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Enhanced QOS Enabled Multipath Routing (EQAMR) For MANETs Inspired by Swarm Intelligence.

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ABSTRACT

Mobile ad hoc networks (MANETs) are infrastructure-less networks proficient of transferring data among themselves in autonomous fashion. Ad hoc network is very popular because of the spread of wireless devices among the users these devices need to communicate with others in the absence of centralized authority. The act of transmitting information between communication end points is a challenging task due to its characteristics like highly dynamic topology, limited bandwidth and energy. The author proposes a multipath routing algorithm based on foraging behavior of ant colonies for routing path selection. Route discovers and maintenance is carried out using Ant-like agents called forward ant (FANT) and backward ant (BANT). The path with maximum path preference probability is selected for communication between endpoints. The path preference probability is calculated by considering QoS metrics like bandwidth, remaining battery power along with node stability and pheromone concentration. Simulations performed in network simulator 2 prove that the proposed algorithm is climbable and performs better at higher traffic compared to the existing algorithms.

Keywords: MANET, FANT, BANT, QOS

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INTRODUCTION

Telecommunication and computer networks play a major role in satisfying people need. To lead day-to-day life people need the internet, it creates a demand to be connected anytime, anywhere. Wireless communication networks play a major role in satisfying these needs.

Wireless ad hoc network is topology free/infrastructure less networks. These types of network were further classified into infrastructure based and infrastructure less networks. In infrastructure based network wireless access points and routers are present to fulfill the communication between source and destination. In infrastructure less network node, it was acting as a router to route the packets between the nodes which needs communication with each other.

Active research was carried out to solve the complex routing problem. Many routing protocols are there in the literature, they are inspired by traditional wired network. These routing protocols are widely accepted as the state-of-art solutions, non-intelligent mechanisms were used to collect topology information for routing. When the user needs change, it increases the cost in terms of processing power and additional resources. Due to these reasons research community has proposed agent based networking systems.

Swarm Intelligence (SI) has revolutionized, in providing solutions to such complex system. The mechanisms used under SI are based on the observations done over social insect like ant colonies and bee colonies. These colonies are used my most of the research community, since they are capable of finding and storing foods, guarding their nest and young ones, creating goods such as nectar, wax irrespective of their size.

Mobile ad hoc networks:

The research community or literature focuses on two major types of wireless ad hoc networks are wireless Sensor Networks (WSNs) [1] and the Mobile Ad hoc Networks (MANETs) [2].

WSNs characteristics are almost similar to MANTEs, except that, it had a sensor in order to sense a certain physical phenomenon. A large number of nodes which are having sensing capability are deployed in physical environment where certain parameter as to be analyzed. Sensor nodes are very tiny nodes, due to this fact, available resources as to be used efficiently.

MANETs is infrastructure less, self-organizing networks which exchange data among themselves either through single hope or multi-hop. Single hop was used when the target node was within its transmission region, else it uses multi-hop. A node that was not a destination can act as a router to forward data and control packets. MANET Topology was highly dynamic due to this transferring data between nodes are difficult. Designing an effective routing protocol for such highly dynamic network was a difficult task. Finally, network resources are very limited in MANET, protocol as to provide an effective solution in terms of processing power, bandwidth, and delay.

Node mobility and limited energy [2] are the major challenges in MANET. Node mobility was high impact over the performance of the protocols due to frequent link break. In fact, it will affect energy consumption and node density in the network. Network load was high, when the node density is high. Throughput of the network was also affected by node density, due more control overheads and packet loss.

Energy consumption in a node was there, whenever it sends, receive and discarding packets. In fact, literature shown that route discovery, route maintenance, and the memory allocation of the mobile node consumes power. Finally, power consumption in MANET is directly proportional to hop count. Several types of routing protocols are proposed in the literature for MANET are broadly classified into proactive [3, 4], reactive and hybrid. Each and very node maintain network topology information within it, in the form of the routing table. This table was exchanged and updated periodically to maintain up-to-date network information. Destination sequenced Distance Vector (DSDV) was a state-of-art protocol in proactive category. In fact, proactive routing protocol showed less performance under high node density and mobility.

The reactive routing protocol was also called an on-demand routing [5-7], unlike proactive protocol, it does not use routing table. Rather, it establishes route whenever there was a demand, through route discovery by broadcasting route request message. Route replay was generated by destination node or by intermediate node which had a valid route. Demand Distance-Vector protocol (AODV) is a state-of-art reactive routing protocol, which was analyzed in most of the studies.

