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Original scientific paper

Enhancing Lifetime and Performance in Wireless Sensor Networks with Cooperative Stabilized Proactive Energy-Aware Cluster Routing Protocol

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Abstract: The recent development of wireless communication technology empowers sensing, monitoring, and data transfer in remote areas through a heterogeneous model. However, managing energy levels for data transfer presents challenges, as energy consumption can lead to packet loss, and delay tolerance can cause latency failures, ultimately impacting network lifetime. To address this, we propose the Cooperative Stabilized Proactive Energy-Aware Cluster Routing Protocol (CSP-EACRP) based on self-balanced cooperative communication in wireless sensor networks. Initially, we estimate neighbour discovery node level depletion and determine the Node response behaviour rate to assess the active transmission level, considering energy, delay, transmission, drop ratio, and latency. This estimation helps determine the absolute mean weight when considering active nodes. We then construct the Adaptive Petal Spider Ant Colony Cluster Algorithm (APSAC2A) to enhance link stability for route optimization. Subsequently, the Cooperative Stabilized Proactive Energy-Aware Cluster Routing Protocol (CSP-EARP) is developed to facilitate self-balanced congestion routing (SBCR) with support from the Lookup Energy Constraint Duty Cycle (LECDC), aiming to improve network lifetime. This, in turn, enhances throughput performance and distributes routing energy efficiently among one or more nodes. Compared to existing transmission models, this proposed system prolongs network lifetime and improves Quality of Service (QoS) performance, yielding superior results. The proposed system achieves energy-efficient data transfer, enhancing delay tolerance at the latency level and increasing throughput to improve communication lifetime.

Keywords: cluster routing protocol; delay tolerance; energy-efficient routing; quality of service (QoS); wireless sensor networks (WSNs)

1 INTRODUCTION

WSNs have often been used to monitor environments in remote locations. They consisted primarily of wireless sensor nodes, usually powered by low-capacity batteries but expected to communicate over long distances and continue to operate [1]. Various energy harvesting techniques have been proposed for wireless power nodes to overcome these obstacles, but multi-hop techniques have been used to extend the communication range. For a very long time, scheduling the routing algorithms in a wireless sensor network requires careful consideration of energy and power usage. As parts of wireless sensor networks, sensor nodes serve as efficient power storage devices in communication networks and have deficient energy consumption. For a very long time, scheduling the routing algorithms in a wireless sensor network has been hampered by issues with y and power consumption. As parts of wireless sensor networks, sensor nodes serve as efficient power storage devices in communication networks and have deficient energy consumption [2].

Dynamic route constraints Energy problems are extensive mitigations in route allocation strategies. Due to the overhead of routing protocol, traffic is not permitted to restrict the network or for a local change in link to cause enormous control over traffic through the web. Topology facts must be replaced between nodes on a consistent source to keep efficient directing statistics. This is a comparatively high network upstairs [3]. The advantage of this is that the paths are always available on demand. Every routing table of nodes catalogs reachable targets, subsequent hop nodes, and the count of nodes to achieve. Every routing table marks the sequence number of all entries allotted by the destination node. The machine learning model analyzes the path propagation to transfer the data by intending the information available of the network from each duty cycle to make data analysis to sense the routing to create an efficient transmission. Most routing algebra formalism was considered, together with the extensive literature on routing metric definition, to provide a framework for selecting and composing routing metrics. [4].The paper's contribution is as follows:

- The Self-balanced cooperative communication in CSP-EACRP improves data transmission efficiency and network performance by promoting collaboration among sensor nodes.
- The APSAC2A algorithm enhances link stability, route optimization, and data transmission reliability. CSP-EACRP, with the adaptive clustering algorithm, ensures stable routing paths, reduces routing overhead, and enhances network scalability.
- Additionally, CSP-EARP introduces SBCR using the LECDC mechanism to improve network lifetime and overall performance by efficiently managing congestion and optimizing energy usage.
- Combining the APSAC2A algorithm and CSP-EARP facilitates route optimization, stability enhancement, reliable data transmission, minimized latency, and improved overall routing performance.

