Research and Analysis of WSN Node Location in Highway Traffic Based on Priority

Congrong Tang[1, *]

Abstract: With the rapid development of highway transportation in China, intelligent transportation has become an important part of the traffic structure, and wireless sensor networks are also widely used in intelligent transportation. However, in the wireless traffic sensor network, there is a certain error in the positioning of the anchor blind nodes. In the process of tracking the feedback information, the results of determining the position are very different. Based on the maximum degree of tension, the road traffic wireless Research and analysis of blind node location in sensor networks, and propose solutions and measures to reduce monitoring results.

Keywords: Maximum, degree of road traffic, WSN, blind node, positioning order.

1 Introduction

Sensor network is one of the ten most influential technological changes in the new century, and has huge application prospects in the field of traffic engineering [Yu (2007)]. In a specific environment, in order to complete the task of target detection and tracking, the appropriate sensor nodes are usually placed into it, and the positioning of the nodes in the visual sensor network is achieved through appropriate measurement and positioning methods, and the nodes are completed in an appropriate manner. Coordination work between Coordination work between [Lin, Wu, Xu et al. (2005)].

At present, most network transmission systems can only measure the temperature, humidity, light intensity and other environmental information in the monitored area [Liu, Huang, Wu et al. (2012)]. The measured data, which contains a limited amount of data, is greatly affected by the environment, has insufficient knowledge of the surrounding environment, and has a single role. This limits and restricts the integrity and safety of the sensor, and even Unable to meet the needs of different monitoring tasks. WSN sensors can be practically used in the field of traffic engineering, for on-site monitoring, environmental monitoring, personnel monitoring, etc. The sensor network has extremely important research significance and use value for the positioning and tracking technology of targets in specific traffic areas. At the beginning of the article, the azimuth angle was preliminarily processed to reduce the influence of measurement error. Then through the positioning iteration, the transfer error of the pseudo anchor node (the blind node that has been positioned) participating in the positioning of the next blind node is analyzed, the

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quadratic transfer coefficient matrix of the error is derived, and the blind node positioning is proposed based on the ANP tension Time priority concept. Priority is the maximum value of all ANP's tension when the blind node is located; the algorithm selects the next blind node for positioning according to the priority of the blind node.

In the wireless network of road traffic wireless devices, the blind anchor nodes determine the azimuth between the nodes by mutual positioning, and the anchor nodes are used to identify the blind nodes, so that the blind nodes are integrated into all network systems, and the exact position of the blind nodes is determined.

2 Azimuth definition and adjustment

The data measured under ideal conditions are exactly the same, but the road traffic WSN environment is more complicated, and there are many factors that affect the measurement results, which affect the measurement angle, resulting in deviations corresponding to the directional measurement results. In order to obtain a more accurate azimuth measurement result, it is necessary to adjust the azimuth measurement error, and the anchor nodes are separately set, and the measurement error distribution of each angle is similar and independent of each other. This makes it possible to measure any azimuth $\theta : \theta_o = \theta + \widetilde{\theta}_o , \widetilde{\theta}_o$: Measuring the error value,and $\widetilde{\theta}_0 \sim N(0, \sigma^2_{\theta_0})$.

Due to $\theta_{XS}=\theta_{SX}\pm\pi$, Therefore, in the azimuth measurement of any node, the measured quantity is equivalent to the secondary measurement, and the data are independent of each other. For this feature, in order to obtain a more accurate measurement result, the measured data can be preferentially processed.

