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IMPERIALIST COMPETITIVE ALGORITHM FOR INCREASING THE LIFETIME OF WIRELESS SENSOR NETWORK

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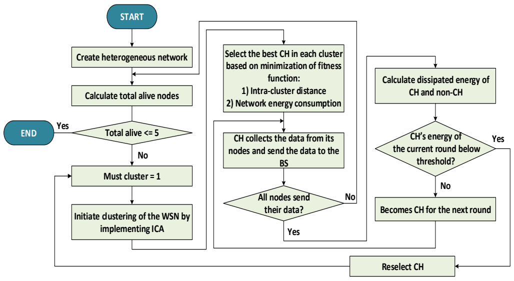
Graphical abstract



Abstract

Recent years have seen the rapid growth in the applications of wireless sensor network (WSN) which is due to the advances of sensor nodes with low cost and tiny size. Despite the various potential applications of WSN, one of the key tasks in sensor network design is to make sure that the network is functional as long as possible. This paper presents an energy-efficient cluster head selection algorithm for the clustering of heterogeneous WSN, inspired by Imperialist Competitive Algorithm (ICA). In order to reduce the network energy consumption and subsequently increases the sensor network lifetime, the clustering problem is transformed into an optimization problem and the specific cost function is used to select the cluster heads in a way that the energy utilization of the network is optimized. Extensive simulation works are done based on MATLAB to test the algorithm in various network scenarios, with different network sizes and number of nodes. Simulation results have shown that the proposed algorithm is able to extend the network lifetime compared to its comparative by up to 154 percent in terms of first node death. Furthermore, choosing the optimum set of cluster heads at every round has proved that our proposed algorithm not only could reduce the network energy consumption, but also improves the total data delivery at the base station up to 59 percent compared to the well-known algorithm.

Keywords: Wireless sensor networks, Imperialist competitive algorithm, Cluster head selection, network lifetime, energy efficient

Abstrak

Beberapa tahun kebelakangan ini, pertumbuhan pesat dapat diperhatikan dalam aplikasi rangkaian sensor tanpa wayar (WSN) yang disebabkan oleh kemajuan nod sensor dengan kos rendah dan bersaiz kecil. Walaupun terdapat banyak potensi aplikasi dalam WSN, salah satu tugas utama dalam reka bentuk rangkaian sensor adalah memastikan bahawa rangkaian dapat berfungsi selama yang mungkin. Kertas ini membentangkan algoritma untuk pemilihan ketua kluster yang cekap tenaga untuk tujuan pengelompokan rangkaian sensor yang berlainan jenis, yang diilhamkan oleh Imperialist Competitive Algorithm (ICA). Untuk mengurangkan penggunaan tenaga rangkaian dan selanjutnya meningkatkan jangka hayat rangkaian sensor, masalah pengelompokan ditukar menjadi masalah pengoptimuman dan formula pengiraan khusus digunakan untuk memilih ketua kluster supaya penggunaan tenaga dioptimumkan. Menggunakan perisian MATLAB, kerja simulasi yang mendalam dijalankan untuk menguji algoritma dalam pelbagai senario rangkaian, dengan saiz rangkaian dan bilangan nod yang berbeza. Hasil simulasi menunjukkan bahawa algoritma yang dicadangkan dapat mempertingkatkan jangka hayat rangkaian sehingga 154 peratus untuk masa nod pertama tidak berfungsi dibandingkan dengan perbandingannya. Seterusnya, pemilihan ketua kluster yang optimum pada setiap pusingan telah membuktikan bahawa algoritma yang dicadangkan bukan sahaja dapat mengurangkan penggunaan tenaga rangkaian, tetapi juga meningkatkan jumlah data yang diterima di stesen pangkalan sehingga 59 peratus berbanding dengan algoritma yang terkenal.

Kata kunci: Rangkaian sensor tanpa wayar, Imperialist Competitive Algorithm, pemilihan ketua kluster, jangka hayat rangkaian, cekap tenaga.

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1.0 INTRODUCTION

Wireless Sensor Networks (WSN) refer to a group of fixed or randomly distributed of tiny devices called sensors that are capable of sensing, monitoring, computing, and recording of the physical environment. Today, WSNs are immensely and diversely used in numerous of applications especially in agriculture for monitoring of plant [1], military for controlling and monitoring the borders [2], environmental control for the detection of wildfire [3], disaster relief [4], traffic control [5], and home automation [6].

Sensor networks require certain protocol for efficient performance. Grouping sensor nodes into several clusters have been one of the efficient approaches to support scalability and network growth in WSN [7]. Clustering divides the nodes of the sensor networks into several groups or clusters in which for every cluster, there is one node appointed as a leader known as a cluster head and the rest of the nodes in the cluster becomes cluster members in which they can directly communicate with their respective cluster head [8]. Furthermore, a base station which acts as a gateway, receives the transmitted data from the cluster heads through single or multi-hop and forward the data to the remote user [9].

