Soft Computing Techniques for Clustering in WSN

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Abstract. The large Wireless Sensor Networks (WSNs) comprises Sensor Nodes (SN) in some hundreds with sensing and communication capabilities. Major limitation of WSN is limited energy source of SN. Clustering is one of energy efficient method for energy conservation in WSNs. Clustering is the process to distribute SN in various logical groups known as cluster. Each cluster bears a Cluster Head (CH), who is responsible for transmitting aggregated data of its cluster to Base Station (BS). The literature is enriched by various clustering protocols proposed with the assistance of soft computing. This paper, presents the survey of soft computing paradigm-based clustering protocols.

Keywords: Soft Computing, Wireless Sensor Networks, Clustering, Genetic Algorithm, Fuzzy Logic, Artificial Neural Network, LEACH, Network Lifetime.

1. Introduction

Since the invention of wireless technology, WSN have gained a lot of researcher attention. WSN contains large number of Sensor Nodes (SN). Every SN is equipped with fair sensing and communication capabilities. WSN is used in variety of applications which includes habitat monitoring, battlefield surveillance, wildlife supervision etc. due to its sensing ability. Major limitation of WSN is limited energy source of SN. It is not possible to recharge or replace battery of node as SNs are deployed in unattended environment [1-3]. And the solutions designed for wired networks are not feasible for WSN. Many energy efficient routing, clustering and aggregation techniques has been proposed to improve the battery conservation of SN and network lifetime [4].

To perform clustering, SNs of WSN are grouped together and these groups are called clusters. CH of each cluster is responsible for transmitting aggregated data of its cluster to BS. LEACH [5] is a vital
protocol for WSN. It selects the CH in network based on probability and threshold value. Many LEACH based clustering protocols LEACH-C [6-9] has been proposed for better energy conservation of WSN.

Soft computing [10] find solutions to complex real-life problems with estimated models. Soft computing based solutions are favorable due to its uncertainty tolerance, ambiguity tolerance, and approximation drawing competence. Soft computing techniques are fuzzy computing with the support of firm fuzzy logics, neuron computing based on neural networks, machine learning, evolutionary computing on genetic-algorithms, and expert systems. Soft computing is major research area in various business-related, domestic, and industrial purposes. The usual developments, like invention of processors and sensors with improved performance enlarge the domain of soft computing. The literature presents rich discussion on various clustering protocols dependent upon soft computing techniques. The remainder of the paper is organized as follow: Section 2 explain different genetic algorithm based clustering protocol for WSN. Section 3 presents fuzzy based clustering and artificial neural network based clustering protocol for WSN are discuss in section 4. Section 5 presents Conclusion and future work.

2. Genetic Algorithm Based Clustering Protocol

Genetic Algorithms [11] are used to define and resolve optimization and search problems. It proposes a solution by designing a method on the principles of genetic process goes with biological evolution. Genetic algorithm (GA) can be applied in WSN to divide network into appropriate clusters. A Fitness function is required to obtain for an estimation of the chromosome’s worth in population.

Raju et. al.[12] proposed LEACH based Energy Efficient Weighted Clustering (EEWC) protocol based on GA. Fitness function of chromosome is based on cluster separation, cluster compactness and the normalized number of CHs. Fitness function of chromosome is directly proportional to separation between cluster and inversely proportional to number of CHs and separation between clusters. Chromosome with minimum fitness function is elected as CHs. Simulation results shows that EEWC is able to keep network active for a longer lifetime along with good overall residual energy and stability period as compared to LEACH, SEP, ERP and IHCR.

Optimized LEACH (O-LEACH) protocol in [13] based on GA. O-LEACH protocol balance the total number of CHs. Fitness function for selection of CHs in O-LEACH are based on residual and threshold energy. O-LEACH performs better as compared to LEACH by improving packet delivery ration, throughput, and energy consumption 7.27%, 17.44% and 17.39% respectively.

