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Ant Colony Optimization Based Routing to Improve QoS in MANETs

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Abstract- A **mobile ad-hoc network (MANET) is a collection of wireless mobile nodes that dynamically self-organize to form an arbitrary and temporary network. The mobile nodes can communicate with each other without any fixed infrastructure. MANET can be set up quickly to facilitate communication in a hostile environment such as battlefield or emergency situation. For routing in MANETs, the complexity increases due to various characteristics like dynamic topology, time varying Quality of Service (QoS) requirements, limited resources and energy etc. QoS routing plays an important role for providing QoS in mobile ad hoc networks. The greatest challenge in this type of networks is to find a path between the communication end points satisfying user's QoS requirement. Intelligent routing 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 improving algorithm for mobile ad hoc network has been proposed. This algorithm combines the motive of Ant Colony Optimization (ACO) with Optimized Link State Routing (OLSR) protocol to identify multiple stable paths between source node and destination node to improve the QoS.**

Keywords- **Mobile ad hoc network, Ant Colony Optimization, Optimized Link State Routing, Quality of Service.**

I. Introduction

Routing in mobile ad hoc network (MANET) is a dynamic optimization problem as a MANET is a collection of mobile nodes which communicate over radio. This kind of networks are very flexible, thus they do not require any existing infrastructure or central administration. Therefore, mobile ad-hoc networks are suitable for temporary communication links. The biggest challenge in this kind of networks is to find a path between the communication end points, what is aggravated through the node mobility. Routing protocols in traditional wired networks could exploit high processing power and bandwidths available for them to implement broadcasting link-state like protocols or high-process demanding AI based algorithms to solve quality of service related optimization problems, QoS based routing becomes challenging in MANETs, as nodes should keep an up-to-date information about link status. Also, due to the dynamic nature of MANETs, maintaining the precise link state information is very difficult.

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 [5]. 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, and 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.

Quality of Service (QoS) based routing is a Routing mechanism under which paths for flows are determined based on some knowledge of resource availability in the network as well as the QoS requirement of flows. The main objectives of QoS based routing are[13]:Dynamic determination of feasible paths for accommodating the QoS of the given flow under policy constraints such as path cost, provider selection etc, optimal utilization of resources for improving total network throughput and graceful performance degradation during overload conditions giving better throughput. QoS routing strategies are classified as source routing, distributed routing and hierarchical routing. QoS based routing becomes challenging in MANETs, as nodes should keep an up-to-date information about link status. Also, due to the dynamic nature of MANETs, maintaining the precise link state information is very difficult. Finally, the reserved resource may not be guaranteed because of the mobility caused path breakage or power depletion of the mobile hosts. QoS routing should rapidly find a feasible new route to recover the service.

The paper is organized as followed: Section II basically gives the brief information about some previous works related to this research work. Section III & IV describe the key concepts of ACO and OLSR protocol respectively. Section V explains the proposed algorithm combining the idea of ACO and OLSR protocol. Lastly conclusion is in Section VI.

II. Previous Work

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 [3]. This proposed routing solution is modeled by ant systems. The proposed routing protocol in [3] uses a new metric to find the route with higher transmission rate, less latency and better stability. Te authors in [7] 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 [6]. But the authors described only bandwidth. Other QoS issues are not considered in [6]. Jaroslav Opatrny et.al in [8] implemented a new ant colony based routing algorithm that uses the information about the location of nodes.

III. ANT COLONY OPTIMIZATION

Ant colony optimization (ACO) is a stochastic approach for solving combinatorial optimization problems like routing in computer networks. The idea of this optimization is based on the observation of how ants optimize food gathering in the nature. Ant colony optimization algorithms use artificial ants to iteratively construct a solution for an optimization problem. We can explain an ant colony optimization algorithm in the figure 1[4] as follows.

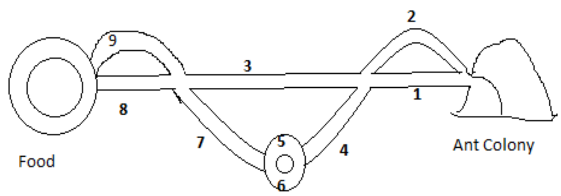

Figure 1: Ant Colony Network

The shortest path out of the above 12 paths is 1-3-8. Though some ants will move through other paths but the pheromone trail evaporation on 1-3-8 path would be lower in rate as compared to other paths and hence the ant follow-rate on this path would be maximum. Since being the shortest path, the ants travelling on this path will return earlier and hence will make deep impression of pheromone trail faster and other ants will follow this shortest path with maximum pheromone amount.

Any data travelling from its source to reach its destination would need to travel a number of intermediary nodes (these nodes can be servers or any service units). This can be seen as being in similar fashion like ants travelling from their colony to food source. Our foremost priority here is to formulate a technique in a manner such that the natural phenomenon of trail (stigmergy) can be implemented artificially for our purpose. What we would follow for our data packets would be a proactive model. In this model, the data packet would not be a function of conditioning and conditions but rather it would be a product of its choice, decision or self-awareness based on our implementation method of pheromone trail.

The ACO metaheuristic is based on generic problem representation and the definition of the ant's behavior as shown in figure 2. 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 Figure 2. A set of ants moves along a straight line from their nest A to a food source B (Figure 2a). At a given moment, an obstacle is put across this way so that side (C) is longer than side (D) (Figure 2b). 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 (Figure2c). 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 $H\tau_{i,j}$ 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.

