Research Article

An Optimized and Energy-Efficient Ad-Hoc On-Demand Distance Vector Routing Protocol Based on Dynamic Forwarding Probability (AODVI)

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MANET (mobile ad-hoc network) is a wireless ad-hoc network made up of mobile devices that use peer-to-peer routing to provide network access instead of using a preexisting network infrastructure. Despite the network infrastructure's simplicity, it faces issues such as changeable connection capacity, dynamic topology, node battery power exhaustion, and inadequate physical security. Broadcasting is a standard MANET approach for sending messages from a source node to all other nodes in the network. Flooding is a frequent method for broadcasting route request (RREQ) packets, which is susceptible to broadcast storms. The high retransmission rate is caused by the standard flooding technique, which causes media congestion and packet collisions, which can drastically reduce throughput and network performance. In a mobile ad-hoc network, efficient broadcasting focuses on selecting a compact forward node set while assuring broadcast coverage. The goal is to find a limited number of forward nodes that will provide complete coverage. In this paper, we propose an optimized and energy-efficient routing protocol for MANET (mobile ad-hoc network) based on dynamic forwarding probability in general and AODV (ad hoc on-demand distance vector) in particular, in which the route request packets are randomly controlled to increase the network lifetime and reduce packet loss in the flooding algorithm. We tested and assessed the results of our proposed solution using various network performance factors after implementing and integrating it into NS-2. According to simulation findings, our proposed technique effectively reduced route request propagation messages (RREQ). The suggested technique is more efficient, has a longer network lifetime, and uniformly utilizes node residual energy, enhancing network throughput and minimizing routing overhead when compared to regular and modified AODV protocols.

1. Introduction

Wireless networks can be categorized mainly into two groups such as infrastructure-based and infrastructure-less networks. In infrastructure-based networks, all the nodes are controlled by a centralized access point or base station; whereas, the nodes communicate with each other through multiple links without any centralized monitoring system in infrastructure-less networks (i.e., ad hoc network). Through the advancements in wireless communication and economy,

portable computing devices have made mobile computing possible [1].

MANET (mobile ad-hoc network) consists of a set of mobile nodes (hosts) that are connected by wireless links. The network topology (the physical connectivity of the communication network) in such a network may keep changing randomly. Routing protocols that find a path to be followed by data packets from a source node to a destination node used in traditional wired networks cannot be directly applied in MANET due to their highly dynamic topology,

absence of established infrastructure for centralized administration (i.e., base stations or access points), bandwidth constrained wireless links, and resource (i.e., energy)-constrained nodes [2].

Routing data packets in a MANET present a number of concerns and obstacles. A routing protocol's responsibilities include exchanging route information; determining a feasible path to a destination based on criteria such as hop length, minimum power requirement, and wireless link life time; gathering information about path breaks; and mending broken paths with the least amount of processing power and bandwidth; and utilizing the least amount of bandwidth [2, 3]. Routing in MANET has always been a challenging and tough task due to the dynamic topology and error prone wireless channel. There are a number of issues like lack of centralized control and constantly moving nodes that have to be considered while routing a data packet from the source to the destination in the ad hoc network. Routing of data packets becomes much more difficult with increased mobility of nodes. Apart from routing, there are some more issues in MANET that need to be addressed. One of the major challenges is dealing with the wireless medium of communication with limited bandwidth. Another important constraint is the constant drainage of energy due to the mobility of the nodes in the network [3].

AODV uses a simple flooding method for route discovery where a source node transmits to all nodes in the vicinity. Each node checks whether it has received this message before. If it had, then the message will be dropped, if not then the message is re-transmitted to all neighboring nodes. This process continues until all nodes get the message. Because radio signals are likely to overlap with others in a geographical area, a straightforward broadcasting by flooding is usually very costly (A host, on receiving a broadcast message for the first time, has the obligation to rebroadcast the message. Clearly, this cost n transmissions in a network of n hosts) and will result in serious redundancy, contention, and collision, which we call the broadcast storm problem. Hence, this method increases the network traffic and depletes battery power [4, 5]. The objective of this research work is to improve performance (i.e., energy consumption, routing overhead and throughput) in the AODV (ad hoc on-demand distance vector) routing protocol by modifying the RREQ forwarding probability. The AODV routing protocol uses an on-demand approach for finding routes, that is, a route is established only when it is required by a source node for transmitting data packets. It employs destination sequence numbers to identify the most recent path. In an on-demand routing protocol, the source node floods the route request packet in the network when a route is not available for the desired destination. It may obtain multiple routes to different destinations from a single route request. The major difference between AODV and other on-demand routing protocols is that it uses a destination sequence number (DestSeqNum) to determine an up-to-date path to the destination. A node updates its path information only if the DestSeqNum of the current packet received is greater than the last DestSeqNum stored at the node. The main advantage of this protocol is that routes are established

on demand and destination sequence numbers are used to find the latest route to the destination. The connection setup delay is less [1].

This paragraph concludes the introduction section. The related works, which cover everything from the previous related works, are examined in Section 2. We examine the approaches in Section 3 together with the proposed algorithm and cost analysis of the AODV. We explore the simulation and result analysis in Section 4. The report concludes with the prospect of future extension of this work after the discussion highlights of the findings offered in Section 5.

2. Related Works

In reference [6] to tackle the broadcast storm problem, the author investigated existing broadcasting strategies for route discovery in MANET, and their future work involves combining existing broadcasting methods to reduce rebroadcasting and boost packet delivery ratio.

In reference [7], the author proposed that improving AODV performance using dynamic density-driven route request forwarding and they optimized the broadcasting in route discovery (modification of RREQ in AODV). It is good in terms of packet reachability but the drawback of this approach is that it is still poor in reduction redundancy of a rebroadcast packet. The author of reference [4] proposed that neighbor coverage-based probabilistic rebroadcast for reducing routing overhead in mobile ad hoc networks by considering AODV as a base. A node may rebroadcast the RREQ packet to its uncommon neighbors based on a probability P. In reference [8], a novel efficient rebroadcast protocol for minimizing routing overhead in mobile ad-hoc networks is proposed. It is good in terms of delivery ratio, energy consumption, and control overhead. However, the drawback of this approach is the complexity of computing rebroadcast probability. The three parameters such as signal to noise ratio, energy, and routing load brought a delay in rebroadcasting the signal (RREQ packects). In reference [5], sensitivity analysis of AODV protocol regarding forwarding probability is proposed. Their study shows that it is important to use probability for forwarding the RREQ in AODV routing protocol and good to minimize power consumption and increase the throughput [9]. Spectral efficiency is also called bandwidth efficiency and it refers to the rate at which information can be transmitted over a given bandwidth, and this paper focuses on examining the relationship between the base station antenna downtilt and the downlink network capacity (ASE). There is an ideal antenna downtilt to obtain the greatest coverage probability for each base station density, according to the analytical results of the coverage probability and the ASE [10]. In this study, we take into account a typical scenario for a delay-tolerant application where a subset of vehicles—referred to as vehicles of interest—have download requests. The distribution of the files to the VoIs is aided by other vehicles without download requests as each VoI downloads a unique huge file from the Internet. The usage of V2I and V2V communications, vehicle mobility, and collaboration between infrastructure and

