Energy Efficient Cluster-Head Selection in WSN's for IoT Applications

Harshitha N[1], Hemanth Kumar A R[2]

[1]M.Tech student, Dept. of ECE, Bangalore Institute of Technology, Bengaluru, India-560004
[2]Prof, Dept. of ECE, Bangalore Institute of Technology, Bengaluru, India-560004

Abstract – *With the recent advancements in technology amelioration, sensor network is in great demand because it is emerging as one of the most promising tools for communicating the data over the network. These days, WSN is rapidly developing its limbs in almost various cross functional areas of science and technology. The WSN consist of many spatially distributed nodes used for sensing the information and transmitting the aggerated data to the relay or sink. The sensor nodes are incorporated with the tiny battery in the network usually has a limited power source. Hence, the primitive task for WSN is to use battery power in a such way to prolong the networks' lifetime. However, clustering algorithms has been adopted in sensor network which plays a major role in the power conservation.*

The main goal is to elevate the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol by employing a new clustering routing topology. In the proposed model, electing the cluster heads remains the same as it had been in the original Leach protocol but based on the high residual energy. However, in the modified version the whole network area is divided into rectangular regions applied the LEACH algorithm, respectively. The routing mechanism is tuned up in the MAC layer which minimizes the congestion in the network and enhances the network performance metrics such as throughput, delay, overhead, and average energy through Network Simulator 2 platform.

Key Words: Sensor Nodes, WSN, Base Stations, R-LEACH, Network Lifetime, Energy Proficient.

1. INTRODUCTION

In the progressive field of science and technology, **wireless sensor networks (WSNs)** have been developed massively as one of the fastest growing emerging technologies for transmitting information over the network [1]. Sensor networks is a communication platform consist of vast number of tiny disposable independent devices knows as sensor nodes as shown in Fig. 1. Wireless sensor network is a promising tool that establishes a link between the physical, virtual worlds and human society [4].

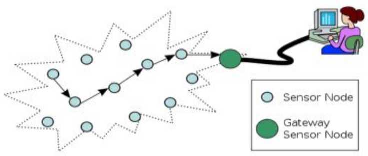

Fig. 1 Wireless sensor network

Sensor nodes are spatially disseminated over the network to monitor the physical world or environmental conditions such as temperature, humidity, vibration, pressure etc. transforms the sensed information directly to the sink which is the central processor of the network [2]. The sensor nodes deployed large in number compared to mobile ad hoc networks [3]. Owing to the rapid development of sensor network it extended its limb in several areas such as surveillance, object tracking, habitat monitoring, health care, industrial management, data gathering, and calamity management [1]. Communications in sensor networks are categorized into 3 types:

- **Direct communication:** In this type of communication all the nodes in the sensor network sends data directly to sink i.e. Node-BS and requires large energy to receive the data.
- **Multi-Hop communication:** In this type nodes route the data to the baste station through intermediate nodes i.e. Node-Node-BS.
- **Communication using clustering:** In this mode of communication nodes are divided into group called clusters. Each node in the group transmits the information to cluster head and then typically forwards to the end user i.e. Node-CH-BS.

Typically, the primitive component of the network is the sensor nodes consist of four essential units such as sensing unit, central processing unit, communication unit, and power unit as illustrated in Fig. 2.

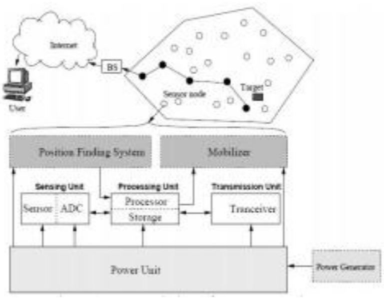

Fig. 2 Structural view of sensor network

i. **Sensing Unit:** Firstly, in this unit it is integrated with the sensor and Analog to Digital converter i.e. ADC. The primeval goal is to collect the data and facilitates the delivery of the data as a request to the converter which transfer the analog sensed information to the processing unit [2].

ii. **Central Processor Unit:** In this unit, where the analog to digital converter acts as translator to the sensor and processor. ADC updates the sensed information to the processor and assign the task to be performed by sensor unit. Processor unit is exhibited as complex unit because it interprets the issues to the converter, reduces the battery power, computes the data to sink [2].

iii. **Communication Unit:** This unit is responsible to receive the issues or queries from the processor and delivers the collected information to the destination or to the real world [2].

iv. **Power Unit:** The major role of this unit to supplies the power to all the units to enhance the lifetime of the sensor nodes in the network for efficient communication to the gateway [2].

