International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:11, No:2, 2017

Energy-Efficient Clustering Protocol in Wireless Sensor Networks for Healthcare Monitoring

Ebrahim Farahmand, Ali Mahani

Abstract**—**Wireless sensor networks (WSNs) can facilitate continuous monitoring of patients and increase early detection of emergency conditions and diseases. High density WSNs helps us to accurately monitor a remote environment by intelligently combining the data from the individual nodes. Due to energy capacity limitation of sensors, enhancing the lifetime and the reliability of WSNs are important factors in designing of these networks. The clustering strategies are verified as effective and practical algorithms for reducing energy consumption in WSNs and can tackle WSNs limitations. In this paper, an Energy-efficient weight-based Clustering Protocol (EWCP) is presented. Artificial retina is selected as a case study of WSNs applied in body sensors. Cluster heads' (CHs) selection is equipped with energy efficient parameters. Moreover, cluster members are selected based on their distance to the selected CHs. Comparing with the other benchmark protocols, the lifetime of EWCP is improved significantly.

Keywords**—**Clustering of WSNs, healthcare monitoring, weight-based clustering, wireless sensor networks.

I. Introduction

IN recent decays, remote sensing systems received significant attention in electronic and computer science in innumerable applications. WSNs have a potential to improve healthcare while reducing the healthcare costs. Wearable and implantable wireless body sensor network systems are perceived as effective tool to achieve this goal. The integration of these sensors allows people to be monitored during their everyday activities. In [1], authors outlined their views on application of WSNs inside and outside of human body to detect emergency situations. WSNs consist large number of sensor nodes, which are capable of sensing, computing and transmitting data from harsh environmental to Base Station (BS) - also called sink. In WSNs, sensor nodes are the basic elements of the network, and they consist of transceiver, microcontroller and power sources [2]. After collecting information from the environment by sensor nodes, useful information can be derived from the remote sensing data by further data processing. Sensor-network technologies [3] enable the deployment of a huge number of sensors and generally the communication of these sensors is wireless.

Application of Wireless Body Sensor Networks (WBSN) is pinpointed in [4]. The article presents a monitoring system that is able to monitor physiological parameters reading from multiple patient bodies. In this system, a coordinator node is attached on patient body to collect all the signals from the wireless sensors. The coordinator node sends collected data further to the BS. In-depth clinical trial that assesses the feasibility of WSNs for patient monitoring in general hospital units is presented in [5]. All of these studies highlight the significance of WSN application in smart healthcare.

E. Farahmand and A. Mahani, are with the Department of Electrical Engineering at Shahid Bahonar University of Kerman, 76169133, Kerman, Iran (e-mail: ebi271@gmail.com, amahani@uk.ac.ir).

In continuous medical monitoring, WSNs are dealing with very important and critical data, and reliability and lifetime of such networks are important parameters. Wireless body area network (WBAN) is a subset of WSN with small node density and coverage area. Consumed energy plays a vital role to improve the reliability and lifetime of the WBANs.

Clustering technique is an efficient and reliable routing to transfer collected data between sensor nodes and BS [6]. In clustering, since the data transmission domain is limited between CHs and also the collected data are aggregated, it is possible to keep the bandwidth usage as low as possible. All cluster members sense local data and send them to their assigned CHs using existing routing table. CHs aggregate data and transmit them further to the other CHs or BS using the shortest route.

In clustering protocols, the nodes of WSN are divided in several groups called clusters. Clustering protocols are effective approaches for improving data collection and scalability of the network [7]. Each clustered network includes three pillar components:

- Clusters: They include a group of sensors created to establish an uncomplicated communication channel to BS.
- CHs: They collect the data from sensor nodes and forward the aggregated data to BS. Data aggregation techniques can be used to combine several correlated data signals into a smaller set of information that maintains the effective data. CHs are the hearts of every cluster that controls the activities of clusters. Their activities include data collecting as well as organizing, and improving the internal cluster communication program.
- BS: It is a central node (platform to receive data) in WSNs. BS provides an interface between WSN and end-users.

The internal and external communication can be a combination of single- or multi-hop communication protocol [2], [8]. In single-hop communication protocol, all nodes can send data directly to BS. However, in multi-hop communication protocol due to limited transmitting domain of nodes, they have to send data using several hops to reach BS ultimately. Since the transmitting domain of CHs is limited, single-hop communication protocol between CH and BS is not scalable.

