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Improved PSO Algorithm with Encoding And Decoding To Enhance The Network Lifetime In Wireless Sensor Network

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Abstract: A key goal in developing and establishing a wireless sensor network is to maximise network longevity. An effective topology control strategy for achieving this aim is clustering sensor nodes. In this research, we provide an improved particle swarm optimization algorithm-based protocol for extending network lifespan, an optimization technique created to choose target nodes. Additionally, approaches for encoding and decoding are utilised to prolong network lifespan by using less time. Relay nodes are utilised when the distance from the cluster head to the base station is greater in order to reduce the cluster heads' excessive power consumption and take into consideration both energy efficiency and transmission distance. The network's lifespan is increased by the suggested protocol's improved distributed sensors and well-balanced clustering architecture. The suggested protocol operates well, as shown by the simulation results, which also display the nodes' energy and longevity. Using Network Animator, the simulation's output depicts how well wireless sensor networks operate. Additionally, graphs showing the energy used by nodes, their average lifespan (First Dead Node, Quarter Dead Node, and Half Dead Node), the number of Alive nodes, and their total remaining energy have been collected.

Keywords— WSN, clustering, energy efficiency, network lifetime, PSO, Encoding and decoding.

1. INTRODUCTION

A wireless sensor network (WSN) is a self-organizing wireless network system made up of many sensors that collect data from their surroundings and communicate it to a base station (BS) or another data sink. The basic goal of WSN applications is to track and gather sensor data before sending it to the BS. Different field sensors may work together to gather data and provide more accurate reports on their own local areas. To increase the accuracy of reported measurements, the majority of deployed WSNs record physical phenomena like temperature, pressure, humidity, or the position of items. Data aggregation lowers network communications overhead, which results in considerable energy savings. WSNs are particularly appealing because to the traits of low-cost, low-power, and multipurpose sensors. WSNs have been quickly used in a wide range of useful applications in the modern day thanks to the development of cloud technology, including home security, battlefield surveillance, tracking the movement of wild animals in the forest, healthcare applications, etc. Extensive study has recently been devoted to investigating novel functions for WSNs in isolated and inhospitable areas. Each node in a sensor network serves as both a sensor and a router, and as a result, its computational power, storage space, and communication capabilities are constrained. Additionally, a lot of WSN applications deploy sensor nodes in challenging locations, which makes it difficult or costly to repair failing nodes. As a result, a wireless node must often function for a long time without battery replacement. Therefore, the most important consideration when creating a network routing protocol with the intention of extending the network lifespan is energy efficiency. The network architecture may be changed, and the routing protocol can control the nodes' transmission power levels to effectively manage energy usage. The clustering strategy may help routing systems use less energy. In a clustering design, sensor nodes are grouped together into clusters where the lower-energy nodes may be employed for sensing activities and convey the perceived data to the cluster head nearby. In order to reduce the quantity of aggregated data sent to the BS, one node in a cluster may be designated as the cluster head (CH), which will remove associated data from the cluster's members. By reducing total energy consumption and distributing energy consumption across the nodes over the course of the network lifetime, the clustering strategy may lengthen network lifespan and enhance energy efficiency. Additionally, it can reduce channel congestion and packet collisions, improving network speed under heavy load.

