# Forward Stepwise Regression Based Load Balanced Energy Efficient Routing in Manet

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***Abstract- Mobile Ad hoc Network (MANET) is a network architecture distributed without any fixed infrastructure. Network nodes communicate with each other without any static infrastructure. The transmission range of the node is limited to the region around the node. Therefore, load-balanced routing is one of the key challenges for effective communication. A novel technique called Forward Stepwise Regression-based Load Balanced Energy Efficient Routing (FSR-LBEER) technique is introduced in MANET. The main objective of the FSR-LBEER technique is to perform efficient routing with minimum energy consumption and routing overhead. Initially, the number of mobile nodes are taken and combined to form the whole network. For each mobile node in the network, residual energy, distance, and bandwidth is estimated for constructing the route paths. Forward Node Selective Stepwise Regression is applied to select the neighboring node with higher residual energy, minimum distance, and lesser bandwidth utilization. The process gets repeated until it identifies the suitable neighboring mobile nodes between source and destination. Then the route path discovery is carried out using two control messages namely route request and route reply. In this way, multiple route paths are established in the mobile network for data transmission. During the data transmission process any link failure occurs, the stable alternate path is chosen from the available paths based on the better link connectivity and the data packets get transmitted to the destination node. In this way, the load-balanced routing gets achieved. Experimental evaluation of the FSR-LBEER technique is carried out on factors such as energy consumption, packet delivery ratio, packet loss rate, delay, and routing overhead with respect to the number of mobile nodes and data packets. The observed results from the simulation show that the FSR-LBEER technique efficiently increases the data packet delivery and minimizes the energy consumption, packet loss rate, delay, and routing overhead than the conventional routing techniques.***

***Indexed Terms- MANET, Load balanced routing, Forward Node Selective Stepwise Regression, route discovery, route maintenance***

## I. INTRODUCTION

MANET is a group of wireless mobile nodes that structure a temporary dynamic and independent infrastructure with a central management facility. Higher energy consumption is a major problem in MANET technology. Thus, the MANET uses the multipath routing to achieve an excellent network performance in terms of network-load-balancing in the high mobility nodes scenarios. Due to the random mobility, the link broken frequently occurs and also uses the alternative multipath to shorten the time of routing reconstruction. Therefore, an efficient machine learning method is required for reliable communication in an unstable network topology.

A Hybrid model based multipath routing (HM-MPR) technique was introduced in [1] for enhancing the efficiency and reliability of routing by selecting the position of the node. The designed technique failed to improve the routing with minimum delay tolerance. Mobility, Contention window, and Link quality sensitive multipath Routing (MCLMR) technique were designed in [2] to identify the intermediate nodes for best route selection. The MCLMR technique increases the throughput and reduces the delay, as well as packets loss but the scheme was not applied for large-scale network deployments as well as multi-hop communication systems.

An Energy consumption-based multipath routing method was designed in [3] using opposition geneticbased fish swarm optimization. The designed method failed to consider the different behaviors of the node such as bandwidth for improving the routing performance and minimizes the delay. An efficient load balancing with the energy constraint routing method was developed in [4] to forward the packets with better stability. The designed technique failed to increase the load balancing with better efficiency. A load-balancing Ad-hoc On-demand Multipath Distance Vector (LBA-AOMDV) was developed in [5] to maintain the load between the nodes using multipath routes. The designed technique failed to minimize the routing overhead.

A QoE-driven multipath TCP (MPTCP)-based data delivery method was introduced in [6] for load-balanced routing. However, the efficiency of the data delivery with a better application-level QoE was not achieved. Ant-based efficient energy and balanced load routing technique were developed in [7] to find the optimal path convergence for transmission. The designed technique failed to minimize the packet drop during data transmission.

An intelligent energy-aware efficient routing was introduced in [8] to enhance the data packet delivery with lesser delay. The designed routing technique failed to obtain the link stability between the mobile nodes for improving the routing efficiency. Mobility, Residual energy, and Link quality Aware Multipath (MRLAM) routing technique were developed in [9]. The designed multipath routing technique finds an optimal stable route with energy-efficient nodes. But the performance of the packet delivery ratio was not improved.

Bat Optimized Link State Routing (BOLSR) protocol was designed in [10] to improve the data transmission based on energy and bandwidth usage. The protocol minimizes the routing overhead ratios and delays but higher throughput was not achieved.

