Improving MPR Selection Algorithm in OLSR Protocol Based on Node Localization Technology

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Abstract— **The MPR technology in the OLSR routing protocol is described, it is pointed out that there are some limitations when the default heuristic algorithm in this protocol is used to find the minimum MPR. In this paper, an improved algorithm based on node localization is proposed combined with node localization technology. Node localization information is used in this algorithm, the blindness is reduced in the MPR selection algorithm in the OLSR protocol, it can make full use of the network resources, the number of routing packets needed to deliver in the network is reduced to a certain extent, and therefore it can improve the network transmission capacity. The improved algorithm is implemented in network simulation environment, the results are analyzed, it shows that the proposed improved algorithm is feasible and applicable, and the location-based heuristic selection strategy is appropriate and correct.**

Index Terms— **Node localization technology, MPR selection algorithm, OLSR routing protocol, routing protocol, Heuristic algorithm**

I. Introduction

It makes the mobile Ad Hoc network used widely in a variety of environments that the characteristics of nodes can freely enter the network topology. Routing algorithm in Ad Hoc network should have to adapt quickly to the changes of network topology and maximize the efficient to use network resources. The OLSR protocol is an important routing protocol in wireless network, and the key technology to support this routing protocol is MPR (Multipoint Relays) technology.

At present, the research is gradually deepening in wireless network, and many researchers have issued the relevant research achievements in the fields of routing algorithm. But the routing protocol research is still the hotspot in wireless network, and the main challenge is making the routing algorithm adapt to the dynamic changes of network topology.

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.

In the early studies, based on the OLSR protocol, 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 nodes' position information was added in the routing table.

We have also improved the accuracy for the positioning algorithm, a prediction algorithm is work out, which uses the current position to calculate the actual position in the routing table, and it makes location information in the routing table is similar to the actual location as far as possible.

The motivation in our studies is to introduces MPR technology in OLSR routing protocol, points out some defects when using the heuristic algorithm to find the minimum of MPR set in OLSR routing protocol [1]–[5]. Combined with the node localization technology [6]–[11], an improved algorithm based on the node positions is worked out, by introducing the node position information, it can reduce the blindness of choosing MPR algorithm, to make up for the defects of its not sufficient utilization of the network resource, it also can reduce the number of routing packets in the network in a certain extent, and so as to improve the network transmission capacity. By simulation, the results show that the proposed improved algorithm is feasible and applicable, and the location-based heuristic selection strategy is appropriate and correct.

II. The analysis in MPR algorithm

By using Hello messages the OLSR protocol at each node discovers 2-hop neighbor information and performs a distributed election of a set of multipoint relays (MPRs). If a node is selected as an MPR Nodes in MPRs, there is always a path to each of its 2-hop neighbors. These MPR nodes then send and forward TC messages that contain the MPR selectors. This function of MPRs makes OLSR unique from other link state routing protocols in a few different ways: The forward path for TC messages is not shared among all nodes but varies depending on the

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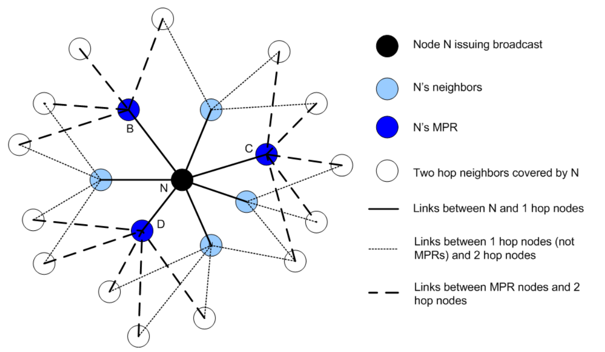

Figure 1. $N's$ links and its MPR within 2-hop range.

source, only a subset of nodes send link state information, and not all links of a node are advertised. Thus, an optimization is achieved by minimizing the number of control messages flooded in the network, and it can largely reduce network bandwidth occupied by the routing protocol.

