A STUDY ON GENETIC ALGORITHM BASED HIERARCHICAL COOPERATIVE TECHNIQUE – GAHCT FOR A N-TIER ARCHITECTURE

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ABSTRACT

Topology control targets to achieve an energy efficient network with limited number of communication links between the sensor nodes. One way to attain a reduced topology is via a cooperative technique. In this paper, a new methodology GAHCT: Genetic Algorithm based Hierarchical Cooperative Technique is proposed and implemented for a N-tier architecture with different node densities. Obtained results prove the effectiveness of our proposed work for a two tier architecture.

Keywords: Topology control, GAHCT, N-tier architecture

I. INTRODUCTION

Wireless Sensor Network (WSN) comprises of small complex sensors with limited battery as the energy resource. The effective utilization of the battery leads to the maximization of the network lifetime which is a crucial factor. Usage of minimum transmission range for communication between the nodes produces maximum power savings and enhanced network lifetime. This also results in a reduced network topology. The foresaid process is called topology control.

Figure 1 depicts a network of 100 nodes with maximum and minimum transmission ranges. The complexity and the region of interference becomes more for a network with maximum transmission range. Thus results in increased collision and number of retransmissions. One solution to avoid these circumstances is applying a topology control technique. The art of coordinating nodes' decisions regarding their transmitting ranges, in order to generate a network with the desired properties is called Topology control. Many topology control algorithms are presented in the literature [1-12]. Widely used applications of sensor networks incorporate large number of sensors. The data collected using these sensors must be transmitted to the sink using direct long distance communication or short multi hop communication. Longer communication distance between the sensors and the sink makes energy consumption more. By making the distance short, the overall energy consumption is reduced. One of the effective mechanisms for short distance communication is clustering. The literatures also showed the drastic increase in network lifetime

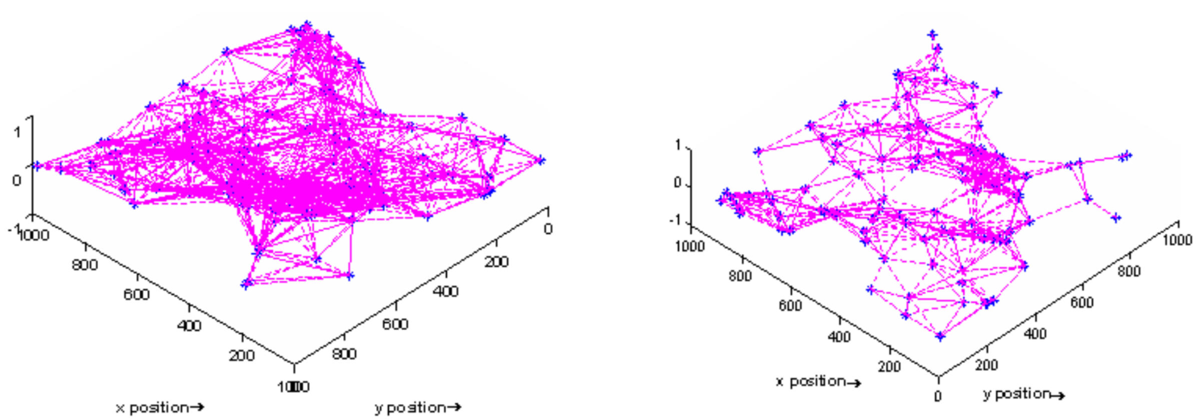

Fig. 1. Network Topology with maximum and minimum transmission ranges

using clustering [11-15]. Using an energy efficient clustering schema in a topology control algorithm leads to the enhancement of network capacity and network lifetime. In one tier architecture the data forwarding from source to sink is via multihop communication through the neighboring nodes. For a two tier architecture, 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 from cluster slaves to sink. In three tier architecture, in addition to the lower and the second tier of the previous a third tier comprising of super heads is formed. Data gathered by the cluster slaves were sent to the cluster heads. The cluster heads forwards the data to the near by super heads. From the super heads the data is forwarded to the sink. Cluster head selection and super head selection are critical processes in N-tier architecture. So an effective optimization tool has to be used for cluster head and super head election from the randomly deployed sensor nodes. Genetic Algorithm (GA) is one such tool.

