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Modified Energy Efficient Quality of Service Provisioning based on Energy and Preemption for Mobile Ad hoc Networks

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Abstract

Mobile Ad-hoc Networks (MANETs) consist of mobile nodes and these participating nodes may communicate with each other without any physical infrastructure. The neighboring nodes may communicate directly within their transmission range and through multi-hop if they are out of their transmission range. The MANET is dynamic in nature and participating nodes are very prone to failure because of consumable power supply. Therefore, the implementation of Quality of Service (QoS) provisioning is one of the challenging tasks in MANET. In the proposed scheme, to reduce the interruption in data transfer from one node to another, the energy of each node is monitored and identifies in case of available battery power is low or the rate of energy consumption is very high during the transmission. The simulation study has been done on the proposed scheme by taken certain parameters into consideration for evaluating packet delivery ratio and throughput. It has been observed that the proposed scheme produces better results comparatively in terms of packet delivery ratio and throughput with a fixed number of participating nodes when compared with existing AODV protocol. Further, the performance of the same scheme can be evaluated for highly dynamic networks and on certain other parameters.

Keywords: MANET, AODV, Energy, QoS

1. Introduction

In this paper, the Quality of Service Routing Scheme is proposed and AODV is modified to provide better data transfer for application. The problem is stated below in detail. The AODV [Perkins, 1999 and Sridhar, 2010] has the bandwidth reservation process fasten with delay and cost constraints. However, AODV does not have the provision to keep the monitoring on node energy to avoid the interruption in data transfer. Due to this, the quality of flow gets degraded in terms of QoS parameters. In this work, a scheme is proposed to address the following issues related to improvement in QoS on AODV:

- To provide a provision of optimal utilization of each node energy.
- A process is based on calculating the remaining energy of each node and the total energy consumed by each node.
- Minimizing the interruption in data transfer due to the low energy of the node.
- Allocation and preemption of flow with fairness.
- Providing best QoS to MANET with respect to node life.

In this paper, we are proposing a Modified Quality of Service Routing (MQR) scheme which provides QoS improvement on AODV [Perkins, 1999 and Sridhar, 2010]. MQR is an extension to the AODV, where node energy is monitored and identifies when the battery is low or when draining speed is high to minimize the interruption in data transfer due to low energy of node. In addition to packet size and the flow oldness (backlog) also consider for fair allocation and preemption of flow.

Flow Admission Control (FAC) is used in MQR to decide whether any flow request should be accepted or not on the basis of available node energy. In case the remaining energy is less than the threshold value, FAC takes the decision on the assignment of new flow on the basis of packet size and in case a node is about to sink it takes the decision for preempting a flow on the basis of flow oldness. It is assumed that an older flow that passed a long time (backlog) should not be preempted to avoid data loss. Hence, the flow having fewer backlogs would be a better candidate for preemption reservations. The preemption process is delayed until the RREP message is

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received at a link. In the following sections, the details of the algorithms for proposed MQR are given.

1.1. Related Work

Open QoS support in Mobile Ad-hoc Networks (MANETs) is a challenging task. QoS parameters include QoS routing, QoS Medium Access Control (MAC), and Resource Reservation. However in the meantime two models IntServ and DiffServ developed for wired networks. In this paper, a flexible QoS model for MANETs (FQMM), this considers the MANET's characteristics and combines the high-quality QoS of IntServ and service differentiation of DiffServ. FQMM features include dynamics roles of nodes, hybrid provisioning, and adaptive conditioning as stated in [1].

A Mobile Ad-hoc Network (MANET) is composed of mobile nodes without any infrastructure. MANET applications such as audio/video conferencing, webcasting requires very stringent and inflexible Quality of Service (QoS). The provision of QoS guarantees is much more challenging in MANETs than wired networks due to node mobility, limited power supply, and a lack of centralized control. In recent years a number of QoS routing protocols with distinguishing features have been newly proposed. However, systematic performance evaluations and comparative analysis of these protocols in a common realistic environment have been performed only in a limited manner. A comparison is being made for existing QoS routing protocols regarding their relative strength, weakness, and applicability. Further classification is done for QoS routing protocols depending on the assurance of QoS and their interaction with MAC protocol as stated in [3].

In today's era, one can have efficient data and voice communication services depending upon the network's ability. As we know the size and amount of data increase very rapidly with the rise in network capability. Communication over the Internet becomes very easy due to the deployment of the newest tools. But the quality of communication remains an issue for a developer. It gives rise to the development of a small temporary network which can be referred to as Ad Hoc Network (MANET). In this paper, most up – to – date view of QoS models, QoS routing, resource reservation techniques have been discussed as stated in [4].

QoS has been provisioned in the Ad hoc environment. Certain issues and challenges involved have been discussed. QoS provisioning can be done at different levels of routing, and Cross-Layer. Certain admission control schemes and scheduling has been proposed as stated in [6].

MANET is a collection of mobile devices that practice a communication linkage system with no established and predefined architecture. During the faster development of mobile, multimedia, and realtime technologies strictly maintains the QoS like throughput, energy depletion, interruption, etc as stated in [7].

IT evolution has created great milestones in integrated communication technologies and led to a drastic change in the life and working styles of people. The transition from static to dynamic infrastructure is quite common which leads to the development of Smart Ecosystems and Smart Cities. The "Smart City" refers to urban development in several domains which include transport, healthcare, home, buildings, etc. by deploying the newest technological and communicational services. Due to heterogeneity in terms of types of devices, the amount of data communication and temporary communication, deployment of MANET is the only solution. Smart city applications require high reliability, bandwidth, delay and loss of packets should be reduced. Therefore, providing Quality of Service (QoS) in such applications is vital as stated in [14].

A mobile ad-hoc network is a collection of mobile devices that form a communication network with no pre-existing infrastructure. Due to the rapid expansion of multimedia technology, mobile technology, and real-time applications has the need to strictly support the quality of service such as throughput, delay, energy consumption, jitter etc as stated in [15].

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Since the last decade, MANETs have become the point of the major attraction in the domain of wireless and multimedia technologies. QoS provisioning in MANETs becomes very challenging due to its infrastructure less nature. Effective determination of constrained route from source to destination is a major challenge. The selection and deployment of appropriate routing protocol is the most important and decisive factor for any sort of QoS provisioning. It must be able to identify as to which route must fulfill the desired QoS requirements for particular and specific applications. Modified technique for bandwidth estimation and route maintenance has been implemented as stated in [16].

MANET is a collection of wireless nodes that can dynamically form a network to exchange information without using any pre-existing fixed network infrastructure. The special features of MANET bring this technology great opportunity together with severe challenges as stated in [17].

