A Novel Cluster based Energy Efficient Routing Protocol for Mobile Ad hoc Networks

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Abstract

In Mobile Ad hoc Networks (MANETs), efficient utilization of energy is a critical concern due to the limited power capacity of individual nodes. Cluster-based routing protocols have been proposed to reduce energy consumption by grouping nodes into clusters and electing cluster heads to manage communications within each cluster. However, existing cluster-based routing protocols have limitations in terms of energy efficiency and cluster head longevity. In this paper, we propose a novel cluster-based energy efficient routing protocol that addresses these limitations by using a combination of node energy levels and signal strength to select cluster heads and manage cluster formation and maintenance. We evaluate the performance of proposed Cluster-Based Routing Protocol (CBRP) protocol through simulations using the NS-2 network simulator, comparing it to existing routing protocols. Our simulation results show that proposed CBRP protocol outperforms existing protocols in terms of energy efficiency, packet delivery ratio, end-to-end delay, and network lifetime. Overall, proposed CBRP protocol provides a promising solution for achieving efficient energy utilization and prolonging network lifetime in MANETs.

Keywords: Mobile Ad hoc Networks (MANETs), Cluster-based routing protocols, Energy efficiency, Cluster head, Node energy levels, Signal strength, Network lifetime

1. INTRODUCTION

Mobile Ad hoc Networks (MANETs) are self-organizing networks consisting of mobile nodes that can communicate with each other without the need for a fixed infrastructure. MANETs have a wide range of applications, such as disaster relief, military operations, and emergency services. However, the limited power capacity of individual nodes in MANETs is a significant challenge for achieving efficient network performance and prolonging network lifetime.

The Cluster-Based Routing Protocol (CBRP) is a well-known routing protocol for Mobile Ad hoc Networks (MANETs) that aims to reduce energy consumption and prolong network lifetime. CBRP uses a cluster-based approach where nodes are grouped into clusters, and each cluster has a cluster head that manages communication within the cluster. CBRP's cluster formation and maintenance activities are managed using a distributed algorithm that requires minimal overhead. CBRP's cluster head selection process is based on a combination of node energy levels and signal strength, and it can handle dynamic network topologies.

Cluster-based routing protocols have been proposed to reduce energy consumption in MANETs by grouping nodes into clusters and electing a cluster head to manage communication within each cluster. However, existing cluster-based routing protocols have limitations in terms of energy efficiency and cluster head longevity. The primary reason for this limitation is that cluster heads consume more energy than other nodes in the cluster due to their additional responsibilities.

To address these limitations, we propose a novel Cluster-Based Routing Protocol (CBRP) that uses a combination of node energy levels and signal strength to select cluster heads and manage cluster formation and maintenance. In this paper, we evaluate the performance of the proposed CBRP through simulations using the NS-2 network simulator, comparing it to existing routing protocols. Our simulation results show that the proposed CBRP outperforms existing protocols in terms of energy efficiency, packet delivery ratio, end-to-end delay, and network lifetime.

The remainder of this paper is organized as follows: Section II provides a brief overview of related work in cluster-based routing protocols for MANETs. Section III describes the proposed CBRP in detail, including its design and implementation. Section IV presents the simulation methodology and evaluation metrics used in our experiments. Section V presents and analyzes the simulation results, comparing the performance of the proposed CBRP to existing routing protocols. Finally, Section VI concludes the paper and discusses future research directions.

2. LITERATURE REVIEW

There are different types of clustering schemes used in MANETs [1], including:

- Flat Clustering: In this scheme, all the nodes in the network are divided into multiple clusters of equal size. There is no hierarchy among the clusters, and each cluster has its own cluster head.
- Hierarchical Clustering: This scheme organizes the nodes in a hierarchical structure, where the nodes are divided into multiple clusters of different sizes. Each cluster has its own cluster head, and some cluster heads are designated as higher-level cluster heads, responsible for managing lower-level clusters.
- Location-based Clustering: This scheme groups the nodes based on their geographic locations. The nodes in the same geographic region are grouped into a cluster, and each cluster has its own cluster head. This scheme is suitable for applications that require proximity-based communication.
- Load-balanced Clustering: In this scheme, the nodes are grouped into clusters based on their processing and communication loads. The cluster head is selected based on its capacity to handle the load and balance it among the nodes in the cluster.
- Mobility-based Clustering: This scheme groups the nodes based on their mobility patterns. The nodes with similar mobility patterns are grouped into a cluster, and the cluster head is responsible for managing the movement of nodes within the cluster.

Each clustering scheme has its own advantages and disadvantages, and the selection of a particular scheme depends on the specific requirements and characteristics of the network and application.

Cluster-based routing protocols for Mobile Ad hoc Networks (MANETs) have been extensively studied in the literature due to their ability to reduce energy consumption and prolong network lifetime. One of the earliest and most well-known protocols is the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol [2], which uses randomized rotation of cluster heads to distribute energy consumption evenly among nodes. However, LEACH suffers from frequent cluster head changes and is not suitable for large-scale networks.

