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Energy-Efficient Routing Protocols for WSN: A Systematic Literature Review

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ABSTRACT

A wireless sensor network is the combination of a hundred devices randomly scattered in the field to sense facts. Sensor devices having the facility of sensing, storing, energy resources, and data broadcasting, but they are not rechargeable or replaceable. The small energy resources of sensors always encourage the development of energy-efficient protocols to make a long lifetime of WSN. It's essential to build routing protocol, which helps us make maximize the network life span through energy efficiency. In this systematic literature review, we have to discuss various researchers' efforts so for concerning the energy efficiency of the Wireless sensor network using the various techniques. Mainly In this systematic literature review we have to discuss about the major issues and their concerned proposed routing protocol reviewed in the literature. This paper also includes the methodology that will descried the method is adopted in this systematic literature review. More over this SLR also described the results in the sense of the digital libraries, major contributions in this literature review, end techniques used in these routing protocols.

Key words: Energy efficient routing protocol, WSN, Clustering, cluster head, Routing, Energy Distribution, Lifetime.

1. INTRODUCTION

There is an immense growth in the development of WSN appliances due to the new studies. A sensor is a small electromechanical device with limited storage capacity, limiting fixed energy capital with a data broadcasting facility [1]. WSN's means to support the application used to monitor the environment of agricultural, industrial, medical, military, etc. [2]. As WSN's have compatibility with various systems, few issues arise for the users of this type of application like design, security, energy efficiency, etc. [3]. This section will present the broad thought of wireless sensor systems, their applications, significant issues, and the development & transmission protocols for WSN's.

A wireless sensor network is an integrated system of small micro-electro-mechanical devices with a base station's central system [1, 54]. Small sensor devices are used in the network to get information from the field at BS. The main focus of WSN is to observe the area. WSN is based on small nodes with the potential of data sensing, communication, and processing of the collected data to generate valuable results. A self-organized system is used to observe the environments for a specific purpose in different areas of life. This system is applied to sense facts from the field by sensor nodes, transmits these facts to the base station via integrated radio transmitters. Such a system can cover up the short precise region but always face limited energy resources for SN's. The architecture of the wireless sensor network is bellowed.

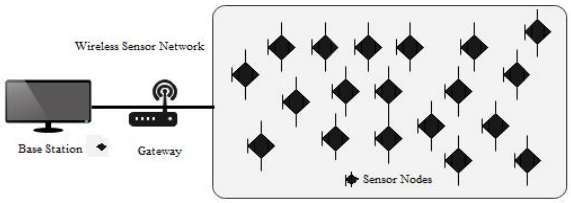

Figure 1: WSN Architecture

As we know, the sensor nodes have limited energy resources, storage space, and sensing potential, That why it's essential to consume less energy to perform the task; for this purpose, it's necessary to reduce and balance energy consumption to enhance network life span to resolve such issues routing protocols are designed. The routing protocols prove much efficient to save energy and meet problems such as congestions, overhead, delay & most excellent route selection, etc. They also provide us with a quality of service for routing in wireless sensor networks. Routing protocol offers energy efficiency to enlarge the network life span by using the techniques of clustering formation, cluster leader selection, and choosing the best route for data broadcasting. Furthermore, we will discuss these techniques in detail.

This paper is organized in the following way. Section two is based on the literature review, which provides a detailed introduction of the existing routing protocols for the energy efficiency of WSN. Section three based on the research sources and the research question considered from the baseline paper. Moreover, section four the results and discussion, which provides the details with ratios of years of publications, the libraries of references papers, etc. In the end, the conclusion drawn.

2. LITRATURE RIVIEW

Energy efficient routing is one of the leading research areas to developing the routing protocol that reduces energy consumption. In previous times various efforts have been made in the development of energy efficient routing protocols for WSN. In this review, we are discussing the most well known routing scheme for WSN. We have categories these routing protocols based on the significant contributions in these schemes. These critical factors which are considered to save the energy are clustering, cluster leader selection, routing, neighbor selection for data broadcasting etc.