In today's ear, MANETs have found its implementation in several applications that provide support communication among several infrastructure-less sources and destinations. As these networks do not have proper infrastructure, so they require a mechanism for routing information from source to destination and we must have to pay more focus upon deployment of routing protocols. Another important issue the method and type of connection between MANET and the Internet and most important is the Gateway Interface between them. As gateways play an important role in maintaining good QoS throughout the communication. The major issue lies here is the discovery and selection of proper Gateway as stated in [19].

Energy consumption of routing protocol is being concentrated upon and performance is evaluated for DSDV, DSR, and AODV with respect to energy consumption indicating their usage of node's energy as stated in [20].

In the first set of results PDR, PLR, Delay, and throughput are recorded by varying the packet size in an Adhoc network of fixed nodes. In the second set, the remaining energy and node's draining energy speed is recorded at different time stamps during the communication in the Adhoc network with the same setup of fixed nodes present in the network as stated in [21].

2. MQR Architecture

The architecture of MQR is shown in Figure 1 which consists of the following components:

- Admission Control
- Remaining Energy check
- Decision on assignment of flow
- Reserving bandwidth
- Preempting a process
- Updating Matrices and Flow table
- Starving Process
- Route Error Message

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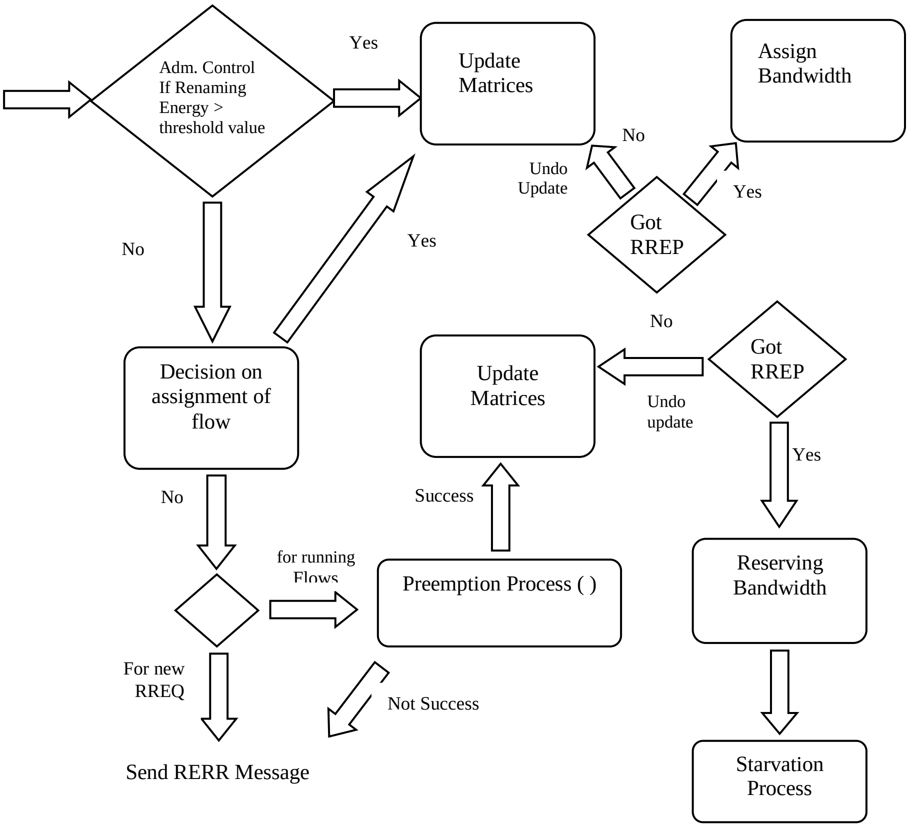

Figure 1. Architecture of MQR

The admission controller is used to check the remaining energy at node 'I'. If remaining energy is available then it is reserved and matrices are re-evaluated. If the remaining energy at node 'I' is less than the threshold value, then a decision on the assignment of flow is done on the basis of packet size and if successful update matrix/ flow table otherwise probability evaluator is used for preemption, Updating Matrices/ Flow table and Starving Process are performed.

2.1. Assumption

The following assumptions are made during the development of the algorithms:

(a) The Threshold Energy value in joule (ΔE_{joule} = 0.0546874).

(b) If remaining Energy at node $RE_{node}(I)$ is greater than the threshold value ΔE_{joule}, then flow 'f_j' can be assign to node *'I'* and a matrix is updated. In case the remaining Energy at node $RE_{node}(I)$ is less than threshold value ΔE_{joule}, then takes the decision for assignment of flow '$f_i(I)$' if the packet size is small. Otherwise, send the RERR message to the sender so that sender could choose another root.

(c) Preemption decisions also associated with the maximum flow time $\boldsymbol{T_{max}(X)}$ (oldness). This will make sure that an increased oldness can change flow from preemptive class to non-preemptive class. Otherwise, there could be a possibility that such a flow would be preempted which violates fairness.

(d) The starvation time for the preempted flows should be less since flows have high QoS constraints. After the starvation time out, the RERR message is sent to the source to reschedule the packets.

(e) The oldness of flow is divided into three stages:
   1. Just started [$\Delta t_x \leq 25\%$ of $T_{max}(X)$]
   2. Growing stage [25% of $T_{max}(X) < \Delta t_x < 75\%$ of $T_{max}(X)$]
   3. Grown [$\Delta t_x \geq 75\%$ of $T_{max}(X)$]

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The probability to preempt the flow decreases with the oldness of the flow. We assume three stages of flow oldness in the time zone as shown in Figure 2.

1. **Just started:** At this stage, the probability of preemption is very high represented by a green bar.
2. **Growing stage:** At this stage, the probability function (*fp*) takes the decision for preemption for flow shown by the white bar.
3. **Grown stage:** At this stage probability of preemption is very less represented by an orange bar.

It is also understood that the time zone of lower priority difference is small, in comparison to the time zone of the higher remaining energy.

