A Stable Ant-based Routing Protocol for Flying Ad Hoc Networks

Xueli Zheng[1, a], Qian Qi[2, b], Qingwen Wang[3, c, *], and Yongqiang Li[3, d]

1Science and Technology on Avionics Integration laboratory, Aeronautical Radio Electronics Research Institute,

Shanghai, China

2Department of Marine, Northwestern Polytechnical University, Xi'an, China

3 Xi'an Research Institute of High Technology, Xi'an, China

a xlzheng68@126.com, b qq_benben@126.com, c wqw013890@163.com, d 598988872@qq.com

Keywords: Flying Ad Hoc Networks; Ant Colony Optimization; Routing Protocol; Stable.

Abstract: A Stable Ant-based Routing Protocol (SARP) for Flying Ad Hoc Networks is proposed in this paper. SARP is based on the Ant Colony Optimization meta-heuristic, which selects the next hop node according the stable value, pheromone and the energy of the link. The stable value is calculated by the transmission range of the node and the distance between the current node and the next hop nodes. SARP let the nodes broadcast HELLO messages periodically to obtain the neighbor information. We describe SARP, implement it and evaluate its performance using NS-2 network simulator. Simulation results reveal that SARP achieves better performance in terms of the packet delivery fraction, throughput and normalized routing load, which is respectively compared with AODV.

1. Introduction

Recently, Flying Ad-Hoc Networks (FANETs) have gained more and more attention in academia and industry. FANETs are basically ad hoc network between UAVs, which are surveyed as a new network family[1]. FANETs share common characteristics with Ad Hoc networks, meanwhile they also have several unique design challenges [2-4]. The dynamic topology of FANETs brings many difficulties to design efficient and effective routing protocols to provide efficient routes between sources and destinations[5]. However, researchers have proposed some routing protocols to the requirements of different applications. The routing protocols that have been proposed for mobile ad hoc networks can be classified into three basic groups[6]: table-driven routing protocols, on-demand routing protocols and hybrid routing protocols.

Table-driven routing protocols are based on the classical wired approach. Using a purely pro-active strategy, they calculate and maintain routes to all possible destinations. Examples of such approach are applied by the Dynamic Destination Sequenced Distance Vector Routing (DSDV)[7] and the Optimized Link State Routing(OLSR)[8]. These types of protocols use a burden of control information to keep the network topology up-to-date. However, as the node mobility increasing, keeping track of topology variations becomes difficult, which leads to a worse network performance for FANETs.

On-demand routing protocols represent another sort of solution where the source node initiates the routing discovery when there is no available path to the destinations. In such case, the route is maintained until the data flow ends its activity or one of its nodes becomes inaccessible. Examples of such kind of protocols are the Ad-hoc On Demand Distance Vector Routing (AODV)[9] and the Dynamic Source Routing (DSR)[10], which uses the classical source routing approach. Both of them display inefficient support for FANETs, as they require significant amount control information during the route discovery process.

In the hybrid routing protocols, the network is divided into clusters and different routing protocols

Copyright © 2018, the Authors. Published by Atlantis Press.
This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

may be used for inter and intra-cluster routing: the goal is to find out an optimal solution by combining both types of strategies. Examples of this kind of routing is the Zone Routing Protocol (ZRP)[11]. In spite of the advantage of this flexible approach, small or highly dynamic networks may not be able to take advantage of hybrid strategies due to the overhead associated with cluster creation and maintenance.

Recently, there is an increasing interest in swarm intelligence (SI) or nature inspired algorithms for routing in MANETs [6, 12-17]. Swarm intelligence is a computational intelligence technique that involves collective behavior of autonomous agents that locally interact with each other in a distributed environment to solve a given problem in the hope of finding a global solution to the problem. Ant colonies, bird flocking, animal herding and fish schooling are examples in nature that use swarm intelligence.

