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An Efficient Restricted Flooding Based Route Discovery (RFBRD) Scheme for AODV Routing

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Abstract – AODV is one of the widely used routing schemes in WSN and MANET due to its on-demand characteristics and low overhead. The excessive flooding at the time of route discovery consumes lots of node energy. The network performance deteriorates due to the unconstrained and blind flooding of route request (RREQ) packets. The excessive flooding mechanism accounts for multiple reception of RREQ packets at nodes. It causes unwanted path loops, and packet collisions thus exhausting the node batteries. The restricted flooding-based route discovery (RFBRD) mechanism introduced in this paper adopts two different strategies for receiving first and subsequent RREQ packets before they are forwarded. On reception of the first RREQ at an intermediate node, the RREQ is forwarded/restricted based on node densities evaluated for the neighbourhood as well as the network. Four regions and five probabilities are considered based on node densities in the neighbourhood and the network. The mobile nodes lying in the low-density region are allowed to transmit the RREQ packets with higher probability as compared to other nodes present in high-density regions when the RREQ is received for the first time. For subsequent RREQ packets at an intermediate node, the RREQ is forwarded/restricted based on energy ratios and is allowed to forward the RREQ packets, if the node has sufficient residual energy concerning neighbourhood and network energies. Simulation analysis showed enhanced and improved performance in terms of end-to-end delay, and network residual energy concerning traditional AODV.

Index Terms – RREQ, Restricted Flooding Mechanism, RFBRD, Residual Energy, Average Energy, Energy Ratios, AODV.

1. INTRODUCTION

The important factor affecting the routing in MANET is random topology due to mobile nodes and the velocity with which they tend to acquire new geographic positions in the network space. The assumption that the nodes have

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deterministic velocity and the maximum velocity is a hypothesis in real time. Much of the literature is proposed while assuming restrictive deterministic node velocities with higher velocity limits [1][2] to model tractable models resulting in accuracy compromise and restricted applicability. There has been always a trade-off between throughput, end-to-end delay, packet delivery ratio, and network overheads. The real challenge lies in maintaining these parameters at a considerable level and increasing the network performance concerning what had been done using simple flooding. The foremost challenge to address in MANET and WSN (Wireless Sensor Network) is to reduce the energy consumption of the sensor elements [3]. The information will not reach the desired destination if any node along the path runs out of energy while transmitting or receiving the data. Nevertheless, flooding is an essential process to route discovery, a node battery may get exhausted if the flooding is concentrated on specific nodes. In most of the cases, battery replacement is not possible. Therefore, considering the software and the hardware, it becomes necessary to reduce the energy consumption from the physical layer to the network layer. Many such reviews have been admitted in [4-8] concerning energy efficiency concerning routing and subsequently, various routing schemes have been developed [9-11].

The overhead caused by exhaustive flooding as compared to actual packet transmission overhead becomes comparable in densely populated networks. In contrast, failure to establish guaranteed links is greatly affected in low-density regions or scarcely populated regions. The idea of a prolonged network can be accomplished only when the burden of node overheads is relieved and energy is saved homogeneously throughout the network. The traditional method of rebroadcasting the RREQs can potentially lead to collisions, contentions, and redundant RREQ transmissions in the network. Work presented by [12-15] focuses on these issues with relatively little attention on the deleterious consequences of broadcast storms. Work proposed in [16-19] suggested probabilistic broadcast schemes as one of the alternatives to mitigate flooding concerning the conventional flooding method. In this method, the received RREQ is rebroadcasted once based on a priory fixed probability used for forwarding. The rebroadcast scheme is independent of the network topological information. Therefore, such localized schemes significantly reduce the associated overhead due to communication with the dissemination of RREQ packets in the network. However, as far as specific applications are concerned such as routing, most of the work found in the literature that incorporates probabilistic broadcast schemes has relatively low investigations on the effects of pure broadcast scenarios.

The possible number of rebroadcast when a source node has to find its destination node are (*M-2*), where M represents the total nodes in the network space. The traditional way was exploited as in AODV [20] and restricted the RREQs depending on two factors: the region density for the first RREQ received and the node residual energy at the node, neighbourhood, and the network for any later RREQ received by an intermediate node. The network region was partitioned based on the node population in 8 colonies (dissolved to 5) and assigned the highest forwarding probability to forward RREQ when the node lies in the scarcely populated colony while the lowest forwarding probability to the node lying in the densely populated colony for the first RREQ received. For subsequent RREQs, nodes were allowed to rebroadcast when the ratio of their residual energy to 1-hop neighbourhood mean energy was greater than the ratio of two-step neighbourhood average energy to mean network energy. This was to ensure guaranteed link in the scarce region and energy conservation in the flooded regions. The former was constrained similar to tossing a coin and finding the probability of occurrence of head (forward) or tail (drop). The nodes having the highest forwarding probability were able to rebroadcast RREQ when the result of the toss (random number generated) was in favor of their assigned probabilities. Thus the overall possible number of RREQ rebroadcasts was limited to *(M-2)/4* to reduce the overhead and increase the lifetime of the nodes. The proposed work considered a dynamic network with nodes moving with velocities ranging from 5-45 m/s with an offset of 5 m/s in a geographical space of 1641x897 m^2. At any given time, the node densities at a particular area of the neighbourhood keep changing due to dynamically changing topology.

1.1. Contribution

1. The proposed work concentrated on energy conservation by restricting the flooding of RREQ packets during the route discovery process in AODV.

2. The proposed work dominates the work proposed in [21][22] and extends the work suggested in [21]. Before forwarding the RREQ packet, the node region density and energies in its neighbourhood and the network are taken into account. The RREQ packet is forwarded if the node lies in a scarce region for better connectivity, where a higher forwarding probability is assigned. The RREQ is dropped when the node belongs to a dense region for energy conservation where a low value of forwarding probability is rewarded. The values of forwarding probabilities are experimentally found after several tests.

3. Subsequent RREQs are handled at nodes by ascertaining the residual energy concerning the neighbourhood and the network energy. On receiving subsequent RREQ, a forwarding node is made eligible based on average network energy, 1-hop average neighbourhood energy, and individual node energy. This maintains an energy balance in the network without losing connectivity in the scarce region and wasting energy in the dense region.