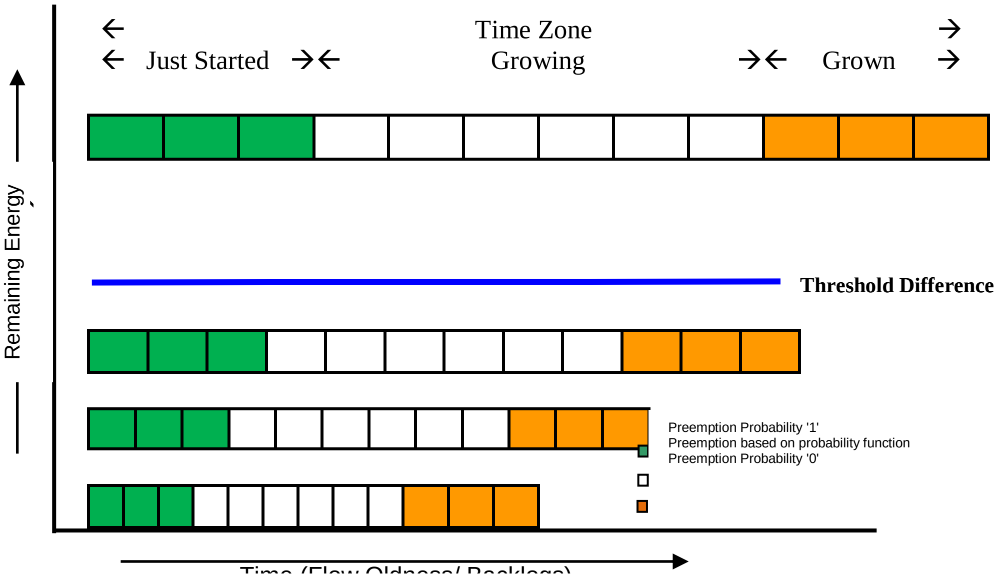

Figure 2. Showing the relation between remaining energy and the flow

2.2 Flow Diagram

Flow Admission Control (FAC) is the process that interacts with the request packet and updates the flow table. If node energy is available then all the matrices and flow tables are updated otherwise FAC calls its sub-process to take a decision on the assignment of flow. If packet size is small then all the matrices and flow tables are updated otherwise call Preemption Process (PP) which uses the probability constraint decides success or failure of the request and passes this decision back to the FAC. If PP sends success to FAC then all the matrices and flow tables are updated and preempted flow is transferred to the Starvation Process (SP) as shown in Figure 3. These processes are detailed in the algorithms in the next section.

FAC : **Flow Admission Control**
PP : **Preemption Process**
SP : **Starvation Process**

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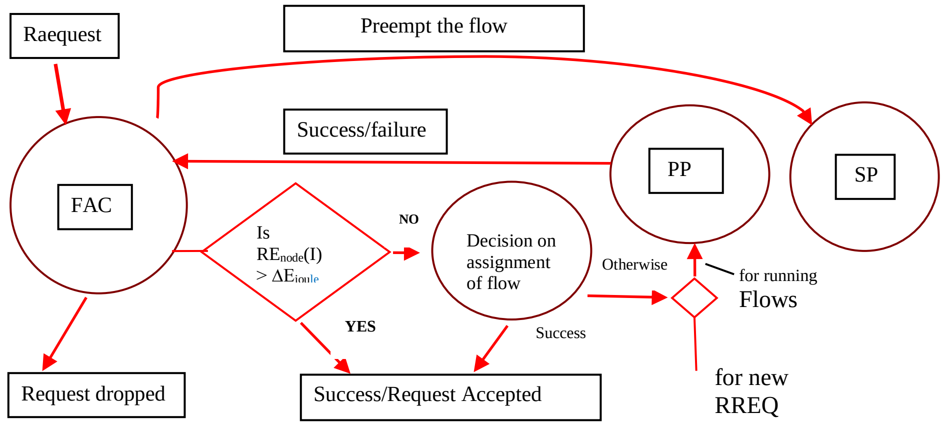

Figure 3. Showing the relation among the processes

3. Flow Admission Control (FAC)

Flow Admission Control (FAC) is the process that interacts with the request packet and updates the flow table. If node energy is available then all the matrices and flow tables are updated otherwise FAC calls its sub-process to take a decision on the assignment of flow. If packet size is small then all the matrices and flow tables are updated otherwise call Preemption Process (PP) which uses the probability constraint decides success or failure of the request and passes this decision back to the FAC. If PP sends success to FAC then all the matrices and flow tables are updated and preempted flow is transferred to Starvation Process (SP). These processes are detailed in the algorithms in the next section.

The network and the nodes behave differently according to the network routing protocol and mobility model. Here, we record the results by using AODV protocols with Random-Waypoint-Mobility-Model. The objective is to find, which protocol among AODV and proposed MQR supports best for network Quality of Service (QoS) on node energy serving mode i.e. with which protocol node survives for the more time on the network. The algorithm Rem_Energy() is designed and tested with these protocols.

Algorithm for remaining energy calculation of a node in the Adhoc network

```
Algorithm Rem_Energy ( oldValue, remainingEnergy)
Begin Module
        Var: speed;outfile1, outfile3
        outfile1="flows_drain_speed7.txt"
        outfile3="nod_remain_energy7.txt"
        write(remainingEnergy)

        If (remainingEnergy  == 0.0546874)
                {
                        write ("BATTERY IS LOW....,Change path")
                        append to outfile3 "battery is low..... change node"
                }

        // Energy draining speed calculation
        speed=(oldValue-remainingEnergy)/(currenttime simulation time in second-(previous
        time of energy drain))

        append to outfile1  "nodes draining speed”=speed
        if (speed<8.0000e-06)
                {
                        write ("draining speed is high...., Change node")
```


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```
                append to outfile1 "draining speed is high...., Change node"
            }
        close outfile1
        close outfile3
End Module
```

FAC is the process, used to provide Admission Control. It also calculates the available energy at the node for the flow 'f_j'. A node will neglect the request if the battery is low or draining speed is high.

The Flow Admission Control (FAC) process can be considered in two cases:

Case 1: if $RE_{node}(I) > \Delta E_{joule}$

flow 'f_j' can be assign to node '*I*' and the matrix is updated.

***Case 2*: if $RE_{node}(I) <= \Delta E_{joule}$**

MQR takes the decision for assignment of flow '$f_i(I)$' on the basis of packet size ΔPkt_{size}.
This process consists of the following two steps:

Step-1: Decision on the assignment of flow 'fj'(I).
Step-2: Preemption Process ( ).

Case 2: Step-1: Decision on assignment of flow 'fj'(I):

The procedure for the decision of assignment of flow '$f_j(I)$' on the basis of packet size ΔPkt_{size} is given below as pseudo-code.

Decision on assignment of flow 'f_j'()

```
{
    If (Pktsize(fj) <= ΔPktsize && REnode(I) > (ΔEjoule /2))
    {
        flow 'fj' can be assign to node 'I' and the matrix is updated.
    {
    Else
    {
        Refuse 'fj' and SEND RERR message to Sender so that the sender could choose
        another root.