Kobra et. al.[14] proposed centralized clustering with improvements in traditional LEACH with GA. Fitness function for CH selection is function of energy, total number of nodes and CHs, and sum of distance of all sink nodes to CH and BS. Lower the energy consumption, fewer number of CHs and shorter transmission distance helps to get high value of fitness function. The proposed clustering method improve network lifetime and reliability.

G.R. Annusha Kumar et. al [15] proposed energy efficient hierarchal clustering protocol based on optimized adaptive TEEN (APTEEN) routing protocol and GA. GA is used to decide CH in network based on following parameters: Average Minimum-Distance, Transmission-Distance, Energy-Left per node, Transmission energy dissipated, cluster distance. The Fitness function is a combination of above parameters. The Fitness function guides to determine the candidate of CH so that network lifetime and energy efficiency of WSN can be improved.

Shashi Bhushan et. al. [16] hybrid clustering protocol KGA (K-means clustering and GA) for WSN based on k-means clustering and GA. In proposed clustering protocol population under GA is seeded with K-means for better clustering performance. The Fitness function needs to count the number of live-nodes, inter and intra cluster distance. The Fitness function works upon a principle to pull-down the energy consumption of network up to a maximum possible extent. The simulation results highlight the improved performance of the KGP in comparison to ERP, IHCR, and SEP by considering residual energy, network life time, and throughput.
Nayak et. al. [17] proposed GA-LEACH multi-hop clustering protocol which is combination of GA and LEACH. Fitness function is summation of distance and energy cost. Distance cost comprises two factors:
1) Distance between SN and CH
2) Distance between CH and BS.

Energy of SN and total residual energy of all SNs find energy cost. In each round CH is elected based on appropriate fitness function. Every CH transmit aggregated data of its member SNs to neighboring CH and process repeats till data reaches to BS.

S.P. Singh et. al. [18] presented static and optimal clustering i.e. Genetic-Algorithm-Based Energy-Efficient Clustering (GAEEC) for homogeneous WSN. GAEEC uses GA algorithm two times with different operators and parameters. Fitness function of node is calculated with help of energy left at node, distance between node and BS, nodes density function. Roulette Wheel Selection (RWS) method is taken for the chromosomes production. Randomly, two chromosomes are selected. Each chromosome has a fitness value, obtained through the sum of fitness value of each gene in chromosome. Crossover operator is applied on both parent chromosomes to create best random offspring. After Crossover operator, mutation operator is applied to add variety into population. Once mutation process done, best chromosome is selected with rank selection method and its genes are elected as CHs for current round. Simulation results shows that throughput of GAEEC is more than LEACH.

Xiaohui et. al. [19] proposed genetic algorithm based, self-organizing network clustering (GASONeC) that dynamically optimize WSN clusters. In GASONeC protocol, CH is elected based on distance to BS, number of SN, residual energy and expected energy expenditure. GASONeC improve network lifetime up to 43%. Simulation of propose protocol shows that network lifetime decrease as the distance between SNs and distance to BS increase.

Nabajyoti Mazumdar et. al. [20] designed an Energy Efficient GA based clustering protocol for WSN (EEGA). In proposed protocol chromosomes population is generated randomly at initial stage. Then fitness function is evaluated to find the fitness of chromosome. Fitness function is calculated using load of CH which depends on number of its member SNs and distance of CH to BS. Crossover and mutation operator is applied on some chromosomes with higher fitness value. Gene with higher fitness value is elected as CH. EEGA perform better than existing GA based clustering protocol LBCA and MOGA in terms of energy efficiency, network lifetime and number of active nodes, as results show.

GAEEC [21] genetic clustering algorithm select CH based on fitness function made up of four parameters CH dispersion, CH energy consumption, total energy consumption per round and standard deviation of energy consumption between clusters. Simulation results show that 21% increase in network lifetime as compared to LEACH.

3. Neural Network Based Clustering Protocol
The main goal of using neural network-based clustering protocol is to improve the longevity of network lifetime to some level. The core features of neural networks are distributed processing and representation, ability of generalization and learning, inherent contextual processing of information, massive parallelism, low computation and fault tolerance [22].