Clustering

A procedure of dividing the nodes into groups is called clustering based on some similarities. Cluster formation has various advantages that become the most active technique practiced in routing protocols for WSN. Clustering facilitates meeting the issue like more scalability, less load, less energy, and more robustness lifetime of a network and the quality of service. In the literature review initially we discuss some well known routing protocols use the clustering technique to achieve the energy efficiency of WSN [12].

Here some well-known routing protocols are discussed base on clustering to get energy efficiency of WSN.

LEACH (Low energy adaptive cluster hierarchy) is designed to distribute the energy load among SN's. Mainly LEACH is based on clustering and rotates the cluster head in each round to distribute the energy load. LEACH performed data fusion to reduce data before delivering to the base station to save more energy [5].

A routing protocol called CODA (Clustering-based self-organized data aggregation) performs data aggregation to save energy. The data aggregation is based on the distance between SN's and BS. In the scheme, sensor nodes were trained sensor using Kohonen SOM's algorithm to aggregate the data. This algorithm is based on three phases, which are initialization, winner finding, and weight updating. According to the requirement of the system, the original algorithm is modified [8].

TL-LEACH is the improvement of the LEACH model with two level clustering head model. TL-LEACH performs random rotation for the local cluster BS. Two-level hierarchical routing protocol performs better distribution energy load [TL-LEACH]. DEEC performs the clustering for energy-efficient routing and selects the cluster leader based on the probability ratio of nodes' residual and average energy. High chance to be the cluster leader for nodes with more initial and residual energy [12].

ELCH based on LEACH that performed mode balanced cluster distribution. ELCH is a multi hope routing model that elects a cluster leader based on the neighbor heaving various intermediate nodes. The basics of ELCH are the same as LEACH with two phases' setup and steady-state phase. In the setup phase, clusters are designed to use nodes' votes to each cluster head candidate node. The main thing

considered for selecting the nodes' group head is the node's importance, not its local properties, and the numbers of votes calculated for each cluster head and distance and residual energy [13].

A cluster based model designed to enhance energy efficiency and latency, minimize overhead and improve the network's worth. The protocol performs randomization, self-configuration, and clustering formation to attain better results, controlling data transmission. In this scheme, clustering and data transmission are exercised, and data aggregation helps obtain healthier outcomes [15].

Improved LEACH is planned with some adjustments in the cluster head technique. In I-LEACH, sub-CH is additionally chosen for each cluster. Sub-CH work as cluster leader in the cause of primary Cluster leader died. CH at each round consumed additional energy. That's why it can die before time, and whole network transmission stooped to keep away from this difficulty concept of Sub-CH was introduced in improved-LEACH replica for the continuity of network processing. When CH dies, Sub-CH is replaced with it and works as CH [25].

It's an unequal cluster base protocol that uses residual energy and distance to cluster head election. There are two critical phases of this protocol, which are initialization, stable working.

In the first phase, called initialization in this division, the cluster head is selected, and the TDMA schedule is scattered among nodes. Sensor nodes also join their ordinary node cluster heads, ordinary base station cluster heads. In each round, every node produces a random figure in among 0, 1; meanwhile, this random digit is measured up to threshold worth. If it's less than the threshold value, it will be considered a false cluster head. In the next, all nodes take their residual energy and compare it with the wrong cluster heads. If this worth is higher than that value, it will be well-thought-out as a cluster head. Else, false cluster chief is considered as cluster leader [26].

A threshold-based scheme that uses the residual energy to elect a cluster head. This model illustrates the residual energy and the distance factor to take cluster leader for an energy efficient routing scheme [30].

A wolf pack algorithm is planned to avoid energy problems for clustering and is based on dynamic clustering. This replica has heterogeneous power capital initially with permanent location sensor devices. In the scheme, sensor devices are accidentally spotted in the two-dimensional section and sense the facts to broadcast to the set-up's sink nodes. This representation proves a high-quality deal by sending facts through short distances & attaining finer fallouts in the end [53].