        Call Preemption Process of all flows (Node I)
        If Preemption Process is successful
            Update Flow Table and Quit.
    }
}
```

***Case 2*: *Step-2: Preemption Process ( )*:**

This process is called by FAC to check whether the flow 'f_x' should be preempted or not. For this, probability constraint is imposed i.e. Δt_x (oldness of the flow '*x*')

Δt_x = Delay-till now | $T_{max}(X)$ = Max. Delay (T_{max})

Preemption_Process_of_all_flows(Node I)

```
{
    i = 1
    While (i <= Size of flow table)
    {
        // find the no of flows
        Q = Q U ( fi at Node I)
        i++
```


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}

While ($Q \neq \varnothing$)
{
X = Del (Q)
If ($\Delta t_x \leq 25\%$ of $T_{max}(X)$)
Preempt flow X from node I, Hence success is returned to process **FAC procedure**.
Else
Probability function fp(Δtx) is evaluated which can be given as follows:

$$fd(T)=\begin{cases} \Delta t_x / T_{max}(X) & \text{if } 25\% \text{ of } T_{max}(X) < \Delta t_x < 75\% \text{ of } T_{max}(X) \\ 1 & \text{if } \Delta t_x \geq 75\% \text{ of } T_{max}(X) \end{cases}$$

$$fp(\Delta t_x) = \{ (fd(T))/ \Delta t_x) - (\Delta t_x * 0.01) \}$$

Decision for the preemption of a flow is given as follows:

$$fp(\Delta tx) = \begin{cases} \text{Preempt flow } f_X & \text{If } fp \geq 0.12 \\ \text{Not to Preempt flow } f_X & \text{If } fp < 0.12 \end{cases}$$

Return success or failure to the FAC Process Accordingly

If successes then call starvation process for the preempted flow 'f_X'
}
}

3.1. Starvation Process (SP)

This process is called by the preemption process after the successful preemption of flow 'f_x'. The flow 'f_x' will only starve in the queue for not more than $\boldsymbol{ST_{max}(x)}$.

Δst_x = Starvation Delay-till now
$ST_{max}(x)$ = Max. Delay for Starvation

Starvation_Process (x)
{
if ($\Delta st_x <= ST_{max}(x)$)
Flow 'f_x' packets will starve in waiting queue for limited time.
Else
It is locally rerouted or the RERR message is passed back to the source for detecting a new path. Alternatively, it can also use a local route repairing scheme.
}

4. Routing with MQR

4.1. Route Discovery Phase

When the source node does not have a route to the destination node, then on-demand RREQ phase is performed. The source broadcast an RREQ packet to all its one-hop neighbors. The RREQ packet contains shown in Table 1. *Delay-till-now field* gives information about the delay that the RREQ packet has experienced so far. *Cost-till-now* gives information about the cost of the path so far traveled. These fields are initialized zero at source node. Whenever an intermediate node receives RREQ it updates these fields. Upon receiving an RREQ packet an admission control decision is made.

ISSN: 2233-7857 IJFGCN

Table 1. Route Request (RREQ) packet format

Seq. No.	Source ID	Destination ID	**QoS Parameter**	Delay-till now	Cost-till-now

Priority	Min.Bandwidth (B_{min})	Max. Delay (T_{max})

It is Decided /Requested/ given by **Application Layer**

4.2 Route Reply

