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A Review On Energy Consumption Model On Hierarchical Clustering Techniques For Heterogeneous WSNs Using Energy Aware Node Selection

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ABSTRACT

This review article scrutinizes the energy consumption model related to hierarchical clustering methods in IoT-based multi-tier heterogeneous networks (WSNs). Since energy efficiency is vital to prolong the operational activities of sensor nodes, this review article concentrated on energy-aware node selection as a significant technique for improving energy consumption. We scrutinize different factors affecting efficient node selection, comprising residual energy, transmission distance, and sensor node reliability, while juxtaposing these techniques with traditional node selection schemes. Furthermore, the importance of developed modeling techniques was highlighted. Finally, future research directions were outlined by accentuating the incorporation of energy harvesting and collective models to improve the stability and operation of Wireless Sensor Networks. This holistic overview aims to offer appreciated insights for authors and practitioners in WSNs. Since energy efficiency is vital to prolong the operational activities of sensor nodes, this review article concentrated on energy-aware node selection as a significant technique for improving energy consumption. The review article deliberates on the challenges posed by dynamic wireless sensor network conditions, node heterogeneity like energy-based, and scalability challenges that affect energy management. We scrutinize different factors affecting efficient node selection, comprising residual energy, transmission distance, and sensor node reliability, while juxtaposing these techniques with traditional node selection schemes. Furthermore, the importance of developed modeling techniques was highlighted. This holistic overview aims to offer appreciated insights for authors and practitioners in WSNs.

1. INTRODUCTION

The fast spread of the Internet of Things (IoT) has changed various industries by allowing a huge network of interconnected devices, mainly in implementations comprising Wireless Sensor Networks (WSNs) [1]-[3] This scheme consists of different sensor nodes organized to monitor environmental parameters, receive data packets, and send data to central systems [4]-[6]. Due to the high need for real-time packet processing and

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evaluation, the ability to manage energy consumption in the network has become a dire concern in the design and implementation of IoT-based multilevel heterogeneous wireless sensor networks [7]-[9].

Hierarchical clustering methods have been developed to enhance energy utilization in wireless sensor networks [10][11]. Hierarchical clustering partitions sensor nodes into clusters to enable effective packet aggregation and minimize the transmission overhead, maximizing the network's operational lifetime [12][13]. However, the heterogeneity of sensor nodes in the network by way of variation in energy level, processing capacity, transmission range, and so on brought in limitations during the clustering approach, which compelled an innovative scheme called Energy-Aware Node Selection (EANS) [14]-[16].

A prospecting key depends solely on applying Energy-Aware Node Selection (EANS) techniques within the hierarchical clustering framework. The scheme prioritizes the cluster heads based on sensor nodes' residual energy, thus improving the total network's energy efficiency. This is done by intentionally selecting sensor nodes that can sustain their operational activities over time. The EANS technique can considerably minimize premature sensor node depletion, which leads to network inefficiency [17]-[20].

As the Internet of Things (IoT) ecosystem grows and the need for sustainable data transmission rises, addressing energy efficiency in Wireless Sensor Networks (WSNs) is critical [21]. Rapid node depletion brought on by inefficient energy use might jeopardize the durability and dependability of networks [22]. Enhancing performance and facilitating the scalability of IoT systems requires optimizing energy-aware node selection in hierarchical clustering approaches [23][24]. The existing approach frequently ignores node heterogeneity and dynamic environment conditions, which results in less-than-ideal energy distribution in WSNs. By combining real-time data analysis and an energy-aware selection approach, which improves network lifetime and efficiency in the Internet of Things scenarios [25]-[28].

The subsequent sections are structured in the following ways: Section 2 discusses a Review of similar works, section 3 presents Hierarchical Clustering Techniques, section 4 discusses Energy Aware Node Selection, and Section 5 concludes the review article.

2. REVIEW OF SIMILAR WORKS

The authors in [28] proposed a scheme called improved stable energy efficient network integrated super heterogeneous routing. In their article, the authors evaluate energy utilization in their respective clusters and a vast range of energy levels in heterogeneous wireless sensor networks. This algorithm is based on the weighted selection of each sensor node to transit into the cluster head due to its distance from the sink node and the remaining energy. Furthermore, they also evaluated the heterogeneity of the sensor nodes in the network in terms of energy. They found that their technique was better in stable regions for suitable energy and distance weight than the existing schemes.

