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# AN ENERGY EFFICIENT TOPOLOGY CONTROL FOR 3-TIER WSN USING GENETIC ALGORITHM BASED HIERARCHICAL COOPERATIVE TECHNIQUE

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## ABSTRACT

Topology control plays a vital role in maximizing the network lifetime and in increasing the network capacity of a Wireless Sensor Network (WSN). In this paper, a three tier architecture based topology control algorithm which increases the overall energy efficiency of WSN is presented. The lower tier involves clustering of sensor nodes which forms cluster slaves for the purpose of data gathering. The second tier comprises of cluster heads, which are responsible for transferring data between cluster slaves and super heads. The third tier consist of super heads, forms a communication network consisting of super heads, where data forwarding between the super heads to the sink node, takes place. The third tier forms a communication subnet. Cluster head selection and super head selection is a critical process in the three tier architecture. So a new methodology based on genetic algorithm for cluster head selection and super head selection, a hierarchical cooperative technique which takes care of the nodes bandwidth, residual energy and memory capacity is proposed and implemented. Simulation results prove the effectiveness of our algorithm.

***Keywords—*** Bandwidth, Clustering, Genetic Algorithm, Memory Capacity, Residual Energy , Topology Control, Wireless Sensor Network

## 1 INTRODUCTION

Wireless Sensor Network (WSN) comprises of complex sensors with limited power supplies, low bandwidth, minimum memory capacity and limited energy. Each sensor has a low power battery as the energy source which cannot be replaced. By the effective utilization of the nodes battery, an energy efficient network can be obtained. This leads to the development of Topology Control, which is nothing but maintaining the desired properties of the network like connectivity, coverage etc., by reducing the energy consumption and enhancing the network capacity.

Topology Control can be broadly categorized in to any of the two approaches. They are power Control mechanism and power management mechanism [1]. Adjusting the transmitting power of each node dynamically is termed as power control [2][3][4][5]. Power management is switching off the redundant nodes that are not involved in transmission nor reception [6][7][8][9][10]. By integrating power control and power management algorithms it is possible to increase the energy efficiency of a wireless sensor network.

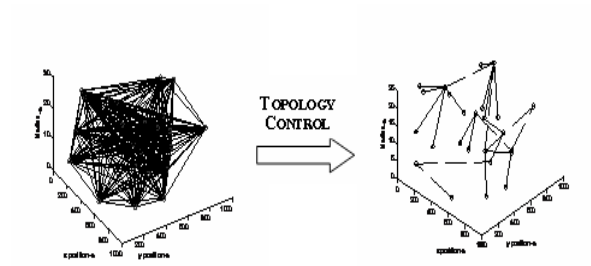
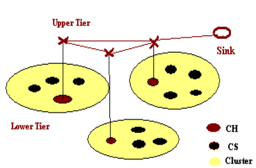



Fig 1. Network Topology

Many topology control algorithms are presented in the literature using single tier and two tier architecture. It has been proved that two tier architecture provides a better performance compared to the other architectures [11-12].Two tier architecture is based on clustering, in which, nodes are grouped into several non overlapping regions called clusters. Clustering greatly reduces the communication costs incurred by sending data to the nearby Cluster head, instead of directly communicating to the sink which is far away. Using clusters for transmitting data to the sink, leads to small transmit distances for the slave nodes and far transmit distances only for few cluster head nodes [11-14].



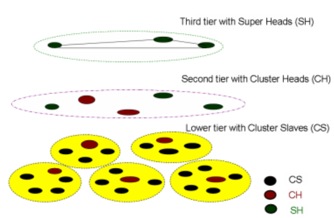




Fig. 2. Two tier Architecture      Fig. 3. Three tier Architecture

In this paper, a three tier architecture is developed. The lower tier forms with cluster slaves, the middle tier with cluster heads and the upper tier comprises of super heads. The cluster slaves gather the data and forward it to their cluster head. The cluster head receives data from the slaves and pass it to their near by super head. The upper tier forms a communication subnet, where the data forwarding to the sink takes place via super heads.  Genetic algorithm is used for the selection of cluster heads and super heads. Once the cluster heads were elected, the resource rich nodes among them were elected as super heads. The total energy consumed and the network lifetime were also calculated for the proposed methodology.

