DLU-Position-Based Routing Protocol In A Hybrid Network Environment

Hatem Hamad[1], Mohamed AbuBaker[2], Mohamed Mortaja[2]
Dept. of Computer Engineering, The Islamic University of Gaza, Gaza, Palestine
[1] hhamad@iugaza.edu.ps
[2] {mabubaker, m_mortaja}@students.iugaza.edu.ps

***Abstract*—In this paper we propose a novel Dynamic Location Update (DLU) algorithm for updating the location information of mobile nodes (MNs) for position-based routing protocols in mobile ad hoc networks (MANETs). Our algorithm is designed to overcome the problem of the overhead caused by static time interval of location update packets and to increase the efficiency of MANET position-based routing protocols by keeping high data packets delivery ratio where the location information of destination MNs is up-to-date. The DLU algorithm is integrated with a position-based routing protocol for a hybrid network environment that consists of MANET and WiMAX networks. WiMAX is used to exchange the location information of MNs. This position-based routing protocol is the OHLAR (One Hop location aided routing) which has a special parameter of updating the location information of MNs based on a constant static time interval. In Our DLU algorithm, the decision of updating the location of MNs is made based on the changes that occur in the Neighbors Location Table (NLT) of each MN, where other mobile nodes can enter or leave the NLT. Simulation results show that the proposed OHLAR-DLU outperforms the OHLAR by reducing the control overhead and increasing the delivery ratio.**

I. INTRODUCTION

A mobile ad hoc network (MANET) consists of a set of mobile nodes MNs that communicate with each other without pre-established infrastructure. This type of wireless networks can be used in disaster recovery, rescue operations, military communications, educational operations and many other applications. The main challenge in the MANETs is how to route data packets to the destinations. Since the nature of MANETs, the network topology is changed very frequently, due to MN mobility which causes unpredictable topological changes [19].

The routing protocols for MANETs can be classified as: Topology-based and Position-based routing protocols [18]. The main difference between them is that the latter has location information about MN derived from position devices like GPS [16, 17]. So they make the routing and forwarding decision based on the location of the destination MNs. The topology-based routing protocols suffer from high control overhead packets for maintaining routing tables as the network size increased, so they have a limited scalability [18].

These routing protocols can be further divided into three categories: Proactive (table-driven), Reactive (on-demand), and Hybrid routing protocols. In Proactive routing protocols, each MN maintains a routing table periodically within the whole network, such as Destination Sequenced Distance Vector (DSDV) [11]. The advantage of such a scheme is that the route to destination MN is available before establishing data packets transmission. But it has a disadvantage of high control overhead produced from maintaining the routing tables via periodic broadcast control packets. In Reactive routing protocols, the routes are discovered by a source MN when it needs to transmit data packets. In this scheme, there are two phases: route discovery and route maintenance. A well known Ad hoc On-demand Distance Vector (AODV) [12] and Dynamic Source Routing (DSR) [8] are considered to be reactive routing protocols. Where control packets are broadcasted in route discovery phase to reduce the overhead in the network. Since the nature of mobile ad hoc network is highly mobile, the route to destination MN is easily broken. So a route maintenance phase is used to keep routes available. The Zone Routing Protocol (ZRP) [15] is considered to be a Hybrid routing protocol. It tries to adapt both proactive and reactive protocols. Each MN maintains a zone of neighbor MNs within n hops from it. This is the inside zone of MN in which this MN acts as a proactive scheme and acts as a reactive scheme when the MN wishes to communicate with a node outside this zone. So, each node periodically sends broadcast packets in its inside zone for building a routing table of all MNs in this zone. When a node attempts to transmit data packets to a destination that resides outside this zone, it starts a routing discovery phase to establish the route and keep a route available in case of broken links. But it still has a disadvantage of both protocols on control overhead and end-to-end delay.

