A Novel Algorithm for Manets using Ant Colony

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Abstract

Mobile Ad-hoc Networks have recently attracted a lot of attention in the research community as well as the industry. Quality of Service support for MANETs is an exigent task due to dynamic topology and limited resource. Routing, the act of moving information across network from a source to a destination. Conventional routing algorithms are difficult to be applied to a dynamic network topology, therefore modeling and design an efficient routing protocol in such dynamic networks is an important issue. It is important that MANETs should provide QoS support routing, such as acceptable delay, jitter and energy in the case of multimedia and real time applications. One of the meta-heuristic algorithms which are inspired by the behavior of real ants is called Ant Colony Optimization algorithm. In this paper we propose a new on demand QoS routing algorithm "Ant Routing for Mobile Ad Hoc Networks" based on ant colony. The proposed algorithm will be highly adaptive, efficient and scalable and mainly reduces end-to-end delay in high mobility cases.

Keywords: *MANET, Quality of Service (QoS), Ant Colony, Routing Protocol.*

1. Introduction

Mobile Ad hoc Networks (MANET) is a communication network of a set of mobile nodes, placed together in an ad hoc manner, without any fixed infrastructure that communicate with one another via wireless links. The devices used to form an Ad Hoc Network possess limited transmission range; therefore, the routes between a source and a destination are often multi hop. As there are no separate routers, nodes that are part of the network need to cooperate with each other for relaying packets of one another towards their ultimate destinations as they do not have central administration, it is easy to deploy and expand. This kind of network is very flexible and suitable for applications such as temporary information sharing in conferences, military actions and disaster rescues. However, multi-hop routing, random movement of mobile nodes and other features unique to MANETs lead to enormous overheads for route discovery and maintenance. Furthermore, compared with the traditional networks, MANETs suffer from the resource constraints in energy, computational capacities and bandwidth. [1]

With the increasing needs of QoS provisioning for evolving applications such as real-time audio/video, it is desirable to support these services in ad hoc networking environments. The network is expected to guarantee a set of measurable specified service attributes to the user in terms of end to-end delay, bandwidth, probability of packet loss, energy and delay variance (jitter). The role of a QoS routing strategy is to compute paths that are suitable for different type of traffic generated by various applications while maximizing the utilizations of network resources. [3] The major objectives of QoS routing are: [2]

1. To find a path from source to destination satisfying user's requirements
2. To optimize network resource usage and
3. To degrade the network performance when unwanted things like congestion, path breaks appear in the network.

The main problem to be solved by QoS routing algorithm is the Multi-Constraint Path problem. Algorithms to solve this family of problems are known to be heuristics which can reduce the complexity of the path computation. [2, 4]

The path computation algorithm is at the core of QoS routing strategies. Instead of using a shortest path algorithm based on statically configured metrics, as in traditional routing protocols, the algorithm must select several alternative paths that are able to satisfy a set of constraints regarding, for instance, end-to-end delay bounds and bandwidth requirements. However, the algorithms to solve such a problem have been shown to have, in general, high computational complexity. [3]

Several approaches have been proposed to address the complexity of multi-constrained path computation problem. The paths that satisfy these multiple constraints are called as feasible paths. The solution of this kind of multi constrained problem requires a path computation algorithm that finds paths satisfying all the constraints. Since the optimal solution of this type of problems with multiple additive and independent metrics is NP-complete, usually heuristics or approximation algorithms can be used to solve such kind of problems. [1] In this paper, I will present a new approach for an ad hoc routing algorithm, which is based on Ant Colony Optimization (ACO) algorithm. We show that for a wide range of different environments and performance metrics, ACO performs better than AODV, AOMDV.

The rest of the paper is organized as; section 2 discusses related ant based routing protocol. Section 3 describes the new proposed routing protocol. Section 4 discusses performance evaluation parameters and results of routing protocol followed by conclusions in section 5.

