Fuzzy based Energy Efficient Clustering Protocols for WSN Systems: A Survey

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Abstract
Wireless Sensor Networks are utilized for collecting physical information from a distant place by using sensing devices called sensors. In order to collect information more efficiently, wireless sensor networks (WSNs) are partitioned into clusters. This approach is an effective way to prolong the lifetime of WSNs. While using clustering approach the major concern is the choice of a suitable cluster head sensor node. Many clustering protocols already formed based on LEACH [15] (Low Energy Adaptive Clustering Hierarchy) which is based on probabilistic modeling. In this paper, we present a survey of various clustering protocols for prolonging the lifetime of WSNs using fuzzy logic approach. The paper concludes with open research issues.

Keywords
Cluster head, LEACH, Fuzzy Logic, Wireless Sensor Networks.

1. INTRODUCTION
A wireless sensor network (WSN) consist of micro electromechanical (MEMS) based autonomous devices equipped with sensors that collectively perform the task of collecting relevant data and monitor its surrounding for variations such as temperature, vibration, pressure, or pollutants. The data sensed by these sensors (or nodes) is then sent to Base Station (BS) for assessment [13]. The fact that wireless sensor network is different from traditional wireless network requires special attention and specialized algorithms meant for the former and that traditional network protocols need to be modified for use in wireless sensor networks. In wireless sensor network, nodes have to operate unattended for a long time without replacement of power sources, so focus is on optimized use of energy so that the lifetime of the network is increased. Energy consumption is not an issue in traditional wireless network as energy source can be replaced and recharged at any time. But the case is not same in wireless sensor nodes that means the batteries used by sensor nodes cannot be replace and recharge by any means. A number of routing protocols have been proposed to make nodes more energy efficient. There are cases that the nearby nodes sense the same data and transmit it to BS, making network inefficient. It is found that to maintain worthy information at the BS, the nodes must be responsible for data aggregation and fusion. So, a reliable network is the one in which the redundant information is negligible. To avoid redundancy, clustering algorithms were proposed. The whole network of nodes is divided into a number of clusters; the data aggregation is performed within the cluster and then transmitted to the BS. Clustering helps in reduction of redundancy and improvement over the lifetime of the network. Recently, a few surveys of clustering routing methods for WSNs have been presented. These surveys mainly aim at outlining some characters of clustering and summarizing some popular clustering routing algorithms with comparison based on different attributes and performances. In this study, we present a comprehensive survey of different clustering routing protocols proposed in literature as well as fuzzy logic based clustering protocols for WSNs in recent years. The representative design is low-energy adaptive clustering hierarchy (LEACH) [15] protocol, which uses a probabilistic model to select cluster heads (CHs) periodically in order to balance energy consumption. However in some cases, inefficient clustering could not maximize the lifetime of WSNs so a number of modifications has been done to improve the energy efficiency of protocol.

2. RELATED WORK
A typical Wireless Sensor Network's architecture is expressed by Figure 1. All the sensor nodes in one cluster send their sensed information to elected respective cluster-heads; the cluster-head in turn then integrate or aggregate and then compress the sensed data and transmit directly it to the base station. Following assumptions are taken for WSN:

• The base station (sink) is stationary and it is established to a stipulated distance from the normal sensor nodes.

• The nodes are homogeneous.

• All the nodes in WSN are energy constrained.

• Propagation channel is symmetric.

• Sink is responsible for the cluster-head election.

