Performance Analysis of Multi-Layered Clustering Routing Protocol for Wireless Sensor Networks

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Abstract

Wireless Sensor Networks are the most efficient networks today, and they are used in many industrial, medical, and security applications. The major drawback of the sensor network is energy consumption due to the smaller size of the sensor node. To overcome the energy consumption, this paper proposes a new routing protocol called Multi-Layered Clustering Routing Protocol. This proposed routing protocol contributes to network's long life and energy efficiency. During data transmission between the source and destination, the clustering approach is used in each layer. This assists in identifying the level of energy at each sensor node, which results in energy consumption reduction. Experimental results analyse the performance of the proposed routing protocol, that regulates the energy consumption and improves the network lifetime compared to the existing techniques.

Keywords: Wireless Sensor Network, Energy Consumption, Clustered Technique, Routing protocol

1. Introduction

The wireless sensor network (WSN) are the group of sensor nodes that is formed as a network without a wired connection. It forms a cooperative network and communicates wirelessly to the different nodes in the network. The steps included in the formation of the WSN are as follows:

1. Node Deployment
2. Network Organization
3. Sensing and Monitoring
4. Data Collection

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5. Transmission

Node Deployment: The sensor nodes are positioned randomly in the network. The size of the sensor node is very small. Each sensor node has a trans receiver. It will transmit and receive the data.

Network Organization: The sensor nodes are connected to the neighbour nodes. The base station is connected between the sensor nodes and network users for efficient communication.

Sensing and Monitoring: The sensor nodes are helpful to monitor the surroundings. It will sense the behaviour of the required fields.

Data collection: This is the process of sensed data collection from the sensor nodes and it will be stored for further process.

Data Transmission: Collected data will be forwaded from the sensor nodes to the base station. The base station will be transmitted the sensed data to the respective user.

Figure 1 shows the structure of the WSN. The sensor node transmits the sensed data to the respective user via the base station.

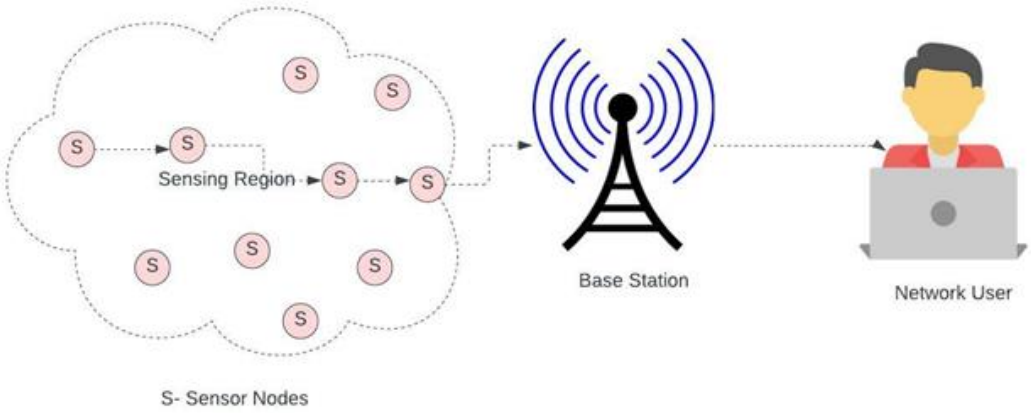

Figure 1. WSN Architecture

WSN is an infrastructure-less network and randomly deployed the sensor nodes. All the sensor nodes are to be connected in an adhoc manner. The size of the sensor node is very less. Connecting the internet of things with WSN provides a huge platform for multi-user communication. In IoT, the low-power wireless network is utilized for a long range of communication. This type of network creates efficient communication with multi-users and long-distance.

The internet of things helps to communicate the sensing information to the respective users. The applications of the WSN include military, home, offices, medical, industries, education, transport, and logistics. The sensor nodes continuously monitor and sense the environmental changes. The Integration of IoT helps to connect the people to know about the sensing information. For the sensing process, the sensor nodes are to be actived at all times.

1.1 Research Issues

The size of the sensor node is a major issue in WSNs. The sensor node size is very tiny but the requirement for storage is very high. Another issue includes energy consumption. The sensor node requires an energy unit for the continuous monitoring of the environment [1]. Due to the tiny size of the sensor node, the battery storage level of the sensor node is very lesser.

