LEACH Robust Routing Approach Applying Machine Learning

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Abstract

Wireless Sensors Network (WSNs) comprised of significant numbers of miniatures and reasonable sensor nodes which sense data from environment that require multi-hop and direct communication to send aggregated data towards the base station through cluster-head-node supported by appropriated routing scheme. The random choice of cluster-head-node (CHN) in WSNs is based on node residing energy. The node residing energy and network sustainability are the hot challenges in WSNs routing. There are many deficiencies in LEACH-RP (Routing Protocol) due to the rapid energy consumption of ordinary and cluster-head-nodes because of direct communication towards the base station. The quick draining of node energy creates large number of the black holes in the network core causing data redundancy, re-transmission of data packet, route update cost and E2E delay. The LEACH-RP faces the issues of data redundancy caused by a single sensor node in a short time and adjacent sensor nodes at the same time. In the proposed approach, the mean method and the minimum distance (MD) method based on LEACH-RP is implemented to solve the issues of data redundancy. A data fusion algorithm (DF) based on Cyclic Neural Networks(CNN) is implemented on LEACH RP. The simulation results indicate that the mean method & minimum distance method can effectively resolve the issues of data redundancy caused by a single sensor node in a short time and the data fusion algorithm of the CNN can effectively solve the problem of data redundancy generated by adjacent sensor nodes at the same time.

Key words:

Multi-hop (MH), CHN, Wireless Sensing Networks (WSNs), Data Fusion Technology (DFT), LEACH RP, CNN

1. Introduction

Now a day, effective routing in WSNs is one of the critical challenge in research field. In present years, WSN applications circle in the numerous fields include weather and pollution monitoring & water pollution monitoring like biological, nuclear, chemical, micro-organism tracking & disaster prevention, military surveillance, medical science, home security, commercial companies etc. WSNs comprise of structured & unstructured (S&US) networks for sensing of big range of information. The deployment of both networks usually depends on environment that needs to be monitored. Wireless sensors are characterized by the distribution of many miniature and inexpensive sensor nodes in the monitoring area [1]. WSNs are collection of static sensing nodes which collect information & send to surface base station (BS). BS collects the data from discovering areas by using the primary function of sensor nodes [2-3]. WSNs are extensively used in video surveillance where the sensor nodes are cameras that send the collected image information or video information to users. In the military, sensor nodes are distributed in enemy areas and transmit the enemy's information to the command headquarters [4-6]. The essential characteristics of sensor nodes use a very low power consumption for the short transmission range. The critical point of the data collection network is how to transmit the collected data from the source nodes to the BS via reliable node. Nodes mainly undertake the task of collecting data and routing data forward. Routing schemes play an imperative role in this regard. The RP select the optimal route based on special parameter for the sensor node for data forwarding toward the base station [7]. In WSNs, RP is the highest rated technology that control the network layer [8]. The RP of the network layer ensures that the sensor node has successfully transmitted the data toward the base station. It is imperative to diminish the consumption of energy and encompass network life. Finally, adding DFT to (RP) can significantly reduce the data traffic to retain valid data and reduce data redundancy. RP has a classical hierarchical less amount of energy adaptive clustering hierarchy. LEACH-RP solves the problems of a planar RP like high energy consumption and longtime delay [9-10]. The practical application proves that LEACH-RP has a 15% longer network lifetime than general planar RP [11]. However, LEACH RP still has some

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shortcomings like uneven division and selection of unstable numbering of the CHN per round without taking into account the remaining energy of the nodes. These shortcomings will increase the energy consumption of nodes and networks which is not conducive to extend network lifetime [12]. LEACH RP stipulates that all nodes and BS communicate directly, so LEACH RP is not suitable for direct communication in very large-scale application [13].

