Energy Aware Routing for Wireless Sensor Networks

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***Abstract*:** Wireless sensor networks are used in improving conditions in the practical field and real life which lead researchers and developers to further research it and work into improving this field. These networks consist of sensor nodes that can help acquire data and information about temperature and pressure dependent on the environment of the location which are sent from. After all that, we are bounded by a really important factor which can determine everything which is Energy. Since sensor nodes send data and information to web applications, they need an energy source to operate. Their main energy source is their batteries which offer limited source of energy. Hence, various protocols are introduced to help in many parameters of a wireless sensor network such as increasing lifetime and decreasing consumption of energy, in other words, increasing the Energy Efficiency (EF). In this paper, we evaluate consumption of average energy for various protocols used in this context after each complete logical round for these protocols, such as Energy Efficient Clustering Scheme and Stable Election Protocol. Finally, we used Matlab tool to generate results which indicate that the protocol used in this paper is efficient and reliable.

***Keywords*:** Energy Efficiency, Energy Efficient Clustering Scheme, Stable Election Protocol, Wireless Sensor Networks.

1. Introduction

Wireless sensor networks (WSN) consist of sensor nodes which can help acquire data. In WSN applications, after data can be sent to a web application, we can really benefit from this information. However, we are bounded by a really important factor which can determine everything which is Energy. This is considered main problem that we need more energy efficiency which could be achieved by reducing power consumption.

Hence, our main objective is to save energy, or in other words, to achieve very high energy efficiency in WSN applications that are completely dependent on the Internet of Things. Among these effective applications are health regulation, irrigation, monitoring systems, forest fires, where all sensors are far apart from each other, where wireless networks and remote communication are adopted by these applications. The energy source is batteries which offer limited source of energy hence, various protocols are introduced to increase the Energy Efficiency (EF) at WSN. Routing at WSN is performed via a protocol that is based on the idea of cluster formation which is divided into two main types: homogeneous and heterogeneous clusters. Initially the routing protocol is a homogeneous protocol that has all components or devices consume the same amount of energy and are considered equal. While, in the heterogeneous protocol, all its components or devices require a different amount of energy and are considered unequal. In a heterogeneous network, the routing protocols used are TEEN, PEGASIS, LEACH and so on which are homogeneous clusters. The heterogeneous protocols use energy efficiently and increase network lifetime, such as Stable Election Protocol (SEP) which has the highest remaining average power of the network nodes.

This paper is divided as follows. First, in Section 2, the background of our work is presented. Then, the state-of-the-art literature is discussed in Section 3. While, our adopted approach is explained in Section 4. In Section 5, we provide our simulation results and discuss them. Finally, in Section 6, conclusion and future work are elaborated.

2. Background and Literature Review

In this section, we provide background of our work and then discuss the state-of-the-art literature.

2.1 Background

Technology is advancing in CMOS-based devices and sensors as shown in [1]. It can be rooted in the real world and spread all over the place. Generally, the missing components are structure and methodology to advance this field. To achieve these advances, we have to specify the main requirements and design a small device representing its classification that can operate on event-based operating system proofing.

One of the huge obstacles encountered by the technology of the Internet of Things (IoT) is connecting low power embedded devices with each other. There are many wireless communication technologies based on IoT and they fall into two very important types. The first type is short range, and the second type is long range. One of the most important wireless access technologies is LoWPAN. This access technology is used for IoT to organize and maintain devices. WSNs are a crucial key characteristic to achieve the main objective of IoT in any advanced and recent communication system. The LoWPAN is described as any communication technology by layered model. The physical layer and data link layer for LoWPAN are related with each other and upper layers such as network layer, transport layer and application layer as shown in [2]. Energy Efficiency in IoT over WSN is the main important parameter which uses the new trend. This new trend depend on one of the technologies in recent world which is called Relay Node (RN).

WSN has got a lot of attention these last years. First, we consider WSN with two tiers in vast applications of real-life as it is shown in [3]. The flow of the sensed data by sensor network acquired from various regions to a single area (sink). Data traffic generated has substantial redundancy because within vicinity of a phenomenon, several sensors may produce same data. It is possible to exploit such redundancy according to data rate, bandwidth, power consumption and energy efficiency for any IoT in WSN. They need good resource management as discussed in [4]. There are many dynamic and static algorithms, and this is one of them as it depends entirely on the cluster, how to choose Cluster Head, and how to effectively exploit the surrounding factors so that the energy is saved in the best way. From here we touch very strongly on the process of controlling the exploitation of all elements and parameters of wireless networks that are totally dependent on the IoT [5].