### 1.1 Our contributions

The above-said problem is solved by introducing the novel machine learning-based load-balanced energy-efficient routing in MANET. The major contribution of the proposed FSR-LBEER technique is summarized as given below,

- A novel routing technique called FSR-LBEER is introduced for link quality-aware multipath routing which takes into consideration the status of the three-evaluation metrics such as the bandwidth, energy, and distance
- To improve the packet delivery ratio, an FSR-LBEER technique uses the forward stepwise regression. The regression function analyzes the node behaviors and finds the energy-efficient mobile nodes as a forwarding node.
- To improve the throughput and minimizes the delay of data transmission, an FSR-LBEER technique finds the optimal route with a stable link between the node whenever the link failure occurs.
- Finally, the extensive and comparative simulation was conducted and also performs the quantitative analysis based on the different performance metrics

### 1.2 Paper structure

The remaining of the paper is arranged as follows: Section 2 explains the related works of the different routing techniques in MANET. Section 3 presents the main contribution of this proposed work with a neat diagram. Sections 4 and 5 explain the simulation model and parameters, the evaluation metrics, and experimental results and discussion respectively. Finally, Section 6 concludes the presented work.

## II. RELATED WORKS

A stable and energy-efficient routing algorithm was introduced in [11] using the learning automata (LA) theory to find the best available routes. The designed algorithm increases the packet delivery and minimizes the delay but the higher throughput was not achieved. A Reliable opportunistic routing technique was designed in [12] based on gradient forwarding to achieve a higher packet delivery ratio. But it failed to apply the machine learning technique to find the energy-efficient node for obtaining a higher packet delivery ratio.

A quality-of-service load balanced connected dominating set based searching technique was introduced in [13] to enhance the network lifetime and minimizes the routing overhead. But the designed technique was not efficient to minimize the delay since it failed to perform the link stability-based routing. A dynamic energy ad-hoc on-demand distance vector routing protocol (DE-AODV) was developed in [14] to reduce the packet delay as well as energy consumption. The model increases the throughput but the overhead was not minimized.

A Transition State MAC Protocol (TSMP) was designed in [15] for improving the energy-efficient routing with lesser overhead and delay. However, the higher packet delivery ratio was not achieved. An efficient power-aware routing (EPAR) technique was developed in [16] to improve the reliable packets transmitting on a particular link. The designed technique minimizes the energy consumption and routing overhead but a higher data delivery ratio was not achieved.

An energy-efficient routing approach (EE-RA) was designed in [17] to minimize the network overhead and increase the throughput. The approach failed to consider the bandwidth to improve load-balanced data delivery. A load-balancing routing method was introduced in [18] for ad hoc networks and minimizing the packet loss ratio and delay. The designed method failed to consider the energy-aware routing in MANET. An Integer Linear programming model was developed in [19] to improve the energy-efficient routing with minimum delay and bandwidth consumption. But the performance of routing overhead was not minimized. In [20], a Synchronized Fuzzy Ant System (SynFAnt) was introduced to find optimal routing of data packets transmitted across the network. Though the system decreases the route maintenance, the energy optimal load-balanced routing was not achieved.

## III. METHODOLOGY

A MANET is a collection of wireless mobile hosts structuring a temporary network without the help of any stand-alone infrastructure management. Mobile Ad-hoc networks are self-organizing multi-hop wireless networks where the network structure changed dynamically. This is mainly due to the mobility of the nodes in MANET. The nodes in these networks cooperate in a significant manner to provide high-quality communication. The nodes in MANET have limited bandwidth, battery power, buffer space, and so on. So it is essential to find the multiple feasible paths between a specified source and destination pair and then distributing the total set of data of packets from the source to the destination along the possible paths. Apart from the reduced time of routing all the message packets through multiple paths, another advantage is to increase the load-balanced routing for minimizing the delay and improving the data transmission. Based on the above motivation, a new technique called the FSR-LBEER technique is introduced for improving the load-balanced routing in MANET.

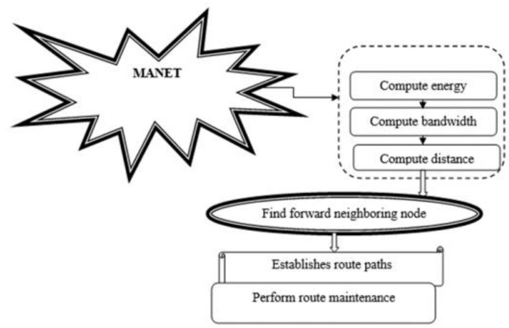


Figure 1 Architecture of the FSR-LBEER technique

Figure 1 given above illustrates the architecture of the proposed FSR-LBEER technique to improve the routing performance in MANET. A collection of autonomous nodes are dynamically connected by means of wireless links and to form an entire network. Then the proposed FSR-LBEER technique has an ability to maintain the constant load among the multiple routes whenever the link failure occurs. The process of the load-balanced routing is explained in the following sections.

