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Solar-Inducted Cluster Head Relocation Algorithm

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***Abstract*—**A special area in the study of Wireless Sensor Networks (WSNs) is how to move sensor nodes, as it expands the scope of application of wireless sensors and provides new opportunities to improve network performance. On the other side, it opens a set of new problems, especially if complete clusters are mobile. Node mobility can prolong the network lifetime. In such WSN, some nodes are possibly moveable or nomadic (relocated periodically), while others are static. This paper presents an idea of mobile, solar-powered CHs that relocate themselves inside clusters in such a way that the total energy consumption in the network reduces, and the lifetime of the network extends. Positioning of CHs is made in each round based on selfish herd hypothesis, where leader retreats to the center of gravity. Based on this idea, an algorithm, together with its modified version, has been presented and tested in this paper. Simulation results show that both algorithms have benefits in network lifetime, and prolongation of network stability period duration.

***Keywords*—**CH-active algorithm, mobile cluster head, sensors, wireless sensor network.

I. Introduction

POSITION of sensors in WSN, because of specific application areas, often cannot be precisely set. Therefore, networks are formed by random positioning of sensors, with assumption that nodes in sensor field are uniformly distributed. The main problem with wireless sensors is energy consumption. Those sensors are battery powered, and replacement of the battery most often is not a simple job, especially when environment is harsh, disaster area, or polluted with chemical trails, radiation or poison. Therefore, it is necessary to save energy wherever it is possible. For this reason, the routing protocols, which take into account energy efficiency, are a constant object of research. There are different approaches to this problem. One large group of protocols is hierarchical protocols. In these protocols, there is no direct communication of base station (BS) with each particular sensor node. There are selected nodes that play a special role in communication in hierarchical networks. These protocols start from the clustering concept. The whole network is divided into a certain number of smaller groups, called clusters, and each cluster has one node with special assignments, CH. Only CH has the ability to communicate directly with the BS [1], [2]. This method reduces the number of nodes which send data to BS. BS is usually located at a relatively large distance and thus performs a significant energy saving. Topology of hierarchical network is shown in Fig. 1. The basic protocol in this family is the famous Low Energy Adaptive Clustering Hierarchy (LEACH), presented in [3].

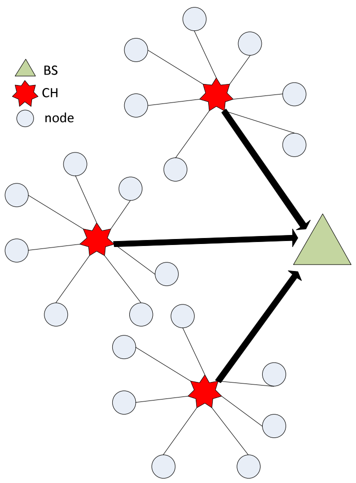

Fig. 1 Model of hierarchical network topology

Most of the energy in the sensor nodes is spent on communication. In relation to this energy, the energy that is consumed for sensing and processing can be almost ignored. The amount of energy consumed during communication mostly depends on the square distance between transmitter and receiver in the network. Therefore, the efforts of researchers have often been focused on how to optimize the distance. With this aim, a great number of solutions based on the various assumptions have been proposed [4]-[6].

A part of those solutions presumes heterogeneous structure of sensor nodes in terms of mobility [7]-[11]. In those proposals a certain number of nodes are allowed to move throughout the network so as to change their location in the sensing field and optimize mutual distance of the transmitter and receiver. Most of the research in this area is focused on the movement of BS in the sensing field. Only a few researches assume moving of CH in order to optimize energy consumption.

This paper proposes method of CH relocation. For this relocation purpose, additional solar powered battery is used. Additional battery is used only to move CH, and not for processing and communication. CH relocation is done occasionally, in order for CH to achieve an optimal distance from all of other sensors in the cluster.

