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Adaptive Broadcast Routing Protocol using Fuzzy Logic System for MANET

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Abstract : In Mobile Ad Hoc Network (MANET), forwarding probability should consider neighbour density, link quality and residual energy of the forwarding nodes. Also, redundant broadcasting by checking the inter-arrival times should be considered. In this paper, we propose to design a adaptive broadcast routing protocol using Fuzzy logic system. In this protocol, a set of forwarding nodes are selected based on the residual energy, coverage probability and channel condition. The rebroadcasting or forwarding probability is adaptively adjusted based on the 1-hop neighbour density and relative mobility of neighbours using the fuzzy logic system. Then the selected forwarding nodes forward the route request packets with the probability given by forwarding probability. Before forwarding the packets, the number of redundant packets exceeding a threshold value, are removed by checking successful status of delivered packets. By simulation results, we show that ABRP minimizes the delay and forwarding ratio by increasing the packet delivery ratio and average residual energy.

Keywords: MANET, self-organizing, Fuzzy, Routing, Adaptive, protocol

I. INTRODUCTION

Basically, MANET is a self-organizing network made up of numerous nodes which are capable of high mobility and are connected to one another in a wireless manner. In MANET, each mobile node is capable of functioning as a router. MANET is used for various types of applications, such as communication between moving vehicles, sensor networks, military communication, disaster recovery, emergency search and rescue operations, policing, firefighting and so on [1]. Due to the constant movement of the nodes, the MANET topology is dynamic in nature. The mobile nature of nodes, limited bandwidth, high error rates, limited battery power and continuously changing topology brings out new complexities while designing the routing protocols for this kind of network [2].

The resource constraint devices and dynamic topology are the unique characteristics in MANET that becomes major problem towards the efficient routing protocol design [3].

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In MANET, network wide broadcasting is an elementary manoeuvre in which a source disseminates topology information throughout the network [3]. The simple model of broadcasting is blind flooding where each node forwards the packet exactly once. But it leads to the broadcast storm problem and increased message redundancy, thereby wasting the channel bandwidth and energy [6].

Numerous enhanced sorts of flooding have been established which are characterized into two major classes: static and adaptive broadcasting systems.

Static broadcasting systems are chiefly associated with certain onset principles or the network topology while in dynamic broadcasting, it is challenging to define these onset principles and to maintain network topology information [7].

The forwarding node selection has been an important process in many broadcasting algorithms. All these algorithms have considered the service quality as a factor for selecting the node. But these algorithms do not reflect the existing dynamism of a node as a factor. Choice of a node with little dynamism degree decreases the steadiness of the message route since that node may exhaust from the dynamism bringing about the collapse of the message network [8].

1.1 Problem Identification and Objectives

In [1], the rebroadcasting probability (Rb) is dynamically varied based on the node density and Signal to Interference plus Noise Ratio (SINR) of the nodes. But it did not consider the energy level of the forwarding nodes. Moreover it assumes that nodes are uniformly distributed over the network, which may not be true in all scenarios.

In [2][5], the forwarding probability is determined based on the neighbour density of 2-hop nodes. But it didn't consider the link quality and residual energy of those forwarding nodes.

In [6], the channel states and coverage ratio of nodes are taken into consideration for the forwarding probability. However it requires the previous history information of broadcasting which leads huge storage overhead.

The approach used in [7] avoids redundant broadcasting by checking the inter-arrival times. But it did not present any standard technique to perform rebrodcasting.

Though [8] uses the energy-distance product to select the intermediate nodes, it did not consider the coverage and channel quality conditions.

From the above identified problems, the objectives of the research work can be formulated as follows:

- Adaptively adjust the rebroadcasting probability based on the local density of nodes
- Select the forwarding nodes based on coverage, SINR and residual energy

○ Reduce the redundant broadcasting

The paper is organized as follows. Section 2 presents the related works done. Section 3 presents the proposed methodology of ABRP. Section 4 presents the experimental results and discussion. Section 5 presents the conclusion of the work.