When the azimuth is compensated, the angle measurement data is subjected to a weighted averaging process to reduce the total deviation of the measurements. In the weighted average, there is a 180° angular difference between θ_{XS} and θ_{SX}, so the average of the measured data cannot be directly used as a result. To solve this problem, you can first measure the data as two and two, and then use $\pm\pi/2$ as the adjustment value to adjust the deviation to obtain the measured average value of the corrected direction. $(\overline{\theta}_{sx}, \overline{\theta}_{xs})$ after compensating the azimuth is given by Eq. (1).

$$(\overline{\theta}_{SX}, \overline{\theta}_{XS})^{\mathrm{T}} = \begin{cases} (\dfrac{\theta_{XS}+\theta_{SX}+\pi}{2}, \dfrac{\theta_{XS}+\theta_{SX}-\pi}{2})^{\mathrm{T}}, & \theta_{SX} > \theta_{XS} \\ (\dfrac{\theta_{XS}+\theta_{SX}-\pi}{2}, \dfrac{\theta_{XS}+\theta_{SX}+\pi}{2})^{\mathrm{T}}, & \theta_{SX} < \theta_{XS} \end{cases} \tag{1}$$

Compensated azimuth $\theta_{sx} = \theta_{sx} \pm \pi$, According to statistical principles: $D(kx) = k^2 D(x)$ and $D(\sum_{i=1}^{n} X_i) = \sum_{i=1}^{n} D(x_i)$, X_1, X_2, …, X_n are not related to each other. The compensated azimuth error satisfies, $\tilde{\tilde{\theta}}_0 \sim N(0, \sigma^2_{\theta_0}/2)$ reducing the variance of the measurement error distribution.

3 Location error and error transmission of wireless sensor network in highway traffic

For a newly arranged road traffic wireless sensor network to share a common anchor node and blind node, to complete the reading and writing operations of all nodes in the work process, it is necessary to use the anchor node to retrieve the blind node. During the retrieval process, the retrieved blind nodes become anchor nodes and participate in the retrieval completion function of other blind nodes. In this process, the positioning accuracy and efficiency may be different.

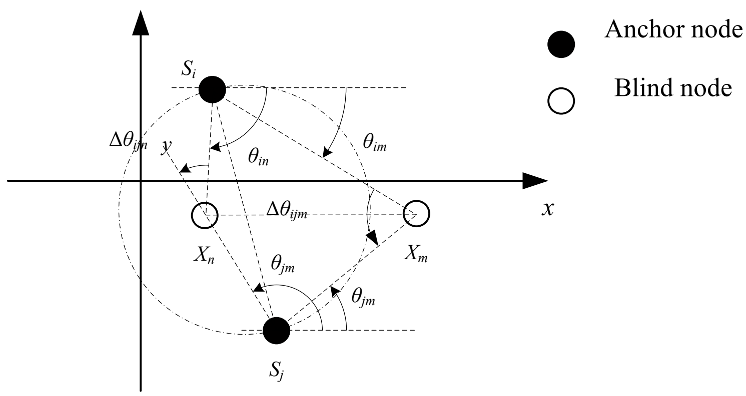

Figure 1: Distribution of blind nodes in some anchor nodes

As shown in Fig. 1, the anchor nodes S_i, S_j, blind nodes X_m, X_n, where $\Delta\theta_{ijn} = |\theta_{in}| + |\theta_{jn}|$, $\Delta\theta_{ijn} = |\theta_{in}| + |\theta_{jn}| - \pi$. Since the range of azimuth variation is defined between [-π, π), $\Delta\theta_{ijm} = \theta_{jm} - \theta_{im}$, $\Delta\theta_{ijn} = \theta_{jn} - \theta_{in} - \pi$.

It can be seen from the analysis in Fig. 1 that when positioning $X_{Tm} = (x_{Tm}, y_{Tm})$ and $X_{Tn} = (x_{Tn}, y_{Tn})$, the surrounding blind nodes are continuously replaced by the anchor nodes, and the next blind node is located as a new anchor node. If the error is not large during the entire positioning process, it can be defined as a new reference anchor node. However, in the actual positioning process, the error will gradually increase, and the error between the results of the measurement will be large. In order to be able to measure more accurate results, we must select the largest among the defined nodes during the positioning process. The most measured basis for the degree of tension.

It can be seen from Fig. 1 that there are two cases of X_m and X_n positioning order, and the two cases are analyzed first:

First locate X_m. From Fig. 1, we can see that there are three anchor nodes S_i, S_j, and X_m and one blind node of X_n. Here, the positioning test is performed with Si and X_m. The azimuth error value is $\tilde{\theta}$, $\tilde{\theta}$ is $\tilde{\theta} \sim N(0, \sigma_0^2)$ By obtaining the $X_{ijm}=(x_{ijm},y_{ijm})T$ according to the principle of trigonometry $X_{ijm}=X_{Tm}+dX_{ijm}$.

