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Presenting a Clustering Method Based on Imperialist Competitive Algorithm for Increasing the Lifetime of Wireless Sensor Networks

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Abstract: As the technology is developing, the issue of classification and clustering in wireless sensor networks is becoming increasingly significant. In this direction, the algorithms of optimization inspired by the nature have come to exist to promote the classic methods and they have already developed significantly. In this study, a novel algorithm of optimization called imperialist competitive algorithm is introduced which it is not a natural phenomenon but is a social-political phenomenon inspired by mankind. It divides such variables as centrality, distance and residual energy of initial population into two groups of imperialist and colony and begins the competition to be clustered in the wireless sensor networks. In this research, in order to make the clustering more uniform and lower the energy consumption of network, a parameter of number of neighbor node is recommended for this algorithm. By evaluation, it is revealed that this parameter improves network lifetime by 4%.

Key words: Wreless sensor networks, imperialist competitive algorithm, number of neighbor node, clustering, cluster-head, lifetime of the network

INTRODUCTION

Development of technologies and people's needs to information more and more, even in the impassable areas, led to invention of wireless sensor networks in the world. But, unfortunately, the energy used by the sensors in these networks wears out over time and turns unusable because of impossibility of recharging or battery replacement. Thus, in order to increase the lifetime of the networks the biggest challenge is the reduction of energy consumption.

Direct transfer of information from the sensors to the central node is very costly and almost impossible. For this reason, a clustering model is used. In this model, there are two nodes ordinary and cluster-head. The latter is responsible for transferring every data collected by the same cluster, compressing the data before transferring them to the base station. Election of an inappropriate cluster-head may lead to disconnect us from that part of the network. Thus, taking into account a productive power in designing of clustering protocols is of great importance. For this purpose, the algorithms of optimization have been widely used. But once they are to optimize the problems, these algorithms ignore the most important evolutional phenomenon naturally originated in the evolution of human. It is because they are obvious and easily formulated. But now, a novel algorithm is developed by Atashpaz-Gargari and Lucas (2007) stimulated by the socio-political phenomenon. Its ability in optimization is the same as or even higher than that of counterpart and quickly reaches an optimal answer. It is known as imperialist competitive algorithm where it uses a series of countries as an initial population. These countries are the possible answer to a problem. They are broken down into two groups of imperialist and colony. The imperialist ones by imposing a policy of assimilation (homogenization) about various optimization axes absorb the colony countries toward themselves. Then by using this algorithm based on imperialist competition accompanied with the policy of assimilation lead the colony countries to an absolute minimum (Atashpaz-Gargari and Lucas, 2007).

Literature review: Up to now, there have been a lot of investigations on the increase of lifetime of wireless sensor networks using protocols based on clustering algorithms. In 2000, the LEACH algorithm was first developed by Heinzelman *et al.* (2000). It gained a special status among the routing protocols in the sensor networks. However, this dynamic and centralized protocol was not free of shortcomings (without taking nodal residual energy, choosing a node with low energy as a cluster-head, non-uniform distribution of nodes, direct transfer of data from cluster-head to base station into consideration). It evoked the scholars to find a most-efficient algorithm. For this purpose, the classical evolutional and fuzzy algorithms were employed.

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In such classic algorithms as HEED (Younis and Fahmy, 2004), H-DEEC, MH-DEEC (Mohamed, 2013), BALC, ECLEACH (Bsoul *et al*., 2013), the scientists, by taking the residual energy and uniform distribution of nodes into account, attempted to improve or evolve the algorithm LEACH. But this measure was not sufficient alone and it does not overcome the LEACH algorithm's limitations entirely.

For this reason, the scientists (Gupta *et al*., 2005) for continuous data clustering has taken two other measures close to central node and the closet sensor to the centroid of cluster. Even (Ando *et al*., 2010; Anno *et al*., 2008) in order to increase the network's lifetime they included the neighboring node parameter. However, these three choices had their own drawbacks, ranging from consecutively replacing cluster-head, due to repeatedly sending of controlling massage, to considering two measures away from centroid and base station that cause the cluster-head to remain stable in several rounds and to lose its energy quickly.

To remove the drawbacks the LEACH and extend its lifetime, the scientists opted to enjoy from optimization algorithms like genetic algorithm (Liu and Ravishankar, 2011), neural network builder and imperialist competitive algorithm (Hosseinirad *et al*., 2014; Enami *et al*., 2010) to establish a balance in building the clusters, non-random choice of the cluster-head and selection of a cluster-head with greater energy.