II. RELATED WORKS

Marimuthu Murugesan et al [3], using curtailed onward node list procedure, have proposed a dependable and effictive dissemination procedure that utilizes 2-hop vicinity data more efficiently in order to lessen unnecessary broadcasts in asymmetric MANET. Only nominated promoting nodes recommunicate the transmission note amongst the 1-hop neighbours of the source. Promoting nodes are nominated in order to protect the unprotected 2-hop vicinities.

Bai Yuan et al [9] have proposed a LAPB procedure which profits benefit of altering the possibility of node based on the thickness. It also selects certain effective transitional nodes to determine path. LAPB enhances the execution whether the nodes are in high-density or low-density zones. The upcoming effort will examine the rapidity data of node and diverse node flexibility replicas.

Cheng Zhan et al [10] have proposed a programming procedure depending on the extreme mass group in the chart. In depth investigation revealed that certain classic claim necessities can be recognised with dissimilar mass purposes that are beneficial for Quality of Service (QoS) strategy. An efficient experiential procedure is suggested in their paper in order to mark shades on the summits of the biased chart to demonstrate the desired packages that can be deciphered by means of the shielded prearranged packages.

Sindhu et al [11] have proposed two efficient algorithms: Sender Based and received based broadcasting algorithms. In both these algorithms, the rebroadcastig probability is adjusted based on the neighbour density. The forwarding nodes are selected based on coverage. But they didn't consider the link quality and residual energy of those forwarding nodes.

Haitham Y. Adarbah et al [12] have presented CAPB (Channel Adaptive Probabilistic Broadcasting) protocol to perform re-broadcasting of RREQ packets in a probabilistic manner. The algorithm considers the neighbor density and SINR to adjust rebroadcast-probability dynamically. But it did not consider the energy level of nodes and coverge conditions.

Madhusudhana Reddy et al [13] have proposed an energy-efficient protocols in broadcasting scenarios and compare a suitable protocol with three other broadcast protocols in Wireless network. They adopted the multipoint relay selection strategy based on residual energy in the EOLSR protocol and use it in the broadcasting scenarios. This EMPR selection strategy takes into account the energy dissipated in transmission and reception up to 1-hop from the transmitter and was verified to prolong the network lifetime and increase the packet delivery rate when combined with the proposed unicast routing strategy. The select repeat sequence approach helps in faster distributing and merging the media file packets at both source and destination ends.

III. ADAPTIVE BROADCAST ROUTING PROTOCOL (ABRP) USING FUZZY LOGIC SYSTEM

3.1 Overview

In this paper, we propose to design an ABRP for stable and energy efficient routing. In this protocol, a set of forwarding nodes are selected based on the residual energy, coverage probability and channel condition or state. The rebroadcasting or forwarding probability is adaptively adjusted based on the 1-hop neighbour density and relative mobility of neighbours using the fuzzy logic technique. Then the selected forwarding nodes forward the route request packets with the probability given by forwarding probability. Before forwarding the packets, the number of redundant packets exceeding a threshold value, are removed by checking successful status of delivered packets. Figure 1 shows the block diagram of the proposed ABRP.

