

CEASP: CLUSTER-BASED ENERGY-AWARE SLEEP SCHEDULING PROTOCOL FOR GREEN IOT NETWORKS

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ABSTRACT

The rapid proliferation of smart devices has increased unconventional opportunities for data-driven applications. However, at the similar time, it has increased concerns about the energy-efficiency and sustainability of IoT networks. Green IoT networks aim to address these challenges by optimizing energy consumption while maintaining network performance. In this context, sleep scheduling protocols have emerged as effective solutions for reducing energy consumed in IoT based devices. The proposed work proposes a novel cluster-based sleep scheduling protocol by dynamically tuning cluster formation based on network conditions and energy levels of the nodes. The model employs a hybrid approach that integrates k-means clustering with a sleep scheduling algorithm. The Cluster-Based Energy Aware Sleep Scheduling Protocol (CEASP) optimizes the cluster heads selection, ensuring that nodes having ample energy and nearer to the base station are prioritized, thereby minimizing energy dissipation during data transmission. The results received after simulation validates this proposed algorithm, CEASP are much better than conventional clustering methods concerning energy efficiency, data transmission, network lifetime and reliability. Furthermore, the protocol's adaptability to dynamic changes in the IoT environment contributes to its resilience and suitability for real-world applications.



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1. INTRODUCTION

Today Internet of Things (IoT) is rapidly transforming our interactions with the world, offering immense potential for innovation across diverse domains. IoT encompasses a vast network of interconnected devices, objects, systems, that seamlessly communicate with each other, thereby enabling unprecedented levels of automation, efficiency and convenience. These

interconnected components interchange the collected data, facilitating monitoring in real-time, analysis and in decision making. IoT comprises of three key elements i.e., sensing and perception, communication and connectivity, and data processing and action. IoT application ranges from industrial IoT, smart home automation, healthcare, telemedicine, smart cities, and agriculture to environmental monitoring (Francisco et al., 2019). The widespread adoption of 5G connectivity and

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falling hardware costs are fueling an exponential increase in IoT devices worldwide.

The proliferation of smart gadgets in recent years has brought significant advancements in various fields and revolutionized the way we interact with the technology. However, the rapid increase in the number of IoT devices has also led to surge in energy consumption, subsequently contributing to a larger carbon footprint. This increased energy consumption puts a strain on existing power grids and may leads to the utilization of additional energy resources, including fossil fuels, which intensify greenhouse gas emissions and worsen climate change (Sharma et al., 2021). Designing energy- efficient IoT devices, optimizing power management techniques, and implementing low power hardware components can significantly reduce energy consumption (Miglani et al., 2014). Energy harvesting techniques, such as solar or kinetic energy, can be employed to power IoT devices and extend battery life.

This work proposes a new energy-aware sleep scheduling protocol that employs k-means clustering technique to optimize green IoT networks. The intention of the protocol is to prolong network's lifespan with decrease in energy consumption of individual IoT nodes. In past few years, many clustering-based approaches have been anticipated to lessen energy usage in a network (Khediri et al., 2014).

Here, an advanced algorithm i.e., Cluster-based Energy-Aware Sleep Scheduling Protocol (CEASP) is proposed for reducing energy usage in IoT networks and reducing the mathematical formulation complexity and time. The objective of the protocol is reducing dead nodes by saving network's energy and hence increasing the network lifetime. This work contributes by providing an optimized protocol that improves network performance and reliability. K-means clustering algorithm groups nodes based on their proximity and energy levels, ensuring optimal resource allocation within each cluster. The clustering minimizes redundant communication and ensures balanced energy usage across the network (Bagga et al., 2019). By combining the strengths of sleep scheduling and k-means clustering, this approach delivers a practical, energy-efficient solution for modern IoT networks while supporting sustainability and scalability.

The remainder of the paper is structured as follows: Section 2 presents the literature review, highlighting the limitations of previous protocols and identifying research gaps. Section 3 details the methodology of the proposed protocol. Section 4 discusses the simulation environment, results, and performance evaluation. Finally, Section 6 outlines the findings and suggests directions for future research.

