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Dynamic Quality of Service Stability based multicast routing for MANET DQSMRP

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Abstract— *Stable routing is a critical factor in mobile ad hoc network due to the lack of stable infrastructure. The MANETs node mobility nature always needs to rediscovery new paths to organize a routing. In order to enhance the Quality of Service and routing stability in MANET, in this paper we propose Dynamic Quality of Service Stability based multicast routing protocol (DQSMRP) by modifying the Cuckoo Search Algorithm (CSA) with the new position updating mechanism. This updating mechanism is derived from the differential evolution (DE) algorithm, where the candidates learn from diversified search regions. Each node in the network periodically estimates the parameters, i.e., node and link stability factor, bandwidth availability, and delays. In the next step neighbour stability and QoS database at every node are created using estimated parameters. Finally a multicast path is constructed by using route request and route reply packets. The QoS and stability information, i.e., link/node stability factor, bandwidth and delays in route are stored in the information cache of nodes, and are used for performing route maintenance in case of node mobility and route failures.*

Keywords— *MANET, QOS routing protocols , Wireless ad-hoc networks,Wireless sensor networks, Multicast routing.*

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are best in class kind of wireless communication networks, in which mobile nodes link on an on-demand basis. MANETs are capable of changing their locations by themselves as well possessing the ability to configure on their own, facilitating peer-level communications among mobile nodes independent of fixed infrastructure. The key challenge in constructing a MANET is to equip each node to continuously retain the information required to appropriately route traffic. Normally, MANETs are used for group communications, where multicast protocols are efficient compared to unicast protocols since they improve the efficiency of the wireless links in MANETs and when an application demands for sending multiple copies of messages from multiple sources to multiple receivers.

Multicasting reduces the communication costs by sending the single copy of the data to multiple recipients rather than sending multiple copies by using multiple unicasts. Thus it minimizes the link bandwidth, processing, and transmission delay. In particular MANETs research focuses on modeling different algorithms which possess high capability in selecting the routing path(s) and can effectively accommodate the desired QoS [1].

This infrastructure results in a highly dynamic topology resulting in a challengeable task for the Quality of Service Routing.

Similar to the other well established wireless networks such as WiFi, GSM, and CDMA, MANETs will not provide reliable services and QoS (Quality of Service). Basically, QoS considered is an imperative component for evaluating the performance of MANETs and henceforth the boundaries on bandwidth, delay, bandwidth delay product, jitter, and packet loss are found to largely influence the QoS factors. Thus QoS routing not only demand a path from a source to a destination but also demands a route that fulfils the end-to-end QoS constraints, prescribed as bandwidth or delay or loss. The prime objective of the route selection method is then to recognize a route that is most likely to fulfil the QoS requirements [2]. The primary objective of a QoS routing strategy is to maximize the utilizations of network resources by determining routes which are appropriate for different types of constraints imposed on MANETs by various applications.

The QoS routing protocol can also work in a stand-alone multihop mobile network for real-time applications [3, 4]. The QoS requirements largely depend on some of the key constraints, namely, link constraint, path constraints, and tree constraints. The main key constraint is the bandwidth; similarly, end-to-end delay is the path constraint and delay-jitter is the tree constraint [5]. Thus, satisfying all these interdependent constraints with conflicting objective makes the problem more complex and robust techniques are required to solve the considered QoS problem with the said constraints being met. When problem with complexities are to be considered, the obvious choice becomes heuristic techniques rather than the deterministic methods. Thus past researchers adopted several heuristic based techniques to solve the QoS routing problems [5, 6]. This is necessary for more improvement of various routing protocols for MANETs, and each proposed protocol claims that the strategy proposed provides an improvement over a number of different strategies considered in the literature [7].

In [8], an AMRoute is presented which deals with specific unicast routing protocol and is made feasible for other different unicast protocols. In another work [9], an on-demand QoS routing is proposed, wherein the link-state multipath QoS routing constructs a network topology employing a link bandwidth at the destination. In [10], a protocol called PUMA for ad hoc networks to establish and maintain a shared mesh for each multicast group is presented. A multiconstraint QoS routing using a new single mixed metrics is discussed [11]. Reference [12] presents an ABMRS in MANETs, which makes use of a set of static and mobile agents for QoS routing [13]. Another proposal called Optimized Link State Routing Protocol was introduced in [14].

