World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:2, No:10, 2008

Enhanced Ant Colony Based Algorithm for Routing in Mobile Ad Hoc Network

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Open Science Index, Electronics and Communication Engineering Vol:2, No:10, 2008 publications.waset.org/1944/pdf

***Abstract*—**Mobile Ad hoc network consists of a set of mobile nodes. It is a dynamic network which does not have fixed topology. This network does not have any infrastructure or central administration, hence it is called infrastructure-less network. The change in topology makes the route from source to destination as dynamic fixed and changes with respect to time. The nature of network requires the algorithm to perform route discovery, maintain route and detect failure along the path between two nodes [1]. This paper presents the enhancements of ARA [2] to improve the performance of routing algorithm. ARA [2] finds route between nodes in mobile ad-hoc network. The algorithm is on-demand source initiated routing algorithm. This is based on the principles of swarm intelligence. The algorithm is adaptive, scalable and favors load balancing. The improvements suggested in this paper are handling of loss ants and resource reservation.

***Keywords*—**Ad hoc networks, On-demand routing, Swarm intelligence.

I. Introduction

THIS section briefly describes the characteristics of mobile ad-hoc network and gives description about swarm intelligence.

A. Mobile Ad Hoc Network

Mobile Ad hoc network consists of a set of mobile hosts connected through wireless links. As they do not have central administration, it is easy to deploy and expand. Further it is convenient and increases productivity.

Some of the applications of ad-hoc network are disaster-management and military application. The disadvantages are limited range, compromises on reliability, security and speed. As the nodes in the network are mobile, the topology of network changes unpredictably. Hence it is difficult to generate path between two nodes. The main issues of ad-hoc network are challenges in routing due to dynamic network topology, power conservation in wireless nodes and providing consistent quality of service. Routing algorithms have the properties like robustness, optimality and stability, which make the routing algorithm challenging [1].

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The current work is centered on enhancing the process of generating routes between nodes in mobile ad hoc network. This paper deals with the development of source initiated on-demand ad-hoc network routing which can achieve load balancing for packet switched network. This paper is an improvement of ARA [2] for handling packet loss and resource reservation. The algorithm is adaptive, distributed and is inspired by swarm intelligence. Ant algorithms are the class of optimizing algorithms under swarm intelligence [3]. Routing in ant algorithm is through interaction of mobile agents called ants. According to this algorithm, a group of mobile agents builds path between pairs of nodes by exchanging information through stigmergy (indirect communication through pheromone) and updating routing tables[3][4].

B. Swarm Intelligence

Swarm Intelligence (SI) is the local interaction of many simple agents to achieve a global goal. SI is based on social insect metaphor for solving different types of problems [5]. Insects like ants, bees and termites live in colonies. Every single insect in a social insect colony seems to have its own agenda. The integration of all individual activities does not have any supervisor. In a social insect colony, a worker usually does not perform all tasks, but rather specializes in a set of tasks. This division of labor based on specialization is believed to be more efficient than if tasks were performed sequentially by unspecialized individuals. SI is emerged with collective intelligence of groups of simple agents. SI offers an alternative way of designing intelligent system, in which autonomy, emergence and distributed functioning replace control, preprogramming and centralization. This approach emphasizes on distributed ness, flexibility, robustness and direct or indirect communication among relatively simple agents [6][7].

Self organization in social insects often requires interactions among insects; such interactions can be direct or indirect. Direct interactions are the obvious interactions, with food or liquid exchange. Indirect interactions are more subtle, two individuals interact indirectly when one of them modifies the environment and others respond to the new environment at a later time. Such an interaction is an example of stigmergy (task related stigmergy) [3].

The agents are autonomous entities, both proactive and reactive and have capability to adapt, co-operate and move intelligently from one location to the other in the communication network.

