International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249 – 8958, Volume-9 Issue-1, October 2019

Non Linear Differential Optimization for Quality Aware Resource Efficient Routing in Mobile Ad Hoc Networks

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Abstract-MANETs is the basic structure less network in which mobile nodes connecting point at which several line comes together to form a network structure. Network resources in MANETs are limited due to their forcefulness study of a given place. A mobile node in MANETs utilizes an interconnected system of things such as data transmission rate and battery power during data packet transmission. Thus the conserving network resource is important to maintain the quality of network services without delay. Therefore, Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique is proposed. The NLDRO-QAR Technique selects the resource optimized route path among multi paths for efficient data packet transmission in MANETs. The resource optimized route path is determined in proposed NLDRO-QAR Technique by choosing mobile node with higher resource availability as optimal nodes. The NLDRO-QAR Technique considers residual energy, residual bandwidth, and delay time as significant factor for computing resource availability of mobile nodes in MANETs. In order to effectively find out the optimal nodes (i.e. mobile node with higher resource availability) in dynamic environment. The NLDRO-QAR Technique chooses the resource optimized nodes in MANETs in order to transmit the packets between source and destination. As a result, NLDRO-QAR Technique efficiently reduces the energy and bandwidth utilization of data delivery in MANETs. The NLDRO-QAR method manage the simulation works on metrics such as energy utilization, average end to end delay, data loss rate and bandwidth utilization rate. The simulations results show that the NLDRO-QAR Technique is able to reduce the energy and bandwidth utilization for routing the data packet in MANETs as compared to state-of-the-art-works.

Keywords: Bandwidth, Quality of Network Service, Packet transmission, Mobile Node, Non-linear Differential model, Energy, Resources

I. INTRODUCTION

MANETs attains great interest in research community over the last decade because of its highly dynamic nature and utility. A MANETs includes collection of wireless nodes that is self-organized to structure a network. MANETs is an infrastructure less network where nodes communicate with each other in a peer-to-peer fashion.

power, other resource constraints and mobility of nodes make Quality of Service (QoS) provisioning is more challenging task in MANETs. QoS routing means not only to find out a route from source to end, but to discover a quality route better in terms of bandwidth, delay or loss probability. In addition, resource aware routing plays an essential role in MANETs in order to lessen the resource consumption for reliable data packet delivery. Thus, this research work focus on quality aware resource efficient routing in MANETs. In existing, a lot of research works has been intended for quality and resource efficient routing in MANET. For example, Reliable Minimum Energy Cost Routing (RMECR) was intended in [5] to enhance energy-efficiency, reliability in MANETs. But, RMECR takes to a greater extent energy for routing process. An adaptive-gossiping routing algorithm was presented in [1] in order to perform network resource efficient routing in MANETs. However, performance of network resource efficient routing was not at required level. Reliable and Energy Efficient Protocol Depending on Distance and Remaining Energy (REEDDRE) was presented in [3] for performing energy efficient multicast routing in MANETs. However, data packet loss was more. An energy-efficient genetic algorithmic rule mechanism was intended in [15] in order to attain quality of service (QoS) multicast routing in MANETs with minimum energy cost. But, end-to-end delay time was not reduced. An energy-aware multipath routing scheme was made in [18] with aid of particle swarm optimization to determine the loop-free paths in a MANETs with minimum energy consumption. However, quality aware routing of MANET was remained unsolved. A Quality of Service (QoS) based multicast rout out rules was introduced in [2] to find dependable route for data transmission in MANETs. But, resource optimization was not considered. An efficient cause driven QoS mesh based simultaneous data transmit routing scheme was presented in [16] to discover the connecting points of several lines which satisfy QoS according to user demand. However, bandwidth consumption was higher. An Energy Aware Optimal Link province Routing Protocol was introduced in [19] for enhancing the group of data delivery ratio in MANETs. But, delay time was higher. In order to get the better of the latter existing issues in MANETs, Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique is introduced.

Revised Manuscript Received on October 20, 2019.