In addition to the above exact methods, the multiconstraint QoS routing was also addressed by several heuristic methods, which are reviewed briefly. In [15], a novel QoS routing algorithm based on Simulated Annealing (SA) is presented. Reference [16] discusses a novel bee colony optimization algorithm called bees life algorithm (BLA) to solve the QoS multicast routing problem; the key point here is three constraints which are delay, allowed jitter, and requested bandwidth which are taken into consideration. Similarly, a Tabu search [17] based method considering two important QoS constraints, bandwidth and end-to-end delay, is included. Again in [18, 19] QoS routing was effectively and efficiently addressed using a globally optimizing ant algorithm. Similarly, a new creative algorithm to find the path of the MANET with the bandwidth-delay-constrained multicast routing problem is proposed based on a harmony search (HS) algorithm [20].

Although several heuristic approaches are applied to QoS routing in MANETs, they almost individually solve this problem. Most of the above algorithms suffer from premature convergence, which leads to the introduction of hybrid methods [21]. Here, a PSO-GA method is hybridized with the strengths of both the particle swarm optimization (PSO) method and genetic algorithm (GA) method which compromises the overlapping between natural selection and social behavior which realizes an effective and efficient search for the solution. Similarly, in [22], new fuzzy genetic algorithm for QoS multicast routing is also discussed.

Thus, in this paper, we propose Dynamic Quality of Service Stability based multicast routing protocol (DQSMRP) for the multi constraint QoS routing problem. Cuckoo search (CS) [23] is one of the recent heuristic search algorithms inspired by the reproduction strategy. This low complexity of CS lends this new algorithm and its power to deal with complex and challenging problems [24, 25]. In this paper it is proposed again to improvise the performance of the CS method by introducing a new egg producing mechanism making the search of CS more exhaustive and leads to quick search of better solutions provide bandwidth satisfied, reliable and robust route .

Rest of paper is organized as follows. The section II of this paper presents problem definition. Tuned cuckoo search multicast routing protocols are discussed in section III. Simulationand performanceevaluation is presented in Section IV. Finally Section V presents the concluding remarks

II. PROBLEM DEFINITION

The QoS routing problem is modelled as an optimization problem whose prime objective is to determine a multicast tree by taking into account the cost function which has to be minimized subject to some of the practical constraints. The present formulation considers four different constraints, namely, delay, packet loss, bandwidth, and jitter. The formulation is taken from [5] and for easy reference it is being presented here gain.

The objective function of the QoS routing is formulated as

$$Min\, C\left(H\,(x,s)\right) = C_c + \delta_1 C_b + \delta_2 C_d + \delta_3 C_{dj} + \delta_4 C_{pl}$$

The two most important reasons to combine both cost optimization and multiconstrained routing are the following:

(1) Practically QoS routing problems are often formulated in terms of multiple constraints and the multicast structure is expected to identify a feasible path for each source and destination.

(2) The significance of the network engineers and thus perfection of the users is to minimize the network resource utilization.

In summation, it can be represented as

$$C\left(H\,(x,s)\right) = \sum_{e \in H(x,S)} c(y)$$

The Delay Constraint (DELAY). It is the allowed delay limit along any branch of the network. A penalty is added if there is no link established between any two nodes. Consider

$$Delay\left(R(x,y)\right) = \sum_{e \in R(x,y)} dl(x) + \sum_{n \in R(x,y)} dl(y)$$

The Bandwidth Constraint (BandWidth). It is the average bandwidth requirement of all the tree branches in the network. Consider

$$Bandwidth\left(R(x,y)\right) = \min\left(bw(x)\right), x \in R\,(x,y)$$

Additionally δ_1, δ_2, δ_3, δ_4 are the penalty constants of bandwidth, delay, delay-jitter, and packet-loss, respectively. In the next section, the proposed solution methodology using the modified Cuckoo search algorithm to solve the multicast QoS routing problem is explained in detail with numerical experiments.

