Research on Indoor Mobile Node Localization Based on Wireless Sensor Networks

Yanhui Lv, Lei Chen, Deyu Zhang, and Jielin Liu

Abstract—**The positioning technology, as one of the key technologies of wireless sensor network, can make each node acquire its own position information in the network to achieve target monitoring, data acquisition and behavior prediction. Under indoor environment, owing to the influence of obstacles, signal transmission between mobile nodes generally is under the non-line-of-sight environment, causing more localization errors. In this paper, focused research on the localization algorithm in the initial state and mobile state when nodes enter the network is conducted under non-line-of-sight environment. Firstly, a multi-signal-based localization algorithm is proposed against the initial localization stage at which mobile unknown enters the network. Appropriate anchor nodes are selected to participate in localization computing through the signal strength value, thereby narrowing the area where unknown nodes locate and improving the localization accuracy of nodes. Meanwhile, aiming at the problem of non-line-of-sight errors, anchor nodes with low errors are selected by introducing non-line-of-sight inhibitory factor to reduce the impact of non-line-of-sight measured value on the localization results. Secondly, aiming at the motion state of mobile nodes, a localization algorithm based on historical localization is proposed. Mobile nodes are located according to the number of anchor nodes around node localization moment in conjunction with the historical localization information of nodes. Meanwhile, the coordinate computing method is modified by introducing a modification value to make the coordinate values of nodes closer to the real value. The simulation result indicates that the proposed localization method can improve the localization accuracy effectively and has good adaptability.**

Index Terms—**mobile node, multi-signal localization, non-line-of-sight environment, wireless sensor network**

I. Introduction

THIS wireless sensor network is a self-organizing network that is composed of a large number of sensor nodes with sensing, computing and communication capabilities. In WSN, nodes are distributed to different detection sites randomly, which are responsible for collecting, processing and transmitting information and sending the obtained data information to the aggregation node, facilitating the manager to perceive and monitor objective physical world[1]. WSN has the powerful data acquisition and processing capabilities, which is widely applied to military reconnaissance, smart household, medical treatment and health, environmental monitoring, warehouse management and other fields.

The localization technology[2],[3] is one of key technologies in WSN. Through the indoor localization technology, the locations of personnel or objects in indoor environment can be determined. When each node in the network is distributed at different sites, it will collect information in the monitoring area, and transfers information through the network to complete data collection, target monitoring and tracking. In the existing localization technology, the outdoor localization technology is relative matured based on GPS or Big Dipper, however, under the impact of obstacles in indoor environment, communication between nodes will arrive at the signal receiving end only through diffraction and reflection, which leads to more errors in localization information and failure to meeting the requirements of indoor high-precision localization. Hence, it is required to make research on the indoor node localization technology applicable to low cost and power consumption in WSN.

Environment in which signal communication between indoor nodes are conducted under the impact of obstacles rather than direct physical connection is referred to as non-line-of-sight (NLOS) environment; under NLOS environment, there are both line-of-sight (LOS) propagation and NLOS propagation between nodes. Hence, one of the research emphasis of WSN is to improve the localization accuracy of nodes under indoor NLOS environment[4].

At present, the common WSN node localization technology is mainly divided into Range-based localization technology[5] and Range-free localization technology[6]. Ranged-based localization can achieve localization with high accuracy, but has high requirement on hardware, which leads to increase in costs and power consumption of the network. For Range-free localization, the localization of nodes is achieved through the connectivity of the network, and owing to low power consumption and no need of increasing hardware, expenditures can be reduced; however, localization errors are larger, so Range-free localization can only complete rough accuracy localization. Such two localization technologies are applicable to static nodes, but there are a few researches on the localization of mobile nodes. At the present stage, there are more and more application scenes of mobile nodes in WSN, i.e., warehousing matters, medical care, robot trajectory tracking, etc. The localization of mobile nodes[7] is mainly divided into three: Anchor nodes are kept in static state, and

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unknown nodes are kept in motion state; anchor nodes are kept in motion state, and unknown nodes keep static; and anchor nodes and unknown nodes are kept in motion state. In the common indoor localization scene, anchor nodes are fixed to the edge or top of the room in advance, and unknown nodes maintain the moving state and are localized after entering the localization area at constant speed or variable speed. The focused research on the localization technology that anchor nodes are kept static and unknown nodes are kept moving is conducted in this paper.

In WSN, the common node coordinate computing method includes the trilateration method[8], [9] and the maximum likehood estimate method[10]. Upon the knowing of the distance of three anchor nodes and one unknown node, the location coordinates of the unknown node can be computed through trilateration; and upon the knowing of more than three anchor nodes and the same unknown node, coordinate solution is conducted through maximum likehood estimate.

Aiming at large limitation of application environment, insufficient application ability, to-be-improved localization accuracy of indoor mobile nodes and other problems in the existing localization technology, the research on the localization technology of mobile nodes entering within the network range is made by taking wireless sensor nodes deployed in indoor NLOS environment as the research object under the research background of WSN in this paper. Firstly, a multi-signal localization algorithm is designed against initial localization of the unknown node upon entering the network, and NLOS inhibitory factor is introduced against the problem of more errors caused by indoor NLOS ranging value to weaken the impact of the NLOS value on the localization result, thereby improving the localization accuracy of nodes. Secondly, aiming at the characteristic of mobile nodes, the localization algorithm for mobile node based on historical state (MNHS) is proposed in this paper. In this algorithm, the successful localization of mobile nodes can be ensured, and localization accuracy can be improved to a certain degree in conjunction with the historical localization information of mobile nodes. Upon the acquisition of relevant localization data through the algorithm, a computing method for node localization in which the modification value is introduced is proposed to reduce errors caused by the computing process of localization, thereby achieving the higher localization accuracy.

II. Research Status at Home and Abroad

A. *Research status of indoor localization technology*

Since 1990s, WSN gradually entered people's life, which was widely applied in smart household, target tracking and other fields. At present, the research and development of the indoor localization system has achieved the affluent achievement.

The Active Badge is an indoor localization system for personnel localization in office environment. Working personnel wear badges that can transmit the infrared signal to conduct localization communication and provide the signal to the central location service institution through the sensor network, and finally, the location coordinates of personnel are computed through trilateration[11]; RADAR is a radio frequency-based system, which is mainly used to conduct localization and tracking on users in the building. The system conducts operation by recording and processing signal intensity information located in multiple base stations, combining experience measurement with signal propagation modeling to determine user location, thereby enabling location awareness service and application program[12]; the Criket system judges distance by transmitting radio and ultrasonic signals, and intercepts beacon in the building using the application program running on mobile and static nodes to compute the physical locations of nodes[13]; and the INEMO system is an radio frequency indoor localization method based on double-layer distribution, in which rooms in an office building are graded, and when the user is close to a certain adjacent room, the user node is in information interaction with the adjacent point to determine the location of the user node[14]. In [15], to treat indoor and outdoor environments, two positioning schemes are presented accordingly. The indoor scheme clusters the localization zone into several subzones based on the strongest received signal, which does not need any location fingerprinting process in advance or location database. In [16], the performance of indoor positioning systems is compared including map matching, weighted centroid and exact positioning algorithms in a small predefined indoor environment. Among them, the weighted centroid algorithm provides the best results.

These shaped localization systems mainly conduct design and application based on different usage occasions, which have respective advantages and deficiencies. It can be seen easily from the development status of the indoor localization technology that there is still certain space for research on the indoor localization technology with low costs, low complexity, high precision and other characteristics [17].

B. *Research status of NLOS localization technology*

In actual application environment, i.e., mountains, cities and rooms, the signal transmission of sensor nodes is always affected by NLOS factors, and the measured value of distance between nodes will contain NLOS propagation errors, which will bring the adverse effect to localization computation. Based on different ideas, scholars at home and abroad proposed some node localization algorithms applicable to NLOS environment.