In this paper, we propose a stable ant-based routing protocol for FANETs, named SARP. SARP is based on the Ant Colony Optimization meta-heuristic, which selects the next hop node considering the stable value, pheromone and the energy of the link. The stable value is calculated by the transmission range of the node and the distance between the current node and the next hop nodes. SARP let the nodes broadcast HELLO messages periodically to obtain the neighbor information. Simulation results using NS-2 network simulator reveal that compared with AODV, SARP achieves better performance in terms of the packet delivery fraction, throughput and normalized routing load.

The rest of the paper is organized as follows: In Section 2, we descript the design and implementation of SARP. The parameters used in the experiments and the performance results and analyses are presented in Section 3. Finally, section 4 concludes the paper and outlines the future work.

2. PROPOSED APPROACH

A. *Route selection of SARP*

In SARP, a source node starts a route discovery process by sending a special control packet, the Forward ANT (FANT), which is replicated by all network nodes until it reaches the destination nodes. Upon the reception of the first FANT, the destination node will send another special control packet back, the Backward ANT (BANT), through the shortest known path. When BANT packets arrive at the source, the path is established and the data flow may start its activity.

At each node r, a FANT selects the next hop node using the same probabilistic rule proposed in the ACO metaheuristic as follow:

$$p_k(r,s)=\begin{cases}\dfrac{\left[T(r,s)\right]^{\alpha}\left[E(s)\right]^{\beta}\left[S(r,s)\right]^{\chi}}{\sum\limits_{u\notin M_k}\left[T(r,u)\right]^{\alpha}\left[E(u)\right]^{\beta}\left[S(r,u)\right]^{\chi}} & \text{if } s\notin M_k \\ 0 & \text{otherwise}\end{cases} \quad (1)$$

where $p_k(r,s)$ is the probability with which ant k chooses to move from node r to node s, $T(r,s)$ is the routing table at each node that stores the amount of pheromone trail on connection (r,s), $E(s)$ is the *visibility* function given by $1/(C-e_s)$.Where C is the initial energy level of the nodes and e_s is the actual energy level of node s. α, β and χ are parameters that control the relative importance of pheromone, visibility and stable value. $S(r,s)$ is the stable value on connection (r,s) which is calculated as follow:

$$S(r,s)=\begin{cases}4 & if\,(0<D(r,s)\le 0.2R) \\ 8 & if\,(0.2<D(r,s)\le 0.8R) \\ 2 & if\,(0.8<D(r,s)\le R)\end{cases} \quad (2)$$

Where $D(r,s)$ is the Euclidean distance between node r and s. R is the radius of each node.

B. *Pheromone update of SARP*

When the nodes receive the FANTs, the amount of pheromone is changed as follow:

$$T_k(r,s) = (1-\rho)T_k(r,s) \quad (3)$$

Where ρ is a coefficient such that $(1-\rho)$ represents the evaporation of trail.

When the nodes receive the BANTs, the amount of pheromone is changed as follow:

$$T_k(r,s) = T_k(r,s)/(1-\rho) + \Delta T_k \quad (4)$$

Where ΔT_k represents the amount of pheromone trail that the ant will drop during its journey.

C. *Hello Messages of SARP*

In the SARP protocol, HELLO messages are periodically broadcasted by nodes and are used for link monitoring. When node A receives a HELLO message from node B, it discovers that node B is in its wireless transmission range and therefore its neighbor. On the other hand, not receiving a HELLO message from a node is interpreted as a broken link. The source ID of the sender is deciphered from the header of the HELLO messages. Every node generates a time-stamped list of its neighbors. The neighbor list is updated periodically and outdated entries are removed. The number of neighbors of a node is the number of entries in the updated neighbor list.