III. TUNED CUCKOO SEARCH MULTICAST ROUTING PROTOCOL

Solving a problem with complexities as shown above requires a solution technique that not only produces quality solution but also should be simple to implement. Due to increasing complexities of the problem in real time situations, this paper takes into account the possibilities of extending the proposed algorithm in future. Thus, this paper uses a Cuckoo search, one of the recent heuristic search algorithms, proven to be one of the best alternatives for the existing meta heuristic techniques. Before the proposed method is discussed, a brief overview of the Cuckoo search is presented.

A.Cuckoo Search (CS): AnOverview

Cuckoo search is one of the recent heuristic search algorithms inspired by the reproduction strategy which differs from other host birds in the way that cuckoos choose nests of other birds to lay their eggs [26, 27]. Fortunately, the host bird easily distinguishes that the eggs are not its own and probably destroys the cuckoo egg. Thus, the cuckoo bird developed evolutionally produce eggs that look similar to the local host birds. Thus, three important points guide this as an optimization procedure, which are as follows:

(i)Initial Solution: the egg of cuckoo represents a set of solutions and its dimensions which are randomly placed at various nests.

(ii)Next Generation: only a part of these eggs (the best eggs) with acceptable solutions will be allowed to move into the next generation.

(iii)Acceptance Rule: if any of the eggs is identified as strange, then that particular (egg) solution will be removed and a new egg will replace this alien in a new nest.

The main steps of the CS are given below:

Randomly Initialize “Pop” host nests, a set of population. (e.g., $P = \sum_{i=1}^{pop} P_i$)
Evaluate the fitness of all nests $F = \sum_{i=1}^{pop} f(P_i)$

Do Iterations <Max.Iterations
Produce a cuckoo egg P^i by applying a Lévy flight from a random nest
3. Evaluate the fitness of $f(P_i)$
Check for existence: choose again a random nest J
if $f(p_i^1) < f(P_i)$ then
$P_j = p_i^1$
end if
Cull a fraction of the worst nests at the rate of R_c
Build new nests randomly at new locations via Lévy flights as replacements
End While

A significant credit to this heuristics is its simplicity. This low complexity lends this new algorithm and its power to deal with complex and challenging problems. Perhaps when compared with other metaheuristic techniques such as particle swarm optimization and Ant colony algorithms, CS method has only a single parameter to be taken care of.

B.*Node Stability*

The stable nodes are necessary in forwarding group to provide better packet delivery services. Node stability in terms of movement around its current position gives an idea of stationary property of node. The authors use node stability metric from their previous work given in [28], to identify stable nodes in a path for forwarding packets from a source to multicast group.

Two metrics to represent node stability as the quality of connectivity are identified: self stability, and neighbor nodes stability. Self stability can be defined as the node’s movement with respect to its previous position.

The steps in finding the stability of a node are as follows:

• All the nodes in MANET find the self stability, i.e., node movement relative to its previous position

• Find neighbour’s stability for all the nodes in MANET by considering the neighbour’s self stability. Each node in a MANET will compute the node stability factor based on self stability, and neighbour nodes stability.

If a node is trying to move away from its position, the distance of the movement and transmission range decides the stability. A node is said to be stable if its movement is within given fraction of its transmission range.

C.Neibhour Node Stability

It can be defined as how well a node is being connected by its neighbor in terms of their self stability. The nodes can exchange messages with each other, if they are within the transmission range. Each node accumulates connectivity information and signal stability of one hop neighbors, and maintains a neighbor list. The degree of a node n is represented as number of links (or nodes) connected to it, and is denoted as ND.

$$N_s(t) = \propto \times \frac{1}{ND} \sum_{i=1}^{ND} S_s^i(t) + (1-\propto) \times N_s(t-1)$$

where α is the weightage factor (lies between 0 and 1), and is distributed between 0.6 and 0.7, since they yield better results in simulation

D. Link Stability

Link stability between the nodes indicates quality and life time of the connection. The link stability estimated in the scheme is based on two parameters: received signal strength and life time of the link.

