Wireless Personal Communications (2021) 121:3309–3328
https://doi.org/10.1007/s11277-021-08878-2

Energy Efficient Multi-hop Cooperative Transmission Protocol for Large Scale Mobile Ad hoc Networks

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Accepted: 8 August 2021 / Published online: 12 September 2021

Abstract

Cooperative Communication (CC) is implemented extensively in mobile Ad hoc networks to leverage the benefits of CC technique. Energy consumption and routing are major challenges for large scale Cooperative Mobile Ad hoc Networks since each node in the network have mobility. To address these challenges, a hybrid multi-hop cooperative routing algorithm is formulated by combining clustering and location-based routing strategies. The main idea of our algorithm is to establish communication between similar mobility nodes to reduce the mobility effect since the link between (approximately) equal mobility nodes was reliable. All the equal mobility nodes are grouped to form a cluster; one of the nodes in this is selected as a cluster head based on its location. Further, we optimize the number of transmitters and receivers in every hop; and an optimal number of cooperative relays are obtained in every hop thereby reducing the end-to-end energy utilization. The evaluation result shows that the proposed algorithm saves energy consumption by up to 53.42% compared to traditional algorithms.

Keywords Energy-efficient routing · Large-scale MANET · Relay selection · Energy optimization · Cooperative routing · Clustering

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1 Introduction

The advancement of wireless multiple-hop technology in recent years has facilitated a promising direction for the ad hoc network [1], in which each node is equipped with a wireless transceiver to share information with other neighboring nodes and, if requisite, route packets via neighboring nodes to destinations that are not within direct communications [2, 3]. The bulk of nodes in an ad hoc network, on the other hand, are typically power-constrained and placed in unsupervised environments where individuals have difficulties replacing or recharging exhausted nodes.

Employing the broadcast aspect of wireless communication, cooperative communication (CC) is an effective approach for combating fading effects by providing spatial diversity by using multiple single radio terminals at the transmitter and/or receiver. Relay nodes retransmit the source's replica of data, which is subsequently combined at the destination for improved decoding of the original data. The CC method boosts network speed, capacity, and reliability by adopting virtual MIMO [4, 5]. Researchers are interested in extending three-stage cooperative communication to large-scale networks due of its effectiveness. However, as the number of neighboring transmission connections grows, there is more interference, which affects network performance even more than direct communication. Electronic devices that implement the IEEE 802.11 network standard [6] can now be fitted with numerous radio terminals at a lower cost thanks to advancements in contemporary wireless technology. Interference can be reduced by allowing neighbor broadcast across multiple orthogonal channels, which increases network capacity [7].

The use of energy is a major concern for MANETs. Many routing protocols, including as flat routing, cluster-based routing, and location-based routing, have been developed to improve the energy efficiency of WSNs. The need for high capacity is quickly growing as a result of high data rate applications, which will increase energy consumption, reduce network lifetime, and reduce network reliability. These issues are addressed by clustering routing methods [8]. One of the most common clustering routing systems is the Low Energy Adaptive Clustering Hierarchy (LEACH). Over the last several years, a variety of improved LEACH routing methods have been developed, concentrating on network topology changed cluster-heads (CHs) selection and network growth [9].

As MANET nodes are battery-powered, energy efficiency is a critical design consideration for the network's long-term viability. When a node's battery runs out, it loses its ability to route network traffic, which reduces the network's lifespan. MANET network lifespan may be extended by either increasing node battery power or lowering total network power usage. Though battery technology has advanced significantly in recent years, it still lags behind semiconductor technology. MANET nodes typically send packets at full power. A packet sent at full power may take fewer hops to reach its destination, but it will reduce channel usage and the node's available energy to a larger extent. At the node level, energy savings can be achieved by lowering the transmission power [9–13]. To save energy, power management-based protocols place as many nodes as feasible into a sleep state. They are, however, more vulnerable to network outages. This is due to the fact that when the nodes go to sleep, the connection may be lost. In [14–17], a few examples of power management approaches are described. However, the energy consumption and routing in large scale cooperative MANET need to be efficiently addressed. Thus this paper proposes Energy Efficient Multi-hop Cooperative Transmission Protocol for Large Scale Mobile Ad hoc Networks.

The remainder of this paper is prepared as follows. In Sect. 2, Literature survey is presented in detail. Our proposed Energy-efficient hybrid cooperative routing and optimization of cooperative nodes are presented in Sect. 3. In Sect. 4, we present the simulation results, and finally, we concluded the paper in Sect. 5.

2 Literature Survey

The earlier works may be divided into two groups based on their design goals: the first is aimed to optimize the end-to-end performance of wireless multi-hop transmission, and the second is designed to maximize the network lifespan. There have been several attempts to improve the end-to-end performance of wireless multi-hop transmission. The goal of minimizing total energy routing (MTE) [18] is to discover the least total energy non-cooperative route possible, which can be accomplished using a conventional shortest path method like Dijkstra or Bellman-Ford. In cooperation along the minimum energy non-cooperative path CAN-l [19], the packet is collaboratively sent to the next-hop node by the last l nodes along the aforementioned non-cooperative path. Progressive cooperative routing PC-l, like CAN-l, merged the previous l nodes into a single node before updating the shortest path from the combined node to the destination node.

Based on the non-cooperative approach, cooperative cluster-based routing (CwR) [20] added the ‘recruiting-and-transmitting’ phase, and the cooperative model was comparable to the multiple-input–single-output (MISO) scenario. The non-cooperative approach with the least amount of energy was used to create the aforementioned schemes. In reality, when looking for the best end-to-end route, the impact of collaboration on performance should be taken into account. Cooperative shortest path algorithm (CSP) [21] was created using CAN-l to identify the best cooperative shortest path while taking into account the benefits of l-to-1 cooperative transmission. The channel model used in this approach, on the other hand, simply took into account the impact of distance and neglected the fading of the wireless environment.

A relay node of each cooperative connection was carefully selected in relay selection-based cooperative routing (CC-OPT) [22] and power efficient location-based cooperative routing (PELCR) [23] from nodes in the intermediate area between the transmitter and the receiver. However, rather than a fixed number, the number of cooperative nodes should be determined by the actual neighbors. Minimum-energy cooperative routing (MECR) [24] presented a probabilistic cooperative routing to discover the network’s minimum-energy route under a link reliability restriction, but it is centralized and has a high computational complexity.

