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An Improved Energy Efficient Clustering Protocol to Prolong the Life Time of the WSN Based IoT

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***Abstract:* - The Internet of Things relies heavily on wireless sensor networks (WSNs)(IoT). However, the energy resources of sensor nodes in a WSN-based IoT network are restricted. By grouping nodes into clusters to reduce the transmission between sensor nodes and base stations, a clustering protocol offers an effective method for ensuring node energy savings and extending network life span (BS). Current clustering protocols, on other hand, have problems with the clustering mechanism, which has a negative impact on their efficiency. We suggest enhanced energy-efficient clustering protocols (IEECP) in this paper to extend the life span WSN-based IoT devices. The proposed algorithm achieved 248.80% improvement compared with the basic LEACH in the concept of network lifetime.**

***Index Terms* – WSN, Internet of things, Clustering protocol, Energy consumption, Network life time etc.**

1. INTRODUCTION

Wireless Sensor Network (WSN) consists of a large number of very small sensors deployed in a specific area depending on the desired application [1]. Each sensor contains sensing, data processing, and communication components. These sensors form WSN nodes that transfer the sensing data to the Base Station (BS) or sink. In the BS, the data is processed and computed to give understandable results. The communication between BS and wireless nodes is arranged by different protocols. One of the energy-efficient protocols is the LEACH routing protocol. In this protocol, the network is divided into different clusters and each cluster has elected Cluster Head (CH) which connected with cluster member nodes and the BS, collecting data from the nodes and then sending the aggregated data to the BS [2][3].

As a cluster head has more functions than the other nodes, so it consumes its energy faster than the other nodes which leads it to die earlier [4][5]. In this paper, we propose a new algorithm called an enhanced energy efficient clustering protocols (IECP) to extend the life span of WSN-based IoT devices.

The proposed IECP is divided into three parts. For the overlapping balanced clusters, an optimum number of clusters is calculated. The balanced static clusters are then developed using atweaked fuzzy C-means algorithm in combination with mechanism minimize the balanced sensor nodes. Finally, clusters heads (CHs) are chosen in optimal locations by rotating the CH function among cluster members using a new CH selection-rotating algorithm that combines a back-off timer mechanism for minimize energy consumption and enlarge network lifetime by picking CH which exhausted high remaining energy and nearest distance to the BS. Prasad simulated LEACH using CH selection and a rotation mechanism for CH rotation.The remaining of this paper is organized as follows. Literature review and related work is given in *Section II*. The LEACH protocol, including the relevant theoretical background about the main components of the proposed system, is presented in *Section III*. Next in *Section IV*, the proposed algorithm is presented. The experimental settings, results, and discussions are thoroughly given along with the supporting and illustrative figures are presented in *Section V*. Finally, the paper is concluded in *Section VI*.

2. LITERATURE SURVEY

Wireless sensor technology is growing rapidly, especially with many new Internet of Things (IoT) applications. In another side, researches are coming out with diversities of approaches to enhance and improve this technology trying to cover the needs in this era. The drawback of sensor Technologies is the low battery and short lifetime. So, most of the following researches considering to sophisticate these weaknesses and suggest different algorithms and approaches overcome these issues.

Sharma [7] proposed novel LEACH protocol in the heterogeneous network and compared the simulation results with LEACH Homogeneous system; They chose 100 * 100 meters area to simulate the protocol. Sharma found that 10 nodes have more energy than the rest of 90 nodes which improves the system lifetime and enhanced wireless sensor network performance.

J. Shen: proposed a new energy-efficient centroid-based routing protocol (EERCP) for WSN-assisted IoT to increase the performance of the network.The proposed

EERCP involves three main parts: a new set of algorithms for adjusting clusters and rotating cluster head centroid on the centroid location to equally spread the energy load across all sensor nodes.

S. Dehghani: proposed a new NS2 tool, it was discovered that using the proposed algorithm resulted in substantial improvements in network life time, throughput, and residual energy, as well as reduction in network delay, when compared to two equivalent algorithms. Cluster head selection algorithm is the main factor of getting better performance in clustering wireless sensor network, as reported by prasad suggested an improved energy-efficient leach protocol (IEEE-LEACH) for aiming to reduce the coefficient of the distance to the base station and to reduce TDMA routing protocol. Also, they surveyed the previous approaches for selecting CH and improving the WSN performance such as Euclidian Distance from a node to BS, remaining energy and number of nodes in the same cluster. Increasing the number of dead nodes in the cluster would be the reason for shortening the WSN lifetime.