vehicles are all explored as part of a cooperative communication strategy that aims to increase the capacity of vehicular networks [11]. The author focuses on the problem of collision which has been addressed with a revolutionary method of mapping correlation of ID for RFID anticollision. Through the mapping correlation of ID, searching on multitrees can become more effective by increasing the linkage between tags, allowing tags to convey their own ID under specific trigger conditions. The method can significantly minimize the number of times the reader reads and writes to a tag's ID when there are not a lot of tags by substituting the temporary ID for the true ID. By using the position of the binary pulse to determine the positions of the empty slots in dynamic ALOHA-type applications, the reader can avoid the efficiency loss that results from reading empty slots when reading slots [12]. This study presented a forward-aware factor-based energy-balanced routing approach (FAF-EBRM). The next-hop node in FAF-EBRM is chosen in consideration of the connection weight and forward energy density. A mechanism for spontaneous reconstruction of local topology is also developed. FAF-EBRM beats LEACH and EEUC in the experiments when LEACH and EEUC are compared to one another because it balances energy consumption, extends function lifetime, and ensures high QoS for WSN [13]. In this work, a brand-new architecture called ApproxECIoT (approximate edge computing Internet of Things, ApproxECIoT) is put forth as a solution for the Internet of Things' real-time data stream processing. To process real-time data streams, it uses a self-adjusting stratified sampling technique. The findings of the experimental investigation, which included both synthetic and real-world datasets, demonstrate that ApproxECIoT can still produce highly accurate calculation results even when using memory resources to basic random sampling. When the sampling ratio is 10% for synthetic data streams, the accuracy loss of ApproxECIoT is decreased by 99.8% compared to SRS and CalculIoT and by 89.6% compared to CalculIoT [14]. The author studies wireless sensor networks (WSN) for mobile education in order to maintain better and lower energy consumption, reduce the energy hole, and lengthen the network life cycle. We offer a unique unequal clustering routing protocol (UCNPD, which stands for unequal clustering based on network partition and distance) for WSNs that uses energy balancing based on network partition and distance and creates unequal clusters by setting various competitive radius. The simulation outcomes demonstrate that the protocol successfully delays node aging, increases network longevity, and evenly distributes energy consumption among all nodes [15]. The PMC algorithm is based on the concept of a multihop clustering algorithm that ensures the coverage and stability of cluster, and the study focuses on a novel passive multi-hop clustering algorithm (PMC) that is proposed to tackle these concerns. A priority-based neighbor-following technique is suggested to choose the ideal neighbor nodes to join the same cluster during the cluster head selection phase. They conduct numerous in-depth comparison experiments using the algorithms of N-HOP, VMaSC, and DMCNF in the NS2 environment to validate the performance of the PMC

algorithm [16]. The network topology varies often, and communication links are unpredictable, making VANET (vehicular ad hoc network) a special case of MANET (mobile ad hoc network). Vehicle movement is the cause of both characteristics, to efficiently forecast the stability of networks between vehicles and to create a reliable routing service protocol to satisfy different QoS application requirements. Based on this heuristic service algorithm, the research study suggests a reliable self-adaptive routing algorithm (RSAR). The RSAR performs well with VANET by combining the reliability parameter and modifying the heuristic function [17]. In this paper, a brand-new OLSR protocol for MANET called QG-OLSR is proposed. The protocol makes use of OLSR's MPR (multipoint relay) technology (optimal link state routing). It can efficiently decrease the consumption of network topology control, improve the delivery rate of data packets, and decrease the time delay of the end-to-end packet transmission between nodes by integrating new augmented Q-Learning algorithm and combining the OLSR algorithm to optimize the selection of MPR sets.

The study of reference [18] focuses on a deep learning-based approach for personalized anticancer treatment recommendation called the Siamese response deep factorization machines (SRDFM) network, which directly ranks the drugs and delivers the most effective drugs. The relative position (RP) between medications for each cell line was calculated using a Siamese network (SN), a form of deep learning network made up of identical subnetworks that share the same architecture, parameters, and weights. The effectiveness of the SRDFM has been demonstrated by the experiment results on both single-drug and synergetic drug data sets. The study of reference [19] focuses on how the Internet of Vehicles (IoV) may gather traffic statistics from a variety of sensor-collected data. The development and use of the IoV, however, have been severely constrained by the lack of data, abnormal data, and other low-quality issues to address the issue of missing data in an extensive network of roads. A new method of estimating missing data using tensor heterogeneous ensemble learning based on fuzzy neural networks, called FNNTEL, is proposed in the study. A large number of experimental tests demonstrate that the new method outperforms other widely used technologies and various models for generating missing data. The study of reference [10] takes into account a typical delay-tolerant application scenario with download requests for a subset of vehicles known as Vehicles of Interest (VoIs) in the study. The distribution of the files to the VoIs is aided by other vehicles without download requests as each VoI downloads a unique huge file from the Internet. The usage of V2I and V2V communications, vehicle mobility, and collaboration between infrastructure and vehicles are all explored as part of a cooperative communication strategy that aims to increase the capacity of vehicular networks. The numerical outcome demonstrates that, especially when the proportion of VoIs is minimal, the suggested cooperative communication technique greatly increases the capacity of vehicle networks. In reference [20], the authors present an LLECP-AOMDV, or link lifetime and energy consumption prediction-based, ad hoc on-demand multi-path distance vector

(AOMDV) routing protocol for mobile edge computing. The outcome demonstrates that the proposed LLECP-AOMDV is superior to the other three protocols under the majority of network performance indicators and parameters, increasing network lifetime, decreasing node energy consumption, and lowering average end-to-end delay. For mobile edge computing, the protocol is highly helpful.

In the study of reference [21], the authors suggest a novel AODV clustering algorithm based on edge computing. The vehicle nodes' energy and speed are taken into consideration when optimizing the AODV routing protocol, which separates communication into vehicle to vehicle (V2V) and vehicle to road (V2R) modes. The algorithm improves the routing efficiency of the high-speed mobile. The method has been shown to be practical in experiments, lowering end-to-end delay, network topology management overhead, and improving packet delivery rate when compared to alternative approaches in a variety of settings. The study of reference [22] focuses on the task offloading system of the Internet of vehicles (IoV). When modeling, it takes into account the presence of several MEC servers and suggests a dynamic task offloading system based on deep reinforcement learning. To prevent dimensional disaster in the Q-Learning algorithm, it enhances the conventional Q-Learning algorithm and blends deep learning with reinforcement learning. According to the results of the simulation, the suggested algorithm performs better under varied workloads and wireless channel bandwidth in terms of delay, energy use, and overall system overhead.

The study of reference [23] suggests a revolutionary multiuser fine-grained offloading scheduling for IoT. In order to optimize the execution location and scheduling order of subtasks, we regard the computation task as a directed acyclic graph (DAG). To solve the CMOP, an improved NSGA-II algorithm is suggested. The suggested approach is capable of achieving local and edge parallel processing, which significantly lowers the delay and energy usage. The proposed algorithm-m can reduce energy consumption by up to 10 to 50% to no-segmentation and related segmentation methods. Additionally, the suggested algorithm is capable of making the best choice in real-world scenarios.