2. Related Work

Numerous routing protocols are created to increase network efficiency within the restrictions of constrained energy, bandwidth, and computational capabilities. One of the most well-known WSN clustering protocols is the LEACH protocol, which chooses a CH based on a specified likelihood of rotating the CH role among the sensor nodes to prevent the CH's energy from being quickly depleted. However, CHs are chosen at random. As a consequence, a low-energy node could be selected as the CH, and the CHs might not be spread equally. The LEACH-centralized (LEACH-C) protocol is put out as an advancement over LEACH, which forms the clusters using a centralised clustering method. LEACH-C improves network performance by distributing the CHs around the network, which leads to better clusters. The probability calculation takes into consideration the residual energy of the nodes, making it more probable that the CHs will be chosen from the nodes with greater energy. The distribution of CHs is random due to LEACH and LEACH-inability C's to apply intelligent CH selection techniques, which leads to excessive energy usage. BCDCP is suggested to create more evenly distributed clusters, therefore. To prevent cluster head overload in BCDCP, each cluster head serves about an equal number of member nodes, and the CHs use CH-to-CH routing to send data to the BS. The methods simply pay attention to the nodes' consistent energy use. Some location-aware protocols are suggested to decrease the transmission costs among the nodes in order to further extend network lifespan. The HEED protocol chooses cluster heads by combining the residual energy of the nodes with a secondary factor, such as the nodes' closeness to their neighbours or node degree. Through multi-hop connections, the cluster heads communicate data to the BS. Only one CH within a certain range is able to produce a homogeneous CH dispersion over the network, thanks to HEED. As a consequence, the head nodes in the HEED protocol use a lot of power, which causes their energy to be depleted quickly. The EECS protocol results in a fair distribution of cluster heads, with cluster heads chosen depending on the location of nodes and leftover energy. In EECS, a competitive procedure is recommended for the CH selection stage, and each volunteer node is given a predetermined competition range. Any node that determines that it is more powerful than the other nodes within its competition radius will declare itself a CH and broadcast to all other nodes. However, this approach might be problematic in dense networks since there are too many nodes vying to be a CH. The data is sent directly to the BS by the chosen CHs. While clusters are only produced once, the Hausdorff clustering approach offers a greedy mechanism to pick cluster heads based on location, communication effectiveness, and network connection. Therefore, when the clusters are first structured inefficiently, the nodes' remaining energy is soon consumed. The heart of the LECP-CP protocol, which is based on the expected local energy consumption ratio of nodes, consists of a unique cluster head election process and an inter-cluster communication routing tree building algorithm. Additionally, the protocol offers a more precise and realistic cluster radius to reduce the overall network's energy usage. Since the BS is often remote from the sensor network in most applications, the cluster heads must use a lot more energy than the other nodes. As a result, job distribution may be made in a manner that the sensor nodes significantly contribute to increasing energy efficiency. Relay nodes, for instance, might be used to balance out the cluster heads' high energy usage. The CH selects the nearest relay node as its next hop in SEECH, which selects certain nodes with greater residual energy as the relay nodes. As a result, the CH gathers and aggregates data from each member of the cluster before sending it to

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the relay node, which then sends it to the BS. By sharing the CH's data transmission, the relay node aids in offloading the CH's energy use. However, two or more CHs may pick the same relay nodes, which would hasten their energy depletion[9]. A CH must also use more energy while selecting its relay node. Furthermore, while choosing relay nodes, nodes' geographic locations are not taken into account.

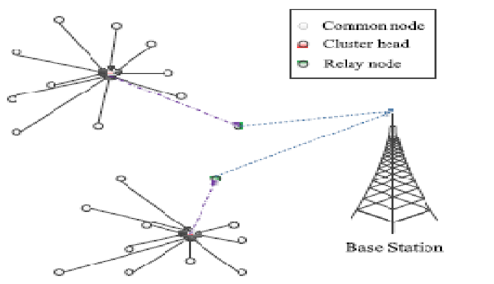

Fig. 1. *Network model*

3. System Model

NETWORK MODEL

Considered is a wireless sensor network with N sensor nodes that is set up in a field and used to continually monitor the environment. A sensor node's parts, including the microcontroller unit, communication unit, and power management unit, are shown in Fig. 1. The sensor network and its sensor nodes are predicated on the following premises: 1) Each sensor node is equally capable of operating in the sensing mode to detect environmental parameters or in the communication mode to send data to the BS or to one another, and each node can collect data packets from the cluster members when acting as the CH. 2) Each node has a data link capable of handling all data traffic. 3) Each node is given an index based on its location. 4) The sensor nodes and the BS are stationary after deployment.

