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Cluster Based Ant Colony Routing Algorithm for Mobile Ad-Hoc Networks

Alaa E. Abdallah, Bajes Y. Alskarnah

Abstract—Ant colony based routing algorithms are known to grantee the packet delivery, but they suffer from the huge overhead of control messages which are needed to discover the route. In this paper we utilize the network nodes positions to group the nodes in connected clusters. We use clusters-heads only on forwarding the route discovery control messages. Our simulations proved that the new algorithm has decreased the overhead dramatically without affecting the delivery rate.

Keywords—Ant colony-based routing, position-based routing, MANET.

I. Introduction

MOBILE Ad Hoc networks (MANET) is a network formed of a wireless nodes which communicate with others nodes without any existing network infrastructure. In MANET, two nodes can communicate directly if and only if they are within the transmission range of each other. If a node wishes to communicate with another node from outside the transmission range, it makes use of multi-hop communication, wherein intermediate nodes relay the packets from the source to the destination node. Mobile nodes in Ad hoc networks may change their position frequently and without notice, thus routing in such networks is a challenging problem. Routing protocols in MANETs classified to two basic types [33]: topology-based protocols [9], [13], [36], [38] and position-based protocols [33], [8], [4], [1], [23], [12], [21]. Topology protocols use global information about the whole network to perform packet routing. Topology protocols can be farther classified as proactive or reactive. Proactive protocols calculate routes before they are needed and try to keep routing-information to all nodes updated when any node moves, DSDV [34] and OLSR [18] are examples of proactive routing. Clearly proactive protocols have undesirable overhead when the mobility rate is big. In contrast a reactive approach, i.e. DSR [26] or AODV [35], discovers routes only when they are needed and does not try to keep routing information to all nodes always up-to-date. Still reactive protocols may still generate a huge amount of traffic when the network changes frequently [16].

Another family of ad hoc network routing protocols that combines both proactive and reactive components [20] are called ant colony routing [27]. In general, these protocols are inspired by real ants behavior and their way to find the shortest bath between food and their nest. The protocols works as follows [19], while searching for food ants deposit on the ground a substance called pheromone to give them a way back to the nest. By time the shorter paths would have more ants going through them, thus more pheromone consecration. Other ants can smell pheromone, and when searching for a path, they tend to choose, in probability, paths marked by strong pheromone concentrations.

A. E. Abdallah Department of Computer Science and Applications, Hashemite University – Zarqa 13115, Jordan (e-mail:aabdallah@hu.edu.jo).
B. Y. A University of Liverpool – Brownlow Hill Liverpool L69 7ZX, United Kingdom.

Because of cheap tools like GPS receivers [14], [28] for approximating the position of nodes in a network, researchers propose position based routing algorithms or online routing [11], [33]. In position-based routing algorithms it is assumed that a node is aware of its position, the position of its neighbors by using periodic hello messages, and the position of the destination by making use of a location service [24], [31], getting the position from a previous communication, or some other mechanism.

Although ant based routing algorithm can find paths close to the shortest path, but it suffer from the huge overhead of the control messages and the delay before find such short paths. In the contrast, position based routing algorithms overhead is almost zero, but they might fail to find a path from source to destination or the if they find a path it might be much longer than the shortest path.

In this paper we introduce the a new routing algorithm that combine the advantage of ant based routing and position based routing, we utilize the network nodes positions to group the nodes in connected clusters. Only the clusters-heads is used to forward the route discovery control messages. Our simulations proved that the new algorithm has decreased the overhead dramatically without affecting the delivery rate.

The rest of this paper is organized as follows. Section II is devoted to background material. In Section III, we briefly review some related position-based and ant-based routing algorithms. In Section IV we give detailed descriptions of the new proposed routing algorithms. In Section V, we present experimental results to demonstrate the much improved performance of the proposed methods in comparison with existing techniques. Finally, Section VI discusses the conclusions drawn in this paper.