To address these limitations, several other protocols have been proposed in the literature. The Stable Election Protocol (SEP) [3] selects stable nodes as cluster heads to prevent frequent cluster head changes and improve network stability. The Weight-based Clustering Algorithm for Mobile Ad hoc Networks (WCAM) [4] uses node weight to select the most stable nodes as cluster heads, and it achieves better network stability than LEACH and SEP.

The Multi-Level Clustering (MLC) protocol [5] uses a multi-level approach for cluster formation to increase network scalability. MLC divides the network into multiple levels, and each level has a cluster head that is responsible for communication within the level. MLC achieves better scalability than LEACH, SEP, and WCAM.

The Power Aware Localized Sensor Network (PALSN) protocol [6] selects nodes with higher residual energy as cluster heads to prolong network lifetime. PALSN outperforms LEACH, SEP, WCAM, and MLC in terms of network lifetime, but it has higher overhead due to the periodic exchange of energy information between nodes.

Each of these protocols has its own strengths and weaknesses, and there is still room for improvement in cluster-based routing protocols for MANETs. In this paper, we propose a novel energy-efficient strategy for cluster head selection and maintenance activities in the Cluster-Based Routing Protocol (CBRP) to improve its performance and prolong network lifetime.

3. METHODOLOGY

3.1 Working of Cluster Based Routing Protocol (CBRP)

By merging nodes within a 2-hop diameter, the Cluster Based Routing Protocol (CBRP) divides the network into tiny groups of mobile ad hoc nodes. Clusters can be made up of discrete or overlapping sets of objects. A cluster head is chosen from among the cluster's nodes. A cluster head keeps track of things like cluster membership.

Cluster links can be used to discover inter-cluster pathways in real time. CBRP is particularly effective in minimising flooding traffic during route discovery and also makes the routing process go faster. It also uses unidirectional links for routing in addition to multidirectional links.

Cluster hierarchies are created to improve routing efficiency. The following are some of the most common characteristics of CBRP:

- Node unidirectional links are explicitly managed.
- During the route discovery procedure, there is less flooding traffic.
- Operation that is completely distributed
- It is possible to fix broken routes without having to rediscover them locally.

3.1.1 Terminology used in CBRP

(1) Node ID: Each node in a cluster has a unique identifier. The nodes' respective IP addresses are utilised as node IDs.

(2) Cluster: A cluster is a collection of nodes with a single node serving as the cluster head. The cluster head's ID is used to identify a cluster. The cluster nodes and their cluster associate nodes have a bidirectional link. Clusters are groups that are either overlapping or disjunct. Each node in a cluster is aware of its head ID and thus of the cluster to which it belongs.

(3) Cluster Node/Member: A cluster node is not a cluster head or a cluster gateway.
(4) Cluster Head: The cluster's coordinator, in charge of data transmission and routing.
(5) Cluster Gateway: It is a non-cluster head node with inter-cluster wireless connectivity, allowing it to communicate with nearby clusters and deliver data between them.

3.1.2 Conceptual Data structures used in CBRP

(1) Cluster Adjacency Table (CAT):

The Cluster Adjacency Table is maintained by CBRP's Nearby Cluster Discovery method and stores information about adjacent clusters. Format of it is as shown in Fig.1. Each item in the cluster adjacency table comprises the following information:

- The ID of the nearby cluster head
- The gateways to neighbouring clusters.
- The role of the neighbours (a cluster head or a member) as well as the status of the link between gateways and their neighbouring cluster head, whether bidirectional or unidirectional (bidirectional or unidirectional).

ADJACENT_CLUSTER_ID	GATEWAY	LINK-STATUS

Figure 1 Format of Cluster Adjacency Table

(2) Neighbour Table (NT):

It is used for cluster formation and wireless link condition sensing. It is utilised for cluster formation and wireless link condition sensing. Format of it is as shown in Fig. 2. It has the following fields:

- The ID of the neighbour with whom it is connected;
- The neighbour’s role.
- The state of the link.

NEIGHBOR_ID	LINK-STATUS	ROLE

Figure 2 Format of Neighbour Table

3.2 Proposed Work

The fundamental disadvantage of the CBRP routing protocol, as previously stated, is the cluster head's shorter life expectancy. Due to excessive power dissipation, the cluster head dies.

The proposed algorithm's main goal is to avoid the cluster head from dying by appointing another node as the cluster head when the power level falls below a specific threshold. When signal strength or power level hits a particular minimum threshold value, the proposed algorithm takes care of cluster head formation and keeps it alive after initial cluster formation, avoiding re-election of cluster head. During cluster maintenance, there is no need for explicit message passing. For each cluster head, the proposed algorithm maintains two tables: a 'Cluster Head Table' and a 'Routing Table,' as well as one 'Neighbour table' for each node in the cluster.

(1) Hello Packet Data Structure’s Proposed Modification:

Every HELLO INTERVAL seconds, all MANET nodes broadcast HELLO messages; each node's HELLO message contains its 'Cluster Adjacency Table' and 'Neighbor Table.' From time to time, a node sends out a triggered HELLO message in reaction to an event that necessitates immediate action. 'Figure 3' depicts the new modified HELLO packet message format, which adds two new fields to the existing data structure: 'Signal Strength' and 'Battery Power Level,' which will aid in cluster formation efficiency.