Since replacement or recharging of batteries in sensor nodes is almost impossible so electing an energy efficient routing protocol becomes one of the major issues which significantly impact on the network's lifetime. On the other hand, electing the cluster head, balancing the threshold energy levels in clusters, and transferring the aggregated data to its destination exhibits some amount of energy are the other crucial design issues in the network.

The Paper is Structured as follows: Section 2 Describes the protocol, Section 3 Proposes the approach, Section 4 Presents the analysis of Network simulator results. Finally, the article is concluded in section 5.

2. LEACH PROTOCOL

LEACH is one of the most primeval energy efficient classical protocol for wireless sensor networks, which was developed by Wendi Rabiner Heinzelman at MIT [4]. The main goal of the protocol is to diminish the energy consumption which extends the lifetime of the network [4]. The hierarchical routing mechanism consists of several nodes over the network which are divided into small set of groups called clusters [3]. Each group is headed by a cluster head which is elected randomly for each round [2]. The job of CHs is to periodically collect the data from its suppliers and also maintains the consistent time schedules for the data transmission to the sink or base station [5] and basic network model of LEACH is illustrated in Fig. 3.

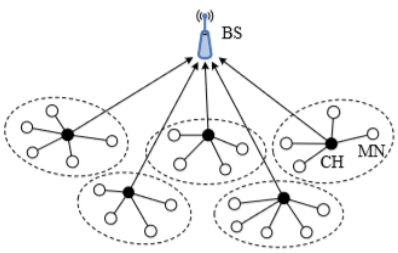

Fig. 3 The basic network model of LEACH

2.1 Operation of LEACH

The basic activity of LEACH is systematized into rounds, where each round begins with a set-up stage, where the set of nodes are organized into clusters and then facilitated with the steady-state phase where block of the data transmitted to the destination as depicted in flowchart [2]. The set-up stage includes phases such as advertising the broadcast message, setting the clusters and maintain the time slots [1]. The steady-state stage includes data routing phase [1]. In order to balance the load in the network, the duration of the steady-state is overlong compared to set-up stage [2]. The basic workflow of the LEACH algorithm is revealed in Fig. 4.

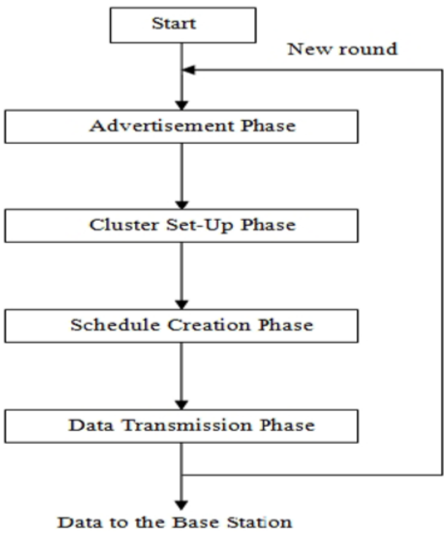

Fig. 4 The basic operational flow of LEACH algorithm

i. **Advertisement phase:** In this phase, each sensor node in the cluster gets a cluster head announcement respectively [1]. The protocol elects the CH randomly and also based on the random number X value ranging from 0 to 1 [2]. If the value is lower than threshold T(n), then that particular node becomes head for the present round [2]. The threshold value is given by:

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \left(\frac{1}{p}\right)\right)}, & if\ n \epsilon G \\ = 0 & \text{otherwise} \end{cases} \quad (1)$$