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The contributions of NLDRO-QAR Technique is described as, To improve the execution of quality aware resource efficient routing in MANETs, Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique is designed. NLDRO-QAR Technique is developed with application of nonlinear differential optimization model.To attain resource aware routing in MANETs, mobile node with higher resource availability is chosen as best node for data packet transmission. To identify the higher resource availability node, NLDRO-QAR Technique considers residual energy, residual bandwidth and delay time as routing metrics. To find out the resource availability and number of available neighbouring node in dynamic environment, this model effectively describes the dynamic nature of MANETs for reliable data packet delivery.The balance of this paper structure is formulated as follows. Part 3 explains Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique with aid of architecture diagram. Section 4 and Section 5 depicts the experimental section with details execution analysis. Section 2 presents the related works. Finally, Section 6 concludes this paper.

II. RELATED WORKS

A Minimal Energy Consumption with Optimized Routing (MECOR) framework was designed in [4] to solve the energy and routing issues in MANETs. However, bandwidth and delay time was not addressed. A Route Energy Comprehensive Index (RECI) technique was presented in [12] chooses the path with minimum hops for broadcasting data in MANETs. But, energy taken for data packet transmission was higher. Multiconstrained and multi route QoS Aware Routing rules was intended in [10] in order to carry out reliable and energy efficient data broadcast in MANETs. However, resource optimization was not advised. Residual Energy based Reliable Multicast Routing Protocol (RERMR) was designed in [13] to increase reliability of simultaneous data transmission to many user on a network routes with minimum energy utilization. But, the performance of routing was not effectual which resulting in higher data packet loss rate. A Cuckoo Search Optimization based AODV protocol (CSO-AODV) was introduced in [17] for increasing the QoS performance in MANETs. But, end to delay was higher. Bandwidth Constrained Priority-Based Routing Algorithm was designed in [14] to perform bandwidth aware routing in MANETs. However, other factor such as energy and delay time was remained unsolved. A Cross-Layer Delay-Aware simultaneous data transmission to many user on a network Routing Algorithm was presented in [9] to solve delay constraints issues of routing in MANETs. This algorithm improves the packet delivery and reduced overhead between next to last nodes. But, energy necessitated for transmitting data packets was more.An Improved Hybrid Technique was intended in [11] for energy and delay routing in MANETs. However, bandwidth utilization was more. Probabilistic [7], Deterministic [6] and Stepwise Regression [8] improves the energy, bandwidth, packet delivery ratio and delay time.

III. NON-LINEAR DIFFERENTIAL RESOURCE OPTIMIZATION BASED QUALITY AWARE ROUTING TECHNIQUE

A Mobile Ad-hoc Networks (MANETs) is a wireless communication interconnected system where mobile node contains limited battery life and network bandwidth. Thus, resource efficient routing is most challenging task in MANETs. The Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique is designed in this research work in order to attain quality aware resource efficient routing in MANETs.

A. System Model

Let consider a MANETs in the form of graph structure like '$G(V_i, E_i)$'. Here 'V_i' indicates the number of mobile nodes in interconnected system whereas 'E_i' refers the links between mobile nodes. The mobile nodes in MANETs represented as'$N_i = N_1, N_2, N_3 \dots N_n \in V$ that are lies within the transmission range $'r'$. The following diagram depicts the routing process in simple MANET structure.

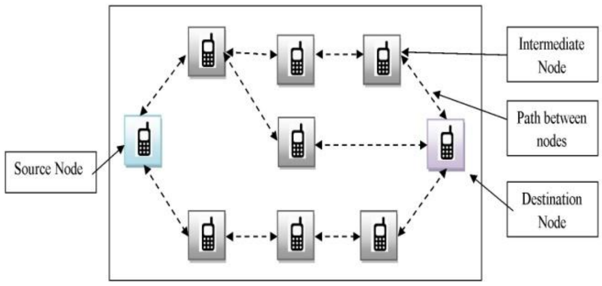

Figure 1 Structure of Simple MANETs

As shown in Figure 1, group of data is broadcasted from source to end node by selecting the best route path in MANETs. The optimal path is determined between the source and destination node through transmitting the route request (RR) and route reply (RP) packets. Due to resource constraints, improving quality of routing through the resource optimization plays a significant role in MANETs. Therefore, proposed NLDRO-QAR Technique is designed. The NLDRO-QAR Technique chooses the resource optimized route path between source and destination node with application of nonlinear differential optimization model to transmit the data packets in MANETs. The detailed explanation about NLDRO-QAR Technique is described in forthcoming sub sections.