A routing protocol designed the resolve the energy problem for wireless sensor networks. This routing protocol divides the sensor nodes in the network into four classes based on their energy levels. The main focus of the scheme is to balance the energy consumption more efficiently and enhance the network performance in the context of energy efficiency [29]

A routing protocol performs clustering using the technique of a cuckoo search based algorithm. It is an outstanding model proposed in this paper. The clustering of sensor networks using this technique is more efficient because the simulation of this model justifies the results of this model compared to some existing clustering routing protocols. This approach is better in the context of the energy efficiency of WNS [39].

An optimized radio energy algorithm is proposed to reduce the energy consumption ad making the network energy efficient. A power aware distance based routing model that performed the clustering to enhance the network life span and energy consumption and the data quality is equalized using the quality of service based routing model. Simulation justifies the performance of this model in the context of network lifetime enhancement [45].

A model based on integrating the non-cooperative game and the distributed clustering to enhance the network life span. Moreover, in the protocol, the activities of the nodes and their neighbor are also controlled to limit the message forwarding’s and reduce the energy consumption in this regard. [44]

In this paper, an energy-efficient routing protocol is proposed based on the improved memetic algorithm to choose the cluster head and balance the load of the clustering scheme in the sense of energy consumption, residual energy, and the network life span. Simulations justify the performance of this clustering protocol is more energy efficient than the existing clustering schemes. [52]

The main contribution is of this article is strengthening the clustering using the relay node. This paper described that the network lifetime and energy efficiency enhance with the relay nodes' utilization. This protocol proposes mutual exclusive distributed clustering with relay nodes. The proposed scheme follows the relay nodes differently as cluster heads prolong the network lifetime [47].

Cluster Head Selection

In this part, we discuss the routing protocol concerned with cluster head selection for the energy efficiency of the network. Some routing protocols discussed below deal with the selection of cluster leader and ensure the energy efficiency of WSN [14].

This protocol is a heterogeneous aware scheme to prologue time interval earlier than the death of the first node. SEP is based on the vote probabilities of SN'ss with remaining energy for Cluster leader selection. SEP develops the stabled section of the clustering hierarchy with the help of heterogeneity restriction, which is named a fraction of advanced nodes and the power aspect among advance and normal sensors.

With this initiative, the chance of advanced nodes becoming the cluster leader is more than the normal sensors, equitant to the fairness constraints on power spending and healthier fallouts in the end [7].

LEACH-SC a distance-based technique that aggregates data to enhance the lifetime of WSN. LEACH-SC base on LEACH but elects cluster head on which is closed to the center point between the nodes and the sink. Nodes and cluster heads are aware of the location of the sink. The processing of this replica is separated into two phases. Node is fixed location work in Setup & steady phase same as LEACH [LEACH-SC]. D-DEEC, the extension of the DEEC method, which takes the average power of the network, uses residual energy to elect the cluster head. However, the distribution of energy expenditure is a crucial concept of this model. DDEEC implements a fair and dynamic way to share the energy spent in the nodes to enhance lifetime [19]. This protocol identifies as TDEEC (Threshold Distributer Energy Efficient Clustering) with heterogeneous nodes based on threshold values to decide cluster head.

The threshold values are obtained from the remaining energy and the nodes' average energy at current nodes. The highest energy node elected as cluster head, and the BS is situated at the midpoint of the set-up. Data hierarchy is considered the first, second, and third levels to communicate [20].

In EDEEC, separate the SN's into three forms identified as Normal, Advanced, and Super sensor nodes. This model base on the DEEC model with some improvements and ensure better results in the context of energy efficiency of WNS [21].