3. PERFORMANCE EVALUATION

We use ns-2 packet level simulator (v.2.33) to simulate a space 1000m×1000m populated with 50 mobile nodes that are uniformly distributed in the region. Protocols :(1) SARP; (2) AODV with Hello. There are one data source node and one destination nodes. The energy consumptions in sending mode, receiving mode and idle mode are 1.6w, 1.2w and 1.15w respectively. Each data point represents an average of ten runs with identical traffic models, but different randomly generated mobility scenarios. We adopt dual channel environment. Other simulation parameters that have been used in our experiment are shown in TABLE I.

TABLE I. SIMULATION PARAMETERS

Simulation Parameter	Value
Simulation time	200s
Transmission range	250m
Initial energy	200J
Queue length	50
Propagation Model	TwoRayGround
Channel	WirelessChannel
Mac Protocol	802_11
Traffic	CBR
CBR PacketSize	512bit

To prove the validity of the proposed approaches, we apply three metrics: (1) Packet Delivery Fraction (PDF) is defined as the ratio of the number of packets successfully received by the destination to the number of packets generated by the source. (2) Throughput is the sum of the data rate delivered to all destinations. (3) Normalized routing load is the number of routing packets transmitted per data packet delivered at the destination.

D. *Varying nodes' speed*

In this experiment all nodes were allowed to move freely using the aforementioned random waypoint model, with all being randomly associated with different mobility speed and power levels. This experiment was performed to examine all possible cases, and to check the protocol's performance and ability to adjust in uncontrolled network behavior, structure and the various mobility speeds of the network nodes.

Fig.1 shows the results obtained for PDF. As it can be seen, SARP performs better than AODV. The reason is that SARP select the next hop nodes based on ACO, which mitigates the contentions and collisions during broadcasting. The number of the packets reach the destination is increased.

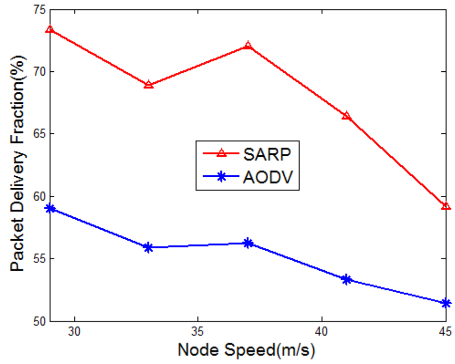

Figure 1. PDF for increasing node density

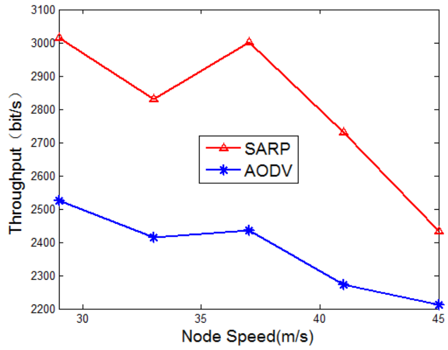

Figure 2. Average delay for increasing node density

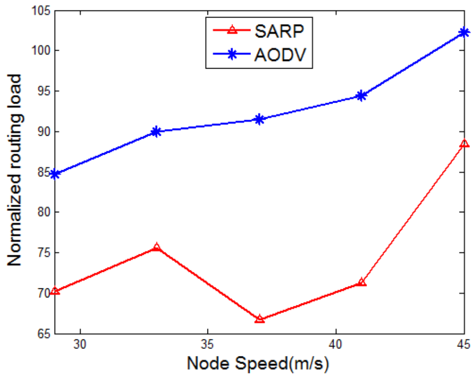

Figure 3. Normalized routing load for increasing node density

Fig.2 shows the results of throughput vs. the network density. Throughput is an important performance metric that measures the transmission ability of a network. The throughput of SARP is better than that of AODV. The reason is that SARP achieves better PDF.

Fig.3 shows the results of normalized routing load vs. the network density. The metric is increased as the network density grows. SARP achieves better performance than AODV. The reason is that SARP reduces the unnecessary rebroadcast of RREQ.