The best features of both proactive and reactive protocols were combined to form a next generation protocol called hybrid protocol [8]. Hybrid protocol approaches a network in the form of zones. The route was determined *proactively* within a zone and reactively outside a zone. Network performance was high, when compare to proactive and reactive approaches.

Swarm intelligence:

Many searching problem solutions were identified through agent-based-system, inspired from social behavior of nature, mostly from insects. Research community identified that challenges found in MANET were similar to challenges faced by insects to width stand. The system was robust and self-organized due to agent's cooperation in achieving the task. The task that goes beyond the control of the individual was achieved by combining the efforts of agents present in the system. Following the same pattern routing protocol agents' behavior was changed dynamically to address routing problem with less complexity. Even though the system was distributed, agents are capable to switch roles and allocate tasks in an adaptive manner. Due to this the system is scalable in terms of population. Finally, scalability allows the system to increase or decrease agents at any time without major changes in global level.

An ant colony and bee colony optimization technique was considered under swarm intelligence by researchers while designing routing protocols.

Ant colony optimization:

The Ant Colony Optimization (ACO) [9] was developed by considering the foraging behavior of ants.

Improved ant colony-based multi-constrained [10] QoS energy-saving routing algorithm (IAMQER) to balance through and energy consumption, node information like queue length, forwarding packets, residual energy are used.

Innovative ACO based Routing Algorithm (ANTALG) [11] the ant like agents are exchanged between the randomly selected source and destination. Round trip time of the nodes was calculated by using the information available in pheromone table.

Quality-of-service-enabled ant colony-based multipath routing algorithm (QAMR) [12] in this approach, routing path was selected by considering node stability and path preference probability. Bandwidth, delay and hop count were used as QoS metric along with parameters like hop count, node stability and path preference probability.

Ant Net [14] for wired network based on that idea a reactive protocol called ARA [15], consist of three phases. The first phase of ARA is a route discovery phase; it uses forward and backward ants to establish a pheromone track from the source and destination respectively. The second phase was a route maintenance phase. Route failure due to broken link was determined through missing ACK packet in the third phase. ARA uses less overhead when compared to any other protocol.

Termite protocol inspired from termite behavior [16]. Routing path was established in the network, using pheromone scent associated with termite in each node. Pheromone gradient was used to guide the packet towards destination node.

A hybrid algorithm called ANTHOCNET [17]. If routing table was not having a valid path for current session, it sends ant-like agent called reactive forward ant, to determine the destination. Once the destination was determined it traces back to the source, during its traversal routing tables are updated. ANTHOCNET was compared with Ad Hoc On-Demand Distance-Vector Routing (AODV), ANTHOCNET performs well in terms of delay. On-demand QOS-aware routing protocol called ARMAN [18]. Multiple QOS parameters are used at each and every node to calculate path preference probability. Highest path preference probability path was selected for data transfer.

Energy Efficient Ant-Based Routing protocol (EEABR) [19] in order to save energy in WSNs. Simulation experiment shown that a special ant used in EEABR's increased network lifetime by maximizing energy and minimizes communication load. A hybrid protocol called HOPNET [20], which divides the network into zones. Intra zone routing was used within the zone and an inter zone routing was used outside the zone. Simulation shown HOPNET protocol was suitable for both high, low mobility network, and network size had no impact on protocol performance.

Node Disjoint Multipath Routing Considers Link and Node Stability (NDMLNR) while finding a path. Bandwidth was used as QOS parameter for path selection. Fault-tolerant routing algorithm (FTAR) ant like agent was used to establish fault-tolerant path. Quality of service for ad hoc optimized link state Routing protocol (QOLSR) delay and bandwidth are considered as QOS metric.

Other nature-inspired routing:

Particle Swarm Optimization (PSO) was used to find the shortest path in wireless network, which mimics flocking behavior of nature. Simple particles are randomly placed in the search space or problem space. Each particle position represents a candidate solution. New candidate solutions are generated by adjusting particle trajectories, velocity and position. These solutions are used in the search space, to find desire goal.

Genetic Algorithms (GAs) probe problem space using natural selection and biological evolution processes. Success of applying GAs in wireless network was there in literature; particularly the success rate of GAs was more in energy-aware routing.

