RESEARCH ARTICLE

Efficient Performance Analysis of Energy Aware on Demand Routing Protocol in Mobile Ad-Hoc Network

Rajendra Prasad P | Shiva Shankar

Department of Electronics & Communication Engineering, Sri Venkateshwara College of Engineering, Bengaluru, India

Correspondence
Rajendra Prasad P, Department of Electronics & Communication Engineering, Sri Venkateshwara College of Engineering, Bengaluru, Karnataka, India. Email: rajisvec@gmail.com

Abstract
In a networking scenario, energy protocols with shortest path routing mechanisms are prevalent. The challenging issue in designing the routing protocols for a mobile ad hoc network (MANET) is to have a network, which is energy efficient so as to maximize network performance. This research article proposes a novel and energy efficient shortest path routing mechanism called the energy aware on demand routing protocol. The protocol maximizes the lifetime of the MANET and provides an economically efficient routing mechanism for the packets depending on the routing condition. The energy efficient routing in MANET simply establishes routes amongst the mobile nodes and protocol functions in the network as long as its energy is available. The protocol is set to minimize transmitter/receiver energy, or inactivate energy consumption when a mobile node is in idle/sleep mode. At the same time, it monitors the wireless medium for any possible communication requests from other nodes in the network. To validate the proposed energy efficient routing protocol, its performance is compared with the performance of other well-known routing protocols wherein the energy utilization in the network is also considered, namely, the dynamic source routing protocol and conditional max-min battery capacity routing protocol in the network simulator-2. The comparison is performed in terms of its packet loss, packet delivery ratio, average energy consumption, and network lifetime. The performance analysis shows that the proposed protocol is superior in terms of energy consumption for the transmission of data in the network.

KEYWORDS
CMMBCR, DSR, EA-DRP, energy consumption, MANET, packet delivery ratio, transmission power

1 | INTRODUCTION

Mobile ad hoc networks (MANETs) of the wireless networks are the future communication system to all the devices. The MANETs operate without any sophisticated architecture built as in the wired infrastructure networks. These networks are able to connect any device at any given time in the network to communicate with each other. This way of data
communication by the mobile nodes are not available in the traditional wired network, as the nodes are static or stationary in this type of network. Researchers are concentrating on the new communication methods, that is, wireless technology for the transmission of the data. A wireless ad hoc network allows the nodes to move around the network and communicates the data, without the constraints of wired networks. Implementing the wireless network in a tough condition is tranquil and deploying of this is done at a profligate time. The MANET has found many applications because of its ease that nodes can move freely, deploy at the fast rate in the network.¹

In MANET, the mobile nodes are distributed randomly wherein the mobile nodes move independently, due to which it has found a large set of applications. The major concern with the present wireless network is being the limitation of battery power, that is, energy used by the nodes, limited bandwidth, and the limited range of transmission. The mobile nodes forward packets to the neighboring nodes and while communicating with different nodes in the networks the nodes consumes the battery energy as the routes are being multihop and the nodes consume energy for their transmission/reception in the network. To consume less energy, one of the alternate methods is to budget the energy with limitation of the usage of its energy in the network. In general, the energy consumption can be affected by the variance in node energy levels, cost/packet, maximum node cost, and time to network partition, which provides the minimum energy route, by which the overall energy consumption for delivering a packet is minimized. The energy consumption in MANETs is affected mainly by, time to network partition, that is, the network should distribute energy consumption evenly to each of the node links in the network throughout the path providing minimum energy consumption path, and the path for data transmission is selected by the existing routing algorithm with it. In providing the minimum energy cost metrics for each node, the network may result in unbalanced disrupting overall functionality due to characteristics of the nodes, which try to burden the network performances and consumes more energy, than the required energy consumption.² This proposed work specifies the energy aware routing techniques in these types of the network. To improve this energy consumption and distribution in the network by the nodes, that maximizes the node lifetime in the network.

A MANET is a collection of \( n \) number of mobile nodes that are randomly deployed in an ad hoc manner as shown in Figure 1, wherein the nodes connect to the wireless medium forming lively network with wireless links in providing paths for data transmission within the network. The MANETs allows the nodes to choose the links for transmission, allowing new nodes to join the network, and also the nodes in the network can leave the network anytime. In MANETs, the nodes are not stationary and it needs to be routed efficiently as the network coverage size is large.