2. RELATED WORK

Various researchers have been working on the energy-efficient deployment of IoT nodes to achieve green environment by reducing carbon emission (Richa &

Kukreja, 2024). Authors in (Jin et al., 2019) have suggested an algorithm for detecting boundary of objects. They have used an optimized greedy algorithm and sleeping mechanism for detection of toxic gases boundary. Authors have defined the boundary condition with the help of convex hull algorithm.

(Aoun & Georges, 2020) also used the concept of sleep scheduling and have given energy efficient oil detection protocol. Authors proposed the 2-D under water Wireless Sensor Network (WSN) to detect leakage in oil at an early stage in oceans, and proposed a protocol based on sleep scheduling strategy, for saving the energy.

In (Pan et al., 2019), the authors modified the chain formation method in Wireless Sensor Net-works (WSN) that was introduces in PEGASIS (Lindsey & Raghvendra, 2002) for optimization of energy efficiency. Their approach creates paired-unpaired set of WSN nodes, according to sensing range ad distance threshold. For achieving energy efficiency, the nodes that are paired switch between active and sleep states. Prim's Minimum Spanning Tree algorithm ensures efficient routing of active nodes to BS.

SSTBC protocol on the basis of tree formation and sleep scheduling strategy in (Nguyen & Nguyen, 2015) aims for improving energy efficiency in WSNs. It functions as two distinct phases: setup and the data transmission. Initially, clusters are established, while during data transmission focuses is on optimizing communication among nodes and the BS for energy conservation.

Several other cluster-based energy-efficient protocols have also been introduced by researchers. One prominent example is Low-Energy Adaptive Clustering Hierarchy i.e., LEACH (Muruganathan et al., 2011). In proposed protocol, sensor nodes are grouped into clusters, all clusters are managed by a Cluster Head (CH). CH collects data, fuses it data which it already has, then transmits this aggregated information to the base station. Member nodes transmit their sensed data directly to their CHs. To ensure continuous operation, when a CH depletes its energy, a new CH is selected dynamically.

This clustering approach minimizes the number of nodes that directly communicate with the BS, effectively distributing the consumed energy across the IoT network. So, protocols like LEACH significantly reduce energy consumed by network and in turn increase the overall lifespan of network. Numerous improved versions of LEACH have been proposed, addressing various limitations and further enhancing energy efficiency (Li et al., 2011; Kukreja et al., 2019; Xinhua & Sheng, 2010).

Authors of (Chenait et al., 2015) proposed a protocol incorporating sleep scheduling for WSN. Their approach involves constructing a broadcast tree where every sensor node has two distinct paths leading to the sink, ensuring higher fault tolerance. To optimize energy usage, the

internal nodes of the tree remain awake to handle routing, while the leaf nodes are placed in sleep mode. Additionally, the protocol prioritizes internal nodes with higher residual energy to enhance network efficiency and reliability.

In (Merah et al., 2022) propose Self-Organizing Map based energy efficient technique (EESOM) with clustering protocol to enhance energy efficiency in IoT networks is introduced. Utilizing the Self-Organizing

Table 1. Comparison of Energy-Efficient IoT Routing Protocols.

Author	Focus Area	Work Proposed	Limitation
(Richa and Deepika, 2024)	Efficient IoT deployment for green environment	Proposed optimized deployment of IoT nodes to reduce carbon emissions.	May not account for real-time environmental changes.
(Jin et al., 2019)	Boundary detection of objects	Used an optimized greedy algorithm and sleep mechanism to detect toxic gas boundaries with convex hull.	High computational complexity in large-scale networks.
(Aoun and Georges, 2020)	Sleep scheduling for oil detection	Developed a 2D underwater WSN to detect early oil leakage using sleep scheduling.	Limited scalability for large ocean areas.
(Pan et al., 2019)	Chain formation method in WSN	Improved PEGASIS (Lindsey and Raghvendra, 2002) by introducing a paired-unpaired WSN node approach with Prim's MST algorithm for routing.	Increased overhead due to additional node classification.
(Nguyen & Nguyen, 2015)	SSTBC routing protocol	Tree-based clustering with sleep scheduling for energy-efficient data transmission in WSNs.	Initial setup phase is resource-intensive.
(Muruganathan et al., 2011)	LEACH clustering protocol	Cluster-based energy-efficient data aggregation, dynamically selecting CHs for optimized energy consumption.	CH selection may lead to unbalanced energy distribution.
(Li et al., 2011)	LEACH improvements	Enhanced LEACH to address its limitations and further optimize energy efficiency.	Increased complexity in implementation.
(Chenait et al., 2015)	Sleep scheduling-based routing	Used a broadcast tree-based routing approach with fault tolerance and prioritized high-energy nodes.	Higher energy consumption in internal nodes.
(Merah et al., 2022)	EESOM clustering protocol	SOM-based CH rotation policy for balanced energy consumption in IoT networks.	Higher time complexity due to dynamic CH rotation.
(Chithra et al., 2024)	CSW-E2F clustering scheme	Combined clustering and sleep-wake techniques with Gaussian Mixture Model and Coyote Optimization Algorithm for CH selection.	High computational cost of clustering techniques.
(Revathi, 2024)	Power consumption reduction	Algorithm proposed to minimize power consumption in networks.	Lack of real-world implementation and validation.

