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Enhanced Cluster Based Energy Efficient Routing Protocol for Mobile Wireless Sensor Network

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Abstract: Mobile Wireless Sensor Networks have gained great attention in recent years due to their ability to offer effective and economical solutions in a variety of fields. Energy saving is the critical issue while designing the mobile wireless sensor networks. In order to enhance the network lifetime there are many routing protocols have been developed. One of these is clustering based in which network is partitioned into small clusters and each cluster is examined and controlled by a single node called Cluster Head (CH). An efficient method for clustering and appropriate cluster head election can drastically reduce the energy consumption and enhance the lifetime of the network. In this paper, a modified fuzzy C-means clustering method for uniformly cluster the sensor nodes and reduce the transmission distance, and a dual stage fuzzy logic approach for cluster head election is proposed. The proposed protocol selects the nodes with the highest residual energy, lowest mobility, highest node concentration and least distance from the center of the cluster as CH. The simulation results showed the proposed protocol improvement over the previous works in this field, LEACH-M and LEACH-ME in terms of number of alive nodes; the first node dies in LEACH-M and LEACH-ME at round 12 and 16 while the first node dies in proposed proactive and reactive protocol at round 30 and 61, number of times cluster head failed in transmission, average energy consumption, packet delivery ratio and the total number of packets transmitted. Finally, the proposed protocol is evaluated and compared with LEACH-M and LEACH-ME in MATLAB.

Keywords: Mobile Wireless Sensor Network, Fuzzy logic, Modified Fuzzy C-means, Energy-efficient, Network lifetime.

I. INTRODUCTION

Wireless Sensor Networks (WSNs) have been identified as one of the most important technologies for the 21st century [1]. It is a sensing technology where tiny devices called sensor nodes or motes are deployed in a remote area to detect phenomena, collect and process data and transmit sensed information to users.

The primary goal in designing WSNs is maximizing network lifetime as the main power source for all nodes is a battery; the energy supply for each sensor node is constrained and it is impractical to change or replace exhausted batteries. Such constraint necessitates energy awareness in designing WSNs. Therefore, many routing protocols have been proposed due to the challenges in designing an energy efficient network. Among all the proposed methods, hierarchical routing protocols greatly satisfy the limitations and constraints in WSNs [**2**]. Hierarchical routing protocols, also known as cluster-based routing, are mainly considered as a two-layer architecture where one layer is engaged in cluster head selection and the other layer is responsible for routing. A Cluster Head (CH) in hierarchical routing is the node, which is responsible for collecting data from other nodes in the cluster, aggregating all data and sending the aggregated data to the base station.

Apart from static deployment scenarios of sensor nodes, mobile wireless sensor networks have gained significant attention recently. Mobile sensors are very effective in random deployment of sensors in many potential working environments, such as disaster relief operations, hostile areas, object tracking, remote harsh fields, and contaminated urban regions, where manual deployment of sensor may not be possible.

The proposed protocol that performs in this paper is a cluster-based routing protocol, which consists of a number of rounds with two phases in each round, setup phase and steady-state phase. In setup phase, base station will apply modified fuzzy C-means clustering technique to uniformly cluster the sensor nodes, and a dual stage fuzzy logic approach for cluster head election to elect the best node in the cluster as a cluster head. The election of cluster head is based on two stages, in the first stage two primary parameters are used: energy level and mobility factor of each node, which is calculated from three parameters; speed, relative mobility and transition count, while in the second stage: chance output from the first stage, and two secondary parameters; node concentration and node centrality are used for calculate the final chance of each node to be cluster head and the node with the highest final chance in each cluster is elected as CH for that cluster. In steady-state phase, this paper takes the proactive and reactive data reporting models for data transfer. The nodes in the proactive network periodically sense the environment and transmit the data of interest. While in reactive networks, the nodes react only to sudden and drastic changes in the value of a sensed attribute. The simulation results had shown the improvement of the reactive behavior over the proactive behavior.

This paper is organized as follows: Section II brief some review related work. Section III illustrates the proposed

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protocol. Section IV discusses simulation environment and analysis of the results. Finally, in section V provides the conclusion.

II. RELATED WORK

One of the main constraints in mobile wireless sensor networks is limited battery power, which reduced the lifetime and the quality of the network. To avoid the energy consuming, the researchers have considered cluster-based approach for data transmission. For example, LEACH [**3**], LEACH-M [**4**], LEACH-ME [**5**], CBR-Mobile [**6**], ECBR-MWSN [**7**] and FTCP-MWSN [**8**] are called cluster based energy efficient protocols.

