Grenze International Journal of Engineering and Technology, Jan 2020

Analysis of Hybrid Broadcasting Schemes in Mobile Ad-hoc Networks

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***Abstract*—In Communication world, mobile ad-hoc networks are continuously evolving since every node communicated with other nodes by setting up one-hop and multi-hop communication paths. Furthermore, the nodes in the mobile ad-hoc network are moving which causes alternative paths to be established among nodes over a period of time. These features of the mobile ad-hoc network established importance in rescue operations, disaster management, and battlefields. Hence, lots of researchers get attracted to efficient network creation in the mobile ad-hoc network. The dynamic topology of the mobile ad-hoc network made routing protocols to use multi-casting and broadcasting mechanisms for routing. In MANET, the traditional broadcast routing protocols use flooding as basic mechanism for route discovery which leads to Broadcast Storm Problem. Although the flooding scheme guarantees better reach-ability, it incurs high energy consumption in the network which in turn leads to system performance degradation. This paper has analyzed the broadcasting approaches for addressing energy consumption in the MANET. The proposed broadcasting schemes such as AMAHB, NE^{2}CBB, AMECBB, TCBB, and PNKHB are compared with existing schemes such as NCPR and DCFR protocol. The performance of proposed schemes is analyzed by computing the average energy consumption, packet delivery ratio, delay and normalized routing overhead.**

***Index Terms*— MANET, Broadcasting, Routing, fourth term, fifth term and sixth term.**

I. INTRODUCTION

The mobile ad-hoc networks have emerged in past years due to its wide applicability in the field of disaster recovery, police operations, crowd management, emergency and military operations such as battle-fields, etc. Furthermore, through the advent of sensor-enabled intelligent mobile devices, MANET's have become a crucial element in the framework of the Internet of Things (IoT) and Smart City developments [1]. The diverse applications of MANET received potential attention towards efficient network creation in MANET. The continuously evolving and uncertain behaviour of MANET's make routing more interesting facet to emphasis upon [2]. Broadcasting is the most fundamental operation used for routing in MANET. Flooding is the elementary operation used for broadcasting in MANET. In flooding, a node when gets the

Grenze ID: 01.GIJET.6.1.504_2

broadcast packet relay the packet to all its neighbours and in return, these neighbours when gets a broadcast packet relay the packet to its neighbours. This process of relaying the packet sustains until all reachable nodes in the network gets the packet. This neighbourhood processing in MANET leads to broadcast storm problem. Broadcast storm causes redundant broadcasts in the network to incur high energy consumption. The basic solution to reduce the impact of BSP is to inhibit some nodes from broadcasting the packets through the network.

The continuous mobility of the mobile nodes results in the varying network typologies of MANET that enables the mobile nodes to be either densely associated or sparsely associated. Accordingly, the MANET's are classified as the dense network and the sparse network. In the dense network, nodes may run out of their energy quickly which in turn causes partitioning of the network decreasing packet delivery. The network partitioning can be inhibited by considering the energy of the nodes into an account while forwarding packets from source to destination. The weak mobile node does not forward the route request control packet, but simply drops it. In sparse networks, shared coverage is lower since very few nodes act as intermediate nodes. If these intermediate nodes are highly mobile, then network partitioning can occur, which decreases packet delivery. To improve it, node mobility must be considered. It eliminates many redundant broadcasts by choosing the nodes with low speed to discover a more stable path. This paper aims to develop the broadcast scheme based on neighbourhood information, mobility and the energy of nodes in order to address broadcast storm problem and energy consumption of the network.