2 RELATED WORKS

Most routing uses existing energy-efficient dynamic stochastic routing algorithms [5]. This traditional flood mechanism produces a large number of duplicate packets that are sent across the network. It exacerbates network conflicts, conflicts, and exchanges. The multiple routing protocols based on the least approach for reliable routing are proposed [6], which finds various routes to reach the endpoint. The packet of data from the source is directed and distributed in multiple paths. The token-based multipath routing algorithm uses hybrid clustering and path selection [7]. The method performs clustering according to the triangle optimization algorithm. The cluster head is designated to confer the trust degree of nodes, where the trust degree is calculated according to energy consumption, network lifetime, mobility, etc [8].

An efficient neural network-based routing protocol is presented where the technique classifies the incline of routes available, rendering priority, distance, and mobility speed [9]. Most offer a sink location-based rate adjustment when sending the packet. The method reduces traffic issues by controlling the sending rate towards each node according to traffic volume [10]. A dependable starfish clustering-based direction-finding algorithm is obtainable, determining the path based on the ratio of sent to received packets [11]. Data transmission reliability is assured by routing based on location details in WSN to safeguard against replay attacks.

In energy and computationally restricted WSN, a multi-hop communication network with many drops optimizes data dissemination for throughput, bandwidth, and energy utilization [12]. Multi-sink scenarios in energy-constrained wireless sensor networks consider network-coding scheme-based transmission through a predefined Minimum Wiener Index Spanning Tree (MWST)-based multi-hop routing approach [13-15]. The author presents the Artificial Intelligence (AI) method for intelligent route allocation that fits capable multi-agent learning on top of the Wireless Sensor Network (WSN) scenario.

A cheap routing system for pack forwarding and vitality intake was essential for gathering and delivering sensory data in WSNs [16-18]. To implement the avaricious and location-insensitive hop-by-hop packet forwarding method, this author presented E-CARP, an improved version of the Channel-Aware Routing Protocol (CARP). Accordingly, data packet forwarding was induced, which may not be advantageous for applications. Terrestrial Wireless Sensor Networks (TWSN) have many similarities despite using distinct communication channels and operating in different settings due to WSNs' struggles with low bandwidth, long latency, and high bit error rates. These have led to several issues with WSNs, including quiet dependability, packet retransmission, and excessive energy usage [19-21].

3 PROPOSED WORK

The development for lifetime improvement considers energy level optimization. This proposed system migrates the data transfer rate under the active node response rate at high precision to evaluate low energy levels to propose a Cooperative stabilized proactive Energy-aware cluster routing protocol (CSP-EACRP) based on self-balanced cooperative communication in the network of wireless sensors. Initially, the neighbor discovery node level depletion s estimated, and the Node response behavior rate finds the active transmission level, which considers the energy, delay, transmission, drop ratio, and latency to estimate the mean weight for evaluating the active nodes. An adaptive Petal spider ant colony cluster was constructed based on the estimation for link stability and route optimization. Then, the Cooperative stabilized proactive Energy-aware cluster routing protocol was intended to make self-balanced congestion routing with the Lookup energy constraint duty cycle (LECDC) support to improve the network's lifetime.

This shortens the lifetime of nodes and causes more significant energy loss. Also, some methods consider the traffic of nodes and routes in cooperative routing to select the secondary thoroughfare used for communication and data transmission.

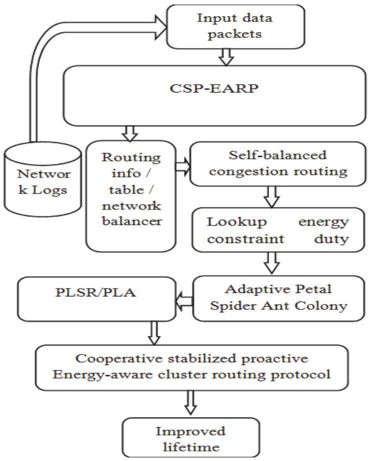

Figure 1 Architecture diagram for a proposed system

This, in turn, enhances throughput performance and obtains the path energy from one or more nodes. Fig. 1 shows the architecture diagram for a proposed system. The WSN sensing environment is monitored through a network of information constructed by simulated network modulation to collect the data. The WSN contains sensors connected to a public network communication medium, a level dependency that manages the time series data from the route table facts. This collects transmission rate, delay tolerance, route propagation, traffic consideration, time duty cycle, and network information. These features are regularly organized in a time series manner to monitor the route information. These are considered as features observed, and the values collected from the sensors unit are processed through route allocation further for data analysis.