2. Ant colony optimization (ACO) algorithm

ACO algorithms have been inspired by the behavior of a real ant colony. The algorithm can find the optimum solution by generating artificial ants. Just as real ants search for food in their environment, the artificial ants search the solution space. The probabilistic movement of ants in the system allows the ants to explore new paths and to re-explore the paths visited earlier. The strength of the pheromone deposit directs the artificial ants toward the best paths and pheromone evaporation allows the system to forget old information and avoid quick convergence to suboptimal solutions. The probabilistic selection of paths allows the artificial ants to search for a large number of solutions. ACO has been applied successfully to discrete optimization problems such as the traveling salesman problem and routing [5, 6]. A number of proofs for the convergence to the optimum path of the ACO can be found in [8, 9].

2.1. Basic and Background

The basic idea of the ant colony optimization meta-heuristic is taken from the food searching behavior of real ants. When ants are on the way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit pheromone1, which marks the route taken. The concentration of pheromone on a certain path is an indication of its usage. With time the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamic into the path searching process. [7]

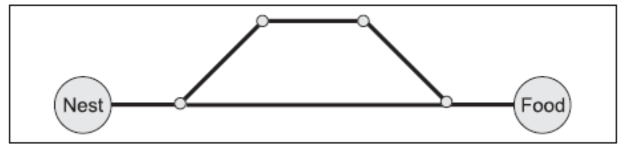

Fig. 1 All ants take the shortest path after an initial searching time. [7]

Figure 1 shows a scenario with two routes from the nest to the food place. At the intersection, the first ants randomly select the next branch. Since the below route is shorter than the upper one, the ants which take this path will reach the food place first. On their way back to the nest, the ants again have to select a path. After a short time the pheromone concentration on the shorter path will be higher than on the longer path, because the ants using the shorter path will increase the pheromone concentration faster. The shortest path will thus be identified and eventually all ants will only use this one.

This behavior of the ants can be used to find the shortest path in networks. Especially, the dynamic component of this method allows a high adaptation to changes in mobile ad-hoc network topology, since in these networks the existence of links are not guaranteed and link changes occur very often.[7]

2.2. Solving Network Routing Using ACO

Mobile ad hoc network routing is a difficult problem because network characteristics such as traffic load and network topology may vary stochastically and in a time varying nature. The distributed nature of network routing is well matched by the multi agent nature of ACO algorithms.[8] The given network can be represented as a construction graph where the vertices correspond to set of routers and the links correspond to the connectivity among routers in that network. Now network route finding problem is just finding a set of minimum cost path between nodes present in the corresponding graph representation which can be done easily by the ant algorithms.

3. Proposed Algorithm

This paper proposes an on demand QoS routing algorithm. Since the requirements for various applications may vary time to time, the approach for QoS routing may not be proactive. The proposed approach has two phases namely route discovery phase and route maintenance phase. When a source node has to pass data to a destination node with QoS requirements it starts with the route discovery phase. Once the route is found, the data transfer will take place. While data transmission is going on, it is also required to maintain the path to the destination. This is very much desirable and required in mobile ad hoc networks and hence is done in the route maintenance phase. The proposed algorithm differs from other similar algorithms because routing from destination to source is done.

3.1. Route Discovery Phase

The outline of this phase is as follows:
Step 1: Let the source node S has data to send to a destination D with QoS requirements delay, energy, bandwidth and hop count. Each node has a routing table.
Step 2: D initiates a ForwardAnt to source S through all its neighbors which it has learned from periodic hello messages.
Step 3: While traveling to the source the ForwardAnt collects transmission delay of each link, processing delay at each node, the available capacity of each link, the number of hops visited and stores in routing table each node.
Step 4: When the ForwardAnt reaches the source, it will be converted as BackwardAnt and forwarded towards the original destination. The BackwardAnt will take the same path of the corresponding ForwardAnt but in reverse direction.
Step 5: For every BackwardAnt reaching an intermediate node or destination node, the node can find the delay, bandwidth, hop count from the received ant to the respective destination. Now the node can calculate the path preference probability to reach the source.
Step 6: If calculated path preference probability value is better than the requirements, the path is accepted and stored in memory.
Step 7: The path with higher path preference probability will be considered as the best path and data transmission can be started along that path.
In similar algorithms, Route discovery is achieved by flooding forward ants to the destination then the backward will take the same path of the corresponding forward but in reverse direction. Finally, the data packets sent from source to destination. While the proposed algorithm, the algorithm starts from the destination node and the data packet is sent with the backward.
The above stochastic strategy, described in Algorithm 1, establishes multiple paths between the source and destination. As a result, in contrast to regular position based routing algorithms which usually find a single route to the destination, proposed algorithm is a multipath routing algorithm (i.e. like other ACO routing algorithms).

