Study on Range-Based Node Localization Method of Internet of Vehicles

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***Abstract*—Internet of Vehicles (IoV) has been considered to be an important branch which is most likely the first breakthrough in the application of Internet of Things (IoT) , and has become the focal point of research. Among them, the localization and the location-aware of vehicles are key technologies of the IoV. These two technologies not only is related to vehicle security, but also affected the prospects for the development of IoV. First, the standards of evaluation on node localization method of IoV have been presented, and range-based nodes location technologies of IoV have been focused, and the algorithm and applications in IoV have been discussed. Finally, in the comprehensive analysis of existing research results at the same time, we conclude the paper by elaborating the future research directions on the IoV.**

***Index Terms*—internet of vehicles, localization method, range-based**

I. Introduction

Internet of Vehicles (IoV), the vehicle nodes and exchange data must be associated with the position, therefore, must take certain mechanisms and algorithms to achieve real-time positioning and location awareness between nodes on the vehicle node, and the establishment of close ties between the vehicle and the location of the implementation, monitoring, vehicle tracking and positioning, so as to realize the dynamic management and control between the vehicles.

Mentioned vehicle positioning satellite positioning, we first thought (such as GPS or Beidou). However, the source application in vehicle navigation and object tracking, the positioning accuracy, response time and controllability are unable to adapt to the application requirements of vehicle networking. At present, a feasible way is to let the city side of the road traffic. RFID reader, video camera and so on the road side unit (RSU) to obtain accurate location information through satellite positioning, as the anchor nodes in the network to provide location information source, running on the road vehicles with the help of RSU positioning[1-3]. At present, there are mainly based on range-based technology and the use of range-free technology in two ways to achieve positioning.

Based on systematic analysis of wireless sensor network (WSN) based on the existing achievements in related fields[4-6], the network according to the characteristics and requirements of Internet of Vehicles(IoV), introduces the positioning technology of car networking, and made a systematic analysis[7]. At the same time, put forward the main evaluation index of car networking research involves the study, combined with the given the research status of vehicle networking technology is the trend of development.

II. Background

A. The basic concept

Knowledge in sensor networks, in order to achieve positioning, nodes randomly spread mainly two: Beacon node and Unknown node. Usually known its position of node said to Beacon nodes and Beacon nodes can be through carrying the existing positioning equipment and other means to obtain its exact position, while the other nodes are called for Unknown nodes, wireless sensor networks in CITIC mark node only account for a small proportion. Unknown nodes and Beacon nodes as a point of reference, through the location information of Beacon nodes to determine its position. The nodes of the sensor network structure as shown in Fig. 1[8].

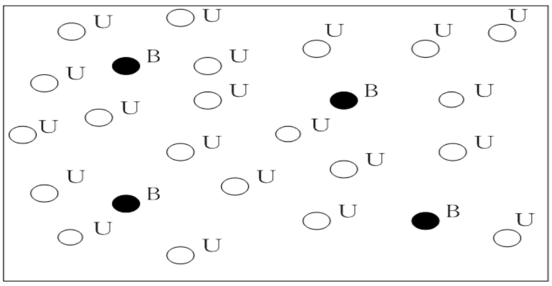

Figure 1. Beacon nodes and unknown nodes of wireless sensor network

In Fig. 1, the entire sensor network consists of four beacon nodes and a large number of unknown node compositions. Beacon node B to represent, it in the network as a whole accounted for less proportion. Unknown node u to represent, unknown nodes by around the beacon nodes or has achieved self-localization of unknown node through certain algorithm to achieve self-localization. Here are some of the commonly used terms in wireless sensor networks:

(1) Neighbor Nodes: nodes that can communicate directly with the other nodes without having to go through other nodes;

(2) Hop Count: two to achieve the communication between the nodes of the minimum number of hops required for the total number of hops;

(3) Connectivity: the number of neighbor nodes owned by a node;

(4) Hop Distance: the sum of the minimum hop distance between two nodes;

(5) Receiving Signal Propagation Time Difference (Time Difference of Arrival,TDOA): in the process of signal transmission, issued at the same time, two different frequency signals reach the same destination when because of the time difference caused by different transmission speeds.