3.1 Network Preliminaries

The sensor node coverage region is extracted using the sensor medium presence medium. The network considers the sensor device-driven medium at the axis of network communication. Let's Sensor medium $M(x, y)$ contain $\{s_1, s_2, s_3, ...\}$ the sensors they randomly connected network of coordinated medium 'M.' Let 'Z' be the medium at the 'n' number of nodes coordinated with sensors with regular distance 'D' in the variation have the sensors.

$$\left(nX_1-nx_2\right)^2(i)+\left(nY_1-ny_2\right)^2(i)+\left(nZ_1-nz_2\right)^2(i)=D^2 \quad (1)$$

The ordinary nodes at the transmission medium get closed coverage response nodes, which are considered cooperative medium 'ρ' to reduce the localization problems. The Min-max coverage region is evaluated to adjust the closest term at the maximum response node with the need for an additional response node.

$$\rho=\sum_i^n\left(\left(nX_1-nx_2\right)^2(i)+\left(nY_1-ny_2\right)^2(i)+\left(nZ_1-nz_2\right)^2(i)-d(i)\right) \quad (2)$$

This reduces further propagation of the distance node without accepting the unknown node N_i in the corresponding node. This considers the only responding relative transmission node (nX, nY, nZ) position.

3.2 Self-Balanced Congestion Routing (SBCR)

In this stage, the self-balancing sensor node energy constraints are estimated. The Network initialization is carried out to create a simulation environment with a connected sensor modulus. Let [N] be the node number representing size $S[n]$ in a dynamic heterogeneous communication medium. Let us use the WSN construction medium. S_{S_i} is the sender, and R_{S_i} is the receiver node with the transmission 'S' in the communication medium with the dedicated route 'R.' The monitoring agent control is based on the controller, and the information is observed from the Route table 'RT' configuration having the communication information.

$$R_{S_i} = \left(i \in N \middle| d_i < d_s \Delta D_{(j,s)} \right) \tag{3}$$

where $D_{(j,s)}$ points to the neighbor node based on Euclidian distance based on the residual energy S_i had the power at the current level. The normalized energy constraints are NFsi in depth 'd' at initialized node 'i' and 's' in the communication medium.

The nodes are randomly traversed to process the sensor medium in WAN topology with base AODV protocol Mac 8011.45 pointed communication medium energy constraints by attaining the Dynamic heterogeneous network. The threshold energy is normalized to consider the medium energy depletion level, whether the node is present or left. The energy is optimized based on the node's participation in the active medium.

The actual threshold energy levels are in Joules, which is represented as:

$$Th_r = E_t\left(T_t\right) \tag{4}$$

Be the node N at an active medium in the communication range; after the dynamic configuration of node variation, the residual energy variation is inactive in communication radius point presentation.

$$th_r = E_t\left(T_t\right) \cdot T_{radj} \tag{5}$$

Each active and inactive presentation in the network is performed by considering the energy at minimum support to be actively diffused in the presence of nodes. This supports only active nodes in the neighbor coverage region. Other nodes are inactive, refusing to avoid energy losses.

3.3 Lookup Energy Constraint Duty Cycle (LECDC)

The sensor node is varied due to each duty cycle at transmission, so the delay constraints are estimated based on delay. The excessive data loss retained in the sensor medium is a probability effect on the delay constraints. To assess the active constraints, the time to consider the base communication is excellent for responding from the Cluster. So, the head of the cluster replaces the node tolerance to transmit the data without delays.

$$\sum\nolimits_p t_p < t_{delay} \tag{6}$$

where p is the cluster response grid at t_{hetp} residence time of response during transmission; it takes maximum support level constraints with minimum transfer delay.

$$t_p > \frac{d_p}{V}, \forall P \tag{7}$$

This covers response dependencies similar to those of the neighbor node. This reduces the maximum support nodes on the singular route on different vertices 'V' at low energy consumption.