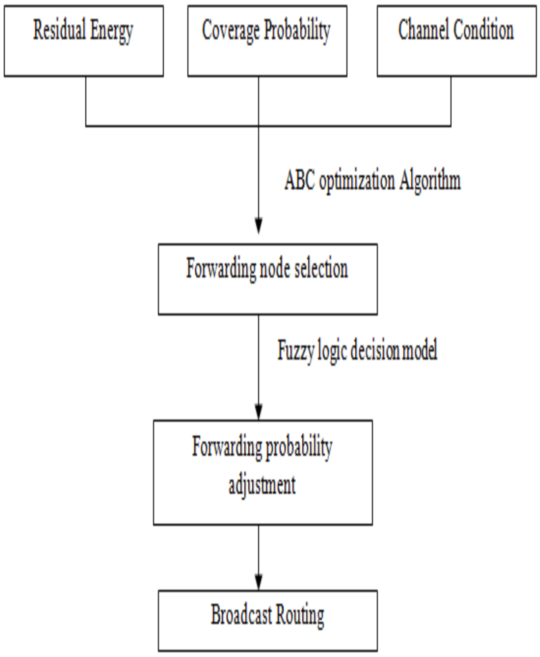

Figure 1 Block Diagram of ABRP

3.2 Estimation of Metrics

3.2.1 Residual Energy

The residual energy (E_{res})of each node following a data transmission, is estimated by means of Eq (1)

$$E_{res} = E_i - (E_{tx} + E_{rx}) \quad (1)$$

where E_i denotes the initial energy level

E_{tx} denotes energy utilized in transmitting

E_{rx} denotes energy utilized in receiving

3.2.2 Channel Condition

Depending on the signal power and signal to noise ratio (SNR) at the recipient, the channel state information (CSI) is calculated. The valuation of signal power by means of Friis equation is known by Eq. (2)

$$P_{rx} = \frac{P_{tx} * \alpha * \beta * h_{tx} * h_{rx} * \sigma^2}{(4 * \sigma * d)^2 * \tau} \quad (2)$$

Where P_{tx} -transmitted power

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α _ transmitter improvement

β _ receiver improvement

h_{tx} - transmitter altitude
h_{rx} - receiver altitude
σ _ wavelength

d - distance amongst the transmitter and receiver
τ _ system drop

Depending up on the calculation of signal power, SNR is calculated by means of Eq. (3)

$$SNR = \log_{10}(P_{tx}) - \log_{10}(P_{rx})\ dB \qquad (3)$$

3.2.3 **Coverage Probability (CP_i)**

The coverage of nodes is explained as the segment sized area in the detecting part of a node enclosed by its nearby node.

Take into consideration two nodes X and Y at an interval c. The description of Y for X, is characterised via the mid angle 2 σ where σ can be formulated as given: The Estimation of the sponsored coverage is shown in figure 3.

$$\text{Cos } \sigma = \frac{d^2 + X^2 - Y^2}{2Xd}, \therefore \arccos\left(\frac{d^2 + X^2 - Y^2}{2Xd}\right) \qquad (4)$$

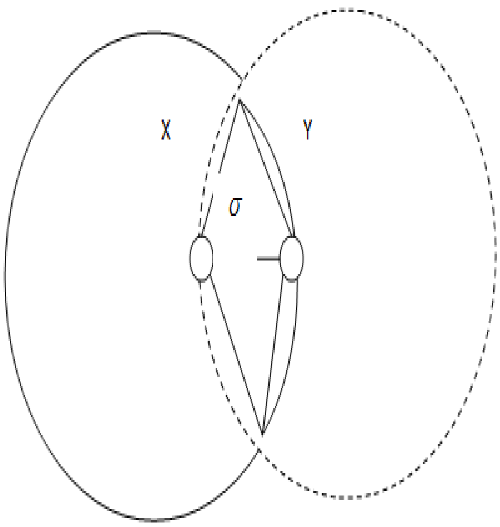

Figure 2 Estimation of the Sponsored coverage.

3.2.4 **Relative Mobility (RM)**

Based on the power level at the receiving node, the relative mobility can be estimated. It is defined as the proportion of RSS amongst two successive package broadcasts from a nearby node. Thus relative mobility $RM_j(i)$ at a node j with respect to i is calculated as follows.

$$RM_j\,(i) = 10 \log_{10} \frac{RSS_{i \to j}^{new}}{RSS_{i \to j}^{old}} \qquad (5)$$

3.2.5 **Node Density (ND_i)**

The nde density of N_i is expected by means of the node degree. It signifies the sum of nodes associated to it.

$$ND_i = CNT\,(N_j)\ |\ D_{i,j}) < R_{tx};\ i \in N_i \text{ and } j \in N_j \qquad (6)$$