Map (SOM) algorithm, the protocol incorporates an energy-aware CH rotation policy considering both the energy levels of IoT nodes and their proximity to the winning neuron. This approach tried to optimize CH selection, ensuring balanced energy consumption across nodes and prolonging network lifespan. The dynamic CH rotation mechanism reduces energy overheads and avoids unbalanced energy usage, but still due to CH rotation policy the algorithm time complexity increased.

The authors propose the Clustering Scheme (CSW-E2F) in (Chithra et al., 2024) for improving the performance of WSNs. This scheme enhances energy efficiency and message reliability through clustering and sleep-wake up

techniques. To address the challenges of WSN, the paper reviews existing techniques. The CSW-E2F scheme employs a Gaussian Mixture Model (GMM) for clustering nodes and uses the Coyote Optimization Algorithm for the random election of Cluster Heads (CHs). Performance evaluation of the CSW-E2F technique includes various network parameters. Various algorithms (Revathi, 2024; Kukreja et al., 2018) have been given for reducing power consumption in the networks. Table 1. represents the comparison of previously proposed protocols for achieving energy efficiency in IoT networks. The comparison also lists the limitations of protocols, due to which a more efficient protocol is required for reducing energy consumed by IoT network.

3. METHODOLOGY

Protocol suggested in the paper firstly groups the active nodes using k-means clustering approach. K-means clustering minimizes intra-cluster distances, thereby reducing energy consumed in transferring data within clusters. This approach balances communication load across clusters, avoiding overburdening any specific CH. Each cluster head communicates with other nodes based on the proposed sleep-scheduling algorithm, which provides the status of the nodes whether they are active or sleep. Periodic re-clustering based on updated energy levels ensures that the network dynamically adapts to changes, maintaining efficient performance even when nodes' energy deplete or sleepy nodes are reactivated. CEASP supports scalability as new nodes can easily join the network and can be allotted to clusters subject to their energy and proximity to existing CHs. This makes the protocol suitable for large-scale IoT deployments. The findings demonstrate that the proposed protocol increases lifespan of the network and reduce energy consumption in such type of irregular networks, in comparison to other previously proposed algorithms.

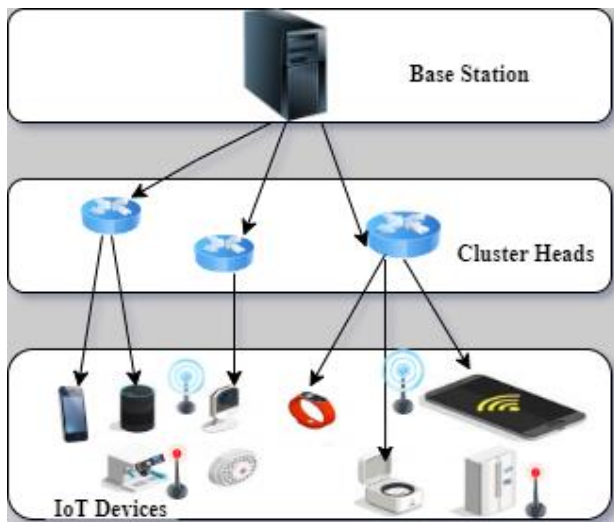


Figure 1. Network Diagram for proposed algorithm.