On receiving the RREQ packet at the destination node, Destination will reply to the source by uni-casting RREP acknowledgment. The RREP contains shown in Table 2. As the intermediate node received RREP then *time_bound(tb)* table got updated.

Table 2. Route Reply (RREP) packet format

Sequence No	Source ID	Destination ID

4.3 Flow Table

Every node consists of a flow table that stores the information of all the flows passing through a node. This is used in finding the flow that can be preempted. A snapshot of a modified flow table is shown in Table 3.

Table 3. Flow Table

Flow No	Source ID	Destination ID	Bandwidth Reserved	T_{max}	Priority	Delay_till_Now

Flow table contains bandwidth reservation information for various flow at the current node. The total reserved bandwidth is calculated by adding up the reserved bandwidth of all flows at the current node.

4.4 Time_bound (tb) Table

The time_bound table is used by the RREP message to preempt/ reserve the bandwidth at the intermediate nodes. A snapshot of Time_bound table is given in Table 4.

Table 4. Time_bound*(tb)* Table

Flow ID (Requested Flow)	Source ID	Dest. ID	Bandwidth_to_Reserve	Flow ID (of Proposed Preempted Flow)	Timer

4.5 Dynamic Route Recovery

Local route repair and QoS violation recovery are critical in a MANET environment because of the mobility of the nodes. Different scenarios for dynamic root recovery are:

Case 1: If data gets starve in the queue and when the waiting time exceeds $ST_{max}(i)$, then **RERR** is sent back to the source. Now the source will discover a new route.

Case 2: When a node does not get a HELLO message from its neighbor node for a specified period of time, then it is considered a link break. In such a case, RERR is sent back to the source.

ISSN: 2233-7857 IJFGCN

Case3: During the data transmission phase, the destination stores the T_{max}, and if Delay_till_now parameter exceeds T_{max} then the RERR message is sent back to the source to discover the path again.

5. Comparative Study

The comparative study of performance based on the theoretical analysis as well as simulation results is made for AODV and the proposed MQR.

5.1. Comparative Study of AODV and MQR

The differences between AODV and proposed MQR are summarized in Table 5.

Table 5. Difference between AODV and MQR

AODV	MQR
Let 'f_j' represents the flow requesting at node '*I*'. The whole process is divided into two cases: **Case 1: if** flow 'f_j' passes Admission Control **then** Assign 'f_j' to node '*I*' and update the matrix. **Case 2: Otherwise** Drop the request for flow.	Consider flow 'f_j' is requesting at node '*I*'. The whole process is divided into two cases: **Case 1: if** flow 'f_j' passes Admission Control and the remaining energy of the node is more than the threshold value **then** flow 'f_j' can be assigned to the node '*I*' and a matrix is updated **Else** The process to assign/ preempt flow includes the following two steps: **(a) Decision on assignment of flow 'fj'(I) -** MQR takes the **the** decision for assignment of flow 'fi(I)' on the basis of packet size ΔPktsize. **(b) Preemption Process() -** Do preemption with fairness on the basis of flow oldness. **Case 2: Otherwise** Drop the request for flow.