The paper is organized in the following order: In section 2 overview of genetic algorithm is given. The proposed GAHCT methodology is discussed in section 3 followed by the results and discussions in section 4. Finally in section 5 conclusion and future work is given.

## II OVERVIEW OF GENETIC ALGORITHM

Genetic Algorithm (GA) is an evolutionary tool that is used to solve different varieties of problem that are not easy to solve using normal methodologies. A GA maintains an initial population for the problem at hand, and makes it resolve by applying a set of stochastic operators iteratively [5].

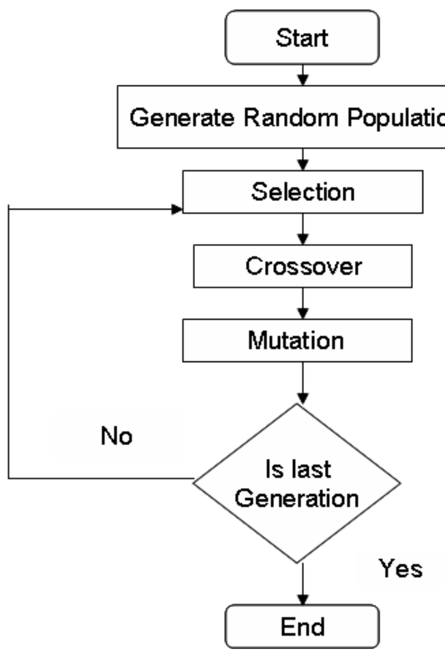



Fig 4: Flowchart of Genetic Algorithm

The repeated processing of the above operations generates best individuals suited for the given application.

## III PROPOSED METHODOLOGY

Energy, Bandwidth and Memory Capacity are the limited resources for a WSN. Taking these factors into consideration, the Genetic Algorithm based hierarchical Cooperative Technique is proposed. Using this methodology an efficient network can be generated. As the initial step, best nodes called Cluster Head (CH) nodes are to be selected. Remaining nodes used for collection of data are called Cluster Slaves (CS). The resource rich nodes among the cluster heads are elected as Super Heads (SH) for data forwarding to the sink node.

Initially nodes are deployed in a random fashion. Every node launches and receives "Hello" messages from its neighbors with its minimum transmission range and wait for a random amount of time. On receiving the "Hello" message each node will calculate its Residual energy, Bandwidth and Memory capacity. These details are sent along with the "Ack" message. Based on the residual energy values in the "Ack" message, nodes are categorized in to Normal Nodes (Residual Energy > 20%), Warning Nodes (Residual Energy between 10 – 20 %), and Danger Nodes (Residual Energy <10 %). The danger nodes are not eligible for involving in the communication. So these nodes are moved to Sleep state for a predefined time period. After considering the residual energy of the neighbors, the Bandwidth and Memory capacity of the Normal nodes and Warning nodes are considered and compared. The node with higher Bandwidth and Memory at a particular time is elected as Cluster Heads and the other nodes are listed as Cluster Slaves. After a predefined time, cluster heads with maximum residual energy, bandwidth and memory capacity are elected as super heads. These super heads form the communication subnet, through which data is forwarded to the sink node. The data transmission between the super nodes takes place using minimum transmission power to reach the sink node.

In the proposed methodology, each node is declared as a boolen operator which can either be True or False. On receiving the Hello message, a comparison on the node's weight NodeWT (based on Energy, Bandwidth and memory capacity) is made with the neighbor NeighWT which sends the Hello message. If the NodeWT > NeighWT then the operator is set as True which means the node is a Cluster Head. If NodeWT < NeighWT then the operator is set as False, which says node is a Cluster Slave. Like wise for a period of time some nodes will act as Cluster Heads and some as Cluster slaves. During that period, Cluster Heads exchange Hello mesaages. The Cluster heads whose NodeWT > NeighWT are declared as Super heads. After a constant period of time, once again Hello messages were exchanged, and a new set of Super Heads, Cluster Heads and Cluster Slaves were selected. By repeatedely changing the heads and slaves, exploitation of energy over a constant set of nodes can be overcome, thereby the network connectivity can still be maintained.

