to construct the RSSI location fingerprint database. The indoor location is abstracted into a signal strength map, and different RSSI represents different AP locations.

2. Online Locating Phase

The online locating phase matches the real-time fingerprints with the offline RSSI location fingerprint database to determine the optimal location point.

After finding unknown Wi-Fi, the first step is locking the target Wi-Fi to get real-time signal vector: $v_{obs} = \{RSSI_1, RSSI_2, \dots, RSSI_n\}$.

Then, the offline signal vector in the database is matched with v_{obs} . Finally, the location with the best similarity is selected as the estimated AP location.

The most common used fingerprint matching algorithms include: Nearest Neighbor (NN) (Tsai et al, 2009), K-Nearest Neighborhood (KNN) (Lin et al., 2009), SVM Regression Analysis Algorithm (Viani et al., 2008), Principal Component Analysis (PCA) (Ci et al., 2013), Nave Bayes (NB) (Chen et al., 2013), Linear Regression Algorithm (LR) (Vanheel et al., 2011) and so on.

Based on the above-mentioned conventional localization methods, many scholars have proposed some improved methods. Koo et al. (2012) present a Serendipity method using the similarity analysis based on multi-dimensional scaling technology to locate the AP, and the fingerprint information is collected by ordinary smart phones. In the office 35×50 square meters in area with 6 APs, the localization error is about 6.8 meters. In the office 27×37 square meters in area with 9 APs, the localization error is about 3.5 meters. Cho Y et al. (2012) analyze a statistical characteristics of Wi-Fi RSSI difference from heterogeneous devices, and explain the effect of device diversity on the RSSI fingerprint measurement. The localization error is reduced to less than 3 meters.

By increasing the distribution granularity of the monitor notes in the offline training phase, the fingerprint-based localization can obtain a higher-precision AP location. Because the problem of NLOS (Non-Line-of-Sight) and multipath propagation is solved well, the localization accuracy of the target Wi-Fi in the complex indoor environment is ensured. But the workload of fingerprint information

collection in the offline training phrase is very large. In addition, because the localization result is susceptible to the change of indoor environment, the fingerprint information should be re-collected regularly, which greatly increases the workload and maintenance cost.

4. LOCALIZATION METHOD BASED ON DISTANCE MEASUREMENT

The localization method based on distance measurement locates the target AP by utilizing the relationship between certain characteristic of Wi-Fi signal and propagation distance. Similar to wireless terminal localization method based on the Wi-Fi signal, existing localization algorithms of AP based on distance measurement mainly include: the TOA-based localization (Ciurana et al., 2006), the TDOA-based localization (Wann et al., 2006), the AOA-based localization (Cho et al., 2012) and the distance-based RSSI localization (Le et al., 2012; Ji et al., 2013; Koo et al., 2011).

4.1. TOA-Based Localization

The schematic diagram of the TOA-based localization algorithm is shown in Figure 4. The distance constraints between the detectors and target AP is calculated based on the propagation time of Wi-Fi signal and the multilateration is used to locate the AP.

As shown in Figure 4, the coordinates of three detectors M_1 , M_2 and M_3 are (x_1, y_1) , (x_2, y_2) and (x_3, y_3) , and the straight line propagation time of Wi-Fi signal to each detectors is denoted as t_i ($i = 1, 2, 3$). Then, the distance between the detectors and the target AP can be obtain by $r_i = c * t_i$ (where $i = 1, 2, 3$ and c is propagation velocity equal to the speed of light). Next, the multilateration with three detectors is used to locate the target AP by the following equation,

$$\begin{cases} (x_1 - x_0)^2 + (y_1 - y_0)^2 = r_1^2 \\ (x_2 - x_0)^2 + (y_2 - y_0)^2 = r_2^2 \\ (x_3 - x_0)^2 + (y_3 - y_0)^2 = r_3^2 \end{cases} \quad (1)$$

where (x_0, y_0) is the location of the target Wi-Fi AP.