The characteristics of a WSN include as follows:

- Self-organization
- Multiple task execution
- Energy reservation
- Tiny size
- Low cost
- Lesser coverage range
- High maintenance required

Sensor nodes are deploying the nodes randomly and it is connected to the neighbour nodes in a self-organized manner [2-5]. It executes multiple tasks at a time like sensing, transmitting, and receiving the data. Due to the smaller size of the node, energy consumption is very high but it is less costly. The coverage ranges are also very smaller due to the small size of the sensor node. Due to the unstructured network, network maintenance is very high in the WSN [6-10]. Energy consumption is the most critical issue in the WSN and that should be monitored properly. This research work provides the solution to overcome the energy consumption that improves the lifetime of the WSN.

2. Related Work

Sahoo et al., [11] developed a hybrid genetic algorithm and particle swarm optimization algorithm for WSNs to reduce the energy-constrained. The genetic algorithm

helped to form the clustering and assigned the cluster head. The particle swarm optimization algorithm helped to form a routing path for efficient transmission. The major goal of this approach was used to regulate the energy consumption compared to the state-of-the-art algorithms with different performance metrics. Babu et al., [12] introduced the new approach of fuzzy if-then rules with the autonomous fashion approach for cluster head selection in the WSN. For efficient routing, the author suggested randomized routing with a location privacy approach. Additionally, to improve the security integrated with secure data aggregation for end-to-end confidentiality. This approach achieved higher network performance in terms of higher delivery rate and lesser delay.

Senthilkumar et al., [13] explained the data traffic trust scheme for WSNs. This approach was used to improve the security concerns in the WSN. Banerjee et al., [14] suggested the modified ant colony optimization algorithm for the construction of an efficient WSN. The ant colony optimization algorithm was used to reduce the cost by obtaining the shortest path in the network. This approach was used to provide cost-effective WSN for efficient data transmission and it improved the lifespan of the network. Tam et al., [15] proposed a multifactorial evolutionary algorithm for prolonging the lifetime of the WSN. It created the random key and performed the crossover process. This was used to optimize the energy level of the sensor network and improved the network lifetime.

Bhushan et al., [16] presented fuzzy attribute-based integrated scheduling for tree formation for WSNs to reduce energy consumption. This technique was used to identify the parent node which has lesser weight among all the nodes. Furthermore, this approach reduced the energy utilization and improves the network lifetime compared to the existing approach. Zhu et al., [17] initiated the RFID reading and writing system for the reduction of energy consumption in WSNs. This approach was implemented by using a cold chain transportation experiment.

Verma et.al [18] structured a cost-effective cluster-based routing protocol for the improvement of routing and cost reduction. This approach provided 33% cost-effectiveness compared to the traditional methods. Mazumdar et al., [19] developed the energy-efficient hierarchical data dissemination routing protocol for WSNs. This routing protocol maintained the network topology changes and energy consumption in the WSN. Rawat et al., [20] proposed the probability-based clustering routing protocol for an improved data transmission in the WSN. This approach was focused on solving the most important issue of sensor networks such as energy utilization and network lifetime.

Khan et al., [21] proposed the intelligent based on-demand routing protocol and it is the advanced version of the adhoc on-demand routing protocol. This routing protocol concentrates on the reduction of energy usage compared to the original LEACH (Low-energy adaptive clustering hierarchy) routing protocol. Chu-hang et al., [22] proposed the genetic algorithm-based clustering routing protocol for the reduction of energy consumption. This approach divides the network into two different sectors and then calculates the energy level of the sector. The data transmission has taken place based on the energy range of each sector.

3. Research Methodology

The major issue in the sensor network is energy utilization due to the lesser battery size. To overcome the energy utilization and prolong the network lifetime introduced the clustered routing protocol. The clustered routing technique helps to reduce the energy utilization and a better network lifetime. Hierarchical approach tracks the leaf nodes for effective communication. This proposed approach work combines the Hierarchical and clustering approaches to provide a better solution for optimization issues in the WSN.

The cluster head is created based on the sensor node's energy level. The clustered head is in charge of efficient communication, which extends the network's lifespan between the nodes. If the cluster head fails due to the energy consumption, it will alter to the next high energy level node as the cluster head. This clustering approach improves the overall network performance by increasing the successful delivery rate and the network lifetime. The major drawback of this technique while changing the cluster head position to another node leads to a high drop rate.