II. Preliminaries

A. The Network Model

Assume that the set of n wireless hosts is represented by a point set S in the $2D$ space. All the network hosts have the same communication range R, which is represented as a circle of radius R. Two nodes are connected by an edge if the Euclidean distance between them is at most R. The resulting graph is called a unit disk graph (UDG). For node u, we denote the set of its neighbors by $N(u)$. Given a unit disk graph UDG(S) corresponding to a set of points S, and a pair (s, d) where $s, d \in S$, the problem of position-based routing is to discover a path in UDG(S) from s to d. At each point of the path, the decision of which node to go to next is based on the local position information of the current node c, $N(c)$, and d. We are interested in the following performance measures for routing algorithms: the delivery rate which is the percentage of times that the algorithm succeeds in delivering its packet, and the overhead which measured as the number of control messages created and exchanged in the network by a routing algorithm.

B. Related Clustering Algorithms

HA distributed algorithm is called local if each node of the network only uses information obtained uniquely from the nodes located no more than a constant (independent of the size of the network) number of hops from it. Thus, during the algorithm, no node is ever aware of the existence of the nodes of the network further away than this constant number of hops. In the following we present some local distributed algorithm to group the nodes to connected clusters:

1) Alzoubi [6], [7], [5] introduced a distributed algorithm to construct a connected dominating set; in this algorithm if the node unique ID is minimum among its neighbors, it adds itself to the dominating set and removes all its neighbors from the consideration of the set members. This process is repeated at each node, such that the resulting set is a non-connected dominating set. The nodes in the resulting set use local topology information for a node, up to 3 hops away, to add gateway nodes to the set until the set becomes a connected dominating set. The main disadvantage of this algorithm is the construction time of the independent set which can be proportional to the number of nodes.
2) Abdallah algorithm [2], [3]: distributed algorithm to construct a connected dominating set in 3D environment ; in this algorithm each node determine its class number and its neighbors class number using a virtual space tiling system. A node x is considered in the dominating set if (a) x is of class 1 (tile id = 1) and closest to the center of its tile. (b) x of class other than 1, closest to the center of its tile and some nodes in the same tile have no neighbors of lower class number. (c) x is of class other than 1, closest to the center of its tile, no nodes in the same tile without neighbors of lower class id, and x is not dominated by a neighbor of lower class id. The nodes in the resulting set use local topology information for a node, up to 3 hops away, to add gateway nodes to the set until the set becomes a connected dominating set.

III. Related routing algorithms

Routing in Mobile ad hoc network depends on many factors including network topology, the type of information available during routing, and the specific underlying network characteristics that could be used to define a heuristic to find a path quickly and efficient. In the following reviews some representative ant-based and position-based routing algorithms that are closely related to our proposed approach. We briefly discuss the algorithmic methodologies as well as their limitations.

- **Greedy [17], [25], [37]:** For this algorithm, the current node c forwards the packet to the neighbor node u that minimizes the remaining distance to the destination node d. the same procedure is repeated until the destination node is reached or no such node u exists. This routing method suffers from the so-called local minimum phenomenon, in which a packet may get stuck at a node that does not have a neighbor that makes a progress to the destination, even though the source and the destination are connected by a path in the network.
- **DREAM [10]:** For this algorithm, the current node c forwards the packet to all neighbors in the direction of the destination d. A node is considered to be in the direction of d if it is located in the cone shown in Fig. 1. In order to determine that cone, c calculates the region around d, called the expected region. It is the circle around d of radius equal to $v_{max} * (t_1 - t_0)$ where t_1 is the current time, t_0 is the time stamp of the position information that c has about d and v_{max} is the maximum speed of the node in the network.
- **LAR [29]:** This algorithm also uses the position information of nodes to restrict the flooding process during the route discovery phase of the flooding-based algorithms. With the available information of the destination node d, the source node s computes the expected zone for d, the same circle as in *DREAM* and uses this zone to define the flooding area, which is a rectangle with the source node in one corner and the expected zone in the other corner. Fig. 1 explains how both algorithms work.
DREAM and *LAR* reduce the flooding traffic compared to general flooding, but it still very high compared to greedy algorithm.
- **ANTNET [15] and ANTHOCNET [22]:** are two well known ant colony based routing algorithms. ANTNET is a proactive and ANTHOCNET is a reactive routing algorithm. They have a very high delivery rate and find routes whose lengths are very close to the length of the shortest path [15], [32]. The drawback of ANTHOCNET is the number of routing messages that needs to be sent in the network for establishing routes to the destination and the disadvantage of ANTNET is the time needed before a system of paths between the nodes of the network is established. This is referred to as the convergence time. Regarding the dynamic nature of mobile ad-hoc networks, a long convergence time is a significant drawback.