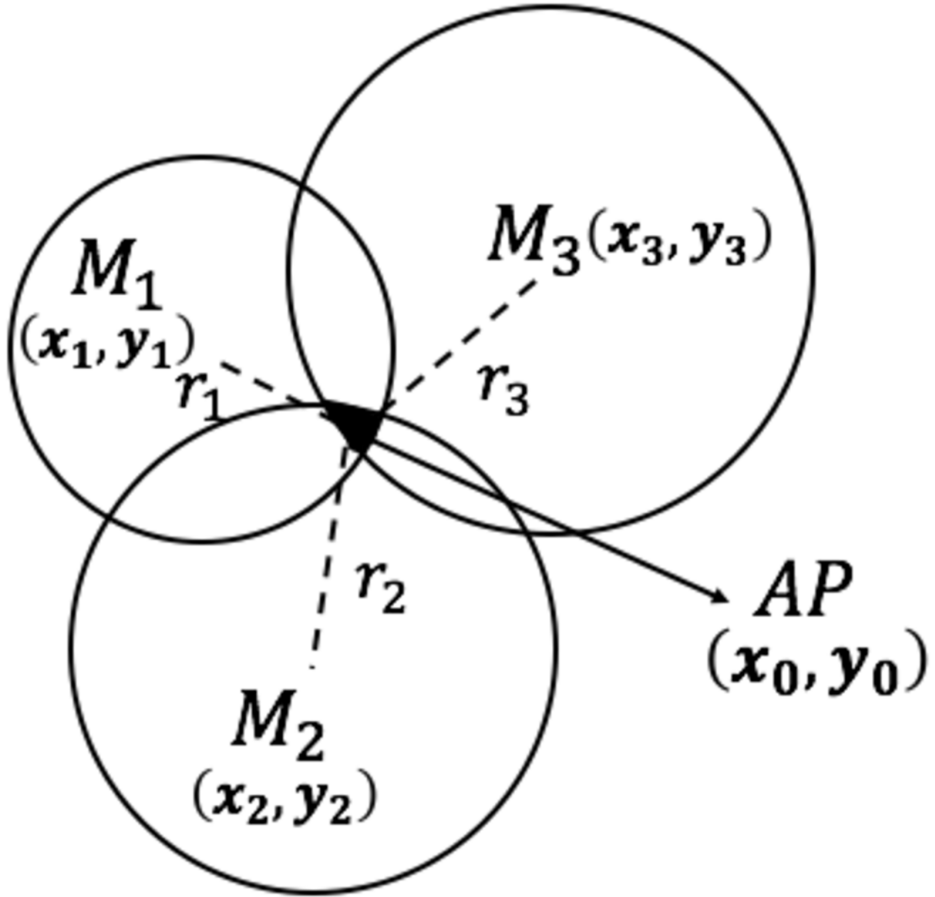
The TOA-based localization is easy to implement with high localization accuracy. And the localization result will not be affected by NLOS, multipath propagation or the distance between detectors and the target AP. However, the hardware cost of this algorithm is high because of the requirement for strict clock synchronization between all detectors and target APs.

4.2. TDOA-Based Localization

The TDOA-based localization is a variant of the TOA-based localization. The schematic diagram is shown in Figure 5. The target AP's location is determined by the time difference of Wi-Fi signal arriving at different detectors.

As shown in Figure 5, the distance between the detectors and the target AP r_1 , r_2 and r_3 is calculated based on the signal arrival time. So the distance deviation from the target AP to M_1 and M_2 is $r_{21} = r_2 - r_1$. Since the target AP is on the hyperbolic curve with M_1 and M_2 as the focal point and the distance deviation to the two focal points r_{21} is a constant value, then the intersection of the two hyperbolic is the location of target AP. The equations are as follows:

Figure 4. Schematic diagram of the TOA-based localization



$$\begin{cases} \sqrt{(x_2 - x_0)^2 + (y_2 - y_0)^2} - \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2} = r_{21} \\ \sqrt{(x_3 - x_0)^2 + (y_3 - y_0)^2} - \sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2} = r_{31} \end{cases} \quad (2)$$

where (x_0, y_0) is the location of the target Wi-Fi AP.