3.4 Maximum Support Energy Constraints

The minimum energy constraints are based on the node in an active medium without requiring additional resources. This estimated the stay node responsibility of sensor nodes to refuse to do active transmission without delay. The difference (Px_i, Py_i) is active sensor point response in active nodes and d_{ij} at N_i in neighbor coverage, having the distance relatively refused by relay node support. The maximum support dependencies path has maximum support without additional resources. The active presence of a node is estimated by:

$$dg_i^p = \sqrt[2]{\left(Px_i - gy_p\right)^2 + \left(Px_i - gy_p\right)^2}\, j \in N_i \tag{8}$$

The 'g' represents the ground truth labels of the sensor node's active constraints with a set of neighboring nodes 'N_i' in the throughput range. The cluster head response point P is located between the router and transmission nodes at a base station.

$$h_i^p = \begin{cases} ldg_i^p < d_{\max} \\ \min_{j \in N_i} \left(h_i^p\right) dg_i^p \geq d_{\max} \end{cases} \tag{9}$$

The maximum throughput energy depletion is pointed at the minimum hop presented from the nearest sensor nodes that share the h_i^p minimum consumption representation point of transmission.

$$h_{ij}^p = \begin{cases} ldg_i^p < d_{\max} \\ \propto dg_i^p \geq d_{\max} \end{cases} \tag{10}$$

The maximum support level of energy nodes is considered to create communication with the hop controller. The heterogeneous presentation is isolated based on the full support needed to communicate.

$$\sum\nolimits_p C_i^p \geq l, \forall i \tag{11}$$

This estimates the maximum scalar support margin in the transmission field. This takes the sensor medium close to the cluster head, responsive to the active transmission nodes. The maximum support on each node is relatively posed on a maximum transmission medium with redundant energy to handle the data.

$$0 \le C_i^p g_i^p + b_i^{p-1} + t_p, s_p \tag{12}$$

where g_i^p refers to the maximum transmitted data of the sensor node, i is reflected when P, the grid center's cluster head node, is situated. S denotes the sensitivity ratio of the sensor node P.

$$b_i^p = \sum\nolimits_p C_i^p \ge l, \forall i \tag{13}$$

where b_i^p signifies the maximum energy consumption of sensor nodes with transmission constraints.

3.5 Adaptive Petal Spider Ant Colony Cluster Algorithm

In this stage, sensor dependencies routes are finalized by getting the static node responsibilities. This maximizes constrain analysis in the route propagation to attain multipath hop counts formed into spider layers. Based on that, hop counts cluster heads determine the route on the multi-way without delay constraints to bind the transmissions on ant deployment link stabilization. This improves the delay tolerances to consume the energy according to the active relay submission to improve the network's lifetime.

$$T_i = \frac{E_{in}}{\sum\nolimits_p C_i^p \ge l, \forall i} \tag{14}$$

Network lifetime is $T = \min(T_i)$.

Optimization prototypical of system lifetime with inadequate data transmission delay.

3.6 Cooperative Stabilized Proactive Energy-Aware Cluster Routing Protocol

The stabilization constructs the Energy-aware routing based on the maximized low-consumption energy utilization nodes. This enhances the energy level optimization of each node at the transmission level without delay tolerance. The working route stabilization procedure is presented in the following steps. The method identifies the list of sensors at higher transmission support and their neighbor's node with time tolerance and strongly links stability-based cluster head control routing.

