International Journal of Information & Computation Technology.
ISSN 0974-2239 Volume 1, Number 2 (2011), pp. 77-86

http://www.irphouse.com

SAHR: Swarm Adaptive Hybrid Routing Protocol for Mobile Ad hoc Networks

B. M. G. Prasad[1] and P.V.S. Srinivas[2]

[1]*Associate Professor & Head, Department of Information Technology, Brindavan Institute of Technology and Science, Kurnool, Andhrapradesh, India – 518218.*
bmgprasad@gmail.com
[2]*Professor & Head, Department of Computer Science & Engineering Geethanjali College of Engineering & Technology, Cheeryal (V), Keesara (M), Hyderabad, Andhrapradesh, India*

Abstract

Ad-hoc networks consist of autonomous self-organized nodes. Nodes use a wireless medium for communication, thus two nodes can communicate directly if and only if they are within each other's transmission radius. Swarm intelligence refers to complex behaviors that arise from very simple individual behaviors and interactions, which is often observed in nature, especially among social insects such as ants. Although each individual (an ant) has little intelligence and simply follows basic rules using local information obtained from the environment, such as ant's pheromone trail laying and following behavior, globally optimized behaviors, such as finding a shortest path, emerge when they work collectively as a group. In this paper, we apply this biologically inspired metaphor to the routing in mobile ad hoc networks. In this paper, we describe an algorithm which draws inspiration from Swarm Intelligence to obtain these characteristics. In an extensive set of simulation tests, we compare our routing algorithm with a state-of-the-art algorithm, and show that it gets better performance over a wide range of different scenarios and for a number of different evaluation measures. In particular, we show that it scales better with the number of nodes in the network.

Keywords: Manet, Swarm intelligence, hybrid routing, unicast routing, ACO

1. Introduction

Mobile ad hoc networks consist of a group of mobile nodes which autonomously establish connectivity via multi-hop wireless communications. Without relying on any existing, preconfigured network infrastructure or centralized control, they are useful in many situations where impromptu communication facilities are required such as battlefield communications and disaster relief missions. A number of ad hoc routing protocols have been proposed, for example, [1], [2], [3], [4], [5]. In proactive protocols such as [5], nodes in the network maintain routing information to all other nodes in the network by periodically exchanging routing information. Nodes using reactive protocols, such as [1], [2], delay the route acquisition until a demand for a route is made. Hybrid protocols, like [4], [6], use a combination of both proactive and reactive activities to gather routes to the destinations in a network – nodes using ZRP, for example, proactively collect routes in their zone, and other routes are collected reactively. In [6], on the other hand, the level of proactive activity and reactive activity are chosen autonomously by the nodes in the network, and proactive activity is only seen around favorite destination nodes. In most traditional reactive protocols, like [1], [2], only when a route breaks irreparably does the protocol mechanisms repair the damage. In reality, route deterioration is most often not sudden but gradual and most often available routes get better/deteriorate gradually and not suddenly. So the routing protocol should continuously maintain information about the nodes in the local area to perform effectively and avoid too may link breakages.

The rest of the paper organized as fallows- Section II explores the most frequently cited related work, section 3 gives the over view of the proposed SAHR protocol. Section IV describes the root discovery and data transmission strategy in SAHR, section V explores the simulation and results discussion and that fallowed by the sections VI and VII contains conclusion and bibliography.

2. Related Work

Swarm systems have recently become a source of inspiration for the design of distributed and adaptive algorithms, and in particular of routing algorithms. Routing is the task of directing data flows from sources to destinations maximizing network performance. It is at the core of all network activities. Several successful routing algorithms have been proposed taking inspiration from ant colony behavior and the related framework of Ant Colony Optimization (ACO) [8]. Examples of ACO routing algorithms are AntNet [6] and ABC [19].