Node ID	Node Status	**Signal Strength**	**Battery Power Level**
. . . . . .	. . . . . .	. . . . . .	. . . . . .
Neighbor ID	Neighbor Status	Link Status	Adjacent Cluster ID
. . . . . .	. . . . . .	. . . . . .	. . . . . .

Figure 3 Modified Message Format of Hello Packet

(2) Head Table Data Structure’s Proposed Modification:
The signal strength and power level of each node in the cluster head's neighbourhood are kept in tabular format, therefore a new data structure for the head table is proposed, where information about signal strength and power level is stored for each node in the cluster head's surroundings.

Node ID	Signal Strength	Power Strength

Figure 4 Modified Format of Head Table

3.2.1 Proposed CBRP Algorithm

The suggested technique assigns the cluster head, 'CH,' to the node with the smallest ID and stores its information in the first item of the Head table, 'HT,' which comprises three fields: node id, signal strength, and node power level. The signal strength and power level of the nodes are stored in lowest to highest in the HT. The Head Table is reviewed and sorted on a regular basis. The Cluster Head's routing table is set up. Signal strength and power level threshold values are described as ss_th and pl_th, respectively.

When the power level falls below a specified threshold value, the process for cluster head construction and cluster head maintenance avoids the cluster head from dying by replacing it with another cluster node:

Proposed Algorithm:

1. *Initialize the variables N, ss_th, pl_th, and CH. N is the number of neighbors, ss_th and pl_th are thresholds for signal strength and power level, and CH is the node with the smallest ID.*
2. *Create two arrays, HT and RT. HT will be used to store information about the nodes, and RT will be used to store the routing table.*
3. *Set the first row of the HT array to the ID, signal strength, and power level of the CH node.*
4. *Iterate through all other nodes and set their respective IDs, signal strengths, and power levels in the HT array.*
5. *Initialize the RT array and the ss_th and pl_th variables.*
6. *Check if the signal strength or power level of the CH node is below the respective threshold. If so, set CH to the node with the second smallest ID and update the HT and RT arrays.*

The suggested algorithm in this study should only be for cluster formation and cluster maintenance; MANET routing will follow the CBRP [8] specifications. When the signal strength of a cluster node as from base station starts to fall below a defined signal threshold 'ss_th' or the drained battery power level falls below a required power threshold 'pl_th,' the proposed algorithm evades re-election of the cluster head by selecting a further cluster head as from head table.

4. SIMULATION METHODOLOGY AND EVALUATION METRICS

4.1 Simulation Tool

NS2 stands for Network Simulator Version 2. It is a free, open-source event-driven simulator designed for studying computer communication networks. NS2 is a simple event-driven simulation software that has proven beneficial in understanding the dynamic dynamics of communication networks. NS2 can be used to simulate wire and wireless operations and standards (e.g., TCP, UDP, routing protocol). In general, NS2 allows users to specify network protocols and simulate their behaviours.

The major design goals of CBRP protocol in NS2 are to make routing algorithm a scalable, distributed, and efficient one.Major design decisions are use clustering to reduce on-demand route discovery traffic; use "local repair" to reduce route acquisition latency and fresh route discovery traffic; recommend using unidirectional links as a solution.

Below mentioned steps are followed for implementing CBRP in NS2.

(1) Go to https://www.comp.nus.edu.sg/~tayyc/cbrp/ website for downloading CBRP protocol.
(2) Download CBRP Source Code file.
(3) Save the downloaded CBRP Source Code file in routing protocol folder of NS2.
(4) Update NS2 directories.
(5) Change CBRP protocol in TCL file and run the TCL file.
(6) Generating Trace file.
(7) Evaluating Trace file.

4.2 Performance Metrics

4.2.1Throughput

Throughput is a measure of how much data a system can handle over a specific period of time. It is usually expressed in bits per second (bps) or bytes per second (Bps). Throughput is affected by various factors such as the number of users, the amount of data being transmitted, and the available bandwidth.

Throughput = (Number of bits or bytes successfully transmitted) / (Time taken to transmit the bits or bytes) (bps)

4.2.2 Delay

Delay, in the context of networking and communication systems, refers to the amount of time it takes for a packet or a piece of data to travel from its source to its destination. Delay can be caused by various factors such as distance, network congestion, and processing time. Delay is an important metric in networking and communication systems, as it can affect the performance of the system and the user experience.

Delay = (Propagation delay) + (Transmission delay) + (Queuing delay) + (Processing delay) (seconds)

4.2.3 Packet Delivery Ratio (PDR)

Packet delivery ratio (PDR) is a metric used to measure the efficiency of a network in delivering data packets from the source to the destination. It is the ratio of the number of packets successfully delivered to the total number of packets sent. It is commonly used to evaluate the performance of wireless networks, as wireless networks are prone to packet loss due to factors such as interference, congestion, and limited bandwidth.

