An Improved Algorithm of the Node Localization in Ad Hoc Network

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***Abstract*—If the destination node is far from the source node, the transmission of the routing control information for the destination node has some delay and will then affect the accuracy of the node localization. An algorithm is proposed to predict the actual location of the destination node based on its current position information in routing table. The original algorithm is analyzed, and the primary reason that the node localization has some deficiency is pointed out. The node localization forecast algorithm is designed and realized, and the forecast algorithm is used to improve the accuracy of the node localization as far as possible. The algorithm is simulated and analyzed, and it proved that the proposed algorithm can effectively reduce the impact of positioning accuracy caused by the node transmission delay and other factors.**

***Index Terms*—Ad Hoc Network; Node Localization; Forecast Algorithm; Routing**

I. INTRODUCTION

Using node location technology to get the localizations of the nodes in the wireless network, it can realize network topology control and improve the performance for the routing algorithm with node location information, and at the same time node positioning technology is also one of the important technologies related to the wireless network applications[1]-[5].

In the early studies, based on the OLSR protocol [6], we have realized node localization in Ad Hoc network, by extending the function of OLSR routing protocol, the node can obtain nodes' distribution information of its surroundings or the entire wireless Ad Hoc network. Routing calculation algorithm was modified, and the destination node's position information was added in the routing table [7]-[16].

The above-mentioned studies are aimed to provide the conditions and convenience for some of the applications which based on the positions in wireless network, such as routing algorithm optimization and packet transmission strategy selection, etc.

But when the distance between the current and destination node is very far, the routing control information from the destination node should undergo multiple hops to reach the current node. For each hop, one of the mainly time should be spent for the routing control information to transmit is the computing time in each node, and the other is the propagation time. The nodes in the ad hoc network move randomly, so when the routing control information reaches the destination after several hops, it may be out of the time already, and use it to calculate the destination node's position can cause some errors obviously, and with the hops increase, the errors will also increase. The details why it can cause transmit delay and errors in computing node's position are described in section II.

As described above, when the destination is far from the current node, the routing control information should occupies more time to transmit, therefore, it brings some of the delay, and then affect the accuracy for node localization in the early studies.

The motivation in our studies is to improve the accuracy for the positioning algorithm based on the previous studies, a prediction algorithm is work out, which uses the current position to calculate the actual position in the routing table. First of all, the original algorithm is analyzed, the main reason that can cause positioning errors is provided; Then the node position prediction algorithm are designed and realized in order to make location information in the routing table is similar to the actual location as far as possible; Finally, the algorithm is simulated and analyzed, which shows that this algorithm can well reduce the impact factors which lead to the positioning accuracy because of the transmission delay.

II. ANALYSIS FOR THE ORIGINAL ALGORITHM

According to preliminary work, we propose that the wireless Ad Hoc network node knows its position (three-dimensional coordinates, through the node equipped with a GPS or other positioning devices), based on the OLSR routing protocol in wireless network, the routing computation algorithm is modified, and the target node's location information is added in the routing table for every node. We try to let the node achieve the positions of its surrounding nodes or the entire wireless Ad Hoc network nodes. Additionally, the OLSR routing protocol which has localization function is analyzed and compared with the original protocol. The content of the research can provide conditions and bring convenience to location-based wireless network applications such as routing algorithm's optimization, packet transmission strategy and so on.

This work was supported in part by Project supported by the National Natural Science Foundation of China (Grant No.61103213).

doi:10.4304/jnw.9.3.549-557

But after the network simulation, we found that part of the positioning information in the routing table can't reflect to the current topology of the network when nodes move frequently and fast, therefore, it is very necessary and valuable to improve the original position algorithm.

In order to validate the positioning accuracy in the routing table for the destination, the following experiment environment is created. At the beginning, the distribution of the 36 nodes is as follow, the horizontal and vertical distance are both 150m, transmission radius of the signal is about 180m. The position of each node is fixed (Constant Position Mobility Model is selected), other experimental parameters are showed in table 1, nodes topology distribution are shown in figure 1.