6) Following deployment, all nodes are left unattended. That is, a battery cannot be recharged;

7) Every node measures the ambient variables at a constant pace and sends data to the target nodes on a regular basis;

8) The number of transmission power levels is set for each node. The connections between nodes are symmetric, and the nodes may alter their transmission power in line with the distance to the target receiver. Since sensed information is strongly correlated, the cluster head aggregates the data collected from its cluster into a fixed-length packet; ten) The BS is externally powered; and eleven) A node may only estimate the distance to another node based on the received signal strength.

B. ENERGY CONSUMPTION MODEL FOR WSN NODES

Communication energy consumption in consideration of path losses. Either the free space (d 2 power loss) or the multipath fading (d 4 power loss) channel model is employed, according to the distance between the transmitter and receiver. Power control can be used to compensate for this loss. If the distance is less than a threshold d0, the free space model is used; otherwise, the multipath model is adopted.

C. NETWORK LIFETIME

In the majority of applications, a network would continue to perform well even if some nodes failed. A node has numerous close neighbours equipped with the same sensing equipment, especially when several sensor nodes are placed in one region, so the network can withstand the failure of certain nodes. As a result, other metrics may be used to assess the network lifespan in addition to the time until the first node died (FND). As a consequence, when assessing the performance in situations with high node density, the lifespan that a portion of nodes dies (PND) is a more useful parameter. We provide the following description of the network's lifetime:

$T k N = T [\xi = k/ N]$

where N is the number of sensors in the network. k is the number of alive nodes. The equation shows that the definition of PND lifetime is time until the fraction of alive nodes falls below a predefined threshold ξ .

Clustering Protocol

In our protocol, nodes are classified into the CHs, relay nodes (RNs) and common nodes (CNs). The operation of the protocol includes two phases, i.e., the clustering setup phase and data transmission phase.

A. CLUSTER HEAD SELECTION

We assume that there are N sensor nodes randomly deployed in the field, which are divided into n clusters. We define the set of cluster heads as CH = {CH1,CH2, . . . , CHj, . . . ,CHn}, and the set of non-CH nodes as CHg. In the proposed protocol, the CHs are responsible for coordinating among the nodes within their cluster, aggregating intra-cluster data, and communicating with its RNs. The energy levels and locations of the nodes are taken into consideration in selecting the CHs. The BS tends to select the cluster heads with higher residual energy and better locations (near the BS), and forms the clusters with an equal distribution of the sensor nodes. This process can be formulated as an optimization problem and mathematically expressed as FCH = α × R CH energy + (1 − α) × R CH location.

B. RELAY NODE SELECTION

To reduce the excessive energy consumption of the cluster heads, relay nodes are used in our protocol to share data transmission task with the CHs. A sensor node ought to be selected as a relay node if it meets the following two criteria. Firstly, the relay nodes and cluster head must have a higher energy level, since they consume much more energy compared with common nodes[7]. Second, the node should have a superior location between the cluster node and the BS so as to minimize the transmission energy, which is the most dominant energy consumption in the WSN. Different from other protocols, the selection of relay nodes in our protocol is related to the cluster heads, each of which has a corresponding relay node. As a result, the communications costs between the cluster heads and relay nodes can be reduced. We define the set of relay nodes as RN = {RN1, RN2, . . . , RNz, . . . , RNm}, and the set of common nodes as CN. Similar to cluster selection in Section IV.A, in order to select the relay node, we define the following fitness function: FRN = β × R RN energy + (1 − β) × R RN location

C. CLUSTERING SETUP PHASE

At the beginning, each node sends a Node-MSG message to broadcast its residual energy information and location information, which are essential for selecting the cluster heads and relay nodes;