Mobile networks have found many applications in the recent years due to infrastructure less network and its ease of use anywhere. As MANETs are infrastructure less types, the source to destination paths are changing, which results in the quality performance of the network. Furthermore, asymmetric links are also possible.³ New energy aware routing protocol is needed to satisfy this specific requirement of networks. Even though many existing protocols are available, but these protocols are limited, such for the shortest path, node cost in terms of overhead incurred those results in reducing the efficiency of the network.

The usage of this network also includes many challenges in the form of its energy consumption by the nodes in the networks. The challenges in the MANETs are as follows, enhancing routing algorithm, which consumes minimum energy for their transmission in the MANETs. MANET routing algorithms use the shortest path for routing from source to destination. The selection of the paths is done using many topologies and each of these methods energy consumption is high. The major possibilities available of the energy consumption in the network considering all the transmitting, idle, routing, and reception power are listed below.

![Infrastructure-less mobile ad hoc networks](image-url)
• A new node enters the network
• A node leaves the network
• Nodes energy consumption per packet
• Selecting the route paths for all the nodes in the network
• A node sending and receiving the frames/packets in the network
• Routing information updation
• Time to network partition

Minimizing this overall energy consumption during active communication in the network is also a challenging issue in MANETs. The proposed research work implementation presents the solution for the challenges in MANETs. The motivation of the proposed research work mainly focused to solve the various challenges and energy related issues in the MANETs, that is, the implementation of the energy aware on demand routing protocol (EA-DRP) for MANETs ensures nodes reduce the consumption of energy in the network by enhancing routing algorithm. The proposed research work implementation and simulation discussion are carried out using network simulator (NS-2) and the results obtained provide that there is a considerable improvements in the energy consumption are obtained and improvement in the increase network lifetime.

1.1 Problem definition

Wireless networks are growing at a very fast rate and the usage of the MANETs is widely spread. The MANETs performance depends on many parameters such as the routing path algorithms, distributed implementation, efficient usage of the bandwidth, and battery capacity. Wherein the extensive research is been going on the routing algorithms and many protocols from a variety of perspectives have been proposed. Various algorithms such as dynamic source routing (DSR) protocol are used for energy management, as it is simple and efficient designed protocols for the MANETs and conditional max-min battery capacity routing (CMMBCR) protocol are considered for the comparison against our proposed protocol. In this proposed work, energy perspective has been considered for the MANETs performance measurement. Since networks utilization of battery consumption is a very important factor for the networks efficiency and lifetime.

The article structure is organized as follows: Section 1 presents introduction and problem definition. Section 2 discusses the DSR protocol and CMMBCR protocols and the proposed EA-DRP in brief. Section 3 explained the mechanism of designing of the EA-DRP and its algorithm. Section 4 presents the comparative results with the different protocols. Finally, the performance evaluation of different energy metrics and conclusions are summarized in the last section.

2 ANALYSIS OF THE EXISTING PROTOCOLS AND PROPOSED PROTOCOL

The major related issues in wireless ad hoc network are the energy consumption in selection of the route path calculation form source node to destination node. That deals to find the best and accurate route to sink node during the mobility and network topological changes and uniformly distributed.

All these problems including reliable energy consumption and gaining accurate spectrum are considered in the earlier research work. Researchers argue with a simple algorithm implementation that describes, and which promises connectivity, strong communication, and stated node limitation to radio range wireless communication. There are many protocols are existing based on shortest path protocol mechanism and flooding algorithm is used in the proposed system. A dynamic routing algorithm is developed for possible elimination of the ideal links at the time of backbone network setup will not yield minimum energy solution for route calculation to establish and maintain the network for connection related sessions, which make use of the knowledge of rerouting configuration to cope with the nondeterministic topology changes. The shortest path routing algorithms are used in MANETs in order to know the number of hops is the path length of the routing protocols.

For a wireless radio spectrum to communicate in a mobile network, MANETs differ significantly from other existing networks, and cooperative network. The mobile nodes are dynamic in nature and also act as administration in the network topology. These nodes are self-configuring and intended to be decentralized control in the network topology. In such
networks, it is not desirable to assume all the nodes will have single hop communication with each other. Therefore, such type of networks need specialized efficient routing protocols, which provide self-starting behavior of mobility. In such situations, existing wired network routing protocols would degrades in performance. In wireless correspondence framework, there is dependably interest for new routing protocols have been on interest in MANETs. Invention of any new wireless routing protocol is classified based on the mobility and character, in which route tables are created, maintained, and updated.\textsuperscript{10}

For multihop communication various routing protocols have been proposed.\textsuperscript{11} These protocols, traditionally evaluated in terms of data rate loss, packet overhead, and route length. A growing emphasis on long-lived networks has added energy consumption as an important metric.