In WSNs, the CHs consume relatively more energy than the ordinary nodes in order to perform data aggregation and communication with BS. Consequently, the prominent challenge in existing clustering routing protocols is inefficient distributed CHs. It is possible that the CHs are located close to each other in a particular network area. This leads to increased concentration of data transmission in the area. In this situation, CHs are burdened with heavy data traffic, and they are running the risk of draining their energy very fast [9]. Moreover, distribution of CHs in an area close to the edge of a network increases the data transmitting time, which in return results in consuming the energy of sensors very fast. On the other hand, it is plausible that CHs are located in a spars area and due to the lack of adjacent CHs in the transmitting range of those CHs, data transmission to BS is not possible, and the energy of nodes is wasted in an effort to transmit the data, which will never reach the BS.

The main focus of this paper is to present an optimal clustering protocol together with routing method in order to enhance the lifetime of WSNs applied in smart healthcare. The chief objective of the EWCP applied in a sensor array of implantable artificial retina is to minimize energy consumption of the network using new method to select optimal CHs. The CHs are selected based on their residual energy level, distance to BS, and network density. Moreover, cluster members are selected based on their distance to the selected CHs. Since the routing method based on hierarchical clustering protocol has more capability for scalability and communication, this method is adapted in designing of the protocol.

II. Related Work

In [10], authors investigated the body sensor helping the chronically ill and elderly people live. The authors provide a comprehensive overview of technologies applied for medical application. However, physical limitations of both implant and wearable sensor set limitation on their usage. As we have already commented limited energy capacity of WSNs has a significant impact on their application. In the following, we reviewed available approached to optimise energy usage of WSNs.

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol proposed by Heinzelman et al. [11] is the popular clustering protocol for WSNs. LEACH is a distributed clustering protocol in which CHs are randomly chosen based on their available energy. This decision is broadcasted as a beacon signal over network to inform all the entire live nodes that new CHs are selected. The remaining nodes select their clusters based on the nearest CH that they can access with the lowest energy consumption. The CHs receive and aggregate data from cluster members and send the aggregated data to the BS by single-hop communication. LEACH protocol operation is divided into several rounds.

LEACH protocol cannot guarantee that CHs are distributed optimally over the network, and it is possible that some sensor nodes do not have any cluster in their neighboring. A large number of improved versions of LEACH have been developed, e.g., HEED [12], TEEN [13] and PEGASIS [14] to solve these problems.

The primary goal of proposed Distributed Weight-based Energy-efficient Hierarchical Clustering (DWEHC) protocol in [15] is to extend Hybrid Energy Efficient (HEED) protocol by building the clusters with balanced size and optimizing the topology of clusters. The main distinguishing feature of DWEHC protocol in comparison with LEACH and HEED protocols is that this protocol incorporates a network structure with several layers for internal cluster communication. The leading advantage of this protocol over HEED is that, it shows a great improvement in both intra-cluster energy consumption and inter-cluster energy consumption. Intra-cluster communication in this protocol is similar to LEACH protocol, where data are transmitted directly from CHs to BS. Consequently, this protocol is not suitable for the network with big environment due to its large energy consumption.

A decentralized energy efficient hierarchical cluster-based routing protocol is proposed in [16]. This protocol comprises a multi-criteria clustering algorithm to prolong the lifetime of the network. In clustering algorithm, the authors utilize each node's local information such as residual energy, distance of sensor node to BS and distance of sensor node from neighboring nodes. In this algorithm, the residual energy of nodes is deemed more important than the other parameters in order to balance energy consumption among CHs. The protocol operation is divided into several rounds. Once the clusters are built, a minimum spanning routing tree is constructed between CHs and BS, which minimizes message transmission cost, and prolongs the lifetime of the network. However, constructing routing tree in each round causes large overhead in the network.

Classical analyses of WSN clustering methods require heavy calculation burden especially in large-scale systems. The computational efforts grow exponentially by the size of WSN. The major challenge in clustering is to select optimal CHs. For N nodes distributed in a network, we need to assess $2^N - 1$ states to select optimal CHs. This indicates that the problem is Nondeterministic Polynomial (NP) hard [17]. Moreover, the optimization methods should search over a vast space to find the cluster members, which comes at the expense of added computational complexity. Hence, the heuristic optimization algorithms become efficient solutions in dealing with selecting clusters and cluster members as well.

