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An Optimal Simulated Annealing Approach for Energy Efficient Data Aggregation in Wireless Sensor Network

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Abstract: WSNs (Wireless Sensor Networks) are distinguished by their elements' low energies & thus useful protocols for better optimization are often important. WSN has important applications, like structural health monitoring, aim military monitoring, habitat monitoring, etc. Due to the availability of cheaper and smarter sensors, but with battery support, they have advanced. Heterogeneous WSNs can enhance network existence and have improved networking and service efficiency than homogenous WSNs. The research, therefore, proposes grid clustering & fuzzy-model-based scheme to optimize network lifetime and energy-efficient data aggregation for distributed WSN. Grid clustering is utilized for cluster formation as well as cluster head (CH) selection. A Fuzzy Sugeno Model is often used for select parameter-based data aggregator nodes, like neighborhood overlap, distance & algebraic connectivity. Eventually, the mobile sink's dynamic relocation is carried out using the simulated annealing algorithm inside the grid-based clustered network region. The experimental findings showed that the proposed data aggregation scheme offers superior energy efficiency and network life performance in contrast with earlier schemes.

Index Terms—Clustering, Heterogeneous WSN, Grid-based clustering, Fuzzy Sugeno, Simulated Annealing.

1.INTRODUCTION

Sensor nodes in WSNs are randomly arranged and connected by radio waves, optical, or infrared. To preserve energy, just a few additional sensors can connect directly with WSN sensors across short distances .Clustering algorithms and rotatable CH (Cluster Heads) to pass data to BS (Base Station) are also increasing living duration, in addition to the traditional approach for energy conservation [1,2]

Environmental monitoring is essential for the provision and regulation of significant disasters in the sensor network's remote regions. The best examples of environmental monitoring applications are as follows: Monitoring sediment flow in coastal areas [1], reviewing forest fires [2], monitoring industrial environmental conditions [3]-[5], forecasting volcano build-up [6],[7], and snowmelt predictions [8] are only a few examples. Temperature, pressure, and ambient vibrations can all be measured using various sensors. Modern sensors are tiny, portable, and compatible with wireless communication systems. When a fixed wired connection topology is not viable for environmental control applications, wireless networking is usually recommended. A Sensor Node (SN) is a device that collects sensory input, processes it, and communicates with other nodes. Individual sensor node data is not useful since wide-area monitoring fields are utilised to establish WSNs [10] for a large number of sensor nodes. The following is a summary of the rest of the work: Section II summarizes relevant papers and our additions; Section III provides a detailed explanation of a suggested algorithm; Section IV presents extensive simulation findings; and Section VI wraps up the paper.

2. RELATED WORK

In heterogeneous sensor networks with switchable data transmission status, this study describes an upgraded clustering protocol. When the perceived information strength reaches a specified level, CHs filter the data and begin data transfer, then send the data to the sink. If not, CHs keep track of the data gathered and begin collecting data from the next phase of cluster nodes. Fortunately, modeling findings show that the network's lifetime is many times longer than the LEACH protocol [11].

Smaragdakis G [12] proposes a heterogeneous network-routing sensor protocol called SEP (Stable Election Protocol) that extends a stable time span. This protocol establishes several thresholds for common and advanced nodes to become cluster chiefs. Depending on the weighted selection probability, the potential of two node shapes being CHs is determined. Based on simulation findings, the protocol will effectively increase network stable election time.

Rashid et al. [13] proposed a system that combines clustering and chain routing for energy efficiency and security. The protocol's creators built it based on a number of assumptions, including the presence of non-mobile nodes. Each node has the ability to send data to other nodes and the BS, and both nodes have the ability to regulate their power. Advanced nodes are higher-energy nodes, while normal nodes are lower-energy nodes. Specialized nodes become cluster chiefs more frequently than conventional nodes. The authors calculate the optimum probability by dividing the network node's initial energy (normal and advanced) by the normal node's beginning energy. This strategy can be used to choose the best CH. To create a chain with all CHs selected, a chain algorithm is used. All cluster members can transfer information to their respective CHs using the TDMA (Time Division Multiple Access) scheduling. This protocol outperforms LEACH, SEP, and HEARP in terms of security and longevity.

