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Energy Centric Data Aggregation Mechanism In WSN Environment

Gajendran Malshetty[1] , Dr. Basavaraj Mathapati[2]

[1]Assistant Professor, Computer Science & Engineering, Appa Institute of Engineering & Technology, Kalaburagi.

[2]Professor, Computer Science & Engineering, Appa Institute of Engineering & Technology, Kalaburagi, India.

Abstract- Internet of Things aka IoT is one of the promising technology that tends to provide a reliable and efficient solution for modernization in several domains; further Wireless Sensor Network is considered to be a primary part of IoT. WSN based IoT provides the solution for automatically monitor the agricultural farm and further reduces human involvement; in this research, we focus on the IoT in the agricultural domain which helps in smart farming. In this research work, we propose ECDA (Energy Centric Data Aggregation)-mechanism for efficient data aggregation, In ECDA we design a specific type of network and then the data are aggregated further we formulate the energy consumption mechanism and later we minimize the energy consumption. Moreover, the energy consumption is optimized through minimizing the distance between Cluster Head and member; this reduces the energy consumption. Furthermore, ECDA-mechanism is evaluated considering the latest data aggregation mechanism; evaluation is carried out by considering the network lifetime and number of failed nodes by varying the number of nodes as 500, 750, and 1000.

Keywords: WSN, IoT, Data Aggregation, ECDA, lifetime maximization.

1. Introduction

Wireless Sensor Network comprises a wide range of small devices that has the capability of processing and monitoring the application; further, WSN has been one of an integral part of IoT(Internet of Things)[1][2]. WSN is effective and ideal for IoT to minimize the cost and power and it is used for several applications especially monitoring, to name a few, health monitoring, and environment monitoring, agricultural monitoring. In agricultural monitoring, WSN plays an unimaginable application due to its dynamic environment and it is considered to be very cost-effective; while monitoring the agricultural field it generates the huge amount of data [3], in many areas it is highly improbable to manage the volume and velocity of the data. Moreover, these sensor nodes are battery-based hence they possess very limited energy for the data transmission mainly in case of asynchronous MAC-based WSN. Hence various researchers focused on minimizing the data volume rather than focusing on the data latency. For instance, few researchers proposed the dataset such as the kernel dataset and e-dominant dataset that can represent the information regarding the data; however, the sample was very less. Hence to overcome such issue DA(Data aggregation) technique was developed which tries to minimize the data; in wireless sensor network, data aggregation aka DA is a major operation which is used in various application [4]. Data aggregation possesses various advantages such as it supports various characteristics as energy consumption, time consumption latency minimization; basically, data aggregation tends to integrate the data from different resources. Furthermore, it helps in avoiding the redundancy in data, reducing the transmission, and thus reduces the energy consumption. Moreover one of the popular methods for data aggregation is via data fusion, here the data aggregation takes place through signal processing; further, it combines few signals and removes the noise.

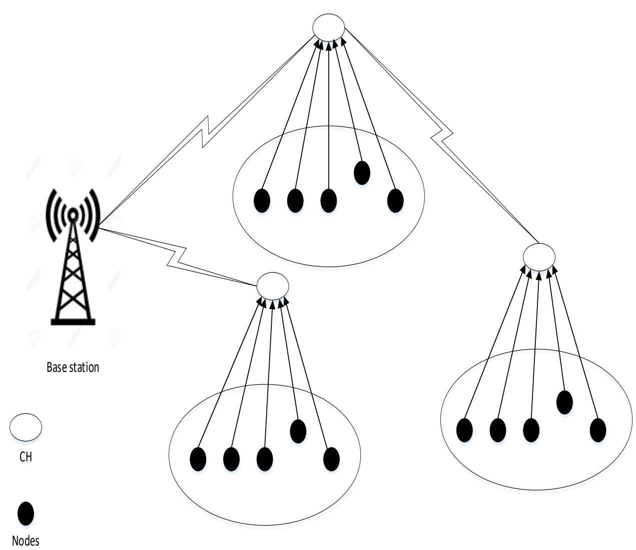


Figure 1: Data aggregation

The above figure shows the general data aggregation and further it comprises the sensor node, Cluster Head and Base station. In general, the data sensed are sent to the cluster head through the optimal route; these data are aggregated and sent to the base station. This aggregated data can be accessed through the application via the internet. It saves a huge amount of energy since whole data transmission requires more energy.