Let max support 'RT' in selected route R contain $\mathrm{Max}\{S_1, S_2, ...\}$ → Transmits node cluster group for higher transmission rate H_{rs} → Ch_1, ch_2 to form Route,

Higher Link stability support:

$$T_s = \frac{\sum_{i=1}^{size(R)} R(i) \cdot Energy(Ch)}{Node(R)} \cdot \frac{\sum_{i=1}^{size(R)} R(i) \cdot NoT(ch)}{node(R)} \cdot Depth(R) \tag{15}$$

The number of successful transactions 'NoT' at average mean depth has maximum support for higher energy consumption. Considering this route's maximum route energy constraints has a maximum lifetime to improve the:

$$LMS = \frac{\sum_{i=1}^{size(R)} R(i) \cdot Energy > T_h}{size(R)} \cdot T_s \tag{16}$$

Consider the different paths for energy levels that support transmission to improve lifetime. The above factors should be considered to achieve a high quality of service, stabilize the network link, and enhance communication. Further, selecting a route from a set of available paths based on the dispatch weight can improve the network's performance. The Transmission Support (TS) value is observed by energy level with higher hops. The technique efficiently finds the list of routes at a cooperative level for each sensor through each neighbor sharing the transmission path in the link closest to each other to improve communication based on the network lifetime.

4 RESULTS AND DISCUSSION

The simulation's goal is to examine the performance of the radio network. The iterative environment is a semantic command language tool created with NS2. It advances as the allowable leader of the Tool Command Language (TCL). The recommended method is to use a network simulator to simulate and run, and then all the codes are generated in the TCL script. The given output simulation results are obtained based on the simulation results.

Table 1 Simulation parameters for proposed method

Parameters	Values
Tool for Simulation	Network simulator (NS-2), Cygwin
Packet size	512 kb
Size of the Network	1200 m × 1200 m
Number of sensors	60
Transferring Packets	200
Routing Protocol	TCP/AODV
Time for Simulation	500 sec
Number of Nodes	100
Simulation area	300 m × 300 m
Node placement	Random placement
Network	Heterogeneous WSN
Number of nodes	20 - 100
Initital energy	100 J

Tab. 1 demonstrates the replication limits study of the Network simulations tool by transferring the extreme number of packets. The proposed system is compared with the Improved Energy Efficient Multipath Routing Protocol (EEMRP), the existing algorithms Energy-Efficient Region Source Routing Protocol (EERSP-LM), and Heterogeneous Energy and Traffic Aware Sleep-Awake Cluster-Based Routing Protocol (HE-TASACR) evaluation with delivery ratio, security of the network, time complexity, Network lifespan, and Packet drop ratio.

A high PDR indicates reliable communication and network performance, which is essential for ensuring data integrity and successful information delivery. Fig. 2 defines the Packet delivery ratio for the proposed algorithm, which achieves 89%, against the existing algorithms HE-TASACR packet delivery ratio performance of 84% and EERSP-LM packet delivery ratio performance of 65%, EEMRP is 77%.

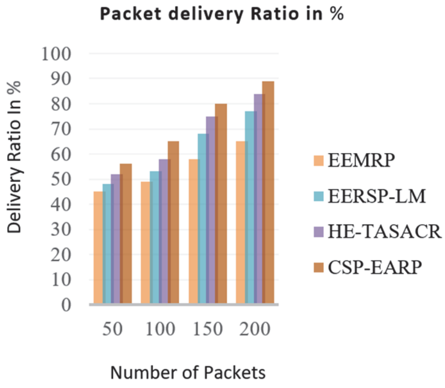

Figure 2 Analysis of packet delivery ratio

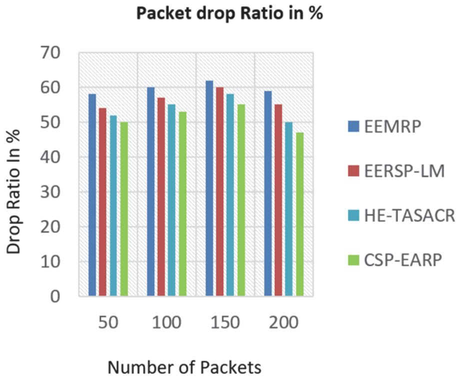

Figure 3 Analysis of packet drop ratio

Fig. 3 Defines the Packet drop ratio for the proposed system CSP-EARP reduces the packet loss rate by 47%, against the existing algorithms EERSP-LM packet drop ratio performance of 50% and HE-TASACR packet delivery ratio performance of 59%, EEMRP is 55%.

The high consumption creates delay tolerance with a lower loss rate and less traffic route propagation, which improves the higher deficiency rate. The proposed system produces a higher evaluation to define low delay than the other methods. Fig. 4 compares the delay performance.