***A GAHCT ALGORITHM*:**

Step 1: Randomly place nodes as initial population

Step 2: Calculate the fitness function for all individual nodes which uses Remaining energy, Bandwidth and Memory capacity

Step 3: Select nodes with best fitness value as cluster heads for reproduction

Step 4: Recombine between individual nodes

Step 5: Mutate individual nodes

Step 6: Calculate the fitness for the modified individual Nodes

Step 7: Repeat till a good new population of cluster heads are obtained

Step 8: The above steps are repeated for the cluster heads to select super heads among them

The flow chart for selection of Cluster Heads is shown in figure 5. The same procedure is repeated for the selection of Super Heads.

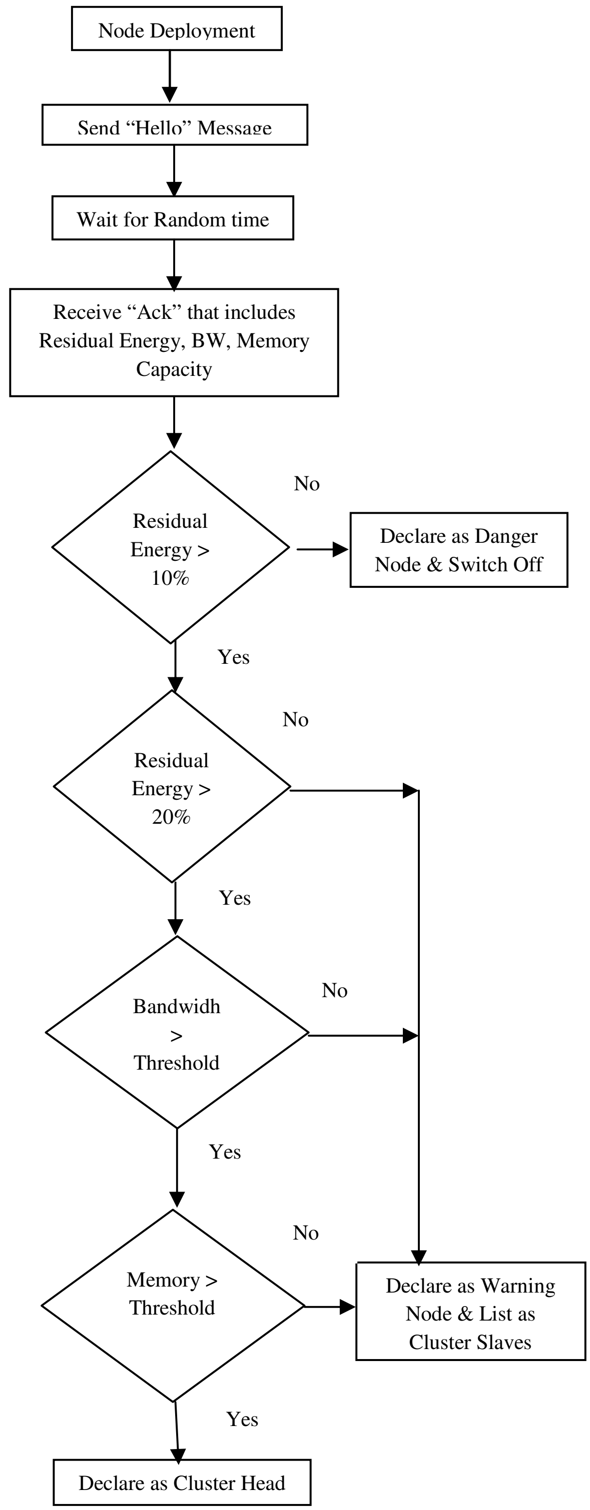



Fig. 5. Flow Chart of GAHCT for Cluster Head Selection

## IV RESULTS AND DISCUSSION

Initially network of 50 nodes is deployed and the proposed GAHCT algorithm is implemented. Since a random initial population has been generated, the number of cluster slaves, cluster heads and super heads in every iteration is different. More number of iterations is done. Average of super heads, cluster heads and cluster slaves is taken and is plotted. in figure 6. From the figure, it is inferred that cluster slaves are more in number when compared to the cluster heads and super heads. This also leads to an effective data gathering process.

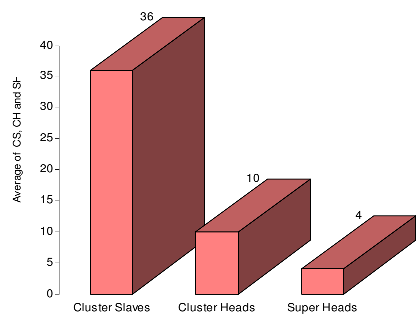



Fig 6. Average of CS, CH and SH