System model:

The objective of the proposed work is to find a path with maximum path preference probability from source to destination node through its neighbors. Path preference probability for route R is calculated as follows

$$P(R) = \frac{\tau_R}{\eta_R}$$

The pheromone quantity of a route R is

$$\tau_R = \sum_{i,j \in R} \tau_{ij}$$

The quality of route R is computed as follows

$$\eta_R = E(R)_E^{\beta} + B(R)_B^{\beta} + LET(R)_{LET}^{\beta}$$

Were

- $E(R) = \min(E(v_i, v_{i+1}), E(v_{i+1}, v_{i+2}) \cdots, E(v_{k-2}, v_{k-1}))$ Minimum energy in route R, were $s = v_i$ and $d = v_k$ are source and destination nodes.
- $B(R) = \min(LB(B(v_i) \cap B(v_{i+1})), LB(B(v_{i+1}) \cap B(v_{i+2})) \cdots, LB(B(v_{k-1}) \cap B(v_k)))$ Smallest link bandwidth in route R.
- $LET(R) = \min(LET(v_i, v_{i+1}), LET(v_{i+1}, v_{i+2}) \cdots, LET(v_{k-1}, v_k)$ Smallest link expiration time in route R.
- $\beta_E, \beta_R, \beta_{LET}$ Denotes link weight factors of route R.

The performance of a network was evaluated by using additive, multiplicative metrics. Concave metric was defined as, minimum value of the nodes or links in that path. Multiplicative metric was a metric defined by all the nodes in that path. Delay of a route is calculated as follows

$$D(R) = \sum_{e \in R} D(e) + \sum_{n \in R} D(n)$$

The hop count is defined as the number of nodes that are visited in that particular path.

$$Hop\ count(p(i)) = count(v_i)\ ; v_i \in p(i)$$

Hop count and delay metrics are not used in path preference calculation, since the time taken for a FANT to reach a destination is high if these metrics are high.

Mobility prediction:

The proposed system uses the free space propagation model, where received signal strength depends on its distance to the transmitter. All the nodes in the network are synchronized by using the GPS clock of itself or NTP (Network Time protocol). Motion parameters like direction, distance, speed, and propagation range are known for any two neighbor nodes, it is possible to determine the connected duration of these nodes.

Let's consider two nodes I and j are in the transmission range of each other and the coordinates are (x_i, y_i) and (x_j, y_j) respectively. Let v_i, v_j are the speeds of mobile node i and j there moving direction are θ_i , θ_j $(0 \le \theta_i, \theta_j < 2\pi)$ respectively. The link expiration time of connected nodes i and j was calculated as follows,

$$LET = \begin{cases} \infty & if\ v_i = v_j\ and\ \theta_i = \theta_j \\ \delta & otherwise \end{cases}$$

$$\delta = \frac{-(ab+cd) + \sqrt{(a^2+c^2)r^2 - (ad-bc)^2}}{a^2+c^2}$$

Were

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$
$$b = x_i - x_j$$
$$c = v_i \sin\theta_i - v_j \sin\theta_j$$
$$d = y_i - y_j$$

Next hop availability (NHA);

Frequent link failure is happening in MANETs due to node mobility and energy level. These two factors are to be addressed while selecting an NHA, since NHA is used to reduce overheads (OH) in MANET. Node energy gets depleted soon, if large volumes of data are processed or passed by a same node due to this, frequent link failures are there in the network. A path will have maximum lifetime, if it is constructed by the nodes having maximum battery power and minimum mobility. Hence mobility and energy factors are considered in NHA computation. Information's required for NHA computation was collected during the response of hello packet.

$$NHA = \frac{B_r}{Mobility}$$

Were

B_r remaining battery power

EQAMR: Enhanced QOS-enabled ant colony-based multipath routing for MANETs:

EQAMR is a QOS enabled on demand multipath routing protocols based on foraging behavior of ants in an ant colony. The proposed approach consists of two phase route discovery and route maintenance phase. A node wants to send data to a randomly selected destination; it starts with route exploration phase. Once a route is determined, it transfers data through that route, during data, transfer it maintains a data transfer route through a rout maintenance phase.

