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Research Article

Distributed and Hierarchical Clustering in Wireless Camera Sensor Networks leading to Internet of Things

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ABSTRACT

The Wireless Sensor Industry is crucial for modern applications like military navigation, home automation, and agricultural security. The effective estab-lishment and operation of Wireless Sensor Networks (WSNs) hinge on maxim-izing efficiency, network longevity, and minimizing power consumption while ensuring reliability. Researchers focus on optimizing these aspects to enhance WSN performance. This study explores various strategies for improving power consumption, energy efficiency, and network lifespan in WSNs. It emphasizes distributed and hierarchical clustering methods for their scalability, stability, ef-ficiency, and cost-effectiveness. The performance analysis of different non-meta clustering schemes considers metrics such as alive nodes, dead nodes, and throughput over time. Starting with an overview of WSNs, the paper ad-dresses design issues across different network types, including camera-based and ad-hoc networks, and compares clustering techniques. The conclusion advocates for cooperative communication and integrating clustering schemes to advance Wireless Camera Sensor Networks (WCSNs) for Internet of Things (IoT) ap-plications, ensuring efficient power management, extended lifespan, and bal-anced load distribution, thereby enhancing IoT deployments.

Keywords: Wireless Camera Sensor Networks (WCSN), Cluster Heads (CH), Energy, Pow-er, Sensor Nodes (SNs), Internet of Things

1. INTRODUCTION

Wireless Sensor Networks (WSNs) [Figure. 1] consist of spatially distributed sen-sors that monitor environmental parameters like temperature, humidity, and motion, transmitting data wirelessly to a central hub for analysis. They are extensively uti-lized in applications such as environmental monitoring, industrial automation, and smart cities due to their ability to provide real-time data and support remote sens-ing. A subset of WSNs, Wireless Camera Sensor Net-works (WCSNs), incorporates cameras to capture visual data, enhancing functionalities for ap-plications like sur-veillance, traffic monitoring, and disaster management. Ad-hoc networks, character-ized by their decentralized nature, enable nodes to route data dynamically, making them ideal for situations without established network infrastructure, including mili-tary operations, emergency response, and mobile communications [1-2]. WSNs, WCSNs, and ad-hoc networks collectively underpin modern communication sys-tems, facilitating a range of complex applications. These networks can operate pro-actively by aggregating data at regular intervals or reactively by responding imme-diately to changes. Key design goals for these networks include minimizing sensor node size, optimizing clustering, reducing costs, ensuring easy configurability and scalability, achieving high throughput, enhancing reliability and fault tolerance, maintaining security, and minimizing power consumption. Successfully addressing these objectives is crucial for the effective implementation and operation of these networks, ensuring they meet the demands of diverse applications [3-4].

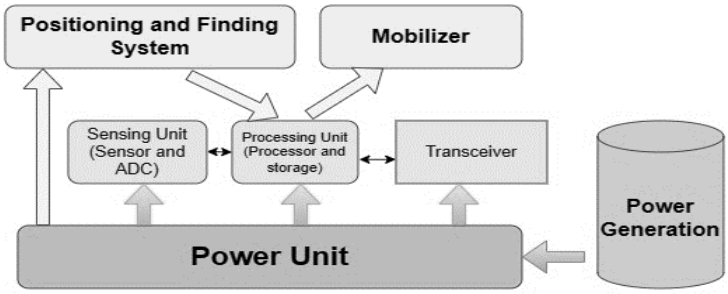


Fig. 1. Wireless Network Setup (Camera-Based/Non-Camera-Based)

Unlike traditional networks, WSNs/WCSNs exhibit unique traffic patterns [Fig-ure.2] where member sensor nodes of a cluster send data to the base station. Differ-ent application domains can result in various traffic topologies for data packet flow [1-4].

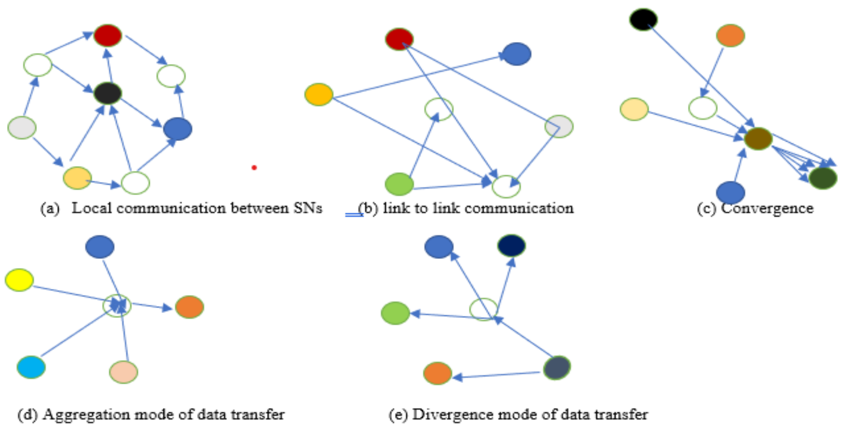


Fig. 2. Traffic patterns in Wireless Sensor Networks/Wireless Camera Sensor Networks

Different sectors employ various sensor technologies to enhance functionality and achieve specific objectives. Below is a reimagined table [Table.1] and [Ta-ble.2] showcasing these applications and the corresponding sensor types used.

Table 1: Application Areas with respect to Wireless Sensor Categories

Field of Application	**Sensor Varieties Utilized**	**Illustrative Use Cases**
Ecological	Symbiotic	1. Smart farming solutions
		2. Monitoring weather patterns in tropical or dense forest regions
		3. Natural disaster preparedness and response
		4. Detecting and tracking pollution levels
Defence	Obtrusive	1. Keeping track of weaponry inventories
		2. Surveillance of adversary activities
		3. Securing national borders
		4. Battlefield intelligence gathering
Healthcare	Bio-hybrid, Symbiotic	1. Tracking cellular activities such as cancer progress
		2. Monitoring patient vitals including heart rate and blood pressure
Residential		1. Home security and automation systems

Field of Application	Sensor Varieties Utilized	Illustrative Use Cases
	Symbiotic, Parasitic	2. Management of smart home devices
Industrial	Parasitic, Obtrusive	1. Regulating environmental conditions in workplace settings
		2. Detecting early warning signs of threats
		3. Overseeing inventory and stock management

Table 2: Parameters for Improving Sensor Nodes' Lifespan

Parameter	Explanation
Deployment Model	Assesses performance of routing techniques/protocols (deterministic or indeterministic)
Data Gathering	Influences energy consumption and route stability from SNs to CHs to BS to the sink
Fault Tolerance	Avoids data duplicity while providing redundancy for fault tolerance
Data Aggregation	Correlates and fuses data to reduce transmitted data size
Reliability and QoS	Ensures data transmission from source to destination with optimized sensor lifespan
Network Clustering	Ensures network performance does not degrade with chosen clustering techniques

2. CLUSTERING

Clustering techniques aim to reduce power consumption per sensor node. Cen-tralized clustering has higher power demands at base stations, while distribu-tive protocols work on residual energy factors. Clustering minimizes energy expenditure, balancing the load within clusters to prolong network life. Hier-archical networks are more efficient, with Cluster Heads (CHs) collecting and transmitting data from member sensor nodes to the base station [5][6]

2.1 RESEARCH GAP

The majority of current research has concentrated on homogeneous sys-tems within Wireless Sensor Networks (WSN) and, to a lesser extent, Wireless Camera Sensor Networks (WCSN) in certain heterogeneous net-work environments. Exploring weighted Sensor Networks (SN) can offer valuable insights into the overall performance of networks in diverse WCSN scenarios.

