A
Dissertation On

# Improved Clustering Algorithm for MANET for IOT Application in Field of Military

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For the Award of Degree of

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*In*

**Software Technology**

*By*


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# DECLARATION

I hereby declare that the thesis entitled "**Improved Clustering Algorithm for MANET for IOT Application in Field of Military"** which is being submitted to the **Delhi Technological University**, in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Software Technology** is an authentic work carried out by me. The material contained in this thesis has not been submitted to any university or institution for the award of any degree.

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# CERTIFICATE

This is to certify that thesis entitled "**Improved Clustering Algorithm for MANET for IOT Application in Field of Military",** is a bona fide work done by Mr. Ashish Maurya (Roll No: 2K15/SWT/507) in partial fulfillment of the requirements for the award of **Master of Technology Degree in Software Technology** at Delhi Technological University, Delhi, is an authentic work carried out by him under my supervision and guidance. The content embodied in this thesis has not been submitted by him earlier to any University or Institution for the award of any Degree or Diploma to the best of my knowledge and belief.

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# ABSTRACT

IOT is continuous developing technology in spanning lot of existing and new developing fields of current world. Various IOT applications are developing and growing enormously covering areas of various technological and non-technological industries. Lot has been done with IOT in field of Consumer Convenience like home appliances, home security, smart energy saving etc. even can be applied in Defense & Military operations.

A military research operation led by hundreds of soldiers and equipped with lot of sensors of different kind moving along with soldiers or independently in random directions with random speeds with purpose of collecting valuable data from field and send it to base station in real time.

Here we are proposing a solution where this IOT based military data can be sent to base station by movable sensors by forming WSN of these sensors as nodes over a large geographical area and WSN sensors connected to each other in form of MANET where each sensor is represented by node in MANET.

LEACH protocol in MANET is widely famous and has main purpose of optimum utilization of energy resources or sensor batteries in WSN and prolonging network life-time. Here we proposed improved mechanism of existing LEACH protocol for MANET formed by mobile sensors of IOT based application i.e. in field of military and achieving whole military operation even more reliably, efficiently and successfully.

First, we have proposed improvement in LEACH protocol by improving its Cluster Head Selection process and then implemented other improvements like multi-hop communication for IOT application to achieve our goal.

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# CHAPTER 1: INTRODUCTION

## 1.1 IOT: INTERNET OF THINGS

Internet of Things (IOT) is future of many upcoming solutions to many problems that are currently faced by us on daily basis. IOT based solutions by capability of having a set of key service backed by respective technologies provides solution to many daily bases consumer and organizational requirements and problems which have not been possible or extremely difficult in earlier days. IOT technology is developed by combining many different technologies together which constituting IOT and providing a next generation solution for real world problems. Sensor which can sense any activity of any occurrence of any event and with help of some tools or digital converter their activity or occurrence sensed can be converted in to some form of data or digital bits. Many such sensors deployed at different locations which have similar or different capabilities can send required activity and produce respective data. To Convert such raw data into meaningful information we need to collect all data together and do some intelligent processing on it to convert it in to meaningful information which can be only be possible if all data are various locations can be received to single destination safely and efficiently. With present advance network solutions which brings connectivity of different located sensors or nodes to some required destination node or server or storage system is very common and popular nowadays. However, things become much more complicated when these sensors or nodes are not fixed in geographical area rather than they are moving because of nature of their application or requirement. It brings requirement of network solutions which can handle these moving objects or sensors and can maintain connectivity with them via some reliable solutions which can accommodate itself as per movement of objects or nodes or sensors and for it required some wireless solution as by its nature it do not have to maintained connectivity with nodes by some fixed wire or line.

IOT application are transforming industry day by day. A lot of development is expected in field of IOT by 2020 in different fields. Few fields having more developments and growing faster in comparison to other.  Some of popular Industrial IOT applications are Inventory management where various events occurring during production of goods and during supply chain can be collected via IOT sensors and can be sent to required destination or server from it can be monitored globally and actions can be taken by utilizing real time conditions and data received. Quality control where with help of IOT sensors data related to product being developed can be sensed and send to server. This data might include composition of raw materials temperature, work environment, impact of transporting goods from one plan to other places and wastes happened. Apart from that IOT can provide data related to customer sentiments regarding final product by aggregating all experience through various sources. Safety – IOT can help in collecting various important factors related to health and safety in various industries, these may include count of injuries and other related details, presence of any employee and attendance, frequency of illness and absenteeism. Smart metering- Smart meters are used to monitor and can be used to control spend of various resources like water consumption, availability of fuel and most important electricity.

Other fields are predictive maintenance, smart packaging, digital industries, many applications in heavy industry. Lesser has been done with application of IOT in field of Defense and Military but actually having a lot of scope of development enhancement.

### 1.2 WIRELESS SENSOR NETWORS (WSN)

Wireless Sensor Networks (WSN) is a solution that has been explored above for network solution for mobile nodes. It is network of all sensors that are present over a big geographical area are connected to each other in one way or other, directly or indirectly via some other intermediate nodes and have some mechanism to transmit and receive data to and from each other. There nodes of WSN are devices with sensors that are having sensing capabilities of various kindly of activity or capability of sensing any physical condition of environment in which device or sensor is present.

Mobile Ad hoc Network (MANET) is a network of nodes in which nodes are connected to each other without any fixed line or wire or infrastructure. Every connectivity is wireless in nature. Also, very special thing about MANET is that connectivity of nodes in a MANET are organized by itself and no need of any external controlling mechanism. Two nearby nodes which are connected to each other directly can communicate with each other directly, but two nodes which far from each other and don’t have any direct connectivity can be connected to each other via some third node or via multiple connecting nodes and thus can still communicate to node that present at far location and out of range of direct connectivity.

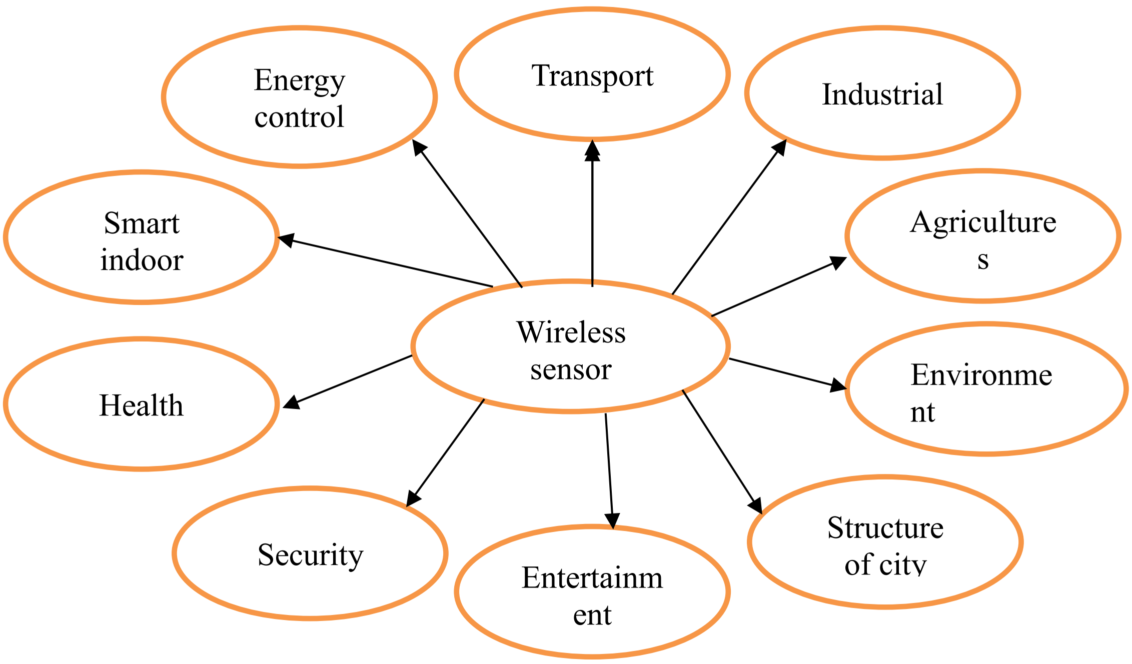


*Figure (1): Application of Wireless Sensor network (WSN)*

**1.3 MOTIVATION**

Application of WSN along with IOT can be used in lot of areas like medical, weather, anthropology, geography research, any physical object movement tracking and even in area of military operations like military search operation, military infiltration, collection of important information of enemy land and sending back to own country land, Military's medical help operation by dropping medical and food packages to some distant wide area and tracking of packages dropped. A military search operation which have to look after a large geographical area where no infrastructure available for transmitting data from each location points. Various military troops searching and gathering different kind of data like temperature or climate conditions, animal or any other human activities, drone, robots machinery installation or related activities (add more from industrial IOT application) and have to send it to their base via WSN they have created locally with sensors which are required to sense required activities and having capability to communicate with each other and transmit and receive data among connected nodes. All sensor nodes powered by battery which actually is large enough but required optimized consumption to secure successful military operation.

A common problem with WSN or MANET is mobility of nodes. Nodes or sensors are always moving close or away to or from each other all the time. Few nodes or in this case military personnel might move fast while other can move slow. Few can move within some bounded location while other nodes might move in unbounded pattern. Few nodes can have some movement pattern while other can have no movement pattern and movement is completely random. No matter how is movement of nodes described above, one thing is sure that network topology of MANET created is keep changing dynamically. This is by its nature and one of the fundamental limitations of WSN or MANET. Due to above limitation these is possibility of disconnection of few nodes from existing network all the time. Apart from above limitation WSN sensors also having limitation of energy source or battery. Chances of having regular feeding or charging to node sensor are rare. All node sensor is usually capacitated with some limited battery which is charged at initial stage of sensors life time. This battery or source of energy keep reducing over the time due to all activities done by sensor or node. These energy draining activities might include keeping sensor active, sensing of required activity, conversion of sensed activity in to some analog or digital data, sending of this data to other node or destination.

Keeping all limitations aside MANET still is most promising and advantageous because of providing network solutions in IOT Applications in wireless domain and most required in area where fixed infrastructure is not present and nodes or sensors are moving continuously. MANET uses technique of clustering of all sensor nodes that are deployed in geographical area followed by Cluster Head selection in each cluster which is responsible for collection of data from all connected nodes and sending aggregated data further towards destination.

There are many factors which are responsible for energy consumption of nodes in MANET. Few are Cluster head (CH) Selection criterion, round time for next round of CH selection, way in which data aggregation is done and data is transmitted or received to and from other nodes.

As discussed above energy consumption is fundamental concern in WSN. Therefore, it very important to optimize energy consumption of sensor nodes to minimum extent. Node energy consumption pattern may be very critical to successful of whole application. Any way which can save a little amount of energy from each node can have a very big impact on network life time and hence can be very big impact on whole solution. Apart from node energy there are many other factors that also causes energy consumption of sensor nodes.

Addressing above problem of defense or military search operation and by motivating it, here proposing a solution with WSN supported by LEACH by improving Cluster Head selection mechanism in existing LEACH protocol and apply it for sensors nodes used in IOT Application of military search operation.

## 1.4 ADVANTAGES OF LEACH PROTOCOL FOR IOT APPLICATIONS

There are various advantages that the LEACH protocols possess which are as follows.

For IOT applications where lot of IOT sensors are deployed over some large area for some specific purpose and number of sensors can be increasing and decreasing regularly due to mobility and other requirements, scalability becomes one of most prominent factors for selecting WSN. LEACH based improved protocols for MANET shall be one of the best solutions for such applications because it limits most of the communication within the different clusters of the network.

Another important advantage is energy efficiency. In IOT based solutions where sensors do not need to transmit data to the base station or destination server all the time, LEACH protocols uses energy of all sensors very efficiently because it works on basic rules of TDMA slots basis access of lot connected sensor nodes to CH, so that nodes need to be active for a small fraction of time to achieve same information sharing with CH and base station or server destination. This advantage shall be very helpful for IOT based applications like military search operation application has taken here.

Development of multi-hop communication in LEACH protocol gives another level of advantage. Due to multi-hop in LEACH all CH do not need to send aggregated data to base station rather all CHs can send data to next level CH. This process again improved energy saving of CHs to a great extent.

IOT Applications where sensors are moving all the time and there is great probability of network topology changing all the time. A sensor close to a number of sensors may move near to some other sensor and get far away from initial set of sensors all the time. LEACH protocol in MANET for WSN is dynamic protocol so if any IOT sensor in changing its position as per requirement it may get attach to some other favorable cluster and continue its data transmission normally.

## 1.5 DISADVANTAGES OF LEACH PROTOCOL FOR IOT APPLICATIONS

There are various disadvantages of the LEACH protocols too that are as follows.

IOT applications where sensor is sensing important data like in case of a military operation kind of data dealt may be very sensitive. In LEACH all sensor data is routed via CH. Therefore, CH stability and situation like CH breakdown becomes critical. There for a great attention required to CH selection in every round. CH selection need to be done in every round and this causes an extra cost on implementation of LEACH in WSN for IOT Applications.

Another disadvantage is extra cost for maintenance of network due to require of energy level of all sensor nodes, cluster heads and whole network all the time for selection of CH dynamically all the time. This cost becomes significant for large scale networks as number of computations increases along with number of sensors and cluster head in the network.

# CHAPTER 2: RELATED WORKS

Lot of work has been done in improvement of existing LEACH protocol in past but lesser has been done for its implementation for IOT Applications. Below is few of works that has been done previously for LEACH improvement.

LEACH is very basic protocol of sending sensor sensed data to destination server which follows hierarchical network topology to aggregate and transmission of data. Cluster Head (CH) selection process in basic leach is random due to which it has incorporated some basic or fundamental limitation. Due to random selection of CH any node in a cluster can become a CH. This node might have higher energy level or very low energy level. This is not a good thing for perspective of network longevity and function because in case of a node being selected as CH, it has probability of become dead soon and hence it can create instability to existing network topology and also leads to data loss. Another case of it when a node selected as CH but is very far from server destination or sink or base station will be required higher energy for sending same amount of data in comparison to a node which is comparatively near to server destination. Another fundamental limitation with basic LEACH is that cluster head selection is done in every round this also consumes additional energy of each nodes participated in CH selection process. Basic LEACH does not consider selection criterion for choosing only some of valid nodes for CH selection. This also includes inclusion of invalid or wrong node for CH but later during operation phase these CH becomes dead soon and again add to instability of WSN. This basic LEACH protocol has a lot of areas of improvement and also lot of work has been done to insure preserving of energy consumption, improvement of efficiency and effectivity of whole WSN.

There have been a lot of areas where improvement has been done previously. Main focus has been made on improving protocols by improving cluster head selection process in order to reduce energy consumption of nodes, data aggregation of all data received at cluster head, considering different type of mobility of nodes and respective incorporation in works and scalability. Scalability is related to how network with given protocol maintains its efficiency and effectivity when network load increases or number of nodes increased in WSN.

