

A SURVEY OF ANT COLONY BASED ROUTING ALGORITHMS FOR MANET

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Abstract

A Mobile ad hoc network (MANET) is a collection of wireless mobile nodes which dynamically join the network and cooperate with each other for multi-hop communication in absence of infrastructure or centralized administration. Routing in MANET is specially challenging due to the variation of network characteristic like traffic load and topology may vary in stochastic and time varying manner. Swarm Intelligence (SI) based techniques such as Ant Colony Optimization (ACO) algorithms have shown to be a good technique for developing routing algorithms for ad hoc networks. Ant based routing algorithms are based on the foraging behaviour of ants. In recent years several ant colony optimization based algorithms were introduced to solve multi constraint QoS routing problems of ad hoc network. They are more robust, reliable and scalable compared to the conventional routing algorithms available in ad hoc network. In this paper, survey of various ant based routing algorithms is done and have been summarize with various attributes to provide a status of research work done in this field.

Keywords: Mobile ad hoc network (MANET), routing protocols, ant colony optimization (ACO)

Introduction:

A Mobile ad hoc network (MANET) is a class of wireless network where mobile nodes communicate with each other without any pre-existing infrastructure network and centralized control. In MANET, communications between neighbouring nodes are done directly while the remote nodes are based on multihop wireless links. Mobile nodes in the network not only acts as hosts but also acts as source of data, destination for data and a forwarder of the data. Besides that they also functions as network router that discover and maintain routes to other nodes in the network. With the use of routing protocol, nodes are capable of communicating with other nodes in the dynamic environment of MANET. Routing in MANET is challenging in the absence of central coordinator as compared to other wireless networks where base station or fixed routers manage routing decisions. Designing of routing protocol in ad hoc network depends on various factors like mobility, bandwidth, resource constraints, communication environment etc. Types of MANET applications and inherent characteristic make data routing quite challenging and general purpose ad hoc network routing protocols cannot work efficiently with it. For effective routing, MANET protocol should provide low control overhead, effective adaption to topological changes, low packet delays, high throughput and optimized battery power utilization. The balance of all these conflicting objectives is very hard. For the optimization of the stated objectives, Swarm intelligent based meta-heuristics approach ACO is more promising than other algorithms in MANETs.

The paper is organized as follows. Section 2 describes basic principles of ant colony optimization. Section 3 describes survey of ant colony based algorithms. Section 4 describes comparison of algorithms in terms of structure attributes, performance metrics and network parameters. Section 5 concludes the paper.

Ant Colony Optimization:

Swarm intelligence (SI) is a kind of artificial intelligence that aims to simulate the swarms behaviour such as ant colonies, honey bees, bird flocks, particle swarm optimization and artificial immune system etc. Ant Colony Optimization (ACO) is a class of optimization algorithms, inspired by an organized collaborative behaviour of ants. Ants are creatures of nature with limited intelligence, which are wandering around their nests to forage for food. The ant colony optimization algorithmic approach models the concept of food foraging, net building, division of labour, cooperative support, self assembly and cemetery organization of real ants for the meta-heuristic approaches [Z. Ali and W. Shahzad, 2013]. ACO has been formalized in to a meta-heuristic computational approach by Marco Dorigo in 1996. While finding root from nest (source) to food (destination), ants communicate with other ants by depositing traces of pheromone (chemical substance) as they walk along their path. This indirect form of communication is called as stigmergy. As more ants travel over a particular path, the concentration of pheromone increases along that path. Pheromone along a path gradually evaporates, decreasing their concentration on that path. Among the multiple path between nest and food ants select the single optimal path on the basis of maximum pheromone concentration along the path and some heuristic functions. In [S. Mangai, A. Tamilarasi and C. Venkatesh, 2008], ACO algorithm is defined as following:

Algorithm 1: ANT Colony based Optimization

Input: An instance x of a combine optimization problem

While termination condition not met do

Schedule activities

Ant based solution construction ()

Pheromone update ()

Daemon actions ()