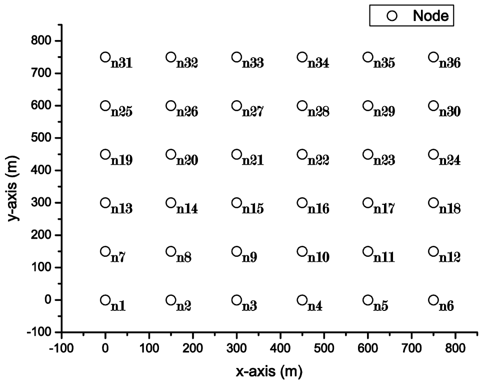

Figure 1. Nodes topology distribution

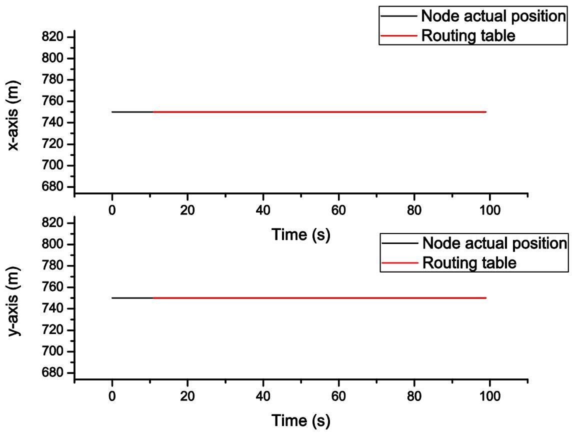

Figure 2. n_{36}'s Current positions in n_1's routing table and its actual position (the node position fixed)

TABLE I. EXPERIMENTAL PARAMETERS

Parameter	Value
Modulation	802.11b
Nodes	36
Simulation Time	100s
RemoteStationManager	ConstantRateWifiManager
DataMode	DsssRate2Mbps
ControlMode	DsssRate2Mbps
PropagationDelay	ConstantSpeedPropagationDelayModel
PropagationLoss	RangePropagationLossModel
FragmentationThreshold	2200 (bit)
RtsCtsThreshold	2200 (bit)
MobilityModel	ConstantPositionMobilityModel

Node n_1 is selected as a reference one, the position of the destination (node n_{36}) in the routing table of n_1 is analyzed in different time. It is clear that those two nodes have the farthest distance and maximum hop counts in the node distribution area which is displayed in figure 1. The current position information of the node n_{36} is obtained from the routing table in node n_1, Similarly, The actual position information of the node n_{36} is also acquired every 1 second. The current position of the node n_{36} in the routing table of node n_1 and its actual position are compared. The experimental results as shown in figure 2 (the node position fixed) and figure 3 (the node position fixed) shows.

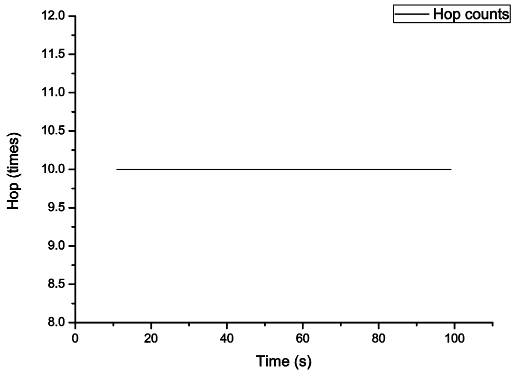

Figure 3. The hop count between n_1 and n_{36} (the node position fixed)

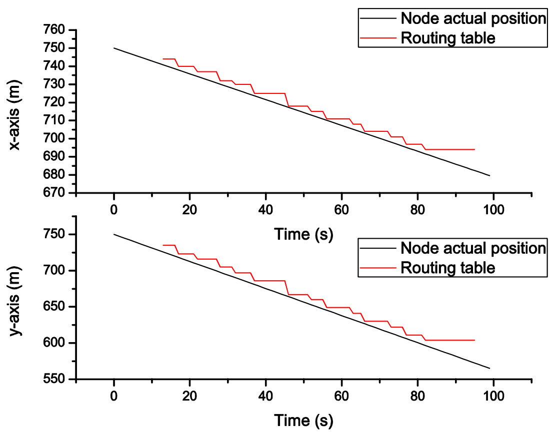

Figure 4. n_{36}'s Current position in n_1's routing table and its actual position (2m/s)

Node n_{36}'s coordinates (x and y directions) in n_1's routing table are displayed in red line while its current actual coordinates are displayed in black. From the chart we can see that the red line appears about 12 seconds later, indicates that about 12 seconds needed for n_1 to locate n_{36} (750m, 750m), the position and hop count for each node is all remain unchanged, so the position information in routing table is also remain unchanged, figure 3 shows that hop count remains unchanged (10 jumps) between the n_1 and n_{36}. It is obviously that when the destination node is far from the source, difficulties arise because of the time delay, the position information in the routing table is already out of date, and it can't reflects the current actual position.

Based on the above experimental environment, let the nodes move according to the RandomDirection2dMobilityModel, nodes initial topology distributions are shown in figure 1. Then nodes move randomly in the two-dimensional space within a 3000m*3000m area in a 2m/s speed. The experimental results are shown in figure 4.