IV. Proposed Routing Algorithms

In the following we assume that the current node is c, the source node is s and the destination node is d.

To get the advantages of both ant-based and position-based routing, we decided to use the network nodes positions to

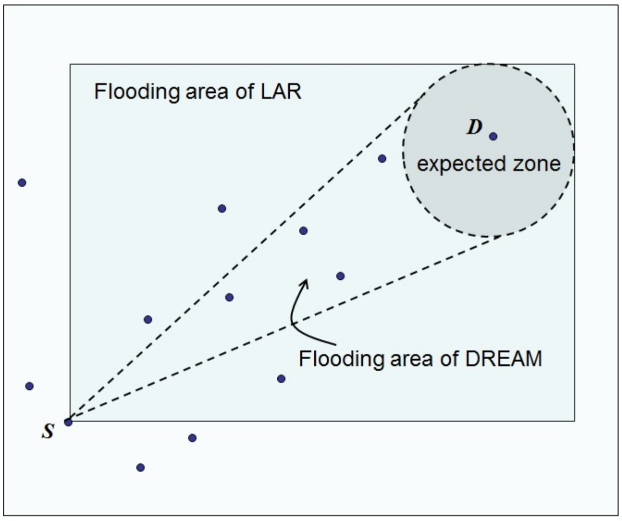

Fig. 1 To route from s to d, with *DREAM* a current node will forward the packet to all the neighbors' nodes inside the cone, while with *LAR* it will forward thepacket to all neighbors' nodes inside the square

group the nodes in connected clusters. Only the clusters-heads are used to forward the route discovery control messages, see Fig. 2. The algorithm starts as follows, when a control packet reaches the node c, c applies Alzoubi algorithm [6] to decide if it belong to the cluster heads or not. If yes, it forwards the packet to the neighbors cluster heads, otherwise, it just discards it. The algorithm then follows the regular ANTHOCNET [22] routing to discover the path. Algorithm 1 shows in details how a node handles a received control packet.

Algorithm 1: proposed routing algorithm

// Algorithm is executed independently by the current node.
// Execution starts either when a source node starts to route a packet to some other node, or if the node c receives a control packet from a neighbor nodes and need to route it.
begin
1 c runs alzoubi algorithm to see if it belongs cluster heads group.
  if *the node* $c \in clusterheadgroup$ **then**
    c finds all neighbors that belong to cluster head group
    c forward the control message to all these neighbors
  else
    c discard the control message
end

V. Simulation results

In this section we describe our simulation environment, demonstrate and interpret the results, and compare the new algorithms with previous published online routing algorithms.

A. Simulation Environment

In the simulation experiments, 100 nodes is randomly generated in a square of side length 100. The maximum transmission radius of each host is set to 25. We first calculate all connected components in the graph. Then select the largest connected component (LCC) among all the connected components to perform the routing algorithms. The source and destination nodes are then randomly picked from LCC. It is suggested in [30] to consider simulations with node density per unit disk of around 5 in $2D$ environment, which would correspond to the graph with average node degrees of around 4. To compute the packet delivery rate, this process is repeated with 100 random graphs and the percentage of successful delivers determined. To compute the average packet delivery rate, the packet delivery rate is determined 100 times and an average taken. Additionally, out of the 10000 runs used to compute the average packet delivery rate, the overhead which measured as the number of control messages created and exchanged in the network by a routing algorithm is computed.