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A network scenario with 50 sensor nodes and 1 sink node, whose x, y and z coordinates were known, is deployed and the scenario is termed as Network Deployment #1. Using NS-2.34, network deployment #1 is simulated with the parameters given in Table 1 and the network animator screen is shown is figure 7. For this scenario the energy consumed by all the nodes in the network is calculated. The energy consumed to transmit k bits message over a distance d is given by,

$$E_{TX}(k,d) = E_{Elec}*k + €_{amp}*k*d^2 \qquad (1)$$

Where $E_{Elec}$ is the radio energy dissipation and $€_{amp}$ is transmit amplifier dissipation. Using the above equation, the energy consumed to transmit data from all the nodes in the network [2] through the cluster heads to the sink node using GAHCT is calculated.

TABLE I. THE SIMULATION PARAMETERS

| Parameters | Value |
|---|---|
| Deployment Region | 1000 m x 1000 m |
| Number of Nodes | 50,100,150,200,250 |
| Initial Energy | 1 , 2 , 3 , 4 Joules |
| Simulation Time | 50, 100, 150, 200, 250, 300 seconds |
| Transmission Power | 0.8 mW |

| | |
|---|---|
| Receiving Power | 0.2 mW |
| Idle Power | 0.003 mW |
| Transmission Rate | 250 Kbps |

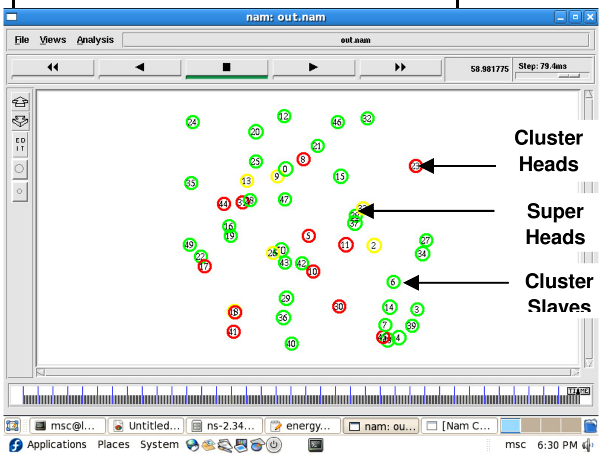


Fig. 7. Network Animator screenshot for GAHCT

For deployment #1, the network lifetime is calculated by finding the time elapsed for the first node to reach a threshold energy level. The initial energy of the nodes is varied from 1 J to 4 J. In each case, different thresholds γ1, γ2, and γ3 are set for election of CS, CH and SH. The average network lifetime and the average of the total energy consumption is calculated and is tabulated in table 2. The network lifetime for deployment #1 is also calculated by varying the simulation time from 50 to 300 seconds. The results obtained are plotted in figure 8.