In this paper, a genetic algorithm based hierarchical cooperative technique which considers the nodes bandwidth, residual energy and memory capacity for cluster head selection and super head selection is proposed. It has also been implemented on N-tier architecture with various network densities. The impact on the network topologies and the total energy consumption over a N-tier architecture is studied.

The paper is organized as follows. In section 2, discussion on the various existing works on GA based clustering is done. The proposed methodology is illustrated is section 3. Results and discussions on the proposed work were made in section 4. Section 5 concludes our work with a future work.

II. REVIEW ON GENETIC ALGORITHM BASED CLUSTERING

The GAs' ability for searching, fast convergence and fast evaluation distinguish themselves from other decision and optimization algorithms. A Genetic Algorithm (GA) is a stochastic search technique based on the mechanism of natural selection and recombination. It starts with an initial *population* of individuals, i.e. a set of randomly generated candidate solutions. The solutions are represented by *chromosomes*, which are collections of numbers or symbols that map onto parameters of the problem. Individuals are evolved from generation to generation, with *selection*, *crossover* (*mating*), and *mutation* operators. These operations provide an effective combination of exploration of the global search space and pressure to converge to the global minimum. The solution quality is measured by a *fitness* function. [12] [15-20].

In [12] G. Ahmed et. al., explained the procedure of using evolutionary computing for the selection of the CHs. The CH selected using any algorithm should be powerful, closer to the cluster-centroid, less vulnerable and low mobility. The above said factors are involved in forming a fitness function. The BS periodically runs the proposed algorithm for a certain time period to select new CHs. Results showed that using evolutionary computing, the network life time is drastically increased.

In [16] Mohamed et. al., proposed the use of GAs to minimize the communication distance in a sensor network by dividing it into K-clusters. The total transmission distance is the main factor used in the fitness function that is to be minimized. The algorithm starts to find an appropriate number of cluster-heads and their locations by adjusting cluster-heads based on fitness function. Once cluster-heads are selected, each regular node connects to its nearest cluster-head. Each node in a network is either a cluster-head or a "member" of a cluster-head. Each regular node can only belong to one cluster-head. Each cluster-head collects data from all sensors within its cluster and each head directly sends the collected data to the sink. It has also been proved that the total distance is minimized as the number of heads is decreased.

In [17] Amol P. Bhondekar et. al., demonstrated the use of genetic algorithm based node placement methodology for a WSN. Design parameters such as network density, connectivity and energy consumption are taken into account for developing the fitness function. A fixed WSN of different operating modes was considered on a grid deployment and the GA system decide which sensors should be active, which ones should operate as cluster-in-charge and whether each of the remaining active normal nodes should have medium or low transmission range. It has also been concluded that it is preferable to use more number of sensors and achieve lower energy consumption for communication purposes than having less active sensors with consequently larger energy consumption for communication purposes.

In [18] Sajid Hussain et. al., investigated intelligent techniques for cluster formation and management. Direct Distance to Base Station (DD), Cluster Distance (C), Standard Deviation (SD), Transfer Energy (E), and Number of Transmissions (T) are used in the fitness function. The GA is used in the Base Station (BS) whose outcome identifies suitable clusters for the network. The BS broadcasts the complete network details like query execution plan, the number of cluster heads, the members associated with each cluster head, and the number of transmissions to all the nodes in the network. All the sensor nodes receive the packets broadcasted by the BS and clusters are created accordingly. The proposed technique extended the network lifetime for different network deployment environments.