Network performance based on energy consumption has been major focusing area for research on routing protocols in MANETs. The designed conservative routing algorithms in Reference 12, which are performance based and optimization fairly power efficiency. For multihop communication various routing protocols have been proposed.\textsuperscript{13} These protocols, traditionally evaluated in terms of data rate loss, packet overhead, and route length. A growing emphasis on long-lived networks has added energy consumption as an important metric.

2.1 | DSR protocol

Routing protocols of this type are classified as the reactive or on demand protocols. In this protocols, the header packets routes from the source, which contains the route information to the destination. The route discoveries are identified by broadcasting query-reply sequence. A source node broadcast a header packet to all the nodes in the network, the destination nodes responses to the request from the source and the route path will be built from the source to destination with intermediate nodes.\textsuperscript{5} The broadcasting of the message from the source is initialized by the RREQ (route-request) and the response from the destination is done by the RREP (route-reply). The source to destination can have multiple paths, wherein the paths with least hop count. This path selection must be regularly updated in order to the latest route discovery between the nodes. The network will have the routing table with multiple paths of the nodes initiated with the RREQ and RREP stored in the route cache and uses this information to find the path from the source to destination. The header packet information of the nodes and its paths are updated regularly that results in more consumption of energy by sending and receiving data. This way of communication for bigger networks makes the node mobility delays, which affects its overall performance.\textsuperscript{14}

2.2 | CMMBCR protocol

The CMMBCR protocol also broadcasts the header packets in the network in search of the destination node. The source node requests the intermediate nodes to provide the information about its energy level, based on the energy level availability of the intermediate nodes.

The source node will identify the nodes to build the path to the destination as shown in Figure 2. The CMMBCR protocol has to identify the shortest path based on the energy level available in the network.\textsuperscript{6}

The protocol identifies three paths from the source (Sr) to destination (Dt) node, that is, the path 1: \{Sr, A, D, G, Dt\}, path 2: \{Sr, B, E, Dt\}, and path 3: \{Sr, C, F, Dt\}. The performance of the CMMBCR depends on the energy level of the node and its threshold for the route selection in the network.

![Figure 2](image-url)  
**Figure 2** Conditional max-min battery capacity routing network model
2.3 | Proposed routing algorithm details

In MANETs, the data transmission between any nodes requires discovering the shortest path and it should be consuming less energy and also secures the data. A routing path is built, with the source node transmitting information through an intermediate node to reach the destination node. The source node should also consider in the selection of the intermediate node with minimum threshold energy so that the node selected should be able to transmit the information till it reaches the destination node if the source and destination nodes are not in the range of transmission. The protocol should also be able to update the paths whenever any of the nodes is no longer available to transmit the information to the destination. The nodes in the network are unavailable for the following conditions:

- **Mobility**: In MANETs, as the nodes are unstable, due to its portable behavioral property, which results in the route failure of the network.
- **Energy**: In MANETs, as the node is battery-powered devices, which consumes energy for the transmission/reception of data. If the intermediate nodes deplete all its energy in the routing path before it reaches the destination node, then the nodes fail to transmit the data in the network. This energy is also one factor for the failure of the network.

In MANETs, nodes are battery limited, hence energy aware routing becomes important in the networks. The sufficient energy for the nodes to transmission/reception of the data from the source to destination is achieved by two aspects.\(^7\)

- Energy saving
- Energy consumption balance of nodes

Both the above metrics are considered in the proposed work, the nodes are energy limited for their operation in routing the information from starting to discover, route and then transmit the data to the destination, wherein the source to destination involves multiple intermediate nodes. Thus, making the energy as the precious resource, which should be efficiently utilized or else the network tends to fail. Hence, energy utilization and its consumption in these types of networks should be managed efficiently. The networks performance is depended on the energy utilization management in the transmission/reception of the nodes, which intern increase the nodes lifetime. These energy utilization resources control the node transmission energy to decide its energy levels for further preceding the data to the destination. There are so many issues and solutions, which witness the need for energy management in ad hoc wireless networks.