In LEACH [**3**], the nodes are organized themselves into local clusters. The operation is divided into rounds with two phases in each round. setup phase and steady-state phase. In the setup phase, the CHs are selected. While in steady-state phase, each non-CH node sends data to its CH and the cluster head nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station, but LEACH does not support mobility. LEACH is enhanced to support sensor nodes mobility by LEACH-Mobile [**4**] protocol which added membership declaration to the existing LEACH protocol. LEACH-ME Cluster head election has been improved by LEACH-Mobile Enhanced [**5**] (LEACH-ME) when the sensor node with minimum mobility factor is elected as cluster head. CBR-Mobile [**6**] supports the sensor nodes mobility by adaptively reassigning the timeslots according to sensor nodes mobility and traffic, but cluster head election in CBR-Mobile is the same as LEACH-M which depends on probability model. Enhanced Cluster Based Routing Protocol for Mobile Nodes in Wireless Sensor Network (ECBR-MWSN) [**7**] is a protocol where the CHs are elected using the parameters of highest residual energy, lowest mobility and least distance from the base station. And Fault Tolerant Clustering Protocol for Mobile WSN (FTCP-MWSN) [**8**] is a protocol that design for reliable and energy efficient routing for mobile wireless sensor networks.

III. THE IMPLEMENTATION OF PROPOSED PROTOCOL

The proposed routing protocol is implemented in a number of rounds with two phases in each round, setup phase and steady-state phase as shows in Fig. 1. In setup phase, cluster formation and CH are selected, while steady-state phase is the data transfer phase.

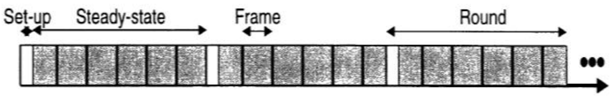

Fig. 1. Time line showing proposed protocol operation.

A. Setup Phase

Formation of clusters and cluster head election are the main goal of setup phase. The model of the proposed routing protocol with mobile nodes is shown in Fig. 2.

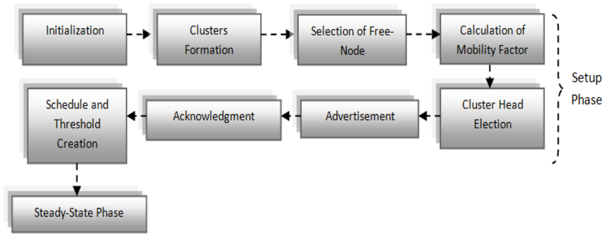

Fig. 2. Proposed mobile WSN protocol structure.

1. Initialization

Every sensor node sends a "HELLO" message to the base station in the beginning of the every setup phase which contains information about residual energy, location and transition count of node.

2. Cluster Formation

The sensor nodes are clustered by modified fuzzy C-means method (FCM). In fuzzy C-means algorithm, the initial means of points is decided randomly; while in the proposed protocol, the initial means of points is calculated, so the fuzzy C-means algorithm is modified by calculating the initial means of points. The setting of initial means of points is very important. It can reduce the iteration time for creating clusters significantly. Considering *n* sensor nodes in the network, let *C* be the center location for all sensor nodes and it can be calculated by:

$$C = \frac{\sum_{i=1}^{n} Xi}{n} \qquad (1)$$

Where X_i is the coordinate of sensor node *i*. Let *R* be the average distance between *C* and all sensor nodes. It can be calculated by:

$$R = \frac{\sum_{i=1}^{n} |Xi - C|}{n} \qquad (2)$$

According to *C* and *R*, the locations of initial mean of point mj (mj_x, mj_y) for the cluster *j* is calculated by:

$$mj_x = R \times \cos(\frac{360}{c} \times (j-1) \times \frac{\Pi}{180}) + Cx$$
$$mj_y = R \times \sin(\frac{360}{c} \times (j-1) \times \frac{\Pi}{180}) + Cy \qquad (3)$$

Where *c* is the number of clusters and *j* = 1, 2,..., *c*. where *c* is equal to c_{opt}. The initial value *c* decided in the first setup phase of the first round. With modified fuzzy C-means, the centroid of a cluster is computed as being the mean of all sensor points, weighted by their degree of belonging to the cluster. By iteratively updating the membership U_{ij} and the new means of point *mj* by (4) and (5), respectively, the modified fuzzy C-means algorithm iteratively moves the cluster centers to the right location.