## 2.1 Basic LEACH Protocol [1]

In basic LEACH protocol CH selection process is random and no measurement is taken to include remaining energy of nodes for CH selection for next round. This is important problem and has been taken in to consideration is centralized LEACH protocol also termed as LEACH-C.

## 2.2 Centralized-LEACH Protocol [2],[3]

In LEACH-C all nodes available in WSN keep calculate its remaining energy for each round of CH selection process. Each node sends in remaining energy to base station. Base station receives remaining posers from each node in WSN, then it performs its protocol to select suitable or eligible nodes for CH selection and then perform its actual CH selection using defines rules or protocols. One important thing about LEACH-C is that it also includes location of each node for CH selection process, so that effective nodes placed at better or required places can be considered for CH selection. It gives LEACH-C an edge over existing LEACH that it includes location wise CH selection process for giving better desired results by reducing energy consumed and prolonging network life time. This whole implementation is done with help of GPS sensors at every node which helps in getting real time position information for every node in term of latitude and longitude and send it regularly to base station. But at same time there is a big limitation that is included fundamentally by incorporating GPS sensors with each of nodes. GPS sensor required power for itself from existing battery or energy source of node for its operation. Since energy requirement of operating GPS sensor is quite considerable, LEACH-C has been impacting WSN network life time badly for cases where energy source is limited and need to be used efficiently. Another problem with LEACH-C is that cost associated with it. Incorporating GPS sensor with each of node can be very much costly as there might be very large number to nodes in WSN, ranging from hundreds to thousands to multi-thousands. There for LEACH-C is not energy efficient and well as also not cost effective for most of the real-world scenarios.

## 2.3 Deterministic-LEACH Protocol [4]

Deterministic CH selection LEACH and Improved LEACH has improved existing LEACH protocol by improving basic formula for threshold value calculation. There is another work LEACH with Coverage Preserving CH selection protocol is proposed which all worked for increasing network coverage of WSN. But a fundamental problem with above LEACH Protocols is that they did not fixed the way in which CH selection process will occur. In above proposed protocols CH selection process is completely random which in challenging for maintain network stability and prolonging its life time.

### 2.4 LEACH-H Protocol [5]

In another work done LEACH H, protocol for CH Selection is such that number of nodes selected as CH in each round is fixed. This did not considered amount of energy remaining in cluster heads of previous round and also do not considered number of active nodes in current round. But number of CH is fixed. Due to this kind of CH selection criterion, this protocol suffers with high amount of payload after certain number of rounds. Due to this LEACH H protocol becomes in efficient and also less effective. Also, this protocol cannot be used where very large number of nodes are present because it will become even more in efficient with increasing number of nodes in WSN.

### 2.5 Primitive-LEACH Protocol [6]

There are many LEACH protocols developed and suggested which have focused to consider remaining energy of nodes. And they have changed or updated chances of a node getting selected as CH is make dependent on amount of energy remaining in node. Primitive LEACH protocol suggested CH selection process on cluster in such a way that it did not consider amount of remaining energy in to account while doing CH selection process. Due this there is a great drawback of this process that eve a node which is almost dying as it doesn’t have much energy remining for complete even next round can also to be allowed in CH selection process and can get even selected as CH. Due to above, this node can die any time after being selected as CH or even before it has been selected as CH. This increase a big risk to network stability in WSN.

### 2.6 V-LEACH Protocol [7],[8]

An effort to provide solution to this problem is taken in V-LEACH. In V-LEACH provision is made to provide an extra CH or vice-CH. Work of vice-CH is same as main CH in the cluster once main CH is died due to some reason and not available for service nodes in cluster. This provide solution to sudden lost of CH in cluster. Once main CH died, all node communicate to vice-CH as vice-CH becomes new main CH and all transmission and reception of data between nodes and CH resumes. The selection of This protocol has been effective while addressing problem of previous protocols in case where

CH is died suddenly due to low energy. But there is a big drawback in this problem that it includes lot of overhead in all communication process and also in CH selection process. Due to selection of two CH- main CH and vice-CH, it required more than double signaling related communication to select a CH and to inform to all nodes. This causes lot of in efficiency in WSN communication as overhead for maintain WSN and CH becomes very high in compare to other protocols. Thus, this protocols also got a problematic area which leads to put limitation on its vast usability and applicability. Also, there is no solution given to a problem that what will happen which vice-CH also dies along with or after main CH.

### 2.7 Deterministic Approach_2-LEACH Protocol [9]

LEACH protocol has been area of improvement in various areas over past many years. Target has been to reduce consumption of energy from nodes, CHs and other related network components. In “Low Energy adaptive clustering hierarchy with deterministic CH selection” deterministic approach has been chosen by author instead of stochastic approach for CH selection process. Author has been successful in demonstrating improved result by increasing network life time considerably.

### 2.8 LEACH-B Protocol [10]

In ‘LEACH-B: an improved leach protocol for wireless sensor network” author has presented a way that can improve network life time by controlling number of CH in network. It actually controls the changes in number of CH that happens over different rounds and provides a balancing approach. In this approach, first network completed CH selection of first round and then second set of CHs are selected by network by utilizing information about residual or remaining energy and used to control or change CH count in set-up phase and thus giving optimized count of CH in each round.

### 2.9 Load Balanced-LEACH Protocol [11]

In ‘Load-balanced energy efficient clustering protocol for wireless sensor networks’ author has introduced new approach of dividing WSN network in to different circle. All clusters located at different locations from base station or sink or server destination has different sizes which depends on distance of this cluster from base station. Author has demonstrated considerable amount of improvement in network life time.

### 2.10 Improved V-LEACH Protocol [12]

V LEACH 'Improvement on leach protocol of wireless sensor network VLEACH' is an improvement to previous V-LEACH in which role of vice-CH comes into picture once main CH dies due to some reason. Vice-CH takes role of aggregation of data collected from various nodes in cluster and then compressing them and sending to sink or base station.

### 2.11 EECS Scheme Protocol [13]

Another work 'EECS: an energy efficient clustering scheme in wireless sensor networks' given which is based on approach of balancing load on CH. In this approach CH selection in next round is done while considering residual energy of CH in previous round. This approach gives opportunity of giving chance or higher probability to node that have more residual energy in compare to other node after completion of last round. Due to this node with higher residual energy CH selection balanced out load on eligible nodes which could be CH but having lower residual energy.

### 2.12 IOT-LEACH Protocol [14]

LEACH Protocol is iterative approach which means this protocol creates cluster in each iteration or each round and also select a CH in each round. Due to iterative approach and doing same repetitive rule and process again and again repeatedly, LEACH causes lot of data transmission as overhead. This overhead also contributes to extra energy consumption from nodes and respective CH. In IOT devices where node sensors having limited energy source and energy is critical parameter to take care of, above approach would not be acceptable.

### 2.13 IOT modified-LEACH Protocol [15]

In 'Energy Efficient modified LEACH protocol for IOT application' approach effort is made to utilize information of CH residual energy and consumption amount in last round for selected of CH in next round. They have modified CH selection process as nodes which have already selected as CH in previous rounds and do not have eligibility to become CH in upcoming or next rounds due to load balancing approach, such node still will be eligible for CH selection in case their residual energy is above some threshold energy level. In this approach author has used hard and soft strategies of threshold energy level for CH Selection process.

Above approach has shown improvement in saving energy of nodes in network by balancing load on CH as per amount of residual energy of CH information. However, this approach can still be improved by improving given formula for threshold value by adding a factor of energy consumption ratio of CH in previous round.

### 2.14 Uniform Energy Consumption in Non-Deterministic WSN [17]

Here author made effort in addressing problem of isolated nodes in WSN. Isolated nodes which don't have any contact with any other single node in network tends to send its sensed data directly to server destination or base station. This causes enormous amount of energy consumption. Here author has provided a solution by including residual energy to distance ratio. Where distance is taken for each node from its location to center of WSN.

### 2.15 Energy Balanced Clustering Algorithm [18],[24]

Here author again made effort in addressing problem remaining energy of sensor nodes in WSN and proposed a modified cluster head selection algorithm based on cluster head selection formula which includes residual energy ratio of each sensor node. Residual energy ratio has been calculated by calculating energy ratio of current energy and initial energy for every node. Author also take distance factor into consideration of calculating threshold value for each node for cluster head selection. Where distance is calculated for each node from its location to base station.

### 2.16 Research on Improved LEACH Protocol of WSN [19],[20],[22],[23]

Here author pointed out some fundamental problems with basic LEACH protocol. First problem addressed about random selection of cluster head in LEACH due to which a node which has lesser remaining energy and another node having comparatively higher energy level may have equal chances of being selected as cluster head. Second problem that is pointed out is about random distribution of number of sensor node for each cluster head. Few cluster head may be position at center of cluster while few might be available at edge of cluster. This can also increase in enormous energy consumption in network and impact network life time badly. Third problem that is addressed by author is about direct communication between all cluster heads with server destination or base station. Author has proposed solutions for above problems by introducing two factors say first energy impact factor which is ratio of remaining energy of a cluster to remaining energy of individual node in respective cluster and second distance impact factor which is ratio of distance of cluster head from base station to distance of individual node in respective cluster from base station.

## 2.17 Energy Efficient Improved LEACH Protocol for WSN [21],[25]

In this work author again discussed fundamental problems with basic LEACH protocol and proposed solution for it by introducing highest ratio of residual energy of nodes to distance of nodes and base station. Here author has taken threshold distance value by calculating mean of distance of all sensor nodes from base station. Author has shown that this new approach of cluster head selection protocol can be helpful in reducing energy consumption considerably and also enhancing network life time.

# CHAPTER 3: PROBLEM STATEMENT

IOT applications with mobile sensors need much robust networking mechanism for data sharing and data transmission. Many challenges faced while implementing LEACH protocol of WSN for IOT based application.

In LEACH their major area of attention for successful implementation of this mechanism are Energy efficiency, Scalability and Prolonging network life time. Energy consumption is caused by three activities: sensing, data processing, and communications. Communication energy constitutes the major part of the consumed energy in the wireless device, whereas energy optimization focuses on the radio module operating modes. The communication energy is defined as the sum of the data transmission energy (i.e., transceiver energy) and the data processing energy.

IoT should operate with optimal energy to increase the lifetime of the sensor nodes, simultaneously ensuring network connectivity and availability. Because of the scarcity of energy in IoT, energy optimization is needed to minimize the energy consumed by the sensor nodes to prolong network lifetime. Thus, energy efficiency must be considered in every aspect of network design and operation, for both operation of the individual sensor nodes and communication of the overall network. During CH selection in next round remaining energy and remaining energy ratio are important paraments that can be utilized in even better way to achieve goal.

Since sensor nodes are always mobile so there is always chance of some node discarded from network or some node adding to network. Number of nodes in Clusters may also be changing all the time. Therefore, network scalability is important factor that need to be put under consideration while implementation.

For CH located at far location from base station or server destination, energy consumption is exponentially high. There these CH may drain out all of their energy very soon and may become dead. Thus, creating a serious situation to network stability, again network life time and data loss.

# CHAPTER 4: SCOPE OF THE THISIS

This research will study and analyze the effectiveness of low-energy adaptive clustering hierarchy (LEACH) and LEACH-based protocols in extending the network lifetime for MANET. Analysis will be done for applying suitable LEACH protocol for MANET in WSN consisting of energy-constrained mobile sensors constituting IoT based application taking example of Military search operation scenario. This research will propose improved LEACH protocol for IOT based application to get better results and increased life time for nodes in WSN and hence increased network life time.

For improving existing LEACH protocol by improving method of Cluster Head selection, an improved mechanism or methodology is proposed which will consider residual energy rate or remaining energy ratio of each sensor in WSN in very specific way. This new CH selection mechanism will help in increasing individual node's life and hence network time.

Addressing problem of high energy consumption by Cluster Heads while transmitting aggregated data to base station, a multi-hop communication model is studied and integrated in the proposed work of improvement in WSN for IOT application by implementing two operating processes of leveling of Clusters and Cluster Heads and then implementation of generic multi-hop routing phase for transmission of cluster members data to base station or server destination via multiple relay through multiple Cluster Heads. An improved LEACH clustering protocol called enhanced multi-hop LEACH is proposed to reduce and balance energy consumption in order to allow increased packet delivery and network lifetime in IoT.

# CHAPTER 5: LITERATURE REVIEW

## 5.1 LEACH: IMPLEMENTATION SYSTEM MODEL [15]

Fundamental LEACH protocol for WSN with large number of nodes distributed over an is a clustering-based technique which uses hierarchical network topology by dividing nodes in WSN to clusters and then selection of CH. It also uses TMDA (Time Division Multiple Access) based MAC protocol which distributes time slots to all nodes or sensors in network for communication with CH. All nodes in a cluster transmits their data to CH in respective given time slot. After data aggregation of all data received, CH send it to sink or base station or destination server as all nodes in cluster cannot communicate with base station or sink normally and they have to follow hierarchy and only CH can transmit node date to base station or sink.

LEACH protocol is iterative model which do its operation in multiple rounds. In LEACH, each round can be categorized in two phases mainly- Initial Setup phase and Steady State Phase.

### 5.1.1 LEACH: INITIAL SETUP PHASE

In Initial setup phase in LEACH, all nodes broadcast to neighbor nodes about its few specific information and participate in CH selection process. Each node generates some random value or priority value for itself and broadcast to all nodes. Basically, this generated value is between 0 and 1. Node also send its basic information like node ID, location, energy etc. After receiving information from neighboring nodes, if number generated by node is less than a threshold value T(n) then node becomes eligible for being selected as CH else it becomes in-eligible. After nodes being selected as CH, they send advertisement packet to all neighboring nodes that they have been selected as CH and with for message from nodes for request to join a particular CH. All nodes which have not been selected as CH wait for message from any selected CH for advertisement packet. After receiving advertisement packet from selected CH, they send request. This way neighboring node join CH and by getting acknowledgement from CH. CH check for all nodes that are connected to it and generate and send TDMA schedule for sleep and awake procedure for all member nodes and inform to all member nodes. All member node receives information about their TDMA sleep and awake schedule and accordingly communicate to CH in their respective time slot.

Threshold value for CH selection given in equation below

$$T(n) = \frac{1}{\{1 - \rho(r \bmod \left(\frac{1}{\rho}\right)\}} \qquad \forall\ n \in G$$

$$T(n) = 0 \qquad \text{otherwise} \qquad \text{Eq (1)}$$

In above equation r is round number, ρ is the desired percentage of CHs in WSN. G is a set of all nodes that have not been selected as CH in last 1/ ρ rounds because as per given LEACH if a node is selected as CH in previous round then it is not allowed to be selected as CH again for next 1/ ρ rounds. This is way to ensure that each node in WSN get equal opportunity for being selected as CH and also it helps in sharing CH selection load on whole network and not on few particular nodes.