In [25], the authors have proposed a virtual cooperative MIMO transmission mechanism and obtained an analytical expression for the optimal number of cooperative nodes for two-stage cooperative networks. A low complexity cooperative routing algorithm was proposed in [26] and presented an optimal power allocation strategy. To minimize the network energy, the authors in [27] have proposed routing algorithms by enhancing the performance of Physical, MAC, and Network layers. For this, the authors have proposed a cooperative automatic repeat request (ARQ) mechanism at the MAC layer. A cooperative routing algorithm based on Quality of Service was presented in [28], to minimize energy consumption. But all the aforementioned authors considered the network, where all the nodes are equipped with a single radio terminal.

The authors in [29] have proposed an opportunistic cooperative packet transmission (OCPT) scheme for multi-hop cooperative networks. In OCPT, before the transmission, a cluster head selects the transmitter and receivers to form MIMO. Because of multiple transmitters and receivers in each hop, the energy utilization of the network is considerably high. A two-stage cooperative routing strategy was proposed in [30] to enhance energy efficiency and network lifetime. Therefore this work has considered the effect of cooperation into link cost evaluation, and then obtains the optimal path based on link cost. But to obtain the best possible path, this scheme needs to evaluate the effect of cooperation and update link cost periodically.

In [31], the performance evaluation of the Rayleigh and Weibull fading channels with the best technology for relay selection for the non-regenerative wireless cooperative network. Yet, a few larger relay nodes which diminish the accuracy of the analytical design and unwanted resource usage. An asymptotically optimum solution is created by converting the original problem into a fixed stage number equivalent Finite-Horizon Markov Decision process (MDP) in [32]. A modern method is then introduced to solve the dimensionality burden, which offers empirical representations of estimated value functions. For the case where these data are unclear, a reinforcement learning algorithm is suggested. In addition, this function often includes energy consumption. [33] carry out a multi stage transfer to improve spectrum effectiveness in wireless information fusion. Often, the core network and the wireless link provide high pressure if many users request the same data.

Sadeghzadeh et al. [34] suggested a plan for physical layer protection in downlink massive MIMO system wireless connection, a systemized block diagonalization precoding that use the Artificial Noise (AN) strategy. However, the packet error rate power (PER), maximization of the confidentiality rate, or compliance with such service quality metrics are not regulated. A new Optimum Power Assignment Method (OPA) is presented in [35] to improve the cooperative Wireless Network's instantaneous secrecy limit. Nonetheless, a low convergence rate and an ineffective solution is attained by this method. [36] described horizontally as two separate homogeneous Possion Point processes (PPPs), the permissible destination and eavesdropper are dispersed, and each UAV is located just above its respective permissible destination for effective secrecy transmission. However, these terthe terms used in it are all too complex mathematically for intuition. From the aforementioned issues, it is essential to develop a new technique of routing algorithms for energy consumption in a cooperative network.

3 Hybrid Multi-hop Cooperative Routing Algorithm

In recent years, collaboration on wireless networks was becoming increasingly attractive since the particularly severe channel impairments resulting from multi-way diffusion could be alleviated. To further enhance structure and performance, the MANET and co-operative transmissions (shown in Fig. 1) are used. However, energy consumption for MANETs is a crucial issue. Due to applications of high data rate, the demand for high capacity is increasingly growing, which in turn increase energy utilization, reduce the lifespan of the network. Mobile ad hoc networks are the purest form of decentralized systems and thus place numerous challenges on cooperative communication. As a result, much ad hoc research on the network has focused on investigating fundamental algorithms for routing and clustering. Specialized protocols for embedded nodes have been built to diminish the process's energy utilization as well as to hit the entire system with high probability in the shortest possible time. Thus there is a great need to develop a new routing algorithm to reduce energy consumption.

Therefore, we proposed a novel hybrid multi-hop cooperative routing algorithm for large scale cooperative networks is proposed by combining clustering and location-based routing strategies in this paper. When a flow request arrives, the network divided into clusters via cluster heads. The formation of cluster considers various metrics which includes link Signal to Noise Ratio (SNR), relative distance, and relative mobility. After forming the cluster, one of the nodes in this is selected as a cluster head based on its location. Further, we optimize the number of transmitters and receivers in every hop; and obtain an optimal quantity of cooperative relays in every hop to reduce the end-to-end energy utilization. It is shown in Fig. 2.

3.1 Large Scale Cooperative MANET

Large Scale Cooperative Mobile Ad hoc Network (LC-MANET) consider as a network, where N nodes are uniformly distributed over an area of LxL m2, as shown in Fig. 3. Every node in the network is assumed to be self-organized and employs the Decode and Forward (DAF) relay protocol. We consider that every node in the network contains M radio terminals; a power control mechanism, which changes the power transmitted based on the distance. R and r denote the transmission coverage area and transmission radius, respectively and Ri is the nodes in the transmission region of node i (Ni) which can communicate directly with a probability of error (Pe) lower than or equivalent to a predefined threshold.

Assume that, all the nodes in LC-MANET are equipped with encoding and decoding capabilities, ideal channel evaluation and synchronization; and Maximum Likelihood (ML) detection at the destination. We consider the channel between nodes is Rayleigh fading. Let a node i broadcasts the information X, which can be successfully decoded by another node $j \in R_i$. The received information (yi) at node j is given by [37]:

$$y_i = \sqrt{P} h_{ij} X + \zeta_j \tag{1}$$

where h_{ij} represents the channel coefficient between nodes i and j designated as complex Gaussian random variable i.e., $\left|h_{ij}\right|^2 = \mu_{ij}^2 d_{ij}^{-4}$; μ_{ij}^2 and d_{ij} are the variance and distance between i and j; X represents the compressed encoded data transmitted by node i and ζ_j represents zero-mean additive Gaussian noise with the variance σ^2.

