Cluster Head Inspired Energy Efficient Data Aggregation Scheme for Wireless Sensor Network

Simarjeet Kaur, Navdeep Kaur, Kamaljit Singh Bhatia

Abstract: ***Data aggregation has come out as a major approach to lessen the number of sensor nodes transmission and thus minimizing overall power consumption in the network. This process is important because of the limited resources available in the network. Path discovery process and energy utilization in a significant manner are important so that all the data can be collected properly and least energy is utilized. This paper presents a grouping mechanism with advanced route discovery process optimized by Cuckoo Search Algorithm and cross-validated by Neural Network. An improved LEACH has been proposed with an aim to decrease energy consumption. To check the efficiency of the proposed work, varied Quality of Service parameters have been considered, such as Throughput, Packet delivery Ratio, Delay and Energy consumption. A comparative analysis has been performed using MATLAB to verify the efficiency of the proposed work with the existing work. The enhancement in the parameters is due to the sophisticated cross-validation of the proposed model by Artificial Intelligence and optimized CS Algorithm.***

Index Terms*: *Cluster Head, Cuckoo Search, Data Aggregation, LEACH, ANN, Wireless Sensor Network

I. INTRODUCTION

Data Aggregation in Wireless Sensor Network (WSN) is a method of combining and collecting significant information in some appropriate region of interest. The efficacy of the communication between the nodes relies on the techniques of the data aggregation being utilized. It could be taken as an elementary processing method for the reduction of energy consumption and for saving limited resources. The enhancement of network lifetime and energy efficiency is dependent on an efficient data aggregation technique[1].

This paper introduces a clustering mechanism adopted from Low-energy adaptive clustering hierarchy (LEACH) protocol in the data aggregation architecture [2]. LEACH is a method of cluster formation by means of energy conserving. It utilizes the process of randomization for the dispersing of energy expenditure between the sensor nodes. The cluster-based mechanism is considered to carry out data aggregation and Cluster head (CH) and is contemplated as Aggregator. It also utilizes the radio energy model for the proportionate energy utilization structure [3]. The aggregation model also requires a root discovery process and then in case of distortion or failure in the network, Cuckoo Search (CS) will be applied [4].

This paper combines the route discovery model with optimized CS and data aggregation [5]. The fitness function of the CS is cross-validated using Artificial Neural Network (ANN) [9]. The general steps according to which the research would be carried out are:

- Cluster Mechanism and Route Discovery
- Optimization Utilizing CS and Data Aggregation
- Cross-Validation of CS

LEACH Topology

LEACH is a routing protocol which is hierarchical Cluster dependent. In this, the information of every node is sent to Cluster Heads (CH) that is integrated and the reduction of data size is taken place and transferred to the Base Station (BS). In the set-up phase, each node selects while it has to be CH or not. Selecting CH is dependent on the node assessment with arbitrary number selection between zero and one. As the number is not greater from the default threshold Q(n), then the node is taken as CH in case of the isting round. Q(n) being a threshold and that could be described as:

$$Q(n) = \begin{cases} \dfrac{Probabilty}{1 - probability(qmodprobability^{-1})} & if\ n \in Grp \\ 0 & else \end{cases} \quad (1)$$

Here, n is an arbitrary number lies between 0 and 1; Probability is the amount of node which is selected as a CH whereas packet data transmission and Grp as the nodes group that were not CHs for traditional rounds.

Improved LEACH

The aim of this research is to decrease energy consumption using LEACH routing protocol to resolve the energy consumption issue. Improved LEACH has a similar method to traditional LEACH. In case of traditional LEACH routing protocol, the CHs amount is the major feature which manipulates the routing protocol performance. When the CH amount is not more, then each CH needs coverage of big regions that addresses the issues that less of Cluster members get isolated from the CH that leads to more energy consumption.