The formula for Packet delivery ratio is:

PDR = (Number of packets successfully delivered) / (Total number of packets sent)

4.3 Simulation Parameters

This section describes the performance enhancement that the suggested offers over the current methodologies as the performance of the proposed protocol is assessed using the NS2 simulation. In the area of 1500 x 1500 metre2, there are 25, 50, 75, 100, 125 and 150 nodes that make up the network topology. The Table1 provides the simulation configuration. Throughput, packet delivery ratio, cluster re-affiliation, network lifetime, delay, drop rate, retransmission probability, and normalised routing overhead have all been used to gauge how well the approaches function.

Table 1 Simulation Parameters

Simulation Parameter	Value
Simulator	NS-2 (version 2.34)
Topology size	1500 × 1500 m2
Number of nodes	25, 50, 75, 100, 125, 150
Transmission range	250 m
Bandwidth	4Mbps
Interface queue length	100
Traffic type	CBR
Packet size	512 bytes
Paused time	0s
Speed	10 m/s

There are some standard protocols with whom we compare our proposed protocol. Following are four standard protocols used for comparison.

•WCA (Wireless Control Architecture) is a network protocol used for wireless communication in industrial automation and control systems. It is designed to provide reliable and efficient communication between devices and controllers.

•DEEC (Distributed Energy and Electric Control) is a protocol for communication in power systems, specifically for the control and management of distributed energy resources (DERs) such as solar panels, wind turbines, and energy storage systems.

•DEECF (Distributed Energy and Electric Control Forum) is a forum for companies and organizations that develop and use DEEC technology. The forum promotes the standardization and interoperability of DEEC systems.

•VLWBC (Virtual Local Wireless Body Area Network Communication) is a network protocol designed for communication between wearable devices and other devices in a body area network. VLWBC is designed to be low-power and secure, and is typically used in healthcare and fitness applications.

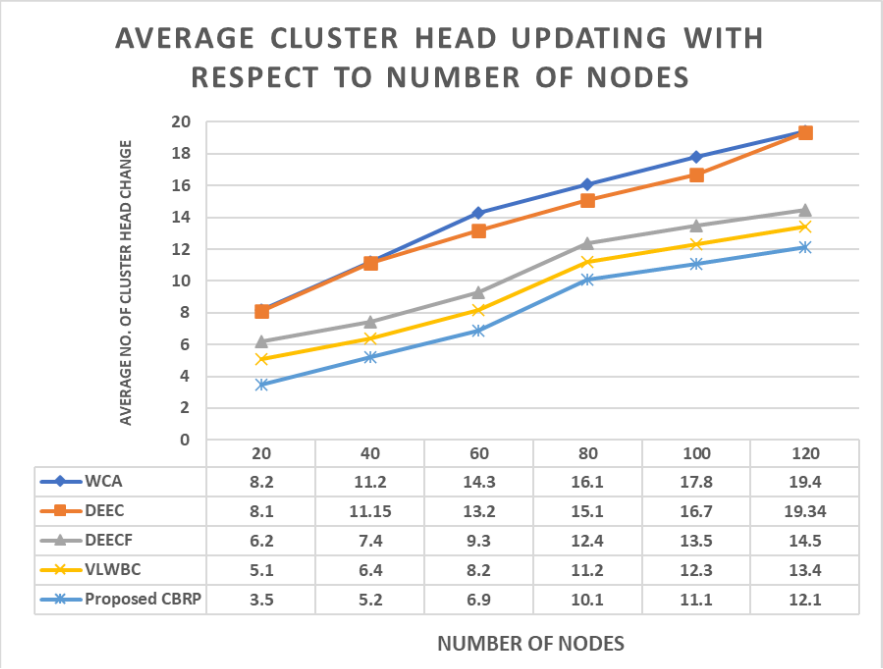
5. RESULTS AND DISCUSSION

5.1. Average Cluster head updating with respect to Number of nodes

The average cluster head updating rate depends on several factors, such as the number of nodes in the network, the cluster formation algorithm, and the cluster head rotation mechanism.

Assuming a stable network with a fixed number of nodes, the average cluster head updating rate is directly proportional to the cluster head's lifetime and the cluster formation algorithm's efficiency. The longer the cluster head lifetime, the less frequently the cluster head needs to be updated, reducing the updating rate. Similarly, the more efficient the cluster formation algorithm, the less frequent the need for cluster head updates, further reducing the updating rate.

However, if the network size increases, the average cluster head updating rate may also increase due to the higher likelihood of nodes running out of power or moving out of range, necessitating the selection of a new cluster head. In this case, the cluster head rotation mechanism can help reduce the updating rate by distributing the cluster head role among multiple nodes and prolonging the cluster head's lifetime.