End scheduled activities

S_{best} \rightarrow best solution in the population of solutions

End while

Output: S_{best} candidate to optimal solution for x

Construct Solutions chooses a subset from the set of components. The solution begins with an empty partial solution and then at each construction step a feasible component is added in that. The choice of the next feasible component is made by the path selection equation which depends on the ant algorithm system being used. *Update Pheromones* serves two tasks: To increase the pheromone values of the components which are good, and to decrease the pheromone values of the components which are bad. The pheromone decrease is achieved through evaporation. Many different algorithms have been proposed with different pheromone update equations. *Daemon Actions* are usually used to perform centralized actions that cannot be performed by a single ant and that may be problem specific. This action decides to deposit extra pheromone on the solution components that belong to the best solution.

The distributed nature of network routing is well matched with multi-agent nature of ACO algorithms. The set of core properties [M. Dorigo, M. Birattari and T. Stützle, 2006] that characterizes ACO instances for routing problems are: a) provides traffic-adaptive and multipath routing b) relying on both passive and active information monitoring and gathering c) making use of stochastic components d) not allowing local estimates to have global impact e) setting up paths in a less selfish way than in pure shortest path schemes favouring load balancing and f) showing limited sensitivity to parameter settings.

Survey of Ant Colony Based Algorithms:

In this section, various research achievements for unicast and multicast routing protocol with ant colony optimization are defined.

S. Mangai et al. (2008) proposed Dynamic Core based Multicast Protocol (DCMP) which is source initiated multicast protocol implemented using ant colony optimization. In DCMP, the number of source nodes which floods join request packets are reduced, thereby reducing the number of forwarding nodes. In DCMP, there are three type of sources named - passive sources, active sources and core active sources. Mesh maintenance is soft state similar to that of On Demand Multicast Routing Protocol (ODMRP). In NS2, 50 nodes move in the region of 1000*1000 m² with node speed between 0 to 20 m/s and pause time is 10 seconds. Simulation time is taken as 600 seconds and Constant Bit Rate (CBR) traffic load is 10 packets/second. Result shows that packet delivery ratio is increased and control overhead is decreased with respect to node speed.

Kewen Li et al. (2008) proposed an improved ant colony based algorithm for multi-constrained QoS routing. During the searching process, two groups of ant carry out the searching separately. One finds the optimal path from the source to destination and other finds the path from destination to source. After one search, they exchange information to avoid stagnation. The optimal one is selected from the two paths combining multi-constrained QoS. In every new search process, the previous received optimal path and the probability of the path are saved. In the selection of next node by each ant, the probability of previous search is introduced to speed up the search process. The path which meets QoS constraints and has minimum cost is the optimal path and the smallest price multicast tree is output. For the simulation purpose 8 nodes are taken and characteristics of the node are described with four vectors as (delay, delay jitter, bandwidth, cost). Proposed algorithm increases delay and reduces cost compared to mini delay algorithm (which provides minimum delay). It increases cost and reduces delay compared to mini cost algorithm (which provides minimum cost).

Wenyang Liu et al. (2009) proposed hybrid multicast routing protocol to support QoS parameters with ACO. According to the characteristics of mobile networks, Improved Zone Routing Protocol (ZRP) is used to get optimized network topology which meets the QoS requirements. The multicast path is calculated according to the topology. Then the optimal multicast tree is established by using ant colony algorithm. 50 nodes move in the region of 1000*1000 m² with speed of 0 to 10 m/s and transmission radius of 250 m. Channel capacity is of 2 Mbps and simulation time is taken as 500 seconds. Performance of the algorithm is compared with the Ad hoc On demand Distance Vector (AODV) and Destination Sequence Distance Vector (DSDV) protocols. The method can effectively reduce the average delay and improve the rate of packet delivery.

Bencan Gong et al. (2007) proposed approach of constructing a multicast tree where ants orderly set out from every destination node, search the multicast tree, then pick out an optimal path and put nodes and edges along the path into the tree. When all destination nodes have joined, the multicast tree is generated. It considers multiple QoS metrics such as cost, delay and jitter. It ensures that the generated multicast tree satisfies QoS requirements and has a lot of advantages including small overhead, good expansibility and distributed characteristic.