$$Uij = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - m_j\|}{\|x_i - m_k\|} \right)^{\frac{2}{m-1}}} \qquad (4)$$

$$mj = \frac{\sum_{i=1}^{n} U_{ij}{}^{m} x_i}{\sum_{i=1}^{n} U_{ij}{}^{m}} \qquad (5)$$

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Where X_i is the coordinate of sensor node i, mj is the coordinate of the mean of point, parameter m is called the "fuzziness index", which is used to control the membership of each node, m is commonly set to 2, and U_{ij} is the degree of membership of X_i in the cluster j.
The iterative updating will stop when $|m_j^{k+1} - m_j^{k}| \leq \varepsilon$, where ε is a termination criterion between 0 and 1, whereas k is the iteration steps. In order to create uniform distributed clusters, the sensor nodes are classified into the clusters according to the maximal degree of membership. If the sensor node i has the maximal degree of the membership in cluster j in the k^{th} execution, the sensor node i will join the cluster j, which can be expressed by:

$$j^k=\{i: U_{ij}^k \geq U_{ij^*}^k \quad \text{for all } j^*=1,..., c\} \tag{6}$$

3. Selection of Free-Node
The free-node is a special node that has a job of receiving data packet from non-cluster head node that leave its cluster and send JOIN-REQUEST message to nearby cluster heads. In other words, receive packets from nodes that does not associate to any cluster. After free-node receive data from all lost nodes, then compress it and send single data packet to BS. BS elected the node nearest to the center of the nodes in the field as free-node and the radius of the free-node, i.e. the range as which the nodes in this range can send data packet to free-node is depend on three parameters for efficient usage of free-node energy and not waste its all energy. These parameters are energy of the node, distance from the center of all nodes and distance from the BS, which can be expressed by:

Free Node Radius =f (Node energy, Centrality, Distance to BS)

When the energy of the node is high and it is closest to the center of the nodes and base station, then radius of free-node is very large. After the election of free-node, this node assumes to be static during the round. The concept of free-node is apply only with the proactive classification of data transmission, since in the reactive behavior, data transfer depends on the range of interest of cluster head, so data packet from sensor node that leaves its cluster and does not a member of any cluster is not important since it is in location that does not known what the range of interest of that location cluster head until it is join a new cluster and known the range of interest of that cluster.

4. Calculation of Mobility Factor
Mobility is an important factor in deciding the cluster heads. In order to avoid frequent cluster head changes, it is desirable to elect a cluster head that does not move very quickly. When the cluster head moves fast, the nodes may be detached from the cluster head and join another cluster head; this case leads to decreasing the number of data packets exchange between the node and the corresponding cluster head. LEACH-ME depended on the concept of remoteness for calculate the mobility factor, but in LEACH-ME extra time slot, called ACTIVE slot needed, in which each node send their broadcast ID through this time slot, and also in LEACH-ME each node calculate its mobility factor which consume a lot of energy of sensor nodes. While in the proposed protocol the mobility factor is calculated by BS, which is more powerful than ordinary nodes and fuzzy logic approach is used to calculate the mobility factor. Three different parameters are used to calculate mobility factor. These parameters are: speed of the node, relative mobility of the node with respect to its neighbors and transition count of the node. The node with lowest speed, relative mobility and transition count has the lowest mobility factor. The mobility factor is calculated for all nodes except for free-node, which assume to be static during the round. To find speed S (s_i) of sensor node s_i, the following formula is used to compute it:

$$S(s_i) = \frac{\sqrt{(x_t - x_{t-1})^2 + (y_t - y_{t-1})^2}}{\Delta t} \tag{7}$$

Where (x_t, y_t) and (x_{t-1}, y_{t-1}) are the coordinate positions of node s_i at time t and t-1 and Δt is the interval time between t and t -1. The relative mobility metric of sensor node s_i, M (s_i) with respect to its neighbors is computed by:

$$M(s_i) = \frac{\sum_{j=1}^{N} |d_{ij}(t) - d_{ij}(t-1)|}{N} \tag{8}$$

Where $d_{ij}(t)$ and $d_{ij}(t$-1) are the distance between sensor node s_i and neighbor s_j at time t and time t-1, respectively, and N is the number of neighbors for sensor node s_i. The transition count is sent from the sensor node to BS in the HELLO message and it is calculated based on the number of times the node moves from one cluster to another during the five previous rounds.
The concept of fuzzy logic is based on four steps: fuzzification, rule evaluation, aggregation and defuzzification. The Mamdani fuzzy inference technique method is used for mobility factor calculation due to its simplicity. These four steps are used in Fuzzy Inference System (FIS) to calculate the mobility factor as follows:

1. Fuzzification of the input variables speed, relative mobility and transition count: The crisp inputs from each of these variables are taken and the degree to which these inputs belong to each of the appropriate fuzzy sets is determined. The linguistic variables used to represent the speed of the node and relative mobility are divided into three levels: slow, medium and fast, respectively, and there are three levels to represent the transition count of node: low, medium and high, respectively. The outcome to represent the node mobility factor was divided into nine levels: very Low (vL), Low, rather Low (rL), rather Medium (rM), Medium, high Medium (hM), rather High (rH), High, and very High (vH). The membership functions developed for inputs and

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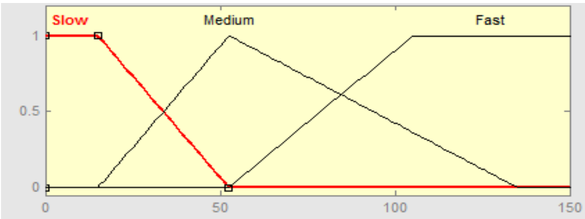
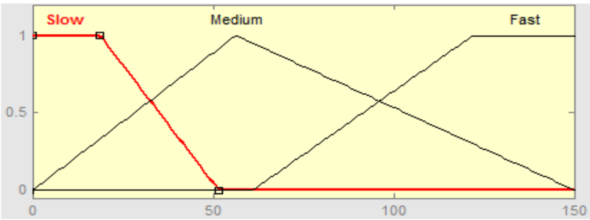
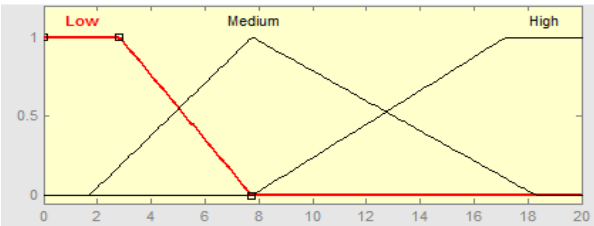
output and their corresponding linguistic states are represented in Fig. 3.



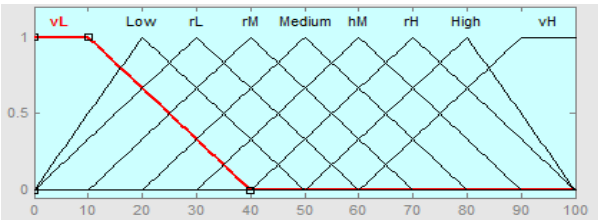
(a)



(b)



(c)



(d)

Fig. 3. Fuzzification functions: (a) Speed of the node (b) Relative mobility (c) Transition count (d) Mobility factor.

2. Rule evaluation: The membership values obtained from the fuzzification step will be supplied to IF-THEN rules to determine new fuzzy output set; these rules are shown in Table I.

TABLE I. FUZZY RULE BASE.

Rule No.	Speed	Relative mobility	Transition count	Mobility factor
1	slow	slow	low	vL
2	slow	slow	medium	L
3	slow	slow	high	rL
4	slow	medium	low	Low
5	slow	medium	medium	rL
6	slow	medium	high	rM
7	slow	fast	low	rL
8	slow	fast	medium	rM
9	slow	fast	high	Medium
10	medium	slow	low	rL
11	medium	slow	medium	rM
12	medium	slow	high	Medium
13	medium	medium	low	rM
14	medium	medium	medium	Medium
15	medium	medium	high	hM
16	medium	fast	low	Medium
17	medium	fast	medium	hM
18	medium	fast	high	rH
19	fast	slow	low	Medium
20	fast	slow	medium	hM
21	fast	slow	high	rH
22	fast	medium	low	hM
23	fast	medium	medium	rH
24	fast	medium	high	High
25	fast	fast	low	rH
26	fast	fast	medium	High
27	fast	fast	high	vH

3. Aggregation of the rule outputs: It is the process of the unification of the outputs of all rules.

4. Defuzzification: The last step is defuzzification, where the chance value for each sensor node will obtain. The input for the defuzzification process is the aggregate output fuzzy set mobility factor and the output is a single crisp number. The Center of Gravity (COG) or Centroid defuzzification method is used and it is calculated and estimated over a sample of points on the aggregate output membership function, using the following formula:

$$COG = \frac{\sum_{i=1}^{s} x_i \times \mu_A(x_i)}{\sum_{i=1}^{s} \mu_A(x_i)} \qquad (9)$$

Where s is the number of sample values of the output, x_i is the value of the output variable at the sample value and $\mu_A(x_i)$ is degree of membership function of fuzzy set A. The mobility factor of each node has been calculated and is used for cluster head election in the next step.