Route discovery phase:

In route discovery phase, when a source node wants to share information to a destination, it generates artificial agent called forward ants (FANT). FANT is transmitted by source nodes to discover destination using packet broadcasting. A node is allowed to send FANT to next level nodes, only if it satisfies $NHA \geq NHA_{thr}$. The initial pheromone value 0.1 is updated by FANT of each and every link it traverses. Packet structure of FANT is shown in Fig1.

$$NHA_{thr} = \frac{B_{\max}}{Mob_{aveg}} * .3$$

Where

$B_{\max}$ Maximum battery power
Mob_{aveg} Average mobility

Starting time	Pheromone value
Source_ IP	
Destination_ IP	
IP_stack	

Fig 1: FANT packet format

Nodes that are visited by a FANT from source to destination, stored in the IP stack field. An intermediate node which receives FANT check weather NHA>NHA $_{thr}$ if so, it verifies whether its own IP was already present in IP_stack or not. If it is already present discards FANT otherwise it appends its IP address in IP_stack field and forwards it to its neighbors. Once FANT reaches destination, it will wait for time T_W to receive other forward ants. T_W is defined as total end-to-end delay of the network. The destination node generates BANT for each FANT it receives.

BANT will collect delay, energy level, bandwidth, LET and these parameters will be updated by each intermediate node. Once BANT reaches the source node, it waits for time T_W to receive other BANT. The source node calculates path preference probability for each BANT and selects a path which is having maximum path preference probability. BANT packet format is shown in Fig2. Pheromone value is reinforced by BANT in each and every node, it travels as follows

$$\tau_{ij} = \tau_{ij} + \Delta_{ij}$$

$$\Delta_{ij} = \tau_{ij} * \frac{1}{P(R)}$$

The pheromone value of a link gets decade by a factor α when there is no data transfer for a finite interval of time.

$$\tau_{ij} = \begin{cases} (1-\alpha) & if\ 1 \geq (1-\alpha)\tau_{ij} > 0.1 \\ 1 & if\ (1-\alpha)\tau_{ij} \geq 1 \\ 0.1 & otherwise \end{cases}$$

Starting time	LET	Bandwidth
Energy level	Pheromone value	
Source_ IP		
Destination_ IP		
Revised IP_stack		

Fig 2: BANT packet format

Route maintenance phase

Preferred routing paths for data transmission is determined through a route discovery phase. Pheromone values in data transfer links are reinforced during transmission makes the links more desirable for further selection. When a session is going on QOS parameters varies so path preference probability as to be checked periodically. Link failures are detected as early as possible before it leads to heavy transmission error and packet loss because proposed approach LET is used in path preference probability. Hello message is not sensed for a predefined time the node will be considered as desertion node. When a node becomes deserted, its corresponding entries will be removed at the routing table, pheromone table and path preference probability table. Link is broken happens due to mobility in such a case, alternate route that is found during route discovery phase is used. In the worst case, all available routes to a particular destination are lost in such case route determination as to be done.

EQAMR Algorithm:

Input:

1. Routing table: A Table which contain routing information.
2. Neighbor table: Table contains 1-hop nodes
3. Pheromone table: Contain pheromone value of the nodes

Output:

Routing path that satisfies QOS metrics
/*---------Forward path---------*/
If node==Source S
Generate FANT and broadcast to neighbors
While node== intermediate node (IMN)
If (NHA>NHA_{thr}) **and** (IP_IMN is present in IP_stack of FANT)

Then:

Update IP_address to IP_satck of FANT

Else:

Discard FANT
If node==destination d
Wait T_w time to receive all FANT
$\forall$ FANT generate BANT
/*---------Reverse path------------------*/
While node==IMN

Collect local information about that node Compare QOS parameters of IMN with BANT and update BANT Update pheromone table

If node == Source node S
Wait T_w time to receive all BANT
∀ BANT compute Path preference probability
Select the path with highest path preference probability
Transfer data packet through selected route

During each transmission, pheromone is reinforced on selected routes and gets evaporated in unused path.

An alternate path is chosen during a link failure. In worst case it determines new routes.

PERFORMANCE ANALYSIS

AODV and AMQR protocols are used to compare the performance of EQAMR. AODV is the most popular proactive routing protocol for MANET. AMQR is QOS enabled on-demand routing protocol. Simulation was carried out using NS2 with the parameters shown in Table1.

