An Alternative Clustering Scheme In WSN

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ABSTRACT

Wireless sensors are an integral part of our daily lives.Despite significant advancements in wireless sensor networks (WSNs), energy conservation in the networks remains one of the most important research challenges. One approach commonly used to prolong the network lifetime is through aggregating data at the cluster heads (CHs). However, there is possibility that the CHs may fail and function incorrectly due to a number of reasons such as power instability. During the failure, the CHs are unable to collect and transfer data correctly. This affects the performance of the WSN. Early detection of failure of CHs will reduce the data loss and provide possible minimal recovery efforts. This paper gives a self-configurable clustering mechanism to detect the disordered CHs and replace them with other nodes. Simulation results verify the effectiveness of the proposed approach.

Index Terms— Backup cluster head, predicted and unpredicted cluster head failure, type-2 fuzzy logic.

I. Introduction

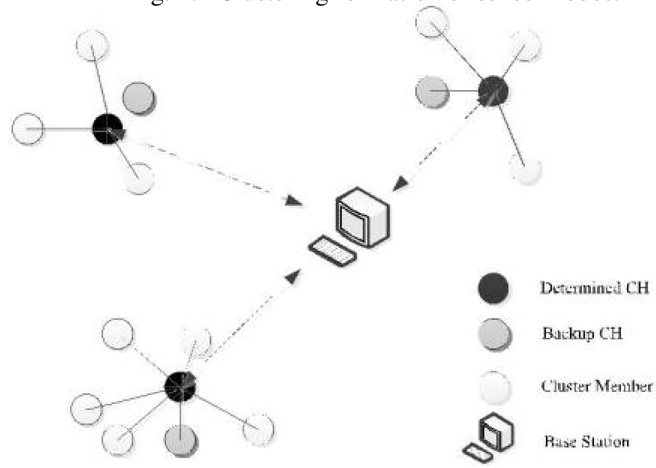
THE most challenging aspect of WSN is that they are energy resource-constrained and that energy cannot be replenished. The problem arises when all the sensor nodes are required to forward the data packets to the sink node. In this process, the available energy in each node can be wasted through idle listening and retransmitting due to collisions as well as overhearing. Cluster-based WSN routing protocols excel network topology management and energy minimization [1]. Clustering methods in WSN lead the sensor nodes to be organized into small disjoint groups, where each cluster has a coordinator referred as CH. In cluster based approaches the sensors do not need to communicate directly with BS. Instead, the CHs are responsible to organize cluster members (CMs) and send the data collected within the cluster to the BS. This process lead to a significant reduction in the amount of transferred data in the network. Consequently, overheads in communication as well as energy consumption

in clustering will be reduced significantl Maintaining the created clusters is the main challenging task

in the methods. To choose a node as a CH, it is necessary to define its eligibility. That is calculated based on local informa-tion of the nodes' current situations such as its residual energy. The eligibility of the selected CHs however, reduces as the sensor nodes are consuming energy for transferring data. If the eligibility of the CHs reduce to a certain level, they may introduced as failed CHs.

CH failure in WSNs could be permanent or temporary. Permanent fault means the node is beyond repairs and needed to be replaced to ensure the QoS in the WSN. This can happen due to reasons such as damaged components

Fig. 1. Clustering formation of sensor nodes.



. In the case, the deployed sensor nodes are required to be re-clustered. As a result, in a period of time the senor nodes cannot collect data. The problem arises if the failure of the CHs is not predicted, which could be a sudden physical damage. Respectively, the CMs keep sending their data to the failed CHs and consequently the data will be lost.

Many developed approaches investigated the problem and suggested to use backup CHs (BCHs) [6]–[8]. Fig. 1 shows a general view of clustered sensor nodes with BCHs.

In those approaches, BCHs take over the responsibility once the defined CHs noticed their eligibilities of being CHs are at a certain level or disordered. They proved that BCHs secure more the created clustering formation in the WSN. These approaches however, did not address the problem sufficiently. That is because they mostly focused on only predicted CH failure. The CMs in the existing approaches cannot define whether their CHs are operating or already failed unless they received an alerting message. Those approaches did not also consider the temporary CH failure. Moreover, they assumed that the determined BCH has been always fully functional and always is the most appropriate node to be replaced with the defined CH. Finally, they only considered maximum of two BCH in their protocols. However, their assumptions are not realistic. That is because in the WSN there is no guarantee that the determined BCHs are always fully functional as the sensor nodes do not consume energy equally. In some situations, the BCHs might be used more than the other nodes. Also, considering maximum two BCHs is not ensuring the created clusters' formation.