Distributed clustering techniques have been investigated only in the con-text of single-network frameworks (organizing SNs in equal quantities). Consideration should be given to a multi-tiered network ranging from small to large scales, and evolving from 2D to 3D configurations.

•Movement-based data aggregation has been explored, but predominantly within limited homogeneous environments.

•Cooperative diversity has been studied using random variables, yet it has not been examined with Gaussian variables or Additive White Gaussian Noise (AWGN). [7]

•Hierarchical clustering in Camera Sensor Networks has not been tested using a distributed approach for multi-tiered networking. The ideal power trade-off related to the overall lifespan of WCSNs remains investigated.

•Security continues to be a critical issue due to significant power demands.

•Optimal load distribution and energy efficiency have not been thoroughly addressed. [6-8]

2.2 CLUSTERING TYPES

Based on network architecture, the following layouts should be considered before implementing the model:

2.2.1 Single or Direct Link Model Network [9-10]
•Each Member Sensor Node (MSN) and sink establish direct links for data transmission.
•Advantage: Easier implementation.
•Disadvantage: Not scalable.
2.2.2 Hop-Based or Peer-Based Link Network
•MSNs will have route-based transmission capability.
•Advantage: Suitable for large networks; scalable as traffic increases.
•Disadvantage: Energy wastage leads to a shorter network lifespan.
2.2.3 Multi-Hopping Based Network Depending on Clustering
•MSNs form groups with a Cluster Head (CH) chosen to transmit data to the Base Station (BS) or sink directly. MSNs send their data to the CH, which processes and forwards it to the sink/BS.
•Disadvantage: The CH's energy depletes faster than other MSNs.
2.2.4 Multi-Hopping, Clustering-Based with Dynamic CH Network Model [9,12,16]
The CH role dynamically rotates among other MSNs. Clustering is an en-ergy-saving procedure in wireless networks, impacting the overall power requirements by dividing MSNs into groups (clusters) that function dif-ferently based on group requirements.
2.2.5 Key Points in Designing a Wireless Camera Sensor Networks

Designing a Wireless Camera Sensor Network (WCSN) involves several key considerations [Figure.3]. Choose between centralized or distributed architectures, ensuring scalability and redundancy for reliability. Select camera sensors with appropriate resolution, frame rate, and field of view, prioritizing energy-efficient hardware to extend battery life. Implement on-board image processing to reduce data transmission load. Use suitable wireless communication protocols like Zigbee or Wi-Fi, balancing range, data rate, and power consumption. Employ interference management techniques to minimize disruptions from other wireless networks. Addi-tionally, consider security measures to protect data and ensure privacy, and establish efficient data aggregation and processing mechanisms to handle large volumes of visual information effectively [11-12].

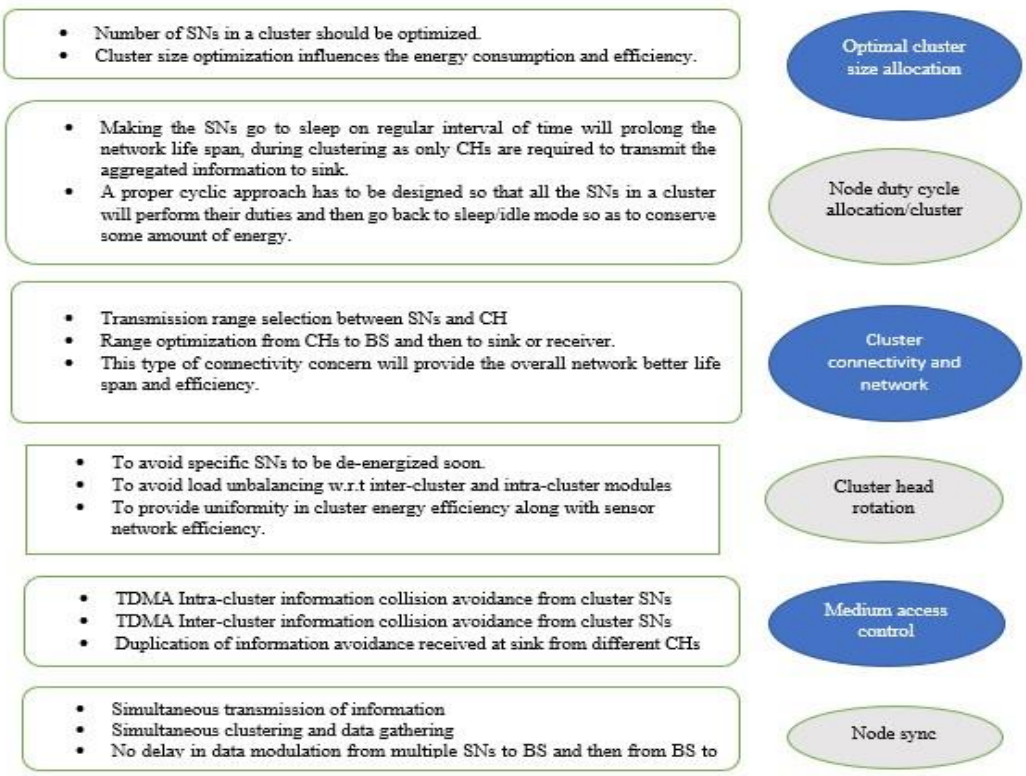


Figure 3 Key issues in designing a sensor network

3. DIFFERENT CLUSTERING TECHNIQUES KEY CHARACTERISTICS AND MATLAB SIMULATION OUTCOMES [FIGURE.4] AND [FIGURE.5]

Homogeneous Clustering (Single Hop-Based) [13-16]

1. LEACH-C (Low Energy Adaptive Clustering Hierarchy-Centralized):
- Centrally initiated algorithm.
- Balanced cluster formation.
- Not energy efficient.
- Not robust for global data of the network.

2. LEACH-F (Fixed):
- Fixed cluster formation.
- Balanced energy consumption among MSNs.
- Reduces complexity and burden in the setup phase.
- Wastes energy before CH dies due to fixed round energy.

3. CLUDDA (Clustered Diffusion with Dynamic Data Aggregation):
- Avoids flooding by eliminating unended data transmission.
- Dynamic data aggregation.
- Long time delay.
- Requires larger memory storage.

