An Improved Energy-Efficient Clustering Protocol to Prolong the Lifetime of WSN Using FCM and CHSRA

K.Penchalaiah[1], K.Kalyani[2] ,V.Lahari[3],

K.Jagadeesh[4],M.SaiKiran[5],M.Mahesh[6]

[1]Assistant Professor, Dept of ECE,PBR VITS, Kavali, Andhra Pradesh-524201
[2,3,4,5,6]UG students Dept of ECE,PBR VITS, Kavali, Andhra Pradesh-524201 India

Abstract-.

A wireless sensor network (WSN) is an important part of the Internet of Things (IoT). However, sensor nodes of a WSN-based IoT network are constraining with the energy resources. A clustering protocol provides an efficient solution to ensure energy saving of nodes and prolong the network lifetime by organizing nodes into clusters to reduce the transmission distance between the sensor nodes and base station (BS). However, existing clustering protocols suffer from issues concerning the clustering structure that adversely affects the performance of these protocols. In this study, we propose an improved energy-efficient clustering protocol (IEECP) to prolong the lifetime of the WSN-based IoT. The proposed IEECP consists of three sequential parts. First, an optimal number of clusters is determined for the overlapping balanced clusters. Then, the balanced-static clusters are formed on the basis of a modified fuzzy C-means algorithm by combining this algorithm with a mechanism to reduce and balance the energy consumption of the sensor nodes. Lastly, cluster heads (CHs) are selected in optimal locations with rotation of the CH function among members of the cluster based on a new CH selection-rotation algorithm by integrating a back-off timer mechanism for CH selection and rotation mechanism for CH rotation. In particular, the proposed protocol reduces and balances the energy consumption of nodes by improving the clustering structure, where IEECP is suitable for networks that require a long lifetime. The evaluation results prove that the IEECP performs better than existing protocols.

Index Terms-Wireless sensor network, Internet of Things, clustering protocol, energy consumption, network lifetime.

I. INTRODUCTION (HEADING 1)

Internet of Things (IoT) is a significant source of technological solutions in several applications. The IoT is pillared by a wireless sensor network (WSN) which decreases the cost of the new technology. Literature verifies that this technology integration will reduce costs and ensure convenience in daily life through smart sensor node networks whereby the nodes have access to internet[1],[2]. WSN, an inexpensive legacy system, has been applied in several fields, such as industrial control, environmental monitoring, military surveillance, and intelligent transportation systems [1], providing large-scale physical data be further utilized. Thus, by integrating the IoT and WSN applications, no massive paradigm shift is needed [2]. WSN-based IoT is advantageous for its convenient deployment and low cost. Furthermore, it can function independently in harsh or high-risk places where human presence is not possible. However, WSNs have defects that need to be addressed [1]. The network lifetime problem is the main challenge in WSN[3]. The sensor’s lifetime is only related to its batteries, which are difficult or impossible to replace or recharge due to the rugged environments where they are operating [4]. This problem undermines the integration of the WSN into IoT, elevating the costs of new technology. Accordingly, prolonged network lifetime is considered as a major challenge in the WSN- based IoT. Consequently, to prolong the network’s lifetime and improve energy consumption, a cluster is used in the WSN. The clustering protocol, where the sensor nodes are divided into small clusters, is an effective technique to reduce energy consumption and prolong network lifetime by avoiding long-distance communication [5],[6]. Each cluster employs one node as a cluster head (CH) that has duties more than member nodes (MNs). Practically, each MN in the cluster transmits its sensing data to its CH, and then the CH transmits these data to BS via a single-hop or multi-hop manner.