Nandi [10] implemented a new protocol for choosing an optimal place for the BS, which overcomes the issues of delivering data and they compared the simulation result with the basic LEACH protocol with TDMA technique. Commonly when the BS located far away from the node, then transmitting data from a node to BS will cost more energy in the node, which leads to reduce the node lifetime and therefore reduce the network lifetime [10]. Moreover, packet delivery time would be reduced when the sink positioned in the center near the nodes [10].

In [11] the authors compared three different WSN protocol, direct transmission protocol, LEACH and EEE LEACH in terms of data communication time and throughput. EEE LEACH has better data transmission time and DTx has minimum throughput [11].

In [12], the authors proposed an algorithm called Distance Based Cluster Head (DBCH) which the threshold value measured by the following equation:

$$T(n) = \frac{p}{1-p\left(r mod \frac{i}{p}\right)} + (1-p)\frac{D_{max}-D_{i\ to\ BS}}{D_{max}-D_{min}}\left(\frac{E_R}{E_0}\right) \quad \ldots\ldots\ldots.. (1)$$

where E_R is the residual energy of the node for the current round and E_0 is the initial energy. This algorithm proposes to select the closest node to the BS as a cluster head. This enhancement considered on two-parameter energy and distance. In addition, it considers the distance from the node to cluster head base station and compared the distance from node cluster head and BS. This study simulated the suggestions on a homogenous network, where all nodes have the same amount of energy.

3. LEACHP ROTOCOL

LEACH protocol or low-energy adaptive clustering hierarchy protocol suggested for wireless sensor networks by MIT's Chandrakasan [13]. LEACH is a self-adaptive cluster formation protocol. The nodes are randomly deployed then one node is selected to be a cluster head which will play a role as a gateway for all nodes in the cluster to the BS. All nodes in the cluster have the same probability to be a cluster head based on the equation (2). The cluster head election occurs in the setup phase of each round in the LEACH protocol. Each node generates a random number between 0 and 1, when the generated number is less than the threshold T(n), then the node would be selected as a cluster head. After that, the cluster head node informs all nodes in the same radio range (each node join the CH based on Received Signal Strength Indicator RSSI [13][14]) that it's the cluster head for the current round and the cluster form. The threshold is defined as in the following equation [15]:

$$T(n) = \begin{cases} p/(1-p\times(r \bmod (1/p))) & n \in G \\ 0 & otherwise \end{cases} \quad \ldots\ldots\ldots\ldots (2)$$

where p is the probability of a node to be a cluster head, r is the number of rounds, G is the set nodes that have not been selected in the last $1/p$ rounds. As the cluster head is known for each node in the cluster and the cluster head form the TDMA slots for each node in its cluster (to prevent interference). Then the steady-state stage of the LEACH protocol process starts. Next, all nodes send the data packet to the cluster head then the cluster head integrates the data packets and sends the fused data to the BS. We have noticed that the cluster head missions are more than the ordinary nodes, so the cluster head consumes more energy than the others which one of the drawbacks of the LEACH algorithm. LEACH disregards the BS and cluster head geographical positions, energy consumption, and instability in the case of cluster head death.

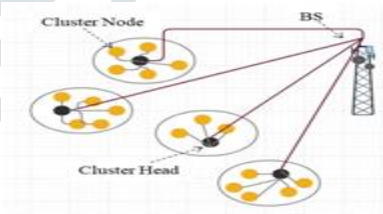

Figure 1: LEACH infrastructure

4. PROPOSED SYSTEM

An improved energy-efficient clustering protocol (IEECP)to prolong the lifetime of the WSN-based IoT based 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 no of clusters. Secondly, 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.

The main combination by the proposed protocol is the prolonging of the WSN base 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:

A. Determination of the optimal number of clusters:

The mathematical model relies on a disk model to represent the distance to the CH. The disk model is often utilized for studying the ESN communication, taking into account the coverage areas for the transmission and entailing a disk of the plane with radius R, as shown in Figure. This value represents the distance to the CH in the mathematical model. The estimated value of radius r has a significant effect on the final result of the number of clusters, as proven later in this paper. Although the other studies consider the distance to CH is the same whether the clusters are overlapping or isolated, in reality, the value of the radius is greater in the overlapping clusters, as shown in figure We assume that the N nodes are deployed randomly in a square sensing area(M2).