The variance D_{ijm} of X_{ijm} is:

$$\begin{bmatrix}\sigma^2_{x_{ijm}}\\ \sigma^2_{y_{ijm}}\end{bmatrix}=\begin{bmatrix}(p_{ijm}\cos\theta_{jm})^2 & (q_{ijm}\cos\theta_{im})^2\\ (p_{ijm}\sin\theta_{jm})^2 & (q_{ijm}\sin\theta_{im})^2\end{bmatrix}\begin{bmatrix}\sigma^2_{\theta_{im}}\\ \sigma^2_{\theta_{jm}}\end{bmatrix}$$

$$=\frac{1}{\sin^2\Delta\theta_{jim}}\begin{bmatrix}(d_{im}\cos\theta_{jm})^2 & (d_{jm}\cos\theta_{im})^2\\ (d_{im}\sin\theta_{jm})^2 & (d_{jm}\sin\theta_{im})^2\end{bmatrix}\begin{bmatrix}\sigma^2_{\theta_{im}}\\ \sigma^2_{\theta_{jm}}\end{bmatrix} \tag{2}$$

which is:

$$\max(|D_{ijm}|)=\frac{1}{\sin^2\Delta\theta_{jim}}[d^2_{im}\sigma^2_{\theta_{im}}(\cos^2\theta_{jm}+\sin^2\theta_{jm})+d^2_{jm}\sigma^2_{\theta_{jm}}(\cos^2\theta_{im}+\sin^2\theta_{im})]$$

$$=\frac{d^2_{im}\sigma^2_{\theta_{im}}+d^2_{jm}\sigma^2_{\theta_{jm}}}{\sin^2\Delta\theta_{jim}}=\frac{d^2_{im}+d^2_{jm}}{\sin^2\Delta\theta_{jim}}\sigma^2_\theta \tag{3}$$

Obtained by $X_{ijm}=(x_{ijm},y_{ijm})T$:$X_{imn}=X_{Tn}+dX_{imn}$

The variance D_{imn} of X_{imn} is:

$$\begin{bmatrix}\sigma^2_{x_{imn}}\\ \sigma^2_{y_{imn}}\end{bmatrix}=\begin{bmatrix}\lambda^2_{xim} & \lambda^2_{xjm} & \lambda^2_{xin} & \lambda^2_{xmn}\\ \lambda^2_{yim} & \lambda^2_{yjm} & \lambda^2_{yin} & \lambda^2_{ymn}\end{bmatrix}\begin{bmatrix}\sigma^2_{\theta_{im}}\\ \sigma^2_{\theta_{jm}}\\ \sigma^2_{\theta_{in}}\\ \sigma^2_{\theta_{mn}}\end{bmatrix} \tag{4}$$

which is:

$$\max(|D_{imn}|)=\max(\frac{1}{\sin^2(\theta_{mn}-\theta_{in})}\bullet$$

$$\left[\frac{d^2_{im}\sigma^2_{\theta_{im}}\sin^2(\theta_{mn}-\theta_{jm})+d^2_{jm}\sigma^2_{\theta_{jm}}\sin^2(\theta_{im}-\theta_{mn})}{\sin^2(\theta_{im}-\theta_{jm})}+d^2_{in}\sigma^2_{\theta_{in}}+d^2_{mn}\sigma^2_{\theta_{mn}}\right])$$

$$=\frac{1}{\sin^2(\theta_{mn}-\theta_{in})}\left[\frac{d^2_{im}\sin^2(\theta_{mn}-\theta_{jm})+d^2_{jm}\sin^2(\theta_{im}-\theta_{mn})}{\sin^2(\theta_{im}-\theta_{jm})}+d^2_{in}+d^2_{mn}\right]\sigma^2_\theta \tag{5}$$

Firstly, use S_i and S_j to locate X_n, then use X_n to locate X_m, and form three anchor nodes of S_i, S_j and X_n and a blind node of X_m. Here, the positioning test is performed by S_i and X_m, also according to the trigonometric method.