The ACO routing algorithms mentioned before were developed for wired networks. They work in a distributed and localized way, and are able to observe and adapt to changes in traffic patterns. However, changes in MANETs are much more drastic: in addition to variations in traffic, both topology and number of nodes can change continuously. Further difficulties are posed by the limited practical bandwidth of the shared wireless channel: although the data rate of wireless communication can be quite high, algorithms used for medium access control, such as IEEE 802.11 DCF[12] (the most commonly used in MANETs), create a lot of overhead both in terms of control packets and delay, lowering the effectively available bandwidth. The challenges of autonomic control are therefore much bigger, and new designs are necessary to guarantee even the basic network functions.

3. SAHR Overview

1) When a route to a destination D is required, but not known at S, S broadcasts a Root Trace Swarm Agent RTSA to discover a route to D.
2) When D receives the RTSA from S, it initiates to transmit TRSA as Root Confirmation Swarm Agent RCSA, which transmits in backward manner through the path that traced by parent RTSA. The RCSA updates the routing table and secretion table of all the nodes in the path from S to D, allowing for data transfer from S to D. Here secretion table is maintained by each node n to store secretion attribute value sav_{ni} of its each forwarding neighbor ni. The secretion attribute value is similar to pheromone repository of the biological swarm agent.
3) When a route fails at an intermediate node X then SAHR reinitiates root discovery process.
4) When a route at D is known to S, SAHR deterministically chooses the path by opting to best forwarding hop level neighbor ni based on their hop level delay and number of hops to reach the destination.

4. Swarm Adaptive Hybrid Routing Protocol

SAHR's style is galvanized by Swarm Agent Optimized routing algorithms for wired networks. It uses swarm agents that follow and update secretion tables in an indirect agent interaction for the modification of the surroundings learning method. knowledge packets are routed stochastically consistent with the learned tables. a vital distinction with alternative Swarm Agent Optimized routing algorithms is that SAHR could be a hybrid algorithm, so as to deal higher with the precise challenges of Manet environments. It's reactive within the sense that nodes solely gather routing info for destinations that they're currently communicating with, whereas it's proactive as a result of nodes try and maintain and improve routing info as long as communication goes on. we tend to build a distinction between the trail setup, that is that the reactive mechanism to get initial routing info a couple of destination at the beginning of a session, and path maintenance and improvement, that is that the traditional mode of operation throughout the course of a session to proactively adapt to network changes. The routing info obtained via indirect agent interaction is unfolded between the nodes of the Manet in hop level neighbor info exchange method to supply secondary steerage for the swarm agents. Within the following we offer a broaden description of the SAHR.

Description of the algorithm proposed

SAHR's design is inspired by swarm agent optimized routing algorithms for wired networks. It uses swarm agents which follow and update secretion tables in an indirect agent interaction about the modification of the environment learning process. Data packets are routed stochastically according to the learned tables. An important difference with other Swarm Agent Optimized routing algorithms is that SAHR is a hybrid algorithm, in order to deal better with the specific challenges of MANET environments. It is reactive in the sense that nodes only gather routing information for destinations which they are currently communicating with, while it is proactive because nodes try to maintain and improve routing information as long as communication is going on. We make a distinction between the path setup, which is the reactive mechanism to obtain initial routing information about a destination at the start of a session, and path maintenance and improvement, which is the normal mode of operation during the course of a session to proactively adapt to network changes. The routing information obtained via indirect agent interaction learning is spread between the nodes of the MANET in a hop level neighbor information exchange process to provide secondary guidance for the swarm agents. In the following we provide a concise description of each of these components.

Pheromone Indicator:
Paths are implicitly outlined by the secretion tables that are kept regionally at every node. An entry g_{ni} of the secretion table ST_i at node i that consider as pheromone indicates about the goodness of the routing from node i to via immediate node ni contains a price indicating the estimated goodness of going from i over neighbor ni to reach destination d. This goodness is derived from the combination of path end-to-end delay and range of hops. These are commonly used quality measures in Manets. Combining the number of hops with end-to-end delay between immediate node ni to current node i and destination node d is a way to swish out presumably giant oscillations within the time estimates gathered by the swarm agents. Since SAHR solely maintains info regarding destinations that are active during a communication session, and due to continuous change at neighbor nodes, the filling of the secretion tables is dynamic.

