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Ant Colony Based OLSR for Improved Quality of Service in Multimedia Traffic

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Abstract

A dynamic multihop wireless network, accomplished by a collection of mobile nodes on a shared wireless channel, is called Mobile Ad Hoc Network (MANET). The process of moving data from a source to a destination across a network is called routing. Due to the mobility of the nodes in MANETs and features such as time varying quality of service (QoS) requirements, energy, and limited resources, the MANET's performance degrades. For providing QoS in wireless ad hoc networks, QoS routing plays a significant role locating a path between the communication end points satisfying user's QoS requirement.This paper focuses on the application of Ant Colony Optimization (ACO) with Optimized link state routing protocol (OLSR) to improve QoS in MANET. Simulation results show that the proposed routing enhances the performance of the network.

Keywords: Mobile ad hoc network (MANET), Quality of Service (QoS), Optimized Link State Routing protocol (OLSR), Ant Colony Optimization (ACO).

Introduction

A dynamic multihop wireless network which is accomplished by a collection of mobile nodes on a shared wireless channel is called Mobile Ad hoc Network (MANET). There are no routers and all nodes serve both as end points of data communication and also as intermediate relay points/routers. MANET also support inter node communication that is indirectly connected by wireless hops through other intermediate nodes. A MANET routing algorithm must be able to find the shortest path between source and destination and must be adaptive, with regard to the node mobility, and the changing environment.

Traditional routing protocols are not efficient for MANETs due to their dynamic behavior and resource constraints. A MANET routing strategy must efficiently use the limited resources i.e., bandwidth and energy while adapting to the changing network conditions like network partitioning, traffic density and network size [1]. It should also work in a distributed manner. MANET routing algorithms are classified into three groups; proactive, reactive or hybrid [2]. Proactive algorithms maintain up-to-date routes between network node pairs always. Examples of proactive routing protocol include Destination-Sequence Distance-Vector routing (DSDV) and Optimized Link State Routing (OLSR) [3]. A reactive algorithm maintains routing information strictly necessary: they set up routes whenever required when a new communication session starts or when an ongoing communication session fails without a route. Examples of reactive routing protocol include Dynamic Source Routing (DSR) and Ad hoc On-demand Distance-Vector routing (AODV) [4]. Finally, hybrid algorithms use both proactive and reactive elements, combining the best of both. An example is the Sharp Hybrid Adaptive Routing Protocol (SHARP) [5]. The proactive routing dues to its periodic updates provide routes to destination immediately thus connection time is fast [6].

The most common type of traffic is Constant Bit Rate (CBR), TCP and multimedia. Traffic imposes different conditions on MANETs. Multimedia applications have gained popularity and are an accepted form of conveying information. Its applications are wide spread in the form wireless network in the domains of advertisement, product presentations, e-learning units, and tourist information. Large bandwidth in wireless communication is required for multimedia applications and is unpredictable because of network constraints such as bandwidth, delay, jitter, routing etc. Due to the mobility of the nodes in MANETs and features such as time varying Quality of Service (QoS) requirements, energy, and limited resources, the MANET's performance degrades. For providing QoS in wireless ad hoc networks, routing plays a significant role in locating a path between the communication end points satisfying the user's QoS requirement. This can be overcome through a biologically-inspired mechanism. Algorithms like ant colony optimization (ACO) algorithms are nature-inspired algorithms that are capable to efficiently construct routing algorithms for MANETs.

Background

Most wireless network protocols proposed in literature rely on the shortest path to reach the destination which may not be optimal in terms of QoS which vary from application to application. For example video conferencing application would require to have constant end to end delay with minimum jitter. To obtain the desired QoS the shortest path may not be a viable solution but the path which has the least traffic and good link quality with minimum time taken by the intermediate nodes to process the data. Selecting the best path is challenging and researchers have proposed various techniques to find routes based on link quality, available bandwidth and distance between the nodes.

Recent studies have shown that Evolutionary Algorithms have had reasonable success at providing solutions to those problems that fall in NP-Complete class of algorithms. Ant Colony Optimization (ACO) algorithm is one of the promising field of evolutionary algorithms that gave acceptable solutions to various Network Routing Optimization problems in polynomial time.