2.2 Literature Review

In this section, literature review on wireless sensor networks and routing protocols is presented. First, an important issue in WSN is energy usage. Plenty of the routing protocols were developed to gear towards energy efficiency. One of the major WSN routing techniques is the clustering method. We will describe a two-level Heterogeneous Protocol and two extensions of the Stable Election Protocol (SEP) as discussed in [6]. WSNs are made up of several tiny sensor nodes that sense surroundings and broadcast information to the base station. Much more sensors are not supplied with a sufficient source of energy; in the smooth execution of WSNs, the energy of each node plays an important role. Therefore, it is necessary to choose a suitable routing protocol. Hierarchical protocols for routing have also been proven to be much more energy efficient. These protocols employ transmitting data using clustering methods. Cluster Heads (CH) gather and send data to the sink or base stations (BS) from their members. Two main categories of clustered sensor systems may be classified: consistent and heterogeneous sensor networks. Homogenous networks presuppose the same level of energy for each node, which then in actual environment is not valid. In heterogeneous networks, each node has varied energies; two or even more types of sensor nodes are utilized with respect to varying amounts of energy. Mostly on premise of respective applications, routing protocols may be divided into two main categories. First, Proactive Routing Protocols where network nodes continue to sense and submit data to the BS on a continual basis. Second, Reactive Protocols where nodes continually detect data, but only communicate whenever there is a dramatic change, and also when specific thresholds in the sensed value are achieved. Throughout homogeneous networks, protocol gives all nodes the same likelihood of becoming CH. Nevertheless, by the time of death of the first node, network tends to be not consistent. The lifetime of nodes for WSN has also been demonstrated by the heterogeneity of their energy levels. SEP and its variations are developed to enhance the efficiency of WSNs. The process of clustering is based on the algorithm disseminated. The objective here is the minimization of energy usage and communication costs while maximizing the durability of network. The network is split into multiple clusters and one node is chosen as CH in terms of the energy level for each cluster. The detected data is transferred to each node by each node and is aggregated by the CH to be sent to sink or base station. SEP is a proactively network protocol with two levels. SEP is trying to keep its energy use under constraints. It presupposes that there is distinct energy for every sensor node. There have been two nodes in SEP, normal nodes, and advanced nodes. Advance nodes contain greater energy unlike normal nodes, and an alpha denotes extra energy among advanced and normal nodes. Assuming n number of network sensor nodes is present, and m is the proportion of advanced nodes that have a time that are more energy efficient than regular nodes. Premised on its starting energy, SEP assigns each node a weighted probability. It enhances cluster formation by reducing the latency of advancing nodes in CH, i.e., advancing nodes are given more opportunity to be CH. The probability is weighted correspondingly for normal and advanced nodes. The threshold value is yet another element to consider. It relies on the node likelihood. An estimate number is produced by each node, and the threshold value is evaluated. If the value produced is below the threshold, then this node would be CH. For the WSN, energy conservation and efficient use are crucial. The connection among CHs and sensor nodes is only maintained by earlier protocols based mostly on clustering, although they overlook large differences. Massive amounts of sensor nodes packed with low price and high-power devices are integrated into a WSN. Only a solitary sensor node can feel and transmit across a narrow range with low constraints. Consequently, the data must be recorded through the joint efforts among several nodes in order to identify and collect these vital data from the world. Throughout this collection period, detecting, collecting and transmitting of data require power of sensor nodes. These sensor nodes are difficult to replace or replenish in almost all of the systems integration. This situation has led towards the network immobility after nodes are exhausted. Conserving energy and efficient energy usage are therefore crucial to WSN research. The WSN gradually takes part in operations and programs in our everyday lives. For the last several years, the system architecture has gained increasing relevance, such as battle field supervision, disaster observation and, as a result of possible sensor usage networks for commercial and military applications. WSN is utilized also in the surveillance field of water contamination in which the WSN is distributed to identify hazardous gases and microorganisms in many nations or the remotest environment. Not only that, but also WSN is used in the smart healthcare, which aid the elderly and the crippled and those living in their own homes with illnesses. In addition, WSNs is used in farming applications, which help farmers in the financing and preservation of industry. Current studies in sensor mapping mainly involve protocols which are energy conscious and sensitive of sensor failure or energy depletion and therefore increase the lifespan of sensor nodes. Nevertheless the advancement of WSNs, the necessity to take into account operation quality is essential, and energy constraint emphasizes challenges. In monitoring an ecosystem, certain sensor nodes are used to follow the implementation changes and to discover relevant information. The information would be sent by sensor nodes to the command center following data collection. Only when the information is sent amongst sensors in real-time can the command center take the correct action. Nevertheless, the process of information transfer has to be gradually transmitted between the sensor nodes, external sensor nodes link to internal nodes and send incidents to the control unit. These internal nodes constantly lose their energy before external nodes due to their high traffic. What would be worse, when the internal node is dead because of lacking energy, other nodes will be disconnected leading to connection breakage. Eventually, many sensor nodes that are still alive would be affected by the monitoring ecosystem. The unbalanced relayed mission, autonomously allocated depending on the distance to the dish, is the key cause for the network operating in those classic two-tier networks. A resolution to the disequilibrium workload. Within this network, there are many intermediate stations in the middle layer that collect the information from various sensors and transmit them to the sink. Our objective is to reduce the number of relay stations while ensuring complete coverage.

