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Prolonging Lifetime of Wireless Sensor Network using Evolutionary Algorithms

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Abstract: The popularity of wireless sensor have been increased in recent time due to growth in MEMS technology. Wireless sensor networks made up of hundreds or thousands of sensing nodes. It is necessary to make these nodes cheap and energy efficient. Most of the attention given to the routing protocol for energy efficient solutions. LEACH has been widely accepted WSN routing protocol for its energy efficiency. Evolutionary algorithm (EA) also used by researcher to resolve cluster based protocol in WSNs. The main goal of EA based clustered routing protocol is to dynamically form clusters in WSNs such that the use of energy resources of the network is minimized and prolong network lifetime. Aim of this paper is to ease the difficulty of undesirable behaviour of EA by formulating a new fitness function by introducing the concept of residual energy. Simulation shows that modified evolutionary routing protocol (ERP-M) prolong the network lifetime and saved more energy as compared to LEACH, SEP and ERP.

Keywords: WSN, LEACH, EA, SEP, ERP, MEMS.

I. INTRODUCTION

Wireless Sensor Network (WSN) contains hundreds or thousands of these sensor nodes which can be networked in many applications that require unattended operations, these have the ability to communicate either among each other or directly to an external base-station and also allows for sensing over larger geographical regions with greater accuracy.

Sensor nodes consist of a micro sensor module (e.g. acoustic, seismic, image sensor etc.) capable of sensing some quantity about the environment, CPU (for data/signal processing from sensors), memory (for data storage), battery (for energy) and transceiver (for receiving and sending signals or data from one node to another). The size of each sensor node varies with applications. For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery. The typical architecture of the sensor node is shown in figure 1.

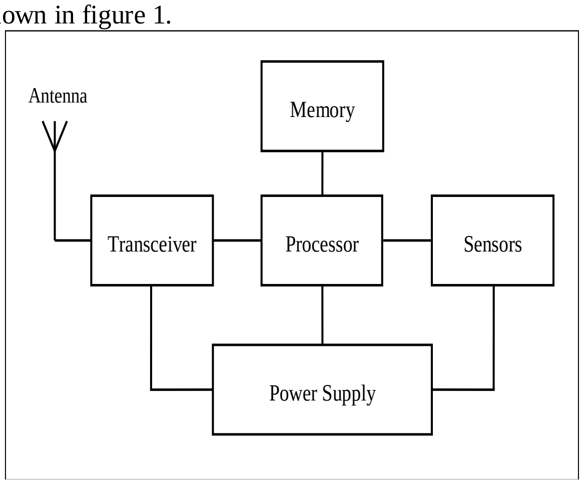

Fig 1: sensor node architecture

II. APPLICATIONS

As mentioned earlier, wireless sensor networks have many potential applications areas, e.g. military sensing, air traffic control, traffic observation, physical security, video surveillance, industrial and manufacturing automation, environment monitoring, building and structure were monitoring, and hospital and health care monitoring. Some of the application areas where sensor networks can be used are: Applications for military use: to detect and collect information about e.g. enemy movements, chemical-, biological-, nuclear attacks and materials. Applications for monitoring environmental changes in e.g. plains, forests, oceans [3].

Applications for monitoring vehicle traffic on highways to collect information about e.g. congested parts of a city. Applications for industrial use to monitor e.g. machines to get an increased knowledge about how the machine functions and about the production quality. For example, rolling machines at pulp and paper mills are big and complex [4,5].A sensor network can detect very small variations in speed and temperature that can have serious effects on the quality of the paper. A sensor network can also monitor the health of the staff working as well as the working environment e.g. temperature and ventilation. Applications for patient care both in and outside the hospital. For example, patients in hospitals that need some kind of health monitoring can use wireless sensor nodes instead of cabled sensor nodes and thus be more mobile.

III. CLUSTERING BASED ROUTING PROTOCOLS

Clustering is one of the methods used to manage network energy consumption efficiently in data gathering where the main aim is to find energy efficient routes. Grouping sensor nodes into clusters has been widely pursued by

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researchers in order to achieve the network scalability. Each group of sensors has a cluster head that aggregates data from member nodes in the cluster and forwards the aggregated data to the BS. The optimal selection of the cluster heads can be seen as an NP-hard problem. Several protocols have been proposed in literature with the objective of maximizing the sensor network lifetime by adopting selection of cluster-heads in these network architectures. A basic and well known clustering protocol is called LEACH, introduced in [6], includes distributed cluster formation in which the nodes elect themselves as cluster heads with some probability. PEGASIS [7], working similar to LEACH, generally consumes less energy per round than LEACH. LEFC [8] is another effective clustering algorithm developed for WSNs, using local information of the nodes defining their belongings to clusters. Although, PEGASIS and LEFC improve network life-time, they show poor performance on data gathering periods.

In this paper, we propose a new centralized clustering approach for the selection of cluster heads and compare the performance of the proposed implementation with the approaches given in [7,8]. The implementations are compared with each other by employing the algorithm.