Ulha. et al. [23] performed data aggregation built upon extreme machine learning (EML) neural network and the clustering of the nodes, in a novel way. The suggested EML neural network model transmitted the data to the sink node after combining the CH with the data. The CH received the data from SNs through Kalman filtration process. Mahala Nobis distance based radial basis function (MDRBF) is used with ELM neural network to accurately locate the parameters of the model that allows well organized data processing. As a result of that there is a reduction in the network traffic which further improves the network’s longevity to a significant degree. Simulation results with the real data sets have shown the outstanding execution of the suggested model in comparison to the other prevalent clustering and data aggregation schemes with reference to the number of live nodes in the WSN, clustering accuracy of the data and energy effectiveness of WSN.
Wang et. al. [24] presented a combination of adaptive clustering technique lies on AP (Affinity Propagation) algorithm to achieve better clustering performance. It can decrease the distance of average data transmission and it provided the effect of load balancing routing. Firstly, it explains the AP algorithm for the calculation of initial cluster centers. Then it uses K-medoids algorithm for the partitioning of the entire network into clusters based upon the preceding cluster centers computed by AP algorithm. The results of simulation show that about 52.5%, 54.21% and 33.33%, performed better with reference to the energy utilization, and network lifetime enhanced by 31.39%, 51.1% and 16.23% in comparison with LEACH-AP, EDDUCA and UCR-H algorithms respectively.

Thangaramya et. al. [25] implemented and analyzed a different algorithm for routing of SNs in IoT. So, as to increase the performance of the network, a cluster formation approach is proposed based upon Neuro Fuzzy rules. In this technique, the formation of clusters in WSNs used the residual energy for modeling and to route the packets. The whole method revolved around machine learning based upon neural network. The lifespan improved to some level by adopting weight regulations with the help of fuzzy rules. The contributory components for the utilization of energy and life span of SNs are residual energy level at CHs, distance between CHs and SNs, CHs’ degree, and distance between CHs and sink nodes. Simulated results shown that the introduced routing algorithm outperformed the HEED, LEACH and FLCFP on the arguments of the network lifespan, and utilization of energy.

Britto et. al. [26] suggested applying soft computing in the field of multimedia rich applications for WSN with the support of cameras and microphones. The clusters are formed with the help of SGP. An artificial neural network by means of three layers is suggested. The method of back propagation is also introduced in the proposed algorithm. The whole network transformed in a form of two clusters, with the help of proposed method. The choice of the cluster method is based upon the eigen vector first and the revolution of the cluster is based upon the reinforcement node utilization.

The outcomes of the simulation demonstrate that the proposed hybrid SGP clustering technique boosted the lifetime of the network in comparison to the former SGP clustering technique. A three-layer artificial neural network helps to estimate most favorable number of energy efficient nodes in all CH and for the transmission of energy efficient, optimum number of CHs is required. A comparison of this hybrid clustering method is done with LEACH, SGP, C-LEACH, and Q-LEACH algorithms and it is observed that the drawn neural hybrid approach achieves better results.

Saleh et. al. [27] established a clustering method for energy sensitive WSN. This method accessed static random-access memory using neural network principles. The achievement of this method is to consume less energy in storage and transmission of data throughout the data dissemination method. As an application in mobile healthcare applications, they proposed two advanced energy-efficient architectures to broaden the lifespan of wireless sensor networks. A new quaternary interconnect technique was introduced. The data used for transmission is converted into quaternary from binary form. A symbol is generated from each two bit for the transmission. On the receiving end again the actual binary form of the received signal is decoded.

This technique is experimented with the help of SPICE. The results of simulations have revealed that it increases the lifetime of WSN. In comparison with binary transmission signaling scheme, the energy consumption has found to be 41% saved and therefore it consumed 59% of the fundamental binary scheme. Due to neural networks, the decreased storage costs helps in consuming the energy in NS-RAM-CBEES for WSN and the reduction of the communication cost. A method consisting of internal latches was proposed for storing the information in binary called neural network static (NN-SRAM). The results of simulation have shown that instead using the conventional temporary memory, there is a decrease in amount of energy to 76.99% using this proposed method.