The fuzzy Logic procedure is used to obtain energy competence using the three attributes: battery level, node density & distance. The three main parts of this LEACH-FL model are four fuzzification rules, an inference engine, and a defuzzification module executed to achieve the energy-efficient routing in WSN [24].

A routing protocol is designed to choose the cluster head with a new technique called three way message exchanges between SN and their neighbors. The cluster leaders are choosing based on nodes' residual energy. This model justifies the best results and is considered the best algorithm of current times in the scenario of network lifetime and cluster head election. [23]

This study identified an equalized clustering leader selection in routing protocol that develops to boost the system's lifetime through equalized clustering. This protocol exercises the Gaussian elimination algorithm to appoint the cluster leader to achieve enhanced fallouts. This routing protocol generates to improve the outcome in comparison with existing replicas in simulations [28].

In this study, a routing protocol is designed that deals with the energy efficiency of WSN through efficient cluster head selection. The main idea of this scheme is to divide and rule to save the energy of the network. This routing scheme chooses the fixed numbers of the cluster head instead of the probabilistic selection. [32]

A routing protocol is designed to choose the cluster head through a new hybrid model adopted based on the glowworm swarm optimization and fruitfully optimization algorithm. The new model is named a fitness based glowworm swarm with a fruitful algorithm. The performance of this model is compared with the previously designed model, and simulation results are justified [41].

An energy efficient cluster routing protocol based on the spacing and residual energy for Wns. The major contribution of this model is the selection of the cluster heads and the cluster head distribution to minimize energy consumption. The cluster head are selected based on the closes around nodes for spacing and the residual energy [50]

Route Selection

In this part of the paper, we discuss the routing protocol mainly concerned with energy efficient routing with efficient route selection. These paper are discussed below.

Initialy there is shortest distance based model describes the shortest hope routing tree procedure. In this projected routing protocol, Cluster leader is chosen based on the highest remaining energy of SN's to ensure the energy efficient routing for WSN [11].

LEACH scheme shifted from single hop to multi-hop to distribute the load equally and ensure all nodes work for a long time. In clustering-based routing protocols, the cluster leader is chosen to get better results. It's based on clustering, and the head is appointed to receive facts from nodes to convey toward the sink that will help make sure energy-efficient routing [17].

In this proposed routing, mathematical approaches are applied to estimate throughput and clustering formation based on sensor nodes along with a sink node. Thomas point process is exercised to choose the location of the nodes and sinks in the system. Because throughput and energy consumption are directly related to the MAC issues, this study mainly deals with the MAC issue using the mathematical model. In this replica, sensors were merging into the clusters, and each cluster in the system has a sink that helps us enlarge the current time of the network [18].

This scheme work to conquer the network in the logical region identified as S1 to S3. Clustered regions named S1, S3, non clustered regions were identified as S2. In the first region, the nodes sense data and convey it to the leader, and the cluster leader accepts facts and then aggregates these facts for forwarding to the base station. S2 nodes accept data from the cluster head and further convey it to the base station.

The main architecture contains three types of devices like sensor nodes, cluster chiefs, forwarders. To equally distributed energy among communication nodes and forwarders used with unlimited energy resources help us save energy of cluster heads and enlarge life spam of the projected replica in the end [43].

Hierarchal routing and a clustering-based scheme deal with nodes by separating them into four quadrants; each quad has two clusters with two hopes to broadcast the fact. Each bunch uses the left overpower and the minimum gap to mark up its leader & greedy algorithm used by the cluster head to deliver the sink. This projected scheme follows these phases like making clusters with quads, cluster head appointing, and data transferring [33].

This study is related to choose the path for data transmission and is specially designed for wireless body area networks in hospitals indoor environments. Metaheuristic technique used to find the path and combine ant colony optimization algorithm to save the energy through load balancing.[37]

A routing protocol is designed by considering the clustering and cluster leader selection scheme and choosing the route tree for cluster heads to send the data with more energy efficiency. The main contribution in this research is the selection of cluster leaders and the route for cluster leaders to send their

data to the base station received from their appropriate clusters. [22]

A genetic algorithm based routing model adjusts the dynamic route with a virtual grid technique. This dynamic approach is not static and distributes the energy load among nodes to enhance the results in the context of the energy; simulation results are justified for this routing protocol [49].