5.2. Simulations and Results

In this work, the simulations are implemented using the ns-3 simulation tool. The MAC layer protocol IEEE 802.11 is used in all simulations. The simulations have been carried out for the Ad-hoc On-demand Distance Vector (AODV) routing protocol and Modified Quality of Service Routing (MQR) scheme. Every simulation run is 100 seconds long. The simulation is carried out

ISSN: 2233-7857 IJFGCN

using different numbers of nodes. The simulation parameters are shown in Table 6. The experiments are conducted by varying network size from 25 to 150 nodes.

Table 6. Simulation Parameters

Simulation Time	100 sec
Topology Size	500m x 500m
Number of Nodes	25, 50,75,100,125 and 150
Node Mobility	5, 10, 15 and 20 m/s
Routing Protocols	AODV
Traffic type	CBR
MAC	IEEE 802.11
Mobility model	Random Waypoint
Pause time	0, 10, 20, 30, 40, 50, 100, 150, 200, 250, 300, 350, 400

5.3. Implementation and Results

The Adhoc network environment is created here with 25 nodes. A sample of pictures is as follows which shows the network and communication between nodes from figure 4-8.

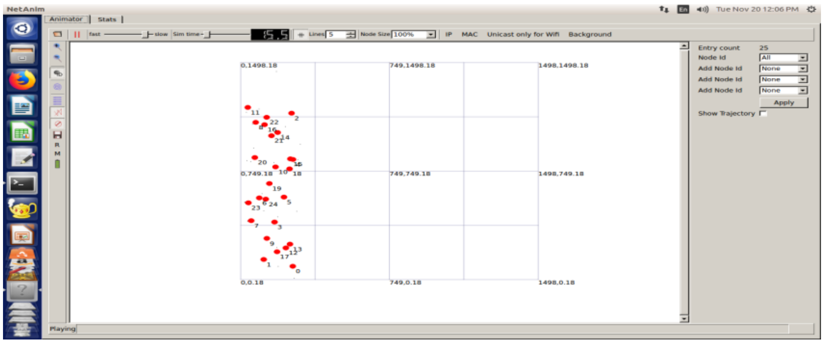

Figure 4. Simulation Output Scenario 1

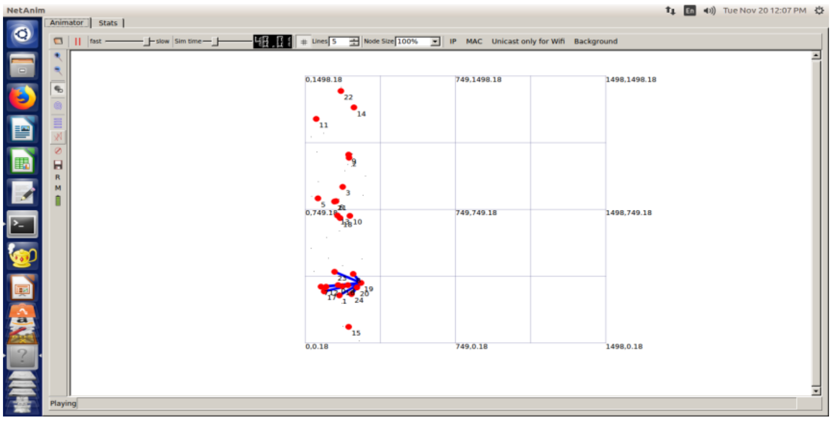

Figure 5. Simulation Output Scenario 2

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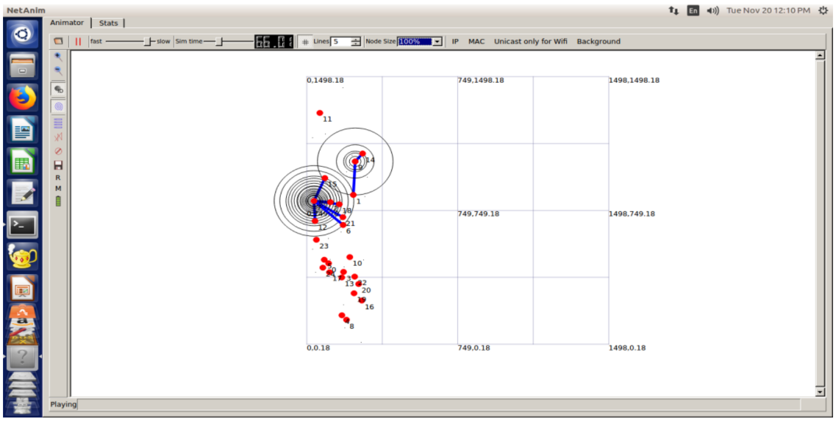

Figure 6. Simulation Output Scenario 3

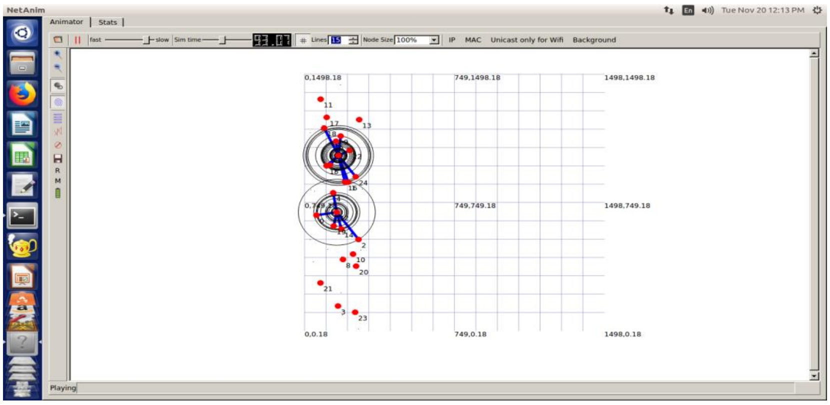

Figure 7. Simulation Output Scenario 4

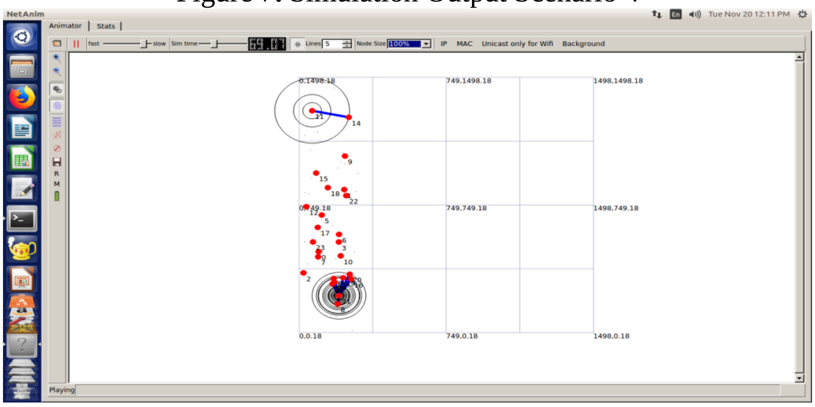

Figure 8. Simulation Output Scenario 5

Node wise trajectory is shown below from figure 9-13 . Here we have shown trajectory of node 0 to node 4 only but if required then we can obtain for any node also.

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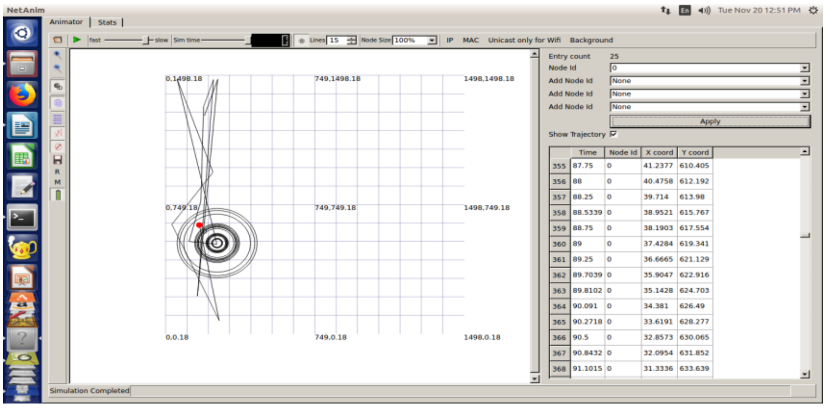

Figure 9. Trajectory of Node 0

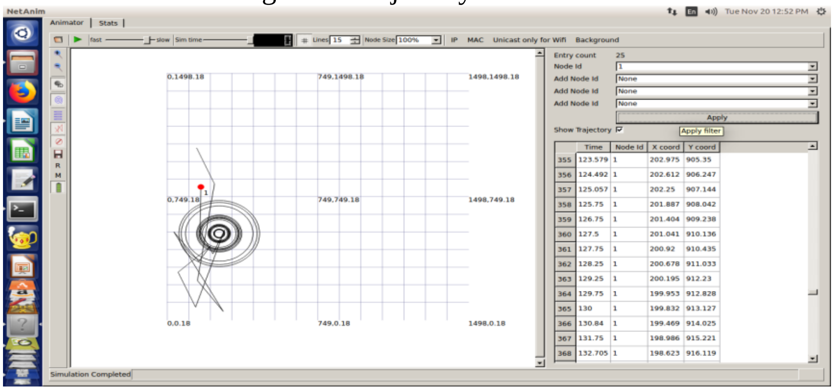

Figure 10. Trajectory of Node 1

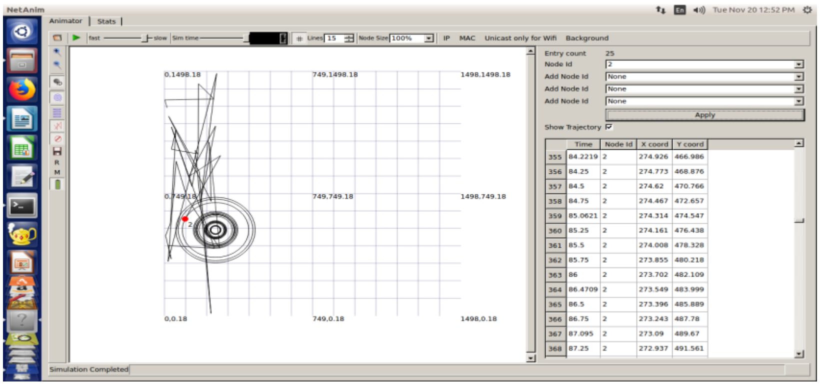

Figure 11. Trajectory of Node 2

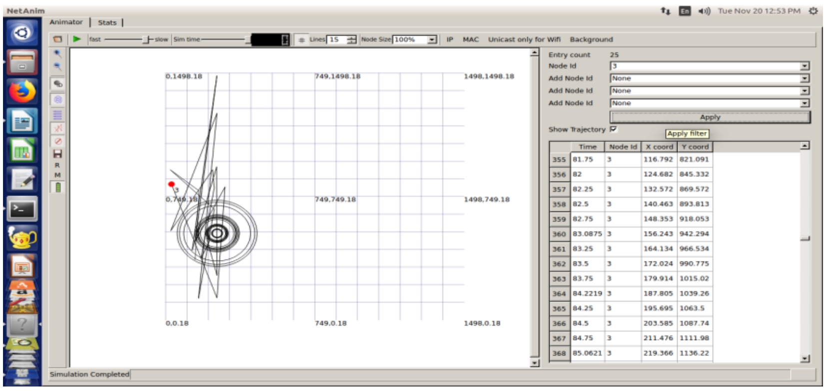

Figure 12. Trajectory of Node 3

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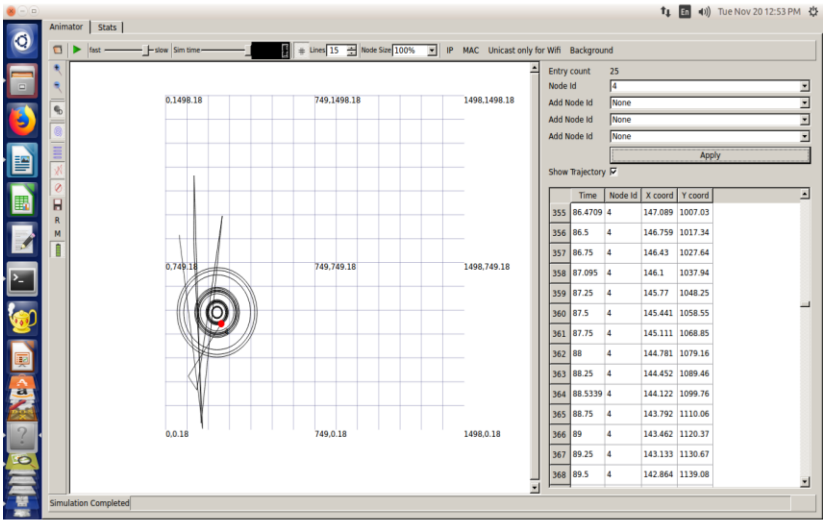

Figure 13. Trajectory of Node 4

In this way, we may find the trajectories of all the 25 (twenty-five) nodes to know the total movement of the node during the simulation. This also shows the mobility of the nodes.

The result of remaining_energy and node's draining_energy_speed is noticed. The samples are taken by the per node at different time stamps and the remaining_energy and draining_energy_speed are recorded. During the execution of the various test, two remarks are added in the recorded results : (1) when node battery power is low, and (2) when the draining speed is high.