E. Varying packet rate of source node

For this experiment, the packet rate of source node is varied from 1 packets/s to 8 packets/s. All nodes were allowed to move freely using the aforementioned random waypoint model. The node’s speed change between 0 m/s to 17 m/s. This experiment was performed to examine the performance of SARP and AODV with varying packet rate of source node.

Fig.4 shows the results obtained for PDF. As it can be seen, SARP performs better than AODV. The reason is that SARP select the next hop nodes based on ACO, which mitigates the contentions and collisions during broadcasting. The number of the packets reach the destination is increased.

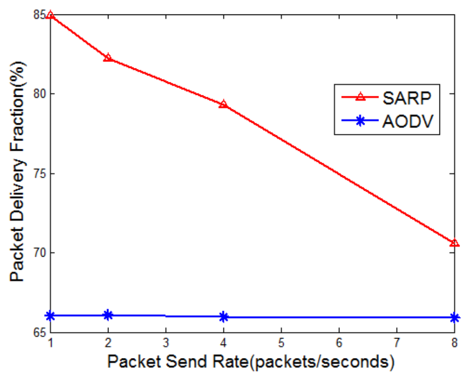

Figure 4. PDF for increasing packet rate

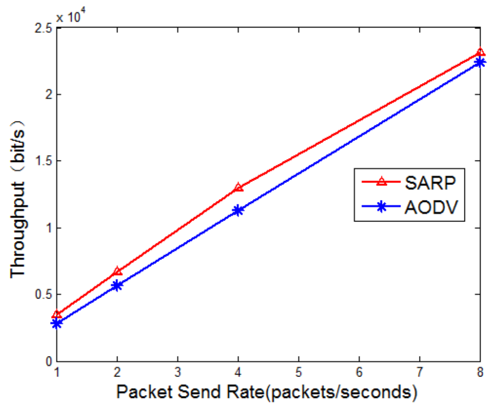

Figure 5. Average delay for increasing packet rate

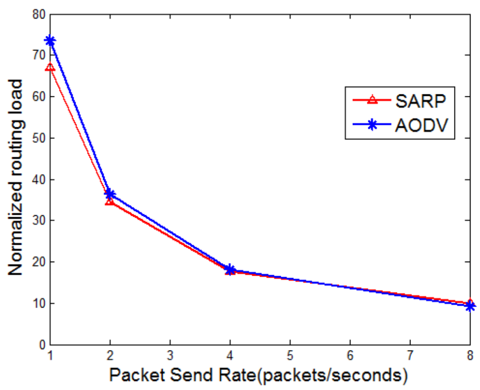

Figure 6. Normalized routing load for increasing packet rate

Fig.5 shows the results of throughput vs. packet rate. Throughput is an important performance metric that measures the transmission ability of a network. The throughput of SARP is better than that of AODV. The reason is that SARP achieves better PDF.

Fig.6 shows the results of normalized routing load vs. the packet rate. The metric is increased as the network density grows. SARP achieves better performance than AODV. The reason is that SARP selects only one neighbor node to forward the FANT, which reduce the unnecessary rebroadcast.

4. CONCLUSIONS

The proposed protocol SARP in this paper has an important role in the performance of routing protocols in FANETs. SARP is based on the Ant Colony Optimization meta-heuristic, which selects the next hop node according the stable value, pheromone and the energy of the link. The stable value is calculated by the transmission range of the node and the distance between the current node and the next hop nodes. SARP let the nodes broadcast HELLO messages periodically to obtain the neighbor information. Simulation results reveal that SARP achieves better performance in terms of the packet delivery fraction, throughput and normalized routing load.

5. Acknowledgment

This work is supported by the Aeronautical Science Foundation of China (201555U8010).

References

[1] İ. Bekmezci, O. K. Sahingoz, and Ş. Temel, "Flying Ad-Hoc Networks (FANETs): A survey," *Ad Hoc Networks,* vol. 11, pp. 1254-1270, 2013.

