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Original Article

Clustering Metric Algorithm for Cost-Effective Routing in Flying Ad-hoc Networks

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Abstract - *Recently, flying ad-hoc networks have become one of the fastest-growing scientific areas (FANETs). The military and civil sectors have many requirements. Clustering is an approach to combining nodes in different communities that have the same geographical proximity. It helps to increase the scalability of the network, reduce overhead and optimize performance. The process of choosing and forming CHs is a crucial component of cluster structure management. CMs (clustered members) can be repositioned subsequently to change the composition of the cluster. CHs should always broadcast their presence on a regular basis to their CMs to report modifications to the cluster structure. Cluster members should report their status to the cluster head. A network's output depends on its algorithm. Nodes are formed into a cluster, and cluster heads are selected using a clustering metric algorithm (CMA). Finally, input from the cluster head is sent to the ground control station and adjacent nodes. According to the results, the average end-to-end delay, packet throughput, and energy consumption per packet are compared to the suggested approaches. The results are calculated and measured. The outcome indicates the efficacy of the process suggested.*

Keywords - *Flying ad-hoc network (FANET)s, Cluster members (CM), Gradient based clustering metric (GCM), Artificial intelligence (AI), Unmanned aerial vehicle(UAV) .*

1. Introduction

A growing number of Unmanned Aerial Vehicles (UAVs) float over our heads; there is a growing necessitate for safety, coordination, information sharing, and communication between these strategies to subsist a sensible option for a range of application that covers rescue and search, military, patrolling, and delivery of goods. FANET clustering involves identifying groups of nodes such that each instance belongs to a single group, so nodes within a cluster are exclusive. In addition to establishing clusters, maintaining topologies, and allocating resources within clusters, cluster heads (CHs) are responsible for clustering. The dynamic nature of mobile nodes makes it essential to keep cluster heads to a minimum because cluster head configurations change constantly. Those nodes in a CH's neighbouring range are its neighbors. The main operation of a FANET is routing, management, and data aggregation, and a few nodes are involved in all these activities, which provides a highly energy-efficient solution. The whole applications of FANET have frequent requirements which could be supported with the use of multi-hop infrastructure between aerial nodes like Aircraft, Helicopters, UAVs, and so on. UAVs were driverless aerial nodes; their actions were proscribed by means of algorithms devoid of some human relations and could be easily deployed in the system. It has been reported that UAVs have been armed with sensors and computing devices in recent years and have been commercialized. As a significant factor of Intelligent Transportation Systems (ITS) and smart cities, FANETs become rising and attracting attention from both industry and research communities [1], which are regarded as a particular kind of MANETs [2], [3] on behalf of several applications that were categorized as infotainment and the safety applications [4], as the assistance of the driver, collision warning, internet access, etc. A FANET differs from other MANETs in that it is traffic-tunnelled, has a large, self-organizing network, is highly mobile, and has no energy constraint [5]. Intelligent vehicles can exchange wireless information with one another using an ad-hoc network [29, 30]. This technology makes transportation systems more secure and practical. Data about traffic conditions, adaptive support, alarms, parking stations, warnings, and infotainment applications might be included. In the environment of FANET, QoS signifies a valid dispute for researchers.

Consequently, several related QoS surveys are present in the literature with various techniques and approaches for offering QoS support in vehicular networks. A real-time application's performance must be guaranteed in the MANET framework by fulfilling two constraints. As can be seen, below, the residual portion of the paper is organized similarly. Section 2 of this report includes a detailed literature review. A description of the research method is provided in section 3. Section 4 will provide a detailed description of the simulation background and parameters. Conclusions are presented in Section 5.