B. Proposed Model

A number of mobile nodes in MANETs like $N_i = N_1, N_2, .. N_n$. For routing the data packet from begin to end, resource availability of each node in network is determined. The resource availability of each mobile node R_{N_i} at time t is determined using below formulation,

$$\frac{dR_{N_i}}{dt} = \alpha R_{N_i} - \beta R_{N_i} N_i \quad (1)$$

From equation (1), R_{N_i} is the resource availability of mobile node and N_i denotes i[th] mobile nodes whereas $\frac{dR_{N_i}}{dt}$ represents the change in resource level over time t. Here, α is a reduction rate of resource at time t, β is searching efficiency of neighbour node. To attain resource aware routing in MANETs, NLDRO-QAR Technique considers the following resource R factors such as residual energy, residual bandwidth, and delay time. The resource availability of mobile node N_i in MANETs is determined as,

$$R_{N_i} = REnergy_{N_i} + RB_{N_i} + DT \quad (2)$$

From equation (2), $REnergy_{N_i}$ and RB_{N_i} represents the residual energy and residual bandwidth of node after data transmission whereas DT refers to the delay time between two nodes. The statistical formula for determining these resource factors are as follows,

i. Residual Energy:

The residual energy is one of main factor considered in MANETs during the group of data transmission between the nodes. If the residuary energy of mobile nodes is low, then the routing of data packets fails due to the link failure which results in the act of reducing complexity of network's efficiency. Therefore, it is very significant to choose the in-between nodes with higher residuary energy to route the group of data successfully between the nodes.

$$REnergy_{N_i} = E_{old} - E_T \quad (3)$$

The residual energy of mobile nodes is evaluated using above mathematical expression.

ii. Residual Bandwidth:

MANETs has limited band width of wireless network. Hence, bandwidth is the important factor to be considered in routing the data packets in MANETs. The residual bandwidth of each mobile node along the paths is determined in order to attain resource effective routing in MANETs. The residual bandwidth of a mobile node is calculated based on the bandwidth consumption. Each node estimates its consumed bandwidth by tracking the packets it transmits into the network. The residual bandwidth of mobile node RB_{N_i} is mathematically obtained as follows,

$$RB_{N_i} = Bd_{raw} - Bd_C \quad (4)$$

From equation (4), Bd_{raw} indicates the raw channel bandwidth i.e. initial bandwidth of mobile node whereas Bd_C represents an amount of bandwidth consumed to broadcasting the data packets. With aid of equation (8), the residual bandwidth of all mobile nodes in MANETs is evaluated to attain resource aware routing in MANETs.

iii. Delay time:

A delay time is other important routing metric to be considered in MANETs in order to perform resource efficient routing. Delay time measure of time taken to transfer the group of data between two neighboring nodes. In MANETs, let us consider all the mobile nodes have the same ability to create, process and transfer group of data. Hence, there is no external factor to affect the delay time. The total delay is occurred when data packets exchanged between two neighboring nodes. Thus, delay time is divided into four parts such as queuing delay, processing delay, propagation delay and transmission delay.

$$DT = Q_d + P_d + T_d \quad (5)$$

From equation (5), the delay time between two mobile is calculated. When group of data are transmitted from the source node to destination node.

$$DT_{total} = n * DT \quad (6)$$

$$D = d(N_i, N_j) = \{[(x_j, y_j) - (x_j, y_j)]^T * Cv^{-1} * xj,yj-xj,yj12 \quad (7)$$

From equation (7), $d(N_i, N_j)$ denotes the distance between two mobile nodes whereas (x_i, y_i) and (x_i, y_i) represents the location coordinates of two mobile nodes and Cv is the sample covariance matrix. Due to the mobility nature of MANETs, population (i.e. counts) of neighbouring nodes is also changed according to time t. To find out the available number of neighbouring nodes with minimum distance at time t, by NLDRO-QAR Technique.

