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Implementation of a New Routing Protocol within the Wireless Sensor Networks with the Target of Minimizing Energy Consumption (Using a Combination of Fuzzy Algorithm and Harmony Search)

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ABSTRACT:
Introduction: Internet of things (IOT) has been following a fast growing trend during the recent years, and the wireless sensor networks account for the basis and, in fact, regulatory framework of the internet of things regarding their functions. Considering the wide-range applications of these sensors, energy consumption will be one the main challenges associated with these equipments in the future. The present study mainly deals with the issue of minimizing energy consumption in the wireless sensor networks.
Materials and Methods: For the purposes of the study, a novel routing protocol will be implemented. Initially, the ground is divided into multiple layers to gain a control over topology. The lower layers transmit the data to successive higher layers so that it finally arrives at the sink. The heads of the final layer clusters, every cluster on the final layer with smaller amount of distance-to-energy ratio i.e. shorter distance and more energy, is chosen as the final cluster. This study makes use of fuzzy algorithm and harmony search to select a set of the most appropriate nodes for becoming cluster heads. In this way, the best sensor nodes with the most desirable characteristics for becoming cluster heads will be chosen, which consume minimum energy. Competency function for harmony search incorporating parameters of density, nodes centrality, and nodes distances from the sink was optimized. Finally, the optimized tree for multistep routing for the purpose of minimizing energy consumption was developed.
Conclusion: The obtained results indicated that the proposed protocol is able to outperform LEACH and HSACP protocols in terms of energy consumption, specifically with a performance which is approximately %65 and %35 higher than them respectively. This property is also helpful in providing much longer lifetime for the network.
Discussion: The results showed that applying the proposed protocol can provide the wireless sensor networks with longer lifetime and lower energy consumption.

KEY TERMS: Internet of Things (IOT), Wireless Sensor Network, Network Lifetime, Routing, Energy Consumption

1. INTRODUCTION

Wireless sensor networks have gained a considerable popularity in the recent years. Development of the Internet Of Things (IOT) has introduced these sensors as a regulatory framework for IOT. Their application in micro-electromechanical systems has acquired a large deal of attention associated with developing and using smart sensors in these networks. These sensors are very small in size, and have limited resources for accounting and processing. They are also relatively cheaper than conventional sensors. The sensors are capable of sensing, measuring, and gathering information from the surrounding environment.

The small size of the nodes has given rise to sensor networks with lots of sensor nodes that cooperate in carrying out complicated operations. Sensors are low-power tools connected to one or more sensors, and are equipped with a radio, a memory, and a processor coupled with magnetic, optic, biologic, thermal, and other types of sensors in order to measure features of the environment. Since the sensor nodes have limited memory and are usually positioned in out-of-reach locations, a radio is needed to gather information and transmit it to the central base wirelessly.

Batteries provide the major source of power for sensor nodes. Sometimes, an auxiliary source may be used to gather energy from the environment. Solar panels are the most common auxiliary sources. These networks comprise a lot of small sensor nodes with high-level power, lower energy consumption, and lower price. They can sense special features including humidity, temperature, pressure, etc. from the surrounding environment and transmit the collected data to the central node. Therefore, we can consider these networks from two perspectives: sensing particular parameters from the environment and establishing a connection in order to sending the findings to the central node. Sensor networks are utilized in a wide-range applications including watching out war zones, environmental monitoring, smart control, traffic management, medical operations, industrial troubleshooting, etc. These applications typically require implementation of the sensor networks in a wireless architecture. These networks typically are composed of either fixed or limited-motion nodes incorporated with a central node. All nodes transmit their information to the central node either directly (single-step) or indirectly (multi-step). In the case of direct transmission, every sensor sends its information directly to the center, thus this operation requires a lot of energy due to the long distance between individual sensors and the center. In contrast to the direct transmission, there are certain designs that make the communication distances shorter, which in turn extend the network lifetime. Therefore, multistep communications are more useful and more cost-effective than single-step ones in such networks. Single-step communications are also more vulnerable to security attacks. In spite of the promising future for the sensors, the processes of designing, execution, and implementation are likely to confront significant challenges. A wide range of studies have focused on dealing with the associated issues so far, and various solutions have been proposed for the sensor networks.