A mobile node localization algorithm n LAEL that can relieve the effect of line of sight is proposed in [18]; and in [19], the map is constructed with the radio frequency technology to acquire the initial estimate location of each sensor node, followed by conducting preprocessing on noise distance measurement in complex propagation environment through Kalman filtering. In this algorithm, the location computation of nodes is conducted using low-cost hardware and lightweight distributed algorithm; in [20], research on the NLOS state discriminating algorithm based on the strict residual selecting mechanism is conducted, and the localization computation of moving targets achieved through the variable node extended Kalman filtering algorithm under NLOS environment is proposed; and a localization algorithm for adjacent vehicles is proposed in [21], which can overcome NLOS errors.

According to the development trend of the current NLOS localization technology, the research on the NLOS localization algorithm applicable to WSN is developing towards low complexity and high practicality. Hence, the research on the localization of sensor nodes under NLOS environment has the profound and far-reaching practical significance and higher actual value.

C. Research status of localization of mobile unknown node

In recent years, the exploration achievements with respect to the localization method for WSN mobile nodes emerge in endlessly.

In [22], Kalman filtering and extended Kalman filtering are applied to WSN target tracking, and localization accuracy is compared; in [23], a RSSI-based Kalman filtering localization algorithm is proposed against the problem of difficulty in localization for mobile robots in indoor environment, and estimate location coordinates of the user are processed through the optimization of the Kalman filtering algorithm to improve the performance and stability of the indoor localization system; in [24], 5% and 12% Gaussian noises during node transmission are eliminated using the genetic evolution algorithm based on the localization of WSN, and the MATLAB simulation test shows that through the method, nodes can acquire accurate localization results; and in [25], a probability-based semi-supervised scene fingerprint localization algorithm is proposed in the process of making research on indoor moving targets, which reduces the workload of the scene fingerprint method in the data collection and processing of the offline stage and improves work efficiency.

A solution for indoor localization of mobile robots is presented in [26]. The global localization is realized by measuring the signal strength of RFID transponders, which are integrated in the floor and detected by the reader. Moreover, other typical algorithms can reference [27]-[29].

With the rapid development of science and technology, there are more and more applications in localization of mobile nodes, so the research on the localization algorithm of mobile nodes is more and more important. Improving or proposing the localization algorithm applicable to WSN mobile nodes has a certain theoretical significance and practical application significance.

The research on the localization technologies of WSN nodes has achieved the large achievement in recent years, however, these existing localization technologies still cannot meet the application of WSN in the current state and future. With the increasing of scientific progress and human needs, the application range of the WSN localization technology will be more and more wide, the localization standard will be higher and higher, and the localization technology of wireless sensor nodes, which is high in precision and low in complexity and costs, will become the development trend inevitably. Therefore, the research on the localization technology of mobile nodes under indoor NLOS environment has the important significance.

III. Research on Localization Technology of Nodes in Initial State

Whatever it is the ranging technology or the non-ranging technology, there are some defects in localization effect, and the single use of any one of ranging methods may have some deficiencies. In several typical ranging technologies, TDOA ranging [30] can ensure the localization result with high precision, RSSI ranging [31] is low in requirement to hardware, and anchor nodes are required to be deployed at the network boundary in non-ranging-based convex programming [32], [33]. Such three ranging technologies are applicable to the localization of sensor nodes under indoor environment. In this chapter, a multi-signal-based localization algorithm is proposed by analyzing the defects and errors of the two ranging technologies and the existing other relevant localization algorithms, which is mainly applied to the initial localization stage at which mobile unknown enters the network. In addition, aiming at the NLOS problem necessarily existing in the localization of WSN nodes under indoor environment, the concept of introducing the NLOS inhibitory factor is proposed from the suppressing of the NLOS value by making analysis on the localization algorithm under the existing NLOS environment to reduce localization errors in the initial state of nodes.

A. BMS Localization Algorithm

A multi-signal-based (BMS) on localization algorithm is proposed in the initial localization stage at which mobile unknown enters the network in this paper, in which radio frequency (RF) and ultrasonic (US) signals are applied, appropriate anchor nodes are selected using the RSSI value to participate in localization computation to fulfill the aim of reducing the area where unknown locates, thereby improving the localization accuracy of nodes. The advantage of the algorithm is to take full advantage of the obtained RSSI ranging value, reduce localization time, improve the utilization rate of ranging information and avoid the waste of ranging information.

The multi-signal-based localization algorithm has the following steps:

(1) The case in which there are 2 neighbored anchor nodes within the unknown communication range

Assuming that upon the launching of broadcast, unknown can receive the RSSI values of 2 neighbored anchor nodes. Owing to the factors of network communications environment, transmission between nodes will be affected by NLOS environment, resulting in decrease in RSSI value. In this way, distance corresponding to the RSSI value from the neighbored anchor nodes received by unknown will be larger than the actual distance between two nodes. Hence, unknown certainly exists in the round area taking the neighbored anchor node as the center of a circle and the RSSI value as the radius.

Taking the Fig. 1 as the instance, assuming that the unknown O can only receive RSSI values, $RSSI_A$ and $RSSI_B$, of anchor nodes A and B, circles (solid circles) are made by taking coordinates of A and B as the center of a circle and communication distance as the radius, and unknown is certainly located in the overlapping area of two circles. It can be known from the RSSI-Convex localization algorithm that when there are only 2 anchor nodes, connection between two anchor nodes and connection between the intersecting points of two circles are perpendicular with each other and divided equally. Similarly, circles (dotted circles) are made by taking $RSSI_A$ and $RSSI_B$ as the radius, unknown is also certainly located in the overlapping area of two circles. The intersecting points of four circles and straight line *AB* are *C*, *D*, *G* and *H*, the intersecting points of two circles with $RSSI_A$ and $RSSI_B$ as the radius are *E* and *F*, and unknown shall be located in a quadrilateral *EGFD*, at which the area where unknown locates is narrowed further.

Assuming that the coordinates of the unknown node *O* are (x, y), and the coordinates of neighbored anchor nodes *A* and *B* are (x_a, y_a) and (x_b, y_b), the equation of the straight line *AB* is (1), and the equations of circles with RSSI values as radius are (2) and (3):

$$y - y_a = \frac{y_b - y_a}{x_b - x_a}(x - x_a) \tag{1}$$

$$(x - x_a)^2 + (y - y_a)^2 = RSSI_A{}^2 \tag{2}$$

$$(x - x_b)^2 + (y - y_b)^2 = RSSI_B{}^2 \tag{3}$$

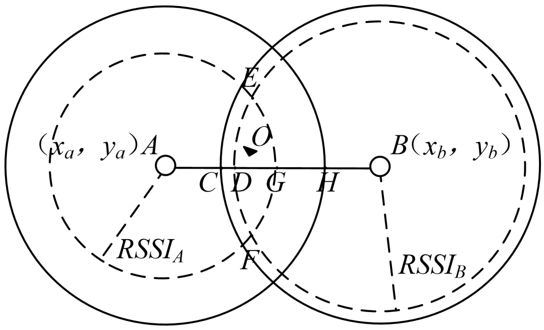

Fig. 1. 2 anchor nodes within unknown communication range

The coordinates of point *E* (x_e, y_e) and point *F* (x_f, y_f) can be obtained by combining (2) and (3). Two intersecting points of straight line *AB* and circle with anchor node *B* as center of a circle and $RSSI_B$ as radius are obtained by combining (1) and (3), distance from point *A* to two coordinates is solved and compared with $RSSI_A$, and the distance smaller than $RSSI_A$ is the coordinates (x_d, y_d) of point *D*. Similarly, *G* (x_g, y_g) can be obtained by combining (1) and (2). The vertex coordinates of quadrilateral *EGFD* have obtained. It can be known from the convex programming algorithm that unknown coordinates can be solved by only three nodes. Hence, four triangles △*EGF*, △*EGD*, △*GFD* and △*EFG* are constituted by any three vertexes in the quadrilateral *EGFD*, and the centroid (x_i, y_i) of four triangles is computed, where i=1, 2, 3 and 4. The average value of four centroid coordinates is the coordinates of unknown.

