T.C.

ALTINBAS UNIVERSITY
Institute of Graduate Studies
Electrical and Computer Engineering

INVESTIGATION, SIMULATION AND IMPROVEMENT OF ENERGY REDUCTION ALGORITHMS IN WIRELESS SENSOR NETWORKS

Rabea MUSSA

Master of Science

Supervisor

Asst. Prof.Abdullahi Abdu IBRAHIM

Istanbul, 2021

INVESTIGATION, SIMULATION AND IMPROVEMENT OF ENERGY REDUCTION ALGORITHMS IN WIRELESS SENSOR NETWORKS

by

Rabea A Ali Mussa

Electrical and Computer Engineering

Submitted to the Institute of Graduate Studies

in partial fulfillment of the requirements for the degree of

Master of Science

ALTINBAŞ UNIVERSITY

2021

The thesis titled “INVESTIGATION, SIMULATION AND IMPROVEMENT OF ENERGY REDUCTION ALGORITHMS IN WIRELESS SENSOR NETWORKS” prepared and presented by “Rabea MUSSA” was accepted as a Master of Science Thesis in Electrical and Computer Engineering.

____

Asst. Prof. Dr. Abdullahi Abdu IBRAHIM

Supervisor

Thesis Defense Jury Members:

Asst. Prof.Dr. Abdullahi Abdu IBRAHIM	School of Engineering and Architecture, Altinbas University	__________________
Asst. Prof.Dr. Sefer KURNAZ	School of Engineering and Architecture, Altinbas University	__________________
Assoc. Prof.Dr. Mohammed ABUBAKAR	Faculty of Economics , Administrative and Social Sciences/Department of Business Administration Antalya Bilim University	__________________

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Approval Date of Institute of Graduate Studies: ____/____/____

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Rabea A. Ali Mussa

ACKNOWLEDGEMENTS

First I would like to ask Allah Almighty for the power of the mind, health, strength, guidance knowledge and skills to complete this study. I would like to thanks my great supervisor Assist Professor Dr. Abdullahi Abdu IBRAHIM for helping me in preparing the thesis. I am highly obliged to taking the opportunity to sincerely thanks all staff members of the electrical and computer department and all staff in university for their generous attitude and friendly behavior. This thesis is wholeheartedly dedicated to my beloved father, who has been my source of inspiration, He tells me that "every success in your life will be the best gift for me". To my mother, who has been supporting me with kind and pure love. To my wife and children who support me in my studies. Last but not least I am thankful to all my brothers and friends who have been always helping and encouraging me through the years.

ABSTRACT

INVESTIGATION, SIMULATION AND IMPROVEMENT OF ENERGY REDUCTION ALGORITHMS IN WIRELESS SENSOR NETWORKS

Mussa,Rabea,

M.Sc, Electrical and Computer Engineering, Altınbaş University,

Supervisor: Asst. Prof. Dr. Abdullahi Abdu IBRAHIM

Date: August/2021

Pages: 58

Today, due to the advantages of wireless sensor networks, which are simple and inexpensive implementation, low power consumption and high scalability, they have been used in many applications. Designing stable wireless sensor networks is a very challenging issue. Sensors with limited energy are expected to operate automatically for a long time. However, replacing broken batteries may be costly or even difficult in harsh environments. On the other hand, unlike other networks, wireless sensor networks are designed for specific small-scale applications such as medical surveillance systems and large-scale applications such as environmental monitoring. In this regard, a great deal of research has been done to propose a wide range of solutions to the problem of energy saving. In this paper, a routing algorithm is designed to produce the best path between the sensor nodes and the local collector node with the aim of achieving a proper traffic distribution and thus creating a balance in the energy consumption of the intermediate nodes. Creating such a balance will help increase the life of the network and improve the energy consumption pattern of wireless sensor networks with limited energy resources. On the other hand, by using the possibility of changing the range of nodes, it is tried to increase the possibility of load distribution in low-density points of the network. The simulation results show a 20% improvement

in network life using the proposed algorithm compared to some of the proposed energy-sensitive routing algorithms in recent years.

Keywords: Wireless Sensor Networks, Energy Sensitive Routing, Energy Rate Balancing

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

LIST OF ABBREVIATIONS

WSN	:	Wireless Sensor Network
QoS	:	Quality of Service
CH	:	Cluster Head
MIMO	:	Multiple Inputs and Multiple Outputs
SISO	:	Single Input and Single Output
TPC	:	Transmit Power Control
NC	:	Network Coding
LEACH	:	Low-Energy Adaptive Clustering Hierarchy

1. INTRODUCTION

1.1 BACKGROUND

Scalability, coverage, latency, quality of service, security and mobility are the main needs of wireless sensor networks used in various applications, including environmental monitoring, public safety, care Medical and industrial and industrial applications. In these applications, the sensor is expected to work automatically for long periods of time, whether weeks or months. However, these networks suffer from limited network life due to the limited battery resources in the sensors.

In recent years, several methods have been proposed to save energy in wireless sensor networks, and there is still much research on how to optimize energy consumption for wireless sensor networks with limited energy resources. In the next section, we describe the existing standards for extending the life of wireless sensor networks with respect to energy storage.

1.2 ENERGY STORAGE MECHANISMS IN WIRELESS SENSOR NETWORKS

In this section, we review the major methods available to solve the problem of energy consumption in wireless sensor networks, which is presented in the article [1]. A classification of the proposed energy storage mechanisms is summarized in Figure 1.1.

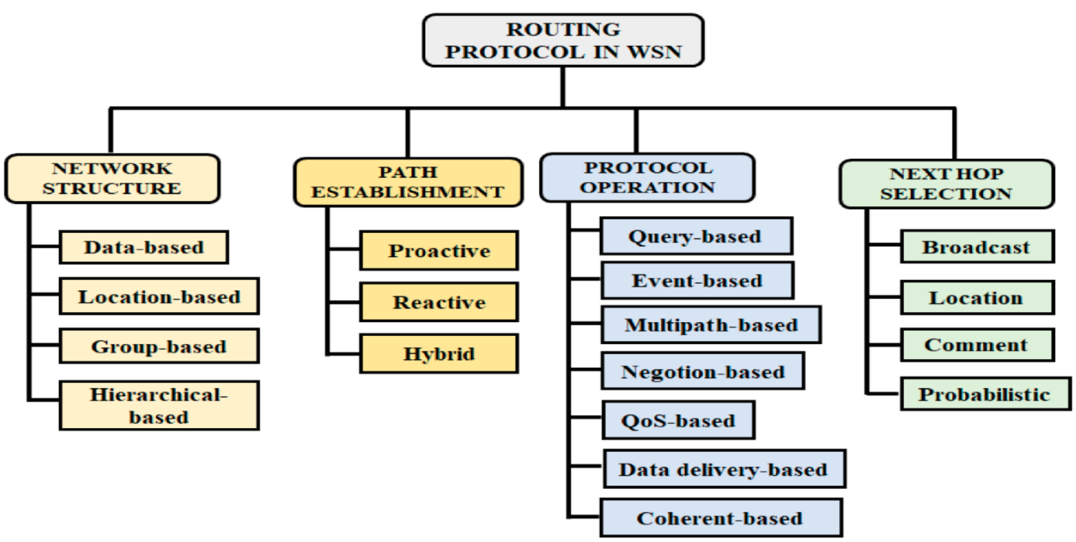

Figure 1. 1: Classification of Energy Storage Mechanisms in Wireless Sensor Networks [2]

A crucial aspect for successful Ambient Technology implementation is effective communication. The flow of information from the source to the end device, which interacts with the environment, should occur without complications. Some of the applications may have wired communications between the source and the end device, but this may not be the most effective solution for all applications. The wired solution has been proven to be costly and inefficient in many cases. For this reason, a new type of communication and sensing network known as the Wireless Sensor Network (WSN) has emerged in the last few years.

The WSN can be a solution for many different real-world applications. Research has demonstrated the flexibility of the WSN to support many applications. Due to this flexibility, no set of rules that clearly define WSN have been developed. For instance, some applications may have the capability of providing wired charging to the WSN components; in other applications, the components should be battery driven.

The future roles of embedded technology involve the use of embedded systems not only in electrical equipment but also in other daily-use objects. Eventually these systems will surround us, support us, and make our lives more comfortable. As mentioned by H. Karl and A. Willig [3], the concept of different devices interacting with humans or physical processes based on the data provided to them by other sources or devices is known as "Ambient Technology".

The flow of data from one device to another can reduce the need for human intervention. By integrating computation and control with the physical environment, the concepts of machine to-machine and person-to-machine communication can be realized. Such communication will be especially useful in addressing physical changes in the environment without requiring human attention.

In WSN scenarios, energy conservation is an important objective. Typically, WSN components consist of a node and a sink. A node consists of a sensor that senses the physical environment and collects the required data. A sink can be a computer or any other control unit that receives and analyzes the data sets that are collected and sent by the sensor node. A typical structure of a WSN is shown in Figure 1.2 [4].

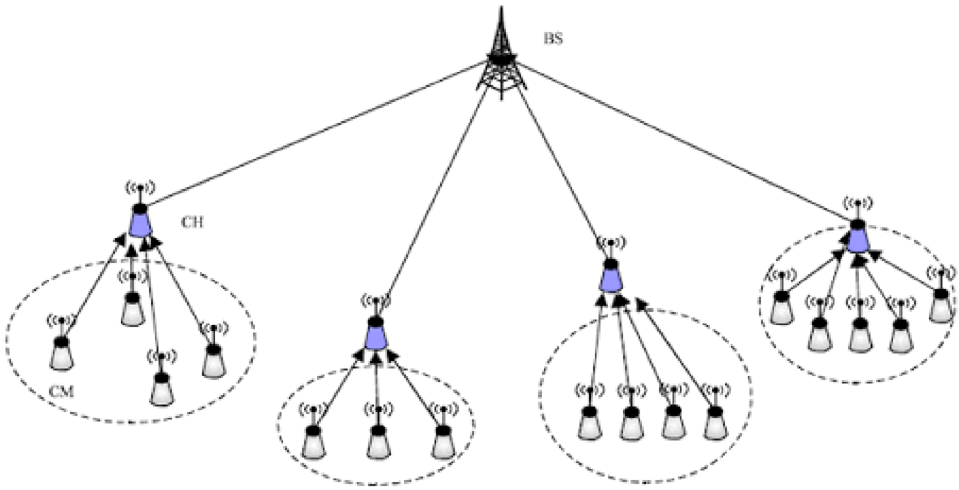

Figure 1.2: Typical Structure of a WSN [4]

1.3 APPLICATIONS OF WSN

Advancements in micro fabrication technology, wireless technology, and embedded systems technology have enabled the implementation of large scale WSNs. In the future, technological advancements can help in the development of affordable sensors that can be used in a wide range of applications.

The data collected with these sensors can be utilized for analysis and for future predictions. Some of the applications for WSNs are covered in the following sections.

1.3.1 Disaster relief operations

Temperature sensor nodes in a WSN can assist in fighting wildfires. These sensors can be aerially dropped in fire-prone regions to form a network. This network can provide a temperature map for firefighters and can help them strategize the task of controlling the fire and its damage. Figure 1.3 shows another application for WSNs in disaster detection during an earthquake or volcanic eruption.