4. sLEACH (Solar Aware LEACH):
- Uses solar power.
- Improves network life.
- Applicable in both centralized and distributed algorithms.

5. LEACH-ET (Energy Threshold):
- Computes rotation policy in LEACH.
- Slightly better energy efficiency.
- Control messages cause significant energy dissipation.

6. E-LEACH (Energy):
- Two-phase process with rounds.
- Some energy wasted in the fixed round phase transmission.

7. RRCH (Round Robin Cluster Head Protocol):
- Gains better efficiency with a single setup procedure.
- Reduces energy consumption.
- Poor load balancing and additional overhead burden.

8. TB-LEACH (Time-Based Cluster Head Selection Algorithm for LEACH):
- Varied CH selection procedure.
- Enhances network lifetime.
- Does not support large networks.
- Poor load balancing and high overhead burden.

9. MLEACH-L (More Energy Efficient LEACH):
- Suitable for dense and vast WSN.
- Enhances setup stage but adds overhead.
- Better energy profile but load balancing issues persist.

10. V-LEACH (New Version LEACH):

- o Improved results with a redundant CH.
- o Increases setup phase time.
- o Possibility of duplication.

3.2 Homogeneous Multi-Hop Based [13-15]

1. M-LEACH (Multi-Hop LEACH):

- o Suitable for large networks with low density.
- o Limited scalability.
- o Not optimal for small networks.

2. TL-LEACH (Two-Level LEACH):

- o Reduces energy consumption.
- o Distributes energy load among MSNs in dense networks.
- o Not suitable for vast dense networks.

3. LEACH-L:

- o Stabilizes network load.
- o Reduces energy usage per MSN.
- o Additional overhead issues.

4. MS-LEACH (Combines Multi-Hop and Single Hop):

- o Reduces energy consumption.
- o Limited scalability and additional overhead issues.

3.3 Heterogeneous Single Hop [17-18]

1. EECHE (Energy Efficient Cluster Head Election Protocol):

- o Enhanced throughput and lifespan compared to LEACH and SEP.
- o Limited scalability compared to SEP.
- o Reduced latency.

2. NEAP (Novel Energy Adaptive Protocol):

- o Improved consistency.
- o Inadequate scalability for dense networks.

3.4 Heterogeneous Multi-Hop Protocols [19-20]

1. SEP (Stable Election Protocol):

- o No need to collect data on nearby MSN energy/round.
- o Poor performance in multi-level networks.

2. HEED (Hybrid Energy Efficient Distributed Clustering):

- o Stabilizes power among MSNs.
- o Manages and controls overhead issues.
- o High latency and limited scalability.

3. EEUC (Novel Energy Efficient Clustering Approach):

- o Minimizes problems using unequal cluster sizes.
- o Imbalanced clusters and poor load balancing.
- o Better energy efficiency.

4. **LEACH-HPR:**

o CH selects the best MSN to stabilize energy consumption.

o Additional overhead issue.

5. **DEUC:**

o Minimizes hotspot issue and overhead.

o Poor load balancing but better energy consumption profile

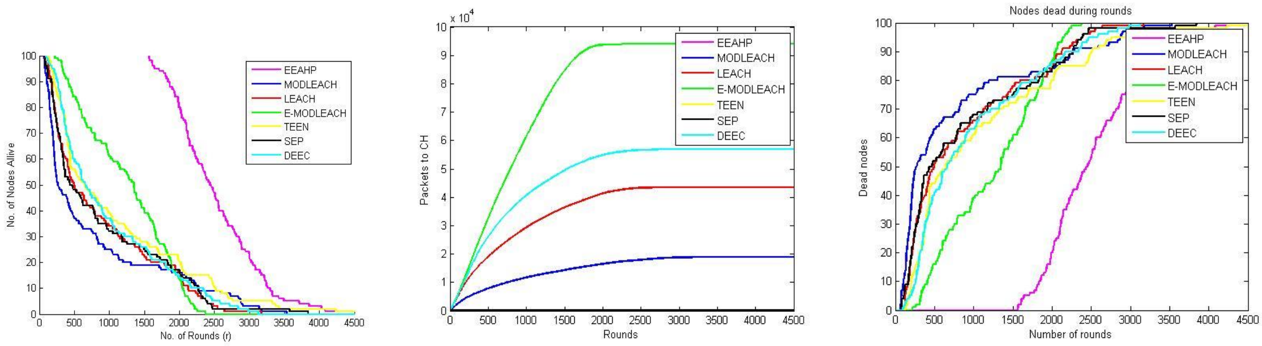


Fig.4(a) Dead Nodes vs Rounds for different Non-Meta Clustering Algorithms
Fig 4(b) Packets to Base Station vs Rounds for different Non-Meta Clustering Algorithms
Fig.4(c) Alive Nodes vs Rounds for different Non-Meta Clustering Algorithms

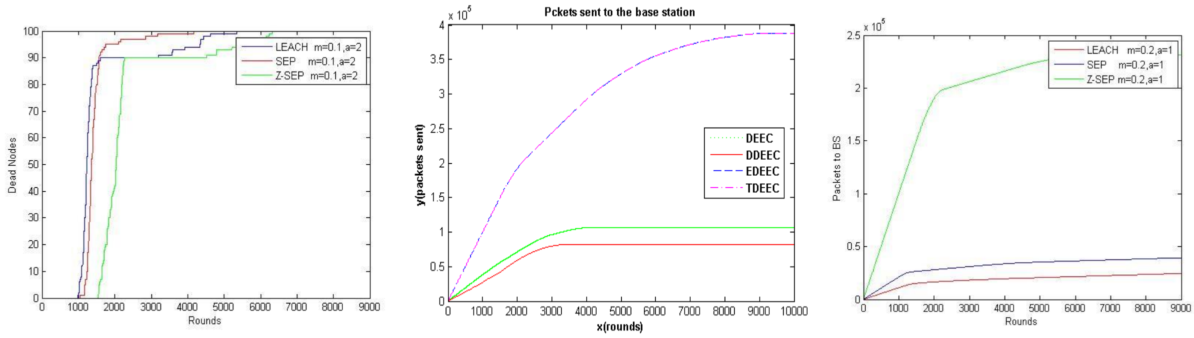


Fig.4(d) Packets to Base Station vs Rounds for different Versions of DEEC
Fig..4(e) Dead Nodes vs Rounds for LEACH, SEP, Z-SEP
Fig. .4(f) Packets to BS vs Rounds for LEACH, SEP, Z-SEP

