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Improving Quality of Services in MANETS using Ant Colony Based Routing

[1]D. Likhith Reddy, [2]V. V. Sunil Kumar
[1]Department of ECE, PBRVITS, Kavali, Andhra Pradesh, India
[2]Associate Professor, Department of CSE, PBRVITS, Kavali, Andhra Pradesh, India

Abstract: Mobile Ad Hoc Network (MANET) is a dynamic multihop wireless network which is established by a set of mobile nodes on a shared wireless channel. One of the major issues in MANET is routing due to the mobility of the nodes. Routing means the act of moving information across an internet work from a source to a destination. When it comes to MANET, the complexity increases due to various characteristics like dynamic topology, time varying QoS requirements, limited resources and energy etc. QoS routing plays an important role for providing QoS in wireless ad hoc networks. The biggest challenge in this kind of networks is to find a path between the communication end points satisfying user's QoS requirement. Nature-inspired algorithms (swarm intelligence) such as ant colony optimization (ACO) algorithms have shown to be a good technique for developing routing algorithms for MANETs. In this paper, a new QoS algorithm for mobile ad hoc network has been proposed. The proposed algorithm combines the idea of Ant Colony Optimization (ACO) with Optimized Link State Routing (OLSR) protocol to identify multiple stable paths between source and destination nodes.

Keywords: MANET, Ant Colony Optimization, Quality of Service (QoS) routing.

I. INTRODUCTION

A mobile ad hoc network (MANET) is a decentralized group of mobile nodes which exchange information temporarily by means of wireless transmission [1]. Since the nodes are mobile, the network topology may change rapidly and unpredictably over time. The network topology is unstructured and nodes may enter or leave at their will. A node can communicate to other nodes which are within its transmission range. This kind of network promises many advantages in terms of cost and flexibility compared to network with infrastructures. MANETs are very suitable for a great variety of applications such as data collection, seismic activities, and medical applications.

Unfortunately nodes in MANETs are limited in energy, bandwidth. These resources constraints pose a set of non trivial problems; in particular, routing and flow control.

Routing in communication networks is necessary because, generally, nodes are not directly connected. The main problem solved by any routing protocol is to direct traffic from sources to destinations, but nowadays, because of increasing complexity in modern networks, routing algorithms face important challenges [2].

The routing function is particularly challenging in these networks because the network structure is constantly changing and the network resources are limited. This is particularly true in wireless ad hoc networks where node mobility and link failures produce constant changes in the network topology. Routing algorithms lack of adaptability to frequent topological changes, limited resources, energy availability reduces network performance.

The demand for real time and quality of services (QoS) in the network has been increased as the internet expands. 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. But the problem of finding multi constrained paths has high computational complexity, and thus there is a need to use algorithms that address this difficulty. The major objectives of QoS routing are i) to find a path from source to destination satisfying user's requirements ii) To optimize network resource usage and iii)

To degrade the network performance when unwanted things like congestion, path breaks appear in the network [3].

In recent years, a large number of MANET routing algorithms have been proposed. These algorithms all deal with dynamic aspects of MANETs in their own way, using reactive or proactive behavior or a combination of both. The proposed algorithm in this paper is hybrid one. The hybrid algorithm is suitable for MANETs because it has flexibility to change according to change in the topology of the network. This is not possible with only proactive or only reactive type of routing algorithms i.e. reactive algorithms are suitable for mobile while proactive are suitable for stable network environment.

The paper is organized as follows: Section II of this paper basically gives the brief information about some previous works related to this research work. Section III describes the key concept of OLSR protocol. Section IV illustrates the basic idea behind ant colony optimization. Section V explains the proposed algorithm combining the idea of ACO and OLSR protocol. Section VI provides the mathematical evaluation of the algorithm. Concluding remarks are given in Section VIII.