Table 1: Simulation Parameters

Parameter	Values
Transmission Range	250m
MAC layer protocol	IEEE802.11
Traffic Pattern	CBR
Data Packet Size	512 bytes
Simulation area	500mX 1000m
Number of Nodes	100
Mobility	0-100 m/s
Mobility Model	Random way point

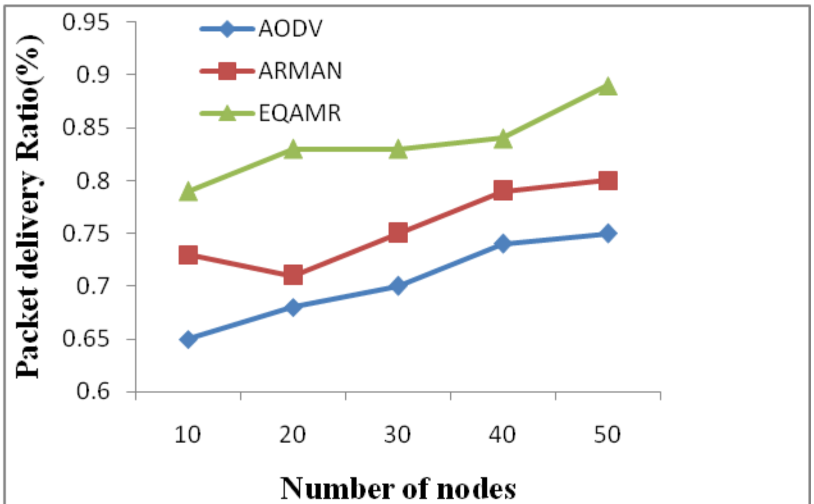

Fig3 Effects of nodes on packet delivery ratio

Figure 3 shows the packet delivery ratio variations with respect to the number of nodes for AODV and EQAMR. The performance difference between them in terms of the packet delivery ratio is very much visible at all levels. Packet delivery ratio increase when there is an increase in the number of nodes due to high availability of intermediate nodes in the network. EQAMR performs well when compared to AODV and ARMAN due to stable multipath identification.

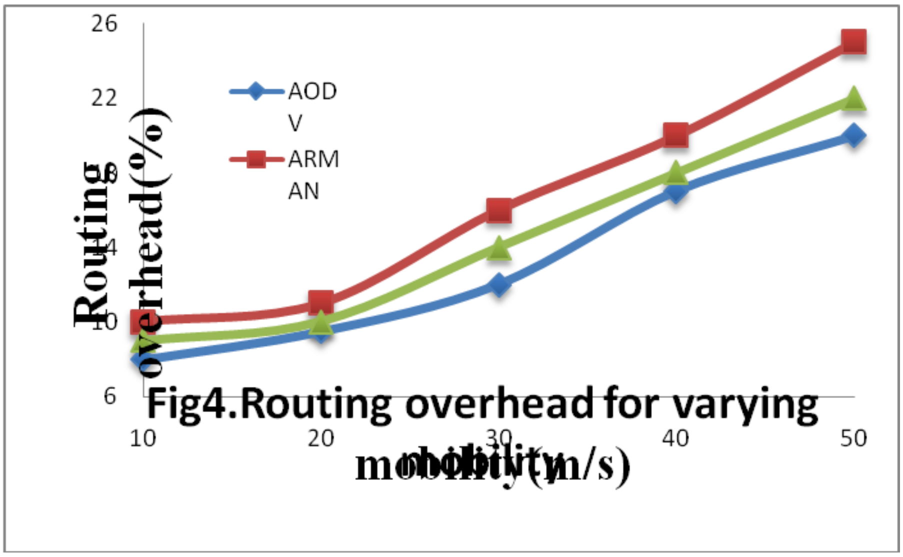

Fig4.Routing overhead for varying mobility

Fig 4 shows the effect of mobility on routing overheads. Whenever mobility is high routing link breaks frequently. Hence, frequent routing is needed, which increases routing overheads. Control packets are used to discover a route and these routes has to be monitored continuously which requires additional control packets. Routing overhead for EQAMR is slightly higher than AODV due to multipath discovery.