Though a large amount of residual energy and the location position are measured by genetic algorithm and neural network builder, there is a lot of loss of energy because the nodes adjacent to the base station should send their data by cluster-head directly to the base station. This issue evoked the researchers to choose the imperialist competitive algorithm, a novel algorithm for evolutional computing based on human social-political evolution (Oranj *et al*., 2015).

Todays, the drawbacks of the LEACH algorithm have been removed. However, to achieve to an ideal consuming energy and increase of network's lifetime, the researchers were not only satisfied by the three parameters of sensor distance from cluster-head, base station and amount of residual energy, so that the researcher included the cluster distance, standard deviation and transfer of energy or by Mehr (2014) and Hosseinirad *et al*. (2014) some models have been proposed for computing the residual energy so that by computing receiving and sending k bit massages, the actual amount of energy consumption are obtained (Liu and Ravishankar, 2011; Shahvandi *et al*., 2011) the computing models have changed the intervals in order to be able to choose an optimal node as a cluster-head.

In this research, by adding the parameter of number of neighboring node previously used in fuzzy-based algorithms (Ando *et al*., 2010; Anno *et al*., 2008) in the wireless sensor networks to the imperialist competitive algorithm, we attempt to improve the wireless sensor networks lifetime.

Imperialist competitive algorithm: The imperialist competitive algorithm is inspired by human social-political evolution. As the other evolutional optimization techniques, it starts with a number of initial populations. Each element of the population is called a country. The countries are divided into two groups: colony and imperialist. Depending on its power, each imperialist dominates a number of countries and controls over them. The policy of assimilation and competition functions as a basic part in this algorithm (Ducrocq *et al*., 2013).

If each emperor is not able to uphold its power and lose its ability, the algorithm will eliminate it from race in the process of competition. It means that it loses its colonies over time and those colonies are occupied by the robust one, making it stronger. Thus, the survival of an emperor is subjected to assimilate more colonies from the competing emperors and to take them over (Atashpaz-Gargari and Lucas, 2007). The emperor's power is an integrality of that of the whole imperialist countries, plus few percentages of total power of its colonies. In turn, for total cost of an emperor we have:

$$TC_n = \text{Cost}(\text{imperialist}_n) + \xi \text{mean} \left\{\text{Cost}\left(\text{colonies of empire}_n\right)\right\} \quad (1)$$

where, the total cost of nth emperors and ξ is affirmative number which lies within 1 and 0 and it is normally taken as approach to zero. Taking this number as small, causes the total cost of an emperor become almost equivalent to that of central government (imperialist country) and increase of ξ leads to increased effect of amount of an emperor's colonies costs when determining its total costs. In typical state, most of implementations have showed desirable answers. In order to acquire more power, the emperors use the policy of homogenous (assimilation) with the aim to analyze the culture and social structure of their colonies ruled by central government. In fact, by imposing a policy of assimilation, a central government tries to manipulate a colony socially and politically in order to direct it toward its own interests.

However, some colonies during moving toward imperialist get a better situation than their superior country. In such a state, the position of colony and imperialist is replaced and the algorithm restarts its work to adjust with this new situation and this time, it is the emergent imperialist that begin to impose its policy of a ssimilation on the colonies.

This algorithm will continue until a convergence condition to be satisfied, or the total number of iterations comes to an end. After a period of time, all the emperors are overthrown and there is only one emperor and the rest of the countries are subordinated to a single emperor (Atashpaz-Gargari and Lucas, 2007; Mehr, 2014; Gargari, 2009).

MATERIALS AND METHODS

The proposed method: The aim of the imperialist competitive algorithm as the other evolutional optimization methods is to find an optimal answer in term of variables of problem where the optimal answer is treated as the best cluster-head. First, given that the energy of the whole nodes are equal, we specify the distance between the nodes of clustering and select the node with the shortest distance and the largest number of neighboring node within cluster as a cluster-head.

