Lifetime Maximization Using Grey Wolf Optimization Routing Protocol with Statistical Technique in WSNs

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The main challenge in Wireless Sensor Networks (WSNs) is to maximize the lifespan of sensor nodes powered by low-cost batteries with limited power. Energy conservation is crucial, and routing mechanisms play a vital role in preserving energy. Energy-efficient routing methods can save battery power and extend the network's lifespan. This study introduces the Grey Wolf Optimization Routing Protocol (GWORP), enhanced with a novel routing mechanism that detects the statistically optimal path. It enables the discovery and reuse of an ideal route from the source to the destination, ensuring balanced energy consumption across WSN nodes and reducing path discovery time. GWORP outperforms the PSORP (Particle Swarm Optimization Routing Protocol) algorithm, significantly reducing energy usage and minimizing end-to-end latency. The findings suggest that GWORP could potentially increase the network lifespan by approximately 73% compared to PSORP.

Povzetek: Namen raziskave je bila primerjava energijske učinkovitosti protokola GWORP z algoritmom PSORP v brezžičnih senzorskih omrežjih.

1 Introduction

Wireless Sensor Networks (WSNs), have a pivotal role in the endeavors taken to build and deploy systems attempts to achieve the mentioned objectives of the Internet of things (IoT**)**. They are formed by many small sensor devices that have wireless transceivers in each of them. WSNs are built without infrastructure and they can self-configure themselves to accommodate some changes. WSN technologies enabled pervasive sensing that covers many areas of modern life. This makes it possible to measure, infer and understand the indicators of an environment, from tiny objects and natural resources to civil environments[1],[2]. The growing number of these devices in a network of communication and actuation results in the creation of IoT, where sensors and actuators are integrated with the surrounding environment conveniently. A WSN consists of a large number of sensor nodes that are scattered in a dense form in an area of interest to monitor the changes in one or more physical phenomena[3]. The network can include different sensors with different tasks such as temperature sensors, pressure sensors, humidity sensors, movement sensors, etc. These sensors gather data relevant to the measurements of specified physical phenomena and process the sensed data in the network before the eventual data collection which is made by a central unit called a sink or base station[4]. The sensed data can be transmitted cooperatively toward the sink through a series of nodes (hops) called multi-hop data transmission. In multi-hop communication, sensors send their data or forward data on behalf of another sensor to deliver the data to the sink for further processing and analysis[5]. Therefore, various applications of WSNs are witnessed including monitoring (environments monitoring, earthquake monitoring, etc.), control (detection and tracking of objects), and surveillance (battlegrounds observation)[6],[7].

Table 1: Summarization table on the related works.