IV. GENETIC ALGORITHM FOR EVOLUTIONARY ROUTING PROTOCOL

The concept of genetic algorithms (GA) was inspired by the evolutionist theory explaining the origin of species. In nature, weak and unfit species within their environment are faced with extinction by natural selection. GA operates with a collection of chromosomes, called a population. The population is normally randomly initialized. As the search evolves, the population includes fitter and fitter solutions, and eventually it converges, meaning that it is dominated by a single solution.

GA uses two operators to generate new solutions from existing ones: crossover and mutation. The crossover operator is the most important operator of GA. In crossover, generally two chromosomes, called parents, are combined together to form new chromosomes, called offspring. The parents are selected among existing chromosomes in the population with preference towards fitness so that offspring is expected to inherit good genes which make the parents fitter. By iteratively applying the crossover operator, genes of good chromosomes are expected to appear more frequently in the population, eventually leading to convergence to an overall good solution. The mutation operator introduces random changes into characteristics of chromosomes. Mutation is generally applied at the gene level [2].

A typical genetic algorithm requires:
1) a genetic representation of the solution domain,
2) a fitness function to evaluate the solution domain.

For the formulation of Fitness Function, consider a WSN of n sensor nodes randomly deployed into the sensing field are organized into K clusters: $C_1, C_2, \ldots, C_K$. In the proposed protocol using GA, CHs need to be selected with higher residual energy among the sensor nodes and then forms the clusters with equal distribution of the sensor nodes based on their information of location and residual energy. This process can be formulated as an optimization problem and mathematically expressed as shown in

$$f_{obj} = w \times f_1 + (1 - w) \times f_2 \quad (1)$$

$$f_1 = \max_{k = 1,2,\ldots,K} \left\{ \frac{\sum_{\forall \text{node}_i \in C_k} d(\text{node}_i, \text{CH}_k)}{|C_k|} \right\}$$

$$f_2 = \frac{\sum_{i=1}^{n} E(\text{node}_i)}{\sum_{k=1}^{K} E(\text{CH}_k)}$$

As presented in Eqn. (1), f_{obj} consists of two parts. The first part f_1 is the maximum of the total distance of the nodes to their CHs and $|C_k|$ is the number of CMs for a particular cluster C_k. By minimizing f_1, the objective is to minimize the intra-cluster mean distance between CMs and their respective CHs. The second part f_2 is the ratio of total current residual energy of alive nodes with the total energy level of CHs in the present round. The sensor node with higher energy level tends to be the CH. Hence, minimizing f_2 results in the selection of the optimal CHs in terms of residual energy in the network. The constant w is a pre-defined weight (set to 0.5).

V. RADIO MODEL FOR WSNS

Currently, there is a great deal of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in the transmit and receive modes, will change the advantages of different protocols [1]. In our work, we assume a simple model where the radio dissipates Eelec =50nJ/bit to run the transmitter or receiver circuitry and Єamp =100pJ/bit/m^2 for the transmit amplifier to achieve an acceptable E_b/N_o see in figure.2

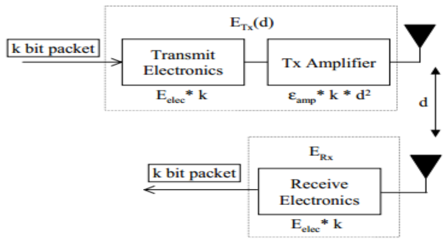

Fig 2. Radio Model

These parameters are slightly better than the current state-of-the-art in radio design. We also assume an r^2 energy loss due to channel transmission. Thus, to transmit a k-bit message a distanced using our radio model, the radio expends:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d)$$
$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2$$

and to receive this message, the radio expends:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k$$

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For these parameter values, receiving a message is not a low cost operation; the protocols should thus try to minimize not only the transmit distances but also the number of transmit and receive operations for each message.

VI. EXPERIMENTS AND RESULTS

In this section, we perform simulations using MATLAB to analyse and evaluate the performance of the proposed Protocol. To compare the proposed protocol with LEACH,SEP,ERP protocols the simulation consists of 100 homogeneous and heterogeneous nodes with initial energy of 0.5J, scattered randomly within a 100x100 m sensor field . The BS was positioned at point (50, 50) m. The radio characteristics used in our simulation are summarized in table 1.

Table 1:Radio Characteristics

Operations	Energy Dissipated
Transmitter Receiver Electronics	E_{elec} = 50 nJ/bit
Data Aggregation	E_{DA} = 5nJ/bit/report
Transmit Amplifier if $d_{toBS} \le d_o$	ϵ_{fs} = 10pJ/bit/m^2
Transmit Amplifier if $d_{toBS} \ge d_o$	ϵ_{fs} = 0.0013pJ/bit/m^2

Figure 3 show the network lifetime for all nodes per round respectively for the proposed protocol and other protocols. From figure it is noticed that the first died after 148 rounds and all nodes died after 356 rounds in LEACH. However in ERP-M protocol, first node died after 202 rounds and all nodes died after 740 rounds. It is clearly that the proposed protocol extends the stability period and shrinks the instability period as compared to the LEACH. Result in fig clearly shows the positive impact of the proposed protocol for decreasing no of dead nodes whiles the protocol round proceeds and increasing the network life time.