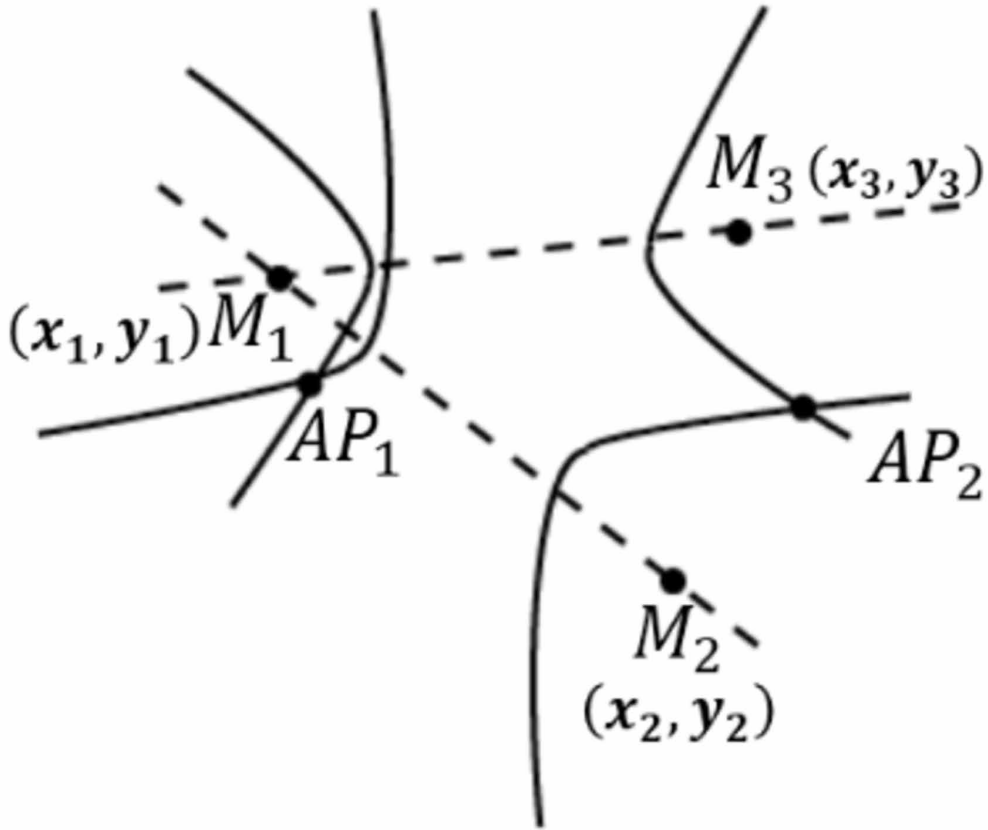
The TDOA-based localization algorithm only needs to ensure strict synchronization between the detectors, while the time between detectors and the unknown target AP is not required. Therefore, the TDOA-based localization is more practical compared with the TOA-based localization, and the localization accuracy is higher. But the hardware cost is still high.

4.3. AOA-Based Localization

The schematic diagram of the AOA-based localization is shown in Figure 6. Its idea is to determine the location of the Wi-Fi AP by examining the angles between two or more detectors and the target AP.

As shown in Figure 6, the coordinates of the two detectors M_1 and M_2 are (x_1, y_1) and (x_2, y_2) . Then, the angle of the signals from the target AP to the detectors is obtained by the antenna array,