The work suggested in this paper make use of the probabilistic broadcast method on the reception of the first RREQ packet and energy ratios on the reception of subsequent RREQ packet to disseminate the flooding due to RREQ packets in the case of AODV routing. AODV has been used due to its popularity, and widespread use, being widely investigated and analyzed. Subsequent sections deal with related work to mitigate the flooding effect of AODV, the analytical approach of the work proposed, and the analysis part with experimental results are described in the last section with a conclusion. As compared to traditional AODV, the experimental evaluation reveals that the proposed RFBRD method reduces the overall routing overhead and improves other performance metrics.

The rest of the paper is organized as follows. Section 2 presents related work on some route discovery techniques. Section 3 provides a brief overview of AODV and presents the proposed probabilistic route discovery methods for two different RREQ packets. Section 4 conducts a performance evaluation of the proposed method. Finally, Section 5 concludes this study and outlines some directions for future research work.

2. RELATED WORK

Earlier work concentrated on probabilistic schemes and did not take into account the global topological information of the network while making rebroadcast decisions. Also, the rebroadcast of RREQ packets is based on forwarding probability with a predetermined constant value. The recent work by [23-26] focussed on probabilistic approaches for MANETs to mitigate the effect of normal flooding during route discovery. An expanding ring search mechanism was incorporated in [27] to search large regions around the source node using consecutive flooding. They used time to leave (TTL) for successive attempts with increasing values of TTL ranging from value 1. The drawback of the scheme is increased latency and overhead routing and failed when the destination was far from the source node. Therefore, the value of TTL was settled as a compromise at TTL=3. Remembering past route histories and following only the same in the future was the concept of work developed by [28]. The protocol maintains lists of nodes engaged on a past valid route between source and destination and makes use of the same nodes to propagate the query on a privileged basis. On the other hand, it also uses the neighbourhood of nodes on past routes when required to send the RREQ toward the destination. But in a highly dynamic network, the route histories remain only histories since they become stale. A zone routing scheme balances the effect of proactive and reactive routing towards maintaining routing tables with route discovery floods and maintaining trade-offs between them [29]. The ZRP considers intra and inter-zone routing using proactive and reactive schemes respectively by considering a zone around each sensor consisting of n-hops neighbors. A mechanism called Bordercasting is used where RREQs are propagated by multicasting them directly (inter-zone) to the peripherals of the zone to reduce overhead [30]. The virtual backbones constructed and maintained [31-32] must guarantee total coverage and form the primary application of cluster-based sets and or connected dominating sets (CDS) in which the backbones are only allowed to process the RREQs [31]. The node in the set or the cluster head is privileged to forward the RREQ [17-18] but the problem lies in establishing and maintaining the proper size of the clusters. Large overheads and poor connectivity are the issues with large CDS and small CDS respectively and possess critical issues to determining minimum CDS for a particular network topology.

The forwarding probability based on the number of duplicate RREQs received by any node was coined by [33]. The features of CDS-based broadcast and probabilistic route search were used in [34]. The combined functionality of the probabilistic approach and region coverage by the broadcast signal using GPS or signal strength at the receiver was adopted [35]. A Gossip-based route discovery scheme was introduced by [36] where the probabilistic methods using 2-threshold schemes were optimized. The strategy of determining the rebroadcasting of RREQ for a particular node relies on its predecessor which forms the demerit of the scheme since the predecessor is unaware of its local topological characteristics. Authors in [37] suggested adaptive location-aided routing (ALAR) and take into consideration the varying topology and node density. The method finds a request zone (optimal network portion) and allows a few nodes to rebroadcast RREQs based on GPS location and communication range. Authors of [38] allowed nodes in specific areas to rebroadcast based on location information and their neighbourhood. The nodes were selected based on their broadcasting probabilities which were indirect functions of the coordinates of the mobile nodes. Work adopted in [39] used a simple concept and allowed nodes to rebroadcast RREQs based on their remaining power.

A rebroadcast routing scheme offering a good delivery ratio, low energy consumption, and overhead is suggested in [40]. It suffered from computational complexity concerning its rebroadcasting probabilities which included noise ratio, routing load, and energy. A machine learning and trust-based AODV routing scheme is presented in [41]. Unnecessary flooding is mitigated through trust estimation to avoid transmission of RREQs to non-existent destinations. They considered hop count, link expiration time, and residual energy for estimating trust. The nodes with higher trust values are chosen for forwarding the RREQs. A similar approach has been suggested in [42]. The S-AODV routing scheme considers hop count and network lifetime to measure the value of trust value to mitigate the flooding effect by preventing transmissions to non-existent destinations.

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AODVI, An optimized and energy-efficient routing protocol that uses dynamic forwarding probabilities is suggested in [43]. The RREQ forwarding by an intermediate node is decided on the fact whether the intermediate node has sufficient neighbors to forward. If the node has neighbors greater than the minimum neighbour's requirement, the RREQ is forwarded, otherwise, the forwarding is limited based on forwarding probability. A random number is generated and the RREQ is forwarded when the random number falls below the minimum requirement. The author used a predefined factor for the minimum neighbour requirement and a controlling factor of C=0.65. A node with higher reliability is selected to forward the RREQ packets in the network during the route discovery. The reliability is governed by the residual energy of the node, stability, and delay. The fuzzy logic-assisted routing scheme known as FL-AODV was used to improve the reliability of paths in the MANET. The scheme offered higher reliability, better link connectivity, and longer path life under high node speed. However, the routing scheme was not suitable for low-density networks below 70 nodes [44].

The techniques discussed above suffer from broadcasting of unnecessary control packets, poor reduction redundancy, complexity towards computing rebroadcast probability, delay due to signal-to-noise ratio, energy, and routing load on the other hand provide good packet reachability, delivery ratio, energy, and power consumption. The proposed RFBRD uses probabilistic broadcasting which is found through experimentation and neighborhood-to-network energy ratios are good in terms of packet delivery ratio, routing overhead, throughput, residual energy, and end-to-end delay.