TABLE II. AVERAGE NETWORK LIFETIME BY VARYING INITIAL ENERGY

| Initial Energy (Joules J) | Threshold value (for CS,CH & SH selection) | | | Total Energy Consumption (Joules) | Average Energy Consumption (Joules) | Average Network Lifetime (Sec) |
|---|---|---|---|---|---|---|
| | γ1 (J) | γ2 (J) | γ3 (J) | | | |
| 1 | 0.75 | 0.5 | 0.2 | 16.9 | 0.33 | 19.4 |
| 2 | 1.8 | 1 | 0.3 | 52.3 | 1.04 | 30.33 |
| 3 | 2 | 1.75 | 0.75 | 54.17 | 1.08 | 31 |
| 4 | 3.5 | 2.5 | 1.5 | 82.78 | 1.65 | 41.31 |

The average network lifetime by varying the initial energy levels for a network density of 50 nodes is obtained as 30.53 seconds. The average network lifetime calculated by varying the network simulation time for a constant density of 50 nodes is obtained as 31.03 seconds. In figure 8 the dip in the graph shows a decreased network lifetime due to more energy drain during that simulation instance. The total energy consumption is also calculated as 101.4 J using the proposed methodology for various network densities and is plotted in figure 9.

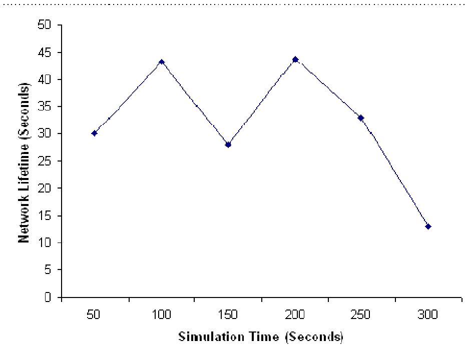


Fig. 8 Average Network Lifetime by varying simulation time

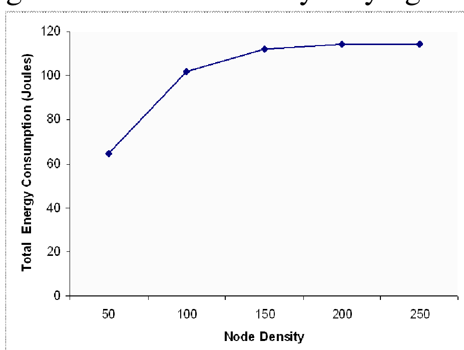


Fig 9. Total Energy Consumption of 3- tier architecture

The network topology of one tier architecture (before applying GAHCT) is shown in figure 10. In this a mesh topology is obtained where each node gets connected to all the nodes in the network. This leads to a more complex network. Figure 11 shows the topology of a two tier architecture using the proposed GAHCT, where only two tiers are present (network with CS and CH). The topology obtained after applying GAHCT for three tier architecture is shown in figure 12, 13, 14 and 15. On comparing figure 10 and figure 15, it is well proved that GAHCT reduced the number of links between the nodes in the network to the maximum. Thus reducing the number of links leads to a more energy efficient network