In the work in [29] the researchers used a technique called compressive sensing (CS) to effectively utilize limited energy and wireless sensor network radio resources, which can minimize the bandwidth required for transmission by reducing the number of communications and the number of data to be processed. Further, they addressed the network energy management of data acquisition by incorporating compressive sensing and hierarchical clustering implementation. They subdivided their network into clusters and cluster heads to coordinate the operations in the clusters, which compress and acquire packets from various cluster members in the network using the scheme above. The result simulation shows that the improved scheme performs better than the existing scheme in terms of energy-efficient packet acquisition, leading to overall network performance.

In [30] the authors proposed an improved hierarchical clustering technique for harvesting energy on a large scale, thereby introducing several relay sensor nodes that get the aggregated packets from the selected cluster heads and then send them to base stations. Further, they also formulate a multilevel weighted selection probability that can support up to n levels of heterogeneous sensor nodes with respect to their initial energies. The simulation result shows that EH-mulSEP is better than the existing schemes regarding "energy utilization, network stability, and network throughput."

The researchers in [31] proposed a multilevel clustering scheme where the sensor nodes' energy is efficiently managed to extend the network lifetime. They subdivided the wireless sensor network's geographical location into three regions due to the network radio range and the clustering of the sensor nodes in the different regions to carry out their functions independently. In their work, they minimize the number of cluster heads in the network because it consumes more network energy due to data aggregation, processing, and transmitting than any other member nodes to maximize network lifetime. The simulation result shows that the proposed algorithm was better than the existing algorithm regarding network lifetime.

In [32], the researchers proposed a scheme called "Power Efficient Cluster based Routing techniques" by taking into consideration organizing cluster heads (CHs) and a main cluster head (MCH), maximal path choice, transmission due to energy usage model are based residual energy, and relative location. In their article, the proposed scheme mitigates the traffic overburden and conserves energy usage, which leads to network lifetime maximization. The simulation results show that the proposed algorithm performs better than the existing algorithms.

The work of [33], proposed a scalable and energy-efficient routing technique to influence multi-hop hierarchical routing technique and reduce the energy usage in the network through a multi-tier based framework. In their article, the authors used the proposed scheme to subdivide it into different zones using an area division algorithm, and the number of these zones increases due to the increase in size of the network to avoid long-distance communication. Furthermore, every zone is partitioned into several clusters, and this number of clusters is increased to the base station, thereby minimizing its size concerning width, where some optimal nodes are elevated to relay and cluster head in a multi-hop technique. Trade-offs exist between energy and distance to maximize network lifetime.

The work of [34] proposed a scheme that addressed efficient energy usage to maximize the network lifetime. Their article uses cluster-based routing techniques alongside optimization techniques to mitigate energy constraints associated with sensor nodes. Furthermore, they evaluated and reviewed the clustering technique's advantages and disadvantages for heterogeneous wireless sensor networks within a range of 2009-2019. They also considered comparing energy-based and hybrid clustering techniques for static and mobile heterogeneous wireless sensor networks based on their different attributes.

In [35], the authors propose a scheme to address energy homogeneity in the network by analyzing its effective performances and investigating its different models. They also subdivided their model into 2 levels to 5 level and multilevel heterogeneous network models and thereafter compared their scheme with that of LEACH, SEP, DEEC, HEED, and PEGASIS. Their work was far better than the existing one.

The work of [36] proposed a scheme that addressed the inability to manage node heterogeneity, which easily leads to uneven energy utilization and load balance across the wireless sensor networks and causes poor performance. The authors employed the "Traffic and Energy Aware Routing technique" that selects choices with low energy and high-frequency rates for CH implementation, thereby realizing load balance by employing a hybrid technique alongside those as mentioned above.