In order to reduce the overhead of routing table, the location information of MNs is used in position-based routing for forwarding data packets. There are two categories of forwarding data packets in position-based routing: the greedy forwarding and directional forwarding flooding [21]. In the first one, the next hop node is selected to be the closet in distance to destination such as Greedy Perimeter stateless Routing Protocol (GPSR) [4]. In the directional flooding [2], the source node floods data packets in a geographical area towards the direction of destination node, such as Location Aided Routing (LAR) [1, 2]. In LAR, the location information of MNs is used to restrict data packets flooding area into two zones: expected and requested zones. Where the expected zone is considered to be the possible area that destination node may reside in it. The requested zone is the rectangular area from source to destination nodes where data packets are flooded just inside this area.

In this paper, we consider how important to know the accurate location information of MNs in MANET on the efficiency of data packets delivery with reduced control overhead produced from periodic update interval of MNs location information.

The rest of the paper is organized as follows: In section 2, we propose some of the related works. Section 3 motivates the proposed technique. Our DLU algorithm is explained in details in section 4. Simulation results are presented in section 5, and the conclusion is given in section 6.

II. RELATED WORKS

The basic One Hop Location Aided Routing (OHLAR) [5] and the improved OHLAR [6] both of them are greedy algorithm of a hybrid network of MANET and WiMAX based on position-based protocol, where all the MNs update their location information via WiMAX BS periodically. In basic OHLAR, the MN forwards a data packet to a MN with shortest distance to the destination MN. These steps are repeated until the data packet reaches the destination MN. This basic OHLAR suffers from the local maximum problem which caused a Ping-Pong Effect. A local maximum problem is occurred when there is no neighbor MN closer to the destination than this MN. So the packet is forwarded between this MN and its neighbor node which it is not closer to destination node. This caused a Ping-Pong between these two nodes. The improved OHLAR solves the local maximum problem in the basic OHLAR, where a MN should not forward the data packet to the same MN again as in [6]. The improved OHLAR is proved to perform well under high node mobility and with various nodes densities. It has a special parameter to update location information of MN periodically which caused a high overhead with small interval period and a reduced data packets delivery with high interval period, and also as increasing in the mobility of nodes the delivery ratio is decreased. We worked on the improved OHLAR by integrated it with our proposed Dynamic Location Update DLU algorithm which dynamically updates the MNs location information according to the changes occurred in the neighbors MNs to improve its performance by reducing the control overhead and increasing in the data delivery ratio.

III. MOTIVATION

In MANET most of the position-based routing protocols use location services to obtain the location information of destination like Quorum [13, 14]. This location services can cause a connection and tracking problems [7]. In the connection problem, the source node must be connected to the location servers at any time and this requires that the source node knows the position of location servers; this is easy if the location server is fixed. Also due to the movement of source node, the route to location servers is broken very often so the design of location servers will be very difficult. In the tracking problem, the location servers must track the position of the MNs in the network and this is impossible without radar technology [7]. Thus the network performance of MANET is reduced with the overhead of querying and updating the location information of MNs and with multi hops data packets transmission.

The WiMAX network is used to overcome the problem of the broadcast storm caused by location query/update. Since the transmission range of WiMAX is several km and has a bandwidth of only 75 Mbps [6]. In fact, it is inefficient to serve a huge amount of mobile data through the WiMAX due to its bandwidth [6]. Therefore, it is used as a hybrid network environment with MANET. The WiMAX base station is used to exchange the location information of MNs. On the other hand, the MANET is used for multi hops data packets transmission.

Since the accurate location information of destination MN in position-based routing protocols leads to more efficient data transmission in the MANET. OHLAR uses a special periodic parameter [6] for updating location information of MN via WiMAX BS. This has a disadvantage of high control overhead when using small periodic location update interval, and also has a disadvantage of reducing transmission delivery ratio when the update interval is large. So in our proposed DLU algorithm, we solve the problem of location update interval via WiMAX. The robustness of our algorithm comes from that it uses the changes occurred in neighbors location table (NLT) of MN to determine the need of updating MN location information or not. Since the changes in NLT reflects a network topological change. Our simulation results show that when integrating our proposed DLU algorithm with a position-based routing protocol of hybrid network OHLAR, it makes a significant improvement on both the data delivery ratio and the control overhead.

