# RECENT TRENDS IN ANT BASED ROUTING PROTOCOLS FOR MANET

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*ABSTRACT*

*A Mobile Ad hoc Network (MANET) is based on a self-organizing and rapidly deployed network. In this network all nodes are mobile and communicate with each other via wireless communications. Nodes can join and leave at any time and there is no fixed infrastructure. All the nodes are equal and there is no designated router nodes that may serve as routers for each other and data packets are forwarded from node to node in a multi-hop fashion. Many routing protocols have been proposed for MANETs in the recent past. Ant-based routing provides promising alternative to conventional approaches. These agents are autonomous entities, both proactive and reactive, and have the capability to adapt, cooperate and move intelligently from one location to the other in the communication network. In this paper, we have provided an overview of a wide range of ant based routing protocols with the intent of serving as a quick reference to the current research in Ad hoc networking.*

*KEYWORDS:* *Ant colony optimization (ACO), Mobile Ad hoc Network (MANET), Routing Algorithms, Quality of Service (QoS), Fuzzy Logic.*

## I.    INTRODUCTION

In MANET, each host must act as router, since routes are mostly multi-hop, due to the limited propagation range (250 meters in an open field). Due to the continuous movement of the nodes, the backbone of the network is continuously reconstructed. To guarantee Quality of Service (QoS) communications in a wireless Mobile Ad hoc Network, routing protocol together with MAC protocols are the crucial points. Routing protocols are thus responsible for maintaining and reconstructing the routes in timely basis as well as establishing the durable routes.

A relatively new field in terms of its application to combinatorial optimization problems is Swarm Intelligence (SI). The concept of Ant Algorithms has been applied to both theoretical and practical optimization problems with great success. The performance exhibited by ant algorithms and the possibility of adaptation to new problems make the study of this field very worthwhile.

Ant algorithms are an iterative, probabilistic meta-heuristic for finding solutions to combinatorial optimization problems. They are based on the foraging mechanism employed by real ants attempting to find a shortest path from their nest to a food source. While foraging, the ants communicate indirectly via pheromone, which they use to mark their respective paths and which attracts other ants. In the ant algorithm, artificial ants use virtual pheromone to update their path through the decision graph, i.e. the path that reflects which alternative an ant chooses at certain points. Ants of the later iterations use the pheromone marks of previous good ants as a means of orientation when constructing their own solutions, which ultimately result in focusing the ants on promising parts of the search

space. In sometimes, a problem might be dynamic in nature, changing over time and requiring the algorithm to keep track of the occurring modifications in order to be able to present a valid, good solution at all times. Ant algorithms have a number of attractive features, including adaptation, robustness and decentralized nature, which are well suited for routing in MANETs.

The remainder of this paper is organized as follows. In Section 2 presents an overview of ACO and its variants. In Section 3 presents the different ant based algorithms available for routing in MANET. In Section 4, describes Recent Research Trends in ACO for MANET. Finally conclusion is drawn in Section 5.

## II.    OVERVIEW OF ANT COLONY OPTIMIZATION (ACO)

Combinatorial optimization problems such as routing can be solved using ACO in computer networks. Observing the optimization of food gathering by the ants is the basic idea of this optimization. The foraging behaviour of real ants has been implemented by Ant Colony Optimization. Initially, the ants walk randomly when multiple paths are available from nest to food. A chemical substance called pheromone is laid by the ants while travelling towards food and also during the return trip. This serves as the route mark. The path which has a higher pheromone concentration is selected by the new ants and that path is reinforced. A rapid solution can be obtained by this autocatalytic effect [1]. Forward ants (FANT) and backward ants (BANT) are used for creating new routes. A pheromone track is established to the source node by a FANT and to the destination node by a BANT. A small packet with a unique sequence number is known as the FANT. Depending upon the sequence number and the source address of the FANT, the duplicate packets can be distinguished by the nodes.

Ant-based routing algorithms were basically developed for wired networks. They work in a distributed and localized way, and are able to observe and adapt to changes in traffic patterns. 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 shared wireless channels. Although the data rate of wireless communications can be quite high, algorithms used for medium access control create a lot of overhead both in terms of control packets and delay thereby lowering the effectively available bandwidth.

