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Energy Efficient Clustering Algorithm for Indoor Wireless Sensor Networks using Grey Wolf Optimization

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Abstract – **Wireless sensor network (WSN) consists of large number of sensor nodes or devices that are distributed spatially and communicates using radio signals. These sensor nodes are usually placed in the geographical area to gather information from the surroundings. Once the sensor nodes are deployed they are typically unapproachable to the humans. Sensor nodes in WSN sense the data from the environment and send it to the base station or sink node where this data is analysed.**

Sensor nodes in WSN are powered with a battery. Sensor nodes consume the battery power mainly in the tasks like data transmission, data reception and sensing. Sometimes it is impractical to replace a battery in WSN because humans can't reach. Therefore once energy or computational resources are consumed, immediate recovery of these resources is a complex task so it is necessary to make use of battery power efficiently to increase the lifetime of the sensor nodes that will also increase the lifetime of the whole network. This paper is based on indoor wireless sensor networks, in conjunction with an appropriate management methodology that allows us to analyze and verify the behaviour of these wireless networks in an internal way. To make WSN energy efficient and to increase the lifetime of the network this paper presents an energy efficient clustering algorithm optimized by Grey Wolf Optimization (GWO). Performance of this approach is evaluated using certain evaluation parameters; Throughput and Network Lifetime.

Keywords – **GWO, SUN, WSN.**

I. Introduction

One issue that has arisen around the world is that of energy efficiency, that is, it refers to the intelligent consumption of energy because most of the energy sources are finite, and what is sought is to have a consumption responsible in the present so that future generations can continue to enjoy them. According to different studies carried out, a considerable increase in the demand for residential electricity is foreseen within the following decades, which is why our traditional electric networks will not be able to meet the requirements of the 21st century [1]. But there have been two major drawbacks for these energy management systems: the large number of residential homes without adequate automation systems that are efficient and the high cost of implementing them [2]. For this reason, for this type of energy management, changes will have to be made in terms of the way in which energy is supplied, and the shape of the energy market [3], which requires different types of networks, such as wireless sensor networks, in addition to different energy management systems within the intact homes. This article focuses on the implementation of these energy management systems using wireless sensor networks, which by maximizing coverage as a basis will allow better and more extensive services to users. It should be noted that this corresponds to the issue of smart grids, which through the use of smart meters, sensors and different actuators will allow obtaining more detailed information on the consumption of each residential area, and even obtain individual consumption of each of the electrical and electronic devices within a specific home, with which you can have a remote control of them [4]. We can also mention that wireless networks are currently playing a very important role in the improvement of technology and our quality of life, because they allow us to have a great freedom to communicate with the world at anytime and anywhere [5].

Due to the growing demand for electrical energy, different studies have been carried out and there are reports that buildings, both residential and commercial, have the highest degree of energy consumption, which equals at 72% of total consumption; In addition, it is worth mentioning that 30% of this energy supplied to residential buildings is wasted [6]. That is why different entities have begun to carry out studies in the field of home automation focused on optimization through energy management systems, which have been developed in recent years through smart grids [7]. Therefore, the researchers seek to have an energy efficiency,

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keeping track in real time of the different electrical devices, that is, a complete control of the state in which they are located, which can be turned on or off [6]. But to achieve this one of the main drawbacks is that the cost of the smart meters that are required for the collection of data in real time is very high, in addition to needing adequate maintenance systems. For this reason, the issue of optimization is important, both in access points and in the different installed equipment, such as sensors in the case of wireless sensor networks. In addition, one of the main goals of this type of technology is the provision of intelligence to electricity grid systems; with this we mean that they will allow offering new services, with which it will be possible to have a more robust system from the point of view of generation, transmission and distribution of energy [8], [9]. It seeks to implement an interactivity between distributors and consumers, which can be both residential and commercial. Renewable energy sources also play a very important role in the vision of the future and of the new energy matrices, where this excess of energy produced by these types of sources can be marketed for re-use. That is, what is sought in the future with the implementation of these new technologies is intelligent networks capable of acting and making decisions, networks that are friendly to the environment and interactive with consumers [8].

