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A Fuzzy System Based Intelligent Clustering For Wireless Sensor Networks

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ABSTRACT

Background: Wireless Sensor Networks (WSNs) are used in different civilian, military, and industrial applications. In order to collect information more efficiently, wireless sensor networks are partitioned into clusters. Clustering provides an effective way to prolong the lifetime of WSNs. Recently many routing protocols have been proposed attempting to find suitable routes to transmit data through clustered nodes in WSN. **Objective:** In this paper we propose a Fuzzy System based Intelligent Clustering Protocol that aims at clustering WSN so that routing data packets can be done through the clustered nodes. **Results:** The simulations were carried out in MATLAB and NS2 and the results shows the better performance of our algorithm compared to the other algorithms. **Conclusion:** The proposed algorithm is able to identify the clusters in the network very quickly and thereby extending the network lifetime effectively due to unequal clustering.

INTRODUCTION

WSNs are envisaged to become a very significant enabling technology in many sectors as they are widely used in many civilian and military as well as industrial applications (Biradar *et al*., 2009, Jamalipour *et al*., 2009). Unlike traditional wireless communication networks, WSN has its own characteristics. It consists of small, low cost, and low power sensors. Each sensor is embedded with a microprocessor and a wireless transceiver to provide data processing and communication capabilities besides its sensing facility. The significant interest in WSNs comes from its importance in many applications. In the healthcare sector, for example, WSNs are used in different applications such as patients monitoring, diseases diagnosis and management, and elderly people homecare (Jamalipour *et al*., 2009, McGrath *et al*., 2010, Pandian 2008, Alemdar et. Al., 2010). As in medical applications, WSNs have a significant role in military applications (Diamond *et al*., 2007, Winkler *et al*., 2008). They can be used in battlefield monitoring, intelligent guiding, and remote sensing to sense chemical weapons and detect enemies' attacks. In industrial applications WSNs are successfully used to monitor manufacturing processes such as products quality and monitoring equipments status (Jamalipour *et al*., 2009, Shen et.al., 2004).

Sensor nodes expend energy while gathering, processing and transmitting information. In the greater part of the cases, these sensor nodes are equipped with batteries which are not rechargeable. Subsequently, the power of the sensor nodes is to be utilized productively to prolong the lifetime of the network. Cluster based design is one of the ways to deal with to save the energy of the sensor devices. Clustering in WSNs ensures essential execution accomplishment with a substantial number of sensor nodes. It also improves the scalability of WSNs.

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In a cluster based design, the sensor nodes are grouped together progressively in clusters. Each cluster has a cluster head (CH) which is allowed to communicate with the base station (BS) or sink. Many researchers have proposed and developed many clustering protocols. The main objective of these clustering protocols is to maximize network lifetime (Rohini and Gunamurthy, 2015). To prolong the lifetime of wireless sensor networks, the clustering algorithm must be designed to achieve both energy efficiency and energy balance together. However, it is hard to optimize energy efficiency and energy balance simultaneously, which is difficult to be accurately described by mathematical model. How to realize the optimal combination of energy efficiency and energy balance is the key issue to extend the network lifetime. Fuzzy logic, on the other hand, has potential for dealing with conflicting situations and imprecision in data using heuristic human reasoning without needing complex mathematical model (Haider *et al*., 2009).

Thus, in this paper we have used the fuzzy c-means algorithm for cluster identification, so as to optimize the usage of energy in the entire network and thereby extending the network lifetime in an effective manner.

Background Study:

Heinzelman *et al*.,(2000) proposed the first clustering routing protocol for WSNs called Low-energy Adaptive Clustering Hierarchy (LEACH). The key idea of this protocol is to select randomly a set of sensor nodes as cluster head and rotate this task to uniformly distribute the energy load among the nodes in the network. There are two phases of LEACH protocol: The setup and steady phases. Firstly, in the setup phase clusters are formed and the cluster head (CH) selection is performed by the member nodes. Secondly the cluster head (CH) compress the gathered data from diverse nodes that belong to the respective cluster. Then the cluster head forwards aggregated data to the base station by single hop communication. Multiple variants of LEACH protocol are proposed to overcome some drawbacks of this protocol such as: LEACH-C by Heinzelman *et al*., (2002), MRLEACH (Dogar *et al*., 2010) and HEED (Younis *et al*., 2004). Bagci and Yazici (2010) proposed another fuzzy based protocol named as EAUCF (Energy-Aware Unequal Clustering with Fuzzy), where the selection of tentative CH is almost like LEACH. BrittoRaj *et al*., (2016) proposed a clustering based protocol which aims at minimizing the overall network overhead and energy expenditure associated with the multihop data retrieval process while also ensuring balanced energy consumption among sensor nodes and prolonged network lifetime.

