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Neuro-Genetic Hybrid Optimization for Multi Objective Wireless Sensor Networks

Vinodh P Vijayan

Research Scholar, Department of Computer Science and Engineering, Vels university, Chennai-600043
vinodhpvijayan@yahoo.com

Dr. E Gopinathan

Dean, School of Engineering, Vels University, Chennai-600043, dean.se@velsuniv.org

Abstract
Optimizing various parameters and obtaining a good network performance in wireless sensor network is a challenging job as this may degrade the performance(s) of other systems or network parameters. Optimizing the various network parameters across the geography is difficult to implement and does not guarantee the best result in time varying applications where the scenarios are expected to change abruptly. Hence optimizing parameters in a particular geography by considering the neighbor information and at the same time considering the global information like average network load, packet delivery ratio of various spatial areas etc. will yield improved network performance. The cooperative nature of intelligent sensors can be used more effectively and hybridizing optimization technique like genetic algorithm with neural network will give good result in multi objective scenario.

Keywords: Wireless sensor network, multi objective, Neuro-genetic optimization, load balancing, coverage.

Introduction

Obtaining the required coverage is the prime objective of the installation of a wireless sensor network. But if the application required is to monitor a large [4] geographical area for a long time, it is required to solve various challenges like life time of the sensor networks and load of the network in different areas. Hence in a sensor network like that shown in figure 1, the problem is multi-objective because it is important to optimize local parameters like data aggregation[8], packet delivery ratio, routing overhead etc and global parameters like average life time[1] of the network, load balancing etc. without compromising on the coverage[4] capacity of the network. As the problem is multi objective, the network performance will purely depends on an efficient optimization technique.
Genetic algorithm based optimization [2] of network parameters in a wide geographical and time varying application is expected to have following challenges.

1. Network performance in various geographical areas will be different.
2. In a real time scenario of time varying and mobile sensor applications, the parameters are dynamic in nature and varies with time [5] and hence the optimization technique without learning approach will fail.
3. The effect of optimization technique on the average load of the network, network life time, coverage of the network etc. are discussed in [3, 4].

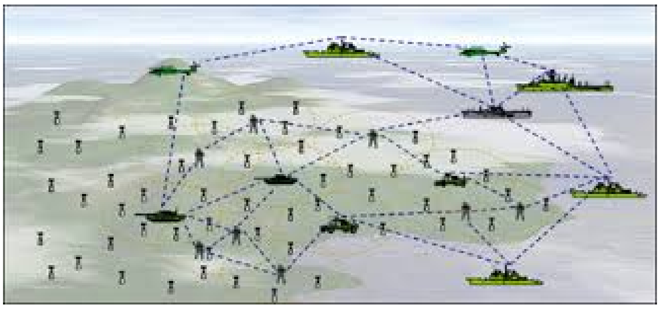

Figure 1 Wireless Sensor Network

As a solution to the first problem, the optimization is considered for the local parameters which are collected from the neighbor nodes which are confined to a particular geographical area [6]. In order to avoid clustering overhead, areas are not grouped using any standard clustering technique.
The second challenge identified is the lack of learning approach in the dynamic environment, which is solved by using neuro-genetic hybrid [2] approach. Here the artificial neural network with back propagation is used for the learning purpose in a time varying network, and hence GA is applied to optimize the parameters. The contribution of local optimization to global parameters such as network load, life time of network and coverage offered etc. are ensured by adding such component in to the chromosomes. This ensures that global focus is included in the optimization which ultimately solve our third challenge. The ratio of local parameter to global parameter included in the chromosomes is 60:40 which ensures a global optimum solution in the dynamic environment.
In order to efficiently monitor the environmental factors for a long interval of time, it is of high significant to structure an extensive data gathering mechanism that extends the network lifetime and coverage without overloading the network. An optimized network where local and global parameters are considered for improving network model was designed by

applying polynomial time algorithm. To derive a solution in distributed manner, a set of communication topologies were designed in [9] and applied to several data collection cycles which not only provided flexibility but also proved to be energy[12] efficient.

Related Works

Over the last two decades, WSN has been adopted in different profitable and non profitable establishments with the main aim of minimizing the cost in addition to energy. In [10], Energy Efficiency (EE) was incorporated to packet transmission using energy conservation mechanisms that resulted in cost minimization. Though the method proved to be energy efficient, integration of several components remains unaddressed. An integration of several components including fault tolerant towards multi hop based cluster with energy efficient protocol [11] was designed to provide critical service.