Authors in [18] have employed centralized clustering protocol using Particle Swarm Optimization (PSO) approach, which has been implemented at the BS. It considers multi-objective optimization problem including both energy and physical distance between each node and its CH. The objective is to minimize the maximum average Euclidean distance between the cluster members and their associated CHs, as well as the proportion of the total initial energy of the entire nodes to the total energy sum of the CH candidates. The approach ensures that the nodes with sufficient energy are good candidates for CHs. In initialing stage of PSO, all nodes send information about their current energy status and locations to the BS. The BS computes the average energy level of all nodes based on receiving information from nodes. The

International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:11, No:2, 2017

nodes with an energy level above the average are eligible to be CHs, and they are candidate to enter PSO. Next, the BS runs the PSO algorithm to determine the best CHs that can minimize the cost function comprising Euclidean distance and energy level of nodes.

In [19], a distributed clustering approach using fuzzy logic is presented. In this approach, the chance of sensor nodes to take CH role is evaluated by Fuzzy logic taking into account node density, node energy and node's centrality. CHs send their information to the BS using single-hop communication, and the BS is updated with the energy status of all nodes, the number of live nodes, and the size of the network. The node that has the greatest chance among the tentative CHs is selected as CH. This method is not applicable in the large networks where CHs cannot communicate directly to BS.

III. Proposed Method

In this section, an approach adapted for clustering of WSN is presented. Taking into account the main challenges in WSN clustering, the CHs are selected. The CHs are distributed in the network in such a way that network has maximum coverage. Before we dive into the details of EWCP, we explain briefly the energy model and the network model that are adapted in this protocol. First, we explain the model of dissipated energy in one sensor node and next the general network model will be explained.

A. Model of Dissipated Energy in One Sensor Node

The presented energy dissipation model in [11], [20] is applied in this paper in order to model energy consumption of one node including dissipated energy in transmitter and receiver. Equations (1) and (2) represent energy dissipation in the transmitter and receiver, respectively.

$$E_{Tx}(l.d) = lE_{elec} + l\, e_{amp}d^{n} \tag{1}$$

$$E_{Rx}(l.d) = lE_{elec} \tag{2}$$

where E_{elect} is the amount of energy needed to run the electronic circuit of transmitter/receiver in order to transmit/ receive one bit of data. It depends on factors such as the digital coding, modulation, filtering, and spreading of the signal. e_{amp} is the amount of energy needed to run the radio amplifier of transmitting node to transmit one bit of data. It depends on the distance to the receiver and the acceptable bit-error rate. l is the length of transmitted/received data package. d is the distance between the transmitter and receiver. n is depending on the distance between the transmitter and receiver. n is 2 for free space channel models, and is 4 for multi path fading channel models.

If the distance is less than a given threshold, i.e., d_0, the free space model is used; otherwise, the multi path fading channel model is applied. The threshold is assumed to be 87.7 throughout simulations in this paper. Equation (3) exposits the energy dissipation model for both free space and multi path fading channel models.

$$\begin{cases} E_t = lE_{elec} + l\varepsilon_{emp}d^4 + lE_{DA} & if\ \ d > d_0 \\ E_t = lE_{elec} + l\varepsilon_{fs}d^2 + lE_{DA} & if\ \ d \le d_0 \end{cases} \tag{3}$$

where E_{DA} is the dissipated energy to aggregate data. The above energy model can be used for one sensor node.

B. Network Model

In Normal vision, specialized photoreceptor (light-receiving) in the retina is struck by light entering the eye. These cells transmute light signals to electric impulses sent to the brain. In retinal diseases, photoreceptor cells are destroyed. The artificial retina device can filter destroyed cells and send out signals to the optic nerve. The device includes a tiny camera and microprocessor that integrated in eyeglasses, a receiver placed behind the ear, and an electrode-studded array that is attached to the retina [27].

The camera captures an image and sends the information to the microprocessor. Furthermore, the receiver sends the signals through a tiny cable to the electrode array, stimulating it to emit pulses. The optic nerve in the eye transfers the pulses to the brain, which perceives patterns of light and dark spots corresponding. Schwiebert et al. [21] developed a micro-sensor array that can be implanted in the eye as an artificial retina to assist people with visual impairments. A retina prosthesis chip consisting of 100 micro-sensors is built and implanted within human eye. In this case study, we investigate how EWCP can help artificial retina to be more energy efficient.