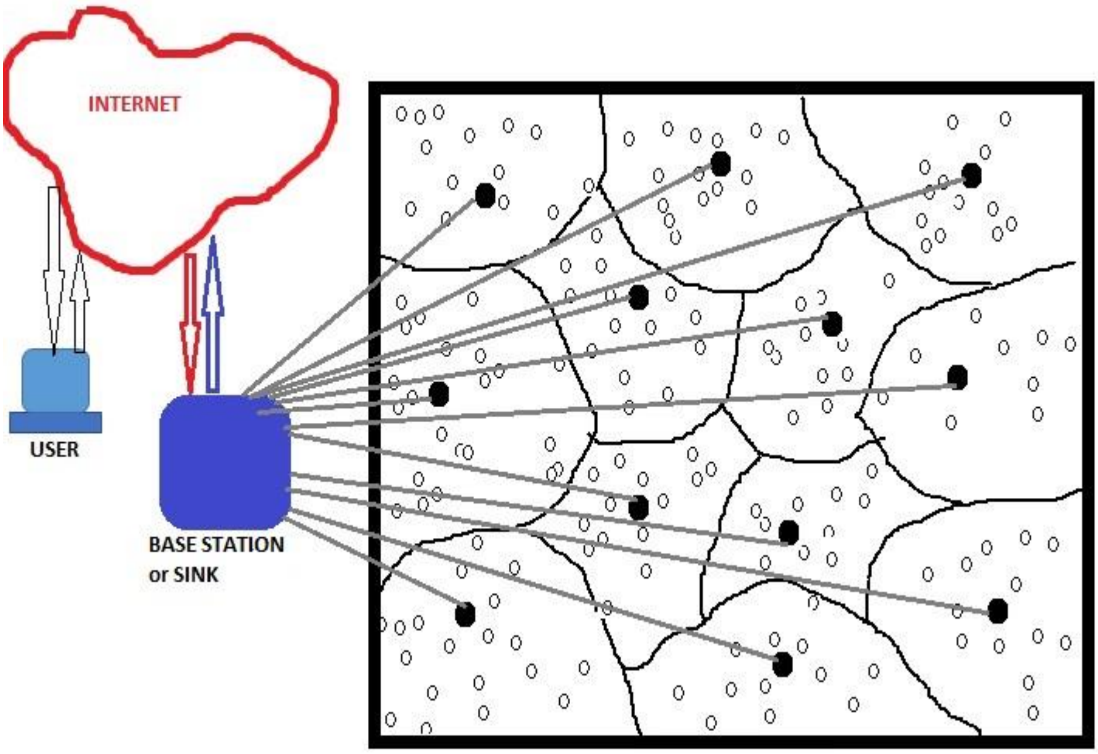


*Figure (2): Existing LEACH System- Cluster Head, Member Nodes and Base Station*

### 5.1.2 LEACH: STEADY STATE PHASE

In steady state phase nodes communicate with CH as per TDMA time slot schedule they have found from CH. During assigned TDMA time slot a node member transmit data to cluster head while rest on node members in same cluster sleeps and wait for their respective time slot. In this way energy of remaining nodes which are not transmitting data to CH can be saved from being dissipating unnecessarily as they are in sleep mode. This mechanism also help is avoiding collision or interference between transmission on two or multiple nodes in a particular cluster.

### 5.1.3 FIRST-ORDER RADIO ENERGY MODEL [15]

First order radio energy model has been used for implementation of many of proposed protocols. It considered distance between two node which are participating in communication to each other in WSN. In order to implement First order radio energy model for purpose of LEACH protocol it is divided in to free space model and multi path fading model which will make use of distance between transmitting and receiving nodes. There are many assumptions taken to realization of model including communication medium to be symmetrical.

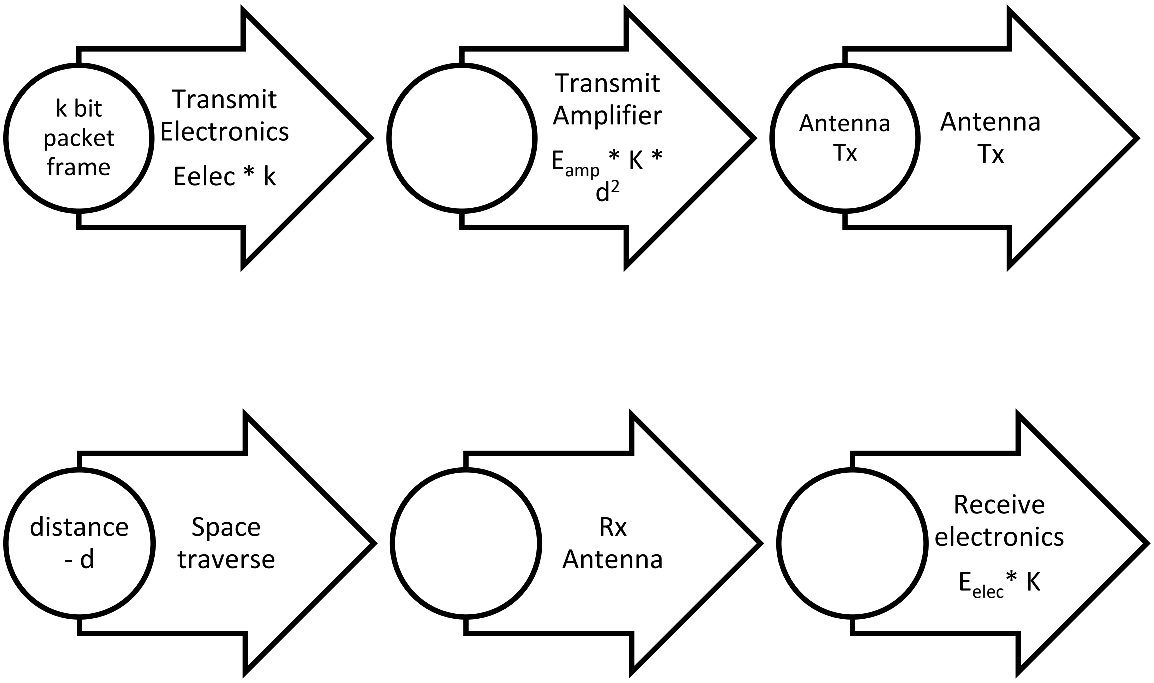


*Figure (3): First Order Radio Energy Model*

Let's take sensor node of IOT takes n bit packet frame structure for sending and receiving data to and from other nodes. Energy requirement or Energy consumption by one sensor node in sending such one frame i.e. k bits per packet information to a receiving node which is d distance away from sending node is represented by E Tx (k, d) then

$$ETx(k, d) = [ETx_{elec}(k)] + [ETx_{amp}(k, d)] \qquad \text{Eq (2)}$$

$$ETx\ (k, d) = [E_{elec}\ .\ k] + [E_{fs}\ .\ k\ .\ d^2],\ \ d \leq d0 \qquad \text{Eq (3)}$$

$$ETx\ (k, d) = [E_{elec}\ .\ k] + [E_{amp}\ .\ k\ .\ d^4],\ \ d > d0 \qquad \text{Eq (4)}$$

In the same way Energy requirement or consumption for a receiving sensor or node in receiving such one frame of say packet i.e. k bits per packet information ERx (k)

$$ERx\ (k) = ERx\_elec\ (k) + k\ .\ Eelec \qquad \text{Eq (5)}$$

$E_{elec}$ = Energy consumption for transmission or reception of one bit by a transmitter or a receiver

$E_{amp}$ = Amplifier parameter corresponding to transmission to a multi-path fading model

$E_{fs}$ = Amplifier parameter corresponding to transmission to a free-space model

For every transmission of packet from one sensor node to another there is always a packet contains information bits and signaling bits. Information bits corresponds to actual bits that transmitting sensor node intended to send to receiving sensor node. Signaling bits corresponds to information related to packet that is being send. This signaling information constitute to naming factors of overhead in communicated data. Due to this reason it is preferable if packet size for communication between nodes are kept as large as possible. This will cause a greater number of information bits in a packet comparative to almost same number of signaling bits. This will increase efficiency of information being sent per packet. This can be better understood by following equations. Let's take

$$E_{Packet} = N_{data}\ E_{data} + N_{overhead}\ O_{verhead} \qquad \text{Eq (6)}$$

$E_{Packet}$ = Energy required for transmission on one complete packet

$N_{data}$ = Number of information or data bits in one packet

$E_{data}$ = Energy required for transmission of data information in one packet

$N_{overhead}$ = Number of signaling or overhead bits in one packet

$E_{overhead}$ = Energy required for transmission of overhead information in one packet

Efficiency of data part being transmitted can be given by

$$\eta = \frac{(Ndata . Edata)}{EPacket} . 100 \qquad \text{Eq (7)}$$

IOT-LEACH allows a cluster head CH to remain as CH for next round too if it retains residual energy above threshold level even after completion of current round. In this way it reduces number of CH selections in WSN and hence it reduces energy requirement for CH selection and maintenance of WSN per round. In WSN with LEACH protocol where CH based hierarchy is maintained and controlled, all try to node sensor can be divided in to three categories

Intra Cluster node transmission and reception. this category of communication exists between sensor nodes and CH. Inter Cluster node transmission and reception. This is communication when CH transmits and receives data from CH of some other cluster. Long haul transmission is category of communication when a cluster head CH transmit data directly to base station of sink which might exist far away from CH.

All above three categories of communication required different amount of energy. For example, intra cluster communication will generally take lesser amount of energy to take place in comparison to inter cluster communication as generally in-side a cluster all sensor nodes are already connected and controlled by CH also distance between sensor nodes and CH is generally lesser. While inter cluster communication involves communication between two CHs. These CHs may be places at comparatively distant places therefore need for energy for such communication will be higher. Similarly, long haul communication takes much more energy generally in comparison to inter cluster communication. Therefore, requirement of energy is different for different kind of communication. In IOT-LEACH author has given an approach in which level of energy amplification is set according to kind of communication is required. For intra clustered communication, low energy level would be enough for communication while for Long haul communication, CH must be assigning to dissipate or transmit with high energy amplification level. If during a round a sensor node is assigned in role of member node then it may assign low energy level by algorithm and it can complete its communication activities with low energy amplification level. Suppose in next round same node become CH then as per algorithm a higher energy amplification level will be assigned to it for completing its all communications.

However, lest consider another possibility as per previous proposed LEACH algorithms as per which if after completion of current round any CH retains energy level higher to some given threshold energy level then it may be eligible for being CH for same cluster for next round. In this situation with IOT-LEACH that a node which will be assigned and selected in role of CH for consecutive rounds will be assigned to higher energy amplification level for longer time duration and all communication will be take place accordingly. This helps in getting energy dissipation from CH which have higher energy level rather than assigning CH to a node with comparatively lower energy level.

In each round completion and next round start there would be changes in cluster formation and respective CH selection.

Let this energy required for every round represented by $E_R$

Let n is number of nodes in each cluster

Let C is percentage of CH in WSN

R is count for replacement of CH. Then,

$$N = n \cdot C \qquad \text{Eq (8)}$$

$$E_R = P_kT_x \cdot E_{Tx} + P_kR_x \cdot E_{Rx} \, (n \cdot C - 1) \cdot R \cdot N \qquad \text{Eq (9)}$$

$P_kT_x$ = Transmitted packet size

$P_kR_x$ = Received packet size

$E_{Tx}$ = Energy required for transmission of packet size of one byte

$E_{Rx}$ = Energy required for reception of packet size of one byte

If we calculate total initial energy of every cluster. Then it can be calculated simply by multiplying number of nodes in cluster with initial energy level assigned to each node. Therefore Total energy of a cluster (Ec ) can be given by a formula

$$Ec = E_{Init} \cdot N = E_{Init} \cdot n \cdot C \qquad \text{Eq (10)}$$

In order to calculate energy consumed by all clusters in changing CH after each round, we need to calculate energy consumed in each (jth) cluster in changing CH in next round in WSN. Total energy consumed. Total energy given in each cluster (jth) in every round can be calculated by calculating energy consumed in each cluster's energy when it acts as cluster's node member and when it acts as CH

$$E_R(j) = [(N_j - 1)P_kT_x.E_{Tx}.P_kR_x.E_{Rx}] + [(N_j - 1)P_kT_x.E_{Tx} + (N_j - 1)P_kR_x.E_{Rx}] \quad \text{Eq (11)}$$

Therefore, we deduce as

$$ER\ (j) = n.\ (5N_j - 3).\ E_{Tx} \quad \text{Eq (12)}$$

Amount of energy required to transmit data from node to CH

$$E_n = n\ .\ E_{Tx} \quad \text{Eq (13)}$$

This energy consumption is done for TDMA slot only for which a member node is allowed to transmit data. For rest of period member node is maintained at sleep mode and no energy dissipation takes place. During this time period over which member nodes remain at sleep mode, CH may be bust in data aggregation for all data received from different member nodes.

Energy consumed in data aggregation can be given by

$$E_a = n\ .\ (N -1)\ .\ E_{Rx} \quad \text{Eq (14)}$$

Energy consumed by CH to send aggregated data to base station or sink or destination server

$$E_b = n\ .\ (N -1)\ .\ E_{Tx} \quad \text{Eq (15)}$$

For taking decision on CH replacement, we need to calculate number of rounds for which a node member has been active. This will be required for calculating threshold value so that CH would be replaced or not.

Number of Round R

$$R = \frac{E_R}{Ec}\ .\ 100 \quad \text{Eq (16)}$$

From last two equations we can deduce

$P_{Th} = R * ( P_k T_x + P_k R_x) * E_{Tx}$ Eq (17)

## 5.2 ROUND TIME COMPUTING

Another area of focus has been increasing network life time by many other various ways. One way of increasing network life time is do some improvement in protocols or in way of doing next round for CH selection process. It has been done by optimizing round time after which next CH selection process will be initiated.

## 5.3 MULTI-HOP COMMUNICATION [16]

Another way of prolonging network life time is to introduce Multi-Hop communication for transmitting and receiving data between CH and server destination or base station or sink. In Multi-hop communication, cluster head which is probably far away from base station or server destination do not send data directly to base station or server destination because it will consume much larger energy for sending data. This situation is very often in real WSN because network coverage area of WSN is always much larger that radio transmission and reception power of individual sensor node. Base station or sink is always located at much more distant comparatively. In multi-hop communication model, a node or CH uses multiple intermediate node as a relay for transmitting aggregated data to base station or server destination.