Related Works

Bibhash Roy et al., [7] proposed an algorithm that incorporates the ACO with OLSR protocol for the recognition of multiple stable routes between source and destination nodes. The proposed routing is optimized for multimedia communication while maintaining user's QoS requirements. The proposed mechanism use both reactive and proactive routing components. Multiple route selection was based on reactive settings and monitoring and improving of routes for transmitting multimedia data was based on proactive components. To select multiple nodes, the ant agents are employed, and the chosen nodes establish connectivity with intermediate nodes using ant agents.

For both pure and hybrid ad hoc networks, the mechanisms of swarm intelligence are used to choose next hops, Rajagopalan, et al., [8] proposed a hybrid routing protocol named Ad hoc Networking with Swarm Intelligence (ANSI). It is a congestion-aware routing protocol that owing to the self-organizing mechanisms of swarm intelligence collects much more information regarding the local network efficiently and makes routing decisions effective than the conventional MANET protocols. ANSI locates the routes and sustains it along a path from source to destination more efficiently by means of swarm intelligence methods and is also capable of gauging the link's slow deterioration and a path along newer links whenever necessary is effectively restored. The design of ANSI makes it able to work on hybrid ad hoc networks. Using both TCP and UDP data flows; simulation study was performed on both hybrid and pure ad hoc network by comparing ANSI with AODV. The results obtained show that ANSI accomplished best performance in terms of end-to-end delay, jitter, packet delivery, number of packets sent compared to AODV in many simulation scenarios. With only few route errors, ANSI achieved better results compared to AODV. Hence, ANSI is capable of performing consistently as demonstrated from the experimental results.

In ACO, to mark the path that is used, the ants drop pheromones. Then the shortest path back is selected by identifying the path with the highest pheromones. But, the network congestion and stagnation are caused by Ant Net Algorithms. Shweta Modi et al., [9] proposed multiple optimal paths to rectify the problem of stagnation with little overhead despite the single optimal path in Ant net routing algorithm. For MANET with minimum overhead, an advanced Multiple Feasible Paths is proposed. Using Network simulator, ns-2 successful simulation of Ant Net is performed. Correct routing tables were generated for all the topologies simulated. The proposed algorithm is efficient and reveals high-throughput.

Ducatelle, et al., [10] examined the performance of two swarm intelligence MANET routing algorithms using simulation. The swarm intelligence paradigm is employed in the two algorithms, ANSI and AntHocNet for the purpose of routing in various ways.A reactive approach applied to ANSI when there is no route availability among the source and destination of a communication session the ants are sent out. However, reactive and proactive mechanisms are incorporated in AntHocNet in order to adapt and enhance existing routes the algorithm continuously sends out ants at regular intervals during the complete duration of running sessions. Comparison of the two swarm intelligence routing algorithms is done with AODV and OSLR. To examine the importance of the various approaches implemented by the algorithms during real-world applications and the peculiarities of urban environments were the main aim of the proposed study. By considering this, a detailed and realistic simulation setup is defined. By limiting node movements to the streets and open spaces of town, the node mobility is modeled, to model the propagation of radio waves, and examine various types of interactive data traffic patterns, ranging from SMS messaging to VoIP communications, a ray-tracing approach is used.

Toutouh et al., [11] proposed various meta heuristic algorithms simulated annealing, genetic algorithm and Particle swarm optimization techniques to tune the parameters of OLSR. Results obtained show the performance of simulated annealing is ideal to obtain the best fitness value with GA able to identify the optimum value.

Gomez et al [12] defined the Route Change Latency (RCL) after link failures and its dependence on routing protocol parameter settings and implementation issues using OLSR. Experiments were conducted with a set of OLSR settings in a real network environment. It was demonstrated that end-to-end connectivity can be enhanced using different parameter settings from the default ones.

Research Gap and Questions

Most work in literature focused on improving the PDR. However from literature study it can be seen that shortest path between source and destination does not guarantee QoS. It not only depend on minimum number of hops to destination but also depend on other parameters including link quality, number of hops to destination, the OLSR tuning parameters including hello interval, neighbor hold time and topology hold time. The above parameters cannot be modeled and hence a NP problem [13].

The research problems that arises are

- Does efficient objective function improve the performance of the overall network in terms of QOS rather than single parameters like PDR?
- Can a relation be created between the QoS parameters?

Problem Statement

Mobility is one of the main challenges for routing in MANETs. The routing must be adaptable to deal with the topology changes and the performance of the network depends upon the adaptability to source routes with the QoS required. Identifying the best route using various network parameters like link quality, RSSI, Bandwidth to achieve minimum jitter, end to end delay and improve Packet Delivery Ratio. Since the problem cannot be solved mathematically, heuristic based algorithms are utilized to find feasible solutions based on objective functions.