To overcome the issue, we propose a clustering mechanism for WSNs. In which we use type-2 fuzzy logic system (FLS) [9] and local information of the nodes to calculate the eligibility of the nodes. The node with maximum eligibility is selected as a CH. The other nodes are saved on a list based on their calculated eligibilities as BCHs. Therefore, there is always a BCH for a failed CH in each cluster. To replace the BCHs with failed CHs we consider both temporary and permanently failure in the CHs. Moreover, we take unpredictable as well as predictable CH failure into account.

The rest of this paper is organized as follows. Section II describes the addressed research problem. An in-depth analysis of the existing approaches is presented in Section III to identify the addressed research gap. Section IV explains the proposed clustering scheme. In Section V the proposed approach is evaluated and finally the paper is concluded in Section VI.

II. Problem Overview

Let $L = \{s_1, \ldots, s_n\}$ be a set of n wireless sensor nodes deployed randomly over a surface area. The sensor nodes and BS are stationary. The clustering problem is to identify and make a collection of CHs and CMs, while they cover the entire deployment area. Generally, clustering protocols in WSN are divided into two main sections. In the first section clusters are organized followed by CHs selection process. In this phase, the sensor nodes cannot collect and transfer data packets among each other. After the clusters were created, the sensor nodes are able to collect and transfer data to each other. They consume energy as they receive and send the data packets. So, each sensor node is at the risk of being disordered due to its energy depletion. The amount of energy lost in the CHs is usually more than the CMs as they are responsible to collect data packets from other nodes and transfer them to the BS. Therefore, they are more at the risk of energy depletion. As a result, they cannot monitor their areas of interest. The problem becomes more challenging if the failed CH was not detected. In this case, the CMs keep sending their collected data to the CHs without noticing that they cannot be received.

CH failure could be predicted and so that the CMs can be informed by a message. Then, the CMs are required to replace their defined CHs with the most optimum BCHs. However, finding and replacing BCHs is needed to be considered carefully. In the real world, the deployed sensor nodes are not consuming their energy equally. That means current situations of the nodes are not changing similarly. As a result, the already defined BCHs are not always the most appropriate node to be replaced with failure CHs. In the case, it is a considerable challenge for the CHs to find and introduce the best current BCH to their CMs.

The problem becomes more challenging if the CHs are failed unpredictably. As a result, the CMs keep sending their data to the failed CHs without noticing that the data are not processed properly by the determined CHs. Thus, it could make the WSN to lose a number of data packets. To prevent the data loss in the network, it is significantly important to determine the failure of CH by the CMs at the earliest moment. The CMs also are required to find and replace a BCH with their CH.

CH failure in WSNs could be permanent or temporary. Permanent fault means the node is beyond repairs and needed to be replaced to ensure the QoS in the WSN. This can happen due to reasons such as damaged components. Temporary fault on the other hand is the one that results from temporary environmental impact or incorrect state of the components. To replace BCHs with the failed CHs, it is also necessary to realize that it is not a temporary failure. That is because the short-term lower density may not be an issue as long as the network remains connected.

III. Related Work

During the past decade, considerable research efforts have been investigated in developing clustering mechanisms for deployed sensor nodes in WSNs. The first well known clustering protocol developed by Heinzelman et al [10] is Low Energy Adaptive Clustering hierarchy with Deterministic CH Selection (LEACH). LEACH has been developed based on a clustering mechanism to select CHs using optimal probability. The protocol works on periodic randomized rotations of the CH within the cluster range between zero and one. If the random number is less than the pre-determined threshold value, the node becomes a CH for the current round. The authors have succeeded to achieve a reduction in energy dissipation compared to direct communication and transmission protocols. However, since in the protocol the number of clusters is predefined, LEACH cannot guarantee an acceptable CH distribution. Additionally, due to lack of support in deploying network with a large number of sensor nodes, the protocol cannot be used in a large region. Moreover, LEACH suffers from significant energy consumption when there is no CH selected in some rounds.