The principle is $=X^T_{ijn}=(x_{ijn},yi_{jn})$, and the variance D_{ijn} of X_{ijn} is:

$$\begin{bmatrix}\sigma^2_{x_{ijn}}\\ \sigma^2_{y_{ijn}}\end{bmatrix}=\begin{bmatrix}(p_{ijn}\cos\theta_{jn})^2 & (q_{ijn}\cos\theta_{in})^2\\ (p_{ijn}\sin\theta_{jn})^2 & (q_{ijn}\sin\theta_{in})^2\end{bmatrix}\begin{bmatrix}\sigma^2_{\theta_{in}}\\ \sigma^2_{\theta_{jn}}\end{bmatrix}=\frac{1}{\sin^2\Delta\theta_{jin}}\begin{bmatrix}(d_{in}\cos\theta_{jn})^2 & (d_{jn}\cos\theta_{in})^2\\ (d_{in}\sin\theta_{jn})^2 & (d_{jn}\sin\theta_{in})^2\end{bmatrix}\begin{bmatrix}\sigma^2_{\theta_{in}}\\ \sigma^2_{\theta_{jn}}\end{bmatrix} \tag{6}$$

which is:

$$\max(|\boldsymbol{D}_{ijn}|)=\frac{d^2_{in}+d^2_{jn}}{\sin^2\Delta\theta_{jin}}\sigma^2_\theta \tag{7}$$

It is inevitable that the error occurs when the WSN is in the working state. At the same time, the error is also transmitted and amplified in the process of information transmission, which has a certain influence on the measurement result. The error formula max|D_{ijn}| and max|D_{imn}| calculated by the above two cases can be It can be seen that the angle and distance have a certain influence on the accuracy of the measurement. Therefore, when selecting the node when positioning, the positioning effect should be determined according to the specific conditions of the angle and the distance.

4 Analysis of the maximum degree of blindness of highway WSN blind nodes

In the road traffic network, there are not many anchor nodes for the newly arranged WSN network. When the blind node is located, only the reference node is used to determine the blind node if there is measurement error and the azimuth is small. The position is not accurate due to the amplification effect of the error transfer coefficient. In order to reduce the measurement error and improve the accuracy of the measurement results, the blind node is often converted into an anchor node to complete the node positioning measurement.

In order to be able to determine the basis of the anchor node, we give a judgment basis. Based on the positioning error expression, we propose multiple degrees of representation. In order to have reference standards for the selection of anchor nodes, here we analyze the problems related to multiple degrees of tension, according to the original degree of Q_{ijm} formula and the maximum variance:

$$Q_{imn} = \frac{\sin^2(\theta_{in}-\theta_{mn})\sin^2(\theta_{im}-\theta_{jm})}{2\sin^2(\theta_{im}-\theta_{jm})+\sin^2\left(\theta_{mn}-\theta_{jm}\right)+\sin^2\left(\theta_{im}-\theta_{mn}\right)} \tag{8}$$

In the above formula, Q_{imn} is used as the extended degree of expansion. In the absence of the anchor node, Q_{imn} can be used as an anchor node to perform positioning work to compensate for the blanks calculated during the error transfer process, and provide data for the WSN calculation when the node is positioned. In the whole process of positioning calculation, the maximum opening degree of the anchor node when the blind node is positioned is denoted by P_{xm}:

$$P_{xm}=\max\,(Q_{ijm}) \tag{9}$$

Q_{ijm}: the degree of tension during positioning.

i: The degree of opening of the anchor node network.

j: The degree of opening of the anchor node network.

The blind node location process is shown in Fig. 2.