• The BS selects the cluster heads by using the algorithm and broadcast a message including the cluster heads' ID to inform the network of the cluster head's location. After the cluster heads know their status, each cluster head introduces itself to the network by broadcasting a small advertisement message (i.e., CH-ADV), which uses the non-persistent carrier-sense multiple access (CSMA) MAC protocol. The message includes the cluster head's ID and a header that identifies it as an advertisement message;

• Then, similarly, the BS select the relay node by using the algorithm in Section III.B. Once a relay node is selected, an advertisement message (i.e., RN-ADV), which includes its ID, the corresponding cluster head's ID and the header, is sent to the network by the BS to declare its status as a relay node. Each common node decides its cluster by choosing the cluster head that requires the minimum transmission energy, based on the strength of the CH-ADV message from each cluster head. Then, a cluster is chosen;

• After each common node has decided which cluster it joins in, it must inform the cluster head of its decision by transmitting a JOIN-REQ message. The message is again very short, consisting of the node's ID[18], the belonging cluster head's ID and the sender's residual energy. In this way, clusters are formed, and the duty of each node in the network is determined.

E. DATA TRANSMISSION PHASE

In this phase, the common nodes send data to their cluster head as scheduled by the TDMA scheduler. The nodes are all synchronized through the BS sending out synchronization pulses to the nodes. The cluster head must be awake at all times to receive all the data from the common nodes in the cluster, and then it aggregates the data to enhance the common signal and to reduce the un-correlated noise among the signals. Afterwards, the cluster head transmits the aggregated data to the relay node. Through analyzing the TDMA scheduler managed by the cluster head, the sensor nodes can turn on or off radio so as to save energy. Then the resultant data are sent from the relay node to the BS.

4. IMPROVED PSO ALGORITHM

Particle Swarm optimization (PSO) [7] is a population based stroke optimization technique developed by Dr.Eberhart and Dr. Kennedy in 1995, this inspired by social behavior of bird flocking or fish school education.

Particle Swarm Optimization (PSO) is a population-based optimization scheme. The random solutions of the system are initialized with a population and search optimal solutions in each generation[24].

The PSO algorithm always stores and maintains a record of results for three global variables such as target value or condition, gbest, and stopping value. Every obtained particle of PSO contains the following details.(i)A data which can represent a global solution.(ii)Value for velocity which will indicate the amount of data to be changed.(iii)lbest value.

The approach consists of the following five main steps:

A. Initialize the optimization problem and algorithm parameters:

Generate a certain number of particles. The size of the particle is defined as M, each particle i has a velocity vector vi = [vi1,vi2,…..,vid], and the position vector xi = [xi1,xi2,…..,xid] is used to indicate its current state, where i is a positive integer indexing the particle in the swarm and d refers to the dimensions of the problem.

B. Calculate the fitness values:

The particles search in a d-dimensional hyperspace, calculating the fitness values of each particle. During the search process, each particle keeps track of the personal best (pbest) solution Pi = [pi1,pi2,….,pid] by itself and the global best (gbest) solution Pg = [pg1,pg2,….,pgd] achieved by any particle in the swarm. Then the local best position and the global best position will be found.

C. Update velocity and position vectors:

Each step influences the velocity of each particle towards its pbest and gbest positions. The velocity of the particle is updated as follows:

Vijk+1 = wvijk + c1r1(pijk – xij) + c2r2(pgik – xgjk),

and the position of the particle is updated as follows:

xijk+1 = xijk + vijk+1

where vij is the jth dimension of the ith particle's velocity and it is usually confined to the closed interval of [vmin,vmax] to prevent the explosion of the particles. The notation of xij,pij and pgi is similar to that of vij. Coefficient r1and r2 are two randomnly generated c1 and c2 are two acceleration parameters commonly set to 2.0 or adaptively controlled according to the evolutionary states. Factor w is the inertial weight, which plays the role of contributing the impact of the balance between the global search (large inertial weight) and local search (small inertial weight).

D. Change the inertial weight:

To avoid the algorithm failing into a local optimum, we use an improved particle swarm optimization algorithm, which modifies the inertial weight and so as to avoid particles being trapped in local optima.

