JACET Journal of Advances in Computer Engineering and Technology, 1(1) 2015

Improving Quality of Service Routing in Mobile Ad Hoc Networks Using OLSR

Forouz Ghaffarizadeh[1],Ahmad Khademzadeh[2]

Received (4-10-2011)
Accepted (20-11-2011)

***Abstract* - Mobile ad hoc networks (MANET) are constructed by mobile nodes without access point. Since MANET has certain constraints, including power shortages, an unstable wireless environment and node mobility, more power-efficient and reliable routing protocols are needed. The OLSR protocol is an optimization of the classical link state algorithm. OLSR introduces an interesting concept, the multipoint relays (MPRs), to mitigate the message overhead during the flooding process. Although very efficient by many points, it suffers from the drawbacks of not taking into account QoS metrics such as delay or bandwidth. To overcome this pitfall, some QOLSR solutions have been designed. IN this paper, we introduce an algorithm for MPRs selection based on Battery Capacity and Link Stability. Simulation results show that our proposed protocol is able to enhance throughput and improve end-to-end delay.**

***Index Terms* - QoS; Ad Hoc Network; MANET; Routing Protocol; OLSR**

I. INTRODUCTION

A Mobile Ad-Hoc network (MANET) is a dynamic multi-hop wireless network that is established by a group of mobile nodes on a shared wireless channel. The nodes are free to move randomly; the network's topology changes rapidly and unpredictably. The Ad-Hoc network may operate standalone, or may be connected to the larger Internet. An example application of Ad-Hoc network is that a group of soldiers move in outdoors while communicating with one another through the radios. Without a central controller to control the communications in the network, without a fixed topology, the most difficult task the Ad-Hoc network faces is routing. Much work has been done on routing in ad-hoc networks, but most of them focus only on best-effort data traffic. However, recently, because of the rising popularity of multimedia applications and potential commercial usage of MANETs, QoS support in Ad-Hoc networks has become a topic of great interest in the wireless area…

In an ad-hoc network, all communication is done over wireless media, without the help of wired base stations. While many routing protocols have been developed to find and maintain routes based on a best-effort service model, quality-of-service (QoS) routing in an ad-hoc network is difficult because the network topology may change constantly and the available state information for routing is inherently imprecise. [1]

Routing protocols in ad hoc networks are categorized in two groups: Proactive (Table Driven) and Reactive (On-Demand) routing.

Proactive Routing Protocols: These routing protocols are similar to and come as a natural extension of those for the wired networks. In

1- Research Institute for Information & Communication Technology, Tehran, Iran.
(frouz_ghaffarizadeh@yahoo.com).
2- Research Institute for Information & Communication Technology, Tehran, Iran.(zadeh@itrc.ac.ir).

proactive routing, each node has one or more tables that contain the latest information of the routes to any node in the network. Each row has the next hop for reaching a node/subnet and the cost of this route.

Various table-driven protocols differ in the way the information about a change in topology is propagated through all nodes in the network.

Reactive Protocols: Reactive routing is also known as on-demand routing. These protocols take a lazy approach to routing. They do not maintain or constantly update their route tables with the latest route topology.

Examples of reactive routing protocols are the dynamic source Routing (DSR), ad hoc on-demand distance vector routing (AODV) and temporally ordered routing algorithm (TORA). [2,3]

The rest of the paper is organized as follows. In Section II, a brief description of OLSR is given. A detailed specification of the QOLSR protocol is presented in Section III, We then present our solution in Section IV. In Section V, we provide simulation results justifying our approach, while in Section VI we draw some concluding remarks and describes our future works.

II. OLSR OVERVIEW

In [4], the IETF MANET Working Group introduces the Optimized Link State Routing (OLSR) protocol for mobile Ad-Hoc networks. The protocol is an optimization of the pure link state algorithm. The key concept used in the protocol is that of Multipoint Relays (MPRs). MPRs are selected nodes that forward broadcast messages during the flooding process. This technique substantially reduces the message overhead as compared to a pure flooding mechanism where every node retransmits messages throughout the network. By doing so, the contents of the control messages flooded in the network are also minimized. So contrary to the classic link state algorithm, instead of all links, only small subsets of links are declared.