IV. PROPOSED DYNAMIC LOCATION UPDATE ALGORITM (DLU)

Since the network topology of MANET has changed very often and to benefit from the MN locations used in position-based protocols. We need a method to take care of maintaining MN location information without negative effects on the performance of MANET. From [6] we show that when the periodic location update interval is small (1 sec), the data delivery ratio is better than the use of large periodic update interval. But in this case it has a larger control overhead than the use of a large periodic update interval. The delivery ratio is decreased as the average speed of MNs increased. This is due to the fact that the periodic location update interval does not maintain an accurate network topology. In fact, the delivery of data packets in position-based routing protocols depends on how accurate the choice of next hop neighbor MN. Thus just considering a mobility change of MN and how long it travels does not always change the one next hop neighbors, so there is no need to update location of MN since the next hop neighbor can deliver data to this MN. On the other hand, a small movement of MN can lead to change in neighbors of MN. Thus a location update of this MN is necessary. So we turn our mind to observe the changes that occurred in the neighbors of MN since these one hop neighbors are responsible of data delivery to this MN.

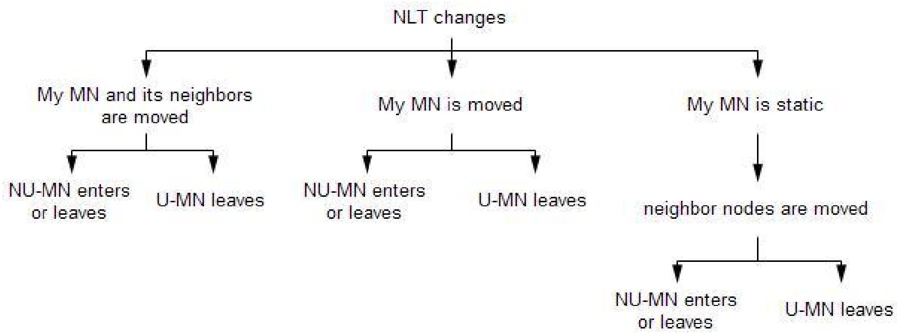

Figure 1. NLT Changes.

A. Neighbors Location Table and Its Changes

To make our decision on Neighbors Location Table (NLT), we add a status value to each MN in this NLT. So the current MNs in NLT can take a status value of U (Updated) or NU (Not Updated). The U status value means that the MN (My MN) which builds this NLT is already made an update of its location information via WiMAX BS when these U-MNs (mobile nodes with U status) are in its NLT. A mobile node with NU status value (NU-MN) in NLT means that it is a MN which is inserted in the NLT of My MN after My MN has updated its location information via WiMAX BS. The NU status value of MN in NLT is changed to U status value, if My MN updates its location information and My MN's NLT contains NU-MNs. Also, it is possible for NU-MN to leave the NLT before My MN decides to update its location information via WiMAX BS.

The change in NLT means that U-MN is left My MN's NLT or NU-MN is entered or left My MN's NLT. These changes may occur due to many cases as shown in Fig. 1.

NLT can be changed even if My MN is not moved and this means that the mobility of my neighbor nodes is the cause of changing my NLT. In this case there is no means to update My MN location information via WiMAX BS, since its location information is not changed. Another issues can make NLT changed are the mobility of My MN and the mobility of My MN with the mobility of my neighbor nodes. In this case the DLU algorithm makes its decision to update its location information or not.

B. Mechanismis of DLU Algorithm

Fig. 2 shows the procedures of our proposed DLU. The algorithm works as follows: first My MN registers its location information obtained from positioning system like GPS via WiMAX BS. And it builds its NLT with an initial status value of U for all MNs in this table. Two variables are used: the first one is used to store the number of all MNs in the NLT and the other one is used to count the number of U-MNs in the NLT. The variables are T and N_u respectively. At the initial case, the two variables have the same value.