$$\frac{dN_i}{dt} = \delta R_{N_i} N_i - \gamma N_i \quad (8)$$

From equation (8) $\frac{dN_i}{dt}$ denotes change in count of neighbouring mobile node over time t in which γ is Predator mortality rate (i.e. inactive neighbour node due to minimal resource), δ is growth rate of mobile node at time t. By using equation (8), available number of neighbour nodes with minimum distance at time t is efficiently identified to transmit the data packets in network. Eliminating time from the above two differential equations (1) and (8), the following mathematical formulation is obtained,

$$\frac{dN_i}{dR_{N_i}} = -\frac{N_i}{R_{N_i}} \frac{\delta R_{N_i} - \gamma}{\beta N_i - \alpha} \quad (9)$$

From equation (9), $\frac{dN_i}{dR_{N_i}}$ represents neighbour mobile nodes with minimum distance and higher resource availability. By this way, the data packets are gets routed from source to destination with minimum energy and bandwidth utilization in MANETs. The algorithmic process of Non-linear Differential Resource Optimization based Quality Aware Routing is shown in below,

Algorithm 1 :Non-linear Differential Resource Optimization based Quality Aware Routing Algorithm

Input: Number of Mobile Nodes : $N_i = N_1, N_2, .. N_n$, Number of Data Packets $DP_i = DP_1, DP_2, .. DP_n$, Source Node: S, Destination Node D
Output: Attain quality and resource aware routing in MANETs
Step 1: Begin
Step 2: For each mobile node in source and destination
Step 3: Compute residual energy using (3)
Step 4: Compute residual bandwidth using (4)
Step 5: Compute delay time between two nodes using (5)
Step 6: Evaluate resource availability of node at time t using (1)
Step 7: Calculate Mahalanobis distance between two nodes using (7)
Step 8: Identify number of available neighbour nodes at time t with minimum distance using (8)
Step 9: Find out resource optimized mobile node at time t to route the group of data from source to destination using (9)
Step 10: End for
Step 11: End

Algorithm 1 shows the step by step process of Non-linear Differential Resource Optimization based Quality Aware Routing technique. As demonstrated in algorithm, residual energy, residual bandwidth, delay time, Mahalanobis distance between two nodes is computed for each mobile node in network. From that, then resource availability and available number of neighbor nodes at time t is effectively calculated. Finally, neighbor mobile node with minimum distance and higher resource availability is selected as optimal node in order to route the group of data between source and destination node in MANETs. The chosen optimal mobile nodes consume minimum amount of energy, bandwidth, and delay time for effective data packet transmission in MANETs. In addition to that, there is no information loss during the transmission of group of data due to the link failure and resource constrained issues. Therefore, NLDRO-QAR Technique attains the quality and resource aware routing in MANETs.

IV. SIMULATION SETTINGS AND PERFORMANCE EVALUATION

A. Simulation Settings

In order to analyze the performance of proposed, Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) Technique is implemented in NS-2 simulator. The NLDRO-QAR Technique considers MANETs with 1200m * 1200m network area for conducting the simulation process. The number of mobile nodes selected for performing simulation work is 500. Further, NLDRO-QAR Technique takes Ad hoc On-Demand Distance Vector (AODV) protocol as routing protocol. The following table shows simulation parameters used for experimental evaluation.

Table 1 Simulation Parameters

Simulation factor	Value
Simulator	NS2.34
Protocol	AODV
Node density	50, 100, 150, 200, 250, 300, 350,400,500
Simulation time	100s
Pause time	10s
Mobility model	Random Way Point
Transmission range	300m
Network area	1200m * 1200m
Data packets	9,18, 27, 34, 45, 54, ,72,81,90

The simulation of NLDRO-QAR Technique is performed for several cases with respect to different number of mobile nodes compactness and group of data and averagely ten results are present in table and graph for analyzing performance. The efficiency of NLDRO-QAR Technique is measured in terms of energy consumption, end to end delay, data loss rate and bandwidth utilization rate. The execution of NLDRO-QAR Technique is equate with existing Stepwise Regression based Resource Optimized Routing (SR-ROR) Technique.

