A GA based Optimized Stable Election Routing Protocol for Hierarchical Clustering in WSN

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ABSTRACT

Recent advancements in technology have enabled the development of low-cost, low-power sensor devices used in wireless communication. A WSN consist of large number of wireless devices, the sensor nodes, able to take environmental measurements and route these measurements to the base station. These senor nodes are very small in size and are powered by battery. In a WSN, the sensor nodes are deployed randomly in the area of interest. Being battery powered, these sensor nodes lose their energy every time they collect or transmit any information and become inactive. The WSN becomes unstable as the first sensor node dies. Thus the routing protocol should be energy efficient should help in increasing the stability period and so the network lifetime of the WSN. In this paper, the genetic algorithm is used as an optimizing tool for the improvement of lifetime & stability period of the network. For the purpose of optimization the GA is applied on SEP. The proposed protocol, when compared with SEP and LEACH shows better outcomes.

Keywords

Clustering, GA, SEP, stability period, network lifetime, WSN.

1. INTRODUCTION

A WSN is a distributed system and composed of a number of minute wireless devices known as the sensor nodes that are capable of measuring the surrounding conditions, aggregation and data routing. These sensor nodes are expected to perform many complex functions of communication and are equipped with data processing, communication capabilities.

However, these sensor nodes are constrained in energy, as they are powered by battery and do not have any source of energy. With these constraints the data routing has become a challenging task. Moreover, the WSN differs from other communication networks in many aspects viz. generation of global addressing scheme for the deployment of a number of sensor nodes. Secondly, in WSN, multiple sensor nodes can generate similar data within the vicinity of the phenomenon. Thus a number of routing protocols have been developed to handle these redundancy and energy constraints properly. Almost all the data routing protocols can be categorized as: data centric, hierarchical or location based protocols [1]. Data-centric protocols help to reduce the redundant transmission of the data and are query-based protocols. Here the base station sends a query to the nearby sensor nodes and waits for the data from the nodes. Flooding and gossiping are the two data routing techniques that fall under the category of data-centric protocols.

The location based protocols use the location information to route the data to the base station. The hierarchical protocols aim to reduce the energy consumption by forming the clusters and cluster heads. Each cluster contains a specific number of sensor nodes and a cluster head (CH). The CH collects data from the nodes of its cluster, aggregates it and finally transmits the data to the base station (BS). The important hierarchical protocols are LEACH (Low Energy Adaptive Clustering Hierarchy), SEP (Stable Election Protocol), PEGASIS (Power-Efficient GAthering in Sensor Information Systems), TEEN (Threshold sensitive Energy Efficient sensor Network), and APTEEN (AdaPtive TEEN). These hierarchical protocols help to improve the lifetime of the network. The network parameters such as network lifetime, Stability period can be further optimized using different optimizing tools such as Genetic Algorithm, Ant colony optimization etc. In this paper, the GA is used as the optimizing tool on the hierarchical protocol and the protocol used is SEP.

2. GENETIC ALGORITHM

Genetic algorithm is a search algorithm based on mechanics of natural selection and natural genetics. GA works from a rich database of points (population of strings) simultaneously and elects most suitable string amongst others to exchange information. Each individual string in the population is known as chromosome. GA generates multiple solutions per iteration. A genetic algorithm has four steps viz. population initialization, fitness evaluation, reproduction and termination.

2.1 Population

Population is a collection of chromosomes or solutions to a given problem. Population initialization is the process of creating random solutions. For a population size of n, GA starts with n random solutions. It then selects the fittest solution for mating to generate the new solution. In a WSN using GA, each chromosome corresponds to a sensor node and in the selection process, the fittest chromosome is elected as CH [3]. The generation of new population is known as reproduction. The new population is generated by the process of selection, crossover and mutation.

2.2 Fitness Function

Fitness function of a chromosome is the ability of the chromosome to pass its genetic material and its quality to survive.