In this study, data fusion technology is not designed for a specific data fusion algorithm. Aiming at the shortcomings of LEACH RP, this study proposed a Low-Energy Adaptive Clustering Hierarchy-Data Fusion Algorithms Based on Cyclic Neural Networks (LEACH-DFACNN) routing scheme that limited the consumption of energy. The experimental results indicate that the LEACH-DFACNN RP can significantly limit the energy consumption as compare to different another LEACH RP like LEACH, LEACH-C, LEACH-M. There have been many improvements based on LEACH protocol in recent ten years. The LEACH-C RP is most remarkable improved version of LEACH routing protocol [14]. The main idea of LEACH-C and LEACH-Mobile (M) RP is to choose the best set of CHN through BS control. To measure the performance of lousy network & less power RP algorithm various mobility models like GMM, RWP, MGM are used [15]. The purpose of DF algorithm is to fuse a large amount of raw data collected by sensor nodes and send a small amount of effective data information to base stations to reduce data traffic and energy consumption of nodes. Neural network is effective in solving the data fusion problem in WSNs. WSNs nodes can be regarded as neurons and each sensor node has the function of collecting and processing data. The communication of WSNs nodes can be regarded as the connection between neurons and the transmission of data. Information's DF and artificial CNN are processing and calculating many data and finally get the characteristic data that can reflect these data. So, it can solve the data fusion problem of WSNs through an artificial neural network.

In this paper, the mean method and the MD method are added to LEACH protocol to effectively solve the problem of data redundancy generated by a single sensor node in a short time. In addition, based on LEACH protocol, a DFT of CNN is designed that effectively solves problem of data redundancy generated by adjacent sensor nodes at similar time.This paper is prearranged in 6 section. In second have overview and working for numerous RP relate to WSN. Section 3 presents the problem description of approaches LEACH, M-LEACH and LEACH-GA RP behalf on data of numerios metric concerning end to end suspension, energy used, network throughput and information delivery ratio (IDR). Sections 4 present the proposed protocol LEACH- DFACNN. In section 5, simulation results are presented, Section 6 included conclusion & the future open research issues .

2. Related Work

Fig. 1 illustrates the architecture of WSNs including sensor nodes, BS, Internet networks and servers and possibly users. Sensor nodes are composed of four modules. The function of the sensor module is to collect data for monitoring area, the function of the processor module is to process the gathered data such as data fusion, communication module is responsible for communication, power module is responsible for providing electricity. WSNs establish data communication links from source nodes to destination nodes through self-organisation [16-19]. Five labelled nodes (ABCDE) form a data communication link from the base node (Node A) to BS node and then BS forwards data collection commands to the node. There are many data collection protocols in WSNs [20-22].

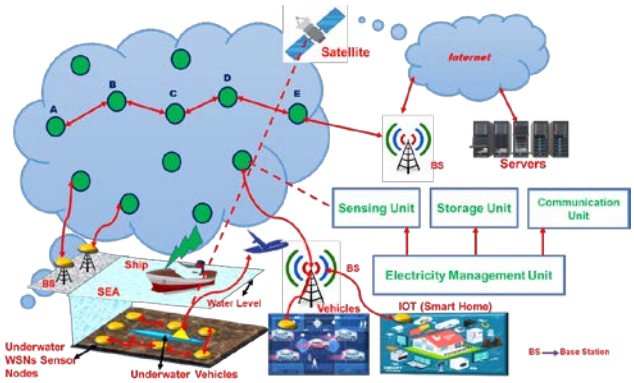

Fig. 1 The Architecture of WSNs

LEACH is a low-energy adaptive layered routing protocol. Later, many-layered RP has enhanced behalf on the LEACH RP. The operation of LEACH RP [23-25] is periodic. Flooding protocol is a classic planar RP for cluster building and data collection. Its advantage is that it does not need to maintain routing information. All the data collected on base nodes are forward to all neighbor nodes and the neighbor node forwards the data from base node to its own near nodes through multi-hop fashion. The Power Efficient Data Gathering & Aggregation in WSNs protocol systematizes the nodes in the whole system into a least spanning tree based on the BS which diminishes the consumption of energy across the entire system [26-27].

LEACH-C RP [28] is a significant LEACH improvement protocol. At the beginning of each round, it is controlled by the BS which choose the optimal CHN set regarding the node's residual energy and location information. LEACH-C is different from the LEACH RP in clustering stage. The nodes of LEACH-C RP know their location, all non-CHN

calculate the nearest CHN regarding the location information of the CHN broadcasted by the BS and join its cluster. Literature [29] proposes an enhanced protocol that improved the performance of LEACH protocol. The improved protocol also runs repeatedly in the unit of "wheel". One round is alienated into cluster building and data the collection stages. The improved protocol [30] follow the remained energy and distance from the BS when choosing CH nodes.