The Algorithm 1 represents a pseudo code for updating link stability status between the nodes. The different parameters used in the algorithm are as follows:

- lifetime – duration of continuous connectivity between the nodes
- lifetime threshold – indicates the maximum limit of link lifetime that decides link stability
- link stability status – is a boolean variable that defines link stability between the nodes
- Recent – indicates most recent response received for a Hello packet from a neighbour
- P – number of Hello packets
- received signal strength – is the strength of signal received from a neighbour
- signal threshold – is an acceptable signal strength to be received from neighbours

***Algorithm** : Link stability status between the nodes*

```
P = No of Hello Packets;
lifetime = 0;
link stability status = 0;
Recent = 0;
lifetime threshold = P × Hello Packet Interval;
while P > 0 do
if received signal strength ≥ signal threshold then
lifetime = lifetime + 1;
Recent = 1;
P = P−1;
else
Recent = 0;
P = P−1;
end if
end while
lifetime sec = lifetime × Hello Packet Interval;
if (lifetime sec > lifetime threshold) and (Recent) then
link stability status = 1;
else
link stability status = 0;
end if
```

E. Delay Estimation

For delay estimation, an arbitrary node that contributes to traffic forwarding using the M/M/1 queuing system is modelled. This queue represents a single queuing station with a single server [29]. The authors assume that the contributing nodes are served by a single server with first come first serve queuing policy. Packets arrive according to a

Poisson process with rate λ, and the probability distribution of the service rate is exponential, denoted by μ. The maximum size of the queue in every node is represented by K.

To satisfy delay requirements in multimedia real time applications, packets must be received by multicast receivers which satisfies the application delay constraints. When a packet is to be sent either by a source node or forwarding group of nodes; it experiences three types of delays: queuing, contention and transmission delay. The total delay considered over a link between two nodes is given by

$$d_{Total} = d_q + d_c + d_t$$

The queuing delay denoted by d_q is the delay between the time the packet is assigned to a queue and the time it starts transmission. During this time, the packet waits while other packets in the transmission queue are transmitted. This is the amount of time a packet is spent in the interfacing queue

F. Bandwidth Estimation

The bandwidth information is one of the important metric of choice for providing Quality of service (QoS). The authors considered their previous work presented in [30], to estimate the available bandwidth based on the channel status of the radio link to calculate the idle and busy periods of the shared wireless media. By observing the channel utility, the measure of the node activities can be taken as well as its surrounding neighbours and thus obtain good approximation of bandwidth usage.

In IEEE 802.11 MANETs, due to the contention based channel access, a node can only transmit data packets after it gains the channel access. Hence, a node first listens to the channel and estimates bandwidth by using the idle and busy times for a predefined interval. This is expressed in following equation

$$BW = \frac{T_{idle}}{T_{interval}} \times C$$

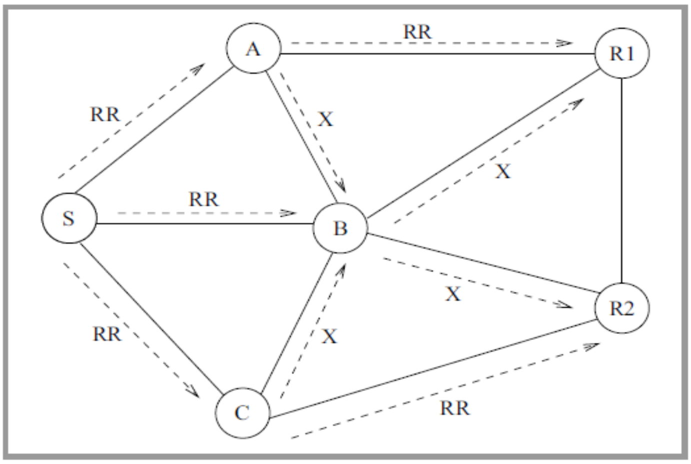

Figure.1 Route request paths from S to R1 and R2

G. Route Discovery Process using Tuned Cuckoo Process

Multicast stable QoS path creation involves two phases: a request and a reply phase. Request phase invokes route discovery process to find routes to group of receivers using stable and QoS intermediate nodes. Reply phase involves updating of RIC and confirming the routes found in request phase. These stable and QoS nodes act as intermediate nodes that help to create multicast mesh from source to group of receivers.