The fitness function of a chromosome is defined as: F = (w_i, f_i) $\forall\ f_i \in \{C, D, E, SD, T\}$, where w_i is the initial weight which is selected arbitrarily and is updated in each round to select the best chromosome [1]. Fitness of a chromosome depends of different parameters viz. cluster distance (C), direct distance (D), transfer energy (E), cluster distance standard deviation (SD) and number of transmissions (T).

2.3 Selection

Selection is the process of generating new population. It is used to determine which two chromosomes will mate to form the new population. Normally the selection step is implemented by Roulette-wheel method. With this method the best fit chromosome is selected according to the probability given by P = $\frac{F_i}{\sum_{i=1}^{n} F_i}$. In roulette-wheel method of selection, all the chromosomes are placed on the roulette-wheel according to their fitness value. The size of the segments of these chromosomes on the wheel is proportional to their fitness value. The chromosome with higher value of fitness is allotted larger sized segment and the smaller segment is allotted to the least fitness value chromosome. Then the virtual roulette-wheel is spinned. The chromosome corresponding to the segment on which the wheel stops is selected. Thus the individual with higher fitness value has the highest probability to be selected [7].

2.4 Crossover

Crossover is process of producing new children chromosomes (offspring) from the parent chromosome. The crossover probability is normally less than 1. The two chromosomes undergo the process of crossover as: an integer position k along the string is selected uniformly at random between 1 and the string length less one i.e. [1, *l*-1]. The children chromosomes are created by swapping all the characters after position k.

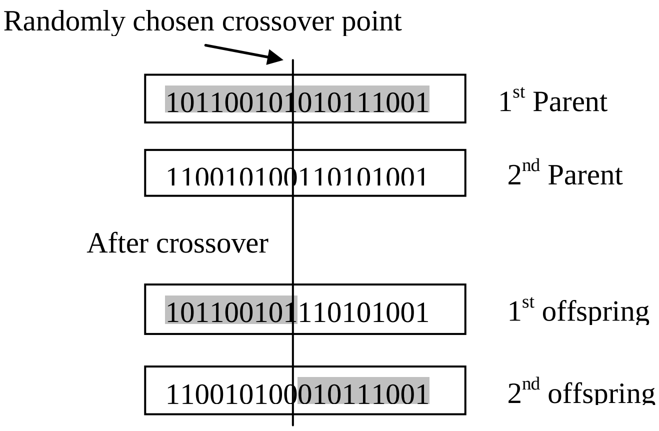

Fig.1. Single point crossover of two chromosomes

2.5 Mutation:

In mutation a gene (mutation node) is selected randomly from one chromosome and is assigned to another chromosome**.** The stopping criteria for the GA could be predefined number of iterations or convergence during a predefined number of iteration. Once the CH is selected using selection procedure, it then generates the new population by the procedure of crossover and mutation [8].

3. SEP- STABLE ELECTION PROTOCOL

SEP is a hierarchical protocol that aims to transfer the information to BS by forming clusters and cluster heads (CH). Unlike LEACH, SEP is a heterogeneous routing protocol that defines the network as combination of normal and advance nodes. Advance Nodes are the fraction (m) of total nodes containing some extra energy as compared to that of normal nodes. If E_0 is the initial energy of the normal nodes then initial energy of the advance nodes is given by $E_0(1+\alpha)$ where α is the extra energy factor. In a homogeneous WSN using LEACH protocol, every normal node ∈ G becomes CH once in every ${}^{1}/_{p_{opt}}$ rounds (epoch). But the scenario of LEACH is less well suited in case of heterogeneous network. In a heterogeneous WSN using SEP, the epoch is defined as $\frac{1}{p_{opt}}$*(1+α*m). Thus a normal node in SEP, becomes CH once in every $\frac{1}{p_{opt}}$*(1+α*m) round and the advance node becomes CH once in every $\frac{1}{p_{opt}} * \frac{(1+\alpha*m)}{(1+\alpha)}$ rounds [9]. The probabilities of normal and advance nodes are given as:

$$p_{nrm} = \frac{p_{opt}}{(1+\alpha*m)} \qquad (1)$$

$$p_{adv} = \frac{p_{opt}}{(1+\alpha*m)}(1+\alpha) \qquad (2)$$

Where, p_{nrm} is the weighted probability for the normal nodes and p_{adv} is the weighted probability for the advanced nodes and m is the proportion of the advanced nodes with α times more energy than the normal nodes. The total energy of the network is given by

$$E_{total} = nE_0(1+\alpha m) \qquad (3)$$

And the threshold in SEP is replaced by threshold for normal nodes, T(s_{nrm}) and threshold for advanced nodes, T(s_{adv}) as follows:

$$T(s_{nrm}) = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}*(r*mod\,(1/p_{nrm}))} & if\ s \in G' \\ 0 & otherwise \end{cases} \qquad (4)$$

$$T(s_{adv}) = \begin{cases} \frac{p_{adv}}{1-p_{adv}*(r*mod\,(1/p_{adv}))} & if\ s \in G'' \\ 0 & otherwise \end{cases} \qquad (5)$$

Where, r is the current round, G' is the set of normal nodes that have not become cluster heads within the last 1/ p_{nrm} rounds of the epoch, and T(s_{nrm}) is the threshold applied to a population of n*(1−m) normal nodes. This guarantees that each normal node will become a cluster head exactly once every 1/p_{opt} *(1 +α*m) rounds and that the average number of cluster heads that are normal nodes per round is equal to n*(1−m)* p_{nrm}. Similarly, G'' is the set of advanced nodes that have not become cluster heads within the last 1/p_{adv} rounds of the epoch, and T(s_{adv}) is the threshold applied to a population of n*m advanced nodes. This guarantees that each advanced node will become a cluster head exactly once every $\frac{1}{p_{opt}} * \frac{(1+\alpha*m)}{(1+\alpha)}$ rounds. The calculation of energy consumption in the communication process can be presented by the first order energy model [4].

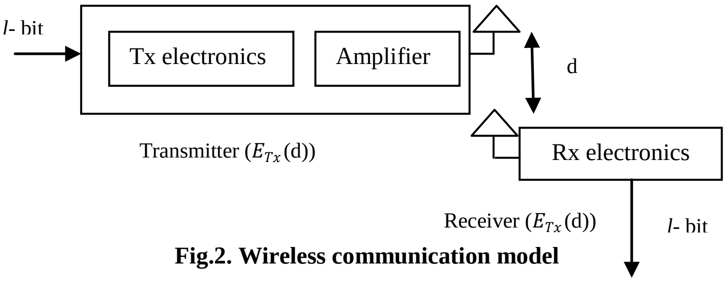

Fig.2. Wireless communication model

Energy spent to operate the transmitter and receiver section is given by E_{elec}. Energy required to transmit an *l*-bit message is given by E_{Tx}.

$$E_{Tx} = \begin{cases} l * E_{elec} + \epsilon_{fs} * l * d^2, & d \le d_0 \\ l * E_{elec} + \epsilon_{mp} * l * d^2, & d > d_0 \end{cases} \qquad (6)$$

4. SIMULATION RESULTS

4.1 Simulation Settings

The different routing protocols are implemented in MATLAB. The simulation is performed on different sensor networks, each composed of 100 sensor nodes deployed randomly in an area of 100 m × 100 m. The initial energy of a normal node is set as E_0 = 0.5 J, E_{fc} =10 pJ/bit/m^2, E_{mp} = 0.0013pJ/bit/m^4 and E_{DA} = 5nJ/bit/report. The message length is taken to be 4000 bits. For GA iterations the population size is taken as 20, crossover probability p_c= 0.6, mutation probability p_m= 0.03. The proposed protocol is tested for different parameters such as: Percentage of advanced nodes (m), Extra energy factor of advanced nodes (α).