Revised Manuscript Received on June 15, 2019

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CH and BS communication needs more energy as contrasted to common nodes, more CH amount can improve the energy consumption of full network and then decrease the network lifetime. Therefore, it is needed to select CH for less energy consumption. For improved LEACH, CS has been utilized for choosing CH with new residual energy.

LEACH algorithm arbitrary selection could lead to energy imbalance of sensory nodes that improves the energy consumption. For balanced energy insurance in the network, more measures, such as residual energy by means of consumed energy for data transmission for CH selection process optimization. The objective of the Enhanced CH selection algorithm is not to select less residual energy nodes with more energy nodes consumption of CH. New $\mathrm{Q_{new}}(\mathrm{n})$ could be delineated as beneath:

As shown in equation (2), $\boldsymbol{E_{n_S}}$ is the residual energy being optimized for communicating nodes and $\boldsymbol{E_{n_j}}$ being the nodes preliminary energy as generated in WSN initialization.

$$\mathrm{Q_{new}}(\mathrm{n}) = \begin{cases} \dfrac{Probability}{1 - probability(qmodprobability^{-1})} X \\ \dfrac{E_{n_S}}{E_{n_j}} \qquad if\ N \in Grp \\ 0 \qquad\qquad else \end{cases} \tag{2}$$

With $\mathrm{Q_{new}}(\mathrm{n})$, the probability of decreased residual energy nodes as CH is fewer and probability for additional residual energy nodes as CH improves. Selecting CH depends on the improved residual energy. For residual energy optimization of nodes, CS fitness function has been described as beneath:

$$\mathrm{f(fit)} = \begin{cases} \text{Conisder as CH}, \ \mathrm{Egg_c} < \mathrm{Egg_o} \\ \text{Not Consider as CH}, \ \mathrm{Egg_c} \geq \mathrm{Egg_o} \end{cases} \tag{3}$$

As shown in equation (3), $\mathrm{Egg_c}$ as the remaining energy of selected node as a current egg and $\mathrm{Egg_o}$ as the threshold energy of each other communicating nodes.

$$\mathrm{Egg_c} = \sum_{i=1}^{\mathrm{Nodes}} \mathrm{E_R(i)} \tag{4}$$

$$\mathrm{Egg_o} = \frac{\sum_{i=1}^{\mathrm{Nodes}} \mathrm{E_R(i)}}{\text{Node Count}} \tag{5}$$