Figure 1 shows how the active IoT devices are connected to CHs and far away devices or devices having energy less than minimum threshold are determined and re-charged using charging stations. Sleepy nodes are sent to charging stations and reactivated, ensuring the sustainability of the network and preventing permanent node failures. The Other than managing its cluster members and efficient communication, cluster heads are also responsible for proficient data communication with the Base Station (BS).

3.1 Framework

This section outlines the proposed framework, which is divided into three distinct phases:

Phase 1: A total of N IoT nodes are randomly deployed in an irregular physical environment at the network's physical layer. The nodes are connected using bidirectional wireless links. Initially, the nodes are assigned two energy levels: one group starts with 50J, while the other group has energy 50J plus α . A base station (BS) is positioned at the core of the network, serving as a central communication hub. The IoT nodes are continuously monitored and assigned unique identifiers (e.g., N_i). Notably, the base station is not subject to energy depletion.

Phase 2: Nodes with energy levels below the required threshold and located too far from all Cluster Heads (CHs) are classified as inactive or sleepy and excluded from communication activities. The remaining nodes, termed active nodes, continue to participate in communication by interacting with their respective CHs.

Phase 3: The IoT nodes are grouped and formed clusters using k-means clustering approach with additional constraints.

3.2 Energy aware model for CEASP

The proposed model utilizes a radio model of first-order, where the radio consumes $E_{\text{elec}} = 50$ nJ/bit for operating the transmission or reception circuits. The network is organized hierarchically, with clusters formed using the k-means approach. To enhance efficiency and prolong network lifetime, nodes with low energy are dynamically managed. High-Energy Nodes are eligible to become Cluster Heads (CHs) due to their greater energy capacity, enabling them to effectively manage communication within their respective clusters. As shown by Figures 2 (a) and (b) the nodes are arranged in clusters the formation of clusters using k-means algorithm. The sleepy nodes are shown in red colour. BS is placed at the core of the IoT network as shown by the figure in square shape. The CHs are chosen by the protocol as the ones having highest energy level.

IoT nodes are deployed randomly in a network area A . Each node i ($i = 1, 2, \dots, N$) has an initial energy E_i . N nodes are partitioned into K clusters $C_1, C_2, \dots, C_K$ such that the distance between nodes within a cluster is minimized.

Every sensor node i is linked to closest cluster C_k by minimizing the Euclidean distance among the node and the center of cluster.

$$d_{i,k} = \sqrt{(x_i - x_{c_k})^2 + (y_i - y_{c_k})^2} \quad (1)$$

Each node i is associated with cluster C_K according to the following equation:

$$\text{Set } C_K = \arg \min_{j \in \{1, 2, \dots, n\}} d_{i,j} \quad (2)$$

Where 'n' is the number of sensor nodes in cluster C_K . As the nodes send and receive packets, their energy tends to decrease. The proposed approach puts the nodes under four categories according to their residual energy levels and their respective distance from the nearest CH.