Ref	Methodology	Performance/Results
[16]	• Two-tiered heterogeneous sensor network	• The authors analyzed a two-tiered heterogeneous sensor network, where sensors are organized into clusters with a high-power head sensor controlling the cluster's low-power sensors. Instead of letting sensors broadcast data at random, they polled them to gather data and save power. They also improved the network's longevity by introducing two new techniques: sectorizing clusters and using multiple frequency channels.
[20]	• ant colony optimization	• Goal of was to optimize the lifespan of heterogeneous WSNs using an ant colony optimization technique. The strategy relies on discovering the largest possible set of disconnected covers that simultaneously meet sensing coverage and network connection requirements.
[21]	• Fuzzy Logic	• The presented new algorithms for the routing of data packets in WSNs. These algorithms make use of Fuzzy Logic (FL) to decide which node is the best to be included in the routing path out of a set of evaluated nodes in order to enhance the lifetime of the wireless sensor network.
[23]	• Yellow Saddle Goatfish Algorithm	• new energy-efficient clustering routing on the basis of the Yellow Saddle Goatfish Algorithm (YSGA), is suggested. The protocol is designed to lengthen the lifespan of a network by lowering its energy usage. In its cluster structure, the network considers a base station and a set of cluster heads. The YSGA method determines the number of cluster heads and the appropriate selection of cluster heads, while sensor nodes are allocated to their closest cluster head. YSGA reconfigures the network's cluster structure to achieve an appropriate distribution of cluster heads and decrease transmission distance.
[5]	• clustering technology	• Offers an energy-efficient routing protocol that utilizes uneven clustering technology to handle the issue of hot spots and a double cluster head method to minimize the energy consumption of cluster heads. In addition, to balance the energy consumption between cluster heads and cluster members, a hybrid time-driven and energy-driven cluster head rotation technique is presented.
[24]	• UWSNs	• the authors suggest a novel routing protocol for the ocean floor that integrates two-dimensional UWSNs with sleep-scheduling routing to detect and report oil traces to the sink as soon as possible.
[25]	• K-NN	• By combining the K-NN algorithm with the clustering technique, the authors of suggest a new routing strategy that may significantly cut down on both latency and power consumption throughout the whole network. This proposal shows how to create clusters using node classifications and the shortest possible distances between them
[26]	• Balanced Routing Protocol	• To lessen the burden on battery life, the inventors of introduced a novel balanced routing method that uses two independent channels. To alleviate network congestion, this proposal provides each node with two shortest pathways to the sink.
[12]	• clustering HWSNs	• An innovative method for clustering HWSNs was reported by the authors, which included an effective method for choosing the cluster's head nodes, the cluster's degree of sensor nodes, and the cluster's remaining energy. The information package is collected and sent using the chaining method as well.
[27]	• Grey Wolf Optimizer	• The presents a revolutionary energy-efficient procedure based on an enhanced Grey Wolf Optimizer (GWO). It considers a fitness value to enhance the optimum solution finding in GWO, resulting in a more equitable distribution of CHs and a more balanced cluster structure. To decrease energy usage, sensor node transmission distances are updated based on the distance to the CHs and the sink.
[28]	• PSO	• The presents a PSO (Particle Swarm Optimization)-based multi-hop routing protocol for uneven dynamic clustering (PUDCRP). In the PUDCRP protocol, the cluster distribution will vary dynamically as nodes fail. The PSO technique is used to identify the location of prospective CHs nodes.

Energy is very limited in WSNs as nodes derive their energy from small-inexpensive batteries with low power capacity. In most cases, these batteries are not rechargeable and irreplaceable due to the harsh conditions and inaccessibility of the deployment area. Thus, conserving the available energy for the longest possible time is the most important challenge to maximizing the lifetime of WSNs. To optimize energy consumption, energy-saving strategies are indispensable in all aspects of the design and operation of WSNs. In this regard, many routing protocols that offer lifetime enhancement have been developed for WSNs because a remarkable amount of energy is drained by communication[8]. The purpose of energy-aware routing methods is to reduce energy consumption in the whole network. This can be achieved by considering different aspects, including 1) Lessening the total energy exhaustion in the network, 2) Decreasing the amount (or the distance) of wireless data transmission, 3) Keeping the maximum possible number of live nodes to achieve a better lifetime, and 4) Equally distributing energy consumption over the nodes in the network to prevent premature network breakdown caused by certain sensors that become out of energy. Once the limited energy is drained out, nodes will stop working and be called "died". In such a case, the network may not finish its assigned mission or not work to its full potential. Therefore, the network lifetime is an essential factor when evaluating the efficacy of routing methods[9]. Time-sensitive applications, such as voice-over IP and other communications, are increasingly using computer networks. QoS is useful in computer networks because it simplifies performance evaluation and provides tools for optimizing a network's operation. Therefore, it is critical for both network users and network service providers to have a firm grasp on the QoS provided by networks to evaluate the degree to which the transmission needs of various applications are met and to put in place enhancements to the network's performance[10].

To meet stringent network requirements, the next generation of monitoring systems will need to do more than just detect a drop in network performance immediately; they will also need to identify the root cause of quality of service issues. As a workaround, we propose a novel fuzzy logic-based approach. Network performance indicators such as latency, jitter, and packet loss were used to draw comparisons between the suggested method and others. Even though PNN and Bayesian did a good job, the fuzzy technique was more accurate in classifying the QoS categories. Accurately assessing the network's QoS leads to a deeper understanding of its performance[2],[11].