Literature [31] represents a solar CHN selection protocol based on Solar-Aware LEACH (sLEACH). The sLEACH protocol requires some sensor nodes that can convert solar energy into electrical energy and can increase their residual energy through the sun's irradiation. In the sLEACH protocol due to solar energy, probability for selection of solar CHN is increased that prolonged the life of the network. Because the sLEACH protocol adds solar energy sensor nodes, it is more effective than the generally improved protocol in extending network lifetime. Machine learning base processes have been used to categorize numerous forms of faults like as calibration, sensor aging, low battery [20]. It also encourages numerous practical results that exploit resource exploitation and extend the lifecycle of the network [22] [41]. Magnetism created wireless vehicle sensors (WVDs) assimilate less power WST which improves the suitability of creation and conservation [34-35]. In LEACH Genetic Algorithm (GA) routing protocol, the preparation phase is presented at start of initial round alongside the setup and steady state (SS) phase. The research step of the LEACH Genetic Algorithm (GA) is used for the selection of CH using Genetic Algorithm (GA). Firstly, all the nodes in network select the CH by conveyance a message to destination station(DS). In DS, Genetic Algorithm (GA) is utilized to discover the optimal node for CH selection have maximum residing energy. LEACH-GA routing protocol reduce the node energy consumption as relate to LEACH & LEACH-C [42]. WSNs have attracted an interest of research community and industry [45].

3. Problem Description

The major inefficiencies of LEACH RP are as follows:

- During the selection of Cluster-head-node(CHN), LEACH RP not deliberate the residual energy of node. CHN can lead to premature death because of quick energy ingesting.
- LEACH RP does not require the number and distribution of Cluster-head-node per round which may cause CHN instability and non-uniform distribution resulting in maximal and minimal clusters.
- LEACH RP does not deliberate the distance difference b/w the CHN and BS. If the communication distance is longer between sensor nodes, the more energy is consumed for communication and to update the route. So, the nodes distance away from the BS may die prematurely.
- LEACH RP requires that all CHN to communicate directly with sensor nodes and BS. Therefore, the LEACH RP is not appropriate for long-distance communication networks.
- The data collected by a sensor node in a short time and longtime application has high redundancy.
- LEACH RP requires a CHN to fuse data collected by cluster, but it is not designed specific data fusion algorithm.

3.1 Scope and Objective

- The CNN includes time factor which can fuse data at different times in a short period.
- The total input of the CNN includes the input of the current time and the output of the previous time, considering the influence of the adjacent time data in the process of data fusion.
- The cyclic neural network can be regarded as a more general representation of BP neural network. The depth and complexity of the whole neural network can be controlled by setting the unfolding time steps of the hidden layer of the CNN, and the parameters of the network are not increased while increasing the depth and complexity of the network. In this way, we can find an appropriate balance between network complexity and efficiency and create an optimal network. The common BP neural network will introduce a new parameter matrix to increase the network depth, which makes the network cost increase rapidly
- For the LEACH protocol without the specific design of the data fusion algorithm, this paper adds the averaging method and the MD method based on the LEACH protocol, which effectively solves the problem of redundant data from a single sensor node in a short period of time. In addition, this article designs a DF algorithm of recurrent NN based on the LEACH protocol, which can efficiently solve the data redundancy problem of the neighboring sensor nodes at the same time [36].

4. Proposed Design for LEACH- DFACNN

Wireless sensor network stipulates that many high-density s-nodes are divided in the monitoring area. The cluster node collect data from the sensor node having data redundancy which is described in the following two aspects.

- The data received by a single s-node in a short time has very high resemblance.

- The data received by adjacent sensor nodes at the current time has high resemblance.

If the node does not fuse the collected raw data, it will waste its residual energy by sending too much redundant data which will directly affect the network life.
In this proposed study, mean method and MD method behalf on LEACH protocol is used. Finally, a DF algorithm based on CNN is designed.