3. Methodology

3.1. Hybrid Broadcasting Method.
This term refers to integrating two or more existing broadcasting systems. We use a combination of neighbor knowledge and probability approaches in our scenario. Because, according to reference [6], it indicates that in the probability technique, the performance in dense and sparse area networks is good, and in the neighbor knowledge method, it is very good. In the probability technique, packet rebroadcasting is moderate, while in the neighbor knowledge method, it is low. We examine the benefits of these strategies in our research. We use neighbor knowledge and probabilistic method to create flooding with a self-pruning and probabilistic scheme.

3.2. Computation of Uncovered Nodes.
The source node sends route request (RREQ) messages to intermediary nodes in this phase of computation. Assume that s is the source node, sending the RREQ packet to node i. The RREQ packet from s can be used by Node I, an intermediary node, to compute how many of its neighbors have been exposed by the RREQ packet from s. According to Node I, the uncovered neighbors set U I is computed [4]:

$$U(i) = N(i) - [N(i) \cap N(s)], \tag{1}$$

where $N(i)$ and $N(s)$ are neighbors set of nodes i and s, respectively.

Figure 1 shows how source node 1 broadcasts an RREQ packet to all of its neighbors' nodes 2, 3, 4, and 5. We assume that node 5, an intermediary node to source node 1, receives an RREQ packet and uses the RREQ neighbor list to compute its uncovered neighbors. As a result, node 4 shares a shared boundary with node 5 and source node 1. We obtain nodes 6 and 7 as the uncovered neighbor nodes for node 5 by ignoring this common node and source node 1 from the neighbor list for node 5.

3.3. The Proposed Algorithm Description.
The standard AODV routing process broadcasts route request to all nodes. In the proposed scheme, only the selected nodes broadcast the RREQ. When a message is transmitted, only a subset of nodes in each neighborhood is allowed to transmit. Our proposed scheme is called an optimized and energy efficient AODV routing protocol based on dynamic forwarding probability (AODVI). In this proposed scheme, some parameters used are defined [7] in Table 1.

3.4. The Proposed Algorithm.
We use the hybrid broadcasting technique by merging two algorithms (as bench mark algorithm reference [7] and adding to it uncovered neighbor nodes [4]). So, our proposed algorithm is defined as below:

Any node n_i, $i = 1, 2, 3, \ldots, n$ receiving the RREQ message will process the packet as follows:

For the RREQ message originating from S destined for node D that is received by node n_i process it if $n_i \neq S$ and $n_i \neq D$ (i.e., n_i is an intermediate node) as follows:

We compute the uncovered neighbors set ($U\{n\_i\}$)

$$U\{n\_i\} = N(ni) - [N(ni) \, n \, N(s). \tag{2}$$

Node n_i resolves its neighborhood density β_i

If the uncovered neighbors set is zero, the intermediate node desists from retransmitting the broadcast packet to its neighbor node.

If $U\{n\_i\} \leq D$ then
Forward the RREQ packet
Else
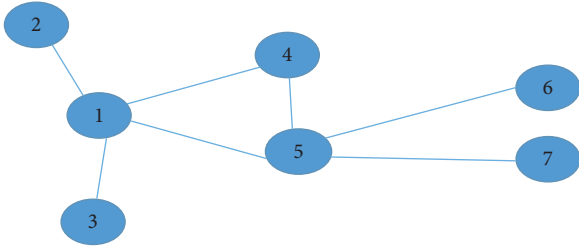Calculate the message forwarding probability P_i at node n_i.

FIGURE 1: Scenario for uncovered neighbors.

$$pi = \left(\frac{U\{n\_i\}}{100} * D * Cf \right) - - - (6) \text{ For } Cf \quad 0 < Cf \le 1. \quad (3)$$

If $R < Pi$ forward the RREQ message otherwise.

Ignore and drop the RREQ message.

Figure 2 shows that when source node (S) wants to send a message to destination node, S searches its route table for a route to destination node. If there is no route, S initiates a RREQ message with the following components:

(i) The IP addresses of S and destination node.

(ii) The current sequence number of S and the last known sequence number of destination node.

(iii) A broadcast ID from S. This broadcast ID is incremented each time S sends a RREQ message.

(iv) Number of neighbors list of S's (which is not present in original AODV RREQ format).

The intermediate node receives the RREQ from S and compute the uncovered neighbor nodes (nodes which are not covered by the sender node). After that, the intermediate node decides to rebroadcast the RREQ packet or not based on the following criteria: If the intermediate node has less than the minimum requirement number of neighbor list (D), then it rebroadcast the RREQ packet to its neighbors, and if the intermediate node has greater than the minimum requirement number of neighbor list, then it will rebroadcast the RREQ packet based on the forwarding probability (P_i) and generated random number (R). If R is less than P_i, then the intermediate node forwards the RREQ to its neighbors otherwise drops the RREQ.

3.5. Cost Analysis of the Proposed AODV and with Other Variants of AODV.
The original AODV routing protocol works as follows:

As shown in the Figure 3, we assume all nodes are active and if node 1 (source node) wants to send data to node 6 (destination node) and node 5 has a fresh route to node 6:

Node 1 checks its routing table whether it has a route to node 6 or not. If node 1 has a route, then it sends the data. Otherwise, node 1 generates the RREQ packet and flooding to its entire neighbor nodes (i.e., 2, 3, and 4). Then, each node receives the RREQ packet and checks their routing table whether they have a route to node 6 or not.

Node 2 checks its routing table and if it does not have a route to node 6, then it rebroadcasts the received RREQ packet to its entire neighbor nodes 1 and 3 but nodes 1 and 3 drop the received RREQ packet because they have the RREQ packet before with the same broadcast id and sequence number.

Node 3 checks its routing table and if it does not have a route to node 6, then it rebroadcast the received RREQ packet to its entire neighbor nodes 1, 4, and 5. Node 5 has a route to node 6 but the other nodes drop the received RREQ packet because they have the RREQ packet before with the same broadcast id and sequence number.

Node 4 checks its routing table and if it does not have a route to node 6, then it rebroadcasts the received RREQ packet to its entire neighbor nodes 1 and 3. Nodes 1 and 3 drop the received RREQ packet because they have received the RREQ packet before with the same broadcast id and sequence number.

Finally, node 5 has a fresh route to node 6; as a result, formation of the reverse path from node 6 to node 1 is created then the formation of forward path from node 1 to node 6 will be created. Therefore, the communication between node 1 and 6 starts. Since the entire active nodes (intermediate nodes) are expected to rebroadcast the received RREQ packet until it reaches to the destination node 6. From the abovementioned scenario, we can understand that in the original AODV, the number of packets drop increases because of the redundant rebroadcasting RREQ packets. As a result, this leads to increase the power consumption and decrease the throughput of the AODV routing protocol in general degraded the performance of MANET.