2. Literature Review

Recent years have seen a rise in interest in multipath routing in the research community [23]. Aadil et al. [9] addressed these issues through competent clustering. Initially, the transmission powers of the UAVs were adjusted through the anticipation of their equipped necessities. In the optimal transmission range, the packet loss ratio amount will be the least, and the link quality will be improved, thus reducing the consumption of energy overall. Afterwards, the cluster heads were selected using a variant of the K-Means Density clustering algorithm. This enhances the cluster's lifetime and decreases routing overhead due to the optimal cluster heads. Khan et al. [10] recognized the optimal route for taking into account the UAVs with superior stability and residual energy in the network of 5G to augment the network's lifetime and decrease the energy consumption and the number of broken relations. Guillen-Perez et al. [11] reviewed propagation models, mobility, and positioning presented for FANETs in the correlated technical literature. A general restriction that influences these three topics is short of studies that estimate the manipulation that an unmanned aerial vehicle (UAV) might have the communication devices that were embedded /onboard, typically assuming omnidirectional or isotropic emission patterns presently. Based on a comprehensive evaluation of the different position-based routing protocols for FANETs, Oubbati et al. [4] categorize and evaluate the various position-based routing protocols. An extensive list of routing schemes is included in the taxonomy of these protocols. Our proposal is to present each protocol's weaknesses and advantages using various criteria. Gankhuyag et al. [31] presented a united directional and omnidirectional transmission scheme, among the alteration of dynamic angle. The proposed hybrid features schemes employ Geocasting and unicasting routing using trajectory and location information. A 3-D inference technique is used to predict the location of intermediate nodes, and directional signals are transmitted in the direction that the location predictions were made. This enables a longer transmission distance, allows a path to be followed with a varying topology, and ensures protocol robustness. Mukherjee et al. FANNETS have been proposed as a promising field along with MANETS and VANETS. As a result of FANET, an ad-hoc network will be created between the multiple UAVs connected to the base station (BS).The BS is capable of ground remotely, depending on the aircraft. As part of their review, Mukherjee et al. [14] considered the constraints, movement models, route path technologies, architectures, and modeling tools related to FANETs. Descriptions, ordering, and relative study of the significant existing routing protocols number devoted to FANETs were comprehensive. Zafar et al. [15] suggested that an ad-hoc network was being recognized among multiple UAVs permitted for communication. The entire UAVs in the network carry communication from UAV to UAV, and only the UAVs groups relate to the ground station. This feature, in turn, eliminates the deployment of complex hardware that wants every UAV does. Also, ad-hoc networks among UAVs prevent link breakdown by the base station due to the UAV communication that breaks down. As a solution to accommodate isolated and localized disruptions in FANET, Pu et al. [32] proposed JarmRout, a multipath jamming-resistant routing protocol. JarmRout achieved this aspiration by combining three major schemes: link quality techniques, traffic load schemes, and spatial distance schemes. In this section, we will present a simple logical representation of the numerical result of the RREP rate at the source node. As part of their analysis of existing routing protocols for flying ad-hoc networks, Pu and colleagues [17] conducted a detailed survey. An exhaustive study of current routing protocols is conducted, along with classifications of UAVs, application architectures, and communications. Various routing protocols and application architectures are analyzed in addition to the classification of UAVs. These models include key features, strengths, weaknesses, and differences. Oubbati et al. [18] supported the employment of information movement and a level of residual energy with every UAV to assure communication stability highly on predicting a rapid breakage of links before their incidence. A strong route discovery process was employed to explore routing paths at which the balanced energy consumption, the prediction of link breakage, and a connectivity paths degree were estimated. Based on topology-dependent routing protocols, FANET routing protocols were briefly described by Khan et al [19]. [23][24] The methods of working on each protocol were also discussed, in addition to their pros and cons. Optimized network engineering tools (OPNET) simulation tools have also been used to simulate and evaluate several topology-dependent routing protocols based on throughput, network load, and end-to-end delay.

Several clustering algorithms have been studied and researched to implement a cluster-based algorithm in FANET. It has been observed that there is still a research gap when it comes to optimizing the network performance using CH selection. The analysis is performed using Euclidean distance estimation, residual energy, coverage area, and optimal power consumption. In order to maximize the packet delivery ratio and minimize power consumption, an algorithm is proposed that determines the appropriate cluster midpoint for each broadcast.