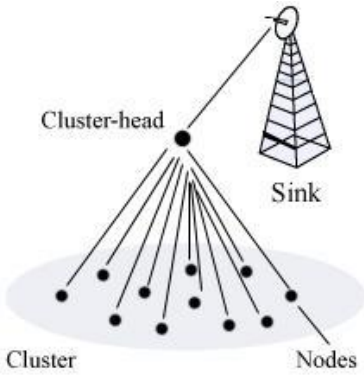

Figure 1 WSN Architecture

Increasing the lifetime is as old topic of research as the wireless sensor network itself, nonetheless a number of researches are going on currently for prolonging the lifetime of wireless sensor network. Many algorithms and strategies have also been proposed in the past and are mostly based on routing algorithms to optimize the energy consumption. LEACH [15] is a hierarchical network routing protocol which forms clusters in a sensor field and elect a

cluster head for each clusters and these cluster are responsible for transmitting the data to the base station. LEACH-C [13] is centralized approach for choosing cluster heads in WSNs. PEGASIS [12] is an enhancement over LEACH protocol and falls under hierarchical network routing protocols. TEEN [14] and APTEEN [11] are other two protocols proposed for lifetime enhancement in time-critical applications. BCDCP [10] (Base station Controlled Dynamic Clustering Protocol) is an extension over LEACH-C by dividing equal number of nodes per cluster. Kumar et.al [6] proposed EEHC (Energy Efficient Heterogeneous Clustering) approach for wireless sensor networks. The main idea is to introduce heterogeneous nodes in the network on energy basis. Singh et.al proposed a cluster head selection approach using Fuzzy Logic. This protocol considers two parameters for the selection of a CH as energy and centrality. Gupta et.al [4] proposed FREEDOM (Fault Revoking and Energy Efficient Protocol for the Deployment of Mobile Sensor Nodes in Wireless Sensor Networks) with the introduction of mobile sensor nodes to improve energy efficiency of WSN by replacing a damaged node by a mobile node. Nguyen et.al [8] introduced energy efficient clustering algorithm for mobile sensor network based on LEACH. In M-LEACH each node sends its information including locations, velocity and energy level to base station as in LEACH-C. Kim et.al [7] proposed CHEF (Cluster Head Election mechanism using Fuzzy Logic) for the selection of cluster head by using two input parameter energy and proximity distance. Sharma et.al [1] proposed F-MCHEL (Fuzzy based Master Cluster Head Election Leach) strategy as an advancement in CHEF.

3. CLUSTERING PROTOCOLS

In LEACH [15] the cluster heads are selected based on a probabilistic model, in which a sensor node is being selected as a CHs node for current round based on a threshold value that is based on total number of sensor nodes present in the network and the predefined number of cluster heads. The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase when data are transferred from the nodes to the CH and on to the base station. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Each node i elect itself to be a CH at the beginning of round r +1 (which starts at time t) with probability Pi (t). Pi (t) is chosen such that the expected number of CHs for this round is k. If there are N nodes in the network, each node would choose to become a CH at round r with the probability as (1).

$$P_i(t) = \begin{cases} \dfrac{k}{N - k*(r \bmod N/k)} & : \; C_i(t) = 1 \\ 0 & : \; C_i(t) = 0 \end{cases} \qquad (1)$$

where Ci(t) is the indicator function determining whether or not node i has been a CH within the most recent (r mod N/k) rounds (Ci(t) = 0 means node i has been a CH). Thus, only nodes that have not already been CHs recently (i.e. Ci(t) = 1) may become CHs at round r + 1. It can be observed that the ratio k/N as a probability to became a cluster head, by putting k/N in equation (1) as p, where p represent the probability factor then a threshold value can be calculate which can be further used as a threshold value to select a node as a cluster head. This decision is made by the node N choosing a random number between 0 and 1. If the number is less than a threshold T(n), the node becomes a cluster-head for the current round. The threshold is given as (2).

$$T(n) = \begin{cases} \dfrac{p}{1 - p*(r \bmod 1/p)} & if \; N \in G \\ 0 & otherwise \end{cases} \qquad (2)$$

where G is the set of nodes that have not been cluster head in last 1/p rounds. The problem with LEACH is poor clustering that means some cluster heads are very near to base station while some are very far so that the CH far away from base station deplete their energy earlier as compared to others.