II. LITERTAURE REVIEW

An existing concept with their theories has been explained below analyze the evident hole in the existing hypothesis of data aggregation in WSN. A novel technique for the safety of data prediction in a wireless sensor network with the concept of Time Series Trust Model (TSTM) on the basis of Toeplitz matrix with Trust based Auto-Regressive (TAR) procedure is given by [7]. Basis Pursuit (BP) is considered to have the best performance. The proposed method has shown a performance with compromised nodes from 10 to 40 % because of the worse mouthing attack. A novel Multi-functional secure Data Aggregation (MODA) scheme is presented by [8]. The homomorphic encryption method is used for enabling in ciphertext aggregation with an end to end security. Random selected encryption based Data Aggregation (RODA) and Compression based Data Aggregation (CODA) are considered for the enhancement of results. The outcome has shown an outperformance from theoretical reviews with three real datasets in varied circumstances. The proposed scheme has shown superior performance as compared to existing methods. [8] Have proposed a model of packet failure estimation with a cross-layer design for the scheduling improvement. The outcome results in efficient lifespan for different sensor devices for the proposed LEACH routing protocol. It is being concluded that the proposed prototype has achieved better performance as compared to existing work by means of energy efficiency and network lifetime. A safe energy saving data aggregation method is presented by [6]. The research has utilized Okamoto-Uchiyama homomorphic encryption algorithm for the protection of end to end delay with MAC for the achievement in data filtering of false network and has utilized a homomorphic MAC algorithm for an end to end integration. The outcome has shown the best performance in the reduction of energy consumption. A novel mechanism, Improved CS based Clustering Algorithm (ICSCA) is given by [7]. The evaluation of the ICSCA has shown effective outcome as compared to existing clustering methods by means of residual energy and total energy consumption. The clustering based aggregation protocol for minimizing communication and enhancing network lifespan is given by [21]. The researcher has analyzed clustering protocols and classified applicable resources in WSN for heterogeneous, homogenous, single with multi-hop. It has been found that data fusion is utilized for the determination of reduces node set to be vigorous in the network and has resulted in network resource consumption. The model of aggregation architecture has been integrated with CS to enhance the data transmission amount with Sensor in using mobility for joint energy replacement and data amalgamation. [22] Has made an effort to enhance the data delivery reliability in data aggregation than to mortify it. The existing results were based on the scalable aggregation functions like COUNT, SUM, MAX, and MIN that executes separately as per the network size. In this research, the researcher has extended the outcome by considering energy efficiency and reliability with semi- scalable aggregation function APPEND and has found the boundary circumstances for the maintenance of data reliability with an enhancement of energy cost. It has been concluded that lossless aggregation with APPEND aggregation function has provided enhanced reliability with lessening energy. Area unit planning to consider varied traditional strategies in WSN for in-network information aggregation idea is presented by [23]. The method has lessened the power consumption in detector network information traffic that productively lessens the information being transferred to the bottom station. The proposed mechanism has caused it to the Bottom station considered as Information aggregation. [25] has presented a comprehensive review of data aggregation methods in Underwater Wireless Sensor Network (UWSN). According to the article, the classification of the aggregation techniques is into varied techniques, such as, cluster-based and non-cluster based. The results have been contrasted with the outcome of a similar technique without using data aggregation methods to depict the effect of data aggregation. Three cluster based techniques viz., RBC, K-means and DUCS clustering are considered with parameters, packet drop, and delay and energy consumption.

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The results have depicted that these parameters have performed well because of decreased collision and redundancy.

Due to random nature, sensor nodes adjust their properties like co-ordinates, transfer rate, energy consumption etc, after initial distribution within the network. Sensor node variability and node failure affects the transmission path, which impacts connectivity in WSN. Unplanned variability can create coverage problem, whereas planned variability can be applied to improve connectivity and for enhancing the lifetime of the network by selecting appropriate CHs. According to the survey, only two types of connectivity is possible in WSN, first is, LEACH based on the node distribution and second is, LEACH based on the energy level of nodes. The first concept is applicable to the static sensor nodes environment. In this paper, the energy level based LEACH routing protocol is presented with Cuckoo Search Algorithm, termed as Improved-LEACH. We have proposed a probabilistic connectivity model to compute connectivity among neighbouring nodes based on the CHs selection technique using the fitness of nodes. The most important contributions of this research work are given below:

- We have proposed Improved-LEACH, where the connectivity and remaining energy of mobile sensor nodes are used as properties for selection of CHs. This proposed scheme has significantly improved the performance as compared with the existing schemes which are well described in the results section.
- The proposed Improved-LEACH is analyzed under different variability like a different number of nodes and to validate the CHs selection, Artificial Neural Network is used.

III. PROPOSED WORK MODEL

The proposed work model is segmented in three parts as follows:

1. Cluster Mechanism

Algorithm 1: Identify_Clusterheads (N, ESA, CH count)

// ESA is the list of Energy associated, N→ Node Count, CH→ Cluster Head

1. for i=1: N
2. currESA t_Node=1; // ESA of current node currESA
3. t_energy=Energy(i) // Energy of current node
4. for j=1: N
5. If(Energy(i)<E(j)// Condition to become a CH
6. Temp_Value=E(j);
7. Temp_Value=Energy(i);
8. Energy(i)=Temp_Value;
9. End if
10. End for
11. End for
12. SE=E(Select(CH_count));
13. Find Nodes associated with SE;
14. End Algo

Above given algorithm is used to select a CH in each cluster of network using CS. Sorting the energy in descending order and then within each region one cluster head will be appointed so that each node has to communicate with one cluster head only [10]. The cluster heads will communicate with other cluster head only. The search space and communication range is also shortened to preserve energy [11]. The cluster heads will have to follow the nearest neighbour mechanism to find the nearest cluster head [12].