Where the p represents the probabilistic idea of cluster heads, r indicates the existing round, and G is the group of the nodes that have not been turned into job of CHs in the past rounds. The dedicated privileged node i.e. CH broadcasts an announcement to their associated member nodes of the cluster, respectively [1]. Based on the received signal strength the carrier nodes send a paring request to the privileged head that they are the members of that particular clusters [1].

ii. **Cluster set-up phase:** In this phase the sensor nodes in the network makes a decision of their joining as supplier members in the corresponding clusters [2].

iii. **Schedule creation:** After the cluster set-up the privileged head assigns time schedules to their members for data transmission and this phase evades signal collisions [2].

iv. **Data transmission phase:** This phase is the steady-state of LEACH operation [2]. Actual data routing occurs in this phase where the gathered data is sent directly to the sink [2].

2.2 Drawbacks of LEACH

- The hierarchical protocol doesn't provide any idea regarding the optimal number of CHs and the location of sensor nodes deployed in the network.
- The major issues of LEACH are, if the cluster-head dies due to any conditions ultimately the received data becomes useless.
- In LEACH one hop distance communication takes place between the cluster-head and main location of the topology. Suppose if the cluster head is far from the destination it dissipates more energy for the transmission of the data than the head situated nearer to the sink and this leads to limited network coverage area.
- Clusters are broken into a small group randomly, so this leads to the unequal distribution of nodes in the Clusters. For example, some groups have more nodes, and some have few nodes. Some heads are at the middle and corner of the clusters, so this leads to shorter life of the network.

3. PROPOSED MODIFICATION

In this paper, we have proposed a LEACH based clustering protocol. The major problem in the LEACH algorithm is that all the cluster heads are selected randomly. Therefore, there is a high possibility that most of the selected cluster heads can be concentrated over a certain part of the entire network.

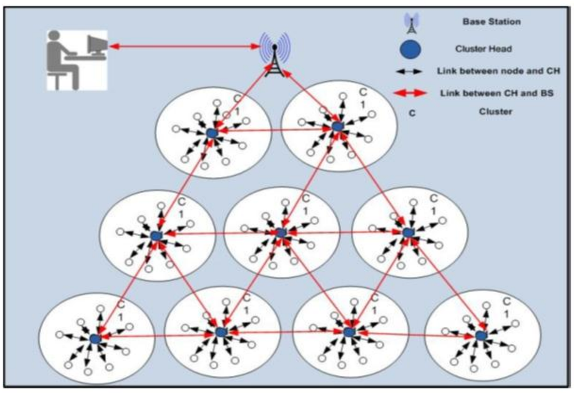

Fig. 5 Architectural view of R-LEACH algorithm

The network topology of the proposed R-LEACH protocol is illustrated in Fig. 5. The N number of sensor nodes with same initial energy deployed randomly over the network in a homogenous manner and the whole network is divided into multiple groups called clusters that are formed dynamically. The protocol elects the cluster head same as in LEACH but based on the parameter such as residual energy for each round .The CH is responsible for the periodic collection of the sensed data from its member nodes and assigns TDMA (Time Division Multiple Access) schedules .The cluster members transmit their data directly to CHs in the given time slot in a single hop and all the cluster heads transmits the aggregated data to base station in either single hop or multi hop manner which acts as middleware between the mobile user and the network.

3.1 R-LEACH Operation

The protocol mechanism is implemented in rounds as depicted in Fig. 6. Each round consists of two stages i.e. set-up phase that includes cluster formation and cluster-head selection and followed by steady-state phase where several frames of aggregated data are transferred to the main location of the network. In order to minimize the protocol overhead, the duration of the setup phase is relatively shorter than steady-state phase.

