

Provide a New Method for Optimizing the Energy Consumption in Wireless Sensor Networks based Colonial Competitive Algorithm

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Abstract

Optimum energy consumption in wireless sensor networks is of vital importance, so that the useful utilization of the network depends upon it. In this paper, using the Imperialist Competition Algorithm, which is implemented in centralized form in base station, as well as taking the remaining energy level of the nodes into account, CHs are determined in such a way that the minimum energy consumption and consequently, improvement of network lifetime and efficiency can be achieved.

Keywords: Wireless sensor network, Competitive algorithm, Energy consumption, Utilization.

Introduction

Recent advances in the field of MEMS, smart sensors and wireless telecommunication made the small, low consumption and cheap sensor nodes possible [1,2,3]. Such sensor nodes, include three parts of sensor, processor and transmitter of information in wireless form. A wireless sensor network includes hundreds or even thousands of sensor nodes of this type which usually has a base station which can communicate with other sensing networks present in network. Data of each sensor node are directly or with an intermediate to base station and then, all collected data for a parameter such

as temperature, pressure, humidity and so on are processed in base station and the actual value of the parameter is estimated relatively accurate. In these networks, location of nodes are not predetermined, but, nodes are randomly dispersed in environment and this necessitates that applied protocols must be self-configured or self-organized. Sensor networks include various types of sensors such as seismic, motion, thermal, gas, strain, optic, pressure and acoustic. By means of sensor networks, we can facilitate activities such as monitoring borders, fire discovery in forests, monitoring battles and controlling industrial automation processes

[4]. In design of wireless sensor networks, limitations such as small dimensions, low weight, energy consumption and low price of sensors prevail [5]. Among these factors, level and method of energy consumption are of great importance, since according to environmental conditions of establishing these networks, replacement of thousands of batteries is an impossible or expensive matter. On the other hand, reducing consumption of the energy in wireless sensor networks is directly related to improvement of their lifetime which itself is an important issue. To improve lifetime of these networks, it is attempted to distribute the energy load equally among network nodes. In other words, the energy distribution of network must be uniform. This uniform distribution causes network nodes lose their energy in a short period and the time interval between deaths of the first node and last one is short. Uniform distribution of energy load together with extending lifetime of the network ensures that data transmitted from the network are collected uniformly from all of the environment. Communication protocol play a crucial role in efficiency and lifetime of the wireless sensor networks and therefore, design of efficient protocols is a requirement for energy consumption of the wireless sensor networks [5] so that by using them, not only energy consumption of network reduces, but also energy consumption will be distributed and balanced throughout the network nodes and as a result, network lifetime increases. Among presented protocols, hierarchical protocol (based on clustering) saved the energy consumed by the network to a considerable extent. In these protocols, all of the network is classified into several clusters and in each of the clusters, a node is selected as cluster head (CH). The role of CH is to collect transmitted data of the cluster, removing repeated data, combining data and sending them into the base station. In these protocols, selection of a node in each cluster and combination of data affects considerably the scalability and lifetime of the network [5]. To now, several protocols based on clustering wireless sensor networks are presented.

However, none of them simultaneously takes parameters of remaining parameters of each node and distance of each node to base station into account in the process of clustering and for this reason, these protocols failed to distribute the energy load throughout the network. In this paper, by means of available hierarchical protocols especially LEACH, by applying parameters of remaining energy and distance in clustering process, an effective communication protocol for energy consumption which maintains the scalability of the network is presented. Since among a lot of nodes, a few of them must be chosen, imperialist competition algorithm which is a smart method of solving problems is used. Then, in section 2, some of the clustering methods are briefly described and in section 3, some of the initial concepts are introduced. Section 4 describes the suggested protocol. In section 5, simulation results are evaluated and finally, in section 6, some conclusions are drawn.