3. MATERIALS AND METHODS

The Ad Hoc On-Demand Vector (AODV) routing scheme uses a simple approach of flooding Route Request (RREQ) packets over the network from the source node into the network to find an appropriate route to the destination node. The intermediate nodes on receiving the first time RREQ just forward the packets to their in-range neighbors. If the 'M' number of nodes in the network is assumed, the possible broadcast using AODV is (*M-2*) where '*-2*' corresponds to the source and the destination. In a randomly distributed network, various regions of varying node densities are formed and therefore the forwarding probabilities associated with each of the forwarding nodes should be properly accounted for and assigned. To manage this, the node densities are evaluated at each node in the network considering its neighbourhood in the transmission range. The neighbourhood information is obtained using the '*HELLO*' packets at the one-step or 1-hop level. That is, a node, its neighbourhood, and its neighbourhood are considered for finding the node densities in the network. Initially, the average network density considering every individual node density in the network was found out. Further, the minimum average and the maximum average densities are evaluated from the nodes having densities less and greater than the average network density value respectively. This provides global information regarding the current network structure. Figure 1 below shows how the average density of the network is calculated and equation (1) expresses the value (*nAD*). Figure 1 is just to give an illustration and neighbors of all nodes are not considered due to complexity and clearness.

$$nAD = \frac{1}{M}\left[\sum_{x=1}^{M}\left\{\sum_{y=1}^{Ngb}\left[N_{xy}\right]\right\}\right] \quad (1)$$

Where $\sum_{y=1}^{Ngb}\left[N_{xy}\right]$ is the number of nodes in the neighbourhood of node N_x *and* N_{gb} represents the number of nodes in the transmission range of node N_x. Here, $M=100$.

Expression (2) calculates the average of those node densities which have densities lower than the average density of the network and expression (3) is the average of those node densities which have densities higher than the average density of the network.

$$min\_nAD = \frac{1}{P}\left[\sum_{x1=1}^{P}\frac{1}{min_{Ngb}}\left\{\sum_{y1=1}^{min_{Ngb}}\left[N_{x1,y1}\right]\right\}\right] \quad (2)$$

$$max\_nAD = \frac{1}{Q}\left[\sum_{x2=1}^{Q}\frac{1}{max_{Ngb}}\left\{\sum_{y2=1}^{max_{Ngb}}\left[N_{x2,y2}\right]\right\}\right] \quad (3)$$

Note that $(x1, x2) < x$ and $(y1, y2) < y$ and P, Q represents node regions having densities below and above/equal average network density.

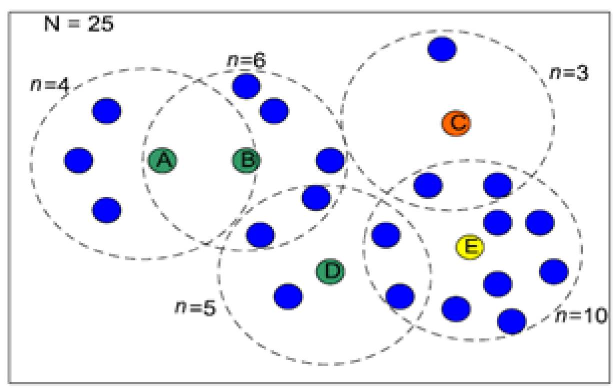

Figure 1 Network with Node Densities Showing Scarcely and Densely Populated Regions [24]

Consider the above network of 25 nodes and the encirclement around any node, node A has 4 neighbors, B has 6, C has 3, D has 5 and E has 10 neighbors respectively. Therefore, the average network density is (4+6+3+5+10)/5 = 6 (rounded). The nodes having densities less than the average density of the network are A, C, and D whereas the nodes having densities higher or equal to the average density are B and E.

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Therefore, the minimum average density is (4+3+5)/3 = 4 and the maximum average density is (6+10)/2 = 8. Considering the node that receives the RREQ, the three parameters in its neighborhood were evaluated at the 1-hop level. Consider node B receiving the RREQ packet in Figure 1, covering 6 neighbors, the neighborhood of all 6 neighbors is considered, and average density, minimum density, and maximum density are calculated using the same expressions (1-3). The only difference in evaluating is that the region is confined to only receiver node B at the 1-hop level. Using similar expressions, all the three parameters can be given by expressions (4), (5) and (6):

$$AD = \frac{1}{m}\left[\sum_{i=1}^{m}\frac{1}{Nb}\left\{\sum_{j=1}^{Nb}[N_{ij}]\right\}\right] \quad (4)$$

$$min\_AD = \frac{1}{p}\left[\sum_{i1=1}^{p}\frac{1}{min_{Nb}}\left\{\sum_{j1=1}^{min_{Nb}}[N_{i1,j1}]\right\}\right] \quad (5)$$

$$max\_AD = \frac{1}{q}\left[\sum_{i2=1}^{q}\frac{1}{max_{Nb}}\left\{\sum_{j2=1}^{max_{Nb}}[N_{i2,j2}]\right\}\right] \quad (6)$$

Where $\sum_{j=1}^{Nb}[N_{ij}]$ is the number of nodes in the neighborhood of node B and N_b represents the number of nodes in the transmission range of node N_i. Note that $(i1, i2) < i$ and $(j1, j2) < j$ and p, q represent node regions having densities below and above/equal average density in the neighborhood of say node B here. Lastly, the current node (here node B) density is calculated using its immediate neighborhood given in equation (7) as

$$N_{curr} = \sum_{k=1}^{nb}[N_k] \quad (7)$$

Where nb is the number of neighbor nodes of the current node under consideration and N represents any individual node in the neighborhood. The current node N is classified into one of the four regions depending on the following criteria. The colonies are separated according to the node densities as shown in figure 2.