3.1 System model

The MANET is organized in a directed graphical form $g = (v, e)$, where the number of mobile nodes $\{Mn_1, Mn_2, Mn_3, \dots . Mn_n\}$ are distributed in a squared area $m * m'$ circumstances and '$e$' denotes the link between the nodes within the communication range '$T_c$'. The network initiates the source node '$Sn$' and finds the neighboring node '$Nn$' for transmitting the data packets $p_1, p_2, p_3 \dots .. p_m$ to the destination node '$Dn$'. The source node finds the neighboring node which having maximum energy $E_{Mn}$ , bandwidth $B_w$ , Minimum distance $dist_{Mn}$.

3.2 Mathematical model

Initially, the proposed FSR-LBEER technique uses Forward Stepwise Regression to find the neighboring nodes. A forward stepwise regression is a machine learning technique used for estimating the relationships between mobile nodes and node behaviors. Here the three behaviors are used to find the neighboring nodes such as energy, bandwidth, and distance.

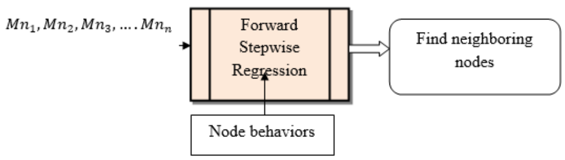


Figure 2 Forward Stepwise Regression-based neighboring node selection

Figure 2 given above demonstrates the block diagram of the proposed technique to find neighboring nodes. Let us consider the mobile nodes positioned in the two-dimensional space and the coordinated are denoted as $(p_1, q_1)(p_2, q_2)$. The distance between the mobile nodes are estimated as follows,

$$D_{(p,q)} = \sqrt{(p_2 - p_1)^2 + (q_2 - q_1)^2} \quad (1)$$

Where, $D_{(p,q)}$ denotes a distance between the two mobile nodes. After that, the residual energy of the node is measured based on total energy and consumed energy. The residual energy of the node is mathematically expressed as follows,

$$R_{(M_n)} = Total_E - Cons_E \quad (2)$$

Where, $R_{(M_n)}$ indicates residual energy of the mobile node, $Total_E$ indicates the total energy of the mobile node, $Cons_E$ denotes the consumed energy of the mobile nodes. Then the other node behavior is the bandwidth consumption which measured using the following equation

$$Band_{cons} = (Band_T - Band_a) \quad (10)$$

Where, $Band_{cons}$ denotes a bandwidth consumption, $Band_T$ denotes a total bandwidth, $Band_a$ indicates an available bandwidth. Then the regression function analyzes the node behavior with the threshold value.

$$Q = \begin{cases} arg\min D_{(p,q)} \ \&\& \ (R_{(M_n)} > R_T) \ \&\& \ (Band_{cons} < Band_{Th}), select\ f \\ otherwisae,\ find\ another\ node \end{cases}$$

(4)

Where, $Q$ denotes an output of the regression function, $arg\,min$ denotes an argument of the minimum function of the distance between the node '$D_{(p,q)}$', $R_{(M_n)}$ denotes residual energy of the node, $R_T$ denotes a threshold, $Band_{cons}$ denotes a bandwidth consumption, $Band_{Th}$ denotes a threshold of bandwidth consumption. The regression function finds the neighboring forward node selection which having minimum distance, lesser residual energy than the threshold, lesser bandwidth consumption than the threshold. This process gets repeated until it reaches the destination node.

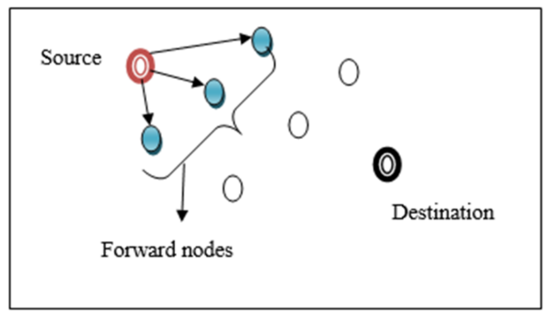


Figure 3 forward node selection

Figure 3 illustrates the directed graphical model of the MANET where the source node '$Sn$' represents brown in color and the destination node is represented by black color. Between the source and a destination node, the forward node is represented by the blue color for reliable data transmission.

3.3 Route path discovery

After finding the neighboring node, the multiple route paths are created between the source and destination through the request messages distribution. The control messages such as route request $\mathrm{req_r}$ and route reply $\mathrm{rep_r}$ are distributed between the nodes. The source node initiates to transmit the route request to the destination node via selected neighboring node

$$Sn \overset{\mathrm{req_r}}{\Longrightarrow} \sum_{i=1}^{n} (Nn_i) \overset{\mathrm{req_r}}{\Longrightarrow} Dn \quad (5)$$

From (5), $Sn$ indicates the source node sends a route request packet $\text{req}_\text{r}$ packet to destination '$Dn$' through the selected intermediate nodes $(Nn_i)$. Upon receiving the request message from the source node, then the destination node sends replies back to the source node.

$$Sn \overset{\text{rep}_\text{r}}{\Longleftarrow} \sum_{i=1}^{n}(Nn_i) \overset{\text{rep}_\text{r}}{\Longleftarrow} Dn \quad (6)$$

Where, '$\text{rep}_\text{r}$' denotes a reply message sent from destination $(Dn)$ to the source node $(Sn)$ through the neighboring nodes $(Nn_i)$. Based on these two message transmission, the multiple routes are created from the source to the destination end.