This paper considers sensor network that delivers data once or few times per day, for applications where changes are rare, and daily reporting is enough to achieve satisfying purpose (e.g. radiation measures, pollution reports etc.). In these

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applications, reporting period lasts one round. Before collecting data from sensor nodes, to save communication energy, every CH tries to take its calculated optimal position, analogue to behavior of some species of animals in the presence of danger or predator (schools of fish, herd, frogs etc., where individuals relocate and try to move to the center of group in order to save lives). This position represents the center of gravity in relation to all other nodes in the cluster. CH first moves back to its initial position, and then aggregates the data and transmits to the sink. Since the data are transmitted rarely, once or few times per day, the node that is determined as CH has enough time and enough energy to move to the optimal location. Simulation showed that this algorithm, among other benefits significantly extends the life of sensor networks.

II. Related Work

LEACH algorithm, which is proposed in 2000, represents the best-known cluster-based protocol. Many recently proposed protocols for hierarchical routing represent improved LEACH or LEACH variant [12]-[15]. The energy consumption on the wireless sensor node depends on the distance of the BS and on the number of transmit and receive operations. The main idea behind many algorithms is to reduce the distances and frequency of communications between the sensor and BS. The way LEACH works is as follows: Communication between BS and sensors is divided into rounds. Some sensors take the role of CH which is done randomly per round. Every round has two phases called setup phase and steady state phase. During the setup phase, every node has to choose a random number. This number has to be from the range (0,1). In order to become a CH, this number has to be less then threshold T(n). Equation (1) shows how the threshold T(n) is calculated based on P (percentage of CH), r (number of ongoing round) and G (nodes which were CH in the last 1/P rounds) [2].

$$T(n)=\begin{cases}\dfrac{P}{1-P\times\left(r \bmod \dfrac{1}{P}\right)} & if \quad n\in G\\ 0 & otherwise\end{cases}, \qquad (1)$$

When node becomes CH, it creates cluster and defines TDMA frame for communication with other nodes in that cluster.

During the steady state (after setup phase) nodes transmit to the CH. CH performs aggregation of received data and forwards them. LEACH protocol and its successors use simple radio model as shown in Fig. 2. This model shows the power consumption, and assumes d^2 energy loss due to channel transmission [2].

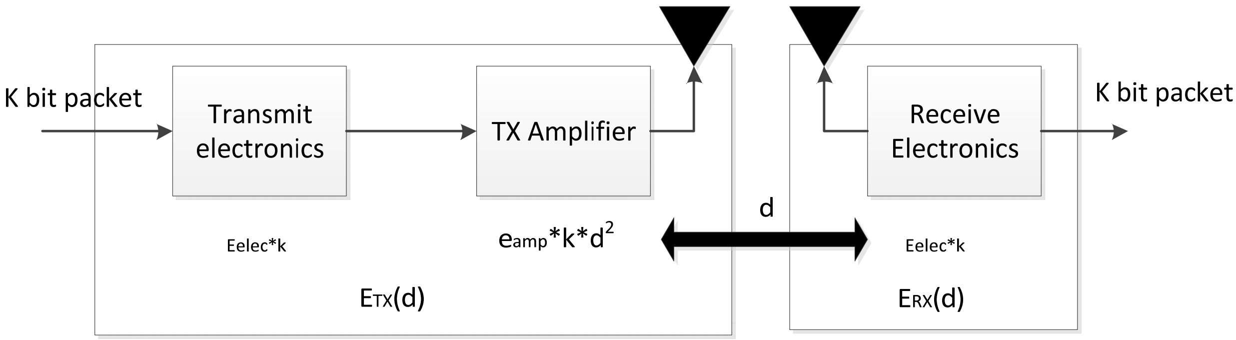

Fig. 2 Radio model of energy dissipation

Limited energy resources of battery power impose the need for alternative energy sources, such as solar power. Solar power of sensors has been proposed in several papers [16]-[18]. Some of the nodes are powered by solar and they are more likely to be chosen for the CH role. The problem with solar power is that this energy source is not permanent. There is a possibility that the node selected for CH at the beginning of the round is solar-powered and has no energy to carry out its task by the end of the round.