Intelligent network systems are based on the support and transmission of data, in addition to the flow of control under the concept of bidirectionality [10]. Most of these works carried out through intelligent networks and wireless sensor networks are focused on controlling the load of the system, taking data in real time in order to control the different equipment or loads [11]. These networks are considered intelligent because they are sophisticated systems, which are responsible for connecting distributed energy networks; In addition, using protocols and measuring instruments, we have real-time monitoring. That is, these networks interact in real time, directly with customers, collecting the information obtained regarding energy consumption and this information is sent to monitoring centers or public service centers [12].

The evolution of technology has progressed in such a way that it can include advanced intelligence, and not only can this type of technology be included in electrical systems, but also in public service systems such as water and wastewater. So, this technology implemented in the different systems will have adaptive capabilities for both detection and control [13]. These systems will help to improve the efficiency and reliability in a considerable way, since, as mentioned, they are systems with advanced intelligence, which will be able to analyze different situations that arise. In addition, they will be able to make decisions and respond appropriately to different situations that may arise, such as anomalies or failures, that is, these systems will be able to respond based on previously realized algorithmic models [13]. This leads to another issue that has been emerging little by little, which is networks of public services, which are also known as Smart Utility Network (SUN), which seeks to implement a considerable improvement in the technology to carry out better management of services public affairs; they basically look for efficiency [13].

As main background it should be mentioned that the exploration of wireless sensor networks has been carried out little by little, until reaching the point of developing this technology to be implemented in different applications and in different fields, such as the detection of objects, in Monitoring systems, traffic management, intelligent transport, demand management, and even some of them have become critical, as is the case of surveillance applications and others that have been applied in security and safety environmental monitoring [14], [15].

Although very advanced signal processing algorithms exist and have been adopted by wireless sensor signals, most analytical studies on the coverage of these networks are carried out in excessively simplistic models, as is the case of the disk model, which does not capture the stochastic nature of detection [16]. This disk model has been analyzed several times and its limitations in obtaining optimal results has been understood and it has provided key information for the design of wireless sensor networks that in some cases have come to adopt something- rates of data fusion [14]. While on the other hand studies have been carried out taking into account the problem of coverage in the wireless networks of sensors, which is similar to some computational geometry problems. For this reason, due to its special geometrical properties, the Voronoi algorithm has been used in this field of wireless sensor network research, especially in the problems related to the coverage of the sensors. Some authors have come to use this algorithm to propose repair methods based on triangular mesh models [17]. In addition, with the implementation of this algorithm some of the problems related to coverage have been solved, that is to say, it is possible to obtain a fairly good coverage of the senders. However, there is little research on each Voronoi polygon, formed by the corresponding points to maximize coverage [17].

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WSN consist of large number of sensor nodes that are deployed in the environment and are powered by battery and replacing the battery of each and every node in the sensor network is impractical so it is necessary to make use of this limited energy efficiently therefore an energy efficient algorithm has to be designed. The nodes in the WSN are distributed spatially and to send the sensed data to the base station or sink node needs multi-hop communication when the base station or sink is not in range so the number of intermediate nodes are required to send this sensed data to the desired destination which consumes more energy of the network because all the intermediate nodes forward the data coming from their neighbour and to do this job they consume energy and this motivate us to reduce the number of hops and intermediate nodes taking part in transmission of data by using clustering algorithm in which the nodes are grouped into clusters and each node in cluster send data only to their concerned cluster head which is then aggregate all the data coming from the member nodes and send it to the sink or base station.