(6) Time of Arrival (TOA): the time required for the propagation of the signal at two different nodes;

(7) Round-trip Time of Flight (RTOF): the signal from one node to another node back to the time back;

(8) Angle of Arrival (AOA): the angle between the node's own axis and the received signal;

(9) Received Signa1 Strength Indicator (RSSI): wireless signal to reach the strength value of the sensor nodes.

B. The node location technology performance evaluation standard

In the wireless sensor network (WSN) positioning technology, different localization algorithm has different influence on positioning results, usually has the following several indicators to measure [9]:

Positional Accuracy: position precision is refers to the spatial location information (usually the coordinates) proximity between its true location, it is a leading indicator of measuring sensor network localization, only reach a certain position precision of localization algorithm is real and effective.

Effective Range of Orientation: positioning system can locate Effective range. To satisfy most of the nodes in WSN can be positioning, only covers a wide range of node location to be meaningful.

Node Density: refers to the spread of sensor Node Density in terms of network nodes. In WSN node density had a great influence on the performance of the positioning, usually Node Density high positioning precision will be higher and higher, the opposite will reduce Positional Accuracy. In view of the different localization algorithm in WSN node density is not required for the same, the performance of the sensor nodes and the price also determines the node of the seeding density.

Density of Beacon Node: Density of Beacon Node refers to the Beacon nodes in the proportion in the WSN. Beacon node has its own positioning function, the price is more expensive, could not sow large area, its node determines the positioning precision of the high and low density.

Fault Tolerance and Adaptability: refers to the so-called fault-tolerance of the presence of Fault system will not fail, the characteristics of can still work normally. Fault Tolerance is Fault how should the Fault, to be exact and not let Error. Adaptability can be thought of as a can adjust itself according to environmental changes can intelligent features of feedback control system, so that the system can work in accordance with the standards of some setting in the optimal state.

Security: Security is refers to the system to legitimate users of response and to resist the illegal request, to protect themselves from the external influence and the ability to attack. WSN usually work in the area of the physical environment is more complicated, positioning system vulnerable to environmental or man-made destruction and attacks, which cannot reach the ideal wireless communication environment to achieve the positioning of the effect, therefore must have a very strong security positioning system and algorithm.

Power Dissipation: refers to the Power loss of Power consumption, Power consumption in the process of WSN design has always been one of the main aspects in its application. Limited due to the energy of the sensor nodes and it is not easy to get, so we need the whole WSN can with less energy consumption and high efficiency of energy utilization to implement security positioning is the first question faced by the current research.

Cost and Consideration: the cost of location algorithm includes time cost, capital cost and space cost. Under the premise of ensuring the accuracy of positioning, the positioning system should be the minimum cost, such as the amount of computation required, the amount of communication, storage space, etc.

III. LOCATION ALGORITHM BASED ON DISTANCE MEASUREMENT

The positioning algorithm based on distance measurement to achieve more complex, first through TOA (Time of Arrival), TDOA (Time Difference of Arrival), AOA (Angle of Arrival), RSSI (Received Signa1 Strength Indicator) and absolute distance ranging technology commonly used to measure each unknown node and beacon node values, this stage is also called after the end of the ranging stage; ranging of positioning (coordinate) stage, namely the use of the node ranging stage distance or direction parameters to calculate the location of the unknown node, during which the commonly used algorithm: three edge measurement positioning method (Trilateration)[10], multilateral localization method of triangulation method (triangulation)[11], maximum likelihood estimation[12] (Maximum Likelihood Method) and angle positioning method (Goniometry)[13]. Following this thesis analyzed in two phases:

A. Ranging algorithm analysis.

TOA is according to the signal propagation time calculation is measured between the node distance. TOA algorithm although the positioning precision is high, but the algorithm requires nodes precise synchronization using complex, the hardware requirements are too high and therefore less suitable to the application of wireless sensor network localization.