II. PREVIOUS WORKS

Some works related to ACO and OLSR are found in the literature. In [1], the authors described a hybrid routing algorithm for MANETs based on ACO and zone routing framework of bordercasting. A new QoS routing protocol combined with the flow control mechanism has been done in [2]. This proposed routing solution is modeled by ant systems. The proposed routing protocol in [2] uses a new metric to find the route with higher transmission rate, less latency and better stability. P.Deepalakshmi. et.al [4] proposed a new on demand QoS routing algorithm based on ant colony metaheuristic. An algorithm of ant colony optimization for mobile ad hoc networks has been described in [5]. But the QoS issues end-to-end delay, available bandwidth, cost, loss probability, and error rate is not considered in [5]. A hybrid QoS routing algorithm has been proposed in [6]. In [6], the authors used ant's pheromone update process approach for improving QoS. But the authors described only bandwidth. Other QoS issues are not considered in [6]. Shahab Kamali. et.al [7] implemented a new ant colony based routing algorithm that uses the information about the location of nodes.

III. OLSR ROUTING PROTOCOL

The Optimized Link State Routing Protocol (OLSR) [3] is a proactive routing protocol. It is introduced by the IETF MANET working group for mobile ad-hoc networks for accuracy and stability. OLSR protocol is the enhanced version of pure link state routing protocol that chooses the optimal path during a flooding process for route setup and route maintenance. In OLSR, only symmetric links are used for route setup process. The key concept here is the selection of Multipoint Relays (MPR) among one-hop neighbors such that they cover all two-hop neighbors. The 'Hello Message' should be small in size to minimize the overhead. All the nodes are informed about the subset of all the available links and the link between MPR and MPR selectors. Every participating node maintains the topological information about the network. This is done by a Topology Control (TC) message. A node generates TC message to only for those neighbors in its MPR selector set after a time interval. Each node in the network also maintains a routing table to all known destinations in the network. Routing table is calculated from Topological Table, taking the connected pairs. The routing table contains Destination address, Next Hop address and Distance. This routing table is recalculated after every change in neighborhood table or in topological table.

The perfect network context for OLSR is low mobile and dense Ad Hoc networks. OLSR overhead control signals do not require for a reliable transmission link, which is suitable for wireless networks. OLSR supports node's mobility as far as it is traceable by its neighbors.

IV. ANT COLONY OPTIMIZATION

The ACO metaheuristic is based on generic problem representation and the definition of the ant's behavior. ACO adopts the foraging behavior of real ants. When multiple paths are available from nest to food, ants do random walk initially. During their trip to food as well as their return trip to nest, they lay a chemical substance called pheromone, which serves as a route mark that the ants have taken [4]. Subsequently, the newer ants will take a path which has higher pheromone concentration and also will reinforce the path they have taken. As a result of this autocatalytic effect, the solution emerges rapidly.

To illustrate this behavior, let us consider the experiment shown in Figure 1. A set of ants moves along a straight line from their nest A to a food source B (Figure 1a). At a given moment, an obstacle is put across this way so that side (C) is longer than side (D) (Figure 1b). The ants will thus have to decide which direction they will take: either C or D. The first ones will choose a random direction and will deposit pheromone along their way. Those taking the way ADB (or BDA), will arrive at the end of the obstacle (depositing more pheromone on their way) before those that take the way ACB (or BCA). The following ants' choice is then influenced by the pheromone intensity which stimulates them to choose the path ADB rather than the way ACB (Figure 1c). The ants will then find the shortest way between their nest and the food source.

In most cases, an artificial ant will deposit a quantity of pheromone represented by $\Delta\tau_{i,j}$ only after completing their route and not in an incremental way during their advancement. This quantity of pheromone is a function of the found route quality.

Pheromone is a volatile substance. An ant changes the amount of pheromone on the path (*i, j*) when moving from node *i* to node *j* as follows:

$$\tau_{i,j} = \sigma \cdot \tau_{i,j} + \Delta\tau_{i,j} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where σ is the pheromone evaporation factor. It must be lower than 1 to avoid pheromone accumulation and premature convergence.