In past several data, aggregation mechanism has been proposed for the efficient and optimized aggregation, however many of them assumed that the original packet can be aggregated into the single packet at the aggregation node; for instance, in case of In-Network data aggregation, GM(Generalized Maximum) function was adopted, this model is mainly suitable for the small network.

1.1 Motivation and contribution of this research work

Data aggregation has been considered as an efficient and effective technique for minimizing energy consumption and increasing the lifetime of the network since the devices that are deployed for monitoring are sensor-based. Moreover considering the advantage of Data aggregation, lot of research has been carried out in past, however, these method does succeed, however further optimization is required, hence this research focuses on developing the energy-aware data aggregation mechanism which helps in increasing the lifetime of a network; further, the research contribution is given through the below points:

- This developed an optimized-Energy aware data aggregation mechanism for aggregating the data efficiently.
- In order to achieve efficient data aggregation, we have designed a novel network design for transmitting and receiving the data.
- Further, we gather the data and compute the energy consumption; energy optimization is carried out through minimizing the distance between the cluster head and its member.
- At last, our model is evaluated by performing the comparison analysis between the existing data aggregation method and it is observed that our methodology outperforms the existing one.

This research work is organized in a classic way, here the first section starts with a background of IoT, WSN, and their application in real-world, later motivation and contribution of the particular research are briefly highlighted, second section reviews the various existing protocol of data aggregation and their shortcomings. Moreover, ECDA-mechanism has been formulated and computed in the third section; further fourth section evaluates the model through comparative analysis to prove the efficiency of the model.

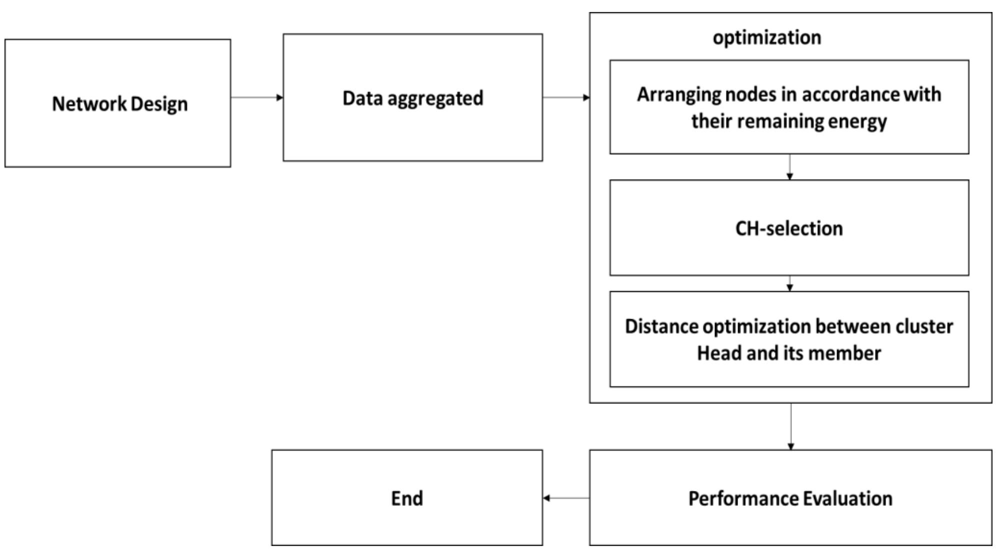
2 LITERATURE SURVEY

[6] Considered the two-phase transmission model where Data Aggregation takes charge for relating the data and handles the resources among the active devices; further, it is shown that choosing the aggregators, hence it is enhanced. [7] addressed the clustering issue is formulated as the optimization issue for determining clusters that result in energy consumption along with hierarchical transmission model; [8] proposed energy-efficient model for the cellular network for huge IoT and it is assisted through the drone scenario; further [9] deployed the strategies for data aggregation through various approach and further it is studied and energy consumption impact are observed. [8] proposed a model named n-CSMA for the in-cluster transmission and further, its impact is noticed and it tries to enhance the network performance through a correlation between the size of the cluster and network performance; it also focused on achieving the better throughput. [10] Proposed two-stage access for the cellular-based IoT, here queuing theory was deployed for