2. PREVIOUS STUDIES

The current researches concerning the specific technologies for wireless networks have proposed several routing protocols which are efficient in terms of energy in receiver networks. The main purpose of such protocols deals with both increasing network lifetime and decreasing energy consumption by nodes. A carefully contemplated way is required to transfer the collected data from receiver zone to the base location so that the network can remain stable for a longer period. Clustering is one the approaches that are usually proposed for this aim. Hierarchical routing protocols based on clustering have been demonstrated to provide a better performance in network location management, minimizing energy level, data collection etc. The following is a short review on some attempts at clustering across wireless sensor networks:

2.1 LEACH Routing

LEACH, among all proposed communication protocols, has a particular importance to researchers, because:

1. Network clusters complying with this protocol are formed in hierarchical, adaptive, and self-configuration fashion. The mentioned features are illustrated by explanations below.
2. Information transmission from nodes of one cluster to the next cluster and finally to the central base is carried out through local control without any need for a external factor or a certain node across the network.
3. MAC protocol which is utilized in LEACH, saves a considerable amount of energy by allowing resting time for the sensors.
4. As mentioned above, the LEACH protocol uses the same process of combining data of every cluster and sending compact data to the central base, similar to other cluster-based protocols. Therefore, not only the number of sends and receives within network is decreased but also the excess data that are formed due to short distances among sensors of a cluster are deleted.

Cluster Head Election Algorithm: The time is divided into similar portions with equal lengths, which are called rounds. Each round is also divided into two phases. The first phase is set-up or cluster-forming phase, and the second is called steady-state phase which is related to ordinary performance of network and data transmission. This phase is composed of a certain number of time frames within which all nodes of a cluster send their data to cluster heads. The heads receive the data and them to the central base. This time division as illustrated by Figure 1.3 below.

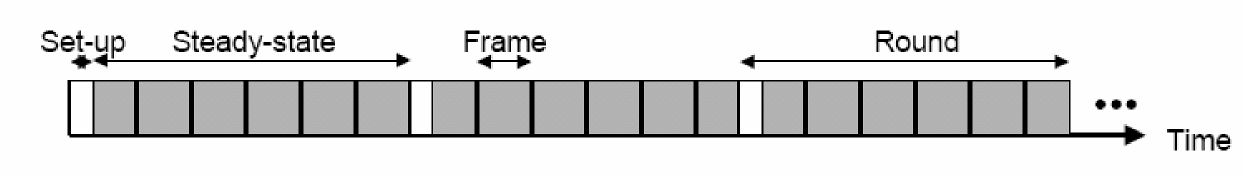


Figure1: Time division in the LEACH protocol

The cluster heads in the set-up phase are chosen by the probability function in the Equation (1). Cluster heads selection is carried out in such a way that every sensor chooses a random number, either 0 or 1. If this number is smaller than the defined threshold by the following relation, it will be chosen as a cluster head throughout that round.

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times \left(rmod\dfrac{1}{p}\right)}, & if\, C_i(t) = 1 \\ 0 \quad , & if\, C_i(t) = 0 \end{cases}$$

where, p is an already determined percentage for the number of existing cluster heads within the network, which equals k_{opt}/N (k_{opt} is optimum number of the cluster heads, which is obtained by a method that will be explained later. N refers to the number on nodes); r refers to the number of the current round; $C_i(t)$ is an indicator function which identifies whether the node i was a cluster head during the last $rmod\frac{1}{p}$ round or not. When $C_i(t)$ is 1, it means that the node i has not been a cluster head during the last $r mod \frac{1}{p}$, but is able to be a cluster head. This relation has been designed in a special way so that we can expect every sensor has a chance to be cluster head after 1/p rounds. In this way, energy consumption will be evenly distributed throughout the network.

2.2 LEACH-C

LEACH-C increases the network efficiency by forming better clusters and dissemination of the cluster heads across the network. Each node sends its own location and residue energy to the central node (sink) then the sink selects the cluster head nodes by a central algorithm. Furthermore, the number of the chosen cluster head nodes also has an influence on the consumed energy in the network.

2.3 HSACP

The present study proposes a framework for design of the centralized cluster-based protocols for wireless sensor networks. The centralized mechanism for the network clustering allows taking advantage of the BS's powerful calculating ability. Thus the optimization algorithm can run during a reasonable period of time for real-time operation. According to this framework, a protocol is designed using HAS and implemented over the wireless sensor network framework.

2.3.1 Formulating the optimization problem

A wireless sensor network with N nodes is randomly located in a region of the environment, and is organized in the form of k cluster: C1, C2, …, Ck. According to the centralized cluster protocol that has been proposed for this network, the central base must choose those cluster heads that contain the highest amount of residue energy among the sensor nodes. Then the clusters take form, using spatial information of the sensor nodes or the residue energy, in a way that there is a consistent distribution of sensor nodes within each cluster. We may formulate this process in an optimized problem which is computationally described as below:

(2)

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

where

$$f_1 = max_{j\in(1,k)}\left\{\frac{\sum_{\forall node_i \in C_j} d(\text{node}_i, \text{CH}_j)}{|C_j|}\right\}$$

$$f_2 = \sum_{j=1}^{k}\left\{\frac{\sum_{\forall node_i \in C_j} V_i^{\text{res}}}{V_{\text{CH}_j}^{\text{res}}}\right\}.$$