Every node can obtain its location using GPS and neighbor nodes location by exchanging beacon signals periodically (i.e., for every β sec). Based on these beacon signals, every node

Fig. 1 Cooperative communication

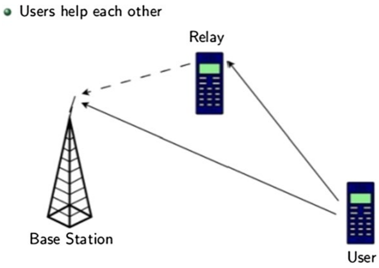
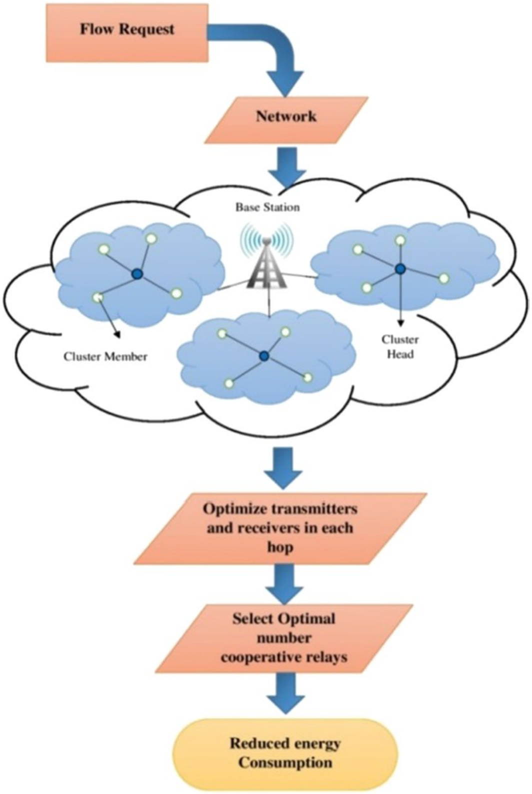


Fig. 2 Hybrid multi-hop cooperative routing algorithm



obtains parameters like link Signal to Noise Ratio (SNR), distance, and relative velocity. The link SNR between node p and node q is evaluated as

$$\zeta_q = \frac{P\left|h_{pq}\right|^2}{\sigma_q^2} \tag{2}$$

Depending on the SNR value, node p measures the relative distance to the node q as:

$$\delta d_{pq} = \left(\frac{P\delta_{pq}}{\sigma_q \delta\zeta_{pq}}\right)^{1/4} \tag{3}$$

where $\delta\zeta$ is the relative SNR, it is obtained as

$$\frac{1}{\delta\zeta_{pq}} = \left|\frac{1}{\zeta_p^{t_2}} - \frac{1}{\zeta_q^{t_1}}\right| \tag{4}$$

and $t_2 - t_1 = \beta$ The relative velocity of the nodes can be given as:

$$\delta v_{pq} = \frac{\delta d_{pq}}{\beta} \mathrm{m/sec} \tag{5}$$

After the cluster has been created, with the SNR then one of the nodes in this is chosen as a cluster head based on its position. The following section explains the routing algorithm.

3.2 Energy-Efficient Hybrid Cooperative Routing Mechanism

We first describe the proposed energy-aware hybrid cooperative routing scheme for LC-MANET and then the optimization of cooperative nodes to minimize energy consumption in this section.

3.2.1 Cooperative Routing Algorithm

If a new flow arrives from source node Ns to destination node Nd, node Ns finds the set of nodes in its transmission coverage region, and measures the metrics; link SNR and relative velocity as mentioned in system model using periodically exchanged beacon signals. Based on measured metrics, the source node forms a cluster and determines the Cluster head (Nh), where $N_h \in R_s$. The source node broadcasts the compressed encoded data $\tilde{X}$ along with destination and cluster head ID.