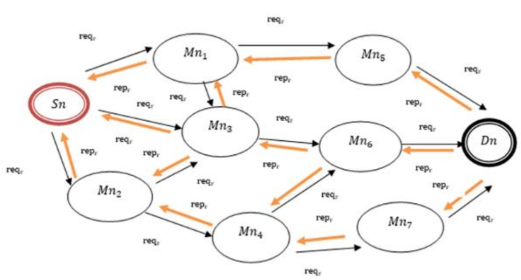


Figure 4 route paths discovery

Figure 4 given above illustrates the multiple route paths discovery between the source $(Sn)$ and destination $(Dn)$ via the selected neighboring nodes. The route paths from the above directed graphical structure are listed in table 1.

Table 1 available route paths

| Route paths | Routing Paths from Source to Destination | Hops |
|---|---|---|
| $R_1$ | $Sn \to Mn_1 \to Mn_5 \to Dn$ | 2 |
| $R_2$ | $Sn \to Mn_3 \to Mn_6 \to Dn$ | 2 |
| $R_3$ | $Sn \to Mn_3 \to Mn_1 \to Mn_5 \to Dn$ | 3 |
| $R_4$ | $Sn \to Mn_2 \to Mn_4 \to Mn_7 \to Dn$ | 3 |
| $R_5$ | $Sn \to Mn_2 \to Mn_4 \to Mn_6 \to Dn$ | 3 |

Table 1 illustrates the multiple route paths between source and destination. There are five route paths $R_1, R_2, R_3, R_4, R_5$ as shown in table 1. The third column indicates the number of hops between the source and destination.

3.4 Route maintenance

Once the route paths are established, the source node starts to perform the data transmission. During the data transmission, any link failure occurs due to node mobility. In this case, the proposed FSR-LBEER technique performs route maintenance to choose the alternate stable route for minimizing the packet loss. Therefore, maintaining the link stability among randomly deployed mobile nodes is essential for effective communication in MANET. The proposed technique measures the link connectivity between the nodes. The link from the node $Mn_i$ to node $Mn_j$ is connected at a particular time instant '$t$' is estimated as given below,

$$L(Mn_i \to Mn_j) = \left[\frac{T_c}{D_{(p,q)}}\right] \quad (7)$$

Where, $L(Mn_i \to Mn_j)$indicates link connectivity between the two nodes $Mn_i$ and $Mn_j$, $T_t$ indicates a communication range of mobile node, $D_{(p,q)}$ is the distance between the two nodes. The transmission range of the mobile node is always greater than the distance between the nodes (i.e. $T_t > D_{(p,q)}$). If the estimated link connectivity is better than the predefined threshold$(\varphi_t)$, then the two nodes are connected at a particular time and the link between the node is stable. The node selects the alternate route with a stable link to minimize the packet loss and balances the load between the mobile nodes. This in turn increases the data delivery and minimizes the packet loss. The algorithmic process of the proposed FSR-LBEER technique is described as given below,

| Algorithm 1: Forward Stepwise Regression-based Load Balanced Energy Efficient Routing |
|---|
| Input: number of mobile nodes $Mn_1, Mn_2, Mn_3, \ldots. Mn_n$ , Number of data packets $p_1, p_2, p_3 \ldots .. p_m$<br>Output: Improve energy efficient load-balanced routing |
| Begin<br>For each $Mn_i$<br>Measure $D_{(p,q)}$, $R_{(M_n)}$, $Band_{cons}$ |