At one point *i*, an ant chooses the point *j* (i.e. to follow the path (*i, j*)) according to the following probability:

$$P_{i,j} = \frac{(\tau_{i,j})^{\alpha} \cdot (\eta_{i,j})^{\beta}}{\sum_{(i,k) \in C} (\tau_{i,k})^{\alpha} \cdot (\eta_{i,k})^{\beta}} \quad \ldots\ldots\ldots\ldots (2)$$

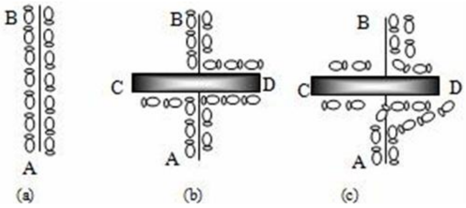

Figure 1: Behaviour of the Ants for searching the food

where,

- $\tau_{i,j}$: is the pheromone intensity on path (*i*, *j*).
- $\eta_{i,j}$: is the ant's visibility field on path (*i*, *j*)(an ant assumes that there is food at the end of this path).
- α and β : are the parameters which control the relative importance of the pheromone intensity compared to ant's visibility field.
- C: represents the set of possible paths starting from point *i* ((*i*,*k*) is a path of C).

A. 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. 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.

B. General Characteristics of ACO algorithms for routing

The following set of core properties characterizes ACO instances for routing problems:

1) Providing traffic-adaptive and multipath routing.
2) Relying on both passive and active information monitoring and gathering.
3) Making use of stochastic components.
4) Not allowing local estimates to have global impact.
5) Setting up paths in a less selfish way than in pure shortest path schemes favoring load balancing.
6) Showing limited sensitivity to parameter settings [4].

V. PROPOSED ALGORITHM

This paper proposes a QoS routing algorithm. The proposed approach has two phases namely path discovery phase and path maintenance phase. When a source node has to pass data to a destination node with QoS requirements it starts with the path discovery phase. Once the path 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 path maintenance phase.

A. Path Discovery Phase

STEP 1: Let the source node *S* has data to send to a destination *D* with QoS requirements higher transmission rate, less delay and more bandwidth. A list of nodes that are progressively visited by the ant is called visited nodes list. This list forms the route R from the source node to destination node.

STEP 2: Initially choose the source node S. The visited nodes list will be initialized to source node (S).

STEP3: S initiates a Path_Request_Ant to destination *D* through all its neighbors which are in 1-hop distance from S. The Path_Request_Ant contains source address, destination address, hop count and bandwidth.

STEP 4: After that the pheromone evaporation of all the 1-hop distance nodes will be calculated. Each node *(i)* maintains a table called "PMtab" a table of Pheromones specifying the quantity of available pheromone on each link (V_i, V_j). This quantity is initialized to constant C.

STEP 5: Then we calculate the pheromone evaporation of all the 2-hop distance nodes.

STEP 6: At last we calculate the path preference probability value of each path from source S with the help of pheromone evaporation of every node. A node j from a set of adjacent nodes (j, k, …., n) of i is selected as MPR node such that it covers all the 2-hop distance nodes and its path preference probability is better than others.

STEP 7: If calculated path preference probability value is better than the requirements, the path is accepted and stored in memory.

STEP 8: When the Path_Request_Ant reaches the destination, it will be converted as Path_Reply_Ant and forwarded towards the original source. The Path_Reply_Ant will take the same path of the corresponding Path_Request_Ant but in reverse direction.

STEP 9: The path with higher path preference probability will be considered as the best path and data transmission can be started along that path.

B. Path Maintenance Phase

When the data transmission is going on, the paths are reinforced positively making it more desirable for further selection. Also when session is going on, the load on the selected path may increase causing more delay and less available bandwidth; Nodes might have moved causing link failures. In such case, the path preference probability will automatically decrease and hence alternate routes can be used which are found during route discovery phase. The alternate routes are also periodically checked for their validity even though they are not currently used.