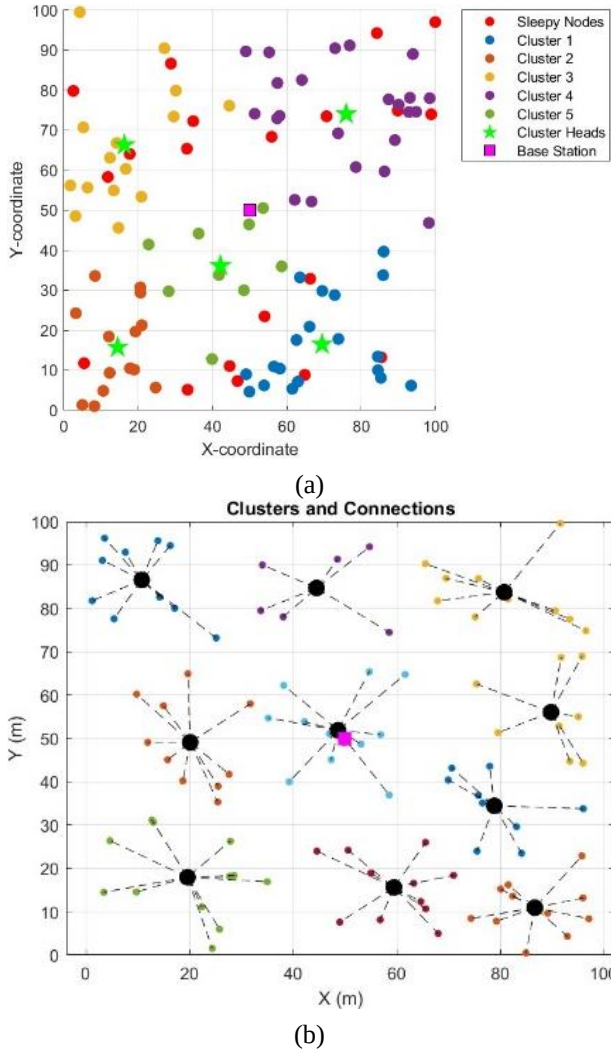


Figure 2. (a) Cluster Formation, (b) Cluster Connections

Active Cluster Member:

A sensor node is categorized as active Cluster Member (CM) if it has energy greater than or equals to the minimum energy level (E_{min}) required to function suitably as a cluster member or an active network node. And, also its distance to its CH is less than or equals to the threshold distance, d_{th} . The threshold distance, d_{th} , is decided based on maximum transmission and receiving power of the CH.

Sleepy cluster member:

A node is categorized as sleepy cluster member if it has energy less than E_{min} required to function suitably as a cluster member and its distance to its CH is less than or equals to the threshold distance, d_{th} . Sleepy CM are moved to the charging station if and, when available.

After charging period is over, these nodes change their mode from sleepy cluster member to active cluster member.

Active node:

A node is categorized as active node if it has energy greater than or equals to E_{min} required to function suitably as a network node but its distance to its previously assigned CH has crossed the threshold distance, d_{th} . This may happen in a case when clusters are reformed.

Sleepy node:

A node is categorized as sleepy if it has energy less than E_{min} required to function suitably as a network node and, also its distance to its previously assigned CH has crossed the threshold distance, d_{th} . This may happen in a case when clusters are reformed. These nodes are moved to the charging station for a certain defined period and then the nodes change their mode from sleepy node to active node.

A function f that categorizes nodes on the basis of level of energy E_i also their distance from the nearest cluster head d_i :

$$f(E_i, d_i) = \begin{cases} \text{Active Cluster Member,} & \text{if } E_i \geq E_{min} \text{ and } d_i \leq d_{th}, \\ \text{Sleepy Cluster Member,} & \text{if } E_i < E_{min} \text{ and } d_i \leq d_{th}, \\ \text{Active Node,} & \text{if } E_i \geq E_{min} \text{ and } d_i > d_{th}, \\ \text{Sleepy Node,} & \text{if } E_i < E_{min} \text{ and } d_i > d_{th}. \end{cases} \quad (3)$$

There are different network scenarios that require clusters' reformation. Clustering is performed to adapt to energy dynamics and network changes. The different conditions where clustering is required are the following:

- The CH's energy goes below the energy required to function as a cluster head, E_{CH} .
- Most of the cluster members have become energy deficit and they have moved to the charging station. Charging stations can accommodate a certain number of nodes only and hence few nodes must wait. If the waiting time is more than cluster formation time, then clusters are reconstructed.
- According to the scheduling algorithm employed at the charging station, some low priority nodes may never get a chance to get themselves charged. This also causes cluster reformation as few nodes may become dead forever.

IoT or wireless sensor nodes are frequently deployed in environments where consistent on-site charging is impractical. There are two solutions to deal with energy deficit nodes. First solution for energy-deficit nodes involves physically transporting them to charging stations, often located at a considerable distance from the IoT network. Second, new IoT nodes replace these nodes.

The second solution is cost exorbitant and hence it is ideal to bring the low energy nodes out of the network and put them on charging. As charging points are not always in use. To, further reduce the deployment cost number of charging points at a given charging station are limited. Due to the energy-aware nature of the proposed model, a limited number of nodes typically require charging simultaneously. In instances where the demand for charging surpasses the charging infrastructure capacity, a scheduling algorithm is employed to prioritize nodes with critical energy levels at the charging station. The scheduling algorithm implemented in the proposed model is priority-based scheduling.