A source node finds the route to its group of receivers by using RR packets. The sequence of operations that occur are as follows:

Step-1. Source node prepares a RR packet with application bandwidth and delay requirements.

Step-2. Selective transmission of RR packet to neighbours who satisfy stability criteria, i.e., SFBN greater than SFTH, and bandwidth requirement, i.e., estimated bandwidth greater than twice the application requirements.

Step-3. A node receiving RR packet will discard it, if it is already received (by using sequence number and source address).

Step -4. If RR packet is not a duplicate, checks Routing Information Cache (RIC) for availability of route; if available, RP packet will be generated and start reply propagation to source.

Step-5. If RR packet is a duplicate, then discard it and stop transmission of RR packet.
Step-6. If not duplicate and no route available in RIC, transmit the RR packet by updating its fields (route record, Stability Factor Between Nodes (SFBN) record, bandwidth record, delay record, time to live, and next hop address to its neighbours as in step 2.
Step-7. Perform steps 3 to 6 until destination is reached.*Step-8*. If receiver is not reached within certain hops, send RE packet to the source node.

IV.SIMULATION AND PERFORMANCE EVALUATION

In this section, the performance of proposed protocol with DQSMRP and fully distributed multicast routing protocol (FDMRP) [31], is compared, through extensive set of simulations. These protocols have been taken for comparison because both are mesh based. These protocols are compared in terms of packet delivery ratio, control overhead, and average end-to-end delay. Simulation considers the values of the performance parameters taken for several iterations, and the values are used for computing the mean. The values lying within 95% of the confidence interval of the mean are used for computing the mean value, which are plotted in the graphs in result analysis section. The various network scenarios have been simulated. Simulation environment consists of four models: Network, Channel, Mobility, and Traffic. In network model an ad hoc network is generated in an area of l × b square meters. It consists of N number of mobile nodes that are placed randomly within a given area. The coverage area around each node has a limited bandwidth that is shared among its neighbours. It is assumed that, the operating range of transmitted power and communication range are constant.

Table 1
Simulation Parameters

No. of Nodes	**50,100,150 and 200.**
Routing Protocol	DQSMRP
Area Size	1000 X 1000
Mac	802.11
RadioRange	250m
Simulation Time	10 sec
Traffic Source	CBR
Packet Size	512
Receiving Power	0.395
Sending power	0.660
Idle Power	0.035
Initial Energy	10.0 J
Node Speed	5,10,10 and,20 ms
No of destinations	2,4,6 and 8

A. Performance Parameters

Following metrics have been used to analyse the performance:
– Packet Delivery Ratio (PDR) – it is the ratio of number of average data packets received at the multicast receivers to the number of data packets sent by the source;
– Packet Overhead – it measures the ratio of control packets sent to the network to the total number of average data packets delivered to the receivers;
– Average end-to-end Delay – it is the average delay experienced by the successfully delivered packets in reaching their receiver

B. Result Analysis

The simulation results of DQSMRP and FDMRP presents the comparison results by varying number of multiple destinations and node speeds. According to the simulation results in Fig 2 to Fig 7 the performance of DQSMRP is more reliable than FDMRP.
As figure 2 and 3 show, the performance of DQSMRP packet delivery ratio increased more than 14.2% compared to FDMRP. More over figure6 and fig 7show that the performance of DQSMRP end to end delay is less than FDMRP, and that the delay ratio varied with respect to node speed and number of destinations. Figures 4, 5 show the overhead with

respect to node speed and number of destinations and it is found that the overhead rate of DQSMRP is 22% less than FDMRP.