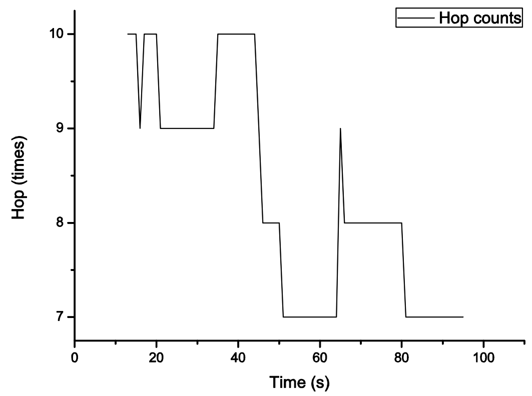

Figure 5. The hop count between n_1 and n_{36} .(2m/s)

n_1 is selected as a reference one, the position of the destination (n_{36}) is analyzed in different time, $n_{36}'s$ position in $n_1's$ routing table and its actual position varied as the change of time, and the characteristics is shown in figure 4. $n_{36}'s$ coordinates (x and y directions) in $n_1's$ routing table are displayed in red line while its current actual coordinates are displayed in black. n_{36} move constantly in the two-dimensional space according to the RandomDirection2dMobilityModel within a 3000m*3000m area in a 2m/s speed, and the actual values of $n_{36}'s$ coordinates (x and y directions) reduce continuously. In $n_1's$ routing table, the distance between n_{36} and n_1 is farthest, and the hop count is maximum, At the beginning, more time is spent for n_1 to the locate n_{36}, and that exists larger delay, about 13 seconds. The hop count that is shown in figure 5 is also changing constantly between the two nodes.

Meanwhile, the red line is always located in the upper part of the black that means position errors in $n_1's$ routing table. During this period of time, the path between n_1 and n_{36} maybe invalid already owning to $n_{36}'s$ movement, if n_1 still uses the path to send data to n_{36}, it may cause data transmission failure there for. In addition, the red line changes uneven relative to the black one, it reflects that there are some hysteresis phenomena for $n_{36}'s$ location information in $n_1's$ routing table. The main reason is that routing control information with location is transmitted periodically. In the above experiment, HELLO message is transmitted every 2s, and TC message 5s, nevertheless, the nodes' position is continuous uninterruptedly changed, therefore, the destination nodes can't be continuously and accurately located.

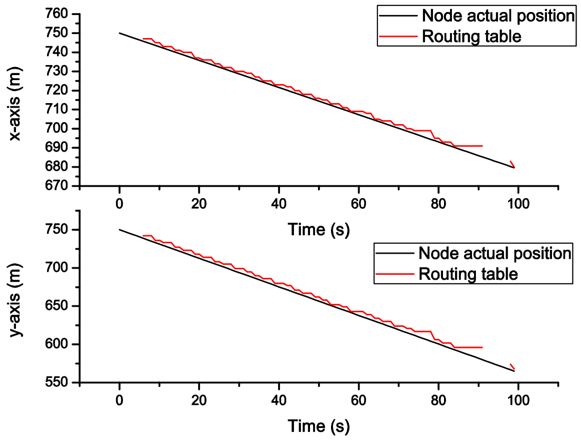

Figure 6. $n_{36}'s$ current position in $n_1's$ routing table and its actual position (2m/s, HELLO: 1s, TC-2.5: s)

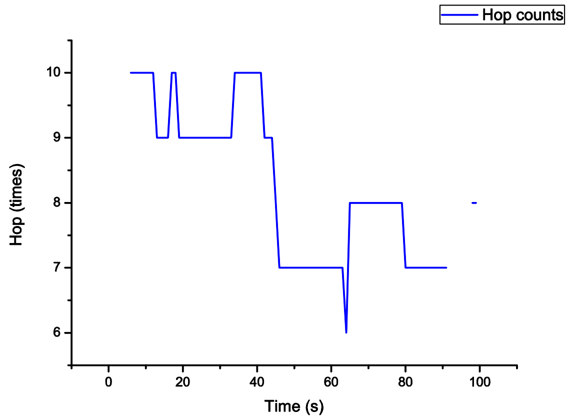

Figure 7. The hop count between n_1 and n_{36} (2m/s, HELLO: 1s, TC: 2.5s)

The above experiment parameters are changed, HELLO message is transmitted every 1s, TC message 2.5s, and the result is illustrated in figure 6. Compare with the figure 4, the red line changes more even, and it also becomes more close to the actual position, the accuracy for $n_{36}'s$ location information in the routing table is improved.