In [37], the researchers proposed a scheme that addressed the inability to manage the usage of energy efficiently in the network due to the limited energy associated with sensor node devices with the help of clustering and multi-hop transmission techniques. This scheme suffers from unequal load balancing and hotspot problems due to uneven energy utilization between sensor node members and its cluster head. Furthermore, they considered a hierarchical layer-balanced clustering technique to address these issues, as mentioned earlier, by improving the cluster head selection and minimizing intra-communication distance in the network. This is where multi-objective optimization-based ratio evaluation comes in by evaluating the three critical characteristics, "Residual energy, sensor node centrality, and range to relay,". They also considered Shannon entropy-driven characteristics for choosing cluster head, with the help of an enhanced "Dijkstra-based minimum spanning tree formation scheme" based on "remaining energy, and distance to the relay been evaluated to mitigate IACD and spread the load on members nodes equally". Based on these evaluations of their network, the three performance measures: "dead node, energy utilization, and a lifetime of the network", the proposed scheme performed better than the existing ones in terms of metrics above at "round 201.341, and 417 for scenario 1 and 254,309, and 382, and so on."

The researchers in [38] proposed a scheme called "Technique for order of preference by similarity to ideal solutions (TOPSIS)" that would be employed for a prime location for packet collection centers. In their article, the proposed scheme is dynamic in nature by connecting to different networks as needed by the Internet of Things. It enhances energy efficiency, uneven clustering driven on communication distances with the aid of cubical and spherical segmentation techniques for 3D HN, and a formation of shape that is independent to extend its adaptability and scalability of the uneven clustering. The simulation result shows that the proposed algorithm performs better than the existing algorithm in terms of network lifetime, up to 14.2% and 18.8% compared to "Fuzzy Logic Based unequal clustering and IUCR, respectively." It also minimized the total network energy utilization by up to 61.4%, juxtaposed to the state-of-the-art uneven clustering schemes.

The work of [11] proposed a scheme called EEHCT to mitigate network utilization by the application of heterogeneous wireless sensor nodes with various functionalities and capabilities such as energy levels, sensing ranges, processing capacities, and so on for their transmission strategies. In their article, the network is partitioned into rounds; each round consists of the set-up and steady-state phases. The network is divided into clusters in the setup phase, while the actual data transfer occurs in the steady state phase. The simulation result shows that the improved scheme performs better than the existing schemes regarding stability, throughput, and network lifetime.

In [39] the authors proposed Threshold-based Minimum Cost Cross-layer Transmission (TMCCT), which functions at sensor node levels and ensures effective packet transmission control by considering "current sensor value, heterogeneous event thresholds, and the previous data records." The simulation result shows the

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improved algorithm performs better than the existing algorithms in terms of energy saving, lifetime extension, and transmitted data reduction by 29%, 68%, and 26%, respectively.

In [40], the researchers proposed a scheme called Balanced Grouping Scheme (BGS) to improve on the limitations that are associated with the existing schemes considering the principal challenge, which is the inability to estimate the average energy of the previous round in a dynamic clustering protocol which required a lot of time to choose the cluster heads. In their article, BGS partitioned the nodes into groups using the double mean technique, allowing lesser energy nodes to be conserved for later rounds. The simulation result shows that the improved algorithm performs better than the existing algorithm regarding stability and packet delivery, with 44% and 8%, respectively.

In [41], the authors proposed the Energy Efficient Memetic Clustering Method (EEMCM) to combine paralyzed PMA with AlexNet architecture to enhance the detection efficiency of challenges in IoT WSNs. In their work, the formation of clusters and cluster head selection is carried out by PMA, and anomaly detection, such as attacks, is carried out by AlexNet architecture. The proposed scheme outperformed the existing schemes.

In [42], the researchers proposed a scheme to mitigate the security effect of WSN's energy consumption model by incorporating IoT and blockchain technologies into the system. In their article, IoT end nodes are low-powered devices that maintain any blockchain node's energy utilization and allow it to survive without battery replacement. Their work also considered the temperature reached in devices employed for blockchain security measures.

Table 1: Critical Analysis of the Existing Work

Ref	Metrics Performance	Clustering Techniques	Potential Improvement
[27]	Energy & Distance	E- BEENISH	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[28]	Energy & lifetime	CBHRP-CS	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[29]	Energy & Lifetime	EH- mulSEP	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[30]	Energy & lifetime	MLGenetic	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[31]	Residual energy&Lifetime	PECR	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[32]	Energy, distance & lifetime	SEEP	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[33]	Energy Utilization & lifetime	HetWSN	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[35]	Energy, & lifetime	TEAR & ETASA	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[36]	Node death rate, energy, & lifetime	HLBC	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[37]	Energy &lifetime	TOPSIS	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[7]	Stability, throughput, network lifetime	EEHCT	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[38]	Energy saving, lifetime & transmitted data reduction	TMCCT	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[39]	Stability, Packet delivery & lifetime	BGS	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[40]	Energy, Lifetime	EEMCM	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs
[41]	Nodes' temperature, Security	Blockchain	EANS to mitigate the rapid depletion by inefficient use of energy in WSNs