B. Result and Discussions

In this part, the result analysis of NLDRO-QAR Technique is presented. The strength of NLDRO-QAR Technique is equate against with Stepwise Regression based Resource Optimized Routing (SR-ROR) Technique. The performance of NLDRO-QAR Technique is measured along with the following factor with the help of tables and graphs.

i. Impact of Energy Consumption

In NLDRO-QAR Technique, the Energy Consumption (EC) determines the amount of energy needed to efficiently transmit the data packets from a source to destination node in MANETs. Therefore, energy conserve is defined as product of the energy utilized by a single mobile node and total mobile nodes in a group of nodes. The energy conserve is evaluated in terms Joules (J) and mathematically formulated as,

$$EC = N * energy\ ultilized\ by\ a\ signal\ node\ for\ data\ transmission \quad (10)$$

From equation (10), the amount of energy required for data packet broadcasting is determined with respect to different number of mobile nodes (N). When energy consumption is lower, the method is said to be more effectual.

Table 2 Tabulation for Energy Consumption

Number of Mobile Nodes (N)	Energy Consumption (J)	
	SR-ROR Technique[8]	NLDRO-QAR Technique
50	0.08	0.06
100	0.10	0.07
150	0.11	0.09
200	0.13	0.11
250	0.16	0.14
300	0.17	0.15
350	0.19	0.17
400	0.22	0.19
450	0.24	0.22
500	0.27	0.24

Tabulation results obtained for energy consumption using two methods found on various numbers of mobile nodes is depicted in Table 2. NLDRO-QAR Technique considers framework with many number of mobile nodes in the range between 50-500 for carried outing the simulation process in NS-2 simulator. When 300 mobile nodes are to be compared with proposed NLDRO-QAR Technique utilizes 0.15 J energy to transmits the data packets in MANETs whereas SR-ROR Technique [8] takes 0.17 J. From that, energy utilization using proposed NLDRO-QAR Technique majority of node is low exist methods.

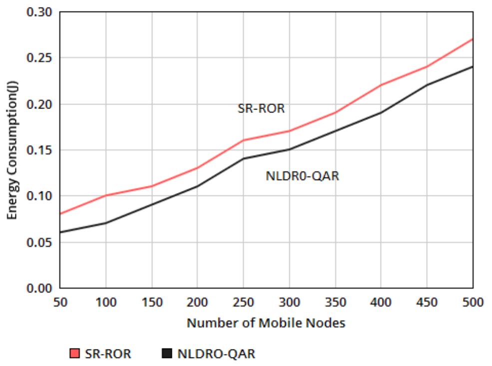

Figure 2 Measurement of Energy Consumption

Figure 2 presents performance analysis of energy conserve versus unrelated number of mobile nodes in the ranges from 50-500 using two methods. As depicted in numeric, the proposed NLDRO-QAR minimum energy providing consumption for efficient group of data transmission in MANETs, it equates with SR-ROR Technique [8]. Further mobile nodes, the energy utilized for data packets transmission is also increased. But comparatively energy consumption using proposed with NLDRO-QAR Technique is lesser.

ii. Impact of End to End delay

In NLDRO-QAR Technique, the Average End–to-end Delay (AED) determination time needed for broadcasting group of data from source to destination node in MANETs. Thus, average end to end is measured, difference between the receiving time of packet at the destination node $RT_{packets}$ and sending time of packet at source node $ST_{packets}$. The average end to end is estimated in terms of milliseconds (ms) and expressed as far as,

$$AED = RT_{packets} - ST_{packets} \qquad (11)$$

From equation (11), the average end to end delay is evaluated with respect to various group number of data. When the average end to end delay is lower, the method is said to be more effective.