OLSR operates as a table-driven and pro-active protocol. The node n, which is selected as a multipoint relay by its neighbors, periodically announces the information about who has selected it as an MPR. Such a message is received and processed by all the neighbors of n, but only the neighbors who are in n's MPR set retransmit it. Using this mechanism, all nodes are informed of a subset of links between the MPR and MPR selectors in the network. For route calculation, each node calculates its routing table using a Shortest Hops Path algorithm based on the partial network topology it learned. The algorithm finds the minimum hop paths from the source node to all the destinations. In addition to re-transmitting topology control messages, the MPRs are also used as a backbone network to form the route from a given node to any destination in the network.

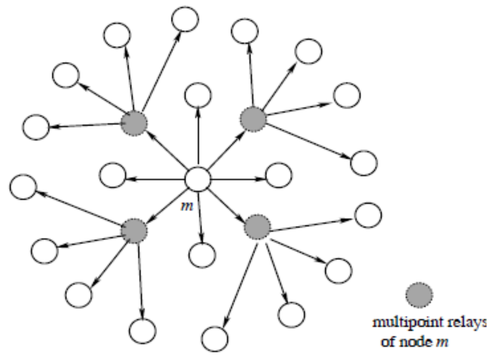

Figure1. Multipoint relays of node m [8]

Each node m maintains the set of its "multipoint relay selectors" (MPR selectors). This set contains the nodes which have selected m as a multipoint relay. Node m only forwards broadcast messages received from one of its MPR selectors.

As mentioned before, MPR selection is the key point in OLSR. The MPR set is selected such that it covers all nodes that are two hops away. This means that the union of the neighbor sets of the MPRs contains the entire 2-hop neighbor set of a node. Each node selects its MPRs independently. The smaller the MPR set, the less overhead the protocol

Introduces the proposed heuristic in [4] is as follows:

1. Start with an empty MPR set

2. For each node y in the 1-hop neighbor set N, calculate D(y) The degree (the number of neighbors) of y.

3. Select as MPRs those nodes in N which provide the .only path. To some nodes in the 2-hop neighbor set N2.

4. While there exist nodes in N2 which are not covered. {Select as an MPR a 1-hop neighbor, which reaches the maximum number of uncovered nodes in N2. If there is a tie, the one with higher degree is chosen.}

5. As an optimization, process each node y in

MPR. If MPR\{y} still covers all nodes in N2, y should be removed from the MPR set.

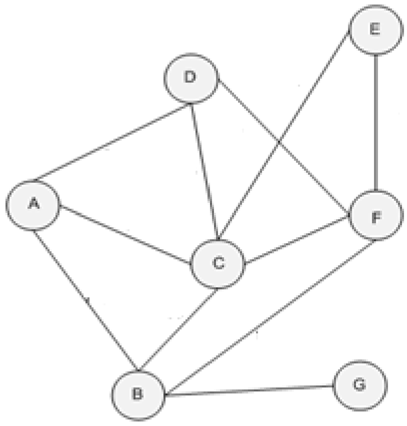

Figure2. Network Example for MPR Selection

An example of how this algorithm works is shown below based on the network depicted, in Figure.2:

TABLE I. :MPR SELECTED IN THE ORIGINAL OLSR

Node	*1 Hop Neighbors*	*2 Hop Neighbors*	*MPR(s)*
B	A, C, F, G	D, E	F

From the perspective of node B, both C and F cover all of node B's 2-hop neighbors. However, C is selected as B's MPR as it has 5 neighbors while F only has 4 (C's degree is higher than F).

III. QOS ROUTING IN OLSR

As mentioned, OLSR is a routing protocol for best-effort traffic, with emphasis on how to reduce the overhead, and at the same time, provide a minimum hop route. So in its MPR selection, the node selects the neighbor that covers the most unreached 2-hop neighbors as MPR. This strategy limits the number of MPRs in the network, ensures that the overhead is as low as possible. However, in QoS routing, by such an MPR selection mechanism, the good quality links may be hidden to other nodes in the network. As an example, we will consider the network topology in Section II again (see Figure.3.)

The numbers along the lines indicate the available bandwidth over the links. As explained in Section II, in the OLSR MPR selection algorithm, node B will select C as its MPR.