As can be seen from the Eq. (2), f_{obj} includes two parts. The first part, f_1, equals the maximum total Euclidian distances of $node_i$ ($\forall i \in C_j$) from corresponding Ch_j heads. |Cj| equals the number of clusters that belong to the C_j cluster. By minimizing f_1, the average internal distances between sensor nodes and their cluster heads will be minimized. The second part, f_2, equals the total sum of the current residue energy ratios of all alive nodes within the $\sum_{\forall node_i \in C_j} V_i^{res}$ network with CHj energy level which is assumed $V_{CH_j}^{res}$ in the present stage. As the target function, f_{obj}, minimizes, both the cluster formation and WSN cluster head selection are expected to be optimized in order to increase efficiency of energy consumption across the network. In a practical system within which batteries provide the required power for individual nodes, the residue energy of a typical node i, V_i^{res}, can be shown by voltage of the current battery terminal i.e. V_i^{pre}. In the present study, it is possible to locate the nodes. In order to minimize f_2, the term $\sum_{\forall node_i \in C_j} V_i^{res}$ needs to be minimized while $V_{CH_j}^{res}$ is required to be maximized. A sensor node with the highest amount of energy within each cluster has a tendency to be chosen as the cluster head. Therefore, minimization of f_2 leads to selection of optimum cluster heads in terms of the residue energy in the network.

The constant α represents f_1 and f_2 portions of the target function f_{obj}. In order to exclude low-energy nodes from the list of candidates for being cluster head, the cluster head nodes are chosen as a set of candidates: $\{node_i \mid V_i^{res} \geq V_{ave}\}$. Thus only those sensor nodes will be chosen as candidates that have more energy than average energy level (V_{ave}) of all existing nodes within the network.

2.3.2 Clustering Protocol

Protocol operation comprises two phases: clustering setup phase and data transfer phase. During the setup phase, sensor nodes are grouped into several clusters in a way that the target function can be optimized. Then the cluster heads collect pertinent data of the members and transfer it to the central base during the transfer phase. These phases are alternately iterated during each stage of the network operation.

1) Phase 1 - Clustering setup: sensor nodes transfer the advertised (ADV) and geographical data to the central base. Battery voltage indicates the residue energy of the nodes. This information is successively sent to the computer through the gate node so that can be calculated. Once the formation of the optimum cluster has been recognized, the central base attaches the head information to the cluster which its member nodes belong to task message (ASG), then this message is sent to all sensor nodes.
2) Phase 2 – Data transfer: once the ASG message has been received by all nodes and the transfer program has been determined, the sensor nodes start receiving (sensing) operation and send the data to the cluster heads. Since the spatial distance from the cluster's member nodes to cluster heads is at minimum, their transfer power will be optimized.

3. RECOMMENDED PROTOCOL

3.1 Demonstrating how the proposed protocol works

Nodes are randomly positioned in an environment:

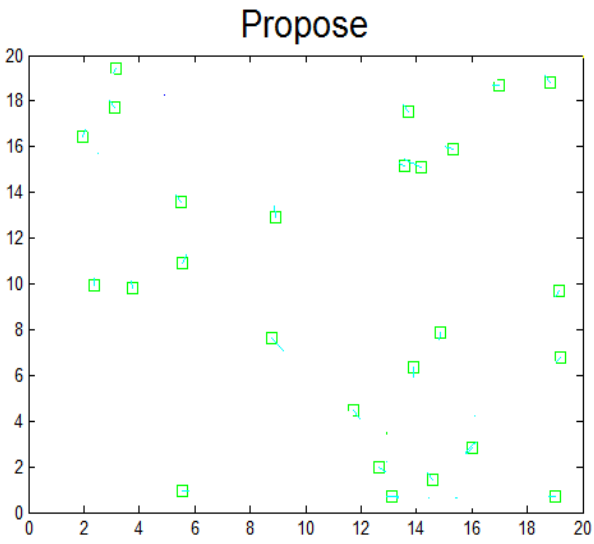


Figure (2): Random positions of the nodes in an environment

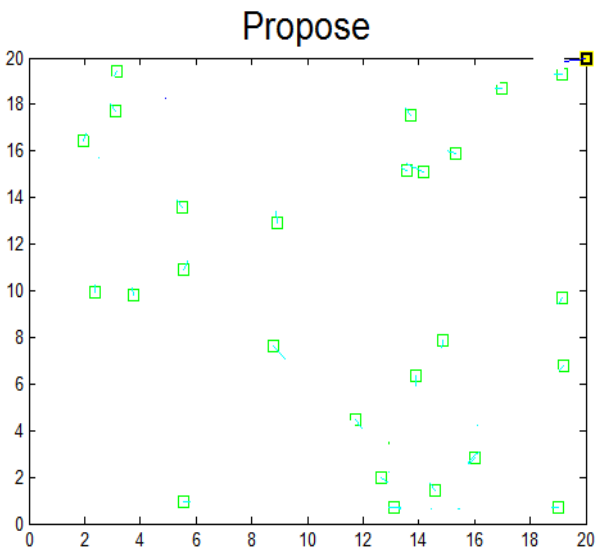


Figure (3): Sink's position out of the simulation environment

Cluster heads are obtained by fuzzy logic and Cuckoo search algorithm:

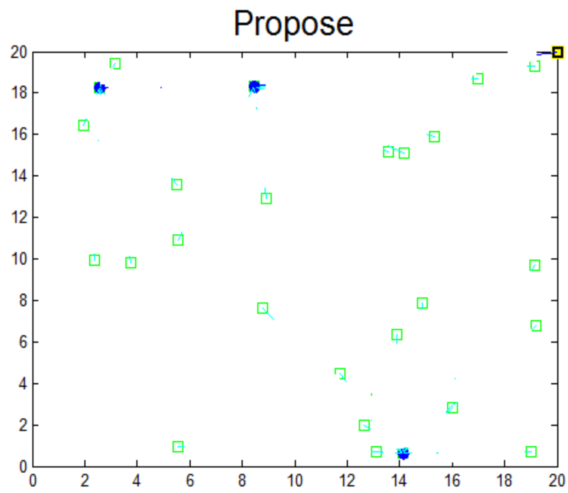


Figure (4): Determination of cluster heads

Ordinary nodes join the closest cluster head:

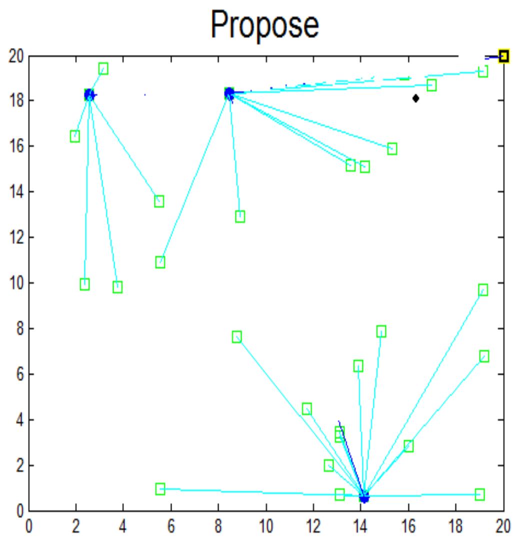


Figure (5): Becoming members of the clusters

Each cluster head is connected to the closest adjacent cluster head so that routing is carried out:

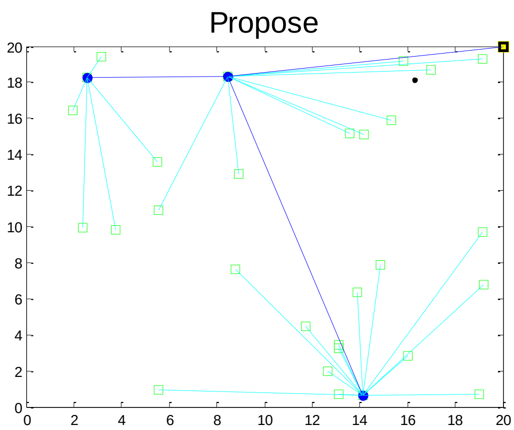
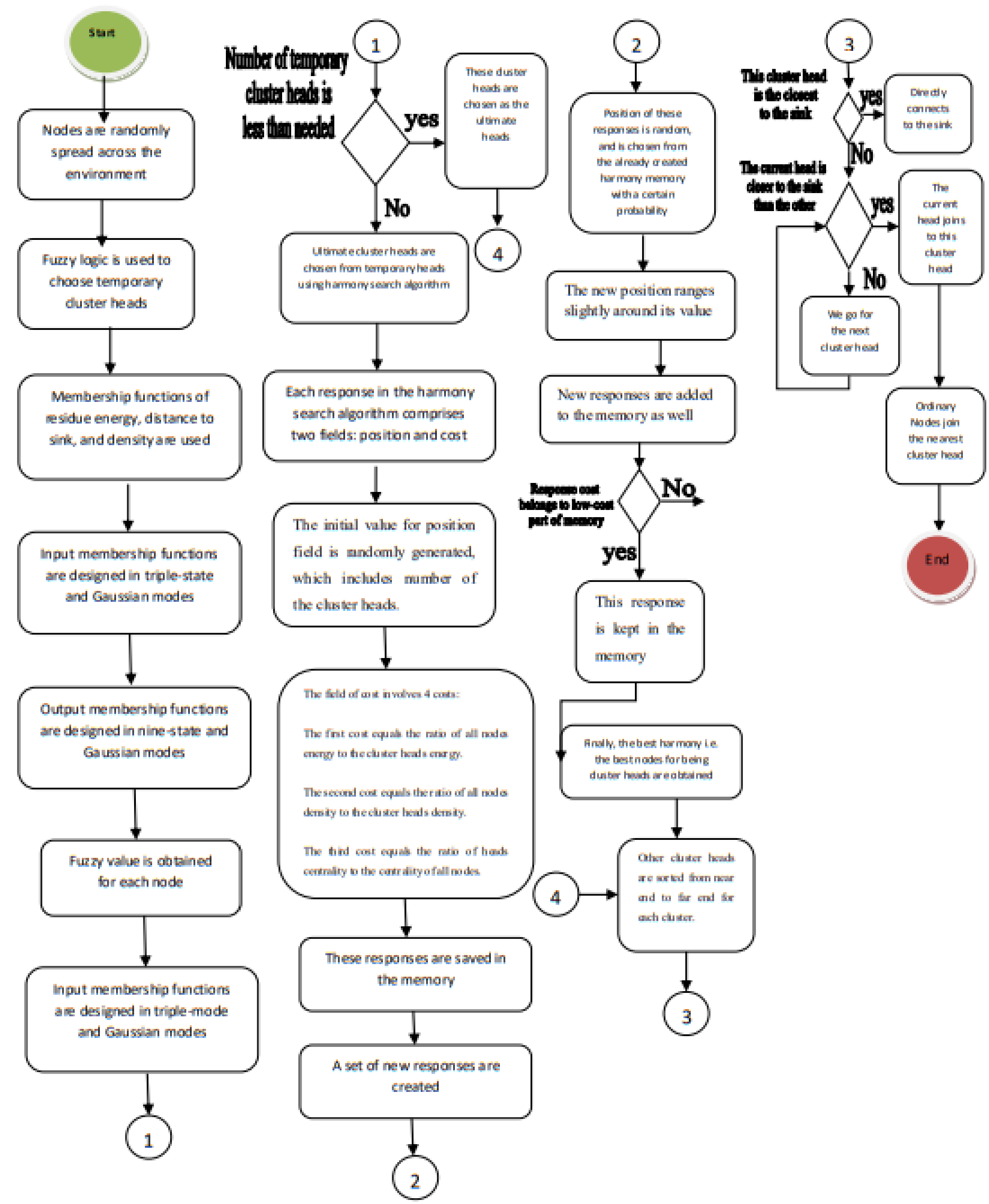


Figure (6): Routing among cluster heads

3.2 Flowchart of the proposed protocol

The flowchart below presents the proposed approach in a more illustrative way:



In order to clarify the flowchart above, the algorithm procedure is explained in individual steps as follow:

1. Nodes are randomly spread across the environment.
2. Fuzzy logic is used to choose temporary cluster heads.
3. Membership functions of residue energy, distance to sink, and density are used.
4. Input membership functions are designed in triple-state and Gaussian modes.
5. Output membership function is used in nine-state and Gaussian modes.
6. Fuzzy amount of each node is obtained.
7. Nodes which their fuzzy amounts are higher than the average fuzzy level will be chosen as temporary cluster heads.
8. These temporary heads are chosen as the final heads if the number of temporary heads is less than the required number.

9. If this number is higher than the required, harmony search algorithm will be used to choose final cluster heads from the temporary heads.
10. Each response to harmony search algorithm includes two fields: position and cost
11. The initial value for position field is randomly generated, which includes number of the cluster heads.
12. The field of cost involvees 4 costs:
    - The first cost equals the ratio of all nodes energy to the cluster heads energy.
    - The second cost equals the ratio of all nodes density to the cluster heads density.
    - The third cost equals the ratio of heads centrality to the centrality of all nodes.
    - The fourth cost equals the ratio of distance from heads' sink to distance from all nodes' sink.
13. These responses are saved in the memory.
14. A set of additional new responses will be generated.
15. The positions of these responses are either random or are chosen from harmony memory with a certain probability.
16. The new position ranges slightly around its value.
17. New responses are added to the memory as well.
18. Memory is arranged on the basis of costs.
19. The harmonies with better costs – less cost – are chosen matching the memory size.
20. Finally, the best harmony or the best nodes for being cluster heads are obtained.
21. Other cluster heads are sorted from near end to far end for each cluster.
22. If the distance of the other cluster from the sink is less than the distance of the current cluster from the sink, the current cluster will attach to this cluster head.
23. Otherwise, we will go to the next cluster head.
24. The closest cluster head to the sink is directly connected to the sink.
25. Ordinary nodes become the members of the closest cluster head.