Analyze the behaviours with threshold
If { $arg\min D_{(p,q)}$ && $(R_{(M_n)} > R_T)$ && $(Band_{cons} < Band_T)$} then
$Mn_i$ is selected as forward node
else
Find another forward node
End if
End for
// Route discovery
Construct route paths between the source and destination
$Sn$ sends $\mathrm{req_r}$ to destination $i.e\ Sn \overset{\mathrm{req_r}}{\Longrightarrow} \sum_{i=1}^{n}(Nn_i) \overset{\mathrm{req_r}}{\Longrightarrow} Dn$
$Dn$ sends $\mathrm{rep_r}$ to source I.e. $Sn \overset{\mathrm{rep_r}}{\Longleftarrow} \sum_{i=1}^{n}(Nn_i) \overset{\mathrm{rep_r}}{\Longleftarrow} Dn$
Obtain multiple routes
$Sn$ sends a data packet $p_1, p_2, p_3 \ldots\ldots p_m$ to $Dn$
// Route maintenance
for each route $R_i$
for node $Mn_i$ and node $Mn_j$
Calculate link connectivity $L(Mn_i \rightarrow Mn_j)$
if $(L(Mn_i \rightarrow Mn_j) > \varphi_t)$ then
Node $Mn_i$ and $Mn_j$ are connected at time 't'
The link between the node is stable
Select the stable route
else
Node $Mn_i$ and $Mn_j$ are not connected at time 't'
Link between the node is not stable
The route is not selected
end if
Route the data packets and balances the load
end for
end for
end

The algorithmic process of the energy-efficient load-balanced routing in MANET. For each node in the MANET, three different behaviors are estimated and analyzed. The stepwise regression function analyzes the node behavior with the threshold value. If the node has minimum distance and lesser energy consumption as well as bandwidth utilization is selected as a forwarding node. Otherwise, the nodes are not selected as a forwarding node. After selecting the forwarding nodes, the route paths are constructed between source and destination. The route path discovery is carried out by distributing the two control messages from the source to the destination and vice versa. Then the source node starts to transmit the data packets along the route path. If any link failure occurs, the node finds the alternative route which has a stable link is chosen for efficient transmission. As a result, the loads between the mobile nodes are balanced and minimize the packet drops.

## IV. SIMULATION SETTINGS

The simulation of the FSR-LBEER technique and existing methods are implemented using the NS2.34 network simulator. In order to conduct better simulation, a totally 500 mobile nodes are distributed in a squared area (1100 m * 1100 m) in MANET. For each mobile node in the network, the residual energy, bandwidth consumption is measured to find the neighboring node. The route paths are constructed with the help of control messages. Then the source node performs the data packet transmissions. Whenever the link failure occurs, the stable route is chosen for efficient transmission. To improve the energy-efficient load-balanced routing, a Random Waypoint model is used as a mobility model. The mobile nodes are moved in the network with a speed of 0 to 20m/sec. The total simulation time is set as 300 sec. The Dynamic Source Routing (DSR) protocol is implemented for scalable and reliable routing in MANET. The simulation parameters with the values are listed in table 7.

Table 2 Simulation parameters settings

| Simulation parameters | Values |
|---|---|
| Network Simulator | NS2.34 |
| Simulation area | 1100 m * 1100 m |
| Number of mobile nodes | 50,100,150,200,250,300,350,400,450,500 |
| Number of data packets | 25,50,75,100,125,150,175,200,225,250 |

| | |
|---|---|
| Mobility model | Random Waypoint model |
| Nodes speed | 0 – 20 m/s |
| Simulation time | 300sec |
| Routing Protocol | DSR |
| Number of runs | 10 |

## V. PERFORMANCE ANALYSES

Performance analysis of the proposed FSR-LBEER technique and two existing methods HM-MPR [1], MCLMR [2] are evaluated with different metrics such as packet delivery ratio, packet drop rate, end to end delay, throughput, and routing overhead. The performance of different methods is analyzed with the help of a table and graphical representation. The parameters are described as given below,

Packet delivery ratio: It is defined as the data packets are correctly received to the total number of (i.e. no. of) data packets transmitted from the source mobile node. The delivery ratio is mathematically estimated as given below,

$$Ratio_{PD} = \left[\frac{No.of\ packet\ received}{No.of\ packets}\right] * 100 \quad (8)$$

Where, $Ratio_{PD}$ symbolizes the packet delivery ratio is measured in the unit of percentage (%).

Packet drop rate: The packet drop rate is measured as the ratio of no. of data packets dropped to the total number of data packets transmitted. Therefore, the packet drop rate is estimated as follows,

$$Rate_{PD} = \left[\frac{No.of\ packet\ received}{No.of\ packets}\right] * 100 \quad (9)$$

Where $Rate_{PD}$ symbolizes the packet drop rate which is measured in terms of percentage (%).

End to end delay: It is measured based on the expected arrival time of the data packets and the actual arrival time of the packet at the destination end. The overall end to end delay is measured using the following expression,

$$D_{ETE} = [T_{actual}] - [T_{ex}] \quad (10)$$

Where, '$D_{ETE}$' represents the end to end delay, $T_{ex}$ denotes an expected arrival time and '$T_{actual}$' symbolizes the actual arrival time. The overall end to end delay is estimated in terms of milliseconds (ms).

Throughput: It is defined as the size of the packets delivered at the destination end at a specific time. The throughput is mathematically estimated as given below,

$$T_{put} = \left(\frac{size\ of\ packets\ received(bits)}{time\ (sec)}\right) \quad (11)$$

Where, '$T_{put}$' symbolizes the throughput. The throughput is measured in terms of bits per second (bps).