So for all the other nodes, they only know that they can reach B via C. Obviously, when D is building its routing table, for destination B, it will select the route D-C-B, whose bottleneck bandwidth is 3, the worst among all the possible routes.

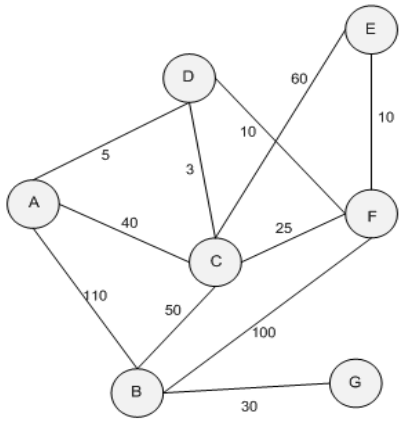

Figure3. Bandwidth-QoS Network Example for MPR Selection

Also, when bandwidth is considered to be the QoS constraint, in building the routing tables, nodes can no longer use the Shortest Hops Path algorithm as proposed in [4], as the path with the minimum hops may not be the path with best bandwidth. Because of these limitations of OLSR in QoS routing, we revise it in two aspects: MPR selection and routing table computation, which are described in the following two subsections separately.

The decision of how each node selects its MPRs is essential to determining the optimal bandwidth route in the network. In the MPR selection, a good bandwidth link should not be omitted. In other words, as many nodes as possible that have high bandwidth links connecting to the MPR selector must be included into the MPR sets. Based on this idea, three revised MPR selection algorithms are presented.

OLSR_R1:

In the first algorithm, MPR selection is almost the same as that of the original OLSR described in Section II However, when there is more than one 1-hop neighbor covering the same number of uncovered 2-hop neighbors, the one with the largest bandwidth link to the current node is selected as MPR:

1. Start with an empty MPR set.
2. Select as MPRs those nodes in N which provide the only path to some nodes in 2-hop neighbors N2.
3. While there exist nodes in N2 which are not covered. {Select as an MPR a 1-hop neighbor which reaches the maximum number of uncovered nodes in N2. If there is a tie, the one

with higher bandwidth is chosen. }

4. As an optimization, process each node y in MPR. If MPR\(y) still covers all nodes in N2, y should be removed from the MPR set.

The network in Figure.3 would select MPRs for node B as follows, based on OLSR_R1:

TABLE II. MPR SELECTED IN OLSR_R1

Node	*1 Hop Neighbors*	*2 Hop Neighbors*	*MPR(s)*
B	A, C, F, G	D, E	F

1. Between C and F, F is selected as B's MPR because it has the larger bandwidth.

OLSR_R2:

The idea behind OLSR_R2 is to select the highest bandwidth neighbors as MPRs:

1. Start with an empty MPR set.

2. Select as MPRs nodes in neighbors N which provide the .only path to some nodes in 2-hop neighbors N2.

3. While there exist nodes in N2 which are not covered.

{

3.1. Select as MPR a node that has the highest bandwidth link connected with the current node. If there is a tie, the one that covers more uncovered 2-hop neighbors is selected.

3.2. Mark the neighbors of the newly selected MPR as covered in the 2-hop neighbor set of the current node.

}

For example, using this algorithm, based on Figure.3, node B's MPR(s) would be:

TABLE III. MPR SELECTED IN OLSR_R2

Node	*1 Hop Neighbors*	*2 Hop Neighbors*	*MPR(s)*
B	A, C, F, G	D, E	A, F

Among node B's neighbors, A, C, and F have a connection to its 2-hop neighbors. Among them, link BA has the largest bandwidth. So A is first selected as B's MPR, and the 2-hop neighbor D is covered. Similarly, F is selected as MPR next and E is covered, so all 2-hop neighbors are covered and the algorithm terminates.

OLSR_R3:

The third algorithm selects the MPRs in a way such that all the 2-hop neighbors have the optimal bandwidth path through the MPRs to the current node. Here, optimal bandwidth path means the bottleneck bandwidth path is the largest among all the possible paths.