A. Sabari et al. (2009) proposed an Ant agent based Adaptive Multicast Routing Protocol (AAMRP). It exploits group member's desire to simplify multicast routing and invoke broadcast operations in appropriate localized regimes. By reducing the number of group members that participate in the construction of the multicast structure and by providing robustness to mobility based on broadcasts in densely clustered local regions. The proposed protocol achieves packet delivery statistics that are comparable to a pure multicast protocol but with significantly lower overhead. AAMRP dynamically identifies and organizes the group members into clusters which correspond to areas of high group member affinity. In each of these "dense" neighbourhoods, one of the group members is selected to be a cluster

leader. Cluster leader establishes a sparse multicast structure among themselves and the source. They use broadcasting to deliver the packets to other group members in their cluster. Each group member in AAMRP can be in 3 states. It can be a temporary node just joining the session, it can be a cluster leader or it can simply be the member of a cluster. Each node maintains a Group Member Table (GMTTable) and cluster leader maintains a Cluster Member Table (CMTTable). In NS2 simulator 25, 50, 75 and 100 nodes move in the region of 600×600 m² with the speed of 10 m/s. Random Way Point (RWP) model is considered with CBR traffic and node transmission radius is set to 250 m for simulations. Control overhead, routing load, end-to-end delay and packet delivery fraction are performance metrics evaluated with respect to varying number of nodes and group size. The method effectively increases packet delivery fraction and reduce the end-to-end delay and routing load.

Bencan Gong et al. (2007) proposed ant algorithm with multiple constraints. Approach of constructing a multicast tree is to find the shortest paths from the source to each destination separately using ant algorithm based on state transition rule and pheromone rule. Then it merge the resulting paths to form a multicast tree. Algorithm can find the optimal or near-optimal solution quickly. For simulation experiments 100 nodes are taken as network size and cost of edge is taken as distance between two nodes. Delay of edge is taken in range of (0, 10] and delay jitter of edge is in range of (0, 5]. Test result shows that the algorithm can construct the multicast tree that minimizes the total cost in a few iterations and performs better than ACO algorithm.

Kewen Li et al. (2008), established a multi constrained QoS routing model with mobile agent as the node. The effect of QoS parameters are determined by orthogonal experiment of statistical methods. According to the general scope of the search path, a suitable orthogonal table is implemented to confirm the effect of every QoS parameter. The volatility of pheromone dynamically employs an improved measure to speed up the convergence and to setup an optimal multicast tree which meets multiple QoS constraints. According to the scope of the search path, orthogonal table $L_9(3^4)$ is adopted. Here 9 stands for number of searching, 4 stands for number of QoS parameters and 3 is noted as the number of levels about searching path. In simulation experiments 8 nodes are taken with constrained function of 4 dimensional vector as (D, DJ, B, C). Algorithm can quickly achieve the optimal solution and satisfy multiple QoS constraints.

Genhang Ding et al. (2012) proposed an Improved Ant Colony Algorithm (IACA). It includes multi strategies for solving QoS routing problems by changing pheromone update rule and substituting the piecewise function $Q(t)$ for the probability constant which is chosen by ants when a route is selected. Improvements of algorithm are defined in number of stages. In stage one: set lower bound and upper bound for pheromone. In stage two: use $Q(t) = \log(t+1)$ instead of Q based on the stage one. In stage three: use piecewise function $q_0(t)$ instead of constant q_0 chosen by ants based on the stage two. In beginning of the iteration, the value of $Q(t)$ should be smaller so that the increment of pheromone in each route will be small to avoid too strong positive feedback. In later iterations, the value of $Q(t)$ becomes bigger to speed up the convergence. The algorithm makes the search space as large as possible for finding optimal solution interval and also makes full use of the current available information for focusing on searching the ranges that likely to have good fitness individuals, thus to converge to the global optimal solution as soon as possible. Algorithm set (cost, delay, delay-jitter, packet-loss) for each node and set (cost, delay, delay-jitter, bandwidth) for each link. Number of ants taken as 30 and maximum number of iterations is taken as 100 for the simulation purpose. Experimental results show that the success rate of the improved ant colony algorithm in solving QoS routing problems and the ratio to obtain the optimal solution reach up to 99.81 % and 99.65 % respectively. The results are much better than those obtained by the basic ant colony algorithm.