The link duration and path duration metrics can be defined as follows: For number of nodes N in the network, let $D_{ij}(t)$ be the Euclidean distance between nodes i and j at time t and R be the transmission range of the mobile nodes [14].

The connectivity graph is the graph G=(V,E), such that $|V| = N$. At time t,

$$link\ (i, j) \in E\ iff\ D_{ij}(t) \leq R$$

Let X (i, j, t) be an indicator random variable which is assigned a value 1 iff a link exists between nodes i and j at time t. Else a value of 0 is assigned.

Link Duration is the maximum time interval $[t_1, t_2]$ wherein the two nodes i and j, at time t_l are within the transmission range of each other. Besides when these two nodes are not within the transmission range at time $t_l - \in$ and time $t_2 + \in$ for $\in > 0$ [14].

$$LD(i, j, t_1) = t_2 - t_1$$

iff $\forall$ t $t_l \leq t \leq t_2$, $\in > 0$: $X(i, j, t) = 1$ and $X(i, j, t_l - \in) = 0$ and $X(i, j, t_2 + \in) = 0$. Otherwise, $LD(i, j, t_l) = 0$.

Path Duration is the length of the longest time interval $[t_l, t_2]$, during which each of the k - 1 links between the nodes $\{n_l, n_2, ...n_k\}$exist [14]. Moreover, at time $t_l - \in$ and time $t_2 + \in$, $\in > 0$, at least one of the k links does not exist. At time t_l , path duration is the minimum of the durations of the k-1 links $(n_1, n_2),(n_2,n_3)\ldots(n_{k-1},n_k)$ at time t_1.

$$PD(P, t_1) = \min_{1 \leq z \leq k-1} LD(n_z, n_{z+1}, t_1)$$

Objectives

This paper focuses on application of Ant Colony Optimization and varied routing techniques for mobile ad hoc networks with multimedia traffic. The reminder of this paper presented is organized as follows: Section 7 presents descriptions of OLSR routing. Ant Colony Optimization (ACO) is detailed in Section 8, and Section 9 describes the proposed technique followed by reviews of performance analysis in section 10. Section 11 presents the comparison of results of the proposed method with Toutouh et al., [11] and Gomez et al., [12] and section 12 concludes the paper.

Optimized Link State Routing Protocol (OLSR)

As OLSR [2] is a proactive routing protocol routes are available when needed. OLSR is an optimized version of a link state protocol; topological changes flood topological information to available network hosts. The aim is to reduce network overhead the protocol using Multipoint Relays (MPR) to reduce broadcast flooding by reducing broadcast in some network regions. Another way to reduce is by providing the shortest path. Reducing time interval for control message transmission brings more reactivity to topological changes [15, 16]. To route packets optimally, OLSR pursues the following steps:

Knowledge of The Neighbors:
Each node broadcasts a HELLO message locally with information about the neighborhood and link status at regular intervals.

Selection of MPRs:
Each node constructs a set of MPRs to create a neighbor subset whose links are symmetrical and which covers all neighbors in two hops. A node's MPRs are reported in subsequent HELLO messages.

Declaration of MPRs:
Each node is an MPR periodically diffuses topology control(TC)messages to all network nodes to build relative information foundation for network topology. Nodes forward TC messages in the network at specific times to ensure that each MPR declares a list of neighbors selected as MPR.

Routing Table:
A routing table is calculated from a topology table and the first neighbor. Whenone table is modified a shortest path algorithm transmits data with the aid of routes in the table. Each route entry has destination node address, intermediate nodes on the route and hop count.

OLSR protocol suits applications which do not allow long delays in data packet transmission. The best OLSR protocol working environment is a dense network, where most communication is concentrated among many nodes [17]. Reaction to topological changes is adjusted by changing time intervals for broadcasting Hello messages. It improves theprotocol's suitability for MANET with rapid source and destination pair changes. OLSR protocol does not need the link to be reliable for control messages as messages are sent regularly and delivery is not necessarily sequential.