We use Member Function to define the membership functions. We should calculate quantities of density, residue energy, and distance from the sink for each node. Then a blank fuzzy network will be generated. We should normalize the distance from the sink between 0 and 1. Membership function of distance will be defined by Gaussian functions as follow.

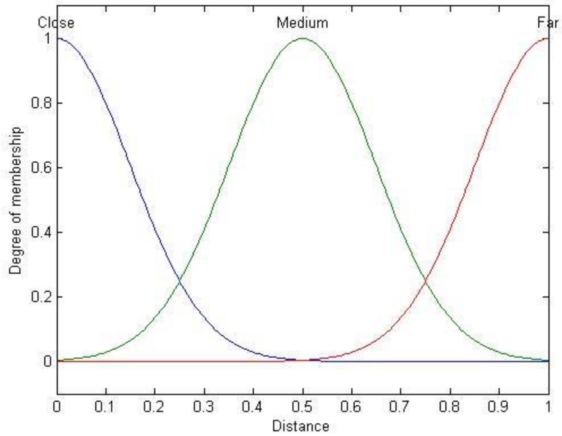


Figure 8: Membership function of distance

We do the same for energy:

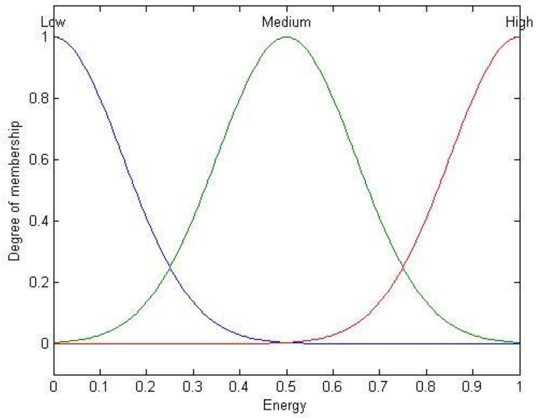


Figure 9: Membership function of energy

We do the same for density:

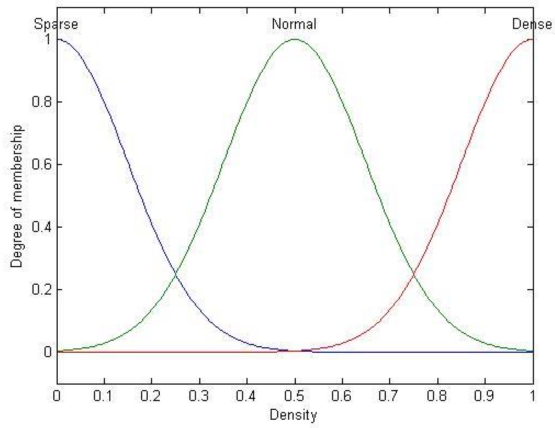


Figure 10: Membership function of density

Output membership function is created:

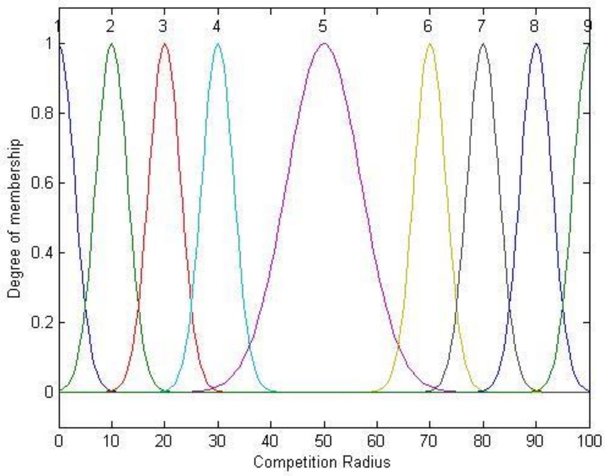


Figure 11: Output membership function

Fuzzy rules are defined. We have three input membership functions, and each function has three modes. So there will be 27 modes totally. One output must be assigned to every mode. Fuzzy rules are applied to the created fuzzy network. A fuzzy value is obtained for each node using the fuzzy logic function. A fuzzy value is obtained proportionally to parameter amounts of each node. Nodes with more fuzzy amounts than the fuzzy average will be chosen as temporary cluster head. Values of density, centrality, and distance from the sink should be calculated for each node. Cluster heads are obtained by the HSA2 function. This function is similar to the HAS function except that we use a different cost function, namely Cost Function2.

We should determine the amounts of residue energy, density, centrality, and distance from the sink for all nodes.

F1=sum(CHe)/sum(CHe(CHs));

The first cost equals the ratio of all nodes energy to energy of cluster heads.