Routing overhead: The overhead is defined as the amount of time taken to route the data packet from source to destination. The routing overhead is estimated as given below,

$$Route_{overhead} = no.of\ \ packets * T\ [route\ one\ packets] \quad (12)$$

From (22), '$Route_{overhead}$ indicates a routing overhead measured in the unit of milliseconds (ms).

Table III packet delivery ratio

| No. of data packets | Packet delivery ratio (%) | | |
|---|---|---|---|
| | FSR-LBEER | HM-MPR | MCLMR |
| 25 | 88 | 84 | 80 |
| 50 | 92 | 88 | 84 |
| 75 | 93 | 87 | 83 |
| 100 | 90 | 85 | 82 |
| 125 | 93 | 88 | 85 |
| 150 | 94 | 87 | 84 |
| 175 | 92 | 86 | 83 |
| 200 | 90 | 85 | 81 |
| 225 | 93 | 84 | 80 |
| 250 | 94 | 88 | 82 |

Table III describes the result of the packet delivery ratio using three different methods. The packet delivery ratio is measured based on the number of data packets taken from 25 to 250. For the different counts of the input data packets, the different results of the packet delivery ratio are observed. The observed results indicate that the FSR-LBEER technique outperforms well in terms of achieving a higher delivery ratio than the existing routing techniques. This is proved through the statistical evaluation. By considering 25 data packets being sent from the source node, 22 data packets are successfully received at the destination end using the FSR-LBEER technique and the packet delivery ratio is 88%. Whereas 21 and 20 data packets are successfully received at the destination by applying two existing routing techniques HM-MPR [1], MCLMR [2], and their percentage of packet delivery ratio are 84% and 80% respectively. Among the three different routing techniques, the FSR-LBEER technique increases the packet delivery ratio. The observed results of the proposed routing technique are compared to the packet delivery results of the existing routing techniques. The obtained comparison results indicate that the average packet delivery ratio is increased by 7% when compared to [1] and 12% when compared to [2].

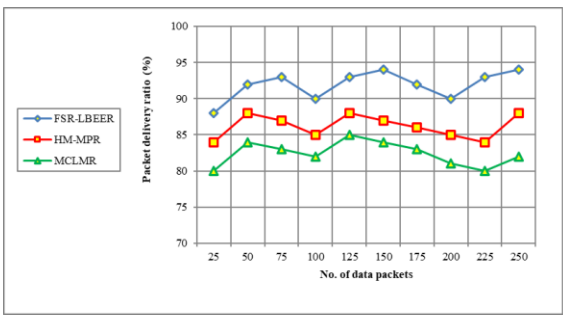


Figure 5 packet delivery ratio versus no. of data packets

Figure 5 indicates the simulation results of the packet delivery ratio versus the number of data packets taken in the ranges from 25 to 250. The test is conducted for different numbers of data packets and different results are observed. As illustrated in figure 5, the numbers of data packets are considered in the horizontal axis and the simulation results are obtained at the vertical axis. From the result, it is observed that the packet delivery ratio is comparatively higher in the proposed FSR-LBEER technique and it compared to existing methods. The reason is that the FSR-LBEER technique selects the Forward Node Selective Stepwise Regression to analyze the mobile node behaviors such as residual energy, lesser bandwidth consumption, and the minimum distance is chosen as the neighboring node. With the selected neighboring nodes, the route paths are constructed to deliver the data packets efficiently. As a result, a higher packet delivery ratio is achieved.

Table IV Packet drop rate

| No. of data packets | Packet drop rate (%) | | |
|---|---|---|---|
| | FSR-LBEER | HM-MPR | MCLMR |
| 25 | 12 | 16 | 20 |
| 50 | 8 | 12 | 16 |
| 75 | 7 | 13 | 17 |
| 100 | 10 | 15 | 18 |
| 125 | 7 | 12 | 15 |
| 150 | 6 | 13 | 16 |
| 175 | 8 | 14 | 17 |
| 200 | 10 | 17 | 19 |
| 225 | 7 | 15 | 20 |
| 250 | 6 | 12 | 18 |

Table IV reports the simulation results of the packet drop rate with respect to the number of data packets. From the results of all the three routing techniques**,** the FSR-LBEER technique minimizes the packet drop rate. Let us consider 25 data packets being sent from the source node, 3 data packets are dropped at the destination end using the FSR-LBEER technique and the drop percentage is 12%. Similarly, 4 and 5 data packets are dropped and their percentages are 16% and 20% using HM-MPR [1], MCLMR [2]. The observed statistical results of the FSR-LBEER technique is compared to the packet drop rate of the existing routing techniques. The average comparison results show that the packet delivery ratio of the FSR-LBEER technique is increased by 42% and 54% when compared to existing [1] [2] respectively.