Centroids of each cluster is recalculated using equation (4):

$$x_{ck} = \frac{1}{|n|} \sum_{i \in ck}^x x_i$$

$$y_{ck} = \frac{1}{|n|} \sum_{i \in ck}^y y_i \quad (4)$$

Node having energy $E_i \geq E_{CH}$ is eligible to become cluster head. CH for a cluster C_k is selected using hybrid approach that apply k-means method and based on proposed energy model. Equation (5) is used to determine the node having maximum energy:

$$CH_k = \arg \max_{i \in C_k} E_i \quad (5)$$

The energy consumption for transmitting and receiving data are typically based on models such as the first-order radio model.

$$E_{tx} = E_{elec} \cdot L + \epsilon_{amp} \cdot L \cdot d_{i,CH}^n \quad (6)$$

$$E_{rx} = E_{elec} \cdot L \quad (7)$$

Where, E_{tx} , energy consumed for transmitting data, E_{rx} , energy consumed for receiving the data and E_{elec} , Energy required per bit to operate the transmitter or receiver circuitry, ϵ_{amp} , energy consumed by the amplifier for transmission, n , Path loss exponent, typically 2 (free space) or 4 (multipath). L is the number of bits. Total energy consumption of node E_i is updated as given in equation (8):

$$E_i = E_i - (E_{tx} + E_{rx}) \quad (8)$$

Sleepy nodes that become active after charging are reassigned to clusters based the proposed model. Given below is the algorithm for the proposed protocol CEASP.

Algorithm for Cluster-based Energy-Aware Sleepy Protocol

Input:

- Total number of nodes
- Energy consumed per bit for transmission/reception (50 nJ/bit)
- Amplifier energy constant

- Threshold distance
- Minimum energy for node functionality
- Minimum energy for cluster head functionality
- Data packet size (in bits)
- Maximum number of communication rounds

Output:

- Optimized clusters, updated energy levels

Initialize:

1. Deploy nodes randomly in area with initial energy for each node.
2. Partition nodes into clusters using the k-means algorithm:
 - Calculate Euclidean distance between each node and cluster centroids:
 - Assign each node to the nearest cluster.
3. Assign initial CHs for each cluster:
 - Select highest energy level node in each cluster.

While (communication rounds $\leq$ max_rounds):

- **Step 1: Communication Phase**
 - For each node in cluster:
 1. Compute energy consumption for transmission:
 2. Compute energy consumption for reception (at CH):
 3. Update node's energy.
- **Step 2: Node Categorization**
 1. Node is categorised in one of the four classes as per equation (3).
- **Step 3: Re-clustering and CH Re-selection**
 1. Recalculate cluster centroids using equation 4
 2. Reassign nodes to clusters based on the nearest centroid.
 3. Select new CHs for each cluster.
 4. If any CH energy $< E_{CH}$, reform clusters using k-means.
- **Step 4: Sleepy Node Management**
 1. Move Sleepy Nodes to the charging station (if available otherwise schedule).
 2. Recharged Nodes are reassigned to clusters once their energy is restored.

End While

Output:

- Final cluster assignments, CHs, and residual energy of nodes.

4 RESULTS AND ANALYSIS

To assess the efficiency of CEASP, simulations are done using MATLAB R2023a. Proposed algorithm effectiveness is validated through comparative analysis with EESSTBRP and FUZZY-SLEEP-SCHD. A base station is centrally deployed within the network, and the IoT nodes are considered stationary. Table 2 outlines the network parameters utilized in the simulations.

The simulation is carried out for 2000 rounds. A comparative analysis of CEASP with EESSTBRP and FUZZY-SLEEP-SCHD, is depicted in Figure 3-6.

Table 2 Network Attributes.