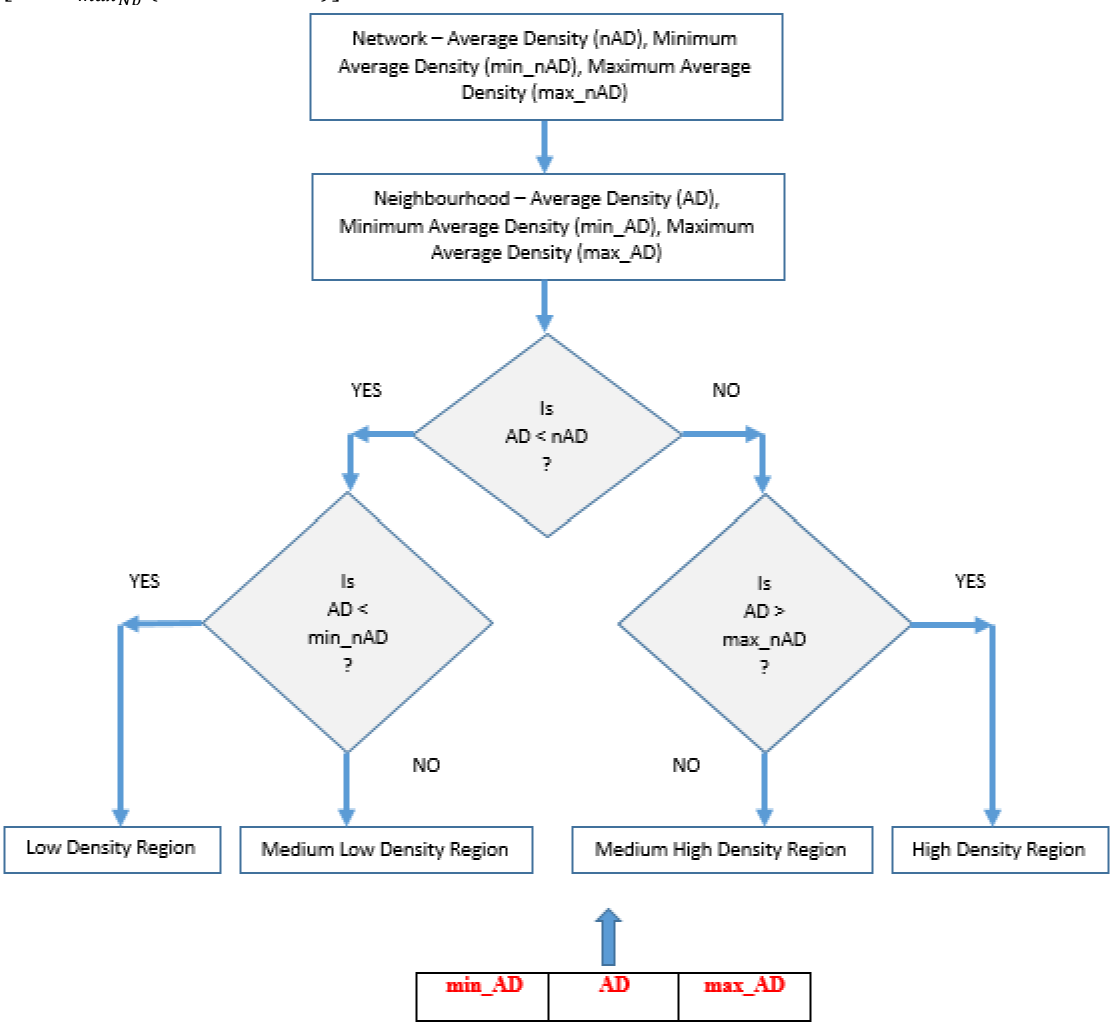

Figure 2 Classifying a Node Based on Network Average, Minimum Average Maximum Average, and Neighbourhood Average Density

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Table 1 Forwarding Probabilities and Regions

Regions	Node Density - D	Region No.	RREQ Forwarding probability T
	Above LDR	1	1
Low-Density Region- LDR			
	Below LDR	2	0.8
	Above MLDR		
Medium Low-Density Region- MLDR			
	Below MLDR	3	0.6
	Above MHDR		
Medium High-Density Region-MHDR			
	Below MHDR	4	0.4
	Above HDR		
High Density region-HDR			
	Below HDR	5	0.2