Ant Colony Optimization
Ant Colony Optimization metaheuristic (ACO) is a multi-agent framework for combinatorial optimization where the main components are: set of ant-like agents, use of memory and of stochastic decisions and strategies of collective/distributed learning [18]. It has roots in observation of foraging behavior of ant colonies, which selects the shortest path from the nest to a food site. In ACO, ants use pheromone deposits as evaluation for a travelled route. In routing, rather than RREP and RREQ packets, 'forward' and 'backward ant' agents ago across routes, where ant agents deposit pheromones as nodes arrive. Initially, ants have an equal chance of choosing between routes from source to destination. Over time the route which is shorter, receives more pheromone from ants going in both directions. The shorter route tends to attract the ants due to the extra pheromone which leads to more pheromone accumulation [19].

General ACO algorithm characteristics for routing:

- Provision of traffic-adaptive and multipath routing,
- Reliance on passive and active information monitoring/gathering,

- Using stochastic components,
- Setting up paths in less selfishly than through the shortest path schemes which favor load balancing,
- Showing limited sensitivity to parameter settings.

In Ant Colony Optimization, problems are modeled as a graph. Let G (V,E) be a connected graph with n = V nodes [20, 21]. Hence components c_{ij} are represented by either edges or graph vertices. The aim is to locate the shortest path between the source node V_s and the destination V_d. Each G edge maintains a value τ which denotes artificial pheromone concentration value over that node, modified whenever an ant goes over it. To simulate natural ant foraging, following three equations are used [22]:

$$\tau_{ij} \leftarrow 1-\rho \;\; \tau_{ij} + \sum_{K=1}^{m} \Delta\tau_{ij}^{k}$$

where τ_{ij} is pheromone concentration over link, ρ is the evaporation rate, m number of ants and $\Delta\tau_{ij}^{k}$ is the quantity of pheromone laid is given by:

$$\Delta\tau_{ij}^{k} = \begin{cases} Q/L & \text{if ant } k \text{ used edge } i, j \\ 0 & \text{otherwise} \end{cases}$$

Where Q is a constant parameter and L is the length of the tour. The probability of choosing the next node during path selection is given by:

$$p_{ij}^{k} = \begin{cases} \left(\tau_{ij}^{k} / \sum_{j \in N_i} \tau_{ij}^{k} \right) & \text{if } j \in \mathrm{N}_i \\ 0 & \text{otherwise} \end{cases}$$

Where the ant is node d transitioning to node j from node i, Ni is set of neighbors, k is route selection exponent which determines the sensitivity of the ant algorithm to pheromone changes.

Proposed ACO

In this work a novel fitness function is proposed based on end to end delay, packet delivery ratio and neighborhood hold time. The Total Route Fitness (TRF) is given by

$$TRF = (\alpha_1 e^{-n} + \alpha_2 * T_{hold}) * \frac{E2ED}{PDR}$$

where

α_1 and α_2 are constants such that $\alpha_1 + \alpha_2 = 1$

n is the number of hops between src and dest

T_{hold} is the neighbor hold time

$E2ED$ is the end to end delay

PDR is the packet delivery ratio

The block diagram of the proposed configuration is shown in figure 1.

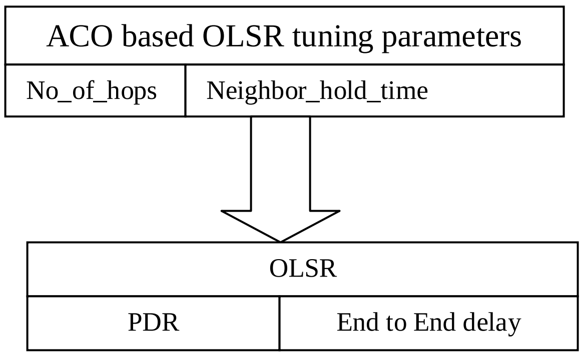

Figure 1: The proposed architecture

Each ant will follow one route and with each ant acting like an agent having the following tasks:

- Selecting a route and storing the values of the parameter along its path,
- On reaching destination, pass the parameter values information to be further processed by the algorithm
- Based on the values, calculate the value of the objective function for its route, and
- Based on the value of the objective function, pheromone is updated on each node visited along its route.

Once all ants complete traversing the network, one 'iteration' is completed. Eventually the trail will be used to score a route. The route with low value will cease to exist and new routes evolve around high scoring routes.

Experimental Setup

Traffic shaping is done through The Weighted Fair Queuing (WFQ) mechanism so that multimedia traffic has double the priority of normal traffic. Traffic is shaped to represent Pulse Code Modulation (PCM) compressed to eight bits of logarithmic data.

The *ITU-T Rec. G.711* presents two PCM audio codecs called A-law and µ-law and both transform linear PCM signals into logarithmic PCM and both operate on single samples.