II. BACKGROUND AND RELATED WORK

In MANET, many routing protocols have been proposed to reduce the broadcast storm problem [3]. Traditional broadcast schemes divide them into three categories, heuristic-based schemes, topology-based schemes, and other schemes. In heuristic-based schemes, broadcasting decision is taken based on heuristics such as probability, counter, location, and distance. In topology-based schemes, broadcasting decision is taken based on topological information such as neighbouring nodes, number of nodes in the network, type of network (dense network or sparse network), etc. Other scheme includes energy-aware schemes and mobility-aware schemes. The energy-aware schemes aim to eliminate many redundant broadcasts by selecting the high energy nodes to discover a route bypassing the low energy nodes. Likely, the mobility-aware schemes aim to reduce routing overhead by mitigating many redundant broadcasts to choose more stable paths. The hybrid broadcast schemes combine the advantages of two or more broadcast routing schemes in order to decrease the number of retransmissions so as to optimize broadcasting in MANETs.

In [4], the authors suggested an algorithm that achieves broadcast savings and high reach-ability with the aim to mitigate the broadcast storm problem by combining the features of the counter-based scheme and neighbour-knowledge based scheme. The algorithm is devised based on the conception that when a low counter threshold is set then it does provide broadcast saving but does not provide significant reachability. Likely, when a high counter threshold is set then it does not provide broadcast saving but does provide significant reach-ability. Hence, the algorithm dynamically adjusts the counter threshold-based nodes neighbourhood.

The neighbour coverage-based probabilistic rebroadcast protocol (NCPR) is one of the probabilistic broadcast schemes [5] for reducing routing overhead in MANET's. It calculates the rebroadcast delay to determine the forwarding order. The idea behind NCPR is that when a node has more common neighbours with the previous node then it has a lower delay. Therefore, this rebroadcast delay enables the information that the nodes have transmitted the packet spread to more neighbours. Then accurate additional coverage ratio is obtained by sensing neighbour coverage knowledge. Thereafter, a connectivity factor is obtained to provide the node density adaptation. Finally, by combining the additional coverage ratio and connectivity factor, the rebroadcast probability is computed. NCPR was proposed to mitigate the routing overhead problem caused by RREQ redundant packets. This protocol manages to reduce the number of such packets based on the self-punning scheme, relying on the total number of nodes in the whole network. However, this number is insufficient when the network is congested. Another, important challenge of NCPR is the performance degradation resulting from the routing overhead from the RREQ and an excessive number of hello messages.

The dynamic connectivity factor routing (DCFR) protocol addresses the NCPR protocol problem, which considers the pre-set variables of the total number of nodes while reducing routing overhead [6]. It eliminates the need for the network global density information for any routing protocol such as the NCPR. It computes the dynamic connectivity formula (DCF) which relies on local information gathered from the node itself. The average number of neighbours plays an important role in forwarding decision on whether the request packets should be forwarded or dropped.

The energy-aware schemes aim to eliminate many redundant broadcasts by selecting the high energy nodes to discover a route bypassing the low energy nodes [7]. As each mobile node in a mobile ad-hoc network is responsible for routing packets during route discovery, there is a possibility of link failure due to low energy of nodes. Specifically, in dense region nodes may run out causing link failure which would affect the network lifetime. Hence, energy-aware schemes achieve network lifetime reducing re-transmissions. In [8], the proposed algorithm aims to achieve higher energy consumption to consider residual energy and hop count as parameters. The routing path selects the largest residual energy with a minimum hop count. This algorithm dynamically adjusts the transmission range of the node according to the neighbour's range of the node.

The mobility-aware schemes aim to reduce routing overhead by mitigating many redundant broadcasts to choose more stable paths [9]. The MA-AODV algorithm relies on the fact that if the mobility of nodes is high then it causes the link breakages which increases the routing overhead. The MA-AODV algorithm involves two steps; the first step completes mobility quantification of nodes founded on the locally available information of neighbouring nodes and the second step selects the nodes based on the low mobility. Thus the MA-AODV algorithm achieves more stable and reliable routes by increasing the overall routing performance.

On the way to manage link-failures, there some schemes that depend on the link stability to select stable routes to improve the performance of MANET. The nodes signal strength from the other nodes is used as a metric to estimate the link stability of the nodes. Stability of the link of two nodes is considered as stable if a node receives a strong signal from a neighbour node. In [10], the authors focused on the link stability and the lifetime of a route to find a route with a longer lifetime.