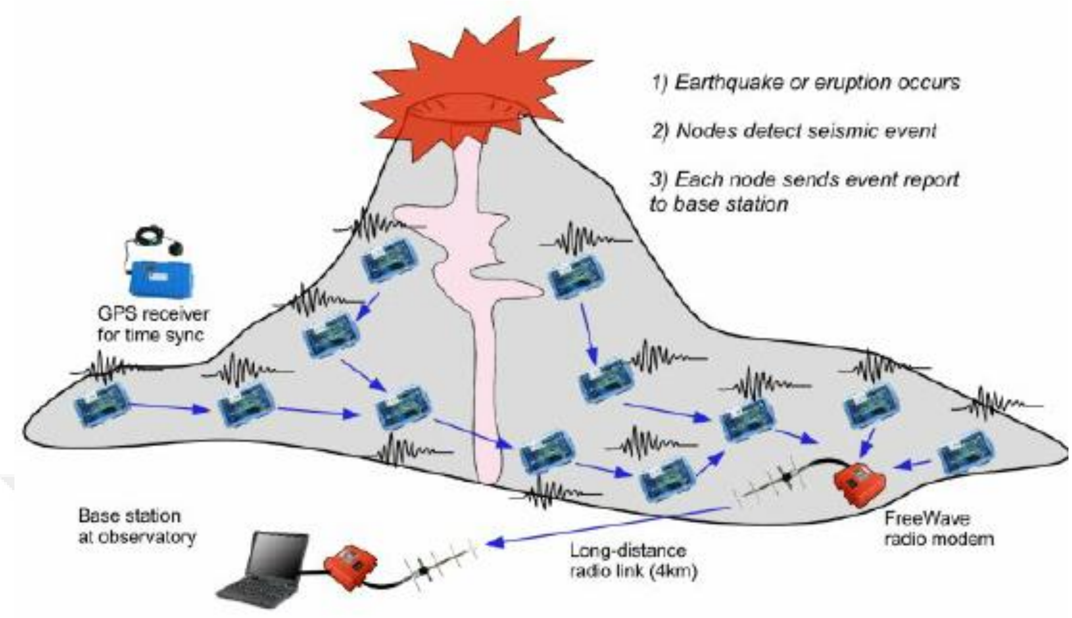

Figure 1.3: Application of WSN in Volcanic Eruption Detection [5]

1.3.2 Natural habitat monitoring

Scientists studying the natural habitats of various animals and birds can use sensor networks to wirelessly obtain the data. Before the arrival of the WSN technology, scientists had to travel to habitat locations to collect the data. Because of this human intervention, the species under study would at times change its habitat making it more difficult for the researchers to study the population. When placed strategically, sensor nodes can provide the desired data by monitoring certain physical parameters (temperature and pressure) in the habitat. This data can be sent wirelessly to the researchers who are located miles away.

1.3.3 Military operations

Military operations can be carried out with the use of WSNs. The sensors can detect the movement of enemy combatants through variations in the physical parameters such as temperature or pressure. This scenario requires the sensor nodes to be affordable enough so that they are disposable. In the military service, energy needs are not a constraint because lifetime of the sensors is not an issue.

1.3.4 Medical and health care applications

With the invention of sensors that can be worn on the body, the use of sensor networks in health care applications is being widely researched. These sensors, as discussed by [6], can monitor the health of a person, and, in case of an emergency, can contact a nearby medical facility for assistance. Figure 1.4 shows a practical scenario of healthcare application.

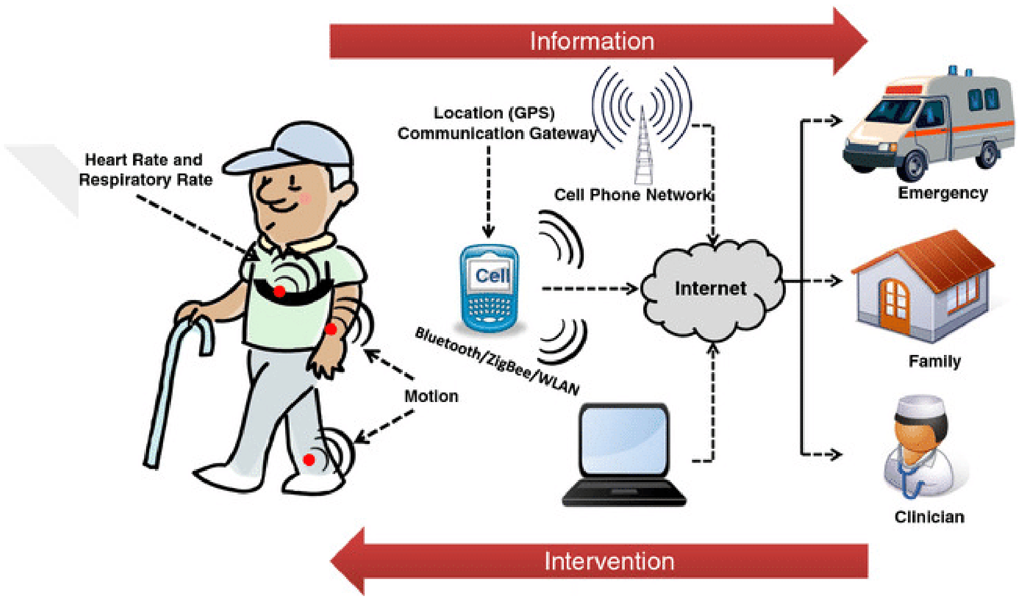

Figure 1.4: WSN in Medical Field [6]

Sensors can effectively monitor the wellness of elderly people that require health supervision. A major concern with such a network, however, is latency. The delay for the transmission of the data from the patient to the facility can prove to be very critical. Hence, there exist certain concerns about the practical use of this technology, especially in potentially life-threatening situations.

1.3.5 Agriculture

By placing humidity and soil composition sensors in the field, farmers can gather the direct measurements from the field. This data can be used to make necessary decisions, benefitting the crops. By strategically placing the sensors, a large field can be covered. Similarly, sensors can be used for pest surveillance. Livestock oversight can also benefit from this technology; by placing a sensor on each cow or lamb, a farmer can monitor the health of the livestock and take necessary steps in case of any abnormality.

1.4 FEATURES OF WSN

Common traits appear in the wide range of applications that can be addressed by WSN technology. These common traits are unique to this technology, and pose certain technical challenges that are usually not found in other wireless networks. The technical challenges are as follows [7]:

1.4.1 Low power consumption

In most of the applications, it is advisable that the nodes survive on a limited amount of energy (batteries).

The replacement of such energy sources upon exhaustion may not be possible in all scenarios. Hence, a network must be energy efficient to function for the required lifetime.

Energy scavenging can be performed at the sensor node so that the batteries can be replenished by any available energy sources in the environment (solar and pressure). This method can extend the lifetime of a network. When considering the power consumption factor, however, it is important to note that a tradeoff may exist between the quality of service and the lifetime of a network. If the quality of service is the most important aspect of the application’s function and requires increased power consumption, additional support to maintain the power level may be necessary.

1.4.2 Quality of Service (QoS)

This feature varies from application to application. Certain applications require a transmission of data infrequently, whereas others require data more frequently. The latency factor depends on the function of the application. For habitat monitoring, latency may not be significant; whereas in other applications such as those used in human healthcare, latency is an important factor. Therefore, it is important to understand the goals of the application and optimize the QoS accordingly.

1.4.3 Fault tolerance

Failure of sensor nodes can happen because of power failures or other technical issues. Most of the applications, however, do not allow manual repair or the replacement of nodes. In such cases, the network should be able to reconstruct its structure so that the end user does not have to intervene. Redundant deployment can be implemented so that the functioning of the WSN is not interrupted.

1.4.4 Programmability

It is important to have the nodes to be easily programmable. The nodes' functions can be changed as an application evolves if they are reprogrammable. Providing only a fixed way of processing and transmitting information may make the functioning of the WSN inflexible.

1.5 MECHANISMS FOR REQUIRED FEATURES

The realization of the features mentioned in the previous section requires innovative mechanisms as discussed by H. Karl and A. Willig [3]. These innovations can be generalized for a wide range of applications. Building an application from scratch, and testing it, should take into account the following mechanisms.

1.5.1 Multi-hop wireless communication

With available energy as a constraint, sending and receiving information over a long distance may be challenging. Instead of a node sending the data to a sink located at a distance, the concept of multi-hop communication can be implemented. With the use of intermediate nodes as relays, information can be sent to a sink with less energy consumption as compared to a direct transmission to the end user. This technique, as discussed by H. Karl and A. Willig [3], also helps to avoid obstacles as shown in Figure 1.5.

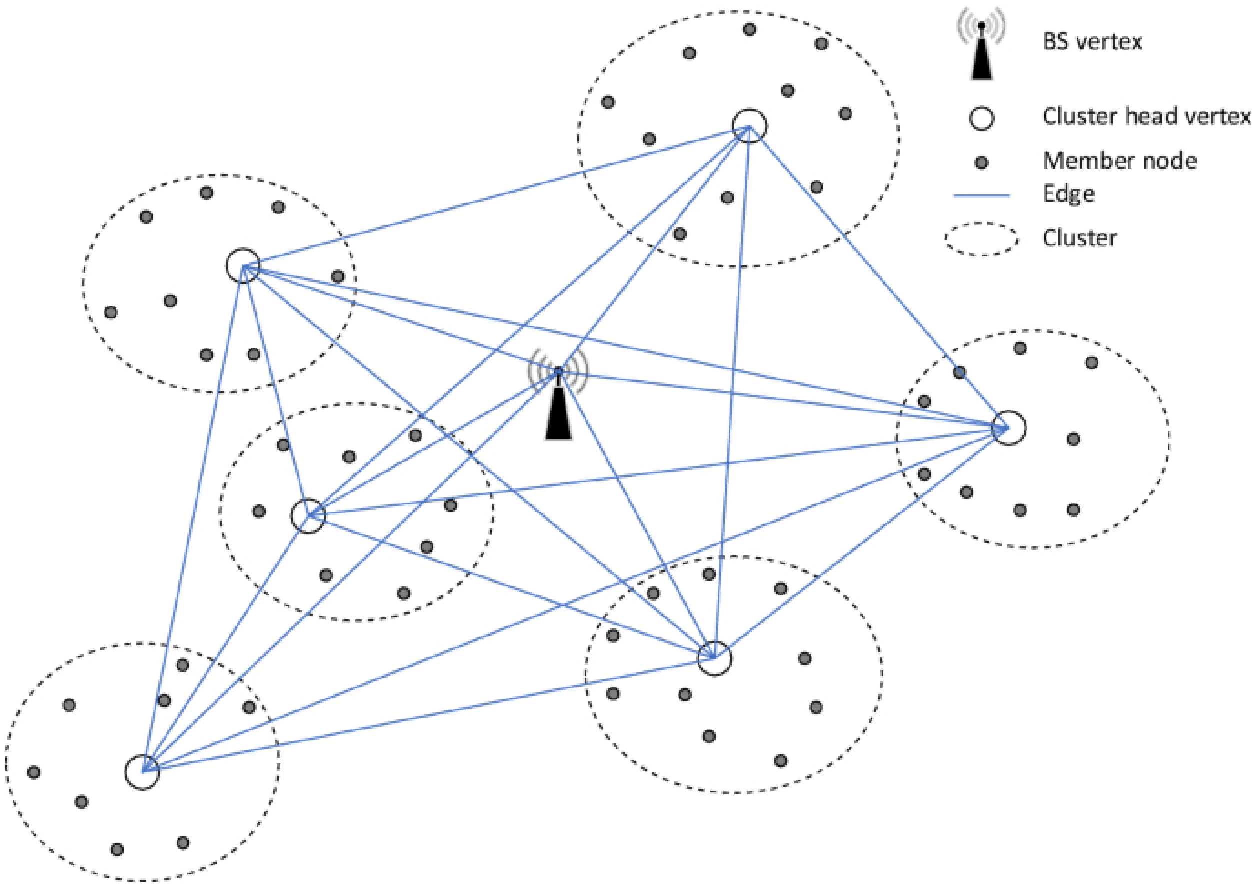

Figure 1. 5: Multi-hop Communication for Avoiding Obstacles [8]

1.5.2 Auto-configuration

Most applications require that the WSN its operational parameters autonomously. This includes the ability of the nodes to determine their location with respect to their neighboring nodes and to maintain network topology. The network should be able to tolerate faults, and should be able to itself in case of node failure.