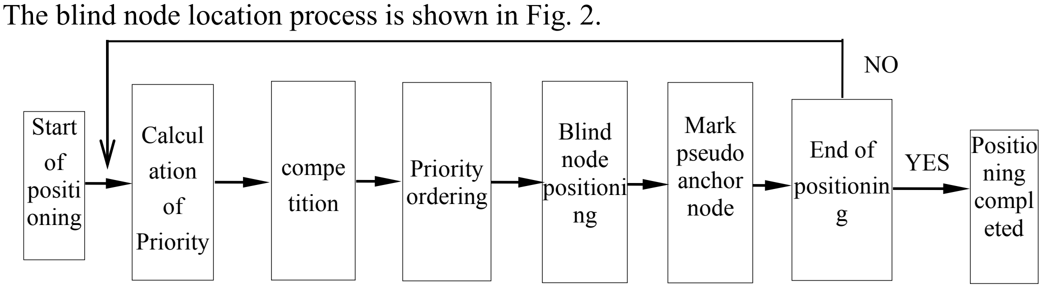

Figure 2: Blind node positioning flow chart

5 Maximum tensile test analysis of blind nodes in highway WSN

The maximum tensile test procedure for blind nodes of highway WSN is: randomly generate 10 nodes, calculate the azimuth as the actual value, increase the Gaussian noise as the measured value in the azimuth, and implement the azimuth correction algorithm to obtain the corrected azimuth to be calibrated.

The azimuth angle before and after is compared with the actual value error.

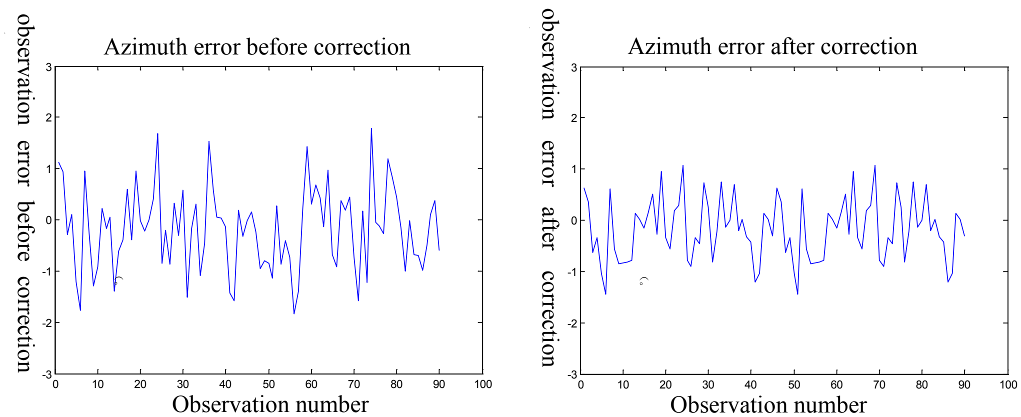

Figure 3: Comparison of error experiments before and after azimuth correction

It can be seen from Fig. 3 that the measurement error dtheta=1°, the correction algorithm can slightly suppress the measurement error, and can optimally utilize the data redundancy measured at each node to improve the positioning accuracy.

Table 1: Error standard deviation before and after multiple experiments

Number of experiments	1	2	3	4	5	6
Before correction	1.0309	0.9415	1.0095	0.9486	1.0263	1.0123
After correction	0.7029	0.5982	0.6778	0.6186	0.7781	0.6461

Ten nodes are randomly arranged in the range of 1 square kilometer, four nodes are used as anchor nodes, and other nodes are blind nodes, as shown in Fig. 4.