To compute the distance between sensors, it should be noted that each node of sensor or country has two routes to send the sensed data to base station: one is direct sending of the data and the other by means of cluster-head. For this reason, the following intervals are calculated by euclidean equation:

- The distance of each node up to base station
- Distance of each node up to cluster-head
- The cluster-head distance up to base station

Then, to check the loss of energy, the optimal route is computed by Eq. 2:

$$D = \min\left(DRS_i, \left(DRC_i + DCS\right)\right) \tag{2}$$

Where:

DSR_i = The sum of distances between the entire nodes to the base station
DRC_i = The distance of the whole nodes with cluster-head
DCS = The sum of intervals of cluster-head to base station

In turn, the nodes having the shortest distance from base station up to cluster head send their data directly to the base station rather than their cluster-head. After computing the intervals and constructing a table of number of neighbors based on a half away measuring the environment, for each sensor the node of primary cluster-head should be computed by Eq. 3:

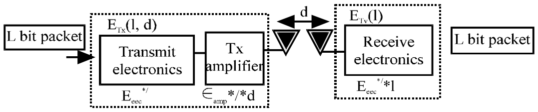

Fig. 1: Energy consumption radio model

$$Dl = \sum_{i=1}^{M} D \times \frac{1}{W} \tag{3}$$

Where:

D = The shortest distance between the nodes
W = The number of neighboring nodes

After doing the primary divisions, we begin the imperialist competition between decision variables (number of clusters) and in this way we define the cost function based on residual energy. It is because the sensor network nodes lose their consumption energy over time and selecting an energy-free node as a cluster head causes loss of a part of the network. For this purpose, in the proposed method we use a radio model to compute the node's energy. In this model, eelec is a needed energy for transmitting/receiving electrical circuit through which it receives or transmits each bit from data package. An energy consumption model is schematically shown in Fig. 1. Several parameters are calculated in this model. The required energy for transmitting inside the cluster:

$$4E_{Tcs} = k \times E_{elec} + k \times \in_{fs} \times d_{ij}^{2}\, d < dco \tag{4}$$

Where:

$\in_{fs}$ = The consumption energy amplifying radio of the transmitter node for sending a bit from data within a channel with a length of d between transmitter and receiver inside the cluster
k = Length of the transmitted massage

The required energy for transmitting outside the cluster:

$$E_{Trs} = k \times E_{elec} + k \times \in_{amp} \times d_{ij}^{4} < dco \tag{5}$$

Where:

$\in_{amp}$ = The consumption energy amplifying radio of the transmitter node for sending a bit from data within a channel with a length of d between transmitter and receiver outside the cluster
K = Length of the transmitted massage

The needed energy for sensing a data bit from environment:

$$ER = k \times E_{elec} + k \times E_{BF} \tag{6}$$

where, E_{BF} implies the cost of realizing the approach of consumption energy reduction to minimize the consumption energy and increase the network's lifetime. The minimum required energy for transmitting a massage from the head to the base station:

$$LE = E_{Tcs} + ER \tag{7}$$

Where:

E_{Tcs} = The needed energy for transmitting inside the cluster

ER = A radio energy for sending to the base station. The required energy for transmitting a massage to the base station directly

$$E_{T_{drs}} = \sum_{i=0}^{n} E_{T_{rs}} + m \times ER \ m \geq n \tag{8}$$

where, E_{trs} denotes to sum of required energy to transmit a massage from the whole nodes to central node and ER is a radio energy that is dropped for receiving m. The needed energy for sending a massage from the nodes within a cluster to cluster-head and its transmitting through cluster-head to the base station:

$$E_{T_{rcs}} = \sum\nolimits_{i=0}^{n} E_{T_{rcs}} + m \times ER + E_{T_{cs}} \quad m \geq n \tag{9}$$

Where:

E_{Trs} = The total needed energy to send a massage from the nodes laying in a cluster to its cluster-head

M×ER = Represents the sum of required energy to receive a massage from the nodes within a cluster

E_{Tcs} = The sum of energy needed to transmit a massage from cluster-head to central node

The minimum energy required to transmit a massage from a node to the base station:

$$SE = E_{Tdrs} - E_{Trcs} \tag{10}$$

Where:

E_{Tdrs} = The total of energy needed to send a massage from the whole nodes to central node

E_{Trs} = Represents the summation of energy required to send a massage from a node in a cluster to the cluster-head

Residual energy in a network:

$$E = LE + \frac{1}{SE} + (1 - RE) \tag{11}$$

Where:

LE = The minimum energy required to receive a massage by a cluster-head and base station

1/SE = The minimum energy needed to send a bit massage from a node to the base station and

1-RE = The energy consumed in the network

RESULTS AND DISCUSSION

In the proposed algorithm, it is attempted to choose the nodes with the shortest possible distance and the largest neighboring nodes as a cluster head so that the cluster-head to be elected within high density points and a more uniform clustering and as well as a smaller energy consumption is achieved. Figure 2 exhibits an extended algorithm flowchart.