Where $D_{i,j}$ = distance among N_i and N_j
R_{tx} = node's transmission range
CNT = node count

3.3 Forwarding Node Selection

Let Z be the solutions

1. For each candidate neighbour node N_j
2. If E_{res} = Maximum and SNR=Maximum and CP_i = TRUE , then
   Include N_j as forwarding node set {FN}
   Else
   If E_{res} = Maximum and SNR=Maximum or CP_i = TRUE ,
   Include N_j as forwarding node set {FN}
   End if

   End if

3. End For
4. The nodes with maximum Eres, maximum SNR with coverage probability are selected as forward nodes (FN).

3.4 Fuzzy based Forwarding Probability Adjustment

The rebroadcasting or forwarding probability (FP) is adaptively adjusted based on the following metrics:

- 1-hop neighbour density (ND)
- Relative mobility of neighbours (RM)

For this Fuzzy logic decision model (FLD) is applied in which the above metrics are considered as input variables. Based on the Fuzzy rules, FP is returned as output.

3.4.1 Fuzzification

This comprises of fuzzification of input variables such as RM and ND. The exact inputs are chosen from these variables and these inputs are provided with a grade to suitable fuzzy groups. The exact inputs are a mixture of RM (say R) and ND (say D). We select three options, high, average, and low for D and R. (shown in table 2). The potentials of exact inputs are shown in the Table 1.

D \ R	Low	Medium	High
Low	LD, LR	LD,MR	LD,HR
Medium	MD,LR	MD,MR	MD,HR
High	HD,LR	HD,MR	HD,HR

Table 1 Possibilities of Crisp Inputs

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The membership functions for the input and output variables are shown in Figure 3 to 5. In all the functions, the triangular Fuzzy sets are used.

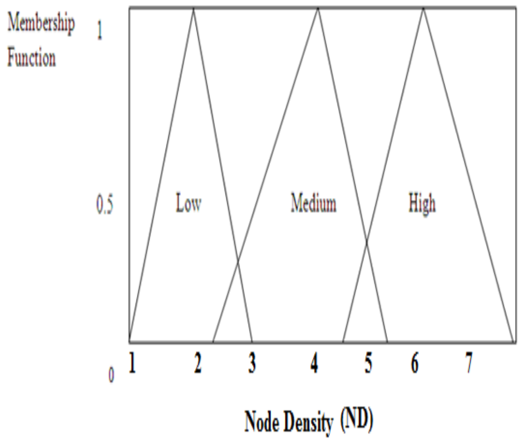

Figure 3 Membership function of Node Density

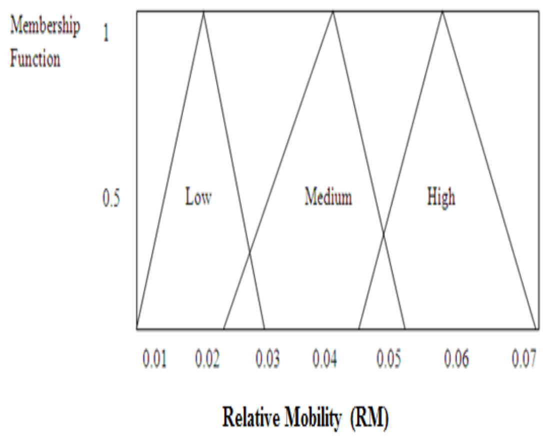

Figure 4 Membership function of Relative Mobility

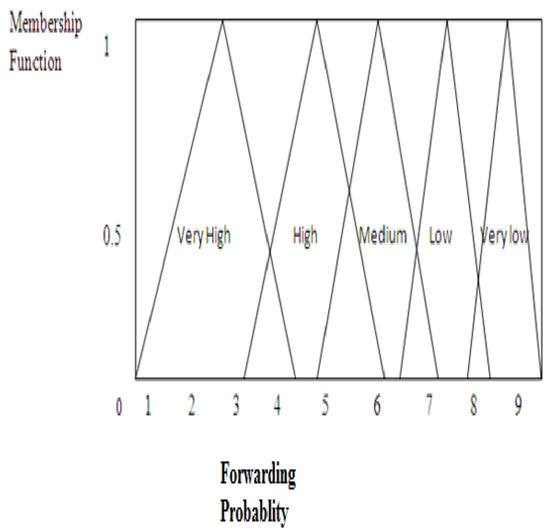

Figure 5 Membership function of Forwarding Probability

Table 2 presents the Fuzzy rules for the membership functions with Low , High and Medium values.