A cluster head has several important roles in the cluster. It has the ability to collect all the sensed data from its group member, may or may not aggregate the data for reducing the overhead and finally compresses the information data prior to forwarding it to the sink node [10]. However, all these responsibilities added huge burden to the cluster head and resulted in significantly greater energy consumption at the cluster head node [11]. In addition, the location of a cluster head with respect to its cluster members is also crucial to reduce the energy dissipation in the network. Hence, the cluster head selection process is the most important phase in the cluster-based routing protocols to increase the lifespan of a network.

Various mechanisms to maximize the lifetime of the WSN have been numerously proposed by other researchers focusing mainly on efficient clustering and routing protocol techniques, data assembling and aggregation process and many other areas. A protocol known as LEACH-C (Low Energy Adaptive Clustering Hierarchy - Centralized) is presented in [12] for the selection of the cluster heads with the aim to prolong the network lifetime of the WSN. This protocol is proposed as an improvement to the original LEACH protocol that utilizes random probability in the cluster head election process. The simulation results disclose that LEACH-C outperformed LEACH protocol due to optimal cluster head selection using simulated annealing at the base station. However, there is a drawback by using this technique such that, a number of sensor nodes which are situated at a better location are prevented from being chosen as cluster heads due to their below-average energy in which they are still able to become the cluster head in the consecutive round.

In [13], the authors proposed a centralized and energy-aware clustering technique that employed Particle Swarm Optimization (PSO) algorithm. The nodes which particularly have energy level above the average are capable of selected to be cluster head candidates in that round. The cluster heads that can minimize the cost function which is minimization of intra-cluster distance and optimizing energy efficiency of the network are chosen as cluster heads in that particular round. It is shown from the results that PSO-based clustering algorithm improves the data delivery and network lifetime compared to LEACH and LEACH-C. However, the algorithm is not evaluated in terms of scalability and network density.

In [14], the authors presented a dynamic cluster head selection method for cluster head selection by analyzing the energy consumption of sensor network with regards to the redundant nodes and heterogeneity characteristic of energy of the nodes.

In addition, the partitioning of nodes into cluster in the monitoring area are being formed by implementing Voronoi diagram. The redundant nodes which have death priority but do not affect the performance of network coverage are selected as the first kind of cluster head nodes. The division of clustering in the monitoring area have the capability to make some part of the nodes inactive or sleep. The new set of cluster head nodes are chosen by using survival time estimation algorithm rightly after the death of the first kind of nodes. Nonetheless, some nodes can be disconnected to the network before waiting for their new cluster head to be selected. In addition, although the method has demonstrated an improvement in terms of network lifetime, there is no result shown in terms of data delivery at the base station. The data delivery indicator is important to show that the algorithm does not only conserve the network energy, but also improves the packet delivery ratio at the base station.

Based on the paper in [15], the authors presented a technique called Hybrid BSA (Backtracking Search Optimization Algorithm) and K-Means for optimal cluster head selection in the clustering of WSN. The BSA scheme employs three fundamental genetic mechanism known as selection, mutation and crossover in order to develop trial individual while hybridization with K-Means is used to arbitrarily generate K-centroids to categorize the data points in accordance to the nearest distance to the centroid. The fitness function is chosen such that such that the utilization of energy consumption in the network and the distance between sensor nodes to their respective cluster head are minimized. Furthermore, this algorithm gives significant advantage of capability to adaptively tuning parameters to effectuate the maximization of data transmitted and network lifetime in each of applications. This algorithm however is only tested at the quite dense area with 100 nodes at the area of 100 m x 100 m.

A Hybrid Ant Colony (ACO) and Artificial Bee Colony (ABC) Optimization Algorithm-based Cluster Head Selection (HACO-ABC-CHS) is presented in [16]. The problem of stagnation in the intensification process of ACO is prevented by utilizing employee bee agents for exploration while delayed convergence issue in onlooker bee phase of ABC is resolved by partitioning the process of exploitation into two levels through the incorporation of employee bee phase for primary level of exploitation [16]. Based on this proposed technique, parameters such as delay, distance, energy, temperature, and load are taken into consideration for determining or selecting the cluster head. However, this technique has high complexity and require high computational efforts both in terms of software and hardware.

A current research work that focuses on clustering of mobile sensor nodes in WSN-IoT is proposed by authors in [17]. The optimum clusters are obtained using memetic algorithm which aims to balance the load among clusters in a dynamic manner. A set of cluster head is found as soon as it is necessary and they are elected based on parameters such as nodes’ current energy, degree, and mobility. Based on random waypoint mobility model, several experiments were conducted for up to 500 mobile sensor nodes, for varies node’s speed between 1 km/h until 80 km/h. This method outperforms other state of the art clustering method in terms of control messages overhead, cluster count, network lifetime and reaffiliation rate. Nonetheless, more message exchanges are involved using this method during the cluster creation due to the need to consider parameters such as node’s degree, energy and relative mobility.