Figure 5. Schematic diagram of the TDOA-based localization



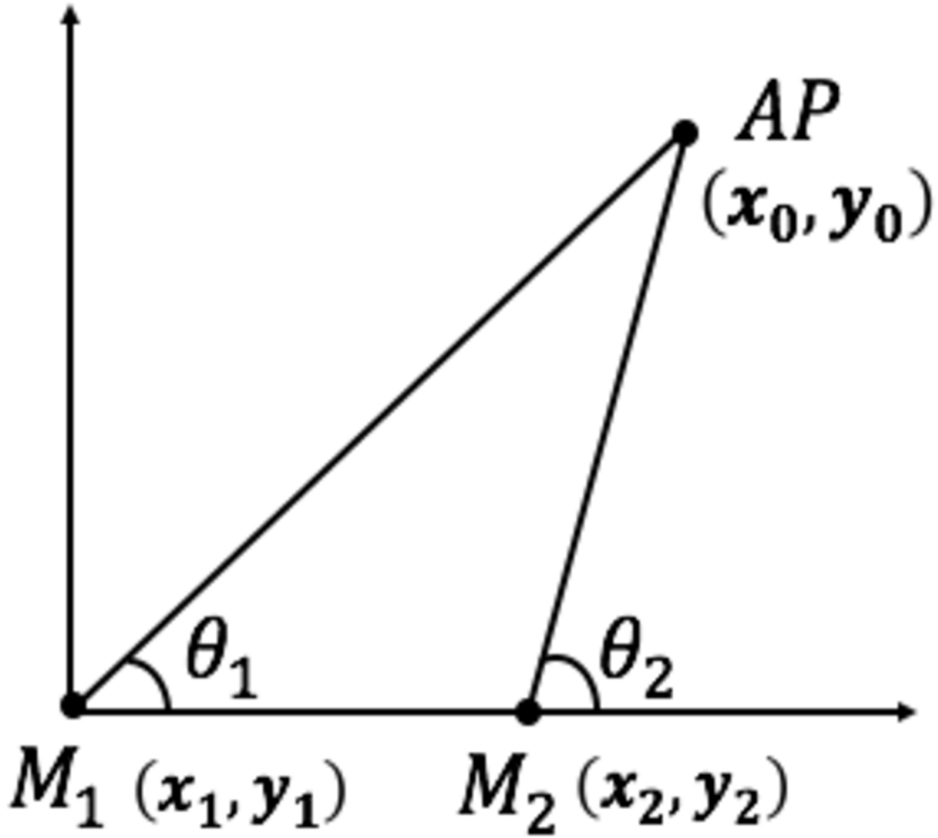
which is represented as θ_1 and θ_2 . At last, the location of the target Wi-Fi AP is determined by the nonlinear equations:

$$\tan \theta_i = \frac{x_0 - x_i}{y_0 - y_i} \quad (i = 1, 2) \quad (3)$$

where (x_0, y_0) is the location of the target Wi-Fi AP.

The time synchronization device is not necessary in the AOA-based location algorithm because it does not require time synchronization. In the area with fewer obstacles where the received signal is less affected by reflection and diffraction, the localization accuracy of this algorithm is high. On the contrary, the localization accuracy will be significantly reduced in a complex environment because of the NLOS and multipath propagation, and some locations will even become a localization scotoma. In addition, an antenna array is required to measure the arrival angle of the received Wi-Fi signal in this algorithm which makes the hardware costs high.

Figure 6. Schematic diagram of the AOA-based localization



4.4. Distance-based RSSI Localization

The idea of the distance-based RSSI localization algorithm is converting the received RSSI into distance between the detectors and target AP according to signal attenuation model. The location of Wi-Fi AP is determined by the Trilateration method. Usually, the following signal attenuation model is used,

$$P_r = P_0 - 10\gamma \lg\left(\frac{d}{d_0}\right) + X_g \quad (4)$$

where P_r expressed in dBm is the RSSI at d meters from the target AP. P_0 is the reference RSSI at d_0 meters from the target AP (d_0 is usually set to 1), which depends on the power of the AP transmitter. In IEEE 802.11, P_0 is generally less than 15 dBm . The pathloss exponent is denoted as γ which depends upon the propagation environment, and usually range from 2 to 4 in the indoor environment. X_g is a random variable satisfying the Gaussian distribution and often ignored when the scale of collected signal data is large enough.

There are two linear unknown parameters P_0 and γ in equation (4), and they can be estimated by measuring the RSSI at some known locations in advance using the following matrix equation:

$$p = Ab$$

where $A = \begin{bmatrix} 1 & -10 \lg d \end{bmatrix}$ and $b = \begin{bmatrix} P_0 \\ \gamma \end{bmatrix}$. Then, we can get the maximum likelihood estimated value of b , which is $b = (A^T A)^{-1} A^T p$. And the unknown parameters P_0 and γ in current environment can be obtained.

