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SODMRP: Stable On-Demand Multicast Routing Protocol

***Abstract**. A mobile ad hoc network (MANET) is a dynamically reconfigurable wireless network that does not have a fixed infrastructure.The group-oriented services are one of the important application classes that are adopted by mobile ad hoc networks (MANETs). To support such services, multicast routing is used. But, stable multicast routing is difficult in MANETs due to limited resources and mobility of nodes. This paper proposes an energy-aware approach to develop a stable multicast routing protocol. By offering some modifications over ODMRP protocol, we involve nodes' energy information in the proposed protocol, to increase routes stability. Simulation results show that the proposed protocol improves route stability and hence leads to more packet delivery rate (PDR), more throughput and longer route life time, in compare with ODMRP.*

***Streszczenie.** Mobilne bezprzewodowe sieci ad-hoc MANET nie mają stałej infrastruktury. W artykule zaproponowano stabilny protokół przesyłania grupowego informacji umożliwiający zwiększenie szybkości komunikacji pakietowej. (**SODMRP – stabilny protokół grupowego przesyłania informacji w bezprzewodowych sieciach mobilnych**)*

Keywords: MANET, Multicast, ODMRP, Stability, Energy Consumption.
Słowa kluczowe: MANET, sieci bezprzewodowe, sieci mobilne, routing protocol – protokół trasowania.

Introduction

In the application level, MANET users communicate with together as teams. Thus applications need for group communication (multicasting) to data forwarding and real time traffics. With the rapid growth of group communication services, the multicast routing in MANET has attracted a lot of attention recently [1][2][3][4][5]. Existing protocols are either tree or mesh-based. Examples of tree-based schemes include [6][7][8]: Ad hoc multicast routing protocol (AMRoute), ad hoc multicast routing utilizing increasing ID-numbers protocol (AMRIS), and multicast ad hoc on-demand distance vector routing protocol (MAODV). On the other hand, some examples of mesh-based schemes are (a) on demand multicast routing protocol (ODMRP [9]), (b) forwarding group multicast protocol (FGMP[10]), (c) core assisted mesh protocol (CAMP[11]), (d) neighbor supporting ad hoc multicast routing protocol (NSMP[12]), (e) location-based multicast protocol[13], and (f) dynamic core-based multicast protocol (DCMP[14]). ODMRP is one of the well established protocols, whose major advantage is its high packet delivery ratio and throughput even under highly mobile network conditions. The disadvantage of ODMRP is that the control overhead grows higher and higher with network size [15][16][17][18]. Another important issue that has attracted remarkable attention is route stability. Because of this importance, [19] constructs a new metric of node stability and selects a stable path by using entropy metric to reduce the number of route reconstruction.

This paper provides an extension to ODMRP protocol that makes it more stable by using an energy-aware approach. While ODMRP uses only movement information to provide route stability, the proposed approach considers also nodes' residue energy to increase the route stability.

ODMRP Protocol

ODMRP [9] is a mesh-based rather than a conventional tree-based scheme and uses a forwarding group concept. ODMRP uses two types of packet to establish and update routes: Join-Query and Join-Reply. We can summarize route discovery phase of ODMRP as follows:

1. Multicast source originates a Join-Query packet. When location and movement information is utilized, it sets the MIN_LET (Link Expiration Time) field of the packet to the MAX_LET_VALUE.

2. When a node receives a Join-Query packet, checks if it is a duplicate. If duplicate, then discard the packet.

3. If it is not a duplicate, insert an entry into message cache with the information of the received packet (i.e., sequence number and source IP address) and insert/update the entry for routing table (i.e., backward learning).

4. Use movement information to predict the duration of time the link between the node and the upstream node will remain connected. Assume node *i* is the upstream node and node *j* is the current node. Let (x_i, y_i) be the coordinate of node *i* and (x_j, y_j) be that of node *j*. Also let v_i and v_j be the speeds, and θ_i and θ_j be the moving directions of nodes *i* and *j*, respectively. The information of node *i* can be obtained from the Join-Query and the current node's location and mobility information can be provided by the GPS. The duration of time that the link between two nodes will stay connected, i.e. LET, is given by equation (1).