The energy efficient nature, data aggregation, load balancing, and improved network lifetime of hierarchical cluster based routing motivate us to use them for this research. These parameters are centralized or distributed depends on the process of selecting cluster heads. The location of every node in the cluster and their residual energy are used to make decision for selecting one of them as a cluster head using some clustering protocols. Most of the protocols are chain based protocol in which each node communicates only with its previous and next neighbour and reduces the number of communicating nodes which helps in reducing energy consumption.

Although there is a drawback of using fixed cluster head because all the data of member nodes are routed through the cluster head which lead to higher energy consumption at cluster head and due to this reason they die soon but it also improves the life time of the network. Increasing the size of cluster head or providing more power as compared to the member node will increase their lifetime. Hence to increase the lifetime of the network and to make it energy efficient the best approach is hierarchical based clustering. This paper presents an efficient clustering algorithm for Indoor Wireless Sensor Networks [18] optimized by Grey Wolf Optimization (GWO) algorithm.

II. PROPOSED METHOD

A. Method of Cluster Head Election

The threshold formula given by Qian Liao et al. [19] is:

$$T(n) = \frac{p}{1-p^*\left(r\bmod\frac{1}{p}\right)} * \frac{E_{cur}}{E_0} \qquad (1)$$

Where, E_0 and E_{cur} represent initial energy and current energy of the node respectively. The improvement in proposed protocol takes place using the increment in probability of high energy nodes, by which the nodes turn into the cluster-head. Although, this process causes an issue. The threshold $T(n)$ turn out to be small if the residual energy becomes very low resulting a reduction in nodes of the network. It will results the early death of nodes and finally the network lifetime will be less. Also, the threshold formula in equation (1) does not contains any impact of the distance between base station and nodes for cluster-head election.

Then the improvement in threshold is given as:

$$T(n) = \begin{cases} f(E_{cur}) * \left[\dfrac{(1-\alpha)p}{1-p^*\left(r\bmod\dfrac{1}{p}\right)} + \alpha p^* h(D_{toBS})\right] & n\epsilon G \\ 0 & n \notin G \end{cases} \qquad (2)$$

Where, $f(E_{cur})$ is the function related to the current residual energy of the node. It shows the impact of node energy on the election probability. It is given by:

$$f(E_{cur}) = \frac{E_{cur}}{E_{ave}} \qquad (3)$$

E_{ave} is the average residual energy of entire nodes in the current round.

In generalized protocol, the optimal cluster-head are selected by normal nodes and the communication takes place between base station and nodes. While the proposed protocol calculates the distance between base station and normal node. If it is found to be minimum then there is no selection takes place for cluster head which causes a direction transmission of controlling packages to the base station and data transmission occurs.

B. Optimized Cluster Head Election using Grey Wolf Optimization

Let n_{alive} represents the number of alive nodes with residual energy greater then the threshold energy and p be the clusterhead election probability, then the optimum number of CH elected for a given round will be:

$$P_{opt} = n_{alive} * p \qquad (4)$$

Here P_{opt} is optimized using Grey Wolf Optimization which is described as:

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1) Grey Wolf Optimization (GWO)

The GWO algorithm simulates the natural behaviour of a mob of wolves to hunt its prey. Within the wolves different categories are distinguished as in a more forceful way in the search space. The pseudo-code is presented in GWO Algorithm. At the end of the execution, the best individual is going to be starts with a value of 2 and decrementing along the evaluations until they reach 0. They help the candidate solutions, moving them in the search space. The key to the algorithm is found in the function *updateposition*(..) (See line no.8 of GWO Algorithm) which is defined as [20]:

$$\vec{X}_{li} = \frac{\vec{X}_1+\vec{X}_2+\vec{X}_3}{3} \quad (5)$$

Where each $\vec{X}_1$, $\vec{X}_2$ and $\vec{X}_3$ is obtained as follows:

$$\vec{X}_1 = |\vec{x}_\alpha - \vec{A}_\alpha * \vec{D}_\alpha|, \quad \vec{X}_2 = |\vec{x}_\beta - \vec{A}_\beta * \vec{D}_\beta|, \quad \vec{X}_3 = |\vec{x}_\delta - \vec{A}_\delta * \vec{D}_\delta| \quad (6)$$