A-law uses 13-bit linear PCM vector transforming it into 8-bit logarithmic PCM vector through an encoding process. µ-law uses 14-bit linear PCM and transforms it into 8-bit. Non-professional sound devices are unable to generate either 14-bit sample. In this implementation, 16-bit samples are passed and are the input of the coder. All samples are converted to 14-bit samples by cutting away least significant bits. Fair queuing forwards packets from a buffer, in which data packets are temporarily stored till transmission. Usually buffer space is divided into multiple queues, and each has packets of one flow. The packet transmission order in a fair queue depends on approximate finish time; the packet with earliest finish time being chosen for the next transmission. Weighted fair queuing (WFQ) calculates each packets weightby multiplying packet size with the inverse of an associated queue weight.

All mobile nodes are equipped with IEEE 802.11g network interface card, with data rates of 54 Mbps. The energy needed to transmit a packet *p* from node n_i is [23]:

$$E_{tx}\left(p, n_i\right) = i * v * t_p \text{ Joules,}$$

where *i* is the current (in Ampere), *v* the voltage (in Volt), and t_p the time taken to transmit the packet *p* (in seconds). In simulations, the voltage *v* is chosen as 5 V and the packet transmission time t_p is calculated by

$\left(p_h / \left(6*10^6\right) + p_d / \left(54*10^6\right)\right)$ seconds, where p_h, is the packet header size in bits and p_d the payload size. It is assumed that the energy consumption caused by overhearing a packet is the same as the energy consumed by actually receiving the packet. The energy $E\left(p, n_a\right)$ consumed to transmit a packet from node n_a to node n_b is given by [23]:

$$E\left(p, n_a\right) = E_{tx}\left(p, n_a\right) + E_{rx}\left(p, n_b\right) + \left(N-1\right) E_o\left(p, n_i\right)$$

where E_{tx}, E_{rx}, E_o denote the amount of energy spent to transmit the packet from node n_a, to receive the packet at node n_b and to overhear the packet, respectively. *N* represents the average number of neighboring nodes affected by a transmission from node n_a.

The simulation environment consists of nodes running a multimedia application over UDP. Nodes have a transmitting power of 0.005 watts. Nodes are distributed in a 2000 meters by 2000 meters area with each node having a random trajectory. Based on priority, video packets are queued through assigning double the weight of normal packets. The parameters used in OLSR routing protocol are seen in Table I.

Table 1: OLSR Parameters used in the Experimental Setup.

Hello interval in seconds	2
TC interval in seconds	6
Neighbor hold time in seconds	1-15
Topology hold time in seconds	15
Duplicate message hold time in seconds	30
Addressing mode	IPV4

The routes are selected using the proposed method. The simulations are run using classic OLSR and the proposed ant routing OLSR. The performance is measured in terms of Packet dropped, Jitter, End-to-End delay and Throughput.

Results and Discussion

Figure 2 shows the packet dropped for both OLSR and proposed ACO OLSR.

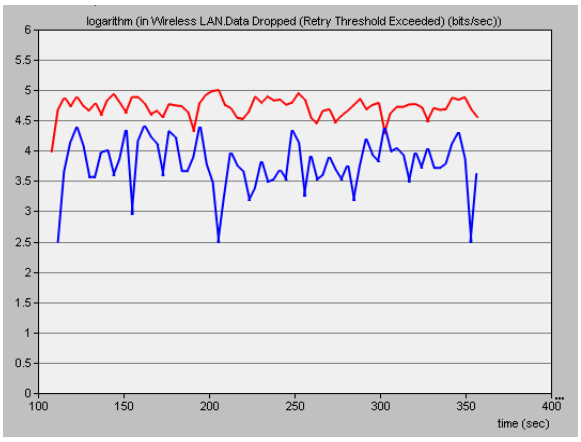

Figure 2: Packet dropped in logarithmic scale for OLSR and proposed ACO OLSR

The packet dropped decreases by 20.83% in the proposed protocol compared to OLSR. Figure 3 shows the jitter for the proposed ACO OLSR and compared with OLSR.