Table 3 Tabulation for Average end to end delay

Number of Data packets (N)	Average end to end delay (ms)	
	SR-ROR Technique [8]	NLDRO-QAR Technique
9	4.3	3.8
18	9.5	8.2
27	14.2	12.9
36	17.6	15.6
45	22.1	19.1
54	28.3	26.4
63	31.8	29.8
72	35.9	33.2
81	38.4	35.7
90	42.5	39.5

Table 3 presents tabulation results of average end to end delay using two methods based on different numbers of data packets in the range of 9-90. When considering 54 data packets for conducting simulation process, proposed NLDRO-QAR Technique acquires 26.4 ms average end to end delay whereas SR-ROR Technique obtains 28.3 ms. From that, average end to end delay using proposed NLDRO-QAR Technique is lower when compared to other existing methods.

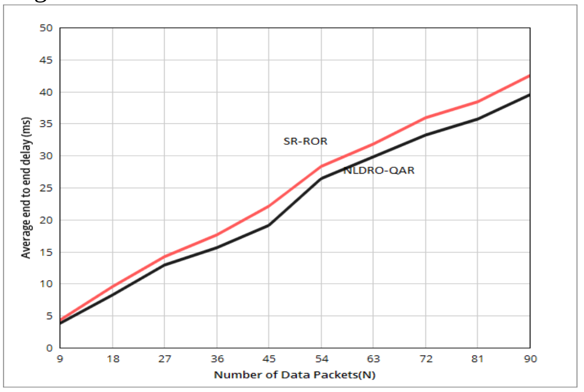

Figure 3 Measurement of End to End delay

Figure 3 explains performance analysis of average end to end delay versus dissimilar number of data packets in the range of 9-90 using two methods. As portrayed in figure, the proposed NLDRO-QAR Technique provides minimum average end to end delay for efficient data packets transmission in MANETs when compared to SR-ROR Technique [8]. As well, while increasing the number of data packets, the average end to end delay of data packets transmission is also increased. But comparatively average end to end delay using proposed NLDRO-QAR Technique is lower.

iii. Impact of Data Loss Rate

In NLDRO-QAR Technique, Data Loss Rate (DLR) is precise as the ratio of group number of data dropped to the total number of data packets pass from one place to another in MANETs. The data loss rate is precise in terms of percentages (%) and precisely represented as,

$$DLR = \frac{number\ \ of\ data\ packets\ \ dropped}{\mathrm{N}} * 100 \qquad (12)$$

From equation (12), the data loss rate is calculated with respect to different group number of data (N). When the data loss rate is lower, the method is said to be more effectual.

Table 4 Tabulation for Data Loss Rate

Number of Data packets (N)	Data Loss Rate (%)	
	SR-ROR Technique [8]	NLDRO-QAR Technique
9	19	11
18	20	13
27	22	15
36	25	18
45	26	19
54	28	23
63	31	25
72	35	28
81	37	29
90	41	34

Table 4 portrays tabulation results of data loss rate using two methods varied the data packets in the range between 9-90. When assuming 72 data packets for performing simulation work, proposed NLDRO-QAR Technique [8] attains 28 % data loss rate whereas SR-ROR Technique acquires 35 %. From that, data loss rate is lower than existing method.

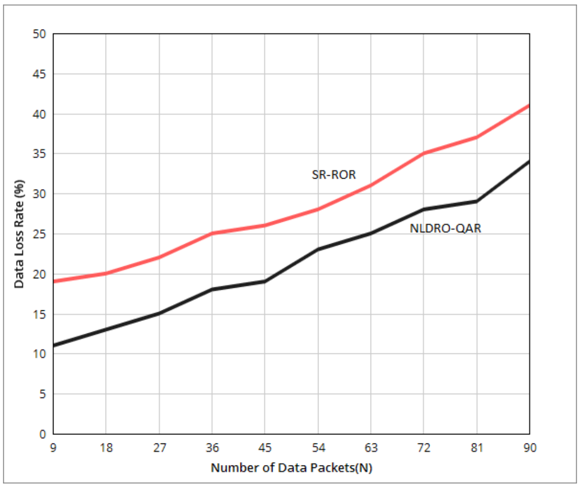

Figure 4 Measurement of Data Loss Rate

Figure 4 give details about performance analysis of data loss rate versus different group number of data in the range of 9-90 using two methods. As illustrated in figure, the proposed NLDRO-QAR Technique provides minimum data loss rate for attaining quality aware resource efficient routing in MANETs when compared to SR-ROR Technique [8]. In addition, while mounting the group number of data, the data loss rate is also increased. But rather data loss rate using NLDRO-QAR Technique is lower.