We assume that N implanted sensors are distributed randomly in the squared m×m sensor array of implantable artificial retina [22]. Every sensor knows its own location and they should be energy efficient. The source of energy in every sensor is not rechargeable. The communication channel is bidirectional and the range of the monitoring is the same as the range of communicating. This radius is identical in all nodes. BS knows the positions, energy levels and IDs of all nodes distributed in the network. Every node is aware of the existing nodes in its radius of communication, which are considered as neighboring nodes

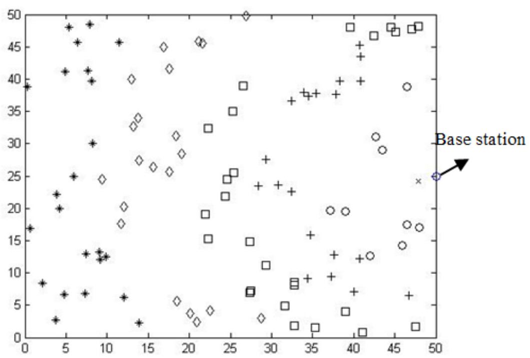

Fig. 1 Sample of network with layer and random node distributed

The network is divided into several layers with a fixed radius and BS is placed at the fixed point. Nodes are uniformly dispersed across the layered network. All nodes have identical initial energy level, sensing range, and physical as well as processing characteristics. Consequently, the network can be deemed as a homogenous network. The example of the network layout and node distribution is illustrated in Fig. 1. Fig. 1 is an example of uniformly distributed 100 nodes dispersed randomly in a 50×50 square unit. The BS node is located at the coordinate of (50,25) and the network is divided into six layers, and similarly the nodes shown by +, □, ◊ and * are located in second, third, fourth, fifth and sixth layers, respectively.

As we have already explained, a weight is associated to every nodes in EWCP. Equation (4) represents the formulation to compute this weight.

$$node.weight = \alpha \times E + \beta \times distance + \delta \times D \quad (4)$$

where, *E* is the residual energy level in a given node, and distance is a normalized Euclidean distance (ED) between the node and BS, which is calculated by (5). *D* is a density of node within its communication radius, and can be calculated using (6). Furthermore, *α, β,* and *δ* are dynamic coefficients, which dynamically change by the number of rounds in EWCP, and can be calculated using (7) to (9).

$$distance = \frac{(max\ ED\ to\ BS) - (ED\ between\ given\ CH\ and\ BS)}{(max\ ED\ to\ BS) - (min\ ED\ to\ BS)} \quad (5)$$

$$D = \frac{the\ number\ of\ neighboring\ CH}{the\ number\ of\ all\ alive\ nodes} \quad (6)$$

$$\alpha = 0.3333 \times \left(\left(\frac{r}{rmax} \right) + 1 \right) \quad (7)$$

$$\beta = \frac{0.3333}{\frac{r}{rmax} + 1} \quad (8)$$

$$\delta = 1 - \alpha - \beta \quad (9)$$

The EWCP operation is divided into several rounds and *r* is the number of current round. The total number of rounds is limited by parameter *rmax* as the maximum possible round that the protocol can operate. The defined coefficients in (7)-(9) are determined dynamically in every round.

As we have already explained, three parameters are incorporated to assign a weigh to each sensor node. These parameters are *residual energy*, *distance* and *density*. At each round, sensor nodes dissipate part of their limited energy capacity, and since the CHs is more energy intensive than the other cluster members, a node with larger residual energy is eligible to become a CH. In general, if there are many nodes concentrated in a given area of the network, more CHs should be allocated in that area. This can help WSN to balance network load, and reduce the possibility of collision, which in return reduce energy consumption and improve the lifetime of WSN. The impact of density factor is assumed to be constant in all rounds of the protocol.

At the beginning of each round, dead nodes, the nodes whose energy is less than a predefined threshold, are excluded from the network. In this paper, the threshold level is assumed zero. The weights of all the live nodes are calculated using (4). The live nodes exchange control message with their neighboring nodes, which contain their weight information. Then, every node selects a number of CH candidates using a distributed CH selection, where nodes make autonomous decisions without any centralized control. This selection is done using multi-layer set-up according to distance between nodes and BS. The nodes located in the same layer can autonomously decide on selecting their CH. This selection is implemented taking into account the following conditions:

- The distance between CH candidates and BS should be greater than a pre-defined threshold distance, which is determined based on communication radius of every sensor node. Consequently, the condition can help the network to evenly distribute CHs, and enhance the network coverage.
- The weight of CH i.e. (8) should be greater than the average weights of its neighbor nodes. The condition can help the network to balance its total energy consumption.