In this genetic algorithm-based model of the routing scheme, add the optimal solution obtained from the previous round as the initial population for the current round. The routing and the clustering are integrated into single chromosomes to find out the energy consumption. The fitness function is built based on total energy expenditure to find out the energy efficiency. Also, perform the load balancing to energy dissipation [48]

A flat, hierarchical routing protocol with desired numbers of sensor nodes based cluster having the cluster leader. The multi-hope routing is performed within the clusters within the clusters between the nodes and cluster leaders and further transmitted to the sink.

Intracluster data broadcasting happens in two scenarios first maximum residual power neighbour SN selection, and selfish nearest SN selection as next hop. Our approach refrains SN's for conveying with links, thus reducing the power expenditure of the WSN [46].

A routing protocol is designed to meet the issues when the base station is located at a massive distance from the network regions. In this scenario, these two protocols are proposed: the distributed energy efficiency and connectivity aware routing to solve the routing problem. These schemes are on-hole children reconnection (OHCR) with local nature and on whole Alert (OHA) with global nature.

The proposed models protect the connection of all single setup phase, single route networks with any topology in a resourceful power way by keep away from topology renovation.[40]

Energy Distribution

Here we discuss the routing model that mainly deals with the energy distribution for energy-efficient routing and increasing the network lifetime. The following papers are as described below.

A routing protocol is the improved model of LEACH. That used to select the neighbor for data broadcasting. These ways follow toward a chain created by the nodes with the help of a greedy algorithm or by the base station to communicate data more effectively in the system [6]

BCDCP's model distributes the energy of SN's to reduce the overall energy expenditure. The BS location is fixed, and the energy of nodes also identical initially. Stationary nodes are used in the system along with data fusion to ensure energy competence [9]. This replica chooses cluster as primary & secondary Cluster leader also makes sure equal energy distribution ensures energy efficiency.

The secondary cluster leader receives data from sensor nodes and executes fusion & additionally sent it to the cluster leader. In the appointment of cluster chief, sensor nodes produce the random number in between 0, 1 which is compared with the threshold value. It is less than the threshold worth; it will be considered as cluster head [31].

The projected algorithm identified as (MSA) Mobile sink assisted. Because we know about sensor devices that are not talented to effort after the total energy dispatch and have limited energy capital, why this scheme used a static sink and four movable sinks that can recharge in the scenario of power expenditure, mobile sink devices can go to its location which is controlled by the static sink device. This mobile sink device can be talented to move in the specific rectangle-specific region to make the possibility of data communication for a long time [34].

This scheme considers nodes as usual and advances nodes based on their energy degree. Various techniques discussed in the research practical have to make sure the advanced nodes become the cluster's head. The simulation shows the supremacy of this system in the end [35].

A routing protocol based on the unequal energy distribution for nodes enhances the network lifetime. The basic contribution deals with eh topology of the network. We formulate an optimization problem and define objective functions that incorporate network coverage and life span enhancement. An updated topology is evaluated in each convergence point and a near optimal node position to achieve results. This scheme justifies the results by near optimal topology leads to more excellent coverage and life span in comparison [38].

A energy efficient routing protocol that use the two scenario of forwarder nodes selection and rotation to enhance the stability period of the network. This routing protocol especially designed for WBAN[42].

In this article, a routing protocol for wireless sensor network is proposed that is based on the fuzzy-based distribution of cluster head selection cost; equally, it is identified as FBECS, which consider the remaining energy, distance from the sink, and the density of the node in its surrounding area as input to Fuzzy Inference System. The eligibility catalog is calculated for each SN to choose the cluster leader role. This algorithm helps to ensure the best energy distribution to enhance the system's performance in the context of energy efficiency for WSN. [55]

A routing protocol is tries to find out the better scheme of routing of data through optimizing the load balancing. To attain the task of energy efficient routing the nodes remaining energy, distance among nodes, density, and auxiliary cluster head in the model. This scheme performed the simulation in the NS2 to justify its performance with existing model [51].