Algorithm 1 routing algorithm

```
{S is the source node, D is the destination node and
C is the current node}
for each clock time do
if C = S then
Send one BackwardAnt from reverse direction
else
Send one ForwardAnt to neighbors
end if
for each message m in D's buffer do
if (m→type = ForwardAnt)  then
send m to NextHop
if NextHop = S then
m →type = Backward
end if
else if m→type = BackwardAnt then
find NextHop in C's BackRouting table
send m to NextHop
IncreasePheromone(NextHop,m)
if NextHop = D or NextHop = Intemediate node then
update averages of packet delays and remaining energy
drop m
end if
end if
end for
Evaporate()
/*calculate higher path preference probability will be
considered as the best path and data transmission can be
started along that path*/
end for
```

3.2. Route maintenance phase

As mentioned before, the values of pheromone trails are stored in a table at each node. Suppose that a data is currently residing in node N and this node has k neighbors H_1, H_2... Hk and φ_i is the amount of pheromone assigned to e_i and d_i. The data will select H_i as the next node with a probability p_i (ed) which is calculated using the equation 3.

$$P_i(e) = \frac{e_i}{\sum e_i} \quad (1)$$

p_i (e) measure of energy consumption at node i is compared with the total energy consumption.

$$P_i(d) = \frac{1/d_i}{\sum 1/d_i} \quad (2)$$

pi (d) measure of routing delay at node i is compared with the total routing delay.

$$P_i(ed) \frac{P_i(e) + \boldsymbol{\theta} P_i(d)}{(\sum P_i(e) + \boldsymbol{\theta} P_i(d))} \qquad \boldsymbol{\theta} < 0 \qquad (\mathbf{3})$$

Where:
e_i: energy level of node i.
d_i: latency of node i.
θ : Constant value $\theta < 0$

Algorithm 2 Select Next Hop

Input: node N
for i = 1 to the number of N's neighbors do

$$P_i(ed)\frac{P_i(e)+\theta P_i(d)}{\sum(P_i(e)+\theta P_i(d))}$$

Return neighbor i with probability p_i
end for

Each node scans pi(ed) and selects the node with the highest preference and forwards the data packet (BackwardAnt) to this node. This process is repeated until the destination node is reached. The ants move from one node to another and carry table 1.

Table 1: route information

Node	Energy	Time	Estimated Waiting
X	Ex	t	Δt

4. Simulation and Performance analysis

VC++ 6.0 program is used to realize the simulation of the algorithm. For our results we assumed 50 mobile nodes communicating via IEEE 802.11. The nodes move inside a simulation area of 1500m*300m. The simulation time is 900 seconds. The nodes move with a maximal velocity of 10 m/s and according to the random waypoint mobility model.

4.1. Simulation and Performance analysis

A new routing algorithm should show its performance in comparison with existing and known algorithms. The simulated traffic is Constant Bit Rate (CBR). We compare our protocol with AODV and AOMDV. We evaluate mainly the performance according to the metrics packet delay, overload and packet delivery.
Our proposed algorithms are named MPAC (Multi Path Ant Colony). We will first discuss the robustness of the routing protocols. Figure 2 shows the delivery rate, i.e., the part of packets a certain routing protocol was able to deliver properly. This value is important, since it describes the performance which transport protocols will see, i.e., the throughput is restricted by this value.
In situations with very high dynamics MPAC shows the best performance. With less dynamic, down to 300 seconds of pause time, AODV has best performance. Because AODV uses particular route, over time this will destroy the path and find a new path will lead to delay. But in the proposed protocol does not caused a problem because use of different routes.
Figure 3 shows the overhead of MPAC. All results are very close through all simulation scenarios. This shows that MPAC creates much less routing overhead for all considered mobility scenarios.

Figure 4 depicts the needed number of packets to perform the routing job for all three routing algorithms. In the cases with high mobility it is obvious that MPAC and AOMDV create the least overhead. Especially MPAC shows here a better performance than AOMDV in high dynamic. With less, the overhead of MPAC and AODV are very close. AOMDV shows here again their poor performance by creating large numbers of routing packets.
Figure 5 show average remaining energy for all three routing algorithms. Remaining energy of MPAC is high than AODV and AODV. That is because optimum tour is established by the way of flooding, costing more time in MPAC, and lead to increasing consumption energy of network.