2. Literature review

Among presented protocols, LEACH which is introduced in [6] and [7] is of great importance. In this protocol, clusters of network are formed in randomized, adaptive and self-configured form. In LEACH, data transfer is performed from cluster nodes into CH and from CH into base station by local control and there is no need for an external agent of a certain node in network. LEACH, like other clustering-based protocols, combines all data of the cluster and then sends the compressed data into the base station. In this way, frequency of send and receive in network reduces and also unnecessary data produced as a result of proximity of cluster networks, are removed before sending to base station. In this protocol, time is divided into equal intervals called period. Each period is divided into phases as well. The first phase which is called setup phase, is the phase of cluster forming and the second phase which is called steady state phase, is related to data transfer. Second phase is composed of a series of time frames and in each frame, all of the nodes of a

cluster, send their data to CH and CHs forward received data into base station. Fig. 1 illustrates this time division.

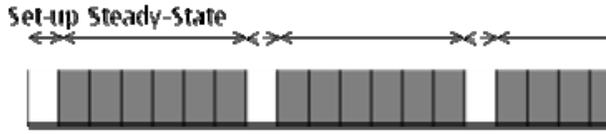


Fig. 1: time division in LEACH

In setup phase, CHs are selected according to the probabilities function of Eq. 1. Selection is such that each sensor chooses a value between zero and one. If this value is less than the threshold of Eq. 1, corresponding sensor is selected as CH in that period.

$$T_{(n)} = \begin{cases} \frac{p}{1 - p * (r \bmod \frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where, in Eq. 1, p is the suggested percent for the number of CHs in present network which is predetermined and is equal to K_{opt}/N , in which K_{opt} is the optimum number of clusters and N is the number of network nodes and these two parameters are programmed in nodes. R is the number of periods and $C_i(t)$ is an indicial function which shows that whether node i in the previous period has been CH or not. It is important to note that $C_i(t)$ is unity if node i has not been CH in previous period and in this way, it is capable of being CH in coming period. Protocol LEACH ensures that each node in each period becomes CH only once and we call the number of periods epoch. In LEACH, two types of MAC protocol is used, in setup phase, CSMA and in steady state one, DSSS protocol is applied. Another protocol is LEACH-C introduced in [7]. In this protocol, an algorithm of formation of central cluster is used. In setup phase, LEACH-C of each node, sends information regarding its location (which collected by its GPS) and its current energy status to base station. Base station calculates the average of the energy levels of the network nodes, nodes whose energy level is below

average, cannot be CH for the next period. Steady state of LEACH-C is exactly the same as LEACH.

3. Basic concepts

3.1. Imperialist competition algorithm (ICA)

ICA is a new algorithm in the field of evolutionary computations which is based on the sociopolitical evolution of human. Like other evolutionary algorithms, this algorithm initiates with a random initial population each of which is called a country. A number of best elements are selected as imperialist and remaining are called as colony. In optimization problems, by considering function $f(x)$, we intend to find x in such a way that its associated cost can be optimal (usually minimum). In optimization problem, next N_{var} , a country is an array of $1 * N_{var}$ and is defined as follows:

$$Country = [P_1, P_2, P_3, \dots, P_{iNvar}] \quad (2)$$

The cost of a country is found via variables $P_1, P_2, \dots, P_{iNvar}$. Therefore,

$$Cost_i = f(country_i) = f(P_{i1}, P_{i2}, P_{i3}, \dots, P_{iNvar}) \quad (3)$$

In ICA algorithm, for startup, number of countries, $N_{country}$ is selected and N_{imp} of the best members of the population are selected as the imperialist. Remaining countries form a colony and each belong to an emperor [12, 13].

Imperialist countries attract colonies to themselves for the sake of applying attraction policy, along with various optimization processes. Due to their power, imperialists attract these colonies to themselves according to Eq. 4. The overall power of an emperor is determined by means of calculation of the capability of each of two parts which form its power plus a percent of the average power of its colonies.

$$T.C_n = \text{Cost}(\text{imperialist}_n) + \xi \text{mean}\{\text{Cost}(\text{colonies of empire}_n)\} \quad (4)$$