VI. QUANTITATIVE EVALUATION

Let G = (V, E) represents a mobile ad hoc network, where V denotes the set of network nodes and *E* denotes the set of bi-directional links. To find a route, our routing algorithm uses the pheromone accumulation ants laid on crossed links. This deposited quantity is the same on any link (V_i, V_j) along the route *R*. It is noted $\Delta\tau$ (V_i, V_j) and it is a function of the global quality of the route *R*. It is expressed by the following equation:

$$\Delta\tau\,(V_i, V_j) = \frac{B(R)^{\beta_B} + T(R)^{\beta_T}}{D(R)^{\beta_D}} \quad \ldots\ldots\ldots\ldots\ldots (3)\ [2]$$

where,

- $B(R) = min(B(V_i, V_i{+}1), B(V_i{+}1, V_i{+}2), \ldots, B(V_k - 1, V_k))$; The smallest link bandwidth in route *R* while V_i is the source node and V_k the destination node.
- $T(R) = min((T(V_i, V_i{+}1), T(V_i{+}1, V_i{+}2), \ldots, T(V_k - 1, V_k))$; The smallest link expiration time in route *R*.
- $D(R) = D(V_i, V_i{+}1) + D(V_i{+}1, V_i{+}2), \ldots + D(V_k - 1, V_k)$; The sum of delays on all links in route *R*.
- β_B, β_T and β_D denote the link weight factors that show the relative significance of each QoS parameter during pheromone update on a route *R* [2]. Although the pheromone is deposited on the link, its quantity (equation 3) is only defined after finding the route. It permits to appreciate in the same way all links forming the route. Nevertheless, the local quality of a link is taken into account in its choice. This local quality represents the heuristic factor or the visibility of the ant. It is given by the following equation:

$$\eta_{i,j} = \frac{B(V_i, V_j)^{\alpha_B} + T(V_i, V_j)^{\alpha_T}}{D(V_i, V_j)^{\alpha_D}} \quad \ldots\ldots\ldots\ldots (4)\ [2]$$

where αB, α_T and αD are parameters showing the relative importance of each QoS parameter during the link selection.

The pheromone quantity on the link (V_i, V_j) is:

$$\tau\,(V_i, V_j) = \rho \,.\, \tau\,(V_i, V_j) + \Delta\tau\,(V_i, V_j) \ \ldots\ldots\ldots(5)\ [2]$$

where ρ is the evaporation factor ($0 < \rho < 1$). It is used to avoid the infinite increment of pheromone on the link that may lead to stagnation route.

When an ant searches for a route, it chooses probabilistically one node among its neighbour's nodes that are not visited yet. The routing probability value between V_i and V_j is computed by the composition of the strength of pheromone values (equation 5) and the visibility values (equation 4).

$$P_{i,j} = \frac{[\tau\,(V_i, V_j)]^{\alpha} \cdot [\eta_{i,j}]^{\beta}}{\sum_{k \in M} [\tau\,(V_i, V_k)]^{\alpha} \cdot [\eta_{i,k}]^{\beta}} \quad \ldots\ldots\ldots (6)\ [2]$$

where:

- τ (V_i, V_j) is the amount of pheromone on the link (V_i, V_j).
- $\eta_{i,j}$ is the visibility of the link (V_i, V_j).
- α and β are two parameters that show the relative significance of the pheromone and the visibility during the process of QoS route discovery.
- M: is the set of all possible neighbor nodes V_k, not visited yet by the ant.

VII. CONCLUSIONS

This proposed routing strategy can be optimized to support multimedia communications in mobile ad hoc networks based on Ant Colony framework. The major complexity in mobile ad hoc network is to maintain the QoS features in the presence of dynamic topology, absence of centralized authority, time varying QoS Requirements etc. The challenges reside in ad hoc networks is to find a path between the communication end points satisfying user's QoS requirement which need to be maintain consistency. The algorithm consists of both reactive and proactive components. In a reactive path setup phase, an option of multiple paths selection can be used to build the link between the source and destination during a data session. For multimedia data to be sent, we need stable, failure-free paths and to achieve that the paths are continuously monitored and improved in a proactive way. Our previous work [8] also guaranteed QoS based proactive routing using flooding technique by best utilization of network resources. This proposal is based on ant-like mobile agents to establish multiple stable paths between source and destination nodes. Ant agents are used to select multiple nodes and these nodes use ant agents to establish connectivity with intermediate nodes. In future, this work can be extended for multicasting by using swarm intelligence with other QoS objectives such as load balancing, energy conservation, etc.

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