2.3.1 | Energy aware packet forwarding

Energy limitation strategies in the research work play an important part in the networks and minimum energy routing where the energy for a source to destination nodes transmission is reduced based on the propagation model, where the consumption of energy in the nodes idle time is made less by making the nodes sleep mode when possible.\(^8\) The nodes in the network consume energy for forwarding the packets to the intermediate nodes and when this intermediate node is chosen as the router, its consumption of energy increases at a higher rate. Thus, the nodes outstanding energy is also essential for the determination of the path without disturbance. Hence, an energy routing protocol that considers residual energy will perform better than the protocols that do not.

2.3.2 | Minimum power routing

In MANETS, the routing can be simplified by consideration of the energy, which discovers the paths through a multihop type of ad hoc network, which minimizes the total consumption of energy for the transmission/reception for the source to the destination of data packets information from the nodes. This process of energy saving is not suitable for batteries types of node. As the total number of nodes energy increases because all the nodes use the constant transmission power, thus the conventional minimum hop routing will be the most energy efficient. In this minimum hop routing, the nodes can be adjusted in accordance with the required energy of that particular node as the propagation path loss with the signal power \(p\) and distance to the next hop node \(d\) is given in Equation (1).
\[ p = \frac{1}{d^n}, \text{ where } n \geq 2. \] (1)

The nodes transmit data packets with high transmission power that can send the data through multiple intermediate nodes with low signal transmission energy, which result in lower energy consumption.9

### 2.3.3 Maximizing energy saving mode

In MANETs, energy consumption can be reduced by setting energy levels to the nodes and energy saving modes as much as possible. Energy saving mechanism can be implemented in four modes:

- **Transmitter**: nodes broadcasting, sending, or transmitting packets in the networks consumes energy.
- **Receiver**: nodes reception and replying packets to the other nodes in the network consumes energy.
- **Idle**: nodes in the network have no traffic to handle, but the nodes can overhear the traffic as the network is still active, till the destination node data is transmitted.
- **Sleep**: nodes in this will be off and stays in the saving mode.

Hence, the nodes energy consumption is transmitting, receiving, idle, and sleep mode. The consumption of energy can be reduced by making the nodes active while transmission/reception, and when the nodes are not active it can switch to sleep mode for the energy saving.

### 3 DESIGN OF PROPOSED EA-DRP

The energy saving mechanism implementation has been focused by many researchers in the recent past in the MANETs. The nodes in the network discover the paths, establish the communication between them to perform the routing functions on it. Many of the nodes fail in the network, due to energy exhaustion. This affects the overall performance of the network. In the proposed work of implementing the EA-DRP, the sending node initiates the route path mechanism from the source to destination, the source node transmits the packets through the intermediate nodes reaching to the destination with the path initiated by the source. The selection of the route is been implemented by monitoring the available energy at each of nodes and selection of the nodes is made possible by proving its energy capable of transmitting to the next node successfully.15

The key idea that we use in the design of EA-DRP for the MANETs is to avoid the direct transmission from source to destination, as it requires huge and high battery energy for transmission of data, instead of this the protocols relays on the intermediate nodes, which have minimum energy that can transmit the packets in the networks. The challenge in this protocol is to design routing algorithms, which are able to consider not only the heterogeneity power supply of nodes in route selection, but also the energy cost of packet transmission and reception over a wireless link.10

To implement this protocol let us consider a network with an energy related cost function “\( X(P) \)” to each path “\( P \)”, which is the energy cost of using that path from source to destination node.15 The cost function is given in Equation (2)

\[
X(P) = \sum_{i=1}^{h(p)} \emptyset(n_i, n_{i+1}),
\] (2)

where \( \emptyset(n_i, n_{i+1}) \) is the energy cost of forwarding a packet over the route path represented by \( (n_i, n_{i+1}) \in P \).

The nodes with minimum energy to direct the relay traffic, no energy cost is considered for forwarding to the neighboring nodes, as there is no energy lost when forwarding the packets, that is, the energy consumption is zero if both \( n_i \) and \( n_{i+1} \) are having minimum energy. However, if the \( (n_i, n_{i+1}) \) are battery power, \( \emptyset(n_i, n_{i+1}) \) includes the energy cost of packet transmission at the source node by \( (n_i) \) as well as energy cost of packet reception at the destination node by \( (n_{i+1}) \).
The node energy cost function $X(P)$ of a route path from source to destination packet transmission, which must be reduced in the network. Reducing this energy cost function, without allowing for the power cost of the minimum energy of $(n_i$ and $n_{i+1})$ will increases the number of hops in the selected route, as the longer route can be considered instead of the shorter routes with high transmission power nodes.