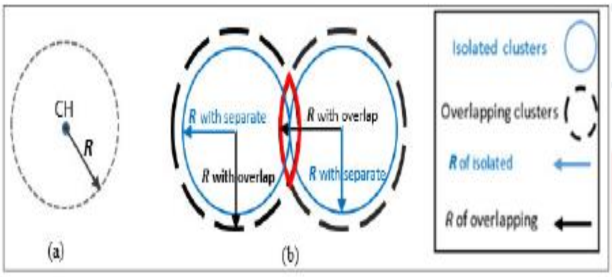

Figure 2.1 (a) disk model, and 2.1 (b) difference in radius between Overlapping clusters and separate clusters.

The optimal number of clusters can be obtained and given by:

$$K = \sqrt{\frac{1.262N}{2\pi}\frac{M}{d_{BS}}}. \quad \ldots\ldots (3)$$

B. Formation of balanced clusters:

For the formation of balanced clusters, a modified fuzzy C-means algorithm (M-FCM) is proposed in this study by combining the FCM with a centralized mechanism. Before discussing the proposed algorithm to form balanced clusters, the conventional FCM algorithm.

1) FCM ALGORITHM OVEREVIEW:

The FCM algorithm has been widely used in the clustering processes for WSN cluster formation. The goal of FCM is form better clusters by reducing the summation of distances between the objects(N) and the cluster centres (c) by using the objective function for organizing nodes into clusters in the WSN can be formulated as follows

$$J_{FCM} = \sum_{i=1}^{n} \sum_{j=1}^{k} \mu^{m} d\,(x_i, x_c)^2,$$

$$i = 1, 2 \ldots N,\ j = 1, 2 \ldots K$$

The normalization condition is

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

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

$$C_j = \frac{\sum_{i=1}^{n} (\mu_{ij})^m * d\,(x_i, c)}{\sum_{i=1}^{n} (\mu_{ij})^m}, \quad \ldots.. (4)$$

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), Euclidean distance, and m is the value of the fuzzifier that is chosen as a real number greater than 1, m approaches to 1 clustering tends to become crisp but when it reaches infinity, clustering becomes fuzzified.

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
2. Balanced cluster formation, which is based on the CM.

In the initial cluster formation, the FCM is applied to form the clusters are 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 (Thcluster) is determined based on below equation
2. Clusters are sorted based on size. Minimum cluster size is compared with that of Thcluster
3. If the size is greater than the Thcluster, then the FCM creates balanced clusters. Otherwise, the process shifts to the second subphase.

$$Th_{cluster} = \frac{N * Pe}{K}, \quad \ldots\ldots\ldots (4)$$

Where Pe is the permittivity value equals to 0.825, 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.

Algorithm-1

Input

Number of sensor nodes=N

Number of clusters=k

Maximum iteration=100

Improvement value=e

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 µ 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 $|J^{(i)}-J^{(i-1)}|<€$, then
7. break;
8. else
9. $J^{(i)} = J^{(i-1)}$
10. end if
11. End for
12. Calculate the cluster threshold ($Th_{cluster}$) using eq.24
13. for x=1 to C do
14. sort cluster based on cluster size
15. Sort cluster based on cluster size
16. find the minimum cluster size (min_cluster)
17. end for
18. if min cluster >$Th_{cluster}$, then
19. break;
20. else
21. for x=1 to C do
22. for j=1 to N do
23. calculate the distance between the centroid (initial point) and nodes
24. sort nodes based on distance from the initial point
25. end for
26. end for
27. for x=1 to C do
28. initial point selects a $Th_{cluster}$ number of nearest nodes
29. end for
30. 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)
33. end for
34. end if
35. end

CH selection and rotation algorithm:

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

1) CH selection phase:

The back-off timer mechanism is used to select the CH, which is a distributed mechanism. In this mechanism, each node in the cluster sets its timer (Tb) and the advertisement 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, the timer expires and the node does not receive any message, it broadcasts the ADV message and becomes a CH. The timer value is the converse of the objective function as follows

$$Tb=1/F$$

This is the presumably, the first time that the back-off timer mechanism is applied to select the CH within members of the cluster.