The change in NLT of My MN reflects the topological change in the network. So the check in the algorithm is triggered when a change occurs in the NLT. This means U-MN has left the NLT or NU-MN has entered or left the NLT as explained previously. In this case we will check if the change is occurred due to My MN movement or not. If the My MN movement (or movement of My MN and its neighbor nodes) is the cause of the change in NLT, the total number of current MNs (T_c) in NLT is compared with variable T:

If $T_c < T$: this means that the NLT may contain both U-MNs and NU-MNs. The number of current MNs with U status value U-MNs in NLT (Now_u) is compared with the variables N_u:

- If $Now_u == N_u$: this means that no one of the U-MNs left my NLT, but the change in NLT is occurred because there is NU-MN has left NLT. In this case, the DLU will not add a control overhead of updating the location information of My MN in the network, since all my U-MNs are still in my one hop neighbors. And DLU just need to update the variable T to be equal to the number of all MNs in the NLT.
- If $Now_u < Nu$: in this case another condition will be checked which is if there is NU-MN in the NLT or not:
  If there is NU-MN in the NLT, it means that U-MN has left the NLT and there exist NU-MNs in the NLT. So, My MN updates its location information via WiMAX BS and the status value of all MNs in the NLT are set to U and the two variables (T, N_u) are updated according to the current number of MNs in the NLT. My MN updates its location information due to a significant change that occurs in the one hop neighbors where U-MN has left which is used as one hop to deliver data packets to My MN, but My MN became outside its transmission range so it cannot deliver data packets My MN based on the old location information of My MN and there is already NU-MN in the one hop neighbors. Thus it is important for My MN to update its location information via

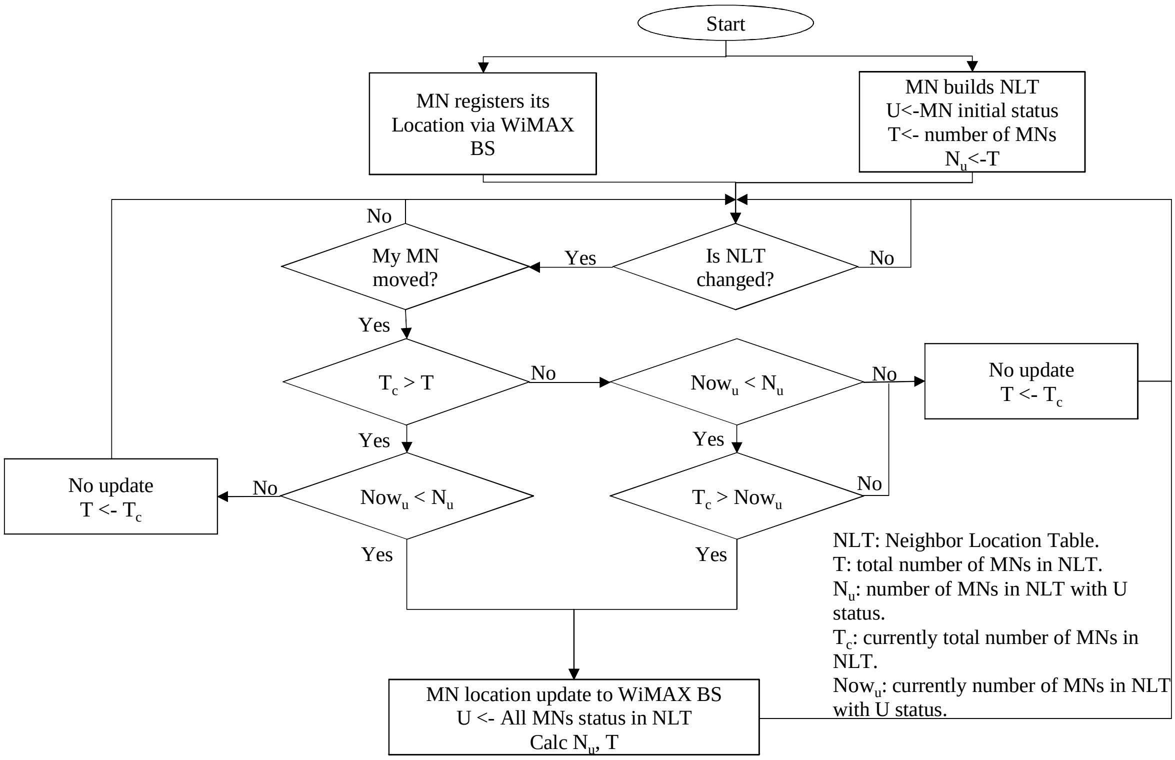

Figure 2. Dynamic Location Update Algorithm.