As shown in Figure 3, we assume all nodes are active and if node 1 (source node) wants to send data to node 6 (destination node):

(i) If node 1 has a route to node 6; the procedure is the same with the original AODV. Otherwise, node 1 initiates the RREQ packet and broadcasts to its neighbor nodes 2, 3 and 4; the procedure is the same with the original AODV. Nodes 2, 3, and 4 receive the RREQ packet and check their routing table whether they have a route to node 6 or not which is the same with the original AODV but in addition to that they rebroadcast the received RREQ packet depending on the probability (p). p depends on the number of neighbors (Bi), minimum number of neighbors (d), control factor (C), and random number (R). As a result, only a subset of nodes rebroadcast the received RREQ packet or a node is not expected to rebroadcast the received RREQ packet to its entire active nodes like the original AODV routing protocol. AODVE compared to the original AODV reduces the redundant number of RREQ packet. This shows that as compared to AODV good in performance.

TABLE 1: The proposed algorithm parameter description.

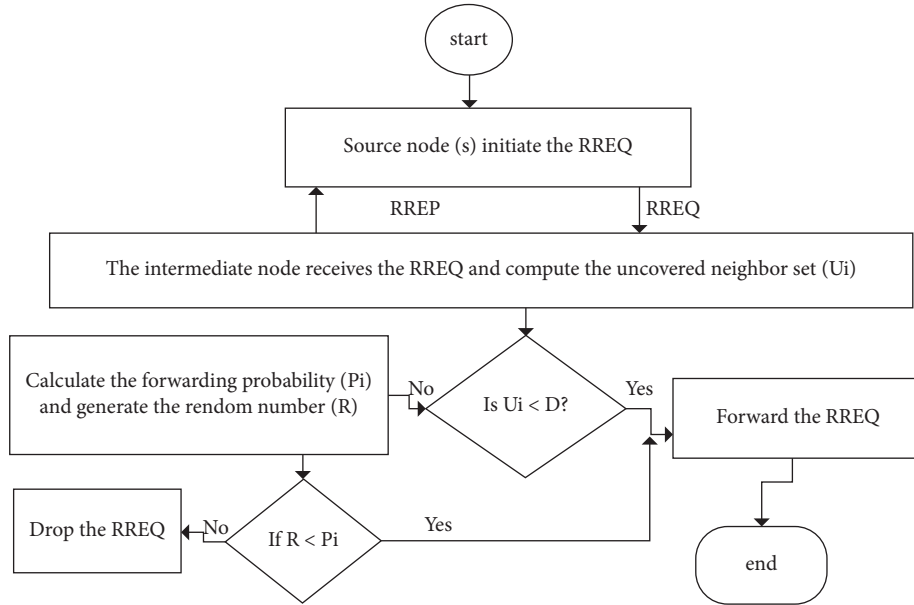|	
N	The total nodes in the networks
n_i	Any node n_i, $i = 1, 2, \ldots, n$ that receives the RREQ message
P_i	Packet forwarding probability
β_i	The number of neighboring nodes of node ni
D	Minimum number of neighboring nodes—if the number of threshold values at a forwarding node ni, is less than or equal to D, then that node will forward the RREQ message to avoid path failure or network partitioning
Cf	It is a control factor which can be used to adjust the probability Pi
R	Random number (between 0 and 100). This is used to generate varying conditions in the network
$U \{n_{\_i}\}$	Uncovered neighbors set of nodes ni

FIGURE 2: The flowchart of the proposed algorithm.

Node 1 rebrodcast RREQ

Node 2 rebrodcast RREQ

Node 3 rebrodcast RREQ

Node 4 rebrodcast RREQ

Node 5 has a fresh route to node 6

communication between node 1 and 6

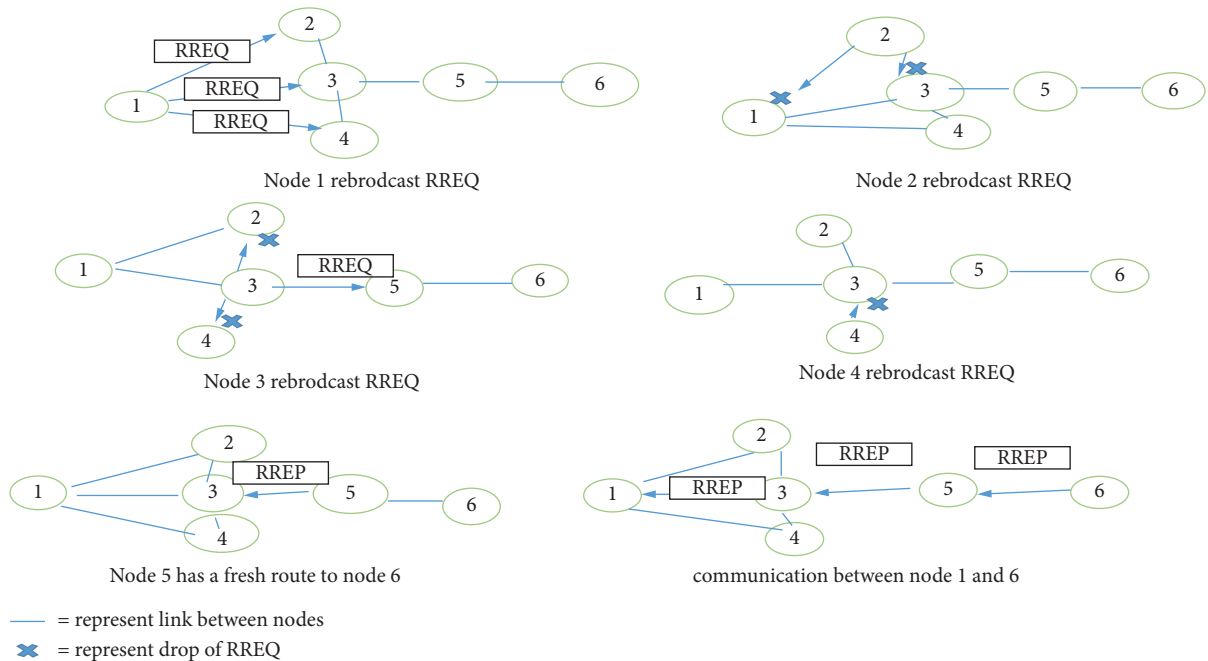⎯⎯ = represent link between nodes

✖ = represent drop of RREQ

FIGURE 3: AODV RREQ mechanism.

An optimized and energy efficient AODV routing protocol based on dynamic forwarding probability (AODVI):

As shown in Figure 4, we assume all nodes are active and if node 1 (source node) wants to send data to node 6 (destination node):

(ii) The procedure is the same with original AODV and AODVE. The difference is nodes 2, 3, and 4 compute the uncovered neighbors with node 1 (source node) before deciding to rebroadcast the RREQ packet based on formula (1) the uncovered neighbor nodes between 1 and 2 is null or zero, 1 and 3 is 5, and 1 and 4 is zero.