(1)

$$LET = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-cd)^2}}{(a^2+c^2)} \quad (1)$$

where:

$$c = v_i Sin\ \theta_i - v_j Sin\ \theta,\ d = y_i - y_j,$$
$$b = x_i - x_j, a = v_i Cos\ \theta_i - v_j Cos\ \theta_j$$

The minimum between this LET value and the indicated value in MIN_LET field of the Join-Query is included in the packet. Minimum LET in any route is known as RET (Route Expiration Time).

5. The receiver then chooses the most stable route (i.e., the route with the largest RET) and transmits a Join-Reply packet.

More details about ODMRP can be found in [9].

Proposed Protocol: SODMRP

To more carefully predict of rout expiration time and hence improve route stability, we include residue energy of nodes in our protocol. As the first step, let's define a parameter that plays important role in our work, namely, Residue energy (RES). For any node, RES is the amount of remaining energy of the node. To update RES, any node uses E_{tx} and E_{rx} that are amounts of energy required to transmit and to receive of a packet. Thus, node energy consumption (NEC) of the node is computed as follows for transmission of *n* packets (original and retransmitted packets) by energy module:

(2) $$NEC = n * (E_{tx} + E_{rx})$$

Now, we can update *RES* of the node by using equation (3).

(3) $$RES_{new} = RES_{old} - NEC$$

As the first requirement of this protocol, we add a new field called MIN_RES to Join-Query packet header, to carry minimum RES of the routes. Now, we can describe main operations of SODMRP as follows:

1. At the beginning, multicast source originates a Join Query packet and sets the MIN_LET and MIN_RES fields to the MAX_LET_VALUE and MAX_RES_VALUE, respectively.

2. When a node receives a Join-Query packet, checks if it is a duplicate. If yes, then discards it.

3. If it is not a duplicate, inserts an entry into message cache with the information of the received packet.

4. Updates MIN_LET and MIN_RES fields of received Join-Query packet:

4. a. Predicts the duration of time the link between the node and the upstream node will remain connected (LET), same as ODMRP, by using equation (1). The minimum between this LET value and the indicated value in MIN_LET field of the Join-Query is included in the packet.

4. b. Computes RES value and includes the minimum between this RES value and the value in MIN_RES field of the Join-Query in the packet.

5. To select a route, the receiver chooses the most stable route which is selected based on the weighted equation of (4), in which, $MaxRET_k$ and $MaxRES_k$ are the largest MaxRET and MaxRES received at source k. Each route i has its own RET_i and RES_i, hence receiver can compute W_i by using equation (4). Finally receiver selects the most stable route (i.e., the route with the largest W_i) and then transmits a Join Reply packet.

(4) $$Wi = C_1 * \left[\frac{RET_i}{MaxRET_k}\right] + C_2 * \left[\frac{RES_i}{MaxRES_k}\right]$$

In equation (4) constants C_1 and C_2 represent the weights of RET and RES. C_1 and C_2 are positive constants, and we take $C_1+C_2=1$. The values of C_1 and C_2 should be chosen according to the system requirements. Suitable selection of C_1 and C_2 provides a better QoS for multicast applications. For example in military environment energy may be more important than mobility, therefore C_2 should be selected larger than C_1 e.g. $C_1=0.3$ and $C_2=0.7$. In this paper we use $C_1=C_2=0.5$ to give same importance to energy and mobility information.

Other operations of SODMRP are same as ODMRP protocol.

Evaluation of ODMRP Protocol

In this section SODMRP is evaluated in terms of design necessity and performance.

a. Evaluation of ODMRP Protocol

Note that there are many routing protocols for MANETs and ODMRP is one of them that offers high throughput even in highly mobile network conditions. Naturally, each protocol has some advantages and also suffers from disadvantages. In ODMRP protocol, instability of routes is an important weakness that results in links breakage and leads in turn to low performance and high control overhead of network. This work aims to design an efficient routing algorithm for MANETs by considering this issue. It can be found in Tab.1 how this work differs from other protocols derived from ODMRP.