1.5.3 In network processing

Most research studies have shown that processing data locally at a node consumes less energy as compared to sending the data to the sink. Aggregating data within a network can conserve energy. For example, temperature sensors can transmit an average temperature over a period of time instead of transmitting each reading during that period. Various data aggregation techniques have been developed and researched; the selection of a technique depends on the type of application.

1.5.4 Data-centric approaches

Wireless communication techniques typically use both a receiver and a transmitter, each with its own address. This address provides a unique identity and allows the devices to communicate. Using a redundant node deployment in a WSN instead of an address-centric approach will be more useful. For example, it is easier to obtain temperature data from a particular group of nodes than from an individual node. All the nodes in the sink should work together to provide the results needed.

1.5.5 Exploit trade-offs

Each application will have its own unique requirements. Catering to these requirements will require certain trade-offs. For example, the accuracy of the results can be improved with the expenditure of higher energy. But, this in turn, decreases the lifetime of the nodes. In other example, redundant node deployment in certain applications can make the WSN to perform efficiently, but increasing density of nodes can create challenges in addressing node failures.

2. LITERATURE REVIEW

2.1 BACKGROUND

Radio transactions in sensor nodes play a major role in draining battery power. Due to the nature of wireless communications, researchers have developed methods based on optimizing radio parameters such as modulation and coding schemes, transmission power control, and directional antennas to reduce energy loss in wireless sensor networks.

2.1.1 Modulation optimization

Modulation optimization aims to find the optimal modulation parameters to minimize radio energy consumption. Existing research seeks to create an optimal balance between set size (number of characters used), rate of information sent (number of bits of information per symbol), connection time, distance between nodes, and Find noise [9][10][11].

2.1.2 Collaborative communication schemes (multi-hub)

To improve the quality of the received signal using the cooperation of multiple antennas, which creates a virtual transmitter with multiple antennas. The idea behind this scheme is that information is usually heard by the neighbors of a node due to the nature of the broadcast through the channel. Much research has been done comparing the energy consumption of SISO networks (single input and single output) and virtual MIMO networks (multiple inputs and multiple outputs). The results of these studies show better energy savings and less end-to-end latency at longer distances than the node transmission range in MIMO systems, even with the additional overhead energy required to power these algorithms [12][13][14].

2.1.3 Transmit power control

Transmit power control (TPC) has been studied in order to increase energy efficiency in the physical layer by adjusting the power of radio transmitters. Therefore, a node with higher residual energy can increase its transmission power, which activates the transmission power reduction algorithm in other nodes, ultimately saving energy along with has it. The TPC strategy reduces the risk of interference not only in energy but also by reducing transmission power. In addition, fewer nodes are located in the auditory region of a node. On the other hand, increasing the transmission capacity can lead to the development of the telecommunication range and increase the number of neighbors. This can increase the ability to distribute traffic in nodes with few neighbors and improve network life [15][16][17].

2.1.4 Directional antennas

Directional antennas have the ability to receive transmitted signals at the same time and in one direction. This improves the transmission range and energy consumption. These antennas may require local techniques, but are capable of receiving multiple communications simultaneously. This makes more use of bandwidth. Therefore, this algorithm can improve network capacity and lifetime while it can also affect latency and connectivity. However, some problems that are specific to the directional antenna, such as signal interference, antenna settings, and deafness problems, should be considered when using these antennas [18][19][20].

2.1.5 Energy Efficient Cognitive Radiography

Cognitive radiography (CR) is intelligent radio that can dynamically select its communication channel in the wireless spectrum and adapt itself to the send and receive parameters. Based on the defined software technology, the radio is expected to fully automatically reset its transmitter and receiver to the parameters required by the network, which improves network awareness. However, the most important radio cognitive requirement is the power consumption of the node due to the complexity of the antenna and the new features compared to conventional devices. In this regard, the design of radio cognitive sensor networks is key to solving the challenge of intelligent use of battery energy. Recent radiological studies are in the areas of transmitter power control, residual energy channel allocation, and the combination of network and radiological coding [21][22][23].

2.2 REDUCE THE VOLUME OF INFORMATION

Another way to save energy is to reduce the amount of information sent to the collector node. The two methods of limiting unnecessary samples and limiting the measurement tasks of each node can be used together. Because obtaining and sending information is expensive in terms of energy consumption.

2.2.1 Aggregation

In information aggregation scheme, nodes perform aggregation information along a path to the aggregator node to reduce the amount of information sent. In addition, information aggregation can reduce latency by reducing traffic. However, data collection methods may reduce the accuracy of the information collected. In fact, after the aggregation operation, the information can not be retrieved by the collector and as a result, the accuracy of the information is lost [24].

2.2.2 Agreed sampling

Measuring unnecessary samples affects communication resources and processing costs. Conventional sampling techniques adjust the sampling rate in each sensor according to the needs of applications such as coverage and obtaining accurate information [25].

2.2.3 Network Coding (NC)

Network coding (NC) is used to reduce traffic in broadcast scenarios by sending a linear combination of several packets instead of one copy of each packet. Receiver nodes can also decode packets using linear decoding equations [26].

2.2.4 Information compression

Using special techniques with computational capabilities and wireless node powers, data encoding is performed to obtain transmitted loads with fewer bits, which makes this method It becomes energy efficiency [27].

2.3 SLEEP AND WAKE PLAN

Radio units are the main source of energy consumption in times of unemployment. The purpose of the sleep-wake plan is to put the radio in sleep-wake mode due to the activity of the node in order to save energy.

2.3.1 Sensor cycle on / off program

Designed to change the mode of the radio node unit depending on network activities to minimize idle listening time. These programs are usually divided into three categories depending on the demand, asynchronous and in accordance with the program. Turn-on and off-cycle protocols certainly increase energy efficiency, but greatly increase communication latency. Nodes also suffer in these conditions for sending information when they or the next node is asleep [28][29].

2.3.2 Wake up side radio

To eliminate the weaknesses of the program, turn on and off the sensor periods, a low-power radio is used to receive information when a node is asleep, and to send information. Traffic uses a powerful radio [30].

2.3.3 Topology control

When too many sensor nodes are deployed to ensure good coverage of the space, some nodes can be maintained by keeping network operations and connections in a non-state state. Make it active. Topology control protocols dynamically determine the number of active nodes according to the needs of the program in order to use more energy in the network [31][32].

2.4 ROUTING WITH ENERGY EFFICIENCY

Excess load on routing can seriously affect energy reserves. In particular, in multi-step algorithms, nodes close to the collector lose their battery power faster than other nodes, leading to network breakdown. What we are looking for in this dissertation is the energy saving mechanism in various routing algorithms. In the following, we will examine some energy-sensitive routing methods to better understand the subject of this dissertation.

2.4.1 Clustering methods

Clustering techniques are performed to improve energy efficiency by limiting energy consumption through the following various methods.

a) reducing the range of communications within the cluster that require less transmission capacity;

b) reducing the number of transmissions using data aggregation by the cluster;

c) reducing the energy of operations such as coordination and aggregation at the head of the cluster;

d) disabling Some nodes within the cluster are suggested when the cluster is responsible for sending information, (and) balancing the energy consumption between the nodes in the cluster by rotating the cluster node.

In addition to energy efficiency, clustering architecture improves the scalability of networks by maintaining a hierarchical network [33][34].

2.4.2 Energy-based routing

Considering energy as a criterion in the path-setting stage is another solution to extend the life of sensor networks. By performing this algorithm, the sensor nodes in routing not only focus on the shortest path but also consider the residual energy of the next step [35].

2.4.3 Multi-route routing

While single-route routing protocols are generally simpler than multi-route routing protocols, they can quickly drain the energy of the node selected as the next hop. . In contrast, multi-route routing is able to balance energy consumption among nodes by alternately selecting transmitted nodes. Multi-route routing protocols provide the network with the ability to retrieve the network after draining the energy of a node by providing multiple routes, whereas in single-route routing, when a node runs out of power, one route The new must be recalculated [36][37].

2.4.4 Relay node placement

The routing algorithm can avoid premature depletion of node energy in a specific area by adding several relay nodes due to the long distance from the next node. This helps to improve the energy balance between the nodes, and prevents the creation of a high-consumption sensor [38][39].

2.4.5 Mobile collector node

In a wireless sensor network architecture that uses a fixed base station, nodes near the base station discharge their batteries faster than other nodes. They lead to premature disconnection in the network. It is a fact that all the traffic is sent to the collector node and increases the workload in the nodes close to the collector node. To increase the life of the network and the possibility of balancing the load between the nodes, a mobile base station is used that collects information from the nodes by moving around the network. Aggregate node mobility improves connections in distributed network architecture and increases reliability due to single-step communication. Therefore, it also reduces competition time, collision and message loss [40][41].

2.5 CHARGING SOLUTION

Recent research studies have focused on energy recovery and wireless charging techniques. The purpose of both solutions is to charge the sensor battery without human intervention.

2.5.1 Energy harvesting

New technologies have been developed to enable sensors to harvest energy from their environment, such as solar, wind and kinetic energy. Compared to traditional sensors, rechargeable sensors can theoretically operate continuously for an indefinite period of time. They convert environmental energy into electrical energy and then consume it directly or store it for later use [42][43].

2.5.2 Wireless charging

With recent advances in wireless power transmission, wireless sensor networks are expected to be more stable. This technique can be used to send power between devices without the need for any contact between the transmitter and the sensor. Wireless charging in a wireless sensor network can be achieved in two ways: electromagnetic radiation and magnetic resonance coupling. Recent research focuses on sharing the energy of nodes among their neighbors. Thus, it is predicted that in the future, each node in wireless sensor networks will be able to receive energy from the environment and send energy to other nodes, which will provide a self-sufficient network. Gives [44][45].

It is clear that many efforts have been made through a variety of energy storage mechanisms to extend the life of wireless sensor networks. It also appears that energy efficiency and other applications are highly interdependent and require different performance optimization criteria in common.

2.6 CHARACTERISTICS OF WIRELESS SENSOR NETWORKS FROM A ROUTING PERSPECTIVE

Due to the fact that in this dissertation, increasing the life of the network using routing methods has been considered. For this reason, in the next section we have stated some of the requirements of the routing algorithm used in sensor networks. Before addressing the requirements of routing protocol design, we briefly mention the characteristics of sensor networks from a routing perspective.

2.6.1 Network characteristics

Number and density of nodes and network diameter:

This property is based on the number of options in routing tables. It is effective in nodes as well as the amount of delay and loss caused by the steps taken by packets.

Connection:

Due to the conditions of the physical environment, network links may experience different modes of connection. This highlights the need for high dynamics in the routing algorithm and not limited to unique paths in sensor networks.

Dynamics:

Sensor and wireless operator networks have dynamic correlation due to the possibility of moving some nodes, and changing the correlation often causes a change in the path of the packets. In addition to moving the nodes, the entry of new nodes into the network or the exit of some nodes due to battery depletion can also change the network connection.

Deployment:

The location of nodes in sensor networks can be random, for example by spreading the nodes through the aircraft in the desired environment. In addition, the location of aggregation nodes, which also act as gateways to other networks, is effective in routing protocol performance.

Traffic plans:

Depending on the specific application, different traffic plans such as point to point, point to group and group to point are conceivable in these networks.

Service quality:

If different applications require different service quality, we may need to define multiple service classes and use different routing criteria together.

2.6.2 Properties of nodes

a) Processing speed and memory size:

   Limits on these parameters affect the size of routing tables and how they are processed.

b) Node power consumption and energy source:

   The number and location of nodes with battery source and power nodes in the network will have a direct impact on routing policies based on increasing network life.

c) Transmission range:

   The transmission range of nodes that depend on the strength of their radio signal can be effective in network connectivity and the density of nodes and their connection to each other.

d) Traffic load:

   The amount of traffic load of nodes can affect the quality of routing. Load sharing between nodes can be one of the important policies in optimal routing in such networks.