WiMAX BS; to tell other MNs that the left U-MN is no more in my one hop neighbors, and to take an advantage of the NU-MN to be globally known as my one hop neighbors.

But if there is not any of NU-MN in the NLT, it means that one of the U-MN has left the NLT with no other nodes inserted in the NLT. In this case, there is no need to update the location information of My MN.

If $T_c > T$: in this case, the NLT has changed due to the entrance of NU-MN in the NLT. We want to examine if U-MN has left NLT previously or not. So the number of current U-MNs in the NLT (Now_u) is compared with variable N_u:

- If $Now_u < N_u$: the change means that U-MN left the NLT previously and the check condition of our DLU algorithm decided not to update the location information of My MN. Then another change is occurred when NU-MN enters the NLT. In this case, My MN updates its location information via WiMAX BS and the status value of all MN in the NLT are set to U and the two variables (T, N_u) are updated according to the current number of MNs in the NLT.
- If $Now_u == N_u$: no one of the U-MN has left the NLT, but the change in the NLT occurs due to NU-MN enters the NLT. Since all of the current U-MNs of My MN have not changed, My MN does not need to update its location information via WiMAX BS.

C. *Example*

In Fig. 3, we study a simple numeric example of the changes in My MN's NLT and the mechanisms of our DLU algorithm. First the initial case of NLT is shown in Fig. 3 (a) where My MN updates its location via WiMAX BS when the nodes with IDs 1,2,3,4 are in NLT and the status value of these nodes are set to U, thus variable T and N_u are equal to 4. Then the NLT is changed where a MN with ID of 5 enters into the table as shown in Fig. 3 (b) with a status value of NU, at this moment the total number of current MNs (T_c) is equal to 5 and it's greater than the value of T, so the algorithm will check if there is a U-MN has left the NLT or not. In this case, the number of current U-MNs (Now_u) in the NLT equals to 4 which is the same value of N_u, thus My MN does not update its location information via WiMAX BS and the value of T is updated to be 5 which is equal to the value of T_c, and the status value of MN with ID 5 is not changed. Because the entrance of this NU-MN will not affect the delivery ratio of data packets since all my previous U-MNs are in my current NLT. In Fig. 3 (c), U-MN with ID 3 has left the NLT thus the value of T_c is less than the value of T, and there is already NU-MN in the NLT. So, My MN updates its location

MN ID	Location	status
1	loc1	U
2	loc2	U
3	loc3	U
4	loc4	U

(a)

MN ID	Location	status
1	loc1	U
2	loc2	U
3	loc3	U
4	loc4	U
5	loc5	NU

(b)

MN ID	Location	status
1	loc1	U
2	loc2	U
~~3~~	~~loc3~~	~~U~~
4	loc4	U
5	loc5	NU

(c)

MN ID	Location	status
1	loc1	U
2	loc2	U
4	loc4	U
5	loc5	U

(d)

MN ID	Location	status
~~1~~	~~loc1~~	~~U~~
2	loc2	U
4	loc4	U
5	loc5	U

(e)

MN ID	Location	status
2	loc2	U
4	loc4	U
5	loc5	U
6	loc6	NU

(f)

MN ID	Location	status
2	loc2	U
4	loc4	U
5	loc5	U
6	loc6	U

(g)

MN ID	Location	status
2	loc2	U
4	loc4	U
5	loc5	U
6	loc6	U
7	loc7	NU

(h)

MN ID	Location	status
2	loc2	U
4	loc4	U
5	loc5	U
6	loc6	U
~~7~~	~~loc7~~	~~NU~~

(i)

Figure 3. Numeric Example of NLT changes of My MN.