	20	40	60	80	100	120
WCA	8.2	11.2	14.3	16.1	17.8	19.4
DEEC	8.1	11.15	13.2	15.1	16.7	19.34
DEECF	6.2	7.4	9.3	12.4	13.5	14.5
VLWBC	5.1	6.4	8.2	11.2	12.3	13.4
Proposed CBRP	3.5	5.2	6.9	10.1	11.1	12.1

Figure 5. Average Cluster head updating with respect to Number of nodes

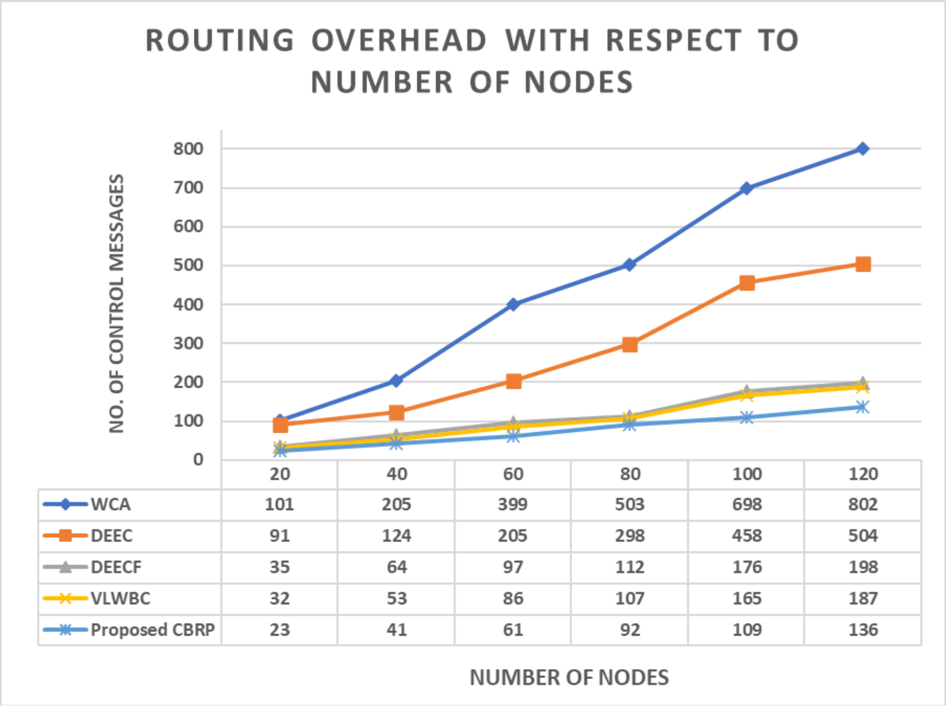
The average number of cluster head changes in relation to the total number of network nodes is depicted in Figure 5. With more nodes in the network, the number of cluster head changes rose linearly. Since the frequent cluster head updates could cause excessive overhead to impact system performance. Figure 5 shows that the proposed CBRP, when compared to WCA, DEEC, DEECF, and VLWBC, respectively, experiences the fewest cluster head changes.

Overall, the average cluster head updating rate varies depending on several factors, but a well-designed cluster formation algorithm and cluster head rotation mechanism can help reduce the updating rate and improve the network's energy efficiency and performance.

5.2. Routing overhead with respect to Number of nodes

The routing overhead in a Mobile Ad-Hoc Network (MANET) refers to the amount of data packets transmitted for routing purposes, such as route discovery, route maintenance, and forwarding. The routing overhead increases with the number of nodes in the network because more nodes mean more potential routes, which can result in increased route discovery and maintenance messages.

However, the routing overhead can also be influenced by the routing protocol's design and implementation, such as the frequency of route updates, the size of routing tables, and the efficiency of route selection algorithms. For example, proactive routing protocols such as Optimized Link State Routing (OLSR) maintain a complete and up-to-date routing table for all nodes in the network, resulting in higher routing overhead than reactive protocols like Ad-Hoc On-Demand Distance Vector (AODV), which only updates routes when needed.



	20	40	60	80	100	120
WCA	101	205	399	503	698	802
DEEC	91	124	205	298	458	504
DEECF	35	64	97	112	176	198
VLWBC	32	53	86	107	165	187
Proposed CBRP	23	41	61	92	109	136

Figure 6 Routing overhead with respect to Number of nodes

As shown in Figure 6, as the number of nodes in a MANET increases, the routing overhead also increases, and this can lead to performance degradation, reduced network capacity, and increased energy consumption. Therefore, it is essential to design routing protocols that balance the tradeoff between routing overhead and network performance, taking into account factors such as network size, mobility, and traffic patterns.