analyzing the performance delay. However, it is also observed that the above-discussed method works on data aggregation along with the node clustering; moreover, in the case of a huge number of devices the data aggregation possesses a great challenge and parameter optimization is very important. Hence in [11], NOMA was proposed for the potential sharing model in order to enhance the number of devices; here two techniques such as SIC and multi-user detection were used which allows a large number of devices to perform on the same radio channel. Similarly, for better performance it was compared with the OMA (Orthogonal Multiple access) [12], however, OMA based does provide the network performance optimization, hence much existing protocol has considered such as [13][14] whereas only a few of them considered NOMA due to its complexity. Hence [15] were proposed for reducing the redundant transmission through the neighbor information; on a similar note [16] proposed two-node disjoint path, if any one link fails the other link used for the data transmission to the sink; here hexagon routing protocol is adopted where the nodes are clustered into the hexagon architecture by their locations. Moreover, this protocol does good data latency and data delivery, however, fails for the energy consumption in case of a large network, hence another protocol in [17] used the ant colony algorithm, which also optimizes the route, however, all these methods focused on the routing and ignored the data aggregation.

3 PROPOSED METHODOLOGY

The below figure shows the process flow of ECDA-Mechanism; in general, it is parted into four blocks and each block is considered as the step. The first block indicates the Network Design, here the particular network is designed as network design, and data aggregated, optimization, and performance evaluation.



3.1 SYSTEM MODEL

Let's consider any network, where A and B are the cluster member and C is cluster head; further, both nodes i.e. X and Y transmit the data of desired size τ to Node Z. For instance, the time taken to transmit the data from one node to another node is given as s_{trans} and the energy at the transmitter and receiver node is indicated by $\mathrm{eng_{trans}}$ and $\mathrm{eng_{rcv}}$ respectively. Hence the total energy can be computed through the below equation.

$$\mathrm{eng_{WE}} = 2\tau'(\tau)^{-1} + 2(\mathrm{eng_{WE}} + \mathrm{eng_{WE}}) \tag{1}$$

$$\mathrm{eng_{WE}} = \tau'(\tau)^{-1}(\mathrm{eng_{trans}}) + \mathrm{eng_{rcv}} + 2\,\mathrm{eng_{trans}} \tag{2}$$

The proposed network structure is a tree-based network, which guarantees its data aggregation duration will not be greatly increased, even when in-network data fusion does not yield any size-reduction in outgoing data. In the proposed network structure, wireless sensor nodes are organized into multiple single-layered clusters of different sizes, such that clusters can communicate with the FC in an interleaved manner. Under such tree-based structure, a network will be organized into C clusters if the network has N wireless sensor nodes, which provides the guarantee that the duration of DA will not be increased; further, we consider

$$\sum_{j=1}^{O-1} l_j < O \leq \sum_{i=1}^{C} l_j \tag{3}$$

m_i is the maximum number of nodes in the given cluster further this is computed through below

$$l_1 = 1, l_j = 2l_{j-1} \tag{4}$$

The above equation can be simplified using the GP (Geometric progression); further equation

$$2^{l-1} - 1 < O \leq 2^{l-1} \tag{5}$$

3.2 ENERGY CONSUMPTION

In WSN, transceiver consumes the energy for instance $\mathrm{eng_{trans}}(p)$ is the energy to transmit data that has size α in such a way that the receiver has enough signal strength to retrieve the data at distance p.