(2) The case in which there are 3 anchor nodes within the unknown communication range

Taking Fig. 2 as the instance, assuming that upon the launching of broadcast, unknown can receive the RSSI values of 3 neighbored anchor nodes. Assuming the RSSI values from 3 neighbored anchor nodes *A*, *B* and *C* are $RSSI_A$, $RSSI_B$ and $RSSI_C$ respectively, and $RSSI_A > RSSI_B > RSSI_C$, △DEF can be obtained through the RSSI-Convex localization algorithm. Circles are made by taking *A*, *B* and *C* as centers of circle and $RSSI_A$, $RSSI_B$ and $RSSI_C$ as the radius, and △GHI is obtained by selecting three vertexes *G*, *H* and *I* in the overlapped area. At this moment, it is considered that unknown is located inside two triangles, the intersecting points of the two triangles are *G*, *F* and *J*. For the purpose of illustration, they are indicated in Fig. 3. Distance from three intersecting points to neighbored anchor nodes is computed, the location of the intersecting point from the nearest neighbored anchor node is the area of the neighbored anchor node, to which the intersecting point belongs. The reciprocal of the RSSI value between unknown and the neighbored anchor node is used as the weight *w* during the localization computation of the intersecting point within the range of the anchor node, which is given by (4).

$$w = \frac{1}{RSSI} \tag{4}$$

As shown in Fig. 3, assuming that the coordinates of *J* are (x_j, y_j), the coordinates of neighbored anchor nodes *A*, *B* and *C* are (x_a, y_a), (x_b, y_b) and (x_c, y_c), and distance between *J* and 3 neighbored anchor nodes is d_a, d_b and d_c.

$$d_a = |AJ| = \sqrt{(x_j - x_a)^2 - (y_j - y_a)^2} \tag{5}$$

$$d_b = |BJ| = \sqrt{(x_j - x_b)^2 - (y_j - y_b)^2} \tag{6}$$

$$d_c = |CJ| = \sqrt{(x_j - x_c)^2 - (y_j - y_c)^2} \tag{7}$$

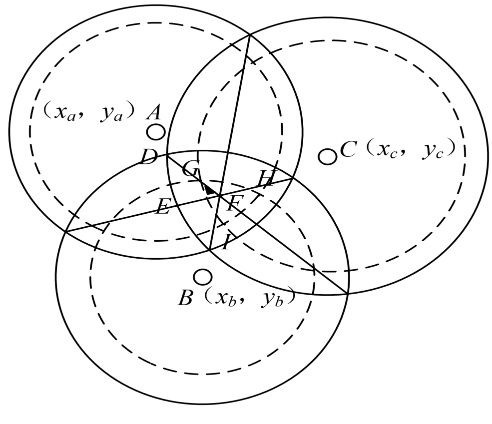

Fig. 2. 3 anchor nodes within unknown communication range

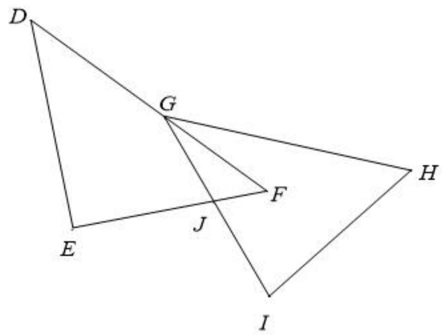

Fig. 3. 3 anchor nodes within unknown jump

If $d_a < d_c < d_b$, point *J* is assigned to the area where the neighbored anchor node *A* locates, and the weight of the point during localization computation is w_A. If the coordinates of unknown are (x, y), and three intersecting points *G* (x_g, y_g), *F* (x_f, y_f) and *J* (x_j, y_j) for computing are assigned to anchor nodes *B*, *C* and *A*, the weights of points *G* and *F* during localization computation are w_B and w_C, and the coordinates computing formula of unknown is (8).

$$\begin{cases} x = \dfrac{w_B \cdot x_g + w_C \cdot x_f + w_A \cdot x_j}{w_A + w_B + w_C} \\ y = \dfrac{w_B \cdot y_g + w_C \cdot y_f + w_A \cdot y_j}{w_A + w_B + w_C} \end{cases} \tag{8}$$

(3) The case in which there are multiple anchor nodes within the unknown communication range

It can be known from the convex programming localization principle that during the convex programming localization algorithm, at most 3 anchor nodes are only required, so when there are multiple neighbored anchor nodes within the unknown communication range, the algorithm process is as below: The RSSI value of each neighbored anchor node to unknown is recorded, the coordinates of unknown are computed by selecting the RSSI values of any 3 anchor nodes through the algorithm that there are 3 neighbored anchor nodes within the unknown communication range, and the average value of all coordinates of unknown is obtained across all RSSI values as the final coordinates of unknown.

B. Introduction of NLOS inhibitory factor

During the localization of indoor wireless sensor nodes, it is inevitable for the non-line-of-sight propagation of signals between nodes. Owing to many indoor objects and variable placing locations, signals between nodes under indoor environment may be propagated along the NLOS path, and the NLOS transmission of signals will pose a serious impact on the localization accuracy of nodes. Hence, we will consider how to suppress NLOS errors to the maximum extent to weaken the adverse effect of the errors on localization accuracy on the basis of the multi-signal-based localization algorithm in this paper, and where there is a strong suppressing effect on NLOS errors, we can obtain the excellent localization result.

Assuming that the coordinates of anchor node are (x', y'), the coordinates of unknown are (x, y), d is actual distance between nodes, d_i is measuring distance between nodes, and *NIF* (NLOS Inhibitory Factor) is NLOS inhibitory factor.

$$d^2 = (x - x')^2 + (y - y')^2 = NIF d_i^2 \tag{9}$$

When the NLOS effect exists, $d \le d_i$, so $0 < NIF \le 1$. When $NIF = 1$, $d = d_i$, at which it is in the line of sight propagation environment. The value of *NIF* is computed to judge whether or not d_i is data measured by the measured value of NLOS distance, and the neighbored anchor node in which the *NIF* value is close to 1 is selected for localization.

IV. Research on Localization Technology of Nodes in Moving State

In the previous section, the multi-signal-based localization algorithm is proposed by making analysis on the ranging localization technology under indoor environment, which can improve the initial localization accuracy when unknown enters the network. Aiming at the characteristic of mobile nodes, the localization algorithm for mobile node based on historical state (MNHS) is proposed in this paper. This algorithm is mainly applied in the state that unknown acquires its own initial localization coordinates and starts to move in the network. In the MNHS localization algorithm, the most appropriate localization strategy is selected by combining environment information around nodes during localization every time based on the historical localization information of nodes to improve the utilization rate of localization information, and achieve the high-precision and low-cost localization of mobile nodes. In addition, coordinates are computed by introducing the concept of the modification value, making the localization result more accurate.

A. MNHS localization algorithm

The localization algorithm for mobile node based on historical state (MNHS) is proposed by combining the historical localization information of mobile nodes in this paper. In this algorithm, the appropriate localization strategy is selected using the localization coordinate information of nodes at the previous moment, and the known ranging information in the network is utilized fully, making mobile nodes acquire the high-precision localization result in the localization process.