Simulation parameter	Value
Network Size	100
Simulation area	100m×100m
No. of simulation rounds	2000
E_{elec}	50 nJ/bit
E_{amp}	.0013pJ/bit/m ⁴
E_{fs}	0.34pJ/bit/m ²
Packet size	200
Sensing Range	15m
Threshold Distance	25m

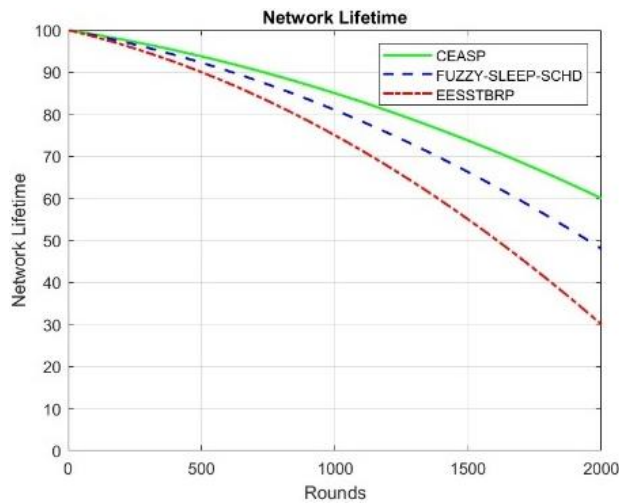


Figure 3. Network Lifetime vs. Rounds

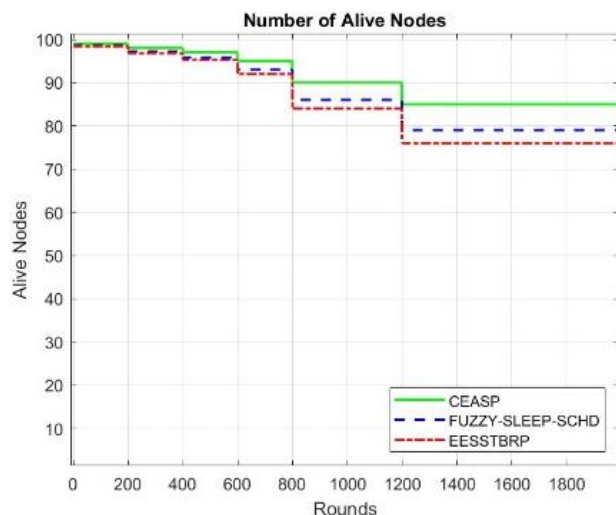


Figure 4. Number of Alive nodes vs. Rounds

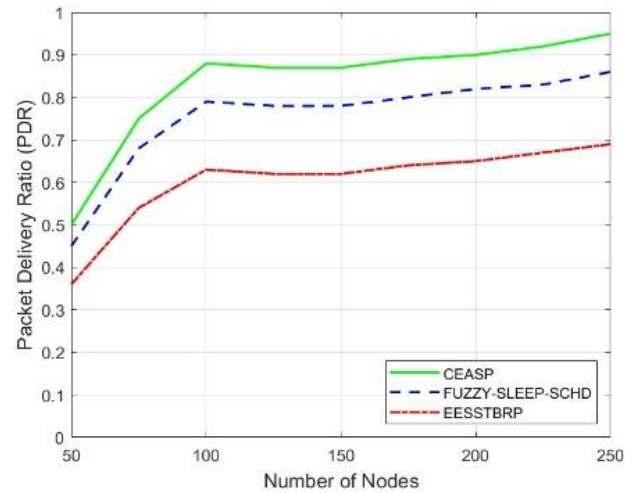


Figure 5. Packet Delivery Ratio vs. Rounds

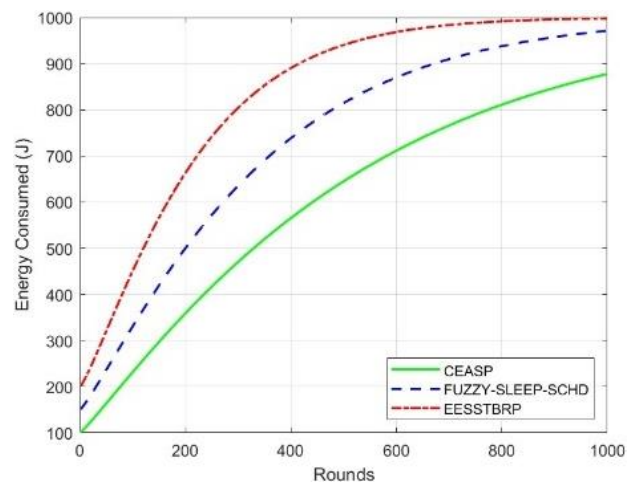


Figure 6. Energy consumed vs. Rounds

4.1 Network Lifetime

Network Lifetime: Network lifetime referred as the duration a network remains functional, the time until the first network node depletes its energy or when the network can no longer meet its operational objectives.