F2=sum(CHdens)/sum(CHdens(CHs));

The second cost equals the ratio of all nodes density to density of cluster heads.

F3=sum(CHcent(CHs))/sum(CHcent);

The third cost equals the ratio of cluster heads centrality to centrality of all nodes.

F4=sum(CHsinkdis(CHs))/sum(CHsinkdis);

The fourth cost equals the ratio of distance of cluster heads from the sink to distance of all nodes from the sink.

Fobj=alpha1*F1+alpha2*F2+alpha3*F3+alpha4*F4;

The sum of these costs is considered as the total cost. Cluster heads are arranged from far distance to near distance in relation to the sink. Distances of each cluster head from other cluster heads are obtained, and are arranged from near distance to far distance. The first cluster head with the shortest distance from the current cluster head and shorter distance from the sink compared to distance of the current cluster head from the sink will be selected as the route of the current cluster head. Then connection is established along this route and energy is calculated. The current cluster head will be directly connected to the sink if it has the shortest distance from the sink compared to others.

4. SIMULATION RESULTS

This section shows the observed results from simulating the proposed approach in various modes using Matlab program and comparing them with HSACP and LEACH protocols.

A land of 20 in 20 square meters in area was assumed for the present study. We also considered 30 sensor nodes and a primary energy of 0.5 a Joule.

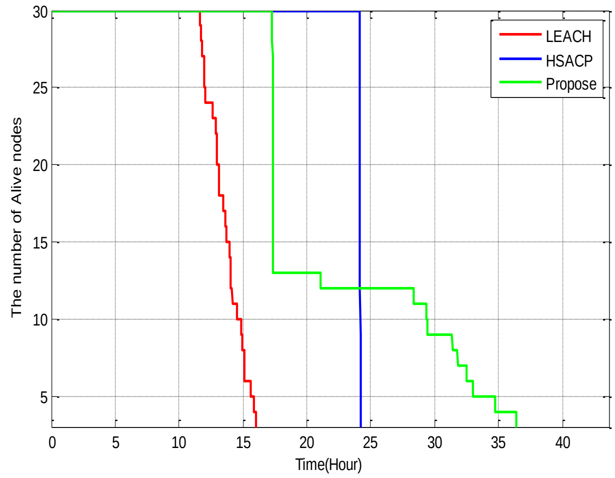


Figure 12: Comparing the number of alive nodes in each round with other protocols

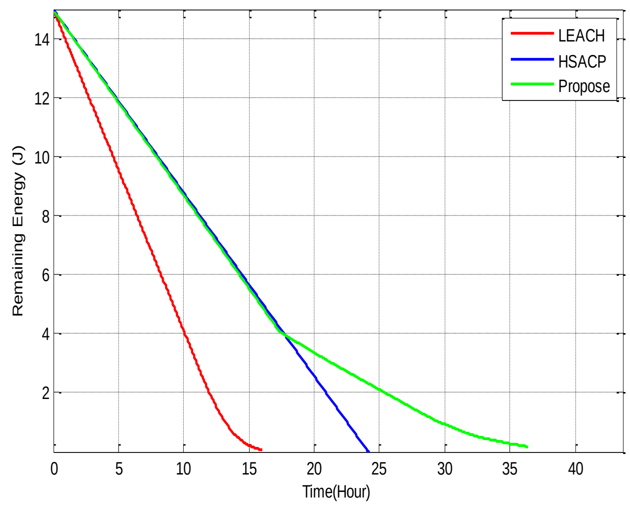


Figure 13: Comparing residue energy within the network in each round with other protocols

Considering the figures above and the made comparisons, we can come to this conclusion that the LEACH algorithm has a weaker impact on elimination of the first sensor node compared with other algorithms, and the proposed algorithm has a better performance on elimination of the first node compared to the LEACH algorithm. In the case of the last node death we reach a conclusion, based on the observations, that the proposed algorithm has a better performance compared with the other two algorithms, since it improved the network lifetime.

5. CONCLUSIONS AND SUGGESTIONS

The most significant innovation introduced by the present study is a novel combination of fuzzy algorithm and harmony search aiming at choosing a set of appropriate notes to be cluster heads. By applying this method, the best sensor nodes in terms of required properties to be cluster heads and the minimum energy consumption rate will be chosen. Competency function for harmony search was used to optimize the parameters of density, nodes centrality, and distance from the sink. Finally, optimization tree for multi-step routing was created.

Followings are some suggestions for potential areas to be examined in the future studies focusing on making more useful developments in the proposed protocol:

- Applying methods such as duty cycle (waking and sleeping sensors) in order to save sensors energy within the network while conserving its coverage.
- Using an appropriate mechanism to allow better control over clustering topology so that cluster heads can accept an even distribution of members.
- Using various methods to improve routing among cluster heads e.g. innovative algorithms.
- Using sink movement in order to collect the sensors-sensed data.