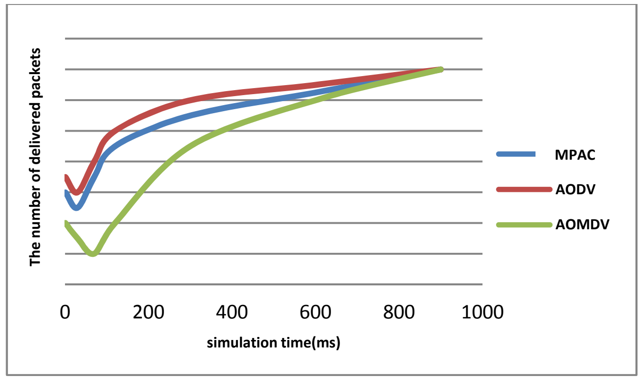

Fig. 2 Delivery rate

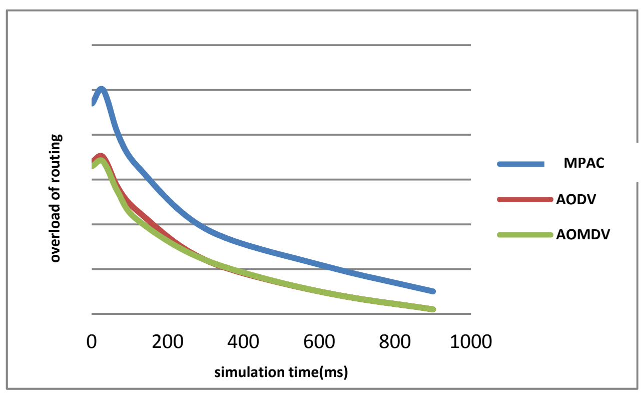

Fig. 3 Overhead

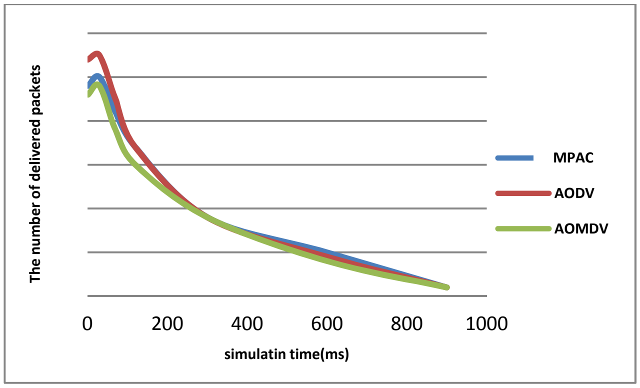

Fig. 4 Comparison of three protocols by the number of needed routing packets

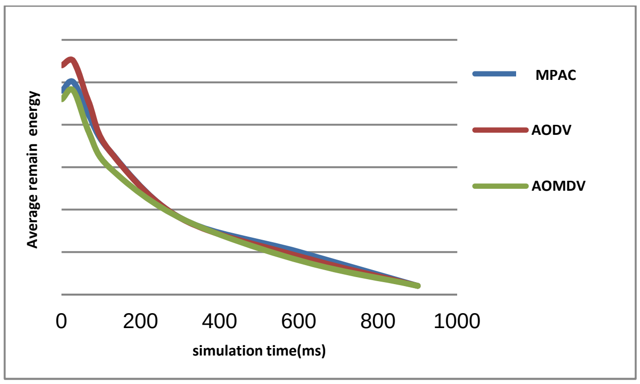

Fig. 5 Average remaining energy

5. Conclusion

In this paper, we have proposed an ant based routing protocol for mobile ad hoc networks. ACO based algorithms have specialized to provide adaptive and efficient solutions to network routing. AMPC provides multiple paths with comparatively less overhead in the network. The simulation results indicate that proposed scheme can perform better than AODV and AOMDV under high mobility because of alternate route maintenance scheme. In future, we have planned to investigate the performance of the algorithm for real-time multimedia data using various mobility models.

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