However, given brittle conditions of multiple copies of the same packet in WSN, where collision and interference nodes are quite high among various sensor nodes, CNNA method works well by introducing variance and weighted variance values along with the genetic optimization procedure. This was possible since we have used different geographical routings. Furthermore, it also helps in minimizing the search time taken for identifying the collision and interference nodes in wireless sensor networks which results in collision removal and balancing the load between nodes in a network system.

Neuro-Genetic Optimization of network parameters

In Figure 2 depicts, in a pictorial form, the overall step involved in the design of optimization [2] method. The optimization require preparation of initial chromosome which consists of two phases. In first or the initial phase, local optimizing parameters are collected from a node based on its neighbor information, which is given a weightage of 60% in the chromosome representation. The optimization of local parameters will improve the network performance in a particular geographical area. In the second phase global information like network load, network life and coverage are collected from maximum area [7] of the networks and is included in the preparation of chromosome with a 40% which ultimately help us in recovering a global optimum solution.

A neighbor information tree is prepared from local information with n-d tree structure which makes the data aggregation easy and also ensures the removal of collision or interference occurring nodes. The n-d data structure uses the binary search tree to identify the collision occurring nodes and removes the collision occurring nodes in an effective manner using the segregation procedure. With the aid of the segregation procedure, the interference occurring node is removed by way of comparison of variance count.

The genetic approach improves the load balancing factor in hybrid optimization method. The interference free network is selected and then the crossover and mutation operation is processed based on the weighted variance. Figure 3 shows various steps involved in the genetic based optimization. The optimization performance depends on the ratio of local and global parameters in the chromosome, crossover probability Pc, and Mutation probability Pm.