Table 1. SODMRP and other protocols derived from ODMRP [16,20-26]

Protocols	Main Idea
ODMRP-LR	Link failure detection and recovery
RODMRP	Offers more reliable forwarding paths in face of node failure and network failures
SC-ODMRP	Tries to increase scalability of ODMRP
CODMRP	Attempts to improve PDR efficiency by minimizing the data redundancy
PSO-ODMRP	Uses nature principle exists in the form of fitness function (PSO algorithm)
IODMRP	Improves ODMRP by decreasing control overhead in case of increased multicast group
EODMRP	Uses motion adaptive refresh technique for route local recovery to achieve minimum overhead
RDTODMRP	Cuts down the unnecessary redundant routes and their data transmissions for obtaining better result
E-ODMRP	Use local recovery technique for decrease link breakage
SODMRP	Use residue energy of nodes for obtaining route expire time for select stable route by route weight function

b. Performance Evaluation

To investigate the impact of our enhancements, we implement SODMRP by making some modifications on ODMRP module of GloMoSim [27] software package. A total of 100 nodes are simulated for duration of 600 second in an area of 1000m×1000m. The mobility model is the random way point to model the mobility of the nodes in the network with the pause time of 10 ms. The MAC layer protocol used is IEEE 802.11. The transmission range for each node is 250 m and the channel capacity is 2 Mbps. The initial energy of the node is 1500 joules. We simulate this network once under ODMRP protocol and then under SODMRP protocol to compare their performance. The metrics used for comparison are packet delivery, throughput and life time of the selected routes. The performance of the protocols and evaluation results are illustrated versus mobility speed and number of nodes. We consider two set of experiments for both SODMRP and ODMRP. In the first set of experiments, the mobility speed is set constant to 20 m/h and number of mobile nodes is varied from 10 to 100. In the second experiment the number of nodes is set to 100 and mobility speed is varied from 10 to 70 m/h.

Figs. 1 and 2 shows the simulation results. Fig.1 shows that as the number of nodes increase (from 10 to 100), there is an increase in route life time, PDR and throughput, for both ODMRP and SODMRP. This is reasonable, since there is a possibility of decreased hop length between the nodes with increase in number of nodes, which enhances the link stability and reduces link breakages and packet drops. On the other hand, according to this figure SODMRP behaves better than ODMRP in terms of throughput and packet delivery rate for various numbers of nodes. This is due to the higher stability of SODMRP routes that reduces packet loss in case of link or node failures. Fig. 2 on the other hand, shows how SODMRP outperforms ODMRP for a wide range of mobility speed. As the previous experiment, because of the higher stability, SODMRP experiences less route breakage and hence achieves better performance in compare with ODMRP.

As another step in performance evaluation of SODMRP, Tab. 2 shows its average behavior in compare with other ODMRP-based routing protocols. This table covers those protocols that been evaluated in terms of throughput, packet delivery rate and route life time in corresponding papers [20-24]. It shows that improvement percentage made by SODMRP over ODMRP is remarkably more than other ones.

Table 2. Average improvement percentage over ODMRP for various protocols

Parameters	RDTODMR	EODMRP	SC-ODMRP	SODMRP
Throughput	7%	8%	11%	14%
PDR	5%	7%	9%	13.5%
Lifetime	2.5%	4.5%	9.5%	15%

Conclusion

This paper proposed a stable on-demand multicast routing scheme in MANET. The scheme finds stable multicast routes to receivers by considering node's residue energy. It uses a route weighted function in ODMRP route discovery process, to consider both movement and energy information in its operation. Simulation results illustrate that this approach leads to better performance in terms of packet delivery rate, throughput and route life time, in compare with ODMRP and other ODMRP-based protocols.