Since link-state routing requires the topology database to be synchronized according to the changes of the network, OSPF and IS-IS perform topology flooding using a reliable algorithm, and such an algorithm is very difficult to be designed for ad-hoc networks, OLSR simply floods topology data available to make sure that the database does not remain unsynchronized for some periods of time [12].

In order to minimize the amount of control information in the network, MPR collection should be calculated as small as possible. Figure 1 illustrates $N's$ links within 2-hop range, B, C, D is $N's$ minimum MPR set which can be calculated. In the usual Flooding method, All $N's$ neighbors (7 nodes) need to forward $N's$ information, but using the MPR set, only 3 neighbors nodes are needed , this method can effectively save resource in the network.

MPRs are selected nodes which forward broadcast messages during the flooding process. This technique substantially reduces the message overhead as compared to a classical flooding mechanism. The second optimization is achieved by minimizing the number of control messages flooded in the network. As a third optimization, an MPR node may choose to report only links between itself and its MPR selectors. Hence, as compared to the classic link state algorithm, partial link state information is distributed in the network. This information is then used for route calculation. OLSR provides optimal routes (in terms of number of hops), and it is particularly suitable for large and dense networks as the technique of MPRs works well in this context.

OLSR routing protocol also has some limitation, it is proved that the calculation of the minimum MPRs is a NP complete problem [13]. Therefore, to calculate a node's MPRs is very difficult, and some heuristic algorithm must be used to find the approximate optimal solution.

For the relatively slow speed of mobile nodes of Ad Hoc network, it can significantly reduce the routing protocol information, save network bandwidth, and improve the transmission ability of network. But for high speed of mobile nodes, node moving speed is a very important factor, the constructed MPRs maybe not completely valid according with the network topology now [14]–[16].

The rest of this paper proceeds as follows. In section III, the original MPR select algorithm is described, and the ideas for the improvements of MPR selection are illustrated. Finally, the method to improve the MPR algorithm is described which try to further improve the performance of the Ad Hoc network, Node localization information is used in this algorithm, MPR selection algorithm in the protocol is improved, the blindness is reduced in the algorithm, it can make full use of the network resource, the number of routing packets needed to deliver is reduced to a certain extent, and therefore it can improve the network transmission capacity. Section IV evaluates performance, NS3 is used as simulation tool to compare the performance before and after the MPR algorithm is improved. Finally, Section V surveys related work, and concludes the paper.

III. The improvements of MPR selection algorithm

A. The original MPR select algorithm

In original OLSR protocol [17]–[19], N is the subset of neighbors of the node, $N2$ is the set of 2-hop neighbors , but excluding:

(i) the nodes only reachable by members of N with willingness WILL_NEVER

(ii) the node performing the computation

(iii) all the symmetric neighbors: the nodes for which there exists a symmetric link to this node on some interface.

$D(y)$: The degree of a 1-hop neighbor node y (where y is a member of N), is defined as the number of symmetric neighbors of node y, EXCLUDING all the members of N and EXCLUDING the node performing the computation.

The proposed heuristic is as follows:

(1) Start with an MPR set made of all members of N with N_willingness equal to WILL_ALWAYS

(2) Calculate $D(y)$, where y is a member of N, for all nodes in N.

(3) Add to the MPR set those nodes in N, which are the *only* nodes to provide reachability to a node in $N2$. For example, if node b in $N2$ can be reached only through a symmetric link to node a in N, then add node a to the MPR set. Remove the nodes from $N2$ which are now covered by a node in the MPR set.