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SI gives raise to intelligent behavior through complex interaction of thousands of autonomous swarm members. During food searching process, the individual ants make their decisions on which direction to go randomly. As ants move they leave behind a chemical substance called pheromone, which other ants can smell and identify that an ant has been there before (indirect communication). The stronger the pheromone level, the more likely an ant is to take that route. The concentration of pheromone decreases over time. Complex group behavior emerges from the interaction of individuals. Some thing is created that is greater than sum of its parts.

Ant agents have numerous applications in the real world such as industry, design, vehicle routing, network and gaming to name a few.

1. General Characteristics of SI
   - SI provide network adaptive feature and generates multiple path for routing. SI algorithms are capable of adapting for change in network topology and traffic while giving equivalent performance [3].
   - It relays on both passive and active information for gathering and monitoring. They collect non local information about the characteristics of solution set, like – all possible paths.
   - It makes use of stochastic components. It uses stochastic component like pheromone table for user agents. User agents are autonomous and communicate each other through stigmergy [5].
   - It sets path favoring load balancing rather than pure shortest path. The algorithm also supports for multiple paths, so that load balancing can be achieved.
2. Principle of SI - The ability of ants to self organize is based on four principles. They are positive feedback, negative feedback, randomness and multiple interactions.
   - Positive feedback – This is used to improve the good solution. When ants move from one node to another, the concentration of the pheromone along that path increases. This helps other ants to travel in this path.
   - Negative feedback – This is mainly used to destroy bad solution. It can be done by decay of pheromone concentration with respect to time. The rate of decay is problem specific. Low decay rate encourages the bad solution not being destroyed for longer time and higher decay rate destroys good solution early [6].
   - Randomness – Path to be taken by ant is completely random, hence there is possibility of generation of new solutions.
   - Multiple interactions – The solution is found by interaction of many agents. In food searching process, one ant cannot find the food, as the pheromone would decay. Hence more ants can find food faster [8].
3. SI Advantages - Following are some of the advantages:
   - Multipath routing - Possible to generate multiple paths between pairs of nodes.
   - Fast route recovery - If optimal path fails, then packets can easily be sent to other neighbors by recomputing next hop probability, i.e., choosing second best path.
   - Distributed and fault tolerance – SI algorithm are inherently distributed. There is no centralized control mechanism, so if any node or link fails, there is no heavy loss [9].
   - Scalability and adaptation– Population of ants may change based on the size of network. The agents may die or reproduce, with little effect on performance.
   - Speed – Change in the network can be adapted very fast.

There are different types of ant algorithm which are used for routing in networks. They are Ant Based Control algorithm, Antnet algorithm, Mobile Ant Based Routing, Ant Colony Based Routing Algorithm and Termite. In this work, the main interest is routing in mobile ad-hoc network using Ant Colony Based Routing Algorithm [10][6].

II. Literature Survey

In data networks, the main function of network layer is routing. Routing is the process used to determine route for packet traveling from source to destination. Routing is performed by the routers, which updates the routing tables with minimizing cost functions like physical distance, link delay, etc. The metric for optimization can be distance, number of hops or estimated transit time. Protocols are used to implement handshaking activities such as error checking and receiver acknowledgements.

Some of the algorithms used for routing in ad hoc networks are destination-sequenced distance vector routing, wireless routing protocol, ad hoc on-demand distance vector routing and dynamic source routing protocol [11]. The algorithm presented in this paper has the following difference compared to the existing ones.

- All the above algorithms have overhead involved as they have to transfer their routing tables to other nodes over the network. They either transfer them on time-based approach or event based approach. This problem does not exist with ant algorithm as there is no need for the transfer of the routing tables [9].
- Some of the algorithms do not support multiple paths and hence there is no possibility of load balancing, in case the optimal path is heavily congested. Ant algorithm supports generation of multiple paths and hence favors load balancing [12].
- Above algorithms require special packets for the purpose of route maintenance. Ant algorithm uses data packets for route maintenance.