Clustering is one of the simplest ways to communicate effectively while also extending the life of a network by reducing energy consumption. WSNs will disperse and scatter several sensor nodes at random. In these networks, the resources of a network must function well. A heterogeneous WSN faces extra challenges in obtaining this efficiency since nodes may not be equally energy efficient [14]. For heterogeneous networks, several algorithms designed for this purpose are capable of successful clustering.

Kumar et al. [15] present the EEHC (Energy-Efficient Heterogeneous Clustering) scheme for distributing a CH in WSNs with hierarchical structures. In compared to many other nodes in the network, the likelihood of selection is determined by the node's residual energy. This method outperforms LEACH in terms of network lifetime.

For heterogeneous wireless sensor networks, Sahoo et al. [16] proposed an enhanced stable routing algorithm (ESRA) (HWSN). Incorporating the distance factor into the threshold formula improves CH selection. Energy consumption is lowered as a result, and the stability period is greatly extended. When compared to P-SEP and DSEP protocols, the stability period of ESRA is increased by 15.43 percent, 64.39 percent, and the network lifespan is increased by 30.95 percent, 73.16 percent, respectively, through simulation in MATLAB.

In this study [17], a hybrid technique called the Energy & Traffic-Aware Mechanism for Sleep-Awake (ETASA) is proposed for improving energy efficiency and load balancing in a heterogeneous WSN environment. Unlike earlier systems, the paired nodes in ETASA switch to and awaken according on the node's energy and traffic rate. Furthermore, typical TDMA scheduling has been altered in SEED, with one slot dedicated for pair groups in the cluster. To save energy, it is necessary to solve the problem of continuous listening.

The Energy & Traffic-Aware Mechanism for Sleep-Awake (ETASA) is a hybrid technique described in this paper [17] for increasing energy efficiency and load balancing in a heterogeneous WSN environment. Unlike previous systems, ETASA's paired nodes switch to and awaken based on the energy and traffic rate of each node. In addition, in SEED, standard TDMA scheduling has been changed, with one slot dedicated to pair groups in the cluster. It is vital to overcome the problem of constant listening in order to preserve energy.

The following is the remainder of the paper: A comparative analysis of state-of-the-art approaches is presented in Section 2. Section 3 discusses the theoretical foundations of the approaches used, whereas Section 4 describes the dataset used. Sections 5 and 6 provide the experimental data as well as a discussion of the findings. Section 7 brings the work to a close and outlines future research directions in stock market forecasting.

3. PROBLEM FRAMEWORK AND IMPLEMENTED METHODS

Fruit fly optimization was done using a 5000-round algorithm, but the algorithm's efficacy in the mobile sink network was not up to par. The grid clustering method and the fuzzy Sugeno model were used in this study to

develop an energy-efficient data aggregation method for optimizing network lifetime and DA for dispersed WSNs. Grid cell clusters are first built to achieve a robust data aggregation for the suggested system by separating the complete sensor n/w.
The tree structure will be generated between all obtainable nodes in the grid cell cluster area and will select CH for external data transfer. After that, the Fuzzy Sugeno model was used to choose data aggregator nodes. This algorithm considers three parameters, including CH distance, NOVER, and AC, while analysing individual aggregator nodes inside a tree-based grid cell cluster region.

Simulated annealing in the grid-clustered network region is also used to perform dynamic relocation of the mobile sink. When a path breakdown occurs, the mobile sink is introduced between CH nodes and mobile sink nodes to reduce the source to the endpoint for communication and provide alternate paths. The aggregator node is chosen and sent to the CH node in each cluster for data processing. Data transmission from the CH node to the mobile base station node is therefore reduced to a minimum.

3.1. SYSTEM MODEL

The proposed method includes over 100 (experimental data-selected) SNs, which are used based on the hierarchical setup of the gird-based system.
• All sensor nodes on the network are connected to a certain configuration and 2J of energy.
• Nodes are arranged in a grid in a hierarchical order.
• After implementation, the sink and all other nodes in this network are stationary and cannot move elsewhere on the network.
After all of the sensor nodes have been deployed, the sink node is added to the network. Create a grid-based clustering system and choose CH based on leftover energy. A fuzzy rule system is a model of a fuzzy algorithm that aids in the selection of the correct aggregator node.
For energy-efficient DA in highly distributed wireless sensor networks, the fuzzy Sugeno grid clustering approach is developed. Initially, the network region is separated into several grid clusters, and CH is assigned to each community based on the highest energy residual factor. To choose a precision DA node, the fuzzy rule approach is applied to three parameters: distance, neighbourhood overlap (NOVER), and algebraic connection (AC).