In figure 6, the red line is interrupted from 92 to 97 seconds, and there isn't $n_{36}'s$ position information in $n_1's$ routing table in this period of time. In figure 7, the hop count between n_1 and n_{36} changes over time, and the line also interrupts during this period of time. Nevertheless, in figure 4 the red line doesn't interrupt, and the loss of path information isn't reflected in $n_1's$ routing table, this is caused by the storage time for the neighbor information table and topology information table is set to 3 times of the HELLO and TC message in OLSR protocol. In figure 4 transmit interval for HELLO and TC message are 2s and 5s, so the storage time for the neighbor information table and topology information table are 6s and 15s. although n_1 have not received n_{36}'s TC messages for a long time, n_{36}'s topology and position information were still recorded in n_1's topology information table, those information is invalid now, and the routing information is calculated according to it, so it is also invalid. If those routing information is used to transmit, it will lead to the failure of the transmission.

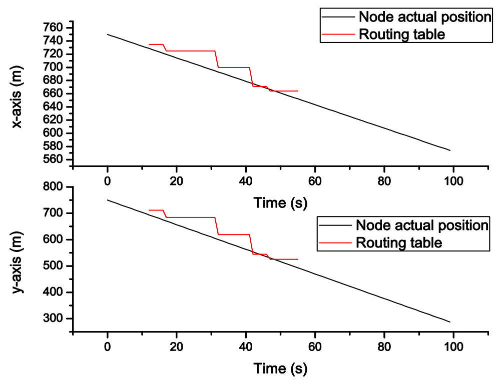

Figure 8. n_{36}'s Current positions in n_1's routing table and its actual positions (5m/s)

In figure 6, transmit interval for HELLO and TC message are 1s and 2.5s which is half of the figure 4, so the storage time for the neighbor information table and topology information table is set to 3s and 7.5s which is reduced obviously. This is helpful for n_1 to find location information of destination nodes in a short time. If the routing location information is calculated according to it, it can improve the accuracy of routing and positioning, but it will greatly increase the amount of routing information in network, at the same time, the burden of network is increased and the network performance is reduced.

The movement speed of the nodes are improved to 5m/s, and other experimental conditions and parameters are kept constant. HELLO message is transmitted every 2s, TC message 5s. The results are illustrated in figure 8 and figure 9, and the connection is lost in 42-46 s and 60-99s. In figure 8, Node n_{36}'s coordinates (x and y directions) in n_1's routing table are displayed in red line, it changes more uneven compared with the figure 4, indicates that it will become more difficult to locate as the moving speed increases.

In order to verify the influence of different topologies and mobile way for the localization algorithm, let the nodes move according to the Random Waypoint Mobility Model within a 1-5 m/s speed, and the Random Box Position Allocator model is used as the initial topology distributions which are in an 800m*800m area. Figure 10 illustrator the nodes' topology and the experimental results are shown in figure 11 and figure 12.

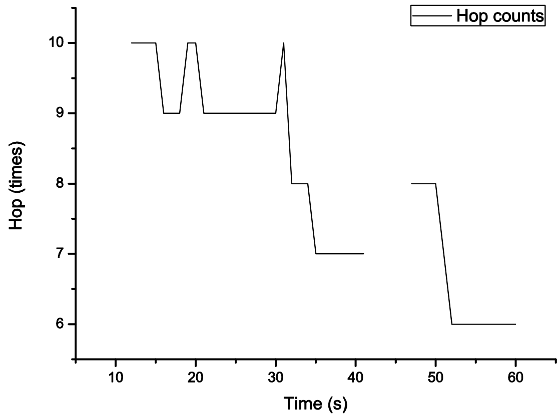

Figure 9. The hop count between n_1 and n_{36} (5m/s)