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5. Cluster Head Election

After the formation of clusters, cluster head has been elected using the dual stage fuzzy approach. BS computes chance for all nodes except for free-node. Fig. 4 shows the proposed model for fuzzy based cluster head election.

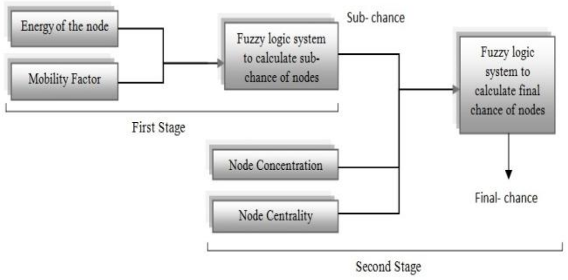


Fig. 4. Dual stage fuzzy logic system for cluster head election process.

Base Station computed the final chance of all the nodes except free-node and then nodes are compared based on final chance, and the node with the maximum final chance in a cluster is then elected as the cluster head for that cluster. If there are multiple nodes having the same maximum chance, to break the tie among them, the node having more energy is selected. Then the node having smallest mobility factor is selected. After the formation of clusters and cluster head election for each cluster, the BS broadcasts the routing information of the clusters to all sensor nodes. Hence, each sensor node knows its task (e.g., cluster head, non-cluster head or free-node). Also, BS broadcast location and ID of free-node to be known to all nodes and free-node should not leave its location during the round.

6. Advertisement

Cluster heads broadcasts an advertisement messages to all sensor nodes.

7. Acknowledgment

Non-cluster head node after receiving the advertisement message from cluster head, it sends an acknowledgment message to its CH to inform it that it is belong to it.

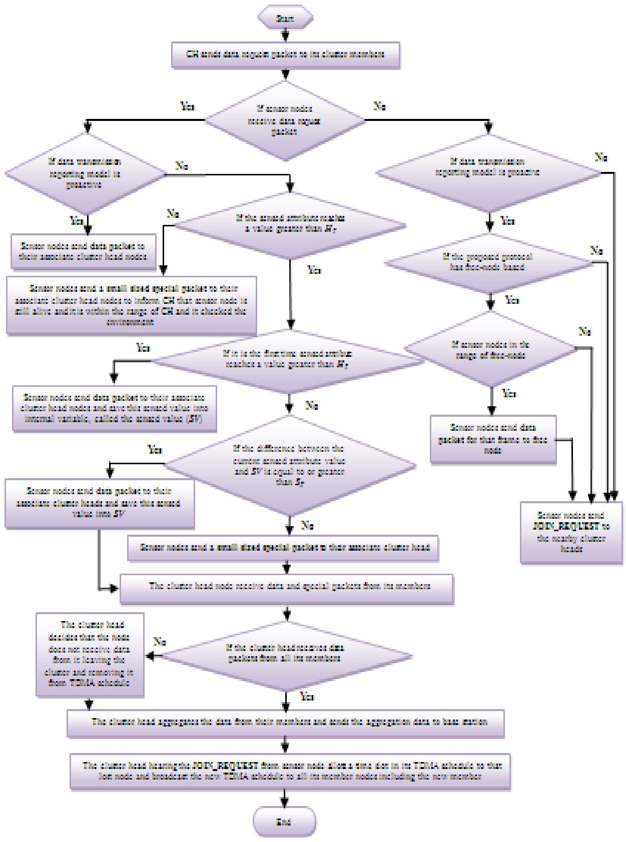
8. Schedule and Threshold Creation

After receiving the acknowledgment message from non-cluster head nodes, CHs makes the TDMA schedule to allocate the time for the cluster members and broadcast it to each sensor node in the cluster. For the reactive classification of data transmission, the cluster head broadcasts to its members two thresholds: ***Hard Threshold*** (H_T) and ***Soft Threshold*** (S_T). The hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest; above the hard threshold, while the soft threshold further reduces the number of transmissions by allowing the nodes to transmit only when there is a change above the hard threshold in the sensed attribute.

B. Steady-State Phase

For each round, steady-state phase consist of number of frames, in each frame a data transmission is occurred. Fig. 5 shows the flowchart of one frame.

After the end of one frame, another frame begins and so on. After the end of the last frame, steady-state phase ends and another round with new setup phase and steady-state phase is, begin.