Colony moves x units toward the connection line of the imperialist and is drawn to the new position. In Fig. 2 the distance between imperialist and the colony is denoted by d and x is a random number having uniform distribution; that is, for x , we have

$$x \sim U(0, \beta * d) \quad (5)$$

Where, β is a value more than unity and close to two. An appropriate for β can be 2. Moreover, the movement angle is considered by the following uniform distribution:

$$\theta \sim U(-\gamma, \gamma) \quad (6)$$

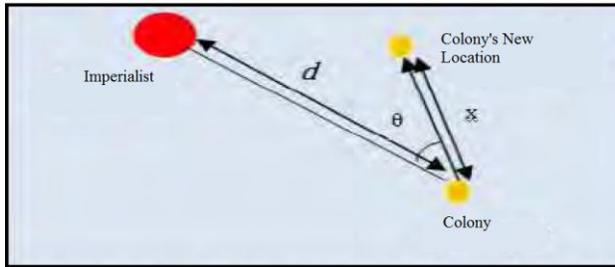


Fig. 2: movement of colonies toward imperialist (attraction policy)

In ICA algorithm, with a probable deviation, colony progresses toward the imperialist attraction. This deviation is shown by θ which is selected randomly and with uniform distribution. During movement of colonies toward the imperialist, it is probable that some of these colonies achieve a better position compared to imperialist. In such case, imperialist and colony are replaced. To model such competition, initially, the probability of seizing colonies by each emperor is computed by considering the overall cost of the emperorship:

$$N.T.C_n = \max_i \{T.C_i\} - T.C_n \quad (7)$$

In this equation, $T.C_n$ is the total cost of the n th imperialist and $N.T.C_n$ is the normalized cost of it and the probability of seizing the colony is as follows [12, 13]:

$$P_{p_n} = \left| \frac{N.T.C_n}{\sum_{i=1}^{N_{imp}} N.T.C_n} \right| \quad (8)$$

3.2. Model of energy consumption

Here, the energy consumption model presented in [14] is used for radio elements of the network. In this model, E_{elec} is the required energy for the electric circuit of the transmitter/receiver for sending of receiving each bit of data package and is given by J/bit . ϵ_{amp} is the consumed energy of the radio amplifier of the transmitter node for sending a bit of data in a channel with the length d between transmitter and receiver. The schematic of the energy consumption model is demonstrated in Fig. 3.

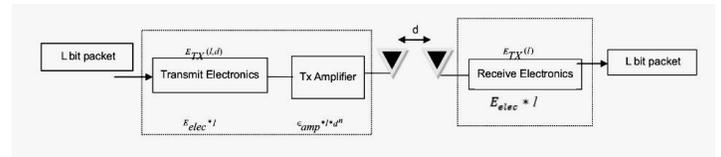


Fig. 3: model used for energy consumption of radio elements

For calculation of send and receive energy, Eq. 9 is used:

$$\begin{aligned} E_{T_x}(l, d) &= l E_{elec} + l \epsilon_{amp} d^n \\ E_{R_x}(l, d) &= l E_{elec} \end{aligned} \quad (9)$$

In Eq. 9, l is the length of sent/received package, d is the distance between transmitter and receiver in meters, n is the exponent of path loss for free space and fs is equal to 2 and depending upon the environment and topology of the network, can approach 6 [14]. For simulations to be closer to reality, for distances less than a threshold, d_0 which is equal to 87.7, an open

space is used which is shown in the following model:

$$\epsilon_{amp} = \epsilon_{fs}, n = 2$$

(10)

For distances more than d_0 , a multipath model is used and in this model we have:

$$\epsilon_{amp} = \epsilon_{mp}, n = 4 \tag{11}$$

Furthermore, CHs of the LEACH protocol are responsible for combination of the cluster members' data and in the case of complete correlation, a representative signal is created by combining nodes signals. Energy required for combining data of the received signal by CH is considered to be lE_{DA} for which in experiments, the value of 5nJ/bit/signal is assigned. In this equation, E_{DA} is the required energy for combining data and l is the number of received signals.