In order to locate the target AP, its RSSI is obtained by n monitor nodes in different locations. We denote the target AP's location as loc_{AP} , each detector's as loc_i ($1 \leq j \leq p$) and the estimated distance from each detector to the target AP as d_i . Then, the location of the target AP is determined by the least squares method:

$$loc_{AP} = \arg \min_j \sum_i (\|loc_{AP} - loc_i\| - d_i)^2$$

Compared with the localization algorithm based on AOA, TOA and TDOA, the distance-based RSSI localization algorithm is easy to operate and the hardware cost is low, which make it widely used nowadays. However, the localization results are very sensitive to the environment because the parameters in the path loss model is estimated in different environment.

Among the above-mentioned localization methods based on distance measurement, the algorithms based on TOA, TDOA and AOA have not yet been widely used. Existing research results about locating wireless terminal based on Wi-Fi signal show that these three algorithms perform well. For example, Strang T et al. (2005) use TOA and Trilateration in Wi-Fi environment to locate indoor wireless terminal in the room of 50×50 square meters. Their experimental results show that the accuracy of 90% location results reach 1.4 meters, and 66% reach 0.9 meters. Vanheel et al. (2011) propose a three-dimensional joint WSN localization algorithm based on AOA and TDOA to locate indoor wireless terminal in the three-dimensional space. In an office building $400 \times 400 \times 50$ cubic meters in area with 100 nodes tested, the localization accuracy declines with the distance increasing, and the minimum is about 5 meters.

At present, there are many researches on Wi-Fi AP location algorithm based on RSSI distance measurement, and the experimental verification results are present. For example, Ji M et al. (2013) introduce an algorithm based on Monte Carlo simulation and path loss model. In this algorithm, P_0 and γ are estimated by measuring the distance between detectors and the APs placed at known locations. They tested 55 Wi-Fi APs in a four-story office building of a total area about 3500 square meters. The experiments show that all the localization error is within 10 meters and the minimum reaches 5 meters below. Koo J et al. (2011) linearly approximate the exponential relationship between RSSI and the distance by using the polygon technology. In a room of 35×50 square meters with 4 detectors, they present that the localization accuracy is about 15 meters. When the number of detectors increased to 9, the localization accuracy is about 5 meters. The RAPDL (Rogue AP Detection and Localization) system (Le et al., 2012) combined the signal attenuation model and the fingerprint matching. The location results show that the average localization accuracy 80% reaches 4.5 meters and 50% up to 2.5 meters.

Table 1. Comparison results of typical indoor localization algorithms of Wi-Fi AP

Indoor localization method of Wi-Fi AP		Device	Cost	Accurac-y	Implement- ation complexity	NLOS	Multipath propagation
Localization method based on signal strength	Convergence-based localization (Apel et al., 2010)	Signal strength detector omni-directional antenna	Medium to low	Medium to high	Easy to implement	Less affected	Less affected
	Vector-based localization (Apel et al., 2010)	Signal strength detector unidirectional antenna	Medium to low	Medium to high	Easy to implement	Less affected	Less affected
Localization method based on fingerprint feature	Fingerprint-based localization (Koo et al., 2012; Cho et al., 2012; Le et al., 2012)	Signal strength detector	Low	High	Heavy workload	Make good solution	Make good solution
Localization method based on distance measurement	AOA-based localization (Vanheel et al., 2011)	Antenna array	High	Medium to high	Difficult to practical application	Vulnerable	Vulnerable
	TDOA-based localization (Vanheel et al., 2011)	Time synchronization device	High	High	Difficult to practical application	Unaffected	Unaffected
	TOA-based localization (Strang et al., 2005)	Time synchronization device	High	High	Difficult to practical application	Unaffected	Unaffected
	Distance-based RSSI localization (Ji et al., 2013; Koo et al., 2012; Le et al., 2012)	Signal strength detector	Low	Medium to high	Easy to implement	Vulnerable	Vulnerable

5. COMPARISON OF TYPICAL ALGORITHMS

The comparison results of the typical indoor localization algorithms of Wi-Fi AP are shown in Table 1.

Table 1 shows the comparison of existing typical algorithms in terms of device dependency and localization cost, localization accuracy, practical application and interference factors.