A clustering protocol based on the fractional grasshopper optimization algorithm (Fractional-GOA) is projected in [18] where the technique generates control over the sensor nodes' turn-on or off. Active sensor nodes engage in sensing and monitoring the distributed environment, as well as data transmission to the base station. Furthermore, the implementation of sleep/wake scheduling in the sensor nodes has reduced the overall energy consumption. Unlike other described works that are intended for stationary sensor networks, this work considered mobility of sensor nodes to determine the performance of sensor nodes while transmitting a data.

Another energy efficient cluster head selection method is proposed in [19] using K-Means algorithm. Unlike most other techniques in the literature, this method which is called the Cluster Centered Cluster Head Selection Algorithm (C3HA) necessitates two clustering steps. The network is first grouped using K-means, and then a subset of nodes in each cluster is determined. This unique subset is known as CC (Cluster Centered), and the nodes in CC have a higher priority to be selected as cluster head. However, network performance comparison is limited to LEACH only whereas the performance of C3HA against the improved and centralized algorithm LEACH-C was not evaluated.

The utilization of Imperialist Competitive Algorithm (ICA) for optimizing the cluster head selection process has been proposed by [20]. In this method, the cluster head chosen has the maximum energy and better connectivity than others, and each cluster is equally distributed in terms of cluster members. The process of cluster head selection is also centralized at the base station. Even though the proposed work in this paper has shown an improvement in terms of network lifetime over LEACH, there is no comparison made with LEACH-C, which is an improved version of LEACH that is based on centralized algorithm and Simulated Annealing. Moreover, there is no guarantee that the data delivery is also maximized even if the network lifetime is prolonged since there is no result presented based on this performance metric. Hence, the network lifetime may be extended due to less data delivered to the base station compared to other algorithms.

The work in [21] has also proposed ICA as an evolutionary approach to find load balancing for clustering in WSN. In the proposed method, the fitness function for the cluster head selection is based on the standard deviation of the cluster head load. The aim is to minimize the maximum load of a cluster head and also to achieve balance load distribution among all the cluster heads. It has been shown from the results that the proposed ICA-based algorithm outperforms the other two methods which are based on Genetic Algorithm, in terms of energy consumption, the number of active sensor nodes, convergence rate and execution time. Nonetheless, there is no performance comparison for data delivery which is one of the most important metrics to show that the algorithm can work successfully in WSN.

In this paper, an energy-efficient cluster head selection algorithm for WSN based on Imperialist Competitive Algorithm (ICA) is proposed with the aim of enhancing the overall network performance, in terms of energy consumption and network lifetime of the WSN. The proposed algorithm is therefore dynamic because it is efficient and adaptive to multiple network architecture and network growth. Moreover, excessive number of simulations are performed, and we compared the proposed method with the well-known clustering protocol in WSN.

The organization of the rest of this paper is as follows: In Section 2, the details methodology of the proposed method is described. In Section 3, the simulations' results and analysis are presented. Finally, Section 4 concludes the paper.

2.0 METHODOLOGY

2.1 Imperialist Competitive Algorithm (ICA)

Imperialist Competitive Algorithm (ICA) is an optimization algorithm based on the human social-politically evolution on the basis of the imperialistic competition [22]. ICA begins with a random initial population or empires. Within the empire, there exist individual agent known as a country. The countries can be distinctly divided into two different groups in which they are called colony and the other is known as an imperialist. The combination of the colonies and imperialists collectively made up an empire. In ICA, imperialistic competition phase refers to the situation in which the powerful empire tries to take possession of the collapsed, weak empire with the aim to colonizing the weakest empire to extend its political control. The output of the imperialistic competition is expected to converge to a particular condition in which there are only one empire left with the colonies that have the similar position and cost as the imperialist. The flowchart of ICA presented in the Figure 1 summarized the important steps involve in this algorithm.

ICA has been proved to have better convergence than PSO and GA to achieve response for certain problems [22]. In ICA, an empire with no colonies which indicates the weakest empire is eliminated, whereas one or several colonies are selected from this empire to be injected into stronger empires. This process opens up an opportunity to strengthen the weak responses so that it can survive and becomes stronger. This feature on the contrary, is not available in PSO and GA [21].

2.2 Cluster Head Selection Algorithm

The proposed cluster head selection algorithm based on ICA comprises two distinct phases known as setup phase, and steady state phase. Like most of other works that addressed the problem of clustering in wireless sensor networks, the setup phase is where two major processes are carried out which are cluster formation and cluster head selection [23]. This is the initial phase where clustering protocol is executed by the base station using optimization algorithm. On the other hand, the steady state phase involves the transmission of data from the cluster member to its respective cluster head. The cluster head will then send this aggregated information to the base station.