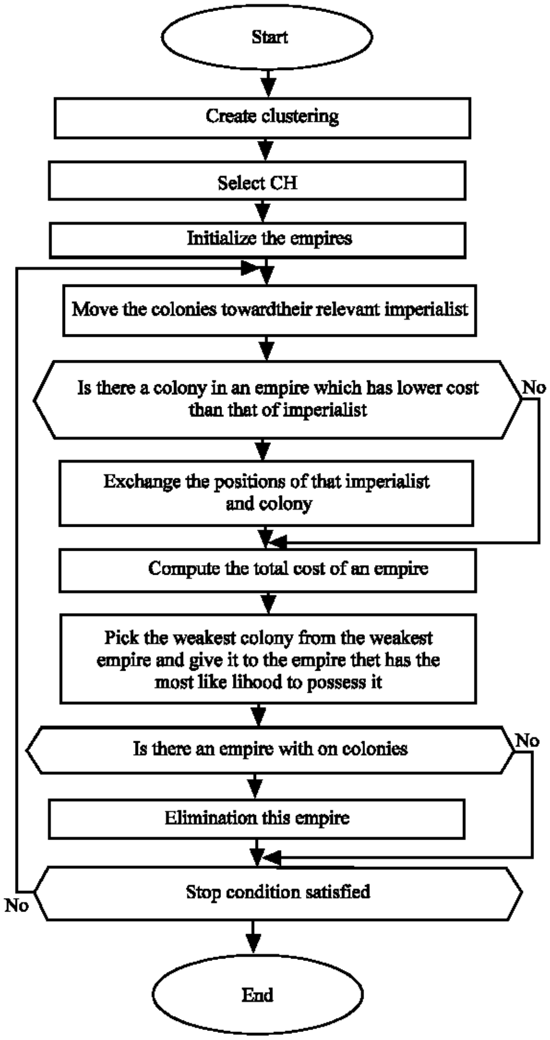

Fig. 2: Imperialist competition algorithm flowchart

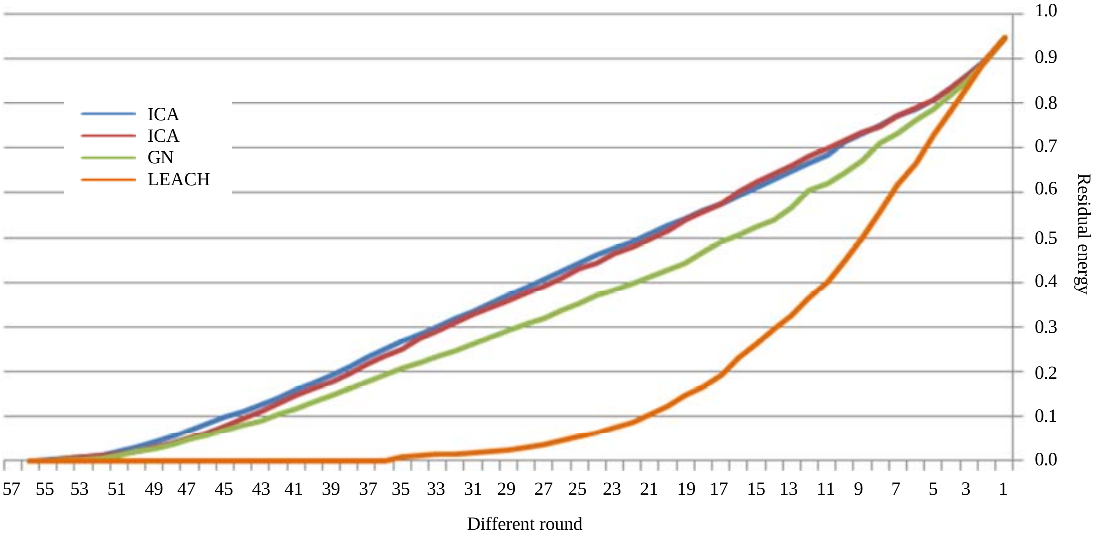

Fig. 3: Residual energy along different rounds

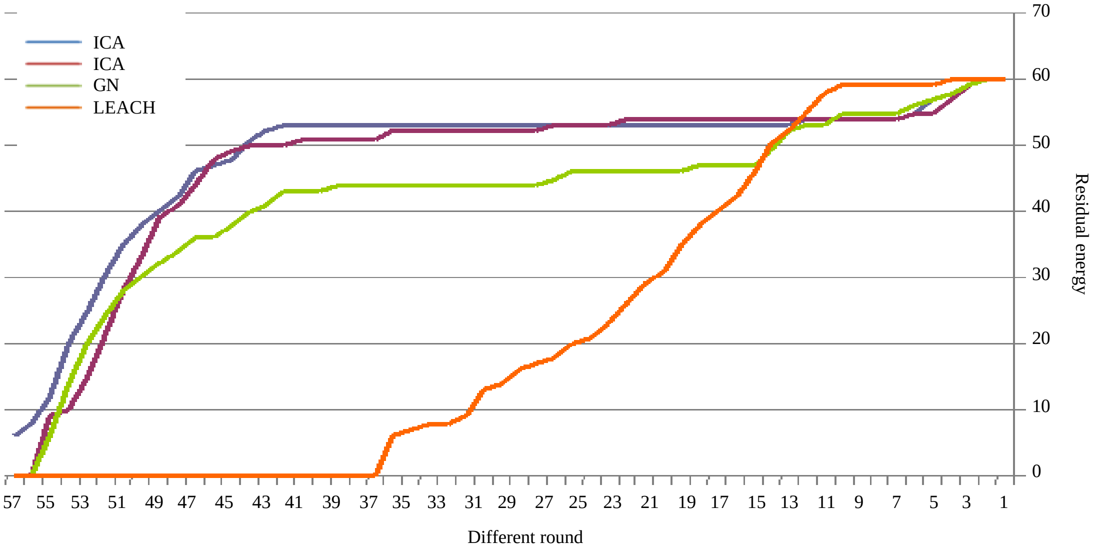

Fig. 4: Number of live nodes along different rounds

Simulation of the proposed method: In this study, we implement the proposed model based on primary parameters included Table 1 by the MATLAB simulator version 7. In this simulation, the proposed method is compared with algorithm Leach, geneticalgorithm (Liu and Ravishankar 2011) and imperialist competitive algorithm mentioned by Mehr (2014) based on time of response, residual energy, the number of live nodes and cluster-head distribution.

Frist, we compare the summation of node's residual energy in the proposed algorithm, Leach protocol and the procedures mentioned by Mehr (2014), Liu and Ravishankar (2011) along different rounds. First, the residual energy, algorithm Leach and those by Mehr (2014), Liu and Ravishankar (2011) along various rounds are compared. As is seen Fig. 3, the life of the network is ended using algorithm leach in iteration 35 and by both genetic and imperialist competition algorithms (Mehr, 2014) in iteration 54. But the proposed method with uniform energy consumption increases the network's lifetime compared to the other methods. Now, the number of live nodes in the introduced algorithm, algorithm Leach and those by Mehr (2014), Liu *et al*., 2011) along various rounds are compared. The results from this examination are shown in Fig. 4. It can be seen that the proposed protocol in both rounds has more live nodes during