Sanhaji et. al. [28] designed a new WSN routing protocol based upon the Neural Network. The main concern for the process of communication in WSNs is energy utilization. It describes a new technique to choose the cluster head in LEACH routing protocol by utilizing the notion of neural network in WSNs. The SN with uppermost energy is chosen as the CH because CH is responsible for the communication with the member nodes as well as with the base station. This proposed routing protocol performs better as compared to the classical WSNs routing protocols.
Eldhose et al. [29] proposed a method using neural network called dynamic clustering node method. Sensor node has limitation of energy constraint and it acts as main issue in the deployment. In neural networks, each and every SN has to send the data to all other SNs in the network which further requires a large quantity of energy. Instead of this cluster’s formation is done and, in each cluster, cluster node is elected. It is the responsibility of the cluster node to process the data and to honestly send the data to the BS or with the help of some other cluster node. The collection of data is performed by the CH. Cluster and cluster nodes are altered frequently to stabilize the defined energy limitations. This dynamic clustering node method is compared with some other methods and this method is more efficient than other methods.

Julie et. al. [30] highlighted a dynamic clustering scheme NFEACS based on neural network to resolve the energy consumption problem and lifespan of WSN.

To limit the consumption pattern of energy and to increase the life span of WSN, it is necessary to develop an energy conscious clustering protocol in WSN. NFEACS consists of two portions: Neural Network and Fuzzy subsystem. These two achieved the effectiveness in the energy for the formation of cluster heads and clusters in WSN. Neural network based NFEACS helps in obtaining effective training set related to received signal strength and energy of all SNs for the estimation of energy anticipated for the tentative CHs. The higher energy SNs are trained with center location of BSs. These are used to decide on the energy conscious CHs. Fuzzy logic is implemented as an input to form clusters. NFEACS saved 37% of the energy in contrast with the further related proposals. The effectiveness of the introduced scheme is studied by applying constraints such as network life span and energy utilization.

Sharma et. al. [31] introduced a new technique in WSN. This new technique is used to choose the CH by utilizing the artificial neural network. This method enhanced the life span of the network. To select the CH, a SN that has the utmost energy left is pointed out as the CH. The analytics of this method is dependent upon artificial neural network. A network function is defined on the basis of radial approximation to obtain CHs amongst SNs. The postulated algorithm is examined on the basis of a variety of factors like: Energy consumption of the protocols, Counts of SNs dead to the total number of rounds performed, Total number of packets sent to the CH, SNs dying per unit round. The extended version of LEACH-C protocol with artificial neural network gives better end result as compared to LEACH-C and LEACH. It infers a better lifetime of the network.

Ahmadnezhad et. al.[32] presented a new clustering scheme with a focus on the energy consumption. The suggested scheme EBC-S is drawn from SOM neural networks. The clustering input parameters used are the levels of energy and coordinates of nodes. It uses highest energy SNs as weights units to attract nearest SNs with lower energy. This new algorithm enables us in the formation of energy balanced clusters and it uniformly distributes consumption of energy. Simulation results proved that in first scene, when compared with LEACH and LEA2C, this new algorithm has a profit of 50% and a profit of 38% respectively and in the second scene when compared with LEACH and LEA2C, this new algorithm has a profit of 27% and a profit of 11% respectively with reference to rising first burn out time while guaranteed the total exposure during 90% up to 95% of network life span in these two occurrences. Also EBCS is different from other algorithms in the way the clusters are formed besides; it shows improved network coverage of 8% and 24% when compared with LEACH and LEA2C respectively in the same conditions. This new algorithm established to expand the lifetime of WSN when compared with previous protocols.