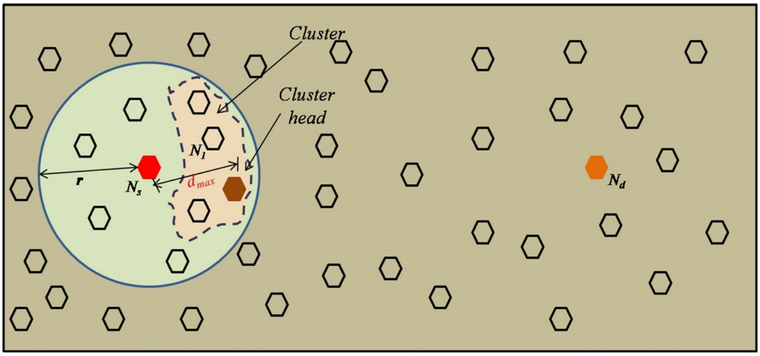


Fig. 3 Large scale cooperative MANET

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Algorithm: Energy Efficient Hybrid Cooperative Routing
Input: A new flow arrival source $(N_s)$ to destination $(N_d)$
Output: Routing path from source to destination with each next hop's Cluster Head and/or Cooperative relay nodes.
While source $\neq$ destination do
    The source node measures the metrics using periodically exchanged beacon signals.
    Find a set of nodes $(R_s)$ in its transmission coverage area R.
    If $N_d \in R_s$ then
        Cluster head=destination
    else
        The source forms a cluster with the nodes which are having the relative velocity (with source) less than a predefined threshold i.e.,
        $V_h = \{ l | (\max(\delta v_{si}) - \delta v_{si}) < v_{r;} | l \in (R_h - R_{h-1}) \bigcup N_{h-1} \}$
        From the above cluster, source selects cluster head for the next hop as:
        $N_h = \arg\max_{l \in V_h} \{ d_{N_{h-1},l} \} \forall h \geq 2$
    end if
    The other nodes in the cluster cooperate with the source to forward the data to the cluster head.
    Source node= cluster head
end while
```

It denotes h_{th} hop cluster head and set of cluster nodes as N_h and V_h respectively. The $(h+1)_{\text{th}}$ transmission required only when the destination node is not in the range of transmission of N_h i.e.,$N_d \notin R_{N_h}$. Whenever, the destination node is not in the transmission coverage area of source node, a new cluster formed with the cluster head different from the destination node. The flow diagram of the proposed energy efficient hybrid cooperative routing algorithm is given in Fig. 4.

3.3 Energy Utilization Analysis

In this section, present a cooperative MISO transmission scheme and developed an energy consumption model for a single hop. Based on this model, we obtained an optimal number of cooperative nodes.

The source node (Ns) forms a cluster (as described in Algorithm), and transmit the data in two phases.

3.3.1 Phase I

In the first phase, the data is broadcasted to all the nodes in the cluster. Consider that there are n nodes in the cluster. The average energy utilization for MQAM modulation can be expressed as [38]:

$$E_{P_1} = \frac{\xi}{\eta} Q_0 E_{b,P_1} r^2 + {(P_{tx} + nP_{rx})}/{bB} \tag{6}$$

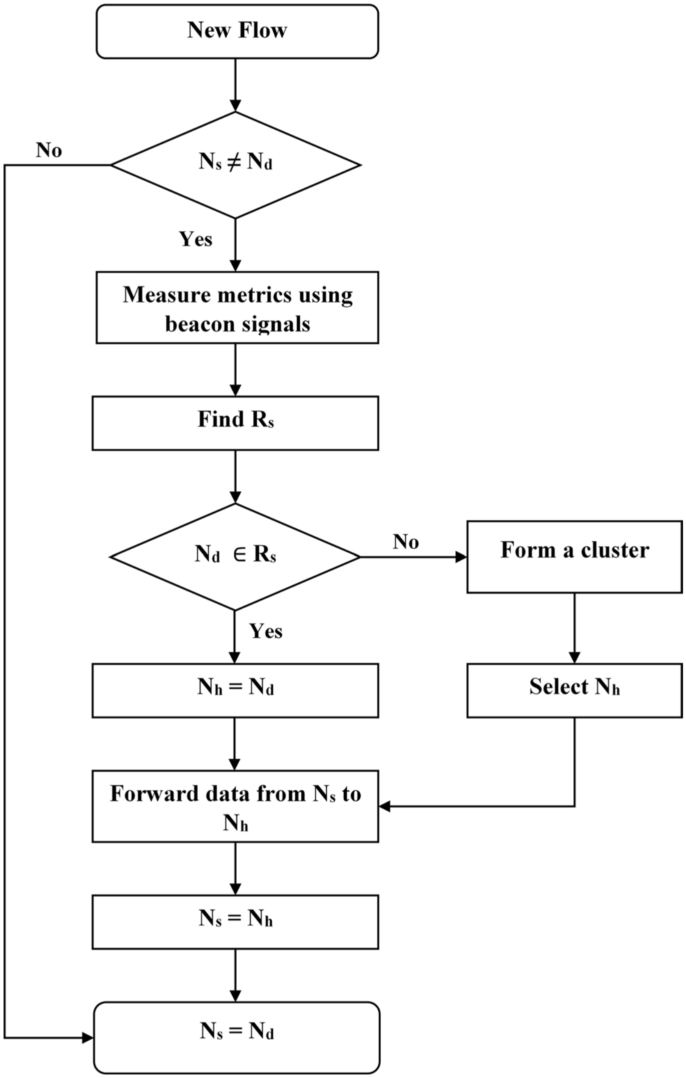


Fig. 4 Flow chart for energy efficient hybrid cooperative routing algorithm

where $Q_0 = \frac{(4\pi)^2 M_l N_f}{G_{tx} G_{rx} \lambda^2}$, $\xi = 3\frac{2^{b/2}-1}{2^{b/2}+1}$; G_{tx} and G_{rx} are the gains of source and destination respectively.

M_l is the link margin, N_f is the receiver noise figure, λ is the carrier wavelength, $\overline{E_{b,P_1}}$ the average received energy pet bit in phase 1, bis the transmission bit rate, B is the modulation Bandwidth, P_{tx} and P_{rx} are the transmitter and receiver circuit powers respectively.

The average number of nodes in the cluster is

$$n = \frac{\pi r^2 N}{L^2} P(\delta v). \tag{7}$$

After phase 1 broadcast the cluster then it processes phase 2 with n nodes for transmitting the data to the cluster head.

3.3.2 Phase II

In phase 2, n nodes (n – 1 cluster nodes and source node) are used for data transmission to the next-hop cluster head. The average energy consumption can be given by

$$E_{p_2} = \frac{\xi}{\eta} Q_0 \overline{E_{b,P_2}} d_{\max}^2 + \left(nP_{tx} + P_{rx}\right) / bB \tag{8}$$

The average energy consumption per bit of every hop is $E_h = E_{p_1} + E_{p_2}$.

The upper bound $\overline{E_{b,P_2}}$ can be obtained by Chertoff upper bound with several receiving antennas equal to one.

$$\overline{E_{b,P_2}} \le \frac{2\left(2^b - 1\right) N_0 n}{3b} \left(\frac{4}{bP_e}\right)^{1/n} \tag{9}$$

$\overline{E_{b,P_2}}$ can be obtained by substituting n = 1. By approximation Eq. (9) as equality, we obtained closed-form of expression for the average energy consumption per bit as:

$$E_h = C_b \left[\frac{C_e L^2}{\pi N P(\delta v)} + \left(C_e\right)^1 / n d_{\max}^2\right] n + C_p(n + 1) \tag{10}$$

where $C_b = \frac{\xi Q_0 2(2^b - 1) N_0}{3b\eta}$, $C_e = \frac{4}{bP_e}$ and $C_{{}_p} = \frac{P_{tx} + P_{rx}}{bB}$. According to the proposed algorithm, hthHop cluster head should be in the transmission coverage area of $(h - 1)$th hop cluster head. Hence the distance among the two cluster heads $\left(d_{\max}\right)$ should be $d_{\max} \le r$.

The average number of nodes in a cluster becomes

$$n \le \frac{\pi N d_{\max}^2 P(\delta v)}{L^2}. \tag{11}$$

where $P(\delta v)$ the probability of the node having relative mobility difference is less than the threshold. We approximate the optimal value of n to minimize the average energy consumption per bit $E(h)$ $when\ d_{\max}^2 \ge \frac{nL^2}{\pi N P(\delta v)}$ as:

$$\min_n E_h\, s.t. 2 \le \frac{\pi N d_{\max}^2 P(\delta v)}{L^2} \tag{12}$$

Otherwise, n = 1 transfers the data in the SISO transmission scheme. We obtain the critical value of a function E_h by differentiating concerning n is:

$$d_{\max}^2 \left(C_e\right)^{1/n} \left[n - 1n\left(C_e\right)\right] + \left[\frac{C_e L^2}{\pi N P(\delta v)} + \frac{C_p}{C_b}\right]_{n=o} \tag{13}$$

Since the above equation is positive, n should be less than $\ln\left(C_e\right)$. Let the positive real-valued solution of the above equation is n_p. Then the optimal value of E_h is obtained as:

$$n_0 = \begin{cases} [n_p] & if\ 2 \leq n_p \leq \frac{\pi N d_{\max}^2 P(\delta v)}{L^2} \\ 2 & if\ n_p < 2 \end{cases} \tag{14}$$

Thus the proposed routing algorithm reduces the energy consumption with the analysis of multi-hop channels.

4 Results and Discussion

This section clearly explains the feasibility of our proposed method by evaluating and contrasting the experimental results obtained with traditional methods. Specification tools for implementation are given below.

4.1 System Specification

The methodology proposed is described in Sect. 3 above and is analyzed in detail in this section. The suggested approach is applied with the following device specification in the MATLAB work platform.

Platform	MATLAB 2019a
OS	Windows 8
Processor	Intel core i5
RAM	8 GB RAM

4.2 Simulation Results

Simulation analysis of the proposed algorithm is presented in this section. We simulated our algorithm using MATLAB with the parameters listed in Table 1:

Table 1 Parameters for simulation

Notation	Meaning	Value
N	Number of nodes	[100–1000]
P	Transmitted power	1 mW
N_0	Noise power spectral density	− 171 dBm/Hz
B	Modulation bandwidth	10 kHz
	Combining strategy	MRC
β	Periodic interval	1 μs
M_l	Link margin	40 Db
N_f	Noise figure	10 dB
P_e	Target BER	10^{-3}
G_{tx}, G_{rx}	Transmitter and receiver gain	5 dBi
P_{tx}	Transmitter circuit power consumption	97.8 mW
v_T	Velocity threshold	5 m/sec
P_{rx}	Receiver circuit power consumption	119.8 mW

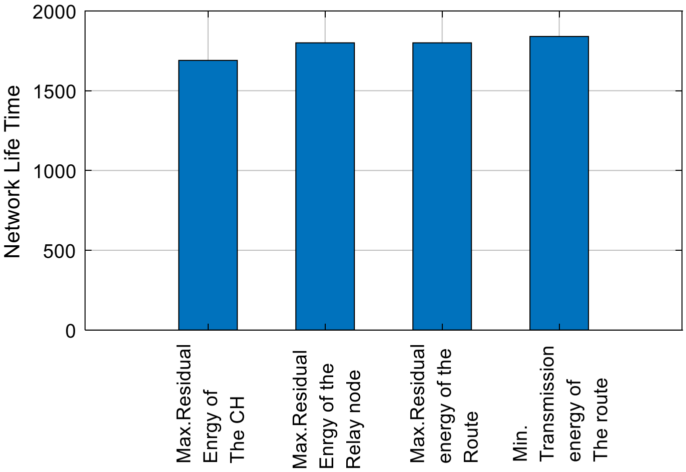


Fig. 5 Comparison of four fitness criteria's network lifetimes

Table 2 Network lifetime

Fitness function	Network life time
Max. Residual energy of the CH	1690
Max. Residual energy of the relay node	1800
Max. Residual energy of the Route	1800
Min. Transmission energy of the route	1840

Figure 5 demonstrates a network span with the maximum cluster head residual energy, maximum relay node residual energy, maximum path residual energy, and minimal energy transmission of path. Criterion 4 is the longest possible life. As presented in the previous section, the lifetime of the network has been reduced with the increase of energy consumption. Here, the criterian 4 consumes minimum transmission energy for routing, such a way, the network lifespan under criterion 4 has been increased. This implies that criterion 4 is fair and holds a balance of load. Consequently, Criterion 4 is used for the fitness of hybrid multi-hop cooperative routing.

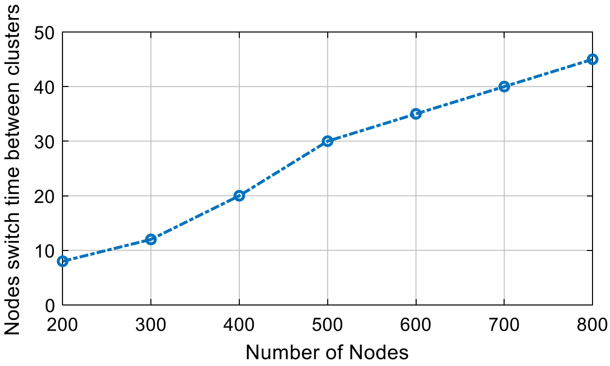
Table 2 demonstrates the network life in which the overall residual energy of CH is 1690, the overall residual energy of the relay node network lifespan is 1800. The network lifetime is 1800, Min. Residual energy of the path. Network life is 1840 with transmitting energy from the path.

As presented in the proposed routing algorithm, if the destination node is not in the transmission coverage area of the source node, the new cluster has been formed. The time for new cluster formation has been presented in the Fig. 6.

4.3 Comparison Analysis

In this section we are comparing the lifetime and residual network energies of the EECC (energy-efficient cooperative communication method) sensor nodes [39] and of the HEED

Fig. 6 New cluster formation time



(hybrid-energy efficient distributed clustering approach) [41], and SOSAC [Self-Organized and Smart Adaptive Clustering] [40], which are the most common inter cluster routing.

The network lifetime relation is shown in Fig. 7. We compare the lifetimes of the EECC network (use of relay nodes), SOSAC (without relay nodes), and HEED, to claim the legitimacy of the collaborative method of communication.