III. METHODOLOGY

In this section, five different schemes, viz., novel counter-based broadcasting scheme (TCBB) using TOPSIS multi-criteria decision making (TCBB), Advance mobility-aware hybrid broadcasting (AMAHB), Novel energy-efficient counter-based broadcasting (NE^{2}CBB), Adaptive Mobility-aware Energy-efficient Counter-based broadcasting (AMECBB) and Proactive Neighbour-knowledge based Hybrid broadcasting scheme (PNKHB) have been discussed.

A. Advance mobility-aware hybrid broadcasting scheme (AMAHB) [11]

This scheme is a hybrid scheme of counter-based [4], neighbour knowledge-based and speed based scheme [9] which achieve low energy consumption and high packet delivery in the network. This research aims to eliminate many redundant broadcasts by choosing the nodes with low speed to discover a more stable path. In a simple counter based scheme, a node maintains a counter to keep track of redundant broadcast packets. On reception of packet, a counter is incremented by one. Then the delay is introduced to enhance the broadcast saving. During the period, counter is updated. After expiry, counter associated with a node is compared with the counter threshold. If the counter reaches to counter threshold then it suppresses some re-transmission. Otherwise, it will re-transmits the packet. The basic counter-based scheme is modified to refine thresholds according to the mobility of mobile nodes. It is classified into three different phases, viz, identification of network structure, classification of network structure, broadcasting. When a node receives a packet, it starts the process of identification of network structure. During the process of identification, it does the following steps:

1. It keeps track of a number of duplicate packets received.
2. It determines the number of neighbouring nodes.
3. It determines the speed fraction of the node received the packet.

After the identification, the process of classification of network structure starts. Classification takes at two levels. At the first level, it classifies the node as Sparse if the number of neighbouring nodes is less than the average number of nodes in the network and classifies the node as Dense if the number of neighbouring nodes is more than the average number of nodes in the network. At the second level, it classifies the node as stable node if the speed of node is less than the speed threshold and classifies the node as unstable node if the speed of node more than the speed threshold. Finally, in the broadcasting phase, the counter threshold is set as per the classification of network structure. This step decides how many re-transmissions to be allowed for the node.

B. Novel energy-efficient counter based broadcasting (NE^2CBB)[12]

The NEECBB aims to minimize the energy consumption of network by the use of packet counter, neighbour knowledge information and remaining energy [7][13][14]. In network, there exist some nodes those holding less energy and some are holding high energy. In a dense network, nodes may run out causing link failure. Therefore, NE^2CBB favours the nodes with more remaining energy for the broadcast process. The different phases of NE^2CBB scheme are highlighted as follows:

A. Initialization phase
B. Computation phase
C. Characterization phase
D. Broadcast decision-making phase

Initialization Phase: Upon receiving a packet at node (n), each node exchanges HELLO packets with each neighbour nodes to get one-hop neighbouring nodes N(nbg). It does not immediately broadcast the packet to its neighbours, instead, it waits by initializing the timer to random delay. Next, to keep track of duplicate packets, it initializes a packet counter (c). Subsequently, sets up the initial energy E(Init) of each node in the network and the energy threshold (E(Th)) before the broadcast starts.

Computation Phase: At the start, it computes the average neighbouring nodes N(avg) at a node (n) in the network of an area, A(M) and the total number of nodes (N) with transmission radius (R) using the following equation.

$$\mathrm{N(avg)} = \frac{\mathrm{N} \times \pi \times R^2}{\mathrm{A(M)}} \quad (1)$$

Afterward, it computes the remaining energy E(Rem) as the difference of initial the energy of node E(Init) and the current energy of the mobile node E(N).

Characterization Phase: This phase evolves the two broadcast decision making parameters viz., neighbourhood density N(d) and the energy efficiency N(e) of the mobile node. Initially, the algorithm characterizes a mobile node as sparse if the number of neighbouring nodes N(nbg) is less than the average number of nodes N(avg) in the network, and characterizes the mobile node as dense otherwise. Afterward, it determines the energy efficiency N(e) of the mobile node. The algorithm characterizes a mobile node as strong if the energy of mobile node E(N) exceeds the energy threshold E(Th) and as weak otherwise.