As explained in [7], challenges of enhancement related to network architecture, design, implementation, and maintenance of wireless sensor systems typically lead to multi-target optimization models where several desired targets contest with one another and the responsible party needs to choose one compromise solution. These many goals may clash or may not overlap. Taking into account the nature of the application, the perceiving scenario and the situation's entry/output, the problem type varies. A large variety of optimization solutions are available to handle the many sorts of optimization challenges associated with the design, implementation, functioning, planning and placement of wireless sensors. In order to illustrate if they clash, complement each other or are design dependent, we examine and evaluate distinct desirable aims. So, a general multifunctional wireless communication optimization consisting of input variables, necessary output, and the scope needs to be offered. A list of limitations will also needs to be provided to give an understanding of the many limitations that are considered in developing WSN optimization issues. With this multifaceted discussion on multi-objective optimization in mind, new study pathways in the field of multi-objective enhancements in WSNs will be opened up. The optimization may generally be classified in WSNs into a solitary and multifunctional problems for optimization. The primary purpose of the optimizer is to minimize or maximize one goal under set of regulations in the clear specific enhancement. Whereas several targets are simultaneously tuned in multi-target optimization. Most real-world issues have multiple goals, with all targets concurrently optimized. This makes multi-target optimization a hard endeavor and a very important research issue for theoreticians and engineers. Typically, the issue definition is carried out as an early stage, during which the required situations are described as multi-target optimization problems and solved with various methods. The numerous goals can be contradictory or not, but in most situations the goals clash. Therefore, contrast to the issues of a solitary objective enhancement, a worldwide optimum solution is far less likely to be found. There are several optimum approaches in multiple objective optimization, and choosing a solution needs to pick the best option according to the priority of the targets to be reached. The enhancement issue may be dealt with utilizing different approaches depending on the choice of the numerous targets. The most frequent technique is to integrate several goals with one single character by assigning various relative importance of various targets and then using a single goal optimization algorithm. Weight values can be allocated by direct allocation, own vector, entropy technique and a minimum method of information to numerous conflicting purposes. In the observation of ecology, wildlife, climate, atmosphere, water systems, and human health, WSNs are extensively utilized. Furthermore, WSNs have shown to be an excellent tool for automated systems, smart home, and factory equipment, etc. WSNs for small nodes are built where information is felt from the surroundings by the nodes and transferred to the control unit. The nodes generally have low power, energy levels and relatively small memory. The implementation, operation and maintenance of WSNs are complex due to their constrained on-board capabilities while at the same time meeting performance requirements. In an effort to use resource-limited WSNs properly, researchers suggested and used several methods. In order to tackle the coverage and connections problem, and to increase network life performance in relation to WSNs, a multi-target hybrid optimization approach using the Genetic Algorithm is introduced [8]. The formulations of data aggregation problems have been utilized as a linear multiple objective optimization problem in view of the multi carrier interference restrictions, reducing the total energy. There is much literature where multiple object orientation is utilized to address various challenges related to WSN optimizations. An actual overview of approaches used to tackle various challenges pertaining to the design, functioning, implementation, location, plan, and administration of WSNs. The study gives an overview of the various choices for various competing purposes. It can therefore give ways of setting up WSNs for different compromise settings amongst different development criteria, based on the WSN's application context. Furthermore, the occurrence of a multiplicity of objectives which clash with each other defined many real-life issues in relation to engineering. Various realistic situations for the effective implementation, functioning, configuration, architecture, planning and administration of network sensors are also used for formulating multi-objective optimization. The design of WSNs is a very complex process that has considerable effect on many performance characteristics such as reliability and cost effectiveness of real-world sensor applications. One of the design objectives is to increase the battery lifespan of the network so that sensors may efficiently evaluate the area of concern and send the information seen to the base station. In the modularity system configuration of quality-of-service, a multi-target optimization technique has been developed to ensure a uniform energy usage rate [9]. Lifespan of the network has indeed been handled at many levels, including architecture, implementation, and deployment, and is a highly efficient sensor network. In order to optimize the aggregate usefulness and increase the bandwidth utilization for instance, a stochastic multi-objective method for WSNs has been recommended. For a desired conclusion, it is essential to have a trustworthy and comprehensive information of an occurrence of an event. In the field of plant surveillance, administration, and live enhancement, for instance, modern and reliable plant status information is necessary. The precision and reliability of various estimations of different metrics depend mainly on the system's sensor network. A stochastic optimization approach for determining the kind, quantity and placement of the nodes is used to explore the best design for wireless sensor systems in chemical plants. WSNs are employed in the process sector to accurately measure various process parameters at varying sample rates. For instance, temperature and humidity are more commonly monitored in chemical processes, but molecular mass and saturation are less often recorded. Multi-target method is needed to reach a compromise amongst measurement quality and measuring costs. The use of a discounted approach has resulted in a compromise between the two conflicting goals of maximizing measurement precision and minimizing energy usage. Problems of enhancement related to network architecture, implementation, operation, and administration of wireless sensor systems typically lead to multi-target benchmarking formulations where several desired targets contest with one another and the responsible party needs to choose one compromise solution. These various goals might be mutually exclusive. For instance, maximizing coverage issues with the error margin of the packet, delays, system life and overall system costs. While there are several objectives which are not directly connected to each other in certain situations, instead, they are design dependent; maximizing coverage does not have a direct link to output. The utilization of WSNs is becoming essential for several areas of interest.