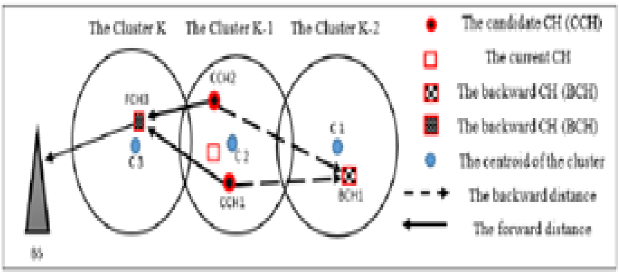

Figure 3: CH selection mechanism using backward and forward distance.

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

$$E_r = E_{ini} - E_{con}, \quad \ldots\ldots (5)$$

Where Eini refers to the initial energy and Econ refers to the consumption energy of the node.

1) Euclidean distance from the nearest forward CH (dFCH) to reduce the energy for the candidate CH(j)

$$d_{FCH} = \begin{cases} \min(\|x_i - CH_j\|)\, d_{BS} > d_F \\ < d_0, otherwise \\ \|x_i - BS\| \end{cases} \quad j = 1,\ldots,K \quad \text{and } i = 1,2,\ldots,n \quad \ldots\ldots(6)$$

2) Euclidean distance from the nearest backward CH (dBCH) to reduce energy for backward CH(j-1)

$$d_{BCH} = \begin{cases} \min\left(\left\| x_i - CH_{j-1} \right\|\right) j > 1; \text{Otherwise} \\ 0 \end{cases}$$ ……………. (7)

3) ACD for the node; this coefficient is responsible for showing the balance between FCH abd BCH

$$ACD = \frac{\min(d_{FCH}, d_{BCH})}{\max(d_{FCH}, d_{BCH})}$$ ……… (8)

According to these parameters, the objective function F for CH selection is

$$F_i = \frac{E_r}{d_{FCH} + d_{BCH}} + ACD.$$ ….. (9)

Tye selected CH based on this proposed algorithm overcomes the following two issues:

1. The energy overhead in the CH selection process is minimized by using the back-off time mechanism with the members of the cluster rather than using all nodes in the network as in the current studies.
2. The CH is selected optimally because the required criteria for a balanced energy consumption in the selection are considered.

2) CH ROTATION PHASE:

In the proposed mechanism, the energy consumed and the ratio from the initial energy (T) is used to estimate the threshold value. The first action taken by the selected CH directly after selection is calculating the value of its threshold for rotation.

$$E_{TH} = \begin{cases} E_{con} + (E_{ini} - T) * E_{ini} \text{ if } (E_{con} + T * E_{ini}) \\ \quad \leq E_{ini} \\ E_{con} + E_r \text{ if } (E_{con} + T * E_{ini}) > E_{ini}. \end{cases}$$ …………. (10)

Where Econ is the consumption energy of the node, Eini is the initial energy of the nide, Er is the residual energy of the node, and T is a constant value of initial energy but may differ from one cluster to another subjects to the number of members in the cluster. The T value is estimated only once for the cluster throughout the network lifetime. The T value can be calculated as follows:

$$R_{CHs} = (n-1) * \left(E_{TH} / E_{CH-perrnd}\right),$$
$$E_{rth} = E_{ini} - E_{TH},$$
$$R_n = E_r / E_{n-rnd},$$ ……….(11)

Where RCHs refers to the rounds of all CHs in the cluster at ETH, with Erth as the residual energy of the node at ETH value, Rn represents the rounds of the member nodes in the cluster at the ETH, $E_{CH-per-rnd}$ is the energy consumption per round of the CH, E_{n-rnd} is the energy consumption per round for the nodes; and ETH is the threshold value within the range from 0.1 to 0.9 of the initial energy values for the node.

$$\mathbf{T} = \mathbf{R_{CHs}} \cap \mathbf{R_{n}},$$ ………..(12)

The appropriate value of T represents the intersection point of the curve of all CH rounds with the curve of members rounds

Algorithm 2 CHSRA

input:
Number of sensor nodes=N
Number of clusters =K
Cluster size =[ ]
Maximum iteration =X
Output
Cluster heads with dynamic threshold for rotation
Process:

1. For i=1 to K do
2. For j=1 to cluster size (i) do
3. Each node in the cluster computes the Er. dFCH, dBCH, and ACD according to Eqs.26,27,28, and 29.
4. Setup the timer for nodes based on objective function (F)in eq.30
5. End for
6. Max (F) =CH(i)—broadcast join message for members of the cluster
7. Members that received the join message cancel theur timer and join CH
8. Calculate the energy threshold Eth for CH rotation using Eq.31
9. End for
10. For x=1 to max iteration do
11. 11. For i=1 to K do
12. For j=1 to cluster size (i) do
13. Members send sensing data to CH
14. Update the residual energy Er of nodes based on the energy model
15. End for
16. If Ecom (CH)> Eth then
17. Re-select the CH (return to step 3)
18. End if
19. End for
20. End for
21. end