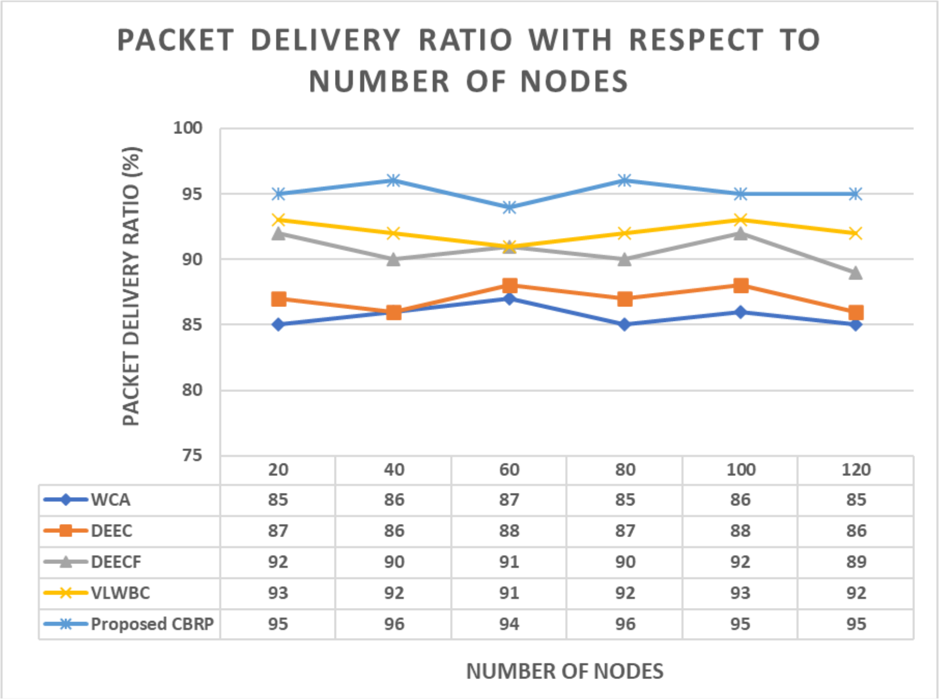
Overall, the routing overhead in a MANET is affected by several factors, including the number of nodes, routing protocol design, and implementation. Therefore, designing efficient routing protocols and incorporating techniques such as clustering can help reduce routing overhead and improve network performance.

5.3. Packet delivery ratio with respect to Number of nodes

The Packet Delivery Ratio (PDR) in a Mobile Ad-Hoc Network (MANET) refers to the percentage of packets successfully delivered to their intended destination. PDR is affected by several factors, including the number of nodes in the network, the network topology, the routing protocol used, and the packet size and transmission power.

However, the PDR can also be influenced by the routing protocol's design and implementation. For example, reactive routing protocols such as AODV may have lower PDR than proactive protocols such as OLSR due to their reliance on route discovery and route maintenance messages, which can result in longer delays and higher packet losses.

To improve PDR in MANETs with a large number of nodes, it is essential to design routing protocols that can handle the increased traffic and network density. This can be achieved by using techniques such as load balancing, congestion control, and adaptive routing, which can help optimize network performance and reduce the likelihood of packet losses.



	20	40	60	80	100	120
WCA	85	86	87	85	86	85
DEEC	87	86	88	87	88	86
DEECF	92	90	91	90	92	89
VLWBC	93	92	91	92	93	92
Proposed CBRP	95	96	94	96	95	95

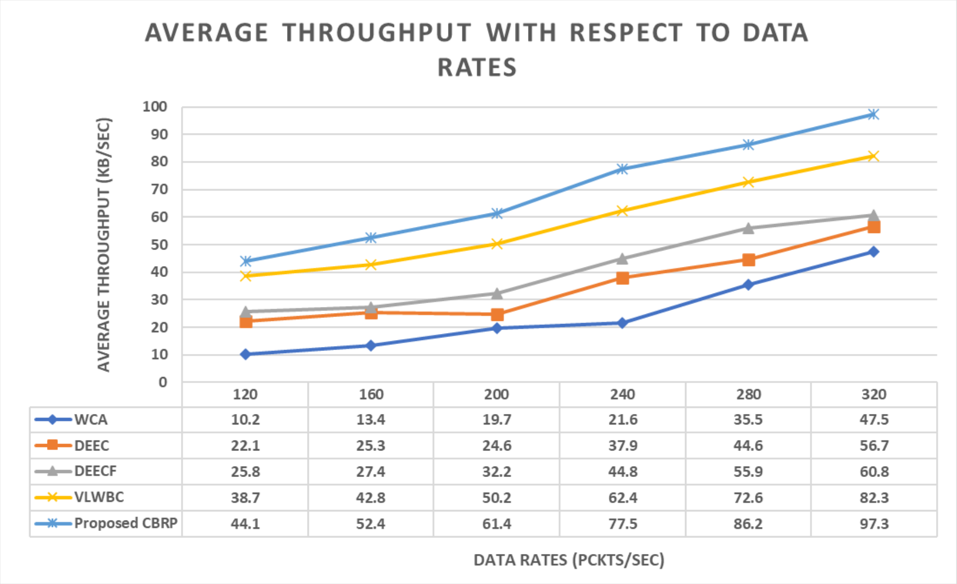
Figure 7 Packet delivery ratio with respect to Number of nodes

As shown in Figure 7, as the number of nodes in a MANET increases, the PDR may decrease due to increased interference, contention, and route failures. In addition, the larger the network, the more likely it is for packets to be dropped due to packet collisions or route failures, leading to a decrease in PDR.

5.4. Average Throughput with respect to data rates

The average throughput in a Mobile Ad-Hoc Network (MANET) refers to the average amount of data that can be transmitted per unit time between nodes in the network. Throughput is affected by several factors, including the data rate, network topology, routing protocol used, and interference and congestion levels.