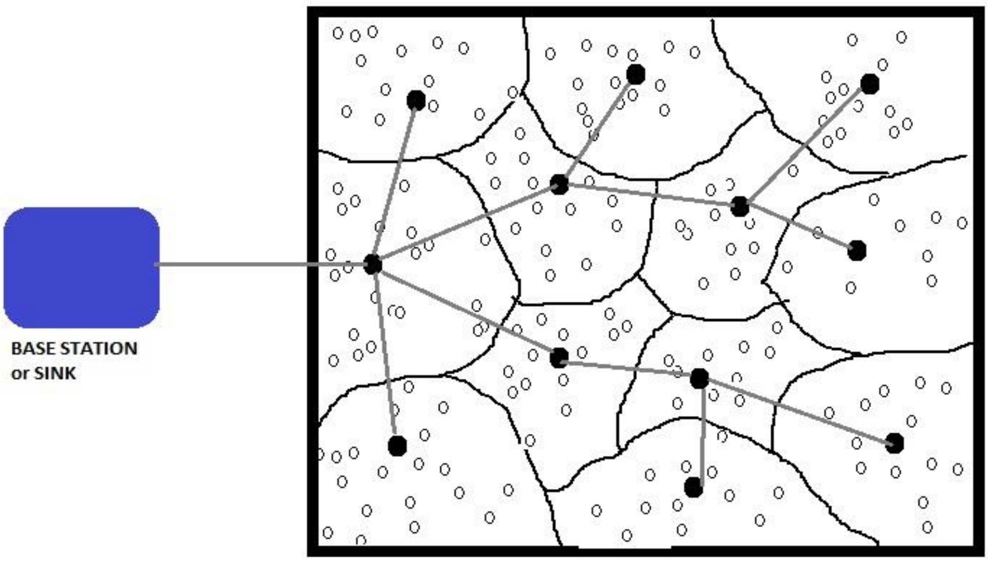


*Figure (4): Multi-Hop Mechanism in WSN*

Radio transmission and reception is major factor of energy consumption is WSN. Various protocols are developed for power saving by finding suitable medium and utilizing optimized routing process. In each Multi-Hop communication models two major reason for energy consumption are radio network strength path loss while communication done by transmitting and receiving of data between two nodes and second factor is power consumption done by node when they are operating in different modes. For establishing successful channel between transmitting node and receiving node, it is mandatory that transmitting signal strength of transmitter node is greater or equal to receiving node's threshold signal strength. When transmitter node transmits data with initial signal strength, while traversing over space, this signal strength reduces with distance it traverses. This loss in signal strength is called path loss. Another problem in signal traversing in real life is number of random obstacles faced by traversing signal, due to which same signal is reached to same destination node following different path and with different traverse times. This causes reception of same signal repetitively but at different phase difference. This is called multi path fading is Wireless Communication. Overall actual real-life scenario which actually happens in communication between transmitting and receiving nodes are very complex due to inclusion of large number of impacting factors. If we minimize all minor impacting factors by assumption of ideal environment and focus on major impacting factors. One most impacting factor that reduce signal strength over space with traversing is distance between transmitter and receiver node. If we assume free path with no obstacle in space between transmitter and receiver, then path loss is proportional to square of distance between transmitter and received.

$$\text{Path Loss PL} \propto d^2 \qquad \text{Eq (18)}$$

$$\text{Received Signal Power (Prx)} \propto \left(\frac{1}{d}\right)^2 \qquad \text{Eq (19)}$$

If consideration is made for multi path fading and other factors then path loss then square factor may be changed to some real factor say "a" then revised path loss and received signal power can be written as

$$\text{Path Loss (PL)} \propto d^a \qquad \text{Eq (20)}$$

$$\text{Received Signal Power (Prx)} \propto \left(\frac{1}{d}\right)^a \qquad \text{Eq (21)}$$

$$\text{Received Signal Power (Prx)} = \text{Po}\left(\frac{do}{d}\right)^{a} \qquad \text{Eq (22)}$$

Where PL is Path loss, Prx is received Signal Power, d, do are distances, Po is received signal strength at distance do.

Above model of radio transmission has basic assumption that all power that is to be transmitted by transmitter is transmitted and there is no power loss at transmitter end while transmitting signal. Similarly, assumption is all receiving power at receiving end is received successfully without any power loss at receiver while receiving. Power loss occurring only in space while traversing from transmitter to receiver.

Below figures are showing transmission of Signal from transmitter to receiver with example of single hop and multi-hop.

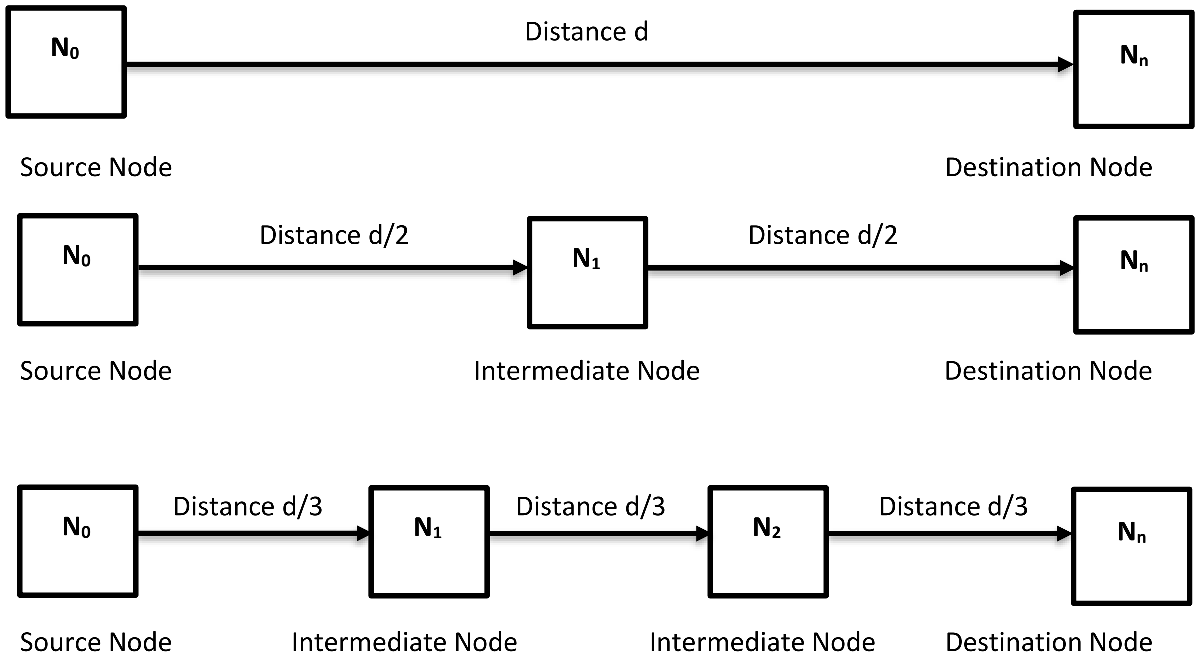


*Figure (5): Signal Transmission in Single-Hop and Multi-Hop Communication*

If we take power transmitted at transmitter end as Po, then in case of single hop with received power sensitivity threshold Pt at receiver node and required power at transmitter node just to get sensed by receiver P1 then they can be written as

$$\mathrm{Pt} = \mathrm{P1}.\left(\frac{do}{d}\right)^{a} \quad \text{Eq (23)}$$

In-case of double-hop with required power at transmitter node just to get sensed by receiver P2, same can be formulate as

$$\mathrm{Pt} = \mathrm{P2}.\left(\frac{do}{d/2}\right)^{a} \quad \text{Eq (24)}$$

For triple-hop can be written as

$$\mathrm{Pt} = \mathrm{P3}.\left(\frac{do}{d/3}\right)^{a} \quad \text{Eq (25)}$$

For n-hop communication it can be generalize as

$$\mathrm{Pt} = \mathrm{Pn}.\left(\frac{do}{d/n}\right)^{a} \quad \text{Eq (26)}$$

Equalizing all above equation, we can get relation between P1, P2, P3…Pn as

$$P_1 = P_2.2^{a} = P_3.3^{a} = P_4.4^{a} \ldots = P_n.\, n^{a} \quad \text{Eq (27)}$$

Now transmitter power consumed for single-hop, double-hop, triple-hop and n-hop communication can be written as

$$P_{1H} = P_1 \quad \text{Eq (28)}$$

$$P_{2H} = P_2 + P_2 = 2.\,(P_1.2^{-a}) = P_1.\, 2^{-(a-1)} \quad \text{Eq (29)}$$

$$P_{3H} = P_3 + P_3 + P_3 = 3.\,(P_1.\, 3^{-a}) = P_1.\, 3^{-(a-1)} \quad \text{Eq (30)}$$

Similarly,

$$P_{nH} = P_n + P_n \ldots + P_n = P_1.\, n^{-(a-1)} \quad \text{Eq (31)}$$

This equation proves for all number of multi-hop communication, path loss for it will be always lesser that single hop communication. So far, we have been assuming that receive is ideal and do not consume any power from it side while reception of signal. In case if real environment scenario, let's take power loss by receiver with receiving signal is $P_R$. then we can update above equations as

$$P_{1H} = P_1 + P_R \quad \text{Eq (32)}$$

$P_{2H}$ = 2. [P1. $2^{-a}$ + $P_R$] Eq (33)

$P_{3H}$ = 3. [P1. $3^{-a}$ + $P_R$] Eq (34)

$P_{nH}$ = n. [P1. $n^{-a}$ + $P_R$] Eq (35)

This put condition on multi-hop communication's effectivity by condition

$$P_R < \frac{(n^{a-1} - 1).\ P1}{(n-1).\ n^{a-1}} \quad \text{Eq (36)}$$

Above equation is also termed as necessary condition for effectivity of multi-hop communication.

# CHAPTER 6: PROPOSED WORK

## 6.1 CLUSTER HEAD SELECTION: REVISED FORMULA

In all above LEACH protocol discussed has included remaining energy of CH of current round under consideration for CH selection eligibility criterion for next round. Consider a situation where a CH has dissipated lot of its energy during operations and transmission of role of CH but it has still left sufficient amount on residual energy so that it can qualify criterion on CH selection for next round. After being reelected as CH in next round this sensor node will act fine for next round too if it has enough energy for completing next round. This is the case when residual energy in CH is quite larger than dissipation energy. Consider a case when energy consumption in current round is very high so that it amounts more than threshold limit of residual energy being required by CH to be selected as CH for next round as well. In this case sensor node might selected as CH for next round too but soon enough it will consume all of its residual energy and become dead. This proposed work addresses this problem by considering an important factor energy dissipation ratio or remaining energy ratio (β).

Modified formula for threshold value for CH selection-

$$T(n) = \frac{1}{2}\left[\frac{\beta}{\{1-\rho(r \text{ mode}\left(\frac{1}{\rho}\right)\}} + (1-\beta)\frac{E_{residual}}{E_{initial}}\right] \quad \forall\ n \in G$$

$$T(n) = 0 \quad \text{otherwise} \qquad \text{Eq (37)}$$

Where $\beta = E_{residual} / E_{initial}$. Where $E_{residual}$ & $E_{initial}$ are residual and initial energy level of sensor nodes.

ρ = percentage of required CH in WSN

r = current round number

G = Set of nodes that have not been CH for last 1/ ρ rounds

β is the weight attributed to the percentage ρ.

At initial round of first round no need to check about residual energy of nodes in WSN as all nodes are set to initial or generally full energy level. There for first round of CH selection, value of β is set to 1. Therefore, modified formula will work as basic leach for first round. For next upcoming rounds, the with round number increases, value of r increases and value of β decreases. Consequently, value of 1 − β increases. One factor β decreases with increasing rounds while at the same time other factor 1 − β increases concurrently which balances the weight between the percentage and residual energy needed to select cluster-heads.

As first part of proposed solution, new equation is given. This equation for threshold value is constituted by the sum of two terms. These 2 terms include the percentage of CH required (ρ) with coefficient β and the remaining energy ratio ($E_{residual}$ & $E_{initial}$) with different coefficient 1 – β. At time of first round of CH selection, initial value of β is 1, Due to this other factor 1- β becomes 0 therefore CHs selected based only on the first term i.e. percentage of CH required (ρ). During first round our proposed solution of formula for threshold value for CH selection works in same way as previous or basic LEACH. In further round if CH selection, value of β deceases from 1 and value of second term in the proposed equation for remaining energy ratio ($E_{residual}$ & $E_{initial}$) with different coefficient 1 – β comes in to picture. Hence both terms contribute to select the suitable CHs in the network. As more round followed β decreases & (1 – β) increases, making the percentage of CH required (ρ) and the remaining energy ratio ($E_{residual}$ & $E_{initial}$) inversely proportional values for CH selection. Ultimately when number of rounds reached to very large value the residual energy ratio ($E_{residual}$ & $E_{initial}$) included in the second term becomes the most deciding factor for CH selection.

There could be another way where value of β can be changed dynamically from initial value 1 to final value 0 at end of the network lifetime. During the end of network lifetime, the residual energy and hence residual energy ratio ($E_{residual}$ & $E_{initial}$) decreases to 0 from initial. In other words, we can say that β i.e. ($E_{residual}$ & $E_{initial}$) becomes a parameter that is derived from the network condition itself.

In the setup phase, two steps follow the CH selection: cluster formation and schedule creation. At the time of formation of cluster in WSN, all selected CHs send advertisement packet to all neighboring nodes. CH utilizes their maximum power for advertisement and uses CSMA technique. After receiving advertisement packets from various CHs, other nodes best suitable CH or may be closest CH on the basis of RSS received in the advertisement packets. After that node send request to join CH. The CH accepts node's request and send acknowledge to all connected member nodes. At this time CH also decided TDMA based timeslots for each connect member node and informed to member nodes. After setup phase completed, next phase is steady-state phase. In this stage each member node uses assigned time slot for transmits data and during other time they entered in to sleep mode and reduces energy consumption. During this time CH aggregates the data received from other member nodes and sends it to base station or sink or destination server.

## 6.2 DATA AGGREGATION

During data Aggregation phase, cluster head collects data from all nodes and aggregate it. Cluster head normally needs lot of energy to get its job done as managing data received from all member nodes and working out during most of the time slot required much energy. This required a lot of energy in comparison to a normal member node. Secondly Cluster Head additionally have to transmit aggregated data to other Cluster Head of base Station or sink. This task again required a lot of energy to get it complete. This causes too much of burden on cluster head's energy source. There becomes a chance that due to drainage of energy of CH, it become lost and lot of data from member nodes in WSN is lost. To prevent this situation of depleting the Cluster Head residual energies and to prevent losing more data, Enhanced Multi-hop LEACH provide a solution by adapting the round time according to the residual energy remaining in the entire network. To evaluate remaining energy in network there is actually no over-head on network component or no extra task has to be performed by network components. Reason is that remaining energy for each member node or cluster head in network is normally included and informed by the sensor node in the data packets and transmitted to cluster head and finally to base station or sink. And for transmitting this information to base station or sink, member node so not consume any extra packet to transmit this data. This information collected at base station can be utilized to calculate round time at run time based on real time situation and in this way adaptive round time-based approach which is based on total residual energy on all components or members nodes, Cluster Heads etc. leads to fair distribution of energy consumption among all nodes.

$$\text{Round Length} = \text{Initial Round Length}.\left(1 - \frac{1 - \text{Energy Rate}}{\alpha + \text{Energy rate}}\right) \qquad \text{Eq. (37)}$$

Above equation for round length calculation which is based on energy rate of all nodes in network.