W = (wmax – wmin)* Iterationmax – Iterationi

Iterationmax

Where wmax and wmin represents the maximum and minimum inertial weights, and are always set to 0.9 and 0.4, respectively. Iterationmax is the maximum number of allowed iterations, while Interstioni represents the current interation.

E. Go to step 3 until the termination criterion is met:

The current best solution is selected after the termination criterion is met. This is the solution for the optimization problem formulated.

5. Extension Technique to Reduce time Consumption

Network coding is a technique which allows the intermediate nodes to encode data packets received from its neighboring nodes in a network. The encoding and decoding methods of linear network coding are described below.

Encoding operation:

A node, that wants to transmit encoded packets, chooses a sequence of coefficients q = (q1, q2, ..., qn), called encoding vector, from GF(2s). A set of n packets Gi(i = 1, 2, 3, 4, ..., n) that are received at a node are linearly encoded into a single output packet. The output encoded packet is given by

$$Y = \sum_{i=1}^{n} q_i G_i, \qquad q_i \in GF(2^s)$$

The coded packets are transmitted with the n coefficients in the network. The encoding vector is used at the receiver to decode the encoded data packets.

Decoding operation:

A receiver node solves a set of linear equations to retrieve the original packets from the received coded packets. The encoding vector q is received by the receiver sensor nodes with the encoded data. Let, a set (q1, Y 1), ..., (qm, Y m) has been received by a node. The symbols Yj and qj denote the information symbol and the coding vector for the jth received packet respectively. A node solves the following set of linear equations (2) with m equations and n unknowns for decoding operation.

$$Y^j = \sum_{i=1}^{n} q_i^j G_i, \quad j = 1, ..., m$$

At least n linearly independent coded packets must be received by the recipients for proper decode of the original packets. The only unknown, Gi, contains the original packets that are transmitted in the network. The n number of original packets can be retrieved by solving the linear system in equation (2) after getting n linearly independent packets.

The XOR network coding, a special case of linear network coding, has been used in this work. The coded packets that are transmitted in the network are elements in GF (2) = {0, 1} and bitwise XOR in GF (2) is used as an operation.

6. Results and Discussion

This section presents the performance evaluation results of the proposed protocol via computer simulations. Our approach can be used to construct energy-efficient hierarchies for routing protocols, in which higher tier nodes should have more residual energy. Moreover, the protocols can also be effective for sensor applications requiring efficient data aggregation and prolonged network lifetime, such as environmental monitoring applications.

This graph is obtained by changing the number of nodes and getting the energy consumed by each number of nodes.

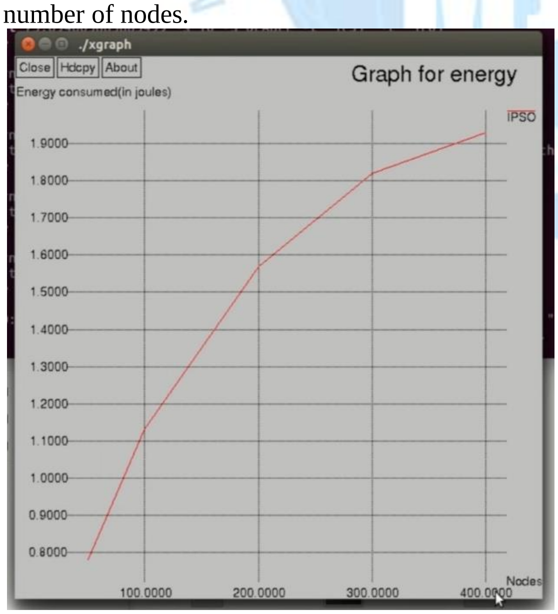

Fig. 2. *Energy consumed by nodes*

This graph is obtained by changing the number of nodes and getting the average lifetime of each number of nodes. First Node Dead is the time span from the start to the first node dead.