(iii) Node 2 checks its routing table and if it does not have a route to node 6, then node 2 rebroadcasts the received RREQ packet to its uncommon neighbor nodes between 1 and 2 which is zero. Therefore, node 2 will not rebroadcast the received RREQ packet to its entire neighbor nodes (1 and 3).

(iv) Node 3 checks its routing table and if it does not have a route to node 6, then node 3 rebroadcasts the received RREQ packet to its uncommon neighbor nodes between 1 and 3 which is node 5. Therefore, node 3 rebroadcasts the received RREQ packet from node 1 to node 5 with probability p which is the same procedure with AODVE [7].

(v) Node 4 checks its routing table and if it does not have a route to node 6, then node 4 rebroadcasts the received RREQ packet to its uncommon neighbor nodes between 1 and 3 which is zero. Therefore, node 4 will not rebroadcast the received RREQ packet to its entire neighbor nodes (i.e., 1 and 3).

(vi) Finally, node 5 has a fresh route to node 6 and then formation of reverse path from node 6 to node 1 will be created and the formation of forward path from node 1 to node 6 will be also created. Therefore, the communication between node 1 and 6 starts. But AODVI as compare to original AODV and AODVE, it reduces the number of rebroadcasting RREQ packets due to avoiding of RREQ packets to the common neighbors.

The proposed algorithm is different from the original AODV and AODVE because of the following reason.

(vii) First, it computes the uncommon neighbor nodes before deciding to rebroadcast the RREQ packet (i.e., nodes which are not covered by the sender node). After that, the procedure is the same with AODVE.

4. Simulation and Analysis of Results

After implementation of the system is done, it must be tested for its performance. Then, the results are obtained in trace files and manipulated accordingly to calculate the required parameters. The simulation of our proposed algorithm is done with Network Simulator 2 (NS2), since NS2 is an open source (easily available).

4.1. Simulation Parameter Setup. We must demand the setting of simulation parameters for simulation and outcome analysis. Table 2 depicts the aggregated simulation parameter.

4.2. Performance Evaluation Metrics. To evaluate the performance of routing protocols, various quantitative metrics are practiced [24]. Three separate quantitative indicators were used in our research study to examine the performance of routing protocols against node mobility, traffic load conditions, and the size of mobile nodes. The following are the three key performance parameters that are taken into account while evaluating various routing protocols [24]:

(a) Throughput: The throughput of a network is a measure of how quickly packets can be sent.

$$\text{Average Throughput} = \frac{\text{Number of Bytes Recevied} * 8}{\text{Simulation time} * 1000} \text{ kbps.}$$

(4)

(b) Energy: Because energy plays such a crucial part in communications, a wireless network routing system must be energy efficient. The initial value of the energy model defined in a node is the level of energy the node has at the start of the simulation. The variable "energy" in simulation reflects the energy level in a node at any given time.

(c) Routing Overhead: It is the number of routing packets sent to the destination per data packet sent. Routing overhead is defined as all packets transmitted or forwarded at the network layer. It is also the number of routing packets needed to communicate over a network.

$$\text{Routing Overhead} = \frac{\text{Numbe of RTR packets}}{\text{Data packets}}.$$

(5)

4.3. Simulation Results: Effect of Mobility. The stop period was varied from 0 seconds (high mobility) to 100 seconds (low mobility) to examine the influence of mobility (low mobility). The maximum number of connections is set to 20 and the number of nodes is set to 40. The graphs in Figures 5–7 indicate the impact of mobility on three performance indicators for the AODV, AODVE, and AODVI protocols (throughput, energy and routing overhead).

4.3.1. Throughput. As shown in Figure 5, the throughput of AODVI is good at pause times (0, 15, 30, 50, 80, and 100 seconds), so the performance of AODVI protocol improves as mobility increases, and the throughput is increased by 29.42 percent and 6.8 percent for pause time 0, 28.6 percent and 7.2 percent for pause time 30, 34.9 percent and 2.4 percent for pause time 50, and 30.8
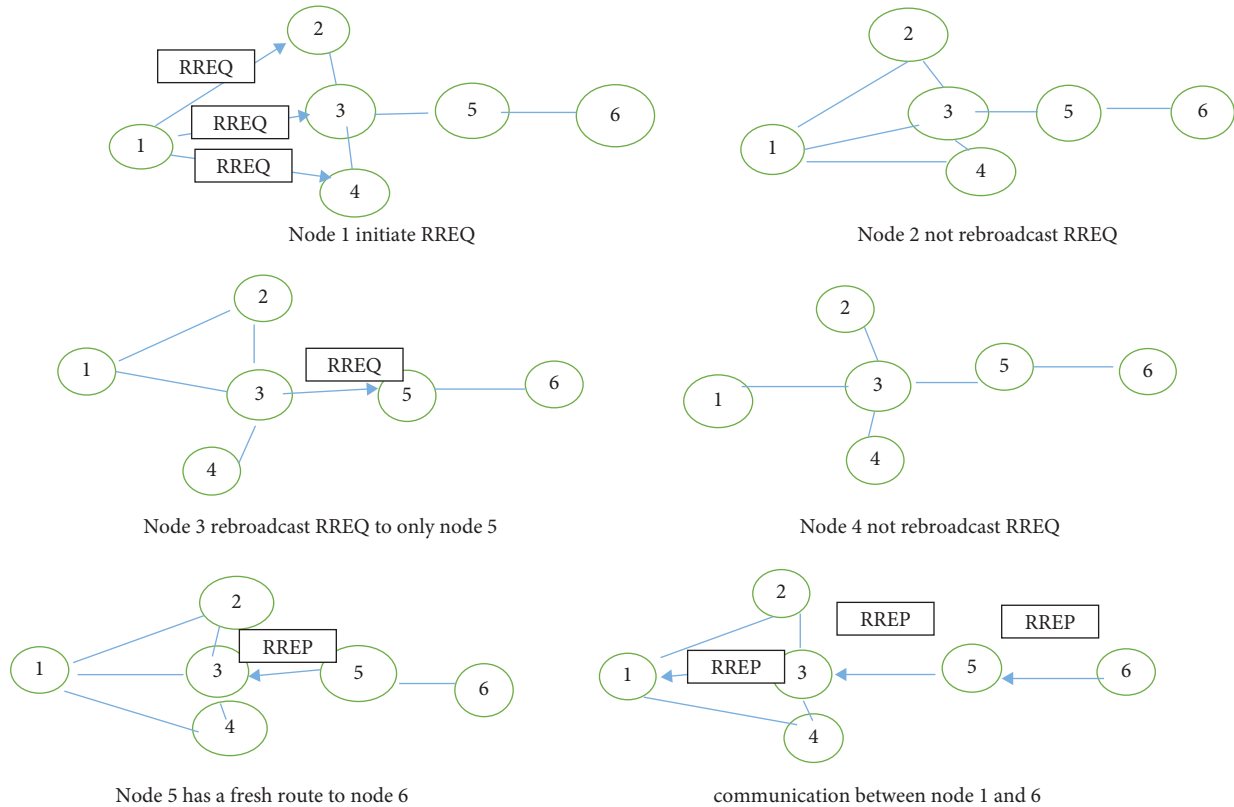
Node 1 initiate RREQ

Node 2 not rebroadcast RREQ

Node 3 rebroadcast RREQ to only node 5

Node 4 not rebroadcast RREQ

Node 5 has a fresh route to node 6

communication between node 1 and 6

FIGURE 4: AODVI RREQ mechanism.