In the MNHS localization algorithm, unknown localization information shall store historical localization records of the recent three times. Assuming that current time is tn, the unknown information packet may store localization information of nodes at tn-3, tn-2 and tn-1 moment, including coordinates of nodes, relative change angles θ of nodes and motion displacement s of nodes.

When the historical localization record of unknown is updated, the information packet will delete the earliest localization information automatically, hence, at most three historical localization records can only be stored in the information packet of nodes. The MNHS localization algorithm is divided into three cases:

① There are no neighbored anchor nodes within the unknown communication range

The initial localization of unknown after entering the network is completed through the multi-signal-based algorithm, so unknown will store at least one historical localization record in the mobile localization stage. When there are no anchor nodes that can be used for ranging within the unknown communication range, in this paper, the coordinates of mobile nodes are obtained by the historical localization record of nodes through the angle localization algorithm, as shown in Fig. 4.

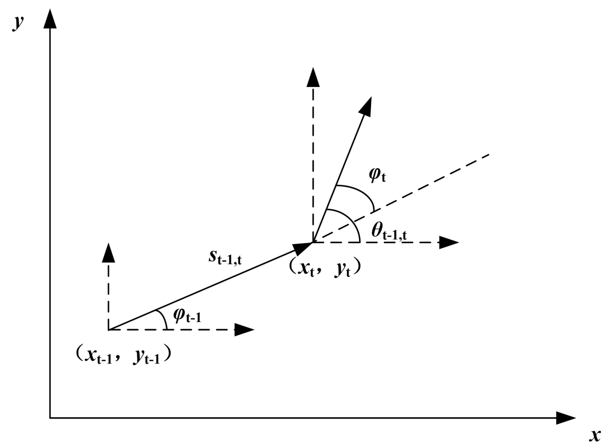

Fig. 4. HSML localization algorithm diagram in which there are no neighbored anchor nodes within unknown communication range

Assuming that the absolute localization angle measured at t moment is φ_t, and the historical localization record contains coordinate information (x_{t-1}, y_{t-1}) at t-1 moment, relative moving angle $\theta_{t-1,t}$ and relative motion displacement $s_{t-1,t}$, the coordinates (x_t, y_t) of the mobile nodes at t moment is obtained through (10).

$$\begin{cases} x_t = x_{t-1} + s_{t-1,t} \cdot \cos\varphi_{t-1} \\ y_t = y_{t-1} + s_{t-1,t} \cdot \sin\varphi_{t-1} \\ \varphi_{t-1} = \varphi_t - \theta_{t-1,t} \end{cases} \tag{10}$$

② There is only one neighbored anchor node within the unknown communication range

Assuming that upon the launching of broadcast, unknown only receives the return information of one neighbored anchor node, at which the coordinates of unknown are computed by combining the historical localization information of nodes. Assuming that the coordinates of anchor nodes are (x_m, y_m), distance between unknown (x_t, y_t) and neighbored anchor nodes is d, location coordinates at t-1 moment are (x_{t-1}, y_{t-1}) in the historical localization record of unknown, and the relative motion displacement of nodes is $s_{t-1,t}$, the coordinate computing equation of mobile unknown at t moment is shown in (11).

$$\begin{cases} (x_m - x_t)^2 + (y_m - y_t)^2 = d^2 \\ (x_t - x_{t-1})^2 + (y_t - y_{t-1})^2 = s_{t-1,t}{}^2 \end{cases} \tag{11}$$

Through the solution of (11), two solutions can be obtained, and the centers of two coordinates are used as the final localization coordinates of unknown.

③ There are two neighbored anchor nodes within the unknown communication range

Assuming that upon the launching of broadcast, unknown can receive the return information of two neighbored anchor nodes, followed by constructing the equation set by combining with historical localization information; and assuming that the coordinates of two anchor nodes are (x_{m1}, y_{m1}) and (x_{m2}, y_{m2}), distance between unknown (x_t, y_t) at t moment and two neighbored anchor nodes is d_1 and d_2, location coordinates at t-1 moment are (x_{t-1}, y_{t-1}) in the historical localization record of unknown, and relative motion displacement is $s_{t-1,t}$, the coordinate computing equation of mobile unknown at t moment is shown in (12).

$$\begin{cases} (x_{m1} - x_t)^2 + (y_{m1} - y_t)^2 = d_1{}^2 \\ (x_{m2} - x_t)^2 + (y_{m2} - y_t)^2 = d_2{}^2 \\ (x_t - x_{t-1})^2 + (y_t - y_{t-1})^2 = s_{t-1,t}{}^2 \end{cases} \tag{12}$$

The predictive coordinates (x_{t1}, y_{t1}) of unknown can be obtained through (12). According to the angle localization algorithm, the predictive coordinates (x_{t2}, y_{t2}) of unknown can be obtained through (10), and the final coordinates of mobile nodes are as follows.

④ There are three and more than three neighbored anchor nodes within the unknown communication range

When there are only three neighbored anchor nodes within the unknown communication range, assuming that the coordinates of the three anchor nodes are (x_{m1}, y_{m1}), (x_{m2}, y_{m2}) and (x_{m3}, y_{m3}), distance between unknown (x_t, y_t) at t moment and three anchor nodes is obtained, i.e., d_1, d_2 and d_3, coordinates at t-1 moment are (x_{t-1}, y_{t-1}), and relative motion displacement measured at t moment is $s_{t-1,t}$, the coordinate computing equation of mobile unknown at t moment is shown in (13).

$$\begin{cases} (x_{m1} - x_t)^2 + (y_{m1} - y_t)^2 = d_1{}^2 \\ (x_{m2} - x_t)^2 + (y_{m2} - y_t)^2 = d_2{}^2 \\ (x_{m3} - x_t)^2 + (y_{m3} - y_t)^2 = d_3{}^2 \\ (x_t - x_{t-1})^2 + (y_t - y_{t-1})^2 = s_{t-1,t}{}^2 \end{cases} \tag{13}$$

The first three equations subtract the fourth equation sequentially, and the quadratic term is eliminated to obtain (14).

$$AX = B \tag{14}$$

Where,

$$A = 2\begin{bmatrix} x_{t-1} - x_{m-1} & y_{t-1} - y_{m-1} \\ x_{t-1} - x_{m-2} & y_{t-1} - y_{m-2} \\ x_{t-1} - x_{m-3} & y_{t-1} - y_{m-3} \end{bmatrix} \tag{15}$$

$$B = \begin{bmatrix} x_{t-1}{}^2 - x_{m-1}{}^2 + y_{t-1}{}^2 - y_{m-1}{}^2 + d_1{}^2 - s_t{}^2 \\ x_{t-1}{}^2 - x_{m-2}{}^2 + y_{t-1}{}^2 - y_{m-2}{}^2 + d_2{}^2 - s_t{}^2 \\ x_{t-1}{}^2 - x_{m-3}{}^2 + y_{t-1}{}^2 - y_{m-3}{}^2 + d_3{}^2 - s_t{}^2 \end{bmatrix} \tag{16}$$

$$X = \begin{bmatrix} x_t \\ y_t \end{bmatrix} \tag{17}$$

Equation (14) is solved in the standard minimum mean square error estimate method to obtain the coordinates (x_t, y_t) of unknown shown in (18).

$$X = (A^T A)^{-1} A^T B \tag{18}$$

When there are more than three neighbored anchor nodes within the unknown communication range, the first three neighbored anchor nodes with smallest w are selected based on the weight w of neighbored anchor nodes for localization in the previous section. Assuming that the coordinates are (x_{m1}, y_{m1}), (x_{m2}, y_{m2}) and (x_{m3}, y_{m3}), distance between unknown (x_t, y_t) at t moment and three anchor nodes is obtained, i.e., d_1, d_2 and d_3, coordinates at t-1 moment are (x_{t-1}, y_{t-1}), and relative motion displacement measured at t moment is $s_{t-1,t}$, the coordinates of unknown are solved. When unknown has only three neighbored anchor nodes, assuming that the coordinates of the three anchor nodes are (x_{m1}, y_{m1}), (x_{m2}, y_{m2}) and (x_{m3}, y_{m3}), distance between unknown (x_t, y_t) at t moment and three anchor nodes is obtained, i.e., d_1, d_2 and d_3, coordinates at t-1 moment are (x_{t-1}, y_{t-1}), and relative motion displacement measured at t moment is $s_{t-1,t}$, the coordinate computing equation of mobile unknown at t moment is shown in (19).