When the remaining_energy of the node is higher than 0.0543445, the results are recorded and as the remaining_energy reaches to 0.0546874, the message "battery is low ….. change node" will be displayed. When the draining speed is higher than 8.0000e-06 (i.e. 0.000008), the message "draining speed is high …, Change Node" will be added to the log, and the node will be changed or the current node will be now out of trace. Otherwise, the draining speed of the node will be recorded at every transaction. We have recorded around one lakh something records at different times during simulations. Some of the result samples are shown in table 7 below:

Table 7. Results of Node Energy and Draining Speed

Time of Data Recorded	Old Value of Node Energy	Remaining Node Energy	Nodes_draining_Speed
0.018136	0.0999534J	0.0999463J	7.10E-06
0.0181361	0.0999534J	0.0999454J	8.04E-06
0.0181361	0.0999543J	0.0999463J	8.04E-06
0.0181362	0.0999613J	0.0999532J	8.04E-06
0.0181363	0.0999613J	0.0999532J	8.04E-06
0.0181366	0.0999622J	0.0999542J	8.04E-06
0.0181366	0.0999613J	0.0999532J	8.04E-06
0.0181366	0.0999622J	0.0999542J	8.04E-06
0.0181366	0.0999613J	0.0999532J	8.04E-06
0.021	0.1J	0.0999732J	2.68E-05
draining speed is high …, Change Node			

The results show that the algorithm Rem_Energy (oldValue, remainingEnergy) works well with simulation on a network as defined earlier. This is also illustrated in figure 14 that the algorithm is regularly calculating the node energy on every millisecond and Change of Node takes place when energy-draining speed is high.

ISSN: 2233-7857 IJFGCN

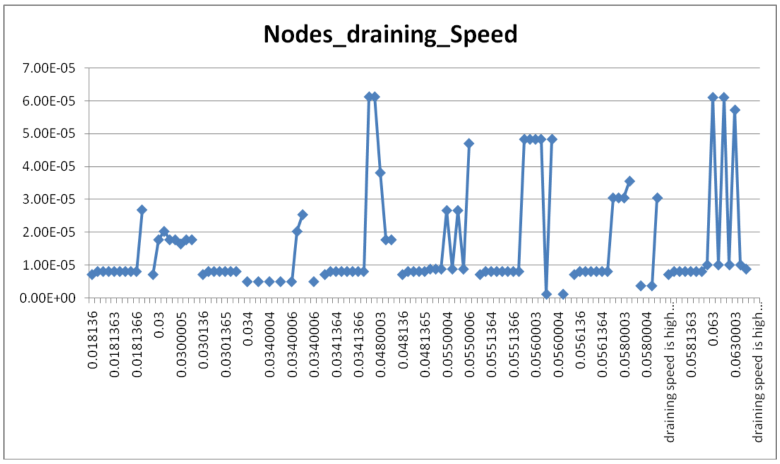

Figure 14**.** Change of Node takes place when energy draining speed is high

Now, the comparative study of AODV and Proposed Algorithm, the simulation environment is designed with 802.11b WiFi standard, the modulation is done with DSSS 11 Mbps at 2.4 GHz, the channel is YansWifi, propagation is fixed propagation loss, the delay is constant, Wifi MAC is Ad-Hoc, RTS/ CTS threshold is 2200 bytes, packet size is 4096 bytes, number of nodes are varied from 10, 20 to 30and 50. Mobility Model Gauss-Markov Mobility Model, Area size is 1000x1000 m, Messages include Text message, video, audio, photographs, speed of nodes is average walking speed 2 m/s, simulation time is 180 sec. Packet Delivery Ratio (PDR) represents how reliable the communication is i.e. higher the PDR, the better the communication reliability. Here we have measured the PDR ratio of AODV with proposed scheme.

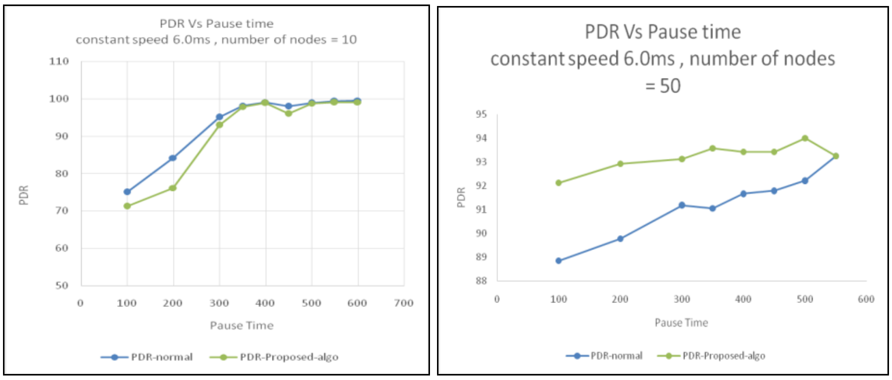

Figure 15**.** Packet Delivery Ratio Vs. Pause Time

Figure 15 shows that the ratio of Packet Delivery with Pause Time for 10 nodes performs similar to AODV. But in case of 50 nodes proposed algorithm performs slightly better than AODV.

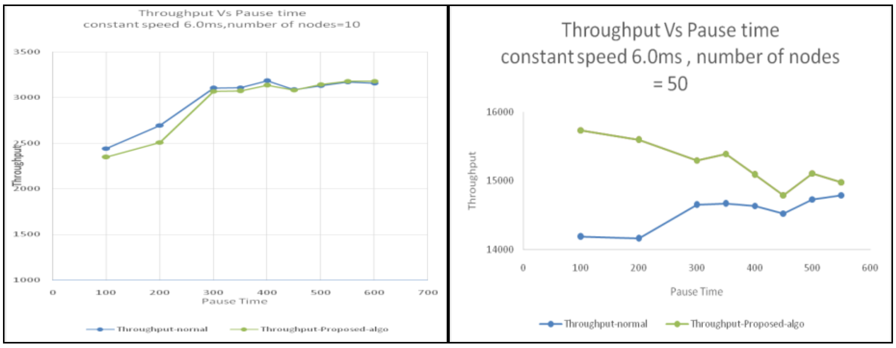

Figure 16. Throughput Ratio Vs. Pause time

ISSN: 2233-7857 IJFGCN

Figure 16 shows the ratio of Throughput with respect to Pause time parameter. For 10 nodes, proposed algorithm performs similar to AODV. But for 50 nodes, proposed algorithm has maximum throughput in comparison to AODV

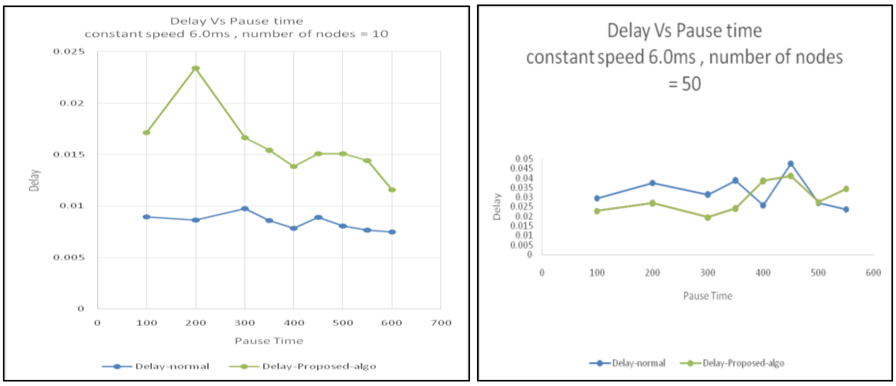

Figure 17. End to end Delay Vs. Pause time