Although the clustering protocol is considered as an effective way to conserve energy for the nodes in WSNs, clustering structure remains a major issue, which adversely affects the network lifetime through the inefficient energy consumption of nodes [4],[7],[10]. Furthermore, the WSN poor clustering structure frequently affects the subsequent procedures of the network, such as data aggregation and routing discovery, where it prepares the network for operation [11]. Consequently, the clustering structure efficiency has a considerable effect on the WSN lifetime. The first of those issues is when determining a sub-optimal number of clusters (less or more than the optimal number), leading to the increase in the energy consumption of nodes [12]. Most of the clustering protocols that create balanced overlapping clusters suffer from the inaccurate determination of the optimal number of clusters when using current mathematical models because the distance to the CH has not been estimated correctly. The second issue is related to cluster formation, which can drastically affect the lifetime of WSN [13]. On certain occasions, an FCM algorithm (that is widely used in the WSN domain for cluster formation) produces unbalanced clusters (large and small) because of the random nodes deployment in the area, hence, resulting in unbalanced energy consumption for nodes. In large clusters, the selected CHs are burdened by data more than the CHs of the other clusters, thus, consuming more energy for the transmission of data [10],[14]. The third issue is improper CH selection, where most of the distributed methods do not consider the routing information as a parameter in the CH selection. Consequently, an irregular distribution of the CHs occurs, where the transmission distances among the CHs in the network are uneven. Hence, some CHs are obliged to increase their signal strength in order to transmit data to the next hop, leading to unbalanced energy consumption for CHs in the network [15],[16]. The final issue of the clustering structure is the rotation of the CH function among members of the cluster. As a fixed value of energy is used as a threshold for CH rotation, the nodes demonstrate a dysfunctionality in terms of the CH and MN functions in the cluster. This dysfunctionality leads to unbalanced energy consumption for nodes that have been sequentially selected as CHs in the cluster, which subsequently accelerates the first node death (FND). As a result, two problems occur in relation to the CH that generate unbalanced energy consumption [17]. The problems include the unbalanced transmission distances among CHs in the network, and the use of a static value of the threshold to rotate the CH function among members of the cluster. Therefore, this research is very significant as it addresses the main research question: how to prolong the network lifetime for the WSN-based IoT? Several sub-questions are identified as follows: How to determine the optimal number of clusters in case of the formation of the overlapping-balancing clusters? How to form balanced clusters with little cost of the intra-distance of clusters in the random nodes distribution?, How to achieve balanced energy consumption among the CHs of clusters?, How to achieve balanced energy consumption of the successive CHs in the cluster? To address these issues pertaining to the clustering structure that adversely affects the network lifetime through the inefficient energy consumption of nodes, and to answer the posed questions, this study proposes an improved energy-efficient clustering protocol (IEECP) to prolong the lifetime of the WSN-based IoT which consists of three parts: Firstly, a modified mathematical model is proposed based on the analysis of the energy consumption model for multi-hop communications and overlapping clusters in order to determine the optimal number of clusters. Secondly, a modified fuzzy C-means algorithm (M-FCM) is proposed in order to produce balanced cluster [18]. Thirdly, a new algorithm is proposed known as CH selection and rotation algorithm (CHSRA) that integrates the back-off timer mechanism for CH selection, with a new rotation mechanism for CH rotation among members of the cluster. The main contribution by the proposed protocol is the prolonging of the WSN-based IoT lifetime that depends on the node's battery, which extensively increases the applications' range of the WSN-based IoT. This major contribution can be achieved through the following tasks: 1) Selecting the optimal number of clusters based on the modified mathematical model by considering the overlapping case among clusters and multi-hop communications, 2) Forming balanced clusters that reduce the cost in the intra-distance based on modified fuzzy C-means algorithm (M-FCM) that result from a combination of the FCM algorithm with a centralized mechanism, 3) Reducing the energy overhead that results from the CH selection process in each round by a new integration of the back-off timer mechanism for CH selection with rotation mechanism in one algorithm known as CH selection and rotation model (CHSRA), 4) Balancing the communication distance among the CHs in the network based on a new objective function for the back-off mechanism, and 5) Balancing the life of the selected CHs in the cluster based on a new dynamic threshold.

For straightforward ease in reading, most of the abbreviations used in this study are illustrated in Table 1. The rest of this paper is organized as follows: Section 2 provides a brief survey of the clustering algorithms and their advantages and disadvantages in literature. In section 3, the radio energy consumption model is introduced. Section 4 details the protocol. Then, the results of the discussion are explicated in Section 5. Finally, section 6 concludes the study.