In [19] Jenn-Long Liu et. al., proposed a GA-based adaptive clustering protocol (LEACH-GA) to determine the optimal thresholding probability for cluster formation in WSN. The fitness function involves energy dissipation for aggregating data, number of Cluster Candidate Head (CCH), number of cluster members and the transmitter electronics. Initially all the nodes perform cluster head selection process and decides whether to become CCH or not. This status along with the geographical position is send to the base station. The base station then searches for an optimal probability of nodes being cluster heads via a genetic algorithm by minimizing the total energy consumption required for completing one round in the sensor field. Thereafter, the base station broadcasts an advertisement message with the optimal value of probability to the all nodes to form clusters. Simulation results showed that the proposed algorithm produces optimal energy consumption resulting in an extension of network lifetime of WSN.

In [20] Dr. Sajid Hussain et. al., proposed a methodology using genetic algorithm (GA) to generate balanced and energy efficient data aggregation spanning trees for WSN. In a data gathering round , the energy resources of heavily loaded nodes gets depleted earlier than others. This necessitates a collection of trees to balance load among nodes and consume less energy. The fitness is determined by residual energy, transmission load, receive load and the distribution of load. Data aggregation tree is created at the base station using GA and schedule packet is broadcasted to all the nodes. Each sensor node extracts its own information from the schedule packet and use the schedule for a given number of rounds, as specified in the schedule. At the last round of the current schedule, each node appends its residual energy level to the data packet. Then, base station uses the current energy resources to generate the next data aggregation tree. The results showed that GA is better than other data aggregation tree-based approaches in terms of extending network lifetime.

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.

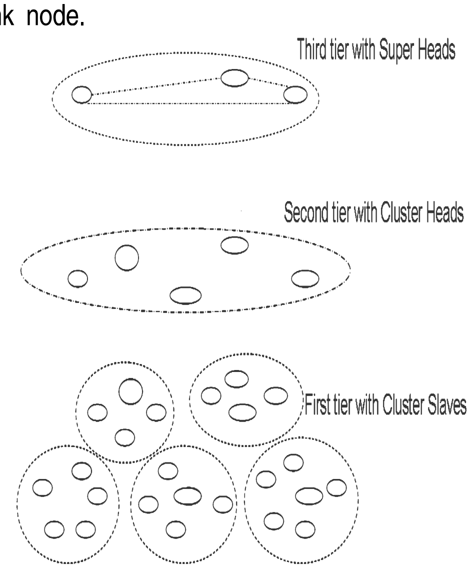

Fig. 2. N-Tier Architecture

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

IV. RESULTS AND DISCUSSIONS

The proposed GAHCT is implemented for a N-tier architecture with network densities of 25 nodes and 50 nodes. A network scenario with 25 sensor nodes and 1 sink node, whose x, y and z coordinated were known, is deployed and the scenario is termed as Network Deployment #1. Another network scenario with 50 nodes is deployed and is named as Network Deployment #2. Using NS-2.34, network deployments #1 and #2 were simulated with the parameters given in table 1. For both the scenarios the energy consumed by all the nodes in the network were calculated. The energy consumed to transmit k bits message over a distance d is given by,

$$E_{TX}(k,d) = E_{Elec} * k + \in_{amp} * k * d^2 \quad (1)$$

Where E_{Elec} is the radio energy dissipation and $\in_{amp}$ is transmit amplifier dissipation. Using the above equation, the energy consumed to transmit data in a N-tier architecture using the simulation parameters in table 1 for our proposed GAHCT is calculated.

The figure 3 shows the screenshot of network deployment #2 of a N- tier architecture for a network density of 50 nodes using NS 2.34. The total energy consumed by individual nodes for both the deployments were compared in figure 4 and figure 5. Figure 6 proves the effectiveness of our proposed GAHCT, for a two tier architecture by comparing the total energy consumption for a N-tier architecture using different node densities.