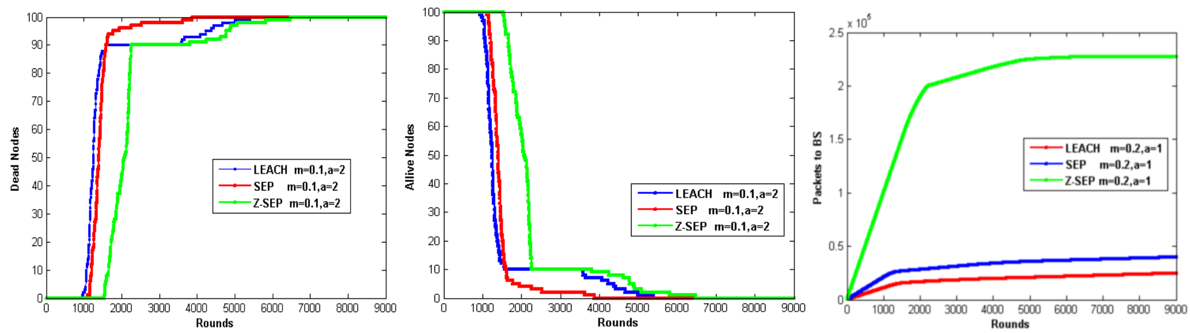
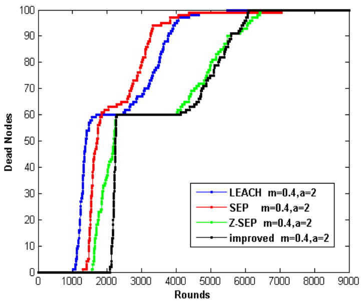
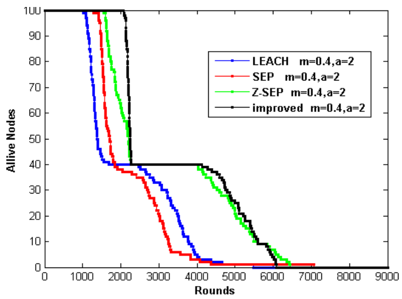


Fig..4(g) Alive Nodes vs Rounds (9000) for LEACH, SEP, Z-SEP
Fig. .4(h) Packets to BS vs Rounds (9000)for LEACH, SEP, Z-SEP
Fig.4(i) Packets to BS vs Rounds (9000) for LEACH, SEP, Z-SEP





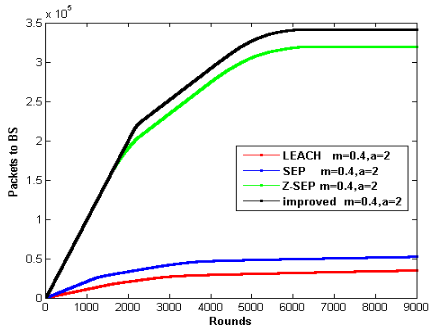
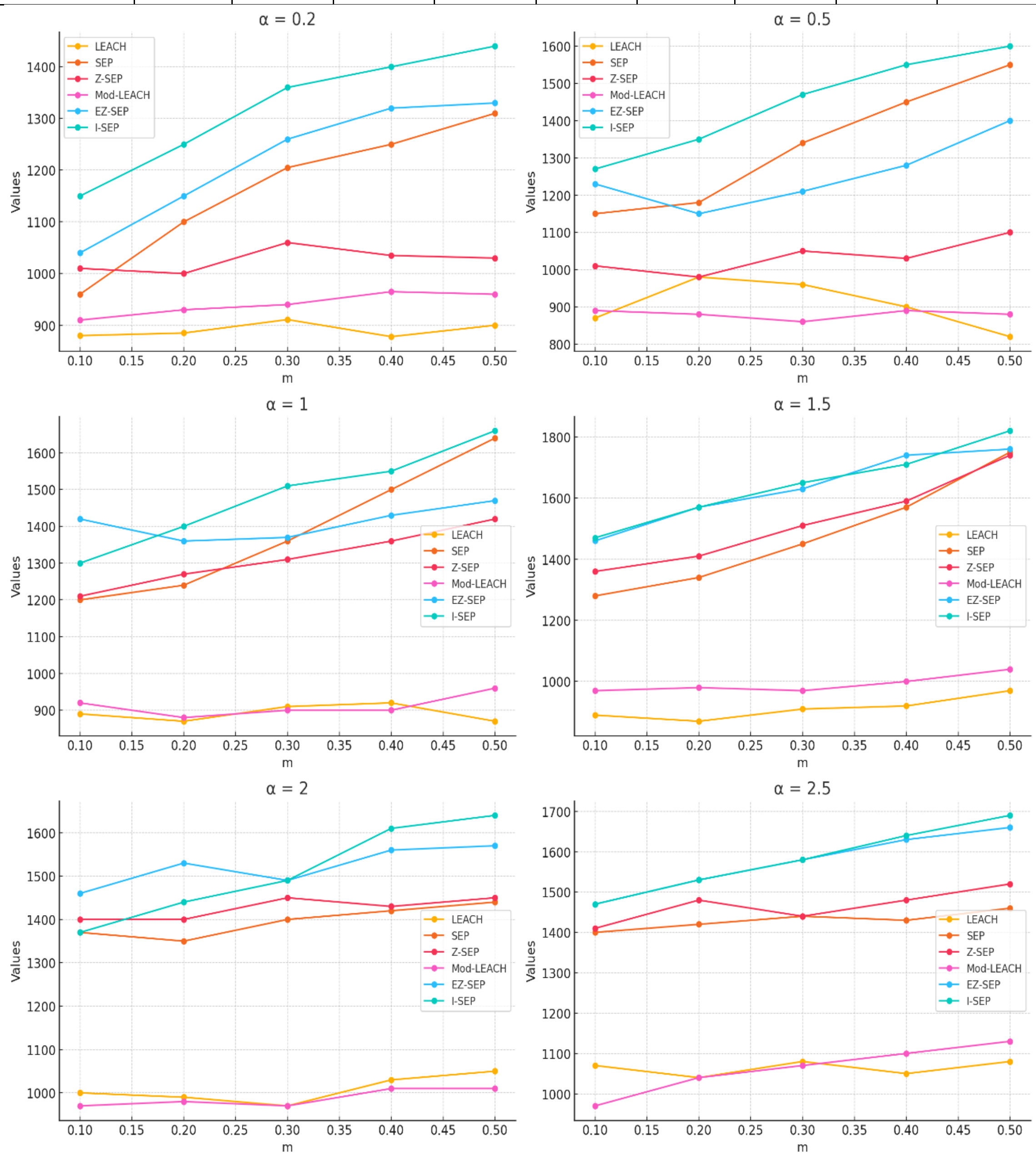


Fig.4(j) Packets to BS vs Rounds (9000) for LEACH, SEP, Z-SEP, Improved-ZSEP
Fig..4(k) Alive Nodes vs Rounds (9000) for LEACH, SEP, Z-SEP, Improved-ZSEP
Fig..4(i) Dead Nodes vs Rounds (9000) for LEACH, SEP, Z-SEP, Improved-ZSEP

Table 3: Data Point table (MATLAB Simulation)