The TDOA is formed on the basis of the TOA algorithm. In this algorithm, using two kinds of wireless signal transmitting node and different frequency information to send a group of the same area specified, because the transmission speed of the two signals are different, so the arrival time will be different according to the receiving node. The time difference and two kinds of signal transmission speed can be calculated between the receiving node and transmitting node distance value. This method can get the accurate positioning in NLOS conditions. But the requirements of sensor nodes are equipped with RF transceiver and ultrasonic wave transceiver, thus increasing the cost. And the signal is easily affected by the environment applicable occasions, single. TDOA method is applicable to the line of sight environment, obstacles in the NLOS environment will be reflected on the acoustic wave refraction and diffraction, which would increase the ultrasonic transmission time , produced a lot of errors, and ultimately affect the accuracy of the positioning.

AOA is through Triangulation calculate the location. In the AOA algorithm, unknown nodes first to calculated with respect to a reference node of the azimuth angle, which makes the algorithm positioning performance in complex electromagnetic environment is very poor, but also improves the energy, which eventually led to the lifetime of the network is shortened. The WSN with low cost, the goal of low energy consumption contrary, so the measurement method of practicality is very low.

RSSI is using the channel attenuation model to realize the function of positioning nodes according to the received signal strength. The regularity of RSSI value is not strong, so there is in the measurement when the error is large, so the need for multiple anchor nodes and position, which requires a large number of anchor nodes. In practical application, signal will inevitably encounter interference during transmission, reflection, absorption and other effects, which greatly reduce the positioning accuracy. At present, the RSSI value ranging technology can be divided into two kinds: one is based on the method of pretesting of environmental information, namely in the laboratory before the start of the treatment side area for large values of RSSI test that will be a different value saved to the database, then the query and call in the laboratory. Another is the method does not require pretesting of environmental information, such as hyperbolic model, distributed iterative algorithm, and combined with the dew flooding is introduced RSSI mechanism of HCRL (hop-count-ratio based localization) algorithm.

PDOA（Phase difference of arrival) is measured by measuring the phase difference of the received signal, and the signal transmission of the round-trip time, and then calculate the distance between the signal.

NFER（Near-Field Electromagnetic Ranging） near field electromagnetic distance, is measured by the phase difference between the near field and the magnetic field to measure the distance.

B. Positioning stage algorithm analysis.

Trilateration through three known coordinates of beacon nodes and the three beacons to unknown nodes of distance information, according to the two-dimensional spatial distance formula established equations and linearization method is used to solve the unknown node location information.

As shown in Fig.2, assuming that there are three anchor nodes B, C, a to participate in positioning, and their coordinates are (x_a, y_a) 、 (x_b, y_b) 、 (x_c, y_c) .

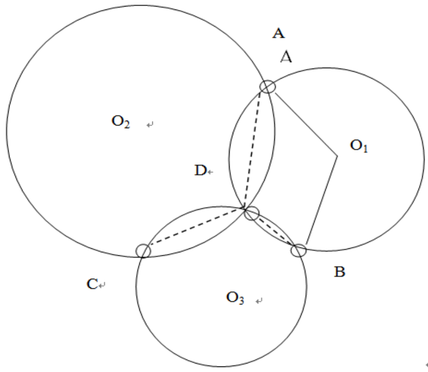

Figure 2. Trilateration

Hypothesis three anchor nodes have been measured by antenna array have node D signal direction of arrival, after determining the azimuth can be calculated angle the ADB, ADC angle, BDC angle size. Node A, B and proposed ADB can determine the only round O_1, and O_1 center coordinates (x_1, y_1) and radius r_1 , which A O_1 B angle = 2 PI was ADB. Circle center coordinates and radius can be calculated by the following Eq. 1:

$$\begin{cases} \sqrt{(x_1 - x_a)^2 + (y_1 - y_a)^2} = r_1 \\ \sqrt{(x_1 - x_b)^2 + (y_1 - y_b)^2} = r_1 \\ (x_a - x_b)^2 + (y_a - y_b)^2 = 2r_1^2 - 2r_1^2 \cos AO_1B \end{cases} \quad (1)$$

Similarly, we can calculate the center of O_2 , O_3 coordinate, and radius r_2 , r_3 the trilateration calculated node D coordinates (x, y) , namely Eq. 2:

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

The coordinates of the D (Eq. 3) of the node to be measured can be determined by the Eq.2:

$$\begin{bmatrix} x \\ x \end{bmatrix} = \begin{bmatrix} 2(x_1 - x_3) & 2(y_1 - y_3) \\ 2(x_2 - x_3) & 2(y_2 - y_3) \end{bmatrix}^{-1} \begin{bmatrix} x_1^2 - x_3^2 + y_1^2 - y_3^2 + d_3^2 - d_1^2 \\ x_2^2 - x_3^2 + y_2^2 - y_3^2 + d_3^2 - d_2^2 \end{bmatrix} \quad (3)$$

Multilateration known more than three beacon nodes coordinate information and beacon node to the unknown node distance information, using the distance formula between two points can be calculated the distance between unknown nodes and beacon nodes. Finally, by using the LS (Least Square), MLE(Maximum Likelihood Estimation) or MMSE(Minimum Mean Square Error) and for the coordinates of the unknown nodes.

Triangulation is the unknown nodes of the receiver antenna array to measure peripheral beacon signals sent by the incidence angle information and the angle information and the beacon nodes coordinate information. According to the coordinates of the Trilateration calculate the unknown node. Maximum Likelihood Method principle as shown in Fig.3.

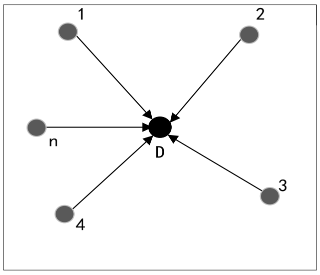

Figure 3. Maximum Likelihood Method

Known in the algorithm 1,2,3,... The coordinates of n and other n beacon nodes are: (x_1, y_1), (x_2, y_2), (x_3, y_3), $\cdots(x_n, y_n)$. They are the distance to unknown node D, respectively: d_1、d_2、$d_3 \cdots d_n$, assuming that the coordinates of the unknown node D are as follows Eq.4:

$$\begin{cases}(x_1-x)^2+(y_1-y)^2=d_1\\ \vdots\\ (x_n-x)^2+(y_n-y)^2=d_n\end{cases} \quad (4)$$

Starting from the first equation minus the last Eq.5::

$$\begin{cases}x_1^2-x_n^2-2(x_1-x_n)x+y_1^2-y_n^2-2(y_1-y_n)y=d_1^2-d_n^2\\ \vdots\\ x_{n-1}^2-x_n^2-2(x_{n-1}-x_n)x+y_{n-1}^2-y_n^2-2(y_{n-1}-y_n)y=d_{n-1}^2-d_n^2\end{cases} \quad (5)$$

Eq. 5 can be expressed as: $AX=b$, in which: A, X, b, as the following Eq. 6 to Eq.8 as shown:

$$A=\begin{bmatrix}2(x_1-x_n) & 2(y_1-y_n)\\ \vdots & \vdots\\ 2(x_{n-1}-x_n) & 2(y_{n-1}-y_n)\end{bmatrix} \quad (6)$$

$$b=\begin{bmatrix}x_1^2-x_n^2+y_1^2-y_n^2+d_n^2-d_1^2\\ \vdots\\ x_{n-1}^2-x_n^2+y_{n-1}^2-y_n^2+d_n^2-d_{n-1}^2\end{bmatrix} \quad (7)$$

$$X=\begin{bmatrix}x\\ y\end{bmatrix} \quad (8)$$

By using the maximum likelihood estimation method or the least square method, the coordinates of D can be estimated as Eq.9:

$$\hat{X}=(A^TA)^{-1}A^Tb \quad (9)$$

Ⅳ. CONCLUSION

The Internet of Vehicles is a research hotspot in recent years and focus on positioning technology and a large number of algorithms are constantly emerging, however a large number of existing localization algorithms are improved for typical localization algorithm basic positioning principle. Based on application or improvement is also a kind of innovation, the innovation of ideas and methods of network positioning technology in the Internet of Vehicles is worth learning, localization method based on ranging technology although the error is small, but there are some contradictions between the rapid response time and vehicle positioning efficiency relatively low requirements of network application. Although the Internet of Vehicles is a new concept and application, but the related theoretical research and technology application can be on the basis of existing achievements deeply and innovation. However, at present, the research on range-based node localization method of Internet of vehicles is still at the initial stage, so there are a lot of problems to be solved and unknown problems to study.

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