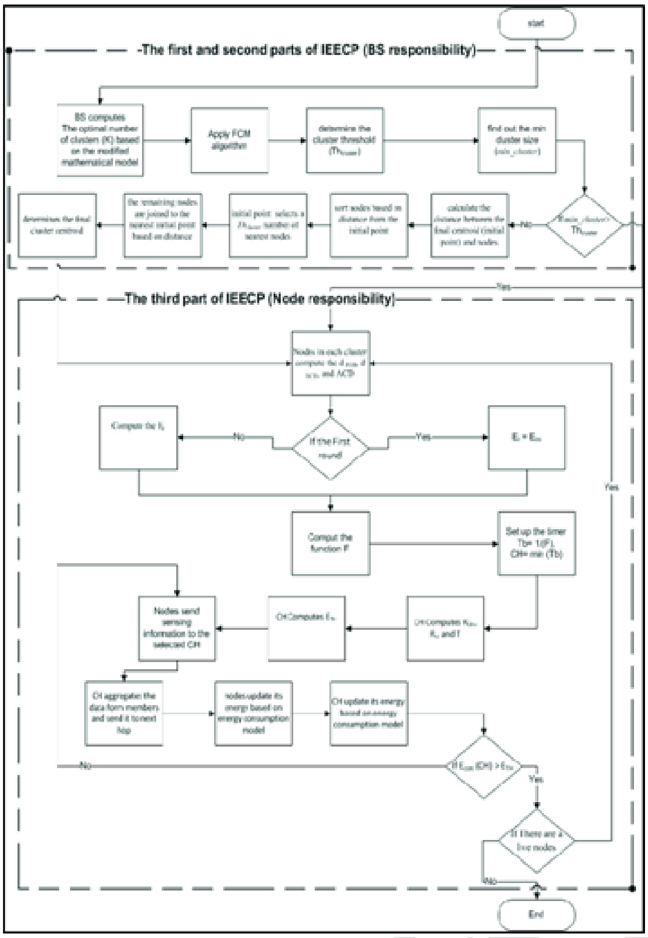

Figure 4: IECEP flow chart

The execution of the IEECP protocol process occurs in two different process occurs in two different places. The first place is the BS, where the number of clusters is computed initially based on the modified mathematical model, then the balanced clusters are formed based on the M-FCM. The second place is the node, where the CH selection and rotation are processed based on the CHSRA algorithm. The determination of the number of the clusters does not contribute to any complexity, hence, it is deemed suitable for real-time applications.

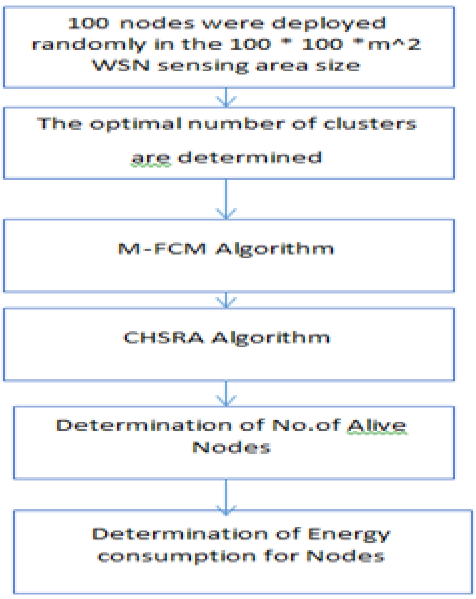

Figure 5: Block diagram

5. SIMULATION RESULTS

Considering the major issues of the Wireless Sensor Networks, we focus on the most common algorithm. LEACH protocol, which enhanced the performance of the WSN such as Energy efficient, Transmission time, transmission rate, optimal position of the sink, the optimal position of the cluster head, node density and network lifetime.