Further, by the network model, the network has nodes with equation 2, these nodes are organized into k clusters.

$$\begin{aligned}&Eng\\&= + \sum_{k=1}^{l'_C -1} [eng_{trans}(p_{memberj\_CHi})\\&+ eng_{rcv}]\\&+ \sum_{j=2}^{C-1}\sum_{k=1}^{l_{j-1}}[eng_{trans}(p_{memberk\_CHj})\\&+ eng_{rcv}] + \sum_{k=1}^{l-1} l_j\, eng_{trans}(p_{CHj\_FC})\\&+ l'_C eng_{trans}(p_{CHi\_FC})\end{aligned} \quad (6)$$

In the above equation, $p_{memberk\_CHj}$ is described as the distance between the jth cluster and kth member including its corresponding CH; d_{CHi_FC} is communication distance between the cluster head and FC. l'_j indicates the total number of nodes in the kth cluster; further, in the above equation there are three terms, two-term represents the communication in inter-cluster and the other term as the communication occurs in cluster head and FC.

Further more,we formulate the upper bound, this is achieved through $\widehat{eng}_{tans}$, $\widehat{eng}_{TX}$ is the maximum of e_{TX}

$$\begin{aligned}\widehat{Eng} = (l'_j - 1)[\widehat{eng}_{trans} + eng_{rcv}] + \sum_{j=1}^{C-1} l_j \widehat{eng}_{trans} + l'_j \widehat{eng}_{trans}\\ + \sum_{ij=2}^{C-1}(l_j - 1)[\widehat{eng}_{trans} + eng_{rcv}]\end{aligned} \quad (7)$$

Further, the above equation can be written as

$$\begin{aligned}\widehat{Eng} = + \sum_{j=1}^{C-1}\left[\left(Q^{l_j -1} + \sum_{k=1}^{l_j -1} Q^k\right)\hat{e}ng_{trans}\right]\\ + \sum_{j=2}^{C-1}(l_j - 1)[\widehat{eng}_{trans} + eng_{rcv}] + (l'_j - 1)[\widehat{eng}_{trans} + eng_{rcv}]\end{aligned} \quad (8)$$

$$+\left(Q^{l_j'-1}+\sum_{k=1}^{l_j'-1}Q^k\right)\hat{eng}_{trans}$$

Moreover, the sensor node is organized into the $Cluster(O)$ clusters, this can be given in the below equation.

$$Eng=\sum_{j=1}^{Cluster(O)}\left(Cluster_j+1\right)eng_{trans}\left(p_{CH_j\_FC}\right)+\sum_{j=1}^{Cluster(O)}\sum_{k=1}^{Cluster_j}\left[eng_{trans}\left(p_{member_k\_CH_j}\right)+eng_{rcv}\right] \quad (9)$$

Further Eng can be formulated as

$$\widehat{Eng}=\sum_{j=1}^{Cluster(O)}\left(Cluster_j+1\right)\widehat{eng}_{trans}+\sum_{j=1}^{Cluster(O)}Cluster_j[\widehat{eng}_{trans}+eng_{rcv}] \quad (10)$$

In general, the above equation is written as

$$\widehat{Eng}=\sum_{j=1}^{Cluster(O)}\left[\left(Q^{Cluster_j}+\sum_{k=1}^{Cluster_j}Q^k\right)\widehat{eng}_{trans}\right]+\sum_{j=1}^{Cluster(O)}Cluster_j[\widehat{eng}_{trans}+eng_{rcv}] \quad (11)$$

Further, we consider the network and it is organized in a tree structure; here node j have a set, which is considered as the sub-node S_j; however, it has one node. Moreover, while collecting the data with $Q=1$; further node j consumes the energy and depicted through the below equation.

$$Eng_j=\begin{cases}g''(j)eng_{trans}\left(p_{Cluster_jM}\right)+\sum_{j\in M_i}g'(j,k)eng_{rcv}, & |S_j|>0\\ eng_{trans}\left(p_{Cluster_jM}\right)\end{cases} \quad (11)$$

$$Eng_j=\begin{cases}g''(j)eng_{trans}\left(p_{Cluster_jM}\right)+\sum_{j\in M_i}g'(j,k)eng_{rcv}, & |S_j|>0\\ eng_{trans}\left(p_{Cluster_jM}\right)\end{cases} \quad (12)$$