There are a wide variety of applications where the mobility of sensors is in use, either active or passive. During the passive navigation, under external influences, and not using their own energy, the sensors change clusters inside a round. This complicates the problem of establishing an energy-efficient organization of sensor network [19]. However, there are applications where the sensors move using their own energy to cover the sensing area dynamically, to replace depleted sensors, or because of the nature of sensing phenomenon. Therefore, the energy of the sensors of this type makes even more critical resource [20]. However, some researchers have figured out that sensors, which have the capacity to move with the help of their own energy, could take advantage of the savings in total energy consumption in the network. Ma and Yang [21] offered a solution of a network that is heterogeneous in terms of the mobility of nodes. This network contains a small number of resource-rich specialized CHs. Sensor nodes have limited amount of energy and can only reach nearby nodes within a limited range, while CHs can move to anywhere within the working area. Each CH knows the location and connectivity pattern for all of its sensors.

Location of the CH in the network can affect network lifetime significantly and thus by moving CH to better location network load can be balanced and lifetime can be prolonged. Banerjee et al. [22] consider the case when the sensors and the sink are static, and the CHs are mobile and work as relay nodes. The low energy static sensor nodes sense physical parameters and route the data to the higher energy-rich nodes called MCHs which transmit data directly to the BS. The MCHs move within its own cluster to change its neighborhood nodes so as to avoid the fixed set of sensors to continuously forward data to the MCH which may otherwise result in network partitioning. Thus, a CH can regulate the flow of energy among the sensors in the cluster and thus increases total network lifetime. Three mobile strategies are discussed based on (i) event, (ii) residual energy and (iii) combination of both (i) and (ii) i.e., hybrid mobility. The hybrid strategy makes moving decision based on the event as well as the residual energy.

Many researchers have suggested improvements of some of the characteristics of WSN, based on knowledge of animal behavior [23]-[26]. Many species of animals have shown some form of social behavior. In order to observe sensor networks as bioinspired systems, it is in many cases useful to observe the behavior of birds in the flock [27]-[29]. A whole range of characteristics of this and other social communities as well, (schools of fish, monkeys, sheep etc.) can be applied to the organization of wireless sensors in the network.

Ruihua et al. presented an algorithm based on the flock optimization algorithm [30]. This algorithm takes into account two factors in the CH selection algorithm. The first factor is in regard to the minimum distance between the CHs and the member nodes. The second one is the residual energy of the nodes. In [31], a WSN using multi-hop routing for communication is considered, and an algorithm based on Particle Swarm Optimization (PSO) has been implemented for finding the optimal location of the sink. Algorithm presented in [28] suggests a way to establish a minimum distance between CH and its associated nodes. The algorithm is based on the migration behavior of flock of birds in the process of searching food.

In the proposed algorithms, idea of moving CH to the center of masses is based on behavior of many animal species, as elaborated in selfish herd hypothesis by Hamilton in 1971 [32]. In this hypothesis, selfish prey group members move to the center of group in order to avoid predator attack from outside. This behavior, as explained in hypothesis, causes aggregating, which, in some cases (such as grouped schools of fish in open sea) makes it even easier for predator to catch the prey. Hamilton argues that individuals within the herd behave selfishly, by moving toward the center, leaving the other members on the periphery of the herd, exposing them to attack from predators. Dominant members are placed in favorable and secure position and subordinate members are moving into the zone of higher risk. Domain of risk can be estimated by construction of Voronoi diagram around the members of the group. Such architecture is formed by a set of convex polygons, where all points, inside the polygon, are closer to the corresponding member than to any other member in the field. Model of the behavior shown in the Hamilton theory is used, but the motivation is completely different. Unlike Hamilton's theory, moving of CH, in our algorithm, brings gain to this “selfish” CH and also to all other members of the group. In our case, CH protects itself and other nodes from fast battery drain, by shortening the communication distances between sensors (see formula presented on Fig. 2). By moving to the center of masses, CH is minimizing the distance to cluster members and saving energy during receiving. In proposed algorithm, CH also helps other members, as they will save energy during transmitting to the CH. In order to avoid aggregating of nodes, and therefore loosing effective coverage of sensing field, each time after receiving all of the messages, CH in proposed algorithm moves back to initial position, aggregate data, and send them to the sink.