Sun Gai-ping et al. (2010) proposed an ant colony optimization algorithm ANBRA for ad hoc network routing based on the network link and node status. In ANRBA, it uses the load accepted rate, topology variety rate and routing delay time as measurement value to select the routing paths. After establishing routing paths, use the ant colony algorithm to gather the routing paths' measurement and dynamically update the pheromone table, which dynamically distribute the network load. In NS2, 50 nodes move in the region $1000*1000 \text{ m}^2$ with varying pause time in range of 0 to 300 seconds. Node speed is taken as 10m/s with bandwidth 2 M b/s. Simulation time is taken as 400 seconds with 10 CBR traffic connections. ANBRA performs much better in packet switched rate and average delay time with varying pause time.

A. Sabari et al. (2008) proposed Ant colony based Multicast Routing (AMR) which optimizes several objectives simultaneously to solve the traffic engineering multicast problem. Algorithm calculates one more additional constraint in the cost-metrics, which is the product of average delay and the maximum depth of the multicast tree and try to minimize this combined cost metrics. Algorithm calculates the shortest path tree from root using ACO technique. With modified heuristic function to form degree bounded spanning trees, it ensures that all hosts connect to the source through a host that is closer to the root. Each node must be connected to a parent that is closer to the root than itself, that is if a's parent is b then $dM(b, \text{root}) \leq dM(a, \text{root})$. This helps to reduce the delay introduced by deviations from the optimal path. In NS2, 25 to 75 nodes move in the region of $600*600 \text{ m}^2$ and node's maximum speed is 10 m/s with pause time of 5 seconds. Traffic is taken as CBR and simulation time is 50 seconds. Performance metrics are packet delivery ratio (PDR), delay multiplied with depth and control overhead. Result shows that packet delivery ratio is increased while control overhead and routing overhead are reduced with varying node density.

P. Deepalakshmi et al. (2011) proposed an Ant based Multi objective on demand QoS Routing algorithm (AMQR) for MANET is highly adaptive, efficient, scalable and reduces end-to-end delay in high mobility cases. Proposed approach has phases of route exploration and route maintenance. Ant like packets are used to locally find new paths. Artificial pheromone is laid on communication links between adjacent nodes and route reply and data packets are inclined towards strong pheromone, where as next hop is chosen probabilistically. Each node running this algorithm contains three tables namely neighbour, path preference and routing. The neighbour node which has a higher path preference value will be copied to routing table for the related destination on desired. In NS2, 50 to 100 nodes move in the region of $1500*1500 \text{ m}^2$ with node mobility in the range of 10 to 80 m/s and simulation period of 900 seconds. AMQR has been compared with AODV and ANTHOCNET in terms of delay, throughput, jitter with various flow counts, node mobility and various pause times. It provides good packet delivery ratio, reduces delay and jitter but with high routing overhead.

Miae woo et al. (2008) proposed an ant-based multi-path routing algorithm with both reactive and proactive elements. Route setup and recovery phases are reactive elements. In the algorithm, pheromone heuristic control is used for stagnation. Used factors for the heuristic function are queue length and average delay at the MAC layer. A reactive backward ant can also be generated by any legitimate intermediate node, which is a unique feature in the proposed algorithm based on the conditions: 1) There should be no backward ant generated by any other previous visited node enroute to the intermediate node. 2) The routing information to the destination should be fresh enough. 3) The hop count between the source and intermediate node should be within some range values. 4) In proposed algorithm, the number of entries for a specific node in the routing table is controlled in order to reduce the overhead in the routing table. Priorities are given to the entries updated by backward ant generated from the destination and entries with fresh pheromone values. In Qualnet, 100 nodes with 20 traffic sources move in the region of $3000*1000 \text{ m}^2$ with pause time in range of 0 to 300 seconds and simulation period of 300 seconds. Performance metrics are taken as average number of

forward ant delivered, average number of backward ant delivered, end-to-end delay and packet delivery ratio with various pause times. The proposed algorithm effectively control the overhead generated by the ants, while achieving faster end-to-end delay and improved packet delivery ratio.