Fig. 3. **Average lifetime (First Node Dead)**

This graph is obtained by changing the number of odes and getting the average lifetime of each umber of nodes. Quarter Node Dead is the time span from the start to the one fourth nodes dead.

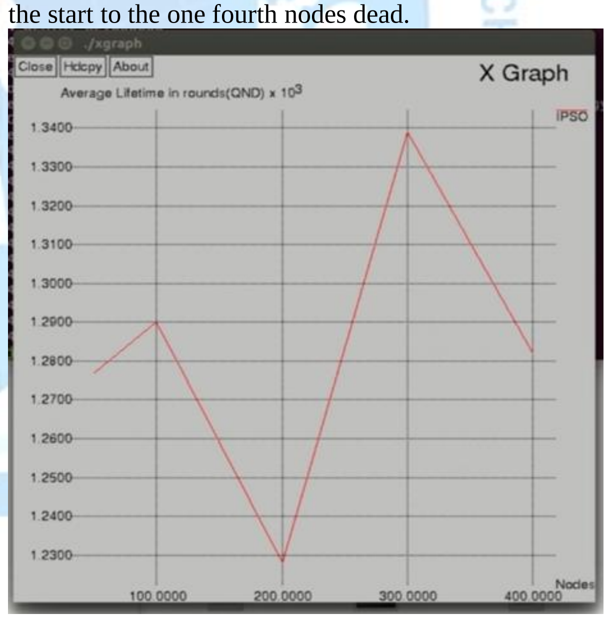

Fig. 4. *Average lifetime (Quarter Node Dead)*

This graph is obtained by changing the number of nodes and getting the average lifetime of each number of nodes. Half Node Dead is the time span from the start to the half nodes dead.

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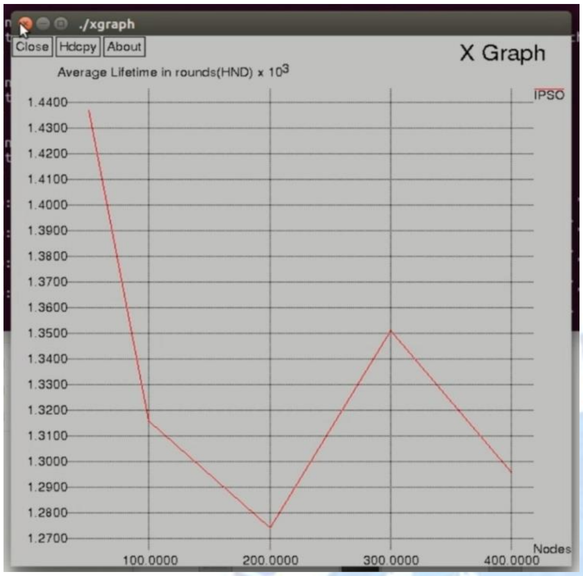

Fig. 5. *Average lifetime (Half Node Dead)*

This graph is obtained for number of Alive Nodes with respect to the network lifetime. Alive Nodes are the nodes with long battery life.

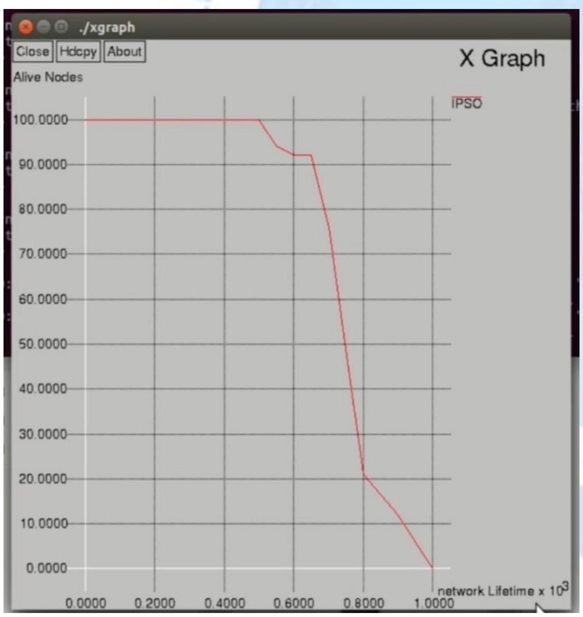

Fig. 5. *Average lifetime (Half Node Dead)*

This graph is obtained by changing the number of nodes and getting the total remaining energy by each number of nodes.