III. Proposed Algorithms

Based on selfish herd hypothesis, an algorithm called CH-reconfigure is proposed in this paper. Its modification, called CH-active, is proposed as well and compared to CH-reconfigure and LEACH.

For the simulation purposes, a MATLAB simulation is developed. Simulation saves all of the parameters and sensor states in each simulation step in four-dimensional matrix. Those history data, covering complete lifetime and every parameter of all sensors, are then used to generate precise figures.

CH-reconfigure algorithm and CH-active algorithm have the same setup phase as LEACH. In each round, new set of CH clusters is chosen. However, the steady-state phase is quite different as it includes solar powered CH relocations. After all the CHs are chosen, each CH relocates itself to the center of masses of the cluster. In case of CH-reconfigure algorithm, center of masses is calculated as center of all nodes from the formed cluster. This center is not changing in later steps, so it does include the dead nodes during the observation time. In case of CH-active algorithm, center of masses is calculated each time as center of live (active) nodes in the formed cluster. This center is roaming slightly inside the cluster in later steps.

After moving to the center of masses in either algorithm, CH collects the data from cluster members, and relocates itself back to the position it has before relocating to center of masses. This is done to avoid grouping of all the nodes in one spot during time. Then it aggregates data, and send them to the sink. Pseudo code for CH-reconfigure algorithm and CH-active algorithm is given in Fig. 3.

CH-reconfigure Algorithm and CH-active Algorithm
Parameters **n**: number of nodes on terrain **n_active:** number of active nodes **x,y:** dimensions of the field **x_sink, y_sink:** sink pozition (x,y) **node_energy:** energy dedicated to the nodes **node_energy:** initial energy per node **message_length:** length of the messages

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round_number: number of round in progress
epoch_number: number of epoch in progress