To determine $\vec{D}_\alpha$, $\vec{D}_\beta$ and $\vec{D}_\delta$, used in equation (6), the following formulas are used:

$$\vec{D}_\alpha = |\vec{C}_1.\vec{X}_\alpha - \vec{X}|, \quad \vec{D}_\beta = |\vec{C}_2.\vec{X}_\beta - \vec{X}|, \quad \vec{D}_\delta = |\vec{C}_3.\vec{X}_\delta - \vec{X}| \quad (7)$$

2) GWO Algorithm

1. generate (X) / / Initialize the population of grey wolves
2. initialize Parameter (a, A, C);
3. evaluate X (0);
4. select new (Alpha, Beta, Delta, X (0));
5. for e = 1 to EVALMAX to do
6. for every Wolf l in Omega do
7. for i = 0 to DIM do
8. updatePosition (l, i); // Update current position
9. end for
10. adjust parameters (a, A, c); // adjust the algorithm parameters
11. evaluate X (e + 1);
12. select new (Alpha, Beta, Delta, X (e + 1));
13. e = e + 1;
14. end for
15. end for

III. Simulation And Results

A. Evaluation Parameters

1) Throughput

It is the ratio of the total number of successful packets in bits received at destination in a specified amount of time.

$$\text{TH} = \sum \text{Transmission of Routing Packets}$$

2) Network Lifetime

The lifetime in a WSN is the time period throughout which the system constantly justifies the provision necessity.

3) Simulation Results

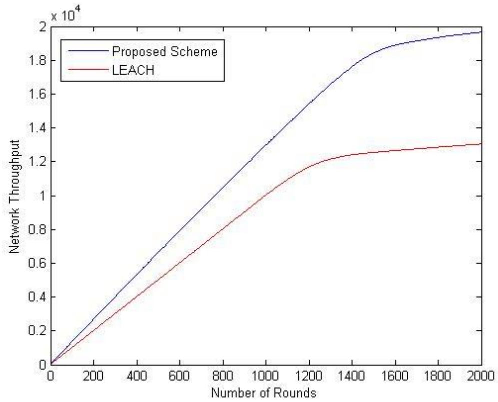

Figure 1: Network throughput comparison for proposed algorithm

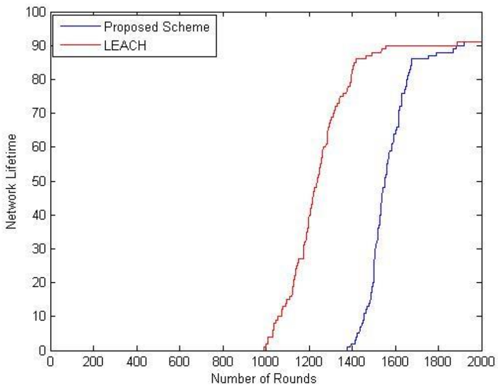

Figure 2: Network lifetime comparison for proposed algorithm

IV. Conclusion

In this paper, we have improved the existing state of proposed clustering algorithm, particularly concerning their power and reliability quality necessities. In wireless sensor networks, the energy limits of nodes assume a pivotal part in planning any protocol for execution. Moreover, Quality of Service measurements, for example, delay, data loss tolerance, and network lifetime uncover dependability issues when designing recovery mechanism for clustering methods. These paramount characteristics are regularly contradicted, as one frequently has a negative effect on the other.

We have implemented an energy efficient clustering algorithm for Indoor Wireless Sensor Networks optimized by Grey Wolf Optimization (GWO) for heterogeneous WSNs containing different level of heterogeneity. Simulation results show best

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performance in terms of throughput and network life time.

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