These review articles scrutinize previous work on Energy consumption models in hierarchical clustering techniques for heterogeneous wireless sensor networks. Most of the articles considered more of the following areas: energy efficiency, quality of service, routing protocols, privacy and security, network lifetime, packet delivery, and so on, using the various clustering techniques in Table 1. However, none of the articles has given thorough attention to the Energy Aware Node Selection and its estimation of model equations, which ensures efficient energy consumption, and maximized networks' lifetime.

3. HIERARCHICAL CLUSTERING TECHNIQUES

Hierarchical clustering in wireless sensor networks is a technique that organizes nodes into regions or sections on their spatial or operational relationship. It helps do justice to inefficient data management, transmission, and resource allocation in wireless sensor networks. In the network, hierarchies are structured in this manner. Sensor nodes are organized in a tree-like setting, where each sensor node can be a parent (cluster head) or a child of another node (member nodes) based on predefined criteria. Cluster heads are liable for packet aggregation, minimizing the number of direct transmissions to the base station and coordination transmission within the clusters, as shown in Figure 1. Energy Aware Node Selection is a technique employed in WSNs to optimize the performance and continuous process of wireless sensor networks by selecting a node for specific assignments, such as data transmission and processing, based on their energy levels and utilization rates, thereby maximizing WSNs' lifetime, Load balancing, and energy efficiency. Here are some ways Hierarchical clustering could be applied in the networks:

- Data Aggregation: Cluster Head Selection: nodes are categorized into clusters, each with a selected cluster head. The role of the Cluster Head is to aggregate data from its member nodes before transmitting it to a base station, thereby reducing the number of packets transmitted and conserving energy.
- Energy Efficiency: Adaptive Clustering: this is where nodes with higher energy levels are in a hierarchical state to allow WSN to adjust dynamically based on the energy level of the nodes, thereby balancing energy utilization across the WSN.
- Hierarchical Data Fusion: Layer data Processing Fusion; this is where packets from sensor nodes can be processed at various hierarchical states such as local, regional, and global. This stratified technique enables more efficient packet fusion schemes, leading to better decision-making and resource use.

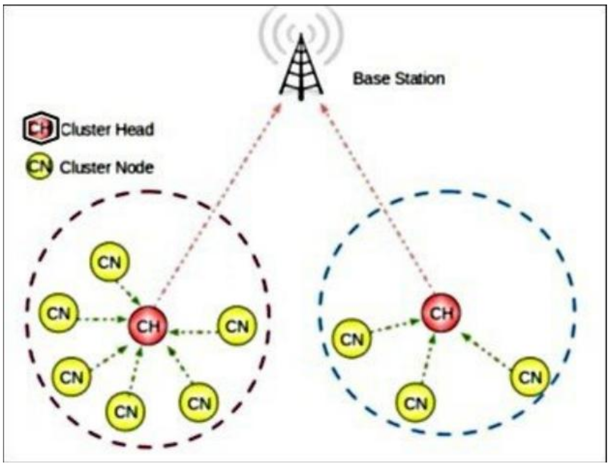

Figure 1: Hierarchical clustering [54]

Generally, hierarchical clustering is subdivided into two categories [35][38][39]:

- ***Agglomerative Clustering***

This is where sensor nodes start as individuals and finally merge into clusters based on similarity. Agglomerative clustering is easy to implement and offers a clearer representation of packet relationships through the dendrogram [37][43][44].

- ***Divisive Clustering***

This is where sensor nodes start with one cluster and recursively split into smaller clusters. Divisive clustering can efficiently coordinate complex packet structures and offer a more refined grouping by focusing on the most crucial data points first [37][43][44].