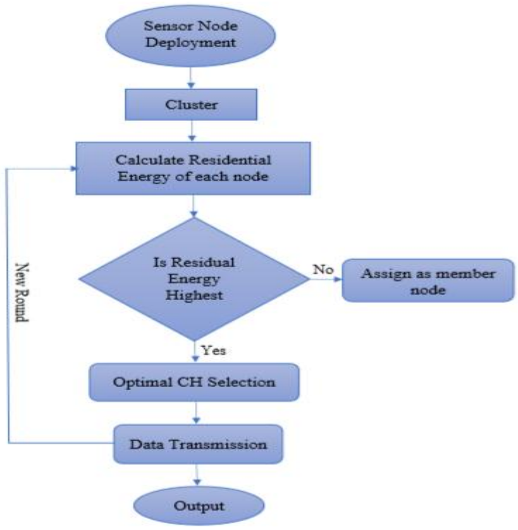

Fig. 6 Pictorial flow of R-LEACH protocol

i. **Set-up phase:** In this phase, the main objective is to create several clusters and opting the cluster head respectively for each region. The cluster head is elected based on the high residual energy among the sensor nodes. The set-up stage process is illustrated in Fig. 7. The activity of Set-up phase includes 3 primitive steps as follows:
   - Cluster set up.
   - Cluster head announcement.
   - Manage scheduled transmission.

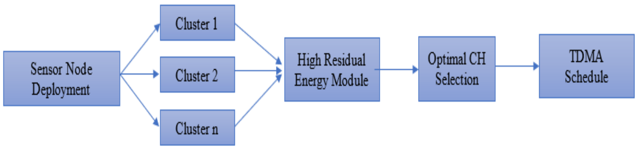

Fig. 7 Set-up phase of R-LEACH algorithm

Initially, cluster head broadcast an advertisement message to its member nodes that they have opted as CH respectively for each region hence this phase is referred as cluster formation period. For the first round, the selection phase of the cluster head is same as that in the classical LEACH algorithm as given in the equation (2). Each node in the cluster chooses a random number R value ranging from 0 to 1 and it is measured by threshold value i.e. T(n).

$$T(n) = \frac{p}{1 - p * \left(r \bmod \left(\frac{1}{p}\right)\right)}, \quad if\ n \epsilon G$$
$$= 0 \quad \text{otherwise} \qquad (2)$$

Here, n indicates the given node and where p signifies the chance for a node to serve as CH, r refers the present round, G represents the group of nodes that have not been a CH in the previous rounds. If the value is lower than threshold value, then the node turns out to be a cluster head for the present round. For the next on going round the cluster head is selected based on the remaining energy among the nodes that increase the network life and hence the modified equation (3) is given as

$$T(n) = \begin{cases} \frac{P}{1 - P(r \bmod \frac{1}{P})} \times \frac{E_{residual}}{E_{initial}} k_{opt}; \ for \text{ all n ò G} \\ 0; \text{ Otherwise} \end{cases} \qquad (3)$$

Where E $_{initial}$ = initial energy level assigned, E $_{residual}$ = remaining energy of the node and K $_{opt =}$ optimal number of clusters in the network is written as

$$k_{opt} = \sqrt{n/2\pi}\sqrt{\frac{E_{fs}}{E_{amp}d^4(2m-1)E_0 - mE_{DA}}}M \qquad (4)$$

Here, 'M' indicates the diameter of the network and E_0 signifies the transmit energy to the node. The elected node cannot serve as cluster head again until each node in the cluster becomes cluster head once.

During the second step the cluster head transmits the advertisement packets to their fellow nodes, respectively. Based on the received signal strength non cluster members send a paring request to the CHs that it want to be a part of member under a particular cluster head. While communicating to the cluster head the transmitting node remains on and other nodes remains off to save energy which prolongs the network life.

In the final step, based on the optimal number of nodes in the cluster the cluster head assigns Time Division Multiple Access (TDMA) schedule for their members. The data is transmitted in the given time slot to avoid data collisions and then the process lasts for several rounds until all the nodes dissipate their energy.

ii. **Steady-state phase:** The data routing occurs in this phase, so the duration of this phase is relatively long than that of set-up stage. The steady-state state stage process is illustrated in Fig. 8. The activity of steady stage includes three fundamental steps as follows:
   - Periodic data collection
   - Data fusion/aggregation
   - Delivery of data to main location of the network

The cluster head periodically collects the data from the sensor nodes in given time via single hop. The data packets are fused in order to eliminate the redundancy bits and compress the information for fair utilization of the bandwidth. The cluster head transmits the data directly to BS or to other cluster heads via mutli-hop fashion. After certain period, these phases would be repeated.