We used default values for the initial round length and the energy rate of all nodes. During initial rounds, initial round length is fixed to 1.5 times higher than normal LEACH round time. As round increases in network, residual or remaining energy of entire network is also reducing and consequently round length is also reducing gradually. At final stages round length decreases to 0.5 times on LEACH round time. This is the case when remaining e or residual energy in network is at lowest level and respectively round length is also get reduced to shortest level. Base of works and experiments that has been done previously for this equation for energy rate base round length, best results were obtained for α value equal to 1.5. Above formula is a hyperbolic equation and the value of α is estimated to decrease round time length at run time dynamically as residual energy.

### 6.3 LEVELING PHASE

In LEACH normal way to send aggregated data to base station or sink is to send it directly to base station or sink by cluster head but this mechanism of transmitting aggregated data to base station or sink directly by CH require a high-power energy data transmission and consequently it consumes a lot of energy of node or CH for transmitting data. Another mechanism to avoid this enormous energy consumption by reducing high-power energy data transmission to a comparatively low-power energy data transmission. But with low power transmission distance through which data can be transmitted successfully and error free will also be reduced. This can be compensated by multi-hop transmission where aggregated data is transmitted to base station or sink via several intermediate nodes or CHs. During setup phase base station or sink broadcast a setup packet to all nodes in network and also assigns a level number with broadcast setup packet with initial level 0 from base station or sink. When this setup packet is received by any node, its level number is incremented and thus a receiving node is updated with its level number. After that node again broadcast same packet for other nodes in network. Consequently, next receiving node which received this setup packet will get higher level in the network. This way this setup packet is traversed across the network and each next receiving node increments its level number and according level number is assigned to all receiving nodes in the network. For large networks where number of nodes are very large, this setup packet will take a greater number of traverses to cover all nodes and consequently finally a higher-level number will be assigned to last nodes. Therefore, number of levels in larger network will be higher.

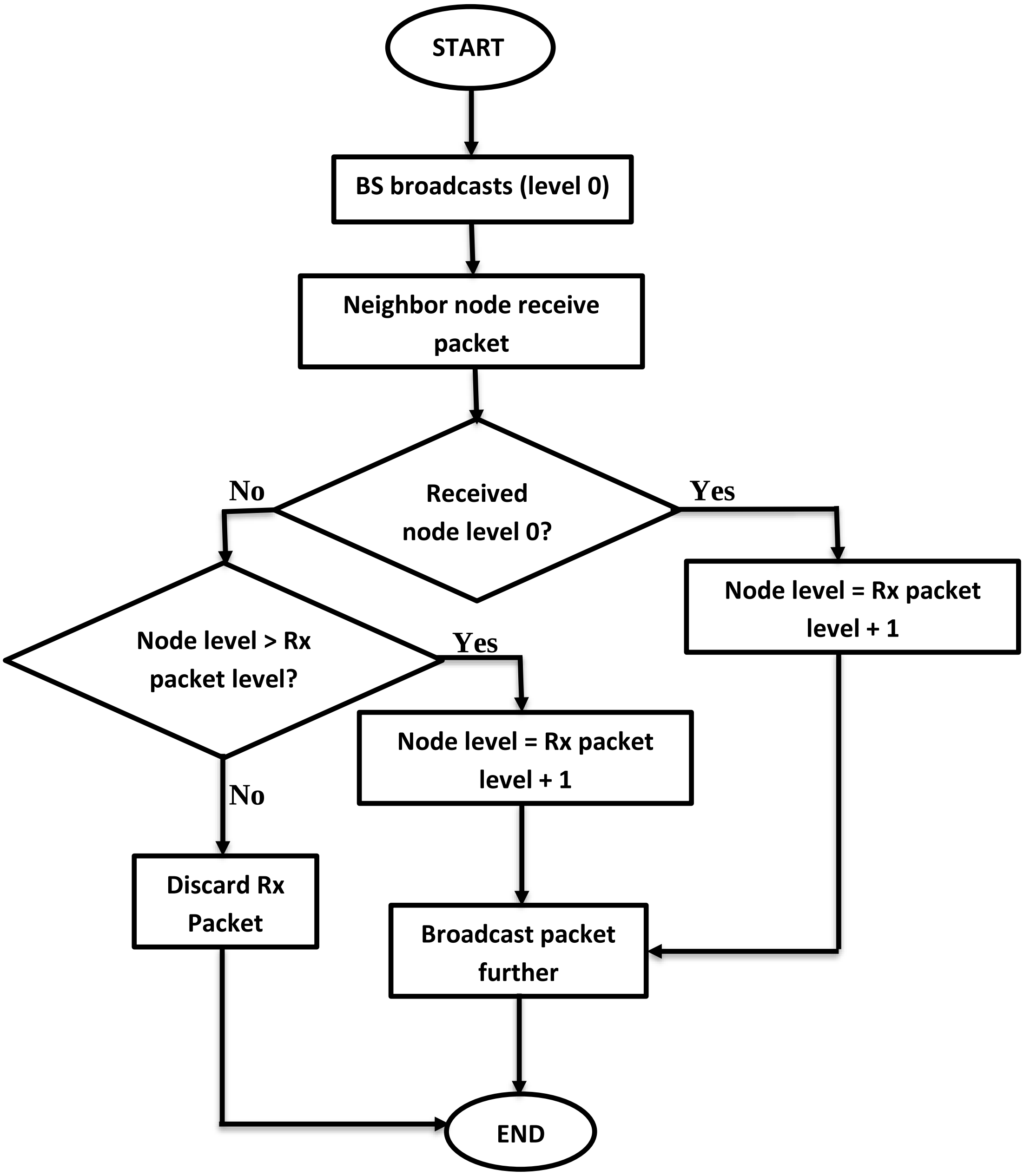


*Figure (6): Leveling Phase in of Nodes in LEACH*

Overall purpose of leveling process is to assign some level number to each node in network or in other words align all node hierarchically from lower level nodes at base station or sink towards higher level at far locations. This can be like a tree structure of establishment of connected network nodes. This helps considerably for transmitting aggerated data to base station or sink in multi-hop clustering.

## 6.4 MULTI-HOP ROUTING PHASE

In multi-hop routing phase, all members nodes in a cluster sends data to respective CH with level number N. CH aggregates data received and send data to another CH with lower level number (N-1) or lower. This way lower level CH received data from its connected higher-level CHs and after aggregating data received from various higher-level CHs, a lower level CH send this data to next lower level CH connected to it. Over all this mechanism of transmitting data from higher level CHs to lower level CH continues till finally CH at level 1 received all aggregated data. After this CH at level 1 send all data to base station or sink.

During Setup phase for selection of CH, all members nodes transmit or broadcast for advertisement packet with maximum power for transmission using CSMA technique. All members nodes choose CH with in same level and having maximum signal strength as per advertisement packet. Thus, at every level, CH formation is occurred using equation (2). If at any level any CH advertisement packet not received from same level then node will search for CH advertisement packet from next level (N). Once found advertisement packet from next level (N) and connected to it, member node also changes it level number to N. in worst case when any CH advertisement is not received to a node then in this case node will send its data directly to base station or sink.

In cluster formation step, synchronously setup formation of multi-hop organization occurs. This is done to save time and network energy as in both processes it takes similar information by nodes or CHs to select CH with in same level and CH at next level. In this setup every CH sent or broadcast its advertisement packet using full transmission power. CH at other level which can sense this advertisement tries to choose its closest CH. It checks for suitable CH by checking it this advertisement packet is received from a lower level CH or not, what is signal strength of CH which has broad cast advertisement packet. In worst case if no advertisement packet received to a CH from any of next level CH, then this CH can send or transmit it data directly to base station or sink. This also helps in case when any at next level CH or node got dead or node failure occurred due to some other reason like mobility or loss in signal strength, then transmitting CH can send it data directly to base station or sink rather than being fully dependent on next level CH connection. This mechanism helps to WSN to be prepared dynamically with any event of any node failure.

Cluster formation step and multi-hop formation setup takes place at same time. Like both processes are executed periodically at next round of LEACH so that any changes in WSN members node condition can be considered and next stable organization can be re-formed.

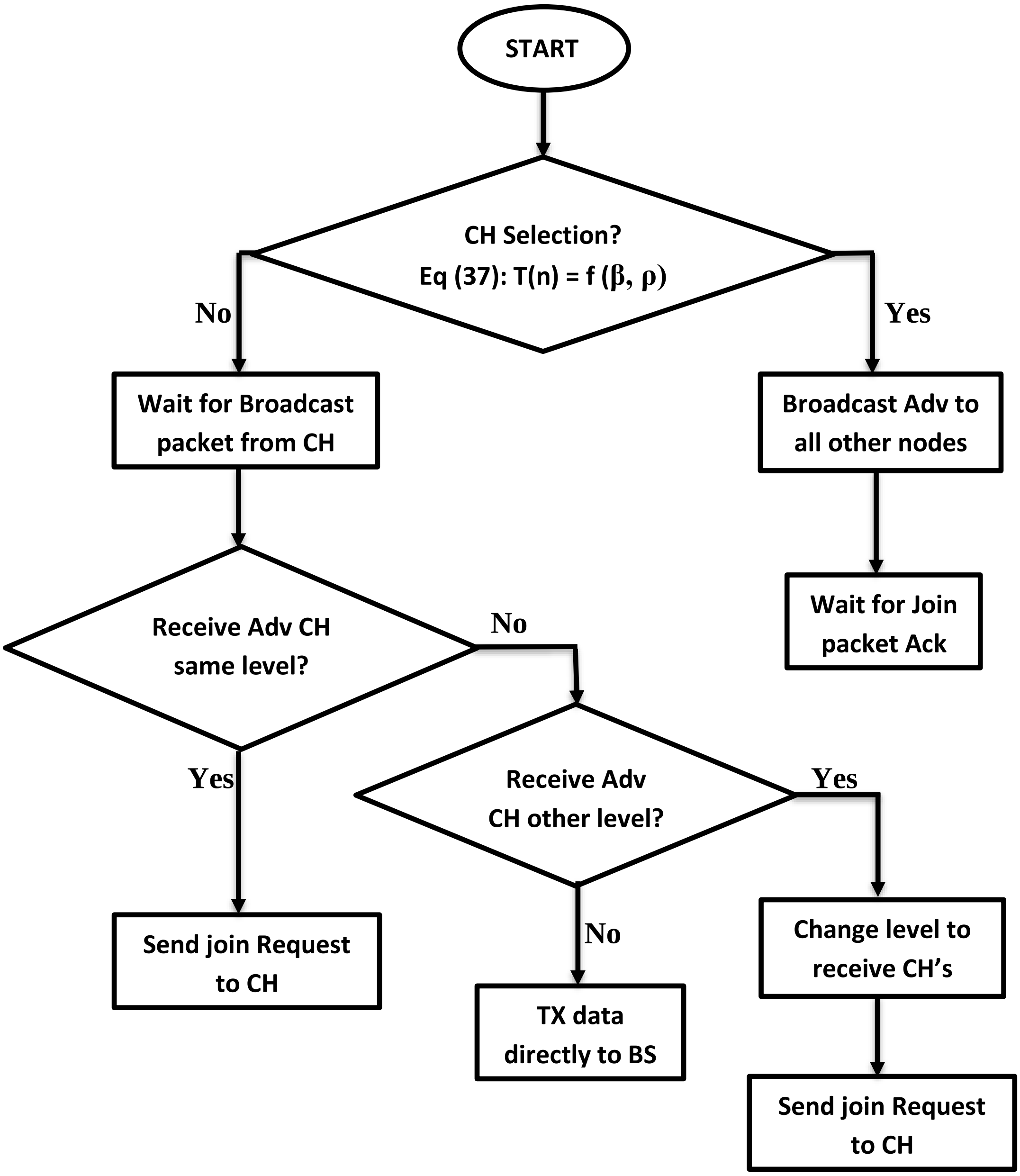


*Figure (7): Joining of Cluster Head by Nodes in Multi-Hop Communication Model*

LEACH protocol is prone to the apparition of partitions, because after transmitted power from any member node or CH is degraded and due to this it is unable to radiate transmitted signal over a long distance. This problem is also solved by Multi-hop organization setup in LEACH. In Multi-hop LEACH during steady state phase, all CHs is assigned a TDMA time slot to send its aggregated data to next level CH, just like inside a cluster all member nodes send their data to their CH in assigned time slot and keep themselves in sleep mode in other's node time slots.

At the end of each round, the base station or sink measures for the remaining or residual energy of each node in the network and also calculate overall energy status of network and accordingly calculate the energy rate. This calculated energy rate is used for computation of round time for next round.