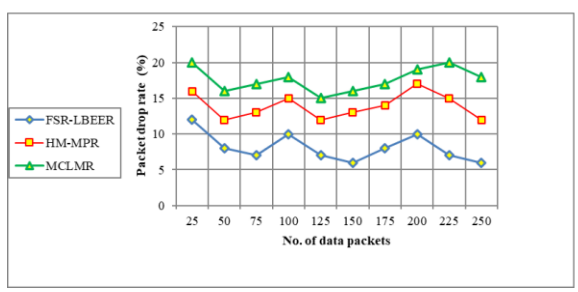


Figure 6 packet drop rate versus no. of data packets

Figure 6 shows the simulation results of the packet drop rate using different routing techniques FSR-

LBEER technique HM-MPR [1], MCLMR [2]. As shown in figure 6, the drop rate of the FSR-LBEER technique is represented by the blue color line chart. The red and green color lines indicate the packet drop rate of the existing routing techniques [1] [2] respectively. The plot indicates that the packet drop rate is reduced using the proposed FSR-LBEER technique. This is due to the FSR-LBEER technique performs load-balanced routing to minimize the packet drop. While transmitting the data packets, the link failure occurs due to the node movement. In this case, the mobile node selects the alternate stable route for continuous data delivery and balances the load across the mobile nodes. This helps to minimize the packet drop rate.

Table V End to end delay

| No. of data packets | End to end delay (ms) | | |
|---|---|---|---|
| | FSR-LBEER | HM-MPR | MCLMR |
| 25 | 9 | 11 | 12 |
| 50 | 10 | 12 | 14 |
| 75 | 11 | 13 | 15 |
| 100 | 12 | 14 | 16 |
| 125 | 14 | 16 | 20 |
| 150 | 16 | 18 | 21 |
| 175 | 17 | 20 | 22 |
| 200 | 19 | 21 | 23 |
| 225 | 21 | 23 | 25 |
| 250 | 23 | 26 | 28 |

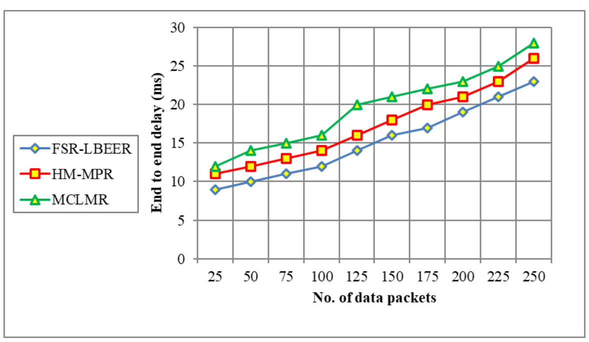


Figure 7 end to end delay versus no. of data packets

Table V and figure 7 depict the simulation results of the end delay versus the number of data packets taken in the counts from the 25 to 250. The simulation analysis of the end to end delay during the number of data packets being transmitted is estimated as shown in figure 7. While increasing the number of data packets, the end to end delay of the data transmission gets increased for all the methods. But comparatively, the chart indicates that the delay is minimized using the FSR-LBEER technique. The main reason for this achievement is the FSR-LBEER technique firstly finds the energy-efficient and lesser bandwidth utilization nodes which help to obtain the data packets. Besides, the alternate stable link selection is performed whenever the link failure occurs and hence it minimizes delay of data transmission. As a result, the end to end delay of the FSR-LBEER technique is considerably reduced. The obtained results of the FSR-LBEER technique is compared to the existing results. The average end to end delay is considerably minimized by 13% and 23% when compared to HM-MPR [1], MCLMR [2] respectively.

Table VI Throughput

| Data packet size (KB) | Throughput (bps) | | |
|---|---|---|---|
| | FSR-LBEER | HM-MPR | MCLMR |
| 15 | 190 | 170 | 160 |
| 30 | 290 | 240 | 220 |
| 45 | 360 | 330 | 300 |
| 60 | 460 | 420 | 380 |
| 75 | 530 | 490 | 450 |
| 90 | 650 | 580 | 530 |
| 105 | 770 | 670 | 630 |
| 120 | 880 | 790 | 740 |
| 135 | 1050 | 910 | 840 |
| 150 | 1260 | 1090 | 960 |