3. Research Method

The purpose of this section of the paper is to discuss the methodology used in this study. Figure 1 exhibits the flowchart for this part, which contains a detailed explanation of the suggested structure.

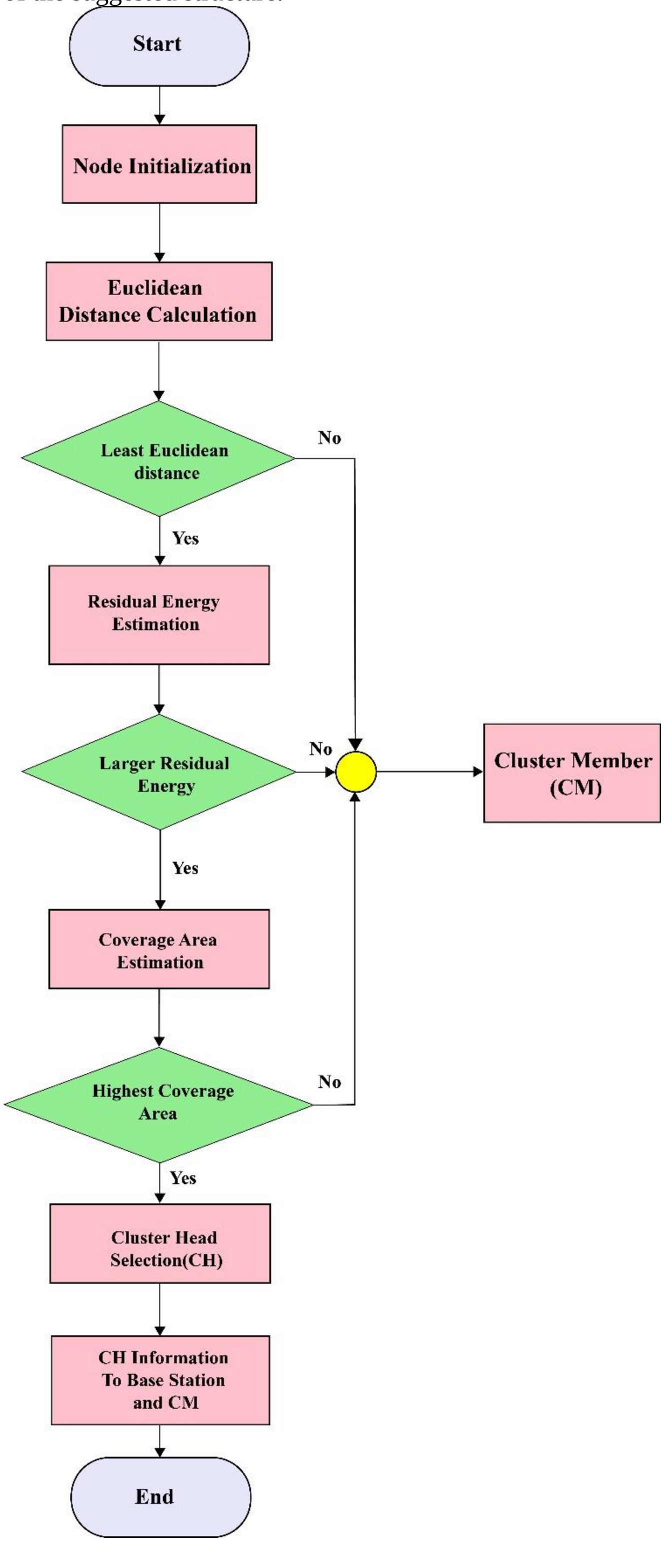

Fig. 1 Flow of the proposed system

3.1. System Model

Using several nodes to cover a large region for fire detection, the suggested model is based on a cluster-based architecture. The following assumptions were made in the proposed model as specified in table1. In order to manage many UAVs efficiently over other topologies, the cluster network topology is preferable. One node, among many, serves as the cluster leader, while the others function as cluster members. When a fire is detected, packets are exchanged along the cluster head that has chosen routes. The packets are sent from the cloud storage to the BS via the Internet of Things (IoT) technology. Therefore, the quantity of energy used for data exchange determines the network's overall energy efficiency.