III. Design

The network under consideration is represented as G = (V, E), a connected graph with N nodes. The metric of optimization is number of hops between the nodes. The goal is to find the shortest path between source node V_s and

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destination V_d, where V_s and V_d belong to V. The path length is given by the number of nodes along the path. Each link/edge e(i,j) ε E of the graph connecting node V_i and V_j has a variable $\varphi_{i,j}$ indicating the artificial pheromone value. An ant located in node V_i uses pheromone $\varphi_{i,j}$ of node V_j belong to N_i to compute the probability of node V_j as next hop. N_i is the set of one hop neighbors of node V_i. The probability at node V_i can be computed as follows

$p_{i,j} = \varphi_{i,j} / (\Sigma\varphi_{i,j})$ for $j \varepsilon N_i$

$= 0$ for j does not belong to N_i (1).

The probability $p_{i,j}$ of a node V_i has the constraint that

$\Sigma_{j \varepsilon N_i} p_{i,j} = 1$

The value of $\varphi_{i,j}$ is incremented by Δ by the ant packet which move along the path V_i to V_j. ie $\varphi_{i,j} = \varphi_{i,j} + \Delta$. The concentration $\varphi_{i,j}$ indicates the usage of the link. As the concentration of the pheromone should decrease with time, at every constant interval t, the value of $\varphi_{i,j}$ between the nodes V_i to V_j is decreased by α ie $\varphi_{i,j} = \varphi_{i,j} - \alpha$. If $\varphi_{i,j}$ becomes less than zero, it is set to zero, indicating no pheromone. The rate of increase in pheromone (Δ) greater that the rate of decrease in pheromone (α).

IV. Working of Ant Algorithm

Mobile Ad Hoc network consists of nodes which are mobile hence the route from source node to destination node changes. The routing algorithm has to detect the dynamic topology and generate path between nodes and it should also handle route failures. The routing algorithm is performed in three phases. The three phases are:

- Route discovery phase – This phase finds all possible paths from source node to destination node. Route maintenance phase – This phase strengthens the path between the nodes.
- Route maintenance phase – This phase strengthens the path between the nodes.
- Route failure handling – If any node along the source to destination fails or moves away from the network, alternate paths will be generated [2].

V. Data Structure

Each node in the network consists of mainly two data structures viz., routing table and neighbor list.

Routing table: Routing table at each node stores the list of reachable nodes and their pheromone value. It is represented as structure consisting of following fields:

- destination_id – This represents the address of the destination node
- next_id – This represents the address of the adjacent node used to reach destination node.
- pheremone – This represents the value used by the node to calculate the probability of each adjacent node to be the next hop in order to reach the destination.

Neighbor list: Neighbor list is used to store the information of all the neighboring nodes.

VI. Route Discovery

Route discovery is responsible for generating all possible routes between source and destination. It uses control packet to discover route. The control packets are mobile agents which walk through the network to establish routes between nodes. Route discovery uses two mobile agents called Forward Ant (FA) and Backward Ant (BA). These two ants are similar in structure but differ in the type of work they perform. A FA is an agent which establishes the pheromone track to the source node and BA establishes pheromone track to the destination. A forward ant is broadcast by the sender and relayed by the intermediate nodes till it reaches the destination. A node receiving a FA for the first time creates a record in its routing table. The record includes destination address, next hop and pheromone value. The node interprets the source address of the FA as the destination address, the address of the previous node as the next hop and computes the pheromone value depending on then number of hops the FA needed to reach the node. Then the node forwards the FA to its neighbors. FA packets have unique sequence number. Duplicate FA is detected through sequence number. Once the duplicate ants are detected, they are dropped by the nodes. When the FA reaches the destination, its information is extracted and it is destroyed. BA is created with same sequence number and sent towards the source. BA reserves the resources at along the nodes towards source. BA establishes path to destination node. Once the source receives the BA from the destination, the path is generated and the data can be sent along the path. Working of this phase is as follows:

- At source node create FA and broadcast to nodes in neighbor list.
- At source node, wait for BA. If BA not received within timeout period, generate FA with new sequence number and broadcast to nodes in neighbor list. If BA is received within timeout period send data packets along the path generated.
- At any node, when it receives FA, it does the following
  if current node = destination node
  {
    - Set type of control packet to BA with same sequence number as FA.
    - Reserve resource at current node
    - Send BA to node from which it has received FA.