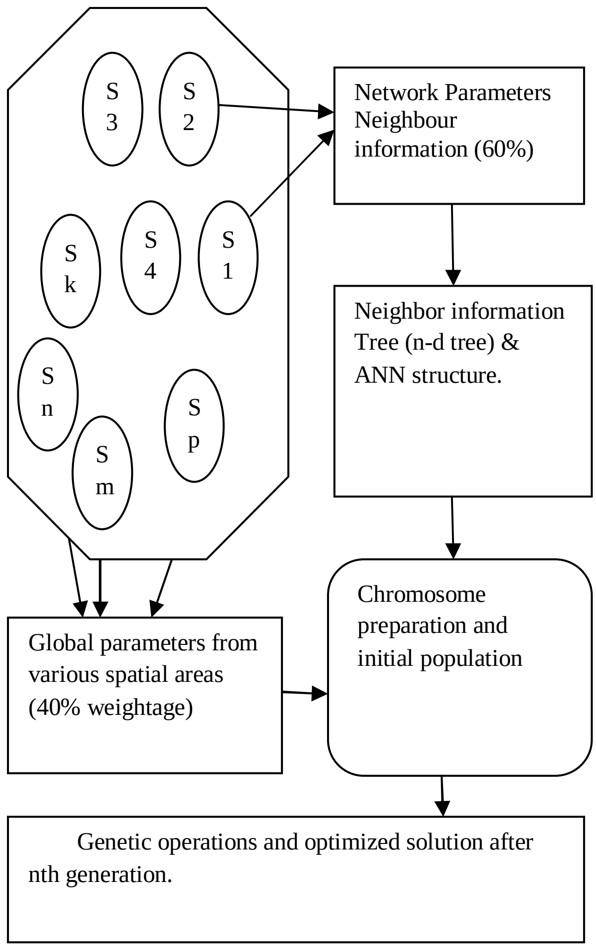

Figure 2 Overall Structural Diagram of hybrid optimization Method

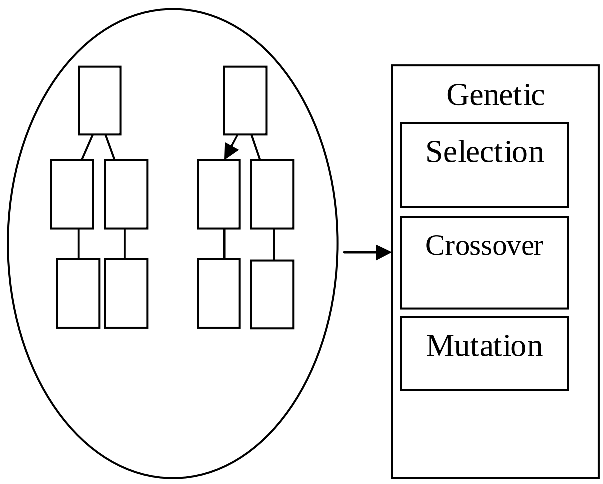

Figure 3 Genetic Optimization Approach

In the second phase, balancing the load factor and other global parameters are done by applying the genetic optimization procedure since the interference occurring nodes are removed using the n-d data structure with the aid of segregation procedure. The genetic optimized rule uses the selection, crossover and mutation operation to balance the load on the neighboring packet transfer nodes in the sensor network. The weighted variance is also computed which balances the load on environmental sensor network structure with higher packet delivery rate. The design consideration of n-d data structure with the aid of segregation procedure followed by load balancing of collision free network by applying genetic optimization procedure is explained below with the help of pseudo code for easy representation.

A. Construction of n-d data structure

The first step involved in the design of proposed method is the construction of n-d data structure. The procedure of constructing the n-d data structure using hybrid method takes the input set as 'X', where 'X' represents the 'n' observation vectors made by 'k' environmental sensor nodes. Broadcasting of multiple packets from source nodes to the neighboring nodes are then measured from time 't' to't_n '. With this, the n-d data structure procedure returns the transferred packet count and gets stored in set 'X'. The search of collision node is carried out using the binary search tree.

B. Binary Search Tree with Segregation Procedure

In the proposed method, Binary Search is carried out on a sensor node based data structure where each node has similar variance values while transferring the packets. With this, the value of the variance satisfies the specified variance count, and as a result, the environmental network is structured with collision free system. If the variance in any node of left sub tree is larger than the variance of all other nodes in the sensor network, then it is said that the collision or interference has occurred on a specific node. In a similar manner, the variance on the right sub tree is also computed in order to identify the interference node. The advantage of using the binary search tree in this method is that, it provides the quicker searching process with minimal time count.

Figure 4 describes the binary search process with variance value computation involved in the design of CNNA method. The conventional n-d data structure identifies the interfered node and the removal of node takes place using the segregation procedure. The segregation procedure variance value is computed as

$$Variance\ Value\ (\sigma^2) = \frac{\sum_{i=1}^{n} x_n - (\sum_{i=1}^{n} x_n)^2}{K} \quad (1)$$

The computed $Variance\ Value\ (\sigma^2)$ is constructed to segregate the collision occurring node on the K environmental sensor nodes. In (1), X denotes the set with n observation vectors in the environmental sensor network. The sensor with the largest variance has been noticed as the interference node. The n-d data structure in CNNA method reduces the dimensional factor to the largest extent. The segregation procedure clearly removes the collision node from the network structure.

```
Begin
Binary Tree (Tree sensor node, IntMinPacketsize,
IntMaxPacketsize)
{
If (Sensor node variance value ==S)
Return Collision Free System;
Else (Sensor node variance value! = S)
Return Collision Occurred node;
End If Else
}
Collision occur sensor node identified;
End
```

Figure 4 Pseudo code for the binary search process.

Neuro-Genetic Optimization Procedure

The second phase involved in the proposed method is to construct artificial neural network and apply genetic optimization procedure for weight balance to perform load balancing or for improving expected network performance. This genetic optimization procedure for balancing the load includes selection, crossover and mutation operation. The weight variance on each of the neighbor node is measured to balance the load factor in sensor network. From all the search space, via binary tree search, load balancing is attained by applying the neuro-genetic hybrid optimization concept.

To illustrate the above concept, assume that we have to setup an ANN with 4 input nodes, 3 hidden layer nodes and one output node. This implies that there will be 10 weights to be adjusted. The chromosome can be represented as shown below. Further, the composition of a gene decides the representation of local factor and global factor which is shown in table 1.

Table 1 chromosome structure used with hybrid optimization.