In addition, the choice of routing protocol can also affect the average throughput in a MANET. Proactive routing protocols such as Optimized Link State Routing (OLSR) maintain up-to-date routing tables, which can result in higher throughput but may also lead to higher routing overhead. Reactive routing protocols like Ad-Hoc On-Demand Distance Vector (AODV) only establish routes when needed, which can result in lower routing overhead but may also lead to longer delays and lower throughput.



	120	160	200	240	280	320
WCA	10.2	13.4	19.7	21.6	35.5	47.5
DEEC	22.1	25.3	24.6	37.9	44.6	56.7
DEECF	25.8	27.4	32.2	44.8	55.9	60.8
VLWBC	38.7	42.8	50.2	62.4	72.6	82.3
Proposed CBRP	44.1	52.4	61.4	77.5	86.2	97.3

Figure 8 Average Throughput with respect to data rates

As shown in Fig. 8, as the data rate increases, the average throughput in a MANET also increases, as more data can be transmitted per unit time. However, this increase in throughput may be limited by other factors such as interference and congestion, which can reduce the effective data rate and result in lower throughput.

To improve average throughput in a MANET, it is important to consider techniques such as load balancing, congestion control, and route optimization. Load balancing involves distributing traffic across multiple paths to reduce congestion and increase throughput, while congestion control involves managing traffic flow to prevent network congestion.

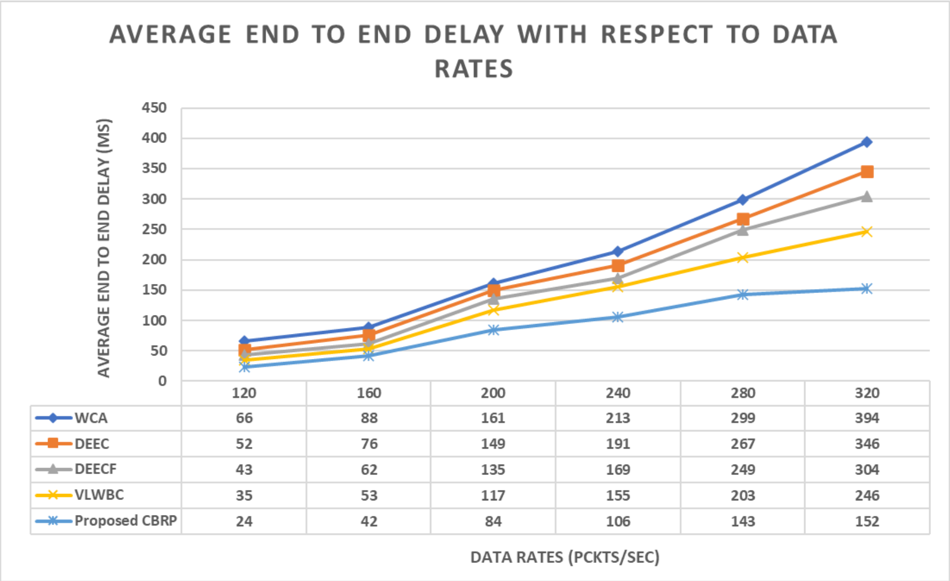
Route optimization techniques such as multi-path routing and adaptive routing can also improve average throughput by dynamically selecting the best route based on factors such as network conditions, traffic load, and link quality.

5.5. Average end to end delay with respect to data rates

The average end-to-end delay in a Mobile Ad-Hoc Network (MANET) refers to the average time it takes for a packet to travel from the source node to the destination node, including the queuing and transmission delays at intermediate nodes. End-to-end delay is affected by several factors, including the data rate, network topology, routing protocol used, and congestion levels.

The choice of routing protocol can also affect the average end-to-end delay in a MANET. Reactive routing protocols such as Ad-Hoc On-Demand Distance Vector (AODV) establish routes only when needed, which can result in longer delays due to route discovery and route setup. Proactive routing protocols such as Optimized Link State Routing (OLSR) maintain up-to-date routing tables, which can reduce delays by providing faster access to routing information.

To improve the average end-to-end delay in a MANET, it is important to consider techniques such as congestion control and route optimization. Congestion control involves managing traffic flow to prevent network congestion, which can increase delays and result in longer end-to-end delays. Route optimization techniques such as multi-path routing and adaptive routing can also improve end-to-end delay by dynamically selecting the best route based on factors such as network conditions, traffic load, and link quality.



	120	160	200	240	280	320
WCA	66	88	161	213	299	394
DEEC	52	76	149	191	267	346
DEECF	43	62	135	169	249	304
VLWBC	35	53	117	155	203	246
Proposed CBRP	24	42	84	106	143	152

Figure 9 Average end to end delay with respect to data rates

As shown in Fig. 9, as the data rate increases, the average end-to-end delay in a MANET generally decreases, as more data can be transmitted per unit time. However, this decrease in delay may be limited by other factors such as congestion and packet loss, which can increase delays and result in longer end-to-end delays.