As a result, the UAV's overall energy consumption is expressed analytically as in Equation 1.

$$\text{Residual Energy (ER)} = \sum_{i}^{n}(E_i - E_F) \tag{1}$$

The energy that remains in the UAV after data exchange is referred to as ER.

E_i is the energy present at the initial level before data exchange.

The energy at the following level after the exchange is referred to as E_F.change.

3.2. Channel Availability and Geographic Location Prediction

Initially, the geographic locations of the nodes employed in the network should be identified by setting a limit/range. The nodes within that specified range are assigned their respective base station accordingly. E.g., if the user limit is set as 100 in a specific range, then the users within this area are grouped and connected to their respective base stations, and communication will occur among these nodes[21]. In the proposed mechanism, geographic location identification is segregated into three stages. At first, the spatial correlation among the node is identified using the Euclidian distance metric. Then, the predictions of neighboring nodes are carried out. In the next stage, the temporal correlation between two nodes will be estimated within the primary user's coverage criteria. The third stage is the prediction of common idle channels. After that, the confidence level regarding idle channel sensing is estimated, thereby broadcasting the channel information to the cluster head. At last, the residual energy is being updated to check the energy efficiency of the routing and communication system.

3.3. Prediction of Geographic Location and Channel Availability

A WSN might stay idle until an event occurs while it reacts and builds a routing framework for delivering the sensed data. The spatial correlation of the data sensed exists once nodes detect an event that is close geographically. Thus they have related values [22]. Nodes spatially close are liable for the detection of similar values. On the other hand, the closeness, i.e., Euclidean distance among nodes, sense-related values, based on characteristics, event and application requirements together. Some of the applications are highly significant with the less lenient discrepancy in sensed values on an event that is pragmatic, demanding that nodes closer let know the data sensed (the region of correlation is minor). Other applications might be further lenient to the sensed value discrepancies. However, closer nodes are not needed to report the sensed data (the correlation region is better). As energy reduction consumption is a foremost issue for enhancing the existence of a network, exploitation of spatial correlation is made for managing the set of nodes which in turn collect similar/redundant data.

Euclidean distance estimation is represented in Equation 2.

$$dist_e = \sqrt{(u_{nk}(1,i) - u_{nk}(1,j))^2 + (u_{nk}(2,i) - u_{nk}(2,j))^2} \quad (2)$$

Estimate spatial correlation represented as in Equation 3.

$$\tau = \min(x, y) \quad (3)$$

$$Node \in_{node} = 1 - \frac{\delta_i(x,y)}{\tau} \quad (4)$$

Data gathered at various intervals of time from the specific sensor might be interrelated once the data set collected differs in a related manner. This is too specified as the temporal correlation [23-27]. The readings of Sensors regarding the atmosphere are naturally periodic; accordingly, the time-dependent series of sensed data constitute a time series. Because of physical occurrence, there was a considerable temporal relationship between each successive sensor node examination, and cumulated data were usually comparable over a small time period. Therefore, sensor nodes do not want to broadcast their reading in these conditions if the present analysis had an adequate threshold error concerning the preceding reading reported. The sink node can suppose immediately that any unreported information is altered from the previously conventional ones. The correlation rate among consecutive sensor measurements may differ according to the phenomenon characteristics. After that, the common idle channel prediction is carried out. Following this, the confidence level is estimated regarding the sensing idle channel, after which the information about the channel is broadcasted to the cluster head, and the updation of residual energy is updated.