S.No	ND	RM	FP
1.	Low	Low	Low
2.	Low	Medium	High
3.	Low	High	Very high
4.	Medium	Low	Medium
5.	Medium	Medium	Medium
6.	Medium	High	Low
7.	High	Low	Very Low
8.	High	Medium	Low
9.	High	High	Low

Table 2 Fuzzy Inference Rules

3.4.2 Defuzzification

In defuzzification, a crisp value is returned from the output fuzzy set, by applying the centroid of area method.

The formula (11) labels the defuzzifier technique.

$$\text{Fuzzy\_cost} = [\sum_{allrules} z_i * \lambda(z_i)] / [\sum_{allrules} \lambda(z_i)] \quad (11)$$

Where fuzzy_cost denotes the degree of decision making, f_i is the set of fuzzy rules and variable and $\alpha(f_i)$ is its membership function.

3.5 Routing based on Forward Nodes

It involves the following process:

1. The node with high FP is selected to forward the route request packets.

1) FN_i broadcasts the RREQ message to its intermediate nodes (N_i).

$$FN_i \xrightarrow{RREQ} N_i$$

The format of RREQ message is shown in table 3

Table 3- Format of Route request message				
Source ID	Destination ID	Previous hop node ID	Previous Nodes State	Nodes State

2) On getting RREQ, N_i keeps informed its steering table with the evidence that contains source ID, terminus ID, former hop node ID and its position. It adds its position to the nodee position to RREQ note and examines the terminus ID.

If $N_i \neq D$

Then

N_i retransmits RREQ to the nearby nodes

Else

$N_i \xrightarrow{RREP} S$

End if

The rule above said suggests that when intermediary realizes that it is terminus node, it directs RREP note to source. Else, it retransmits RREQ to its nearby nodes.

3) If suppose N_i obtains two or more RREQ with same terminus ID, then it takes into consideration the note it obtain initially and removes the additional note.
4) When D obtains RREQ note, it adds its position to RREP and unicasts the response note in the converse way in the direction of S. D executes this same act for each RREQ it obtains.

$D \xrightarrow{RREP} S$

5) On getting the RREP note, N_i adds its position to the note and also apprises its routing table. After that it unicasts the RREP in the way of S exploiting the preceding hop node evidence that is stowed earlier.
6) Step 5 is repeated till RREP reaches S.
7) S selects the way with finest nodes to transfer the data package.
8) Before forwarding the packets, the number of redundant packets exceeding a threshold value, are removed by checking successful status of delivered packets.

IV. SIMULATION RESULTS

4.1 Simulation Parameters

The proposed Adaptive Broadcast Routing Protocol (ABRP) is simulated in NS2 and compared with Regret-tracking broadcast (RTB) [6] protocol.

Figure 7 shows the simulation topology and Table 4 shows the simulation settings. The performance of the two protocols is evaluated in terms of end-to-end delay (E2D), packet delivery ratio (PDR), forwarding ratio (FR) and average residual energy (RE).

Number of Nodes	20,40,60,80 and 100
Size of deployment area	1000 X 1000m
MAC Protocol	IEEE 802.11b
Traffic Model	CBR
Number of connections	5
Propagation model	Two Ray Ground
Antenna model	Omni Antenna
Initial Energy	10.0 Joules
Transmission Power	0.5 watts
Receiving Power	0.3 watts
Speed of the node	10,20,30,40 and 50m/s

Table 4 Simulation parameters

4.2 Results and Discussion

A. Varying the Number of Nodes

In this section, the performance of the three protocols is evaluated by varying the number of nodes from 20 to 100 with node speed as 10m/s.