Distributed Unequal Clustering using Fuzzy logic (DUCF) proposed by Baranidharan and Santhi (2016) elects CHs using fuzzy approach. DUCF forms unequal clusters to balance the energy consumption among the CHs. Fuzzy inference system (FIS) in DUCF uses the residual energy, node degree and distance to BS as input variables for CH election. Chance and size are the output fuzzy parameters in DUCF. DUCF assigns the maximum limit (size) of a number of member nodes for a CH by considering its input fuzzy parameters. The smaller cluster size is assigned for CHs which are nearer to BS since it acts as a router for other distant CHs. DUCF ensures load balancing among the clusters by varying the cluster size of its CH nodes. DUCF uses Mamdani method for fuzzy inference and Centroid method for defuzzification. Logambigai and Kanan (2016) proposed an algorithm called fuzzy based unequal clustering (FBUC) which is an improvement of fuzzy energy-aware unequal clustering algorithm.

Researchers have compared algorithms DUCF and FBUC with LEACH and EAUCF and found DUCF and FBUC to be better algorithms. Both DUCF and FBUC use unequal clustering approach. According to Liao *et al*.(2013) the unequal clustering approach proves to be better than equal clustering in most forms of deployments. Thus, in this paper the proposed Fuzzy System Based Intelligent Clustering Protocol uses unequal clustering .The major advantages of the proposed system are reduction in cluster formation delay, an enhanced life time of node and reduced power consumption.

Fuzzy System based Intelligent Clustering Protocol:

This protocol considers network applications in which sensor nodes are deployed randomly in order to continuously monitor the environment. This method works well when the locations of the nodes are overlapping. The algorithm for clustering based on fuzzy c-means method is shown in Algorithm 1.

Let NC be the total number of clusters;

Let C_i be the centroid for cluster i, where $i = 1.....NC$;

Randomly initialize the membership matrix U, such that $\sum_{i=1}^{NC} u_{ij}$, $\forall j = 1,...,n$;

$$C_i = \frac{\sum_{j=1}^{n} u_{ij}^m x_j}{\sum_{j=1}^{n} u_{ij}^m}, \text{ where } m \in [1, \infty);$$

Compute d_{ij};

/* d_{ij} *is the Euclidian distance between* i^{th} *centroid and* j^{th} *node */*

Compute dissimilarity function $J(U, C_i) = \sum_{i=1}^{NC} J_i$

$$= \sum_{i=1}^{NC} \sum_{j=1}^{n} u_{ij}^m d_{ij}^2;$$

Compute new U, where $u_{ij} = \frac{1}{\sum_{k=1}^{NC} \left(\frac{d_{ij}}{d_{kj}} \right)^{2/(m-1)}}$;

Perform the above steps until cluster identification is over;

Algorithm 1. Cluster Identification Algorithm:

The algorithm starts with an initial guess for the cluster centers which are intended to mark the mean location of each cluster. In addition, the algorithm assigns a membership grade for every data point in each cluster. By iteratively updating the cluster centers and the membership grades for each node, the algorithm moves the cluster centers to the right location within a data set. This iteration is based on minimizing an objective function that represents the distance from any given node to a cluster center, weighted by that node's membership grade. A list of cluster centers and several membership grades for each node is the output of the algorithm. The algorithm employs fuzzy partitioning such that a node can belong to all groups with different membership grades between 0 and 1.

RESULTS AND DISCUSSION

The proposed fuzzy based unequal clustering algorithm has been evaluated using MATLAB since the MATLAB Fuzzy Tool box considers all types of fuzzy membership functions and hence is more suitable for implementation. We considered fifteen nodes that are generated randomly as 3 sets of clustered data points. These data points are plotted in Figure 1.