Route Discovery:
The source node s determines the path to node d via broadcasting Root Trace Swarm Agent $RTSA$. At each neighbor hop that received $RTSA$, broadcasts the same to their neighbor hops. This process is recursive for each $RTSA$ till it received by destination node d. Upon receiving the $RTSA$, the destination node d initiates to transmit Routing-path Confirmation Swarm Agent $RCSA$ that derived from $RTSA$. $RCSA$ Transmits in backward manner through the path that traced by parent $RTSA$. Upon reaching each node i in the routing path, $RCSA$ updates pheromone indicator value g_{ni} of relay hop node ni of the current node i in the routing path opted by $RCSA$. The process of updating the pheromone indicator value is as follows:

During the transmission of swarm-agent $RCSA$, it collects the time $t_{ni \to i}$ taken to reach each node i from relay hop node ni the ‘ $RCSA$ ’is coming from. The estimated time $t_{i \to d}$ to transmit a data packet from node i to destination node d via $\{ni, ni+1, ni+2 ... ni+n\}$ is measured using equation (1).

$$t_{i \to d}^{ni} = t_{(ni+n) \to d} + \sum_{k=n}^{1} t_{(ni+k-1) \to (ni+k)} \ldots\ldots \quad (1)$$

And then pheromone indicator value will be measured using equation (2) and (3) that fallows

$$\left(t_{i \to d}^{ni}\right)' = \left[t_{i \to d}^{ni}\right]^{-1} * 100 \ldots.. \quad (2)$$

$$g_{ni} = \frac{\left(t_{i \to d}^{ni}\right)'}{hc_{i \to d}^{ni}} \ldots. \quad (3)$$

Here in equation (3), $hc_{i \to d}^{ni}$ indicates the hop count in path from current node i to destination node d via relay hop node ni.

The inverse value of the estimated time $t_{i \to d}^{ni}$ for a data packet to travel from node i to destination node d indicates the optimality of the path between nodes i to destination node d via relay node ni. Hence the equation (2) is significant.

Upon receiving swarm agent $RCSA$, the source node s also updates its secretion table with pheromone indicator value g_{ni} of each neighbor hop ni the $RCSA$ coming from.

Data Transmission and Routing-path maintenance

The routing-path maintenance will be carried out in proactive manner and will be initiated at destination node d. The data transmission and path maintenance strategies explored in fallowing subsections.

Data Transmission

In the process of transmitting data, source and hop level node selects the target neighbor relay hop dynamically. Initially source node finds best neighbor ni based on pheromone indicator value of the nodes registered in its secretion table. Opting to a neighbor relay hop ni with best pheromone indicator value g_{ni}, transmits data packet to selected neighbor relay hop ni. Upon receiving the data packet the neighbor relay hop registers the sender's information in routing cache. The strategy of selecting neighbor relay hop dynamically and transmitting data packet is recursive at each neighbor hop relay node. This process will be halted once the data packet received the destination node d.

Routing Path maintenance

Upon receiving a packet dp_i, the destination node d verifies the time $t(dp_i)$ taken by dp_i to travel from source node s to destination node d and then measures the end to end delay for data packet dp_i. If end to end delay of dp_i is exceeding the delay threshold τ then it initiates a swarm agent $RCSA$ and transmits towards source node that opts to the path accessed by data packet dp_i. Hence the ‘ $RCSA$ ’ performs the process of updating pheromone indicator value g_{ni} at each hop level relay node in the path. This process explored in equations (1), (2) and (3).

Handling link failures

The destination node d initiates swarm agents $RCSA$ to each neighbor relay hop nodes in fixed time intervals. Hence the pheromone indicator values in secretion table of each node will be updated in fixed time interval ς.