TABLE 2: Simulation parameters.

Parameter	Value
Simulator	Network Simulator (NS-2) (version 2.35)
Routing protocol	AODV, AODVE, and AODVI
Simulation time	200 seconds
Number of nodes	20, 40, 60, 80, and 100
Traffic model	Constant bit rate (CBR) over UDP
Packet size	512 bytes
Pause time	0, 30, 50, and 100
Mobility	1 to 40 meter/second
Area	800 m * 8000 m
Packet rate	4 packets/second
Maximum number of CBR connection	5, 10, 15, 20, and 30
Mobility model	Random way point
Network interface type	WirelessPhy
Max packet in queue	50
MAC layer protocol type	IEEE 802.11
Interface queue type	Drop Tail/PriQueue
Antenna model	Omni Antenna
Tx power of the nodes	0.4 watts
Rx power of the nodes	0.3 watts
Initial energy of the nodes	100 joules

percent and 7.4 percent for pause time 100, respectively, when compared to AODV and AODVE as the pause period lengthens, the throughput continues to rise. As a result, AODVI has a higher throughput at both high and low mobility. Because the suggested algorithm allows the source node to transfer data to the destination node, this result is realized. Before deciding to rebroadcast the RREQ packet to its neighbor nodes and rebroadcasting the RREQ's with probability p, the intermediate node computes or calculates its unusual neighbor nodes. It reduced the number of RREQ packets supplied to nodes that did not need to receive them and were not expected to rebroadcast the RREQ packets in this circumstance. Only a small portion of the network's nodes are expected
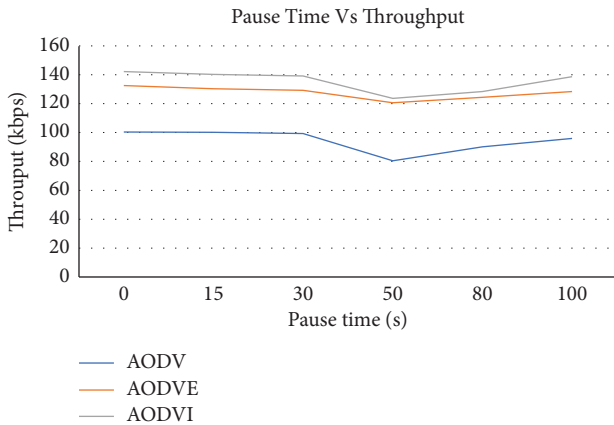
Figure 5: Pause time vs throughput.

to fail rebroadcast the RREQ packets. Generally, it reduced number of redundant rebroadcasts RREQ packets and number of packets dropped.

4.3.2. Energy. Figure 6 shows that AODVI consumes less power (power used for transmitting and receiving) and the remaining energy increased by 8.97% and 2.58% for pause time 0, 6.27% and 2.63% for pause time 30, 8.05% and 2.44% for pause time 50, and 6.33% and 2.63% for pause time 100, respectively, compared to AODV and AODVE protocols. However, we did not add the power consumed by idle in our simulation. Because the proposed algorithm only forwards the message to a particular fraction of the n neighbors dependent on the density of its neighbors, this result is obtained (only a subset of nodes from n nodes in the network are transmitted and received the RREQ packets or the energy consumed for transmitting and receiving is reduced). This preserved the battery power and double the lifetime of the network.

4.3.3. Routing Overhead. As shown in Figure 7, the proposed AODVI has less routing overhead (in both high and low mobility) than AODV and AODVE, which is reduced by 58.2% and 22.4% for pause time 0, 47.4% and 15.8% for pause time 30, 34.3% and 10.1 percent for pause time 50, and 58.9% and 23.5% for pause time 100, respectively. Because only a portion of the network's nodes engage in sending and receiving control packets, the suggested technique is limited. This results in a drop in the number of control or routing packets generated by the routing protocol, as well as a reduction in the number of packets delivered or forwarded at the network layer. It decreased the number of RREQ packet broadcasts, which add to the network's routing stress.

4.4. Simulation Results: Effect of Traffic Load. The number of connections was varied as 5, 10, 15, 20, 25, and 30 connections, and the number of nodes was taken as 40 to evaluate the effect of traffic load on the network. The network was simulated with a pause duration of 0 seconds for a high mobility scenario. Figures 8–10 depict the impact of traffic load on throughput, energy, and routing overhead performance parameters for the AODV, AODVE, and AODVI protocols.

4.4.1. Throughput. As illustrated in Figure 8, as traffic load grows, the proposed AODVI performs better and throughput increases (improves) by 25.0% and 4.0% for maximum connection, respectively. In comparison to AODV and AODVE, 10, 18.6% and 2.4% for maximum connection 15, 21.7% and 2.3% for maximum connection 20, and 19.7% and 9.9% for maximum connection 30. As a result, when the network's traffic load increases, AODVI's throughput outperforms the competition. Because the neighbor knowledge information is used in the route discovery phase in our suggested approach (not flooding the RREQ route discovery into the entire node in the network which consumes network resource).

4.4.2. Energy. In comparison to AODV and AODV, the proposed AODVI consumed less power and the remaining (residual) energy increased (improved) by 7.3% and 3.1% for maximum connection 10, 4.2% and decreased 0.2% for maximum connection 15, 7.3% and 3.1% for maximum connection 20, 7.3% and 3.1 percent for maximum connection 30, 7.3% and 3.1% for maximum connection 30, and 7.3% and 3.1% for maximum connection 30. As a result, AODVI's energy usage is lower when compared to traffic load. As a result of our suggested approach, the number of participating intermediate nodes in the network was reduced. This translates to fewer nodes in the network consuming electricity for transmitting and receiving data.

4.4.3. Routing Overhead. As it can be seen in the Figure 10 AODVI has less routing overhead (in both high and low traffic load) and decreased by 40.3% and 11.3% for maximum connection 10, 49.6% and 12.6% maximum connection 15, 56.5% and 17.2% for maximum connection 20, and 43.3% and 16.2% for maximum connection 30 than AODV and AODVE, respectively. Since the proposed algorithm reduced RREQ packet broadcasts that increase the routing load in the network.

4.5. Simulation Results: Effect of Size of Mobile Nodes. The number of mobile nodes was modified as 20, 40, 60, 80, and 100 to evaluate the influence of network size on the network, with the maximum connection set at 20 for each. The network was simulated with a pause duration of 0 seconds for a high mobility scenario. Figures 11–13 show the effect of increasing the number of mobile nodes in the network on throughput, energy, and routing overhead performance parameters for the AODV, AODVE, and AODVI protocols.