The effective deployment, which ensures less sensors while ensuring the connection and coverage amongst these sensors, is a difficult job when installing such networks. That would also contribute considerably to an extended network lifespan. Much research has tackled this topic with different techniques.

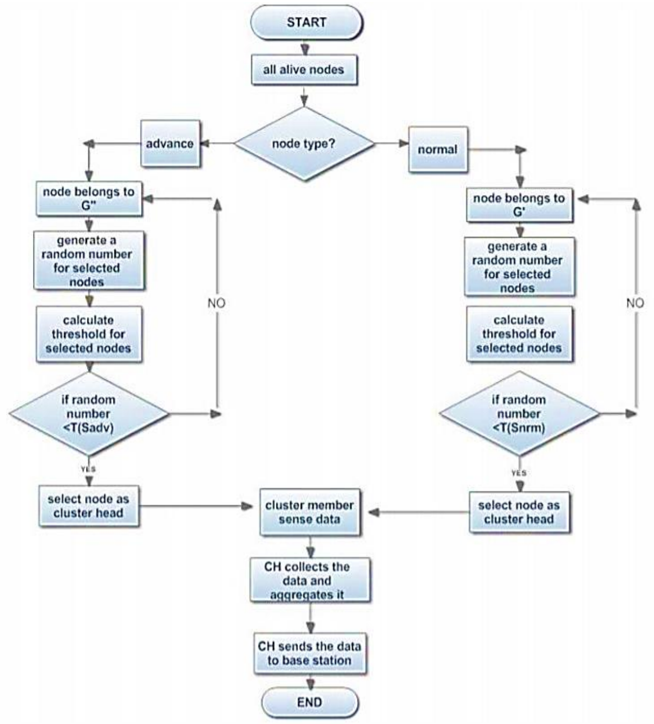

Figure 1. The main flowchart of chosen algorithm

The fast growth of wireless communication has indeed resulted in the wide acceptance of deploying WSNs, for a variety of settings, such as retail centers, clinics and other army and commercial buildings. Numerous restrictions such as power consumption, connection amongst nodes, reliability of transmission of data and addressing the areas of importance are decided according to the implementation of these kind of networks. The challenge has therefore seemed to be an optimization challenge, in which an optimum use of WSNs to ensure lower power use, preserving communication between the nodes and providing broad coverage are the objectives. These are critical issues in WSN implementation because data communication accuracy is substantially linked to service qualities, although sustaining minimal power usage, such as lowering battery usage and storage, would contribute to extended network lifespan [10]. Scientists have therefore addressed these issues, in which certain studies focused separately on certain problems. Nevertheless, addressing distinct problems would help one problem but harm others. For example, to provide broad coverage would need greater energy usage. Significant information is needed. Therefore, it would be a challenge to balance these concerns with a compromise WSN implementation.

3. Adopted Approach

In this section, we are going to calculate the average energy consumption for each of the various protocols after each complete logical round for these protocols, such as Energy Efficient Clustering Scheme (EECS) and Stable Election Protocol (SEP) based on MATLAB Simulation tool. SEP is a breakthrough in maintaining consistency in the efficiency of the energy also referred to as the time taken till the death of the first network node. Furthermore, SEP is a heterogeneous, it does not need to share energy information throughout the whole network but it is dependent on the probability of each to node to be nominated as Cluster Head relying on the value of the node's energy. By utilizing this technique, we guarantee that the cluster head is picked at random depending on the energy percentage from every node, ensuring that the energy of each node is being used evenly. The main target is the solution of problem of power consumption which is decreasing power consumption to give high energy efficiency. There are two sorts of nodes which are examined in SEP which are normal and advanced nodes as shown in Figure 1. They are considered upon balanced nomination of the Cluster Head corresponding to the nodes existing in the network, this helps in expanding the life expectancy of the network nodes.