1. Start with an empty MPR set.

2. Select as MPRs nodes in neighbor N which provide the .only path. to some nodes in 2-hop neighbors N2.

3. While there exist nodes in N2 which are not covered.

{

3.1. select as MPR a node so that the current node has the optimal route through the MPR to a 2-hop node.

3.2. Mark the 2-hop node as covered

}

The algorithm chooses the route with the largest bottleneck (in 2 hops). In this case the chosen MPR is F. In the same way, C is chosen as MPR by B to cover E.

TABLE IV. MPR SELECTED IN OLSR_R3

Node	*1 Hop Neighbors*	*2 Hop Neighbors*	*MPR(s)*
B	A, C, F, G	D, E	F, C

The three revised OLSR MPR selection algorithms may improve the chance that a better bandwidth route is found. However, by using such algorithms, the overhead may also increase compared with the original OLSR algorithm because we may increase the number of MPRs in the network, especially for OLSR_R3, which may select a different MPR for each 2-hop neighbor.

IV. LIMITATIONS OF QOLSR

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

A. Link Stability

MANET is a collection of wireless mobile nodes that communicate with each other using multi-hop wireless links without any existing network infrastructure or centralized administration [1]. Each node in the network behaves as a router and forwards packets for other nodes.

The mobility of the nodes affects the number of average connected paths, which in turn affect the performance of the routing algorithm.

Connectivity failures between MPRs and

MPRs selectors, resulting from nodes movement, are a major problem in QOLSR routing protocol. In this paper, we present a performance study of MANET that uses routing based on link expiration time prediction. We propose an algorithm based on the Global Positioning System (GPS).The aim is to enable ad hoc mobile nodes to predict the remaining connectivity time with their neighbors in order to avoid disconnections, between MPRs and MPRs selectors.

We define link stability in terms of link expiration time which means maximum time of connectivity between any two neighbor nodes. In order to calculate the link expiration time we assume motion parameters of any two neighbors are known. Let n_1 and n_2 be two nodes within the transmission range r and x'_1‹y'_1 and x'_2‹y'_2 be the coordinate for node n_1 and n_2 with velocity v_1 and v_2 and direction $\theta_1$and θ_2 respectively. Let after a time interval t the new coordinate will be x_1, y_1 for n_1 and x_2, y_2 for n_2. For time t let d_1 and d_2 be the distance traveled by node n_1 and n_2. We can calculate d_1 and d_2 using the following formula: [6]

$$d_1=v_1t$$
$$d_2=v_2t$$

New coordinates (with respect to old coordinates) can be calculated using the following formula:

$$x_1=x'_1+x_1=x'_1+d_1\cos\theta_1=x'_1+t(v_1\cos\theta_1)$$
$$y_1=y'_1+y_1=y'_1+d_1\sin\theta_1=y'_1+t(v_1\sin\theta_1)$$
$$x_2=x'_2+x_2=x'_2+d_2\cos\theta_2=x'_2+t(v_2\cos\theta_2)$$
$$y_2=y'_2+y_2=y'_2+d_2\sin\theta_2=y'_2+t(v_2\sin\theta_2)$$

Distance between two nodes at time t will be obtained from:

$$D=\sqrt{\begin{matrix}\{(x'1-x'2)+t(v1cos\theta1-v2cos\theta2)\}2\\ \{y'1-y'2)+t(v1sin\theta1-v2sin\theta2)\}2\end{matrix}}$$

When the distance between two nodes becomes larger than the transmission range the nodes will be disconnected. For transmission range r link stability St between any two nodes overtime period t can be calculated by:

$$Lst=\frac{r}{\sqrt{\begin{matrix}\{(x'1-x'2)+t(v1cos\theta1-v2cos\theta2)\}2\\ \{y'1-y'2)+t(v1sin\theta1-v2sin\theta2)\}2\end{matrix}}}$$

Note that Lst is the link stability of individual links between any two nodes and for a path it is a concave parameter and it is same as the minimum link stability along the path.

B. Battery Capacity:

As QoS provisioning is an important aspect for mobile ad hoc networks, similarly energy conservation is a critical issue in ad hoc wireless networks for node and network life, as only battery power nodes. Therefore energy must also be treated as an indirect measure of QoS, because path selection without energy efficiency may lead to premature depletion of a network or a node.