(4) While there exist nodes in $N2$ which are not covered by at least one node in the MPR set:

(a) For each node in N, calculate the reachability, i.e., the number of nodes in $N2$ which are not yet covered by at least one node in the MPR set, and which are reachable through this 1-hop neighbor;

(b) Select as a MPR the node with highest N_willingness among the nodes in N with non-zero reachability. In case of multiple choice select the node

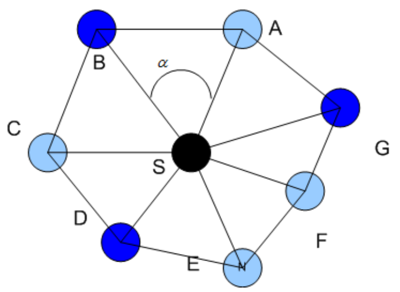

Figure 2. Calculation of the angles between the neighbors.

which provides reachability to the maximum number of nodes in $N2$. In case of multiple nodes providing the same amount of reachability, select the node as MPR whose $D(y)$ is greater. Remove the nodes from $N2$ which are now covered by a node in the MPR set.

B. Preparation for the improvements of MPR selection algorithm

Let $MPR(S)$, $N(S)$ and $N2(S)$ as the MPR, N and $N2$ of the node S which are computed as the original OLSR protocol. In order to make fully use of neighbors' position information in MPR calculations, first calculate the angle among S and its adjacent nodes, the triangle area among S and its adjacent nodes and the distance between its neighboring nodes and so on. Calculation method and process are as follows:

(1) For each node L in N, calculate the reachability $D(L)$, i.e., the number of nodes in $N2$ which are not yet covered by at least one node in the MPR set, and which are reachable through this 1-hop neighbor;

(2) The node L is selected as a reference node whose $D(L)$ is maximum;

(3) The angle among S, L and its adjacent nodes is calculated as follows:

(a) Using the method we studied before, The node can obtains positions of its own, 1-hop neighbors and 2-hop neighbors;

(b) Set $S's$ neighbor distribution are illustrated in Figure 2, A is selected as a reference node. Calculates the angle of $\angle BSA, \angle CSA, \angle DSA, \angle ESA, \angle FSA, \angle GSA$. $\angle BSA$ is an example to illustrate the calculation method. Then calculates the angle of $S's$ two adjacent neighbor node.

The length of the AB, AS and BS can be obtained using the position information of the nodes.

$$\alpha = \cos(\angle BSA) = \frac{BS^2 + AS^2 - AB^2}{2 * AB} \quad (1)$$

$$\angle BSA = \arccos(\alpha) * 180/\pi, \pi = 3.1415926 \quad (2)$$

There are the following problems in the calculation method above which is illustrate in Figure 3. A is selected as a reference node, if using the algorithm above to calculate the angle of $\angle BSA, \angle DSA$, there are both 90°, actually, the angle of$\angle DSA$ is 270°. In addition,

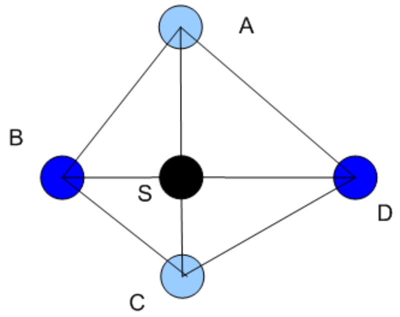

Figure 3. Distinguish between B and D.

the algorithm should make corresponding processing for other nodes on both sides of line AS.

Linear equations (go through A and S) is calculated, set $S's$ coordinate, (x_1, y_1), $A's$ coordinate, (x_2, y_2). To simplify the algorithm, only considers the node distribution in the plane. The slope of the line is:

$$k = (y_2 - y_1)/(x_2 - x_1) \quad (3)$$

Equation of the line is:

$$y - k(x - x_1) + y = 0 \quad (4)$$

Input the coordinates of other neighboring nodes into the linear equation of the left side, the output value can be divided into the following several cases respectively:

(a) if its value is greater than 0, indicates that the node locates above the line, it can directly use equation 2 to calculate the value of the angle;

(b) if its value is less than 0, indicates that the node locates under the line, equation 2 should be changed as:

$$\angle BSA = 360 - \arccos(\alpha) * 180/\pi, \pi = 3.1415926 \quad (5)$$

(c) If the line (equation 4) is parallel to the Y axis, node which located on the right side of the line (equation 4) is defined as above the line (equation 4), otherwise, located on the left side of the line is defined as under the line.