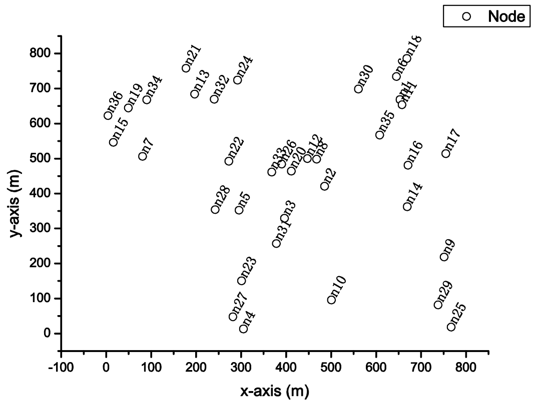

Figure 10. The nodes' topology

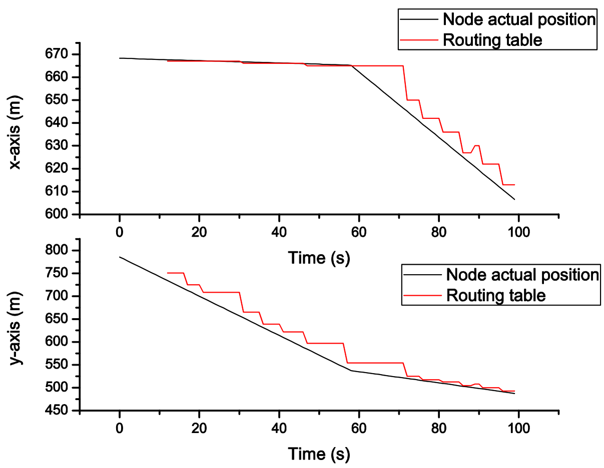

Figure 11. The current positions in routing table and its actual positions (maximum speed: 5m/s)

n_4 is selected as a reference one, the position of the destination (n_{18}) is analyzed in different time, the Variation characteristics of the n_{18}'s current positions in routing table and its actual positions is illustrator in figure11. At the beginning, more time is spent for n_4 to locate n_{18}, and that exists larger delay , about 13 seconds, thereafter, the delay is still there, n_{18} may have move out the range that n_4 can reach, and then the data transmission failure may appear in this period of time. The hop count that is shown in figure 12 is also changing constantly between the two nodes.

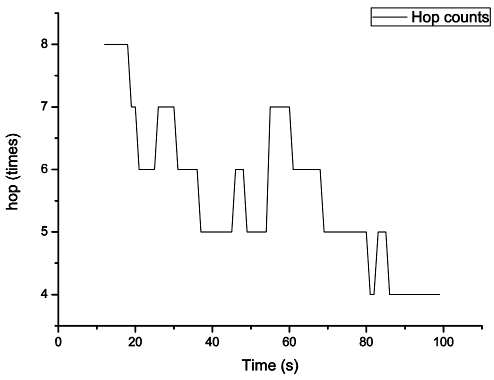

Figure 12. The hop count between n_4 and n_{18} in routing table (maximum speed: 5m/s)

The moving speed is improve to 20m/s, n_1 is selected as a reference one, the position of the destination (n_{36}) is analyzed in different time, n_{36}'s position in n_1's routing table and its actual position varied as the change of time, and the characteristics is shown in figure 13, and the hop count that is shown in figure 14 is also changing constantly between the two nodes. There is only one hop at the time of 31s, thereafter, the n_{36}'s current positions in routing table and its actual positions is nearly the same which further indicates that it will become more difficult to locate as the hop count increases.

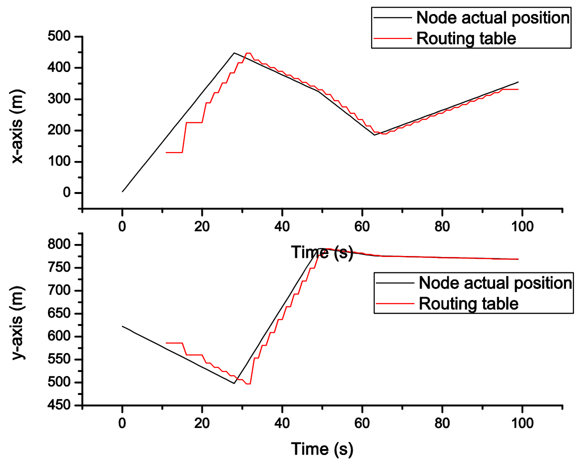

Figure 13. The current positions in routing table and its actual positions (maximum speed: 20m/s)

According to the above analysis, the localization algorithms proposed previously are able to achieve localization to a certain extent, but there are the following main defects:

(1) A certain delay exists to transmit control information between source and destination nodes, it is obviously that when the destination node is far from the source, difficulties arise for node localization because of the time delay, therefor, the position information in the routing table is already out of date, and it can't reflects the node's current actual position.

(2) The node's movement speed and direction are not known in advance, and it is difficult to accurately forecast its location of the next moment, therefore, it will become more difficult to locate as the node's moving speed increases.

(3) The hop count has important influence for the location algorithm, when there is only one hop, thereafter, the node's current positions in routing table and its actual positions is nearly the same, which indicates that it will become more difficult to locate as the hop count increases.

(4) Reducing the transmitting interval for routing control information can improve the accuracy of routing and positioning, but it will greatly increase the amount of routing information in network, at the same time, the burden of network is increased and the network performance is reduced.