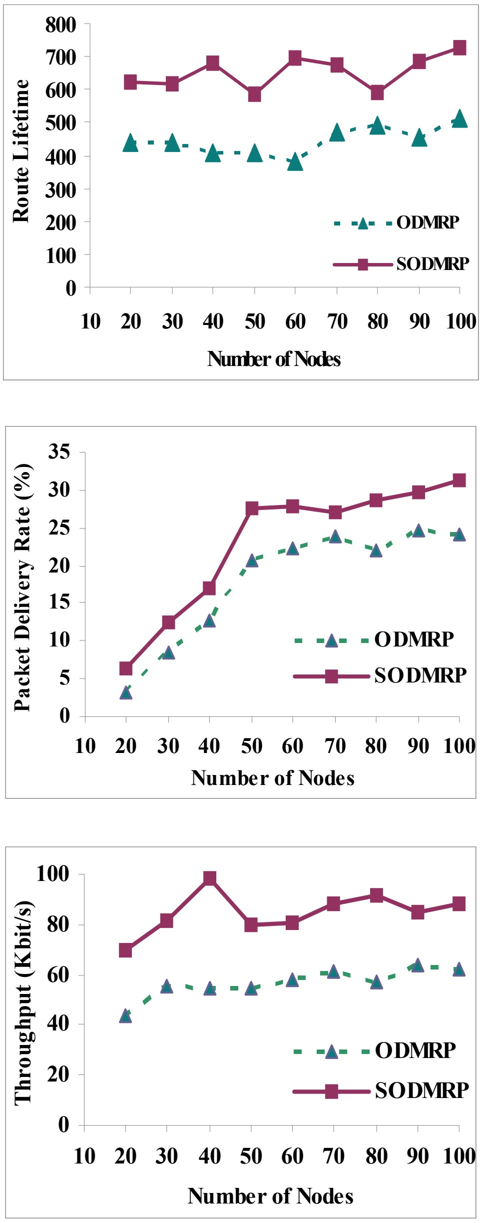

Fig.1. Experiment 1: Mobility speed=20 m/h.

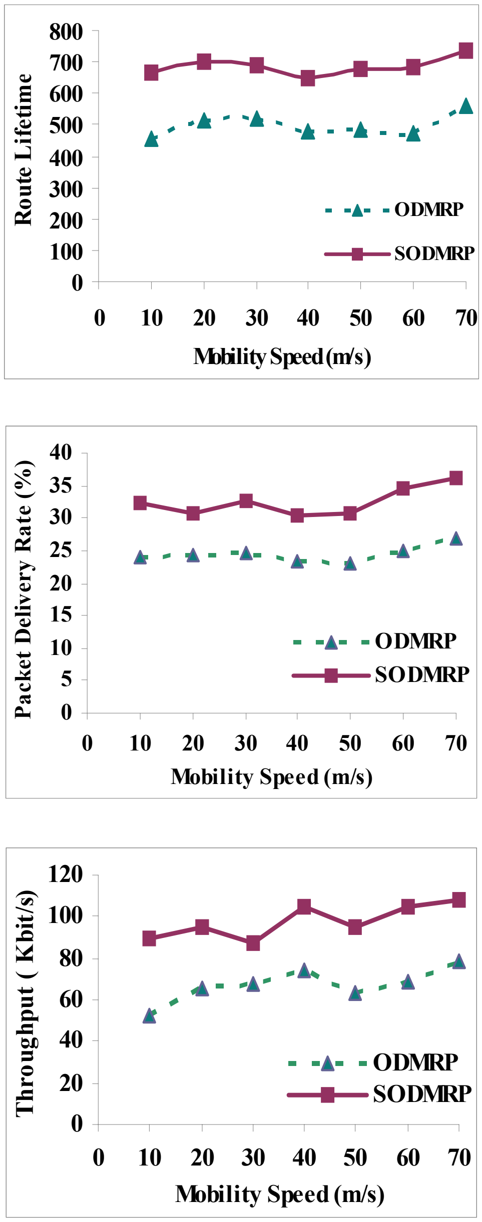

Fig.2. Experiment 2: Number of nodes=100.

REFERENCES

[1] K. Bur, C. Erosy, "Ad Hoc quality of service multicast routings", *Computer communications*, Vol. 29, 2005.

[2] H. Cheng a, J. Cao, X. Wang, "A fast and efficient multicast algorithm for QoS group communications in heterogeneous network", *Computer communications*, Vol. 30, 2007.

[3] K. A. Farhan, "Network sender multicast routing protocol", *IEEE International conference on networking*, 2008.

[4] H. Dhillon, H. Q. Ngo, "CQMP: A mesh-based multicast routing protocol with consolidated query packets", *IEEE WCNC*, 2005.