$$\begin{cases} (x_{m1} - x_t)^2 + (y_{m1} - y_t)^2 = d_1^2 \\ (x_{m2} - x_t)^2 + (y_{m2} - y_t)^2 = d_2^2 \\ (x_{m3} - x_t)^2 + (y_{m3} - y_t)^2 = d_3^2 \\ (x_t - x_{t-1})^2 + (y_t - y_{t-1})^2 = s_{t-1,t}{}^2 \end{cases} \tag{19}$$

The first three equations subtract the last equation sequentially, and the quadratic term is eliminated to obtain the linear equation, as shown in (20):

$$AX = B \tag{20}$$

Where,

$$A = 2\begin{bmatrix} x_{t-1} - x_{m-1} & y_{t-1} - y_{m-1} \\ x_{t-1} - x_{m-2} & y_{t-1} - y_{m-2} \\ x_{t-1} - x_{m-3} & y_{t-1} - y_{m-3} \end{bmatrix} \tag{21}$$

$$B = \begin{bmatrix} {x_{t-1}}^2 - {x_{m-1}}^2 + {y_{t-1}}^2 - {y_{m-1}}^2 + d_1^2 - s_t^2 \\ {x_{t-1}}^2 - {x_{m-2}}^2 + {y_{t-1}}^2 - {y_{m-2}}^2 + d_2^2 - s_t^2 \\ {x_{t-1}}^2 - {x_{m-3}}^2 + {y_{t-1}}^2 - {y_{m-3}}^2 + d_3^2 - s_t^2 \end{bmatrix} \tag{22}$$

$$X = \begin{bmatrix} x_t \\ y_t \end{bmatrix} \tag{23}$$

Equation (20) is solved in the standard minimum mean square error estimate method to obtain the coordinates (x_t, y_t) of unknown shown in (24).

$$X = (A^T A)^{-1} A^T B \tag{24}$$

When there are more than three neighbored anchor nodes within the unknown communication range, the first three neighbored anchor nodes with smallest w are selected based on the weight w of neighbored anchor nodes for localization in the previous section. Assuming that the coordinates are (x_{m1}, y_{m1}), (x_{m2}, y_{m2}) and (x_{m3}, y_{m3}), distance between unknown (x_t, y_t) at t moment and three anchor nodes is obtained, i.e., d_1, d_2 and d_3, coordinates at t-1 moment are (x_{t-1}, y_{t-1}), and relative motion displacement measured at t moment is $s_{t-1,t}$, the coordinates of unknown are solved in the node computing method in which the modification value is introduced.

B. Node coordinate computation introducing modification value

In the localization computation of WSN nodes, when there are 3 or more than 3 anchor nodes within the unknown communication range, the unknown coordinates are generally subjected to localization computation using the maximum likelihood estimate method, which is the common distributed localization algorithm. There are many factors that affect the localization errors in the maximum likelihood estimate method, including ranging error, accuracy of coordinates of anchor nodes, residual error, etc. In this section, the maximum likelihood estimate method is improved by analyzing the errors in the maximum likelihood estimate method and introducing the concept of the modification value to fulfill the aim of improving the accuracy of localization computation.

Analysis of maximum likelihood estimate errors

In WSN localization, when there are 3 or more than 3 neighbored anchor nodes of unknown, the coordinates of nodes are computed using the maximum likelihood estimate method. In the maximum likelihood estimate method, neighbored anchor node information of unknown in the network can be utilized fully. Theoretically, the more the anchor nodes for localization computation are, the smaller the overlapped range of circles with anchor nodes as centers of circle and distance between unknown and neighbored anchor nodes as radius will be, and the higher the localization accuracy of unknown will be. However, there is ranging error in each ranging information, the more the neighbored anchor nodes for localization computation are, the larger the accumulative ranging errors will be, resulting in reduction in localization accuracy. Starting with ranging errors, the computation result of the maximum likelihood estimate method is modified by introducing the concept of the modification value to reduce errors in the localization computation process, making the localization computation result more accurate.

Introduction of modification value

Let the real coordinates of unknown be (x, y), measuring coordinates be (x', y'), the coordinates of neighbored anchor node be (x_1, y_1), (x_2, y_2), ... (x_i, y_i), actual distance between unknown and neighbored anchor nodes be d, and measuring distance between unknown and anchor nodes be d', introduced x_v and y_v are modification values of x and y, and d_v is modification distance, difference between actual distance and measuring distance of unknown is modification distance, as shown in (25).

$$d - d' = dv \tag{25}$$

The modification distance d_1 between unknown and anchor node (x_1, y_1) is defined as:

$$d_1 = \frac{x_1 - x'}{x_1 - x} \cdot x_v + \frac{y_1 - y'}{y_1 - y} \cdot y_v \tag{26}$$

The modification distance d_v between unknown and all neighbored anchor nodes is as follows.

$$d_v = \frac{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x'}{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x} \cdot x_v + \frac{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y'}{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y} \cdot y_v \tag{27}$$

Input d_v into (25):

$$d = d' + \frac{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x'}{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x} \cdot x_v + \frac{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y'}{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y} \cdot y_v \tag{28}$$

Arrange (28) as $A=BV$, where,

$$A = d - d' \tag{29}$$

$$B = \begin{bmatrix} \frac{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x'}{(\frac{1}{i}\sum_{i=1}^{n} x_i) - x} & \frac{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y'}{(\frac{1}{i}\sum_{i=1}^{n} y_i) - y} \end{bmatrix} \tag{30}$$

$$V = \begin{bmatrix} x_v \\ y_v \end{bmatrix} \tag{31}$$

The V is solved in the standard minimum mean square error estimate method to obtain (32).

$$V = (B^T B)^{-1} B^T A \tag{32}$$

The final coordinates of unknown are ($x'+x_v$, $y'+y_v$). The coordinates of unknown, obtained using the localization computation method in which the modification value is introduced, is more accurate. Hence, such computation method is used for the localization computation of multiple anchor nodes. Taking only three anchor nodes within the unknown communication range as the instance, assuming that the real coordinates of unknown at t moment are (x_t, y_t), measuring coordinates are (x', y'), the coordinates of neighbored anchor node are (x_1, y_1), (x_2, y_2) and (x_3, y_3), actual distance between unknown and anchor nodes is d_t, measuring distance between unknown and anchor nodes is d', modification distance is d_{tv}, and x_{tv} and y_{tv} are modification values of $x_t'$and y_t' respectively, difference between actual distance and measuring distance of unknown is modification distance d_{tv}.

$$d_t - d_t' = d_{tv} \tag{33}$$

Where, the modification distance d_{tv1} between unknown and anchor node (x_1, y_1) is defined as:

$$d_{tv1} = \frac{x_1 - x_t'}{x_1 - x_t} \cdot x_{tv} + \frac{y_1 - y_t'}{y_1 - y_t} \cdot y_{tv} \tag{34}$$

The modification distance d_{tv} between unknown and 3 neighbored anchor nodes is:

$$d_{tv} = \frac{(\frac{x_1+x_2+x_3}{i}) - x_t'}{(\frac{x_1+x_2+x_3}{i}) - x_t} \cdot x_{tv} + \frac{(\frac{y_1+y_2+y_3}{i}) - y_t'}{(\frac{y_1+y_2+y_3}{i}) - y_t} \cdot y_{tv} \tag{35}$$