Applying Type 1 fuzzy system in distributed protocols improves the performance of the networks significantly. For instance, Gupta et al [11] introduced a CH election method using fuzzy logic to overcome the drawbacks of LEACH. The achievement of the protocol efficiently increased the network's lifetime. However, this centralized approach is not suitable for networks with a large number of deployed nodes. LEACH-FL [12] is also an improvement of LEACH that employs a similar approach to [11]. In this protocol, the BS selects nodes with higher chance as CHs. Although this method has the same drawback of Gupta's method, it presents a better result than LEACH protocol. To overcome the drawback of centralized algorithms, Jong-Myoung et al put forward CHEF routing protocol [13]. To a certain extent, CHEF extends the network lifetime. However, it selects the nodes with less neighbour nodes as CHs easily that destroys the balance of energy consumption.

Gateway and CH election using fuzzy logic in heterogeneous WSN (GCHE-FL) [14] is a developed protocol that uses two fuzzy based elections to evaluate the chance of sensors to become a gateway and CH. In the first election (Gateway Election), the qualified nodes are selected based on their energy and distance to the BS. Then, in the second election (CH Election), residual energy of each node and cluster distance are used. Cluster distance is the sum of distances among cluster members. Simulation results show that the proposed approach enhances the energy efficiency in the network.

Qing et al [15] proposed a distributed energy efficient clustering (DEEC) algorithm for heterogeneous WSNs. In DEEC, the CHs are selected using probabilistic models based on the residual energy of each node and the average energy of the network. In DEEC the responsibility of CHs is rotated among all the nodes in the network based on their residual energy. To accomplish that, all the deployed nodes need to be informed about the total energy and the network lifetime. That information is broadcasted by the BS. Then, each node compares the received information and its residual energy against a predefined threshold to realize that if it can be a CH on that round. After that, Elbhiri et al [16] enhanced DEEC by proposing stochastic energy efficient clustering (SDEEC). In this approach, the intra-clusters transmissions are reduced and also increased the energy efficiency by making the CMs into sleep mode. In this protocol, all the CMs are allocated a transmission time to transfer their collected data to their respective CHs. When the CHs start to aggregate the received data the CMs will be deactivated. In this approach, although the authors to some extend reduced the energy consumption in the network, they did not clearly explain about the CH rotating and also the collected data in rotation process.

Liaw et al [17] proposed a steady group clustering hierarchy (SGCH) with the purpose of stabilizing clustered WSNs. In the proposed approach, all the deployed nodes are clustered into different groups based on their initial energy. In this centralized algorithm, BS broadcasts a message, called group head request (GHR) to obtain local information of all the nodes. Then, the sensor nodes send back an acknowledgement includes ID and initial energy information of the nodes. After that, BS finds and informs group heads for each group. Finally, each group head or CH defines its cluster members. The results in this study show that the stability and energy consumption are increased however, the traffic overhead in the network is quite high as it is a centralized approach. Table I compares the various existing clustering approaches respect to QoS features.

All the explored approaches to some extent increased the energy efficiency in WSN. However, in their considerations to select CHs they did not take CHs failure into account. In fact, the main drawback of the existing approaches is the sensor nodes are sending data packets without noticing whether they are received or not. Traffic overflow problem also was not fully addressed in the approaches. Moreover, they did not fully accommodate the linguistic and numerical uncertainties such as noisy input signals and inaccurate transmitted data packets. To sum up, as it is presented in Table I, a comprehensive distributed clustering protocol that is capable of providing an acceptable energy efficiency and overhead rate while consid-ering inherent uncertainties in WSN has not been developed.