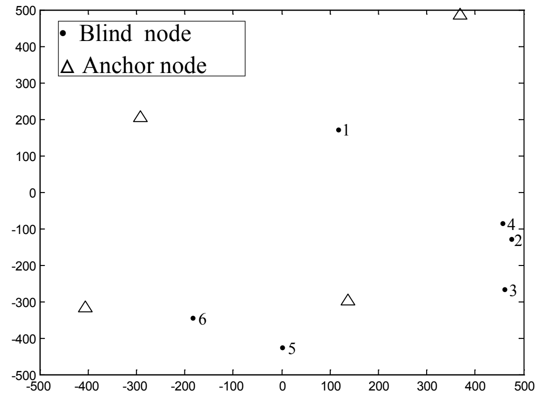

Figure 4: Sequence of blind nodes being located in the area

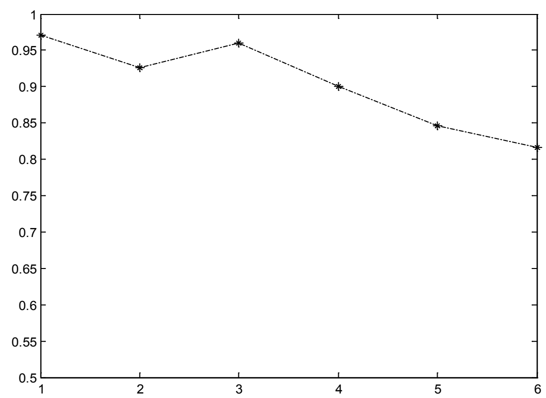

Figure 5: Recorded maximum priority data trend

It can be seen from the positioning sequence of Fig. 4 that node 1 is in the best position and the first one is positioned. The positions of nodes 2, 3 and 4 are relatively close, and their positioning order is not much different. Node 6 is close to the center of the anchor node distribution area, but its span is not large in the WSN network calculation, and the azimuth is close to zero, so it is finally positioned.

Table 2: Maximum priority data

Serial number	1	2	3	4	5	6
Maximum opening	0.970704	0.926687	0.960444	0.900519	0.846521	0.816521

It can be seen from Tab. 2 and Fig. 5 that the maximum degree of positioning of the node 3 is significantly increased, because the positioning is to select the blind node No. 2. The positioning in the later stage is declining. The reason is that the blind node positioning has errors, and the transmission of errors increases during the node positioning process, resulting in greater errors in the later positioning.

It can be seen from Fig. 6 that the positioning effect of the sequential algorithm is significantly more than that of the random positioning algorithm, and is closer to the actual value. For some edge nodes, because the distribution area of the anchor node is far, the azimuth angle is small, the degree of calculation calculated by the WSN network is low, and the error generated by the anchor node direct positioning algorithm is relatively large, and the positioning accuracy is not high. For anchor nodes with a long distribution area and a small azimuth angle and low waviness calculated by the WSN network, if the blind nodes that have been located are used in the sequential positioning algorithm, the positioning range of the blind nodes can be effectively increased, and the road traffic network can be improved. Self-positioning feature.

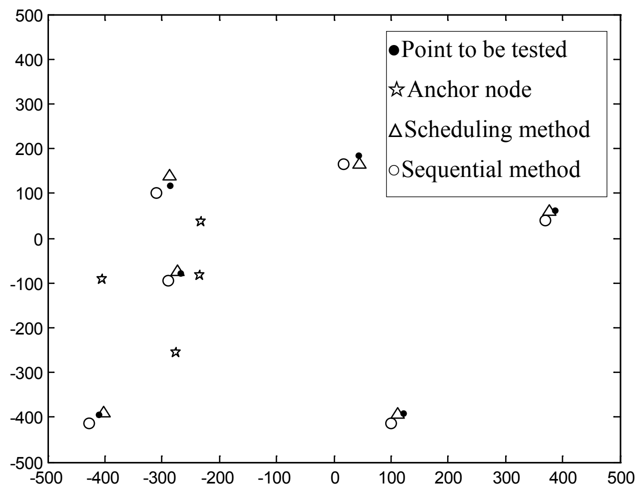

Figure 6: Comparison of positioning completion

6 Conclusion

In the highway WSN network, all nodes can measure the azimuth of other nodes, and the azimuth angles measured by each pair of nodes are different by π. Using this feature to process the measured azimuth can effectively reduce the variance. To make the measurement data more accurate and the positioning result is accurate. Based on the error analysis of the position of the pure anchor node, the error propagation of the blind node is used to compare the maximum degree of blindness of each blind node, and the blind node that is preferentially located is selected to improve the accuracy of the measurement result.

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

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