IV. RESULTS AND PERFORMANCE ANALYSIS

The simulation was run on a computer system and the tool that is used to evaluate the proposed protocol is MATLAB. The simulation environment is consisting of 100 sensor nodes, which are distributed randomly within a 100×100 square region. Assume that nodes after deployment can change their position by following the random waypoint mobility model [**9**]. All simulation parameters that used in the proposed system are presented in Table II. For each sensor node, the energy is dissipated because of receiving and transmitting data. The energy dissipated in transmitter to transmit *K*-bit packet is given by:

$$E_{TX}(K,d) = \begin{cases} KE_{elec} + K\varepsilon_{fs} d^2 & if\, d < do \\ KE_{elec} + K\varepsilon_{mp} d^4 & if\, d \geq do \end{cases}$$

(10)

Where ,The threshold d_o is defined by:

$$do = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \qquad (11)$$

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• E_{elec} is the energy dissipated to run the electronics circuits.
• E_{fs} and E_{mp} are the characteristics of the transmitter amplifier.
• d is the distance between the two communicating ends.

Energy dissipation to receive a K-bit packet :

$$E_{RX}(K) = KE_{elec} \qquad (12)$$

In addition to above energy expansions, cluster head also dissipates energy because of data aggregation. The data aggregation energy is EDA. The simulation of the proposed protocol and comparison with LEACH-M and LEACH-ME protocols is illustrated below.

TABLE II. SIMULATION PARAMETERS.

Parameter	Value
Network size	100m ×100m
Number of nodes (n)	100
Base station position	[50,50]
Initial energy (E_o)	0.5 Joule
HELLO packet size	128 bits
Data packet size	6400 bits
Special packet size	640 bits
Control packet size	320 bits
Data request packet size	128 bits
Hard threshold (H_T)	100^0 F
Soft threshold (S_T)	2^0 F
Number of frames	19
Optimal number of cluster (c)	5
E_{elec}	50 nJ/bit
E_{fs}	10 pJ/bit/m^2
E_{mp}	0.0013 pJ/bit/m^4
EDA	5 nJ/bit/packet
Sensor speed	[0,10] m/s
Mobility model	Random waypoint model

1. Lifetime of the Network
Fig. 6 shows the lifetime of the network for LEACH-M, LEACH-ME, the proposed proactive with free-node, proactive without free-node and proposed reactive protocols with respect to alive nodes in a number of rounds. As compared to LEACH-M and LEACH-ME, proposed proactive with and without free-node protocols has an improvement over them. The first node dies in LEACH-M and LEACH-ME at 12 and 16, respectively, whereas in the proposed proactive with and without free-node, the first dead node is at 30 and 33, respectively, while proposed reactive protocol has an improvement over LEACH-M, LEACH-ME and proactive protocols as the first node dies in proposed reactive protocol at 61. It is observed from Fig. 5 that the instability period of LEACH-M and LEACH-ME is very large as compared with proposed protocols because in LEACH-M and LEACH-ME after the death of first node, most of the times cluster head dies before the end of the round, since election of cluster head does not depend on energy. This makes the nodes in this cluster not able to send their data and then save their energy; therefore, the instability period of LEACH-M and LEACH-ME is longer than the instability period of the proposed protocols.

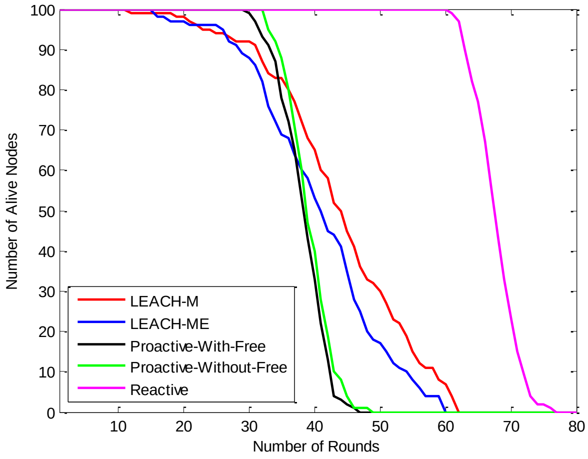

Fig. 6. Network lifetime of the protocols (Alive nodes versus number of rounds).

Fig. 7 shows the number of times CH fails in transmission per round due to the death or move out of CH. It is shown that LEACH-M has the higher number since the election of cluster heads does not depend on energy and mobility of the nodes, while LEACH-ME has a number less than LEACH-M since CHs are elected based on the remoteness of the nodes. Proposed protocols have the very small number of the failure.