The performance of the implemented signal processing are usually negatively influenced by dynamic errors or uncertainties related to insufficient or noisy data in many real world applications. Therefore, it is vital for WSN to be

TABLE I
COMPARISON OF DIFFERENT CLUSTERING PROTOCOLS
WITH RESPECT OF QoS

Algorithm	Clustering Method	Energy	Overhead Rate	CH Failure
LEACH [10]	Distributed	Low	Not Considered	Not Considered
Gupta et al [11]	Centralized	Low	High	Not Considered
LEACH-FL [12]	Centralized	Low	High	Not Considered
CHEF [13]	Distributed	Low	Not Considered	Not Considered
(GCHE-FL) [14]	Distributed	Moderate	Not Considered	Not Considered
DEEC [15]	Distributed	Moderate	High	Not Considered
SDEEC [16]	Distributed	Moderate	High	Not Considered
SGCH [17]	Centralized	Low	High	Not Considered

capable to cope with uncertainty related to the networks and thus process the data realistically with less complexity and computational effort. To achieve that it is decided to use fuzzy logic system technology as it is flexible with a better capability to cope with uncertainty of data compare to many techniques includes statistical and Covariance Intersection (CI) based methods [18]. In this paper, we use type-II fuzzy logic system (T2FLS). Type-1 Fuzzy Logic Systems (T1FLSs) use fixed fuzzy memberships that cannot directly address those variable conditions. Therefore, uncertain measured parameters in applied systems would be neglected by T1FLS and the performance obviously will be negatively influenced. In [19], [20] the effects of the measurement noise in type-1 and type-2 FLSs and identifiers are simulated to perform a comparative analysis. It is concluded that the use of T2FLSs in real world applications that exhibits measurement noise and modelling uncertainties can be a better option than T1FLSs.

The concept of fuzzifire, inference rules and also defuzzifire in T2FLS is very similar to T1FLS. However, there are two main differences that needs to be considered in developing T2FLS. First, membership functions that is totally different to the fuzzy sets for T1FLS. There are many methods and techniques such as Z-slices [21], ∝-planes [22], [23] can be applied to develop fuzzy sets. However, due to the complexity of using these methods and even the generalized T2FLS, interval T2 (IT2) fuzzy sets in T2 FLS are used [24]. The basic concept of IT2 fuzzy sets consider a footprint of uncertainty (FOU), which can be described by two bounding of T1 fuzzy membership functions. Apart from the member-ship fuzzy sets type reduction is also another different existing stage in developing T2FLS. Type reduction is a new and complicated concept that is to reduce the type-2 to type-1 fuzzy sets. Detail of some popular methods in type reduction can be found in [25].

IV. SELF-CONFIGURABLE CLUSTERING

To develop SCCH, we first need to select an appropriate CH for each cluster. For that purpose, we develop a T2 FLS to find the most appropriate CHs for the clusters. As in previous

Fig. 2. A deployed node with neighbors.

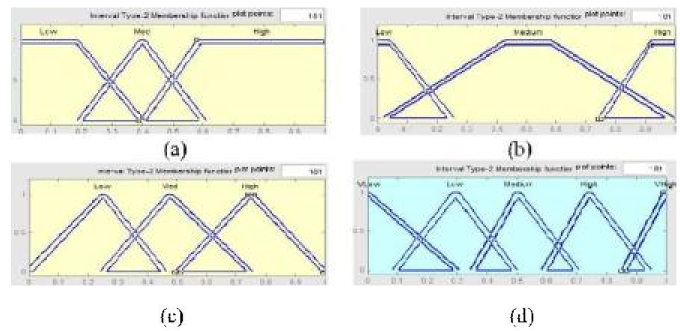


Fig. 3. Interval fuzzy membership function for inputs: (a) Energy. (b) Node centrality. (c) Local distance and for (d) output.

works [26]–[29], the sensor nodes will be embedded with a fuzzy system. For each input synthetic data is used. For each data we use a Gaussian distribution with its mean and covariance matrix representing the expected value and its uncertainty (10% of the value). Then, the values are normalized to fit in the [0, 1] as the inputs of the fuzzy system. Then, we extract linguistic variables out of the normalized data. The linguistic variables used to represent them are divided into three levels: Low, Medium and High. The consequent or the output of the FLC is divided into five levels: Very Low (VLow), Low, Medium, High and Very High (VHigh). 20% of the data is used to determine the membership functions and also the rules. The inputs of the system are as followed;

1) Energy (E): residual energy in CHs candidates is used in electing CHs with an acceptable energy level. All nodes are aware of their remaining energy.