Algorithm 2: Nearest Neighbor

Let λ be the area covered by any node for communication within the network.

1. λ= Network_width * 28/100;
2. Communication_List=[ ];
3. Communication_dist =[ ]; // List of distance of nodes from other nodes.
4. For each n_d in nodelist
5. x_i= xloc (n_d); // finding the xlocation of the node
6. y_i= yloc (n_d); // finding the ylocation of the node;
7. Communicationcount=0;
8. For each n_j in the node list
9. If n_d != n_j // if both the nodes are not same
10. x_p= xloc (n_j); // x-co-ordinate of node
11. y_p= yloc (n_j); // y-co-ordinate of node
12. d = sqrt ((⟦x_i-x_p)⟧^2+(y_i-y_p)^2);
13. if d<=λ
14. Communication_list[n_d,Communicationcount]=n _j;Communication_dist
15. [n_d,Communicationcount]=d;
16. Communication_count=Communicationcount+1;
17. end if
18. end for
19. end for
20. Communication_list = [Node d, Node p, Node j, Node l]- Node x
21. Communication_dist = [220,240,250,245];

2. Optimization Utilizing Cuckoo Search and Data Aggregation

As followed by the Clusters, each cluster will provide data segments and the cluster head will associate the data file in the route. In case of failures, CS will come into action [14]. CS has been developed by Yang and Deb in 2009. They get inspired by natural behaviour of cuckoos, special the obligate brood parasitism of some cuckoo species by laying their eggs in the nests of other host birds [15]. For defining CS algorithm authors set three sets of rules that are listed below:

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- Every cuckoo lays one egg at a time and dumps it in an arbitrarily chosen nest.
- The best nests with high-quality eggs will be carried over to the next generations.

The number of available host nests is fixed and the egg laid by a cuckoo may be discovered by the host bird with a probability pa ∈ (0, 1). In this case, the host bird can either get rid of the egg or simply abandon the nest and build a completely new nest. According to the rule, every egg in the nest indicates a candidate solution [16]. Thus in original form, one candidate can lay only one egg in their nest but in general, multiple eggs representing a set of solution. The main aim of CS is to provide a better solution in the current net population. On the basis of objective function, their quality has been measured [17].

Algorithm 3: Application of CS

Input: Node_enegy (ALL), N: Total Nodes
Output: SuspectList

1. For i: 1;N
2. Ecurr=Node.Energy(i); //energy of current node
3. Eavg=$\sum_{i=1}^{N}$ Node_energy/N;
4. Time_variation(tv)=Mathematical random ();
5. If (Ecurr>tv>Eavg*tv); //average energy of node
6. SLcount++;
7. SuspsectList[SLcount]=Ecurr.Id;
8. End if
9. End for

Above mentioned algorithm is delineating the procedure of CS in the proposed mechanism. Its aim is to decide which node is CH and which is not. In this algorithm, CH is selected from total number of nodes using fitness function.

3. Cross-validation of CS

The selection for the data aggregation node is decided by CS but it has to be cross-validated [18]. Hence a Feed Forward Back Propagation Neural Network (FFBPNN) is utilized. NN is a 3-way propagation model with the sigmoid function at the hidden layer [19] [20]. Fig. 1 shows the NN propagation model.