Broadcast Decision Making Phase: In this phase, NE2CBB incorporates prior articulation of chances for the broadcast process before finding the optimal route. If a node evolves as a strong-dense node then high dense threshold value is assigned to counter threshold to get more chances for broadcasting. On the contrary, if a node evolves as a strong-weak node then the counter threshold is set to Low Dense threshold value to get less chance for broadcasting. It works similarly for the sparse node and assigns High Sparse threshold value and Low Sparse threshold value for a strong-sparse node and weak-sparse node respectively to decide chances for the broadcast process. Finally, the packet counter is compared with the rebroadcast threshold in order to find an optimal path.

C. Adaptive mobility-aware energy-efficient counter-based broadcasting (AMECBB) [15]

It attempts to reduce energy consumption in the sparse network ensuring high packet delivery. The AMECBB scheme proposed here is a hybrid of AMAHB and NE2CBB approaches and focuses on mobility and node energies to have stabilized long-lasting paths from source to destination.

The classification of the network structure has been modified in AMECBB and occurs at three different levels. At first level, the algorithm classifies the node as sparse if the number of neighbouring nodes is less than the average number of nodes in the network, and classifies the node as dense if the number of neighbouring nodes is more than the average. The conditional attribute (F1) evolves as (Nnbg < Navg) to specify the type of mobile network (MN). At the second level, the process classifies a node as stable if its speed of node (S) is less than a speed threshold (S_{th}), and classifies the node as unstable otherwise. The conditional attribute (F2) evolves as ($S < S_{th}$) to specify the mobility of the network (M). During the third level, a node is classified as strong if its energy fraction (E) exceeds the energy threshold (E_{th}), and as weak otherwise. The conditional attribute (F3) evolves as ($E > E_{th}$) to specify the energy efficiency of the network (E). Additionally, it includes Rebroadcast Threshold Estimation (R_{th}) which determines how many retransmissions will be allowed for a node. The AMECBB refines counter threshold to d counter thresholds (R_{th}) as High Sparse, Low Sparse, High Dense, Low Dense, High Moderate and Low Moderate from three conditional attributes viz., F1, F2, and F3. The AMECBB is methodized as follows in table 2.

TABLE 1: CHARACTERISTIC TABLE

No.	F1	F2	F3	F1^F2^F3	Threshold (R_{th})
1	1	1	1	d = 1	HIGH SPARSE
2	1	1	0	d = 2	HIGH MODERATE
3	1	0	1	d = 3	LOW MODERATE
4	1	0	0	d = 4	LOW SPARSE
5	0	1	1	d = 5	HIGH DENSE
6	0	1	0	d = 6	LOW MODERATE
7	0	0	1	d = 7	HIGH MODERATE
8	0	0	0	d = 8	LOW DENSE

The selection of the counter threshold is most important in AMECBB as rebroadcast probability depends on the rebroadcast threshold. These refined counter thresholds adjust the rebroadcast probability dynamically. Assume R_{th} be the estimated broadcasting threshold from the N_{th} maximum broadcasting thresholds. The maximum-likelihood estimate calculates the rebroadcast probability (P) as (R_{th}/N_{th}).