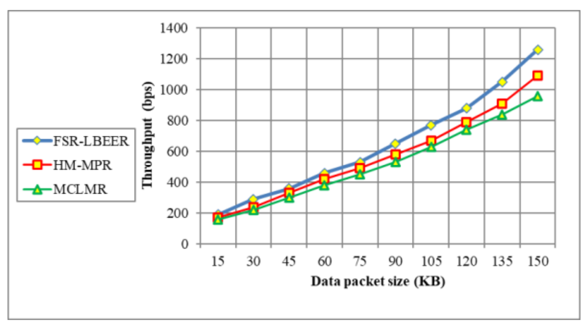


Figure 8 throughput versus no. of data packets

Table VI and figure 8 depict the performance results of the throughput versus the number of data packets. As shown in the above graph, the horizontal axis indicates the size of data packets being sent from the source node and the vertical axis exposes the number of packets successfully received in terms of the bits per second. According to the observed results, the proposed FSR-LBEER technique delivers higher sizes of the data packets per second. Let us consider 15$KB$ size of data packets considered and it is transmitted from the source node. By applying the FSR-LBEER technique, 190 bits of the data packets are delivered at the destination end. Whereas by applying the HM-MPR [1], MCLMR [2], the 170 bits, and 160 bits of data packets being successfully received at the destination node. The different results of throughput are obtained for three different methods. The viewed results designate that the FSR-LBEER technique increases the throughput by 13% and 23% when compared to existing routing techniques. This development is accomplished by selecting the energy-efficient and lesser bandwidth utilization nodes to improve data delivery. Besides, a stable link between the nodes is also used to improve the throughput.

Table VII Routing overhead

| No. of data packets | Routing overhead (ms) | | |
|---|---|---|---|
| | FSR-LBEER | HM-MPR | MCLMR |
| 25 | 16 | 18 | 20 |
| 50 | 21 | 24 | 25 |
| 75 | 23 | 26 | 30 |
| 100 | 26 | 29 | 33 |
| 125 | 30 | 33 | 36 |
| 150 | 33 | 36 | 41 |
| 175 | 35 | 39 | 44 |
| 200 | 38 | 42 | 46 |
| 225 | 41 | 43 | 47 |
| 250 | 43 | 45 | 50 |

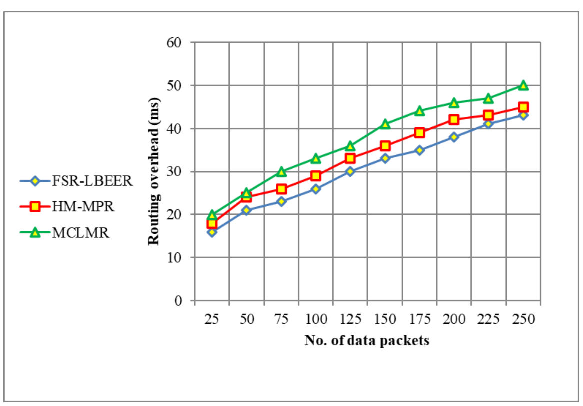


Figure 9 routing overhead versus no. of data packets

Table VII and figure 9 displays the performance results of routing overhead with respect to different numbers of data packets. For each method, 10 different runs are conducted based on the number of data packets. As revealed in figure 8, the routing overhead is considerably minimized using the FSR-LBEER technique. The simulations are conducted for 25 data packets being sent from the source node, the routing overhead is observed using the proposed FSR-LBEER technique is 16$ms$ whereas the observed routing overhead of HM-MPR [1], MCLMR [2] are 18$ms$ and 20$ms$ respectively. Among three different routing methods, the proposed FSR-LBEER technique comparatively minimizes the routing overhead. The observed results of the proposed FSR-LBEER technique are compared to the existing results. Ten results are obtained for each method. The average of ten results indicates that the routing overhead of the FSR-LBEER technique is significantly reduced by 9% when compared to [1] and 18% when compared to a [2]. The major reason for the lesser routing overhead is the energy-efficient node selection. The node which has the higher residual energy performs well and rapidly distributes the multiple packets with minimum time consumption. The proposed regression function analyzes the node behavior and finds the well efficient node to route the data packets with minimum time.

## CONCLUSION

A novel technique called FSR-LBEER is introduced for load-balanced energy-efficient routing in MANET. The FSR-LBEER technique finds the multipath routing to improve the effectiveness of data delivery. The main aim is to propose an adaptive solution to improve throughput and data delivery by analyzing the node performance behaviors such as energy, bandwidth. Moreover, a forward stepwise regression is applied to examine behavior analysis. Based on the analysis, the best forward node is chosen to route the data packets. After finding the nodes, the multiple paths are constructed through the request and reply message distributions. Finally, the link stability-based route maintenance is carried out to achieve better throughput and minimizes the end to end delay. The FSR-LBEER technique is implemented using the Network Simulator and different types of routing parameters are discussed with different routing techniques. The proposed FSR-LBEER technique shows that our simulation results offers a better energy efficient load balancing with minimum packet loss and increases the packet delivery and throughput.

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