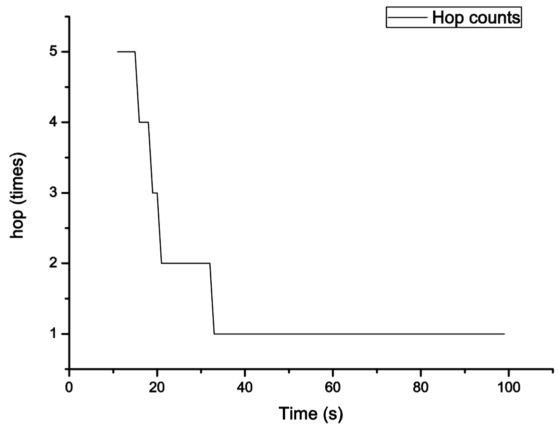

Figure 14. The hop count between n_1 and n_{36} in n_1's routing table (maximum speed: 20m/s)

Because of the existence of the problem above, it brings some adverse effects to compute the MPR set and routing information, and also it can affect data transmit. Some analysis is presented below.

(1) Firstly, in standard OLSR protocol, the interval between two HELLO messages is 2s, and the neighbors' information remains unchanged until the node receives next HELLO message of its neighbors. The node may sends HELLO messages to other nodes before it receives next HELLO message of its neighbors. Secondly, the hold time for the neighbors' information is generally 6s, it is 3 times of the HELLO interval, in the neighbor hold time, some neighbors may have moved out of the range of the current node, using those neighbors' information in MPR select algorithm can cause some nodes in MPR set invalid. Finally, the MPR calculation is performed in current node only when the HELLO message is received or some link loss are detected. When receiving a HELLO

message or detecting a link loss, one corresponding record in neighbor node set will be updated, while others remain unchanged. Under these circumstances, using the neighbors' information in MPR select algorithm can also cause some nodes in MPR set invalid. It will lead to some nodes which depend on these invalid MPR nodes can't receive TC messages, Thus will adversely affect the routing calculation, therefore, it can cause no path, longer path or even invalid path in current node's routing table.

(2) In OLSR protocol, the node's neighbors set, two hop neighbor set, and topology information (which rely on the TC message) are the key data for routing computing. As described before, the records in neighbor information table may be outdated, it can cause some nodes in MPR set invalid, and also, it will lead to some nodes can't receive TC messages, it further affects the routing calculation and the performance of network.

(3) The node's movement speed and direction, a certain delay and more hop count can cause routing calculation inaccurately, the topology may have changed after the routing calculation, the node may have moved out of the range of current node and so on. In these cases, the transmission of packet data will produce errors, and it also can affect the performance of the network.

We attempts to make the improvement to the location algorithm in OLSR, the records in neighbor node table, two hop neighbor table and routing table are used as the forecast data for localization, the node's location information are dynamic adjusted to get more accurate positioning, which will further produces more convenience in location based application in wireless network.

III. Improved Method

Let the destination node $n_d's$ position is $P_0(X_0,Y_0,Z_0)$ at time t_0, $P_1(X_1,Y_1,Z_1)$ at time t_1, at the same time, let n_d to move at a constant speed, and its direction remains unchanged from t_0 to t_1, then its velocity at X, Y, Z direction are:

$$v_x = \frac{X_1 - X_0}{t_1 - t_0} \tag{1}$$

$$v_y = \frac{Y_1 - Y_0}{t_1 - t_0} \tag{2}$$

$$v_z = \frac{Z_1 - Z_0}{t_1 - t_0} \tag{3}$$

Similarly, at time t_1, its position at X, Y, Z direction can be presented as:

$$X_1 = X_0 + (t_1 - t_0) * v_x \tag{4}$$

$$Y_1 = Y_0 + (t_1 - t_0) * v_y \tag{5}$$

$$Z_1 = Z_0 + (t_1 - t_0) * v_z \tag{6}$$

Actually, $n_d's$ law of motion in the next moment is often just the same as now, so that it tends to move forward with the approximate speed and direction as before. According to the above hypothesis, at time t_2, its position at X, Y, Z direction can be expressed as:

$$X_2 = X_1 + (t_2 - t_1) * v_x \tag{7}$$

$$Y_2 = Y_1 + (t_2 - t_1) * v_y \tag{8}$$

$$Z_2 = Z_1 + (t_2 - t_1) * v_z \tag{9}$$

In the preliminary work, $n_d's$ position $P_0(X_0,Y_0,Z_0)$ at time t_0 is recorded in any nodes' neighbor information table, two hop neighbor information table and routing table within the whole network, when the node receives other node's HELLO and TC messages at time t_1, it can update the corresponding position $P_1(X_1,Y_1,Z_1)$ at time t_1 in its neighbor information table, two hop neighbor information table and routing table, then v_x, v_y, v_z can be work out using formula 1 to 3, similarly, X_2, Y_2, Z_2 can be figure out with formula 7 to 9.