D. Novel counter-based broadcasting using TOPSIS multi-criteria decision making (TCBB) [15]

It attempts to reduce energy consumption in the sparse network ensuring high packet delivery and least delay, thereby increasing performance of the network. Here, we describe the novel counter-based broadcasting scheme (TCBB) using TOPSIS multi-criteria decision-making [16] that determines whether to broadcast and is a good approximation of a quality model according to a set of parameters. In order to address the issues of MANET, it considers the three main decision parameters of the mobile node, the neighbourhood (MN), mobility (M) and energy (E). The weights of these criteria reflect their relative importance in the decision-making process. As all the decision attributes are equally important, they are equally weighted.
In this scheme, each time a node receives a broadcast packet it does not broadcast the packet immediately. It waits for Random assessment time to reduce the storm effect and initializes the three attribute weights. Next, it constructs a table of neighbouring nodes (N_{nbg}) by periodic transmission of HELLO packets. The neighbourhood criterion (MN) is estimated as the ratio of neighbouring nodes (N_{nbg}) to the average neighbouring nodes (N_{avg}). In spite of estimation of mobility criteria (M) and energy criteria, it finds its speed (S), energy (E_N), maximum speed (S_{max}) and initial energy (E_{ini}) of the mobile node. To choose low-speed nodes to discover more stable paths, the mobility criteria (M) is estimated by taking the ratio of the speed of node(S) to the maximum speed (S_{max}) of the mobile node. Likely, to choose strong nodes to have the long-lasting routing path the energy criteria (E) is estimated by taking the ratio of the energy (E_N) of node to the initial energy (E_{ini}) of the node. The TCBB scheme constructs a rebroadcasting probability function by way of a multiple parameter mapping functions that aggregates the neighbourhood (MN), mobility (M) and energy (E) parameters into a single parameter. The TCBB computes a random probability (P_{rand}) in between values zero and one [0,1] and compares with the rebroadcast probability (P). If rebroadcast probability is more than or equal to random probability then the packet is transmitted, otherwise, the packet is dropped.

E. Proactive neighbour knowledge based hybrid broadcasting (PNKHB) [17]

It aims to reduce routing overhead, the energy consumption of the network and to maintain Packet delivery. The previously proposed broadcast schemes and an adaptive neighbour knowledge-based hybrid broadcasting scheme [18] are reactive routing schemes which do not make the nodes to initiate a route discovery process until a route to a destination is required. The PNKHB uses a proactive approach to route discovery to form the routing table entry for the second hop and multi-hop neighbours. The corresponding forwarder node is selected by checking the neighbour connectivity and the energy along with the link connection and disconnection probability. By taking the energy capacity and energy accumulation rate as reference parameters, the value of the energy contribution is estimated. The energy conversion efficiency for each link and the energy contribution factor are related together to compute the energy degree. The real-time residual energy degree is calculated by considering the estimated energy degree and the remaining energy of nodes. In order to perform the multi-hop forwarder selection process, the route performance coefficient is estimated by checking the lowest link break probability and the highest network lifetime.
The probability of the connection and the disconnection are computed from the value of the probability of mutually exclusive event for the solid connection, dotted connection and the dashed connection which represents the strength of the connection. The energy drain rate coefficient and the degree of the link break

along with the residual energy degree are combined together to estimate the route performance coefficient. The mobility extension area is estimated by identifying the intersection of the three circles which includes the current node, one hop forwarder node and the multi-hop destination node. The forwarder node selection is performed by checking the maximum connectivity and the minimum link failure along with the minimum energy drain rate which is considered inside the area of the mobility extension.

IV. METHODOLOGY

This section describes the evaluation setup and performance measures used for evaluation of the proposed protocols.

A. Evaluation Setup

The performance of the proposed protocols for mobile ad-hoc networks is evaluated in the network simulator (NS-2). The constant transmission range of the network is 250 meters. The MAC layer scheme follows the IEEE 802.11 MAC specification. Each mobile node in MANET follows the random waypoint model to decide the movement pattern of them. The two-ray ground reflection model used for experimenting with the routing protocols performs propagation to consider both the direct path and a ground reflection path. The omni directional antenna used to configure the transceiver of MANET. The size of the network has been taken as 1000*1000. The simulation experiments run for 250 msec. over the varied network densities (50, 100, 150, 200). The parameters used in the following simulation experiments for Mobile Ad-hoc network are listed in Table 4.1.

B. Performance Measures

The performance measures, viz, average energy consumption, packet delivery ratio, delay and routing overhead are used to evaluate the effectiveness of the proposed schemes. The readings obtained from simulations over varied network densities are summarized in table 4.2 to 4.5.