2) Node Centrality (NC): is a value that shows how central the node is among its mobile neighbors within the entire network. The lower value of the centrality, the lower amount of energy required by the other nodes to transmit the data through that node as CHs. NC is calculated using (1):

$$NC = \frac{\sqrt{M}}{NZ} \quad (1)$$

where $M = \sum_{j \in S(i)} \frac{d^2(i,j)}{|S_i|}$, d is the distance between the CH candidate i and its member nodes, $|S_i|$ in the number of neighbors of node i and NZ is the size of the sensing field area.

3) Local Distance (LD): This is sum of the distances from a deployed node to its neighbors. Fig. 2 shows the deployed sensor node (A) and its neighbors within r radius.

In order to calculate LD, we first determine the radius (r). Radius is calculated using (3.2) [13].

$$r = \sqrt{\frac{NZ}{\pi \cdot |L| \cdot P}} \quad (2)$$

Next, we consider only the neighbors within the confine of r radius for each node and then, sum up the distance (d_i) of the node to them, using (3.3) [30].

$$LD_{CH} = \sum_{i=1}^{n} d_i \quad (3)$$

Fig. 3 presents the inputs and outputs interval fuzzy membership functions of the FLS.

Based on the fuzzy variables shown in Figure 3, fuzzy rules are defined as shown in Table I. Since each input variable has 3 fuzzy states, e.g. Low, Medium and High. Thus, the total number of possible fuzzy inference rules for the developed system, is 3 × 3 × 3 = 27.

Next, the output of the FLS for each sensor node will be sent by a beacon message to neighbors to be informed. Fig. 4 shows the structure of the beacon message for sending the output of FLS.

Packet Type	Node-ID	FLS-OUT

Fig. 4. Eligibility of each node.

Where Packet Type presents the purpose of the message, Node-ID is the ID of the node that creates the message and FLS-OUT is the output of the fuzzy system. The nodes that have received the message from the other nodes need to check FLS-OUT. They compare the received FLS-OUTs against its calculated fuzzy output as well as the received other nodes.' A Sensor node with the highest FLS-OUT introduces itself as a CH. It also lists the other sensor nodes, based on their FLS-OUT. In the list, they are ordered from the highest to the lowest FLS-OUT of the nodes. In fact, the list priorities the sensor nodes to be BCHs. Therefore, sensor nodes with lower FLS-OUT knows that they are BCH of the node with higher FLS-OUT. That is to ensure there is always a BCH for defined CHs. Fig. 5 presents structure of the CH joining message.

Packet Type	CH-ID	BCH-IDs

Fig. 5. CH joining message.

Where Packet Type presents the purpose of the message, CH-ID shows the ID of the elected CH and BCH-IDs is the list of sensors' IDs are ordered from highest to the lowest FLS-OUT. Next, each sensor node that received the CH joining message sends an acknowledgement message to join to the CH. Once the clusters are created, the CHs allocate a TDMA (Time Division Multiple Access) for the CMs. Then, the sensor nodes can start transferring data packets in the WSN based on the allocated TDMA schedule. At this stage, the sensor nodes include CHs consume energy. As a result, either CHs or CMs might face to energy depletion. If CHs die, the entire area of their interest will be unmonitored. Thus, replacing the failure CH is necessary. Disordered CMs also influence the eligibility of the elected

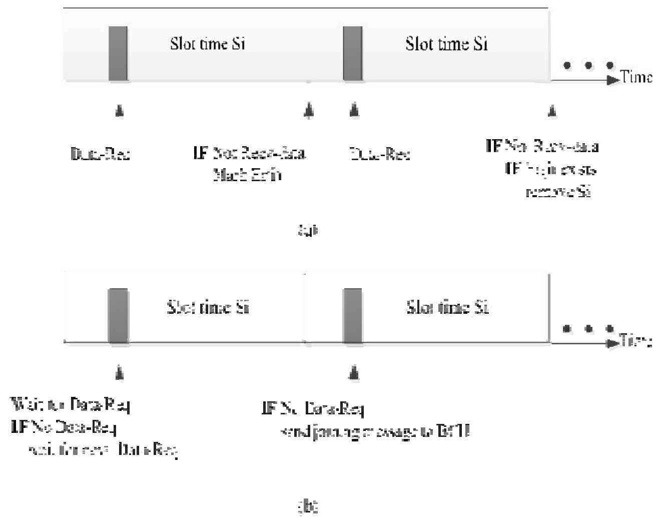


Fig. 6. Allocated TDMAs for (a) CH and (b) CM.