After this stage, the CH candidates broadcast a control massage (CH-msg) to their neighbors. In this way, the nodes in each layer are informed of the number of CH candidates. If the number of candidates is smaller than one third of the nodes in a given layer, some CH candidates must be selected from non-candidate nodes to reach one-third of the nodes existing in the layer. Once the candidates are selected, these nodes report their new status to BS by sending a second control massage to BS. Hence, BS receives and stores the location information and ID number of each node. In the next step, BS transfers this information to optimization algorithm. The optimization algorithm used in this paper is PSO. In this algorithm, the selected CH candidates are considered as initial swarm of particles. Along with these nodes their location information, communication radius and their assigned ID numbers are transferred to the optimization algorithm. The optimization routine is operated in an iterative way. At each iteration, in order to find the best position of each particle, the fitness value of every particle is calculated using (10).

$$\text{Fitness function} = \min \left((1 - \text{network coverage})^2 \times \frac{\text{the number of selected CH}}{\text{the number of candidate CH}} \right) \quad (10)$$

The fitness function in (10) is a minimization problem, and the objective is to maximize the network coverage with minimal number of nodes. Using square value of network coverage indicates that this parameter is primarily more important than the number of the nodes. In order to calculate the network coverage, we have applied “grid base” method [23].

After the optimal set of CHs and their associated cluster members are identified, cluster members sense local data and send them to their assigned CHs. CHs aggregate data and transmit them further to BS using multi-hop communication. Transmitting data from CH to BS is done in such a way that each CH sends data to the CH in a lower layer until data packages reach BS. If the CH in the next lower layer is not accessible, the upper CH can send aggregated data further to the next accessible CH in the next two lower layer. In this situation, the upper layer hop over the dead layer. This situation is mainly valid in the final rounds when all the nodes of a layer are dead due to fact that their total energy is drained completely. In this situation, data packages are transferred to the lower available layers, which encompass live CH.

Once data package is transferred to BS, the associated weight to every CH is reduced according to (11).

$$weight_r = weight_{r-1} - \frac{cluster\_count}{rmax} \quad (11)$$

where, $cluster\_count$ is the number of times the node has been a CH. $rmax$ is the maximum number of rounds, and $weight_{r-1}$ is the weight of the node inn previous round. This weight reduction declines the chance of this node to be selected as CH in the next round. It gives a chance to the other nodes to be selected as CH, and consequently the load is evenly divided among nodes.

IV. Result and Analysis

In this section, we investigate the impact of EWCP on mitigating the constraint of limited energy resources in WSNs. We compare the results of EWCP with common clustering protocols. All the clustering protocols are compared with respect to energy consumption, lifetime and coverage of the network.

TABLE I
PARAMETERS OF THE NETWORK

Parameters	Value
E_{elec}	$50 \times 10^{-6}\ nJ/bit$
E_{DA}	$5 \times 10^{-6}\ nJ/bit\ /signal$
ε_{emp}	$0.0013 \times 10^{-6}\ pJ/bit\ /m^4$
ε_{fs}	$10 \times 10^{-6}\ pJ/bit\ /m^2$
d_0	$87\ \mu m$
l	$2000\ bits$

A 200-node network with initial energy level of 0.5 µJ is assumed as the first case study. Sensor nodes are distributed randomly across 200 × 200 sensor array. Implementation of clustering is iterated based on lifetime of the network (until all sensor nodes die). In all rounds of simulation, the nodes are considered in an active mode, and in every round, they collect sensing data and transmit them to their CHs using single-hop communication. Once CH aggregates the data, it transmits the aggregated data further to the BS using multi-hop communication through network layers. The BS is located at the coordinate (x=100, y=250). The sensing radius of every sensor ($R_{sensing}$) equals 25 µm and their communication radius ($R_{communicatio}$) is 50 µm. The parameters of the applied dissipation energy model are presented in Table I. Moreover, the tuned parameters of PSO are listed in Table II.

The selected benchmark clustering protocols for comparison are GCA [24], SCP [25] and UCIFA [26]. In addition to these common clustering protocols, the research conducted in Mirsadeghi et al. [19] (Mir) is selected as an additional benchmark since similar case study is analyzed in this research work.