3.1. Benefits of hierarchical Clustering in WSNs

Hierarchical clustering provides various advantages for energy management in Wireless Sensor Networks, especially in multi-tier heterogeneous networks [37][43][44]:

- Efficient Data Aggregation: Hierarchical clustering minimizes the number of packets transmitted across the network by portioning nodes into clusters. Cluster heads can aggregate packets from their member nodes, thereby reducing transmission overhead and minimizing energy.
- Scalability: The hierarchical strategy permits the wireless sensor network to scale efficiently. As new sensor nodes are added, they can be easily incorporated into existing clusters without crucial reconfiguration, thereby maintaining energy efficiency.
- Load Balancing: The hierarchical technique enables load balancing by spreading the communication load evenly among cluster heads. This mitigates overburdening any single node to premature depletion, thus prolonging the network's operational life.

- Adaptive Clustering: The hierarchical scheme can adjust to vicissitudes in network circumstances, such as node depletions or varying energy levels. Dynamically adapting to cluster memberships and heads enhances the network performance.
- Improved Lifetime: By improving packet transmission and reducing energy utilization, hierarchical clustering schemes contribute to network lifetime maximization. This is especially crucial in implementations where sensor nodes are deployed in remote and inaccessible areas.

4. ENERGY CONSUMPTION IN WSNS

Wireless Sensor Networks (WSNs) are inherently resource-constrained environments whereby node devices function with limited battery energy. The energy management issues in the WSNs are vital because sensor nodes are implemented in remote or inaccessible locations, causing battery replacement to be problematic or difficult. Due to this, efficient energy management is significant in maximizing network lifetime. The main limitations comprise high transmission overhead, repeated data communications, and the need for continuous examination. These limitations mentioned above play rapid energy depletion in the network. Furthermore, the dynamic nature of Wireless Sensor Networks, comprising sensor node mobility and varying environmental situations, complicates energy management techniques.

4.1. Factors affecting energy consumption

Energy-efficient management guarantees a stable network and its overall performance; hence, there need to enhance continuous network operation. Numerous factors significantly encourage energy consumption in Wireless Sensor Networks [45]-[47].

- Communication Protocols: The choice of communication protocols in the wireless sensor networks can significantly influence energy utilization. Protocols that necessitate numerous acknowledgments or retransmissions can lead to higher energy expenditure.
- Data Transmission Distance: The energy consumed during transmission is distance-related. The distance between sensor nodes affects energy consumption, and the longer the transmission distance is, the more energy it consumes. Hence, keeping the finest distances between sensor nodes and cluster heads is indispensable.
- Node Density: The number of sensor nodes deployed per unit area can affect energy consumption. When nodes are concentrated in a location, the tendency to reduce energy consumption is high through data aggregation and also can cause high competition in terms of wireless channel access, which may lead to incremental energy utilization.
- Operational Modes: In a bit to manage the energy wastages in the network, Sensor nodes regularly have numerous functional modes (“e.g., sleep, active, and idle”). The running of these modes, particularly how long these sensor nodes will remain in active mode, directly influences energy utilization.
- Environmental Factors: Environmental parameters, like temperature and humidity, can affect sensor nodes' performance and energy utilization, necessitating adaptive techniques.

4.2. Importance of energy models in network design

Energy models play a dire role in the entire architectural structure when designing and enhancing wireless sensor networks. These models offer an understanding of energy utilization configurations, allowing network designers to make knowledgeable decisions that improve energy efficiency. Key advantages of employing energy models include [48]-[51]:

- Performance Prediction: A well-performance predictability of energy models enhanced the overall performance and lifetime of the wireless sensor networks under different scenarios, thereby helping in the choice of suitable clustering techniques and protocols required.
- Optimization of Resource Allocation: The more accurate knowledge of energy consumption dynamics a designer has, the better the models that can allocate the resources. Like By understanding energy consumption dynamics, models can guide the allocation of resources, such as influencing the best number of cluster heads or the best transmission protocols.
- Enhanced Network Longevity: By accurately effecting energy-efficient designs based on correct models, it can significantly maximize network lifetime and extend sensor networks' operational lifespan, minimizing maintenance costs and improving reliability.