In OLSR protocol, when the node receives the OLSR routing control packets, after the message are processed, the node's routing table will be recalculated, at the same time, if the link loss occurs, the routing table is recalculated as well. The updated algorithm's purpose is to calculate node's position more accurately and effectively using the existing information in current node. The process is as follows:

(1) Compare the hop count changes of destination node for the last two times in the routing table, the average value of the hop count for the last two times is obtained, and it is used as the estimated hop count which causes the delay.

(2) The destination nodes' routing information changes Uninterrupted, when the destination node has only one hop from the source, its time difference of its routing information changing for the last two times is calculated, and according to the time difference of one hop counts, the approximately delay for multi-hop count destination nodes can be obtained.

(3) The moving speed and direction of the destination node can be calculate according to the changes of the position of last two times, the speed and direction are used as the parameters to predicate the actually position of the destination node.

IV. Performance Evaluation

In order to validate the positioning accuracy in the routing table for the destination node with the improved algorithm, the following experiment environment is created. At the beginning, the distribution of the 36 nodes is display in figure 1, the horizontal and vertical distance are both 150m, transmission radius of the signal is about 180m, and other experimental parameters are showed in table 1. RandomDirection2dMobilityModel is used, and nodes move randomly in the two-dimensional space within a 3000m*3000m area in a 2m/s. The experimental results are shown in figure 15. Then the moving speed is improved to 5m/s, other experimental parameters remain unchanged, and the results are shown in figure 16.

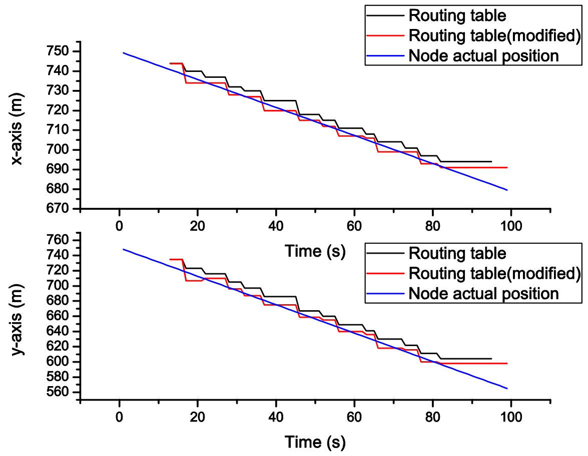

Figure 15. The current positions in routing table and its actual positions (2m/s)

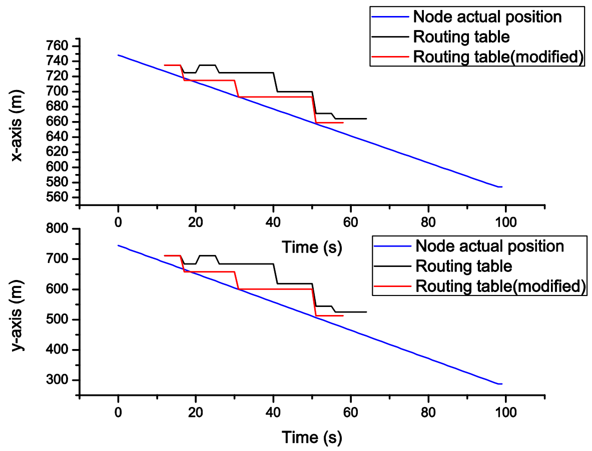

Figure 16. The current positions in routing table and its actual positions (5m/s)

In figure 15 and 16, n_{36}'s coordinates (x and y directions, before the algorithm improved) in n_1's routing table are displayed with black line, its coordinates (x and y directions, using the algorithm improved) are displayed with red line, while its current actual coordinates are displayed in blue.

The red line is more close to the blue line (which represents node's current actual coordinates in real time) than black line, it shows that the improved positioning algorithm can predict its current position using the law of motion of the destination node, the position of the destination node in its routing table is closer to its current actual position, and the improved algorithm can improve the accuracy.

The figure 15 and 16 are compared, it shows that when the node's moving speed is changed, it has important influence for the accuracy of the improved algorithm. Higher moving speed means lower accuracy of the algorithm.

In order to verify the influence of different topologies and mobile way for the localization algorithm, let the nodes move according to the Random Waypoint Mobility Model within a 1-5 m/s and 1-20m/s moving speed, and the Random Box Position Allocator model is used as the initial topology distributions which are in an 800m*800m area. Figure 10 illustrator the nodes' topology and the experimental results are shown in figure 17 and figure 18.