distribute nodes randomly on terrain
prepare the (4D) matrix for storage of all node parameters and statuses in all rounds and all epochs
While number of active nodes>0
Start new round
If round_number>20 start new epoch
filter-out the nodes with no power
chose the CHs from live nodes
mark used CH statuses for chosen CHs in matrix
choose the CH for each individual sensor node – create clusters
calculate the center of masses of all nodes in each created cluster
Case 1:
    if Method= CH-reconfigure
move the CHs to their center of masses of the cluster
    endif
Case 2:
    if Method= CH_active
move the CHs to the center of masses of live (still active) nodes of the cluster
    endif
for i=1 to n
If i is not in cluster: send the sensed data to sink
If i is in cluster: send the sensed data to CH
Move the CH back to initial position
Aggregate data on CH
Send their data from CH to the sink
endif
End while
```

Fig. 3 Pseudo code for CH-reconfigure algorithm and CH-active algorithm

IV. Simulation Results

Simulation is designed to run three different algorithms in parallel, on the same set of sensor nodes, in order to track network behavior and energy preserving in identical conditions. MATLAB simulation for the well-known LEACH code is developed, as well as for two of our proposed algorithms: CH-reconfigure algorithm (CH reconfiguration algorithm, with moving to center of gravity), and CH-active algorithm (CH reconfiguration active algorithm, with moving to the gravity center of active nodes).

The simulation runs on 500 × 500 m field, with 100 uniformly distributed nodes. Each node has been set initially to have 5 J of total energy. Because of their nature, it is expected that new algorithms will accomplish better results from the very reconfiguration, when the terrain itself is wider. In simulation on 100 × 100 m terrain these two algorithms showed small improvement. The reason is as follows: when all cluster members are close to each other, considerable gain in radio transmission cannot be achieved by moving one of them to the center, since the distance to the gravity center will be similar as distance to the CH initial position. Suggested application of proposed algorithms is on wider terrain, and in harsh environment with periodical and not intensive reporting (one to several times per day sensors report to CH). In this application, CH has enough time to move to the gravity center and collects all the data from appertaining clusters there. After that, CH returns to its initial position and reports to BS from the initial position. In the meantime, data aggregation is done. On Fig. 4, a number of active nodes is presented related to rounds. Simulated terrain is 100 × 100 m wide. Simulation is running until the last node switch off in CH-active algorithm. Simulation ends when none of the nodes is active any more (more than 1200 rounds in case of CH-active algorithm).

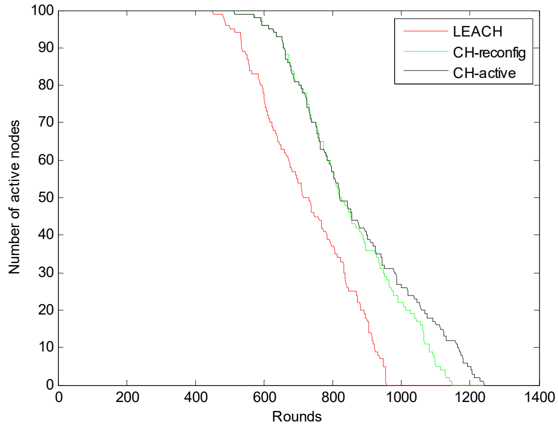

Fig. 4 Number of active nodes per round

It can be seen that after instability period has begun, CH-reconfigure algorithm brings advantage over LEACH in this application. While the most batteries are in good condition, both algorithms give very similar performances. However, CH-active begins to be more advanced than CH-reconfigure after 60% of nodes die. Along with decreasing the number of active nodes, distance between nodes gets bigger, and then moving to the center of active nodes (CH-active algorithm) begins to gain notable advantage. It is shown that the rest of nodes in following rounds stay active for 10% more rounds, so that network is alive longer time with CH-active than with CH-reconfigure. This is because in CH-active algorithm, CH moves to the active center (center of active nodes), and not to center of all of the nodes, which is the case in CH-reconfigure algorithm.