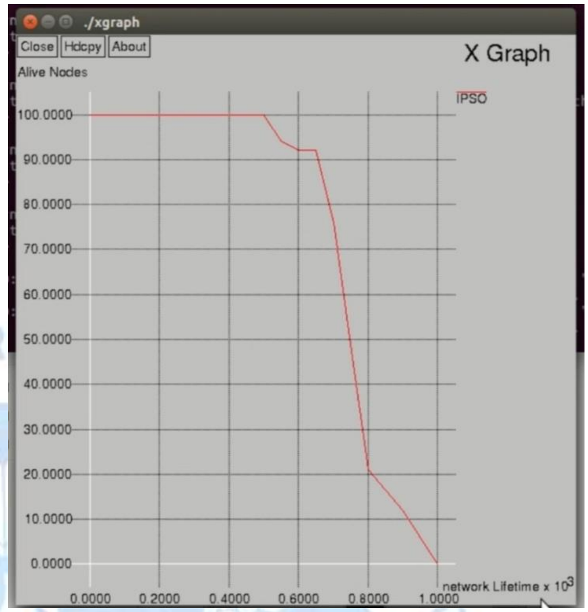

Fig. 6. *No.of.Alive nodes*

This graph is obtained by changing the number of nodes and getting the total remaining energy by each number of nodes.

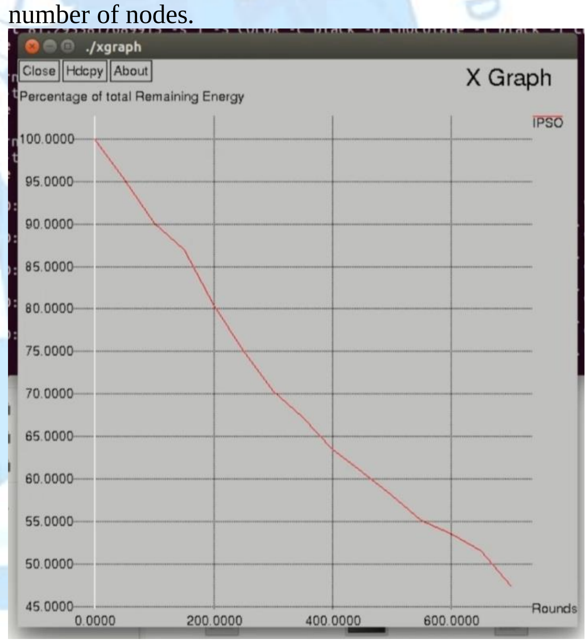

Fig. 7. *Total remaining energy*

7. CONCLUSION

The proposed Improved PSO algorithm created the cluster structure so as to minimize the transmission distance and to optimize the energy consumption of the network. In this way, the network lifetime can be prolonged. And also encoding and decoding is used to reduce time consumption in packet transmission. Under a variety of node densities, the network area sizes and BS positions, it has been shown that the network can improve energy efficiency by minimizing the overall energy consumption and balancing energy consumption among the nodes during the network lifetime.

The Improved PSO aims to reduce the high power consumption of wireless sensor network. The protocol takes into account both energy efficiency and transmission distance, and relay nodes are used to alleviate the excessive power consumption of the cluster heads. The proposed protocol results in better distributed sensors and a well-balanced clustering system enhancing the network's lifetime. Simulation results show that the proposed protocol performs well and also shows the energy and lifetime of the nodes

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