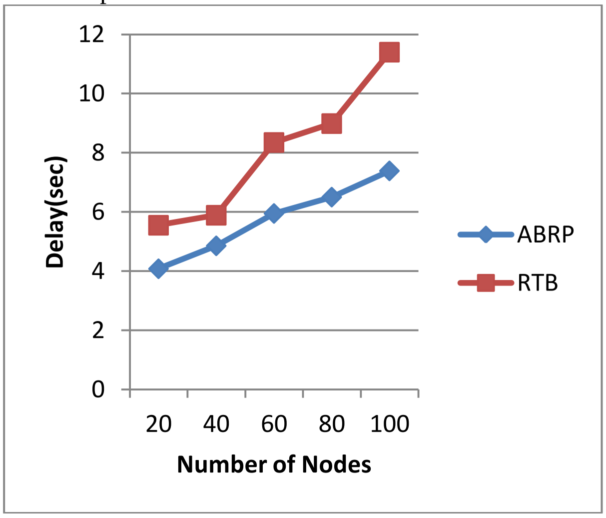

Figure 9 E2D for Varying Nodes

The graph showing the results of E2D for varying the nodes, is shown in Figure 9. The figure depicts that the E2D of ABRP ranges from 4.0 to 7.3 seconds and E2D of RTB ranges from 5.5 to 11.4 seconds. Ultimately, the E2D of ABRP is 27% less when compared to RTB.

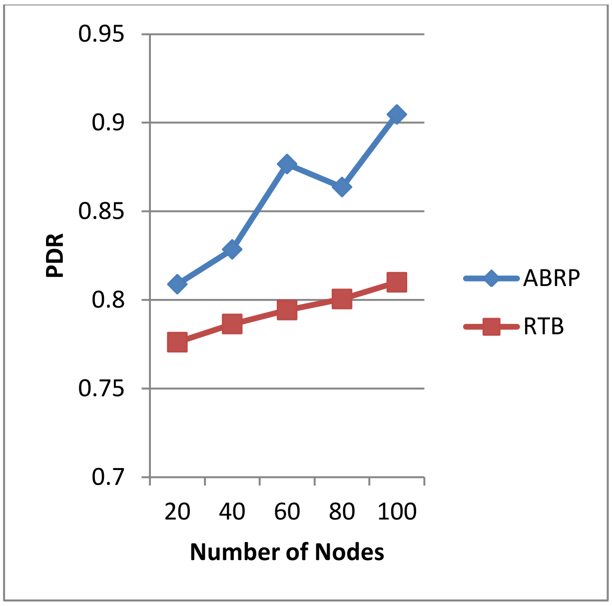

Figure 10 PDR for Varying Nodes

The graph showing the results of PDR for varying the nodes, is shown in Figure 10. The figure depicts that the PDR of ABRP ranges from 0.80 to 0.90 and PDR of RTB ranges from 0.77 to 0.80. Ultimately, the PDR of ABRP is 7% high when compared to RTB.

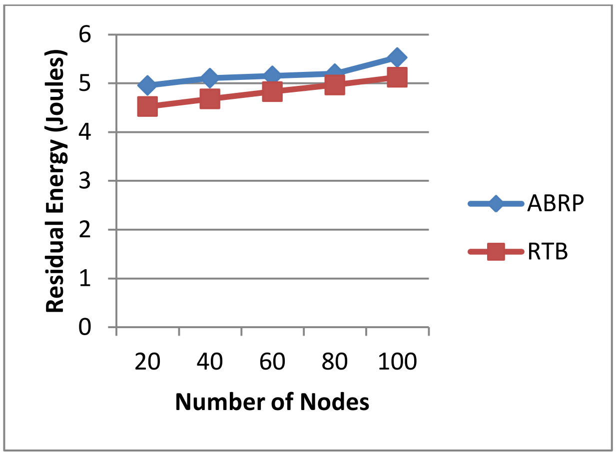

Figure 11 Residual Energy for Varying Nodes

The graph showing the results of residual energy for varying the nodes , is shown in Figure 11. The figure depicts that the residual energy of ABRP ranges from 4.9 to 5.2 joules and residual energy of RTB ranges from 4.5 to 5.1 joules. Ultimately, the residual energy of ABRP is 5% high when compared to RTB.