2.6.3 Properties of links

a) Bandwidth

Wireless bit link rates on IEEE802.15.4 based networks are low and up to a maximum of 250 kbps. Of course, this bit rate can be less than this based on the conditions of the physical layer as well as the amount of interference of adjacent links. In addition, sleep-wake periods or prevailing traffic conditions can also reduce bitcoin rates.

b) Delay

The transmission delay on an IEEE802.15.4 link can be increased due to queuing at the nodes as well as the time required to compete over the channel.

c) Connection quality

Sensor networks have unreliable links due to physical layer conditions and low power consumption. This link property is indicated by factors such as received signal strength index, connection quality index or channel error rate.

2.7 REQUIREMENTS FOR DESIGNING ROUTING ALGORITHMS IN SENSOR NETWORKS

Considering the features mentioned in the previous section on sensor networks, the requirements in designing routing algorithms for these networks are conceivable, which we will mention in the following.

2.7.1 Requirements to support network features

a) The routing algorithm must consider the non-response conditions of the nodes due to their periodic dormancy. In order to achieve this feature, the use of lower layer information can be considered. Depending on the application implemented in the network, nodes generate packets at rates such as 1 packet per second or per minute or more, and therefore spend the rest of their time in order to save energy. They go to sleep. Nodes that act as conductors of the packet of other nodes may always be awake due to the power connection; Otherwise, their sleep time increases packet latency and the likelihood of their loss, which can be reflected as a cost in the route selection function.

b) The routing algorithm using the lower layer information on the amount of energy remaining in the nodes should create or update routing tables. Also, the link quality index should be considered as a criterion in choosing the appropriate path.

c) The routing algorithm should be designed to be scalable as well as use the least resources to update routing tables. Sensor and wireless operator networks may consist of several million nodes. In such a situation, grouping nodes in groups of 100 to 10,000 and using hierarchical routing algorithms to simplify network routing and increase scalability is known as the best solution [46][47].

d) Use the methods of repairing and retrieving routes so that if part of the route is lost, there is no need to repeat the routing process from origin to destination. This reduces the overhead caused by routing packets on the network and improves packet throughput and latency.

e) Support for network connection changes due to node movement or link condition changes. For example, in home networks, the time required to apply interconnection changes and route reconstruction by the routing algorithm should not exceed 20 seconds [48]. Some applications that require instant information exchange may take less time to converge the routing algorithm. In the routing algorithm used in sensor networks, due to the limitation of processing power, it is not possible to track the path of moving nodes, and the movement of nodes is only by removing them from a place or group and connecting them to a base station or The new group should be well supported.

f) Routing algorithms in sensor networks must support point-to-group, group-to-point, and sometimes point-to-point traffic plans. Traffic in sensor and operator networks usually travels from one point to several points or from several points to one point. Some applications also require point-to-point communication, but the predominant traffic is of the first two types. The special traffic scheme in such networks simplifies the design of the routing algorithm compared to the flat networks where all nodes can exchange data with each other.

2.7.2 Requirements to support node properties

a) The routing algorithm must have small software code and few routing modes to be implemented with the memory conditions and processing power of the nodes in the sensor networks.

b) The routing algorithm should be able to manage routing operations with the minimum necessary control packages to minimize the energy overhead in the network. Due to the fact that routing packages are usually multi-broadcast, the energy overhead consumed by them will also be high. Therefore, optimizing the transmission rate of routing packets is one of the key factors in designing algorithms in sensor networks.

2.7.3 Requirements to support link properties

a) Routing packets should not exceed the length of a data link layer frame as much as possible overhead. Minimize their fragmentation and reconstruction. Also, due to the unreliability of the links in the sensor networks, if the control packets are fragmented, the possibility of error in the protocol will increase.

b) The routing algorithm must observe the packet loss rate that can be tolerated by the application implemented in the network by selecting the appropriate paths for the packets. For this purpose, the routing algorithm must be aware of short-term and long-term changes in the quality of links and select the appropriate route to have a tolerable error rate by determining the cost of routes according to the quality index of links.

c) The routing algorithm must know the amount of tolerable latency of the application implemented on the network and select the appropriate route according to the latency of the physical links along the route. For example, industrial automation or building automation applications may have a maximum tolerable delay of a few tens of milliseconds.

d) Routing algorithms must be resistant to correlation changes due to changes in link quality or node loss and must converge in the shortest possible time depending on the implementation implemented. In addition to the need for speed in convergence, the routing algorithm must converge with the least network resources occupied so as not to violate paragraph 8 of the above requirements.

e) The routing algorithm must be able to support asymmetric links. Asymmetry of links means the impossibility of sending two-way sending by two-node nodes of a link, which occurs frequently in sensor networks due to unstable radio conditions.

f) The routing algorithm, in order to ensure network security, must support authentication and encryption mechanisms in its control packets.

g) The routing algorithm should be able to establish multiple routes between origin and destination to create backup routes as well as load distribution in the network in order to achieve the appropriate service quality for applications sensitive to latency or reliability.

2.8 INVESTIGATE THE SHORTCOMINGS OF EXISTING ROUTING ALGORITHMS

Due to the severe energy constraints on wireless sensor nodes, routing using a multimeter can be a routing tree topology with energy storage to deliver information to the base station. Where the middle nodes aggregate their information with their children's information and send the aggregated information to the base station [49][50][51]. The aggregation of functions is divided into two main groups, complete aggregation and imperfect aggregation. For complete aggregation, the amount of output information is constant and independent of the amount of input information. Examples of this type of aggregation are maximal functions. Complete aggregation can be fully utilized in sensor networks. The mean function is an example of an incomplete aggregation, which requires all the information to be present [52].

The topology of routing trees starts with sending a flood routing message from the base station and is sent by nodes to all levels of the tree. Each node can receive a number of these routing messages from nodes that it can consider as a parent. Each node after the broadcast of the routing message according to the different policies for parental selection such as random selection, selection based on distance or based on selection based on link quality, which is implemented in the algorithm, ¬ Able to select a parent from among their potential parents to send their data to it [53][54].

Blind selection of parent nodes creates an unbalanced distribution of children among parents. In this case, it is very likely that some parents will have more children than other parents and even some parents will be childless. The number of children indicates the amount of traffic in a particular node due to receiving, processing and sending information. High traffic causes a rapid depletion of energy, and the node that suffers from this has a shorter lifespan than nodes that have less traffic. Given this, it is important to consider the load on a node in dense networks to eliminate rapid energy depletion and node loss [55]. To solve this problem, using routing with proper distribution of traffic between nodes is the best and most logical solution. Numerous methods and algorithms for routing in wireless sensor networks have been proposed by researchers [53]. But we are still far from reaching a standard protocol in this regard. Given that the topic of this dissertation is balanced load routing using energy criteria, we focus on routing methods. Routing methods in terms of load balancing are also divided into three main groups:

2.8.1 structure-based routing;

In which information transmission paths are generated from the beginning and used during network activity [56].

2.8.2 Improper routing on the structure;

They do not seek to create routing graphs and generate routes based on network needs. The need for more paths in these methods is determined by the bandwidth, latency or energy of the nodes [36].

2.8.3 coding-based methods;

Which fragment the packets and send the various components to adjacent nodes using coding methods, the destination node retrieves the original packets using decoding mechanisms. These methods are mainly used to increase telecommunication security [57].

Among the above methods, structure-based methods are more effective for our intended applications, i.e. data collection periodically and structurally from nodes with a specific location and mostly fixed. Non-structured methods are more suitable for adhoc networks with mobile nodes and random, low-volume traffic. Coding methods do not distribute traffic independently and, on the other hand, are not suitable for delay-sensitive applications due to the need to reach all the components to retrieve the original packets.

Since the proposed protocol in this dissertation is designed to move towards standardization of routing protocols in wireless sensor networks, the use of a structured method for generating routing graphs is preferred and the UDDR algorithm as A standard, structured approach was identified as the best option for our platform.

One of the issues that can be observed and improved in routing algorithms is the mechanism of traffic distribution between nodes. In most of the proposed algorithms, traffic distribution, which are purely experimental algorithms, is done according to service quality criteria; That is, different nodes are evaluated based on different routing criteria, and the traffic of different classes is directed to the node with the most profit. For example, the algorithm [58] based on the distance from the collector node and the algorithm [59] use the combination of delay service quality and reliability to decide on the next step.

On the other hand, to create load balance and prevent overuse of some nodes, the combination of node energy criteria with the main routing criteria is used to achieve more balance between nodes. This method reactively creates a proper traffic distribution and balance the energy consumption of the nodes. However, determining the coefficient of importance of energy relative to the main criteria, as well as the coefficient of importance of the main criteria relative to each other, in the combined criterion used can drastically change the behavior of this algorithm.

Other categories of experimental traffic distribution algorithms, which are mainly non-structured routing methods, include animal intelligence methods such as ant theory [60][61] or artificial intelligence based on logic such as logic. Use fuzzy [62] or machine learning methods such as Q-learning [63]. Such methods are mainly slow convergence towards optimal paths, which causes the loss of a large part of the packages during the search and learning operations for the best paths.

On the other hand, the overhead of these algorithms is high due to their search nature. For example, in ant theory-based algorithms, we need to send ants in all possible directions in order to find the best path; Or in an algorithm based on Q-learning, each node gradually scores the nodes in front of it using end-to-end feedback received from the collector node. However, the use of structured methods can identify the optimal nodes from the beginning and provide a good estimate of the cost of the node for the nodes along it.

In contrast to these experimental methods, algorithms have been proposed to achieve optimal traffic distribution using clustering methods. These algorithms are used to solve the problem of balancing energy consumption by moving maps and distributing more energetic nodes as headers. The methods of moving the maps mainly have a high information overhead, so they affect the energy of the nodes [64][65]. Also, due to the distribution of nodes, some eclipses may have more traffic load, and some children may have to use multi-hop connections to send loads to the node.

3. METHODOLOGY

3.1 ALGORITHM

The following conditional command is created for the purpose of moving the threads in the circuit, in other words, causing a balanced distribution of nodes in the circuit. The first command states that if the circuit number is even, then shift the position x of the headers to the right-hand side of the angular width of a circuit, otherwise place it in its previous position.

```
if rem(k1,2)==0
        ybS1=cos(2*pi*x2(1:areanum)+(pi/areanum));%x cluster location of orbit radius(points)
        ybS2=sin(2*pi*x2(1:areanum)+(pi/areanum));%y cluster location of orbit radius(points)
else
        ybS1=cos(2*pi*x2(1:areanum));%x cluster location of orbit radius(points)
        ybS2=sin(2*pi*x2(1:areanum));%y cluster location of orbit radius(points)
end
```

For each circuit, a cycle is created along the regions whose job is to draw lines between the circuits. The position of the current head is determined. And then its direct position is determined, which is the eclipse in the lower circuit of the netter (by reducing the radius and multiplying it in the current position of the eclipse.

Then the initial energy of each header is determined depending on the number of nodes that are loaded on it, in other words, the load of the transmitter nodes is divided between the headers. he does.

The number of each heading is also determined by the number of cycles as follows.

S(KT).ind=KT;%node index

Each node will have an estimate of its energy consumption when it collects node information, which is initially equal to zero.

S(KT).EnergyConsumNeed=0;%node index

The following command is used to control and quantify the sink, and using the following command, it is determined that the current thread is actually the lowest thread and must send its information to the sink. Therefore, the position of the sink as the next position The current header is determined and the sharp index of the sink is placed in the header slot.

```
if KT>areanum*(orbitNum-1)
    S(KT).ch=clusterH;
```

If the eclipse is not present in the last and lowest circuit, then the present eclipse completes a complete circle and points to its lower circuit and adjusts its next position to the corresponding eclipse position of the cluster in the lower circuit. And it adjusts its distance as before.