In terms of device dependency and localization cost, the algorithms based on convergence, vector, fingerprint and the RSSI distance measurement only need signal strength detector and antenna which make the hardware cost is low. The TOA-based localization and the TDOA-based localization require time synchronization device, and the AOA-based localization need to analyze the different angles which is very complex, so the localization cost is high.

The comparison result on localization accuracy shows that the fingerprint-based localization can get accurate result, as well as the TOA-based localization and the TDOA-based localization in the case of time synchronization. The AOA-based localization, the convergence-based localization and the vector-based localization have lower accuracy. And the accuracy of the distance-based RSSI localization is the lowest.

Comparing the above algorithms in the aspect of practical application, the convergence-based localization, the vector-based localization and the distance-based RSSI localization are easy to implement and the operation is simple. The workload of the fingerprint-based localization is very large in the offline training phase and it requires regular maintenance. While the AOA-based localization, the TOA-based localization and the TDOA-based localization, are more common in theoretical research and difficult to practical application due to the high localization cost.

In addition, we can also see from Table 1 that the TOA-based localization and the TDOA-based localization are not affected by multipath propagation and NLOS. And the fingerprint-based localization makes a good solution of environmental interference factors. The convergence-based

localization and the vector-based localization are less affected by multipath propagation and NLOS. The AOA-based localization and the distance-based RSSI localization are vulnerable to multipath propagation and NLOS which affect the localization accuracy.

6. PROBLEMS WORTHY OF FUTURE STUDY

The current researches on indoor localization techniques of Wi-Fi AP have gotten some results. However, the complicated and changeable indoor environment, such as the placement of indoor items and personnel walking, have a great impact on the signal propagation which will seriously affect the location accuracy. Therefore, there are still some problems in the indoor localization techniques of Wi-Fi AP need further study.

1. How to reduce the impact of multipath propagation and NLOS problem?

Non-line-of-sight propagation and multipath propagation have a great impact on the indoor localization of Wi-Fi AP. When an obstacle is encountered during propagation, Wi-Fi signal will be reflected and diffracted. As a result, the arrival time, angle and signal strength of Wi-Fi signal received by the signal detector will have a great difference with the ideal situation. And the calculated distance between the detector and the target AP will have a deviation from the actual distance which reduces the accuracy of the localization method based on the distance measurement.

2. How to improve the localization efficiency?

The localization method based on signal strength is widely used, but its localization efficiency is low. The detector usually need to hold a signal strength detector to search the localization area and divide the rectangular multiple times. To locate the target AP usually requires at least 3 rectangular divisions and 12 detections which takes about several minutes or more. But in practical application of the search for illegal Wi-Fi AP, it is often necessary to quickly locate the Wi-Fi AP.

3. How to improve the adaptability of localization algorithm?

As mentioned above, the Wi-Fi signal propagation is susceptible to environmental factors. However, the existing algorithms often rely on the environment which resulting in poor adaptability. For example, the fingerprint-based localization needs to collect a large amount of training data in advance in different localization environment, and the parameters P_0 and β in the distance-based RSSI localization will also change with the different environment. As a result, the adaptability of the algorithms need to be improved. Besides, it is often impossible to collect data in the localization area ahead of time in actual localization when locating the illegal Wi-Fi.

4. How to locate micro Wi-Fi AP?

Wi-Fi AP is becoming more and more micro with the development of wireless technology, which posing a new challenge to Wi-Fi AP localization. With the feature of small size, portable, mobile, and small signal coverage, Micro Wi-Fi AP is difficult to be located accurately when the distance between signal detectors and AP is far.

7. CONCLUSION

Wi-Fi AP indoor localization has been an important and difficult problem for network management and secret department. This paper surveys the current indoor localization techniques of Wi-Fi AP. Localization methods based on different principle are discussed and divided into three categories: the localization method based on the signal strength, fingerprint feature and distance measurement. The existing algorithms are compared on the aspects of localization cost, efficiency and accuracy, etc. Although the existing method can locate Wi-Fi AP roughly, the localization accuracy is easy to be affected by the environment. Therefore, how to reduce the influence of multipath propagation and NLOS on the localization results, enhance the robustness and adaptability of the localization algorithm and improve the localization accuracy are worthy of further study.

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