3.4. Channel Availability Forward and Clustering Metric Algorithm (CMA)

Figure 2 illustrates the clustering technique, which is helpful for ad hoc network partitioning since it dynamically groups physically adjacent nodes into clusters. The clustering

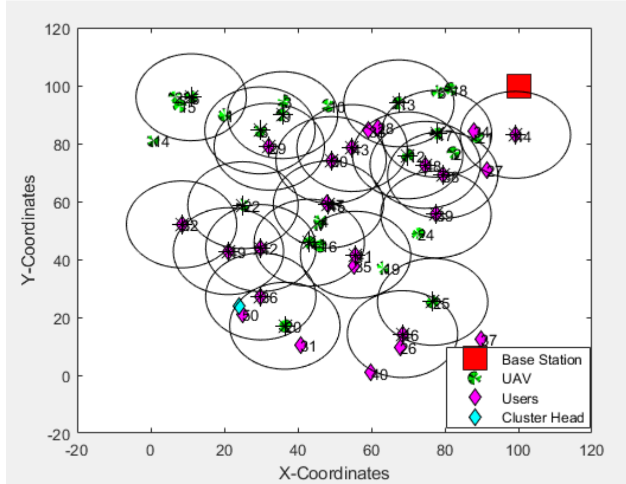

Fig. 2 Cluster formation

mechanism offers a competent allocation of radio resources, energy and location management, and routing and backbone formation. It is an effective method for scalability issues tackling relevant to the networking domain of FANET. In this paper, the Gradient-based clustering metric is considered. In this, the gradient is estimated from the communication of data between the nodes, and thus the cluster is formed by assigning a cluster head for each group. If the node has less coverage, then that node is considered as the cluster member of that particular hop which is mathematically represented in Equation 4.

4. Results and Discussion

Our goal in this section is to evaluate and compare the CMA algorithm in different traditional methods such as improved harmony algorithms (IHA), stability-based routing, link scheduling and channel assignment (SRLC) algorithm, joint stable routing and channel assignment (J-SRCA), which is based on end-to-end delay, energy consumption, goodput, and energy usage per packet transmission. Comparative analysis of proposed and existing mechanisms based on the node count. In an existing and suggested algorithm, the average end-to-end delay, the average goodput, and the average energy usage were evaluated against different numbers of nodes based on (a) average energy usage per packet, (b) and (c) goodput. Below are the results. Thus, the proposed method is better than other available methods [20] based on its novel technique.

4.1. Analysis of Proposed and Existing Mechanisms Based on the Number of Nodes

Compared with a traditional method with different nodes for different end-to-end delays and goodput, the proposed scheme has significantly lower average end-to-end delays. The end-to-end delay increases significantly as the number of nodes increases in Figure 3. The projected mechanism has a greater end-to-end delay than the existing technique. In the proposed mechanism, the major intention is over the node's protection from the interference of nodes. If there is a low number of nodes, sufficient channels could be optimally selected. Therefore, once the number of nodes is small, the end-to-end delay will be improved. Figure 3b depicts that the goodput of the presented mechanism outperforms the good put existing scheme considerably. Figure 3c relates the energy usage per packet transmission in the existing and the presented algorithms. Compared to existing methods, energy exploitation for packet transmission decreased as the number of nodes increased.

4.2. Analysis of the Maximum Speed of Existing and Proposed Mechanisms

Based on the original and proposed algorithms, we evaluated the (a) average end-to-end delay, (b) goodput, and (c) energy usage per packet transmission for the existing and proposed algorithms vs maximum speed. As a result, a comparison between the proposed technique and other existing techniques showed that the proposed technique was superior. Higher speeds lead to greater chances of link breakage and reconstruction of excess routes; as previously stated based on Figure 3c, the presented approach provides better end-to-end delay than the proposed scheme, thus reducing the possibility of link breakages. This neighbor selection method significantly improves the accuracy of link lifetime calculations compared to existing methods. It depicts the energy usage amount for packet transmission vs different maximum speeds. The proposed protocol performs better than the existing mechanism with a velocity increase, regardless of the energy usage amount increase.