Input d_{tv} into (33) to obtain (36):

$$d_t = d_t' + \frac{(\frac{1}{3}\sum_{i=1}^{3} x_i) - x_t'}{(\frac{1}{3}\sum_{i=1}^{3} x_i) - x_t} \cdot x_{tv} + \frac{(\frac{1}{3}\sum_{i=1}^{3} y_i) - y_t'}{(\frac{1}{3}\sum_{i=1}^{3} y_i) - y_t} \cdot y_{tv} \tag{36}$$

Arrange (36) as $A=BV$, where,

$$A = d_t - d_t' \tag{37}$$

$$B = \begin{bmatrix} \frac{(\frac{1}{3}\sum_{i=1}^{3} x_i) - x_t'}{(\frac{1}{3}\sum_{i=1}^{3} x_i) - x_t} & \frac{(\frac{1}{3}\sum_{i=1}^{3} y_i) - y_t'}{(\frac{1}{3}\sum_{i=1}^{3} y_i) - y_t} \end{bmatrix} \tag{38}$$

$$V = \begin{bmatrix} x_{tv} \\ y_{tv} \end{bmatrix} \tag{39}$$

The V is solved in the standard minimum mean square error estimate method to obtain modification values x_{tv} and y_{tv}, and the final coordinates of unknown at t moment are ($x_t'+x_{tv}$, $y_t'+y_{tv}$).

$$V = (B^T B)^{-1} B^T A \tag{40}$$

V. Algorithm Simulation and Test

The feasibility and accuracy of the localization algorithm mentioned above are subjected to performance analysis and verification using the MATLAB simulation tool platform in this paper.

A. Simulation parameter

In simulation, the network range is set as the square area of 30m×30m, 10 moving unknown nodes are deployed randomly using the rand() function of MATLAB, and the number of anchor nodes ranges from 3 to 15 according to the simulation requirement. The communication radius of each node is R=7m, the CRW model is used as the random walk mobility model of unknown, and the RSSI ranging model applied in simulation is the log-distance path loss model. In this paper, MABLAB is used as the simulation platform, and assuming that the WSN model meets the following conditions:

(1) The communication radii of all sensor nodes in the network are the same R=7m;

(2) The sending power of all sensor nodes in the network is the same;

(3) All anchor nodes in the network are static nodes, and upon setting, the nodes are no longer moved. If the minimum moving speed and maximum moving speed of unknown are $v_{min}=0m/s$ and $v_{max}=4m/s$ respectively, the initial moving speed of nodes is $v_0=2m/s$.

The parameters of test and simulation scenes in this paper are shown in Table 1.

TABLE I
SCENE PARAMETER

Simulation element	Specification parameters
Area size (m)	30×30
Number of unknown	15
Number of anchor nodes	3-15
Path loss exponent	2
Initial communication radius of node (m)	7

In this paper, node localization error ERROR, average localization error AVEERROR, root-mean-square error RMSE, localization coverage and network energy consumption are used evaluation parameters. Assuming that the actual coordinates of unknown are (x, y), the coordinates obtained using the localization algorithm are (x', y'), localization time is n, and the communication radius of the node is R, the expressions of localization errors, average localization errors and root-mean-square errors of nodes are shown as (41), (42) and (43).

$$ERROR = \frac{\sum_{i=1}^{n} \sqrt{(x-x')^2 + (y-y')^2}}{n} \tag{41}$$

$$AVEERROR = \frac{\sum_{i=1}^{n} \sqrt{(x-x')^2 + (y-y')^2}}{nR} \times 100\% \quad (42)$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (x-x')^2 + (y-y')^2}{n}} \quad (43)$$

Furthermore, localization coverage means the ratio of anchors to total nodes in the network after WSN is done. The higher the localization coverage is, the more effective nodes will be in the network and the better the network availability will be. Network energy consumption means the energy consumption at all the nodes in the network. On the basis of ensuring adequate localization accuracy and coverage, the network energy consumption should be reduced as much as possible.

B. Simulation result and analysis

(1) Under the same simulation condition, the localization errors of TDOA, RSSI and RSSI/TDOA localization technologies are compared, and the simulation results are shown in Fig. 5.

In Fig. 5, errors of RSSI, TDOA and RSSI/TDOA localization technologies are compared under the same simulation condition, in which the localization error of RSSI ranging is the maximum, since the RSSI measuring data is easily affected by multipath, reflection and other environment factors under indoor environment, which leads to inaccuracy in ranging information and larger localization error; the localization error of TDOA ranging is far smaller than that of RSSI, and since measuring distance errors between nodes can be reduced effectively through its ranging principle in which time difference of arrival is applied, the higher localization accuracy is ensured; and the localization error of the RSSI/TDOA localization technology is basically in line with that of TDOA, and when there are a few anchor nodes and wide ranging range, the RSSI/TDOA localization technology not only enlarges the localization range and solves the problem of short measuring distance of TDOA, but also ensures the localization accuracy.

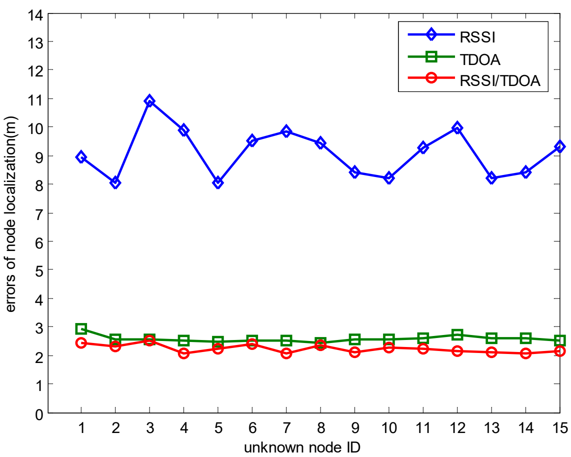

Fig. 5. Comparison of localization errors in three algorithms

(2) Under the condition of different anchor nodes, the localization errors of RSSI/TDOA and BMS localization algorithms are compared.

It can be known from Fig. 6 that when there the number of anchor nodes is less, upon the broadcast of unknown, it is difficult to ensure that the information of three or more than three anchor nodes is received, at which the accuracy of both RSSI-Convex and BMS localization algorithms is low. When the number of anchor nodes in the network is increased gradually, the errors of the localization algorithm are also reduced; and when the number of anchor nodes is increased from 3 to 8, the localization errors of the BMS localization algorithm are reduced significantly. With continued increase in the number of anchor nodes, the localization accuracy of BMS continues to be improved and tend to be stable gradually; and when the number of anchor nodes is 15, the localization errors of nodes of the RSSI-Convex localization algorithm are 1.81*m*, and the localization errors of nodes of the MS localization algorithm is 1.59*m*.

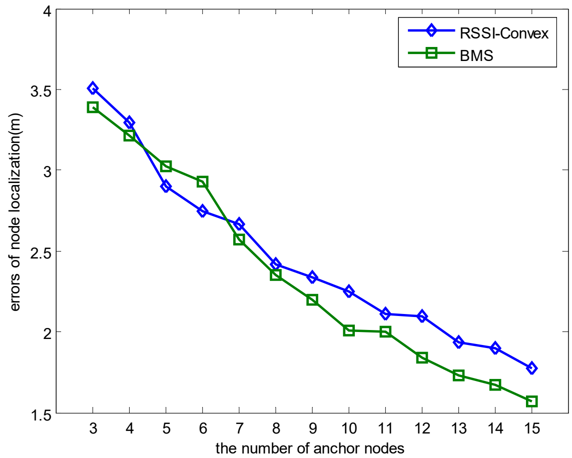

Fig. 6. Comparison of localization errors with changes in number of anchor nodes

(3) Under the condition of different ranging errors, the localization errors of RSSI-Convex and BMS localization algorithms are compared.