Alive Nodes: The number of alive nodes denotes the sensor nodes that are still active at a given time. A larger number of alive nodes translates to better network performance and reliability. CEASP dynamically reduces the transmission power of the nodes based on the distance. This diminishes unnecessary energy consumption.

Figure 3 shows networks lifetime vs. rounds, the increase in network lifetime of CEASP is because it prioritizes nodes with higher residual energy for leadership roles. This significantly reduces premature cluster head failure and hence, prolongs the network's operational lifespan. This can also be seen in figure 4 that shows on an average, 35% increase in total alive nodes in comparison to EESSTBRP and 20% increase as compared to FUZZY-SLEEP-SCHD protocol.

Forming clusters of nodes and electing cluster heads can distribute the energy more evenly across the network. Sleep scheduling method is implemented that further contributes to conserve network's energy.

4.2 Packet Delivery Ratio

It represents the percentage of data packets that reach the intended destination successfully out of the total packets

sent. PDR is a crucial indicator of network reliability and efficiency.

Figure 5 illustrates the number of packets successfully delivered across the network, highlighting an improved packet delivery ratio with CEASP. As the cluster nodes are put on recharging before their entire energy gets exhausted, this guarantees the network nodes survival for longer time. Prolong survival of the network contributes to higher PDR.

Table 2 Alive Nodes and Energy Consumed Analysis.

Parameters	Rounds	CEASP	FUZZY-SLEEP-SCHD	EESSTBRP
Energy Consumed(J)	200	98.69	119.19	148.59
	400	171.84	211.53	270.32
	600	252.42	313.66	403.32
	800	341.41	426.71	548.56
	1000	438.81	551.01	707.09
	2000	701.11	900.44	1002.4
Alive Nodes	200	98	97	97
	400	96	96	96
	600	95	94	94
	800	95	90	88
	1000	93	88	77
	1200	90	83	76
	1400	86	79	77
	1600	86	79	77
	1800	86	79	77
	2000	86	78	77

4.3 Energy Consumption

Reducing energy usage extends lifetime of IoT network and individual sensor nodes. By reducing the number of transmissions over the network with effective CH selection and clustering technique, CEASP shows significant reduction in energy consumption. Figure 6 presents average energy consumed of IoT network. Total energy consumed is directly proportional to the transmission and receiving power of the nodes. Energy spent while transmitting data depends directly on the distance, as CEASP approach maintains the minimum distance between the CH and members of cluster. Consequently, minimum power disbursement contributes to energy savings.

Prolonging network lifetime can keep more nodes operational for extended periods. The results as shown by figures shows the effectiveness of CEASP protocol in achieving energy efficiency, Packet Delivery Ratio and network lifetime. Table 2 shows the comparison of CEASP with EESSTBRP and FUZZY-SLEEP-SCHD based on number of alive nodes and energy consumption.

5. CONCLUSION AND FUTURE WORK

The Cluster-based Energy-Aware Sleep Scheduling Protocol (CEASP) proves significant contribution in IoT networks by leveraging a hybrid approach of clustering and sleep scheduling. The algorithm initially applies the k-means clustering algorithm to organize nodes into clusters, ensuring an optimized and balanced spatial distribution of nodes. Within each cluster, CH is chosen dynamically based on the energy levels of nodes, prioritizing the nodes with higher residual energy to act as leaders, thereby reducing premature CH failure and extending the network lifetime. By designating nodes into different classes, the protocol significantly reduces idle energy consumption while maintaining the necessary network functionality and connectivity. This dual-stage process of efficient clustering and energy-aware sleep scheduling results in prolonged network lifetime, higher packet delivery ratio and a balanced energy distribution across the network. The CEASP approach has promising applications and potential advancements in IoT networks, where energy efficiency, scalability, and reliability are paramount. IoT nodes with energy harvesting capabilities can further enhance CEASP efficiency. The future work can also include the security mechanism while achieving energy efficiency.

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