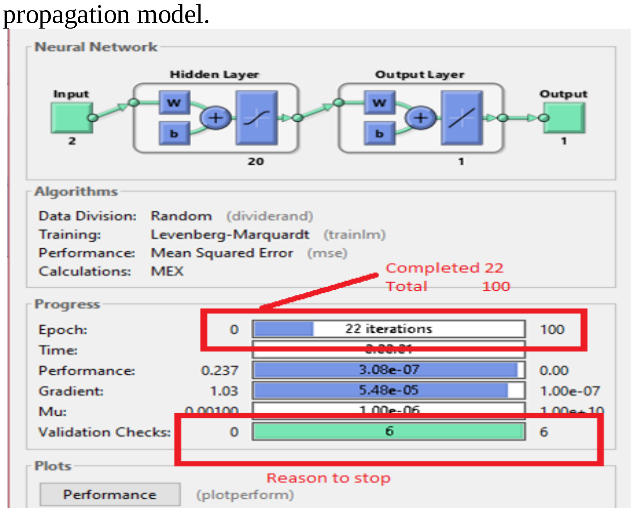

Figure 1: Propagation Model of Neural Network

IV. RESULTS AND DISCUSSIONS

The evaluation of the result is based on the following parameters:

- **Average Throughput:** Average Throughput is the average of the total received packets in the given time frame.
- **Packet Delivery Ratio (PDR):** It is the ratio of total received packets to the total sent packets.
- **Delay:** Total produced a delay in the procedure of data transfer from one end to another end.
- **Energy Consumption:** Total consumed energy in a given interval of time.

For the computation, parameters, such as Throughput, PDR, Delay and Energy Consumption are considered. The evaluation of throughput is shown in Table 1 and Figure 2, evaluation of PDR is shown in Table 2 and Figure 3, evaluation of Delay is shown in Table 3 and Figure 4 and the evaluation of energy consumption is shown in Table 4 and Figure 5.

Table 1: Computation of Throughput

Total Number of Simulation Rounds	Average Throughput Proposed	Average Throughput LEACH Aggregation
10	180	123
100	1256	859
200	2369	1530
500	5988	3569
1000	8788	5214

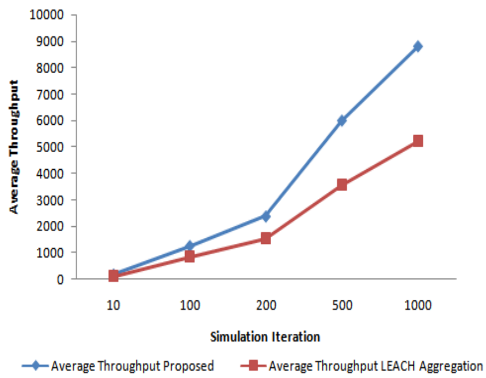

Figure 2: Evaluation of throughput

Table 2: Computation of PDR

Total Number of Simulation Rounds	Average PDR Proposed	Average PDR LEACH Aggregation
10	0.65	0.32
100	0.69	0.41
200	0.6922	0.42
500	0.6952	0.4236
1000	0.6966	0.4311

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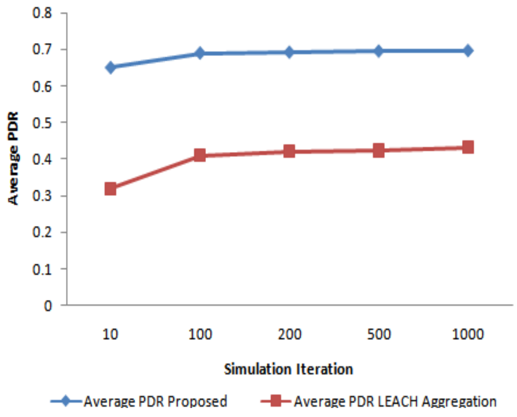

Figure 3: Evaluation of PDR

Table 3: Computation of Delay

Total Number of Simulation Rounds	Average Delay Proposed in ms	Average Delay LEACH Aggregation in ms
10	13	42
100	16	45
200	17.2	49
500	18.1	52
1000	23	53