In the proposed protocol, when the node receives messages/commands packets from its associates, the minimal energy required for forwarding packets is denoted by $(E_M)$ and $(E_L)$ the energy included to overcome the problem of unstable links due to channel fluctuations. The channel attenuation is calculated as the difference of the transmitted energy $(E_{TM})$ and the receiver energy $(E_R)$. The average energy consumption is computed by the following Equation (3).

$$E_T = E_{TM} - E_R + E_M + E_L.$$  

(3)

The residual energy $E_{RE}$ of the node can be computed by difference of initial energy $(E_I)$ with the consumed energy $(E_C)$ as given in the Equation (4)

$$E_{RE} = E_I - E_C.$$  

(4)

Total energy consumption of all the nodes $(N)$ in the network is given by the Equation (5)

$$E_{Total} = N * E_I - E_{RE}.$$  

(5)

To understand the energy consumption in the network for the multiple paths, consider a network model as shown in Figure 3 to understand the proposed system energy routing protocol for MANET.

In the network model, the source node {S} transmits the route request [RREP] packets to all its associates node and measures the available energy of each of the node and calculates the overall energy required for the nodes for forwarding this route information till it reaches all the nodes in the network or till it reaches the destination node {D}. The route paths from {S} to {D} are as follows.

Route 1 = {S-1-5-D}, Route 2 = {S-2-3-D}, and Route 3 = {S-4-D},

The Route 2 has maximum energy compared with the Route 1 and Route 3. Based on the available multi route path considering the remaining energy at the node in the network are given in Table 1.

The benefit of having multiple hops in the network that reduces the energy consumption, instead of having high transmission power nodes to transmit data packets from source to destination. This intern increases the lifetime of the nodes in the network, as high power is not been used in these types of networks. The main focus of the research work is to implement the energy lifetime metric and balancing the energy load in all the nodes that are participating in the network.

**FIGURE 3** A mobile ad hoc mobile network model

**TABLE 1** Available energy at route path in the network

| Route path | Available energy in percentage |
|------------|--------------------------------|
| Route 2    | 80% energy available           |
| Route 1    | 43% energy available           |
| Route 3    | 39% energy available           |
3.1 | Algorithm for EA-DRP

The algorithm implementation splits the protocol functions into packet handling, which consists of forwarding application data messages, sending and receiving of control messages. This is implemented by the C++ method, loss recovery/error detection is done in C++. However, the loss recovery is entirely done through instance procedures in OTcl and session message activity, that is, sending and processing of messages is accomplished through C++, the policy about when these messages should be sent is decided by instance procedures in OTcl.

The proposed model for implementation is as shown in Figure 4.

The MANET simulation consists of the following:

- MANET formation

  The MANET formation considers parameters of the number of nodes that are randomly deployed within the space boundary. It also finds the node positions and maximum transmission radius.

- Mobile nodes migration and packet delivery event generator

  In this, the network formation of the number of active communication paths can be varied. The nodes are dependent on mobile node migration and pause interval, which are inputted at simulation setup and are handled by the routing protocol engine.

- Routing protocol engine

  In this, the routing protocol employs the route discovery and route selection process and achieves reliable packet delivery.

- Statistics analyzer

  In this, it processes packet transmission or node migration events, measures, and analysis are recorded of the energy consumption, packet loss, packet delivery ration, and network lifetime in the network.
Algorithm: The proposed EA-DRP incorporates the energy transmission control as

Step 1: In the network, an energy level of the nodes is recorded and forwarded to the next node from source to destination through the route path selected.

Step 2: When the neighboring node receives that data packet at power $P_r$, it reads the energy transmission as $P_t$ from the packet, and updates the minimum energy requirement $P_{\text{min}}$, for the neighboring nodes as following:

$$P_{\text{min}} = (P_t - P_r) + P_{\text{threshold}} + P_{\text{margin}}$$

where, $P_{\text{threshold}} \rightarrow 3.652 \times 10^{-10}$ W is the threshold power in LAN, to overcome the problem of unstable links due to channel fluctuations, a margin $P_{\text{margin}}$ is included.

Step 3: The updated minimum energy transmission, $P_{\text{min}}$ is transmitted to the neighboring nodes through acknowledgment (ACK).

Step 4: When the ACK packet is received by the neighboring nodes, it records the updated energy valve in the table and transmits the remaining packets with $P_{\text{min}}$.

Step 5: When a node in the network cannot find the energy information of the neighboring node in the routing table, which is the case of the two nodes never interchange packets before, then the node transmits with the default energy level of 280 mW.