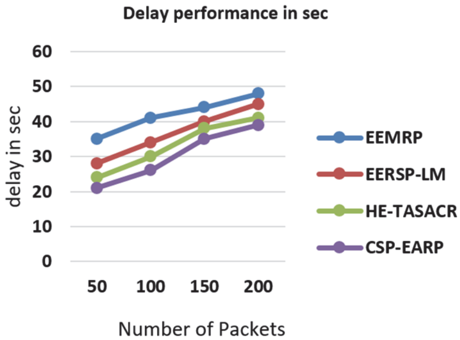

Figure 4 Analysis of delay performance

An essential benefit of multipath communication is inherent route diversity (i.e., it is anticipated that the loss process would function separately via several pathways.). To attain this objective, multitasking routing is an efficient method, as demonstrated by network data that may be exchanged over several channels to lessen congestion in the network. An evaluation of the proposal is shown in Fig. 5 with existing techniques. The existing technique EEMRP is 67%, EERSP-LMat at 71%, HE-TASACR at 86%, and the proposed CSP-EARP with 95%.

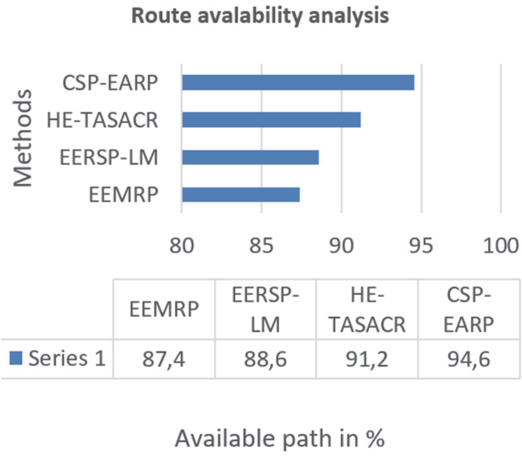

Figure 5 Route availability analysis

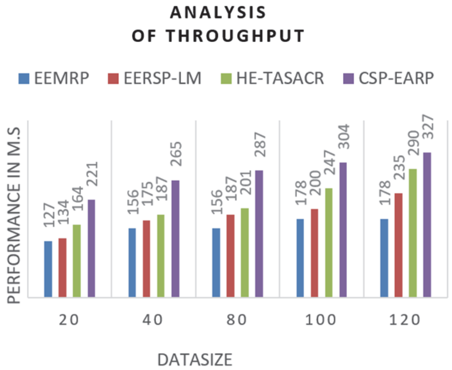

Figure 6 Network throughput performance

The successful packet delivery rate is the minimum packet delay in the active network. Throughput Level Routing Multipath performs preferable to ignoring the network's route. It may receive data from the target source and use that data to generate the outcome level and precision function. High enactment is due to the distinguishing loss of packets through the existing system, which is EEMRP, which is 327 Ms, and radio-induced determinations. The proposed CSP-EARP is 178 Ms, HE-TASACR is 235 Ms. EERSP-LMs is 290 Ms. Throughput of Network exploration is shown in Fig. 6. This proves the proposed method has a more efficient throughput ratio than the others.

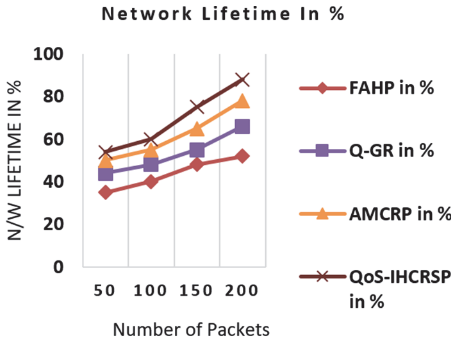

Figure 7 Analysis of the network lifetime

Fig. 7 explains the suggested algorithm's Network lifespan. It is determined by dividing the number of packets by the data's endpoint using ordinary packets.

$$Transmission\ rate = \frac{Total\ recived\ packets}{Total\ \text{packets}\ send} \cdot 100 \tag{17}$$