4.5.1. Throughput. As shown in Figure 11, as the size of mobile nodes grows, AODVI performs better and throughput increases (improves) by 15.3 percent and 8.2% for size of mobile nodes 20, 21.7% and 7.2% for size of mobile
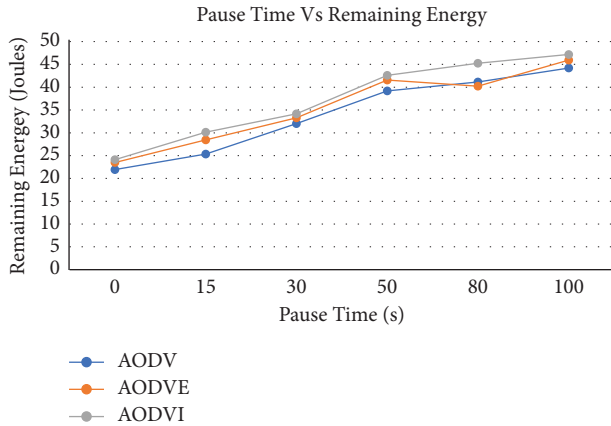
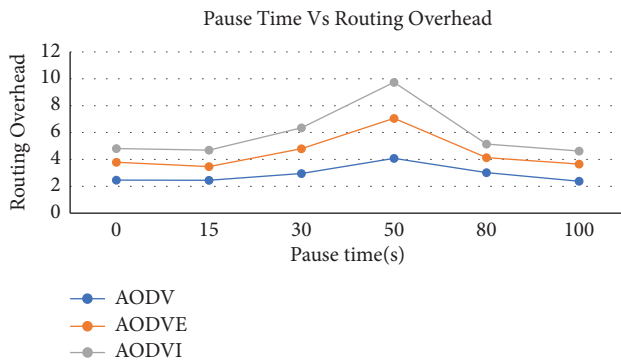FIGURE 6: Pause time vs remaining energy.

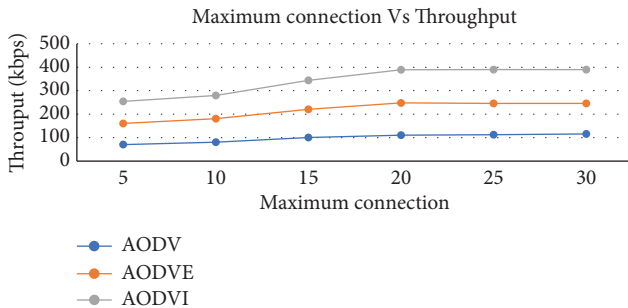FIGURE 7: Pause time vs routing overhead.

FIGURE 8: Maximum connection vs throughput.

nodes 40, 30.8% and 0.5 percent for size of mobile nodes 80, 30.2% and 8.9% for size of mobile nodes 80, and 23.6% and 4.1 for size of mobile nodes 100, respectively, as compared to AODV. As the size of mobile nodes increases, AODVI throughput outperforms others.

4.5.2. Energy. As shown in Figure 12, AODVI consumes less power and increases (improves) the remaining (residual) energy by 26.2% and 13.5% for sizes of mobile nodes 20, 7.3% and 3.1% for sizes of mobile nodes 40, 4.2% and 2.3% for sizes of mobile nodes 60, 9.5% and 3.9% for sizes of mobile nodes 80, and 3.6% and 1.4% for sizes of mobile nodes 100, respectively, when compared to AODV As a

result, AODVI's energy consumption is lower when compared to the size of mobile nodes.

4.5.3. Routing Overhead. As shown in Figure 13, AODVI has lower routing overhead than AODV and AODVE, decreasing by 3.0% and 2.0% for size of mobile nodes 20, 46.7% and 28.2% for size of mobile nodes 40, 45.5% and 8% for size of mobile nodes 60, 41.3% and 16.6% for size of mobile nodes 80, and 47.6% and 18.9% for size of mobile nodes 100, respectively. AODVI has a lower routing overhead than the competition. However, according to our suggested method, when a source has data to send to a destination, it broadcasts an RREQ and its neighbor list for that destination. Before using the route ID, intermediate nodes receiving the RREQ check to see if they have received the same request. It is not the destination and does not have a current path to the destination; hence, it rebroadcasts the RREQ to nodes that are not neighbors of the sender and recipient nodes. As a result, the network's routing overhead is decreased.

5. Discussion

In general, we simulated and assessed the performance of the original AODV, AODVE, and AODVI routing protocols using various situations such as mobile node size, traffic load, and stop time in this work. We employed the simulation parameters provided in Table 2, as well as performance evaluation parameter metrics such as throughput, used power, and routing overhead, to simulate. In terms of throughput, routing overhead, and used power, the simulation results show that the suggested method outperforms the original and improves AODV. For route discovery, the original AODV uses a basic flooding mechanism in which a source node broadcasts to all nodes in the network. This strategy, on the other hand, increases network traffic and depletes battery power. However, our proposed solution effectively solves the performance issues caused by AODV routing protocols by converting to a probabilistic message forwarding scheme (a forwarding scheme that uses a probability to choose the number of nodes to forward the messages) which reduces the routing message overhead and thus AODV power consumption. This can be accomplished by eliminating any redundant broadcasting from nodes using a dynamic probability, with the forwarding probability being the most critical aspect in this system. As a result, the suggested system performs admirably in terms of throughput, routing overhead, and power consumption. However, due to the utilization of neighbor node information, routing overhead and consumed power issues still exist, and those nodes selected to relay the route request may not have enough energy to do so.

Broadcasting in MANETs is basic operation especially in AODV routing protocol. In the original AODV, when the source node wants to communicate with the destination node it floods the RREQ to all neighbors until it gets a route to the destination. This leads to redundancy of RREQ packet. Since there are several papers [6, 8, 10, 12, 14, 17, 25–28],
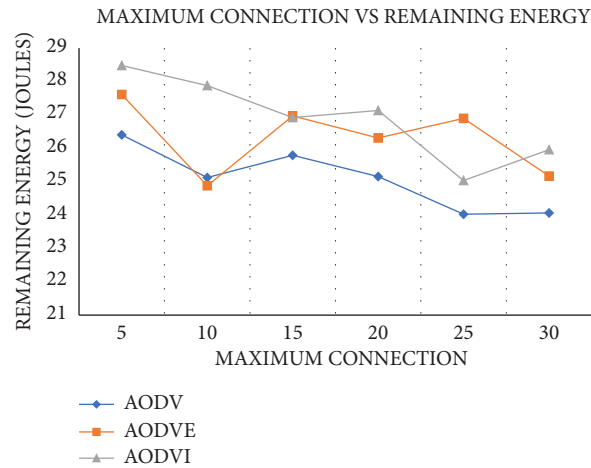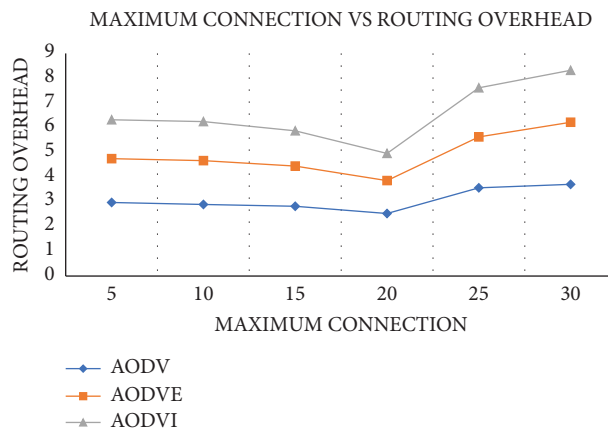
MAXIMUM CONNECTION VS REMAINING ENERGY

FIGURE 9: Maximum connection vs remaining energy.