The properties of ant based algorithm which make them suitable for MANET routing are:

• Dynamic topology:

This property is responsible for the poor performance of many 'classical' routing algorithms in mobile multi-hop ad-hoc networks. The ant algorithm is based on autonomous agent systems imitating individual ants. This allows a high adaptation to the current topology of the network.

• Local work:

In contrast to other routing approaches, the ant algorithm is based only on local information, i.e. no routing tables or other information blocks have to be transmitted to other nodes of the network.

• Link  quality:

 It  is   possible to   integrate   the connection/link quality into the computation of the pheromone concentration, especially into the evaporation process. This will improve the decision process with respect to the   link quality.  It is important to note that the approach can be modified so that nodes can also manipulate the pheromone concentration independent of the ants, e.g. if a node detects a change of the link quality.

• Support for  multi-path:

Each node has a routing table with entries for all its neighbours, which also contain the pheromone concentration. The decision rule for selection of the next node is based on the pheromone concentration at the current node, which is provided for each possible link. Thus, the approach supports multipath routing [2].

## III.    ANT COLONY BASED ROUTING ALGORITHMS FOR MANETs

A relatively new approach to routing is the mobile agent based routing (MABR) or ant routing which combines the routing protocol and the routing algorithm into a single entity. MABR [3] is a proactive routing protocol. In ant based routing the nodes maintain probabilistic routing tables, which are

updated periodically by mobile agents (ants) based on the quality of paths. The quality of paths is expressed in terms of metrics such as hop count, end-to-end delay, packet loss etc. The probabilistic routing tables contain the probability of choosing a neighbour as the next hop for destination. This protocol is responsible for updating the routing tables of logical routers and determining logical paths for routing packets [4].

A Probabilistic Emergent Routing Algorithm for MANETs (PERA) which presented in [5] is a proactive routing algorithm for MANET based on the swarm intelligence paradigm and similar to the swarm intelligence algorithms. The algorithm uses three kinds of agents, regular forward ants, uniform forward ants and backward ants. Uniform and regular forward ants are agents (routing packets) that are of unicast type. These agents proactively explore and reinforce available paths in the network. They create a probability distribution at each node for its neighbours. The probability or goodness value at a node for its neighbour reflects the likelihood of a data packet reaching its destination by taking the neighbour as a next hop.

Backward ants are utilized to propagate the information collected by forward ants through the network and to adjust the routing table entries according to the perceived network status. Nodes proactively and periodically send out forward regular and uniform ants to randomly chosen destinations. Thus, regardless of whether a packet needs to be sent from a node to another node in the network or not, each node creates and periodically updates the routing tables to all the other nodes in the network. The algorithm assumes bidirectional links in the network and that all the nodes in the network fully cooperate in the operation of the algorithm.

A new proactive routing algorithm for MANET (NPR) [6] is proactively sets up multiple paths between the source and the destination. The two factors that affect the performance of a probabilistic algorithm are exploration and exploitation. In a dynamically changing topology of the MANETs where there are frequent link breakages due to node mobility, an optimal balance between exploration and exploitation is required. More emphasis on exploitation will cause the probabilities of few routes to saturate to 1 and the probabilities of other routes to saturate to 0. As a result new routes will never be discovered. Author suggested a modification of the state transition rule in ACO to balance exploration and exploitation. According to the modified rule, the ants may be unicast or broadcast at a node depending on the route information. If the route information to the destination is present, the ants are unicast, otherwise it is broadcast.

PACONET [7] is a reactive routing protocol for MANETs inspired by the foraging behaviour of ants. It uses the principles of ACO routing to develop a suitable problem solution. It uses two kinds of agents: Forward ants (FANT) and backward ants (BANT). The FANT explore the paths of the network in a restricted broadcast manner in search of routes from a source to a destination. The BANT establishes the path information acquired by the FANT. These agents create a bias at each node for its neighbours by leaving a pheromone amount from its source. Data packets are stochastically transmitted towards nodes with higher pheromone concentration along the path to the destination. FANTs also travel towards nodes of higher concentration but only if there exists no unvisited neighbour node in the routing table. This algorithm focuses on efficiency and effectiveness of the approach as a solution to the routing problem in a simulated ad hoc environment.