information via WiMAX BS and the status value of NU-MN in the NLT is set to U as in Fig. 3 (d), and also the values of T and N_u are set to be equal to 4. Because there is a significant change occurred in the one hop neighbors where U-MN has left which is used as one hop to deliver data packets to My MN, but My MN became outside its transmission range so it cannot deliver data packets My MN based on the old location information of My MN and there is already NU-MN in the one hop neighbors. Thus it is important for My MN to update its location information via WiMAX BS. In Fig. 3 (e), the U-MN with ID 1 has left the NLT without any NU-MNs in the one hop neighbors, so there is no need to update the location information of My MN. The only change is occurred on the variable T which is updated to be equal to the value of total number of current MNs in the NLT which is 3, but the variable N_u is still has the same value which is 4 since My MN does not update its location information. In Fig. 3 (f), we have NU-MN with ID 6 appears in the NLT, thus the value of T_c is greater than the value of T, but from the previous step there is U-MN with ID 1 has left My NLT. So, the location of My MN is updated via WiMAX BS and the current NLT becomes as in Fig. 3 (g). When the NLT is changes due to the entrance of NU-MN with unchanged current U-MNs as explained previously there is no need to update the location of My MN via WiMAX BS, and when the same NU-MN has left the NLT and also there is no change in the current U-MNs as show in two Fig. 3 (h) and (i). My MN does not update its location information via WiMAX BS.

V. Simulation Results And Analysis

In order to verify our DLU algorithm, it is integrated with the position-based routing protocol OHLAR [6] using the NS-2 simulator [23]. Since the OHLAR used a static location update interval. It is not consider the dynamic change of network topology where it is changed very often in MANETs. The simulation parameters are shown in TABLE I. The duration of our simulation is 600 seconds in a network area of 2000x2000 m that includes 100 mobile nodes. A Constant Bit Rate (CBR) is generated as a data traffic pattern at a rate of 2 packets per second, where 20% of the mobile nodes are selected randomly as CBR sources. The scenario of nodes mobility is generated randomly based on random way point model [22] where a mobile node is moved to it is destination and it pauses for time between 0 to 3 seconds, then it is moved to another destination.

TABLE I. Parameters of our Simulator

Parameters	**Settings**
Simulation time	600 sec
Network area	2000x2000 m
No. of mobile nodes	100
Mobility model	Random way point model
Pause time	0 to 3 sec
Node transmission range	250 m
Data packet size	512 bytes
No. CBR sources	20
CBR rate	2 packets per second
Speed	5 to 30 m/s
Location update interval	DLU algorithm

The analysis consists of comparing our algorithm with OHLAR that includes different location update intervals. The OHLAR is proved [6] to outperform each of the well-known position based LAR, and the well-known AODV under high mobility and with different node densities. Our main metrics of comparison are the data packets delivery ratio and the control overhead. The simulation results show that our OHLAR-DLU algorithm outperforms the static location update interval of OHLAR.

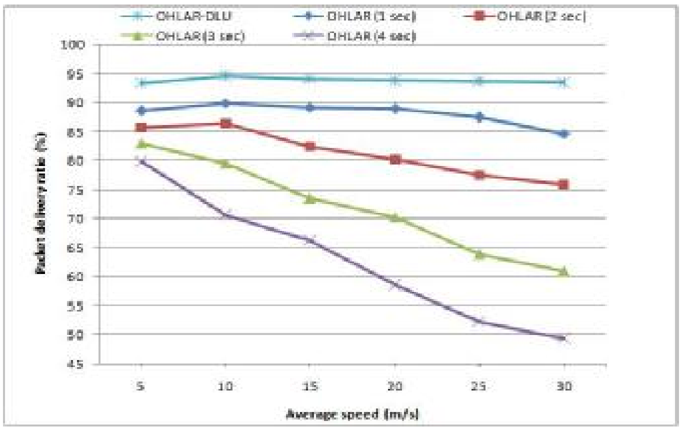

Figure 4. Data Packet Delivery ratio vs. Average speed.