REFERENCES

1. Aqeel-Ur-Rehman, A. Z. Abbasi, N. Islam, and Z. A. Shaikh, "A review of wireless sensors and networks' applications in agriculture," *Computer Standards and Interfaces*, vol. 36, no. 2. pp. 263–270, 2014.
2. G. Han, J. Jiang, L. Shu, J. Niu, and H.-C. Chao, "Management and applications of trust in Wireless Sensor Networks: A survey," *Journal of Computer and System Sciences*, vol. 1. pp. 1–16, 2013.
3. N. A. Pantazis, S. A. Nikolidakis, and D. D. Vergados, "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey," *IEEE Commun. Surv. Tutorials*, vol. 15, no. 2, pp. 551–591, 2013.
4. S. Chand, S. Singh, and B. Kumar, "Heterogeneous HEED Protocol for Wireless Sensor Networks," *Wirel. Pers. Commun.*, vol. 77, no. 3, pp. 2117–2139, 2014.
5. V. Safdar, F. Bashir, Z. Hamid, H. Afzal, and J. Y. Pyun, "A hybrid routing protocol for wireless sensor networks with mobile sinks," *Wireless and Pervasive Computing (ISWPC), 2012 7th International Symposium on*. pp. 1–5, 2012.
6. X. Min, S. Wei-ren, J. Chang-jiang, and Z. Ying, "Energy efficient clustering algorithm for maximizing lifetime of wireless sensor networks," *AEU - Int. J. Electron. Commun.*, vol. 64, no. 4, pp. 289–298, 2010.
7. S. Nikolidakis, D. Kandris, D. Vergados, and C. Douligeris, "Energy Efficient Routing in Wireless Sensor Networks Through Balanced Clustering," *Algorithms*, vol. 6, no. 1, pp. 29–42, 2013.
8. J. Wang, Z. Zhang, J. Shen, F. Xia, and S. Lee, "An Improved Stable Election Based Routing Protocol with Mobile Sink for Wireless Sensor Networks," *Green Computing and Communications (GreenCom), 2013 IEEE and Internet of Things (iThings/CPSCom), IEEE International Conference on and IEEE Cyber, Physical and Social Computing*. pp. 945–950, 2013.
9. A. M. Zungeru, L.-M. Ang, and K. P. Seng, "Classical and swarm intelligence based routing protocols for wireless sensor networks: A survey and comparison," *J. Netw. Comput. Appl.*, vol. 35, no. 5, pp. 1508–1536, 2012.
10. A. Ali Ahmed, "An enhanced real-time routing protocol with load distribution for mobile wireless sensor networks," *Comput. Networks*, vol. 57, no. 6, pp. 1459–1473, Apr. 2013.
11. R. Rahmatizadeh, S. A. Khan, A. P. Jayasumana, D. Turgut, and L. Boloni, "Routing towards a mobile sink using virtual coordinates in a wireless sensor network," *Communications (ICC), 2014 IEEE International Conference on*. pp. 12–17, 2014.
12. J. Zhu, C.-H. Lung, and V. Srivastava, "A hybrid clustering technique using quantitative and qualitative data for wireless sensor networks," *Ad Hoc Networks*, vol. 25, Part A, no. 0, pp. 38–53, Feb. 2015.
13. N. Baccour, A. Koubaa, L. Mottola, M. Zuniga, H. Youssef, C. Boano, and M. Alves, "Radio Link Quality Estimation in Wireless Sensor Networks: a Survey," *ACM Transactions on Sensor Networks*, vol. 8, no. 4. 2012.
14. C. Tunca, S. Isik, M. Y. Donmez, and C. Ersoy, "Distributed Mobile Sink Routing for Wireless Sensor Networks: A Survey," *Communications Surveys & Tutorials, IEEE*, vol. 16, no. 2. pp. 877–897, 2014.
15. [15] R. C. Carrano, D. Passos, L. C. S. Magalhaes, and C. V. N. Albuquerque, "Survey and

Taxonomy of Duty Cycling Mechanisms in Wireless Sensor Networks,” *Communications Surveys & Tutorials*, *IEEE*, vol. 16, no. 1. pp. 181–194, 2014.

16. W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, “An application-specific protocol architecture for wireless microsensor networks,” *IEEE Trans. Wirel. Commun.*, vol. 1, no. 4, pp. 660–670, 2002.
17. D. C. Hoang, P. Yadav, R. Kumar, and S. K. Panda, “Real-time implementation of a harmony search algorithm-based clustering protocol for energy-efficient wireless sensor networks,” *IEEE Trans. Ind. Informatics*, vol. 10, no. 1, pp. 774–783, 2014.