Fig. 7 shows comparison of increase in the errors of the RSSI-Convex localization algorithm and the BMS localization algorithm with ranging errors in the case of 10 anchor nodes deployed in the network. It can be seen that the performance of two localization algorithms will be affected by ranging errors between nodes; when the ranging errors are increased, the errors of the localization algorithm will also be increased; when the ranging errors are 10%, the average localization error of the RSSI-Convex localization algorithm is 13.85%, and the average localization error of the BMS localization algorithm is 9.98%; and when the ranging errors are 50%, the average localization error of the BMS localization algorithm is 29.37%, but the average localization error of the RSSI-Convex localization algorithm is up to 42.09%. Thus, it can be seen that the BMS localization algorithm has the excellent performance.

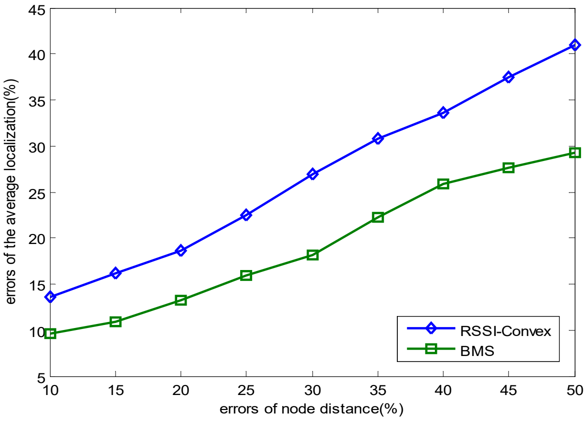

Fig. 7. Trend of change in localization errors with ranging errors

(4) Under the condition of different NLOS errors, the localization errors are compared upon the introduction of NLOS inhibitory factor (INIF) in Chan algorithm, residual weighting (Rwgh) algorithm and the MNHS localization algorithm.

After receiving TDOA return information of more than 3 anchor nodes in the localization process, unknown selects appropriate anchor nodes for localization computation using the INIF localization algorithm. In TDOA localization computation, the common localization algorithm includes the Chan localization algorithm, and the classical NLOS suppression method includes the Rwgh algorithm, hence, Fig. 8 shows that comparison of performance between INIF localization algorithm and Chan algorithm and between INIF localization algorithm and Rwgh algorithm in the case of that NLOS errors are determined values, from which the relationship between NLOS errors and RMSE can be seen. When NLOS errors are 0, the RMSE of three algorithms is basically the same; when NLOS errors are large, the performance of the Chan algorithm is reduced obviously, but Rwgh and INIF algorithms can better inhibit the effect of NLOS errors, showing the excellent performance.

(5) Under the same ranging method and simulation condition, computing errors of MLE and IMV localization algorithms are compared.

15 fixed anchor nodes are deployed uniformly within the network range, 15 unknown nodes are generated randomly and are subjected to simulation test for 100 times, and the average localization error of 15 unknown nodes is used as the computing error of MLE and IMV. Under the same simulation condition, the ranging errors of two algorithms shall comply with the same function distribution. It can be known from Fig. 9 that the maximum error of the MLE localization algorithm is 5.95*m* and the average error is 3.86*m*, while the maximum error of the IMV localization algorithm is 3.76*m*, and the average error is 2.31*m*; and the IMV localization algorithm is superior to the MLE localization algorithm.

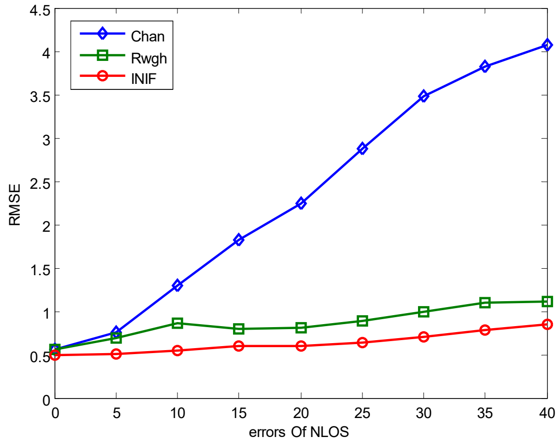

Fig. 8. Comparison of changes in root-mean-square errors with NLOS errors

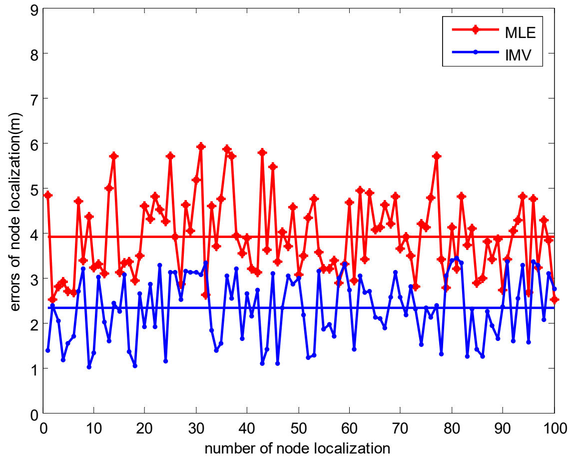

Fig. 9. Comparison of errors of MLE and IMV localization algorithms

(6) Under the condition of different anchor nodes, the localization errors of HISL and MNHS localization algorithms are compared.

Fig. 10 shows the comparison of performance between MNHS localization algorithm and HISL localization algorithm under different anchor nodes when unknown makes uniform motion at 0.5*m/s* in the network When the number of anchor nodes in the network is 3, unknown enters the network and broadcasts, which cannot receive the location information of 3 anchor nodes necessarily within the broadcast range, but at least one historical information record is stored in unknown. In the HISL algorithm, the current location information is obtained with such record, and in the MNHS localization algorithm, not only the historical information record can be used, but also the current location information is computed by combining the return information of 1 or 2 anchor nodes, thereby reducing the localization errors. When the number of anchor nodes is increased gradually, the performance of the HISL localization algorithm tends to be stable, the localization errors of nodes are kept at about 4*m*, but the localization errors of MNHS are about 2.5*m*, so the MNHS algorithm is obviously superior to the HISL algorithm.

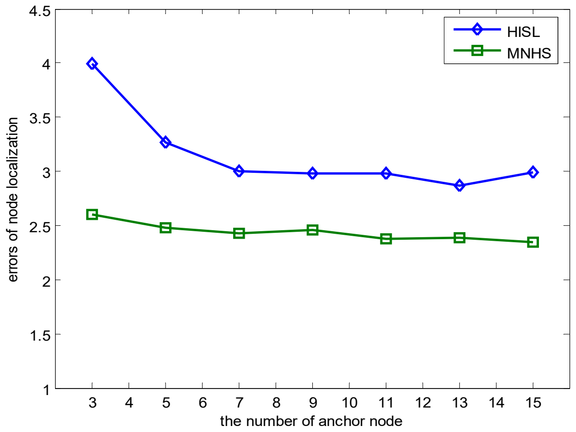

Fig. 10. Comparison of localization errors with changes in number of anchor nodes

(7) Under the condition of different algorithm operating time, the localization errors of RSSI/TDOA and MNHS localization algorithms are compared.

In the localization process, moving unknown is selected randomly, the initial moving speed of nodes is 2*m/s*, the maximum moving speed is 4*m/s*, and the CRW mobile model is used. The localization errors of nodes are subjected to simulation within continuous time segments, and the recording result is shown in Fig. 11. Under the same condition, nodes move with time change, and errors between the RSSI/TDOA localization algorithm and the MNHS localization algorithm in this paper are compared. It can be seen that the localization errors of such two algorithms are relatively stable, with reasonable floating range. In most cases, the errors of the MNHS localization algorithm are smaller than those of RSSI/TDOA, which are basically kept at 3*m*, and the adaptability of nodes is higher than that of the RSSI/TDOA algorithm.