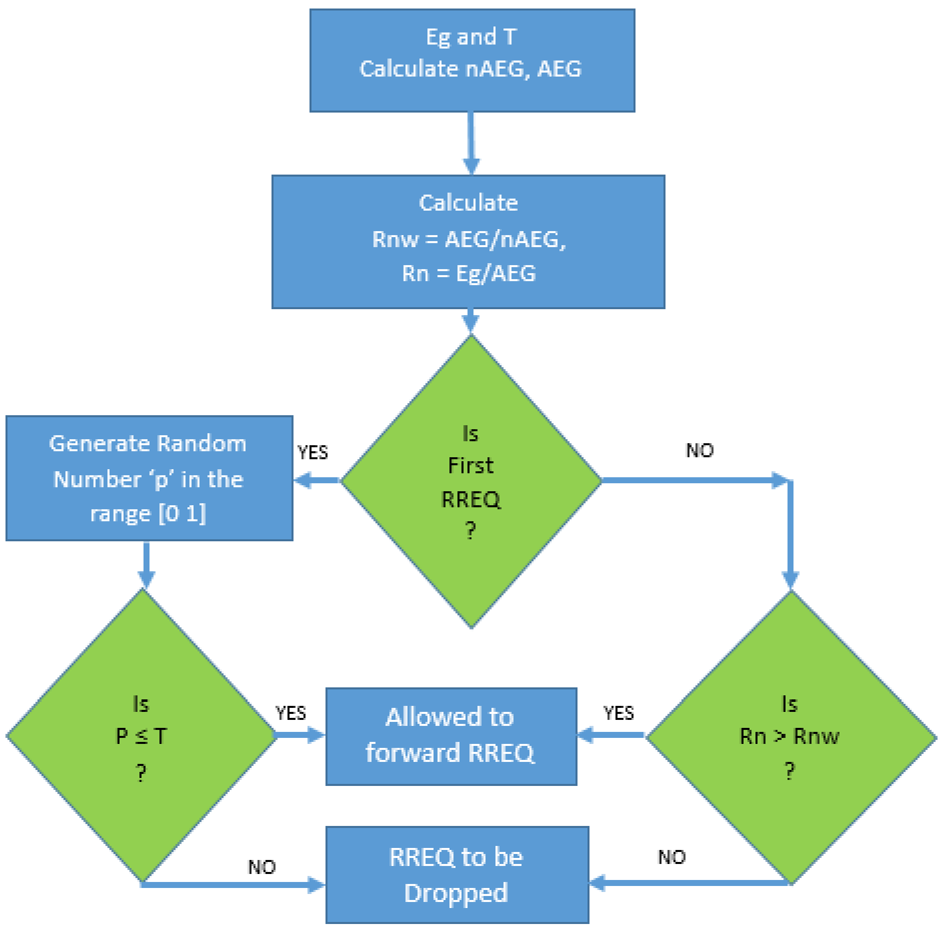

Figure 3 Decision Based on T and Energy Components in the Network

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The whole region was partitioned into 16 distinguished parts but analysis showed that three sub-partitions based on *min_AD, AD, and max_AD* concerning node density N_{curr} do not show significant performance over the metrics evaluated. Therefore, the final regions were restricted to five sub-regions after dissolving 8 regions as depicted in Table 1, and assigned the forwarding probabilities from a value of 0.4 to 1 from the densely populated region (High-Density Region) to the scarcely populated region (Low-Density Region). The forwarding probabilities assigned are depicted in Table 1. The same forwarding probabilities have been assigned and merged regions 2 & 3, 4 & 5, 6 & 7 since they represent the nearer node densities.

The objective of assigning a higher probability to the Low-Density Region is to ensure better coverage and connectivity and a lower probability to the High-Density Region for saving energy and mitigating flooding. The forwarding probabilities are set after experimental analysis and it is observed that these values outperform others in terms of performance parameters. The above scheme is applied when a node receives the first RREQ. To improve the performance of the proposed system, another criterion was introduced to improve the lifetime conserving energy by restricting nodes to forward RREQ when subsequent RREQs are received. The average energy of the network *nAEG*, neighbourhood energy *AEG*, and the node energy *Eg* were calculated. Further, two ratios as given by the following equations (11) and (12) using (8), (9), and (10) were found. The decisions to forward RREQ by a receptor node are indicated in Figure 3.

$$\text{nAEG} = \frac{1}{M}\sum_{k=1}^{M}[E_k] \tag{8}$$

$$\text{AEG} = \frac{1}{m}\left[\sum_{i=1}^{m}\frac{1}{Nb}\left\{\sum_{j=1}^{Nb}[E_{ij}]\right\}\right] \tag{9}$$

$$\text{Eg} = E_k \tag{10}$$

$$\text{Rnw} = \frac{AEG}{nAEG} \tag{11}$$

$$\text{Rn} = \frac{Eg}{AEG} \tag{12}$$

Where E_k is the node energy.

At subsequent reception of RREQ by a node, the node is allowed to forward the RREQ packet when the following conditions as given in equation (13) and (14) are met, otherwise, the RREQ packet is dropped at the node.

$$Node\ status = \begin{cases} forwardRREQ, & Rn > Rnw \\ dropRREQ, & Rn \leq Rnw \end{cases} \tag{13}$$

And at first RREQ,

p = Generate Random Number in the range [0 1].

$$Node\ status = \begin{cases} forwardRREQ, & p \leq T \\ dropRREQ, & p > T \end{cases} \tag{14}$$

The implementation used NS-2.35 Simulator cloned the AODV protocol and made the changes in the "receiveRequest" function of the AODV protocol as depicted in Figure 2 and Figure 3. Also, the packet structure has been changed as per requirement. The "HELLO" packets were made active to access the geographical locations of the nodes. The system was implemented with an i5 processor, 2.70 GHz, 6 core processor, 16 GB RAM, 512 GB SSD on Ubuntu 22.04 environment. The algorithm for the proposed system based on the probabilistic broadcast and energy ratio method is shown in Algorithm 1.

Input – RREQ Packet at the "receiveRequest" function

Output – RREQ forwarded or RREQ dropped

Calculate: nAD, min_nAD, and max_nAD for the network and the neighbourhood of the receiving node

T - Identify the Regions and Assign the probabilities as depicted in Table 1

Calculate nAEG, AEG, Rn and Rnw

If first RREQ

Generate random number P : P in the range [0 1]

If P is less than equal to T

RREQ forwarded: RREQ Received by a node in Scarce Region

Else

RREQ Dropped: RREQ Received by a node in the Dense Region

Else: Subsequent RREQ

If Rn is greater than Rnw

RREQ forwarded: Node has Sufficient energy

Else

RREQ Dropped: Node energy less than the average energy of the neighbourhood/network

Algorithm 1 Probabilistic Broadcast and Energy Ratio Based RFBRD Routing Scheme for AODV

4. RESULTS AND DISCUSSION

The method of zone-based selective neighbors (ZBSN) proposed in [22] deals with mitigating the flooding effect while maintaining the trade-off between the quality of service (QoS) parameters successfully in an AODV-based environment. It performed superior at node speed below 25 m/s but failed to maintain QoS parameters when the node speed was increased beyond 25 m/s. Also, the work includes concentrating on adjusting the probabilistic route discovery mechanism proposed by [43] to the environment where 100

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nodes are randomly moving with speeds ranging from 5-45 m/s, the performance does not show any improvement for the 3-P scheme over AODV. Therefore, the work worked out their 3-P scheme and analyzed the network with different adjustable parameters such as density thresholds and node energies concerning average network energies at any instant for the first time and subsequent RREQ packets received by any node when the RREQ is flooded in the network.

Several experiments were carried and the parameters were adjusted to optimize the performance of the network at various node speeds. The main drawback of the system proposed was the random number ‘*p*’ generated as a threshold to check against the value of factor ‘*T*’ belonging to the node density region it acquires on comparing with the overall network density at network and neighbourhood level. Since the generated random number is not certain, it may allow RREQ packets to get forwarded when it is not required and disallow them when they are potentially needed to find the path. The balancing challenges between different QoS parameters have been studied in detail in [45]. The regions were weighted in descending order from low-density regions to high-density regions by assigning the RREQ forwarding factor to nodes so that nodes will have high chances of allowing RREQ packets in low-density regions to discover paths and minimum chances to forward in high-density regions so that the flooding effect in high-density regions is mitigated and saves ample amount of energy while maintaining other QoS metrics. The forwarding of RREQs at nodes for subsequent RREQ packet reception was restricted using the energy criteria.