4.1 Data Redundancy Removal Algorithms (Mean Method and Minimum Distance Method)

In the proposed study two classical data redundancy removal algorithms, mean method and minimum distance method were used to remove redundancy of data received by a single s-node in a short duration on LEACH protocol [37]. Each sensor node collects the original monitoring data. The accuracy of the data is affected by the external environment (temperature, humidity etc.). Therefore, the data collected in a short time may be noise data. Accordingly, sensor nodes should first remove the noise data. The judgment of noise data is based on the normal monitoring threshold range and the monitoring value within the threshold range is considered as valid data. Otherwise, it is regarded as noise data. After removing the noise data, the data collected in a short period keep the change of the data in a relatively small fluctuation range. In this work, the mean method and minimum distance method is used to remove data redundancy. These two methods for eradicating of data redundancy are simulated and compared with the LEACH protocol. The mean method is to obtain the arithmetic mean of all valid data and formula is shown in (1).

$$x_T = \frac{\sum_{i=1}^{n}(x_i * \delta i)}{\sum_{i=1}^{n} \delta i} \quad (1)$$

Where $\delta i = \begin{cases} 1 & x_{min} < x_i < x_{max} \\ 0 & \text{otherwise} \end{cases}$

The X_T in equations (1 and 2) represents the characteristic value of the collected data set in T period, n represents the collected data in T period and delta I indicates whether the data collected in the first period is valid. If Xi is between the specified threshold X_{min} and X_{max}, then the accurate data is determined. Otherwise, it is judged to be invalid data. The minimum distance method is to find the data whose second-order centre distance of all valid data is the smallest as the eigenvalue of this group of data. The formula is as follows:

$$x_T = \sum_{i=1}^{n}(x_i * \delta i - d)^2 \quad (2)$$

In equation (2), d is the characteristic data value and satisfies the minimum xT value. For sensor nodes with limited energy, this study tends to use the mean method. The steps mentioned in this section to remove data redundancy are accomplished in cluster member nodes.

4.2 Data Fusion Algorithms Based on Cyclic Neural Networks (DFACNN)

In theoretical model of DFACNN, LEACH layered routing protocol combine with cyclic neural network structure. The original data collected by the LEACH protocol is fused with neuron function resulting the reduction in data redundancy and energy saving.
All s-nodes have the capability of DF to eliminate data redundancy and cluster member nodes processing neuron function in i/p layer and the calculation of hidden & the o/p layer is accomplished in CHN. At the start of each round, all CHN send the relevant information of the cluster to the base station which trains the weights of each CNN model. After parameter training, the BS sends the parameters of each cluster to all CHN and the CHN send the parameters of the cluster to their cluster members. CN first do simple data redundancy removal processing for the collected data and then input layer neurons do preliminary processing for the received data. The cluster member node sends the processed data directly to the CHN and the CHN calculates the function of the hidden layer neuron of the R order recursively. After the last recursive calculation, the hidden layer neuron outputs the result to the o/p layer and the o/p layer neuron does the final calculation and processing. Finally, the CHN sends the processed information of o/p layer to BS. The output layer of cyclic neural network processed data by using data fusion techniques.

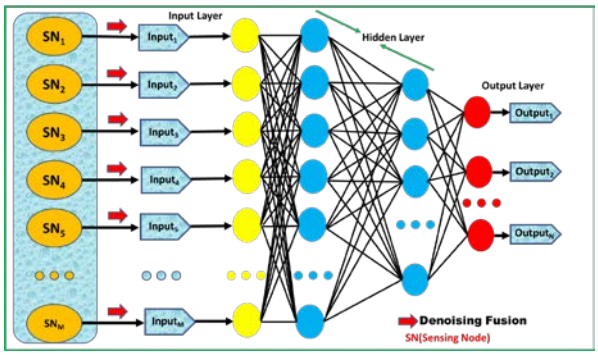

Fig. 2 Data Fusion Algorithms Model Based on Circulating Neural Networks

Fig.2 illustrate the architecture of cyclic neural network. Circulating neural network (DFACNN) is working like an ordinary BP neural network but the middle-hidden layer needs R times of recursive operation. The total amount of neurons in i/p layer are same as total amount of s-nodes in the cluster. The o/p is the characteristic data forwarded by the CHN to BS. About the total amount of neurons in the middle-hidden layer, the empirical formula $z = \sqrt{m+n} +$

a is used to determine the number of neurons in the middle-hidden layer [38], where m & n characterizes total amount of neurons in i/p & o/p layer and is *a* constant.