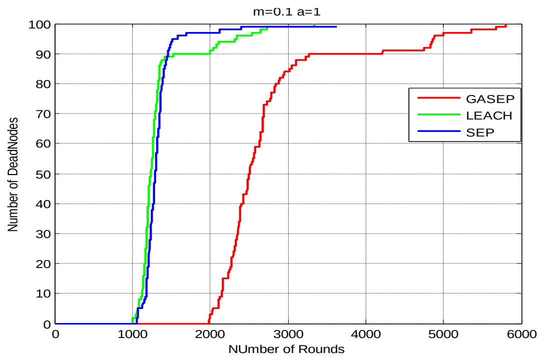

Fig.3. Results of different protocols with 10% advance nodes and α=1

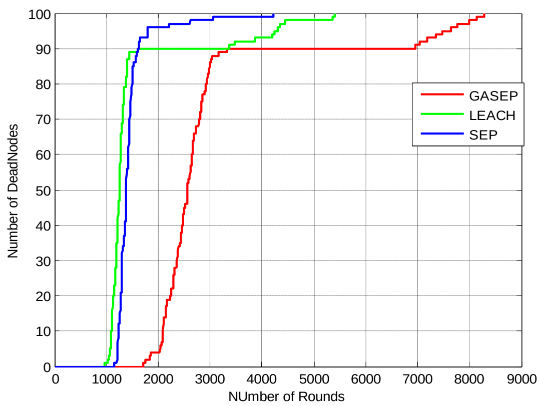

Fig.4. Results of protocols with 10% advance nodes and α=2

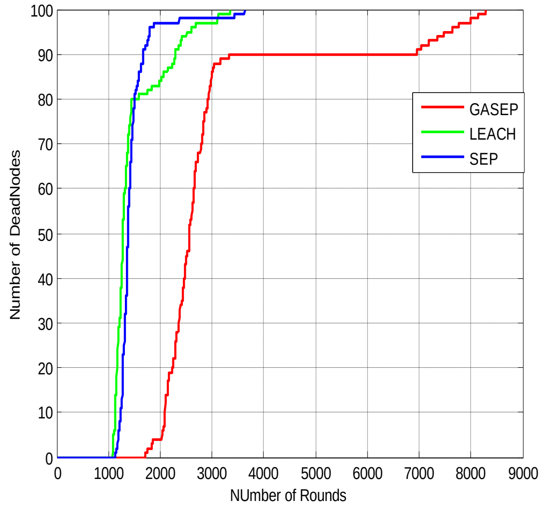

Fig.5. Results of different protocols with 20% advance nodes and α=1

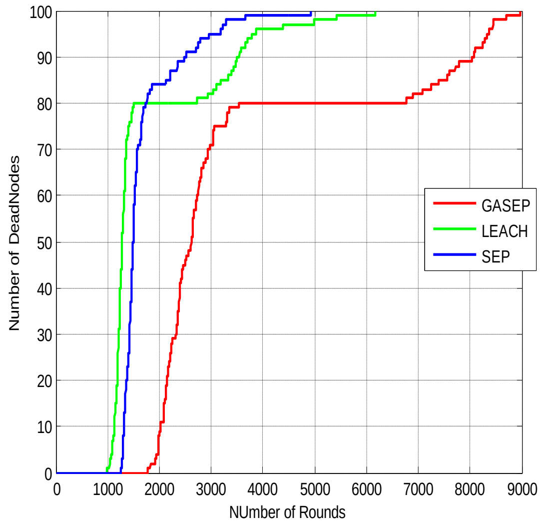

Fig.6. Results of different protocols with 20% advance nodes and α=2

5. CONCLUSION & FUTURE SCOPE

In WSN, CH selection and thus energy consumption are very important aspects. Thus the process of clustering for data communication should be energy efficient. The proposed protocol aimed to increase the stability period of the network and hence the network lifetime. This paper concludes that the outcomes of the proposed protocol are better than other protocols in terms stability period and well as the network lifetime of the WSN. In future the network parameters can further be modified by using other optimizing tools.

6. REFERENCES

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