Table I. The Simulation Parameters

Parameters	Value
Deployment Region	1000 m × 1000 m
Number of Nodes for Deployment #1	25
Number of Nodes for Deployment #2	50
Sink Node Id	25
Sink Node Position	800, 800, 0
Number of Bits transmitted	500
Transmission Power	0.8 mW
Receiving Power	0.2 mW
Idle Power	0.003 mW
E_{Elec}	50 nJ/bit
ϵ_{amp}	100 pJ/bit/m^2
Simulators	NS-2.34, Matlab

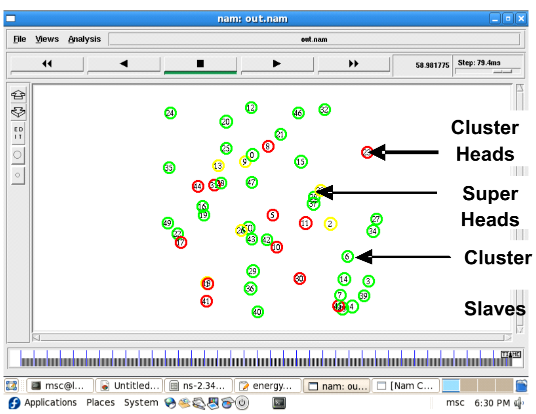

Fig. 3. NAM screen shot of a N-tier architecture

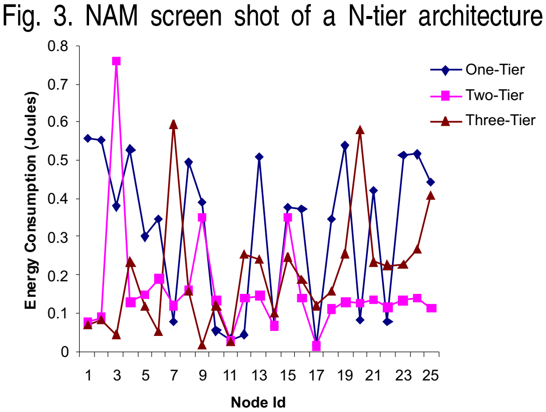

Fig. 4. Comparison on the energy consumed by the individual nodes for deployment #1 in a N-tier architecture using GAHCT

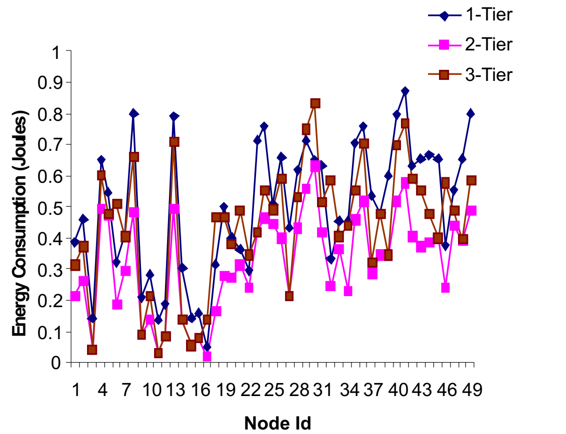

Fig. 5. Comparison on the energy consumed by the individual nodes for deployment #2 in a N-tier architecture using GAHCT

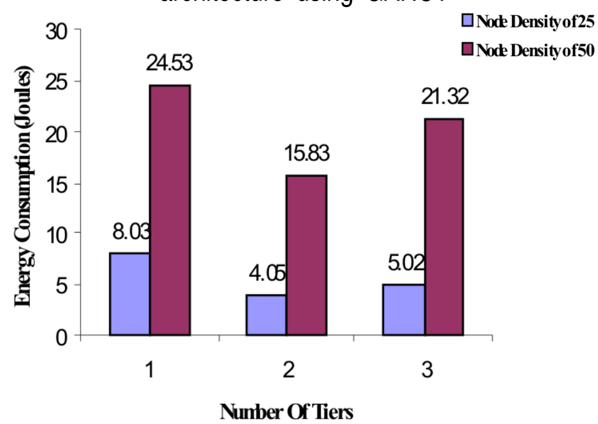

Fig. 6. Comparison on the Total Energy Consumption for a N- tier Architecture for various node densities