Figure 17 shows the ratio of end to end delay with respect to pause time parameter. For 10 nodes, the proposed algorithm has more end to end delay compare to AODV. But for 50 nodes, it is seen that packets without malicious node AODV perform slightly better than with malicious code in MQR.

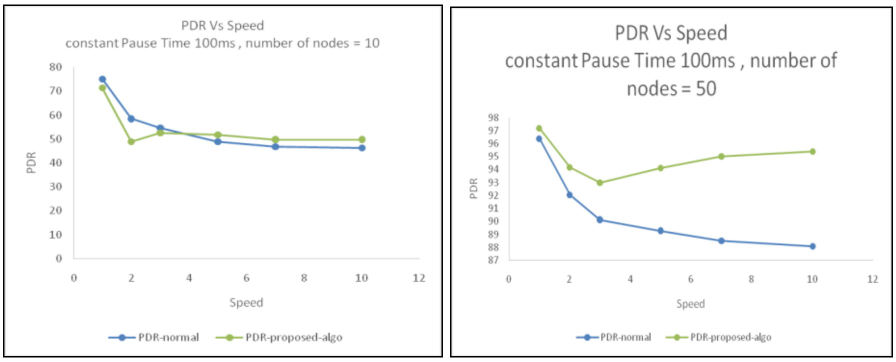

Figure 18. Packet Delivery Ratio Vs. speed

Figure 18 shows the ratio of Packet Delivery with respect to speed parameter. For 10 nodes, the proposed algorithm performs similar to AODV. For 50 nodes, the proposed algorithm performs slightly better than with AODV.

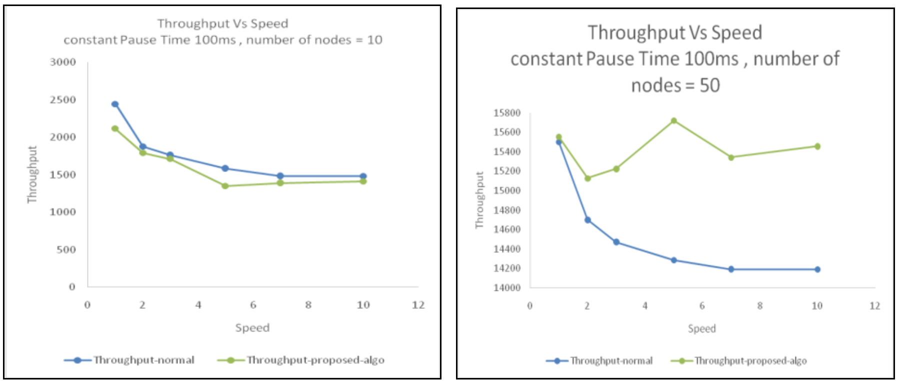

Figure 19. Throughput vs. Speed

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Figure 19 shows the ratio of Throughput with respect to speed. For 10 nodes, the proposed algorithm performs similar to AODV. For 50 nodes, the proposed algorithm performs better than AODV.

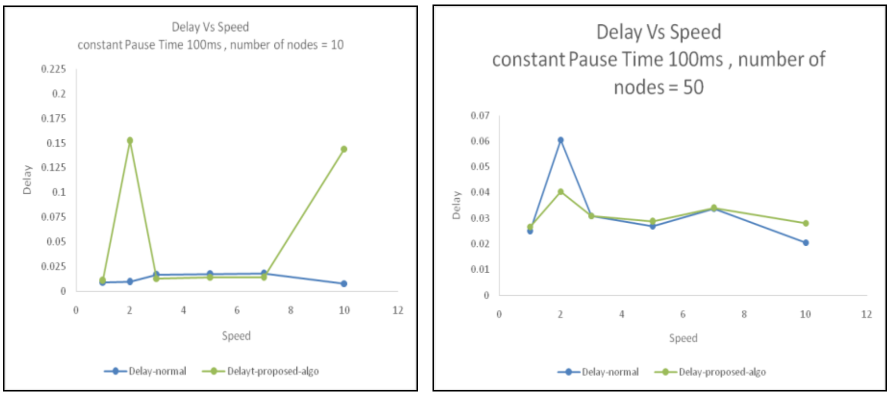

Figure 20. End to end delay ratio vs. speed

Figure 20 shows the ratio of end to end delay with respect to the speed parameter. For 10 nodes, the proposed algorithm has a higher end to end delay ratio as compared to AODV. For 50 nodes, AODV end to end delay is slightly less than the proposed algorithm

From the results, our proposed scheme outperforms than AODV. The comparison of two protocols is conducted with Packet Delivery Ratio (PDR), throughput and delay for performance measurement. These performances are measured by varying pause time and speed. It is clear from Figures that the proposed MQR scheme outperformed AODV in terms of Packet Delivery Ratio and throughput for varying values of pause time and speed. Therefore, the MQR scheme shows a better performance against AODV.

6. Conclusion

The Quality of Service Routing Scheme for AODV is modified to provide better data transfer. We have proposed a QoS aware routing scheme MQR for MANET, which includes monitoring energy of all nodes and preemption with the fairness of flow based on remaining energy of node, packet size and flow oldness as AODV does not have the provision to take care of this. The objective of the proposed work is to provide best QoS to MANET and improve packet delivery ratio (PDR) in network on the basis of remaining energy and energy draining speed.

Through simulation results, it has been shown that the proposed MQR fairly preempts the flows on the basis of remaining energy, packet size and flow oldness (backlog). The performance analysis of MQR over AODV is done through simulations on ns-3, which shows that PDR for MQR is better as the pause time increases with a fixed number of nodes. The simulation results also represent that initially the PDR for MQR increases in comparison to AODV with mobility and fixed number of nodes. But later on, the difference tends to decline. To be summarized, MQR shows QoS improvement against AODV in both cases. The performance of the proposed scheme has not been evaluated on the high-density network and for high speed. Therefore, further, there is scope to extend the same scheme for high-density networks and as well as for high speed participating mobile nodes.

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