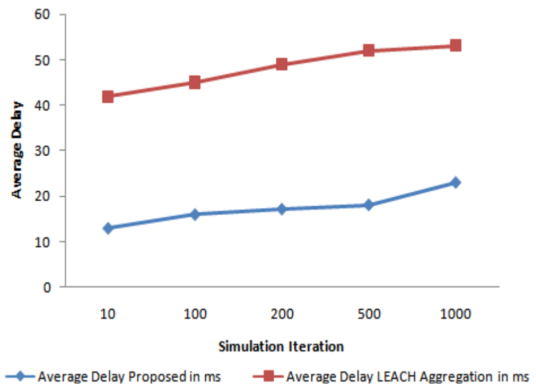

Figure 4: Evaluation of Delay

Table 4: Computation of Energy Consumption

Total Number of Simulation Rounds	Energy Consumption Proposed in mJ	Energy Consumption LEACH Aggregation in mJ
10	60	85
100	65	102
200	77	123
500	111	169
1000	125	201

A total of 1000 simulation iterations are propagated. The proposed algorithm is also compared with LEACH aggregation mechanism [24].

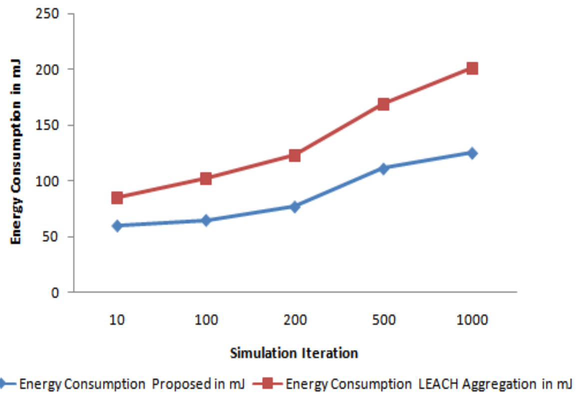

Figure 5: Evaluation of Energy Consumption

The maximum throughput attained by the proposed algorithm is 8788 whereas, for the same scenario, LEACH aggregation mechanism demonstrates a total value of 5214. In a similar fashion, PDR for proposed is .6966 whereas for the LEACH it stands a value of .4311. The proposed algorithm stands a total improvement of $\frac{8788-5214}{8788} * 100 = 40\%$ is noticed. In a similar way, PDR improves by $\frac{.6966-.4311}{6966} * 100 = 38\%$. The story is similar for energy consumption and delay.

IV. COMPARISON OF PROPOSED WORK WITH EXISTING WORK

In this section, we have compared proposed work with existing work based on energy consumption, PDR and delay with respect to packet size.

Table 5: Comparison of Energy Consumption

Packet Size	Proposed Work	Nitin Goyal et al. (2017) [25]
50	92	210
100	96	211
150	93	210
200	90	210
250	97	211

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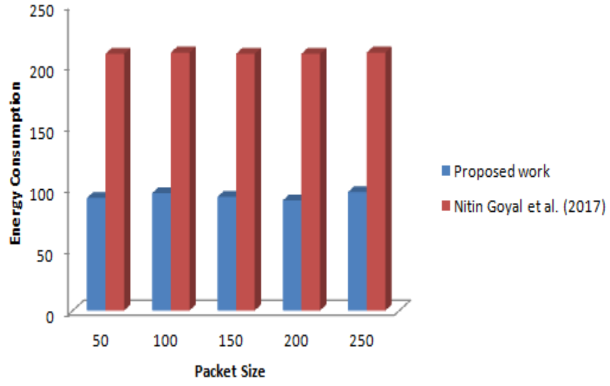

Figure 6: Comparison of Energy Consumption

Table 5 and Figure 6 are depicting the comparison of energy consumption with proposed and existing work [25] to check the efficiency of the proposed work. The comparison has been drawn on the basis of packet size that ranges from 50 to 250. The average value of energy consumption for proposed work is 93.6 whereas the average value of energy consumption for existing work is 210.4. The reduction of energy consumption in the proposed work is 50%. So it is evident that the proposed work has less energy consumption rate than the existing one.