2.2.1 Setup Phase

In the setup phase, the base station will execute the clustering algorithm and as it is assumed that sensor nodes literally are location-aware, they will inform their location to the base station. The base station will collect all the appropriate information such as sensor nodes' locations, their respective ID numbers and energy levels and finally performs the clustering algorithm and cluster head selection. After that, the base station will inform to every sensor node regarding their clustering information such as in which cluster that they belong to. In this situation, the base station is assumed to contain high power resources and located in a fixed position. Nonetheless, unlike most of the clustering algorithms, our proposed algorithm performs the cluster head selection process only if the chosen cluster head's energy level is below the predefined threshold. By opting to this strategy, the frequency of the setup phase can be reduced and hence, more data can be delivered uninterrupted to the base station. Figure 2 illustrates the steps taken in details.

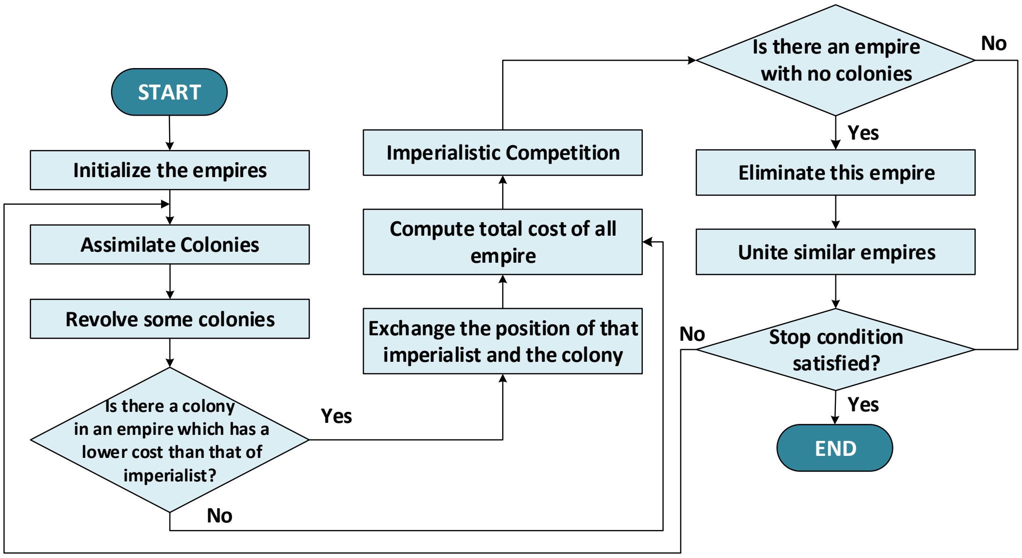

Figure 1 Flowchart of ICA

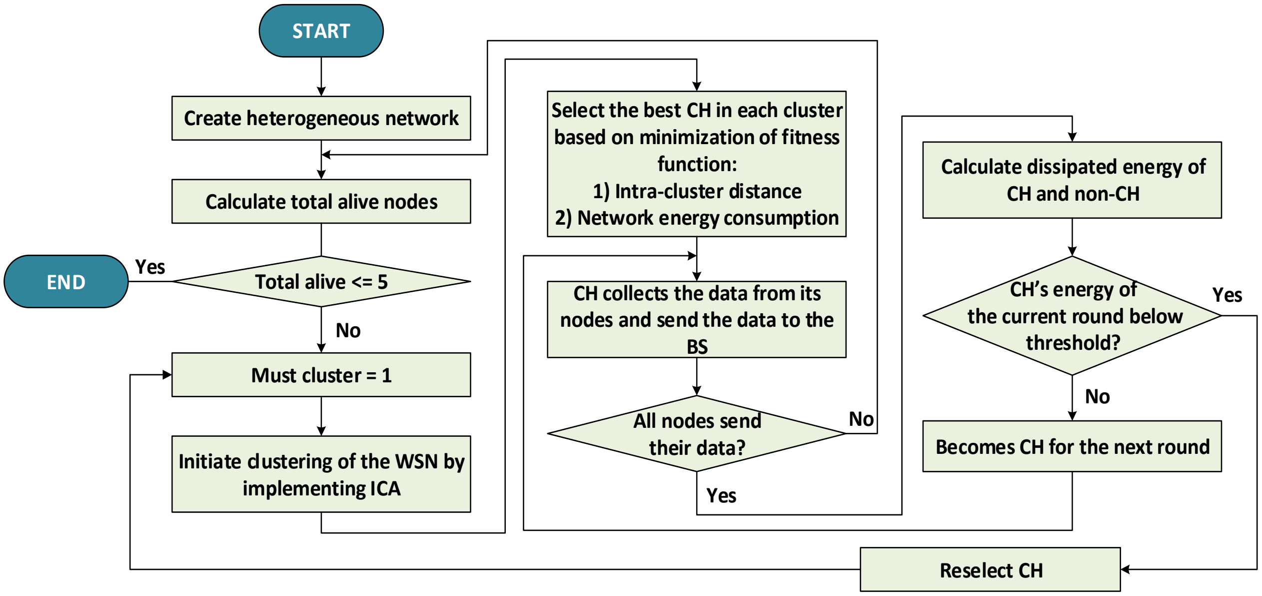

Figure 2 Flowchart of proposed ICA-based clustering method

2.2.2 Cluster Head Selection Phase

The cluster head selection phase is a state where the clustering algorithm try to find the best cluster head in certain rounds. The process is being done at the base station by leveraging the information on each node's location and energy level. During this phase, the clustering problem is transformed into an optimization problem and several cost functions are taken into consideration for the selection of cluster heads such that energy consumption in the network is efficient. In this paper, we have specified two fitness function that need to be optimized in the selection for the best cluster head which are the minimization of total energy consumption in the network and the minimization of average intra cluster distance. The fitness function for the multi-objective optimization clustering problem for cluster head selection is adopted from [15] and presented as follows:

$$f = w_1.f_1 + w_2.f_2 \tag{1}$$

where $w_1 + w_2 = 1$ are the weighting factors. The function f_1 refers to the total energy consumption of the network and is defined as follows:

$$f_1 = K \cdot (E_{elec} + E_{DA}) + \sum_{k=1}^{K} \left(\frac{\varepsilon_{mp} d_{k\ to\ BS}^4}{|C_k|} + \frac{|C_k| - 1}{|C_k|} E_{elec} \right) + \sum_{k=1}^{K} \sum_{j=1}^{|C_k|} (\varepsilon_{fs}\, d_{j\ to\ CH}^2) \tag{2}$$

The parameters E_{elec} , E_{DA}, ε_{fs} and ε_{mp} are the energy-related parameters from the first-order radio model as described in [12] which refer to energy dissipated per bit to run the transceiver circuit, energy consumed for data aggregation, communication-energy parameters for free space and multipath fading channel, respectively. Meanwhile, K is the total cluster in that particular round, $d_{k\ to\ BS}$ is the distance from the cluster head to the base station, $d_{j\ to\ CH}$ is the distance from each cluster member to its cluster head, and $|C_k|$ is the total number of members in each cluster.

The f_2 function on the other hand, aims to minimize the intra-cluster distance between the sensor nodes and their cluster head as defined in (3) [15].

$$f_2 = \max_{k=1,2,\ldots K} \left\{ \textstyle\sum_{\forall n_j \in C_k} d_{CH_k S_j} \right\} \tag{3}$$