Where $g''(j)$ is computed through the below equation

$$g''(j) = 1 + \sum_{k \in L_j} g'(j, k) \tag{13}$$

In equation 10, $p_{Cluster_j M}$ indicates the distance among the sub-node j to the node; hence the total network energy is formulated in the below equation.

$$Eng = \sum_{j=1}^{O} Eng_j \tag{14}$$

Moreover, let us consider the undesired scenario where the nodes are connected in the different structure in that case leaf node have $|S_j|$ as zero whereas other nodes have $|S_j|$ as unit. For instance, if the leaf node has j as 1 whereas the root node has j as O, in that case, the energy is given through the below equation.

$$Eng_j = j eng_{trans}\left(p_{Cluster_j M_j} + 1\right) + (j-1) eng_{rcv} \tag{15}$$

$p_{Cluster_j M_j}$ indicates the distance between the two nodes, further we compute upper bound and given in equation 16.

$$\widehat{Eng}_j = j\widehat{eng}_{trans} + (j-1) eng_{rcv} \tag{16}$$

Furthermore, for other value of Q, energy consumption is given as

$$\widehat{Eng}_j = \begin{cases} \left(Q^{j-2} + \sum_{jk=1}^{j-2} Q^j\right) eng_{rcv} \\ + \left(Q^{j-1} + \sum_{j=1}^{j-21} Q^k\right) \widehat{eng}_{trans}, \quad j \geq 3 \\ eng_{rcv} + 2Q\widehat{eng}_{trans}, \quad j = 2 \\ \hat{eng}_{trans}, \quad j = 1 \end{cases} \tag{17}$$

Once the energy consumption is formulated, we tend to minimize

3.2.1 Optimization of Energy Consumption

ECDA (Energy centric Data Aggregation)-algorithm

Further, In this section, the energy is optimized and the optimization algorithm can be written as follows:

Step1: Let us consider the network that has

$2^{C-1} - 1 < O \leq 2^{C-1}$ number of nodes

Step2: These nodes are sorted in accordance with their remaining energy levels.

Step3: These sorted nodes are set into a set as

R=$\{r_1, \ldots\ldots, r_O\}$ such that $Eng_{res}(r1) \geq Eng_{res}(r2) \geq \cdots \geq Eng_{res}(rO)$

Step4: Choose first C elements in set R as the cluster head of the network.

Step5: Optimize the distance between the cluster head and cluster member.

$$\sum_{j=1}^{l} \sum_{k=l+1}^{O} w_{jk} p_{j,k}^{2}$$

$p_{j,k}$is the distance between r_k and r_j; further $w_{jk}$is the indicator between the nodes r_j and r_k.

Step6: Moreover, Cluster Head gathers the data from cluster member and performs data aggregation on the gathered data;

Step7: Cluster head consumes more energy than any other node; further, we try to allocate the nodes with the higher energy as CH. Later we optimize the distance between the cluster head and cluster member.

Furthermore, we design a constraint which helps in optimizing energy; the first constraint is given through the below equation that ensures that the cluster member is associated with the particular Cluster Head

$$\sum_{k=1}^{C} w_{jk} = 1, \quad \text{for all } j \in [C+1, \ldots\ldots\ldots\ldots, O] \tag{18}$$

The second and third constraints are such that Cth cluster has to be the last one for feeling the cluster member is given through equations 16 and 17.

$$\sum_{k=1}^{C} w_{jk} = l_{c-k+1} - 1, \quad \text{for all } k \in [2, \dots \dots \dots \dots, C-1] \tag{19}$$

$$\sum_{j=1}^{C} w_{jk} \leq l_c \tag{20}$$

4 RESULT ANALYSIS

4.1 SYSTEM PARAMETER

In this section we evaluate ECDA (Energy Centric Data Aggregation)-mechanism; in order to evaluate we have considered the system environment of windows 10 operating system that possesses a 64-bit Quad-core processor packed with 2GB NVIDIA CUDA graphic card packed with 16 GB RAM. Furthermore, simulation is carried out using the .Net based Sensoria simulator and use C# programming language. Moreover, the simulation has been performed including the parameter as the lifetime of the network and failed nodes through varying the size 500, 750, and 1000; further evaluation is carried out through comparing with the existing Leach protocol. Table 1 shows the simulation parameter.