iv. Impact of Bandwidth Utilization Rate

In NLDRO-QAR Technique, Bandwidth Utilization Rate (BUR) refer to consumed bandwidth related to achieved throughput i.e. the average rate of successful data transfer through a communication path. Thus, bandwidth utilization rate is measured as ratio of amount of bandwidth utilized for transmitting the data packets to total available bandwidth of node in MANETs. The bandwidth utilization rate is precise in terms of percentages (%) and

$$BUR = \frac{amount\ \ of\ bandwidt\ h\ utilized\ \ for\ \ data\ packet\ \ transmission}{total\ available\ \ bandwidt\ h} * 100 \qquad (13)$$

From equation (13), the bandwidth utilization rate is evaluated with respect to different group numbers of data (N). When the bandwidth utilization is lower, the method is said to be more efficient.

Table 5 Tabulation for Bandwidth Utilization Rate

Number of Data packets (N)	Bandwidth Utilization Rate (%)	
	SR-ROR Technique [8]	NLDRO-QAR Technique
9	37	28
18	39	31
27	42	35
36	45	37
45	46	40
54	50	41

63	53	43
72	55	47
81	56	48
90	58	50

Table 5 depicts tabulation results of bandwidth consumption using two methods based on various group number numbers of data in the range of 9-90. When considering 81 data packets for accomplishing simulation work, proposed NLDRO-QAR Technique utilize 48 % bandwidth whereas SR-ROR Technique [8] acquires 56%. From that, proposed NLDRO-QAR Technique consumed lower bandwidth.

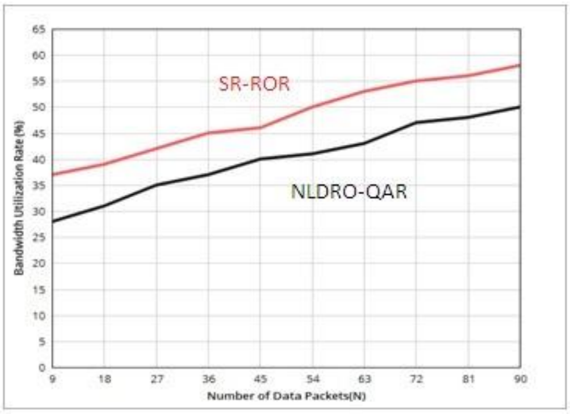

Figure 5 Measurement of Bandwidth Utilization Rate

Figure 5 describes performance analysis of bandwidth utilization rate versus diverse group number of data in the range of 9-90 using two methods. As exposed in figure, the proposed NLDRO-QAR Technique provides minimum bandwidth utilization rate for attaining quality aware routing in MANETs when compared to SR-ROR Technique [8].

V. CONCLUSION

An efficient Non-linear Differential Resource Optimization based Quality Aware Routing (NLDRO-QAR) is designed with objective of highlighting the performance of quality aware resource efficient routing in MANETs. The key objective of NLDRO-QAR Technique is to attain quality aware routing in MANETs through minimizing the amount of resource utilization for data transmission. The goal of NLDRO-QAR Technique is attained with application of Non-linear Differential model. With assists of NLDRO-QAR Technique find outs the mobile nodes with higher resource availability as best nodes in order to obtain the group number of data from source to destination in MANET. Thus, NLDRO-QAR Technique significantly minimizes the resource consumption for efficient data delivery in MANET. Therefore, NLDRO-QAR Technique reduces the energy and bandwidth utilization rate of data transmission in MANETs. The performance of NLDRO-QAR Technique is measured in terms of energy utilization, data loss rate, average end to end delay and bandwidth utilization rate and compared with two existing methods. The simulations outcome reveal that NLDRO-QAR Technique provides better performance with a reduction of energy utilization and bandwidth utilization rate for reliable data packet delivery in MANETs when compared to state-of-the-art works.

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