II.LITERATURE SURVEY:

S. NO	Journal Type with year	Authors	Title	Outcomes
1	IEEE Access, vol. 5, pp. 1846918479, 2017.	J.Shen,A.Wang, C.Wang,P.C. K. Hung,and C.-F. Lai	An efficient centroid-based routing protocol for energy management in WSN-assisted IoT	Studied about the centroid based routing protocol
2	Int. J. Electr. Comput. Eng., vol. 9, no. 1, pp. 439444, 2019.	V.Reddy and P. Gayathri,	Integration of Internet of Things with wireless sensor network	Studied about IOT with WSN
3	IEEE Sensors J., vol. 15, no. 5, pp. 29842992, May 2015.	H. P. Gupta, S. V. Rao, A. K. Yadav, and T. Dutta	Geographic routing in clustered wireless sensor networks among obstacles	Studied about clustered WSN
4	EURASIP J. Wireless Commun. Netw., vol. 2018, no. 1, pp. 111, Dec. 2018.	Q. Wang, S. Guo, J. Hu, and Y. Yang,	Spectral partitioning and fuzzy C-means based clustering algorithm for big data wireless sensor net-works	Studied about the fuzzy C-means based clustering algorithm
5	Wire-less Pers. Commun., vol. 98, no. 1, pp. 16051635, Jan. 2018.	S. Dehghani, B. Barekatain, and M. Pourzaferani,	An enhanced energy-aware cluster-based routing algorithm in wireless sensor networks	Studied about cluster-based routing algorithm

III.EXISTING METHOD:

The LEACH protocol is the first proposed clustering protocol. The main idea is to choose the CH in a clustered manner at each round and then have the nodes join the closest CH to form a dynamic cluster. This network topology is built on the chosen CHs, which is inefficient due to the lack of consideration for node residual energy. Furthermore, prioritizing CH selection results in the forming of complex clusters at each round, resulting in an increase in energy overhead due to cluster formation after each re-selection phase for CHs .A LEACH-centralized protocol (LEACH-C) is another variant of the protocol in which the optimum number of clusters K is calculated using a statistical model. In comparison to LEACH, Base Station BS is in charge of CH selection and cluster creation by the use of the simulated annealing optimization procedure, in which nodes with more than the average energy send their information to the BS at the end of each round.

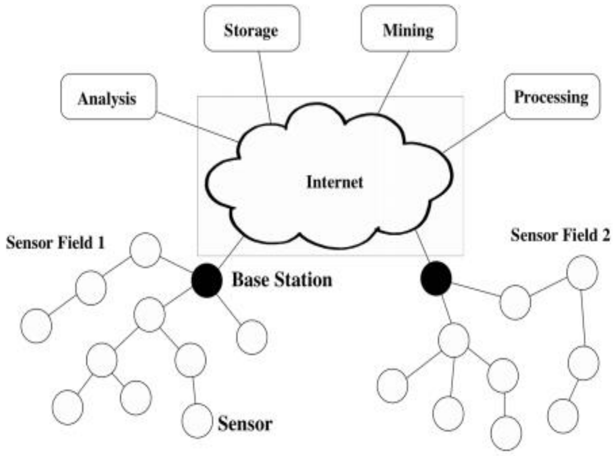


Figure: General System Model of a WSN

IV.PROPOSED METHOD:

An improved energy-efficient clustering protocol (IEECP) is proposed to prolong the lifetime of the WSN-based IoT which consists of three parts:

Firstly, a modified mathematical model is proposed based on the analysis of the energy consumption model for multi-hop communications and overlapping clusters in order to determine the optimal number of clusters. Secondly, a modified fuzzy C-means algorithm (M-FCM) is proposed in order to produce balanced cluster. Thirdly, a new algorithm is proposed known as CH selection and rotation algorithm (CHSRA) that integrates the back-off timer mechanism for CH selection, with a new rotation mechanism for CH rotation among members of the cluster. This major contribution can be achieved through the following tasks:

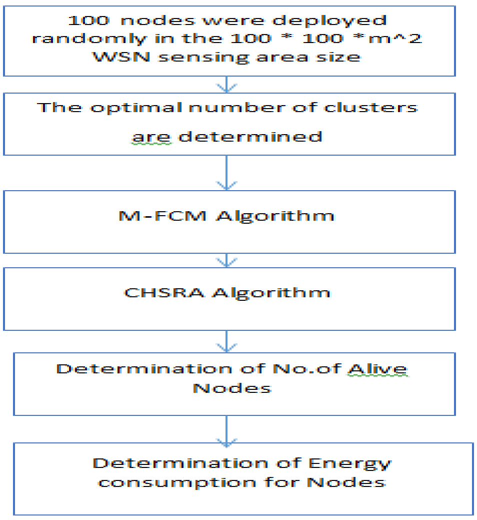
Selecting the optimal number of clusters based on the modified mathematical model by considering the overlapping case among clusters and multi-hop communications,