(d) If the node is just on the line (equation 4), when the node is in the extension line from S to A, the value of the angle is 0, otherwise, the value of the angle is 180;

(E) If the line (equation 4) is parallel to the X axis, node which located above the line is defined as *above*, otherwise, located under the line is defined as *under*.

(f) If two nodes located in the same line, the node is select who is farthest from S which is shown in Figure 4. E and D are located in the same line SD, D is selected as the MPR candidate node.

(4) The calculated values of the angle are ordered from small to large, the adjacent location relationship of the nodes is figure out and it is shown in Figure 4. Set the reference node as A, when the sorting is completed, the sequence is $A - B - C - D$. E and D are located in the same line SD, D is selected as the MPR candidate node, and the algorithm can let $\angle ESD$ not participate in ordering.

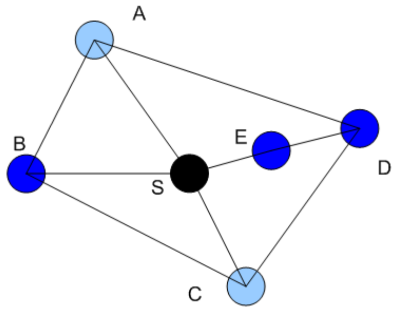

Figure 4. Two nodes in the same line.

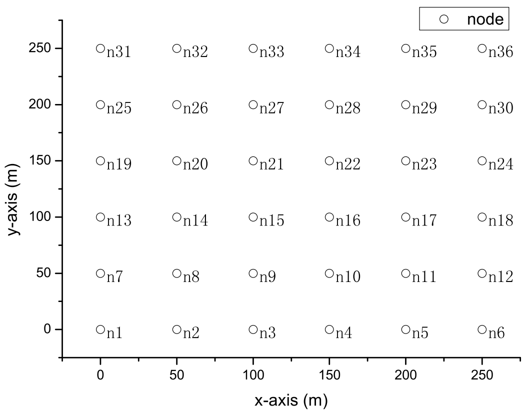

Figure 5. Nodes topology distribution.

(5) The vertex angle is calculated which is illustrated in Figure 4, $\angle BSA, \angle CSB, \angle DSC$ and $\angle ASD$ should be separately calculated.

(6) The corresponding triangle area is calculated, calculation formula is:

$$S = \sqrt{s(s-a)(s-b)(s-c)}, s = \frac{a+b+c}{2} \quad (6)$$

a,b,c are length of the three sides of the triangle.

(7) If the adjacent nodes are located in the same line, the calculated area is zero which is illustrated in Firgure 4 , the area of ΔSED is zero, ignoring this triangle does not affect the distribution of nodes in the improved algorithm, because the adjacent triangles can provided distribution information of these nodes.

In order to verify the calculation accuracy of the angle, triangle area and the distance between adjacent neighbors, 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 50m, transmission radius of the signal is about 180m. The position of each node is fixed (ConstantPositionMobilityModel is selected), nodes topology distribution are shown in figure 5.

In table I, n_{21} is the node that calculate the MPR, n_{15} is selected as the reference node. So the baseline is a straight line go through from n_{21} to n_{15}. The algorithm calculates the angles between baseline and the line go through other neighbor and n_{21}.