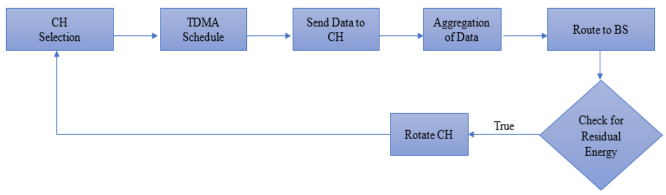

Fig. 8 steady-state phase of R-LEACH algorithm

The clustering procedure is same as that of the R-LEACH protocol but the primitive advancements in the proposed system are extending the transmission range and setting up the frequency high in the physical layer in order to control the congestion. The Congestion windows is made dynamic by adjusting its min and max values so based on incoming bytes window is set this leads to less delay and retransmission of the data is reduced. Data processing rates of MAC layer is also set, so faster the data rates larger the coverage area of nodes and ultimately energy is conserved.

4. SIMULATION AND RESULT ANALYSIS

4.1 Simulation Setup

The simulation and performance analysis of the proposed mechanism is evaluated through the Network Simulator-2 tool. The system performance is estimated by comparing the R-LEACH protocol with its modified version using the same initial values and following the same techniques. The nodes are deployed randomly over the network area about 1300m × 1000m.The general simulation parameters are depicted in Table 1. The following steps are utilized for the simulation:

- The sensor devices are deployed randomly over the whole network area
- The nodes deployed in the physical network area are initialized with same energy hence the network is homogenous.
- The Sensor nodes in the network must be fixed.
- The Base station is placed at middle of the network field.

Parameters	Values
Simulation Area	1300*1000 meters
Channel type	Channel / Wireless
No of Nodes	103
Antenna Model	Antenna / Omni antenna
Interface queue type	Queue/ Droptail/ Priqueue
Link layer type	LL
Simulation time	26s
Initial Energy model	100 J
Type of MAC	MAC / 802-11
Packet Size	500 bytes
Radio Propagation mode	Propagation Model / Two ray Ground

Table 1. Simulation metrices

4.2 Performance Metrices

To evaluate the performance the comparison is made between the proposed system and an existing system. In Existing framework different routing procedures are used which was not energy proficient and tedious and the existing scheme also updates the node location using localization algorithm and minimum distance, which also results in less energy consumption. In the proposed work the elective way with high residual energy is implemented which reduces the congestion in the network.

The estimation criteria of modified R-LEACH are based on the significant measurements such as throughput, end to end delay, packet delivery ratio, overhead, and energy of existing and proposed systems. The simulation work is carried out in network simulator 2.35 platform and where NAM window gives the graphical representation of the simulation. The outcome and execution analysis are discussed below, the red line designates the existing method and green line demonstrates the proposed method.

i. Throughput

It is the measure of the number of the packets or data transferred successfully over particular intervals and which is measured in kbps. The throughput comparison between the existing and proposed system is depicted in Fig. 9. The x-axis signifies the time slots and y-axis signifies the throughput. As the time varies, the number of packets delivered per unit time is more thus results less throughput in an existing method. Due to high frequency cycles and data processing rates in the proposed scheme, gives high throughput. The throughput obtained in existing is 283.56 kbps where in proposed is 370.45 kbps.

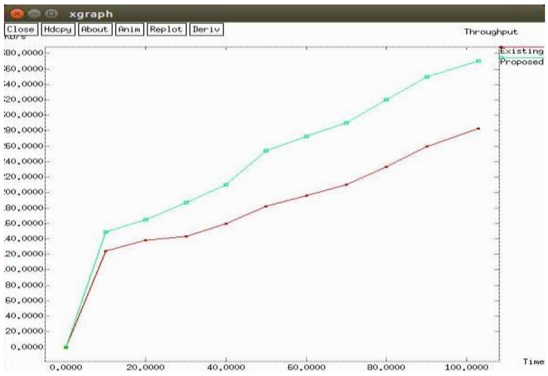

Fig. 9 Throughput comparison

ii. End to end delay

It is defined as the total time taken by each packet to communicate in the network from source to destination. It is estimated in milli seconds. The delay comparison of the existing and proposed system is depicted in Fig. 10.