## 6.5 PROPOSED ALGORITHMS

### LEACH Algorithm

**// Node deployment over area 100 X 100 $m^2$ field //**

```
N: Total number of nodes in WSN
n: array consisting location on all node's in WSN
XA: array consisting location of X-co-ordinates for each node in WSN
YA: array consisting location of Y-co-ordinates for each node in WSN
Xm = 100, Ym =100   /* Field Dimension for deployment of nodes */
{
   for i = [1 : N]
      Xn.(i) = random (1, 1) * Xm;          /* node deployment x-co-ordinate */
      Yn.(i) = random (1,1) * Ym;           /* node deployment y-co-ordinate */
}
   n(i). Type ='N';                         /*Initially there are no cluster head*/
   temp_rand = i;
{
   if (temp_rnd > m * n+1)                  /* set initial node energy Eo to all node */
   n(i).E = Eo;   [Eo=0.5]
}
EXIT
```

EXIT

**// Plotting Base Station or Server destination //**

```
n(N+1).xd = 0.5 * Xm;          /* base station x-co- ordinates*/
n(N+1).yd= 0.5 * Ym;           /* base station y-co- ordinates*/
```

**// Coverage points of each node //**

```
S_R: Range of Sensor Node
for each round r : r→1;
 set S_R;
{
   for  i = [ 1 : n]
   θ = (0, 2 π);
   Xp = 2 X (S_R) X (cos θ)          /* node co-ordinate x is assigned to XR(i) */
   Yp = 2 X (S_R) X (sin θ)          /* node co-ordinate y is assigned to YR(i)  */
 }
```

**// Draw circle-point for each node//**

```
x-co-ordinate for first node taken from array
y-co-ordinate for first node taken from array
Locate ← draw circlepoints (x , y, 2 X S_R);
Extract values from second node to n node
X1 ← XR.(i);
Y1 ← YR.(i);
 Locate ← draw circle-points (x1 , y1 , 2 X S_R);
EXIT
```

**// Setup Phase //**

N = Total number of nodes

ρ = desired percentage of CH

r = current round

n = set of alive nodes ∀ n ∈ N

Eo = Initial energy

Er = Remaining energy in $r^{th}$ round

n(i).E = Energy of $i^{th}$ alive node $\forall$ i ∈ n

**// Cluster Head Selection //**

```
for i = [1 : n]
{
   if n(i).E = Eo                      /* Energy calculation: Remaining Energy. First Round*/
   {
      Er = n(1).E = Eo        /* First Round. Remaining Energy is equal to initial energy */
      T(n) = f ( ρ , β) = f (ρ);            /* Cluster Head Selection as per basic LEACH */
   }
   if ((n(i).E) < Eo)                                              /* 2nd round onwards */
   {
      Er = n(i).E;                                /* Remaining energy of each alive node */
      β = Er/Eo;                                     /* Energy ration of each alive node */
      T(n) = f ( ρ , β);                            /* CH Selection as per proposed LEACH */
   }
}
For i = [1 : N]
{
   x = rand (0,1)                              /* Random value assignment to each node */
   if (x < T(n) )
   {
      n.(i) → CH;                                  /* node selection as CH successful */
      CH_count ++;
      CH → n(i) : id(CH);                   /* CH Advertisement broadcast for join CM*/
   }
   else
   {
      n.(i) → CM
      CM_count ++;                                 /* node selection as Cluster member */
   }
}
```

```
for i = [1 : N]
{
   if (state (j)  = CM)
   {
      n(i) → CH(j) : [ id(n(i)) , id(CH(j)) ]                    /*  join request from Node */
      CH(j) → n(i) : id(CH(j)) , [ t(i) , id(n(i) ]         /* Join request acceptance by CH */
   }
}
```

**// Steady State phase and Multi-Hop routing //**

Different symbols that have been used above are:

S: Set of all alive nodes in WSN

id: identification number for each node CH & CM

t:  time–slot assigned to each CM to send the sensed data

```
for j = [ 1 : CH_count ]
distance(CH(j) , BS);                    /* distance calculation between each CH with BS */
levelNumb(CH(j), L(j));                           /* level number assignment to each CH */
 for i = [1 : n]
{
   distance(n(i),CH(j));     /* distance calculation between each CM and respective CH */
   n(i) → CH(j) : [ id(n(i)) , id(CH(j))]; /* Each CM send data to CH in given time slot */
}
   for j = [ 1 : CH_count ]
   {
      for i = [1 : CM_count]
      dataAggreg(CH(j), n(i));              /* Data Aggregation at each CH for its cluster */
   }
for j = [ 1 : CH_count ]
{
   CH(j) → CH(k) : id(CH(k));              /* CH(j) join request to CH(k) at lower lever */
   CH(k) → CH(j) : id(CH(k)) , [ t(j) , id(CH(j)];     /* Join req accpt by CH. TS assign */
   CH(j): dataAggreg(CH(j)) → CH(k);               /* k<<j, next hop to lower level CH */
   till k→1;
```

```
}
   for k = 1
{
   CH(1) : dataAggre() → BS : id(CH) , id(BS);       /* CH Send aggregated data to BS */
}
EXIT
```

# CHAPTER 7: SIMULATION AND RESULTS ANALYSIS

## 7.1 TOOL USED: MATLAB

MATLAB (matrix laboratory) developed by MathWorks is well known and highly performing language and tool for computing various specific kind of problems. Advantage of using MATLAB tool is that it makes programming environment very easy because all the complicated thing related to programming, its complex computation of various process and mathematical expressions and also representation of these programming and all visualization in very easy and user-friendly way. One of most important things about MATLAB that makes it so easy is its structure that its data at basic level is an array. Because of this any computation that is required to express in array or matrix form can be easily computed with help of MATLAB language, while a great extent of effort may require in programming of same level of computation if we program same thing in other conventional languages like C++ etc. MATLAB provide many functionalities that are very much useful in programing world like implementing complex algorithms, visual supports like plotting of data or required functions or equation against some variable. Though above features and functions in MATLAB are written in languages like C, C++, Python, Fortran or Java but comparatively MATLAB provides a great and user-friendly interface to the programmers.

MATLAB user structure array as data types and all variables are arrays in MATLAB. Not only above functions but MATLAB also supports Object-Oriented based programming as well by supporting Class, package, pass by value, pass by reference, inheritance etc. For classed that has handle as super class is term as reference class and the classed that has not handle as a super class is termed as value classes in MATLAB. A great feature about MATLAB is that it supports development or programming of any solution with features of graphical user interface with graphical designing because it includes Graphical User Interface Develop Environment also termed as GUIDE. A powerful feature using Graphical User Interface Develop Environment is feature of plotting graphs for a function on x-axis and y-axis using two vector X & Y.

MATLAB language has interfacing with other languages like C & FORTRAN. MATLAB can subroutines or call functions that are written in FORTRAN or C. There are many alternatives of MATLAB like Maple, Mathematica, IDL, TK Solver etc. and also few open source alternatives to MATLAB like Sage-Math, Sci-lab, GNU Octave, Free-Mat etc.

### 7.1.1 Advantage of using MATLAB over other languages

MATLAB has many good advantages over other methods or languages. One of the big advantages is that MATLAB’s basic data element is a matrix. Any simplest data type even an integer is structured and defined in a form of a matrix consisting of single-row and single-column. So, it is very easy to perform an operation on these data type in MATLAB which operation are designed to be performed on a matrix or an array. It may be very complex to perform and to develop code for matrix operation like inverse matrices, dot-products, determinants, cross-products and vectorized operation in other software language but sample can be programmed and implemented very easily using MATLAB. For example, if we make a program for adding two arrays or dot product of a matrix, then we need to write code for it using loop and need to put effort on it, but in MATLAB this operation can be achieved in just one to two lines of command.

Beside above MATLAB provides us functionality of optimization of user interface by provide functions of changing colors, templates, axis and size etc. In addition to above MATLAB also have additional tool box which is helpful a lot by enhancing range of functionalities provided by MATLAB. MATLAB provide link to excel by using which data can be written or saved or taken as an input in format or excel. There are many tool box available related to statistics which are very useful in statistical manipulation of data in MATLAB.

### 7.1.2 Disadvantage of using MATLAB

Using MATLAB language has few disadvantages also. One of very common problem is that MATLAB is very heavy software in the sense that it uses large amount of memory in RAM & much amount of CPU time of computer being used. After installing MATLAB computers becomes very slow and it becomes very difficult to use computer normally as there is always sluggishness and delay in response by compute for every command.

## 7.2 SIMULATION & RESULTS ANALYSIS

We simulate Existing approach and proposed approaches using MAT lab software and compare the results between two for number of parameters or factors to evaluate performance of both approaches in comparison to each other. Total dimension or area for deployment of nodes for simulation taken as 100m × 100m. Total number of sensor nodes has been changed to 50, 100 & 150 to take results for different size of WSN. Spreading of these nodes over given area will be random. Rest of important parameters taken for simulation are given below in table (1).

| Important Parameters | Simulation Value |
|---|---|
| Area | 100m X 100 m |
| No. of Nodes | 50, 100, 150 |
| Radio Model | First order radio energy model |
| Channel Type | Wireless Channel |
| Probability of CH Selection (P) | 0.05 |
| Initial Energy | 0.5 |
| Base Station Location | 50,50 |
| Packet Data length | 6400 bits |
| Packet length node to BS | 200 bits |
| Transmitter energy (ETX) | 50 X 10^(-9) |
| Receiver energy (ERX) | 50 X 10^(-9) |
| Free space energy | 10 X 10^(-12) |
| Multi path energy | 0.0013 X 10^(-12) |
| Data aggregation energy | 5 X 10^(-9) |
| INFINITY | 999999999999999 |
| Infinite distance | 999999999999999 |
| Maximum rounds | 9999 |

*Table (1): Simulation parameters*

### 7.2.1 Deployment of IOT Devices

As explained above, three sets of total number of sensor nodes has been taken with 50, 100 & 150 nodes to take results for different size of WSN. Below figure illustrates the deployment of IoT devices with respect to distance in analysis deployment is considered as 100 meters.

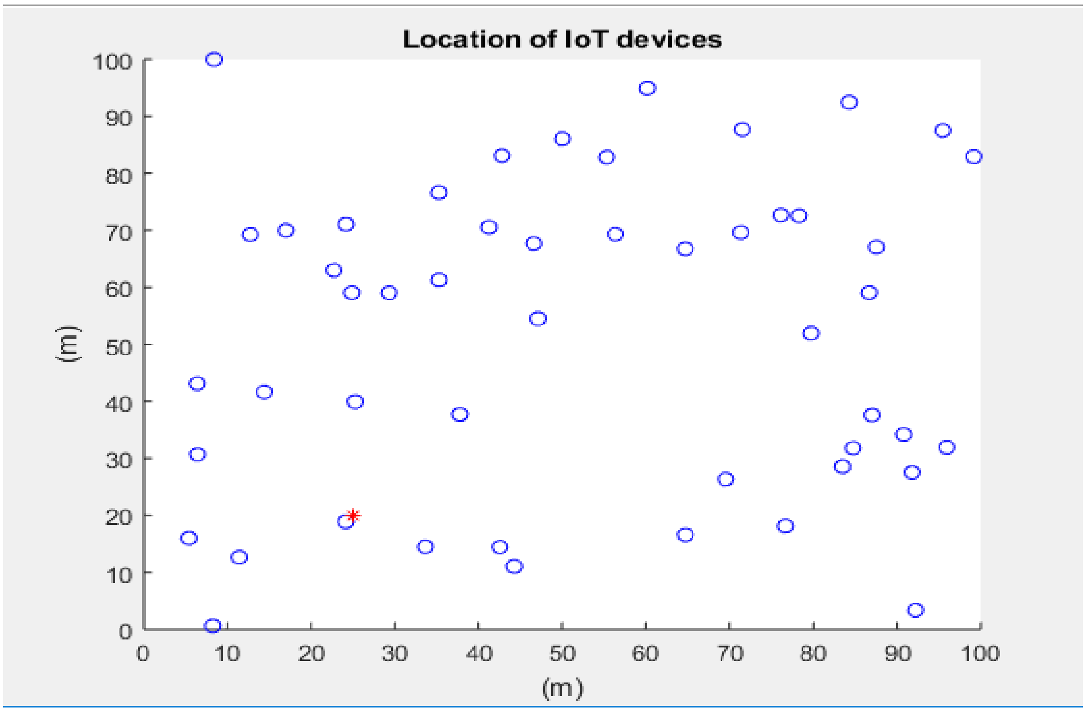


*Figure (8): Deployment of IOT devices on area 100x100 $m^2$*

### 7.2.2 Number of Operating Nodes vs Rounds

For Number of nodes= 50, In Existing approach all live or operational nodes becomes dead after 3800 ~ 4700 rounds. While is proposed approach all live or operational nodes are becoming dead after 9400 ~ 13800 rounds which is quite impressive in comparison to existing approach.

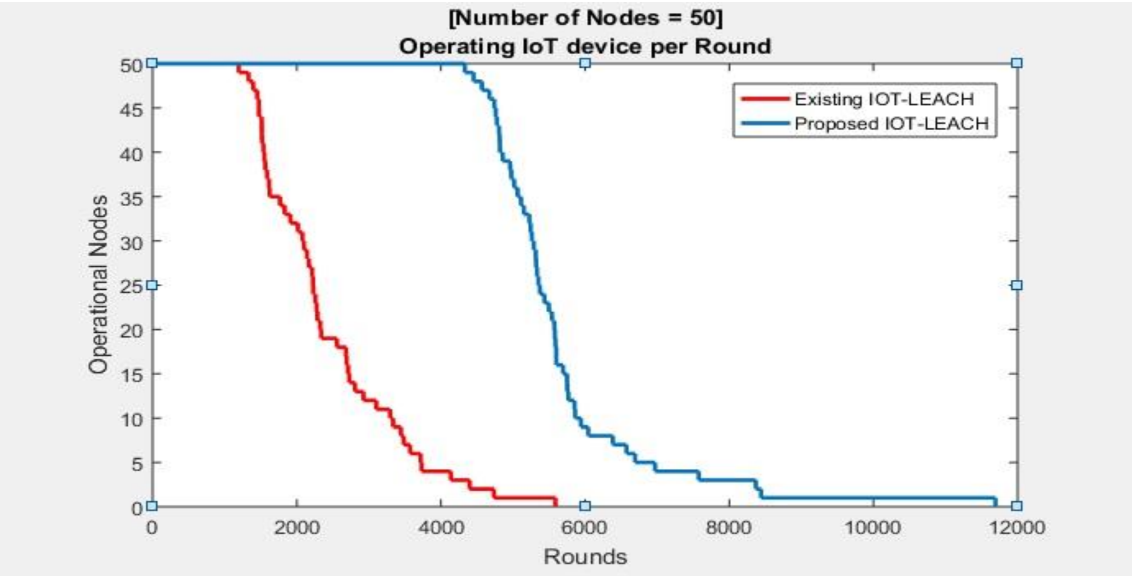


*Figure (9): Measurement of number of operating nodes with increasing number of rounds*

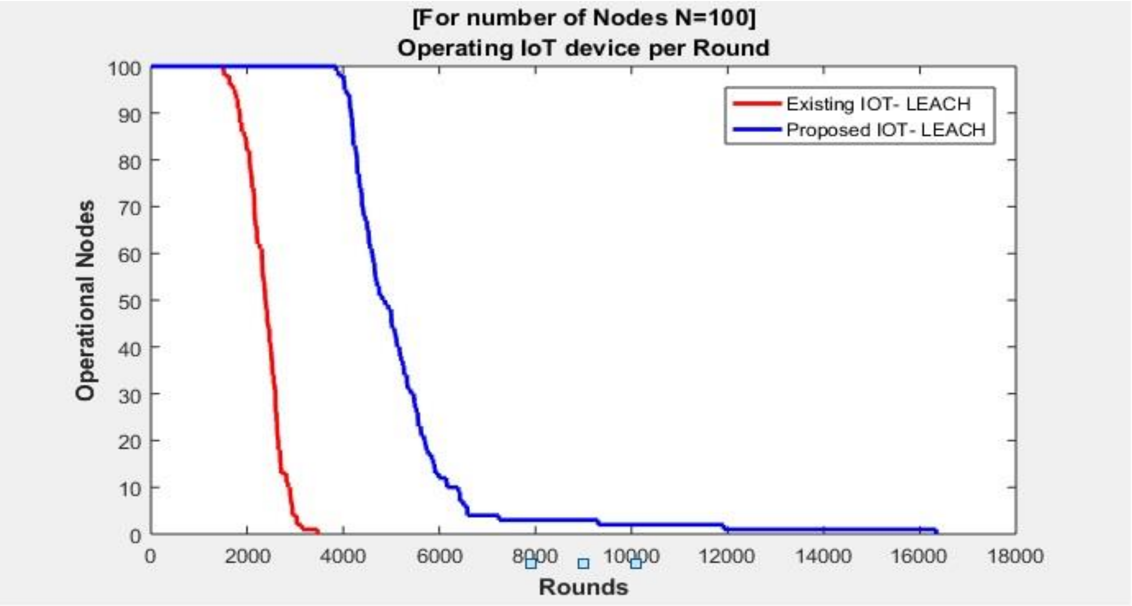


*Figure (10): Measurement of number of operating nodes with increasing number of rounds*

For Number of nodes= 100, In Existing approach all live or operational nodes becomes dead after ~3600 rounds. While is proposed approach all live or operational nodes are becoming dead after 6600 ~ 16300 rounds which is quite impressive in comparison to existing approach.