PBANT [8] algorithm which optimizes the route discovery process by considering the position of the nodes. The position details of the nodes (position of the source node, its neighbours and the position of the destination) can be obtained by positioning instruments such as GPS receiver to improve routing efficiency and reduce the algorithm overhead. PBANT is basically ARA where position details of the nodes are known in advanced. PBANT is a robust, scalable reactive routing algorithm suitable for MANETs with irregular transmission ranges.

Ant-E [9] proposed by Sethi and Udgata is a novel metaheuristic on-demand routing protocol, using the Blocking Expanding Ring Search (Blocking-ERS) to control the overhead and local retransmission to improve the reliability. Blocking-ERS does not resume its route search procedure from the originating source node when a rebroadcast is required if the destination is not found. The rebroadcast can be generated by any appropriate intermediate node instead of originating source node. The rebroadcast can be performed on behalf of the originating source node act as relay. This method enhances the efficiency of MANET routing protocol. Ant-E is used to solve complex optimization problems and utilizes a collection of mobile agents as "ants" to perform optimal routing activities.

Ant-AODV [10] forms a hybrid of both ant-based routing and AODV routing protocols to overcome some of their inherent drawbacks. The hybrid technique enhances the node connectivity and decreases the end-to-end delay and route discovery latency. Ant-AODV ant agents work independently and provide routes to the nodes. The nodes also have the capability of launching on-demand route discovery to find routes to destinations for which they do not have a fresh enough route entry. The use of ants with AODV increases the node connectivity (the number of destinations for which a node has un-expired routes), which in turn reduces the amount of route discoveries even if a node launches a RREQ (for a destination it does not have a fresh enough route), the probability of its receiving replies quickly (as compared to AODV) from nearby nodes is high due to the increased connectivity of all the nodes resulting in reduced route discovery latency. As ant agents update the routes continuously, a source node can switch from a longer (and stale) route to a newer and shorter route provided by the ants. This leads to a considerable decrease in the average end-to- end delay as compared to both AODV and ants-based routing. Ant-AODV uses route error messages (RERR) to inform upstream nodes of a local link failure similar to AODV.

ARAMA [11] is a combination of on demand and table driven algorithms proposed by Hossein and Saadawi. The main task of the forward ant as in other ACO algorithms for MANETs is to collect path information. However, in ARAMA, the forward ant takes into account not only the hop count factor, as most protocols do, but also the links local heuristic along the route such as the node's battery power and queue delay. ARAMA defines a value called grade. This value is calculated by each backward ant, which is a function of the path information stored in the forward ant. At each node, the backward ant updates the pheromone amount of the node's routing table, using the grade value. The protocol uses the same grade to update pheromone value of all links.

It focuses on optimizing different Quality of Service parameters, other than number of hops. Such parameters include energy, delay, battery power, mobility etc. ARAMA proposed a path grading enforcement function that can be modified to include these QoS parameters. One of the important attributes of this algorithm is that the lifetime of the ad hoc nodes have been extended by using a fair distribution of energy across the network.

HOPNET [12] based on ants hopping from one zone to the next is highly scalable for large networks compared to other hybrid protocols. The algorithm has features extracted from ZRP and DSR protocols. The HOPNET algorithm consists of the local proactive route discovery within a node's neighbourhood and reactive communication between the neighbourhoods. The network is divided into zones which are the node's local neighbourhood. The size of the zone is not determined locally but by the radius length measured in hops. Therefore, a routing zone consists of the nodes and all other nodes within the specified radius length. A node may be within multiple overlapping zones and zones could vary in size. The nodes can be categorized as interior and boundary (or peripheral) nodes. Boundary nodes are at a distance from the central node. All other nodes less than the radius are interior nodes. Each node has two routing tables: Intrazone Routing Table (IntraRT) and Interzone Routing Table (lnterRT). The IntraRT is proactively maintained so that a node can obtain a path to any node within its zone quickly.