Particulars		**Total data cycle to Base Station for 1st dead node keeping m and α as variable**					**Total data cycle to Base Station for 10th dead node keeping m and α as variable**				
α	**Clustering Technique**	**m=0.1**	**m=0.2**	**m=0.3**	**m=0.4**	**m=0.5**	**m=0.1**	**m=0.2**	**m=0.3**	**m=0.4**	**m=0.5**
α=0.2	LEACH	880	885	911	878	900	980	990	1000	970	1000
	SEP	960	1100	1205	1250	1310	1050	1180	1260	1340	1410
	Z-SEP	1010	1000	1060	1035	1030	1100	1120	1170	1100	1120
	Mod-LEACH	910	930	940	965	960	990	1020	1070	1070	1080
	EZ-SEP	1040	1150	1260	1320	1330	1170	1280	1360	1460	1470
	SBCP	1150	1250	1360	1400	1440	1260	1320	1420	1460	1540
α=0.5	LEACH	870	980	960	900	820	980	1080	1070	1080	960
	SEP	1150	1180	1340	1450	1550	1280	1310	1430	1460	1580
	Z-SEP	1010	980	1050	1030	1100	1070	1090	1090	1100	1190
	Mod-LEACH	890	880	860	890	880	990	970	950	980	970
	EZ-SEP	1230	1150	1210	1280	1400	1330	1260	1290	1370	1480
	SBCP	1270	1350	1470	1550	1600	1360	1440	1460	1620	1680
α=1	LEACH	890	870	910	920	870	980	980	1010	1020	990
	SEP	1200	1240	1360	1500	1640	1310	1360	1450	1540	1650
	Z-SEP	1210	1270	1310	1360	1420	1290	1380	1470	1490	1560
	Mod-LEACH	920	880	900	900	960	1010	970	1010	980	1050
	EZ-SEP	1420	1360	1370	1430	1470	1540	1450	1460	1540	1570
	SBCP	1300	1400	1510	1550	1660	1620	1650	1710	1720	1750
α=1.5	LEACH	890	870	910	920	970	1020	1030	1020	1060	1070
	SEP	1280	1340	1450	1570	1750	1410	1520	1600	1690	1830
	Z-SEP	1360	1410	1510	1590	1740	1530	1630	1700	1810	1910
	Mod-LEACH	970	980	970	1000	1040	1050	1070	1180	1260	1420
	EZ-SEP	1460	1570	1630	1740	1760	1590	1690	1790	1910	1940

	SBCP	1470	1570	1650	1710	1820	1620	1720	1900	2000	2260
α=2	LEACH	1000	990	970	1030	1050	1140	1130	1150	1160	1170
	SEP	1370	1350	1400	1420	1440	1560	1530	1580	1610	1620
	Z-SEP	1400	1400	1450	1430	1450	1550	1510	1560	1650	1710
	Mod-LEACH	970	980	970	1010	1010	1140	1080	1130	1170	1180
	EZ-SEP	1460	1530	1490	1560	1570	1620	1640	1720	1730	1740
	SBCP	1370	1440	1490	1610	1640	1530	1560	1600	1930	2390
α=2.5	LEACH	1070	1040	1080	1050	1080	1190	1150	1240	1250	1390
	SEP	1400	1420	1440	1430	1460	1560	1580	1630	1690	1830
	Z-SEP	1410	1480	1440	1480	1520	1650	1660	1750	1740	1830
	Mod-LEACH	970	1040	1070	1100	1130	1080	1190	1240	1300	1390
	EZ-SEP	1470	1530	1580	1630	1660	1730	1740	1850	1950	2360
	SBCP	1470	1530	1580	1640	1690	1650	1790	2030	2140	2440



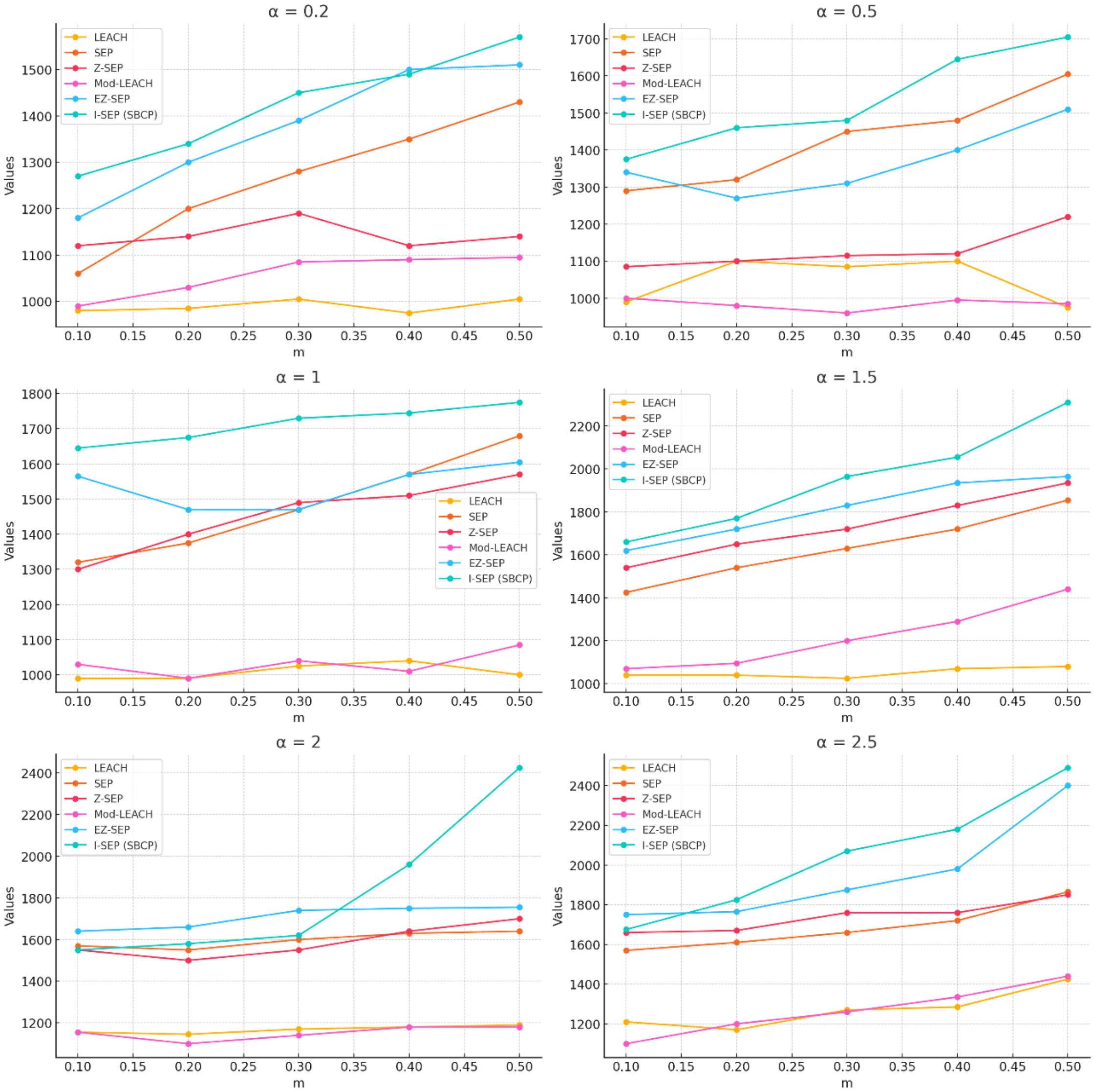


Figure.5 Comparative Outcomes of Energy Efficiency for Comparative Clustering Techniques

Performance Analysis Report

This analysis evaluates the performance of various non-meta clustering techniques (LEACH, SEP, Z-SEP, Mod-LEACH, EZ-SEP, I-SEP (SBCP)) across different values of heterogeneity (α) and proportion of advanced nodes (m). Non-meta clustering techniques are essential for understanding the robustness and efficiency of network clustering protocols in heterogeneous wireless sensor networks (WSNs).