Fig. 5 shows total network energy, which is the sum of energies of all nodes in each round. Using CH-active algorithm, due to the fact that sensors are active longer time, total energy of network is not expanded so quickly as with CH-reconfigure and LEACH.

Fig. 6 shows the number of active nodes per round on 500 × 500 m field, with 100 uniformly distributed nodes. Energy assigned to each node at the simulation start is 5 J. It can be seen that the gain in number of rounds is bigger on wider terrain, as expected (compare Figs. 4 and 6). Difference in duration on 500 × 500 m terrain between two proposed algorithms is more than 1000 rounds, and the difference in duration between CH-active algorithm and LEACH is 1750 rounds. As noted on Fig. 4, when the number of live nodes is decreased, and/or if the distance between nodes is bigger, moving to the center of active nodes (CH-active algorithm) begins to gain advantage, as shown on Fig. 6, after 50% of nodes die.

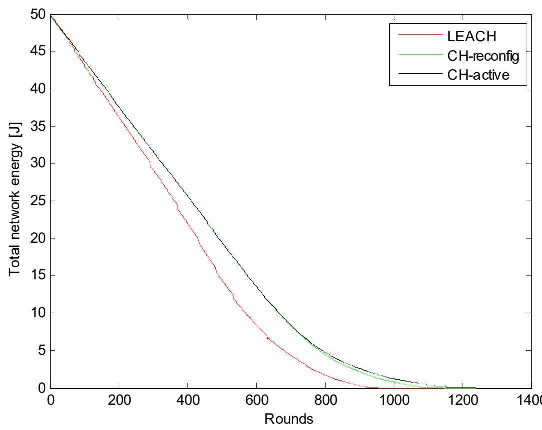

Fig. 5 Total network energy on 100 × 100 m terrain

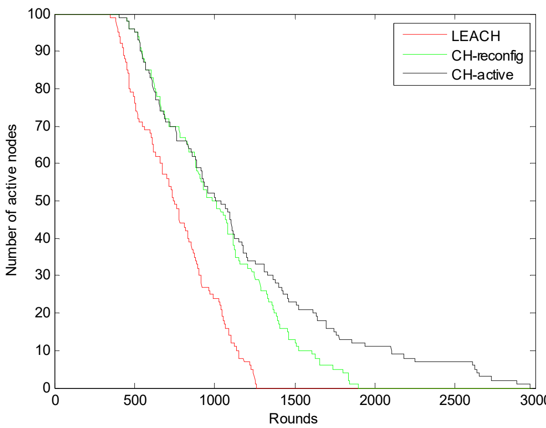

Fig. 6 Number of active nodes per round on 500 × 500 m field

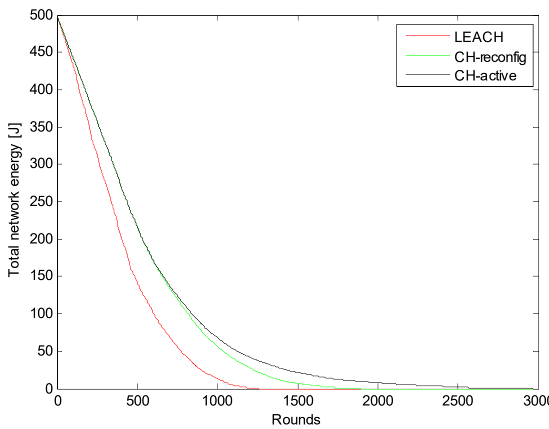

Fig. 7 Total network energy on 500 × 500 m terrain

Fig. 7 shows total network energy on 500 × 500 m terrain, with 100 uniformly distributed nodes. Fig. 8 shows average energy per node on 500 × 500 m terrain. It can be seen that the best energy balance in network is achieved when CH-active algorithm is used. It shows that with CH-active algorithm, nodes have usable energy for more than 1000 rounds after network is exhausted under CH-reconfigure algorithm, and for more than 1600 rounds after network is exhausted under LEACH.

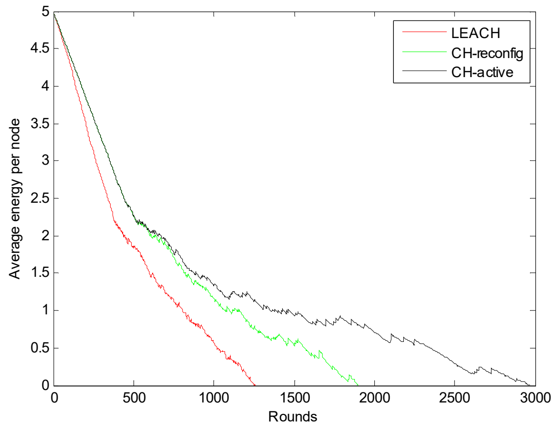

Fig. 8 Average energy per node

V. Conclusion

In this paper two algorithms based on moving of the CHs have been proposed: CG-reconfigure, and CH-active. Mobilizers on these CHs are solar powered. The idea is founded on selfish herd hypothesis. Computer Simulation to compare three algorithms (LEACH, CH_reconfigure and CH_active) is made in MATLAB. CH-active shows the best performance comparing to CH-reconfigure and CH LEACH. When used on 100 × 100 m terrain, it showed better results after instability period has begun. On this terrain, CH-active algorithm gives better results than CH-reconfigure when 60% of nodes die, and in total, networks stay alive for 10% more rounds. When CH-active algorithm is deployed on 100 × 100 m terrain, total energy of network is expanded more slowly as opposed to deployed CH-reconfigure or LEACH algorithm. Both proposed algorithms give better performances when the terrain itself is wider. This is because more considerable energy saving can be achieved in radio transmission when moving CHs to the center of cluster, if the distance from other cluster members to the gravity center is bigger than the distance from cluster members to the CHs initial position. When used on 500 × 500 m terrain, difference in duration between two proposed algorithms is more than 1000 rounds, and difference in duration between CH-active algorithm and LEACH is 1750 rounds. With two proposed algorithms, deployed on wider terrain, simulation runs almost 400 rounds more then with LEACH, before network energy drop to 100 J. Measuring the average energy per node showed that best energy balance in network is achieved when CH-active algorithm is used. Generally, it can be concluded that CH-active algorithm shows best performances in comparing to other two. In future work, intention is to research the influence on network performances in situation when relocating other nodes, as well as in the situations when solar charging is not ideal.