CHs as NC and LD are affected. Therefore, to maintain the created clusters the CMs are needed to send their resid-ual energy with their sensory data in a single message to their CHs. The CHs are also required to check their own FLS-OUT frequently. In each round of checking the FLS-OUT, the CHs compare it against a defined user value (β). In the proposed system, the value is provided by users to decide if the fuzzy output should be considered. If the FLS-OUT of each CH is less than the value, it will be required to inform the CMs and a BCH about the switching time. So, the sensor nodes can replace their CHs with the introduced BCH.

The available BCH cannot be chosen on the exact order from the created list. That is because the BCHs might be physically damaged or in some situations their residual energy might be changed. Therefore, CHs change the order of the BCHs in the created list based on receiving their residual energy. The updated list is sent to the CMs periodically with a data request message to make sure that the most suitable BCH is available.

In the WSN the determined CHs also could be suddenly disordered due to for instance, physical damage. If a CH dies, the CMs are required to be noticed quickly to prevent of data losing in the network. Also, if the CMs die, their CHs are required to remove them from their list. To achieve that, it is proposed to monitor the CHs and CMs using TDMA. Fig. 6 presents the allocated TDMAs for a sensor node (S_i).

As it can be seen from Fig. 6(a), the CMs need to transfer their data packets upon receiving a data request message (Data-Req). If the CH did not receive the requested data at the end of the frame, it will mark an error for the CM. The error mark is to prevent of assuming the temporarily dead as a permanent failure. Then the CH sends another request. If the CH did not receive data from the CM by the end of the frame it will check the error mark. If the error mark is existed, the CH realizes that it is a permanent failure and it needs to be removed from its CMs' list.

Apart from the CM, failed CHs are also needed to be detected. Fig. 6(b) presents the TDMA of the CMs. The CMs in the WSN need to wait for a

TABLE II

APPLIED FUZZY RULES

Rule NO	Input Variable			Output
	Energy	Node centrality	Local Distance	Chance
1	High	Low	High	VHigh
2	High	Low	Medium	VHigh
3	High	Low	Low	High
4	High	Medium	High	High
5	High	Medium	Medium	High
6	High	Medium	Low	Medium
7	High	High	High	Medium
8	High	High	Medium	Medium
9	High	High	Low	Low
10	Medium	Low	High	Medium
11	Medium	Low	Medium	Low
12	Medium	Low	Low	Low
13	Medium	Medium	High	Medium
14	Medium	Medium	Medium	Medium
	Medium	Medium	Low	Low
16	Medium	High	High	Medium
17	Medium	High	Medium	Low
18	Medium	High	Low	VLow
19	Low	Low	High	High
20	Low	Low	Medium	Medium
21	Low	Low	Low	Low
22	Low	Medium	High	Medium
23	Low	Medium	Medium	Low
24	Low	Medium	Low	VLow
25	Low	High	High	Low
26	Low	High	Medium	VLow
27	Low	High	Low	VLow

data request (Data-Req) from their determined CH. If a CM does not receive Data-Req, it will wait for the next frame to receive the request as it might be a temporary failure. In case of not receiving the request in the second frame, it will be required to replace its CH. To replace the CH, the CM needs to check the latest and updated of its received BCHs' list. Then it sends a joining message to the first available BCH and waits for acknowledging the message. However, there is a possibility that the defined BCH might be disordered. In the case of not receiving the acknowledge message from the BCH, the CM sends another joining message to the second available BCH until it joins to a CH.

V. PERFORMANCE ANALYSIS

In this section, we use simulations to evaluate the performance of the proposed shame. As a performance metric, we compare the efficiency of energy consumption of the networks. The communication model for energy consumption used in this evaluation is as explored in [10]. The transmitter dissipates energy to run the power amplifier and radio electronics is shown in Fig. 7.