Table 6: Comparison of PDR

Packet Size	Proposed work	Nitin Goyal et al. (2017)
50	0.359	0.124
100	0.406	0.125
150	0.415	0.123
200	0.435	0.126
250	0.445	0.125

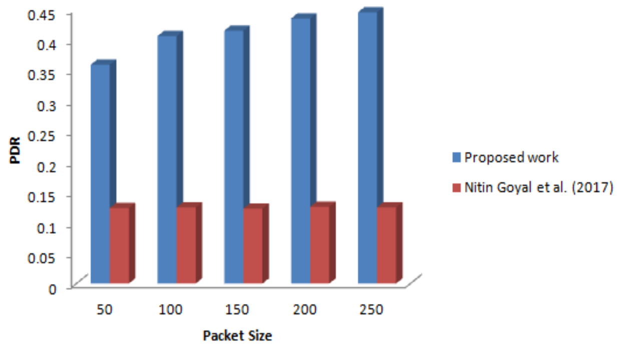

Figure 7: Comparison of PDR

Table 6 and Figure 7 are depicting the comparison of PDR with proposed and existing work [25] to check the efficiency of the proposed work. The comparison has been drawn on the basis of packet size that ranges from 50 to 250. The average value of PDR for proposed work is 0.412 whereas the average value of PDR for existing work is 0.124. The enhancement in PDR in proposed work is of 30% as compared to the existing work; therefore, it is clear that packets that are delivered in the proposed work are more.

Table 7: Comparison of Delay

Packet Size	Proposed work	Nitin Goyal et al. (2017)
50	0.044	0.059
100	0.046	0.058
150	0.050	0.057
200	0.055	0.059
250	0.054	0.056

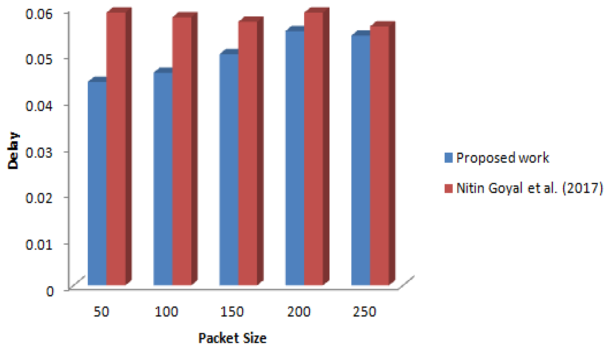

Figure 8: Comparison of Delay

Table 7 and Figure 8 are depicting the comparison of Delay with proposed and existing work [25] to check the efficiency of the proposed work. The comparison has been drawn on the basis of packet size that ranges from 50 to 250. The average value of Delay for proposed work is 0.049 whereas the average value of Delay for existing work is 0.057. The percentage decrement of delay in proposed work is 14.14, which is very much better as compared to the existing work.

V. CONCLUSION AND FUTURE SCOPE

The proposed algorithm utilizes the data aggregation mechanism enhancing the LEACH aggregation mechanism. The proposed research work uses CS for the enhancement of the routing process in order to aggregate the data without flaw. The proposed architecture is cross-validated utilizing FFBPNN. A total of 100 simulation iterations is passed and it is observed that the cross-validation completes within 20 epochs. The proposed architecture is evaluated utilizing Throughput, PDR, Energy Consumption and Delay. The proposed algorithm stands a good growth of 38-40% for each parameter. To check the effectiveness of the proposed work, the comparative analysis has been performed of proposed work with the existing work. The comparison has been drawn between delay, PDR and energy consumption. The enhancement in PDR in proposed work is of 30% as compared to the existing work. The reduction of energy consumption in the proposed work is 50%. The percentage decrement of delay in proposed work is 14.14, which is very much better as compared to the existing work.

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Therefore, it is evident that the proposed system has outperformed as compared to traditional work.

The current research work opens a lot of possibility for future research workers. The proposed work can be combined with other cross-validation techniques like Support Vector Machine (SVM), Linear Discriminant Analysis (LDA) etc. A simulation environment varying a total number of nodes can also be checked.

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Blue Eyes Intelligence Engineering
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