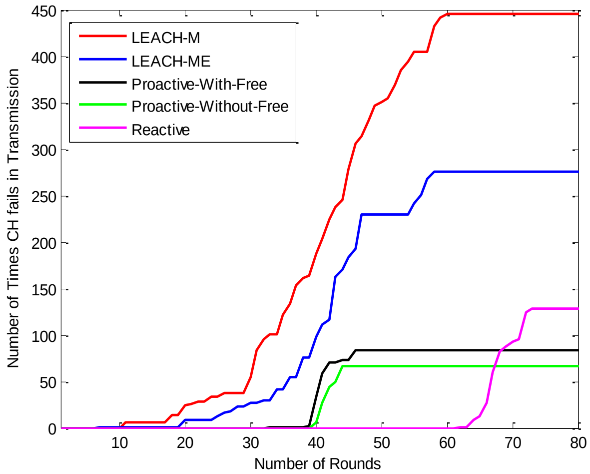

Fig. 7. Number of times CH fails in transmission versus number of rounds.

2. Average Energy Consumption
Fig. 8 shows the network average energy consumption. It is observed that the rate of energy consumption of LEACH-ME is higher than the rate of LEACH-M due to the use of extra slot for remoteness calculation, while proposed

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proactive is more efficient than LEACH-M and LEACH-ME. This improvement is due to the formation of the clusters by modified fuzzy C-means method, and using fuzzy based method for cluster head selection. The average energy consumption of the proposed proactive with free-node is higher than from it without free-node; this is due to extra energy consumption of the free-node. The proposed reactive is the most energy efficient protocol, since in this protocol, sensor nodes have to send data only when the sensed value is in the range of interest, otherwise a special packet is sent to inform the CH that sensor node is still alive or within the communication range of CH which saves the sensor node energy for long time.

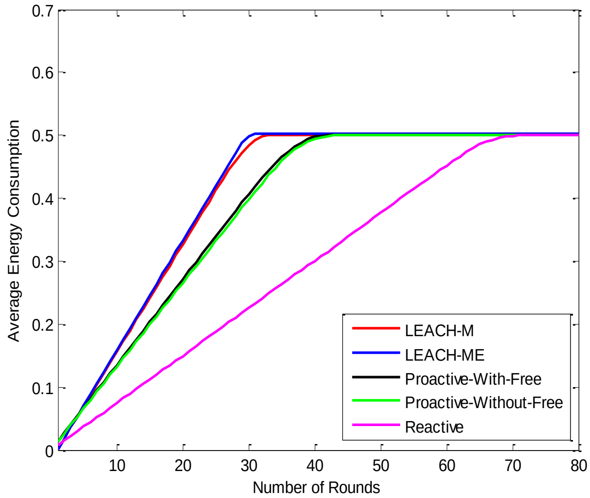

Fig. 8. Average energy dissipation in each round.

3. Packet Delivery Ratio

Fig. 9 shows the packet delivery ratio of the simulated protocols. Packet delivery ratio of the proposed proactive and reactive protocols is higher than packet delivery ratio of LEACH-M and LEACH-ME, since cluster heads are elected in an efficient way by taking into consideration fuzzy based mobility factor, energy, concentration and centrality in cluster head election. Packet delivery ratio of LEACH-M and LEACH-ME is very oscillate, since cluster heads are elected without taking energy in consideration, which makes cluster head die before the end of the round and nodes in this cluster lose their data.

4. Total Number of Packets

Fig. 10 shows the total number of packets transmitted in each protocol; small number of packets is transmitted in the case of LEACH-M and LEACH-ME. Proposed proactive with free-node has higher packets transmitted than protocol without free-node due to the presence of free-node, while a high number of packets is sent in the case of the proposed reactive protocol. Fig. 11 shows the total number of data packets transmitted. Less number of data packets is transmitted in the case of the proposed reactive since sensor nodes in this protocol have to send data packet to CH only when the sensed data is in the range of interest to improve the network lifetime and decrease the energy dissipation.

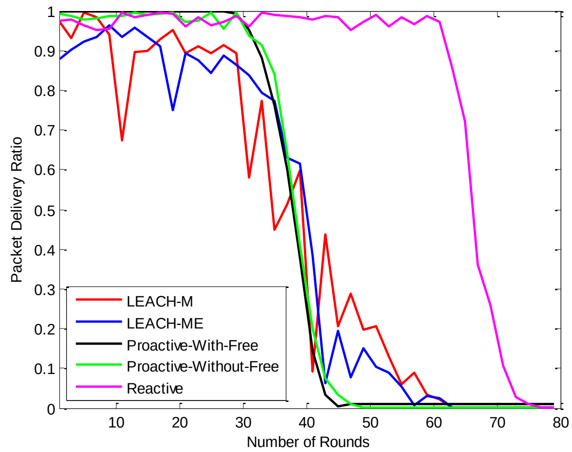

Fig. 9. Packet delivery ratio.