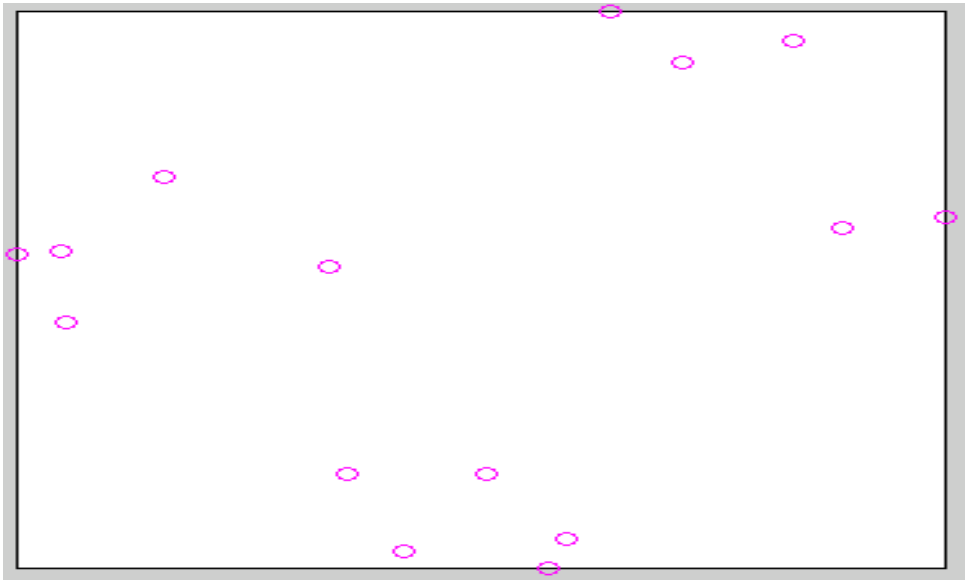


Fig. 1: Location of the nodes for cluster identification

The Membership Function (MF) for various clusters are plotted in Figure 2. The Fuzzy C-Means method is useful when the locations of the node set are overlapping.

