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Improved Fuzzy Based Clustering Algorithm for Wireless Sensor Networks

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Abstract: Clustering is most efficient technique to reduce energy consumption for Wireless Sensor Networks (WSN). The Cluster Heads (CH) are selected in each cluster and nodes belonging to that cluster will aggregate their data to the cluster head. In this study, improved version of MOFCA protocol is introduced which addressed the issue of energy consumption in WSN. The improved MOFCA is the fuzzy clustering algorithm which includes node density, remaining energy, node mobility and distance from Base Station (BS) as input parameters to generate final output in terms of node radius. The simulation of improved MOFCA is done in MATLAB and compared with MOFCA. It has been analyzed that efficiency of improved MOFCA is increased after introducing node mobility parameter in the fuzzy rules.

Key words: WSN, clustering, multi-objective, fuzzy rules, energy

INTRODUCTION

WSN have Sensor Nodes (SN) which are small in size, cheap and also have self-contained battery powered systems. The input received from adjacent sensor is processed by the sensor nodes. Further, the result is transmitted to transit network within the network. There are various resource constraints such as low amount of energy, low bandwidth, storage and low processing present within each node of a WSN (Al Rubeaai *et al*., 2016). There a certain design constraints as well which are completely depend on application and are also based on the monitored surroundings. It completely depends on the surroundings to define the deployment scheme, network topology as well as the size determination of the network. The few nodes required for the internal environments where as a large number of nodes are required for the external environments. The SN can communicate with one another or also with the external BS of a network. The important part of a node is the battery which is very important as it affects the network's lifetime directly (Tolle *et al*., 2005). There are various energy-optimized solutions proposed at various levels of the system for improving the battery consumptions of sensor nodes.

There are various applications which use WSN and also include non-conventional paradigms which help in protocol design which involve various constraints. There are various categories according to which the routing protocols are classified (Werner *et al*., 2006). The reactive and proactive are one of the types of classifications of routing protocols. Before the demand of a routing traffic the routing paths as well as the states are provided in the network using the proactive routing protocols. The protocols which trigger the routing actions when the data is to be sent to various nodes are known as the reactive routing protocols. On the basis of their initiation which is source-initiation (Src-initiated) or destination initiation (Dst-initiated) the routing protocols are classified. On the demand of source node, the source-initiated protocol provides the routing path which begins from the source node. The routing path is initiated from the destination node in case of destination-initiated protocol. On the basis of the sensor network architecture also the routing protocols are classified which are the homogeneous nodes as well as the heterogeneous nodes (Li and Liu, 2009).

LEACH protocol: The hierarchical protocol with the help of which the nodes are transmitted to cluster heads is known as the Low Energy Adaptive Clustering Hierarchy (LEACH). Its two phases are explained below (Xu *et al*., 2004).

The setup phase: The organization of clusters and selection of cluster heads is done within this phase. With the help of a stochastic algorithm within each round (Vicaire *et al*., 2009) each node is checked to be chosen as a cluster head. Each node can be chosen only once as a CH and cannot be repeatedly elected as one.

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The steady phase: The data is transmitted to the BS in this phase. For reducing the overhead across the network, the time duration of this phase is longer than the previous one.

MOFCA protocol: In order to create a wireless sensor network that is distribution independent along with its property of being energy efficient a novel technique has been evolved. An efficient method which gathers data considering the energy consumption as a parameter in the network is known as clustering technique. The gathered data is transmitted to a CH to which the node belongs within the clustered networks. Once the data is gathered by the CH amongst all the member nodes, the gathered data is forwarded to the bs. The transmitted data can be in a compressed of uncompressed form. Through the cluster heads, the data is transmitted within the multi-hop network scenario. Due to the huge inter-cluster dependency, the cluster-heads that are near to the sink deplete at much faster rate within such networks. This complete issue is named as hotspots problem. There are numerous unequal clustering methods being proposed for solving this issue. There are small sized clusters created by the unequal clustering methods when they are moving towards the sink. This helps in reducing the intra-cluster dependency within the network. Due to the modification in the area of node deployment, the energy-hole problem also arises here. There are no studies proposed on solving both of the issues within the uniform and non-uniform distributed networks. Here, Fuzzy Clustering Algorithm (MOFCA) in both static and mobile networks which solves both of the discussed issues. With the help of some common clustering algorithms a proper analysis on the performance is performed and the results are achieved. It is seen here that as compared to the already existing algorithms, the MOFCA technique provides better results within the same scenario. There are various efficiency metrics that provide estimation for the lifetime of WSN as well as the efficiency of the protocols.