Table 2 Simulation Parameters

Simulation parameters	Value
Simulation time	100s
Dimension of Network Area	1641 m x 897 m
Number of Nodes	100
Transmission Range	250 m
Data Rate	2.0 Mbps
MAC Protocol	802.11
Traffic type	TCP
Packet size	1500 Bits
Routing Protocol	AODV, RFBRD
Initial Energy of Node	1000J
Velocity of nodes	[5 – 45 m/s]
Movement	Random displacement in Range [-50 50]
Queue Length	50

The simulation parameters initialized for the 100-node mobile network are listed in Table 2 below. Random positions were pre-generated for the nodes during a time interval of 5-95 seconds and maintained in a separate file which was then used for both routing schemes. For each simulation, a node was allowed to move to the same new position (stored in a file) but at a different velocity, and data was transmitted from node 21 to node 99. The model was evaluated in terms of Packet Delivery Ratio (PDR), Network overhead (RO), Throughput (TP), Average end-to-end delay (AE2E), number of packets delivered and received, and Residual Energy.

Figure 4 shows the comparison of the PDR of the proposed RFBRD with AODV. At node lower speed of up to 20 m/s, the proposed RFBRD performs inferior as compared to AODV. At higher node speeds beyond 20 m/s, the RFBRD outperforms AODV. The black color horizontal line and the green line show the average of PDR values considering values at all node speeds from 5-45 m/s for RFBRD and AODV respectively. The average PDR values from Figure 9 are 98.06 and 98.04 respectively for RFBRD and AODV.

The value of the region probabilities (T) is set by maintaining a balance between the packet delivery ratio and the throughput of the network. There is a trade-off between both these parameters. For better connectivity in the scarce region, the value of T is kept high so that when the random number (P) is generated, the condition on the left side of Figure 3 is always satisfied and the RREQ is forwarded. This ensures the possibility of a route in the scarce region. Whereas, the value of (T) in the dense region is kept low (0.2) ensuring a very low possibility of RREQ being transmitted by a node in this region. The transmission of RREQ in the dense region is a function of parameter P. A node in the dense region is allowed to forward an RREQ if the generated random number P falls below the value of T, which is very low (0.2). The values of T for all five regions are experimentally found to ensure and validate the former criteria. The value of T can be changed for improved PDR, but it will affect the throughput.

Figure 5 shows a significant difference between AODV and the RFBRD routing scheme in terms of network overheads due to routing and shows that the RFBRD underburdens the network. The restricted flooding controls excessive RREQ packets into the network and saves significant energy for the nodes. The average values for AODV and RFBRD from Figure 9 are 11510 and 10538 packets respectively. RFBRD reduces the routing overhead by 8.44% obtained using equation (15) which is comparatively less than the work suggested in [22] but it balances the parameters by outperforming at higher node speed compared to ZBSN.

$$\text{Overhead Reduction} = 1 - \frac{\sum \text{Network Overhead at different node speed(RFBRD)}}{\sum \text{Network Overhead at different node speed(AODV)}} \times 100 = 8.44\% \quad (15)$$

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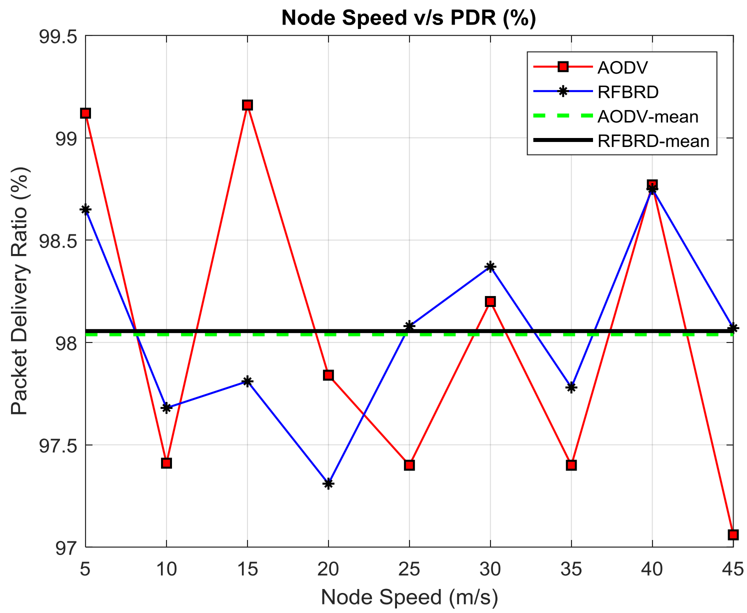

Figure 4 Speed v/s PDR

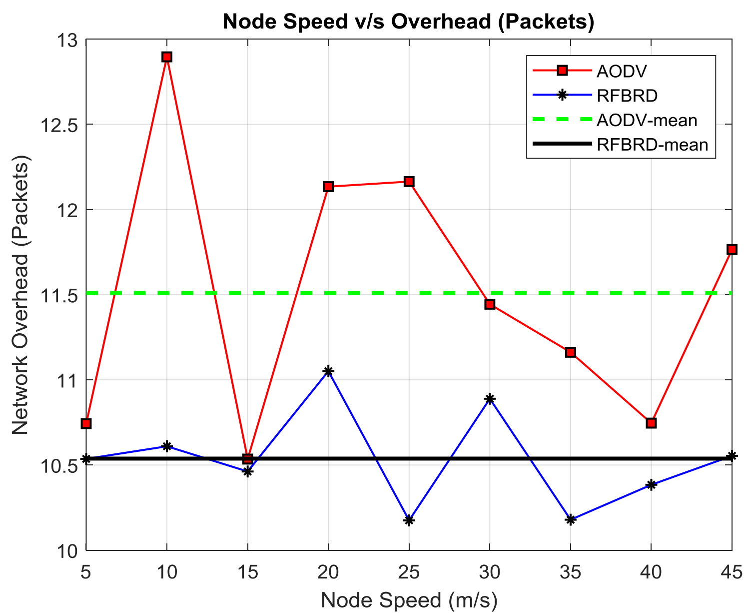

Figure 5 Speed v/s Overhead

A low overhead implies more energy saving and improved network lifetime. As seen from Figure 9, a reduction of 8.44% in the routing overhead saved (3274-3250) = 24 J of energy in the network. This is due to the restriction imposed to forward RREQ on the nodes situated in the dense region. It also reduces congestion in the crowded region caused due to the control packets. As seen clearly from Figure 9, the overall throughput (1.02) is maintained by RFBRD. The problem with ZBSN was drastic low throughput at higher node speed. RFBRD can maintain the throughput above AODV after 15 m/s as shown in figure 6. If the value of forwarding probabilities is changed, it is possible to achieve higher throughput even at low node speed above AODV, but it will dominate other performance parameters like PDR.