4.3 Parametric Training of Cyclic Neural Networks

There are many parameters in DFACNN model. Because of the abundant energy and strong computing ability of the base station, the training of parameters at the beginning of each round is completed by the base station. Fig. 3 is a simple CNN schematic.

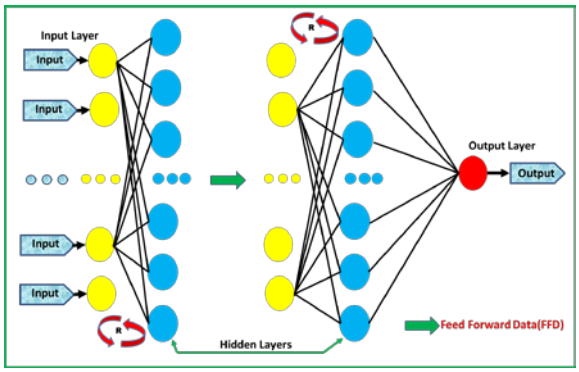

Fig. 3 Cyclic Neural Network

To weight matrix determination of each layer of CNN and to train the CNN model, training method and minimum error training methods are used [43]. The fusion process is carried out in the CHN. In designing and planning of WSNs, the energy consumption is the main concern [44]. The structure of simple CNN consists of an i/p & o/p and hidden layer. In Equation 3, g indicates the weight matrix b/w the i/p and the hidden layer, p denotes the weight matrix between the hidden layer & z (t) stands for the i/p at time t, q (t) indicates the o/p of hidden layer at time.

$$q_j(t) = f\left(\sum_i^l z_i(t) g_{ij} + \sum_h^m s_h(t-1) p_{hj} + b_j\right) \quad (3)$$

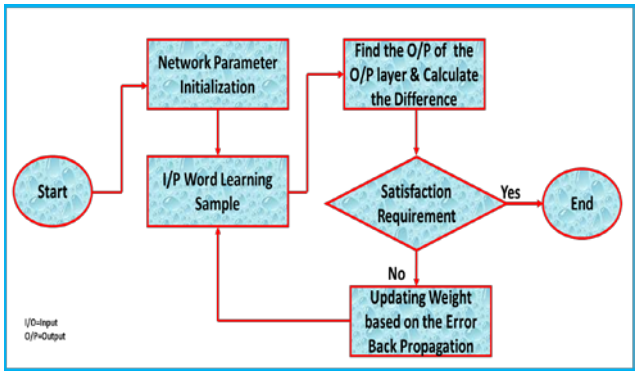

Fig. 4 Flow Chart Training Algorithm

5. Performance Evaluation

The performance evaluation, verification and validation of robust LEACH-DFACNN was compared with such as M-LEACH, LEACH protocol & GA LEACH [42] adaptive clustering protocol by using the tool, MATLAB 2018(b). A network of 200 nodes was employed using the Parameter Value. The mean method and the MD method are simulated and verified on the LEACH protocol. The LEACH protocol implements the mean method and minimum distance method to remove redundancy without incorporated data fusion technology. The results indicate that the LEACH protocol using the mean method has the best de-redundancy effect.

5.1 Simulation Parameters

The two-dimensional environment of WSN with two layers was implemented. In simulations, network dimension of 200mx200m is assumed. 2000 s-nodes are randomly installed in the environment. The proportion of cluster head nodes is 0.05. The coordinate position of the BS is set at 100,250. The energy loss model and simulation constraints of LEACH-DFACNN for experiment are like GA, M-LEACH protocol and LEACH protocol. The routing protocol uses the LEACH protocol. The total amount of cycles in the hidden layer of INN is two.