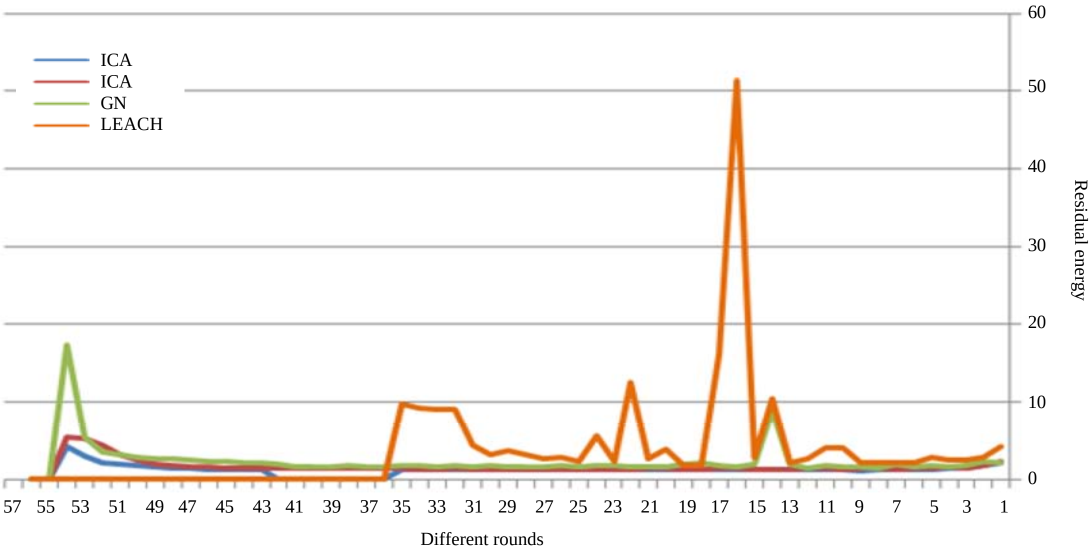

Fig. 5: Time of response

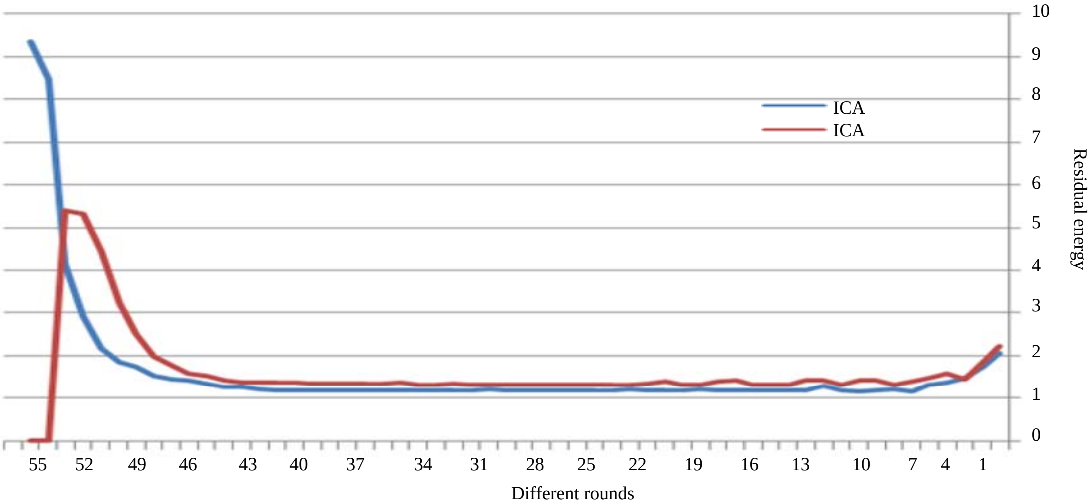

Fig. 6: Response time of proposed method and imperialist competition protocol

lifetime of the network compared to the studied protocols. In the other experiment, we compere the response time of the proposed algorithm with the mentioned ones. As is seen Fig. 5, this experiment demonstrated that the proposed method is of the shortest possible time to reach a desirable response.

To make the time of response more clear, the proposed method and the imperialist competition are recommended by Mehr (2014) as is exhibited in Fig. 6 separately. The proposed method is conceivably better than the matched methods. Finally, the cluster-head distribution in the proposed method is studied. Figure 7-10 represent the cluster-heads in the four compered protocols.

Table1: Initial parameter

Parameters	Primary value
Primary population	200
Number of emperor	20
β	2
γ	45
The majoring range of each node	20 m
Range of majoring computation of neighboring node	10 m
Network dimensions	100×100 m^2
Initial energy of each node	1 jules
Package size	400 bits
Number of iteration	100
E_e	50 nj/bit/m^2
$€_{fs}$	10 pj/bit/m^4
$€_{amp}$	0.0013 pJ/bit/m^4
d_{co}	10 m
Consumption energy for sending a bit	1 nj/bit