C. Average Energy Consumption

The nodes in MANETs are mobile nodes with limited power resources. Therefore, the proposed schemes consider this evaluation measure. The energy consumption is defined as the difference between the current and initial energies of nodes. A lower total energy consumption means better performance for a proposed scheme. Figure 4.1 shows a graph of average energy consumption over varied network densities for all the proposed schemes and comparative schemes. AMAHB, AMECBB, and TBB reduced the average energy consumption by 46% compared to the NCPR protocol, while PNKHB reduced it by 44%. AMAHB, AMECBB, and TBB reduced the average energy consumption by 45% compared to the DCFR protocol, while PNKHB reduced it by 43%.

TABLE II: SIMULATION PARAMETERS

No	Parameter	Value
1.	Network Area	1000*1000
2.	Transmission Range	250 m
3.	Simulation time	250 msec.
4.	Number of nodes	50,75, 100,125
5.	Traffic pattern	CBR(UDP)
6.	Routing Protocol	NCPR, DCFP
7.	MAC protocol	IEEE 802.11
8.	Packet Size	512 bytes
9.	Interface Queue Length	50
10.	Mobility Model	Random Way point Mobility model
11.	Propagation Model	Two Ray Ground
12.	Antenna	Omni directional

Table III: Energy Consumption

No. of	NCPR	DCFR	AMAHB	NE^{2}CBB	AMECBB	TCBB	PNKHB
Nodes	Reactive routing		Proactive Routing				Reactive Routing
50	5.9	5.8	2.89	2.89	2.42	2.42	2.79
100	6.4	6.3	3.4	3.37	3.26	3.24	3.08
150	6.5	6.4	3.67	3.55	4.01	3.63	3.85
200	6.9	6.8	3.83	3.83	4.3	4.59	4.6
Performance Improvement							
% of	Energy	NCPR	46%	46%	45%	46%	44%
Decrease	Consumption	DCFR	45%	46%	44%	45%	43%

Table IV: Packet Delivery Ratio

No. of	NCPR	DCFR	AMAHB	NE^{2}CBB	AMECBB	TCBB	PNKHB
Nodes	Reactive routing		Proactive Routing				Reactive Routing
50	97	96	100	100	100	100	99.91
100	95	95	99.97	100	99.79	100	99.73
150	94.5	94	99.94	99.97	98.89	100	100
200	87	87	100	100	99.69	99.66	98.57
Performance Improvement							
% of	Packet Delivery	NCPR	7%	7%	6%	7%	6%
Increase	Ratio	DCFR	8%	8%	7%	8%	7%

Table V: Delay

No. of	NCPR	DCFR	AMAHB	NE^{2}CBB	AMECBB	TCBB	PNKHB
Nodes	Reactive routing		Reactive Routing				Proactive Routing
50	0.1	0.1	0.037	0.05	0.018	0.018	0.02
100	0.1	0.1	0.058	0.055	0.04	0.02	0.05
150	0.12	0.12	0.03	0.06	0.062	0.03	0.07
200	0.225	0.22	0.048	0.048	0.05	0.07	0.13
Performance Improvement							
% of Decrease	Delay	NCPR & DCFR	68%	61%	68%	75%	50%

TABLE VI : REACTIVE ROUTING VS PROACTIVE ROUTING

Performance Measure	Reactive Routing	Proactive Routing	% of Decrease
Routing Overhead	1.46	1.07	26 %

D. Packet Delivery Ratio

The packets are dropped in the network if they fail to reach to the destination because of congestion in the network. The congestion can occur in the network because of excess broadcasts. Therefore, it is desirable to have less broadcast packets. Figure 4.2 presents a graph of packet delivery ratio over varied network densities for all the proposed as well as comparative schemes. The proposed schemes caused considerable incremental growth of 6-8% in the packet delivery ratio compared with the NCPR and DCFR protocol.