The hierarchical routing protocol creates the hierarchical level of data transmission between the nodes. The parent node creates the effective path via the child node. The energy level is evenly distributed among the parent and child nodes. The selection of parent and child nodes is more difficult. To overcome those issues, proposed a new routing protocol called Multi-layered Clustering Routing Protocol (MCRP).

4. Proposed Routing Protocol

A multi-layered clustering routing protocol is the proposed approach and the main objective is to regulate the energy utilization and prolong the lifetime of the network. The proposed routing protocol has two different phases. Phase 1 includes node formation based

on the different layers. The second phase includes cluster formation in each layer. By selecting this proposed routing protocol, each layer cluster head completely monitors the energy level of the remaining nodes in the respective layer. Hence it improves the overall network performance with the reduction of energy consumption.

The WSN consists of wireless nodes and those nodes will be designed based on the three different layers. Each layer has a cluster head which helps to know the energy level of the remaining nodes.

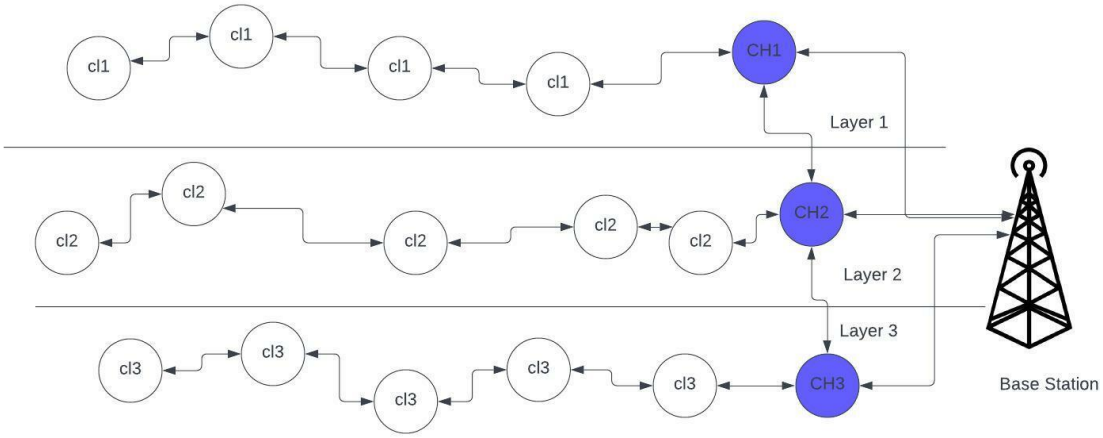

Figure 2. Proposed Routing Protocol Architecture

All the sensor nodes are divided into different layers. The cluster head selection depends on the higher energy level of sensor nodes. Each layer contains at least one cluster head. The cluster head contains the energy level of each cluster member in the respective layer. In figure 2, three different layers are defined. Each layer contains a cluster head and cluster members. The cluster head is denoted as CH and the cluster members are denoted as Cl1, Cl2, etc. Three different cluster heads are interconnected and also connected to the base station. The Base station helps to transmit the sensing information to the respective users via the internet.

After constructing the sensor network, the network will be split into different layers. Each layer has its cluster head and that will be selected depending on the energy level. Each sensor node carries some energy level to sense the environment. It requires battery power to operate the system. If the energy drains, the entire network will be shut down and communication will not take place. Henceforth, maintaining the energy level of the sensor node is more important for the improvement of network efficiency.

Energy calculation of sensor nodes depends on the energy consumption and residual energy with respect to the simulation time. Energy consumption calculation to be analyzed on the continuous-time between starting to ending time. The residual energy level is the difference between the initial energy level and the consumed energy level.

$$E(res) = E(it) - E(con) \quad (1)$$

Equation 1 states the residual energy E(res) calculation. Where E(it) is the initial energy and is noted before the simulation starts and E(con) is the consumed energy level that is noted after the simulation ends.

The residual energy calculation helps to analyse the overall network performance. The proposed routing protocol transmits the data by using the cluster head in different regions. The cluster head controls the energy consumption of cluster nodes by avoiding unwanted data transmission between the cluster members. Multi-layered clustering routing protocol maintains the energy level in each layer with the help of the cluster head. This proposed routing protocol improves the network lifetime and reduces energy consumption.