Fig. 4 shows the importance of the considering a correct MN location obtains from the WiMAX base station in the efficiency of the data packets delivery as the average speed of MNs increased. It is shown in the Fig. 4 the data delivery ration versus average speed of MNs with parameters of Table 1. According to the Fig. 4, the data packets delivery ratios of OHLAR with different static location update intervals are decreasing as the average speed of MNs increased. But in our OHLAR-DLU this ratio is almost not changed by the average speed. This is due to the fact that the DLU depends on the changes in MNs neighbors and their movements, not on a static time interval or how much the MN travels a specific distance with a specific speed. At an average speed of 5 m/s, our OHLAR-DLU improves the ratio of data packets delivery by 6% and 17% over OHLAR (1 sec) and OHLAR (4 sec) respectively. Since the position based routing protocol OHLAR is hop by hop data delivery, so maintaining an accurate topology by considering the movement of MNs and the changes in their neighbors will lead to an improvement in the data packets delivery ratio. Suppose an MN moves away from the range of another MN just 1 m, this will result a change in the topology of hop by hop delivery network, thus the DLU algorithm is triggered to maintain locations of MN, but in case of 1 second location update interval, the MN will move 5 m away from the range of another MN without taking into consideration the topology changes of this movement. As the average speed increased to about 30 m/s, the delivery ratio of OHLAR-DLU outperforms the OHLAR (1 sec) and OHLAR (4 sec) by about 11% and 89% respectively.

Fig.5 shows the control overhead generated from our OHLAR-DLU and OHLAR with different periodic location update intervals (1, 2, 3, and 4 sec). The control overhead is the numbers of location query and update packets divided by the number of delivered data packets. According to the Fig. 5, the control overhead of OHLAR (1 sec) is almost the same as average speed is increased; this is due to the static update interval each 1 second. As the location update interval time of OHLAR is increased (2, 3, and 4 sec), the control overhead is decreased. The control overhead of OHLAR-DLU is decreased by about 78% and 44% from OHLAR (1 sec) when the average speeds are 5m/s and 30m/s respectively. When using the DLU algorithm the control overhead is increased as the increase average speed of MN. This due to the changes of network topology; where more neighbors are moved in and out the range of MN. And these movements are considered valuable to the hop by hop delivery packets.

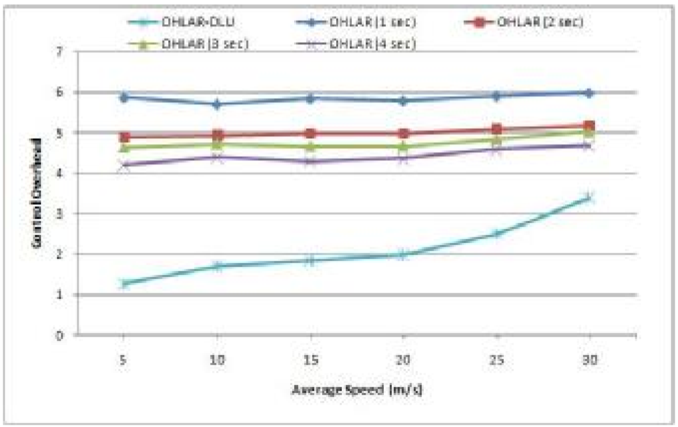

Figure 5. Control overhead vs. Average speed.

VI. CONCLUSIONS

This paper shows the importance of maintaining accurate location information of MNs on reducing the control overhead and increasing the data packets delivery ratio of the position-based routing protocol. The proposed DLU solves the problem of updating this location information periodically. Based on the changes of NLT, the simulation results show that our DLU algorithm when integrated with OHLAR protocol, it makes significant improvements by reducing overhead and increasing the delivery ratio of the network since the location information of MNs are updating based on the network topological changes.

REFERENCES

[1] T. Camp, J. Boleng, B. Williams, L. Wilcox, and W. Navidi, "Performance comparision of two location-based routing protocols for ad hoc networks," Proceedings of the IEEE INFOCOM, pp. 1678-1687, 2002.

[2] Young-Bae Ko and Nitin H. Vaidya, "Location-aided routing (LAR) in mobile ad hoc networks," Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking, 1998

[3] W. Zhao and M. H. Ammar, "Message ferrying: proactive routing in highly-partitioned wireless ad hoc networks," Distributed Computing Systems, 2003. FTDCS 2003.