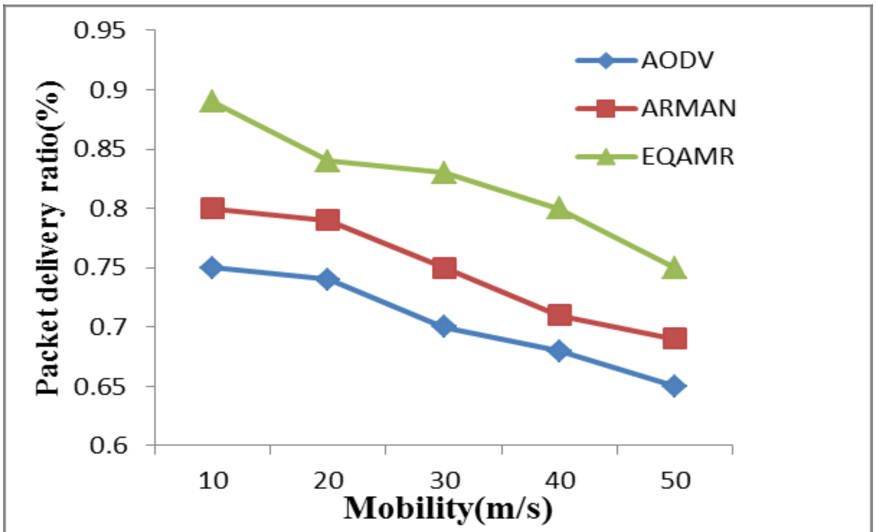

Fig5 Mobility effect on packet delivery ratio

Fig5 shows the effect of mobility on the packet delivery ratio of the three protocols. The network loss rate is identified through packet delivery ratio, so it is an important metric. The packet delivery ratio decreases as the node mobility increases due to communication route between end points will break frequently. Mode mobility cause high network delay, owing to subsequent route repairing and new route exploration process. EQAMR is having a high packet delivery ratio when compare to AODV and ARMAN the reason is EQAMR has multiple paths and these paths are selected based on path preference probability. EQAMR can go for new route exploration when all the identified paths are broken.

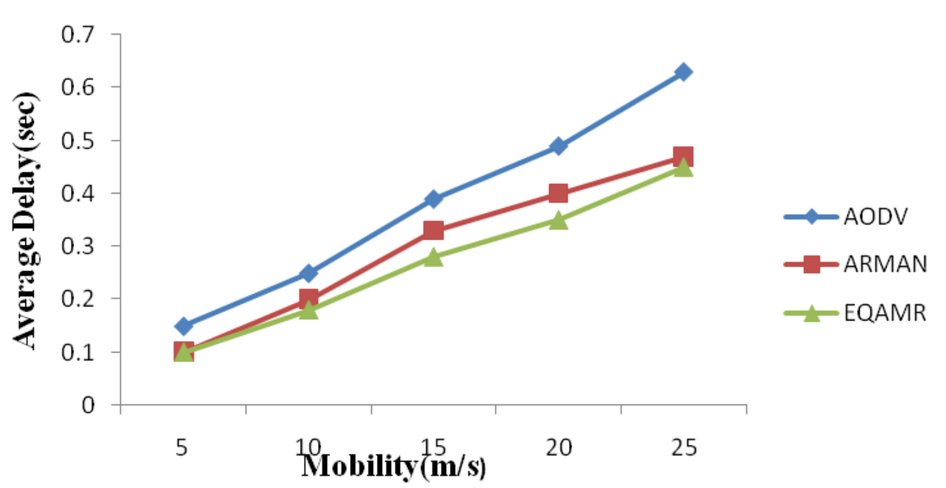

Fig6 Averrage delay for various flow count

Fig6 shows an average end-to-end delay for various flow counts. There is a possibility that some links are shared by more than one shortest path in case of AODV. Packets that are transmitted through these shared links may face additional delay due to congestion. Delay gets aggravated if more number of links is shared by the shortest path. In case of EQAMR a path is selected based on path preference probability, bandwidth was used as a metric in calculating path preference probability. If a link is used by a path the available bandwidth of the link get reduced, which in turn reduce the path preference probability. This will avoid the scenario of selecting the same link in more than one shortest path, so alternate path will have less traffic. Hence, waiting time of a packet in the queue is less.

CONCLUSION

In this paper, Swarm Intelligence based protocols for routing in wireless ad hoc inspired by Ant Colony Optimizations is discussed. Furthermore, a new routing protocol inspired by Ant Colony Optimization is presented. EQAMR is able to discover QOS enabled multi paths reactively between source and destination. Computation of path preference probability shows the novelty of the proposed protocol. The results obtained by comparing EQAMR with state-of-the-art routing protocols shows that EQAMR performs well.

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