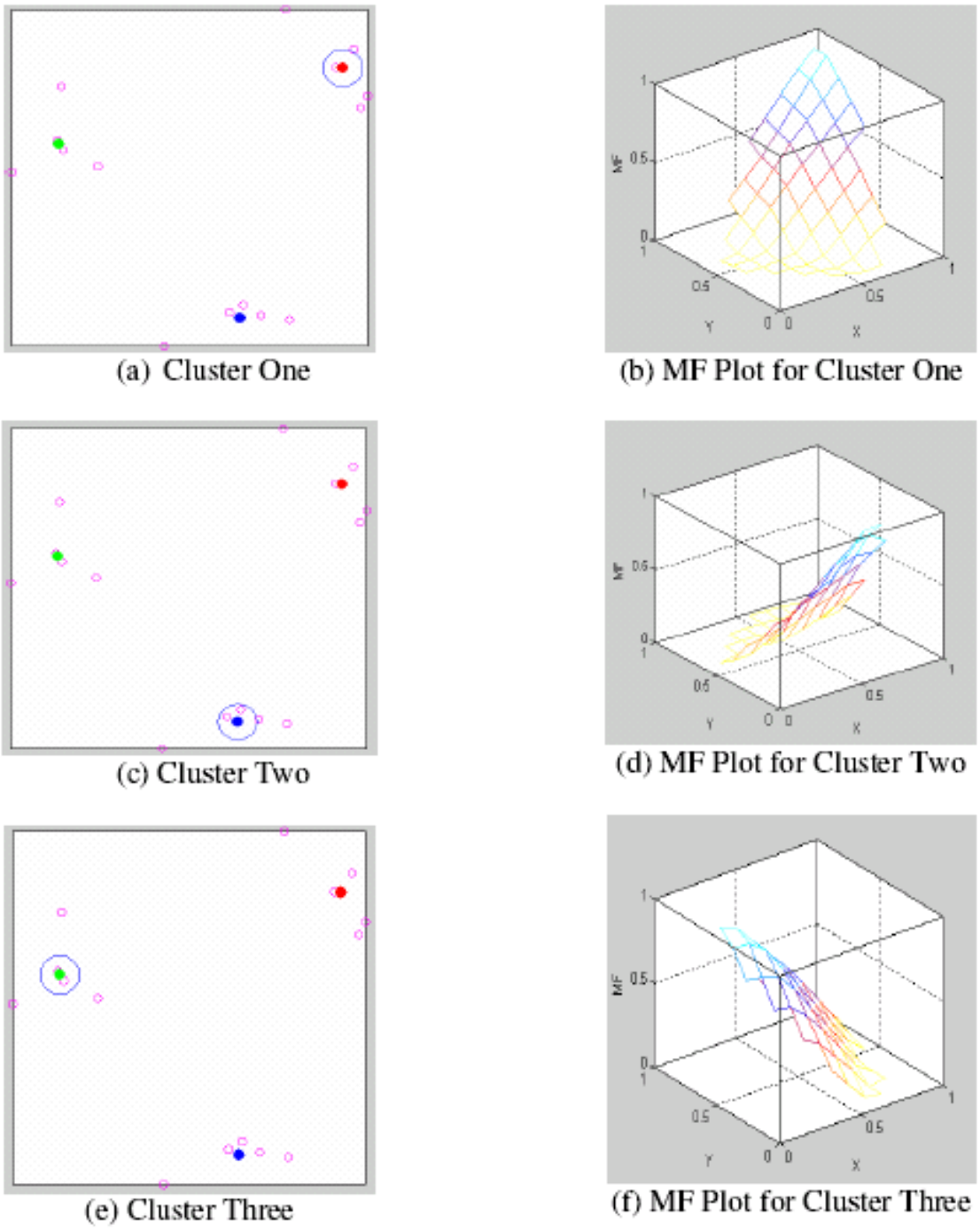
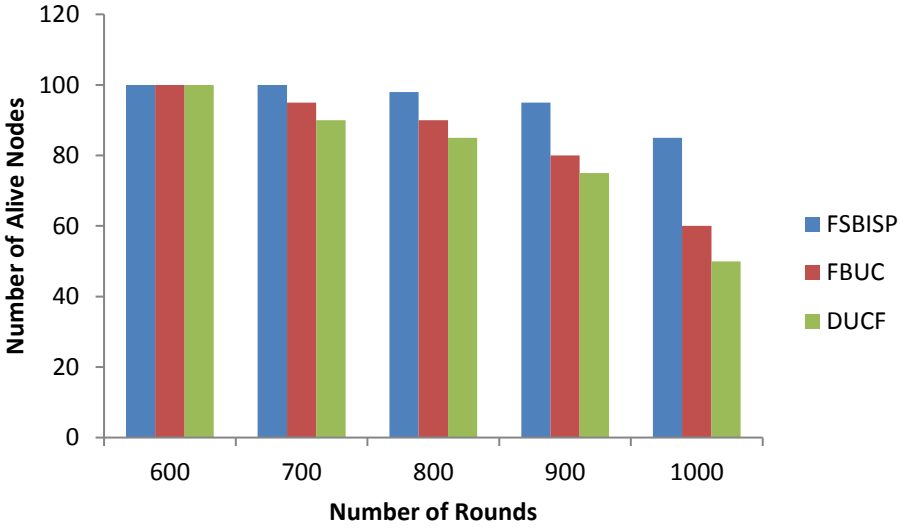
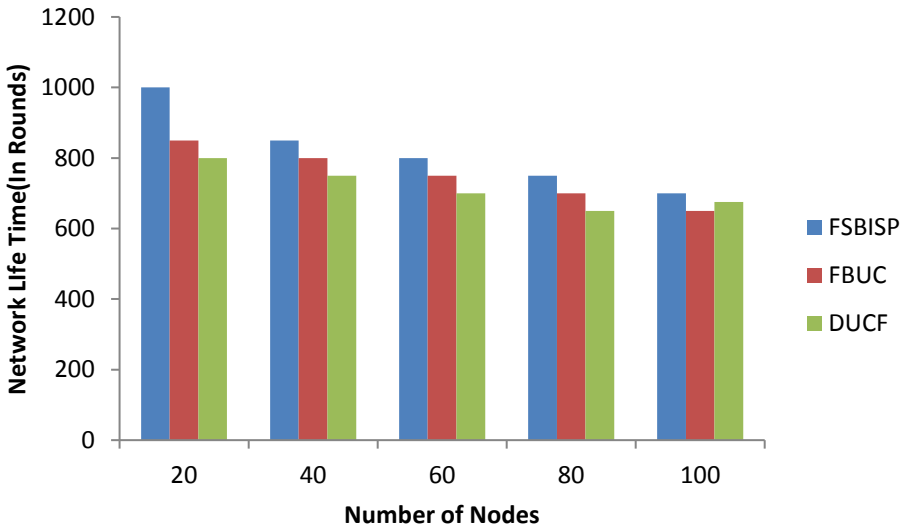


Fig. 2: MF Plot for cluster identification

We further used NS2 to compare our proposed Fuzzy System based Intelligent Clustering Protocol (FSBICP) with DUCF and FBUC. We considered 100 sensor nodes deployed over an area of (200 X 200) m^2. We assumed the initial energy of each sensor node as 0.5 J. The experimental results shown in Figure 3 indicate that FSBICP performs better than other clustering algorithms. FSBICP ensures more number of alive nodes thereby improving the network lifetime compared with its other counterparts.



a) Alive Node Details



b) Network Life Time Details

Fig. 3: Comparative Results

Conclusion:

In this paper we have proposed a Fuzzy System based Intelligent Clustering Protocol that can identify all the clusters in the network. The identified clusters are used to transmit data packets across the network. The members are made to join a cluster based on fuzzy c-means algorithm. Simulations were carried out using MATLAB and NS2 to evaluate the proposed protocol. The results showed that the proposed protocol performs better than the other existing protocols in terms of number of alive nodes and network life time.

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