Usually, in many data routing methods, an optimal path is constructed for data forwarding from the sender node to the sink. If the same founded path is used for data forwarding over and over aiming at fast data transmission, then sensors involved in that routing path will exhaust their energy in a fast manner. The disadvantage of these routing techniques is that they reduce the overall energy drainage in the wireless network to the detriment of uneven energy consumption in the network. These algorithms result in network partition problems (i.e., two or more parts of the network become unreachable to each other) after particular sensor nodes run out of their battery capacity. This phenomenon may impair the usefulness and effectiveness of the whole network. Additionally, using complex algorithms for routing may reduce energy consumption, but this can produce much processing delay[12],[13]. Table 1, shows the Summarization of the Related Works.

This paper analyzes algorithms and approaches designed exclusively for WSNs, resulting in not only a separate categorization, assessment, and debate on diverse application areas, but also a diversity of solution alternatives. The objective is to determine how data routing methods will be utilized to construct sensor network applications intelligently. The remaining sections are grouped as follows: In the second part, is the organization of a heterogeneous network. In the third part, the proposed model, with an emphasis on the need and significance of the model. In the fourth part, parameters for the network simulation are presented, along with the results of the suggested method. In the last part, a summary of the research is offered.

2 Organization of network

The organization of a heterogeneous network requires the usage of both S-sensors and CH-sensors. The S-sensors stand in for the basic sensors, whereas the CH-sensors represent their leaders. Distributed deployment of a high number of typical sensors (S-sensors) is required for an HWSN. Additionally, the network has many sensor nodes that may act as cluster leaders (CH-sensors). Here, the CH must be deployed cautiously, taking into account the calculation of the distance between the sensor and the cluster head and the sink, to ensure that all S-sensors are secure and can be linked to at least one CH. Clustering techniques are utilized in homogeneous WSNs [14], [15] and heterogeneous HWSNs [16], [17]. In this configuration, CH-sensors transmit messages that identify themselves by cluster and precise position. A first-place finish goes to the CH-sensor with the smallest ID number. The S-sensors rank the strength of each received signal and create an ordered list of the CH-sensors they've heard, beginning with the strongest. From this point forward, each S-sensor will provide CH-sensor preference as its preferred CH-sensor as it is a potential contender. Afterward, CH-sensor moves forward with selecting S-sensors for clustering. No matter how big or little a cluster is, it will be treated the same. As part of this coordination, we check that each of the basic sensors has a working connection to the cluster's central node.

In Figure 1 we can see the clustering mechanism that is used by the method for HWSNs.

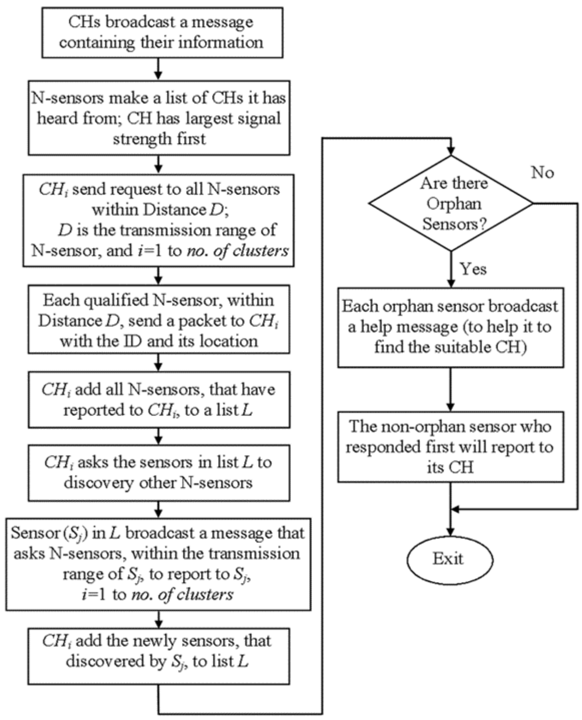

Figure. 1: Clustering method flow-chart

3 Proposed model

Over a long period, it used to be thought that deterministic approaches had the lead in the field of optimization due to their regularity and clearness. Optimization techniques like gradient-based algorithms or linear programming were easy to understand and implement since it was built up relying on common mathematical methods such as directional derivatives. However, harder real-world problems were continuously appearing in the last three decades which made the optimization techniques move toward the idea of randomness, which is adopted by the met heuristic techniques.