Then the variable kt as the index of the headers becomes one more number. So that the index stores all the euphemisms.

Then use the following command to go down the circuit one step to create and adjust the headers of that circuit as well.

Then, the last spark plug, which is the sink, is set as follows in this section, and the next spark plug is the sink itself, so its energy consumption will be zero.

```
S(clusterH).ch=clusterH;
S(clusterH).X=0;
S(clusterH).Y=0;
S(clusterH).nXcoor= sink.X;
S(clusterH).nYcoor= sink.Y;
S(clusterH).distanc=0;
S(clusterH).ind=clusterH;
S(clusterH).E=20000;
```

The following commands are used to draw dividing lines. After creating the points, including the central points and the points on the last circuit, the area lines are drawn.

Then the positions x and y of the present node are plotted using the finite radius r inside the last circuit and sink, and this cycle is repeated for all nodes to create a unique position for each of them.

After creating the nodes and drawing the circuit, and the headers, and now the cycle begins as follows, in which each node and each header selects its own header to the process of sending information one step through the nodes and sending several steps or Take a step through the sprigs, in a set interval, and each time their energy consumption is deducted from their current energy value.

After the above actions and clustering, the energy consumption of each node is corrected along with the changes of the eclipse and the distances of the nodes and eclipses, all of which are copied to the node vector after returning through the function. It is used to calculate the energy fraction and other operations to update the status of the nodes.

Flush selection function:

This function, called the header selection function, finds a number of inputs, including the node vector, the last header index, and the parameter variable. The position of the header performs the nodes and the header, and the return value includes the vector of the updated nodes and headers, which must be copied to the input vector of the same S.

And for each node, all the ellipses are lined up, and the node selects one of them to have the best and the shortest distance with him. He does not choose any node, so it is natural that the node that is not selected will not consume energy unless the conditions for his selection are provided in the next steps.

Then, for every ninety, one cycle is created along the length of the headers.

Then, after selecting the header, it is checked whether the distance of the present ninety with the header is less than the base distance or not, and if it is, then its power consumption parameters are set similar to the headers.

Each time Node selects Sarkhosheh, Sarkhosheh determines the number of its members using the following command, based on which the total energy consumption is estimated. In fact, the following command states how many ninety have chosen the current headline so far.

If the number of nodes is greater than zero, the work variable as the control variable allows the energy consumption to be estimated, otherwise the energy consumption for it is considered zero.

The energy consumption of the head is then calculated based on the number of nodes that have selected it as follows.

```
enNeed=( (kB*Eelect*((NselByNods))) + (kB*EDA*NselByNods)+(kB*Eelect + (kB*eFaM)*d1.^np))*work; %identity enrgy consumpation till now for ch(i)
% if distance and the energy need for aggregating and sending of nodes information of ch(i) is Sufficient then can select by current node
```

And this required energy consumption is stored inside the eclipse to reduce the amount of energy consumed in the original file.

The eclipses then select the eclipses, which eventually transfer the information to the sink in the form of one step or several steps.

For each area, the entire circuit is in a cycle. In this case, the eclipse is performed in a deep form, ie each eclipse selects its eclipse from the lower circuits, and if there is no circuit downstream, the sink Selects as eclipse and sends its information to it.
And if all the deep springs have lost their energy, then the sink will be selected as the last resort and direct information will be sent to the sink.

Finally, the lines between the nodes with the headers and the headers with their own headers are drawn in this section, and each time this function is called, the route and distance information update is performed and drawn.

Comparison with Low-energy adaptive clustering hierarchy (LEACH):
In terms of reducing energy consumption:
In this implementation technique, the threads can be distributed in a circular fashion between the nodes, so that the transmission distance corresponds to the transmission and receive board and it can be rotated around the circuits as desired.
Therefore, with a balanced distribution, energy consumption can be drastically reduced, according to the LEACH implementation technique, each node can be both eclipse and as a sensor, although this method can reduce energy consumption in the network, but due to change Headings occur at each stage of the overhead cost of header replacement, which is not included in the simulation of the LEACH as an energy consumption factor, in other words, each time the header is changed, at least 2 * N times of Broadcasting is performed, which consumes energy. Will follow and also in this case the specialized work of the sensor nodes is sometimes ignored. Which in itself can have consequences. Although some nodes in the LEACH are permanently eclipsed and have no sensory action, they are constantly assigned this task to normal nodes, and in general it should be said that a large part of their time is spent without any useful action. To be. However, the energy of these headers is determined twice as much as other nodes,
In the present technique, the task of sending and collecting information is given to certain nodes with appropriate distribution, the distribution of which can be changed. This action causes the

headers to be present in all areas. Secondly, it causes all nodes without the need for Replace the cap as soon as possible in the form of a step and send information at the base distance.

However, the limitation of this technique goes back to the energy of fixed headers like a LEACH, so it is possible to select the header energy more than normal nodes and in accordance with the average load of each node to the network, so in this project energy consumption Nodes By selecting four times the energy of normal nodes (in the LEACH, the energy of the headlines is twice as high as normal nodes), the network can be used for a long time, and by selecting three times the energy of normal nodes, the time of the first death is equal to the LEACH. However, in Lech, the average energy consumption is higher than the current technique, because normal nodes are involved during data transmission, which in turn consumes the energy of the entire network. Therefore, the average energy consumption in the present technique will be less than the LEACH.

In the LEACH, all the nodes are involved and therefore the onset of death will be from normal nodes. Unlike the LEACH in the present technique, it will be the first death in the nodules and if their energy is higher than normal nodes, the network life will be much longer.

As the number of nodes increases, the life of the network increases.

The distance between nodes and threads is important in this technique and a long distance causes a lot of energy consumption, so we have tried to keep the distance between the base and the transmission for normal nodes and threads as low as possible, and in general increase the number of circuits It has a beneficial effect on increasing the number of areas in energy consumption.

4. EXPERIMENTAL RESULT

We utilized in this section, we will describe the network model under consideration in terms of connectivity, node density, telecommunication link model, etc., and in addition, we will define the optimal routing problem we want. The contents of this section will acquaint the reader with the conditions we want from the network as well as the problem we are trying to solve.

4.1 NETWORK CONNECTION

The network under study consists of a number of sensor nodes and wireless operators that are randomly distributed evenly across the target environment. The study environment is considered as an a * a square with the dimensions of a personal or local network and the number of nodes in it does not exceed 100 nodes. The reader should note that assuming hierarchical routing capability in wireless sensor networks, the above assumption does not impose a limit on the dimensions of the overall network. The number of collector nodes in the implementation environment is considered 1 and the routing algorithm operates in such a way that it sends the information generated by the nodes to the collector node appropriately. As a result, the type of traffic considered in this paper is also multi-point to one point. Various experiments during the simulation as well as logical arguments indicate that the location of the collector node should be close to the center of the implementation environment, because thus the possibility of adjusting the traffic load across the network under investigation. It is more desirable. To make our network model a little closer to reality, the location of the adder node in a square with dimensions of a / 2 * a / 2 and in the middle of the main implementation environment is randomly selected. Such an assumption would be largely possible given the actual implementation conditions.

4.2 DENSITY OF NODES

The higher the density of the nodes in a given range, the greater the probability of a collision and the more time the nodes need to access the frequency channel. On the other hand, the low density of nodes may lead to the creation of routing holes and the disconnection (thinning) of the routing graph due to the excessive distance of some nodes.

We have not found a suitable and direct criterion for high or low density in wireless sensor networks in the existing articles. Only in the reference [66] it is mentioned that in order to prevent the network from becoming thinner and creating a connected network, it is better that the network density is such that each node has at least 5 neighbors around it on average. The results of the simulations also showed the relative correctness of this hypothesis, so that in lower density conditions, part of the generated traffic is practically lost due to lack of route to the destination. For this reason, we also use the above criterion to determine the minimum density of nodes in the network model under study. Thus, the density of nodes should be selected so that the order of the graph (average number of neighbors of the nodes) is between 5 (minimum) and 10 (maximum). The simulation results show that the packets are lost too much due to collisions in graphs with order greater than 10.

4.3 WIRELESS TELECOMMUNICATION LINK MODEL

The standard single disk model is used to model the wireless telecommunication link that operates under the IEEE802.15.4 standard. In this model, it is assumed that the node can only exchange data with nodes that are in a circular environment within the radius of its telecommunication range. Thus, the set of node neighbors also includes the nodes located on this disk.

In order to model the physical layer and the effect of reducing the received power due to the distance between nodes and environmental factors such as fading and wave reflection, log-normal shadowing model has been used to calculate the signal strength received at the destination node. The received signal strength index or RSSI on the link (i, j) resulting from the above model is calculated using the famous following formula [67].

$$\boldsymbol{RSSI(i,j) = P_t(i) - PL(l_0) - 10\beta \log\left(\frac{l_{ij}}{l_0}\right) - X_\sigma} \qquad (4.1)$$

On the other hand, this indicator is used to decide whether to receive the package correctly or incorrectly in the physical layer, so that if the received signal strength is less than the sensitivity of the receiver antenna, the package is lost and otherwise it is considered healthy.

4.4 SIMULATION RESULTS

First of all, the wireless sensor network area is setup. This scenario is shown in figure 4.1.

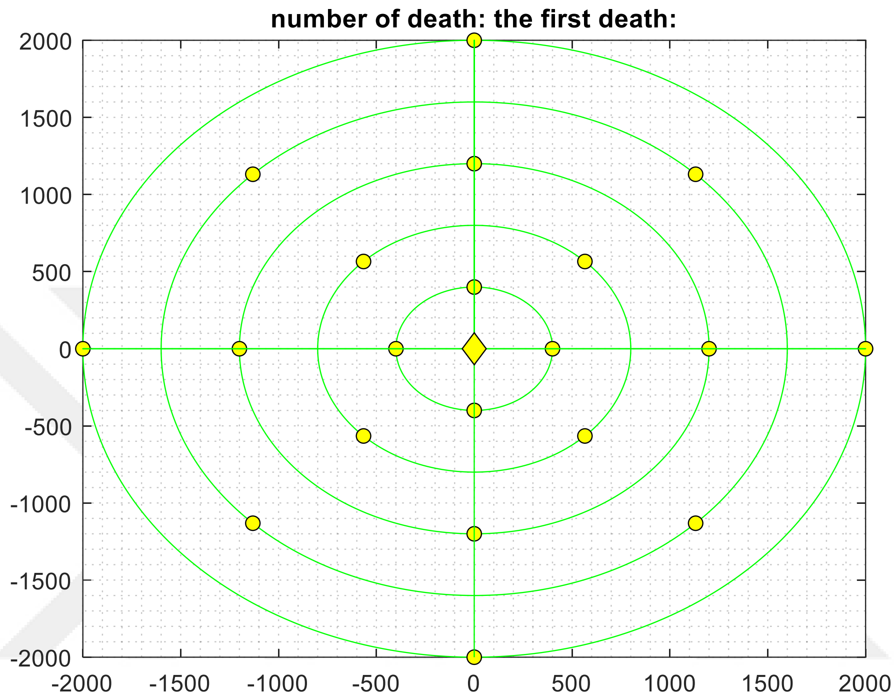

Figure 4. 1: First Step of the Setup

The area/clustering parameters is shown in table 4.1.

Table 4. 1: Area/Clustering Parameters

Parameter	Value	Description
N	250	number of nodes + clusters
rmax	25	around
r	2000	orbit radios
R	2000	second orbit radios
orbitNum	5	number of orbit
AreaUnit	2000/5 = 400	area unit setting

AreaNum	4	number of area
clusterH	AreaNum*orbitNum+1 = 21	clusters
nodN	250-clusterH = 229	nodes

The energy parameter is shown in table 4.2.