The parameter $d_{CH_k S_j}$ is the distance between the cluster head and its cluster members based on Euclidean distance. The aim of minimizing the intra-cluster distance in the fitness function is due to the fact that the shorter the distance between the cluster head and its respective cluster member will cause less power for sensor nodes to transmit the data to the cluster head and subsequently reduces the energy dissipation of cluster head and the normal nodes. Noted that only alive nodes are taken into computation of the fitness function.

Based on the fitness function in (1), the ICA algorithm calculates the cost of each country and countries with the lowest cost become imperialist. In an empire, the remaining countries belong as colonies of that empire. As shown in Figure 1, the next process is the movement of colonies which involves assimilation, revolution, and exchange of position of the colony and imperialist until similar empires condition is reached. The total cost of all empires is then computed, and imperialist competition process begins. During this competition, the weakest empire collapses and the powerful empires which have the most likelihood to possess it takes control of its colonies and becoming more powerful. The powerless empire is then removed in the elimination process and its possessed colonies are handed to another powerful empire. By the end of the algorithm, there will be just one empire left in the result of the terminating criteria control based on a determined maximum number of iterations is reached or determined running time. The winning empire is the set of selected cluster heads with their associated cluster members for that particular round.

2.2.3 Steady State Phase

During the steady state phase, each sensor node sends the data to its corresponding cluster head in an allocated time slot. As a leader, cluster head receives the data from its respective group members, performs aggregation of the transmitted information and forwards the data to the base station based on this specified mechanism. If any of the cluster head's energy level is less than the threshold, the cluster head selection phase is activated and the process of clustering using ICA algorithm is run.

3.0 RESULTS AND DISCUSSION

The proposed algorithm is run using MATLAB software and examined comparatively to the LEACH-C protocol. In the simulation, heterogeneous sensor nodes in term of energy heterogeneity are randomly deployed in 500×500 area. Throughout the simulations, several random network topologies were considered to get the accurate average result. The other parameters of simulation are listed in Table 1.

Table 1 Simulation parameters

Parameters	Values
No of colonies	92
No of imperialists	8
Energy of normal nodes	0.5 J
Energy of advanced nodes	1.0 J
Packet Length	6400 bits
Control Packet Length	200 bits
Energy for transferring each bit, $\boldsymbol{E_{elec}}$	50 nJ/bit
Energy for receiving each bit, $\boldsymbol{E_{elec}}$	50 nJ/bit
Energy of multi path model, $\boldsymbol{\varepsilon_{mp}}$	0.013 pJ/bit/m^4
Energy of free space model, $\boldsymbol{\varepsilon_{fs}}$	10 pJ/bit/m^2
Data aggregation energy, $\boldsymbol{E_{DA}}$	5 nJ/bit/message

In the first experiment, the simulations are being conducted based on two different placements of the base station which are at the centre (250,250) and outside (250,500) of the sensor area. For the network lifetime evaluation, we analyzed the respective round number for the death of the first node (FND), death of the half of nodes (HND) and the death of the last node (LND) in the network.