For generating a system model, various assumptions are made that are listed below: all the nodes present within the network are identical. There is a manual deployment of the nodes which further generates a non-uniform distribution manually or in a random manner. Within the Area-of-Interest (AOI) the base station can be located anywhere. There is no need of locating the base station far from the sensing region. There are however, chances of the presence of base station out of AOI.

Once the deployment phase is completed, movement can occur within the sensor nodes. The initial position of the remote control is not necessarily changed due to the mobility of nodes. Due to the terrestrial movements there are various changes occurring within the network such as erosion or displacement which is mainly due to external objects. The networks being evolved are also targeted through this assumption.

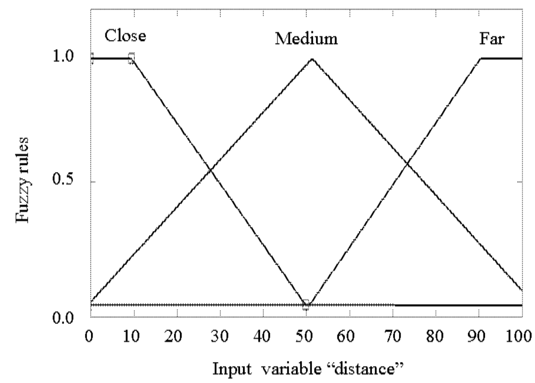

Fig. 1: Variable distance defined through fuzzy rules

There are various external sources to be created due to the assumptions of mobility. The energy consumption by the nodes is not caused here. When the nodes are developed, there is similar amount of energy in all the sensor nodes. There is one Joule of battery-power at the first point. For the purpose of adjusting transmission power the nodes provide it as per the distance of the receiving nodes. As per the received signal strength, the distance between the nodes can be computed:

$$E^{TX}(l, d) = \begin{cases} lE_{elec} + l_{efs} d^2, & d < d_0 \\ lE_{elec} + l_{emp} d^4, & d \geq d_0 \end{cases}$$

As shown in Fig. 1, the fuzzy set which defines the input variables is presented. The CH competition radius is computed with the help of descriptors which are the three fuzzy input variables. The initial variable is the the BS distance. There are close, medium as well as far present fuzzy sets related to the linguistic variables. There is a trapezoidal membership function chosen for the fuzzy sets near and far. In case of medium distance of membership function, the triangular membership function is utilized.

As shown in Fig. 2, the input variable that is presented by the fuzzy set is depicted. The number second fuzzy input variable provided is the left energy of CH. There are low, medium as well as high linguistic variables within the fuzzy set. A trapezoidal membership function is presented for the low as well as higher linguistic variables. Using the medium set, the triangular membership function is chosen.

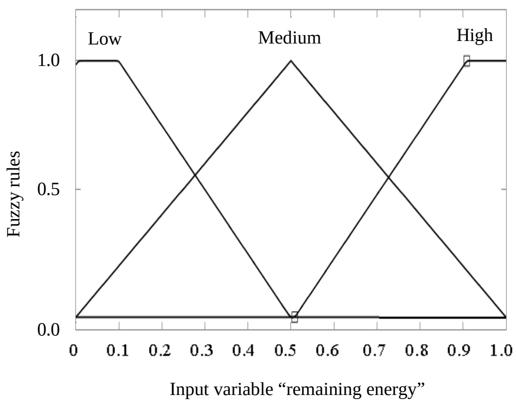

Fig. 2: Variable left energy defined through fuzzy rules

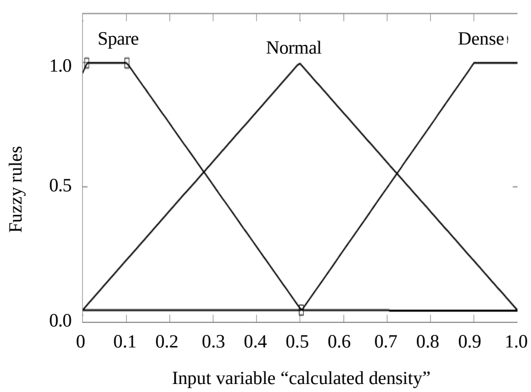

Fig. 3: Variable density defined through fuzzy rules

As shown in Fig. 3, the fuzzy set which shows the third fuzzy input variable which is the density of the unconfirmed CH that represents the density of input variable. The variables of the particular fuzzy set are sparse, normal and dense. For the normal the triangular membership is utilized. However, the trapezoidal membership is utilized for sparse as well as dense linguistic variables:

$$d_i = \frac{\text{Total alive nodes in radius}}{\text{All alive nodes in network}}$$