TABLE II
PSO TUNED PARAMETERS

Parameters	Optimal value
Number of particles	40
Number of Iterations	200
Inertia weight (*W*)	0.7298
Learning factor 1 (*C1*)	1.4962
Learning factor 2 (*C2*)	1.4962
Number of particles	40

A. Energy Consumption Comparison

Increasing the network coverage reduces the number of orphan nodes and leads to high energy consumption. Orphan nodes cannot establish a connection to any CH or directly to BS. Hence, their dissipated energy to collect the environment information is wasted since this information cannot reach BS. Consequently, declining the number of orphan nodes can effectively help the network to save energy consumption. The rate of network coverage and rate of orphan nodes are compared in Fig. 2.

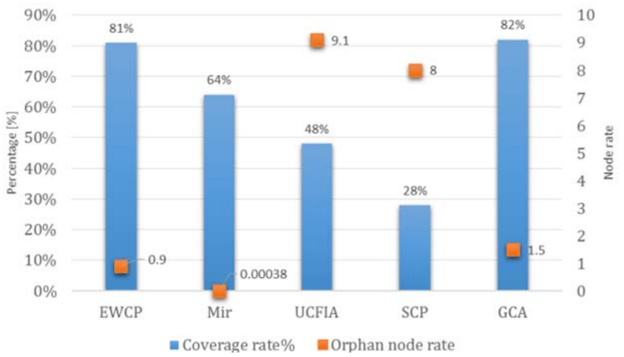

Fig. 2 Coverage rate and orphan node rate

As shown in Fig. 2, the EWCP has relatively low orphan node rate compared to the other protocols. Mir protocol has slightly lower orphan node rate than EWCP, however EWCP has higher coverage rate than Mir protocol. These results are valid for coverage rate as well, where EWCP has relatively high coverage among other protocols. GCA has higher coverage rate yet lower orphan node rate than EWCP. On the other hand, an important criterion to evaluate energy consumption of WSNs is the average number of CHs along all rounds. If the number of CHs is high, energy consumption increases. Table III represents the average number of CHs in each protocol. Based on the results of Table III, it turns out that despite GCA has the highest coverage rate, it requires many CHs at each round. This in return increases energy consumption of the network drastically. Hence, this protocol cannot be considered as an effective energy efficient protocol. As shown in Table III, the number of CHs is optimized in EWCP and leads to optimal point of coverage and orphan nodes. Consequently, it is evident that EWCP significantly improves energy consumption of the network and at the same time, it offers a relatively high network coverage rate and few orphan nodes.

TABLE III
AVERAGE NUMBER OF CHS

Method	Average number of CHs
EWCP	18
Mir	37
UCFIA	8
SCP	15
GCA	83

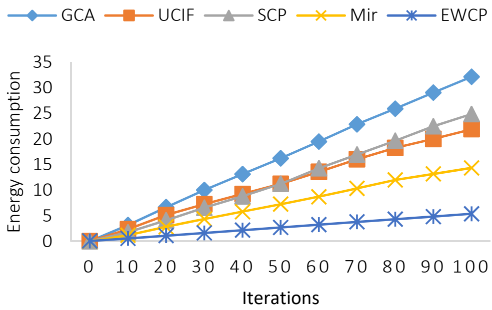

Fig. 3 Energy consumed in 100 iterations

Fig. 3 compares the energy consumption of different clustering protocols in 100 iterations. As shown, EWCP has the lowest energy consumption in comparison with the other benchmark protocols. So (4) helps us to extend the lifetime of networks by tuning the weight of consumed energy during CH selection procedure.

B. Lifetime Comparison

WSN lifetime enhancement can be attributed to energy consumption of the network. Hence, it is expected that the presented method can extend the lifetime of the network effectively due to its positive impact on decreasing the energy consumption. In order to compare the lifetime of different protocols, three criteria are introduced:

- First Node Dies (FND) indicates the number of rounds before the first sensor node dies
- Half Nodes Die (HND) indicates the number of half sensor nodes dies
- Last Node Dies (LND) indicates that the last sensor node dies.

In Table IV, all lifetime criteria, i.e. FND, HND and LND values of different protocols are compared. This figure advocates that EWCP exhibits better solution than the other considered protocols. It is clear especially in FND and HND criteria.

The number of live nodes in each round is shown in Fig. 4. This figure validates the previous results that EWCP has more live nodes in several iterations than the other benchmark clustering protocols. Mir protocol has more live nodes around iteration 2500, however EWCP shows longer lifetime than Mir protocol. Therefore, it turns out that EWCP has an edge over the other protocols.