A met heuristic is a subfield of stochastic optimization that deals with optimization algorithms by randomly deploying intelligent populations in the search space of a function. The core principle of met heuristic algorithms is to implement an iterative generation procedure that guides the exploration and exploitation of the search space for discovering the optimal solution of complicated functions. During the last few decades, there have been substantial progress and invention of approximation solution met heuristic algorithms because they are fixable, simple, free-gradient approaches, and local optima avoidable. Various met heuristic methods have been proposed as mentioned earlier in this chapter. On the other hand, Ethology is referred to the science that studies the behaviors of biological creatures in nature, and thus, ethology has influenced the invention of a met heuristic group of methods known as swarm intelligence (SI)

SI refers to a wide variety of nature-inspired algorithms that mostly originate from the behaviors of natural herds, flocks, schools, and colonies. Compared with other classes of algorithms, those algorithms have the upper hand. For instance, they do not discard any information related to the search space along with their ability to store the best solution to obtain so far by utilizing memory; furthermore, they have fewer operators and fewer adjustable parameters. Moreover, they are characterized by robustness, flexibility, and self-organization.

GWO has been proposed by S. Mirjalili et al., 2014, [18], is a recently developed SI optimization method that impersonates the grey wolf hunting style in nature and the hierarchy of leadership in their community. Grey wolves usually prefer to live in a pack with a group size between (5...12) on average. In a pack, wolves have a very rigorous social hierarchy consisting of four categories of wolv0es which are alpha (α), beta (β), delta (δ), and omega (ω).

The main rule of high-class $\alpha\alpha$ wolves is decision-making about sleeping location, hunting, and wake-up time. The β grey wolves are the second level in the hierarchy which are subordinate wolves that help the alphas in their decision-making by sending commands to the lowest classes. The third class is the $\delta\delta$ wolves which contain sentinels, scouts, elders, and hunters. The lowest class is the ω which keeps the disputes out of the herd or be a babysitter, as shown Figure 2 of the proposed model.

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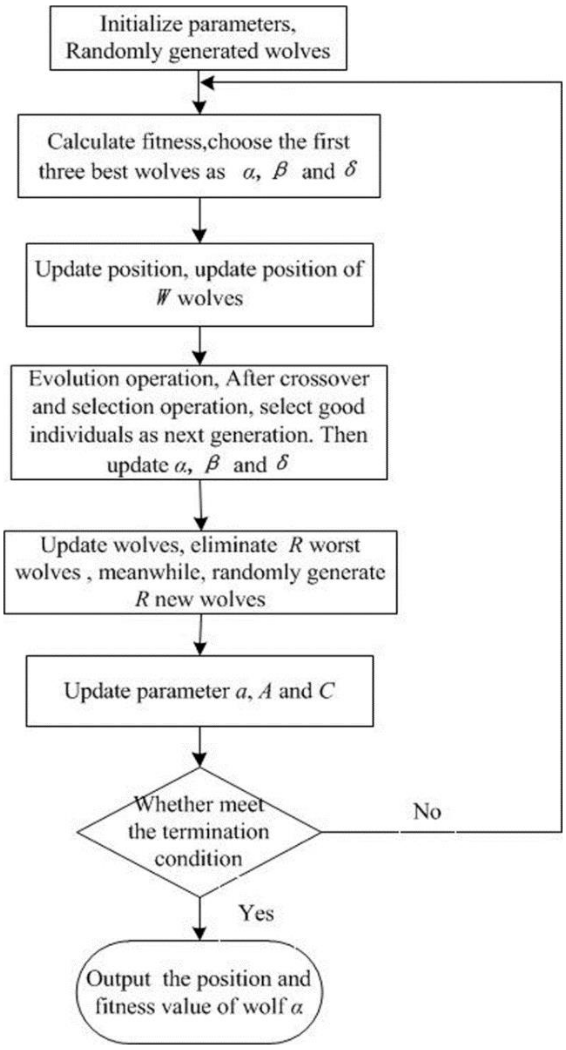

Figure 2: The proposed model.