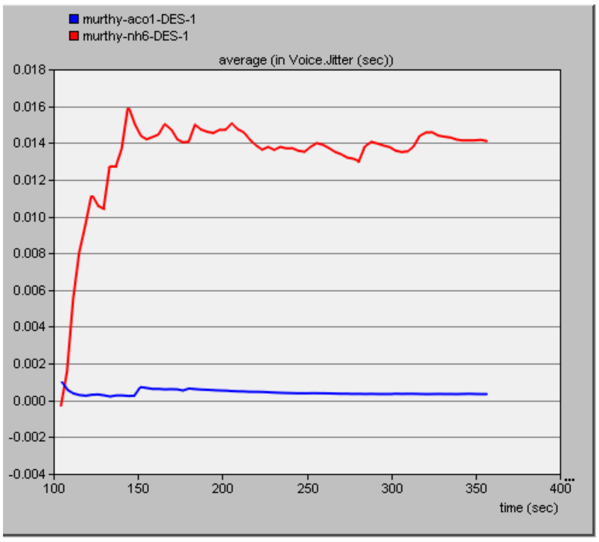

Figure 3: Average Voice Jitter for OLSR and proposed ACO OLSR

The jitter decreases drastically compared to OLSR protocol. It is evident from the above graphs that the packet dropped and jitter reduces in the proposed ACO OLSR.

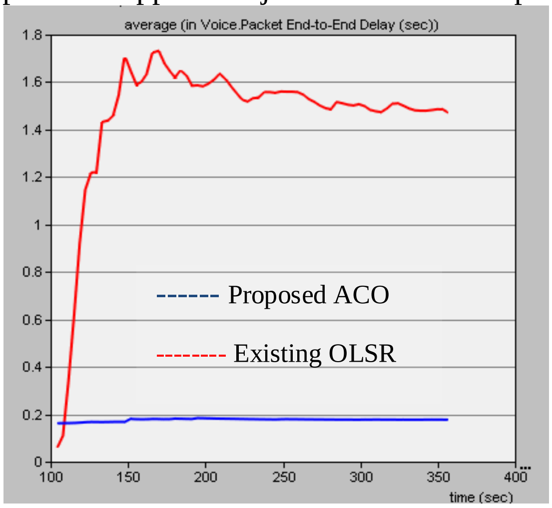

Figure 4: End-to-End delay

Figure 4 shows the end to end delay for the proposed and existing OLSR and figure 5 shows the throughput of the system with respect to the simulation time.

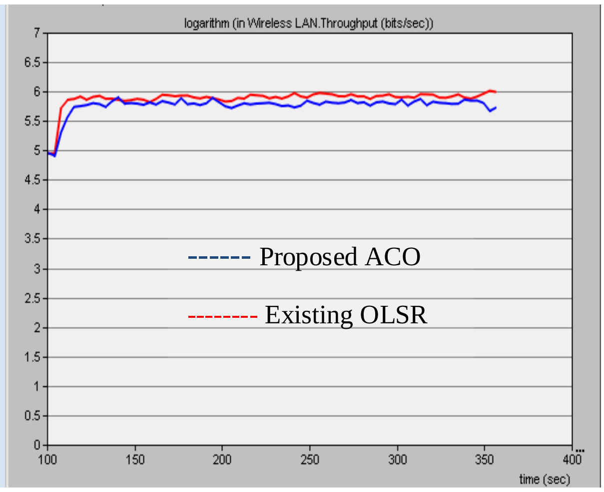

Figure 5: Throughput in bits/sec (logarithmic scale)

Comparison

To bench mark the proposed work, experiments were conducted in a 1000, 2000 and 3000 sq m area with nodes moving at 10-50 kmph with channel bandwidth of 5.5 Mbps. Using UDP transport protocol and Constant Bit Rate (CBR) traffic, simulations were carried out for three minutes and compared with [11] and [12]. The statistical analysis of mean and best fitness function obtained after conduction 10 runs for each scenario is shown in Table 2 and 3 respectively.

Table 2: Comparison with other techniques in literature for Mean Fitness

	1000 sq m	2000 sqm	3000 sqm
GA (with Toutouh et al., setup)	0.1799± 0.0331	0.1878± 0.0308	0.2183± 0.0416
SA (with Toutouh et al., setup)	0.1752± 0.0253	0.1851± 0.0419	0.2081± 0.0267
Proposed ACO	0.1704± 0.0377	0.1764± 0.0389	0.2038± 0.0416

Table 3: Comparison with other techniques in literature for Best Fitness

	1000 sq m	2000 sqm	3000 sqm
GA (with Toutouh et al., setup)	0.1469	0.157	0.1766
SA (with Toutouh et al., setup)	0.1498	0.1433	0.1816
Proposed ACO	0.1328	0.1377	0.1624

Figure 6 shows the best fitness achieved for number of iterations for network size of 1000 sqm.