The pheromone indicator value of any neighbor relay hop ni in secretion table of any node i is not valid if time since last update of g_{ni} is greater than time interval ς. This indicates the link failure between node i and destination node d.

5. Experimental Results

The evaluation of SAHR was carried out in a number of simulation tests. The SAHR performance was compared with the standard and state of the art protocol of the Manet called AODV with local repair strategy[1]. As simulation software, we use NS2. The protocol has been verified under various routing protocol evaluation metrics. All of the test scenarios are obtained by varying parameters in a specific base scenario. In this scenario, 100 nodes move in a flat, rectangular area of 3000 X 1000 m^2. Movement patterns are generated according to the random waypoint mobility model (RWP) [13]: they choose a random destination point and a random speed, move to the chosen point with the chosen speed, and rest there for a fixed amount of pause time before they choose a new destination and speed. The speed is chosen between 0 and 20 m/s, and the pause time is 30 seconds. Each simulation runs for 900 seconds. 20 different Constant Bit Rate sources start sending at a random time between 0 and 180 seconds and keep sending till the end. At the Medium Access Control layer, the IEEE 802.11b DCF protocol is used. As measures of performance, we use the average end-to-end delay for data packets and the ratio of correctly delivered versus sent packets. These are standard measures of effectiveness in Manets. We also report delay jitter, the average difference in inter-arrival time between packets. As measure of efficiency, we consider routing overhead, in terms of number of control packets forwarded per successfully delivered data packet.

We investigate SAHR’s performance for varying levels of mobility and node density, for increasing network sizes, and for different data traffic patterns.

To obtain scenarios with different levels of mobility, we vary the pause time. Higher pause time means lower mobility, but also lower connectivity (due to specific properties of RWP mobility, see [2]). The results are reported in figures 1 and 2. SAHR shows much better effectiveness than AODV, in terms of average delay, delivery ratio, and jitter. AODV has better efficiency, measured as routing overhead, but the difference is rather small. The bad performance for high pause times is due to the reduced connectivity.