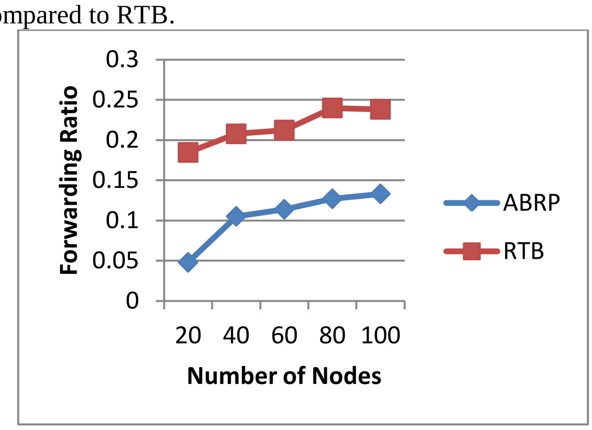

Figure 12 Forwarding Ratio for Varying Nodes

The graph showing the results of forwarding ratio for varying the nodes, is shown in Figure 12. The figure depicts that the forwarding ratio of ABRP ranges from 0.04 to 0.133 and forwarding ratio of RTB ranges from 0.184 to 0.238. Ultimately, the forwarding ratio of ABRP is 52% less when compared to RTB.

B. Varying the Node Speed

In this section, the performance of the three protocols is evaluated by varying the node speed from 10 to 50 m/s for 100 nodes.

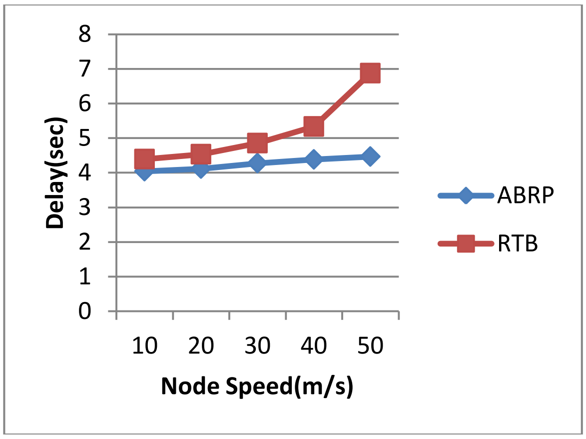

Figure 13 E2D for Varying Speed

The graph showing the results of E2D for varying the speed, is shown in Figure 13. The figure depicts that the E2D of ABRP ranges from 4.0 to 4.4 seconds and E2D of RTB ranges from 4.3 to 6.8 seconds. Ultimately, the E2D of ABRP is 16% less when compared to RTB.

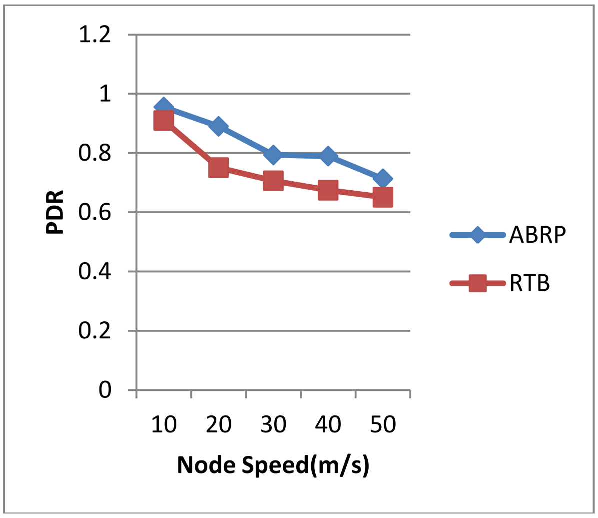

Figure 14 PDR for Varying Speed

The graph showing the results of PDR for varying the speed, is shown in Figure 14. The figure depicts that the PDR of ABRP ranges from 0.95 to 0.71 and PDR of RTB ranges from 0.90 to 0.65. Ultimately, the PDR of ABRP is 11% high when compared to RTB.