3.3. Optimum number of clusters

In [7] and [15], the optimum number of clusters which is a systematic parameter of LEACH protocol, is analytically computed. In this computation, it is assumed that model of energy consumption which is described above is governing over the network. For a network consisting N sensor nodes distributed in an $M \times M$ region, Eq. 12 gives the optimum number of clusters.

$$k_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}} \frac{M}{d_{toBS}^2}} \tag{12}$$

4. Suggested algorithm

In this method, we assume that all nodes of the sensor network are the same and each network node can have either of the following cases: cluster head and normal node. Since the level of energy consumption in cluster head nodes is higher compared to normal nodes, we try to

select CHs so that less energy is consumed for transferring data to the base station. First, a set of possible answers are defined randomly as a country. Each country includes the index of countries which are going to become CH and proposes a method for clustering nodes; that is, nodes marked by the index of countries become CH and other ones must join the closest CH. Countries are classified into groups, the most powerful of which of each cluster is considered as the imperialist and the others as colonies. In each period, imperialists try to homogenize their colonies; that is, by applying changes in the structure of their colonies, attract them to themselves. However, along with attraction, some shifts are done as well and it is possible that the power of a colony exceed that of the imperialist. In such case, they replace each other. It is supposed that all clustering operations are performed in base station. Then, CHs are informed and they inform each other by sending messages. In base station, user can determine the number of required CHs. Moreover, the base station is aware of the energy level of each node and as a result, it can compute the average energy of the network. In each country, k_{opt} is the number of CH nodes indices whose energy level is higher compared to the average energy of the system. Function f which denoted the costs of the country, is defined as follows:

$$Cost_i = \frac{\sum_{i=0}^k \sum_{x \in C_i} ch(x_i, ch_i) / ([C_i] - 1)}{k_{opt}} \tag{13}$$

$\frac{\sum_{i=0}^k \sum_{x \in C_i} ch(x_i, ch_i) / ([C_i] - 1)}{k_{opt}}$ Where, C_i is the i^{th} cluster, $[C_i]$ is the number of i^{th} cluster nodes, CH_i is the CH of cluster C_i , $d(x, ch_i)$ is the distance between the node and CH, $\sum_{x \in C_i} ch(x_i, ch_i) / ([C_i] - 1)$ is the average of the distance between the nodes of the cluster and CH, k_{opt} is the optimal number of clusters and the average distance of the nodes to CHs is denoted by . .

The costs of a country are directly related to the level of energy consumption of the suggested

method for clustering nodes; that is the more costs a country has, the more optimized method it suggests and it is more powerful. After several periods, we can select the most powerful imperialist as the final result.

5. Simulation

To simulate the suggested algorithm, MATLAB software with the parameters shown in table 1 is used.

Table 1: simulation parameters

Parameters	Value
<i>Network size</i>	<i>100 *100</i>
<i>Node Number(N)</i>	<i>100</i>
<i>Initial Energy</i>	<i>0.1 J</i>
<i>E_{elect}</i>	<i>50 nJ/bit</i>
<i>ε_{fs}</i>	<i>10 pJ/bit/m²</i>
<i>D₀</i>	<i>87 m</i>
<i>E_{da}</i>	<i>5 nJ/bit/signal</i>
<i>Packet length(L)</i>	<i>50 Bytes</i>

In each period, the number of live nodes are evaluated and compared to LEACH algorithm. Since the energy consumption is lower in suggested method, in each period, the number of live nodes will be higher and network lifetime improves. This issue is illustrated in Fig. 4.

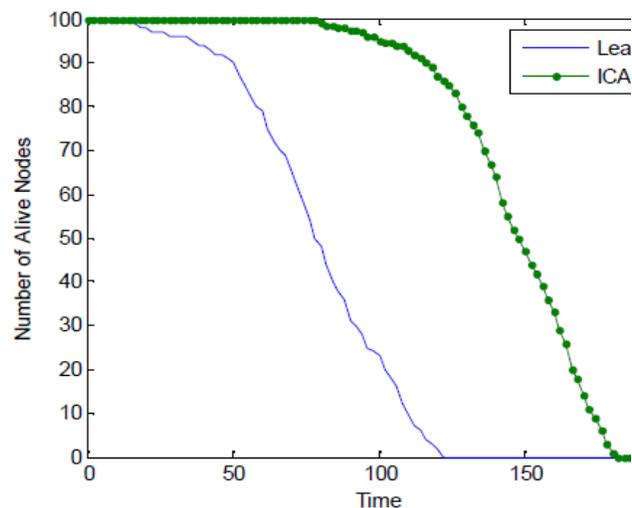


Fig. 4: number of live nodes in each period in suggested method with LEACH protocol

Conclusion

Wireless sensor networks which are used for monitoring and control of a certain environment, are composed of a series of cheap sensor nodes which are dispersed in compressed form in an environment. One of the main challenges of these networks is the limitation of energy consumption which affects the lifetime of the network directly. Clustering is one the well-known methods which is extensively used for facing such challenge. In this paper, an efficient method has provided for clustering wireless sensor networks based on the imperialist competition algorithm. The presented method recognizes the cluster heads based on parameters such as energy level and nodes dispersion and creates balanced clusters with higher energy level compared to regular nodes.