As shown in Fig. 4, the fuzzy set is presented which defines the output variable. The competitive radius of the unconfirmed CH is the only fuzzy output variable present. The 27 number of linguistic variables are presented here. They are 12xs that is extra small. The trapezoidal membership function is adopted by 12xs and 12xl. The triangular membership functions are utilized for rest of the linguistic variables. As shown, the functions are not in the form of symmetric triangular function which is due to the enhanced results achieved by the simulations performed.

Table 1: MOFCA protocol utilizing fuzzy rules

Base station distance	Energy remaining	Node density	Competition radius
Close	Low	Dense	12xs
Close	Low	Normal	11xs
Close	Low	Sparse	10xs
Close	Medium	Dense	9xs
Close	Medium	Normal	8xs
Close	Medium	Sparse	7xs
Close	High	Dense	6xs
Close	High	Normal	5xs
Close	High	Sparse	4xs
Medium	Low	Dense	3xs
Medium	Low	Normal	2xs
Medium	Low	Sparse	xs (Extra small)
Medium	Medium	Sparse	s (Small)
Medium	Medium	Normal	m (Medium)
Medium	Medium	Dense	l (Large)
Medium	High	Sparse	xl (Extra large)
Medium	High	Normal	2xl
Medium	High	Dense	3xl
Far	Low	Sparse	4xl
Far	Low	Normal	5xl
Far	Low	Dense	6xl
Far	Medium	Sparse	7xl
Far	Medium	Normal	8xl
Far	Medium	Dense	9xl
Far	High	Sparse	10xl
Far	High	Normal	11xl
Far	High	Dense	12xl

In Table 1, the fuzzy rules are provided. For the purpose of analyzing the various rules, the Mamdani controller is used which provides the fuzzy related scheme. The Center of Area (COA) helps in providing the defuzzification of the comparative radius.

Literature review: A trust and energy aware routing Protocol is the method utilized for the purpose of detection and isolation of malicious nodes (Ahmed *et al*., 2015). This distributed trust model is used. According to, the simulation results achieved there is a reduction in the energy consumption, enhancement in the throughput as well as lifetime of the network when the this is used as compared to other protocols.

A directional transmission based energy aware routing protocol named as PDORP is proposed (Brar *et al*., 2016). The properties of Power Efficient Gathering Sensor Information System (PEGASIS) as well as DSR routing protocols are combined. There is also an improvement in the throughput which results in providing better QoS and which further results in increasing the lifetime of the network.

For various underwater applications, the Underwater WSNs (UWSNs) are being used a lot. The routing protocols are classified into two categories on the basis