R. Ashokan et al. (2008) proposed Ant DSR (ADSR), a QoS dynamic source routing protocol using ant colony optimization. It takes consideration of three QoS parameters delay, jitter and energy. In DSR, mobile nodes are required to maintain route caches that contain the complete routes about which the mobile node is aware and entries are updated as new route is learnt. The mechanism was based on the forward ant (FANT) and backward ant (BANT) packets added in the route request and route reply. The proposed protocol selects a minimum delay path with the maximum residual energy at nodes. In NS2, 100 nodes move in the region of $500 \times 500 \text{ m}^2$, with communication range of 50 meter, node speed between 0 to 100 m/s and pause time of 0 to 500 seconds. Performance metrics are taken as end-to-end delay, energy, jitter, throughput and routing overhead with varying mobility and pause times. Result shows improvement in packet delivery ratio, end-to-end delay and residual energy while slightly high overhead than DSR.

Bibhash Roy et al. (2012) proposed algorithm which combines the idea of ant colony optimization with Optimized Link State Routing (OLSR) protocol to identify multiple stable paths between source and destination nodes. 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. Ant agents are used to select multiple nodes and these nodes further use ant agents to establish connection with intermediate nodes.

Salim Bitam et al. (2012) proposed MQBM, a bio-inspired protocol which is based on the bee's communication while searching their food. MQBM is considered as an on-demand, adaptive and tree-based protocol. It broadcasts its route request to a limited number of neighbours to find the multicast group. MQBM detects multiple paths between sender and receiver. They can be used to send out packets in parallel in order to optimize data transmission. End-to-end delay and the average bandwidth satisfy the QoS requirements. MQBM takes two phases: the first step aims to find one of the group members using unicast and multipath routing and in second step, packets are disseminated to other members through the head of the group. In NS2, 50 nodes move in the region of $1500 \times 300 \text{ m}^2$ with simulation period of 900 seconds. Number of members in multicast group varies between 10 to 50. Result shows improvement in packet delivery ratio and bandwidth.

S. Samadi et al. (2012) proposed Adaptive Multipath Ant Routing algorithm (AMAR) which is hybrid multipath algorithm, designed along the principles of ACO routing and multipath routing. It consists of reactive path setup, stochastic data routing, proactive path maintenance and exploration and link failures. In Qualnet, 100 nodes move in the region of $2400 \times 800 \text{ m}^2$ with node speed between 0 to 30 m/s. Pause time is taken in the range of 0 to 500 m/s and simulation period is of 900 seconds. Result shows improvement in packet delivery ratio and end-to-end delay.

Se-Young Lee et al. (2005) proposed Ad hoc Network Multicasting with Ant System (ANMAS) which is based on ant colony optimization system. Algorithm in particular utilizes the indirect communication method of the ants via "pheromone" to effectively obtain dynamic topology and to generate multicasting paths. It adopts the well-known CBT (Core Based Tree) into the ANMAS framework with proper modifications to make "tolerable" multicasting group in the MANET environment. The pheromone of each node contains its distance to the core and the measure of its "safety" on the path to the core. The newest pheromone information is used so that multicasting routes are adaptively constructed depending on dynamic topology changes. 50 nodes and 200 nodes are taken for two simulations in an area of $1000 \times 1000 \text{ m}^2$ with bandwidth of 2 Mbps. Node velocity is taken between 0 to 20 m/s and

simulation time is taken as 330 seconds. ANMAS provides a good packet delivery ratio with a small increase in the number of control packets, which do not depend proportionally on the number of sources. ANMAS will be highly effective for the domains that need multiple-to-multiple node multicasting.