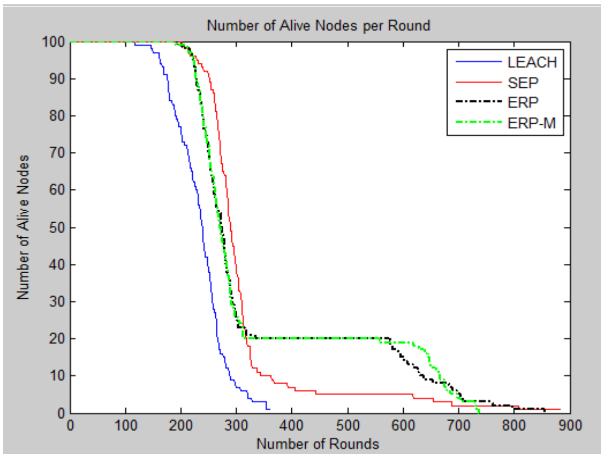

Fig.3 Total number of alive node in the network versus rounds with initial energy 0.1Joule.

The individual results prove that ERP-M can extend the time until LND more than LEACH, SEP (in all runs). On the other hand, the stable region of ERP-M until FND is extended compared to that of LEACH, SEP by 7-8%. As compared with SEP, we found that the stability region provided by ERP-M is comparable to SEP for the first group of WSNs (with 10% advanced nodes) but shorter for the second group of WSNs (SEP gains 6-7%). Clearly, there are tradeoffs between the stability period and the network lifetime, but ERP-M (on average) achieves better tradeoffs than SEP and ERP. Individual results shown in fig 4.

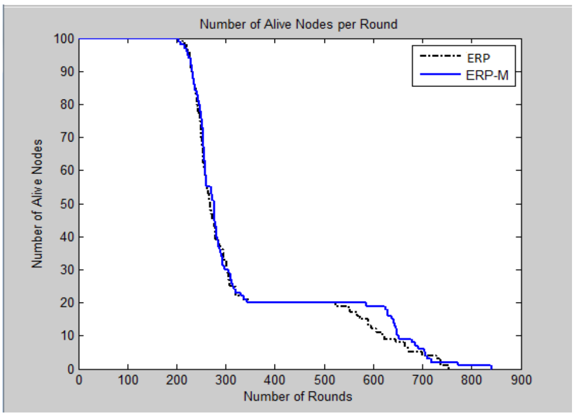

Fig.4 ERP-M compared with ERP.

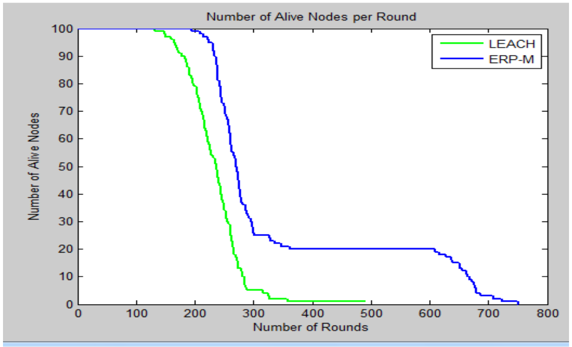

Fig. 5 ERP-M compared with LEACH

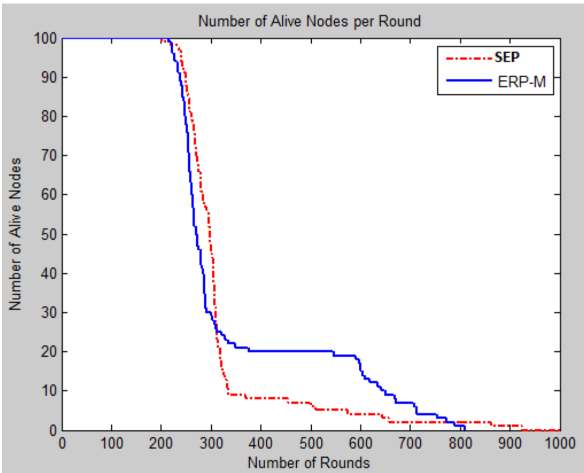

Fig.6 ERP-M compared with SEP.

From above results it is clear that ERP-M perform better than ERP,LEACH and SEP. It not only increase the stability period but also save energy by using effective fitness function with residual energy.

VII. CONCLUSION

In this paper, a new Genetic Algorithm-based evolutionary routing protocol (ERP-M) has been presented to efficiently maximize the lifetime and stability period of wireless sensor networks. ERP-M uses genetic algorithm to improve the network lifetime and stability period of the wireless sensor networks by finding the optimum number of cluster heads and their locations based on minimizing the energy consumption of the sensor nodes. Matlab simulation results showed that the proposed protocol is more energy efficient and more reliable in clustering process as compared to LEACH, ERP,SEP protocols .Moreover, it outperforms the previous protocols in terms of energy dissipation rate, network lifetime and stability period in both homogeneous and heterogeneous cases.

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