As illustrated in Figure 3, for the base station's position at (250,500), using LEACH-C, the FND occurred at round 8 while in the proposed algorithm using ICA is slightly longer which is at round 15. For HND, LEACH-C managed to maintain the life of 50% of nodes until round 56 and all the nodes died in round 431. However, the proposed clustering using ICA surpassed the result of LEACH-C with the HND happened in round 100 and LND occurred in round

498 resulted in increasing of the network lifetime by 15%. This implies a better cluster head selection algorithm using the proposed protocol as wireless sensor network lifetime managed to be extended even when the base station is far from the sensor area.

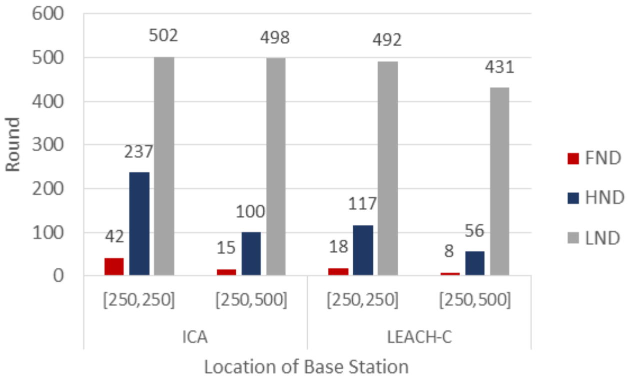

Figure 3 WSN lifetime for different placement of base station

In Figure 4, it is shown that the proposed algorithm using ICA outperformed LEACH-C protocol in both different placement of base station in terms of total data delivered. When the base station is located at the middle of the sensing area, the proposed algorithm using ICA improved the data delivery by 47% compared to LEACH-C. Even when the base station is positioned at the edge of the sensing area, there is still apparent improvement by 29%. This performance metric is important to indicate that the proposed algorithm could improve the data delivery at the base station, whilst prolonging the network lifetime.

The proposed algorithm is also evaluated based on the rate of energy consumption of the network. Based on the results shown in Figure 5, the energy of the sensor nodes has drastically drained in LEACH-C protocol in comparison with the proposed method for both different base station locations, which indicates that the clustering using LEACH-C consumed energy faster than using ICA. The proposed algorithm using ICA has the capability to reduce the total amount of energy used by the sensor network even when the base station is situated at the outside of sensing area since it provides better load balancing due to optimization of cluster head selection. Consequently, the proposed clustering method using ICA is more efficient than LEACH-C in terms of prolonging network lifetime.

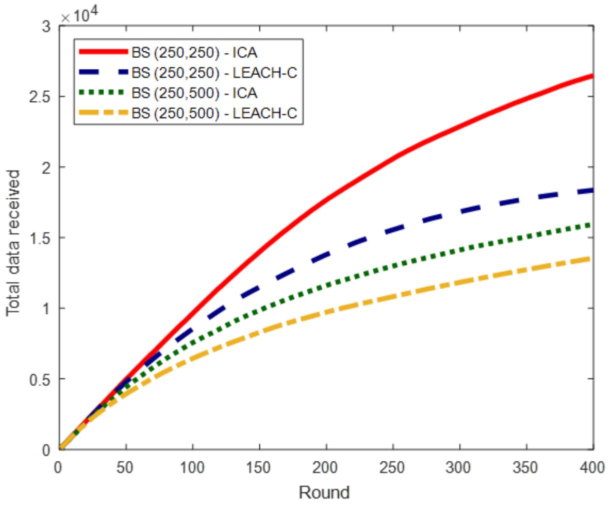

Figure 4 Total data received at the base station for different placement

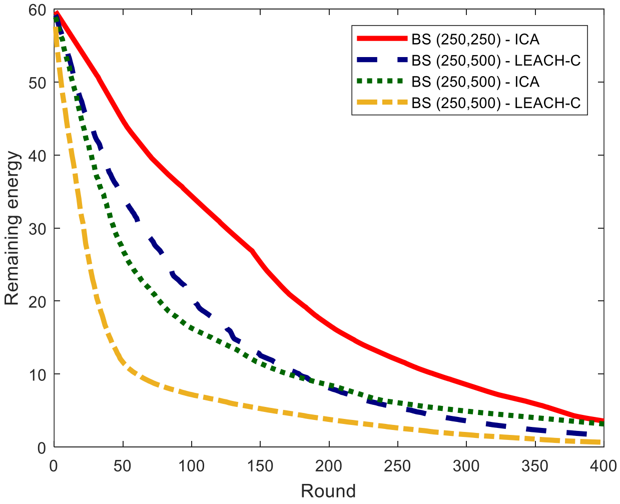

Figure 5 Remaining energy per round for different placement of base station (BS)