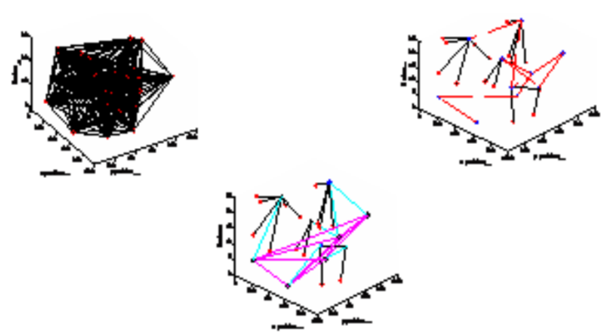

Fig. 7. Network topologies of deployment #1 for One tier, Two tier & Three tier Architecture

The network topology diagrams of deployment #1 and #2 for a N-tier architecture using the proposed methodology is shown in figure 7 and figure 8. From

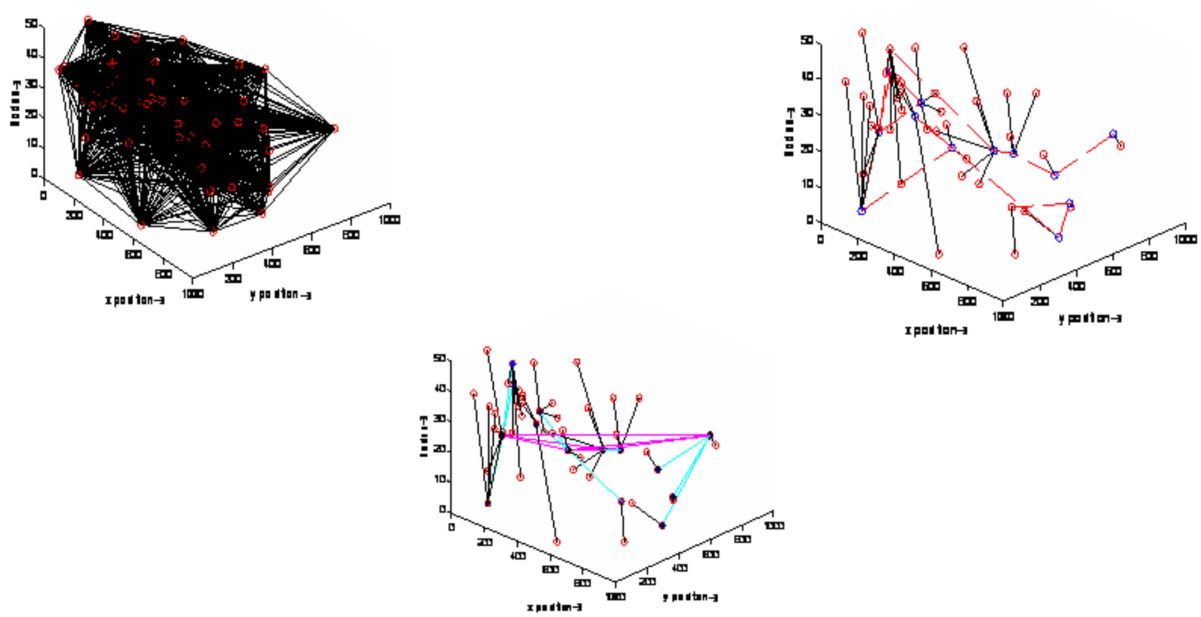

Fig. 8. Network topologies of deployment #2 for One tier, Two tier & Three tier Architecture

the figures, it is very clearly seen that implementation of a topology control algorithm reduces maximum number of communication links thereby reducing the overall network complexity.

V. CONCLUSION & FUTURE WORK

A new methodology, genetic algorithm based hierarchical cooperative technique is used for the election of cluster heads and super heads for a N- tier architecture. 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. The study on the impact of total energy consumption over N-tier architecture for various node densities of a wireless sensor network is performed. From the comparison it is well proved that a two tier architecture gives a better performance when compared to others in case of a N-tier architecture.

The hardware implementation on the proposed algorithm can be done to prove the effectiveness on the real time scenario. As an enhancement of this work, a methodology using fuzzy which uses residual energy, bandwidth and memory capacity can be proposed. The results can be compared with GA based methodology.

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