Even though the throughput at low node speeds is lower concerning AODV, the average throughput overall node speeds are the same as AODV. The objective of the proposed

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work is to conserve the energy of the nodes by mitigating flooding storms during the route-finding phase in turn reducing the congestion and improving connectivity.

Figure 7 shows the residual energy at different node speeds in the network. The overall energy saved with RFBRD against AODV is given by the following expression (16). The average packet drop for AODV is 38 packets and 39 packets for RFBRD from Figure 9. AODV on average was able to deliver 13 packets more than RFBRD. The energy saved by the network with RFBRD was approximately 24 Joules.

Overall Energy Saved =

$$\sum \Re E \text{ at different node speed (RBFRD)} - \sum \Re E \text{ at different node speed (AODV)} = 24\text{ J} \quad (16)$$

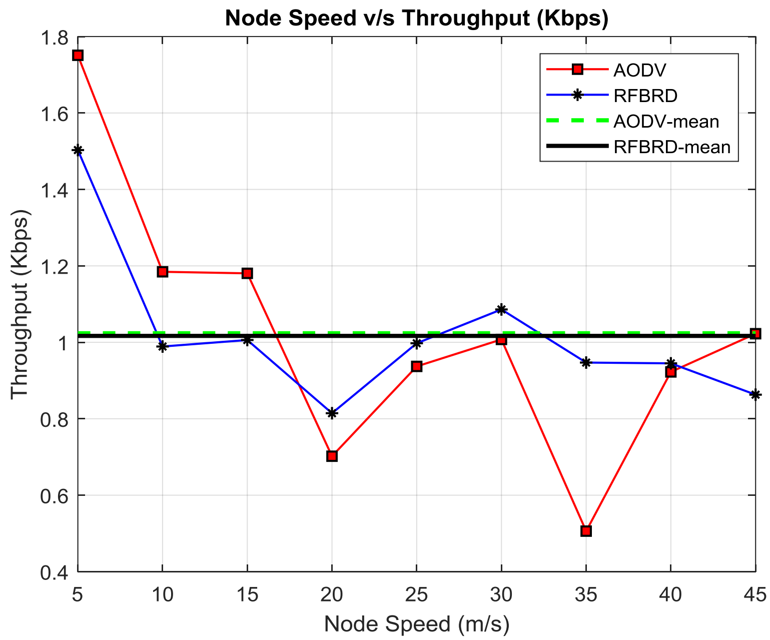

Figure 6 Speed v/s Throughput

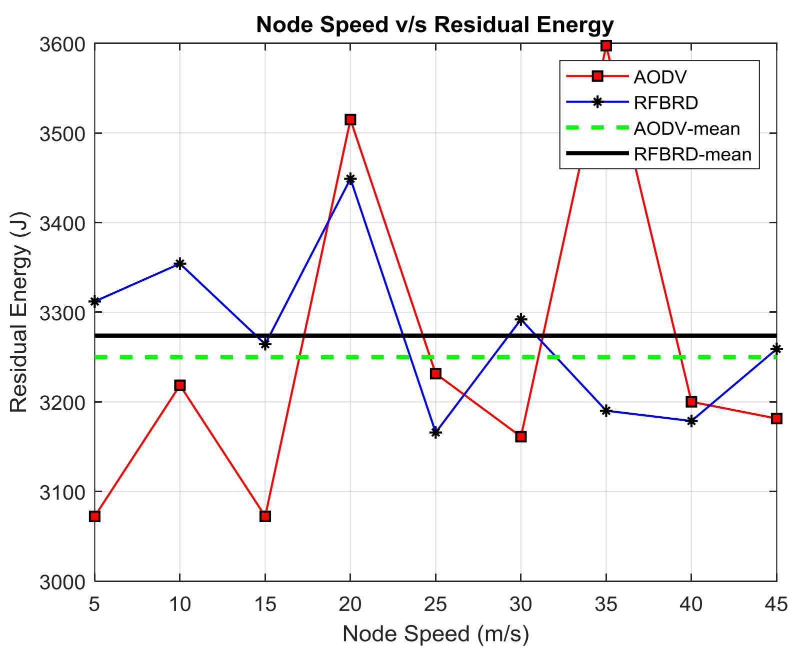

Figure 7 Speed v/s Residual Energy

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The proposed system is to mitigate flooding and concentrate on conserving the energy of the nodes. The simulation considered only 100 nodes and nodes moving with a velocity of 5 to 45 m/s. Better performance can be obtained by increasing the number of nodes in the network. The proposed system was evaluated up to 500 nodes with the same network parameters. It was seen that the average energy saved was approximately 98 Joules.

Figure 8 shows the average end-to-end delay for both the routing schemes where except at 25 m/s node speed RFBRD outperforms AODV. The average values of end-to-end delay over all node speeds are 0.34 and 0.29 seconds. The improvement is due to reduced congestion in the network concerning the flow of the control packets. The network responds differently in finding a route from the source to the destination as compared to conventional AODV routing with the proposed RFBRD routing. This is due to restrictions on the nodes situated in the dense region to forward the RREQ even though they are free to forward in case of the AODV routing. It increases the reliability of the path selected at the cost of hop counts.