TABLE I.
THE ANGLE BETWEEN NEIGHBOR NODES AND THE REFERENCE LINE

Neighbor	Angle	Neighbor	Angle (ascending sort)
n2	18.4349	n3	0
n3	0	n9	0
n4	341.565	n2	18.4349
n7	45	n8	26.5651
n8	26.5651	n7	45
n9	0	n14	45
n10	333.435	n13	63.4349
n11	315	n20	90
n13	63.4349	n19	90
n14	45	n25	116.565
n16	315	n31	135
n17	296.565	n26	135
n18	288.435	n32	153.435
n19	90	n33	180
n20	90	n27	180
n22	270	n34	206.565
n23	270	n35	225
n24	270	n28	225
n25	116.565	n29	243.435
n26	135	n30	251.565
n27	180	n24	270
n28	225	n23	270
n29	243.435	n22	270
n30	251.565	n18	288.435
n31	135	n17	296.565
n32	153.435	n16	315
n33	180	n11	315
n34	206.565	n10	333.435
n35	225	n4	341.565

Table I is divided into two parts, the left two columns are the angles in $n_{21}'s$ neighbor table which are not sorted. In order to obtain the relationship among adjacent nodes in the neighbor table, only need to sort the left two columns according to the angle value with ascending order. After sorting, the results is illustrated in table I on the right two columns, and adjacent relation between neighbor nodes is very clear in table I, for example, n_9 is next to n_2 and n_2 is next to n_8, it also can get the distribution of $n_{21}'s$ neighbor nodes in 1-hop range. At the same time, getting the adjacent relations of the neighbor nodes will be very helpful for the calculation of the angle and area of the triangle, the distance between the neighboring nodes.

Table II is the calculation of the angle and area of the triangle, the distance between the neighboring nodes according to the adjacent relations of the neighbor nodes. For example the triangle is consisted of n_{21}, n_9 and n_2, and n_{21} is the vertex of the angle, the angle is $18.4349°$, area is $2500m^2$, and the distance between n_9 and n_2 is $70.7107m$. The Comparative verification is carry out using table I, table II and figure 5, it shows that the values of the angle and area of the triangle, the distance between the neighboring nodes are correct.

C. The improvement of MPR algorithm

The relative distribution of neighbor nodes (such as the relationship between neighbor nodes, the angle and area of the triangle, the distance between the neighboring nodes) can provide favorable conditions for the algorithm to improve MPR selection [17]–[19]. To simplify the complexity of the improved algorithm, the algorithm sets

TABLE II.
ANGLE, AREA AND DISTANCE

Neighbor 1	Neighbor 2	Angle (°)	Area (m^2)	Distance (m)
n15	n3	0	0	100
n3	n9	0	0	50
n9	n2	18.4349	2500	70.7107
n2	n8	8.1301	1250	50
n8	n7	18.4349	2500	50
n7	n14	0	0	70.7107
n14	n13	18.4349	1250	50
n13	n20	26.5651	1250	70.7107
n20	n19	0	0	50
n19	n25	26.5651	2500	50
n25	n31	18.4349	2500	50
n31	n26	0	0	70.7107
n26	n32	18.4349	1250	50
n32	n33	26.5651	2500	50
n33	n27	0	0	50
n27	n34	26.565	1250	70.7107
n34	n35	18.4349	2500	50
n35	n28	0	0	70.7107
n28	n29	18.4349	1250	50
n29	n30	8.1301	1250	50
n30	n24	18.4349	3750	50
n24	n23	0	0	50
n23	n22	0	0	50
n22	n18	18.4349	1250	111.803
n18	n17	8.1301	1250	50
n17	n16	18.4349	1250	50
n16	n11	0	0	70.7107
n11	n10	18.4349	2500	50
n10	n4	8.1301	1250	50
n4	n15	18.4349	1250	111.803

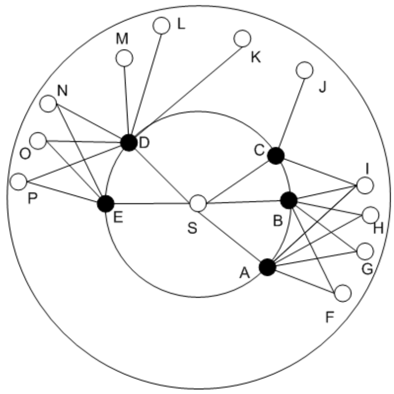

Figure 6. The *only* nodes to provide reachability to a node in $N2$.