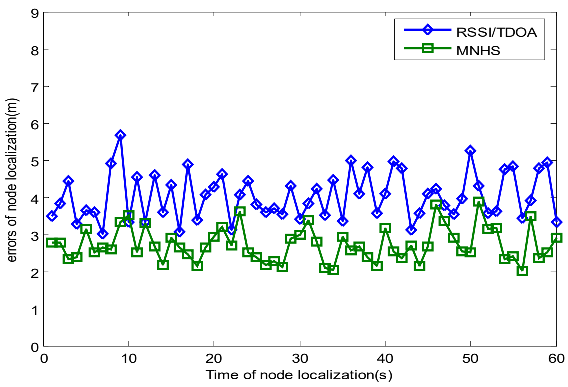

Fig. 11. Comparison of localization errors with changes in localization time

(8) At moving speed of different nodes, the localization errors of SSDLB+MPL and MNHS localization algorithms are compared.

Fig. 12 describes that at different moving speeds of unknown, the localization errors of the SSDLB+MPL localization algorithm mentioned in [34] and the MNHS localization algorithm mentioned in this paper are compared. In simulation, the maximum moving speed of nodes is 4*m/s*; in the test, changes in errors of localization algorithm at moving speed of nodes from 0.5*m/s* to 4*m/s* are recorded; at low moving speed of nodes, the errors of the two localization algorithms are small, and with increase in moving speed of nodes, the localization errors are also increased; when the moving speed of unknown is more than 3*m/s*, increase in the errors of the SSDLB+MPL algorithm is obvious, the localization errors of the MNHS algorithm are low in floating, and the performance of its algorithm is obviously superior to that of the former algorithm.

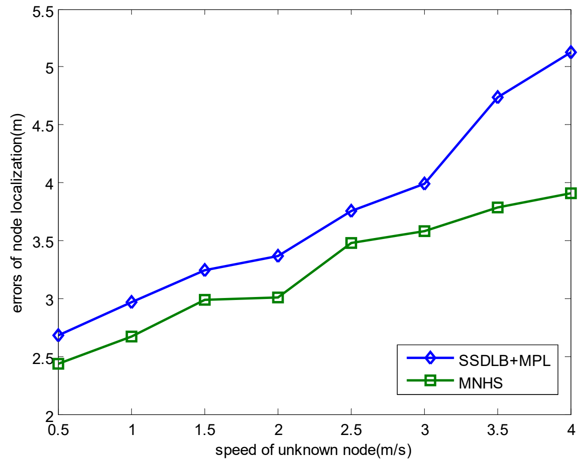

Fig. 12. Comparison of localization errors with changes in moving speed of unknown

(9) Under the condition of different proportion of anchor nodes, the localization coverages of RSSI/TDOA, HISL, SSDLB+MPL and MNHS localization algorithms are compared.

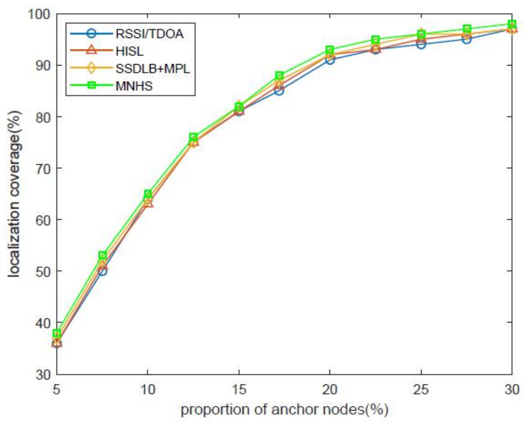

Fig. 13. Comparison of localization coverage with changes in proportion of anchor nodes

Fig. 13 shows that the MNHS localization algorithm is basically the same as other algorithms in terms of localization coverage. Compared with other algorithms, the MNHS localization algorithm improves the localization accuracy of nodes, but the improvement of localization coverage is not obvious.

(10) Under the condition of different proportion of anchor nodes, the network energy consumption of RSSI/TDOA, HISL, SSDLB+MPL and MNHS localization algorithms are compared.

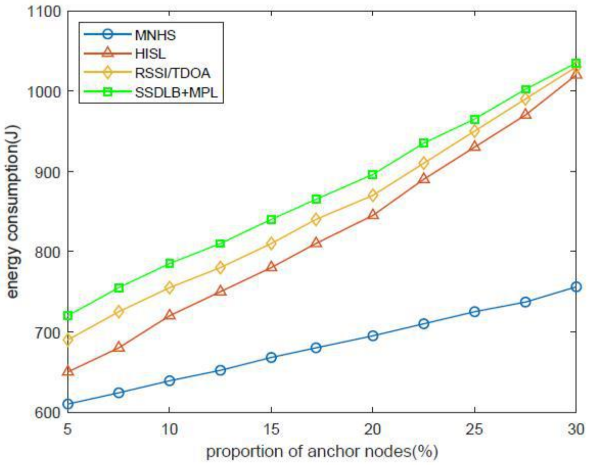

Fig. 14. Comparison of network energy consumption with changes in proportion of anchor nodes

Fig. 14 shows that the MNHS localization algorithm consumes less energy with the increase of the number of anchor nodes. This is because the improvement of the localization accuracy in the MNHS localization algorithm is mainly achieved by introducing modification value, while other algorithms are mainly by anchor nodes.

VI. Conclusion

WSN, as the new generation of sensor network, has the wide application prospect, which has become one of the most competitive application technologies in military defense, intelligent transportation, building automation, environmental monitoring, agricultural production, medical research and other fields. WSN is composed of a large number of nodes, and the location information of such nodes is the premise to monitor and control the sensor network. Hence, the localization technology becomes the key research interest in WSN. At present, the localization technology and system that are suitable for outdoor environment can achieve high precision, and since the localization of nodes under indoor environment is affected by complex environment, localization accuracy still needs to be improved. Regarding the complexity of indoor environment and the motion state of nodes, focused research on the localization of mobile nodes under indoor environment is made in this paper.

Firstly, the multi-signal-based localization algorithm is proposed. This algorithm is suitable for the initial coordinate localization when unknown just enters the network monitoring range, in which appropriate neighbored anchor nodes are selected to narrow the area where unknown locates through the RSSI value, thereby improving the localization accuracy of nodes. In addition, under the introduction of NLOS inhibitory factor, the errors of the NLOS ranging value on localization of nodes are reduced. Secondly, regarding the characteristic of node motion in WSN, the MNHS localization algorithm is proposed, in which the appropriate localization strategy is selected using the historical localization information of nodes in conjunction with the information of neighbored anchor nodes within the communication range of unknown according to different localization conditions to improve the utilization rate of coordinate information in the network, thereby achieving the accurate localization of mobile nodes. On this basis, the maximum likelihood estimate method is optimized by introducing the concept of the modification value, thereby making the localization result more accurate in the computing method. The simulation result shows that the algorithm in this paper achieves the significant effects in enlarging the localization range, reducing localization errors and improving localization accuracy.

In the algorithm of this paper, RSSI ranging information is used for multiple times, the selecting of the propagation model and the dereferencing of relevant parameters have great effect on the localization result; and where there is large difference between actual environment and simulation environment, the localization errors will be larger in the algorithm of this paper. In addition, the algorithm of this paper is only suitable for the moving state of unknown and the static state of anchor nodes. When anchor nodes in the network are also in the motion state, research on the feasibility of the algorithm of this paper needs to be made further.

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