The required energy for transferring a k-bit message to d distance can be calculated using (4).

$$E_{Tx}(k, d) = E_{eiec} \square k + E_{amp} \square k \square d^2 \quad (4)$$

Where E_{eiec} is transmitter energy to run the transmitter or receiver circuitry and E_{amp} is for transmit amplifier to achieve

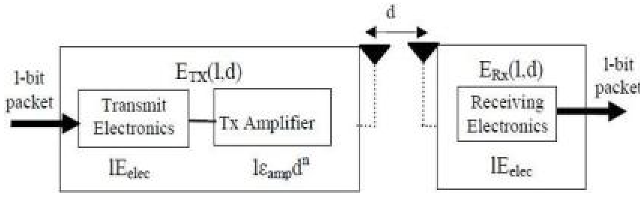


Fig. 7. Radio energy dissipation model.

acceptable signal strength. Energy consumed in receiving k-bit message is calculated using (5). Where based on the referred algorithm E_{eiec} = 50nJ/bit and E_{amp} = 100pJ/bit/m^2 as in [10].

$$E_{Rx}\ (k,\ d) = E_{eiec} \square\ k \quad (5)$$

Apart from energy consumption, we analyze data loss ratio (DLR) of our proposed approach. DLR is a ratio of the difference of total data sent by the sensor nodes and received by the BS to the total data sent by the sensor nodes. DLR is calculated using (6).

$$\text{DLR} = \frac{\text{Total data sent} - \text{total data received}}{\text{Total data sent}} \quad (6)$$

Finally, the traffic overhead of the proposed protocol is also analyzed. To evaluate the traffic overhead of the distributed approach in WSN, the average amount of traffic transmitted within the network is tested.

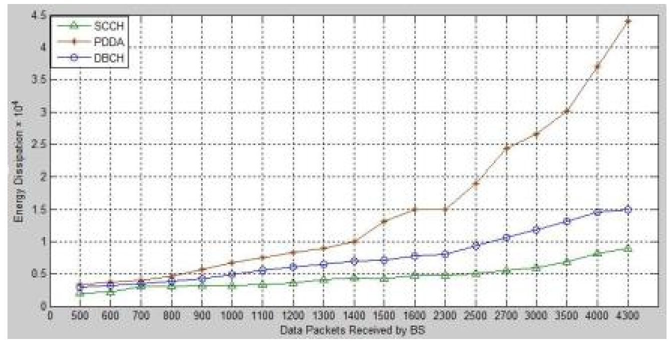


Fig. 8. Energy consumption.

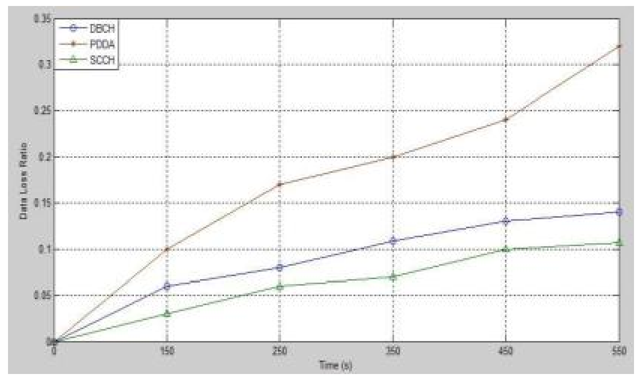


Fig. 9. Data loss rate.

A. Experimental Setup

In this section, we use MATLAB to compare the proposed approach against PDD (Probability, Distance and the sum of Distances) [31] and Achieving Reliability over Cluster-Based WSN using Backup Cluster Heads (DBCH-LEACH-C) [32]. PDD is a fuzzy based approach for increasing the network lifetime and DBCH-LEACH-C is also a clustering WSN that proved using BCHs enhances performance of the WSN.

In the simulation, the network consists of a BS and $L = \{s_1, \ldots, s_{80}\}$ wireless sensor nodes. The sensor nodes are deployed randomly over 200× 200 m^2 surface area. The initial energy for each node is 1J equally. In terms of energy, memory and computational power, there is no limitation for BS. BS is located in the middle of the surface. The packet size is 100 bytes and beacon message is 10 bytes.