The difficulty with the heterogeneous protocols is that if the advanced and normal nodes acquire the same value of threshold. SEP is employed with the following parameters: the advanced node percentage is denoted with symbol (m), the added energy factor between normal and advanced nodes is denoted as (alpha). In SEP, the advanced node has higher opportunity to be a Cluster Head than normal node, this is due to the presence of higher energy value in advanced nodes than normal nodes. At the beginning, rounds in the network assigns the nodes of the network in one of two types which are normal and advanced nodes, where each sensor node is assigned an initial energy. After the assigning the nodes whether normal or advanced, according to SEP, a weighted election takes place according to the node initial energy. Since the advanced nodes have more energy than normal nodes, the former have the chance to become cluster heads more often than latter. In the first round, there is no cluster head, a random election of normal and advanced nodes takes place then sink is assigned followed by cluster head election. After that, calculation of energy dissipated takes place.

A random number is produced for each node and compared with a threshold value such that if the value of the random number is less than that of the threshold of the node, then this node will become the Cluster Head, else node would stay as assigned before according to its type. In some cases no cluster head would be elected where the randomly generated number from the nodes equals to their threshold which leads to the packets not being sent to the sink. Furthermore, if a Cluster Head is elected, each cluster member senses the data from other nodes then the Cluster Head collects these data and aggregates them to send them to the sink (base station).

4. Simulation and Results

In this section, we discuss our experimental work and the main results obtained.

4.1 Experimental Work

Using MATLAB simulation tool, we achieved the following: dimension of the grid network in meters were assigned as xm = 200 and ym = 100, coordinates of the sink were assigned to (0.0). We used 100 nodes in our network with probability of a node to become cluster head = 0.2. Initial energy of each sensor node is set equal to 0.5. The number of elections of transmitting = 50*0.000000001 that will also be the same to number of elections of receiving (ERX) and data aggregation energy (EDA) = 5*000000001. Energy dissipated in free space routing (EFS) will equal to 10*0.000000000001. Energy dissipated in multipath routing (EMP) equals 0.0013*0.000000000001. The percentage of nodes that are advanced is 0.1 (m), the energy factor between normal and advanced nodes is 1 (alpha), the network will have 800 rounds.