References

[1] G. Djukanovic, G. Popovic, "Applying FMEA to multi-tier converged M2M-WMSN," In Proc. *International scientific conference UNITECH 2013,* Gabrovo, 2013, pp. 47-52.

[2] G. Popovic, G. Djukanovic, "Cluster formation techniques in hierarchical routing protocols for Wireless Sensor Networks," *Journal of Information Technology and applications (JITA)*, vol. 1, pp. 5-11, July 2016.

[3] W.R. Heinzelman, A. Chandrakasan, "Energy Efficient Communication Protocol for Wireless Microsensor Networks," *In Proc. IEEE Computer Society Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00)*, Hawaii, 2000, pp. 1-10.

[4] A. Depedri, A. Zanella, Verdone, "An Energy Efficient Protocol for Wireless Sensor Networks," In: Proc. *AINS, 2003*, pp. 1-6

[5] L. Qian, H. Zhu, "An Energy Balanced Clustering Algorithm Based on LEACH Protocol" In: Proc. *2nd International Conference On Systems Engineering and Modeling (ICSEM-13)*, Paris, France, pp-72-73

[6] C. Gongben, W. Shaorong. W, "A Novel Node Deployment and Clustering Scheme in Wireless Sensor Networks," In Proc. *Second International Symposium on Electronic Commerce and Security, ISECS '09*, Nanchang, China, pp.499 – 503

[7] D.S. Kim, Y.J. Chung, "Self-organization routing protocol supporting mobile nodes for wireless sensor network," In Proc. *First International Multi-Symposiums on Computer and Computational Sciences*, 2006, Hangzhou, China

[8] J. Rezazadeh, "Mobile Wireless Sensor Networks Overview," *International Journal of Computer Communications and Networks (IJCCN), 2*, 2012, pp. 17-22.

[9] H. Mansouri, F. Moutaouakil, H. Medromi, "An autonomous intelligent gateway for wireless sensor network based on mobile node," *International Journal of Advanced Computer Science and Applications*, Vol. 5, No. 3, 2014.

[10] T. Razandralambo, M. Erdelj, D. Zorbas, E. Natalizio, "Spread and Shrink: Point of Interest Discovery and Coverage with Mobile Wireless Sensors," *Journal of Parallel and Distributed Computing*, 2016.

[11] B. Wang, H.B. Lim, D. Ma, "A survey of movement strategies for improving network coverage in wireless sensor networks," *Journal of Computer Communications* 2009, pp. 1427–1436.

[12] X. N Fan, Y. L. Song, "Improvement on LEACH protocol of wireless sensor network," In Proc. *International Conference on Sensor Technologies and Applications, Sensor Comm*., 2007. Valencia, pp. 260-264.

[13] D. Dembla, H. Shivam, "Analysis and Implementation of Improved - LEACH protocol for Wireless Sensor Network (I-LEACH)," In Proc. *IJCSC*, IJ, Vol. 4, No. 2, 2013, pp.8-12.

[14] H. Junping, J. Yuhui and D. Liang, "A time-based cluster-head selection algorithm for LEACH," In Proc. *IEEE International Symposium on Computers and Communications (ISCC),* 2008, pp. 1172-1176.

[15] D. Zhixiang and Q. Bensheng, "Three-layered routing protocol for WSN based on LEACH algorithm," In Proc. *IEEE Communications conference on Wireless, Mobile and Sensor Networks (CCWMSN)*, 2007. pp. 72-75.

[16] T. Voigt, H. Ritter, J. Schiller, A. Dunkels and J. Alonso, "Solar-aware Clustering in Wireless Sensor Networks," In Proc. *Ninth IEEE Symposium on Computers and Communications*, Alexandria, 2004, pp. 238-243.