3.1 GRID CLUSTER FORMATION & CH ELECTION:

In every grid cell, a sink node is introduced, as well as the cluster architecture and CH selection procedure. Following the receipt of communications from the base station, the base station sends out a beacon to sensor nodes or clustered nodes. Sensor nodes or clustered nodes respond with position and energy level information. After collecting CH from SNs, only the sink node chooses CH based on the highest residual energy level factor.

Equation 1 is used to implement cluster head selection
1: CH = Distance * C1 + Energy * C2 (1)

3.3 DATA AGGREGATOR NODE SELECTION USING FUZZY SUGENO ALGORITHM:

The grid cluster's CH node is utilized to choose a data aggregator node. The CH distance and quality assessments of the links are seen as inputs by fuzzy systems such as AC and NOVER. NOVER is a well-known direct metric for assessing interlinks between related neighbors. IF-THEN rules and three metric functions based on the three-way membership function form are defined using the fuzzy-based approach.
A standard Sugeno fuzzy rule looks like this:
If x equals A and y equals B, z = f(x, y) (2)
In the foregoing, A 7 B are fuzzy sets, and z=f(x, y) is the crisp function
The mobile sink is dynamically shifted according to a simulated annealing optimization process. The level of duplicity in integrated data is reduced using Canberra's distance metric.

SIMULATED ANNEALING

Annealing

Annealing is a thermal method that provides a solid in a heat bath with low energy.
There are two stages in the process:

- Raise the heat bath temperature to the solid melts' optimum value.
- Shorten the temperature of the heat bath carefully before the particles are arranged themselves in the ground state of the solid. Ground State is the solid's minimum energy state.

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Only if the high temperature is enough and the cooling is achieved slowly is the solid ground state. to embrace moves that lower energy while only allowing bad moves based on the system's temperature' according to a probability distribution.
Distribution utilized to measure whether we accept bad movement is called Boltzman distribution.

$$P(\gamma) = \frac{e^{-E_\gamma/T}}{Z(T)} \qquad (3)$$

$$Z(T) = \sum_{\gamma'} e^{-E_{\gamma'}/T} \qquad (4)$$

This distribution is very well known is in solid physics and plays a central role in simulated annealing. Where γ is the current configuration of a system, E γ is energy-related with it, and Z is a normalization constant.

Table 1: Parameters Used For Simulation

Parameters	Values
Network area size	200 × 200
No. of nodes	100.
Sink location	(100, 100), (100, 50), (200, 200)
Starting energy	0.5J
CHs percentage	10–15%
Packet size	2000 bits