Table 1. Simulation Parameters

Parameters	Values
Network size	1000 ×1000 m^2, 2000 ×2000 m^2
Quantity of node	20,30,40,50, and 60
Node-to-node distance	2m
Nodes Initial energy level	80Wh
Model of mobility	Reference Point Mobility Model
Simulation Runs	10
Interval between positions	2s
Transmission Frequency	2.45GHz
Simulation Time	120s
Transmission Range	Dynamic
Receiver Sensitivity	-90 dBm
Constant Bit Rate	100kbps

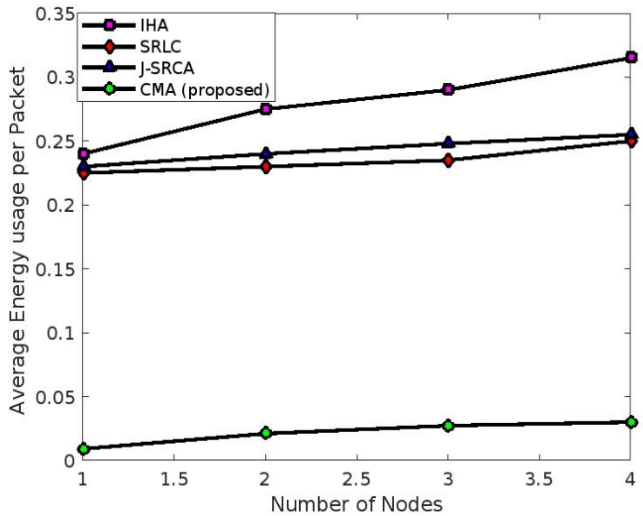

Fig. 3 (a) Average energy usage per packet vs No. Of Nodes Cluster formation

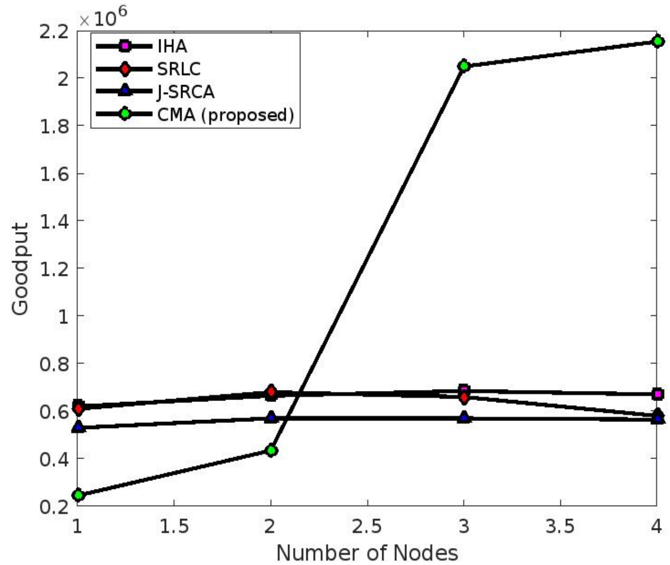

Fig. 3 (b) Goodput vs No. of Nodes

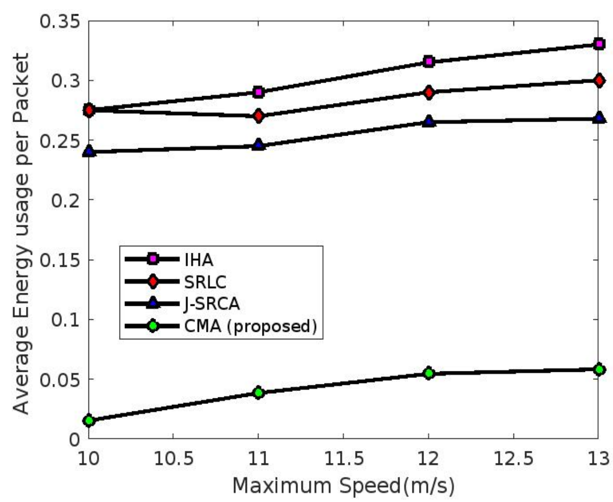

Fig. 3 (c) Average Energy usage per Packet vs Maximum Speed (m/s)