α = 0.2

At the lowest level of heterogeneity, I-SEP (SBCP) and EZ-SEP exhibit the highest values across all m values, indicating superior performance. SEP also performs well, especially as m increases, suggesting its effectiveness in environments with minimal heterogeneity. LEACH has the lowest values, underscoring its limited effectiveness in such scenarios. Mod-LEACH and Z-SEP perform moderately, but not as well as the top-performing techniques.

α = 0.5

With moderate heterogeneity, I-SEP (SBCP) consistently outperforms other techniques, particularly at higher m values, demonstrating its robustness and energy efficiency. EZ-SEP and SEP also show strong performance, highlighting their ability to handle moderate heterogeneity effectively. Z-SEP and Mod-LEACH lag behind, indicating room for improvement. LEACH again shows the lowest values, reaffirming its inefficiency in heterogeneous environments.

α = 1

As heterogeneity increases, the performance gap widens. I-SEP (SBCP) leads, followed by EZ-SEP and SEP, which maintain strong performance across all m values. Z-SEP's performance improves with higher α, indicating its adaptability to increased heterogeneity. Mod-LEACH and LEACH remain less effective, with LEACH consistently underperforming compared to other techniques.

α = 1.5

At higher heterogeneity, I-SEP (SBCP) and EZ-SEP continue to dominate. SEP remains competitive, particularly at higher m values. Z-SEP shows significant improvement, becoming more competitive with increasing α values. Mod-LEACH and LEACH show gradual improvement but still lag behind the top-performing techniques, indicating their limited scalability in highly heterogeneous environments.

α = 2

In environments with very high heterogeneity, I-SEP (SBCP) and EZ-SEP maintain their leading positions. SEP's performance stabilizes, and Z-SEP becomes more competitive, showcasing its adaptability. Mod-LEACH and LEACH show gradual improvement but remain less effective overall. This pattern suggests that I-SEP (SBCP) and EZ-SEP are particularly well-suited for highly heterogeneous environments.

α = 2.5

At the highest level of heterogeneity, I-SEP (SBCP) and EZ-SEP continue to excel. SEP and Z-SEP show strong performance, with Z-SEP becoming highly competitive. Mod-LEACH and LEACH improve but still underperform compared to other techniques. LEACH consistently has the lowest values, reaffirming its limitations in highly heterogeneous environments.**I-SEP (SBCP) Performance:** I-SEP (SBCP) consistently outperforms other techniques across all levels of heterogeneity and proportions of advanced nodes, demonstrating its robustness, energy efficiency, and scalability. Its sector-based clustering approach enhances stability and performance, making it ideal for heterogeneous WSNs. EZ-SEP and SEP Effectiveness: EZ-SEP and SEP also perform well, particularly in environments with moderate to high heterogeneity. Their enhanced and stable election protocols make them suitable for a wide range of heterogeneous settings. **Z-SEP Adaptability:** Z-SEP shows significant improvement with increasing α values, indicating its adaptability and potential for further optimization. It becomes more competitive in highly heterogeneous environments, making it a viable option alongside I-SEP (SBCP) and EZ-SEP. **Mod-LEACH and LEACH Limitations:** Mod-LEACH and LEACH consistently underperform compared to other techniques, especially in highly heterogeneous environments. Their limited scalability and efficiency suggest they are less suitable for modern WSNs requiring robust and adaptive clustering protocols. SEP (SBCP) and EZ-SEP are the most effective non-meta clustering techniques for heterogeneous WSNs, offering superior performance, stability, and energy efficiency. SEP and Z-SEP also show promise, while Mod-LEACH and LEACH are less effective, highlighting the importance of choosing advanced clustering protocols for optimal network performance

Table 4:

Parameter	Description
Network Partition Time	Time until the first SN becomes energy-less, leading to network partitioning
Average Sensor Lifetime	Measures network efficiency and stability by tracking SN lifespan
Average Packet Delay	Time taken for data packets to reach the sink from the source
Network Throughput	Total data packets received at the base station over time
Average Packet Energy	Energy used per data packet during transmission
Average Power Consumption	Power used during data aggregation and transmission by CHs
Standard Deviation Load/Cluster	Variability in load distribution across different network deployments

MATLAB Code Values of different parameters for different clustering methods

4. COMPARATIVE ANALYSIS BASED ON MATLAB SIMULATION FOR DIFFERENT TYPES OF CLUSTERING METHODOLOGIES IN WCSN LEADING TO IOT

S. No	LEACH, Mod-LEACH	SEP, ZSEP, EZ-SEP	DEEC, EDEEC	SEP	MOD-LEACH
Field Dimensions - x and y maximum (in meters)	xm=100;	xm=100	xm=100;	xm=100	xm=400
	ym=100;	ym=100	ym=100;	ym=100	ym=400
Initial Energy	Eo=2	Eo=0.5;	Eo=0.5	Eo=0.5;	Eo=0.5
Energy required to run circuits J/Bits	Eelec=50*10^(-9)	Eelec=50*10^(-9)	Eelec=50*10^(-9)	Eelec=50*10^(-9)	Eelec=50*10^(-9)
	ETx=50*10^(-9)	ETx=50*10^(-9)	ETx=50*10^(-9)	ETx=50*10^(-9)	ETx=50*10^(-9)
	ERx=50*10^(-9)	ERx=50*10^(-9)	ERx=50*10^(-9)	ERx=50*10^(-9)	ERx=50*10^(-9)
Nodes	n=100	n=100	n=100	n=100	n=100
Data Aggregation Energy J/bit	EDA=5*10^(-9)	EDA=5*10^(-9)	EDA=5*10^(-9)	EDA=5*10^(-9)	EDA=5*10^(-9)
Suggested percentage of cluster head	p=0.05	p=0.1	p=0.1	p=0.1	p=0.1
Rmax	5000	5000	5000	5000	5000
Emp		0.0013*0.000000000001	0.0013*0.000000000001	0.0013*0.000000000001	0.0013*0.000000000001
Efs		10*0.000000000001	10*0.000000000001	10*0.000000000001	10*0.000000000001
EFS1					Efs1=Efs/10

Distributed algorithms select CHs based on dynamic criteria, updating them in subsequent protocol iterations. Power-based clustering considers battery life or residual network lifetime, with protocols like HEED and TEEN utilizing multi-hop communication.