5. Simulation Results

Simulations are performed by using the network simulator version 2.35. The number of nodes selected as 100 to 500 mobile nodes. The initial energy is assigned to each node as 100 joules. The propagation model was selected as two ray propagation model. The antenna is an omnidirectional antenna that helps to cover all regions. The simulation time was taken as 100 seconds. Table 1 indicates the simulation parameters and its specification.

Table 1. Simulation Parameters and its Specifications

Simulation Parameters	Specification
Nodes	100-500 Varies
Mobility	20m/s
Energy	100 Joules
Propogation Model	Two Ray
Antenna Type	Omnidirectional

Simulation time	100 Second
Bandwidth	2Mbps
Data Rate	24Kbps
X & Y Dimension	1000*1000 meter

The proposed routing protocol compares the performance with the two existing approaches such as Cost-effective Cluster-based Routing Protocol (CCRP) and Probability-based Clustering Routing Protocol (PCRP).

The simulation is performed after the simulation ends and calculated the residual energy of each cluster head. The proposed technique cluster head has high residual energy compared to other existing models. The high residual energy in each cluster head helps to improve the network lifetime of the WSN which is shown in figure 3.

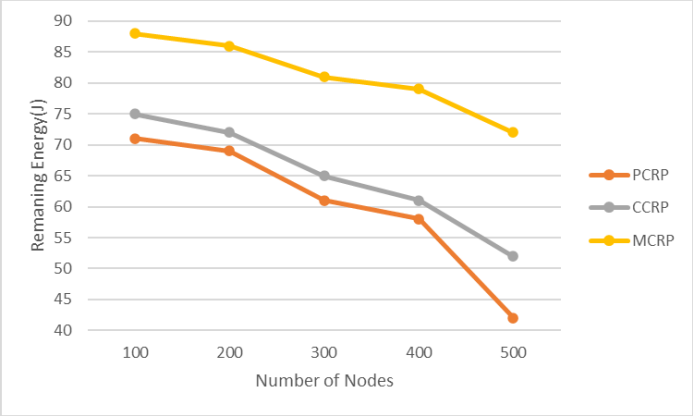

Figure 3. Residual Energy Analysis

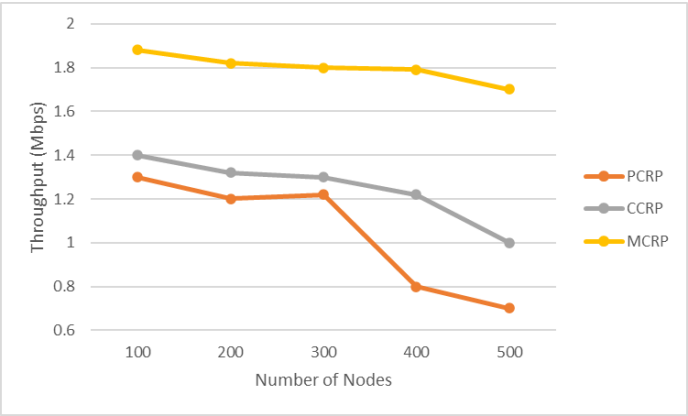

Figure 4. Throughput Analysis

Figure 4 shows the throughput analysis and the proposed routing protocol achieve high throughput due to less energy consumption. Compared to the traditional routing protocols CCRP and PCRP, the proposed MCRP attains high throughput. The throughput is calculated depending on the number of successful packets delivered with respect to the simulation time. Due to the high residua energy in the cluster head, it helps to transmit the data without delay. This throughput analysis helps to know the overall network performance of the WSN.

6. Conclusion

The proposed Multi-Layered Clustering Routing Protocol has achieved high network performance due to the lesser energy consumption. The existing routing protocols such as Cost-effective Cluster-based Routing Protocol and Probability-based Clustering Routing Protocol concentrated on the energy consumption depending on the node density and probability. The proposed routing protocol creates the cluster in each layer and reduces the energy consumption of cluster members. Additionally, it maintains the high residual energy in each cluster node and that leads to prolonging the network lifetime. Simulation result represents the performance of three different routing protocols and compared the residual energy level after the simulation. The proposed routing protocol achieves high throughput and high residual energy levels when compared to the existing routing protocol. The future work would enhance the multi-layered clustered routing protocol with a metaheuristic approach for the optimal path selection process.

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