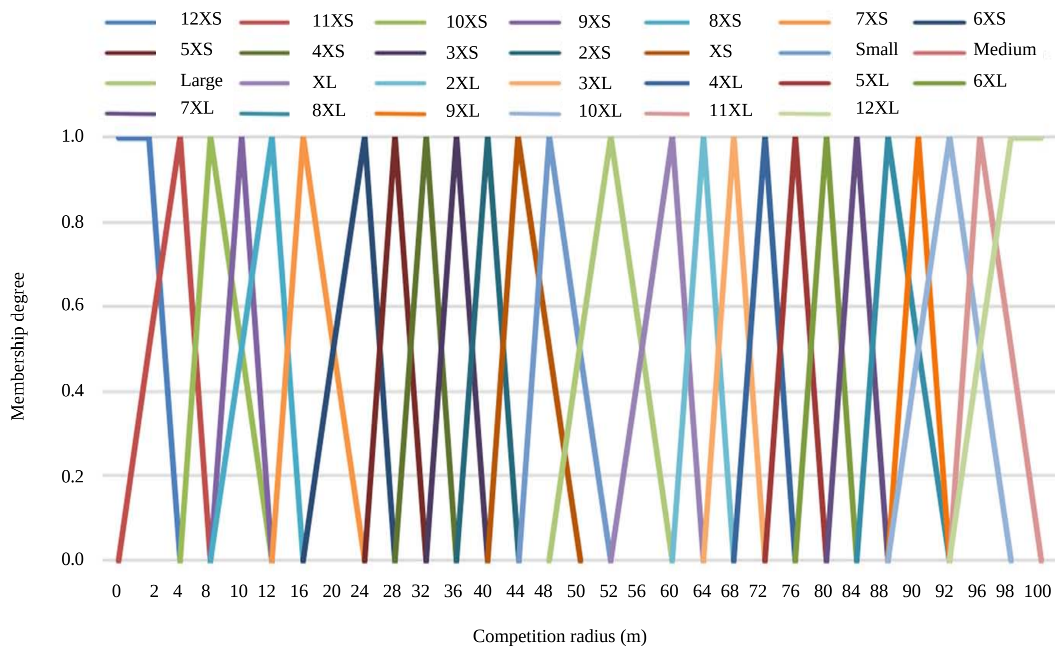

Fig. 4: Competition radius defined using fuzzy set of rules

of the route decision maker they use (Han *et al*., 2015). The results have shown that there are still many enhancements to be made in this technology. In the future work, new technologies are to be evolved to provide better results.

A novel design of secure end-to-end data communication is proposed (Harn *et al*., 2016). A newly designed group key pre-distribution method is proposed here which provides a unique group key which is also known as the path key. Through this protocol, the time which is needed to process data through intermediate nodes is reduced which is an important advantage here.

It is very important to increase the lifetime of a network due to the limited battery available in the sensors (Yan *et al*., 2016). The mobile WSNs provide more enhanced results as compared to the static WSNs which result in improvement. The implementations as well as the deployment costs increase however in these types of networks.

Due to the huge inter-cluster dependency, the CHs that are near to the sink deplete at much faster rate within such networks (Sert *et al*., 2015). This complete issue is named as hotspots problem. Here, Fuzzy Clustering Algorithm (MOFCA) in both static and mobile networks which solves both of the discussed issues.

MATERIALS AND METHODS

The proposed technique is based to improve the efficiency of WSN. The mobility of the SN are created using the random way point model. The fuzzy rules are generated which shown Fig. 5 which define node radius is according to node mobility.

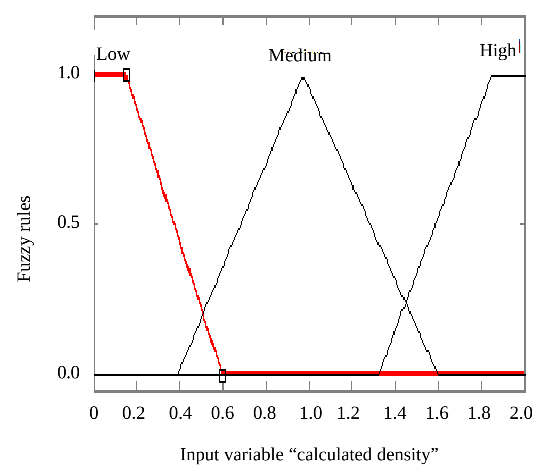

Fig. 5: Fuzzy set defining the fuzzy input variable mobility

As shown in Fig. 5, the input variable that is presented by the fuzzy set is depicted. The mobility of the sensor node is the secondary fuzzy input variable given. There are three types of linguistic variables which are low, medium as well as high. For the purpose of minimizing energy consumption within the network, the novel mobility parameter is added to the existing MOFCA protocol. The fuzzy rules for the improved MOFCA algorithm are shown in Table 2.

Table 2: Fuzzy rules for improved MOFCA protocol

Distance to the base station	Remaining energy	Calculated density	Node mobility	Competition radius
Close	Low	Dense	Low	12xs
Close	Low	Normal	Low	11xs
Close	Low	Sparse	Low	10xs
Close	Medium	Dense	Medium	9xs
Close	Medium	Normal	Medium	8xs
Close	Medium	Sparse	Medium	7xs
Close	High	Dense	High	6xs
Close	High	Normal	High	5xs
Close	High	Sparse	High	4xs
Medium	Low	Dense	Low	3xs
Medium	Low	Normal	Low	2xs
Medium	Low	Sparse	Low	xs (Extra small)
Medium	Medium	Sparse	Medium	s (Small)
Medium	Medium	Normal	Medium	m (Medium)
Medium	Medium	Dense	Medium	l (Large)
Medium	High	Sparse	High	xl (Extra Large)
Medium	High	Normal	High	2xl
Medium	High	Dense	High	3xl
Far	Low	Sparse	Low	4xl
Far	Low	Normal	Low	5xl
Far	Low	Dense	Low	6xl
Far	Medium	Sparse	Medium	7xl
Far	Medium	Normal	Medium	8xl
Far	Medium	Dense	Medium	9xl
Far	High	Sparse	High	10xl
Far	High	Normal	High	11xl
Far	High	Dense	High	12xl