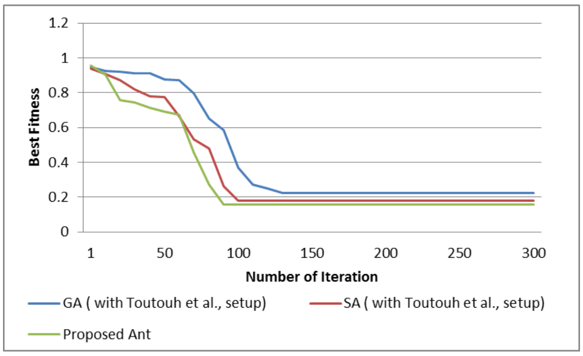

Figure 6: Best Fitness Achieved (1000 sqm)

The obtained packet delivery ratio, end to end delay and number of hops are compared with techniques available in literature and shown in Table 4, Table 5 and Table 6 respectively.

Table 4: Packet Delivery Ratio

	1000 sq m	2000 sqm	3000 sqm
GA (with Toutouh et al., setup)	98.62	86.54	72.18
SA (with Toutouh et al., setup)	99.14	88.31	74.26
RFC	92.36	87.74	81.56
Gomez et al., [12] -#1	70.26	68.46	62.41
Gomez et al., [12]-#2	86.18	77.26	72.62
Gomez et al., [12]-#3	91.36	79.24	74.64
Proposed ACO	95.89	87.62	82.14

Table 5: End to End Delay in ms

	1000 sq m	2000 sqm	3000 sqm
GA (with Toutouh et al., setup)	2.03	3.64	46.28
SA (with Toutouh et al., setup)	2.16	6.92	42.36
RFC	2.36	46.84	61.76
Gomez et al., [12] -#1	4.76	32.44	48.65
Gomez et al., [12]-#2	5.14	41.76	61.32
Gomez et al., [12]-#3	6.02	44.18	58.23
Proposed ACO	1.89	23.04	38.42

It can be seen that the end to end delay is the lowest in the proposed technique. However the PDR is lower than [11] as the experiments were averaged over 10 runs in which it was possible to obtain PDR of 100% in one session.

Table 6: Number of Hops

	1000 sq m	2000 sqm	3000 sqm
GA (with Toutouh et al., setup)	2.62	3.48	4.12
SA (with Toutouh et al., setup)	2.7	3.45	3.86
RFC	2.83	3.78	4.22
Gomez et al., [12] -#1	2.92	3.53	4.07
Gomez et al., [12]-#2	3.19	3.48	4.03
Gomez et al., [12]-#3	2.38	3.62	4.25
Proposed ACO	2.19	3.29	3.78

Conclusion

Traditional routing protocols performance degrades due to the dynamic behavior and resource constraints of MANET. To overcome this issue, in this paper, an ant colony optimization is incorporated with OLSR routing protocol.Algorithms like ant colony optimization (ACO) algorithms are nature-inspired algorithms that are capable to efficiently construct routing algorithms for MANETs. A novel fitness function "Total Route Fitness" is proposed based on end to end delay, packet delivery ratio and neighborhood hold time. Simulation was conducted using multimedia traffic. The observations show the efficiency of the proposed ACO OLSR when compared to OLSR. For the Packet dropped, Jitter and End-to-End delay of the proposed routing performs better than the original OLSR and Throughput is almost same as OLSR. Thus, the proposed routing enhances the QoS of the network.

The proposed ACO algorithm was also compared with the works of Toutouh et al and Gomez et al. It can be seen that the end to end delay is the lowest in the proposed technique. However the PDR is lower than Toutouh et al. Future work needs to be carried out to improve packet delivery ratio.

References

[1] Bansal, M., Rajput, R., & Gupta, G. (1999). Mobile ad hoc networking (MANET): Routing protocol performance issues and evaluation considerations. The Internet Society.

[2] E.M. Royer and C.K. Toh. A review of current routing protocols for ad hoc mobile wireless networks.In IEEE Personal Communications, volume 6, April 1999.

[3] T. Clausen and P. Jacquet."Optimized link state routing protocol (OLSR)". RFC 3626: Optimized link state routing protocol (OLSR), Oct 2003.

[4] C. Perkins. "Ad hoc on-demand distance vector routing. Internet-Draft",draft-ietf-manet-aodv-00.txt, November 1997.