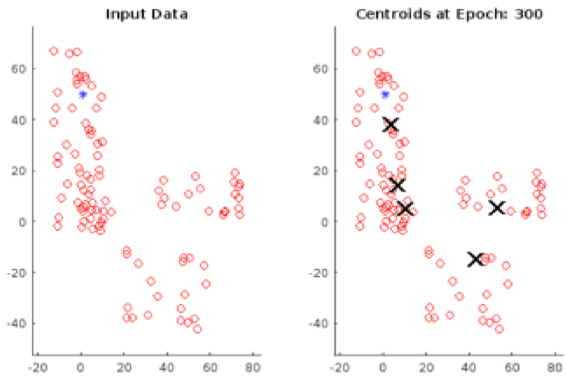

Figure 6: Formation of clusters according to M-FCM

Figure 7: Classified Data

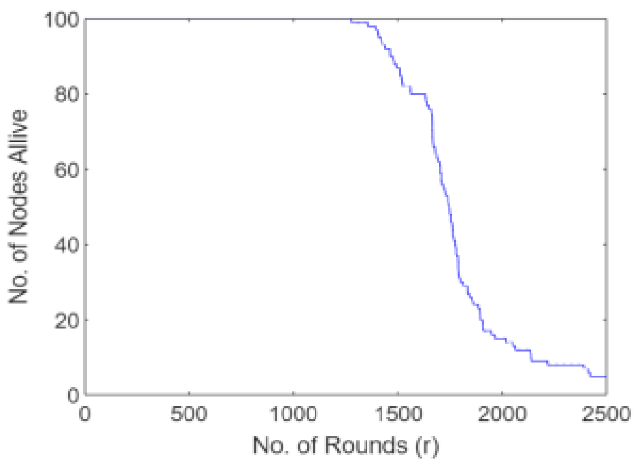

Figure 8: Number of live nodes in first scenario

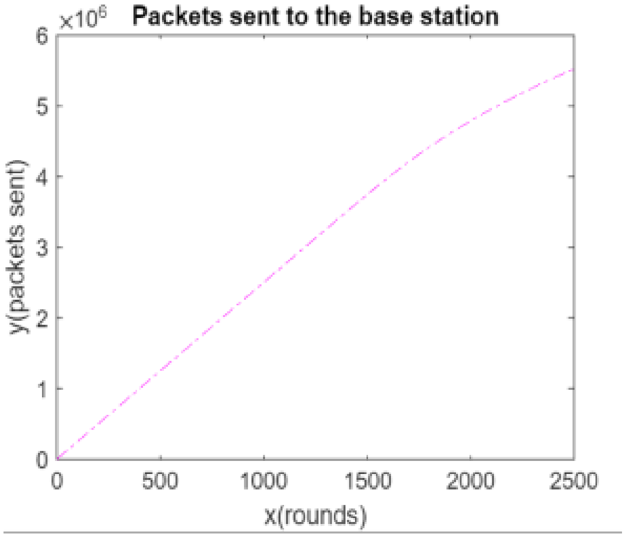

Figure 9: Number of messages received by BS

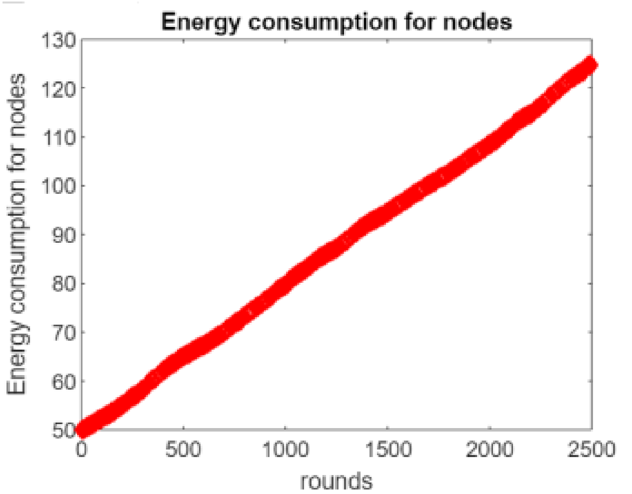

Figure 10: Energy consumption for effective network

6. CONCLUSION

In this paper, we proposed a new algorithm called energy-efficient clustering protocol (IEECP) to prolong the life time of WSN-based IoT network through overcoming the problems of 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 requires a longer lifetime. In general, the results yield that the IEECP performs better than the existing protocols. Our proposed protocol will be a contribution to the enhance that will be a beneficial contribution to enhance that will enhance the daily operations in many areas of life, which utilize WSN in 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 overlapping Clusters.

In further 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.

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