Table 4. 2: Energy Parameters

Parameter	Value	Description
Ein	0.5	initial energy Joul
kB	4000	number of sent bits
Eelect	50*10^-9	Joul / circute consumpation of unit
Eamp	0.0013*0.000000000001	Joul / amplifing for near distance
Efs	10*0.000000000001	Joul / amplifing for near distance
EDA	5*0.000000001	Joul /aggrigation parameters
d0	sqrt(Efs/Eamp) = 8.7706e-11	base distance

The second energy parameters are shown in table 4.3.

Table 4. 3: Second Energy Parameters

Parameter	Value	Description
Ein	200	initial energy Joul
kB	100	number of sent bits
Eelect	50*10^-9	Joul / circute consumpation of unit

Eamp	100*10^-12	Joul / amplifing for near distance
Efs	(7.6923e+03)*Eamp	Joul / amplifing for near distance
EDA	(3.8462e+06)*Eamp	Joul /aggrigation parameters
d0	sqrt(Efs/Eamp)	base distance

The sensors install randomly in the area. Figure 4.2 shows the setup the first sensor that colored by blue color.

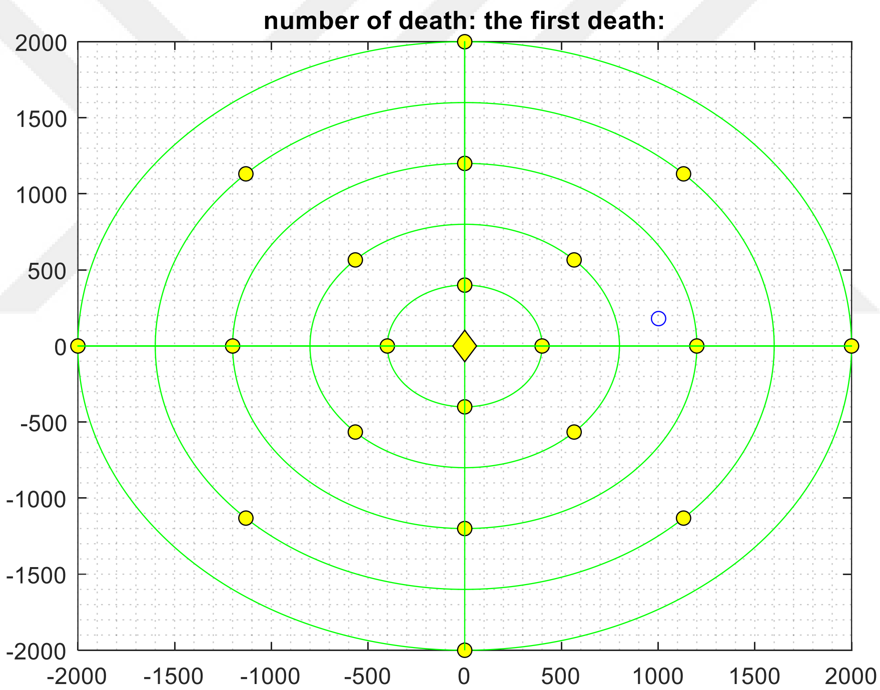

Figure 4. 2: Setup the First Sensor

All sensors setup randomly in the proposed WSN area. This scenario is shown in figure 4.3.

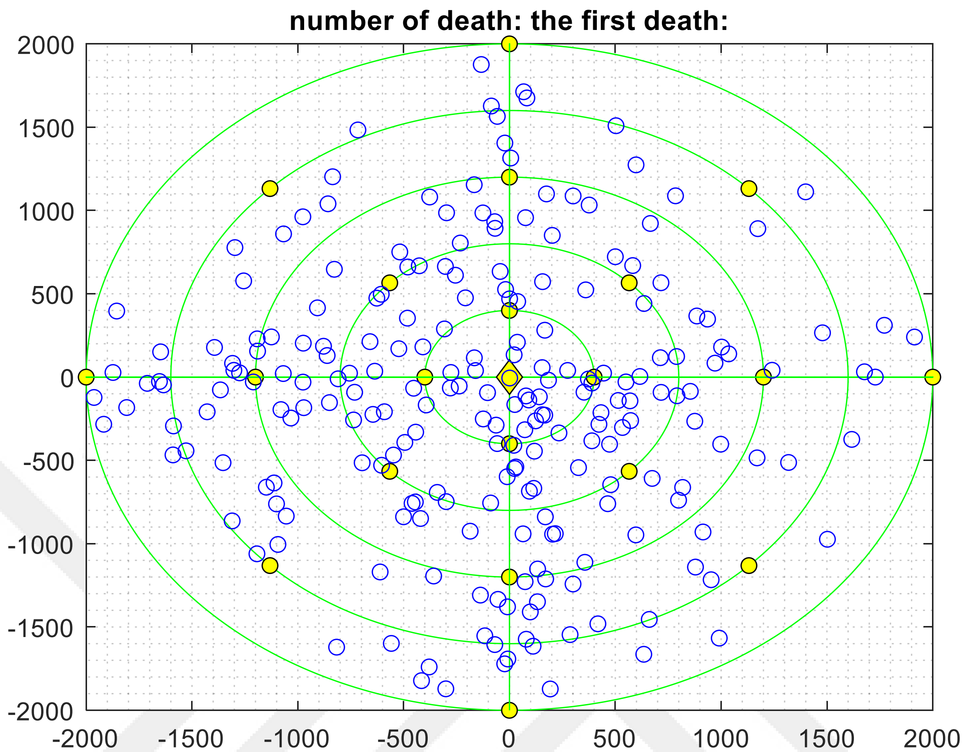

Figure 4. 3: Setup All Sensors

The yellow-colored sensors send their information to the sensors. This scenario is shown in figure 4.4.

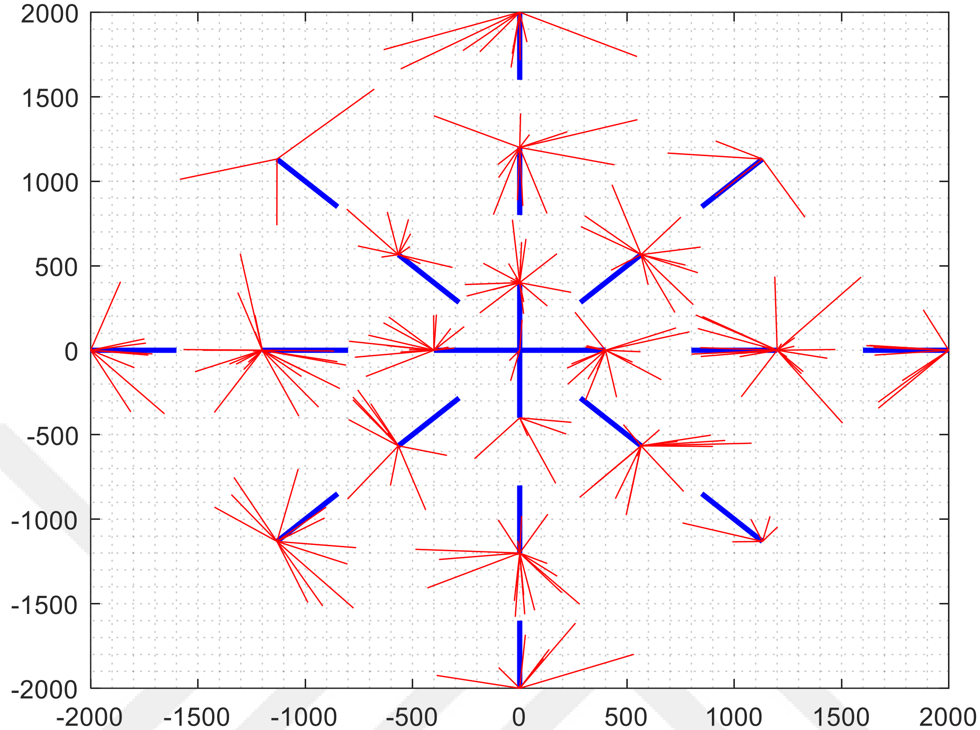

Figure 4. 4: Yellow Sensors Send their Information to Each Other

The sensors start to send their information to the base station. At first the number of death node are zero, round is 1 and the energy is 154.5 Joule. This scenario is shown in figure 4.5.

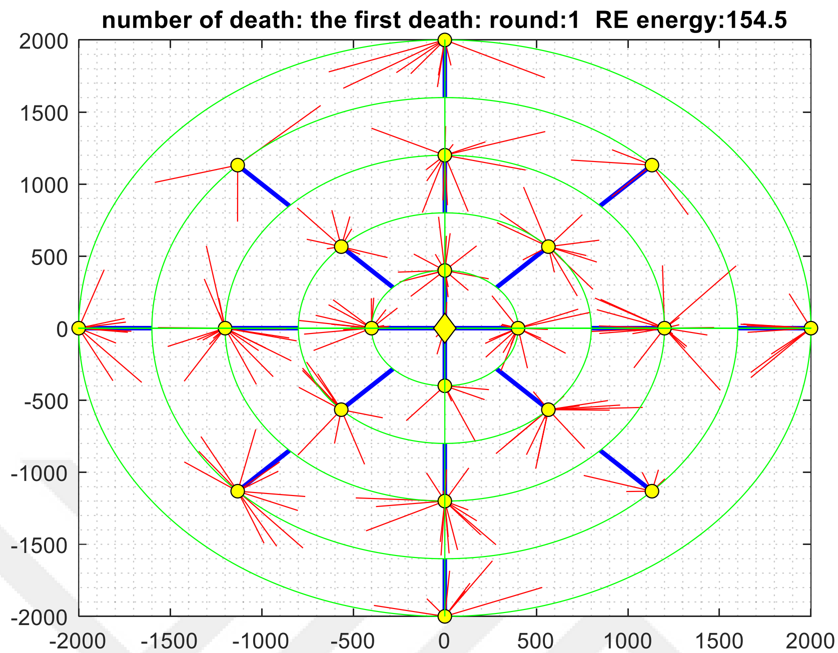

Figure 4. 5: Start the Working of the Network

The system after first death node is shown in figure 4.6.

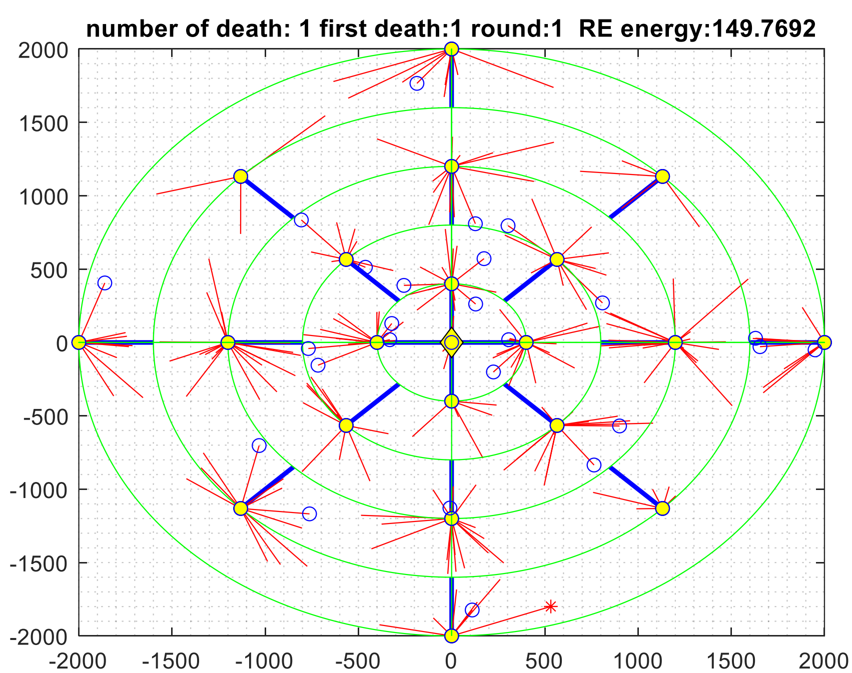

Figure 4. 6: First Node is Death

This state continues and in the middle of the round 1 8 sensors death. This is illustrated in figure 4.7.