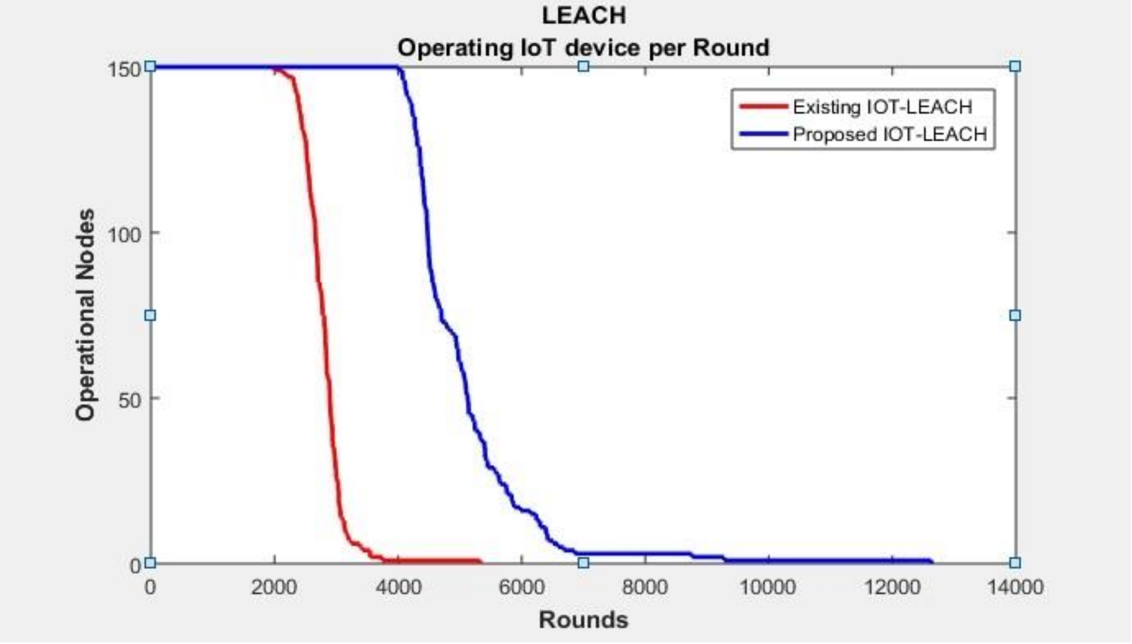


*Figure (11): Measurement of number of operating nodes with increasing number of rounds*

Similarly, For Number of nodes= 150, In Existing approach all live or operational nodes becomes dead after ~ 4000 rounds. While is proposed approach all live or operational nodes are becoming dead after ~ 7000 rounds which is quite impressive in comparison to existing approach.

Simulation results for Number of Operating or Live Nodes vs number of increasing rounds are verified for different sizes of WSN by varying number of nodes to 50, 100 & 150. But Simulation results remain same and proposed approach shown improved results as for each case proposed approach proved to better due to having a greater number of Live or operating nodes after same number of rounds. Below table shows comparative analysis of existing and proposed approaches for all three set of nodes simulated.

| **Number of Operating Rounds** | **Number of Alive Nodes** | | | | | |
|---|---|---|---|---|---|---|
| | **N = 50** | | **N = 100** | | **N = 150** | |
| | **Existing** | **Proposed** | **Existing** | **Proposed** | **Existing** | **Proposed** |
| 001 | 50 | 50 | 100 | 100 | 150 | 150 |
| 500 | 50 | 50 | 100 | 100 | 150 | 150 |
| 1000 | 50 | 50 | 100 | 100 | 150 | 150 |
| 1500 | 50 | 50 | 100 | 100 | 150 | 150 |
| 2000 | 32 | 50 | 89 | 100 | 150 | 150 |
| 2500 | 25 | 50 | 60 | 100 | 113 | 150 |
| 3000 | 13 | 50 | 38 | 100 | 75 | 150 |
| 3500 | 8 | 50 | 2 | 100 | 36 | 150 |
| 4000 | 5 | 50 | 0 | 97 | 1 | 150 |
| 4500 | 3 | 47 | 0 | 60 | 0 | 122 |
| 5000 | 2 | 45 | 0 | 35 | 0 | 95 |
| 5500 | 1 | 27 | 0 | 20 | 0 | 71 |
| 6000 | 0 | 12 | 0 | 12 | 0 | 44 |
| 6500 | 0 | 7 | 0 | 5 | 0 | 17 |
| 7000 | 0 | 6 | 0 | 3 | 0 | 1 |
| 7500 | 0 | 5 | 0 | 2 | 0 | 1 |
| 8000 | 0 | 4 | 0 | 2 | 0 | 1 |
| 10000 | 0 | 1 | 0 | 1 | 0 | 1 |
| 12000 | 0 | 0 | 0 | 1 | 0 | 1 |
| 14000 | 0 | 0 | 0 | 1 | 0 | 0 |
| 16000 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table (2): Measurement of number of alive nodes with increasing number of rounds*

### 7.2.3 Number of Operating Nodes vs Transmissions

Simulation results for Number of Operating or Live Nodes vs number of increasing transmissions are verified for different sizes of WSN by varying number of nodes to 50, 100 & 150. But Simulation results remain same and proposed approach shown improved results as for each case proposed approach proved to better due to having more number of Live or operating nodes after same number of transmissions.

For Number of nodes= 50, In Existing approach all live or operational nodes becomes dead after ~ 2450 number of transmissions. While is proposed approach all live or operational nodes are becoming dead after ~ 6200 number of transmissions which is quite impressive in comparison to existing approach.

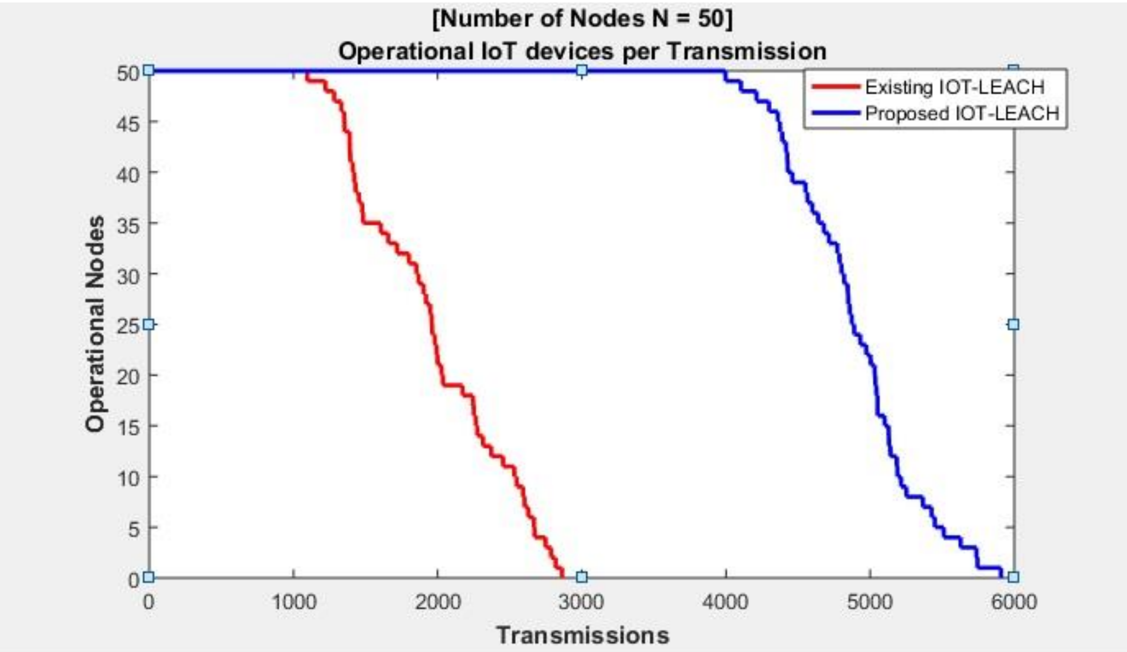


*Figure (12): Measurement of number of operating nodes with increasing number of Transmissions*

For Number of nodes= 100, In Existing approach all live or operational nodes becomes dead after ~ 3000 number of transmissions. While is proposed approach all live or operational nodes are becoming dead after ~ 6200 number of transmissions which is quite impressive in comparison to existing approach.

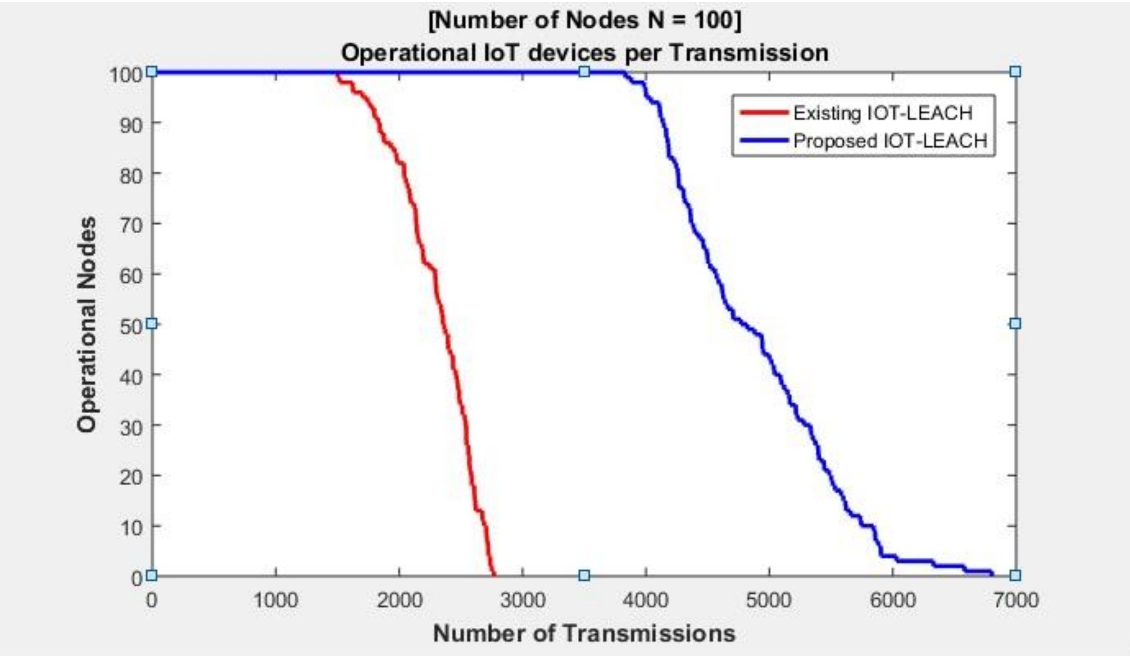


*Figure (13): Measurement of number of operating nodes with increasing number of Transmissions*

The analysis IoT number operation per transmission is constant over 6000 transmission which is almost all IoT devices are transmitting over the selected transmission period.

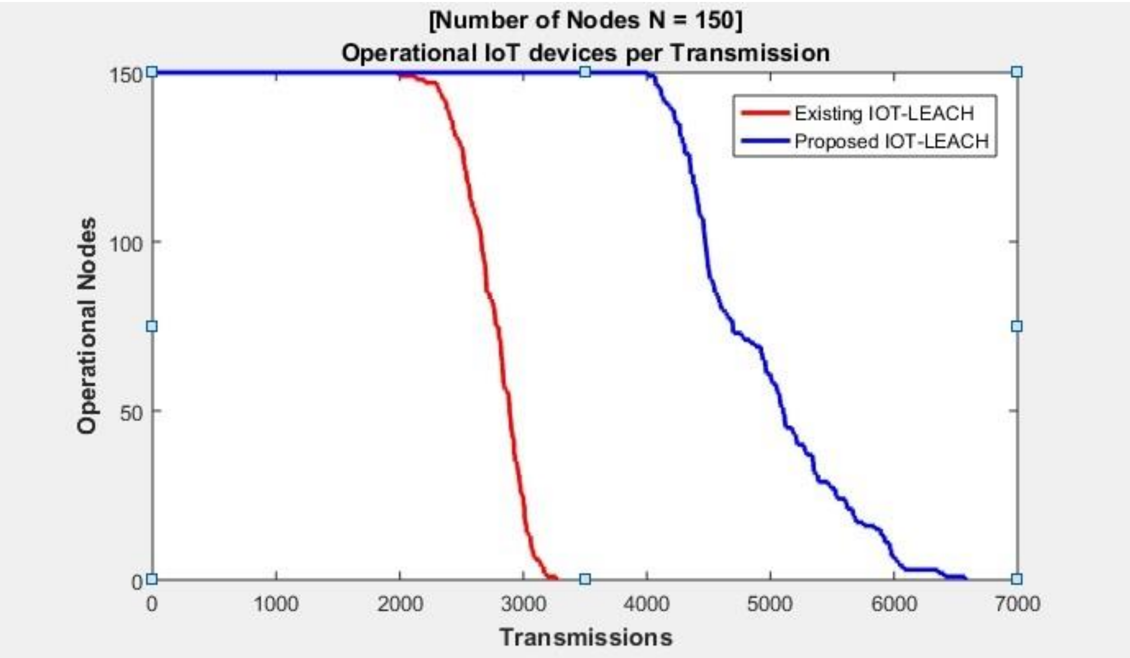


*Figure (14): Measurement of number of operating nodes with increasing number of Transmissions*

Similarly, for Number of nodes= 150, In Existing approach all live or operational nodes becomes dead after ~ 3500 number of transmissions. While is proposed approach all live or operational nodes are becoming dead after ~ 6300 number of transmissions which is quite impressive in comparison to existing approach.

| **Number of Transmissions** | **Number of Alive Nodes** | | | | | |
|---|---|---|---|---|---|---|
| | **N = 50** | | **N = 100** | | **N = 150** | |
| | **Existing** | **Proposed** | **Existing** | **Proposed** | **Existing** | **Proposed** |
| 001 | 50 | 50 | 100 | 100 | 150 | 150 |
| 500 | 50 | 50 | 100 | 100 | 150 | 150 |
| 1000 | 50 | 50 | 100 | 100 | 150 | 150 |
| 1500 | 37 | 50 | 100 | 100 | 150 | 150 |
| 2000 | 25 | 50 | 89 | 100 | 150 | 150 |
| 2500 | 12 | 50 | 60 | 100 | 103 | 150 |
| 3000 | 0 | 50 | 38 | 100 | 50 | 150 |
| 3500 | 0 | 50 | 2 | 100 | 0 | 150 |
| 4000 | 0 | 50 | 0 | 94 | 0 | 150 |
| 4500 | 0 | 36 | 0 | 73 | 0 | 102 |
| 5000 | 0 | 27 | 0 | 49 | 0 | 60 |
| 5500 | 0 | 14 | 0 | 26 | 0 | 41 |
| 6000 | 0 | 1 | 0 | 4 | 0 | 20 |
| 6500 | 0 | 0 | 0 | 2 | 0 | 1 |
| 7000 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table (3): Measurement of number of alive nodes with increasing number of Transmissions*

### 7.2.4 Analysis of Energy Consumption

Simulation results for Energy Consumption by all nodes are checked with number of increasing transmissions for different sizes of WSN by varying number of nodes to 50, 100 & 150. But Simulation results proves that proposed approach shown improved results as for each case Energy Consumption by all nodes are in proposed with increasing transmission is found much lower that Energy Consumption by all nodes in existing approach.