In LEACH-C (Centralized) [13] the problem faced by LEACH was overcome by using a centralized approach for choosing CH instead of using a distributed approach as in LEACH. In LEACH-C base station acquires global knowledge about the position of each node (by using GPS) and their respective amount of energy. On the basis of this information base station declare a node as a CH for current round by utilizing the average node energy as a threshold. LEACH-C suffers from the unequal number of sensor nodes per cluster. TEEN (Threshold sensitive Energy Efficient sensor Network) [14] and APTEEN (Adaptive Threshold sensitive Energy Efficient sensor Network) [11] are two protocols developed for reactive networks in which nodes react to a sudden change. In TEEN cluster head broadcast two threshold values as HT (Hard Threshold) and ST (Soft Threshold). ST is used for putting transmitter of a node in on position from a sleep mode and HT is used for actual transmission of data takes place. Both threshold values allow transmission only when sensed attributes are in the range of interest. The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate; the user will not get any data from the network at all and will not come to know even if all the nodes die. This problem can be overcome by APTEEN in which best features of proactive and reactive networks by creating Hybrid Network with sending data periodically as well as respond to sudden changes. Muruganathan et.al [10] proposed BCDCP (Base station Controlled Dynamic Clustering Protocol) is proposed in which high energy Base Station is utilized to setup clusters and routing paths. The main idea of BCDCP is to form balanced clusters where each CH serves as approximately equal number of nodes to avoid CH overload. Lindsey et.al [12] proposed a chain-based protocol PEGASIS that was an improvement over LEACH. In PEGASIS a chain is formed among sensor nodes so that each node will receive from and transmit to a close neighbor. Gathered data moves from node to node, get fused and eventually a designated node transmit to base station results in reduction of average energy consumption by each node. PEGASIS introduced excessive delay for distant node on the chain. Nguyen et.al [8] introduced LEACH-M energy efficient clustering algorithm for mobile sensor network based on LEACH. This protocol considers mobility of cluster head and member nodes during one round. The node with smallest mobility cost preferred as CH. In M-LEACH each node sends its information including locations, velocity and energy level to base station as in LEACH-C. Kumar et.al [6] proposed EEHC (Energy Efficient Heterogeneous Clustering) approach for wireless sensor networks. The main idea is to introduce heterogeneous nodes in the network on the energy basis. This work mainly focuses on selection probability of cluster head. Three types of heterogeneity introduced as computational, link and energy. In this protocol three different types of nodes are used for sensing an environment such as super nodes, advanced nodes and normal nodes. In this scheme, let m be the fraction of the total number of nodes n, and mo is the percentage of the total number of nodes m which are equipped with β times more energy than the normal nodes, these nodes act as super nodes. The rest n * m * (1 - mo) nodes are equipped with

a times more energy than the normal nodes, these nodes act as advanced nodes and remaining n * (1-m) as normal nodes. Suppose E0 is the initial energy of each normal node. The energy of each super node is then E0*(1+β) and each advanced node is then E0*(1+α). The total initial energy of the new heterogeneous network setting is equal to equation (3).

$$n*(1-m)*E_0 + n*m*(1-m_0)*E_0*(1+\alpha) + n*m*m_0*E_0*(1+\beta) = n*E_0*(1+m*(\alpha+m_0*\beta)) \quad (3)$$

4. FUZZY BASED CLUSTERING PROTOCOLS

In this section we are discussing different energy efficient approaches for WSNs. The model of fuzzy logic control consists of a fuzzifier, fuzzy rules, fuzzy inference engine, and a defuzzifier shown in figure 2 [5]. We have used the most commonly used fuzzy inference technique called Mamdani Method due to its simplicity. The process is performed in four steps:

- Fuzzification - the input variables in which crisp values are converted into fuzzified values based on degree of membership grade it belong to a particular interest.
- Rule evaluation - taking the fuzzified inputs, and applying them to the antecedents of the fuzzy rules. It is then applied to the consequent membership function.
- Aggregation of the rule outputs - the process of unification of the outputs of all rules.
- Defuzzification - the input for the defuzzification process is the aggregate output fuzzy set and the output is a single crisp number.