TABLE IV
LIFETIME CRITERIA OF WSN

Method	FND	HND	LND
EWCP	933	1811	3242
Mir	122	1118	3077
UCFIA	70	661	2980
SCP	51	554	2609
GCA	61	496	1919

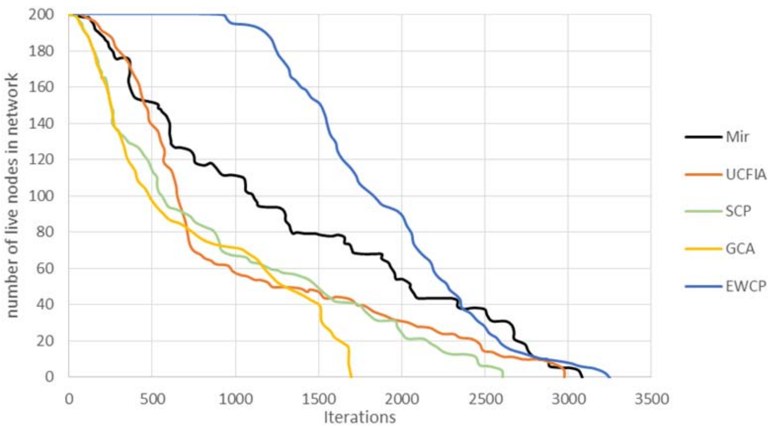

Fig. 4 Lifetime of network

V. Conclusion

WSNs are widely used in medical applications. They offer smart health care for patients, which can significantly improve the health conditions and lifetime expectation for a large number of people. However, WSNs are constrained with limited energy capacity of sensor nodes. Hence, the design of effective and scalable routing protocols is a crucial aspect to prolong their lifetime and increase the performance of WSNs. Clustering protocols are proved as effective approaches to reduce WSN energy consumption and hence extend the lifetime of WSN.

In this paper, we have presented an energy-efficient clustering protocol, i.e., EWCP, using PSO in order to find the optimal set of CHs and their members. Eligible candidate for CHs are selected to be fed into PSO based on their residual energy level, distance to BS, and network density. The objective of PSO is to minimize energy consumption, minimize number of orphan nodes and maximize coverage. Consequently, the lifetime of the network is enhanced.

Using WSNs in implantable artificial retina, the performance of EWCP is compared with common clustering protocols. Simulation results confirm that EWCP exhibits better performance in comparison with the other benchmark protocols in terms of orphan nodes, network lifetime, and energy efficiency. It is concluded that including the energy efficient parameters in selecting CHs and cluster members has a significant improvement on increasing the performance of the presented protocol.

References

[1] Tang, Q.; Tummala, N.; Gupta, S.; Schwiebert, L. Communication scheduling to minimize thermal effects of implanted biosensor networks in homogeneous tissue. *IEEE Trans. Biomed. Eng*. 2005, 52, 1285-1294.

[2] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: A survey," *Computer networks*, vol. 38, pp. 393-422, 2002.

[3] G. Anastasi, M. Conti, M. Di Francesco, and A. Passarella, "Energy conservation in wireless sensor networks: *A survey," Ad hoc networks*, vol. 7, pp. 537-568, 2009.

[4] M. Aminian, H. R. Naji, "A Hospital Healthcare Monitoring System Using Wireless Sensor Networks. *J Health Med Inform*", vol. 4, Issue.121, pp. 1-6, 2013.

[5] O. Chipara, C. Lu, T. C. Bailey, and G.-Ca. Roman, "Reliable Patient Monitoring: A Clinical Study in a Step-down Hospital Unit", *Department of Computer Science and Engineering, Washington University in St. Louis, MO, Technical Report WUCSE-2009-82*, December 2009.

[6] M. A. Mahmood, W. K. Seah, and I. Welch, "Reliability in wireless sensor networks: A survey and challenges ahead," *Computer Networks*, vol. 79, pp. 166-187, 2015.

[7] V. Kumar, S. Jain, and S. Tiwari, "Energy efficient clustering algorithms in wireless sensor networks: A survey," *IJCSI International Journal of Computer Science Issues*, vol. 8, 2011.