5. ENERGY AWARE NODE SELECTION

WSNs encounter significant challenges in terms of energy utilization due to the limited battery life of nodes. A continuous examination of data, packet transmission, and processing phase, which cause a heavy burden on energy resources, must be effectively managed. Otherwise, the network will be in jeopardy. When nodes are not well managed, it causes inefficiency in performance, which leads to premature failure, distracting network performance and minimizing its overall performance [52]. Knowing how energy consumption will be in the design network gives advantages to its network's continuous process. Let the total energy consumed in the network represented by ET, the energy utilized during the transmission of packets, be E_{TX}, the energy employed during the reception of these packets be E_{RX}, and the energy used when the components are not sensing, transmitting, or receiving packets is energy for the Idle process. Therefore, the total energy usage in the WSNs is the summation of all the individual energy used in transmitting, receiving, and idling. Let us use this model Equation to represent the total energy consumed in the WSNs [53][54].

$$ET = E_{TX} + E_{RX} + E_{idle} \tag{1}$$

The choice of energy consumption model can be influenced by cluster heads and transmission protocols in the WSNs, making energy-aware node selection desirable.

5. 1. FACTORS FOR NODE SELECTION

The effectiveness of the performance of WSNs depends on the appropriate selection of node energy; this involves key factors outlined below with their respective model equations.

- Residual Energy: This is the current energy of nodes that have been captured during the operation of the network. These nodes are 'selected based on their remaining energy levels," and this can be modeled as:

$$E_{res} = E_{ini} + E_{con} \tag{2}$$

The residual energy can be evaluated using equation (2): the consumed energy subtracted from the initial energy. Where E_{ini} is the initial energy, that is, the energy of a node before the network starts its operation, E_{con} is the energy consumed during the network operation, and E_{res} is the residual energy of a node.

- Transmission Distance: This is data communication based on distance; the more distance a node is during transmission, the more energy it uses. This can be modeled as:

$$E_{TX} = E_O . d^{\alpha} \tag{3}$$

The energy needed for transmission is given in equation (3), where E_O is energy constant, which means standard energy utilization needed for transmitting a unit packet distance. It is precise to the hardware characteristics of the nodes with the inclusiveness of transmitter and receiver designs, d represents the distance between the sending node and the receiving node, and α is the path loss exponent, which represents the effect of distance on signal strength and energy utilization.

- Node Reliability: Performance metrics, like successful packet transmission over time, can determine this. This can be represented as:

$$R = N_{success}/N_{total} \tag{4}$$

Where: $N_{success}$ represents the number of successful transmissions of data and N_{total} is the number of transmissions attempted. To determine a general single model equation for Energy-Aware Node Selection (EANS) in WSN, we can incorporate the different factors discussed earlier, comprising of residual energy, transmission distance, and node reliability as thus:

$$EANS = E_{res} \cdot R / E_O \cdot d^{\alpha} \tag{5}$$

Where $EANS$ is the general energy-efficient score for choosing a node. E_{res} is the remaining energy of the sensor nodes, estimated as $E_{ini} - E_{con}$. R is the sensor nodes' reliability factor, and it is given by $N_{Success}$ /N_{Total}. E_O the energy constant measured in joules per bit meter represents the baseline energy needed for communication across the network. d is the distance between the sensor node and the cluster head across the network. α is the Path loss exponent representing the increase in energy consumption with distance.

The numerator creates the product of E_{res} and R This emphasizes the significance of the needed energy and reliability in choosing nodes. A higher value specifies a more appropriate candidate for energy energy-intensive role, while the denominator suggested that the term $E_O \cdot d^{\alpha}$ signifies the energy cost related to transmitting packets over a distance d. A lower energy cost gives a sensor node more auspicious for selection. Therefore, by maximizing EANS during the selection of the sensor node process, the WSN can ensure that the most energy-efficient and reliable sensor nodes are chosen for critical roles, like cluster heads, hence balancing the loads, enhancing communication efficiency, and improving the overall energy utilization across the network.

Table 2 shows the recent studies carried out in this area; most of the researchers' proposed techniques do not use Energy Aware Node selection alongside its model equation estimation that ensures mitigation of energy depletion with sensor nodes, poor packet reliability, and network fragmentation. Accurately modeling the networks with an accurate energy-aware node selecting technique alongside its model equations will lead the network to better energy efficiency and maximization of network lifetime.