[5] V. Ramasubramanian, Z. J. Haas, and E. G. Sirer. “Sharp: A hybrid adaptive routing protocol for mobile ad hoc networks”. In Proceedings of The Fourth ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc), 2003.

[6] Abolhasan, M., Wysocki, T., & Dutkiewicz, E. (2004). A review of routing protocols for mobile ad hoc networks. Ad hoc networks, 2(1), 1-22.

[7] Bibhash Roy, SumanBanik, ParthiDey, SugataSanyal, NabenduChaki, “Ant Colony based Routing for Mobile Ad-Hoc Networks towards Improved Quality of Services,” VOL. 3, NO. 1, January 2012.

[8] S. Rajagopalan and C.-C.Shen. ANSI: A Swarm Intelligence-based Unicast Routing Protocol for Hybrid Ad hoc Networks. Journal of Systems Architecture, Special Issue on Nature Inspired Applied Systems, 2006.

[9] ShwetaModi, JitendraPrithviraj, “Multiple Feasible Paths in Ant Colony Algorithm for mobile Ad hoc Networks with Minimum Overhead,” Global Journal of Computer Science and Technology, Volume 11 Issue 4 Version 1.0 March 2011

[10] F. Ducatelle, G.A. Di Caro, and L.M. Gambardella. An evaluation of two swarm intelligence manet routing algorithms in an urban environment. In Proceedings of the 5th IEEE Swarm Intelligence Symposium, St. Louis, USA, September 21–23, 2008.

[11] Toutouh, J.; Garcia-Nieto, J.; Alba, E., "Intelligent OLSR Routing Protocol Optimization for VANETs," *Vehicular Technology, IEEE Transactions on* , vol.61, no.4, pp.1884,1894, May 2012

[12] Gomez, C., Garcia, D., & Paradells, J. (2005, June). Improving performance of a real ad-hoc network by tuning OLSR parameters. In Computers and Communications, 2005. ISCC 2005. Proceedings. 10th IEEE Symposium on (pp. 16-21). IEEE.

[13] Toutouh, J., & Alba, E. (2012, July). Green OLSR in VANETs with differential evolution. In Proceedings of the fourteenth international conference on Genetic and evolutionary computation conference companion (pp. 11-18). ACM.

[14] Sadagopan, N., Bai, F., Krishnamachari, B., & Helmy, A. (2003, June). PATHS: analysis of PATH duration statistics and their impact on reactive MANET routing protocols. In Proceedings of the 4th ACM international symposium on Mobile ad hoc networking & computing (pp. 245-256). ACM.

[15] Toa Lin, Scott F. Midkiff and Jahng S. Park “A Framework for Wireless Ad Hoc Routing Protocols.” Bradley Department of Electrical and Computer Engineering.Virginia Polytechnic Institute and State University. Blacksburg Virginia. 2003

[16] S. Corson and J. Macker “Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations.” RFC 2501, IETF Network Working Group, January 1999.

[17] P. Jacquet, P. Mühlethaler, T Clausen, A. Laouiti, A. Qayyum and L. Viennot “Optimized Link State Protocol for Ad Hoc Networks.” IEEE INMIC Pakistan 2001.
[18] G. Di Caro and M. Dorigo.“Mobile agents for adaptive routing”. In Proceedings of the 31st International Conference on System Sciences (HICSS-31), volume 7, pages 74–83. IEEE Computer Society Press, 1998.
[19] Abbaspour, K. C., Schulin, R., & Van Genuchten, M. T. (2001). Estimating unsaturated soil hydraulic parameters using ant colony optimization. Advances in water resources, 24(8), 827-841.
[20] Dorigo M., G. Di Caro, and L. M. Gambardella. “Ant algorithms for discrete optimization”. Artificial Life, 5(2):137–172, 1999.
[21] Maniezzo. “Exact and approximate nondeterministic tree-search procedures for the quadratic assignment problem”. INFORMS Journal of Computing, 11(4):358–369, 1999.
[22] Dorigo M. and G. Di Caro. “Ant colony optimization: a new meta-heuristic”. In Proceedings of the Congress on Evolutionary Computation, 1999.
[23] De Rango, F., Fotino, M., & Marano, S. (2008, November). EE-OLSR: energy efficient OLSR routing protocol for mobile ad-hoc networks. In Military Communications Conference, 2008. MILCOM 2008. IEEE (pp. 1-7). IEEE.