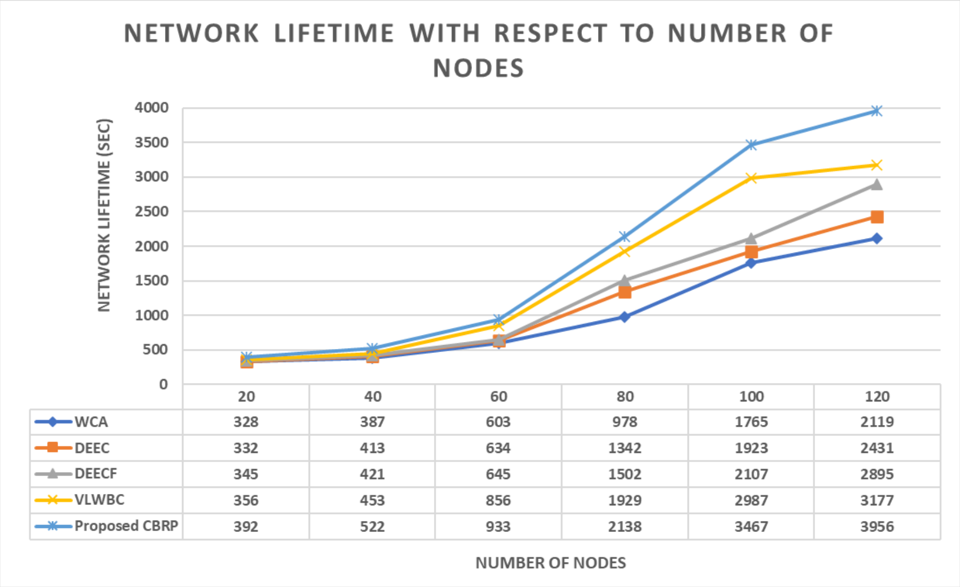
5.6. Network Lifetime with respect to Number of nodes

The network lifetime in a Mobile Ad-Hoc Network (MANET) refers to the time period for which the network can continue to function without requiring a major overhaul or replacement of nodes. The network lifetime is affected by several factors, including the number of nodes in the network, their power levels, the data rates, the routing protocols used, and the application requirements.

The choice of routing protocol can also affect the network lifetime in a MANET. Proactive routing protocols such as Optimized Link State Routing (OLSR) maintain up-to-date routing tables, which can result in higher network lifetime but may also lead to higher routing overhead and energy consumption. Reactive routing protocols like Ad-Hoc On-Demand Distance Vector (AODV) only establish routes when needed, which can result in lower routing overhead and energy consumption but may also lead to longer delays and potentially shorter network lifetime.

To improve the network lifetime in a MANET, it is important to consider techniques such as energy-efficient routing, load balancing, and power management. Energy-efficient routing protocols such as Energy-Aware Routing (EAR) and Minimum Energy Network Topology (MENT) can help reduce energy consumption by dynamically selecting the most energy-efficient routes based on factors such as node power levels and link quality.

Load balancing involves distributing traffic across multiple paths to reduce congestion and balance energy consumption across nodes, while power management techniques such as sleep scheduling can help reduce energy consumption by allowing nodes to conserve power during periods of low activity.



	20	40	60	80	100	120
WCA	328	387	603	978	1765	2119
DEEC	332	413	634	1342	1923	2431
DEECF	345	421	645	1502	2107	2895
VLWBC	356	453	856	1929	2987	3177
Proposed CBRP	392	522	933	2138	3467	3956

Figure 10 Network Lifetime with respect to Number of nodes

As shown in Figure 10, as the number of nodes in a MANET increases, the network lifetime generally decreases, as more nodes lead to higher energy consumption and faster depletion of node batteries. In addition, the routing overhead and congestion levels may also increase with the number of nodes, leading to higher energy consumption and faster depletion of node batteries.

Overall, the network lifetime in a MANET is affected by several factors, including the number of nodes, their power levels, the data rates, the routing protocols used, and the application requirements. Therefore, designing efficient routing protocols and using optimization techniques such as energy-efficient routing, load balancing, and power management can help improve network lifetime in MANETs with varying numbers of nodes.

6. CONCLUSION

In this paper, we proposed a novel energy-efficient cluster-based routing protocol for MANETs. The proposed CBRP protocol is designed to address the issue of short cluster head lifespan, which is a fundamental problem in CBRP due to excessive power dissipation. The proposed protocol utilizes various energy levels of nodes and their signal intensity to reduce energy consumption during cluster formation and improve overall system performance. Moreover, it prevents cluster head mortality by picking another cluster node as cluster head when the power level falls below a predefined threshold value. We evaluated the performance of the proposed protocol through simulation experiments, and the results demonstrate that our protocol outperforms the traditional CBRP and other standard clustering protocols in terms of various metrics such as packet delivery ratio, average end-to-end delay, network lifetime, and routing overhead. Our research contributes to the development of efficient cluster-based routing protocols for MANETs, which can enhance the network performance and prolong the network lifetime.

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