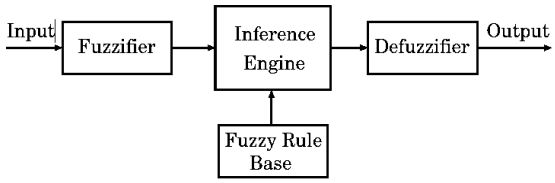

Figure 2 Fuzzy Logic Model

Gupta et.al [9] proposed to use three fuzzy descriptors (residual energy, concentration, and centrality) during the cluster-head selection. The concentration means the number of nodes present in the vicinity, while the centrality indicates a value which classifies the nodes based on how central the node is to the cluster. In every round, each sensor node forwards its clustering information to the base station at which the CHs are centrally selected. This mechanism is a centralized approach. Kim et.al [7] proposed a similar approach (namely CHEF: Cluster Head Election mechanism using Fuzzy logic), but in a distributed manner by using two fuzzy descriptors (residual energy and local distance). The local distance is the total distance between the tentative CH and the nodes within predefined constant competition radius. Hence, the base station does not need to collect clustering information from all sensor nodes. The local distance can by calculate by (4).

$$r = \sqrt{\frac{area}{\Pi \cdot n \cdot p}} \quad (4)$$

where, n is total number of nodes and p is probability factor as in LEACH.

Alkesh et.al [3] proposed a fuzzy logic based for lifetime enhancement in WSN using moving base station scheme. In this algorithm base station move on a predefined path and results are compared with when base station movement is random. The Fuzzy Inference System in this uses two linguistic input parameters as residual energy and distance from base station to decide towards which cluster head the base station will move. For cluster formation LEACH threshold value is used only the movement of BS is based on fuzzy logic. Singh et.al [2] proposed a cluster head selection approach using Fuzzy Logic. This protocol considers two parameters for the selection of a CH as energy and centrality. LEACH use only local information to take decision of cluster-head so using only local information has its own limitations. Since each node probabilistically elects whether or not to become cluster-head, there might be cases when two cluster-heads are selected in the closed proximity of each other. In reality considering only one factor like energy, is not suitable to elect the cluster-head properly. This is because other conditions like centrality of nodes corresponding to the entire cluster, gives an amount of the entire dissipation during transmission for all nodes too. The more central the node to a cluster the more is the energy efficiency for other nodes to transmit through that selected node.

Sharma et.al [1] proposed F-MCHEL (Fuzzy based Master Cluster Head Election Leach) strategy as an advancement in CHEF. Instead of transmission from number of cluster heads this approach select only one cluster head as a master CH on the basis of maximum energy. Like in CHEF, this approach utilizes two input parameter for FIS (Fuzzy Inference System) energy and proximity distance for the selection of cluster head out of these selected CH one Master cluster head will be selected and only this Master CH is responsible for collecting and aggregation data from various cluster heads and then forward to base station.

5. RESULTS & DISCUSSIONS

In this section we compare above discussed fuzzy based clustering protocols with LEACH on the basis of Table I that shows the rounds in which the first node died (FND) for each simulated algorithm.

Table I

Algorithm	FND
LEACH	1132
CHEF	1457
Moving BS Approach	1682
F-MCHEL	1952

Figure 3 represent a comparison as per Table I, this shows that there is a continuous improvement in the lifetime of WSNs indicating the proper utilization of energy resources of sensor nodes.

In this paper, a review of fuzzy based energy efficient protocols for WSNs has been discussed. Lastly, we conclude that the above discussed fuzzy based scheme considered homogenous environment in which all sensor nodes have same amount of energy. In future scope of this work, we can go for fuzzy based heterogeneous environment including mobile sensor

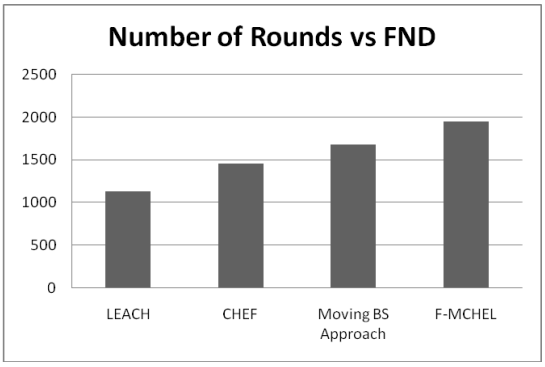

Figure 3 Numbers of Round vs. FND

nodes to replace the dead nodes to prolong the life cycle of wireless sensor network.