  }
  else
  {
    - hop count = hop count + 1
    - $\varphi_{i,j} = \varphi_{i,j} + \Delta$

    //update pheromone value
    - send FA to nodes in neighbor list

  }
- At any node, when it receives BA, it does the following
  if (current node is not source node)
  {
    - Reserve resource at current node

- Send BA to node from which it has received FA

}
else //BA reaches source node
{

- Get pheromone values of all links using neighbor list.
- Compute probability for all nodes in neighbor list using Eqn 1.
- Send packets to that link which has highest probability value.

}

VII. Route Maintenance

Route maintenance phase is responsible for the maintenance of the path generated during the discovery phase. This phase basically helps in maintaining the route which has already been established during route discovery phase. As the topology of the network changes, it is required to refresh the route between the nodes. Once the path between source and destination is set up, it is up to the data packets to maintain the route. When a node V_i forwards the data packet to node V_j to reach the destination V_d, it increments the pheromone value along the path V_j and V_d by Δ thus strengthening the path. An acknowledgement is sent to all the packets received. If acknowledgement is not received with in timeout period then the route error message is transmitted to previous node.

Working of this module is as follows:

- At each node, when it receives data packet, it does the following
  if current node = destination node
  {
  - Extract data
  - Send packet (acknowledge packet) to previous node

  }
  else
  {
  - Get pheromone values of all links using neighbor list.
  - Compute probability for all nodes in neighbor list using Eqn 1.
  - Send packets to that link which has highest probability value.
  - Increment pheromone value for the highest probability link.

  }
- At regular intervals decrement pheromone value by α. If the pheromone value = 0 for any destination then call route discovery phase.
- If acknowledgement is not received at current node before timeout send route error to previous node (handling by error handling phase)
- Refresh route after time out.

VIII. Route Failure Handling

This phase is responsible for generating alternative routes in case the existing route fails. Node mobility in ad hoc network may cause certain links to fail. Every packet is associated with acknowledgement; hence if a node does not receive an acknowledgement, it indicates that the link is failed. On detecting a link failure the node sends a route error message to the previous node and deactivates this path by setting the pheromone value to zero. The previous node then tries to find an alternate path to the destination. If the alternate path exists, the packet is forwarded on to that path else the node informs its neighbors to relay the packet towards source. This continues till the source is reached. On reaching the source, the source initiates a new route discovery phase. Ant algorithm provides multiple paths. If the optimal path fails, it leads to choosing next best path. Next best path will be that path with links having next highest pheromone value (second best path). Hence ant algorithm does not break down on failure of optimal path. This helps in load balancing. That is, if the optimal path is heavily loaded, the data packets can follow the next best paths. Working of this phase is as follows:

At any node if a route error message is received, it performs the following function

- If alternate path exist to reach destination
  send packets through other route

else
{

- Set pheromone = 0 in routing table //deactivate link
- Send route error message to previous node.

}

if route error message reaches source, it calls route discovery phase.

IX. Issues

Study of Ant algorithm is concentrated mainly on two issues. One is Ant loss and other is resource reservation at nodes.

- Ant loss during transmission

There is a possibility of ant loss during the process of determining the reliable path. This can be of two types-the loss of the forward ant and the loss of the backward ant.

Loss of forward ant - Whenever a forward ant is lost, there will be a preset time-out period (say 6 seconds) at the source node within which if the backward ant does not return to the source, then a new forward ant with a different sequence number will be launched.