In OLSR protocol, Since MPR nodes have to perform the functions of a router, if MPR nodes die early due to lack of energy, it will not be possible for other nodes to communicate with MPR selectors. Hence, the network will get disconnected and the network lifetime will be adversely affected.

C. Changing the MPR selection criteria

In this section we detail the algorithm used for selecting MPRs set. We describe our algorithm with two different kinds of metrics:

Link stability and battery capacity.

Select the neighbors as MPRs:

1. Select as MPRs nodes in neighbors, which have greater bandwidth than the threshold bandwidth.
2. Select as MPRs nodes in neighbors, which have greater battery life than the threshold.
3. Select as MPRs nodes in neighbors, which have the highest link expiration time.
4. If there is a tie, select as MPRs nodes in neighbors the one that has the lowest delay.

We defined “bandwidth threshold” as the average bandwidth of neighbors and “battery life threshold” as the half-maximum battery life of neighbors.

V. SIMULATION

We implemented our proposed protocol under Opnet and compared it with OLSR and QOLSR.

A. OPNET's modeling of MANET routing

Creating a simulation model of a communicating system could become a time-consuming and often error-prone task. OPNET Modeler provides a flexible and highly cohesive architecture which allows for reusability and extensibility of existing models. OPNET Modeler is structured in a hierarchical fashion and consists of three distinct layers: the network, the node, and the process domain levels.

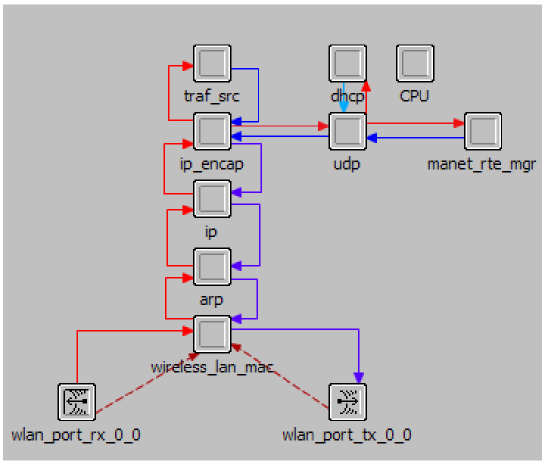

Figure 4. Node model of MANET station[9]

The network topology of a modeled system together with the attribute values are specified at the network domain level which is the top-level view of the simulation study. The attribute values (i.e. protocol parameters, device configuration values, simulation statistics, etc.) that are specified at this level propagate down to the lower hierarchical levels (i.e. node and process). Various network devices, such as routers, servers, switches, etc. are modeled at the node domain level. A network device model usually consists of one or more interconnected modules, each of which is defined either via one or more process models or a set of configuration values and associated external files. Figure.4. illustrates a node level model of a MANET station, where individual modules are depicted as gray squares and the arrows represent the flow of information between them.

A process domain level models operation of a particular networking process or technology, such as a routing protocol, an upper-layer application, load-balancing discipline, etc. Each process model consists of the finite state machine and a set of Proto-C instructions that specify conditions for transitioning from one state into another and a set of actions to be performed in each state. The process models often rely on external files which contain a set of supporting functions or data structures. [9]

We decomposed our performance analysis in two different scenarios, in the first scenario; the objective is to test the influence of network mobility. In the second scenario aims at observing the effect of the network density on OLSR, QOLSR and our LEOLSR (*Link-Stability and Energy Aware OLSR*) protocol.

In each scenario we have considered three metrics in analyzing the performance of routing protocols. These metrics are as follows:

Normalized Protocol Overhead (Kbit): Total number of routing packets (in Kbit) divided by total number of delivered data packets. Here, we analyze the average number of routing packets in Kbit needed to deliver a single data packet. This is needed because the size of routing packets may vary.

Throughput (Kbit/second): Total number of delivered data packets divided by the total duration of simulation time. We analyze the throughput of the protocol in terms of Kbit of messages delivered per one second.

End-to-End delay (seconds): The time it takes a data packet to reach the destination.

This metric is calculated by subtracting "time at which first packet was transmitted by source" from "time at which first data packet arrived to destination".

