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Finding Agent-Based Energy-Efficient Routing in Sensor Networks using Parallel Genetic Algorithm

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Abstract— **Recent advances in wireless sensor networks have led us to search for new routing protocols specifically those designed for sensor networks where energy awareness is an essential consideration. In this paper, a modified cost_energy (MCE) combined scheme for energy efficient routing in sensor networks has been proposed. We have added a parameter to CE combined scheme and obtained better results. We have used parallel genetic algorithm (PGA) to determine the parameters of MCE combined scheme. By using the proposed scheme, due to lower power consumption, the life time of the sensor network is prolonged. Simulation results show about 40% improvement in "average energy consumption per agent" of the network comparing MCE combined scheme with other schemes discussed in this paper.**

I. Introduction

Due to the recent advances in micro-electro-mechanical systems (MEMS) technology, wireless communications, and digital electronics, development of low-cost, low-power sensor nodes that are small in size and can communicate in short distances has become possible [1]. Such sensors are generally equipped with data processing and communication capabilities. The sensing circuitry measures ambient conditions and after simple initial processing, reveals some properties of objects and sends collected data to a sink, usually via a radio transmitter.

One of the most important constraints on sensor nodes is the low power consumption. Sensor nodes carry limited, generally irreplaceable, power sources. Therefore, while traditional networks aim to achieve high quality of service (QoS) provisions, sensor network protocols must focus primarily on power conservation [1], [2].Therefore the ad hoc routing techniques already proposed in the literature do not usually fit the requirements of the sensor networks. It is necessary to design special multi hop wireless routing protocols between the sensor nodes and the sink node with a focus on the energy efficiency. Recently several routing protocols have been proposed for achieving energy efficient routing that are summarized in following:

Small minimum energy communication network (SMECN) is proposed in [3]. It creates a sub graph of the sensor network that contains the minimum energy path. In Gossiping [4] sensor nodes send data to one randomly selected neighbor. Sensor protocols for information via negotiation (SPIN) [5], is another protocol that sensor nodes send data to their neighbors only if they are interested in that data. Sequential assignment routing (SAR) [6] is another proposed scheme that creates multiple trees where the root of each tree is one hop neighbor from the sink; it selects a tree for data to be routed back to the sink according to the energy resources and additive QoS metric. Low-energy adaptive clustering hierarchy (LEACH) is proposed in [7]. It forms clusters to minimize energy dissipation. Directed diffusion [8] sets up gradients for data to flow from source to sink during interest dissemination. After that, gradient-based routing (GBR) [9] is proposed to balance the traffics uniformly throughout the whole network by using some auxiliary techniques such as data aggregation and traffic spreading. In [10] a scheme called energy aware routing that uses a set of sub-optimal paths occasionally to prolong the lifetime of the network is proposed. These paths are chosen based on a probability function which depends on the energy consumption of each path.

In this paper a mobile agent is used to carry the data packet from source to sink. The mobile agent chooses its next hop, regarding local information of current node. We have proposed a new scheme for energy efficient routing in sensor networks and optimized its parameters using PGA. Simulation results show that using proposed scheme increases the performance of the system compared with the other schemes introduced in previous work.

The rest of this paper is organized as follows; in section II a typical routing protocol is described and the assumptions taken into account for sensor nodes are mentioned. In section III previous work is introduced and in the next section proposed scheme is explained. Simulation results are presented in section V. Conclusion of the paper is provided in the last section.

II. Energy Efficient Routing

A. A Typical Routing Protocol

A typical energy efficient routing protocol can be described as the following three phases: in the first phase, sink broadcasts the interest or sensor nodes broadcast an advertisement for the available data and wait for a request from the interested sinks. In the second phase, if the observations of some sensor nodes are matched with the interest list propagated by the sink, then the nodes forward data packets containing the required information to the sink using a certain routing scheme. In the third phase, the sink infrequently initiates a localized flooding in the network in order to keep all paths alive.

In this paper we consider only the second phase due to the fact that data forwarding consumes much more energy than the two other phases.

B. Assumptions about Sensor Nodes

In this paper, we consider some assumptions about sensor nodes: Each node has a forwarding table or neighbors list that contains local information about its neighbors. According to this table each node knows the distance between itself and its neighbors and the remaining energy of its neighbors. Data forwarding table for each node is set up in the first phase.

Another assumption in this paper is that in the first phase that sink broadcasts the interest or sensor nodes broadcast an advertisement for the available data, they also send their forwarding table to the sink. On the other hand the sink knows the information in the forwarding table of each node.

