Method of Enhancing the Accuracy of Indoor Positioning (RSSI to UL-AOA)

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Abstract. Nowadays, with the rapid development of urbanization worldwide, the indoor area has become complex. Even with floor maps and guidance signs, people waste time on self-location in an unfamiliar building for the reason that the mature location services like GPS are limited as outdoor positioning series, and the method of indoor positioning is relatively missing or rough. Therefore, the better indoor positioning systems are in a highly command. The indoor positioning system has the goals for realizing the location marked and tracking of people and objects in indoor scenes. This paper focused on the main positioning method in use, which is distance-based positioning algorithm. Then, the advantages and disadvantages of the mainstream algorithms RSSI and AOA were discussed. At last, by comparing the current research, the author put forward an optimized indoor positioning algorithm based on AOA, which may become the mainstream in the future.

1. Introduction
The rapid development of mobile Internet has led to the penetration of positioning and navigation services into all aspects of people's lives, which people are more and more familiar with. Location services are becoming more and more familiar. The traditional location service positioning accuracy only stays in buildings and streets, indoor positioning based on wireless network is still in a less mature period, and the traditional satellite-based navigation and positioning system cannot meet the demand of indoor positioning. At present, the WIFI-based indoor positioning technology is a popular technology studied because of its high system cost effectiveness, low positioning error, no unnecessary positioning equipment, and wide range of use [10].

As the number of mobile devices continues to increase, the use of positioning services on mobile devices is not new, but indoor positioning is still a challenge for many technology companies to achieve fast and real-time positioning in special indoor environments. According to the results of technology companies research on indoor positioning systems, mobile terminals are not always covered by wireless networks in daily indoor closed environments, which makes indoor positioning even more challenging. There is much space for future development of indoor positioning technologies as the demand for indoor positioning increases [10].

At present, there are three ways to implement wireless network positioning technology: one is based on the arrival time of radio signals; the second is based on the arrival angle of radio waves; and the third is based on the signal reception strength from the base to the target (RSSI). Due to the wide coverage of WIFI signals, indoor positioning algorithms based on WIFI wireless networks have become popular. However, the propagation of wireless signals is limited by short distance and fast loss. Signal arrival time or signal arrival angle positioning techniques are difficult to be used for indoor positioning. Most
of the time, RSSI positioning techniques are used for indoor positioning. However, studies have also shown that even the currently mature RSSI-based positioning algorithms are still somewhat inadequate. Like FTM range accuracy is bandwidth-dependent, but its multipath resistance is still limited without the use of multiple antennas, the accuracy of ranging and positioning is limited [10].

This paper focuses on the existing indoor positioning method received signal strength measurement (RSSI) and angle of arrival measurement (AoA). The principles of these two algorithms and how they can be used for indoor positioning will be introduced. What is more, the author will compare the advantages and disadvantages of the two algorithms to find a better indoor positioning solution from 5G based technique.

2. RSSI and AoA positioning algorithms

2.1. RSSI-based localization algorithm
Traditionally, the main indoor positioning algorithm is based on RSSI (Received Signal Strength Indicator), which is able to receive signal strength in a wireless environment, and represents the power level received by the radio after the antenna and possible cable loss. Therefore, the larger the RSSI value is, the stronger the signal will be. RSSI is logarithmic rather than linear. Thus, a 6dB-increase in RSSI can double the signal strength, while a 12dB-increase in RSSI can quadruple the signal [4].

RSSI is applied to distance measurement between transmitters and receivers. The method is based on the received signal energy strength to determine the distance, which requires high communication channel parameters. Its range measurement theory is based on the principle that radio waves or sound waves are transmitted in a medium and the signal power is attenuated with the propagation distance. According to the transmitted power of the known signal from the anchor node and the received signal power from the unknown node, the distance between nodes can be calculated by the transfer function between the signal strength and the distance. The power strength is influenced by the decays and obstacles during transmission that relatively affects the accuracy [4].

The RSSI-based localization algorithm is relatively simple to implement that does not require additional hardware configuration of the system, and does not involve excessive data transmission interactions, so it is more beneficial to reduce the cost and power consumption of the nodes. This positioning algorithm is also a positioning algorithm currently used by many hardware manufacturers, and many ZigBee chips have registers for storing RSSI values [4].

However, according to research, due to the influence of environmental factors, the measurement of RSSI value is often subject to large errors. In the process of signal propagation, the signal strength is weakened by the influence of obstacles. Sometimes the RSSI value is unstable due to the wireless transceiver used. The RSSI based WIFI positioning has a dramatic degradation of ranging and localization performance in complex multipath environments, with errors of up to a dozen meters [5] [6] [8].