Forming balanced clusters that reduce the cost in the intra-distance based on modified fuzzy C-means algorithm (M-FCM) that result from a combination of the FCM algorithm with a centralized mechanism,

Reducing the energy overhead that results from the CH selection process in each round by a new integration of the back-off timer mechanism for CH selection with rotation mechanism in one algorithm known as CH selection and rotation model (CHSRA),

Balancing the communication distance among the CHs in the network based on a new objective function for the back-off mechanism, and

Balancing the life of the selected CHs in the cluster based on a new dynamic threshold.



Block diagram of proposed method

1) FCM ALGORITHM OVERVIEW

The FCM algorithm has been widely used in the clustering processes for WSN cluster formation. This algorithm was originally presented by Dunn [31]. The goal of FCM is to form better clusters by reducing the summation of distances between the objects (N) and the cluster centers (C) by using the objective function. In WSN, the objects refer to nodes that are already distributed in the sensing area. The FCM objective function for organizing nodes into clusters in the WSN can be formulated as follows

$$J_{FCM} = \sum_{i=1}^{n} \sum_{j=1}^{k} \mu^m d\,(x_i, x_c)^2, \quad i = 1, 2 \ldots N, \; j = 1, 2 \ldots K \qquad (20)$$

The normalization condition is

$$\times \sum_{j=1}^{K} \mu_{ij} = 1, \quad \mu \in [0, 1] \qquad (21)$$

$$\mu_{ij} = \frac{1}{\sum_{j=1}^{k} \left(\frac{d\,(x_i, c_j)}{d\,(x_i, c_k)} \right)^{\frac{2}{m-1}}}, \qquad (22)$$

$$C_j = \frac{\sum_{i=1}^{n} (\mu_{ij})^m * d\,(x_i, c)}{\sum_{i=1}^{n} (\mu_{ij})^m}, \qquad (23)$$

where K refers to the number of clusters, N refers to the number of nodes, µ refers to the membership of node (i) to cluster (j), Cj refers to cluster centroid; d refers to the distance between a node (i) and centroid (cj), commonly described by Euclidean distance; and m is the value of the fuzzifier that is chosen as a real number greater than 1 (m 2 [1;1)). m approaches to 1 clustering tend to become crisp (same as K-means algorithm) but when it reaches to the infinity, clustering becomes fuzzified (unreliable) [32]. Therefore, the value of fuzzifier is usually chosen as 2 in most of the applications [33], [34]. To terminate the algorithm, we use the condition Uij(t)-Uij(t-1)<ε where t is the current iteration, and is a very small number close to zero (e.g., 0.001). On certain occasions, FCM produces unbalanced clusters because of the nature of the random deployment of sensor nodes in the monitoring area, This situation leads to unbalanced energy consumption for nodes, which adversely affects the network lifetime . Some of the studies sought to overcome this problem by rearranging the degrees of belonging for nodes to produce balanced clusters. However, relying on the degrees of belonging is inefficient because of a normalization condition in the membership function, leading to an increase in the intra-distance for the clusters. Consequently, this condition increases the energy consumption of nodes.

To address this issue, a modified clustering algorithm has been proposed in this study to form balanced clusters with minimal intra-cluster distance by relying on the actual distance from centroids rather than the degrees of belonging for nodes.

2) MODIFIED FCM (M-FCM)

The proposed clustering algorithm is executed at the BS and consists of two phases: 1) initial cluster formation, which is based on the FCM, and 2) balanced cluster formation, which is based on the CM. In the initial cluster formation, the FCM is applied to form the clusters as shown in the algorithm, and then the process shifts to the second phase. The balanced cluster formation phase consists of two sub phases. The first sub phase consists of the following steps:

1) The cluster threshold (The cluster) is determined based on below equation

2) Clusters are sorted based on size. Minimum cluster size is compared with that of the The cluster.