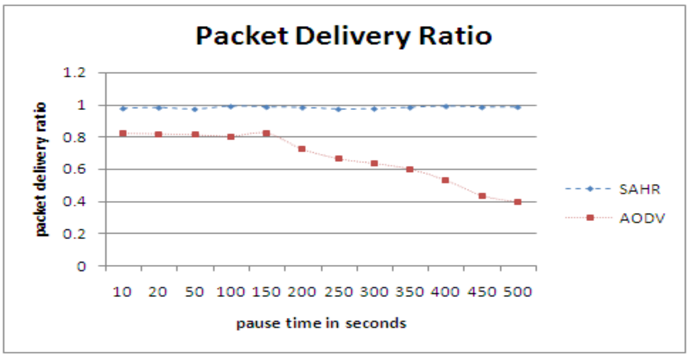

Fig 1: Packet Delivery ratio comparison between AODV and SAHR

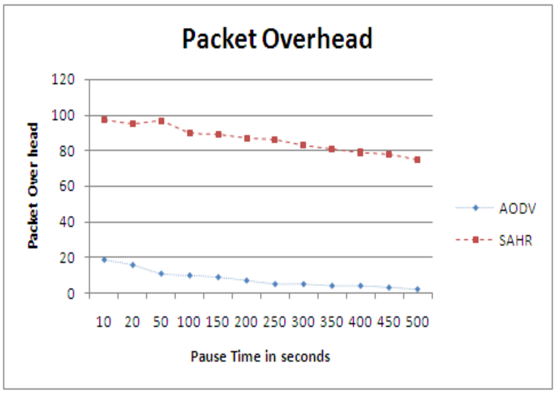

Fig 2: Packet overhead comparison between AODV and SAHR

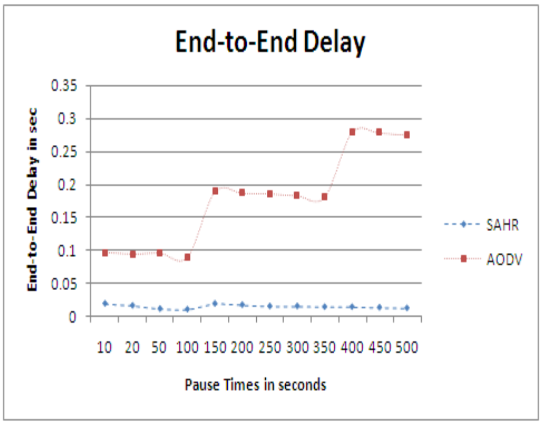

Fig 3: End-to-End delay comparison between AODV and SAHR

Different node density levels are obtained by keeping the area size constant and increasing the number of nodes. The results of these tests are reported in figure 3. Again, SAHR performs better than AODV in terms of average end-to-end delay and delivery ratio, and the difference increases with the density. In terms of overhead, SAHR is worse than AODV for low densities, but better for high densities. Jitter was not reported here, nor for the remaining tests, due to space limitations. It always follows more or less the trend visible for delay and delivery ratio.

For different network sizes, we increase the number of nodes (up to 800) and the area size together, keeping the node density constant. The results are presented in figure 4. SAHR's advantage over AODV in terms of average delay and delivery ratio grows with the size of the network.

SAHR's overhead grows less fast than that of AODV. This is an important result which indicates that SAHR is more scalable with respect to the number of nodes. For all the previous tests the data traffic consisted of 20 randomly placed CBR sessions. In figure 5 we show results of tests which use different traffic loads and patterns. We did tests with 20 and 50 sessions. The sessions are organized around a number of hot spots: 20 (or 50) randomly chosen CBR sources send to a limited number of different destinations. This number of destinations was increased from 1 up to the total number of sessions (corresponding to the randomly placed traffic we used before). Organizing traffic sessions around hot spots reflects the typical situation where traffic is concentrated around a number of important nodes. Again we observe an advantage for SAHR in terms of average delay and delivery ratio. This advantage is smaller for the easier scenarios where traffic is concentrated on a low number of hot spots. For the tests with 20 sessions, SAHR has higher overhead than AODV, while for those with 50 sessions the picture is more balanced.

6. Conclusion

In this paper we have described SAHR, a Swarm Adaptive hybrid routing protocol for MANETs which was inspired by ideas from Swarm Intelligence. The algorithm combines reactive and proactive behavior to deal with the routing challenges of MANETs in an efficient way. An efficient reactive strategy was explored for Routing path discovery. The data transmission and route maintenance was carried with an effective swarm agent based proactive strategy. The proactive strategy used in path maintenance is also equipped to help update pheromone on existing paths that helps to identify best path for further transmission and also helps to deal with link failures.

7. References

[1] C. E. Perkins, E. M. Royer, and S. R. Das, "Ad hoc On-Demand Distance Vector (AODV)Routing, Internet Draft (draft-ietf-manet-aodv-09.txt)," November 2001, work in Progress.

[2] D. B. Johnson, D. A. Maltz, Y.-C. Hu, and J. G. Jetcheva, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR), Internet Draft (draft-ietf-manet-dsr-07.txt)," February 21 2002.

[3] C. Perkins and P. Bhagwat, "Highly dynamic destinationsequenced distance-vector routing (DSDV) for mobile computers," in ACM SIGCOMM'94 Conference on Communications Architectures, Protocols and Applications,