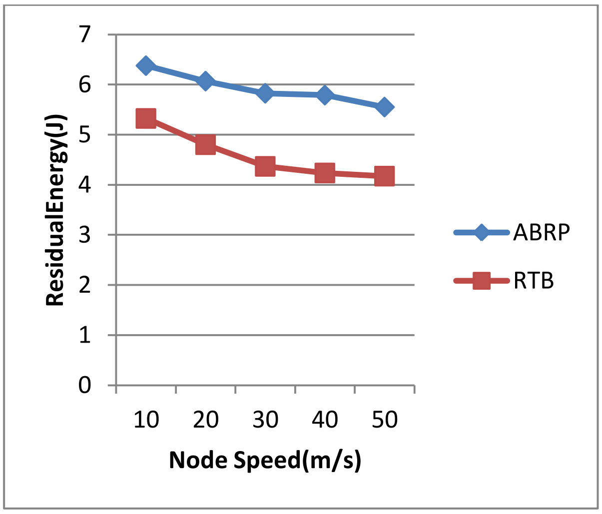

Figure 15 Residual Energy for Varying Speed

The graph showing the results of residual energy for varying the speed , is shown in Figure 15. The figure depicts that the residual energy of ABRP ranges from 6.3 to 5.5 joules and residual energy of RTB ranges from 5.3 to 4.1 joules. Ultimately, the residual energy of ABRP is 23% high when compared to RTB.

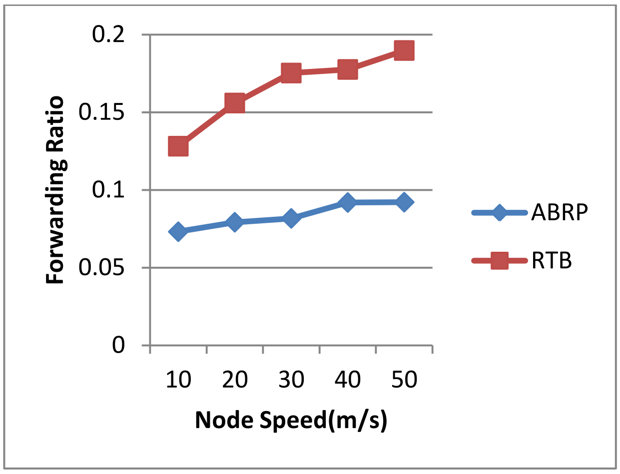

Figure 16 Forwarding Ratio for Varying Speed

The graph showing the results of forwarding ratio for varying the speed, is shown in Figure 16. The figure depicts that the forwarding ratio of ABRP ranges from 0.07 to 0.09 and forwarding ratio of RTB ranges from 0.128 to 0.189. Ultimately, the forwarding ratio of ABRP is 49% less when compared to RTB.

V. CONCLUSION

In this paper, we have proposed ABRP for MANET. In this protocol, a set of forwarding nodes are selected based on the Residual energy, coverage probability and channel condition or state. The rebroadcasting or forwarding probability is adaptively adjusted based on the 1-hop neighbour density and relative mobility of neighbours using the fuzzy logic technique. Then the selected forwarding nodes forward the route request packets with the probability given by forwarding probability. Before forwarding the packets, the number of redundant packets exceeding a threshold value, are removed by checking successful status of delivered packets. By simulation results, we have shown that ABRP minimizes the delay and forwarding ratio by increasing the packet delivery ratio and average residual energy.

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