W11	W12	W13	W21	………	W21	W31
Gene 0	Gene 1	Gene 2	Gene 3		Gene 10	Gene 11
84321	46234	78901	32104	………	87640	14261

The weight variance is measured as,

Weight variance (W)
= Attained load value-Specified Value (2)

The Weight Variance (W) is computed to balance the load between the neighboring nodes in a sensor network. After computing the weighted variance, crossover and mutation is carried out to balance the load. In the proposed technique, the crossover point is selected, and the binary tree of left and right string is used to balance the load. The binary string is selected and the mutation operation converts the overall binary tree structure. The algorithm involved in Genetic Optimization approach in the proposed technique is described as,

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//Genetic Optimization Approach
Input: Initialize numbers of 'G' for genetic optimization of weights
Step 1: Set generation count as g=0
Step 2: Generate initial selection process
//Crossover
Step 3: Nodes are randomly copied from the first or from the sub tree of the n-d data structure
Step 4: Weighted variance computed after crossover genetic operation
//Mutation
Step 5: Probability of a mutation of a bit in factor 'k' is converted
Step 6: Left and Right Neighboring node of n-d data structure are shifted
Output: Balance load with collision free nodes in sensor network

The above algorithm, developed with the genetic optimization approach in hybrid method, improves the load balancing and life time factor. The load balancing is carried out in the environmental sensor network by removing the interference node using the binary search tree in the n-d data structure. The complexity level on packet transmission is also reduced by removing the multiple copies transferring nodes.

Experimental Evaluation

Random Waypoint Model (RWM) is developed to randomly choose and move to another node location point by forwarding the packets to the neighboring nodes. RWM model shifts to an erratically chosen location. RWM uses an average about 80 numbers of nodes for route discovery. The chosen location with an arbitrarily chosen speed contains a predefined quantity and speed count. Dynamic Source Routing (DSR) Protocol is used in the proposed model for effective interference free network developed and balances the load. The randomly selected location with a selected rate provides a predefined speed.

The random progression is constant during the simulation period of the wireless network. The minimum moving speed of the sensor node is about 5.0 m/s for each node. CNNA measures the parametric factors such as collision removal rate, load balancing efficiency, packet delivery complexity ratio and search time taken for identifying the collision in network.

Packet delivery complexity ratio is the rate at which the packet is delivered from the source to the destination node in wireless network.

Results

An experimentation setup has been made in Network simulator 2 with variable node density in a particular area square meter. The parameters measured are packet delivery ratio, search time of neighbor node, and load balancing factor. The scheduling overhead, the average network life time, the routing overhead etc. can be inferred from the various parameter measured. The various node density used for simulation are 60, 80 and 100.

Figure 5 shows the screen shot of simulation where 60 nodes are included in the network. S1, S2 and S3 are three different sources and D1, D2 and D3 are corresponding destinations.

In figure 6, the packet delivery ratio is plotted against varying number of nodes which also show the network performance in a scalable network. The improved packet delivery ratio in the figure 6 shows that there is a significant improvement in network throughput.

The figure 7 shows the comparison of search time requirement for neighbor node information collection. It is evident from this figure that the binary search tree implementation achieves a reduction of search time to logarithmic scale.

The load balancing factor shows the network performance across the geography for a large network. The comparison is taken against varying number of nodes with hybrid techniques; the graph shows that there is a remarkable improvement in the overall network performance.

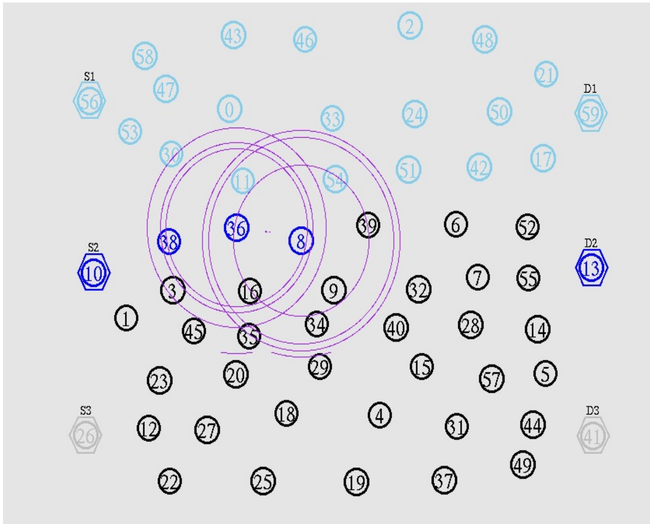

Figure 5 Screen shot of simulation with a node density 60.