1994, pp. 234–244. [Online]Available: citeseer.nj.nec.com/perkins94highly.html
[4] Z. J. Haas, M. R. Pearlman, and P. Samar, "The Zone Routing Protocol (ZRP) for Ad Hoc Networks," July 2002, iETF Internet Draft, draft-ietfmanet- zone-zrp-04.txt.
[5] C. Adjih, T. Clausen, P. Jacquet, A. Laouiti, P. Minet, P. Muhlethaler, A. Qayyum, and L. Viennot, "Optimized Link State Routing Protocol," INRIA Rocquencourt," Internet Draft (draft-ietf-manet-olsr-09.txt), April 15 2003, work in Progress.
[6] V. Ramasubramaniam, Z. J. Haas, and E. G. Sirer, "SHARP: A Hybrid Adaptive Routing Protocol for Mobile Ad Hoc Networks," in The ACM Symposium on Mobile Adhoc Networking and Computing (MobiHoc 2003), Annapolis, Maryland, June 1–3 2003.
[7] E. Bonabeau, M. Dorigo, and G. Theraulaz, Swarm Intelligence – From Natural to Artificial Systems. New York: Oxford University Press, 1999.
[8] J. P. Sterbenz, R. Krishnan, R. R. Hain, A. W. Jackson, D. Levin, R. Ramanathan, and J. Zao, "Survivable Mobile Wireless Networks: Issues, Challenges, and Research Directions," BBN Technologies, Cambridge, MA, September 2002.
[9] J. S. Baras and H. Mehta, "A Probabilistic Emergent Routing Algorithm for Mobile Ad hoc Networks," in WiOpt'03: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, March 3-5, 2003.
[10] G. D. Caro and M. Dorigo, "AntNet: A Mobile Agents Approach to Adaptive Routing," Universite Libre de Bruxelles, Belgium, Tech. Rep. IRIDIA/97-12, 1997.
[11] D. Camara and A. A. F. Loureiro, "A GPS/Ant-Like Routing Algorithm for Ad Hoc Networks," in IEEE Wireless Communications and Networking Conference (WCNC?00), Chicago, IL, September 2000.
[12] M. Heissenbttel and T. Braun, "Ants-Based Routing in Large Scale Mobile Ad-Hoc Networks," University of Bern, Tech. Rep., 2003.
[13] M. Gunes, U. Sorges, and I. Bouazizi, "ARA – The Ant-Colony Based Routing Algorithm for MANETs," in International Conference on Parallel Processing Workshops (ICPPW'02), Vancouver, B.C., Canada, August 18– 21 2001.
[14] F. Ducatelle, G. Di Caro, and L. M. Gambardella, "Using Ant Agents to Combine Reactive and Proactive Strategies for Routing in Mobile Ad- Hoc Networks," International Journal of Computational Intelligence and Applications, Special Issue on Nature-Inspired Approaches to Networks and Telecommunications, 2005, to appear. Also Technical Report IDSIA 28-04.
[15] G. Di Caro, F. Ducatelle, and L. M. Gambardella, "AntHocNet: an ant-based hybrid routing algorithm for mobile ad hoc networks," in In Proceedings of PPSN VIII - Eight International Conference on Parallel Problem Solving from Nature, ser. Lecture Notes in Computer Science, no. 3242. Birmingham, UK: Springer-Verlag, Sept. 2004, best paper award.
[16] M. Dorigo, G. D. Caro, and L. M. Gambardella, "Ant Algorithms for Discrete Optimization," Universite Libre de Bruxelles, Tech. Rep. IRIDIA/98-10, 1999.

[17] E.M. Royer and C.-K. Toh. A review of current routing protocols for ad hoc mobile wireless networks. IEEE Personal Communications, 1999.

[18] Scalable Network Technologies, Inc., Culver City, CA, USA. Qualnet Simulator, Version 3.6, 2003. http://stargate.ornl.gov/trb/tft.html.

[19] R. Schoonderwoerd, O. Holland, J. Bruten, and L. Rothkrantz. Ant-based load balancing in telecommunications networks. Adaptive Behavior, 5(2):169– 207, 1996.

[20] R.S. Sutton and A.G. Barto. Reinforcement Learning: An Introduction. MIT Press, 1998.

[21] G. Theraulaz and E. Bonabeau. A brief history of stigmergy. Artificial Life, Special Issue on Stigmergy, 5:97–116, 1999.