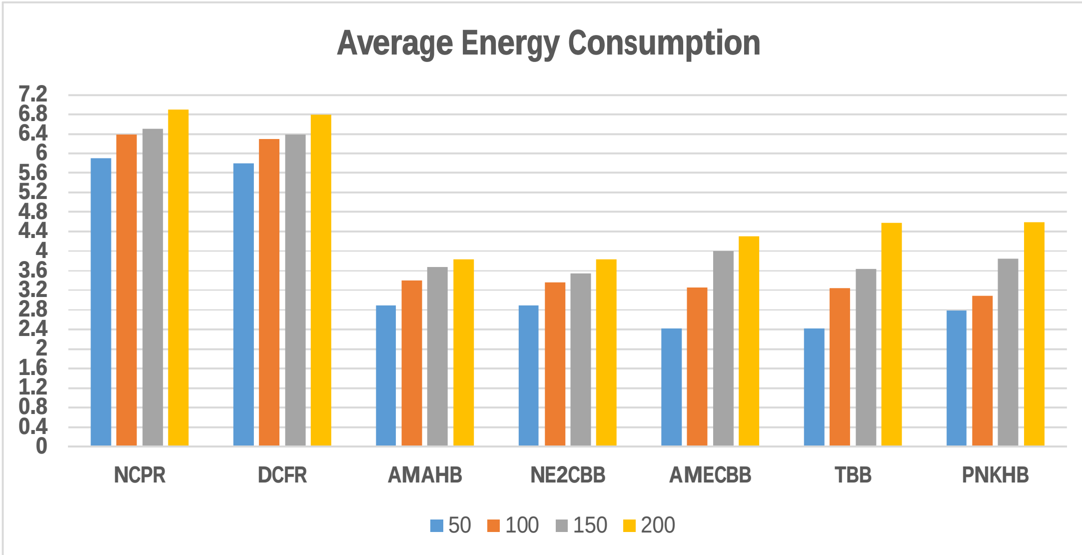

Figure 4.1: Average Energy Consumption over varied network density

E. Delay

Delay is defined as the total time required for the packet to reach from source to destination. Lower the delay better is the performance of the system. Figure 4.3 presents a graph of delay over varied network densities for all the proposed as well as comparative schemes. There is a significant reduction in delay by all proposed schemes ranging from 50% to 75% as compared to NCPR and DCFR schemes. The TCBB outperformed compared to PNKHB. Indeed, TCBB outperformed all the comparative schemes and the rest proposed schemes. NCPR and DCFR protocol in reducing the delay by an additional 75%. TCBB reduced more than 9% of the delay compared to AMAHB and AMECBB. TCBB reduced more than 33% of the delay compared to PNKHB. Indeed, TCBB outperformed all the comparative schemes and the rest proposed schemes.