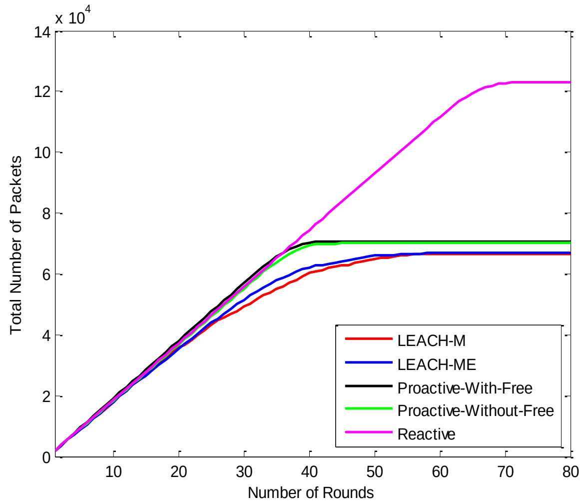

Fig. 10. Total number of packets transmitted.

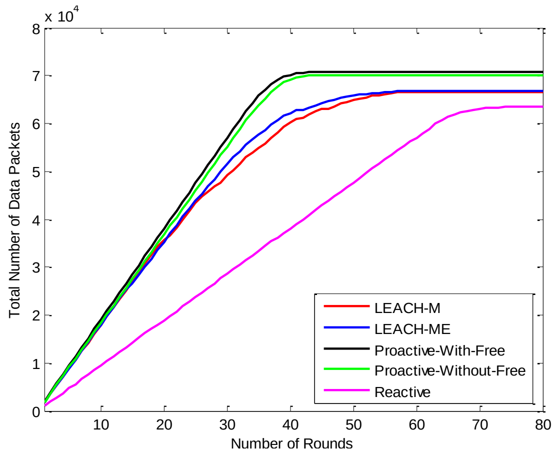

Fig. 11. Total number of data packets transmitted.

5. Overall Comparison between the Routing Protocols

Table III illustrated an overall comparison between LEACH-M, LEACH-ME and the proposed protocol.

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TABLE III. OVERALL COMPARISON.

Features	LEACH-M	LEACH-ME	Proposed
Energy efficiency	Low	Low	High
Packet delivery ratio	Very Oscillate	Very Oscillate	Good
Clustering before CH selection	No	No	Yes using modified fuzzy C-means method
Cluster head selection method classification	Distributed	Distributed	Centralized
Cluster head selection technique	Based on probability model	Based on Remoteness calculation	Based on dual-stage fuzzy logic system
Extra timeslot is required to calculate mobility of nodes	No	Yes	No
Data Transmission Model	Proactive	Proactive	Proactive AND Reactive
Member nodes send special packets to CH if they do not have any subscribed event to notify	No	No	Yes in the case of reactive protocol
Free-Node based	No	No	Yes in the case of proactive protocol
Data transmission	Nodes send data to their CHs; afterwards CHs send the aggregated data to BS	Same as LEACH-M	Nodes send data or special packet to their CHs; afterwards CHs send the aggregated data to BS

V. CONCLUSION

Researchers motivate to design and improve routing protocols that can support mobility of sensor nodes since mobile wireless sensor networks offer an effective solution in a variety of fields. The proposed scheme in this paper aimed to develop a routing protocol that allows the sensor nodes to behave in an efficient way by balancing the energy consumption of the nodes and increasing the number of packets transmitted. Therefore, a method has been built based on clustering the nodes into clusters using modified fuzzy C-means clustering algorithms and using a dual-stage fuzzy logic approach for cluster head election. According to simulation results the proposed proactive protocol, in which sensor nodes periodically send data to its CH enhances the network lifetime, energy consumption, packet delivery ratio and packet transmission as compared with LEACH-M and LEACH-ME. While the proposed reactive protocol has an enhancement over the proposed proactive and other protocols in terms of lifetime, energy consumption, packet delivery ratio and packet transmission by reducing the number of times a data packet is send from sensor nodes to CH, only when sensed value is in the range of the interest, otherwise a special packet is sent.

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BIOGRAPHY

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