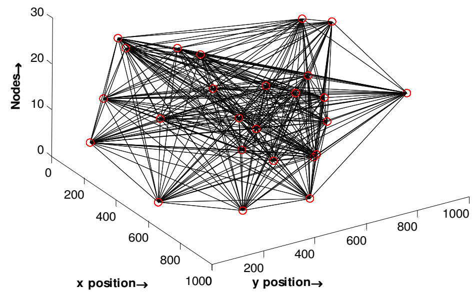


Fig.10. Network Topology of One – tier architecture

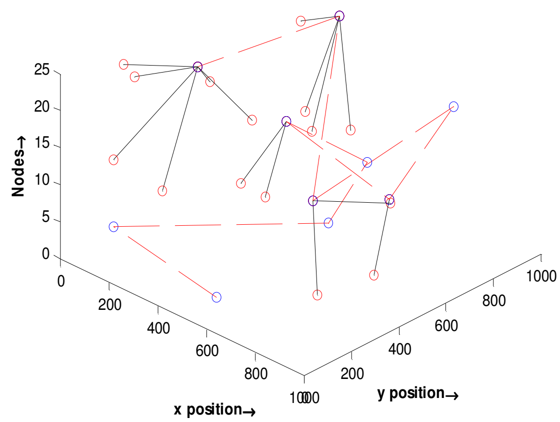


Fig.11. Network Topology of Two – tier architecture

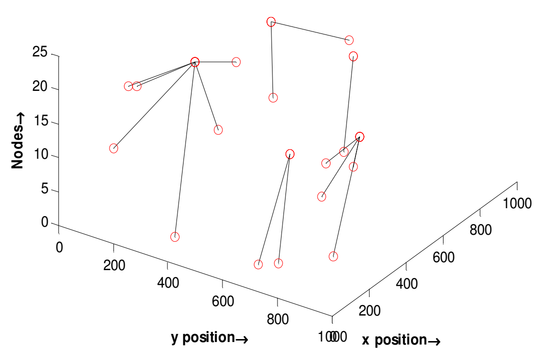


Fig.12. Cluster formation (lower tier) using GAHCT

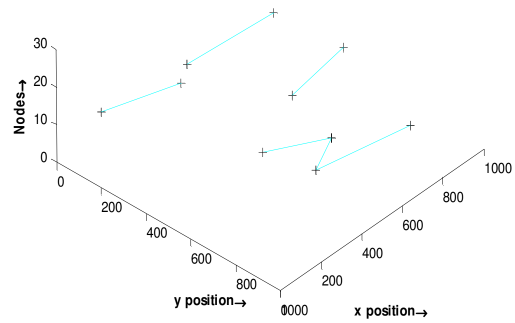


Fig.13. Cluster Heads (middle tier) using GAHCT

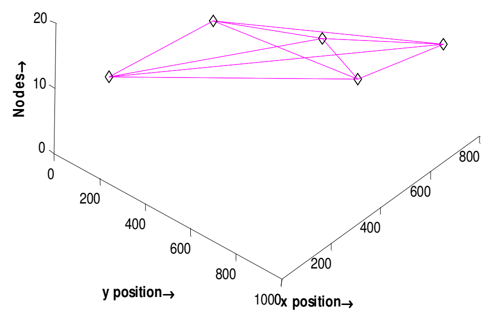


Fig.14. Super Heads forming Communication Subnet (upper tier) using GAHCT

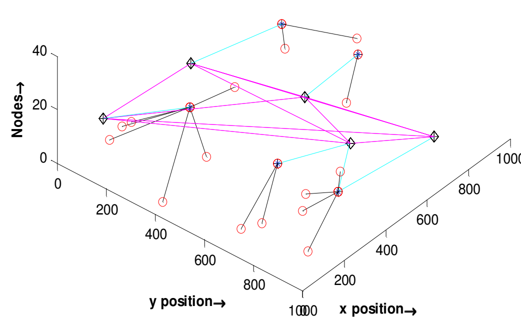


Fig.15. Network Topology of a Three – tier architecture

## V CONCLUSIONS AND FUTURE WORK

The proposed methodology which uses a Genetic Algorithm based Hierarchical Cooperative Technique classifies each node in the network either as Super Head, Cluster Head or as Cluster Slave. Group of Cluster Slave nodes form the lower tier of the network, Cluster Head nodes form the middle tier of the network and Super Head nodes forms the upper tier of the network. The upper tier acts as a communication subnet. Since GA is used and the fitness function includes residual energy, bandwidth and memory capacity, a best set of Super Heads and Cluster Heads were selected. Using these Super Heads, efficient data forwarding takes place using the minimum transmission energy. Network lifetime for a network density of 50 nodes, by varying energy levels is obtained as 30.53 sec which is better than that of previous techniques. As an enhancement of this work, the proposed methodology can be implemented for various network densities and the network parameters can be analyzed.

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