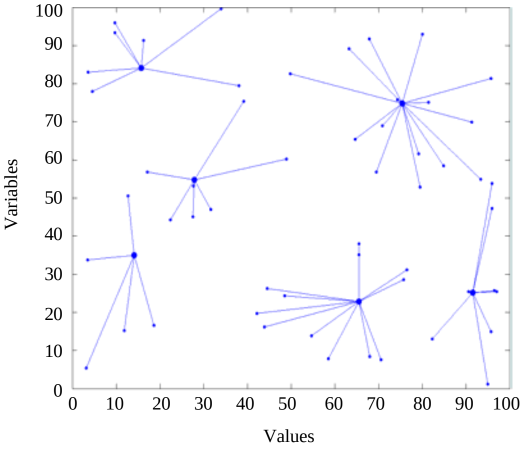

Fig. 7: Cluster head distribution in proposed method

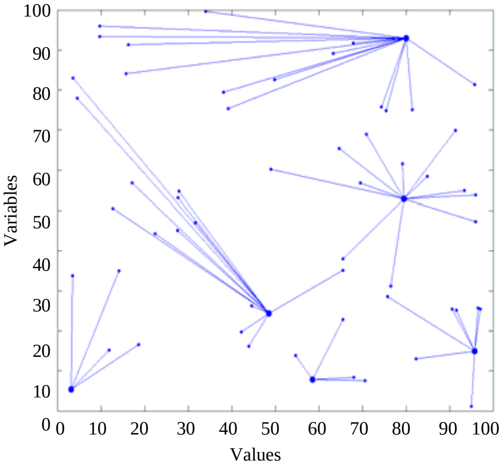

Fig. 8: Cluster head distribution in algorithm Leach

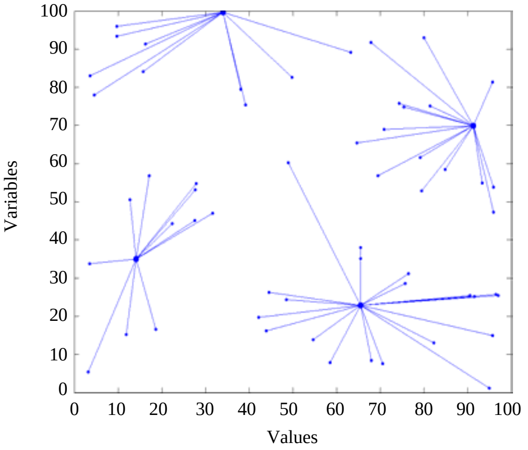

Fig. 9: Cluster head distribution in genetic algorithm

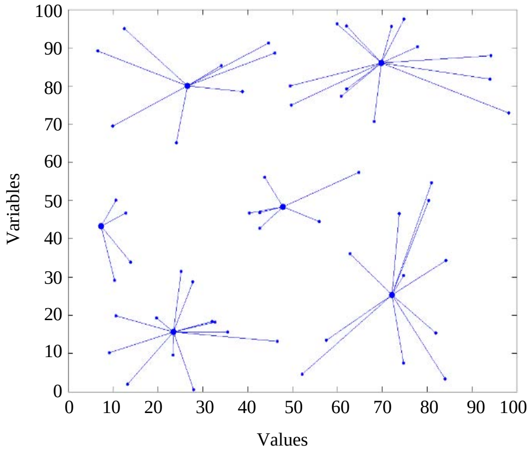

Fig. 10: Cluster head distribution imperialist competition

CONCLUSION

Researchers have much attempt to increase the lifetime of wireless sensor network to improve the clustering and choose a suitable cluster-head. For this purpose, they turned their attention on imperialist competition algorithm inspired by a social-political process and it has the same or higher optimization as well as a better responding reaction than the other evolutional algorithms. This algorithm by using a policy of assimilation and competition between data and countries, lead the population to an absolute optimization. This competition is performed based on cost function that is one of the variables that has to be optimized. So far, researchers have examined such variables as centrality, distance and residual energy in the evolutional algorithm to improve the lifetime of wireless sensor network. But they have ignored the parameter of number of neighboring nodes which plays a significant role as a distance variable in selecting the cluster-head and a suitable clustering of the data. In this study, the parameter of number of neighboring node has been used as an integral part for selecting the cluster-head node. In this way, the nodes with the shortest distance and potentially energized as well as with the largest number of neighboring node, are selected as a cluster-head. The proposed method has a more uniform distribution of the nodes and a low energy conception, reducing the loss of nodes and increasing network`s lifetime. The centrality parameter, distance and residual energy, by adding the parameter of number of neighboring node contribute to create a balanced clusters and a clear selection of cluster-head with highest energy and in turn. The proposed method improves clustering and 4% of network life.

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