Table 1: Simulation Parameters

Network Size	200m x200m
Base station Location	100, 250
Information Packet length	100 (in bytes)
Controlling Package length (bytes)	10
Initial amount of Energy in Normal Nodes	50J
Energy Consumption of Data Fusion	10nJ /bit/message
Eelec	100 nJ/bit
Ɛ fs (Multi Channel Attenuation)	25 pJ/ (bit*m2)
Ɛamp(Multi Channel Attenuation)	0.0030 pJ/ (bit*m4)
d0	120m
Maximum Simulation rounds	2000
Initial Weight Value of INN	2
Threshold of Training	4
Training times	Up to 2500 times
R(Computational Power)	4

5.2 Comparison of LEACH-DFACNN with LEACH M-LEACH Protocol and LEACH GA

Fig.5 shows the assessment of dead node variation in LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA protocol. Based on the simulation result, the total numbers of dead node were 438 after 1890 rounds and in M-LEACH protocol maximum numbers of dead nodes was 423 at 1895 and in LEACH-GA protocol total numbers of dead nodes was 403 at 1895 but LEACH DFACNN still have maximum alive nodes at after 2000 rounds.

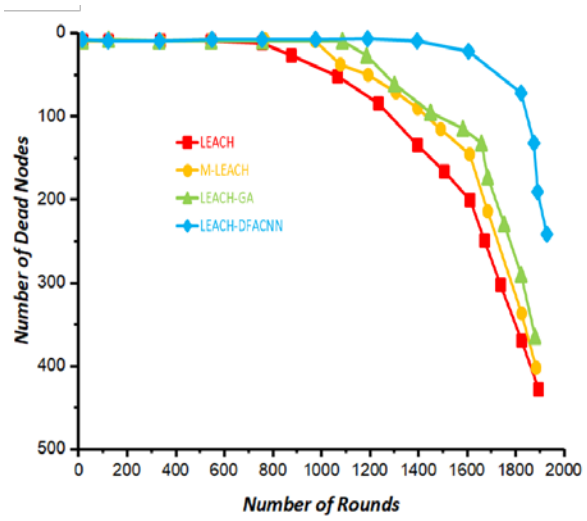

Fig. 5 The comparison of dead nodes between LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA

The LEACH DFACNN show the less dead node ratio as compared to LEACH and M-LEACH,GA protocol. The implementation of Mean method and minimum distance method using cyclic neural network improves the stability period of LEACH-DFACNN which is caused because of removal of redundant data forwarded by neighboring nodes. The load balancing is achieved by LEACH-DFACNN due to mean method and minimum distance method using cyclic neural network nevertheless in other protocols expire earlier because forwarding of huge amount of redundant data. The calculation of the minimum distance method is large, and the time T of the mean method is longer than the minimum distance method. The amount of data of each group containing data redundancy processing by the minimum distance method is less than that by the mean method, so the redundancy removal effect of the minimum mean method is inferior to that of the mean method. Mean method and minimum distance method largely solve the data redundancy problem of a single sensor node in a short time. Comparison of alive nodes during the simulation result between LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA protocol (data fusion technology not added) is show in Fig. 6. In LEACH-DFACNN, first node dies at about 1700 round, in the meantime it also shows the uncertainty period after 2000 rounds. After disappearing of early nodes, the removal of redundancy node delivers extended period to the network. In each single round of simulation, each alive node in the network sends packet towards base station and the packet is forwarded until reaches to the base station. After 2000 rounds have more the 200 alive nodes as compared to the M-LEACH & LEACH-GA,LEACH.

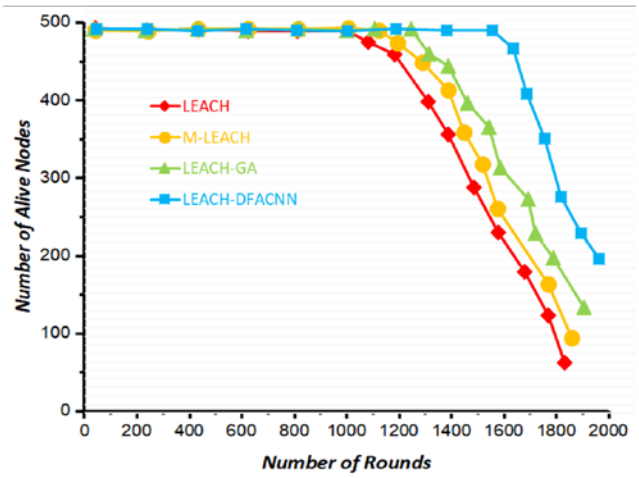

Fig. 6 The Survival Nodes between LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA

Fig.7 describe the average energy ingesting of the networks between LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA protocol. The total remaining energy of LEACH- DFACNN network node is more than LEACH, M-LEACH and LEACH-GA with the increase in number of running rounds.