Next, the evaluation step is performed by evaluating multiple paths simultaneously and selecting the best path. The purpose of the stride is to indicate the best or highest performance produced among the several paths. This step is very important because it has been difficult to analyze the performance of multiple pathways at different times. Thus, in this step, the statistical analysis of paired samples T-test is used to observe the multiple paths and indicate their best path. Statistical analysis of paired samples T-test is performed to test whether the results of metrics such as residual energy differ significantly according to the average of each metric according to the file to which it belongs. The null hypothesis is known as H_0 and indicates that there is no difference between the two measures based on the mean score, while H_1 is the alternative hypothesis which represents the difference between two outcomes from the mean measures. The rule can be simplified into two states so accept or reject. Acceptance and rejection depend on the p-value obtained in the statistical analysis where less than 0.05 indicates a sufficient difference between the means of the measures.

4. Evaluation of performance

The primary goal of this paper is to select an optimal path with detects the statistical best value. In this paper, we assume that many sensors send the events. Thus, the network is optimized by the select an optimal path in sensors. The simulation results for the proposed method are compared to the PSORP.

4.1 Simulation setting

Simulation processes are executed through the use of MATLAB because it provides powerful simulation and plotting tools in addition to a productive software environment. In this simulation, a WSN consists of one hundred sensor devices arbitrarily distributed over a square region that has an area of 10,000 m^2 (i.e., *100-meter* x *100-meter* dimensions). And each sensor is capable of wireless communication within a range of (*30 meters*). The simulated network has only one base station placed in the top-right corner of the area and its (*x, y*) coordinate is (*90 m, 90 m*). The initial energy amount of each sensor is (*0.5 joule*). Energy consumption amounts are calculated using the "*first order radio model*" which is frequently used to evaluate the efficiency of routing protocols and it is described in [19]. As demonstrated in this model, the energy amounts consumed by sending and receiving a data packet are ($E_{elec}*k+ E_{amp}*k*d^2$) and ($E_{elec}*k$) respectively. Where E_{elec} is the energy exhausted for each bit in the circuitries of data transmitting and receiving, E_{amp} is the energy needed per each bit to the amplifier to produce an appropriate signal/noise ratio (SNR), k is the number of bits contained within each packet (i.e., packet size) and d is the distance of wireless communication between sender and receiver sensors. The values assigned for E_{elec} is (*50 nJ/bit*) and for E_{amp} is (*100 nJ/bit/m*^{2}). The traffic load value specified to each node is an integer generated randomly within[1..10] value. Details of the parameters used in the simulations are given in Table 2.

Table 2. Simulations of the parameters

Parameter		Value
Area of topographical		100 m x 100 m
Location of the sink		(90, 90)
Length of control packets		2k
No.of transmission packets (rounds)		2 x 10^3
CH-sensors	Number of nodes	1000
	Limit of transmission distance	20 m
	Initial energy	0.5 J
	E_{elec}	50 nJ/bit
	E_{amp}	100 pJ/bit/m^2
	Max. traffic in node's queue	10

4.2 Simulation results

The life of WSN can be extended by using a select optimal path method with detects the statistical best value that has been optimized to increase energy efficiency. To see how well it worked, it was tested in The amount of power left in each sensor and the number of sensors that survive during each cycle, if the same routing metrics and the same environment were used in both. The network lifetime results obtained using two methods are compared by counting the number of sensors that remain alive after each data round. At this point, Figure 3 shows the proportion of sensors, which are still alive in each method. As a result, the performance of the proposed method outperforms the performance of PSORP. In light of this, we note that the amount of energy consumed in PSORP is larger compared to the proposed method based on the total number of nodes still alive in the network. Here, after sending (2000) packets to two sensors through the network, the network lifetime result achieved in the proposed method is about (73%) more than in PSORP.

The percentage of energy remaining in the sensors varies with the number of transfer cycles depending on the system used. The GWORP outperforms the PSORP method in terms of overall performance and efficiency.

Figure 4 shows how the percentage of residual power for the sensors varies based on the transfer mode used. As you can see, the GWORP method is better than the PSORP by maintaining the stability of the network for as long as possible.