Table 2: Comparison of the existing work done

Ref. Year	Scheme Applied	Problem solved	EANS	Limitations
[55]. 2024	EEMCM	Energy, Residual Energy, Delay	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations.
[56]. 2024	LM-WOA	Distance, Delay, Energy, Cluster density	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations.
[57]. 2024	[39]. 2024	Energy, Packet loss ratio, Networking lifetime, Buffer Occupancy.	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations.
[56]. 2024	NCMLT	Energy, Network life time.	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations.
[58].2024	SEE2PK	Network life time, Security, Computational cost, Scalability, Energy.	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations.
[59].2024	PSO	Energy, Throughput, Packet delivery rates, network life time.	No	• Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation of EANS Model equations. • Increase in energy depletion due to inaccurate estimation of EANS Model Equations. • Poor packets reliability due to inaccurate estimation of EANS model equations. • Network fragmentation due to inaccurate estimation • of EANS Model equations.
[60].2024	DQARL, HPO	DQARL, HPO		

5. 2. CHALLENGES AND FUTURE DIRECTIONS

Wireless Sensor Networks function in unpredictable settings where sensor node mobility, different sensor node energy levels, and changing transmission circumstances can affect wireless sensor network function. Evolving energy-aware selection techniques that can adaptively be conditioned to these vicissitudes remain a weighty challenge.

Due to the increment of the number of network nodes, sustaining efficient energy utilization while confirming an effective transmission and packet aggregation develops into multifaceted.

The various capabilities of sensor nodes in multi-tier heterogeneous networks, such as "varying energy capacities, processing power, and transmission distances, muddle the sensor nodes selection process." Designing techniques that can efficiently justify these variations above to improve energy utilization is a tenacious challenge.

Energy harvesting schemes are evolving but are still not generally implemented and effective across various nodes. The dependence on batteries still poses a significant challenge, ensuring vital techniques that prolong the sensors' energy life via effective energy management.

The precise modeling of energy utilization in hierarchical clustering schemes can be complex because of the relationship between factors such as sensor node characteristics and environmental circumstances. Basic models may undermine critical dynamics, leading to suboptimal sensor node selection and energy utilization.

Researchers should focus on emerging adaptive energy-aware sensor node selection techniques that can allow for the conditions of dynamic wireless sensor networks in real-time. The researchers should employ machine learning schemes to predict energy utilization design and improve node selection adaptively. Incorporating energy harvesting schemes alongside energy-aware sensor node selection can create more appropriate networks. Future research should explore efficiently integrating harvested energy by incorporating sensor node selection techniques to improve WSNs processing time.

By allowing more advanced energy utilization techniques to capture the intricacies of heterogeneous environments, these techniques should contemplate factors such as "sensor node interactions, environmental influence, and real-time packets on energy utilization."

Exploring collective sensor node selection techniques, where sensor nodes can share data concerning their energy levels and transmitting conditions, can lead to more efficient overall wireless sensor network performance by enabling better load balancing and even energy distribution across the wireless sensor network.

Instituting consistent metrics for estimating energy-aware sensor node selection techniques will improve comparability across researchers, and this can initiate innovation and allow progressions in energy efficiency that are effectively communicated and applied.

In conclusion, proffering solutions that are related to energy utilization in hierarchical clustering for IoT-based WSNs need a multilayered method that accepts dynamic schemes, innovation modeling, and collective approaches. By concentrating on these future directions; authors can significantly enhance the efficiency and sustainability of Sensor Networks.

6. CONCLUSION

In this review article, we analyzed energy consumption models' significant role in hierarchical clustering techniques for IoT-based multilevel heterogeneous wireless sensor networks. We highlighted the significance of energy-aware node selection as a crucial tool to enhance energy efficiency and maximize wireless sensor network lifetime. Energy Aware Node Selection in WSNs optimizes the lifetime and performance of the WSN by selecting nodes based on their energy levels. This technique helps balance energy utilization across the network, minimizing node depletion risk. Prioritizing nodes with higher energy reserves improves data transmission efficiency and extends the overall network lifetime. Managing the challenges related to dynamic network conditions, node heterogeneity, energy-based, and scalability creates a new paradigm for WSNs. Energy Aware Node Selection will create a robust framework for future research directions in WSNs by prioritizing energy efficiency and sustainability. By incorporating energy harvesting and collective techniques, this Foundation promises to improve the stability and performance of WSNs. Ultimately, executing an effective energy-aware node selection will be vital for developing robust and efficient networks capable of sustaining the growing demands of IoT implementations. It will allow the development of adaptive energy techniques that enhance resource allocation and improve overall network performance, leading to more resilient and long-lasting network deployment.

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