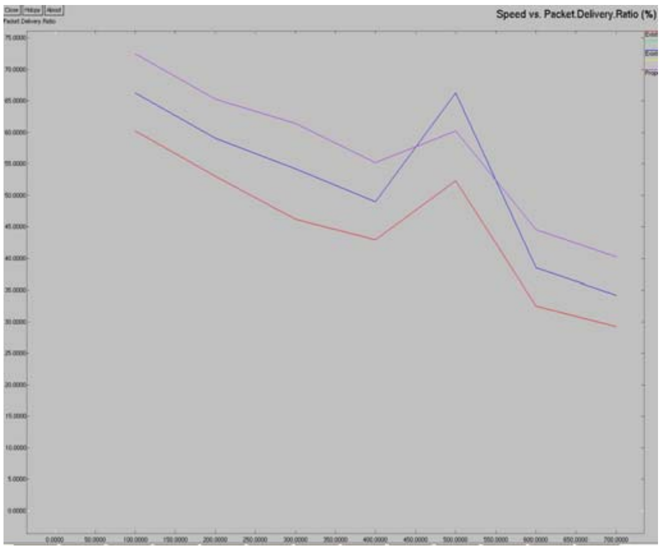

Figure 6 Packet delivery ratio for varying node density.

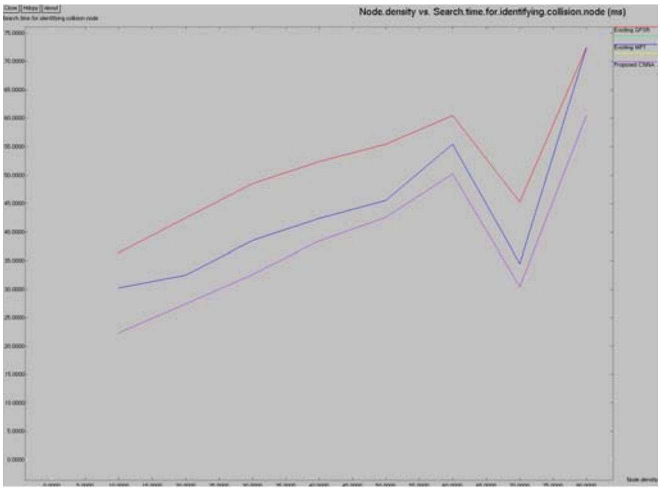

Figure 7 Comparison of search time in n-d tree for inference avoidance.

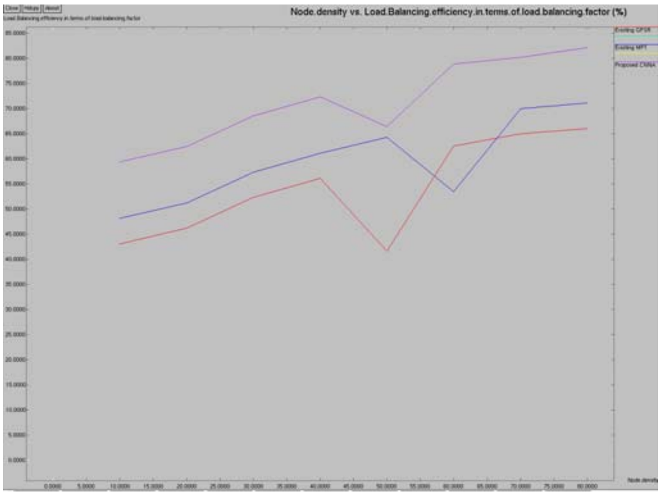

Figure 8 Impact of load balancing efficiency with varying node density.

Conclusion

The challenging issue of optimizing network performance of a large scalable network of wireless sensor network is solved using a Neuro-Genetic optimization. The cooperative nature of nodes are used to share the neighbor node information and thereby local parameters are included in the optimization. The global parameters such as network load, life time, and coverage etc. of various geography also include in a specific rate to optimize over all network performance. The simulation result shows that the use hybrid optimization on local and global parameters ultimately yield an improved network performance in a time varying and scalable network model.

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