4. Fuzzy Logic Based Clustering Protocol
Fuzzy logic [33] is commonly applied to manage various vulnerabilities in a framework. Fuzzy logic can be used in WSN to choose the best possible and productive CH with the goal that effective life time can be accomplished. Since, it can mix various parameters to manage vulnerabilities inalienable in WSNs in a successful way. So, it is appropriate for taking care of clustering issues in WSNs. A fuzzy inference system has 4 significant stages.
• Fuzzifier
• Inference framework
• Mapping rules
• Defuzzifier

The previous or new information of input and output variables is changed by the fuzzifier to appropriate linguistic values. This calibration to achieve a most suitable value delivers a fuzzy membership function. Gaurav et al. [34] recommended an energy effective clustering protocol applicable for WSN utilizing fuzzy. Some modifications are made in LEACH protocol to make it all the more appealing and generally acknowledged. LEACH is a hierarchical routing protocol which choose cluster heads depending on probabilistic model and the role is alternated among the different nodes in system. In this, just CHs are permitted to send collected and compacted information to Base station. This outcomes in packet loss and increased energy consumption to transmit information to base station. The author attempted to handle these issues with the help of fuzzy logics to choose super-CH among CHs. One Super cluster head among the CHs can be chosen to transmit the information to BS to reduce energy consumption of each CH and to use the bandwidth efficiently rather than numerous CHs which can decrease energy consumption and upgrades network lifetime. Appropriate fuzzy descriptors, for example, mobility of BS, remaining energy and centrality of clusters are considered. The resultant node gathers all information from CHs, aggregate them and transmit the compressed information to BS. Experimental results demonstrated the effectiveness of suggested algorithm in contrast to the Hierarchical routing LEACH protocol regarding Packet loss and energy consumed.

Fakhrosadat et al. [35] introduces a fuzzy dependent algorithm- FSFLA, in which the mimetic algorithm based upon frog leaping is utilized to upgrade the fuzzy rule-base table dependent on the details of application. The algorithm depends on the fact that the manageable variables along with fuzzy rules are characterized manually in the various performances of the existing clustering methods for WSNs. This outcome in fixed performance of the protocol and it’s absolutely impossible to adjust it according to application specifications. The proposed FSFLA protocol is helpful to achieve improved network life by keeping the total number of packets’ received; based on the details of every application. It is an energy efficient centralized protocol which modifies itself to various objectives and applications of WSNs. The presented FSFLA is executed in two distinct forms and is contrasted using SIF, LEACH and its popular up-gradation LEACH-DT, ASLPR protocol. The outcomes show that the FSFLA essentially beats other similar protocols in all circumstances. FSFLA extends the stable region by maximum of 46% in comparison to LEACH-DT, whereas the minimum of 3% betterment is achieved in comparison to ASLPR. Furthermore, the increase in FND is reflected with maximum of 114%, and minimum of 89% in comparison to LEACH-DT and LEACH respectively.

Quyuan Wang et. al. [36] points out those current clustering algorithms don't provide the energy consumption model and furthermore they don't have any idea regarding about an optimum number of clusters in WSN. Along these lines, they proposed an algorithm named centralized clustering algorithm which depends upon spectral partitioning to partition WSN and a decentralized execution of the clustering method dependent on fuzzy C-means to select CHs. Simulations for the analysis of the implementation of the suggested algorithm regarding SNs’ remaining energy and WSN life time and the outcomes are contrasted with a distributed scheme- HEED. HEED is an energy conscious algorithm. The results shows that the suggested algorithm performs better than the HEED for clustering as far as energy cost and network lifetime.

SeyyitAlperSert et al. [37] thinks about hotspots issue and energy limitation issue in uniformly and non-uniformly distributed networks. For this a multi-objective clustering algorithm- MOFCA frames. MOFCA is a fuzzy scheme that chooses final CHs through their left over energy levels competition from
the intermediately selected CHs utilizing probabilistic model. The main consideration behind designing this algorithm is that it ought to be energy aware in every single suitable situation and can be executed on real WSN. The algorithm is contrasted with the current clustering mechanisms such as CHEF, LEACH, and other energy aware protocols EEUC, EAUCF. The performance is tested on the basis of: the first node dies, total remaining energy, and half of the nodes alive as effectiveness measurements for evaluating the lifetime of the WSNs and effectiveness of the protocol. Experimental results demonstrated that that MOFCA beats the existing algorithms in the similar arrangement for every efficiency metric.