The EA-DRP structure is used to choose the limited course of energy, thus decreasing the use of energy as the weight, network near the safety procedures near the level of energy consumption. The concentrator is that it lowers and regulates the use of the energy.

The complete process of EA-DRP is as follows:

- Network establishment: Nodes “n” is initialized within the existing network.
- The EA-DRP measures the available cost of transmission energy and also leads to energy consumption function ($P_{\text{min}}, P_t, P_r, P_{\text{threshold}}, P_{\text{margin}}$).
- Apply the EA-DRP to calculate the weight and to predict the optimal energy consumption route.

### 3.2 Key points in implementing EA-DRP

The implementation of the proposed EA-DRP has the key point as listed below:

- The energy remaining at all the intermediate nodes is measured and recorded in route cache before sending the control packets.
- The route request to all the nodes in the network is reached and the node selection based on the energy is done for the route establishment, the RREP packet is then broadcasted from the destination node.
- The neighboring nodes provide the information of the route path from the source to destination, by means of the time taken by the route reply packet to reach it.
- In the network, all the nodes follow the same procedure of selecting the nodes for transmission from the source to destination and the route path are stored in the route cache for future transmission of data.

### 4 SIMULATION SETUP AND METRIC STUDY

The proposed protocol comparative analysis is done with the existing DSR and CMMBCR protocol. For the simulation requirement totally of 50 nodes are considered, which are placed randomly in the network. The nodes in the network have 20 connection-oriented types with a moving speed of around 20 m/seconds with average pause time of 580 seconds. The initial energy capacity of 0.5 J is considered in the network with each node in Omni-Antenna direction and spends 0.4 W of energy each time when a packet is transmitted and 0.6 W when a packet received.

The implementation of the protocol is done in NS-2 and compared the performance of the proposed work EA-DRP with DSR and CMMBCR protocols. Table 2 shows the simulation parameters used in the network setup.
The metrics of the energy efficiency and network performance are studied as follows:

### 4.1 Packet loss

The packet loss for the EA-DRP, DSR, and CMMBCR with increasing the node mobility is shown in Figure 4.

The packets are dropped in network because of failure of node and links in the network. The sender comes to know about the packets dropped by route error message. The packets are then resent in new route to the receiver. Figure 5 shows the packets dropped for three routing protocols. The packets dropped in EA-DRP protocol is least (8%) as compared with DSR (42%), and CMMBCR (21%). The percentage of packet loss is calculated by Equation (7).

\[
\text{Packet loss (\%) } = \frac{\text{Sent packets} - \text{Received packets}}{\text{Sent packets}} \times 100.
\]

As the number of nodes increasing in the network, the packet loss increases in the existing protocols, as a result of more link breakages in the network.

The proposed protocol has minimum packet loss compared with the DSR and CMMBCR protocols as observed in the entire scenario.

### 4.2 Packet delivery ratio

It is the proportion ratio of quantity of bundles received by destination hub to quantity of parcels sent by the source hub. It is an important metric since it depicts the loss rate and thus reflects the throughput. For every one of the simulations,
the quantity of information bundles conveyed is kept steady. The quantity of bundles got at the destinations will give correlation about the effective underlying routing algorithm throughout for similar traffic load. Packets may fail to reach the destination because any of the following factors such as network partitions, routing loop, and interface queue drop. Packet conveyance proportion is characterized as the quantity of packet got by constant bit rate (CBR) sink at destination by number of bundles sent by CBR. It describes the percentage of packets, which reach the destination. Simulation results in this article show characteristic differences in performance between considered routing protocols mechanism used. As shown in Figure 5, achieve high values of packet delivery ratio (PDR), which means they are efficient protocols from the point of delivering packets to their destination.

\[
PDR = \frac{\sum \text{Total number of CBR packets received}}{\sum \text{Total number of CBR packets sent}}.
\]

(8)

For DSR and CMMBCR protocols, PDR is independent of mobility and number of sources, while CMMBCR has approximately the same PDR under low mobility. There is no adaptive to the route changes that occur under high mobility as EA-DRP and DSR protocols since CMMBCR protocol uses a minimum cost approach of maintaining routing information. That is why; it delivers less data packets.

In the following simulations, the mobility is varying from 5 to 50 m/seconds. The maximum node moving speed is increased to see the behaviors of the EA-DRP, DSR, and CMMBCR protocols with high mobility.