WIFI-based indoor positioning is more suitable for using fingerprint algorithms based on RSSI signals, because we do not need to know the location of all APs in advance, and the fingerprint algorithm can cope with changes in AP location or status. The mapping fingerprint database can be stored to the cloud server in advance, and the mobile device will send the surrounding AP information it gets in the positioning area to the server in real time, and the server will match and return the coordinate position to the client to realize the positioning of the device.

2.2. AoA-based localization algorithm
However, the AoA algorithm is actually better than RSSI algorithm in terms of performance when ignore that WIFI is used as the carrier. For AoA, Angle-of-Arrival (AOA) based positioning algorithm is a distance-based positioning algorithm which get the direction of the signal from the anchor node to the target devices, calculates the angle between the target and the anchor node, and then the position of the unknown target node can be calculated by using triangulation. The angle of arrival (AoA)-based
localization algorithm is a self-localization algorithm for wireless sensor network nodes with high localization accuracy [2].

As shown in the figure 1 if we know the angle $\alpha_1$ between the line from base station 1 to the device and the reference direction, we can draw a ray $L_1$; similarly, if we know the angle $\alpha_2$ between the line from base station 2 to the device and the reference direction, we can draw a ray $L_2$. Then the intersection point of $L_1$ month $L_2$ is the location of the device [1] [3].

![Figure 1. AoA localization Algorithm.](image)

In the actual implementation, the acquisition of angular parameters is a more complex process, and the requirements for the size and power consumption of the nodes are higher, requiring the addition of array antennas and the setting of multiple receivers, etc. Considering the characteristics of wireless sensor networks, although the AOA localization algorithm is precise, it is not used frequently in daily life [1] [3].

To summarize, the strength of the signal of the positioning technology based on RSSI algorithm is closely related to the distance: It is strong at a short distance, while weak at a long distance. Furthermore, the RF signal is easily affected by objects, and as long as there are objects between the beacon and the base station, it will greatly affect the signal strength and thus the positioning accuracy. Therefore, the authors believe that the improvement of RSSI algorithm accuracy is difficult in theory.

However, for AoA, the accuracy depends on the accuracy of wireless transmission angle measurement, so as long as the wireless transmission technology is strong enough, AoA can meet the demand of indoor high-precision positioning and thus be practical. Currently, with the development of 5G technology, the demand of this transmission technology can be satisfied, so UL-AoA, an indoor positioning method based on 5G protocol, may become a better solution for indoor positioning [5] [6].

AoA positioning algorithm is relying on the array antenna, after calculating the different antenna arrival signal to calculate the point of view. As it is known, the difficulty of high-precision AoA positioning algorithm is to deal with the planning of antenna array, the elimination of noise signal, and the compensation of RF switching time. With the commercialization of 5G, a consistent standard can be formulated, and the strength of many strong R & D companies to deal with these common problems, so that this part of the processing solution can be integrated into the 5G base station as a consistent standard use.

3. Better solution from 5G--UL-AoA

Nowadays, the AOA-based 5G positioning technology UL-AoA is considered to be a considerable solution with the development of 5G technique that sufficiently signal transmission can be satisfied. 5G uses high frequency or millimeter wave communication, which has very good directionality and can achieve higher precision range and angle measurement; on the other hand, 5G contains large-scale antenna technology with higher resolution beam, which can also achieve higher precision range and
angle measurement characteristics. Therefore, the AOA-based positioning method will have higher accuracy than 4G [7].

Based on the previous cellular network positioning technology, 5G R16 introduces a new Positioning Reference Signal (PRS). At the same time, as the ultra-dense network in 5G increases the diversity of reference points, Massive MIMO multi-beam allows for more accurate AoA estimation which can further enhance 5G positioning capabilities. In the future, 5G positioning capability will be further enhanced, and the R17 version will also improve 5G positioning accuracy to sub-meter level [7].

As a result, that 5G fulfills the transmission requirements of AoA technology, UL-AoA has the following advantages: high frequency wave, large bandwidths (better delay analysis), (D2D) Device to Device Communication (able to do measurement between devices), and high network density.

4. Conclusion

With the arrival of the 5G era, the Internet of Things and intelligence have put forward higher requirements for location-based services, and "5G positioning" as a new direction will play a stronger role in solving the "last mile" high-precision positioning problem indoors (according to statistics, about 90% of people’s time is spent indoors). 5G, like other technologies, estimate the geographical location of the mobile terminal by using specific algorithms with wireless signal data. However, for 5G rule R16, communication is characterized by high speed, low latency, and large number of connections, etc. Its key technologies include large-scale antenna arrays, ultra-dense networking, new multiple access, full spectrum access, and new network architectures. 5G commonly uses millimeter wave communication, which can achieve accurate angle measurement due to the excellent directionality of millimeter wave, UL-AoA as AOA-based positioning methods will have highly accuracy in 5G. The rapid development of 5G mobile communication network positioning technology will cover all aspects of our life, especially in the precise indoor positioning required areas, such as IoT, product tracking, security, to create greater value [5] [6].

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