Table 3 indicates that the network life time of EECC is about 1,300 while the first node is exhausted and, relative to that of the SOSAC network life, about 1890 after the 20th node has been exhausted. For SOSAC when the first node is drained the lifetime is 1000 and 1700 when the last node is drained. Then for HEED, the first node drained value is 600 and the last node drained value was 1800. However, our proposed work drained the first node the lifetime is 1400 and the last node drained lifetime is 2050 it is greater when compared with the above techniques. The experimentation stated the coordination of the CH and relay nodes, by reducing energy consumption and preserving load balance, intensifies the network's life.

Figure 8 shows the comparison graph for the experimentationupon residual energy ratios of various techniques such as EECC (using relay nodes), SOSAC (without relay nodes), and HEED (hybrid-energy efficient distributed clustering approach) with the proposed algorithm.

Table 4 compares EECC, HEED's mean residual energy ratios, which range from 40% (when the first node is exhausted) to 10% (when the twentieth node is exhausted). The HEED ratio is between 70% (when draining the first node) and 25% (when draining the

Fig. 7 Comparison of the network lifetime of the proposed algorithm

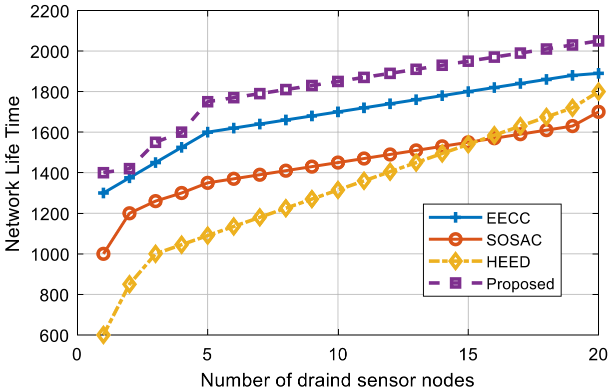


Table 3 Comparison of network lifetime

Number of drained nodes	Network life time			
	EECC	SOSAC	HEED	Proposed
1	1300	1000	600	1400
2	1375	1200	850	1420
3	1450	1260	1000	1550
4	1525	1300	1045	1600
5	1600	1350	1090	1750
6	1620	1370	1135	1770
7	1640	1390	1180	1790
8	1660	1410	1225	1810
9	1680	1430	1270	1830
10	1700	1450	1315	1850
11	1720	1470	1360	1870
12	1740	1490	1405	1890
13	1760	1510	1450	1910
14	1780	1530	1495	1930
15	1800	1550	1540	1950
16	1820	1570	1585	1970
17	1840	1590	1630	1990
18	1860	1610	1675	2010
19	1880	1630	1720	2030
20	1890	1700	1800	2050

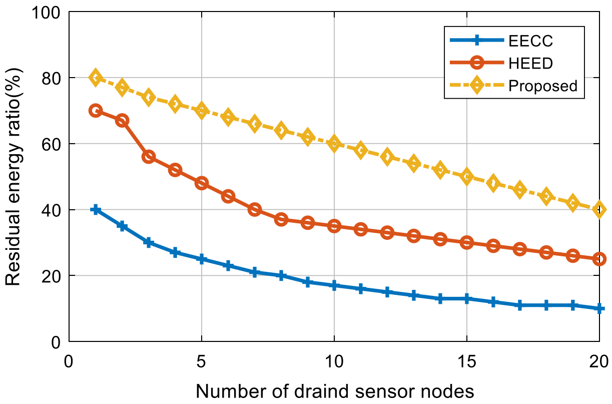


Fig. 8 Experimentation on the residual energy ratios of various techniques

twentieth node). This means that the energy utilization of all EECC sensor nodes is more equal than the energy utilized by HEED.

The above Fig. 9 depicts the network throughput in which Fig. 9a depicts throughput versus pause time, Fig. 9b plots the throughput versus some nodes, Fig. 9c shows throughput versus CBR connection, and Fig. 9d shows the throughput versus packet size. The compared techniques are ANTC (Adaptive Neighbor-based Topology Control), LFTC (Learning-based Fuzzy-logic Topology Control), and LBTC (Location-Based Topology Control

Table 4 Comparison of residual energy ratio

Number of drained sensor nodes	Residual energy ratio (%)		
	EECC	HEED	Proposed
1	40	70	80
2	35	67	77
3	30	56	74
4	27	52	72
5	25	48	70
6	23	44	68
7	21	40	66
8	20	37	64
9	18	36	62
10	17	35	60
11	16	34	58
12	15	33	56
13	14	32	54
14	13	31	52
15	13	30	50
16	12	29	48
17	11	28	46
18	11	27	44
19	11	26	42
20	10	25	40

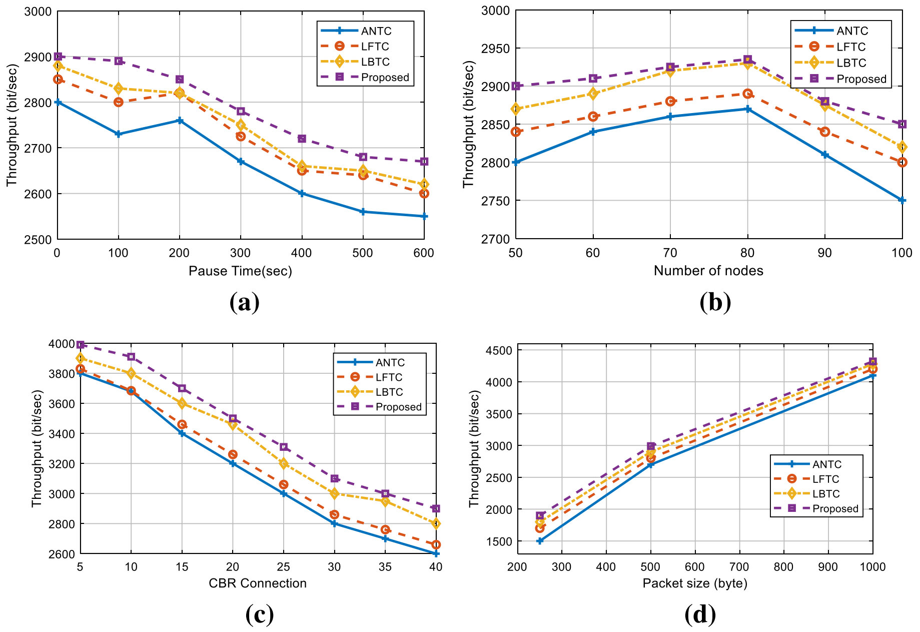


Fig. 9 Network throughput

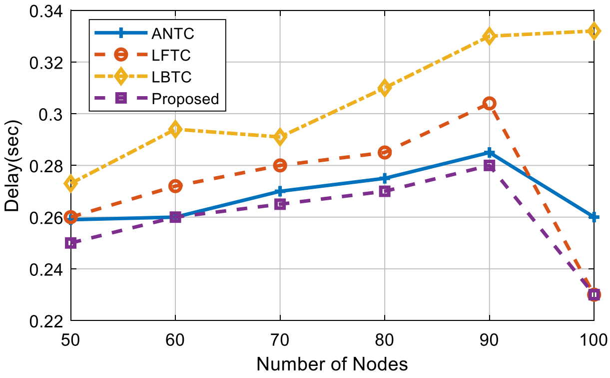


Fig. 10 Delay versus number of nodes

Table 5 Comparison of end-to-end delay

Number of nodes	Delay (sec)			
	ANTC	LFTC	LBTC	Proposed
50	0.259	0.26	0.273	0.25
60	0.26	0.272	0.294	0.26
70	0.27	0.28	0.291	0.265
80	0.275	0.285	0.31	0.27
90	0.285	0.304	0.33	0.28
100	0.315	0.23	0.332	0.23

with Sleep Scheduling). Figure 9 demonstrates that the proposed achieved higher throughput. The improvement in network life through an effective power change is attributed to higher efficiency.

Figure 10 shows the End-to-end Delay versus amount of nodes with the methods like ANTC, LFTC, and LBTC. From Table 5, it is clear that in comparison to LFTC and ANTC, LBTC has a higher end-to—end delay. This is because hop count increases as lower power transmission nodes.

In order to appraise the overall comparison of our proposed algorithm with the existing system, the following approaches are taken into an account likead hoc on-demand distance vector (AODV) routing algorithm [42], Opportunistic Cooperative Packet Transmission (OCPT) [43].

Figure 11 displays the total number of hops depending on the number of nodes for different routing schemes. The proposed routing scheme needs fewer hops than AODV and OCPT schemes, since the possibility of removing a node from the source also increases with the increase in network node density and transfers the data to the destination with minimal path length i.e., in a minimum number of hops.

Figure 12 depicts the comparison of end-to-end energy consumption over the number of nodes for various routing schemes. Since we obtain the optimumamount of cooperative nodes in each hop, the energy consumption of the path will decrease. Our algorithm requires a less number of hops with increased node density; the energy utilization is even minimized by 53.42% as compared to traditional AODV routing algorithms at N = 700 and N = 900.

Fig. 11 Average number of hops

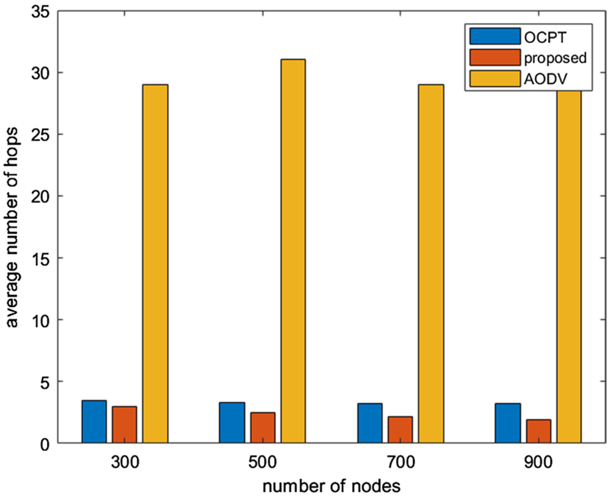
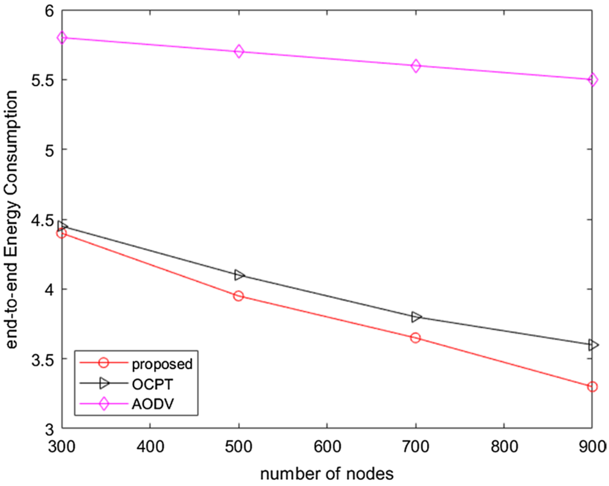