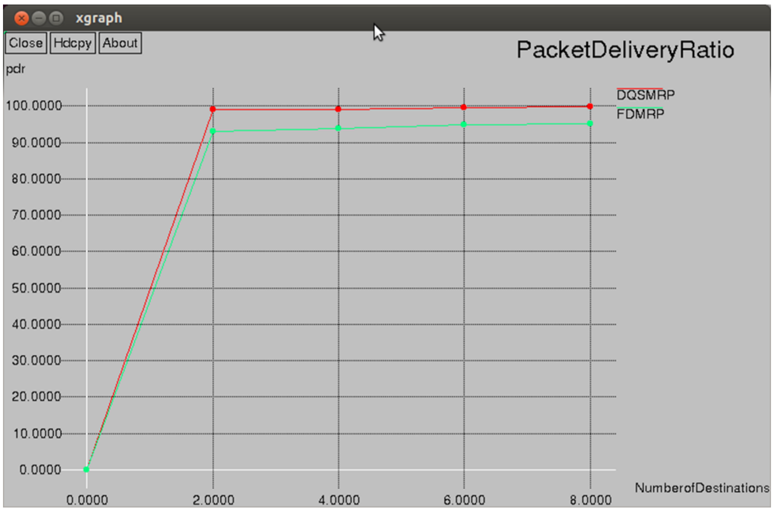

Figure 2: PDR vs Number of Destinations

Figure 3: PDR vs Node Speed

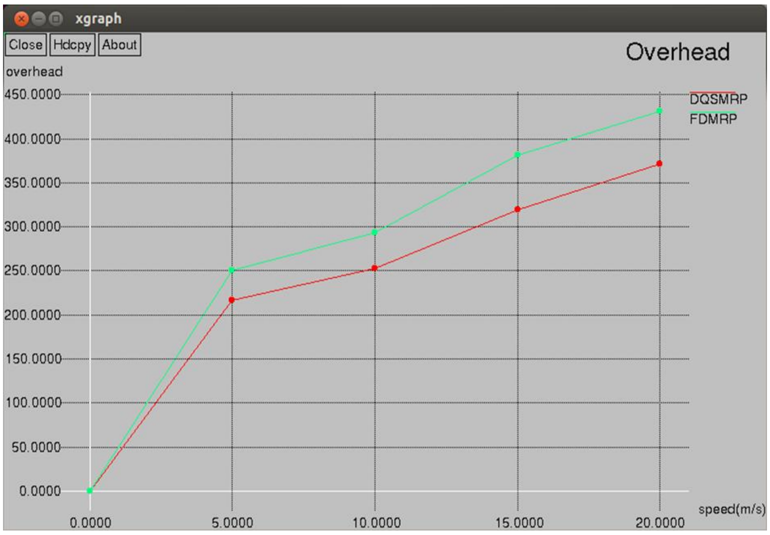

Figure 4: Overhead vs Node Speed

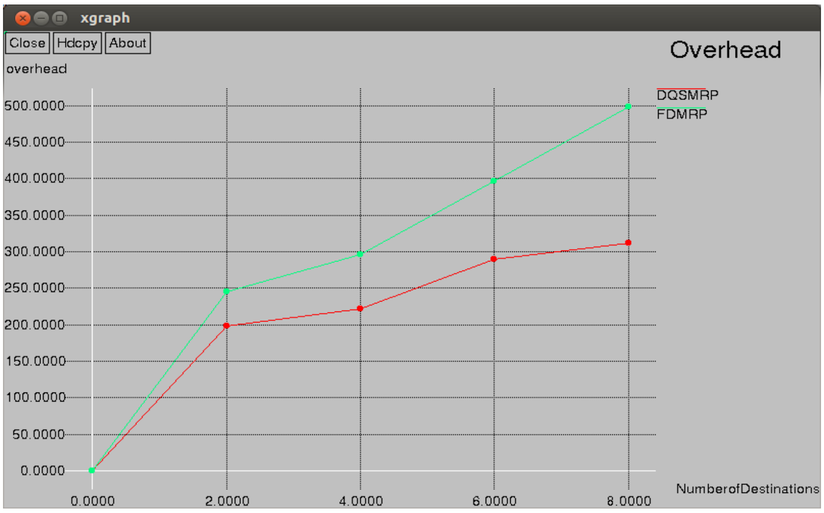

Figure 5: Overhead vs Number of destinations

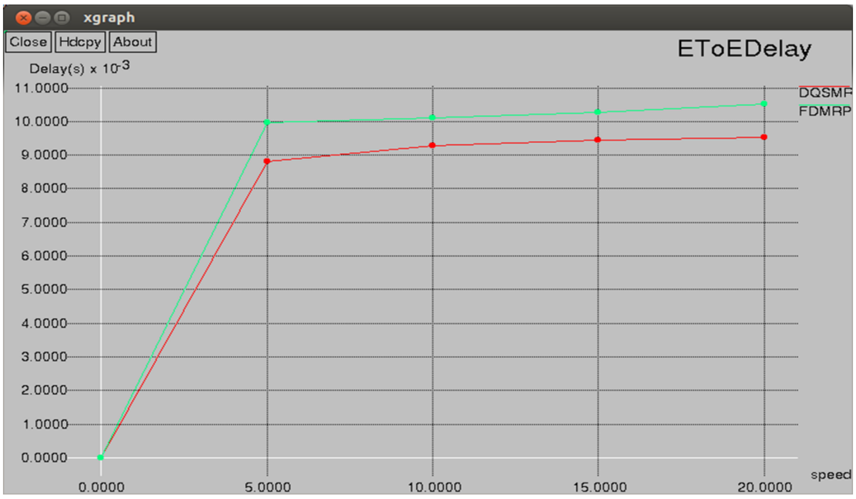

Figure 6: End to End Delays vs Speed

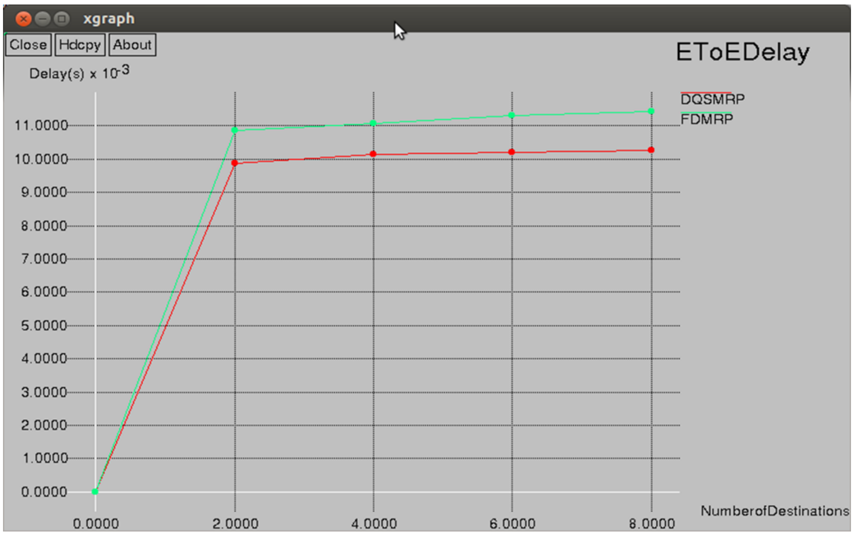

Figure 7: End to End Delays vs Number of Destinations

IV. CONCLUSION

In this paper, a QoS multicast routing method based on a Tuned Cuckoo Search Algorithm is presented. A hybrid computational intelligent algorithm is proposed by integrating the salient features of two different heuristic techniques to solve a multiconstrained Quality of Service Routing (QoSR) problem in Mobile Ad Hoc Networks (MANETs). The QoSR is always a tricky problem to determine an optimum route that satisfies variety of necessary constraints in a MANET The general conclusion from presented simulation experiments reveals that proposed routing protocol performs better than FDMRP in terms of packet delivery ratio, packet overhead, average end-to-end delay as a function of varying number of receivers, sources and nodes speed. In future works, the authors aim to study more by comparing our Tuned Cuckoo Search Multicast Routing Protocol with some more QoS based routing protocols in MANETs. Numerical experiments also demonstrate that the proposed hybrid TCSA algorithm can search better multicast trees with swift convergence with robustness compared with other algorithms. This proposed algorithm may also be extended for real-time networks with necessary modifications when and where required.

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