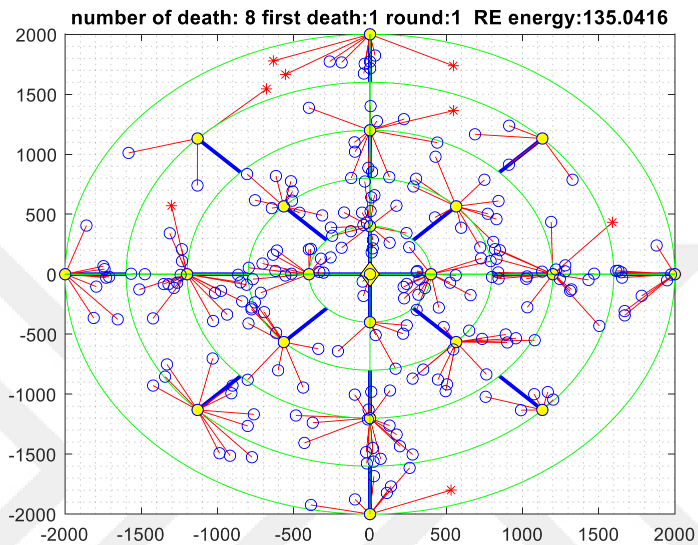

Figure 4. 7: 8 Node Death in First Round

Finally, all nodes are death in round 25. The total remain energy is 2.0503 Joule. This state is shown in figure 4.8.

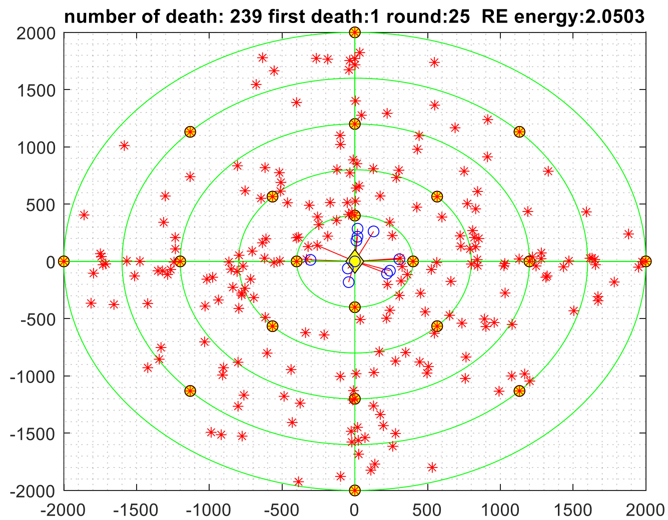

Figure 4. 8: All Sensor are Death

The life time of the sensors is shown in figure 4.9.

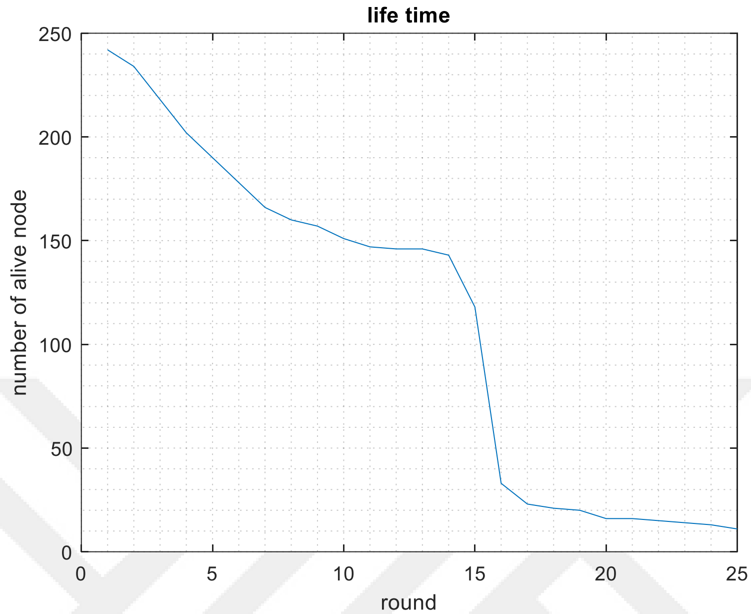

Figure 4. 9: Life Time of The Network

As seen in this figure all sensors are death after 25 rounds.

The residual energy against of the node numbers is shown in figure 4.10.

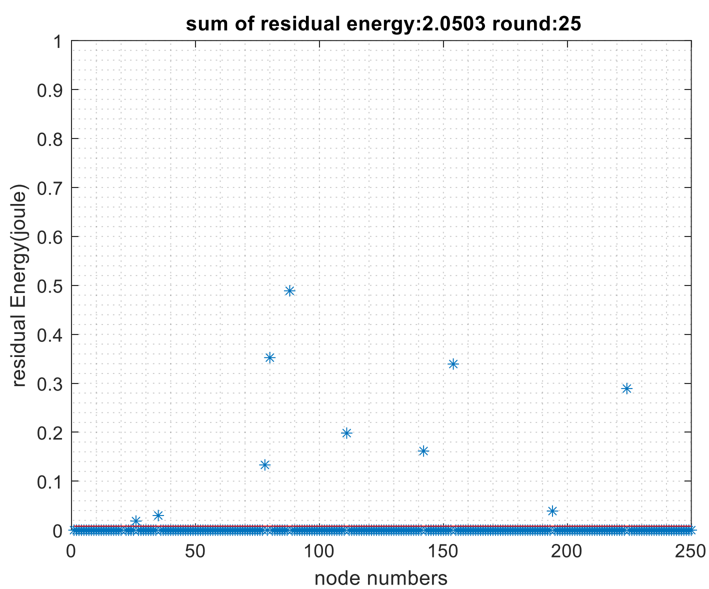

Figure 4. 10: Residual Energy Against of The Node Numbers.

5. CONCLUSION AND FUTURE WORKS

5.1 CONCLUSION

Advances in electronics and wireless communications have provided the ability to design and manufacture sensors with low power consumption, small size, reasonable price, and a variety of applications. These small sensors are able to perform functions such as receiving information from the environment, processing and sending it. Together, these factors have led to the development and expansion of networks called WSN wireless sensor networks. A sensor network consists of a large number of sensor nodes that are distributed in an environment and collect information from the environment. The location of the sensor nodes is not predetermined. And it makes it possible to leave them in inaccessible places. Each sensor node has a processor, which performs a series of initial processes on the received information and then sends the data.

Although each sensor alone has little capability, the combination of hundreds of small sensors offers significant possibilities. In fact, the popularity of sensor wireless networks is in the use of a large number of small nodes that can be organized together and in cases such as simultaneous routing, monitoring environmental conditions (such as ambient temperature, the presence of gases in tunnels), monitoring infrastructure or equipment System to be used.

In these networks, unlike wired systems, the costs of configuration and network configuration are reduced, and instead of installing thousands of meters of wire, only small devices should be placed in the desired points. The network is easily expanded by adding a few nodes and does not require special design and configuration. Today, reducing the volume and weight of sensors and increasing their sensitivity is the main goal of many research laboratories and various companies. But shrinking the size of the sensor nodes meant shrinking their energy-producing batteries.

Wireless sensors are often used to receive and process information remotely, so node power consumption is an important issue in wireless sensor networks. Because in wireless sensor networks, nodes must operate for a long time with a limited power supply. The power consumption of the nodes is usually supplied by the battery, which in most cases cannot be replaced and the life of the sensor ends when the battery runs out. Another important point is that batteries often make up about 50% of the volume and weight of sensors. Power saving in general is possible in two ways. The first way is to build sensors with less energy consumption and the second way is to use power management methods in network software design.

Wireless sensor networks have recently attracted the attention of many researchers. These networks are expected to penetrate all elements of human life in the coming years due to their many applications, but the most important challenge facing sensor networks is to increase their lifespan. Many routing algorithms have been proposed for wireless sensor networks. However, due to the lack of attention to traffic patterns and the amount of energy remaining in each node, they cannot use the energy in the network efficiently, and sometimes even relying on a particular node due to the conditions of the algorithm, the life of the network. In this paper, a balanced load routing tree algorithm for routing information in a wireless receiver network is proposed. The proposed Power balanced tree routing algorithm is specifically designed to solve the problem of load balancing and reduce energy consumption in wireless sensor networks. For this purpose, a theoretical game approach has been considered in which the nodes in the network appear in two roles of child and parent. In the role of the child, the nodes are selfish players who choose their parent to earn more profit at a lower energy consumption rate, while the nodes in the role of the parent with participatory connections among themselves on the traffic load. Reduces other parents who are two leaps apart and on the same level with them and suffer from overload. This algorithm has been evaluated in different scenarios below.

REFERENCES

[1] T. Rault, A. Bouabdallah, and Y. Challal, “Energy efficiency in wireless sensor networks: A top-down survey,” *Comput. Networks*, vol. 67, pp. 104–122, 2014.

[2] D. Wohwe Sambo, B. O. Yenke, A. Förster, and P. Dayang, “Optimized clustering algorithms for large wireless sensor networks: A review,” *Sensors*, vol. 19, no. 2, p. 322, 2019.

[3] H. Karl and A. Willig, *Protocols and architectures for wireless sensor networks*. John Wiley & Sons, 2007.

[4] S. P. Singh and S. C. Sharma, “A survey on cluster based routing protocols in wireless sensor networks,” *Procedia Comput. Sci.*, vol. 45, pp. 687–695, 2015.

[5] B. S. Geletu, “Modeling the Behavior of an Electronically Switchable Directional Antenna for Wireless Sensor Networks.” Swedish Institute of Computer Science, 2011.

[6] A. A. V. Rani and E. Baburaj, “Secure and intelligent architecture for cloud-based healthcare applications in wireless body sensor networks,” *Int. J. Biomed. Eng. Technol.*, vol. 29, no. 2, pp. 186–199, 2019.

[7] N. Cao and P. Yu, “A Review of Wireless Sensor Network Simulation Tools,” in *International Conference on Artificial Intelligence and Security*, 2020, pp. 210–220.

[8] H. Rhim, K. Tamine, R. Abassi, D. Sauveron, and S. Guemara, “A multi-hop graph-based approach for an energy-efficient routing protocol in wireless sensor networks,” *Human-centric Comput. Inf. Sci.*, vol. 8, no. 1, pp. 1–21, 2018.

[9] S. Cui, A. J. Goldsmith, and A. Bahai, “Energy-constrained modulation optimization,” *IEEE Trans. Wirel. Commun.*, vol. 4, no. 5, pp. 2349–2360, 2005.

[10] F. M. Costa and H. Ochiai, “A comparison of modulations for energy optimization in wireless sensor network links,” in *2010 IEEE Global Telecommunications Conference GLOBECOM 2010*, 2010, pp. 1–5.

[11] S. Narieda, T. Fujii, and K. Umebayashi, “Energy Constrained Optimization for Spreading Factor Allocation in LoRaWAN,” *Sensors*, vol. 20, no. 16, p. 4417, 2020.

[12] J. W. Jung, W. Wang, and M. A. Ingram, “Cooperative transmission range extension for duty cycle-limited wireless sensor networks,” in *2011 2nd International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE)*, 2011, pp. 1–5.

[13] S. K. Jayaweera, “Virtual MIMO-based cooperative communication for energy-constrained wireless sensor networks,” *IEEE Trans. Wirel. Commun.*, vol. 5, no. 5, pp. 984–989, 2006.

[14] A. K. Sangaiah *et al.*, “Energy-aware Geographic Routing for Real Time Workforce Monitoring in Industrial Informatics,” *IEEE Internet Things J.*, 2021.

[15] L. H. A. Correia, D. F. Macedo, A. L. dos Santos, A. A. F. Loureiro, and J. M. S. Nogueira, “Transmission power control techniques for wireless sensor networks,” *Comput. Networks*, vol. 51, no. 17, pp. 4765–4779, 2007.