[17] C. Gongben, W. Shaorong, "A Novel Node Deployment and Clustering Scheme in Wireless Sensor Networks," In Proc. *Second International Symposium on Electronic Commerce and Security (ISECS '09)*, Nanchang, 2009, pp. 499- 503.

[18] J. Islam, M. Islam and N. Islam, "A-sLEACH: An Advanced Solar Aware LEACH Protocol for Energy Efficient Routing in Wireless Sensor Networks," In Proc. *Sixth International Conference on Networking (ICN '07)*, Sainte-Luce, 2007; Sainte-Luce,

[19] D.S. Kim, Y.J. Chung, "Self-organization routing protocol supporting mobile nodes for wireless sensor network," In Proc. *First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS '06)*; Hangzhou, 2006, pp. 622-626.

[20] G.T. Sibley, M.H. Rahimi and G.S. Sukhatme, "Robomote: a tiny mobile robot platform for large-scale ad-hoc sensor networks," In Proc. *IEEE International Conference on Robotics and Automation, ICRA*, Washington DC, 2002, pp. 1143-1148.

[21] M. Ma, Y. Yang, "Clustering and load balancing in hybrid sensor networks with mobile cluster heads," In Proc. *3rd International Conference on Quality of Service in Heterogeneous Wired/Wireless Networks*, Waterloo, 2006.

[22] T. Banerjee T, B. Xie, J.H. Jun and D.P. Agrawal, "Increasing lifetime of wireless sensor networks using controllable mobile cluster heads," *Wireless Communications & Mobile Computing,* vol. 3, pp. 313–336, 2010.

[23] S. Sendra, L. Parra, J. Lloret and S. Khan, "Systems and Algorithms for Wireless Sensor Networks Based on Animal and Natural Behavior," *Int J Distrib Sens N*, vol. 2, pp. 1-19, 2015.

[24] S. Kumar, S.M. Kusuma, "Clustering Protocol for Wireless Sensor Networks based on Rhesus Macaque (*Macaca mulatta*) Animal's Social Behavior," *International Journal of Computer Applications*, 2014, vol. 87, no 8, pp. 20-27.

[25] T. Camilo, C. Carreto, J.S. Silva, F. Boavida, "An energy-efficient ant-based routing algorithm for wireless sensor networks," In Proc. *5th International Workshop on Ant Colony Optimization and Swarm Intelligence (ANTS), LNCS*, vol. 4150, Springer, Berlin, Germany, 2006, pp. 49–59.

[26] G. Chen, T.-D. Guo, W.-G. Yang, T. Zhao, "A swarm-based routing protocol for wireless sensor networks," In. Proc. *IEEE International Conference on Collaborative Computing: Networking, Applications and Work-sharing*, 2006.

[27] A. Barve, M.J. Nene, "Survey of Flocking Algorithms in Multi-agent Systems," *International Journal of Computer Science Issues (IJCSI)* vol. 6, pp. 110-117, 2013.

[28] S.S. Singh, M. Kumar, R. Saxena and Priya, "Application of Particle Swarm Optimization for Energy Efficient Wireless Sensor Network: A Survey," *International Journal of Engineering Science & Advanced Technology (IJESAT)*, vol. 5, pp. 1246-1250, 2012.

[29] P. Antoniou, A. Pitsillides, T. Blackwell, A. Engelbrecht and L. Michael, From Bird Flocks to Wireless Sensor Networks: A Congestion Control Approach, Tech. Rep. TR-11-5, University of Cyprus, Cyprus, 2011.

[30] Z. Ruihua, J. Zhiping, L. Xin and H. Dongxue, "Double clusterheads clustering algorithm for wireless sensor networks using PSO," In Proc. *6th IEEE Conference on Industrial Electronics and Applications (ICIEA '11)*, Beijing, 2011. pp. 763-766.

[31] M.J. Showkat, B. Paul, M.A. Matin and M.S. Alam, "Optimal Sink Location in Wireless Sensor Networks Using Particle Swarm Optimization," In Proc. *IEEE International Conference on Antennas, Propagation and Systems IEEE INAS 2009*; Johor Bahru, 2009, pp. 116:1-5.

[32] W.D. Hamilton, "Geometry for the selfish herd," *J Theor Biol*, vol. 31, pp. 295-311, 1971.