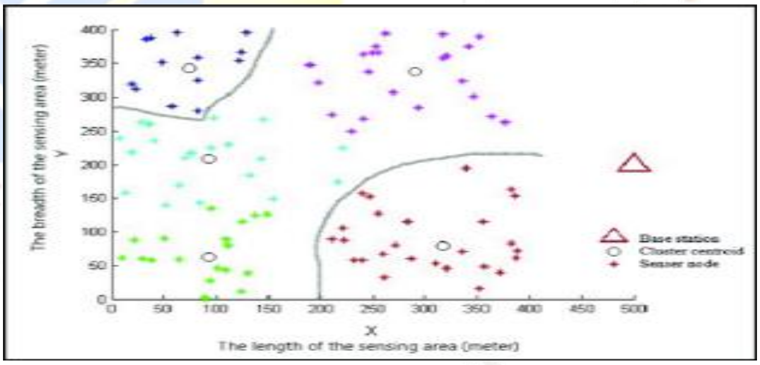
If the size is greater than the The cluster , then the FCM creates balanced clusters. Otherwise, the process shifts to the second subphase.

$Th_{cluster} = \frac{N * Pe}{K}$ where Pe is the permittivity value equals to 0.85 [25], and K signifies the number of clusters.

In the second sub phase, CM considers the final centroids of the clusters that were produced from the previous phase (FCM phase) as initial points to form balanced clusters. Steps of the CM are as follows:

1. The distance between the initial points and nodes is determined.
2. Nodes are arranged based on their distance from the initial points.
3. The initial points select the nearest number of nodes that are equal to the threshold of the cluster value to join it.
4. The remaining nodes that are still non-jointed join the nearest initial point to construct the final clusters.
5. Each cluster determines the new centroid based on the means for node locations.

This procedure ensures that the minimum cluster size is equal to or greater than the threshold cluster range with lower intra- cluster distance.



Algorithm 1 M-FCM

Input

Number of sensor nodes = N

Number of clusters = K

maximum iteration = 100

Improvement value = €

Permittivity value Pe = 0.85

Output

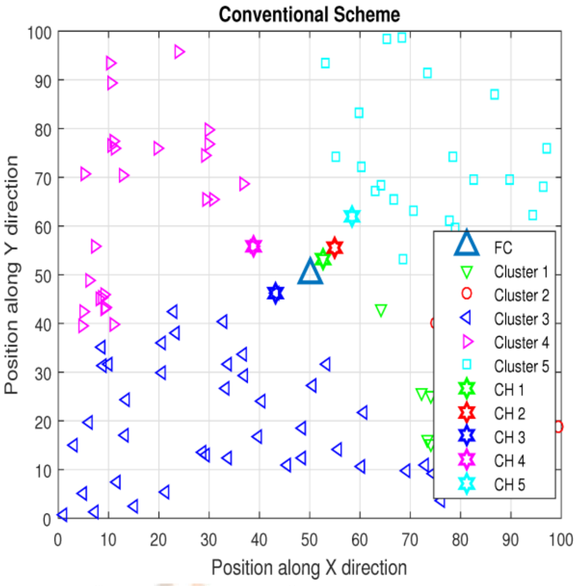
Balanced clusters

Process

1. Select the random K point as an initial centroid C(0)
2. For i = 1 to maximum iteration, do
3. update the membership u matrix using Eq. 22. 4. Calculate the new C centroids using Eq. 23.
5. Calculate the new objective function J using Eq. 20.
6. If J-J-<e. then
7. break:

else.z

8. J = J(-1)
9. end if
10.end for
11. Calculate the cluster threshold (Thcluster) using Eq. 24
12. for x=1to C do
13. sort cluster based on cluster size
14. find the minimum cluster size (min_cluster)
15. end for
16. if mincluster > Thcluster, then



17. break;
18. else
19. for x=1 to C do 22. for j=1 to N do
20. calculate the distance between the final centroid (initial point) and nodes
21. sort nodes based on distance from the initial point
22. end for
23. end for
24.for x=1 to C
25. initial point selects a Theater number of nearest nodes
26.end for
27. the remaining nodes are joined to the nearest initial point based on distance
31 for x=1 to C do
32. C_{final} (x,y)=(($\frac{1}{n}\sum_{1}^{n} x_i$),($\frac{1}{n}\sum_{1}^{n} y_i$))
32. end for
33. end if
34.end

CH SELECTION AND ROTATION ALGORITHM:

The CH selection and rotation issues have gained a great interest in researchers. Furthermore, in this study, a new algorithm has been proposed by integrating the back-off timer mechanism for CH selection with a rotation mechanism called CHSRA. In this algorithm, the CH is selected accurately by using a new objective function. Furthermore, the CH function is rotated among the members of the cluster based on a new rotation mechanism, where it is executed without any contribution to the BS.