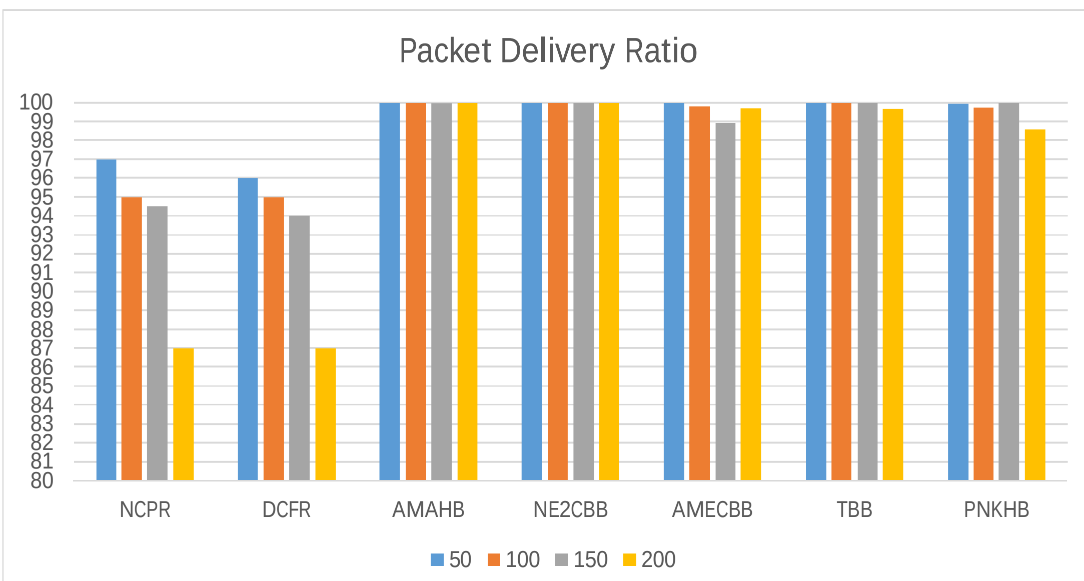

Figure 4.2: Packet Delivery Ratio over varied network density

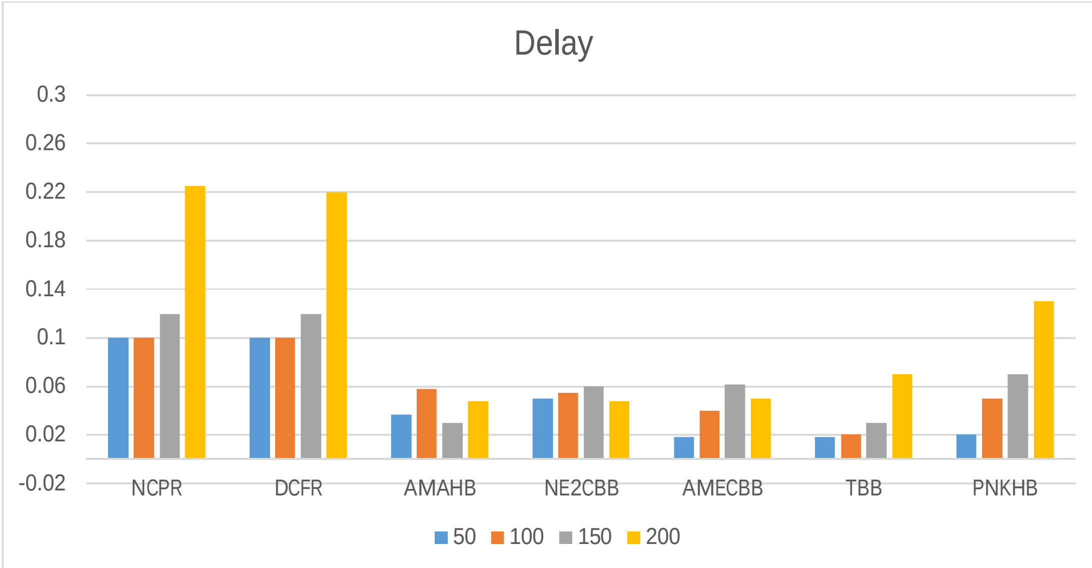

Figure 4.3: Delay

F. Routing Overhead

The continuous changing position of the mobile nodes has an impact on the routing overhead of the network. To overcome this issue, PNKHB attempts to limit the selection of highly stable nodes providing long term connectivity. The AMAHB, NE2CBB, AMECBB, and TBB suffers from increased routing overhead by 23%, while PNKHB reduces it by 18% when compared with NCPR and DCFR scheme.

V. Conclusion

This research paper analyzes the feasibility and effectiveness of the hybrid broadcast routing schemes. AMAHB has been proposed to reduce the energy consumption of the network achieving good packet delivery. NE2CBB aims to reduce energy consumption as well as delay incurred by AMAHB. AMECBB is proposed to take the advantages of both AMAHB and NE2CBB. The TCBB scheme aims to provide the least delay in the network. The PNKHB scheme provides a reduction in normalized routing overhead. Experiments have been conducted on various network densities in the MANET. Experimental results demonstrate that the proposed schemes outperform in increasing the performance of the route discovery in MANET.

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