[2] F. Luo, C. Jiang, J. Du, J. Yuan, Y. Ren, S. Yu, *et al.*, "A Distributed Gateway Selected Algorithm for UAV Networks," *Emerging Topics in Computing, IEEE Transactions on,* vol. PP, pp. 1-1, 2014.

[3] C. Yegui, F. R. Yu, L. Jun, Z. Yifeng, and L. Lamont, "Medium Access Control for Unmanned Aerial Vehicle (UAV) Ad-Hoc Networks With Full-Duplex Radios and Multipacket Reception Capability," *Vehicular Technology, IEEE Transactions on,* vol. 62, pp. 390-394, 2013.

[4] R. V. Kulkarni and G. K. Venayagamoorthy, "Bio-inspired Algorithms for Autonomous Deployment and Localization of Sensor Nodes," *Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on,* vol. 40, pp. 663-675, 2010.

[5] O. K. Sahingoz, "Networking Models in Flying Ad-Hoc Networks (FANETs): Concepts and Challenges," *Journal of Intelligent & Robotic Systems,* vol. 74, pp. 513-527, Apr 2014.

[6] F. Correia and T. Vazão, "Simple ant routing algorithm strategies for a (Multipurpose) MANET model," *Ad Hoc Networks,* vol. 8, pp. 810-823, 2010.

[7] C. E. Perkins and P. Bhagwat, "Highly dynamic destination-sequenced distance-vector routing (DSDV) for mobile computers," *ACM SIGCOMM Computer Communication Review,* vol. 24, pp. 234-244, 1994.

[8] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum, and L. Viennot, "Optimized link state routing protocol for ad hoc networks," in *Multi Topic Conference, 2001. IEEE INMIC 2001. Technology for the 21st Century. Proceedings. IEEE International*, 2001, pp. 62-68.

[9] C. E. Perkins and E. M. Royer, "Ad-hoc on-demand distance vector routing," in *Mobile Computing Systems and Applications, 1999. Proceedings. WMCSA '99. Second IEEE Workshop on*, 1999, pp. 90-100.

[10] D. B. Johnson, D. A. Maltz, Y. C. Hu, and J. G. Jetcheva, "The dynamic source routing protocol for mobile ad hoc networks (DSR)," ed: IETF Internet draft, 2002.

[11] Z. J. Haas, M. R. Pearlman, and P. Samar, "The zone routing protocol (ZRP) for ad hoc networks," 2002.

[12] J. Wang, E. Osagie, P. Thulasiraman, and R. K. Thulasiram, "HOPNET: A hybrid ant colony optimization routing algorithm for mobile ad hoc network," *Ad Hoc Networks,* vol. 7, pp. 690-705, 6// 2009.

[13] A. Giagkos and M. S. Wilson, "BeeIP – A Swarm Intelligence based routing for wireless ad hoc networks," *Information Sciences,* vol. 265, pp. 23-35, 5/1/ 2014.

[14] D. Kadono, T. Izumi, F. Ooshita, H. Kakugawa, and T. Masuzawa, "An ant colony optimization routing based on robustness for ad hoc networks with GPSs," *Ad Hoc Networks,* vol. 8, pp. 63-76, 2010.

[15] S. Kamali and J. Opatrny, "POSANT: A Position Based Ant Colony Routing Algorithm for Mobile Ad-hoc Networks," in *Wireless and Mobile Communications, 2007. ICWMC '07. Third International Conference on*, 2007, pp. 21-21.

[16] M. Gunes, U. Sorges, and I. Bouazizi, "ARA-the ant-colony based routing algorithm for MANETs," in *Parallel Processing Workshops, 2002. Proceedings. International Conference on*, 2002, pp. 79-85.

[17] L. Cobo, A. Quintero, and S. Pierre, "Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics," *Computer Networks*, vol. 54, pp. 2991-3010, 2010.