[8] E. Lattanzi, E. Regini, A. Acquaviva, and A. Bogliolo, "Energetic sustainability of routing algorithms for energy-harvesting wireless sensor networks," *Computer Communications*, vol. 30, pp. 2976-2986, 2007.

[9] A. A. Aziz, Y. A. Sekercioglu, P. Fitzpatrick, and M. Ivanovich, "A survey on distributed topology control techniques for extending the lifetime of battery powered wireless sensor networks," *IEEE communications surveys & tutorials*, vol. 15, pp. 121-144, 2013.

[10] Darwish, A.; Hassanien, A.E. Wearable and Implantable Wireless Sensor Network Solutions for Healthcare Monitoring. *Sensors* 2011, *11*, 5561-5595.

[11] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on*, 2000, p. 10 pp. vol. 2.

[12] O. Younis and S. Fahmy, "HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks*," Mobile Computing, IEEE Transactions on*, vol. 3, pp. 366-379, 2004.

[13] A. Manjeshwar and D. P. Agrawal, "TEEN: a routing protocol for enhanced efficiency in *wireless sensor networks*," in null, 2001, p. 30189a.

[14] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," in *Aerospace conference proceedings, 2002. IEEE*, 2002, pp. 3-1125-3-1130 vol. 3.

[15] P. Ding, J. Holliday, and A. Celik, "Distributed energy-efficient hierarchical clustering for wireless sensor networks," in *international conference on Distributed Computing in Sensor Systems,* 2005, pp. 322-339.

[16] M. Sabet and H. R. Naji, "A decentralized energy efficient hierarchical cluster-based routing algorithm for wireless sensor networks*," AEU-International Journal of Electronics and Communications,* vol. 69, pp. 790-799, 2015.

[17] P. K. Agarwal and C. M. Procopiuc, "Exact and approximation algorithms for clustering," *Algorithmica,* vol. 33, pp. 201-226, 2002.

[18] N. A. Latiff, C. C. Tsimenidis, and B. S. Sharif, "Energy-aware clustering for wireless sensor networks using particle swarm optimization," *in 2007 IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications*, 2007, pp. 1-5.

[19] M. Mirsadeghi, A. Mahani, and M. Shojaee, "A Novel distributed Clustering Protocol using fuzzy logic*," Procedia Technology*, vol. 17, pp. 742-748, 2014.

[20] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on wireless communications*, vol. 1, pp. 660-670, 2002.

[21] L. Schwiebert, S. K. S. Gupta, and J. Weinmann, "Research challenges in wireless networks of biomedical sensors," *7th Annual International Conference on Mobile Computing and Networking, Rome, Italy*, pp. 151–165, 2001

[22] Ian F. Akyildiz, Mehmet Can Vuran, "Wireless Sensor Networks" *ISBN: 978-0-470-03601-3, Wiley*, September 2010.

[23] X. Shen, J. Chen, and Y. Sun, "Grid scan: A simple and effective approach for coverage issue in wireless sensor networks," in *2006 IEEE International Conference on Communications*, 2006, pp. 3480-3484.

[24] S. H. Lee, S. Lee, H. Song, and H. S. Lee, "Gradual cluster head election for high network connectivity in large-scale sensor networks," in *Advanced Communication Technology (ICACT), 2011 13th International Conference on*, 2011, pp. 168-172.

[25] A. K. Tripathy and S. Chinara, "Staggered clustering protocol: SCP an efficient clustering approach for wireless sensor network," in *Information and Communication Technologies (WICT), 2012 World Congress on*, 2012, pp. 937-941.

[26] M. Song and C.-l. ZHAO, "Unequal clustering algorithm for WSN based on fuzzy logic and improved ACO*," The Journal of China Universities of Posts and Telecommunications*, vol. 18, pp. 89-97, 2011.

[27] http://www.eyereview.com/macular_degeneration_research_and_the_artificial_retina.html

Ebrahim Farahmand was born in Iran in 1989. He received the B.Sc. degree in Electrical engineering- communication systems in 2012, and M.Sc. degree in electrical engineering-Electronics in 2016 both from Shahid Bahonar University of Kerman (SBUK). His research interest is the Warless Sensor Network and reliability analysis.

Ali Mahani (Born 1978) received the PhD in Electrical engineering from Iran University of Science and Technology (IUST) in 2009. Since then he has been with the Department of Electrical and Electronic Engineering of Shahid Bahonar University of Kerman, where he is currently an associate professor. His interests focus on Fault tolerant design and Networked systems.