[16] X. Chu and H. Sethu, “Cooperative topology control with adaptation for improved lifetime in wireless ad hoc networks,” in *2012 Proceedings IEEE INFOCOM*, 2012, pp. 262–270.

[17] A. Haider and S.-H. Hwang, “Adaptive transmit power control algorithm for sensing-based

semi-persistent scheduling in C-V2X mode 4 communication," *Electronics*, vol. 8, no. 8, p. 846, 2019.

[18] H.-N. Dai, "Throughput and delay in wireless sensor networks using directional antennas," in *2009 International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP)*, 2009, pp. 421–426.

[19] A. P. Subramanian and S. R. Das, "Addressing deafness and hidden terminal problem in directional antenna based wireless multi-hop networks," *Wirel. networks*, vol. 16, no. 6, pp. 1557–1567, 2010.

[20] R. K. Miranda, D. A. Ando, J. P. C. L. da Costa, and M. T. de Oliveira, "Enhanced direction of arrival estimation via received signal strength of directional antennas," in *2018 IEEE International Symposium on Signal Processing and Information Technology (ISSPIT)*, 2018, pp. 162–167.

[21] M. Masonta, Y. Haddad, L. De Nardis, A. Kliks, and O. Holland, "Energy efficiency in future wireless networks: Cognitive radio standardization requirements," in *2012 IEEE 17th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, 2012, pp. 31–35.

[22] M. Naeem, K. Illanko, A. Karmokar, A. Anpalagan, and M. Jaseemuddin, "Energy-efficient cognitive radio sensor networks: Parametric and convex transformations," *Sensors*, vol. 13, no. 8, pp. 11032–11050, 2013.

[23] R. M. Aileni, G. Suciu, V. Suciu, S. Pasca, and R. Strungaru, "Health monitoring using wearable technologies and cognitive radio for IoT," in *Cognitive Radio, Mobile*

Communications and Wireless Networks, Springer, 2019, pp. 143–165.

[24] E. Fasolo, M. Rossi, J. Widmer, and M. Zorzi, "In-network aggregation techniques for wireless sensor networks: a survey," *IEEE Wirel. Commun.*, vol. 14, no. 2, pp. 70–87, 2007.

[25] Z. Yan, V. Subbaraju, D. Chakraborty, A. Misra, and K. Aberer, "Energy-efficient continuous activity recognition on mobile phones: An activity-adaptive approach," in *2012 16th international symposium on wearable computers*, 2012, pp. 17–24.

[26] S. Wang *et al.*, "Energy efficient broadcasting using network coding aware protocol in wireless ad hoc network," in *2011 IEEE International Conference on Communications (ICC)*, 2011, pp. 1–5.

[27] N. Kimura and S. Latifi, "A survey on data compression in wireless sensor networks," in *International Conference on Information Technology: Coding and Computing (ITCC'05)-Volume II*, 2005, vol. 2, pp. 8–13.

[28] R. de Paz Alberola and D. Pesch, "Duty cycle learning algorithm (DCLA) for IEEE 802.15. 4 beacon-enabled wireless sensor networks," *Ad Hoc Networks*, vol. 10, no. 4, pp. 664–679, 2012.

[29] R. C. Carrano, D. Passos, L. C. S. Magalhaes, and C. V. N. Albuquerque, "Survey and taxonomy of duty cycling mechanisms in wireless sensor networks," *IEEE Commun. Surv. Tutorials*, vol. 16, no. 1, pp. 181–194, 2013.

[30] H. Ba, I. Demirkol, and W. Heinzelman, "Passive wake-up radios: From devices to applications," *Ad hoc networks*, vol. 11, no. 8, pp. 2605–2621, 2013.

[31] S. Misra, M. P. Kumar, and M. S. Obaidat, "Connectivity preserving localized coverage

algorithm for area monitoring using wireless sensor networks," *Comput. Commun.*, vol. 34, no. 12, pp. 1484–1496, 2011.

[32] E. Karasabun, I. Korpeoglu, and C. Aykanat, "Active node determination for correlated data gathering in wireless sensor networks," *Comput. Networks*, vol. 57, no. 5, pp. 1124–1138, 2013.

[33] D. Kumar, T. C. Aseri, and R. Patel, "EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks," *Comput. Commun.*, vol. 32, no. 4, pp. 662–667, 2009.

[34] H. Li, Y. Liu, W. Chen, W. Jia, B. Li, and J. Xiong, "COCA: Constructing optimal clustering architecture to maximize sensor network lifetime," *Comput. Commun.*, vol. 36, no. 3, pp. 256–268, 2013.

[35] A. Liu, J. Ren, X. Li, Z. Chen, and X. S. Shen, "Design principles and improvement of cost function based energy aware routing algorithms for wireless sensor networks," *Comput. Networks*, vol. 56, no. 7, pp. 1951–1967, 2012.

[36] Z. Wang, E. Bulut, and B. K. Szymanski, "Energy efficient collision aware multipath routing for wireless sensor networks," in *2009 IEEE International Conference on Communications*, 2009, pp. 1–5.

[37] M. Radi, B. Dezfouli, K. A. Bakar, and M. Lee, "Multipath routing in wireless sensor networks: survey and research challenges," *sensors*, vol. 12, no. 1, pp. 650–685, 2012.

[38] S. Misra, N. E. Majd, and H. Huang, "Constrained relay node placement in energy harvesting wireless sensor networks," in *2011 IEEE Eighth International Conference on*

Mobile Ad-Hoc and Sensor Systems, 2011, pp. 25–34.

[39] D. R. Dandekar and P. R. Deshmukh, “Energy balancing multiple sink optimal deployment in multi-hop wireless sensor networks,” in *2013 3rd IEEE International Advance Computing Conference (IACC)*, 2013, pp. 408–412.

[40] W. Liang, J. Luo, and X. Xu, “Prolonging network lifetime via a controlled mobile sink in wireless sensor networks,” in *2010 IEEE global telecommunications conference GLOBECOM 2010*, 2010, pp. 1–6.

[41] R. Sugihara and R. K. Gupta, *Optimizing energy-latency trade-off in sensor networks with controlled mobility*. IEEE, 2009.

[42] P. Nintanavongsa, M. Y. Naderi, and K. R. Chowdhury, “Medium access control protocol design for sensors powered by wireless energy transfer,” in *2013 Proceedings IEEE INFOCOM*, 2013, pp. 150–154.

[43] K. Tutuncuoglu and A. Yener, “Communicating using an energy harvesting transmitter: Optimum policies under energy storage losses,” *arXiv Prepr. arXiv1208.6273*, 2012.

[44] L. Xie, Y. Shi, Y. T. Hou, and A. Lou, “Wireless power transfer and applications to sensor networks,” *IEEE Wirel. Commun.*, vol. 20, no. 4, pp. 140–145, 2013.

[45] K. Kaushik *et al.*, “Experimental demonstration of multi-hop RF energy transfer,” in *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, 2013, pp. 538–542.

[46] M. Dohler, T. Watteyne, T. Winter, and D. Barthel, “Routing requirements for urban low-power and lossy networks,” in *RFC 5548*, 2009.

[47] Z. Manap, B. M. Ali, C. K. Ng, N. K. Noordin, and A. Sali, “A review on hierarchical routing protocols for wireless sensor networks,” *Wirel. Pers. Commun.*, vol. 72, no. 2, pp. 1077–1104, 2013.

[48] J. Martocci, P. De Mil, N. Riou, and W. Vermeylen, “Building automation routing requirements in low-power and lossy networks,” in *Internet Engineering Task Force (IETF)*, 2010, pp. 27-pages.

[49] A. Woo, S. Madden, and R. Govindan, “Networking support for query processing in sensor networks,” *Commun. ACM*, vol. 47, no. 6, pp. 47–52, 2004.

[50] S. R. Madden, M. J. Franklin, J. M. Hellerstein, and W. Hong, “TinyDB: An acquisitional query processing system for sensor networks,” *ACM Trans. database Syst.*, vol. 30, no. 1, pp. 122–173, 2005.

[51] S. Madden, M. J. Franklin, J. M. Hellerstein, and W. Hong, “TAG: A tiny aggregation service for ad-hoc sensor networks,” *ACM SIGOPS Oper. Syst. Rev.*, vol. 36, no. SI, pp. 131–146, 2002.

[52] N. Sadagopan, M. Singh, and B. Krishnamachari, “Decentralized utility-based sensor network design,” *Mob. Networks Appl.*, vol. 11, no. 3, pp. 341–350, 2006.

[53] J. N. Al-Karaki and A. E. Kamal, “Routing techniques in wireless sensor networks: a survey,” *IEEE Wirel. Commun.*, vol. 11, no. 6, pp. 6–28, 2004.

[54] L. Zhao, G. Liu, J. Chen, and Z. Zhang, “Flooding and directed diffusion routing algorithm in wireless sensor networks,” in *2009 Ninth International Conference on Hybrid Intelligent Systems*, 2009, vol. 2, pp. 235–239.

[55] F. Bouabdallah, N. Bouabdallah, and R. Boutaba, “On balancing energy consumption in wireless sensor networks,” *IEEE Trans. Veh. Technol.*, vol. 58, no. 6, pp. 2909–2924, 2008.

[56] X. Wang, C. Che, and L. Li, “Reliable multi-path routing protocol in wireless sensor networks,” in *Proceedings of the 2010 International Conference on Parallel and Distributed Computing, Applications and Technologies*, 2010, pp. 289–294.

[57] O. Gaddour and A. Koubâa, “RPL in a nutshell: A survey,” *Comput. Networks*, vol. 56, no. 14, pp. 3163–3178, 2012.

[58] L. Shu, Y. Zhang, L. T. Yang, Y. Wang, M. Hauswirth, and N. Xiong, “TPGF: geographic routing in wireless multimedia sensor networks,” *Telecommun. Syst.*, vol. 44, no. 1, pp. 79–95, 2010.

[59] E. Felemban, C.-G. Lee, and E. Ekici, “MMSPEED: multipath Multi-SPEED protocol for QoS guarantee of reliability and. Timeliness in wireless sensor networks,” *IEEE Trans. Mob. Comput.*, vol. 5, no. 6, pp. 738–754, 2006.

[60] S. Kim, “An ant-based multipath routing algorithm for QoS aware mobile ad-hoc networks,” *Wirel. Pers. Commun.*, vol. 66, no. 4, pp. 739–749, 2012.

[61] S. Pi and B. Sun, “Fuzzy controllers based multipath routing algorithm in MANET,” *Phys. Procedia*, vol. 24, pp. 1178–1185, 2012.

[62] P. V. Krishna, V. Saritha, G. Vedha, A. Bhiwal, and A. S. Chawla, “Quality-of-service-enabled ant colony-based multipath routing for mobile ad hoc networks,” *IET Commun.*, vol. 6, no. 1, pp. 76–83, 2012.

[63] B. C. Villaverde, S. Rea, and D. Pesch, “InRout–A QoS aware route selection algorithm for

industrial wireless sensor networks," *Ad Hoc Networks*, vol. 10, no. 3, pp. 458–478, 2012.

[64] N. Tuah and M. Ismail, "Extending lifetime of heterogenous wireless sensor network using relay node selection," in *2013 International Conference of Information and Communication Technology (ICoICT)*, 2013, pp. 17–21.

[65] Y.-J. Chu *et al.*, "Application of load-balanced tree routing algorithm with dynamic modification to centralized wireless sensor networks," in *SENSORS, 2009 IEEE*, 2009, pp. 1392–1395.

[66] I. Stojmenovic, *Handbook of sensor networks: algorithms and architectures*, vol. 49. John Wiley & Sons, 2005.

[67] T. S. Rappaport, *Wireless communications: principles and practice*, vol. 2. prentice hall PTR New Jersey, 1996.