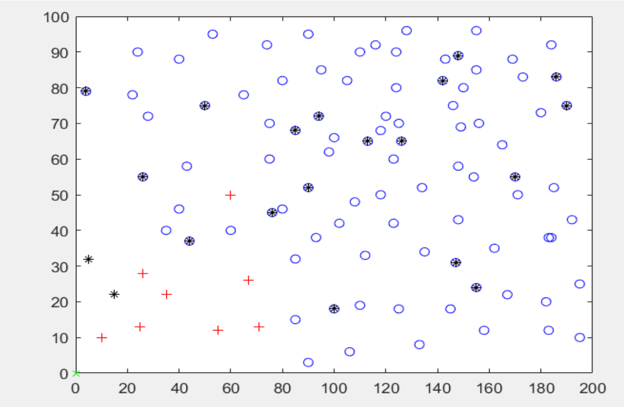

Figure 2. The distributions of all nodes in chosen algorithm

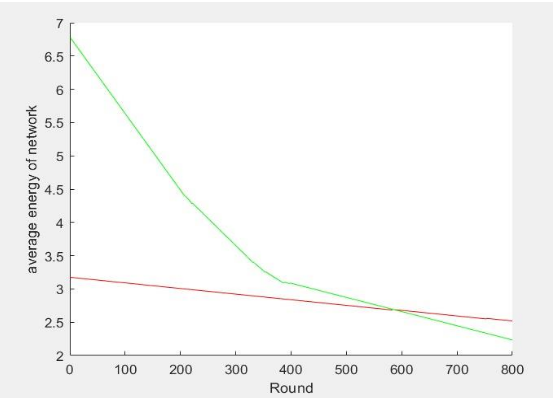

Figure 4. The average energy in network for two different algorithms

At the beginning, we assign the nodes with coordinates on the network with an initial energy for each node. At the first round, no Cluster Head exists, a random election of normal nodes and advanced nodes takes place, the sink coordinates will be assigned to s(n+1) which is equal to 101. On the second round, Cluster Head election takes place for both normal and advanced nodes according to the random number generated from each node which will be compared to nodes' threshold. If generated random number is less than the threshold, then the node will be assigned as the Cluster Head. At the end of each round, energy dissipated is calculated for Cluster Head and nodes, and the Cluster Head collects data and sends it to the sink. This process is repeated for 800 rounds.

4.2 Main Results

As shown in Figure 2, the distribution of nodes across the grid network with coordinates of (200, 100), the blue 'o' stands for normal nodes, the red '+' stands for advanced nodes, the green 'x' stands for the base station, and the '*' stands for the Cluster Head where all nodes can be seen in the figure.

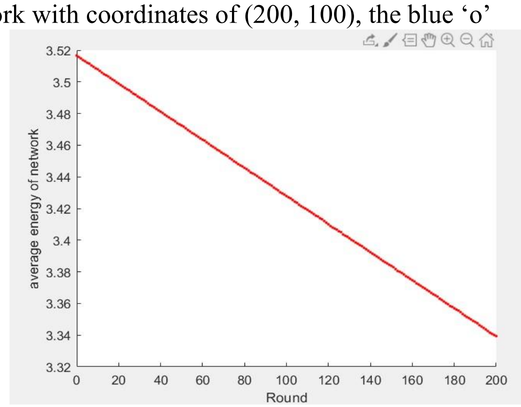

Figure 3. The average energy in network at chosen algorithm

Figure 3 shows the SEP average energy during 200 rounds of testing and going through the whole process. As it is shown in the figure the average energy is about 3.35 at the 200-round mark. The x axis shows round number and y axis shows average energy of each node.

Figure 4 shows a comparison between the SEP and Hybrid Energy Efficient Protocol for Stable Concentric Cluster (HEEPSCC), where x axis refers to number of rounds and y axis refers to the average energy of the network corresponding to each node. As shown in the figure, the HEEPSCC is in green colour and SEP in red colour, the HEEPSCC average energy does not maintain consistency on long period of time as we come closer to the 800 round where the energy had a steep drop unlike SEP that despite its lower average energy at the beginning of rounds it maintained the consistency of its energy throughout the 800 rounds having more average energy than HEEPSCC at the 600 round mark.

5. Conclusion and Future Work

The heterogeneous protocols use energy efficiently and increase network life, such as SEP protocol which has the highest remaining average power of the network nodes. SEP is an efficient algorithm that has more average energy than other algorithms such as HEEPSCC. This future outlook is completely dependent on what has been studied and collected in this research and what has been reached takes us to consider three directions for the future vision of research. The first of them is to search for different algorithms that improve energy efficiency. The second of them is to merge more than one algorithm to try reaching the best solution. The third of them is to make a larger modelling dataset to reach more reliable results and to study other cases.

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