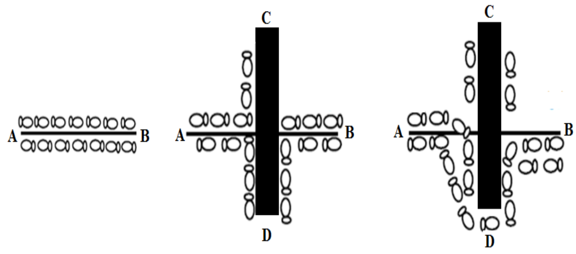

Figure 2: Ants, searching for food

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:

$$\tau_{i,j} = \sigma \cdot \tau_{i,j} + H\tau_{i,j} \quad \text{.....................} \ (1)$$

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:

$$P_{i,j} = ((\tau_{i,j})^{\alpha}(\eta_{i,j})^{\beta}) / (\Sigma_{(i,k)\in C}(\tau_{i,k})^{\alpha}(\eta_{i,k})^{\beta}) \quad \text{........................} \ (2)$$

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.

IV THE OLSR PROTOCOL

An OLSR is a proactive or table driven, link-state routing protocol. It was introduced by the IETF MANET working group for mobile ad-hoc networks for accuracy and stability. Link-state routing algorithms choose best route by determining various characteristics like link load, delay, bandwidth etc. Link-state routes are more reliable, stable and accurate in calculating best route and more complicated than hop count. To update topological information in each node, periodic message is broadcast over the network. Multipoint relays are used to facilitate efficient flooding of control message in the network. Route calculations are done by multipoint relays to form the rout from a given node to any destination in the network. The OLSR protocol is developed to work independently from other protocols. Conceptually, OLSR contain three generic elements: a mechanism for neighbor sensing, a mechanism for efficient flooding of control traffic, and a specification of how to select and diffuse sufficient topological information in the network in order to prove optimal routes [11].

A.*Neighbor Sensing*

In OLSR, neighbor nodes related information are gathered with “HELLO” messages which are send over network periodically [12]. These “HELLO” message detect changes in neighbor nodes and related information such as interface address, type of link symmetric, asymmetric or lost and list of neighbors known to the node. Each node update and maintain an information set, describing the neighbor and two-hop neighbor periodically after some time.

B. Multi Point Relay (MPR)

The idea of multipoint relays is to minimize the overhead of flooding message in the network by reducing redundant retransmission in the same region. In MPR (Multi Point Relay) a node which is selected by its one hop neighbor to “re-transmit” all the broadcast messages that it receive from other node, provided that the message is not a duplicate, and that the time to live field of the message is greater than one [12]. In OLSR protocol, Multi Point Relays use of “HELLO” message to find its one hop neighbor and its two hop neighbors through their response. Each node has a Multi Point Relay selection set, which indicates, which node acts as a MPR. Message is forward after the node gets new broadcast message and message sender’s interface address in the MPR Selector Set. MPR Selector Set is update continuously using “HELLO” message which are periodic because neighbor nodes is called of dynamic nature of MANET.

C. Topology Control Information

Topology Control messages are diffused with the purpose of providing each node in the network with sufficient link-state information to allow route calculation [12]. TC messages are broadcast periodically by a node. Like “HELLO” messages with these TC messages the topological information are diffused over the entire network. A minimum criteria for the node is to send at least the link of its MPR Selector Set [10], [11].

D. Routing Discovery

To work in distributed manner, OLSR does not depend on any central entity [12]. Each node chooses its as multipoint relays (MPR) which are responsible to forward control traffics by flooding. The nodes maintain the network topology information where MPRs provide a shortest path to a destination with declaration and exchange of the link information periodically for their MPR’s selectors. The HELLO messages are broadcast periodically for neighbor’s detection and MPR selection process. It contains how often node send HELLO messages. It also includes node’s MPR willingness and information about neighbor node. The information of node’s is in the form of its link type, interface address and neighbor type. The neighbor type can be one of: symmetric, MPR or not a neighbor. Link type indicates whether link is symmetric, asymmetric or lost link. A node is chosen as MPR if link to the neighbor is symmetric. A node builds a one hop routing table with the reception of HELLO message information. It discards duplicate packet with same sequence number. The node updates when there is change in neighbor r node or route to a destination has expired. OLSR does not require sequenced delivery of messages as each control message contains a sequence number which is incremented for each message.

E. Source Routing

Multiple paths calculated between a pair of source destination are independent, and they have no common nodes. However, because of the characteristic of next hop routing in OLSR, node can forward data based on its own routing table, and it cannot get the correct next node, source will forward, so cross among multiple paths happens. To avoid the problem for the next-hop routing in standard OLSR protocol, we use the source path in our multipath_OLSR algorithm. When a node calculates a path, the information of the path is recorded in its routing table. So, when source send data along the path, it adds the source path to the IP header in the data. Now the intermediate nodes only need to get the path information from IP header of data to forward the data, need not to query its routing table as in standard OLSR protocol. So, the mechanism of source path added to multipath OLSR can avoid the problem of next hop node.

V. PROPOSED 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).

STEP 3: 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 containssource 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. CONCLUSION

The 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. 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,

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