Loss of backward ant - Whenever a backward ant is lost after being dispatched from the destination node, the same time-out mechanism will be used at the source node to handle the ant loss. Another forward ant will be launched, or to make it more time efficient and dynamic, a backward ant with the same sequence number will be launched at the node where it was last seen thereby reducing the time taken for ant movement.

- Reserving memory at each node

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Sometimes, it is necessary to store the packets at intermediate nodes in order to avoid packet or ant loss during transmission. Loss may be due to failure of links. If the packet is stored in the previous node, it can be retransmitted. Hence the algorithm stores packets at intermediate nodes during transmission in a fixed buffer of memory. In case of ant loss, it helps in regeneration of ants for path finding.

X. Results

Consider the following network of Fig. 1. The aim is to send data packets from source node 1 to destination node 5.

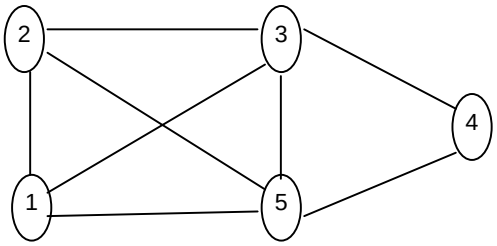


Fig. 1 Example Network

Initially route discovery routine is called by the node 1. This results in generation of following routing tables at each node.

TABLE I
ROUTING TABLE AT NODE 1

Destination	Next hop	pheromone
4	3	0.50
4	5	0.50
4	3	0.33

TABLE II
ROUTING TABLE AT NODE 2

Destination	Next hop	pheromone
1	1	1.00
1	3	0.50
1	5	0.50
4	5	0.50
4	3	0.50

TABLE III
ROUTING TABLE AT NODE 3

Destination	Next hop	pheromone
1	1	1.00
1	2	0.50
4	4	1.00
1	5	0.50
4	5	0.50
4	2	0.33

TABLE IV
ROUTING TABLE AT NODE 4

Destination	Next hop	pheromone
1	3	0.50
1	5	0.50

TABLE V
ROUTING TABLE AT NODE 5

Destination	Next hop	pheromone
1	1	1.00
1	2	0.50
1	3	0.50
4	4	1.00
4	3	0.50
4	2	0.30

Once the data discovery is done, the data packets from source node 1 will be sent to destination node 4 along the path 1-3-5 or 1-4-5, as the probability of these two paths are same. If packets are sent along 1-4-5, the concentration of pheromone along this path increases and further packets follow the same route. If the node 4 fails, then source 1 can redirect the traffic through node 3 will no degradation in throughput. This paper presents the enhancements of ARA [1] to improve the performance of routing algorithm. ARA [1] algorithm is enhanced to accommodate for loss of ants. The paper also describes the significance of resource reservation by which the performance can be improved.

XI. Conclusion

This paper presents an enhanced algorithm for generating all possible paths between source node and destination node in mobile ad hoc network using swarm intelligence. Routing of data packets is only through optimal path which is generated by route discovery phase as defined by ARA [2]. Route maintenance is done periodically to retain optimal path. This is done through data packets. Due to change in topology of ad hoc network, existing routes may fail or new paths may be generated. In order to adapt for the change in topology, route refreshing is done periodically. This paper describes the method for handling loss of ants and avoids retransmission of lost packets by reserving resources at nodes, which in turn enhances the performance.

XII. Future Enhancement

The current algorithm uses hop count as matric for optimization. Further, it can be extended for other matrices for optimization like load and multimedia data. Number of ants in the network is to be controlled as it may lead to congestion. The other improvement can be better distribution of bandwidth among data and control packets.

Acknowledgement

The authors gratefully acknowledge the support of Dr S C Sharma, Principal, R V College of Engineering, Bangalore and Professor B I Khodanpur, Head Department of Computer Science and Engineering, R V College of Engineering, Bangalore for their invaluable support and encouragement.

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