Javad Barbin et al. (2012) proposed ACO based QoS routing algorithm. Algorithm is multipath routing and has two phases namely route discovery phase and route maintenance phase. Proposed algorithm starts from the destination node and the data packet is sent along backward path. In VC++ 6.0, 50 nodes in region of $1500 \times 300 \text{ m}^2$ are defined with simulation period of 900 seconds. Number of packet delivered and overhead routing is identified with varying simulation time in range of 0 to 900 seconds. Multi Path Ant Colony (MPAC) algorithm is highly adaptive, efficient, scalable and mainly reduces end-to-end delay in high mobility cases.

P. Deepalakshmi et al. (2011) proposed source initiated mesh and Soft-state based QoS probabilistic Multicast routing Protocol (SQMP) for MANET based on the ant foraging behaviour. Mesh creation of proposed algorithm involves two phases namely query phase and reply phase. Query phase is invoked by the multicast source node to initiate the mesh route discovery process. The reply phase is initiated by the multicast group receivers to multicast sources through different QoS satisfied paths. Multiple paths have been found with first rate path preference probability. The data is sent over the paths with higher path preference probability which can satisfy the bandwidth requirement and delay of applications. In NS2, 50 nodes move in the region of $1000 \times 1000 \text{ m}^2$ with speed of 0 to 20 m/s for a simulation period of 300 seconds. The proposed algorithm has been compared with ODMRP in terms of PDR, total bytes transmitted per data byte received with respect to mobility.

Sungwook Kim et al. (2012) proposed a multipath QoS aware routing protocol based on ACO. To enhance network reliability, routing packets are adaptively distributed through the established multiple paths. This multipath routing mechanism can ease out the heavy traffic load in a specific link to ensure the balanced network resource consumption. For efficient network management, control decisions in the proposed algorithm are made dynamically by using real-time measurements. In NS2, 100 nodes move in the region of $500 \times 500 \text{ m}^2$ with three different types of CBR traffic taken as 128 kbps, 256 kbps and 512 kbps. Node remaining-energy ratio, packet delivery ratio, packet loss probability and delay commitment ratio are measured with respect to offered load (packet generation rate).

Debasmita Mukherjee et al. (2012) proposed ACO variants for solving MANET routing problems. Variations are related to the selection of next node to visit which depends on the number of adjacent nodes to the current node and modification of the pheromone deposited formula on the basis of transmission time. In some variants, a tabu list (last visited n number of nodes) has been incorporated to enhance the performance remarkably. In NHS1, no node is allowed to select an already visited node to avoid cycle formation. NHS2 allows selecting an already visited node provided that it is not present in the tabu list. In modified versions, number of nodes has been incorporated in the path probability formula for selecting the next node. Another modification is inclusion of the transmission time of the packets in the pheromone deposit formula to make it more suitable for realistic situation. With existing variants of ACO namely, Ant System (AS), Max-Min Ant System (MMAS) and Ant Colony System (ACS), applying two different next node selection criteria six variants of ACO are defined, that are AS-NHS1, AS-NHS2, MMAS-NHS1, MMAS-NHS2, ACS-NHS1 and ACS-NHS2. In NS2, 16 to 100 nodes move in the region of $1000 \times 1000 \text{ m}^2$ with 1 to 20 m/s node mobility. CBR traffic is considered for simulation period of 200 seconds. Performance metrics are considered as packet drop rate and throughput for network. ACS-NHS1 outperforms others in maximizing throughput and MMAS-NHS2 is the best in minimizing packet drop rate. Comparative behaviour of the modified variants remains same as before but absolute performance is better.

Performance Evaluation:

In this section various ant colony based unicast and multicast routing protocols, studied in previous section are compared with respect to different attributes, performance metrics and network parameters.

Protocol attributes can be defined as routing scheme, path type, routing structure, QoS constraints and performance metrics. Simulation area, number of nodes, node speed and simulators are defined under network parameters. Table I defines summary attributes of ant colony based algorithms.