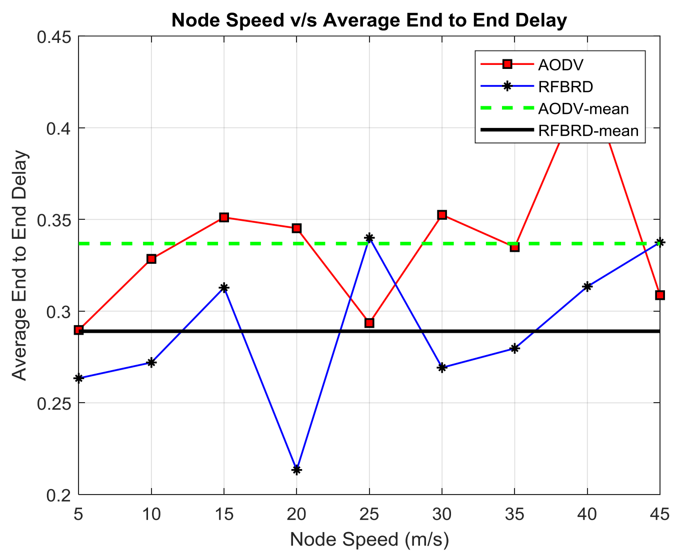

Figure 8 Speed v/s Average End-to-End Delay

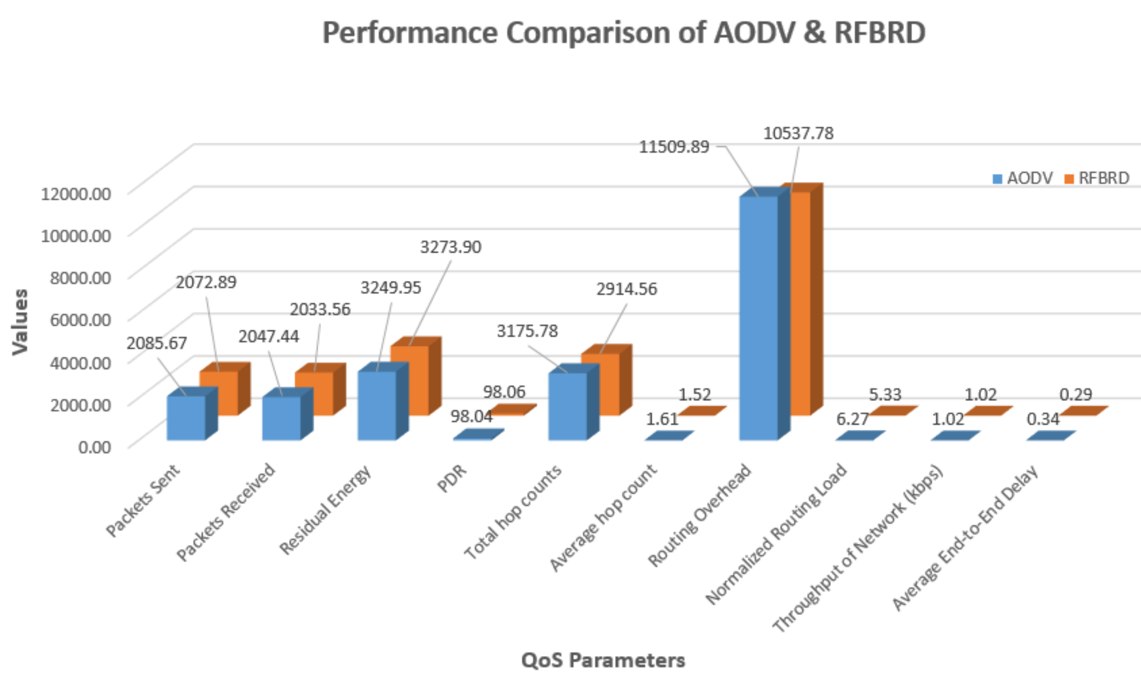

Figure 9 Comparison of Various QoS Metrics (Averaged Over all Node Speed) of AODV & RFBRD

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Analysis showed that AODV has control over PDR and throughput at lower speed especially up to 15 m/s and 20 m/s respectively whereas in all other cases, the RFBRD outperforms AODV. The idea behind suggesting RFBRD is to maintain QoS parameters to an acceptable level and not maximize all of them which is practicably difficult since the parameters are dependent on each other [45].

Good results were obtained in terms of residual energy, hop counts, routing overhead, and average end-to-end delay while comparable metrics such as packet dropped, PDR, and throughput. The future work is focussed on combining the properties of ZBSN and RFBRD routing schemes to achieve better results owing to the ability of ZBSN to perform at low speed and the ability of RFBRD to perform at higher node speed.

5. CONCLUSION

In this paper, the performance of the RFBRD Routing scheme is investigated related to AODV where the network is partitioned into various regions based on the node densities and assigning forwarding probabilities to nodes receiving RREQ packets during route discovery. The work considered the reception of RREQs in two phases (first & subsequent) and controlled the forwarding of RREQ based on node density and residual energy of the forwarding node. The blind flooding mechanism in AODV is compared with the proposed Probabilistic Broadcast and Energy Ratio-based routing scheme. Experimental analysis showed that the proposed scheme is superior in balancing the quality of service parameters as compared to AODV.

The average PDR for RFBRD was found to be 98.06 concerning 98.04 for AODV. RFBRD was able to reduce the routing overhead by 8.44% thus saving 24 Joules over AODV. The throughput was maintained while reducing the end-to-end delay by 0.05 and average hop count by 0.09. The drawbacks of ZBSN routing [23] and the 3-P scheme [21] were eliminated. The computation of values of forwarding probabilities is not mentioned in [21] and the subsequent RREQ packet is allowed to forward.

A single network was considered with 100 mobile nodes at speeds ranging from 5-45 m/s with priory found new geographical locations for the nodes and evaluated the performance. Also, the properties of the ZBSN scheme at lower speed have not been used with RFBRD while extending and fine-tuning the 3-P scheme. The future work will be concentrated on the amalgamation of both schemes, where the low-speed characteristics of ZBSN and high-speed features of the 3-P scheme can be effectively used to outperform AODV to a greater extent. Other networks with varying node densities can be considered. The values of forwarding probabilities can be adaptively found using available network parameters. The fixed values of forwarding probabilities limit the performance even though they are properly tuned.

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