B. Result and Discussion

In order to prove that the proposed approach prolongs the network's lifetime, the required energy for successful transmission of specific number of data packets is calculated. As can be seen from Fig. 8, the results show that the proposed approach outperforms both PDD and DBCH-LEACH-C by transferring the same amount of data with less energy dissipation. PDD has the less efficiency in energy consumption. That is due to lack of consideration of CH and CM failure in the network. In case of CH failure, CMs transfer data packets through the networks without noticing they cannot be received. As a result, the efficiency of energy consumption is negatively influenced. DBCH-LEACH-C enhances PDD as it replaces BCHs with the failed CHs. However, as it is a centralized protocol and did not consider the CM failure energy cannon be consumed efficiently. That is because; the network needs to consume energy to make a data request from a CM by a CH without noticing the CM is already disordered. SCCH on the other hand, enhances the energy efficiency in the network. The reason behind it is because SCCH is a distributed protocol, in which the CHs and CMs of a cluster can define whether they are failing or not. In case of CH failure, the CMs are able to replace the most optimum BCH with it. As a result, data request message as well as data packets are not transferring unless the nodes are ensured that the destination node is fully functional.

Apart from energy consumption, DLR is calculated for the data sent and received at the BS for the whole network. As illustrated in Fig. 9, SCCH has the lowest DLR. That is due to the following reasons. First, it can determine failure CHs and CMs. That prevents of transferring data packets to a failure nodes. However, CMs failure is not considered in both PDD and BCH-LEACH-C. In addition, there is always a BCH for a failed CH. So the CMs do not need to worry about re-clustering process as they can simply replace a BCH with their determined CH. BCH-LEACH-C performs better than PDD as it considers BCH. However, its DLR is lower than SCCH that is due to considering only maximum two BCHs.

Finally, traffic overflow is also used to prove the performance of the proposed approach. In order to evaluate traffic overhead of SCCH, we tested the average amount of traffic transmitted within the network. Fig. 10 compares the

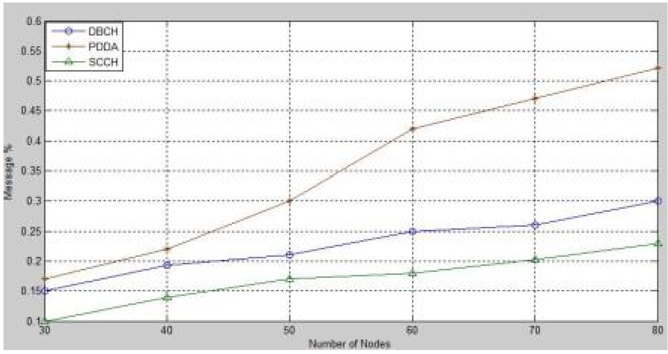


Fig. 10. Message overhead in cluster.

average message for transferring data with different sizes of network. It clearly shows that the traffic in our scheme is lower than PDD and BCH-LEACH-C. The message in PDD is more than BCH-LEACH-C and SCCH because in case of CH failure the nodes are required to be connected to the BS directly.

VI. Conclusion

To prolong WSN lifetime as well as decreasing the created traffic, a new distributed type-2 fuzzy based self-configurable clustering (SCCH) mechanism is proposed. SCCH firstly clusters the sensor nodes. That is followed by selecting CHs. To define CHs a fuzzy system and considered local information of each sensor node is used. The output of the system presents the eligibility of sensor nodes to be CHs. Then, nodes in the network compared their eligibilities against others'. A node with the maximum eligibility will introduce itself as a CH and the rest of the nodes as BCHs. As a result, the CMs can ensure that there is always a BCH for their CHs. Therefore, in case of CH failure the CMs can replace the BCH with the permanent CH failure. The claim was proven by comparing the behavior of the SCCH against a fuzzy and a well-known non-fuzzy approach. It achieves longer lifetime with the ability of reducing overhead in WSNs, compared to existing clustering protocols.

For the future work, the protocol can be extended to meet QoS requirements of WSNs, such as coverage preservation, because complete coverage of the monitored area over long period of time is an outstanding issue.

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