In our modeling, source generates data agents for carrying information which should be transmitted to the sink. This agent starts from source node and travel towards the sink. When the agent reaches an intermediate node, it looks at forwarding table and chooses its next hop according to a certain routing scheme. However it checks some conditions; if the longitude (x) or latitude (y) of the next node is closer to the sink than the x or y of the current node it chooses the next node, otherwise it looks at forwarding table again and chooses another node for the next hop. After the mobile agent arrives at the sink, it passes the data to the sink and then dies.

The energy model we have applied is the same as the model used in [11]. This model is originally introduced in [7]. Assume a data agent carries k bits of data and travels from node N_i to node N_j.

For node N_i, the energy consumption is:

$$E_{N_i}(k,d) = E_{elec}.k + E_{amp}.k.d^2 \quad (1)$$

where $E_{elec} = 50nj/bit$, $E_{amp} = 100pj/bit/m^2$ and d denotes the distance from node N_i to N_j.

For node N_j, the energy consumption is:

$$E_{Nj}(k) = E_{elec}.k \quad (2)$$

For each intermediate node that receives and forwards a data agent, the energy consumption is:

$$E_{N_i}(k) = 2.E_{elec}.k + E_{amp}.k.d^2 \quad (3)$$

III. Previous Work

Some schemes have been recently proposed such as cost based scheme [10], maximum energy based scheme [12] and CE combined scheme. In cost based scheme mobile agent looks at the forwarding table of node N_i, and assigns a choosing probability which is inversely proportional to its routing cost to each neighbor N_j. In maximum energy based scheme the mobile agent compares the remaining energy of each neighbor and chooses the one with the highest remaining energy.

In CE combined scheme [11], combination of routing cost and remaining energy is considered. The data agent which currently locates on node N_i chooses the neighboring node N_j according to the following metric M:

$$M = \max_{j \in FTi}\left(\alpha \frac{E_j}{E_{\max}} + \beta \frac{C_{\max}}{C_j}\right) \quad (4)$$

where C_{max} and E_{max} respectively denote the maximum routing cost and the maximum remaining energy of nodes in the forwarding table. Parameters α and β provide different influences of C and E for route selection.

IV. The Proposed Scheme

A. Adding another parameter

In our proposed method, we have modified CE combined scheme by adding another parameter named λ to the metric M to provide higher degrees of freedom.

$$M = \max_{j \in FTi}\left(\alpha \frac{(E_j)^{\lambda}}{E_{\max}} + \beta \frac{C_{\max}}{C_j}\right) \quad (5)$$

In CE combined scheme, only the ratio of α and β affects the route selecting metric, but in the proposed scheme, E_j is powered by λ and the influence of energy on the metric is increased. Simulation results show that in the previous scheme, the performance of system wouldn't change by increasing the ratio of α and β after a specific value. Adding this parameter, the routing traffic is more distributed over the network. Therefore, the critical sensors which have the minimum energy on optimum path will not deplete quickly.

We have used three factors introduced in [11] in order to evaluate the performance of the proposed scheme with CE scheme. These factors are: Average Remaining Energy (AvgRE) where it denotes the average life time of nodes. The second factor is Minimum Remaining Energy (MinRE) that denotes the shortest lifetime of nodes in the network. The third one is Average Energy consumed per agent (AvgEpa) that is defined as the average energy consumed for data agents traveling from source nodes to the sink.

B. Using PGA to find the parameters

The performance of CE scheme is very dependent to parameters α and β. However, adjusting the exact value of them to find the optimum path is impossible. Any variation in these parameters change the performance of the system; due to this fact finding the optimum values of them is essential to get the best performance of system. There is not any discussion on these parameters in [11]. In this paper we have used PGA to compute the best parameters to improve the performance of the sensor network.

We have used data centric protocol in which the sink sends queries to certain regions and waits for data from the sensors located in the selected region. A sensor that is located in central part of this region is considered as source. Sink can run GA without any problem because it usually does not have any limitations on power and memory.

In each step, sink runs GA regarding to forwarding tables and the interested region or equivalently the location of the source to find the best α, β and λ and then sends them to the source. After that source and the other nodes use this new metric to find the next hop in the agent. We consider that sink has to receive about 10 agents from the source to complete its information about interested region. Sink computes the average of the factors among these 10 agents and finds the optimum values of parameters α, β and λ in order to maximize minRE and AvgRE and minimize AvgEpa. Whenever sink wants to gather the information in another region, it runs GA regarding the new place of the source and the forwarding tables to find the new parameters.

V. SIMULATION RESULTS

In the experiments, 200 sensor nodes are randomly distributed over a 400*m**400*m* region and one source node and one sink node are located as shown in Figure1.