Table 1 Network Parameter considered for ECDA

ECDA_NETWORK_PARAMETER	**Value**
Amplification energy (Emp)	100 pJ/bit/m2
Data packet processing delay	0.1 ms
Network Size	50m * 50m
Bandwidth	5000 bit/s
sensor nodes used	500, 750, 1000
Base station	2
Initial energy	0.2 J
Radio energy dissipation (RED)	50 nj/bit
Data packets length	2000 bits

Transmission speed	100 bit/s
Idle energy consumption (Eelec)	50 nj/bit

5 COMPARATIVE ANALYSIS

5.1 ENERGY CONSUMPTION

Energy consumption is one of the performance metrics to evaluate any methodology; further, in this research work, we have focused on minimizing the energy through the Energy-aware data mechanism. Furthermore, this makes a more important metric. Here, our proposed method is evaluated by varying the number of nodes i.e. 500, 750, and 1000; mean while, energy consumption also decides the lifetime of the network, low energy consumption suggests that better and efficient mechanism and thus increment in the lifetime of the network.

In the below figure, comparison analysis has been carried for 500 nodes, here we observe that as the number of rounds increases the energy consumption also increases, this further shows the lifetime of the network. Similarly, in case of 750 nodes and 1000 nodes the network lifetime is depicted in figure 3 and figure 4; In all three figure i.e. figure 2, figure 3 and figure 4, we see that the energy consumption is more and thus it fails to perform efficiently and maximize the lifetime of a network. Whereas with ECDA mechanism as it consumes less energy in each round this saves energy and results in an outstanding lifetime of the network.