The PDR for the EA-DRP, DSR, and CMMBCR with increasing the node mobility is shown in Figure 6. The performance of the PDR decreases with increasing mobility and it can be observed that the packet deliveries were high when the nodes had low mobility.

The multicast tree structure was mostly static and, therefore, the PDR was increasing. At high frequency data, the tree links broke down quite often, leading to constant branch reconstructions and larger packet losses. In DSR, we used the power information and location information to select the more stable routing paths for multicasting. Thus, the delivery ratio of EA-DRP is higher than that of CMMBCR.

4.3 | Average energy consumption

Average energy consumed is calculated as the ratio of total energy consumed by all the nodes to the number of nodes. It is mathematically defined as

\[
\text{Average energy consumption} = \frac{\sum \text{Total energy consumed by all the nodes}}{\sum \text{Total number of nodes}}.
\]

(9)

Energy consumed (Joule) per 1 Kb data delivered is calculated as the ratio of total energy consumption during communication overall flows to the total data delivered by all the flows. A comparative study is done with respect to power consumption for the EA-DRP, DSR, and CMMBCR. The outcome of the study from Figure 6, determined that the EA_DRP
has a steady and reduced energy usage compared with DSR and CMMBCR. Consumed energy signifies the average power consumption of the sensing devices and the proposed scheme focus the performance of the sensor nodes.

The lower energy consumption observed in the Figure 7 indicates lesser power of data transmission, which intern extends the lifetime of the node and overall performance of the network. The EA-DRP protocol shows improvements in the energy consumption in comparison to the existing DSR and CMMBCR protocols. The reduction of the energy consumption is possible with the reduction of the number of nodes in the network and due to the budget energy allocation to the intermediate nodes for its transmission of data in the networks.

### 4.4 Network lifetime

Network lifetime ratio is the ratio of number of alive nodes to dead nodes in the network. Figure 8 shows the lifetime ratio measure for all three routing protocols. The lifetime ratio of EA-DRP is highest (66%), followed by CMMBCR (33%), and DSR has less than 1% of average lifetime ratio. Lifetime ratio is calculated by Equation (10).

\[
\text{Network lifetime ratio (\%) = } \frac{\text{Number of alive nodes}}{\text{Number of dead nodes}}.
\]

Figure 8 gives the result of a network lifetime for DSR, CMMBCR, and our proposed EA-DRP. The network lifetime is the validity of the mobile nodes in the network and is a vital parameter as it affects the performance of the complete network. The network lifetime can be improved by efficiently using the node energy.

In DSR, the node is always biased to become the cluster head. Thus, it consumes its battery power very fast and becomes dead. CMMBCR consumes more power compare to EA-DRP protocol. Hence, the consumption of battery power is nearly uniform for every node. Thus, EA-DRP improves the node lifetime and as a whole the network lifetime.
The performance of routing protocols such as DSR, CMMBCR, and EA-DRP are considered for the evaluation under high mobility and low mobility. The Figures 9 and 10 show the evaluation of various metrics under low and high mobility conditions.

In the case of networks, the consumption of energy is considered as one of the major issues along with other parameters such as packet loss, PDR, and network lifetime. In low mobility, the CMMBCR routing protocol has the minimum variation with respect to the various metric, but lacks in the performance, but EA-DRP performance is higher in comparison with the DSR and has less variance in compared with other protocols.

At high mobility condition, DSR has a better performance in comparison to CMMBCR. Still, at high mobility environment, the EA-DRP is a preferred choice. The simulation results of the routing protocol in network in the case of lower and higher mobility scenarios shows an optimum value for EA-DRP along with increased performance and less variation in comparison with the other routing protocols.

5 | CONCLUSION

The proposed protocol EA-DRP has been implemented with modification in the existing DSR and the energy consumption has been decreased overall in the proposed protocol. Hence, an enhancement in the energy management can be observed due to the modification and henceforth considered for the efficient energy protocol in the field of MANETs wherein many applications are available, as MANETs are rapidly growing nowadays. The contribution in this article helps a node to listen to the nearby status and decide for the shortest path considering the optimum energy in the nodes. The algorithms performance measured in terms packet loss, PDR, energy consumption, and the network lifetime, respectively. The EA-DRP algorithm averages the energy minimization decreases of the network to the great level as shown in the simulation results. The EA-DRP implemented has low energy exhaustion to facilitate communication within the network, to discover the route paths between mobile nodes in the network. The protocol showed improvement in terms of its low energy consumption for transmission of data in the network and the results show the comparison of new protocol with the existing DSR and CMMBCR protocol have been discussed. The future work is to evaluate the
proposed work against the scalability of nodes, overcome the problem of a node being common to two neighborhoods when the EA-DRP is executed by two different nodes and apply the algorithm for the different types of attacks in the MANET.