MAXIMUM CONNECTION VS ROUTING OVERHEAD

FIGURE 10: Maximum connection vs routing overhead.
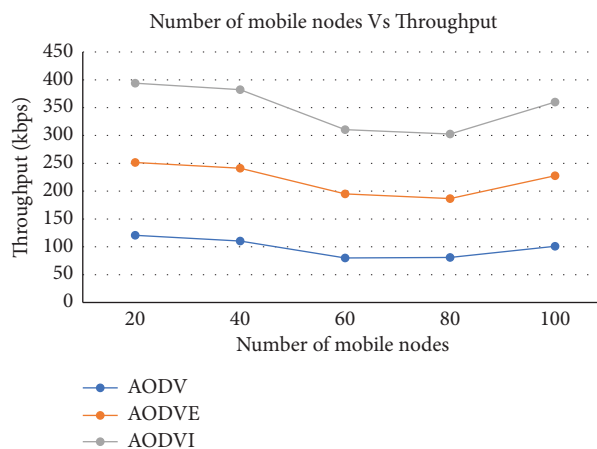
Number of mobile nodes Vs Throughput

FIGURE 11: Number of mobile nodes vs throughput.

broadcasting by flooding is usually very costly and will result in serious redundancy, contention, collision, and so on. Flooding is a commonly used method for broadcasting of the route request (RREQ) packet which is prone to broadcast storm problem, which may deliver packets to too many nodes (in the worst case, all nodes reachable from sender may receive the packet). As a result, there is a need of an efficient routing strategy to build a reliable route which can neglect high variation of signal strength, collision and draining of battery power [6, 28]. The objective of this
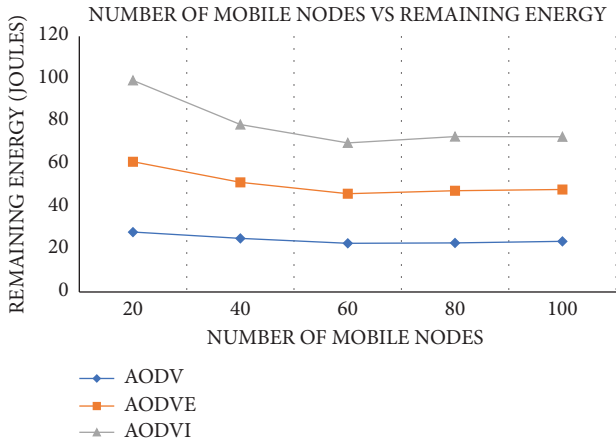
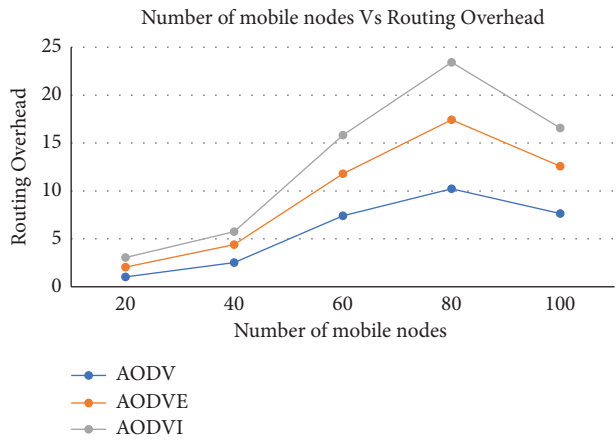FIGURE 12: Number of mobile nodes vs remaining energy.

FIGURE 13: Number of mobile nodes vs routing overhead.

research work is to improve performance (i.e., energy consumption, routing overhead, and throughput) in the AODV routing protocol by modifying the RREQ forwarding probability. The significance of this work is to minimize the number of broadcastings RREQ in modifying the route control mechanism (AODV routing protocol). Thus, the sender node broadcasts the RREQ packets transmit with probability rate on the wireless Ad Hoc network environment. Consequently, the sender node can benefit from bandwidth utilization and energy conservation, increasing the throughput of the network. Generally, the significance of this study is to optimize the resources and to communicate with an efficient way.

6. Conclusion and Future Work

6.1. Conclusion. Broadcasting is a hot topic in MANETs research. One of the most challenging issues is reducing the number of rebroadcast packets while maintaining adequate retransmission and packet reachability. This paper offers a new route discovery process for MANETs that increases routing performance. It incorporates neighbor knowledge as well as probability approaches. As a result, our technique eliminates the amount of redundancy rebroadcast packets when compared to

existing dynamic density driven route request forwarding algorithms. We investigated AODV protocol versions and their performance in three outcome measures as well as in mobile scenarios using simulations generated in NS2. For transmitting route request messages, AODV has been updated to employ a dynamic forwarding probabilistic technique. AODVI is the name given to the modified version. After implementing and simulating our proposed and benchmark algorithms, we discovered that the throughput, energy consumption, and routing overhead of the AODV, AODVE, and AODVI routing protocols with various scenarios were significantly different (varying pause time, maximum connection, and size of mobile nodes). Our proposed technique effectively reduces the number of repeated (unwanted) rebroadcast packets of the AODV routing protocol in MANETs, as demonstrated by the simulation results. For pause time (0, 30, 50, and 100 seconds) in a 40 nodes scenario, the throughput, remaining energy, and routing overhead improved by 30.68%, 7.405%, 49.7%, and 5.95%, 2.57%, 17.95%, for maximum connection (10, 15, 20, and 30) in a 40 nodes scenario, the throughput, remaining energy, and routing overhead improved by 21.257%, 6.25%, 47.425, and 4.65%, 2.275%, 14. This implies that the routing protocol's throughput, energy consumption, and routing overhead have all improved.

6.2. Future Work. We updated the AODV routing protocol in NS-2 for this paper. To achieve so, we employed a dynamic forwarding probability (P) that is dependent on the control factor (C), the minimum neighbors (d), and the random number (R). However, throughout the simulation, we utilize $C = 0.65$ as a constant, making C variable dependent on the application, which is considered a future work. For simulation, we changed the pause duration, maximum connection, and size of the mobile nodes, as well as the throughput, energy, and routing overhead performance evaluation parameters. Other characteristics (such as packet delivery ratio and delay) could be tested in the future. Other MANET routing protocols, such as dynamic source routing protocol (DSR), can be tested with this proposed approach.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Additional Points

The aim of the study was to analyze the performance of the original AODV, AODVE, and AODVI routing protocols; to test the AODV, AODVE, and AODVI routing protocols; and to reduce the number of rebroadcast packets.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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