Clustering Method	Key Features	Pros	Cons
Direct Transfer Protocols (DTP)	Non-clustering, individual SN transmission	Easy implementation, low cost	Energy wastage, short lifespan
Static Clustering	Permanent groupings, one permanent CH	Easy implementation, less energy wastage	Poor lifespan, power mismanagement
Minimum Energy Transfer	Static grouping, CH with energy threshold	Easy implementation, optimal energy use	Average throughput, lacks stability
LEACH	Dynamic grouping, parametric CH selection	Better coverage, flexible, optimal energy use	Stability issues, needs modifications
EECH	Dynamic, hierarchical CH levels	Better coverage, flexible, good throughput	Complex design, load balancing issues
HEED	Dynamic, randomized, two-parametric CH selection	Better load balancing, low energy consumption	Stability issues, moderate lifespan
PEGASIS	Greedy algorithm, two-step clustering	Better coverage, flexible, good throughput	Stability issues, moderate lifespan
GABEEC	Static clustering, CH selected based on energy	Optimal CH selection, minimal energy wastage	Poor load balancing, not suitable for large networks
PSO	Meta-heuristic, society-based swarm imitation	Good coverage, high reliability	Complex architecture, poor load balancing

Clustering Method	Key Features	Pros	Cons
Firefly	Bio-inspired, non-linear optimization	Good coverage, high reliability	Stability issues, difficult power optimization
HBMO	Two-step clustering, CH election	Good coverage, high fault tolerance	Stability issues, difficult power optimization
Deterministic Energy Efficient	Energy-based CH election, CSMA-MAC	Easy CH election, good coverage	Stability issues
CREEP	Assumes energy differences among nodes, multi-hop	Long lifespan, cost-effective	Complex CH formation
SEP	Heterogeneous-aware, weighted CH election	Good stability, better throughput than LEACH	Poor load balancing, complex implementation
M-SEP	Heterogeneous, two aggregators, remote CHs	Long stability, good coverage	Poor load balancing, complex implementation
HEC	Multi-hop, heterogeneous clustering	Long coverage, good energy dissipation	Complex CH election, poor load balancing
DEEC	Heterogeneous, multi-hop, stability-focused	Efficient, reliable, low energy consumption	Complex architecture, stability issues
EDEEC	Heterogeneous, super nodes, multi-hop	Efficient, stable, good coverage	Complex architecture
MED-DEEC	Distributed heterogeneous, easy CH election	Low energy consumption, easy implementation	Complex architecture, difficult cluster formation

Table 5: Comparative Analysis of different clustering techniques being Analysed

This comparison [Table.5] highlights the diverse characteristics of various clustering methods used in Wireless Camera Sensor Networks (WCSNs). Each method offers unique advantages in terms of energy efficiency, coverage, and reliability, while also presenting specific challenges like complexity, stability issues, and load balancing concerns. Integrating these clustering schemes can significantly enhance the performance of WCSNs, making them more suitable for IoT devices. By leveraging the strengths of different approaches, future IoT applications can achieve improved network longevity, efficiency, and reliability.

5. TECHNIQUES AND ALGORITHMS COMPARISON

O-LEACH, simulated in MATLAB, offers medium energy efficiency, better reliability in data transmission, better power optimization, low complexity in implementation, and moderately efficient throughput.

LEACH-C, simulated in MATLAB, provides medium energy efficiency, medium reliability in data transmission, medium power optimization, low complexity in implementation, and moderately efficient throughput.

HEED, simulated in MATLAB, demonstrates better energy efficiency, better reliability in data transmission, better power optimization, low complexity in implementation, and better throughput than LEACH.

EEHC, simulated in MATLAB, achieves better energy efficiency, medium reliability in data transmission, better power optimization, low complexity in implementation, and better throughput than LEACH and HEED.

PEGASIS, simulated in MATLAB, shows medium energy efficiency, good reliability in data transmission, better power optimization, medium complexity in implementation, and very efficient throughput.

PANEL, simulated in MATLAB, exhibits medium energy efficiency, good reliability in data transmission, better power optimization, medium complexity in implementation, and very efficient throughput.

TEEN/APTEEN, simulated in MATLAB, delivers good energy efficiency, good reliability in data transmission, medium power optimization, medium complexity in implementation, and better throughput than EEHC but lower than PANEL.

PSO-based algorithms, simulated in MATLAB, offer good energy efficiency, good reliability in data transmission, good power optimization, medium complexity in implementation, and very efficient throughput.

Firefly algorithms, simulated in MATLAB, provide better energy efficiency, medium reliability in data transmission, good power optimization, medium complexity in implementation, and very efficient throughput.

HBMO, simulated in MATLAB, delivers better energy efficiency, good reliability in data transmission, good power optimization, high complexity in implementation, and more efficient throughput than PEGASIS.

Hausdorff algorithms, simulated in MATLAB, achieve high energy efficiency, high reliability in data transmission, medium power optimization, high complexity in implementation, and more efficient throughput than HBMO.

DEEC, simulated in MATLAB, shows moderate energy efficiency, good reliability in data transmission, good power optimization, medium complexity in implementation, and better throughput than EEHC but lower than PANEL.

HEC, simulated in MATLAB, provides moderate energy efficiency, good reliability in data transmission, medium power optimization, medium complexity in implementation, and very efficient throughput.

SEP, simulated in MATLAB, demonstrates medium energy efficiency, good reliability in data transmission, medium power optimization, medium complexity in implementation, and very efficient throughput.

MED-DEEC, simulated in MATLAB, achieves good energy efficiency, good reliability in data transmission, good power optimization, high complexity in implementation, and better throughput than SEP.

M-SEP, simulated in MATLAB, offers better energy efficiency, medium reliability in data transmission, medium power optimization, medium complexity in implementation, and better throughput than MED-DEEC.

CREEP, simulated in MATLAB, delivers better energy efficiency, medium reliability in data transmission, medium power optimization, high complexity in implementation, and moderately efficient throughput.

DEC, simulated in MATLAB, shows medium energy efficiency, low reliability in data transmission, medium power optimization, low complexity in implementation, and moderately efficient throughput.

From the comparison, it is evident that algorithms such as Housdorff, HBMO, and PSO-based techniques exhibit higher energy efficiency and throughput levels compared to traditional methods like LEACH and PEGASIS. Despite the increased complexity in implementation, these advanced algorithms offer better reliability in data transmission and power optimization, making them more suitable for energy-constrained and large-scale network environment.