TABLE I SIMULATION PARAMETERS

Algorithm Protocol	Routing Scheme	Path Type	Routing Structure	Adherence of Multicast	QoS Constraints	Performance Metrics	Network Parameters			
							Area (m ²)	Nodes	Speed (m/s)	Simulator
S.Mangai et al. [2] DCMF	R	ME	F	Yes		PDR, Control overhead	1000*1000	50	0-20	NS 2
Kewen Li et al. [4]	R	M	F	Yes	D,DJ,B,PL	Cost, Jitter		8		
Wenyong Liu et al.[5]	H	S	F	Yes	D,B,C	PDR, E2E delay	1000*1000	50	0-10	
Bencan Gong et al. [6]	R	S	F	Yes	D,DJ,B,PL	Cost, Delay, Jitter		100		
A. Sabari et al. [7] AAMRP	R	S	H	Yes		PDR, E2E delay, Control Overhead, Routing load	600*600	25-50-75-100	10	NS 2
Bencan Gong et al. [8]	R	S	F	Yes	D,DJ,B,PL	Cost, Jitter		100		
Kewen Li et al. [9]	R	S	F	Yes	D,DJ,B,C	Delay		8		
Genhang Ding et al. [10] IACA	R	S	F	No	D,DJ,B,C, PL	Success rate, % of optimal solution found		30		
Sun Gai-ping et al. [11] ANBRA	R	S	F	No	D	PDR, E2E delay,	1000*1000	50	10	NS 2
A. Sabari et al. [12] AMR	R	S	F	Yes	C,D	PDR,Control overhead, routing overhead	600*600	25-75	10	NS 2
P. Deepal akshami et al. [13] AMQR	R	M	F	No	D,J,B, hop count	PDR, E2E delay, jitter, routing overhead	1500*1500	50-100	10-80	NS 2
Miae Woo et al.[14]	R+P	M	F	No		E2E delay, PDR	3000*1000	100		Qualnet
R. Ashokan et al.[15] ADSR	R	S	F	No	D,J, Energy	Jitter, E2E delay, energy, throughput, routing overhead	500*500	100	0-10	NS2
Bibhas Roy et al.[16]	H	M	F	No						
Salim Bitan et al. [17] MQBM	R	M	F	yes		PDR, bandwidth	1500*300	50		NS2
S. Samadi et al. [18] AMAR	H	M	F	No		PDR,E2E delay	2400*800	100	0-30	Qualnet
Se-yong Lee et al. [19]	R	ME	F	Yes		PDR, Control overhead	1000*1000	50-200	0-20	
Javad Barbin et al.[20] MPAC	R	M	F	No		E2E delay ,PDR, Routing overhead	1500*300	50	10	VC++
P.	R	ME	F	yes		PDR	1000*100	50	0	NS 2

Deepalakshmi et al.[21] SQMP							0		20	
Sungwook Kim et al.[22]	R	M	F	yes		PDR,PLR,E2E delay	500*500	100		NS 2
Debasmita Mukherjee et al.[23]	R	S	F	No		Packet drop rate, throughput	1000*100 0	16 100	1 20	NS 2

Routing Scheme (R: Reactive, P: Proactive, H: Hybrid), Path Type (M: Multipath, ME: Mesh based, S:Singlepath), Routing Structure (F: Flat, H: Hierarchical), QoS Constraints (B: Bandwidth, D: Delay, DJ: Delay Jitter, PL: Packet Loss, C: Cost), Simulator (NS2: Network Simulator, VC++: Visual C++)

Conclusion:

In this paper, various ant based routing algorithms are reviewed and compared in terms of protocol attributes, performance matrices and network parameters. Ant colony based machine learning approach provides more promising result compared to conventional routing protocols. Ant Colony approach is widely used to provide QoS parameters for unicast and multicast routing algorithms. Techniques are more robust as well as computation time is moderate or low. Complexity of algorithm is high compared to other techniques, but even with high complexity, processing time is fast. Many of them do not consider the multi-constraint problems of QoS routing in MANET. Even though some of them deal with multi-constraint QoS parameters, they are restrictive with respect to scalability. Also, they do not explore service differentiation using service classes for QoS provisioning. To get an effective and efficient ant based routing protocol in MANETs, it is required to consider real scenarios and environment constraints during simulation.

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