Fig. 12 End-to-end energy consumption



5 Conclusion

Cooperative communications enable the efficient use of communication resources by allowing communication network nodes or terminals to collaborate in the transmission of information. This paper presented a hybrid multi-hop cooperative routing algorithm for LC-MANET. We combined clustering and location-based strategies to mitigate the mobility effect and reduce the average number of hops. In every hop, we incorporated optimization mechanisms and obtained an optimal number of cooperative nodes by jointly optimizing the number of transmitters and receivers. Implementation outcomes showed that hybrid multi-hop cooperative routing algorithm saves energy utilizationup to 53.42% in contrast with the conventional routingstrategy.

Declarations

Conflict of interest The authors declare that they have conflict of interest.

References

1. Andrews, J. G., Buzzi, S., Choi, W., Hanly, S. V., Lozano, A., Soong, A. C. K., & Zhang, J. (2014). What will 5G Be? *IEEE Journal on Selected Areas in Communications, 32*, 1065–1082.
2. Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor network. *Ad Hoc Network J., 3*, 325–349.
3. Taneja, S., & Kush, A. (2010). A survey of routing protocols in mobile Ad hoc networks. *International Journal of Innovation Management and Technology, 1*, 279–285.
4. Xie, K., Cao, J., Wang, X., & Wen, J. (2013). Optimal resource allocation for reliable and energy efficient cooperative communications. *IEEE Transactions on Wireless Communications, 12*(10), 4994–5007.
5. Xie, K., Cao, J. N., & Wen, J. G. (2013). Optimal relay assignment and power allocation for cooperative communications. *Journal of Computer Science and Technology, 28*(2), 343–356.
6. Group, I.W. (1999). Wireless LAN medium access control (MAC) and physical layer (PHY) specifications - Amendment 1: Highspeed physical layer in 5 ghz band. In *IEEE Strandard 802.11, New York, NY.*
7. Lin, T., Wu, K., & Yin, G. (2015). Channel-hopping scheme and channel diverse routing in static multi-radio multi-hop wireless networks. *IEEE Transactions on Computers, 64*(1), 71–86.
8. Arboleda, L.M.C., & Nasser, N. (2006). Comparison of clustering algorithms and protocols for wireless sensor networks, pp. 1787–1792.
9. Sabor, N., Sasaki, S., Abo-Zahhad, M., et al. (2017). A comprehensive survey on hierarchical-based routing protocols for mobile wireless sensor networks: Review, taxonomy, and future directions. *Hindawi Wireless Communications and Mobile Computing, 5*, 1–23.
10. Krunz, M., Muqattash, A., & Lee, S. J. (2004). Transmission power control in wireless ad hoc networks: Challenges, solutions, and open issues. *IEEE Network Magazine, 18*(5), 8–14.
11. Chiang, M. (2005). Balancing transport and physical layers in wireless multihop networks: Jointly optimal congestion control and power control. *IEEE Journal on Selected Areas in Communications, 23*(1), 104–116.
12. Gomez, J., & Campbell, A. T. (2007). Variable-range transmission power control in wireless ad hoc networks. *IEEE Transactions on Mobile Computing, 6*(1), 87–99.
13. Zhang, X., Anpalagan, A., Guo, L., & Khwaja, A.S. (2015). Energy efficient cooperative MAC protocol based on power control in MANETs. In *Proceedings of the IEEE 29th International Conference on Advanced Information Networking and Applications (AINA '15)*, pp. 48–53.
14. De-yun, G., Lin-juan, Z., & Hwang-cheng, W. (2011). Energy saving with node sleep and power control mechanisms for wireless sensor networks. *The Journal of China Universities of Posts and Telecommunications, 18*(1), 49–59.
15. Wu, S., Tseng, P., & Chou, Z. (2005). Distributed power management protocols for multi-hop mobile Ad Hoc networks. *Computer Networks, 47*(1), 63–68.
16. Zheng, R., & Kravets, R. (2005). On-demand power management for ad hoc networks. *Ad Hoc Networks, 3*(1), 51–68.
17. Ray, N.K., & Turuk, A.K. (2009). A review on energy efficient MAC protocols for wireless LANs. In *Proceedings of the 4th International Conference on Industrial and Information Systems (ICIIS '09)*, pp. 137–141.
18. Toh, C. K. (2001). Maximum battery life routing to support ubiquitous mobile computing in wireless ad hoc networks. *IEEE Communications Magazine, 39*, 138–147.
19. Khandani, A. E., Abounadi, J., Modiano, E., & Zheng, L. (2007). Cooperative routing in static wireless networks. *IEEE Transactions on Communications, 55*, 2185–2192.
20. Elhawary, M., & Haas, Z. J. (2011). Energy-efficient protocol for cooperative networks. *IEEE Transactions on Networking, 19*, 561–574.
21. Li, F., Wu, K., & Lippman, A. (2006). Energy-Efficient Cooperative Routing in Multi-hopWireless Ad Hoc Networks. *In Proceedings of the 2006 IEEE International Performance Computing and Communications Conference, Phoenix, AZ, USA,* 215–222.