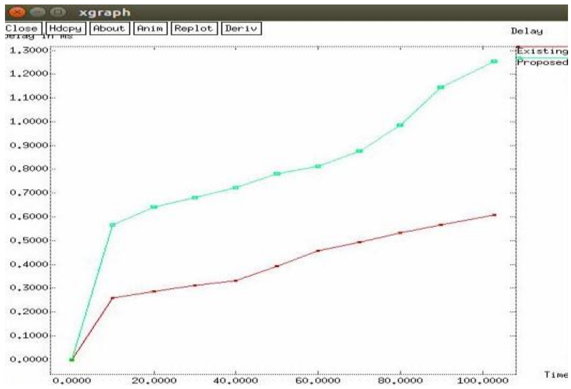

Fig. 10 Delay comparison

The x-axis signifies the time slots and y-axis signifies the delay in ms. In the proposed system delay is high than existing system because of frequency fluctuations for sensing various data which is the limitation of the project. The delay obtained in existing is 608.91ms and increased in proposed system i.e.1253.21ms.

iii. Packet delivery ratio

It is the ratio of the total number of packets transmitted by source and the no of packets ack at the base station. The packet delivery ratio of the existing and proposed system is depicted in Fig. 11. The x-axis signifies the time slots and y-axis signifies the packet loss. In the existing system the nodes with less energy leads to be dead after certain transmissions which do not deliver the packets but in proposed data processing rates is increased which attains more reliability in delivery of the packets. The ratio of packets sent and received in the existing system is s:690, r:592 and its ratio, packets loss is 0.8580,98 respectively. In the proposed method the ratio is 0.8957 and the loss of packets is decreased to 72.

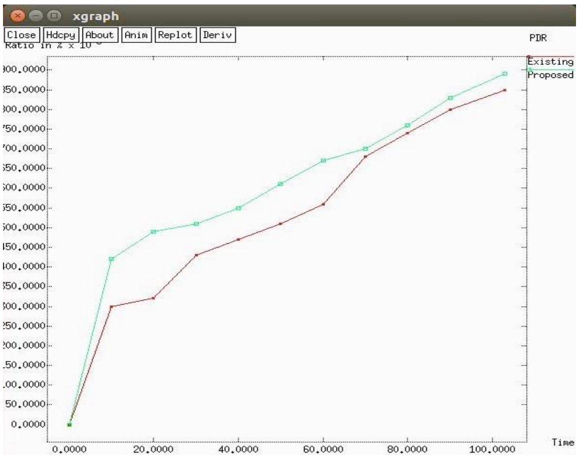

Fig. 11 Packets loss comparison

iv. Overhead

It is the total number of routing packet processed in a network area. The overhead comparison of the existing and proposed system is depicted in Fig. 12.

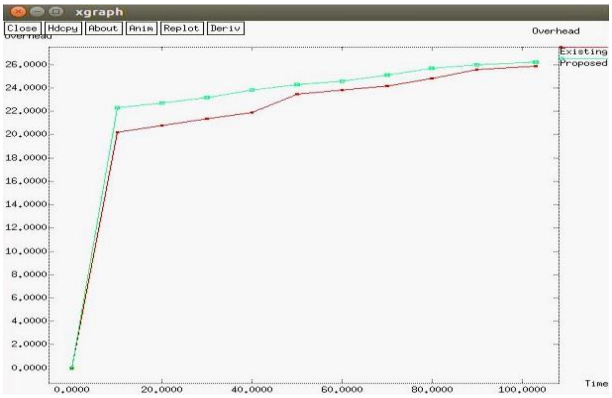

Fig. 12 Overhead comparison

The x-axis signifies the time slots and y-axis signifies the overhead in terms of load. Due to cluster head rotation overhead is delivered which is same as that of existing method at the certain point. The overhead value of each method is around 26.

v. Energy

It is the measure of average energy consumed by the sensor nodes at particular time period. The nodes are battery operated so requires energy for communication and it is estimated in joules. The comparison of energy is shown in Fig. 13. The x-axis signifies the time slots and y-axis signifies the energy. The residual energy dissipates at faster rate in existing system. In proposed system energy consumption gradually decreases due to tune up in the MAC layer thus, extends the network lifetime. The energy consumed by proposed method is 13.973 J where in existing method is increased to 16.72 J.