the value of the willingness to 3 (default), the algorithm process is described as follows:

(1) Build the N and $N2$;

(2) Set the $S's$ MPR set $MPR(S) = \varnothing$;

(3) Add to the MPR set those nodes in N, which are the *only* nodes to provide reachability to a node in $N2$. For example, if node b in $N2$ can be reached only through a symmetric link to node a in N, then add node a to the $MPR(S)$. Remove the nodes from $N2$ which are now covered by a node in the $MPR(S)$;

Which is displayed in figure 6, the node C is the *only* node to provide reachability to node J in $N2$. Put C to the $MPR(S)$. Remove the nodes(J,I) from $N2$ which are now covered by C in the $MPR(S)$;

(4) The reference node is the node who covered most nodes in $N2$, In case of multiple reference nodes providing the same amount of reachability, selected one of them randomly, in figure 6, the node D is selected as the reference node. Add it to the $MPR(S)$, remove the nodes(K, L, M, N, O and P) from $N2$ which are now covered by a node in the $MPR(S)$;

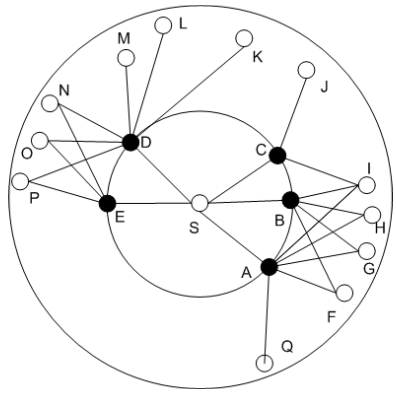

Figure 7. the angle between the reference line and node A is near 180°.

(5) Select the nodes in N like that:

(a) The angle between the reference line and this node are near 180°, 90° and 270°. Check the nodes in $N2$ to find whether there are nodes which are uncovered by this node. If there are, further examine the coverage sets to find whether there are containment relationship, if there are, select the set that covered most nodes in $N2$. Add it to the $MPR(S)$, remove the nodes from $N2$ which are now covered by a node in the $MPR(S)$;

In figure 6, the angle between the reference line and node A is near 180°, it is selected, it is added to the $MPR(S)$, remove the nodes from $N2$ which are now covered by node A in the $MPR(S)$.

The node A and B has the same coverage in $N2$ (F, G, H), the A is selected instead of B, because the node A is more dispersive to the reference node D than B, and it can cover more nodes than B. For example, after a period of time, there is a node Q appeared in $N2$ which is illustrated in figure 7, the node A can reach this node while node B cannot. The node B's coverage is mostly covered by the node C.

(b) If more than one nodes in N available for selected in the above-described algorithm, considering the area of the triangle constituted by the above algorithm, select the largest, there are two neighbor nodes in this triangle, select the farther one from N. Add it to the $MPR(S)$, remove the nodes from $N2$ which are now covered by a node in the $MPR(S)$.

(6) While there exist nodes in $N2$ which are not covered by at least one node in the MPR set:

(a) For each node in N, calculate the reachability, i.e., the number of nodes in $N2$ which are not yet covered by at least one node in the MPR set, and which are reachable through this 1-hop neighbor;

(b) Select as a MPR the node with highest N_willingness among the nodes in N with non-zero reachability. In case of multiple choice select the node which provides reachability to the maximum number of nodes in $N2$. In case of multiple nodes providing the same