**Table 1:** Basic characteristics of Ant based routing protocols

| Algorithm | Algorithm Type | Year | Proposed by | Types of Ants | Ants Sending | Route Recovery |
|---|---|---|---|---|---|---|
| MABR | Proactive | 2003 | Heissen and Braun | Forward Ant, Backward Ant | Periodic | Use alternate route |
| PERA | Proactive | 2003 | Baras and Mehta | Regular Forward Ant, uniform forward ants, Backward Ant | Uniform and regular | Use alternate route |
| NPR | Proactive | 2010 | Mamoun | Forward Ant, Backward Ant | Regular intervals | Use alternate route |

| | | | | | | |
|---|---|---|---|---|---|---|
| PACONET | Reactive | 2008 | Osagie et al. | Forward Ant, Backward Ant | Regular time interval | Modify routing table |
| PBANT | Reactive | 2010 | Sujatha and Sathyanarayana | Forward Ant, Backward Ant | Source launches N forward ants from each zone at regular time interval | Check pheromone trail corresponding to link for alternate route |
| ANT-E | Reactive | 2010 | Sethi and Udgata | Forward Ant, Backward Ant update ants | Broadcast FANT to all its one-hop neighbors | Searches for an alternative link in its routing table |
| ANT-AODV | Hybrid | 2002 | Marwaha et al. | Ant agents work independently | Periodic | Erase route then local route repair |
| ARAMA | Hybrid | 2003 | Hossein and Saadawi | Forward Ant, Backward Ant | Triggered by connection request | Uses the next available path |
| HOPNET | Hybrid | 2009 | Wang et al. | Forward Ant, internal forward ant Backward Ant external forward ant | Periodic | Local path repair or by warning preceding nodes on the paths. |

## IV.    RECENT RESEARCH TRENDS IN ACO

### 4.1 Ant Based Quality of Service (QOS) Routing Algorithms

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.

A first example of a SI based algorithm for QoS routing is the AntNet+SELA [13]. It is a model for delivering both best-effort and QoS traffic in ATM (connection- oriented) networks. It is a hybrid algorithm that combines AntNet-FA with a stochastic estimator learning automation at the nodes. In addition to same best-effort functionalities that have in AntNet-FA, the ant-like agents serve for the purpose of gathering information which is exploited by the automata to define and allocate on-demand feasible paths for QoS traffic sessions.

Ant colony based Multi-path QoS-aware Routing (AMQR) [14] used ants to set up multiple link disjoint paths. The source node stores information about the paths followed by different ants, and combines it to construct a topology database for the network. Based on this database, it calculates n different link disjoint paths, and it sends data packets over these different paths. Pheromone is updated by the data packets.

Swarm-based Distance Vector Routing (SDVR) [15] a straightforward on-demand implementation of an AntNet scheme that uses multiple pheromone tables, one for each different QoS parameter, and combines them at decision time. A pheromone evaporation mechanism is used to reduce the attractiveness of old paths. SDVR systematically outperforms AODV in small networks.

An Effective Ant-Colony Based Routing Algorithm (AMQRA) [16] for MANET, which deals with the routing in 3 steps: routing discovery, routing maintenance and route failure discovery. In this routing scheme, each path is marked by path grade, which is calculated from the combination of multiple constrained QoS parameters such as the time delay, packet loss rate and bandwidth. For route failure the algorithm suggests when a node receives wrong messages, first it set the pheromone value to zero, and then the routing table is searched. If there are alternate routes to the destination node, data

packets would be sent by the new routes else an ERROR messages are sent via inverse routing to inform upper nodes, and the upper nodes will delete failure route.

In [17] presented an overview of the research related to the provision of QoS in MANETs also discussed methods of QoS at different levels including those at the levels of routing, Medium Access Control (MAC), and cross layer.

ARQoS [18] is an on-demand routing protocol for MANET, where the routing table of ARQoS maintains an alternate route to the specified node by considering the bandwidth requirement of the source node. The route is discovered by calculating the corresponding QoS provision parameter (bandwidth) to find the primary route and the alternate route from the source node to destination. ARQoS can significantly reduce end-to-end delay and increase packet delivery ratio under conditions of high load and moderate to high mobility.

Protocol proposed in [19] for wireless mobile heterogeneous networks based on the use of path information, traffic , stability estimation factors as signal interference, signal power and bandwidth resource information at each node    This protocol deal with the inability of the network to recover in case of networks failure, to reduce the maintenance overhead , increase the path stability, reducing the congestion in MANET by using swarm intelligence based routing by introducing a new concept of three ants for path formation, link failure and control.

## 4.2 Fuzzy Logic Approach for Routing in Communication Network

The aim of Soft Computing is to exploit the tolerance for imprecision, uncertainty, approximate reasoning, and partial truth in order to achieve close resemblance with human like decision making. Algorithms developed on the basis of fuzzy logic are generally found to be adaptive in nature. Thus, it can accommodate to the changes of a dynamic environment.