The initial energy and communication range of each sensor node are set identically as 0.5*J* and 80*m* respectively. Data agents which carry 10*1024 bits of data are generated by the source node. The parameters used for genetic algorithm are shown in Table I.

The cost based scheme and the maximum energy based scheme have been compared with CE combined in [11] and their performances are worse than CE scheme. Therefore in this paper we only compare our results with the results of CE combined scheme. The results are measured for α=20 and β=10, which are reasonable values, in the CE scheme. We used similar values for α and β and set λ=1.75 in the proposed scheme. Comparison between the results of the proposed scheme and the CE combined scheme are shown in Table II. The last column in this table shows the objective function used in genetic algorithm which is computed as follows:

$$\text{Objective function} = \frac{\text{AvgEpa}}{(\text{AvgRE} + \text{MinRE})} . \quad (6)$$

As it is seen in the Table II the results for all of three factors are improved comparing the proposed scheme with CE combined scheme. It is also observed that using GA to optimize the parameters, while the AvgRE and MinRE are almost remained constant, the AvgEpa is improved significantly. The value of the objective function for CE combined scheme is 0.2712 while this value for proposed scheme is 0.2377. Moreover, by using GA to optimize the parameters, the performance of sensor network is increased and the minimum value of the objective function is obtained (0.1628).

Snapshots of routing path after the 10th run based on CE combined and proposed scheme are shown Figures 1 and 2. In CE combined scheme the traffic of agents is high in some regions, but in the proposed scheme the load balancing is better and the traffic of agents is spread over the network.

TABLE I. USED PARAMETERS FOR GENETIC ALGORITHM

Population type	Double Vector
Population size	100
Generation	100
Elite count	2
Crossover fraction	0.8
Migration direction	forward
Migration interval	20
Migration fraction	0.2

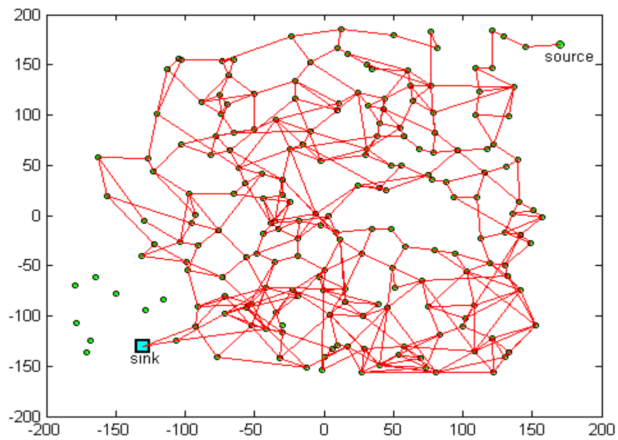

Fig. 1. CE combined scheme (α=20 and β=10).

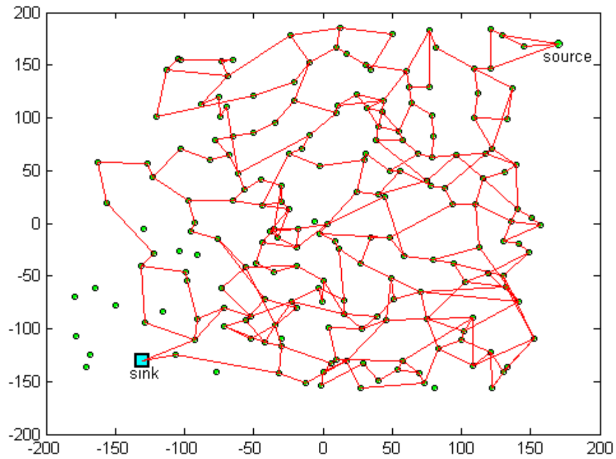

Fig. 2. Proposed scheme (α=11.79, β=1.61 and λ=1.62).

TABLE II. COMPARISON OF THE PROPOSED SCHEME AND CE COMBINED SCHEME

	α, β and λ	AvgRE	MinRE	AvgEpa	Objective function
CE combined scheme	20, 10, 1	0.4872	0.4527	0.2549	0.2712
Proposed scheme	20, 10, 1.75	0.4885	0.4596	0.2254	0.2377
Proposed scheme with optimum parameters	11.79, 1.61, 1.62	0.4924	0.4415	0.1521	0.1628

VI. CONCLUSION

In this paper, we have proposed a new method to find an energy efficient data routing scheme in sensor networks. We have used parallel genetic algorithm to find the optimum parameters of the new scheme. Simulation results show that the proposed scheme has improved the load balancing and traffic spreading over the network. By using the proposed scheme with optimum parameters, we have obtained 40% improvement in average energy consumption per agent, compared with CE combined scheme.

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