REFERENCES

[1] Sharma T., Kumar B., 2012. "F-MCHEL: Fuzzy Based Master Cluster Head Election Leach Protocol in Wireless Sensor Network", *International Journal of Computer Science and Telecommunications*, Vol. 3, Issue 10, pp. 8-13.

[2] Singh A.K., Goutele S., Verma S., Purohit N., 2012. "An Energy Efficient Approach for Clustering in WSN using Fuzzy Logic", *International Journal of Computer Applications*, Vol. 44, No. 18, pp. 8-12.

[3] Alkesh A., Singh A.K., Purohit N., 2011. "A Moving Base Station Strategy Using Fuzzy Logic for Lifetime Enhancement in Wireless Sensor Network", *IEEE International Conference on Communication Systems and Network Technologies*, pp. 198-202.

[4] Gupta M., Prasad D., Patel R.B., 2010. "FREEDOM: Fault Revoking and Energy Efficient Protocol for the Deployment of Mobile Sensor Nodes in Wireless Sensor Networks", *International Journal of Advanced Engineering Sciences and Technologies*, Vol. 1, Issue 1, pp. 001-009.

[5] Ando H., Barolli L., Durresi A., Xhafa F., Koyama A., 2010. "An Intelligent Fuzzy-based Cluster Head Selection for Wireless Sensor Networks and its Performance Evaluation", *13th International Conference on Network-Based Information Systems*, pp. 55-61.

[6] Kumar D., Aseri T.C., Patel R.B., 2009. "EEHC: Energy efficient heterogeneous clustering scheme for wireless sensor networks", *Elsevier Computer Communications Journal*, Vol. 32, Issue 4, pp. 662-667.

[7] Kim. J.M., Park S.H., Han Y., Chung T.M., 2008. "CHEF: Cluster Head Election mechanism using Fuzzy Logic in Wireless Sensor Networks", *Proceeding of International Conference on Advance Communications Technology*, pp. 654-659.

[8] Nguyen L.T., Defago X., Beuran R., Shinoda Y., 2008. "An Energy Efficient Routing Scheme for Mobile Wireless Sensor Networks", *IEEE ISWCS*, pp. 568-572.

[9] I. Gupta, D. Riordan, and S. Sampalli, 2005. "Cluster head election using fuzzy logic for wireless sensor networks," in *Proceeding of Annual Conference on Communication Networks Services*, pp. 255–260.

[10] Muruganathan S.D., Ma D.C.F., Bhasin R.I., Fapojuwo A.O., 2005. "A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks", *IEEE Radio Communications*, pp. S8-S13.

[11] Manjeshwar A., Agrawal D.P., 2002. "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks", *Proceeding of 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing*, pp. 195-202.

[12] Lindsey S., Raghavendra C.S., 2002. "PEGASIS: Power-Efficient Gathering in Sensor Information Systems", *Proceeding of IEEE Aerospace Conference*, pp. 1125-1130.

[13] Heinzelman W, Chandrakasan A, Balakrishnan H., 2002. "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", *IEEE Transactions on Wireless Communications*, Vol. 1, No. 4, pp. 660-670.

[14] Manjeshwar A., Agrawal D.P., 2001. "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks", *Proceedings of 15th International Symposium on Parallel and Distributed Processing*, pp. 2009-2015.

[15] Heinzelman W., Chandrakasan A., Balakrishnan H., "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", *Proceeding of 33rd Hawaii International Conference on System Sciences* held at Maui, USA pp. 3005-3014