TABLE III.
EXPERIMENTAL PARAMETERS

Parameter	Value
Modulation	802.11b
Area	1000m * 1000m
Nodes	64
Mobility Model	RandomDirection2dMobilityModel
Simulation Time	500s
RemoteStationManager	ConstantRateWifiManager
DataMode	DsssRate2Mbps
ControlMode	DsssRate2Mbps
PropagationDelay	ConstantSpeedPropagationDelayModel
PropagationLoss	FriisPropagationLossModel
FragmentationThreshold	2200 (bit)
RtsCtsThreshold	2200 (bit)

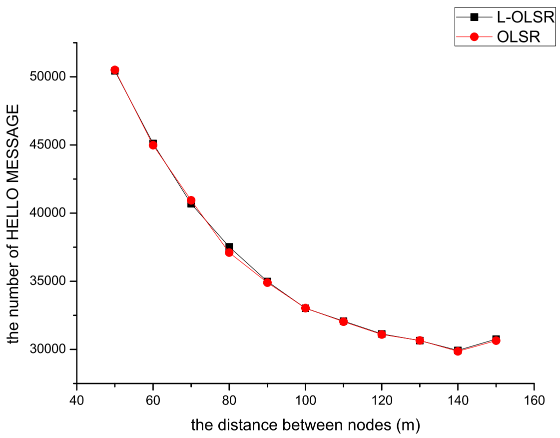

Figure 8. Comparison for the quantity of received HELLO packets.

amount of reachability, select the node as MPR whose $D(y)$ is greater. Remove the nodes from $N2$ which are now covered by a node in the MPR set.

(7) If the nodes's number in $MPR(S)$ is bigger than the original algorithm in OLSR, use the original algorithm to obtain the $MPR(S)$.

IV. RESULTS AND ANALYSIS

NS3 is used as simulation tool to compare the performance before and after the MPR algorithm is improved. The following experiment environment is created. At the beginning, the distribution of the 64 nodes is as follow, the horizontal and vertical distance are both 50m, transmission radius of the signal is about 180m. Let the nodes move constantly in the two-dimensional space according to the RandomDirection2dMobilityModel within a 1000m*1000m area in a 20m/s speed, other experimental parameters are showed in table III.

Figure 8 is the number of HELLO packets received by the 64 nodes in whole network when the initial distance between the nodes from 50m increased gradually to 150m every 10m, the performance of L-OLSR is on behalf of the improved protocol, OLSR represents the general performance of OLSR protocol. It can be seen that the two curves almost overlapped, it shows that the improved MPR algorithm for OLSR protocol has little effect on the HELLO messages, this is because that nodes in the

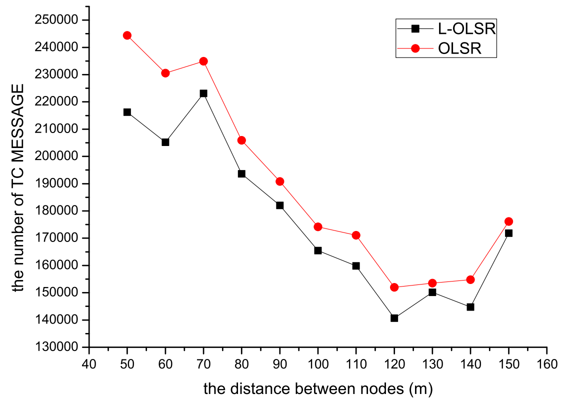

Figure 9. Comparison for the quantity of received TC packets.

network will send HELLO messages to its neighbors at a fixed time interval, and sending and receiving this kind of messages don't depend on the node's MPR set, so the advantages and disadvantages of the MPR set has little relationship with transmission quality of HELLO message.

Figure 9 is the number of TC packets received by the 64 nodes in whole network when the initial distance between the nodes from 50m increased gradually to 150m every 10m, the meaning for L-OLSR and OLSR curves is same as in Figure 8. Improved MPR algorithm of OLSR protocol, the transmission of TC control message in the network is significantly reduced, and there is about 6% performance improvement, resources are conserved to some extent in the wireless network, and thereby the transmission capacity is increased.