In order to evaluate the effect of the proposed algorithm in different network density, several simulations were conducted in the network area size of 500×500 but consists of different numbers of sensor nodes which are 100, 200, 300 and 400 sensor nodes. Table 2 shows the network lifetime in terms of FND, HND and LND. The network lifetime for the proposed method using ICA is longer than LEACH-C in all scenarios with different number of sensor nodes. For instance, when the total node is 400, there were still 200 sensor nodes alive at round 279 for ICA-based algorithm, whereas 200 sensor nodes were recorded alive at round 158 for LEACH-C. In addition, using ICA-based clustering algorithm, the network stopped functioning upon the death of last node at round 944 as compared to LEACH-C at round 918 for total nodes of 400. The highest improvement occurs when the total nodes is 400 where ICA enhances network lifetime in terms of FND by 154% compared to LEACH-C. For HND, the enhancement of network lifetime is by 128% with 200 sensor nodes. The superiority of ICA is also shown in Figure 6 where the data delivered at the base station for clustering using ICA is so much higher when compared to LEACH-C. The improvement can be as high as 59% when the number of nodes is 200.

Table 2 Network lifetime for ICA and LEACH-C

Clustering Protocol	Total Nodes	FND (round)	HND (round)	LND (round)
ICA	100	42	237	502
	200	37	274	632
	300	35	277	698
	400	28	279	944
LEACH-C	100	18	117	492
	200	17	120	581
	300	16	155	683
	400	11	158	918

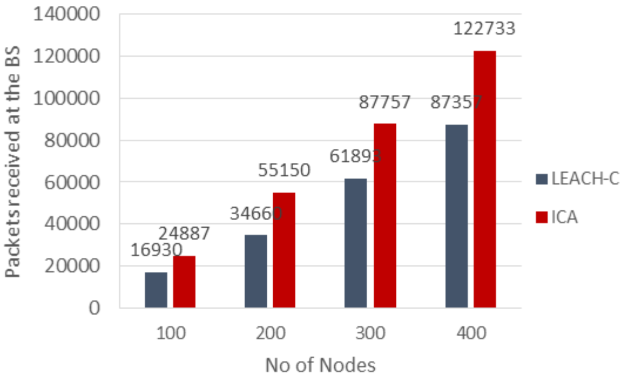

Figure 6 Packets received at the base station for different number of sensor nodes

As shown in Figure 7, the total remaining energy for ICA at round 150, for 100 nodes until 400 nodes are 20.52 J, 52.49 J, 82.11 J and 106.2 J, respectively. Meanwhile, for the clustering using LEACH-C, the total remaining energy at round 150 are 10.4 J, 20.52 J, 41.69 J and 44.07 for 100, 200, 300 and 400 nodes respectively. This shows that, with different number of network density, the proposed method using ICA is still more energy efficient compared to LEACH-C. Hence, the optimization of cluster formation using ICA results in better cluster heads distribution across the network and consequently, reduces the amount of energy being dissipated during the transmission of data packets.

The third set of simulations aimed to investigate the performance of the proposed algorithm with respect to different network area size. The simulations were performed for 100 nodes in different network sizes of 300×300 m^2, 400×400 m^2 and 500×500 m^2 respectively for ICA-based algorithm and LEACH-C. The location of the base station was in the middle of the sensor network area.

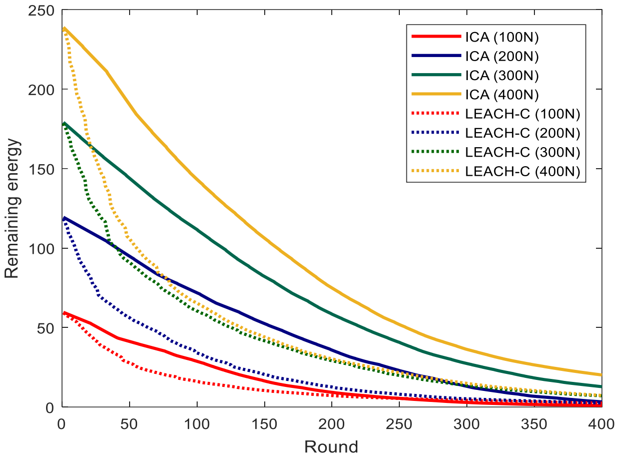

Figure 7 Remaining energy in the network for varies number of sensor nodes

As illustrated in the Figure 8, as the network size increases, the network lifetime decreases for both algorithms. This is because the distance between the sensor nodes and the cluster head becomes higher as the sensor area is bigger. Hence, more energy was being used to transmit the data. Nonetheless, for all scenarios, the proposed algorithm using ICA shows tremendous improvement in terms of network lifetime compared to LEACH-C. For instance, when the network area is 300×300 m^2, the last node died at round 862 for ICA-based algorithm whereas in LEACH-C, the network stopped functioning at round 524. Therefore, these promising results prove that the proposed clustering algorithm based on ICA is able to find the optimum set of cluster heads during the selection of cluster head phase and consequently minimizes the total energy consumption of each sensor node during the data transfer to its cluster head.