B. Observed Result

We present a comparison between different algorithms in terms of packet delivery rate and generated overhead in Table I. It is immediately evident form the result given in Table I that Greedy have the lowest delivery rate less than 65% but it has almost zero overhead, because it does not use any control packets. The delivery rate of LAR algorithm has jump to near 100% but with huge overhead of average about 80%. The delivery rate of the new routing algorithm is near 100% but with overhead almost 30%.

VI. Conclusions

In this paper we introduce a new routing algorithm that combines the advantage of ant based routing and position based routing, we utilize the network nodes positions to group

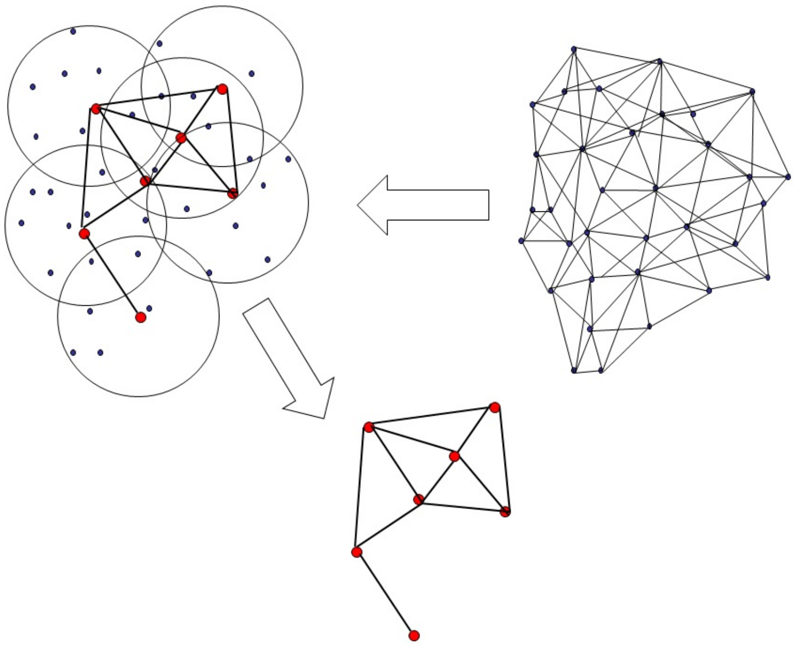

Fig. 2 The new routing algorithm starts by extracting a sub-graph using alzoubi algorithm, after that it uses only cluster heads in the routing process

TABLE I
AVERAGE PACKET DELIVERY RATE, D, AND AVERAGE PATH DILATION, P, AND ASSOCIATED STANDARD DEVIATIONS, σ, IN UDG

Algorithms	D	σ	P	σ
GREEDY	63.60	*5.06*	0.00	*0.0*
LAR	99.56	*0.25*	82.56	*7.18*
NEW ALGORITHM	99.28	*0.61*	32.53	*3.15*

the nodes in connected clusters. Only the clusters-heads is used to forward the route discovery control messages. Simulation results demonstrate that our new algorithm has decreased the overhead dramatically without affecting the delivery rate.

REFERENCES

[1] A.E. Abdallah, T. Fevens, and J. Opatrny. High delivery rate routing algorithms for 3d ad hoc network. *Computer Communications*, 31(4):807–817, 2008.

[2] A.E. Abdallah, T. Fevens, and J. Opatrny. 3d local algorithm for dominating sets of unit disk graphs. In *Proceedings of the Canadian Conference on Computational Geometry (CCCG)*, pages 35–38, Winnipeg-Manitoba, August 2010.