The comparison of simulation time among the two methods within the area of routing is shown in Figure.5. It is often seen that the method suggested has the shortest delay of time compared to the POSRP method. Moreover, Figure. 6 shows that the method suggested achieves a low end-to-end delay compared with POSRP. A shorter delay of time reveals both the energy-saving and the efficient transmission of information (especially important). In other words, packets of data are routed in a select optimal path method with detects the statistical best value that has been optimized to increase energy efficiency and extend the lifetime of the network.

5 Conclusion

WSNs consisted of many nodes. These nodes have restricted capabilities and functions. In addition, these nodes have limited storage capacities and limited communication y of nodes is restricted because of their limited storage capacity and limited communication. Due to the limits and limitations of WSNs, it is more difficult to directly optimize security methods. WSN is subject to several limitations. Energy limitation is the most important restriction in a WSN since the transmission of bits in a WSN requires a substantial amount of energy. Thus, energy conservation is an essential topic in WSNs. This paper offers the Grey Wolf Optimization Routing Protocol (GWORP), extended by using a select optimal path method with detects the statistically best value novel routing mechanism, to improve network efficiency and simulation in terms of power consumption, needed memory, and computing time. The results also suggest that GWORP may be able to extend the life of a network by roughly 73% compared to PSORP.

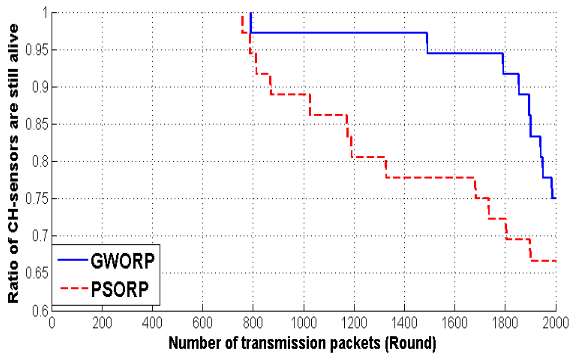

Figure 3 the proportion of sensors, which are still alive in each method

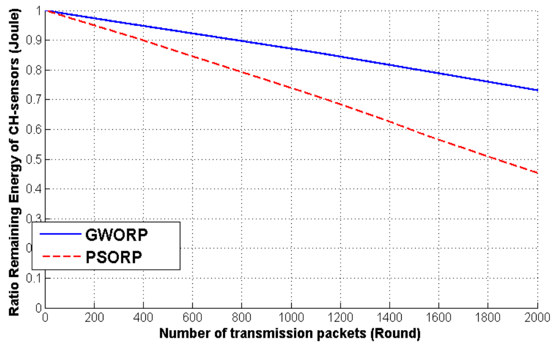

Figure 4. The energy ratio of the remaining sensors

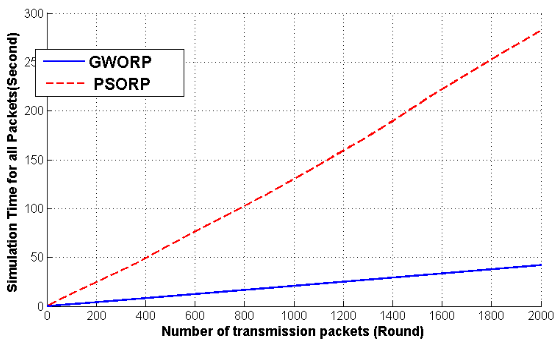

Figure.5 simulation time among the two methods

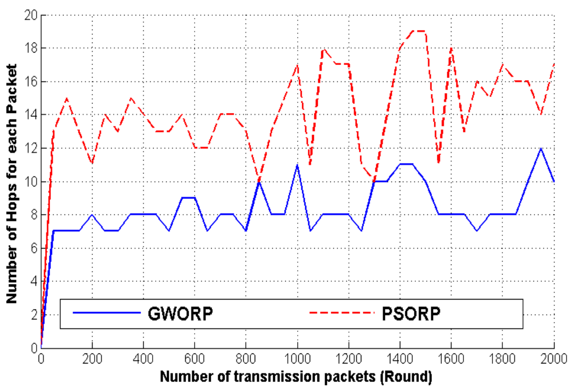

Figure. 6 new method achieves a low end-to-end delay

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