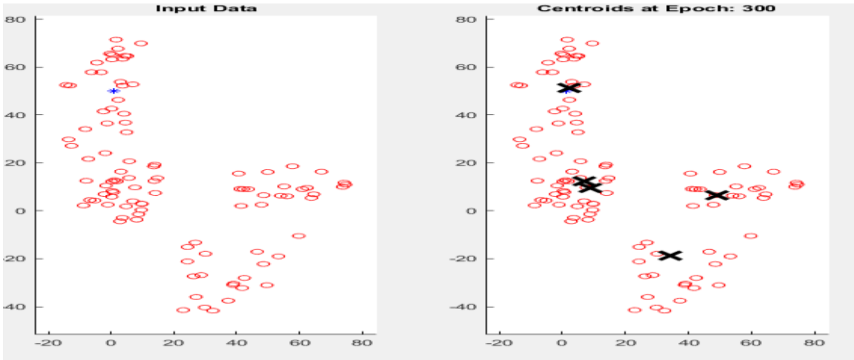
The goal of CHSRA is to reduce the overhead by selecting the CH within members of the cluster only. Furthermore, it balances the distance among CHs in adjacent clusters by adopting the routing information in the CH selection process that leads to balanced energy consumption for CHs. Besides, the CHSRA ensures the balance in energy consumption for the successive CHs of the cluster. The CHSRA comprises two phases:

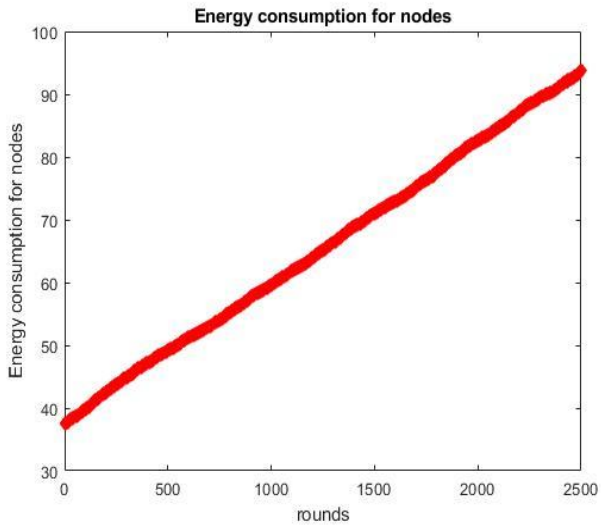
1) CH selection phase implemented by the back-off timer mechanism, and
2) CH rotation phase implemented by the dynamic thresh- old mechanism.