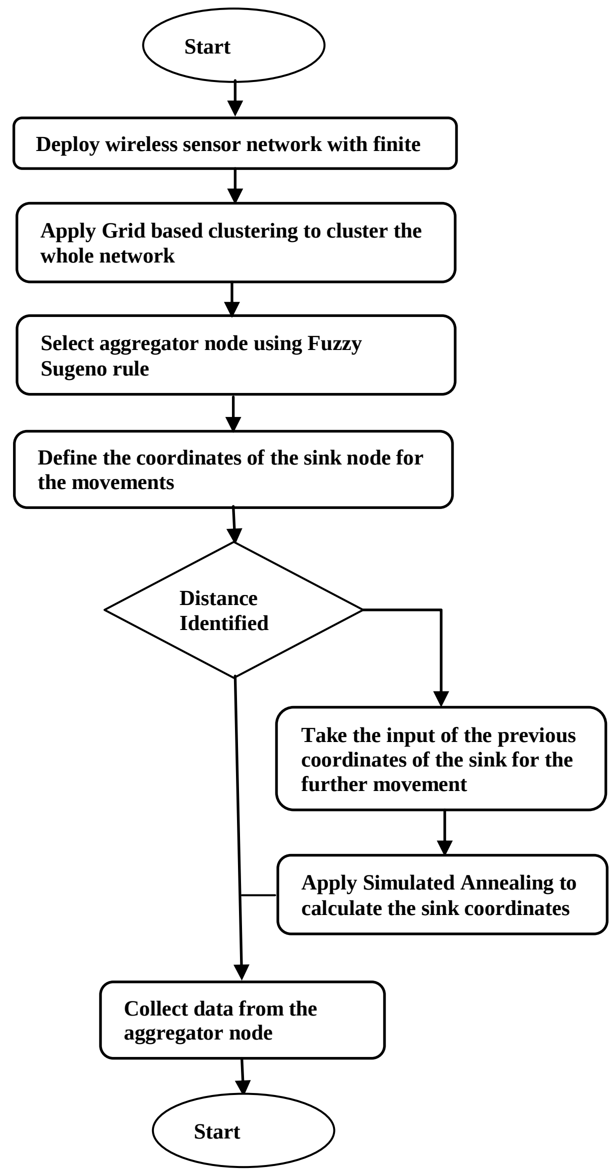

Fig. Flow diagram of proposed method

Figure 1 is a data flow diagram of the proposed methodology in which execution steps of the algorithm are briefly visualized.

4. RESULTS AND DISCUSSION

In the MATLAB platform, network lifetime, QoS, and energy efficiency limitations are simulated with experimental parameters & test results are given as shown below.

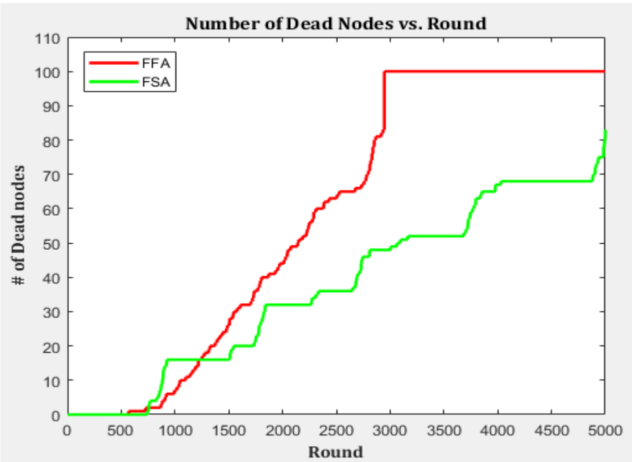

Figure 3. Total number of dead rounds covered by FFA and FSA on 100 number of nodes

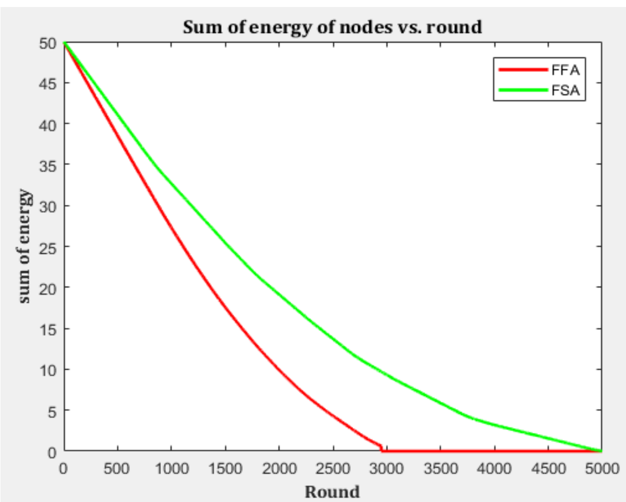

Figure 4. Energy utilization by FFA and FSA on 100

5.CONCLUSIONI

It is contains a detailed examination of heterogeneous wireless network performance, as well as various real-world experimental data. For robust data aggregation, the entire sensor networking region would be uniformly partitioned into grid cell clusters in the proposed approach. All tree linked nodes use the FSA method, which is based on a fuzzy rulesystem, and the FSA robust node selection analysis 3 parameters, such as NOVER, AC, and battery power, to pick precise aggregation nodes in the tree-based grid cell cluster region.

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