B. Scenario for Network Mobility

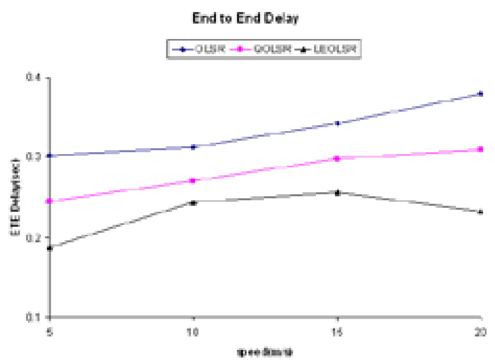

Figure5. End-To-End Delay (sec) of data packets - Network Mobility.

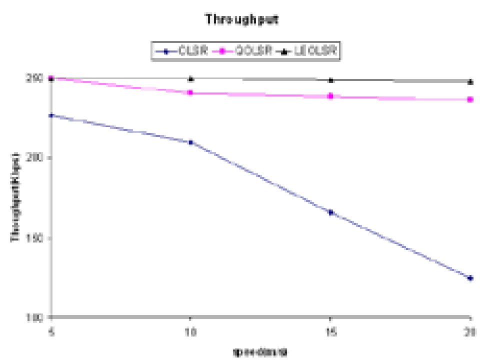

Figure6. Throughput - Network Mobility.

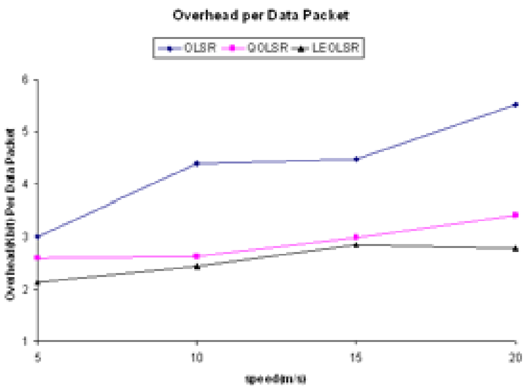

Figure 7. Data packet overhead - Network Mobility.

C. Scenario for Network Mobility

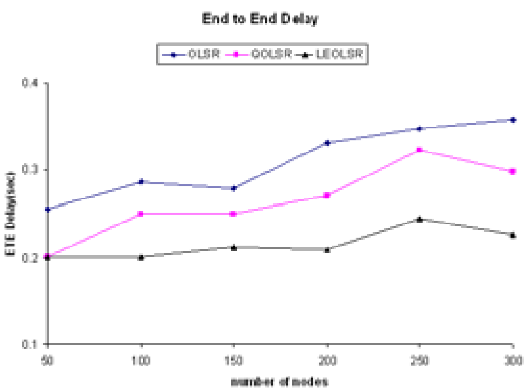

Figure8. End-To-End Delay (sec) of data packets –Network Density.

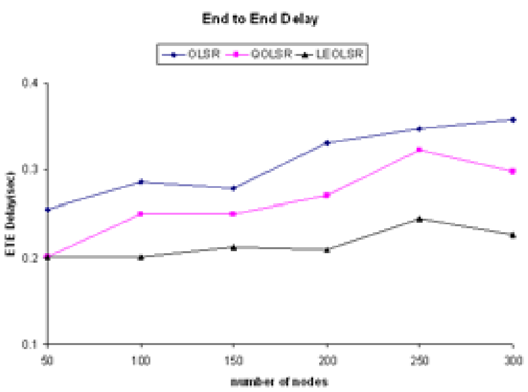

Figure9. Throughput - Network Density.

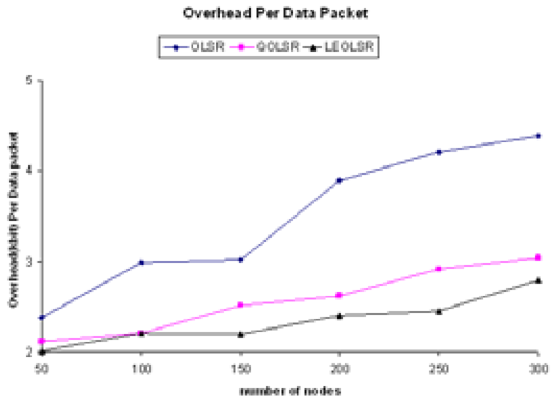

Figure10. Data packet overhead - Network Density.