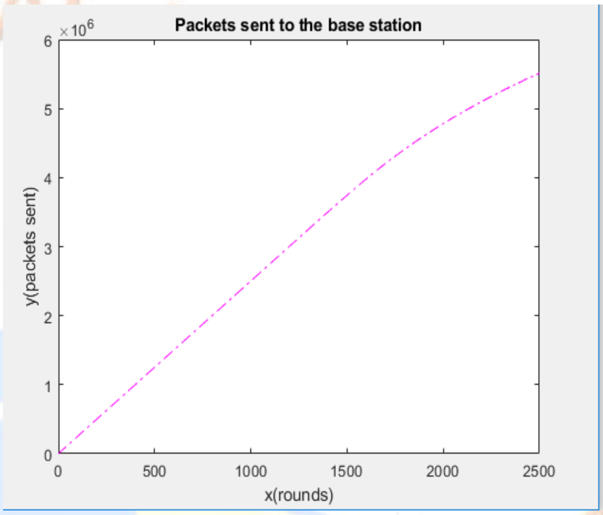
1) CH SELECTION PHASE

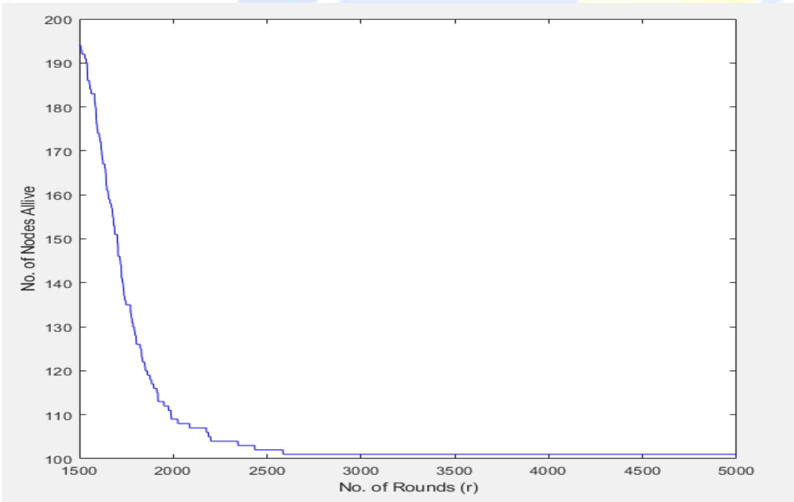
The back-off timer mechanism is used to select the CH, which is a distributed mechanism. This mechanism is widely used in the literature because it reduces the overhead for nodes and has the least delay in the selection process. In this mechanism, each node in the cluster sets its timer. The node is set as either CH or CM according to its timer (Tb) and the advertisement (ADV) message is received before the timer terminates. If the node received the ADV message from another node in the cluster, then it will cancel its timer and become CM. However, if the timer expires and the node does not receive any message, it broadcasts the ADV message and becomes a CH [37]. The timer value is set based on an objective function (F) of the node, where the timer value is the converse of the objective function as follows **Tb=1/th**is is presumably, the first time that the back-off timer mechanism is applied to select the CH within members of the cluster. In the current study, this mechanism is applied to the CH selection in all network nodes, thus, increasing time and energy consumption. Another significant contribution con corning the CH selection is to propose a new objective function for this mechanism that provides efficient distribution for the selected CHs in the network through selecting them in the optimal location. In this new objective function, the distance between a specific node to the forward CH (FCH) and the backward CH (BCH) is adopted along with the adjustment of coefficient for distances (ACD), in order to show the balance of distance between FCH and BCH and the residual energy of the node as the selection parameters for the CH selection process. This procedure ensures that the selected CH is in an optimal location according to the adjacent CHs of the other clusters. The proposed objective function relies on the a fore mentioned parameters rather than the residual energy of the node only [3]or the residual energy of the node and distance to the BS [24], as they do not guarantee the efficient distribution of the CHs in the network. Figure shows the effect of distances on the CH selection. Consequently, each node in certain clusters computes the following parameters to define the objective function F, which are: residual energy Er to prevent selecting CH with low energy. The current value of energy in a node after receiving or transmitting routing packets is the residual energy E_r=E_{ini}-$E_{con,}$Where Eini refers to the initial energy and Econ refers to the consumption energy of the node.

V.RESULTS AND DISCUSSION:









VI.CONCLUSION:

In this significant work, we propose an improved energy efficient clustering protocol (IEECP) to prolong the lifetime of WSN-based IoT network through overcoming the problems of the clustering structure that adversely affect the protocol performance. Evidently, the proposed protocol reduces and balances the energy consumption of nodes by improving the clustering structure. Hence, the IEECP is deemed suitable for networks that require a longer lifetime. In general, the results yield that the IEECP performs better than the existing protocols. Our proposed protocol will be a beneficial contribution to the field that will enhance the daily operations in many areas of life, which utilize WSN in the IoT world. The energy consumption of the network is analysed to compute the optimal number of clusters based on the distance to the CH in the case of the overlapping clusters. Then, the modified FCM algorithm (M-FCM) is proposed by combining it with a centralized mechanism to form static and balanced clusters. Finally, a new CH selection-rotation algorithm (CHSRA) is presented by integrating the back-off timer mechanism for the CH selection with the rotation mechanism for CH rotation. The CHSRA has relied on a new objective function for selecting CHs in optimal locations to balance the energy consumption among CHs for the clusters. Furthermore, it has relied on a new dynamic threshold for CH rotation within members of clusters to balance the energy consumption for the successive CHs in the cluster. In future work, we aim to enhance the protocol by improving the FCM algorithm concerning the random initial selection. Moreover, we believe that improving the objective function of CH selection through the reliance on weighted energy-based distance for adjacent CHs is also crucially significant. We anticipate that the future clustering protocol can perform excellently when these limitations are taken into consideration.

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