FuzzyAntNet [20] which is based on swarm intelligence and optimized fuzzy systems. FuzzyAntNet is a new routing algorithm which is constructed by the communication model observed in ant colonies. Two special characteristics of this method are scalability to network changes and capability to recognize the best route from source to destination with low delay, traffic and high bandwidth. Using this method congestion in data packet transmission can be avoided. FuzzyAntnet showed a scalable and robust mechanism with the ability to reach a stable behaviour even in changing network environment. However it has been investigated only for fixed topology networks.

Fuzzy Logic Ant based Routing (FLAR) [21] inspired by swarm intelligence and enhanced by fuzzy logic technique as adaptive routing. The algorithm shows better performance and higher fault tolerance in state of link failures.

A better approach in the field of communication networks called adaptive fuzzy ant-based routing (AFAR) [22] algorithm uses ants (or intelligent agents) to establish links between pair of nodes and simultaneously exploring the network and exchanging obtained information to update the routing tables. Based on the current network state, the knowledge constructed by the previous set of behaviours of other agents and taking advantage of the fuzzy logic techniques, routing decisions are made. The fuzzy logic technique allows multiple constraints such as path delay and path utilization to be considered in a simple and intuitive way.

The advantages of this algorithm includes increased flexibility in the constraints that can be considered together in making the routing decision efficiently and likewise the simplicity in taking into account multiple constraints. It handles an increased traffic load as well as decreased transmission delay by utilizing network resources more efficiently. However AFAR works well with communication network.

Fuzzy Stochastic Multipath Routing (FSMR) protocol [23] considering multiple metrics such as hop count, battery power, and signal strength to generate multiple optimal paths based on fuzzy logic. Stochastically data is forwarded on these multiple paths resulting into automatic load balancing and fault tolerance, in this protocol route failure is identified through a missing acknowledgement. If a certain link gets fail, it deactivates that link and searches for the alternative path.

An efficient fuzzy ant colony based routing protocol (FACO) [24] using fuzzy logic and swarm intelligence. Unlike other algorithms that find an optimal path by considering only one or two route selection metrics, this algorithm is used to select optimal path by considering optimization of multiple objectives while retaining the advantages of swarm based intelligence algorithm. FACO extends the idea of using fuzzy logic in ant colony based protocol to present a multi-objective routing algorithm in

MANETs for finding the most preferred route by evaluating the alternatives against the multiple objectives and selecting the route which best achieves the various objectives. Fuzzy logic is used in route discovery phase. The fuzzy cost here represents the cost that is calculated or which is dependent on multiple metrics thus giving an optimum route.

Siddesh et al. [25] proposed a protocol for routing in ad hoc networks for establishing the link between the nodes in minimum time it uses soft computing techniques like neural networks, fuzzy logic and genetic algorithm. A judicious mixture of ANN with Fuzzy Logic and Genetic Algorithms personifies a powerful mechanism in protocol development and routing strategies in Ad hoc Networks.

Aromoon and Keeratiwintakorn [26] proposed an algorithm that tries to optimize the performance of the proactive OLSR routing protocol in terms of key metrics for real time services End-to-End Delay and Throughput within the selected stable-connecting route, in terms of the number of link disconnection during a unit of time. The fuzzy heuristic OLSR routing is an improvement OLSR routing protocol by using the fuzzy heuristic means. FTAR [27] algorithm uses fuzzy logic and swarm intelligence to select optimal path by considering optimization of multiple objectives. It ensures trusted routing by using fuzzy logic.

## V. CONCLUSION

This work investigates recent research trends in Ant based routing for MANETs. We found that some issues such as Quality of service routing and route failure management attracted much attention. Many techniques were proposed based on ant based routing protocol which can effectively find the globally best solution in terms of routing for a given ad hoc network. Few existing techniques consider the QoS requirements and bandwidth considerations for the transmission of data. It is observed that due to nodal mobility, unstable links and limited resources in MANET, routing algorithm found to be unsuitable for routing after link failure. To overcome this, some of the ant colony based algorithms use Fuzzy rule-based systems.

Fuzzy based ant routing showed a scalable and robust mechanism with the ability to reach a stable behaviour even in changing network environment, better performance and higher fault tolerance in state of link failures.

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