[5] L. Junhai, Y. Danxia, X. Liu, and F. Mingyu, "A Survey of Multicast Routing Protocols for Mobile Ad-Hoc Networks", *IEEE Computer Communications Surveys and Tutorials*, Vol. 11, 2009.

[6] J. Xie, "AMRoute: Ad hoc multicast routing protocol", *Mobile*

Networks and Applications, 2002.
[7] C.W. Wu, Y.C. Tay, “AMRIS: A multicast protocol for ad hoc wireless networks”, *MILCOM*, 1999.
[8] E. M. Royer, Ch. E. Perkins, “Multicast operation of the ad-hoc on-demand distance vector routing protocol”, *Mobile Computing and Networking,* 1999.
[9] W. Lee, M. Gerla, “On-demand multicast routing protocol in multihop wireless mobile networks”, *Mobile Networks and Applications*, 2002.
[10] Ch. Chiang, M. Gerla, L. Zhang, “Forwarding group multicast protocol (FGMP) for multihop, mobile wireless networks”, *Cluster Computing*, Vol. 1, 1998.
[11] E. L. Madruga, J. J. Garcia-Luna-Aceves, “Scalable multicasting: the core-assisted mesh protocol”, *Mobile Networks and Applications*, Vol. 6, 2001.
[12] S. Lee, Ch. Kim, “Neighbor supporting ad hoc multicast routing protocol”, *ACM International Symposium on Mobile ad hoc Networking and Computing*, 2000.
[13] Y. Ko, N. H. Vaidya, “Geocasting in mobile ad hoc networks: Location-based multicast algorithms”, *IEEE MCSA*, 1999.
[14] B. S. Kumar Das, C. Siva Ram Murthy, “A dynamic core based multicast routing protocol for ad hoc wireless networks”, *ACM International Symposium on Mobile Ad Hoc Networking and Computing*, 2002.
[15] R. Inayat, U. Gardezi, A. R. Shahid, “Adaptive mesh based routing for efficient multicasting in highly mobile ad hoc networks”, *IEEE-ICET*, 2006.
[16] E. Baburaj, V. Vasudevan, “An intelligent mesh-based multicast routing algorithm for MANETs using particle swarm optimization”, *International Journal of Computer Science and Network Security*, Vol.8, 2008.
[17] M. H. Laboid, “A multicast on-demand mesh-based routing protocol in multihop mobile wireless networks”, IEEEVehicular Technology Conference, 2003.
[18] Y. Zhao, Leiming Xu, Meilin Shi, “On-demand multicast routing protocol with multipoint relay (ODMRP-MPR) in mobile ad-hoc network”, ICCT, 2003.
[19] H. Xu, D. Mu, “A Cluster Based Stable Multicast Routing Protocol in Ad Hoc Network”, IEEE International Conference on Embedded and Ubiquitous Computing, 2008.
[20] R. Birdar, S. manvi, M. Reddy, “Link stability based multicast routing scheme in MANET”, Computer Networks, Vol. 54, No. 7, 2010.
[21] R.D. JOSHI, P.P. REGE, “E-ODMRP: Enhanced ODMRP with Motion Adaptive Refresh ”, IEEE ISWCS, 2005.
[22] S.K. Dhurandher, S. Misra, M.S. Obaidat, “An Energy-Efficient On-Demand Routing Algorithm for Mobile Ad-Hoc Networks”, IEEE 15th ICECS, 2008.
[23] Y.X Hu, Y.F Jia, “Improvement of Wireless Multicast Routing with Energy-efficiency Based on ODMRP”, IEEE CNMT, 2009.
[24] R. Ghafouri, M. Fathy, “LF-RDTODMRP: A Robust and Efficient On-Demand Multicast Routing Protocol for Ad Hoc Networks”, IEEE 14th CSICC, 2009.
[25] M. Effatparvar, N. Yazdani, F. Lahooti, “Link Stability Approach and Scalability Method on ODMRP in Ad hoc Networks”, IEEE 7th CNSR, 2009.
[26] N. Naderan-Tahan, A. Darehshoorzadeh, M. Dehghan, “ODMRP-LR: ODMRP with Link Failure Detection and Local Recovery Mechanism”, IEEE ICIS , 2009.
[27] http://pcl.cs.ucla.edu/projects/glomosim.

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