[3] A.E. Abdallah, T. Fevens, and J. Opatrny. 3d local algorithm for dominating sets of unit disk graphs. *Ad Hoc Sensor Wireless Networks*, 19(1-2):21–41, 2013.

[4] A.E. Abdallah, T. Fevens, J. Opatrny, and I. Stojmenovic. Power-aware 3d position-based routing algorithms using adjustable transmission ranges for ad hoc and sensor networks. *Ad Hoc Networks*, 8(1):15–29, 2010.

[5] K. Alzoubi, X. Li, Y. Wang, P. Wan, and O. Frieder. Geometric spanners for wireless ad hoc networks. *IEEE Transactions on Parallel and Distributed Systems*, 14(4):408–421, 2003.

[6] K. Alzoubi, P. Wan, and O. Frieder. Distributed heuristics for connected dominating sets in wireless ad hoc networks. *Journal of Communications Networks*, 4(1):141–149, 2002.

[7] K. Alzoubi, P. Wan, and O. Frieder. Message-optimal connected-dominating-set construction for routing in mobile ad hoc networks. In *Proc. of the Third ACM international Symp. Mobile Ad Hoc Networking and Computing (MobiHoc 02)*, pages 157–164, Lausanne, June 2002.

[8] L. Barrière, P. Fraigniaud, L. Narayanan, and J. Opatrny. Robust position-based routing in wireless ad hoc networks with irregular transmission ranges. *Wireless Communications and Mobile Computing Journal*, 3(2):141–153, 2003.

[9] S. Basagni, I. Chlamtac, and V. Syrotiuk. Dynamic source routing for ad hoc networks using the global positioning system. In *Proc. of the IEEE Wireless Communications and Networking Conference(WCNC'99)*, pages 21–24, New Orleans LA, September 1999.

[10] S. Basagni, I. Chlamtac, V. Syrotiuk, and B. Woodward. A distance routing effect algorithm for mobility (DREAM). In *Proc. of the 4th annual ACM/IEEE international conference on Mobile computing and networking (MOBICOM)*, pages 76–84, Dallas, 1998.

[11] P. Bose and P. Morin. Online routing in triangulations. In *10th Annual International Symposium on Algorithms and Computation (ISAAC '99), volume 1741 of LNCS*, pages 113–122, India, December 1999.

[12] P. Bose, P. Morin, I. Stojmenovic, and J. Urrutia. Routing with guaranteed delivery in ad hoc wireless networks. *Wireless Networks journal*, 7(6):609–616, 2001.

[13] J. Broch, D. Maltz, D. Johnson, Y. Hu, and J. Jetcheva. A performance comparison of multi-hop wireless ad hoc network routing protocols. In *Proc. of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking*, pages 85–97, Dallas TX, October 1998.

[14] S. Capkun, M. Hamdi, and J.-P. Hubaux. Gps-free positioning in mobile ad-hoc networks. *Cluster Computing Journal*, 5(2):118–124, 2002.

[15] G. Caro and M. Dorigo. Ant colonies for adaptive routing in packet-switched communications networks. In *Proceedings of the 5th ACM International Conference on Parallel Problem Solving from Nature*, pages 673–682, 1998.

[16] I. Chlamtac, M. Conti, and J. Liu. Mobile ad hoc networking: Imperative and challenges. *Ad Hoc Network Journal*, 1(1):13–64, 2003.

[17] V. Chvatal. A greedy heuristic for the set covering problem. *Math. Oper. Res. 4*, pages 233–235, 1979.

[18] T. Clausen and P. Jacquet. Optimized link state routing protocol (OLSR). In *RFC 3626, IETF Network Working Group, October 2003.*

[19] D. Caro Gianni Gambardella Dorigo, Marco and L. Maria. Ant algorithms for discrete optimization. *Artif. Life*, 1999.

[20] Caro Gianni Gambardella Ducatelle, Frederick and L. Maria. Ant Agents for Hybrid Multipath Routing in Mobile Ad Hoc Networks. In *Proceedings of the conference on Wireless On-demand Network Systems and Services*, pages 44–53, Swizerland, January 2005.