Table 2 Analysis of transmission ratio in comparison

Comparative Analysis of Transmission Ratio / %				
Number of nodes /methods	EEMRP	EERSP-LM	HE-TASACR	CSP-EARP
20	10	15	25	35
40	40	55	60	70
60	75	85	72	79
80	7.8	8.6	85	89
100	8.5	9.4	90	95

Tab. 2 evaluates and contrasts the transfer ratios of the suggested and current technologies. The TCL script may create a trace file with the outcomes. This field identifies the Number of packets to be sent. The fact that this field requires the recipient to submit a response makes it essential to our guidelines. The receiver will guarantee the endorsement process once the number of traditional packets and lost packages reaches the value specified in the corresponding field.

Fig. 8 explains the percentage of the transfer ratio among the suggested and current systems. The comparison of previous methods in terms of Communication Ratio is as follows: EEMRP has 75%, EERSP-LM has 85%, and HE-TASACR has 90%. With a lower transmission rate, the proposed method has a 95% ratio of the transmission.

Tab. 3 describes the analysis of the performance outcomes related to energy usage. When compared to the prior approach, the suggested algorithm uses less energy.

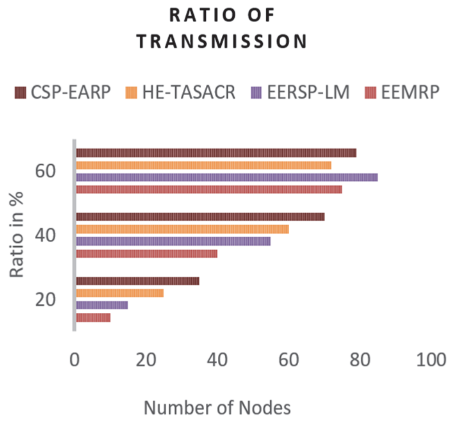

Figure 8 Transmission ratio

Table 3 Performance of energy consumption

Performance on energy depletion in Percentage				
Number of Nodes	EEMRP	EERSP-LM	HE-TASACR	CSP-EARP
20	45	39	35	22
40	51	42	39	25
60	64	55	46	27
80	72	65	59	30
100	78	75	63	32

Fig. 9 presents the results of the evaluation of the consumption of energy performance. The proposed CSP-EARP algorithm has 32%, the existing system, HE-TASACR, achieved 63%, the EERSP-LM algorithm has 75%, and the EEMRP algorithm has 78%. The proposed system has low energy to process the network transmission to improve the link stability and network lifetime.

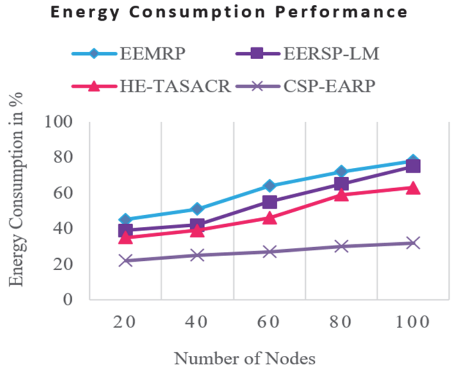

Figure 9 Analysis of energy consumption

5 CONCLUSION

The Cooperative stabilized proactive Energy-aware cluster routing protocol (CSP-EARP) was implemented; this analyses the link stability in higher energy support measures based on routing construction to make self-balanced congestion routing (SBCR). During data transmission support, the Lookup energy constraint duty cycle (LECDC) improves the network's lifetime. This improves the throughput performance and claims the routing energy from one or more nodes. Using the suggested LECDC technique, the goal of choosing the Link durability estimation is to reduce the rate of energy consumption. Subsequently, the CSP-EARP technique utilizes the best route choice determined by node weight, speed, and data transport efficiency. The throughput is 88%, PDR is 89%, energy consumption is 48%, network lifespan is 120 ms, and latency performance is 15.3 ms in the suggested analysis of result performances. This proposed system performs energy-efficient data transfer to improve the delay tolerance in latency level and higher throughput to improve lifetime communication. In future work, an efficient routing protocol will be used to find the shortest path and avoid traffic during data transmission in the network.

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