The improved MPR algorithm has the ability to use the location information of nodes as heuristic information, the blindness of the computation of MPR sets is reduced, and quality of MPR node is improved. The improved algorithm can make the MPR node more dispersed, and also it can make the MPR node as far as possible within one hop away, so that each MPR node can cover two hop nodes as much as possible and improve the effectiveness of these nodes in the TC transmission control message, and in some condition, the number of nodes in MPR set can also be reduced. Therefore, it can help to reduce requirements of transmission number for TC control message in OLSR protocol.

When the node localization information is used in this algorithm, the blindness is reduced in the MPR selection algorithm in the OLSR protocol, it can make full use of the network resources. In our algorithm, the distribution of the MPR nodes are more dispersive, in some circumstance it has the chance to cover more nodes. Figure 10 and 11 is the number of all kind of OLSR control packets (including HELLO, TC and MID message) received and sent by the 64 nodes in whole network when the initial distance between the nodes from 50m increased gradually to 150m every 10m. Figure 10 is the number of routing control

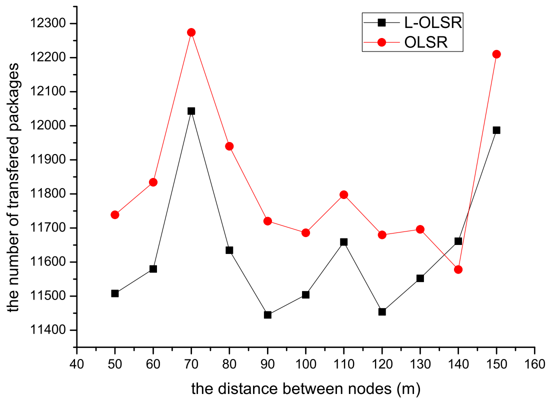

Figure 10. Number of routing control packets which are sent.

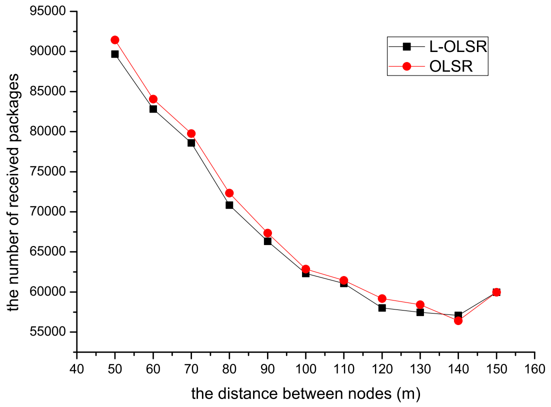

Figure 11. Number of routing control packets which are received.

packets to be sent in the entire network, in most cases, the improved algorithm can significantly reduce the number of routing control packets to be sent. Similarly, figure 11 is the number of routing control packets to be received in the entire network, the number of receive routing control messages are also reduced accordingly. To sum up, the improved MPR selection algorithm can reduce the number of routing control information in a certain extent, network resources are saved, and thereby the performance of the network is improved.

V. Conclusions

In this paper, The MPR technology in the OLSR routing protocol is described, it is pointed out that there are some limitations when the default heuristic algorithm in this protocol is used to find the minimum MPR. An improved algorithm based on node localization is proposed combined with node localization technology. Node localization information is used in this algorithm, the blindness is reduced in the MPR selection algorithm in the OLSR protocol, it can make full use of the network resources, the number of routing packets needed to deliver in the network is reduced to a certain extent, and therefore it can improve the network transmission capacity. The improved algorithm is implemented in network simulation environment, the results are analyzed, it shows that the proposed improved algorithm is feasible and applicable, and the location-based heuristic selection strategy is appropriate and correct.

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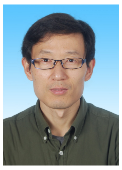

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