[21] T. Fevens, A.E. Abdallah, and B. Bennani. Randomized ab-face-ab

routing algorithms in mobile ad hoc network. In *4th International Conference on AD-HOC Networks and Wireless, volume 3738 of LNCS*, pages 43–56, Mexico, October 2005.

[22] F. Ducatelle G. Caro and L. Gambardella. Anthocnet: An adaptive nature-inspired algorithm for routing in mobile ad hoc networks. *Self-Organisation in Mobile Networking,*, 16(5):443–455, 2005.

[23] S. Giordano, I. Stojmenovic, and L. Blazevic. Postion based routing algorithms for ad hoc networks for ad hoc networks: A taxonomy. In *Ad hoc wireless Networking (ed. X. Cheng, X. Huang, and D.Z. Du), Kluwer*, pages 103–136, July 2003.

[24] J. Hightower and Borriello G. Location systems for ubiquitous computing. *Computer*, 34(8):57–66, 2001.

[25] D. Johnson. Approximation algorithms for combinatorial problems. *Journal of Computer and System Sciences*, pages 256–278, 1974.

[26] D. Johnson and D. Malts. Dynamic source routing in ad hoc wireless networks. In *Mobile Computing (ed. T. Imielinski and H. Korth), chapter 5*, pages 153–181. Kluwer Academic Publishers, 1996.

[27] S. Kamali and J. Opatrny. A position based ant colony routing algorithm for mobile ad-hoc networks. *JOURNAL OF NETWORKS*, 3(4):31–41, 2008.

[28] E. Kaplan. Understanding GPS. Artech house, 1996.

[29] Y. Ko and N. Vaidya. Location-aided routing (LAR) in mobile ad hoc networks. *ACM/Baltzer Wireless Networks (WINET)*, 6(4):307–321, 2000.

[30] F. Kuhn, R. Wattenhofer, and A. Zollinger. Ad-hoc networks beyond unit disk graphs. In *Proc. of the 2003 joint workshop on the foundation of mobile computing (DIALM-POMC)*, pages 69–78, San Diego, September 2003.

[31] J. Li, J. Jannotti, D. De Couto, D. Karger, and R. Morris. A scalable location service for geographic ad-hoc routing. In *Proc. of the 6th ACM International Conference on Mobile Computing and Networking (MobiCom)*, pages 120–130, Boston, August 2000.

[32] U. Sorges M. Gunes and I. Bouazizi. Ara - the ant-colony based routing algorithm for manets. In *Proceedings of the International Conference on Parallel Processing Workshops*, pages 79–89, Vancouver, August 2002.

[33] M. Mauve, J. Widmer, and H. Hartenstein. A survey of position-based routing in mobile ad-hoc networks. *IEEE Network Magazine*, 15(6):30–39, 2001.

[34] C. Perkins and P. Bhagwat. Highly dynamic destination sequenced distance-vector routing (DSDV) for mobile computers. In *Proc. of the SIGCOMM, Conference on Communications Architectures, Protocols and Applications*, pages 234–244, London, September 1994.

[35] C. Perkins and E. Royer. Ad hoc on-demand distance vector routing. In *Proc. of the 2nd IEEE Workshop on Mobile Computing System and Application(WMCSA)*, pages 90–100, San Juan, February 1999.

[36] E. Royer and C. Toh. A review of current routing protocols for ad hoc mobile wireless networks. *IEEE Personal Communications*, 6(4):46–55, 1999.

[37] P. Slavik. A tight analysis of the greedy algorithm for set cover. In *Proc. of the 28th ACM Symposium on Theory of Computing (STOC)*, pages 435–441, 1996.

[38] I. Stojmenovic. Location updates for efficient routing in ad hoc networks. In *Handbook on Wireless Networks and Mobile Computing*, pages 451–471, 2002.