RESULTS AND DISCUSSION

Here, the simulation of MOFCA and improved MOFCA is done to obtain the results of both protocols. The nodes are randomly deployed in the particular area. The CH in the network are selected using the probability based protocol. The CHs in the network is the 10 % of the total number of nodes in the networks. The numbers of nodes taken for simulation are 100 sensor nodes.

As shown in the Fig. 6, performance of MOFCA protocol and improved MOFCA is analyzed on different set of initial energy. It is been analyzed that improvement MOFCA perform batter in terms of number of rounds for the dead nodes.

Table 3 compares the existing and proposed approach in relation of the dead time of last node. In case of the proposed work, the numbers of rounds for last dead node are higher as compared to the existing approach as per the results achieved. As shown in Fig. 7, the performance of proposed MOFCA protocol is compared with existing MOFCA protocol and it is been analyzed that more number of packets get transmitted in the proposed protocol as compared to existing protocol.

Table 4 provides a comparative scenario which provides the difference amongst the existing and proposed methods in terms of the transmission of packets to the base station. Within the proposed work, the numbers of packets sent to the base station are more as compared to the existing method.

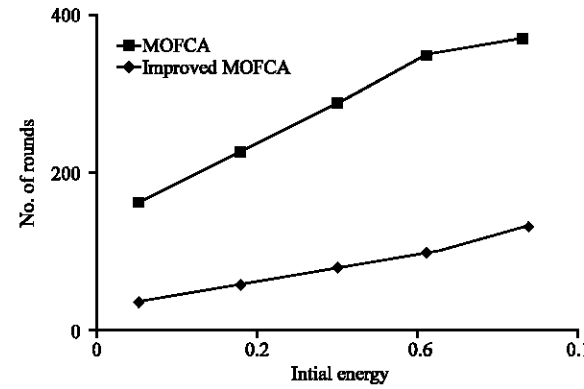

Fig. 6: Energy comparison

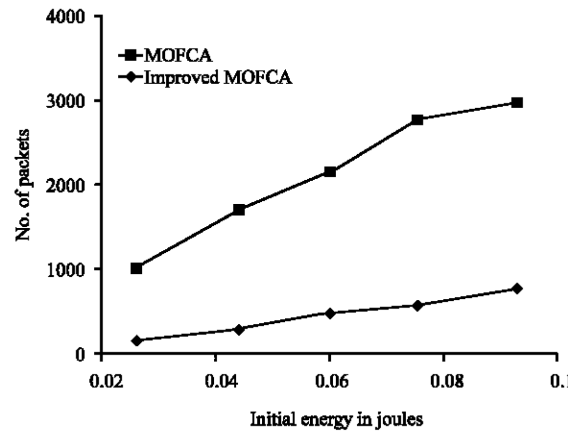

Fig. 7: Packet transmitted comparison

Table 3: Existingp and proposed approach

Energy Initial energy	Existing MOFCAWSN	Proposed Improved MOFCA WSN
0.02	31	155
0.04	47	221
0.06	78	281
0.08	98	351
0.10	131	366

Table 4: Comparative scenario

Energy Initial energy	Existing MOFCAWSN	Proposed Improved MOFCA WSN
0.02	192	1084
0.04	319	1647
0.06	514	2173
0.08	610	2825
0.10	800	3007

CONCLUSION

In this research, fuzzy clustering algorithm is been proposed which is the improved version of MOFCA fuzzy clustering algorithm. The proposed algorithm considers the energy remaining, base station distance, density of nodes and mobility to define radius of the sensor nodes which remove uncertainties from the WSN. The simulation is been performed in MATLAB results shows that on different initial energy values half number of nodes get dead as compared to proposed MOFCA protocol. The packets transmitted to base station also increased in the improved MOFCA protocol as compared to existing MOFCA protocol.

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