A novel energy-efficient protocol named Energy Efficient Clustering Protocol to Enhance Performance of HWSN (EECPEP-HWSN) is presented by Santosh V. Purkar [38]. It is fuzzy based protocol planned with the objectives to decrease internal burden on WSN for its management. This overburden limits the selection of any SN as CH. The proposed scheme highlights a better scalability also. The suggested protocol beats than existing prominent LEACH, DEEC, and SEP with around 188, 150, and 141 percent individually.

DH CFL -a fuzzy based distributed clustering algorithm is proposed by author Baranidharan B[39]. It answers the uneven energy utilization among CHs and CMs by sharing the load of a conventional CH node. The suggested algorithm is contrasted with LEACH, EAUCF and FLECH experimentally and it diminishes the overall energy utilization and expands the network lifetime.

Madiha Razzaz et. al. [40] proposed Fuzzy-Logic Dijkstra-Based energy-efficient and delay tolerant routing scheme for information transmission in WSN. It not only just thinks about the left-over energy of the fellow SNs yet additionally limits the communication within a cluster by calculating cost of communication. By utilizing weighted sum approach for choosing a CH and Dijkstra’s routing algorithm’s for choosing a route with least weight, the algorithm performs better than FML, ESRAD, and SPFL algorithm as far as increased throughput, reduce energy consumption of individual nodes. Deepika Agrawal et al. [41] introduce a fuzzy-based unequal clustering protocol exceptionally intended for nonuniform large-scale WSN with homogeneous nodes. The upside of this protocol is that it additionally considers load among the SNs of WSN with increment in network lifetime. Fitness function for CH selection depends on separation between SN and BS, energy remaining with any SN, SN’s cardinality and its positioning. The proposed algorithm is assessed with some familiar equal and unequal clustering protocols like MOFCA, IGHND and FUCA and it outflanks than these by expanding network life time.

Ying Zhang et al. [42] joins fuzzy logic with clustering algorithm for WSNs and presented an energy-efficient distributed clustering algorithm dependent on fuzzy approach with non-uniform distribution (EEDCF). The algorithm considers some of the input variables defined by the energy level of SN, cardinality of SN as inputs fuzzy parameters for every SN. Fuzzy inference system in a distributed way is utilized by every sensor node to decide the probability of being as CH. The proposed clustering algorithms performs better than EADEEG algorithm and DFLC algorithm by improving average lifetime of sensor nodes, information transmission efficiency and expanding the life cycle of the whole network.

Yiming Zhang et al. [43] consolidates a clustering algorithm CFSFDP. This algorithm clusters among the SNs by performing a less time complex searching method. The clustering requires estimating the SNs’ density among the whole WSN. CFSFDP with energy-efficient hierarchy protocol called CFSFDP-E in WSNs. The fuzzy parameters taken to get proper number of clusters and to select appropriate cluster heads are density, distance and residual energy. By simulation it is demonstrated that the suggested algorithm performs better than LEACH by delay the death rate of first node by approx. 50%. It likewise beats several traditional protocols like PEGASIS, SEP, LEACH and its improvements LEACH-C, KM-LEACH, C-LEACH, K-LEACH, and ALEACH. Along with various traditional protocols, also CFSFDP outperforms some other recently proposed protocols- DBCH and EESCA as far as number of living nodes, total energy consumption and energy – balance.
5. Conclusion and Future Work
Soft Computing techniques was applied in WSN to find optimal clusters. Most Commonly soft computing techniques that has been used for WSN were Genetic Algorithms, Neural Networks and Fuzzy Logic. We have presented the survey of soft computing techniques that has been used for clustering in WSN. Survey conclude that there is still wide scope of soft computing techniques for WSN. Future work includes the discussed protocol can be applied for data aggregation.

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