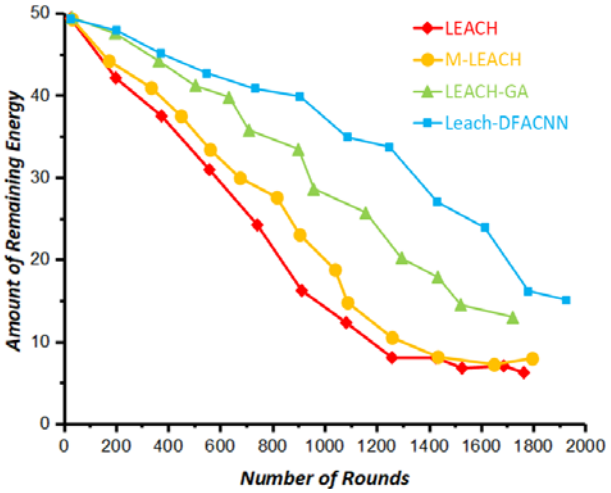

Fig. 7 Network Remaining Energy Comparison between LEACH-DFACNN with LEACH, M-LEACH and LEACH-GA

Therefore, LEACH- DFACNN protocol attained the long network lifetime. In summary, the data fusion algorithm based on LEACH protocol can efficiently solve the data redundancy problem generated by adjacent sensor nodes at the same time. In the previous approaches LEACH, M-LEACH and LEACH-GA protocol, the network stability period rapidly decreases due to increase in energy consumption and unnecessary data forwarding increases end to end time delay. In this method, the approach is energy efficient due to limitation in unnecessary forwarding

of redundant data and optimal selection of neighbour node. Fig. 8 estimates the efficacy during the life period of the network.

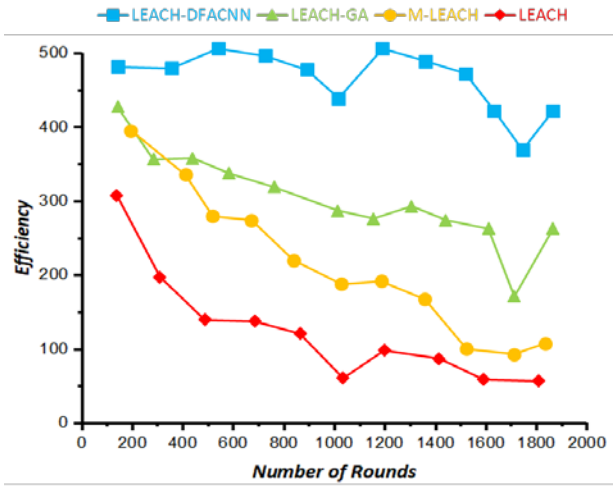

Fig. 8 Performance Analysis using the Efficiency and Number of Rounds

In WSN, the mobile nodes face the route update cost due to node mobility that create collapse in the network link. The path connectivity hole leads retransmission of packets that consumes excessive energy, route-update cost and end-to-end delay time. In our proposed approach, the mean method and minimum distance method ensure the non-redundant data packets delivery at base station. Because of less consumption in node residual energy and constant e2e delay, the network efficacy at the earlier and finale rounds is maintain that improved the data packets deliver ratio in LEACH-DFACNN.

6. Conclusions and Future Work:

As a conventional categorised routing protocol, LEACH resolves the deficiencies of planar routing protocol such as titanic energy consumption and massive e2e delay. The LEACH protocol has its weaknesses and limitation of more energy consumption. The LEACH protocol is not implemented into to large-scale and time critical WSNs. To scope the shortage of energy ingesting in LEACH protocol, the LEACH protocol is needed to advance. In LEACH protocol, the cluster head node is required to fuse the data before sending to the base station. There are many research gaps to design and implement the specific data fusion algorithm to fuse the data redundancy. Aiming at this defect, this paper adds the mean method and the MD method behalf on LEACH protocol and designs a DF algorithm based on CNN. LEACH takes security into account. Insecure routing protocols may leak information or even be damaged by attacks. So, further work is to design a secure routing protocol.

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