Fig. 13 Energy comparison

5. CONCLUSIONS

In designing any routing protocol for sensor network the energy and lifetime are two main constraints so, research has been carried out to attain the goal. The other crucial issue is electing a novel energy-efficient routing approach which distributes the load uniformly in the network. To overcome these issues LEACH ensures an adaptive algorithm but still has some limitations. A new edition of LEACH divides the network area into multiple zones where the original algorithm is applied for each region. The CH selection and formation is done uniformly to reduce energy dissipation and ultimately extends the network life. The enhanced routing process is tuned up in the MAC layer which minimizes the congestion in the network and enhances the network performance metrics such as throughput, delay, overhead, and average energy. The proposed model delivers a better result for homogeneous networks in comparison to LEACH.

The current work can be extended for CH selection in a heterogeneous network by considering additional metrices and different sink positions. The data security protocols can be implemented to secure the data from attacks and to manage the data efficiently.

ACKNOWLEDGEMENT

This research was supported by Bangalore Institute of Technology (BIT). I am thankful to my guide Prof. Hemanth Kumar A.R of electronics and communication department who greatly assisted the research.

REFERENCES

[1] K. Saha, Md. S. U. Khan, and Md M. Rahman, "Region Based Low Energy Adaptive Clustering Hierarchy (R-LEACH) Protocol: Prolonging the Lifetime of WSN," In proceedings of 6th International Conference on Networking, Systems and Security, December 2019.

[2] B. Parmar, J. Munjani, J. Meisuria, and A. Singh, "A Survey of routing protocol LEACH for WSN," IJSRP, Vol 4, Issue 1, January 2014.

[3] K. Manohar, A.I. Darvadiya, "Study of Leach Protocol- A Review," International Journal of Modern Trends in Engineering and Research (IJMTER) Volume 01, Issue 06, December - 2014.

[4] Xuxun Liu, "A Survey on Clustering Routing Protocols in Wireless Sensor Networks," sensors ISSN 1424-8220, August 2012.

[5] T M Behera, S. K. Mohapatra, U. C. Samal, Md. S. Khan, Md. Daneshmand, and A. H. Gandomi, "Residual Energy Based Cluster-head Selection in WSNs for IoT Application," IEEE Internet of Things Journal, 2019.

[6] F. Xiangning and S. Yulin, "Improvement on LEACH protocol of wireless sensor network," in Sensor Technologies and Applications, 2007. SensorComm 2007. International Conference on, 2007, pp. 260–264.

[7] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," IEEE Trans. Wirel. Commun., vol. 1, no. 4, pp. 660–670, 2002.

[8] Y. Li, N. Yu, W. Zhang, W. Zhao, X. You, and M. Daneshmand, "Enhancing the performance of LEACH protocol in wireless sensor networks," in Computer Communications Workshops (INFOCOM WKSHPS), 2011 IEEE Conference on, 2011, pp. 223–228.

[9] J. Xu, N. Jin, X. Lou, T. Peng, Q. Zhou, and Y. Chen, "Improvement of LEACH protocol for WSN," in Fuzzy Systems and Knowledge Discovery (FSKD), 2012 9th International Conference on, 2012, pp. 2174–2177.

[10] S. Hussain and A. W. Matin, "Energy efficient hierarchical cluster-based routing for wireless sensor networks," Jodrey Sch. Comput. Sci. Acadia Univ. Wolfville, Nov. Scotia, Canada, Tech. Rep., pp. 1–33, 2005.

[11] S. H. Kang and T. Nguyen, "Distance based thresholds for cluster head selection in wireless sensor networks," IEEE Commun. Lett., vol. 16, no. 9, pp. 1396–1399, 2012.

[12] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, 2000, p. 10 pp. vol.2.