6. ANALYTICAL CONCLUSION WITH FUTURE SCOPE OF FINDING MORE APPLICATIONS

Based on the performance evaluation of various clustering schemes, non-meta clustering approaches have demonstrated substantial benefits for designing and implementing future IoT applications. Specifically, SEP, LEACH, and Z-SEP have been analyzed and compared, with Z-SEP showing superior performance over LEACH and SEP.

7. RESULTS AND KEY FINDING

While designing any wireless network protocol or algorithm, the energy of member sensor nodes (MSNs), overall network energy, and the network's lifespan are critical factors. Both these aspects need to be optimized to ensure a sustainable network. Z-SEP, with its zonal-based approach, has shown promise for dense networks, though it has its own set of challenges. Advancements in Clustering Protocols: The study highlights the evolution from Z-SEP to an improved version, the Extension of the Zonal Stable Election Protocol (EZ-SEP). EZ-SEP incorporates a dual-level protocol with a modified cluster head (CH) selection approach and node communication with the base station (BS). This enhancement allows data to be transferred among multiple BSs in a mixed zigzag manner directly to the sink, utilizing clustering algorithms to improve the lifespan of the network by accounting for energy dissipation. Enhanced Performance Metrics: Compared to the original Z-SEP, EZ-SEP shows better overall network lifespan due to an advanced routing algorithm that elects CHs based on residual energy. The stability period, defined as the time until the first node dies, is also extended, and the total number of active nodes in the network increases. Simulation results indicate that factors such as the lifespan of the module, the number of packets transmitted per MSN to the sink, and energy consumption have improved in various modified versions of basic algorithms. These include transitions from LEACH to M-LEACH and different versions of DEEC like EDEEC, TDEEC, and DDEEC, as well as SEP advancements to Z-SEP and EZ-SEP. Behavioral Differences with Increased Network Density: Increasing the level of heterogeneity, cluster density, or network area affects how different algorithms perform. Therefore, it is crucial to choose the appropriate algorithm based on the specific network requirements and constraints. The analysis indicates that non-meta clustering schemes, such as Z-SEP and its enhanced versions, offer significant advantages for IoT applications, especially in dense network environments. These schemes effectively balance the network load, extend the network lifespan, and improve energy efficiency, making them highly suitable for future IoT deployments. Wireless sensor networks (WSNs) have evolved into Wireless Camera Sensor Networks (WCSNs), which focus more on picture and video data. This evolution has introduced new challenges, such as increased energy consumption, power management, load balancing, and network stability. Clustering remains a key solution to these issues. Over the past two decades, clustering techniques have been refined to provide more optimal results for sensor networks, with over 30 different clustering methodologies now available. Fundamental clustering techniques like LEACH, PEGASIS, and HEED continue to be benchmarks due to their effectiveness in optimizing energy consumption and reducing average power usage. However, integrating these traditional techniques with modern meta-heuristic and probability-based mathematical solutions can yield more stable networks. Cooperative communication has become essential due to limited bandwidth availability across various communication domains, including military, biomedical, telemetry, telecom, and navigation. Effective clustering technique selection is crucial when designing WSNs or WCSNs, as WCSNs require larger bandwidth compared to traditional ad-hoc or WSNs. This necessitates cooperation across multiple communication domains to efficiently utilize the available frequency spectrum.

The primary challenges in this context include addressing power sensitivity, sensor node energy consumption, network lifespan, and load balancing. Effective solutions to these problems involve better routing methods and improved clustering techniques. The study of clustering methodologies is thus highly relevant in modern wireless communication, with a clear need to merge fundamental distributed hierarchical clustering techniques like LEACH, PEGASIS, EEHC, and HEED with PSO-based or neural-based models for enhanced performance. For IoT devices, this conclusion underscores the importance of selecting appropriate clustering techniques to ensure efficient power management, extended network life, and balanced load distribution. Integrating traditional clustering methods with advanced meta-heuristic and neural-based approaches can provide more robust and stable networks, which are essential for the diverse and data-intensive applications of IoT devices. This integrated approach will help IoT devices operate more effectively in various environments, from smart homes to industrial automation, thereby enhancing their performance and reliability.

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Authors' Contributions Statement

1. PKG conceptualized the research problem, guided the overall study framework, and reviewed the final manuscript. He also contributed to the analysis of results and provided critical revisions for intellectual content.
2. NT was primarily responsible for the coding, infrastructural implementation, and architectural design. He played a key role in developing the algorithms, validating the methodology, and integrating the proposed system's components. He also contributed to drafting the manuscript sections related to technical details.
3. SB assisted in conducting the literature review, comparative analysis, and visualization of results. He contributed to designing tables, diagrams, and charts and supported the drafting and editing of relevant manuscript sections.
4. Akash Rajak (AR): AR was involved in data collection, preprocessing, and conducting experiments. He also supported the manuscript preparation by contributing to the results and discussion sections and reviewing technical content.

5. Vidushi (V): V contributed to the documentation and manuscript preparation, focusing on sections related to the introduction, conclusions, and future work. She also ensured compliance with submission guidelines and formatting requirements.

***Each author has approved the final manuscript and agrees to be accountable for their contributions.**

Acronyms

Acronyms- Full Words

LEACH - Low-Energy Adaptive Clustering Hierarchy
I-SEP-Improved Stable election Protocol
SBCP-Sector based clustering protocol
SEP - Stable Election Protocol
DEEC - Distributed Energy-Efficient Clustering
TEEN - Threshold-Sensitive Energy-Efficient Sensor Network Protocol
APTEEN - Adaptive Threshold-Based Energy-Efficient Network Protocol
ZSEP - Zone-Based Stable Election Protocol
PEGASIS - Power-Efficient Gathering in Sensor Information Systems
MODLEACH - Modified Low-Energy Adaptive Clustering Hierarchy
FCM - Fuzzy C-Means Clustering
EM - Expectation-Maximization
AP - Affinity Propagation
FA - Firefly Algorithm
ABC - Artificial Bee Colony
BA - Bat Algorithm
SA - Simulated Annealing
ACO - Ant Colony Optimization
GA - Genetic Algorithm
PSO - Particle Swarm Optimization
DBSCAN - Density-Based Spatial Clustering of Applications with Noise
HC - Hierarchical Clustering
K-Means - K-Means Clustering
WSN-Wireless Sensor Networks
WCSN- Wireless Camera Sensor Networks
CC – Cooperative Communications
MSN – Member Sensor Nodes of the Network
EZ-SEP- Extended Zonal Stable Election Protocol
O-LEACH - Optimized Low-Energy Adaptive Clustering Hierarchy
LEACH-C - Centralized Low-Energy Adaptive Clustering Hierarchy
HEED - Hybrid Energy-Efficient Distributed clustering
EEHC - Energy-Efficient Hierarchical Clustering
PANEL - Power-Efficient Node Election Protocol
HBMO - Honey Bee Mating Optimization
Housdorff algo - Housdorff Distance-based Algorithm

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