3. METHODOLOGY

Systematic literature review is a type of research that is greatly useful to find the research question by examining the existing studies. The basic aim of systematic literature review is to find the research gap [56]

Research Questions

The primary purpose of the systematic literature review is to identify the research gap from the existing studies that are greatly useful to enhance the network span through energy efficient routing. In this literature review, we have considered an algorithm named ECHERP as a baseline and point out the following research questions.

- Why the selection cluster head to enhance energy efficiency?
- How to enhance energy efficiency through energy thresholds?
- What is the impact of the distribution of energy consumption on network lifetime?

Research Sources

We use the following libraries to find the research papers for this systematic literature review.

- Google scholar
- Elsevier
- IEEE
- Reseachgate
- MDPI

4. Results and Discussions

Papers Distribution

The primary purpose of this systematic literature review is to get aware of the current studies related to the energy efficiency of the WSN. The total 48 research papers included in this systematic literature review which journal and the conference papers. These researches are related to the energy efficiency of the wireless sensor network through the development of energy efficient routing protocols for WNS. The researchers consider these important things as the cluster and CH selection, routing, energy distribution, among nodes. We have discussed these routing models in details in the literature review section. The statistics of these papers about the

journals and major contribution are stated in the figure 2.

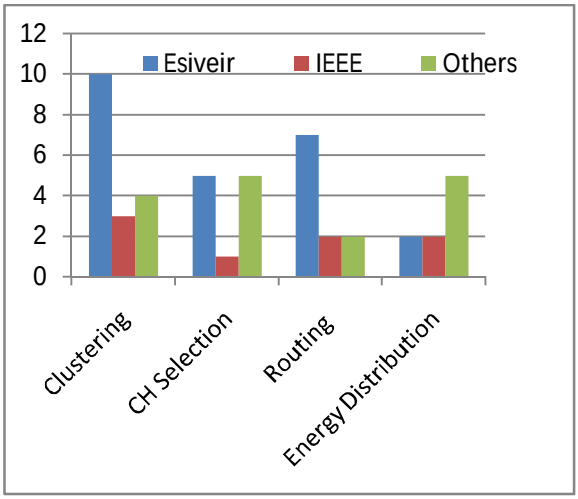

Figure 2: Statistics of the Research papers included libraries.

Common Challenges

Throughout wireless sensor networks, the users face various problems such as data delivery, data security, energy efficiency, delay in data delivery, data accuracy, etc. The most important is the energy of the network that is crucial for the efficient performance of the network because some other issues are based on the energy of the sensor nodes. In previous times various efforts are made to resolve the energy issue of the network. These are discussed in this systematic literature review.

Basic method adopted to resolve the problem

The most considered challenges are the energy efficiency of the wireless sensor network, and the researchers in existing studies adopt various ways. The most common strategies adopted to improve performance are cluster head selection, routing, neighbor selection, and energy load distribution.

5. CONCLUSIONS & FUTURE WORK

This paper is a systematic literature review on energy efficient routing protocols for wireless sensor networks; also, do the analysis and comparisons with similarities and differences. The main positive things along with some drawbacks have also been highlighted. In this paper, the routing protocols are highlighted that mainly deals with the clustering cluster head selection, routing and energy distribution issues for the energy efficiency of WSN. A paper identified as ECHERP that use the novel method for cluster head selection is considered a baseline research paper. Moreover, there is some research question highlighted in this paper for future research work. This systematic literature review will provide the details of exiting energy efficient routing protocol and help us to develop the new routing protocol for energy efficient routing protocol for WSN's.

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