22. Shi, L., & Fapojuwo, A. O. (2012). Cross-layer optimization with cooperative communication for minimum power cost in packet error rate constrained wireless sensor networks. *Ad Hoc Networks, 10*, 1457–1468.
23. Shi, J., Calveras, A., Cheng, Y., & Liu, K. (2013). A novel power efficient location-based cooperative routing with transmission power-upper-limit for wireless sensor networks. *Sensors, 13*, 6448–6476.
24. Dehghan, M., Ghaderi, M., & Goeckel, D. (2011). Minimum-energy cooperative routing in wireless networks with channel variations. *IEEE Transactions on Wireless Communications, 10*, 3813–3823.
25. Li, X., Tao, X., & Li, Na. (2016). Energy-efficient cooperative MIMO-based random walk routing for wireless sensor networks. *IEEE Communications Letters, 20*(11), 2280–2283.
26. Li, P., Guo, S., & Hu, J. (2014). Energy-efficient cooperative communications for multimedia applications in multi-channel wireless networks. *IEEE Transactions on Computers, 64*(6), 1670–1679.
27. Akhtar, A. M., Behnad, A., & Wang, X. (2014). Cooperative ARQ based energy efficient routing in multi-hop wireless networks. *IEEE Transactions on Vehicular Technology, 64*(11), 5187–5197.
28. Zheng, L., Liu, J., & Zhai, C. (2011). Energy-efficient cooperative routing algorithm with truncated automatic repeat request over Nakagami-m fading channels. *IET Communications, 5*(8), 1073–1082.
29. Gao, Y., Kang, G., & Cheng, J. (2019). An opportunistic cooperative packet transmission scheme in wireless multi-hop networks. In *IEEE Wireless Communications and Networking Conference Workshop (WCNCW)*, pp. 15–18.
30. Cheng, J., Gao, Y., Zhang, N., & Yang, H. (2019). An energy-efficient two-stage cooperative routing scheme in wireless multi-hop networks. *Sensors, 19*, 1002.
31. Asshad, M., Kavak, A., Küçük, K., & Khan, S. A. (2020). Using moment generating function for performance analysis in non-regenerative cooperative relay networks with max-min relay selection. *AEU-International Journal of Electronics and Communications, 116*, 153066.
32. Lv, B., Wang, R., Cui, Y., Gong, Y., & Tan, H. (2020). Joint optimization of file placement and delivery in cache-assisted wireless networks with limited lifetime and cache space. arXiv preprint http://arxiv.org/abs/2001.02557.
33. Gao, Y., Ao, H., Zhou, W., Hu, S., Yu, H., Guo, Y., & Cao, J. (2019). A novel AI based optimization of node selection and information fusion in cooperative wireless networks. In *Proceedings of SAI Intelligent Systems Conference,* pp. 14–23.
34. Sadeghzadeh, M., Maleki, M., & Salehi, M. (2019). Large-scale analysis of regularized block diagonalization precoding for physical layer security of multi-user MIMO wireless networks. *IEEE Transactions on Vehicular Technology, 68*(6), 5820–5834.
35. Ragheb, M., & Hemami, S. M. S. (2019). Secure transmission in large-scale cooperative millimetre-wave systems with passive eavesdroppers. *IET Communications, 14*(1), 37–46.
36. Yao, J., & Xu, J. (2019). Secrecy transmission capacity of large-scale UAV-enabled wireless networks. In *2019 IEEE International Conference on Communications Workshops (ICC Workshops),* pp. 1–6.
37. Praveen Kumar, D., Sushanth Babu, M., & Prasad, M.S.G. (2016). Suboptimal comparison of AF and DF relaying for fixed target error probability. In *IEEE International Conference on Computer Communication and Informatics,* pp. 07–09.
38. Cui, S., Andrea Goldsmith, J., & Bahai, A. (2004). Energy-efficiency of MIMO and cooperative MIMO techniques in sensor networks. *IEEE Journal on Selected Areas in Communications, 22*(6), 1089–1098.
39. Lee, K., & Lee, H. (2014). An energy-efficient cooperative communication method for wireless sensor networks. *International Journal of Distributed Sensor Networks, 10*(3), 689710.
40. Lee, K., & Lee, H. (2012). A self-organized and smart-adaptive clustering and routing approach for wireless sensor networks. *International Journal of Distributed Sensor Networks, 13*.
41. Qin, W., Hempstead, M., & Woodward, Y. A realistic power consumption model for wireless sensor network devices. In *Proceedings of the 3rd Annual IEEE Communications Society on Sensor and Ad Hoc Communications and Networks (Secon '06), 1*, 286–295.
42. Perkins, C., & Royer, E. (1999). Ad-hoc on-demand distance vector routing. In *Proceedings of 2nd IEEE Workshop Mobile Comput. Syst. Appl.,* pp 90–100.
43. Gao, Y., Kang, G., & Cheng, J. (2019). An opportunistic cooperative packet transmission scheme in wireless multi-hop networks. *Sensors, 19*(21), 4821.

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