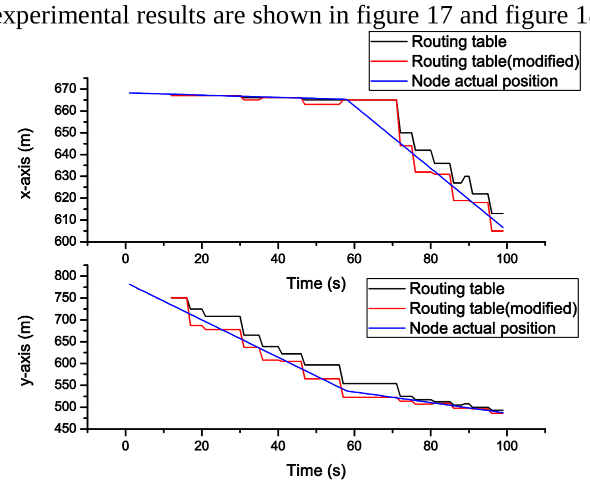

Figure 17. The current positions in routing table and its actual positions (maximum speed: 5m/s)

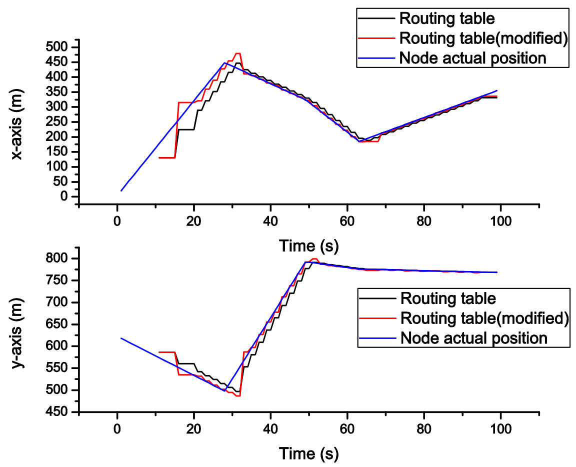

Figure 18. The current positions in routing table and its actual positions (maximum speed: 20m/s)

In figure 17 n_{18}'s coordinates (x and y directions, before the algorithm improved) in n_4's routing table are displayed with black line, its coordinates (x and y directions, using the algorithm improved) are displayed with red line, while its current actual coordinates are displayed in blue. In figure 18, n_{36}'s coordinates (x and y directions, before the algorithm improved) in n_1's routing table are displayed with black line, its coordinates (x and y directions, using the algorithm improved) are displayed with red line, while its current actual coordinates are displayed in blue.

Also, the red line is more close to the blue line (which represents node's current actual coordinates in real time) than black line, it shows that the improved positioning algorithm can predict its current position using the law of motion of the destination node, the position of the destination node in its routing table is more closer to its current actual position, and the improved algorithm can improve the accuracy.

The figure 17 and 18 are compared, it shows that when the hop counts is changed, and it has important influence for the accuracy of the improved algorithm. In figure 18, there is only one hop after the time of 31s, thereafter, the n_{36}*'s* current positions in routing table and its actual positions is nearly the same, and it further indicates that it will become more difficult to locate the node as the hop count increases.

At the same time, in figure 17 and 18, it is obviously shows that when the moving direction of the destination node changed during its moving, near the point of direction changing time, the updated algorithm has a larger deviation. In addition, when the destination node move out of the range that the current node can reach, the hold time for the neighbors' information and topology information table are longer than the HELLO and TC message transmission interval, even for a long time, the current node have not received the HELLO and TC messages of the destination node, the topology and location information of the destination node are still recorded, but it is invalid, using these information to calculate the routing information, it is also invalid.

V. Conclusion

If the destination node is far from the source node, the transmission of the routing control information for the destination node has some delay and will then affect the accuracy of the node localization. An algorithm is proposed to predict the actual location of the destination node based on its current position information in routing table. The original algorithm is analyzed, and the primary reason that the node localization has some deficiency is pointed out. The node localization forecast algorithm is designed and realized, and the forecast algorithm is used to improve the accuracy of the node localization as far as possible. The algorithm is simulated and analyzed, and it proved that the proposed algorithm can effectively reduce the impact of positioning accuracy caused by the node transmission delay and other factors.

Acknowledgment

We thank ZHU Bin for numerous discussions concerning this work. This work was supported by the key discipline (nurture) construction of Shanghai Second Polytechnic University, Computer application technology, XXKPY1301. This work was also supported by the key discipline construction of Shanghai Second Polytechnic University, software engineering, XXKZD1301.

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