To further validate the efficiency of the proposed algorithm in delivering the data to the base station, the total number of packets received at the base station for each algorithm in different network area size is shown in Figure 9. In all scenarios, ICA-based clustering algorithm is able to deliver more data to the base station compared to LEACH-C.

Meanwhile, Figure 10 shows the total remaining energy of the network as the number of round increases. It can be seen from the figure that the proposed algorithm using ICA shows significant improvement in comparison with LEACH-C as the remaining energy per round is remarkably higher at each round. The reason to this finding is that the implementation of the ICA during the clustering process has led to the optimized selection of cluster head that can minimize the energy utilization of each cluster member during the data transfer phase and subsequently, conserves the energy of the network.

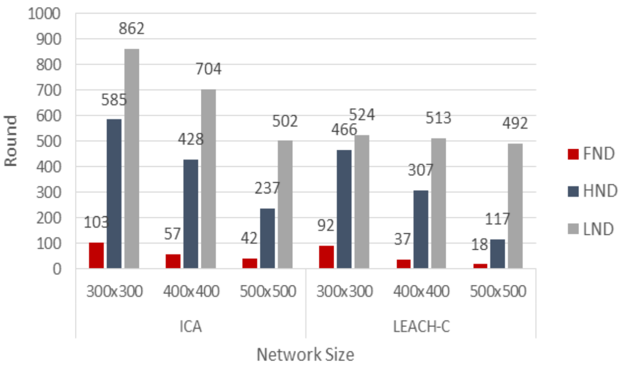

Figure 8 WSN lifetime for different network size

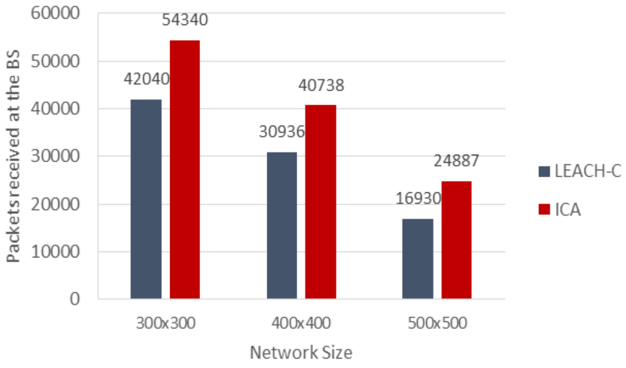

Figure 9 Packets receive at the base station for different size of network area

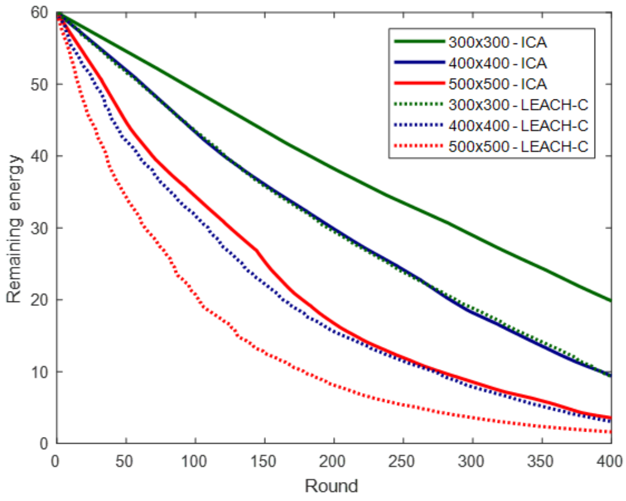

Figure 10 Remaining energy per round for different size of network

4.0 CONCLUSION

In this work, comprehensive simulations were performed to evaluate the performance of the proposed algorithm based on ICA in clustering the sensor network, in accordance with the different performance metrics. Based on the results, in comparison with the widely used routing protocol LEACH-C, it has been proved that the proposed algorithm using ICA is remarkably better in all simulated scenarios, with respect to the evaluations specified. The findings have shown that the implementation of the ICA in the clustering of sensor network can enhance the lifetime of the network, delivers more data to the base station within specified time and provides higher energy efficiency compared to LEACH-C due to the appropriate selection of cluster heads. In the future, the performance of the proposed algorithm may be analyzed with higher number of advanced nodes deployed in the network by implementing more level of heterogeneous energy networks. In addition, the implementation of this algorithm in mobile sensor nodes will also be considered as some sensor network applications involve sensor nodes that are attached to the mobile devices or entities.

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