End-to-End delay: Figure.5 and Figure.8 illustrate end to end delay versus speed. LEOLSR has remarkably maintained a low end-to-end delay throughout the 10 speeds, with a slight increase in delay at speed 15 m/s.

Throughput (Kbit /second): Figure.6 and Figure.9 show the throughput of the protocols measured in

Kbit/second. LEOLSR has maintained a high throughput at more than 100 number of node.

Normalized Protocol overhead (Kbit): Figure.7 and Figure.10 show the routing overhead in Kbit required to deliver a single data packet versus speed. In Fig.7 it is apparent that our algorithm required almost 3 Kbit of routing packets to deliver a single data packet at the speed of 5 m/s.

VI. CONCLUSION

In this paper we presented a QoS routing protocol. It is an extension of OLSR, a proactive routing protocol for MANET.

We explained the algorithm used to select the set of neighbors that respects the link stability and battery capacity as MPRs. Then we compared it with another extension of OLSR for QoS routing, QOLSR. The results show that we obtained better performances in terms of QoS metric than QOLSR and OLSR.

Our algorithm has stronger routing stability and lower probability of link failure because it selects links with large link expiration time.

Our analysis of the simulation results shows that the additional message overhead generated by the proactive QoS routing have a negative impact on the Performance of the routing protocol.

As the added overhead is the main cost that affects the QoS routing algorithm's performance, the future work on QoS routing in Ad-Hoc networks may be focused on how to reduce the overhead.

TC packet collisions at the 2-hop neighbors cause the problem of stale routing tables. To avoid this problem, we can add some jitter mechanism into the OLSR protocol .when an MPR receives a TC message, it waits for a random delay time before it relays that TC message, instead of relaying it immediately.

ACKNOWLEDGMENT

We would like to thank the Iran Telecommunication Research Center (ITRC) for valuable help to can complete this paper.

REFERENCES

[1] Ying Ge, Tomas Kunz and Louise Lamont, "Quality of Service Routing in Ad-Hoc Networks Using OLSR", in the proceedingCs of the 36th Hawaii international conference on system sciences, IEEE, 2002.

[2] G. Santhi and Alamelu Nachiappan, "A Survey of Qos Routing Protocols for Molbile Ad Hoc Networks", International journal of computer science & information Technology (IJCSIT) Vol.2, No.4, August 2010.

[3] Lei Chen and Wendi B. Heinzelman, University of Rochester, "A Survey of Routing Protocols that Support QoS in Mobile Ad Hoc Networks", IEEE Network ,November/ December 2007.

[4] P. Jacquet, P. Muhlethaler, A. Qayyum, A. Laouiti, L. Viennot, and T. Clauseen, "Optimized Link State Routing Protocol", draft-ietf-manet-olsr-0.6.txt, Internet Draft, Mobile Ad-Hoc Networking Working Group, March 2002

[5] S. Singh, M. Woo, and C. S. Raghavendra, "Power-Aware Routing in Mobile Ad Hoc Networks," Proc. Int'l. Conf. Mobile Computing and Networking, 1998, pp. 181–90.

[6] Md. Mamun-Or-Rashid, Choong Seon Hong, "LSLP: Link Stability and Lifetime Prediction Based QoS Aware Routing for MANET", JCCI 2007, Phoenix Park, Korea, May 2-4 2007

[7] Dr.R.Asokan, "Review of Quality of Service (QoS) Routing Protocols for Mobile Ad hoc Networks", IEEE2010

[8] M. Benzaid, P. Minet, and K.A. Agha, "Integrating fast mobility in the OLSR routing protocol", in Proc. MWCN, 2002, pp.217-221.

[9] V. Hnatyshin, H. Asenov, J. Robinson, "Practical methodology for modeling wireless routing protocols using OPNET Modeler", In Proceedings of 21st International Conference on Modeling and Simulation (MS 2010), July 15 - 17, 2010, Banff, Alberta, Canada.