CONFLICT OF INTEREST
The authors declare that there is no conflict of interest regarding the publication of this article.

ORCID
Rajendra Prasad P https://orcid.org/0000-0003-2997-4899
Shiva Shankar https://orcid.org/0000-0003-0917-6216

REFERENCES
1. Wang N-C, Su Y-L. A power-aware multicast routing protocol for mobile ad hoc networks with mobility prediction. *Wireless Pers Commun*. 2005;43:1479-1497.
2. Vazifehdan J, Venkatesha Prasad R, Onur E, Niemegeers I. Energy-aware routing algorithms for wireless ad hoc networks with heterogeneous power supplies. *Comput Netw*. 2011;55:3256-3274.
3. Jinhui S, Harms J. Position-based routing with a power-aware weighted forwarding function in MANETs. Paper presented at: IEEE International Conference on Performance, Computing, and Communications; 2004. https://doi.org/10.1109/pcc.2004.1395026.
4. Floriano De Rango, Fotino M, Marano S. EE-OLSR: energy efficient OLSR routing protocol for mobile ad-hoc networks. Paper presented at: MILCOM 2008–2008 IEEE Military Communications Conference; 2008. https://doi.org/10.1109/milcom.2008.4753611.
5. Nithya V, Ramachandran B, Vaishanavi Devi G. Energy efficient tree routing protocol for topology controlled wireless sensor networks. *Int J Commun Antenna Propag*. 2015;5:1.
6. Parthiban P, Sundararaj G, Maniarasas P. Maximizing the network life time based on energy efficient routing in ad hoc networks. *Wireless Pers Commun*. 2018;101:1143-1155.
7. Shivashankar, Varaprasad G, Narayanagowda SH. Implementing a new power aware routing algorithm based on existing dynamic source routing protocol for mobile ad hoc networks. *IET Netw*. 2014;3:137-142.
8. Loo J, Lloret Muri J, Ortiz J(Eds.). *Mobile Ad Hoc Networks*. Boca Raton: CRC Press; 2012. https://doi.org/10.1201/b11447.
9. Santhi G. Nachiappan A. Agent based adaptive multicast routing with QoS guarantees in MANETs. 2010 Second International conference on Computing, Communication and Networking Technologies, Karur; 2010:1-7. https://doi.org/10.1109/ICCCNT.2010.5591721.
10. Rajendra PP, Shankar. Improvement of battery lifetime of mobility devices using efficient routing algorithm. *Asian J Eng Technol Appl*. 2017;13:10.
11. Venkanna U, Agarwal JK, Velusamy RL. A cooperative routing for MANET based on distributed trust and energy management. *Wireless Pers Commun*. 2015;81:961-979. https://doi.org/10.1007/s11277-014-2165-5.
12. Das SK, Tripathi S. Energy efficient routing protocol for MANET based on vague set measurement technique. *Procedia Comput Sci*. 2015;58:348-355. https://doi.org/10.1016/j.procs.2015.08.030.
13. Silva BMC, Rodrigues JPC, Kumar N, Han G. Cooperative strategies for challenged networks and applications: a survey. *IEEE Syst J*. 2017;11(4):2749-2760. https://doi.org/10.1109/JSYST.2015.2436927.
14. De Rango F, Tropea M. Energy saving and load balancing in wireless ad hoc networks through ant-based routing. Paper presented at: 2009 International Symposium on Performance Evaluation of Computer & Telecommunication Systems (Spects 2009), Istanbul, Vol. 41; 2009; 117–124.
15. Shankar S, Varaprasad G, Suresh HN. Importance of on-demand modified power aware dynamic source routing protocol in mobile ad-hoc networks. *Microwaves Antennas Propag IET*. 2014;8(7):459-464.
16. Kumar KNS, Rajendra PR, Shivashankar, Kumar SS, Gatti R. Opportunistic routing technique for minimized energy consumption for relay node selection in wireless sensor networks. Paper presented at: Proceedings of IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore; 2016; 2093–2097.

How to cite this article: Prasad P R, Shankar S. Efficient Performance Analysis of Energy Aware on Demand Routing Protocol in Mobile Ad-Hoc Network. *Engineering Reports*. 2020;2:e12116.
https://doi.org/10.1002/eng2.12116