4.3. Comparison of the Energy Consumption of Existing and Proposed Techniques

As shown in the graphical representation figure 3(d), a comparison of proposed and existing techniques is shown in terms of their energy consumption. The number of UAVs and energy consumption are estimated as the outcome. The results show that the proposed system is superior to the existing mechanism. This clearly demonstrates the superiority of the alternative system over the conventional mechanism. The graphical representation of the comparative analysis of the proposed and existing techniques in terms of energy consumption is shown in Figure 3 d. using a grid size of 1000 x 1000 m^2. Table 2 presents a comparative energy consumption analysis of the suggested and existing techniques. A comparison between the proposed technique and the IHA shows an energy reduction of 8.2%. Also, the suggested technique results in 19% less energy consumption than SRLC. Likewise, regarding JSRCA, the presented technique demonstrates 2.6% reduced energy consumption with a grid size of 1000 x 1000 m^2.

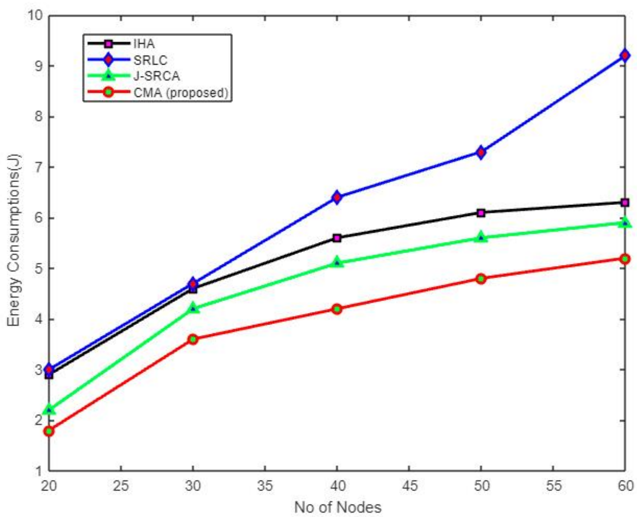

Fig. 3 (d) Energy consumption vs No.of Nodes

Table 2. Comparative Analysis of Energy Consumption

Grid size 1000 X 1000 m^2							
Methodology	**No. UAVs**						**%Efficiency**
	20	**30**	**40**	**50**	**60**	**Average**	
IHA	2.8	4.4	5.2	5.8	6	4.84	51.60%
SRLC	3	4.5	6.3	7	8.8	5.92	40.80%
JSRCA	2.2	4	4.6	5.2	5.4	4.28	57.20%
CMA (Proposed)	3.3	3.3	4	4.5	5	4.02	59.80%

5. Conclusion

An energy-effective FANET is presented for the prediction of the channel using CMA. The recognized geographic locations for each node are employed in the network by using three scenarios, viz. From these scenarios, the channel availability prediction is carried out by forwarding available channels to neighbor hops. The clustering of nodes and the cluster head selection take place using the clustering metric algorithm (CMA). Finally, the cluster head information is sent to the base station and neighbor nodes. Several network performance metrics are improved as a result of the presented algorithm, including average end-to-end delay, cluster count, and packet delivery ratio (PDR). Clustering time, cluster building time, Packet Delivery Ratio (PDR), and average cluster lifetime. Based on the algorithm, the nodes and clusters can be extended according to the requirements of a generalized network. Analyzing the performance efficiency of individual nodes and their corresponding mechanisms will be a future focus of the study. When the artificial intelligence algorithm was applied in a network, the computational complexity was slightly higher and often traded off between energy efficiency and computational complexity. Future work may include consideration of these limitations and corresponding improvements to make the model more effective.

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