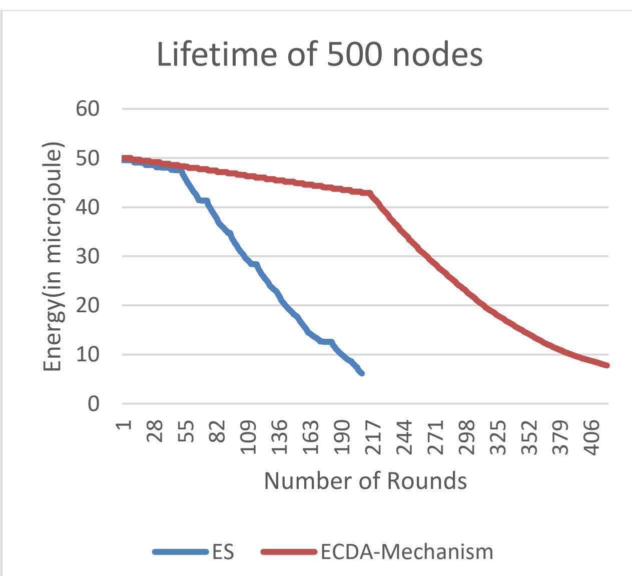


Figure 2 Network lifetime for 500 Nodes

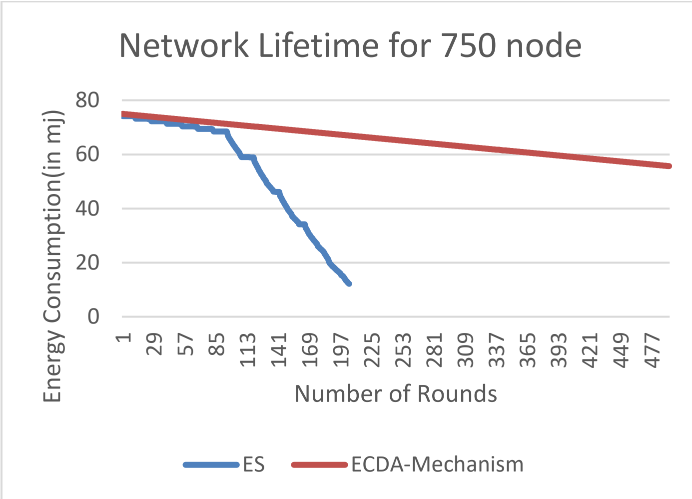


Figure 3 Network Lifetime for 750 nodes

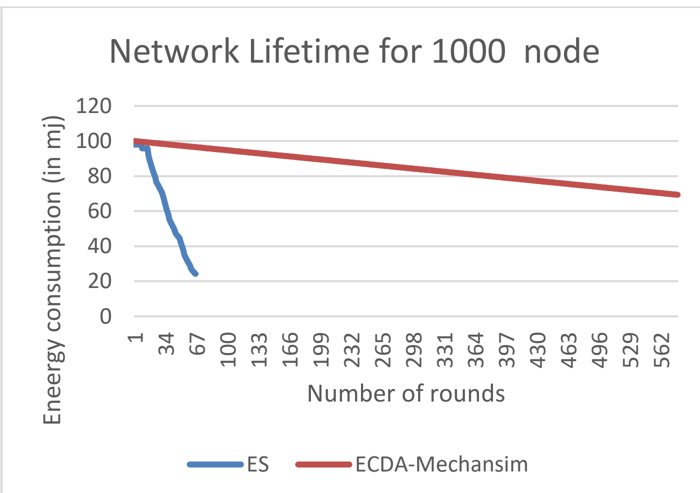


Figure 4 Network Lifetime for 1000 nodes.

5.2 Average Failed Nodes

Further comparison analysis is carried out based on the average failed nodes; this is one of the important performance metrics, which is directly proportional to the lifetime of the network. Less number of nodes indicates the better efficiency of the model; in figure 5, we see that in the case of 500 nodes the average number of failed nodes is 57.84, whereas, in the case of the proposed model, the existing model achieves 47.84. Similarly, in the case of 750 nodes, the average number of nodes failed is 47.4 whereas in the case of ECDA-mechanism the average number of failed nodes is 12.38. At last for 1000 nodes the average number of failed nodes is 95.36 whereas in ECDA-mechanism the number of 30.02. Moreover, through the comparative analysis, we observe that if more number of nodes fail then the data transmission becomes difficult, and further this causes load on the other model and leads to more energy consumption.

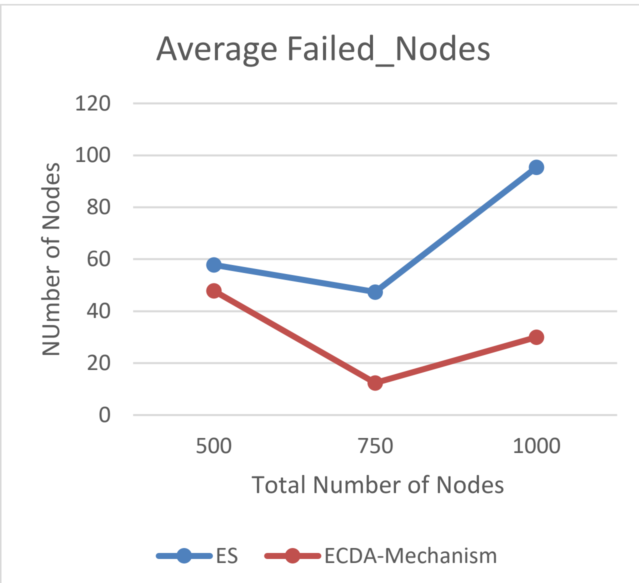


Figure 5 Average number of failed nodes

6 CONCLUSION

In agriculture, IoT is considered as one of the important and evolutionary mechanisms; especially in case of monitoring were through the Wireless Sensor Network, agricultural data are monitored and transmitted; further to save the energy and avoid any kind of leak in the information. Hence in this paper, we developed ECDA aka Energy Centric Data Aggregation Mechanism which aims at minimizing the energy and increasing the lifetime of the network, this is achieved through optimization of the distance between the cluster Head and its member considering energy as the factor. Moreover, ECDA-mechanism is evaluated considering the parameter such as a lifetime of the network and an average number of failed nodes through a number of node variation as 500, 750 and 1000; in case of network lifetime, the energy consumption in each and every round is comparatively very much efficient than the existing one. In future work, we would be focusing on delay and redundancy factors along with energy to increase the lifetime of the network in data aggregation.

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