References:

- [1] Akyildiz I. F., W. Su, Y. Sankarasubramaniam, E.Cayirci., "Wireless sensor networks: a survey", Journal of Computer Networks, Vol. 38, March 2002, pp. 393-422.
- [2] Min R., M. Bhardwaj, S. Cho, E. Shih, A. Sinha, A. Wang, and A.Chandrakasan, "Low Power Wireless Sensor Networks", Proc. Of International Conf. on VLSI Design, Bangalore, India, pp. 205-210, Jan. 2001.
- [3] Katz R. H., J. M. Kahn and K. S. J. Pister, "Mobile Networking for Smart Dust", Proc. of the 5th Annual ACM/IEEE Int. Conf. on Mobile Computing and Networking (MobiCom'99), Seattle, USA, pp. 350-355, Aug. 1999.
- [4] Tanenbaum A. S., C. Gamage and B. Crispo, "Taking Sensor Networks from the Lab to the

Jungle”, IEEE Computer Magazine, vol. 39, no. 8, pp. 98-100, Aug. 2006.

[5] Al-Karaki J. N. and A. E. Kamal, “Routing Techniques in Wireless Sensor Networks: A Survey”, IEEE Journal of Wireless Communications, vol. 11, no. 6, pp. 6–28, Dec. 2004.

[6] Heinzelman W. R., A. P. Chandrakasan and H. Balakrishnan, “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, Proc. of the 33rd IEEE Int. Conf. on

System Sciences, Honolulu, USA, pp. 1–10, Jan. 2000.

[7] Heinzelman W. R., A. P. Chandrakasan and H. Balakrishnan, “An Application-Specific Protocol Architecture for Wireless Microsensor Networks”, IEEE Trans. on Wireless Communications, vol. 1, no. 4, pp. 660-670, Oct. 2002.

[8] Manjeshwar A. and D. P. Agarwal, “TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks”, Proc. Of the IEEE IPDPS, San Francisco, USA, pp 23-26, Apr. 2001.

[9] Manjeshwar A. and D. P. Agarwal, “APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks,” Proc. of the IEEE IPDPS, Fort Lauderdale, USA, pp. 195-202, Apr. 2002.

[10] Khadivi A., M. Shiva and N. Yazdani, “EPMPAC: an efficient power management protocol with adaptive clustering for wireless sensor networks”, Proc. of Int. Conf. on Wireless Communications, Networking and Mobile Computing, China, pp.1154-1157, Sept. 2005.

[11] Subramanian L. and R. H. Katz, “An Architecture for Building Self Configurable Systems”, Proc. of IEEE/ACM Workshop

on Mobile Ad Hoc Networking and Computing, Boston, USA, pp.63-73, Aug. 2000.

[12] Atashpaz-Gargari, E., Lucas, C., “Imperialist Competitive Algorithm: An algorithm for optimization inspired by imperialistic competition”. IEEE Congress on Evolutionary Computation. pp.4661–4667, 2007.

[13] A. M. Jasour, E. Atashpaz, C. Lucas, “Vehicle Fuzzy Controller Design Using Imperialist Competitive Algorithm”, Second First Iranian Joint Congress on Fuzzy and Intelligent Systems, Tehran, Iran, 2008.

[14] Rappaport T., “Wireless Communications: Principles & Practice”, Englewood Cliffs, NJ: Prentice-Hall, 1996.

[15] Amini N., M. Fazeli, S. G. Miremadi and M. T. Manzuri, “Distance-Based Segmentation: An Energy-Efficient Clustering Hierarchy for Wireless Microsensor Networks”, Proc. of the 5th Annual Conf. on Communication Networks and Services Research (CNSR 2007), Fredericton, Canada, pp. 18-25, May 2007.