[4] B. Karp and H. T. Kung, “GPSR: Greedy perimeter stateless routing for wireless networks,” in Proc. IEEE/ACM MOBICOM, Boston, MA, pp. 243–254, Aug. 2000.

[5] H.C Liao and C.J Lin, “A WiMAX-based connectionless approach for high mobility MANET,” The 9th International Conference on Advance Communication Technology (ICACT 2007), Phoenix Park, Korea, February 2007.

[6] H.C Liao and C.J Lin, “A Position-based connectionless Routing algorithm for MANET and WiMAX under high mobility and various node densities,” Information Technology Journal 7 (3): pp 458-465, 2008.

[7] Dong-Woo Seo, Sok-Hyong Kim, and Young-Joo Suh, “System integration of GPSR and ADS-B for Aeronautical Ad-hoc Networks,” Proceedings of IEEE MILCOM, Nov. 2008.

[8] Josh Broch, David B. Johnson, and David A. Maltz. “The dynamic source routing protocol for mobile ad hoc networks,” Internet-Draft, draft-ietf-manet-dsr-03.txt, October 1999.

[9] R. J. La and E. Seo, “Expected routing overhead in mobile ad-hoc networks with flat geographic routing,” submitted to IEEE Trans. on Mobile Computing (TMC), Sep. 2008.

[10] J. Li, et al., “A Scalable Location Service for Geographic Ad Hoc Routing,” in Proc. 6th Annual IEEE/ACM MOBICOM, Boston, MA, pp. 120-30, Aug. 2000.

[11] C. E. Perkins and P. Bhagwat, “Highly dynamic destination sequenced distance-vector routing (DSDV) for mobile computers,” Comp. Commum. Rev., Oct. 1994, pp. 234-244.

[12] E. Belding-Royer et al., “Ad hoc on-demand distance vector (AODV) routing,” draft-ietf-manet-aodv- 13.txt, INTERNET DRAFT, 2003.

[13] Z. Haas and B. Liang, “Ad hoc mobility management with uniform quorum systems,” IEEE/ACM Trans. Networking, vol. 7, no. 2, pp. 228-240, 1999.

[14] Hwang I., Chien C. and Wang, “A novel GPS-based quorum hybrid routing algorithm (GPS-QHRA) for cellular-based ad hoc wireless networks,” J. Inform. Sci. Engi. 21(1): 1-21, 2005

[15] Hass, Z. and M. Pearlman, “The performance of query control schemes for the zone routing protocol,” ACM SIGCOMM, August, 1998.

[16] Egen M, Coleri S, Dundar B, Rahul J, Puri A, Varaiya P, “Application of GPS to mobile IP and routing in wireless networks,” Vehicular Technology Conference, Proceedings of IEEE 56th, volume 2, 1115-1119, 2002

[17] Enge P, and Misra P, “Special issue on global positioning system,” Proceedings of IEEE, 87(1), 3- 15, 1999

[18] Jehn-Ruey Jiang and Wei-Jiun Ling, “SEEKER: An adaptive and scalable location service for mobile ad hoc networks,” International Computer Symposium 2006 (ICS'06), 2006.

[19] I. Stojmenovic, “Home agent based location update and destination search schemes in ad hoc wireless networks,” Advances in Information Science and Soft Computing, pp. 6-11, 2002.

[20] F. Ingelrest, N. Mitton, D. Simplot. “A Turnover based adaptive HELLO protocol for mobile ad hoc and sensor networks,” in Proceedings 15th Annual Meeting of the IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS 2007), Istanbul, Turkey, 2007.

[21] H. Okada, A. Takano, K. Mase, “Analysis and proposal of position-based routing protocols for vehicular ad hoc networks,” IEICE Transactions 91-A(7): 1634-1641, 2008.

[22] W. Navidi and T. Camp, “Stationary distributions for the random waypoint mobility model,” IEEE Transactions on Mobile Computing, 3(1), 2004.

[23] Information Sciences Institute USA Viterbi School of Engineering, .The Network Simulator ns-2, September 2004, http://www.isi.edu/nsnam/ns/