For Number of nodes= 50, In Existing approach Energy Consumption by all nodes over ~ 1000 transmissions is ranged from 0.04 ~ 0.14 J while in proposed approach Energy Consumption by all nodes over ~ 4200 transmissions (which is quite high in comparison to existing approach) is ranged from 0.02 ~ 0.021 J which is quite lower and impressive in comparison to existing approach.

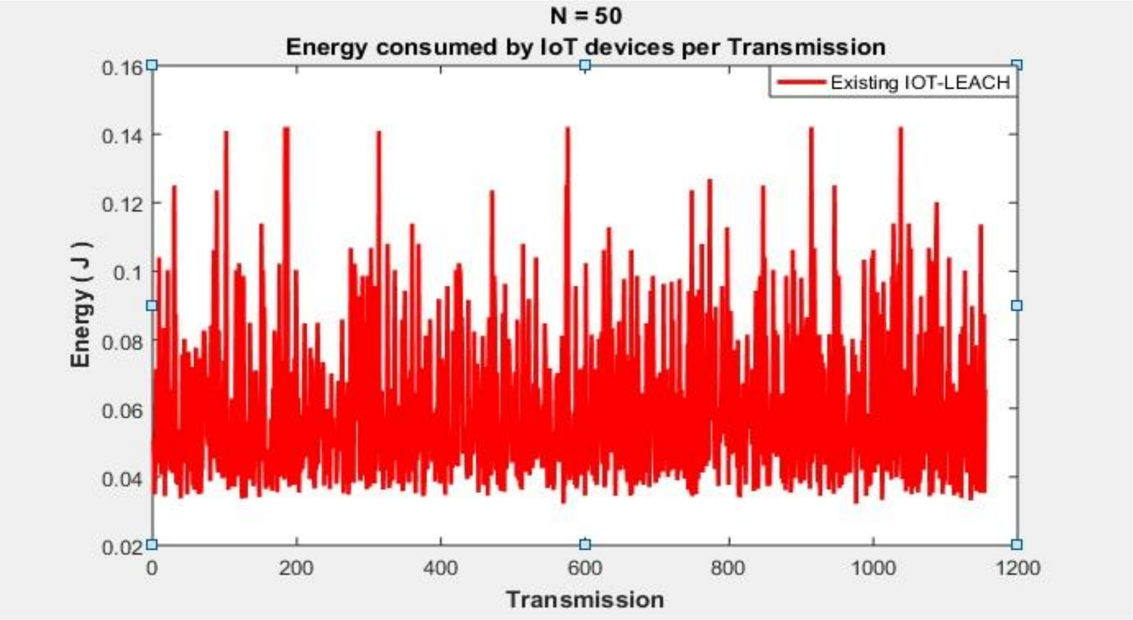


*Figure (15): Energy consumed by IOT devices per Transmission-Existing IOT LEACH*

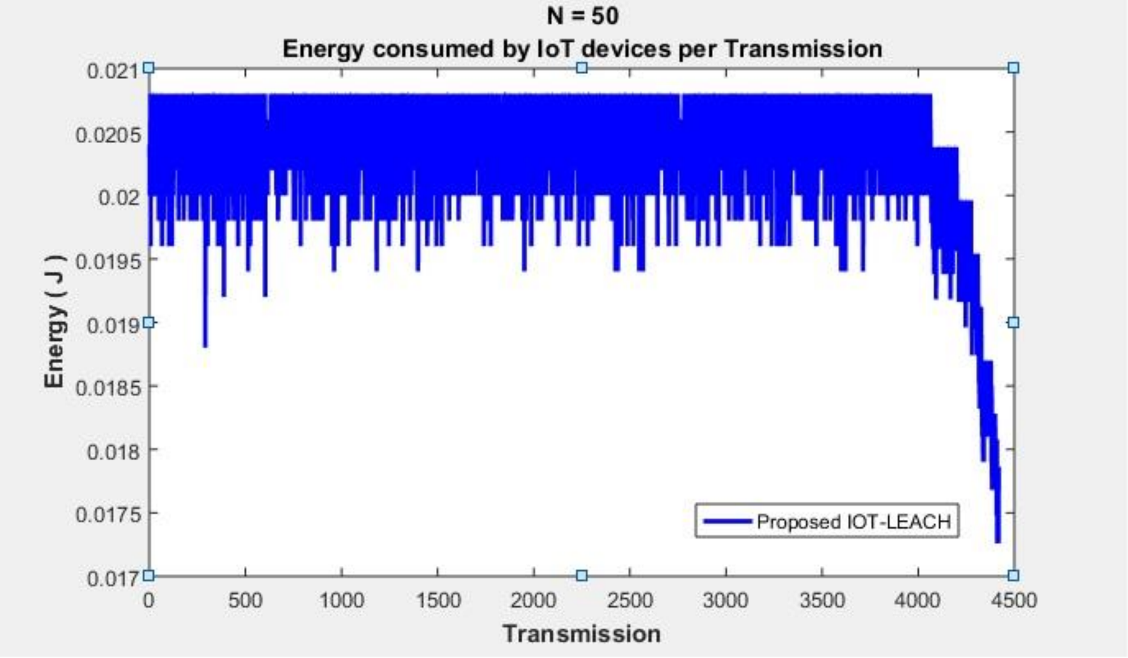


*Figure (16): Energy consumed by IOT devices per Transmission-Proposed IOT LEACH*

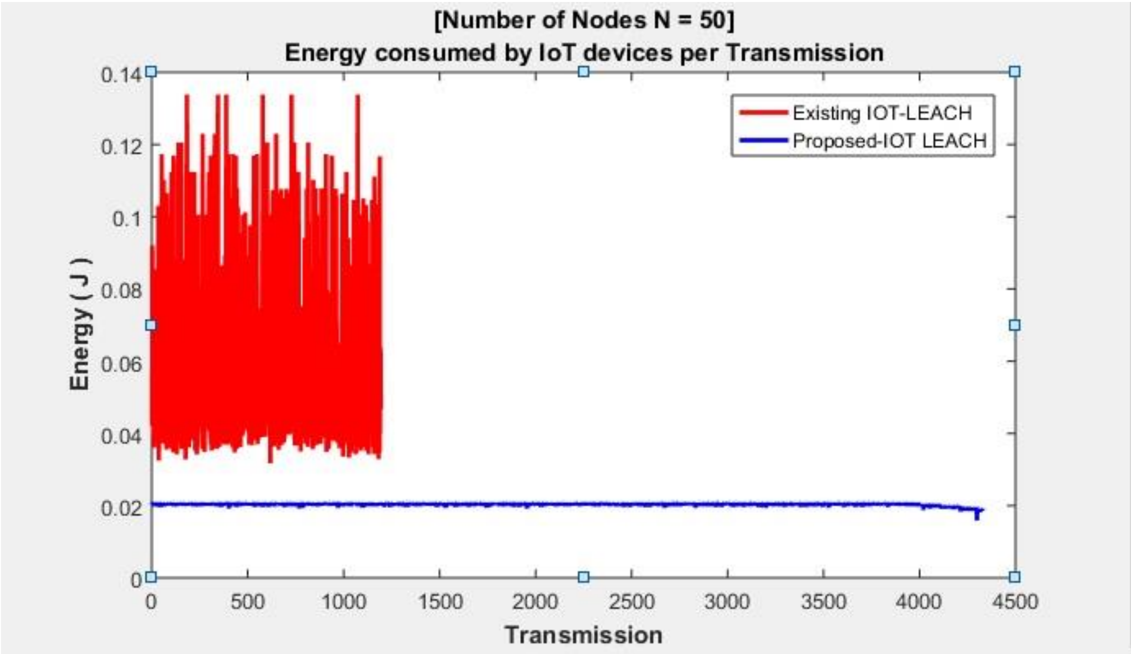


*Figure (17): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

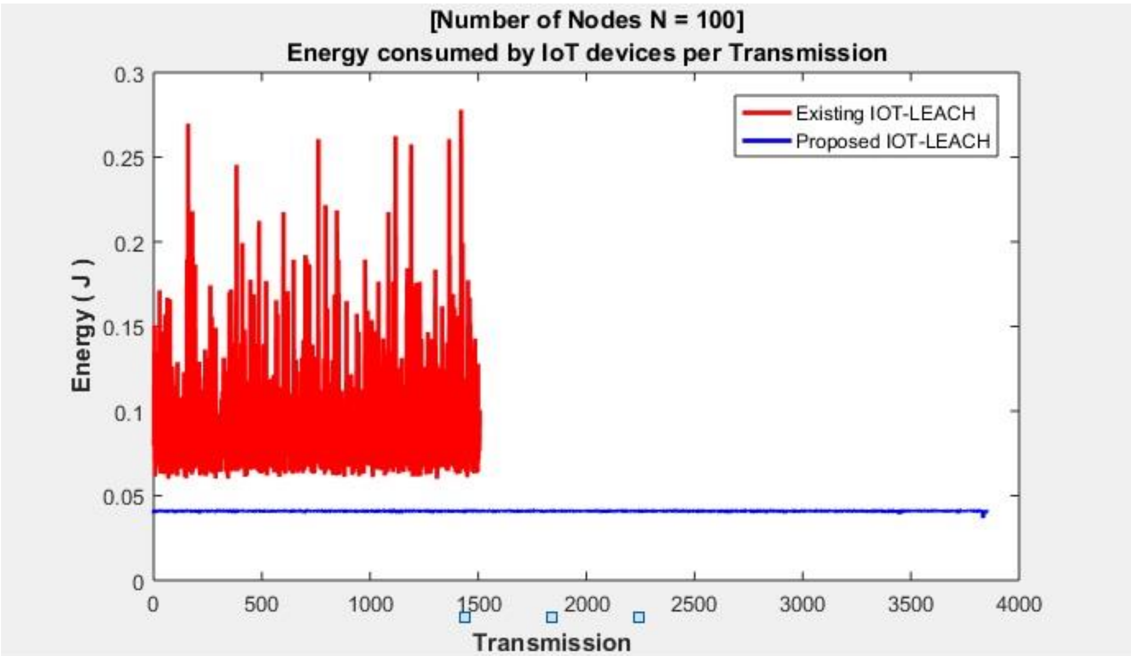


*Figure (18): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

For Number of nodes= 100, In Existing approach Energy Consumption by all nodes over ~ 1200 transmissions is ranged from 0.04 ~ 0.14 J while in proposed approach Energy Consumption by all nodes over ~ 4000 transmissions (which is quite high in comparison to existing approach) is ranged from 0.04 ~ 0.042 J which is quite lower and impressive in comparison to existing approach.

Similarly, as shown for Number of nodes= 150, In Existing approach Energy Consumption by all nodes over ~ 1750 transmissions is ranged from 0.08 ~ 0.25 J while in proposed approach Energy Consumption by all nodes over ~ 4000 transmissions (which is quite high in comparison to existing approach) is ranged from 0.0605 ~ 0.0625 J which is quite lower and impressive in comparison to existing approach.

``

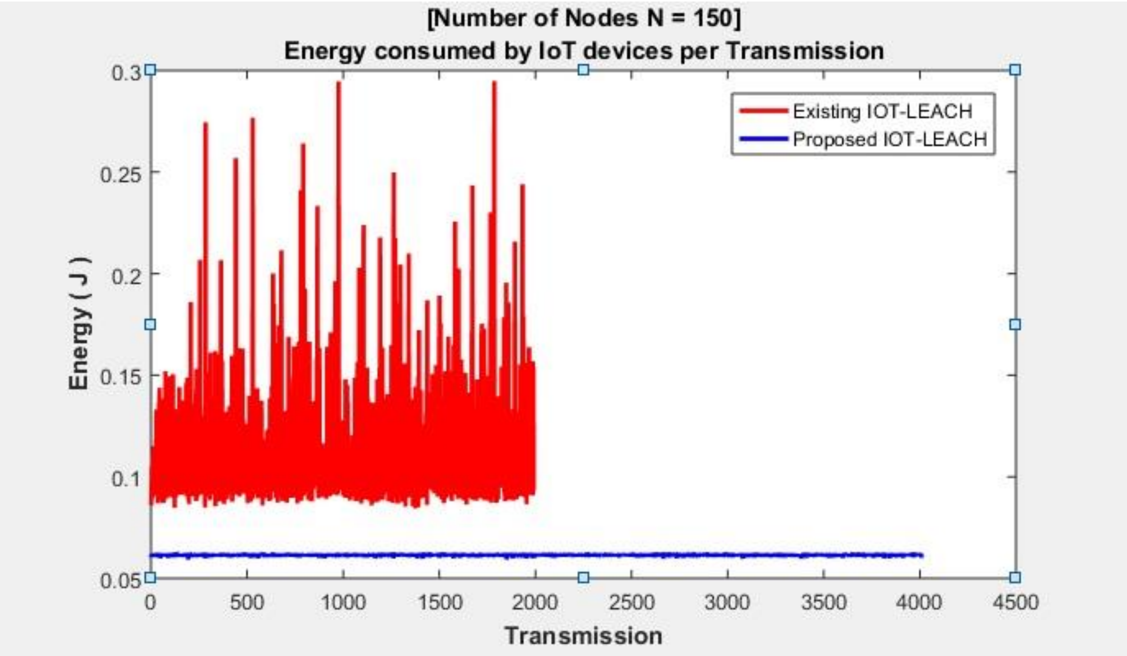


*Figure (19): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

Below Table shown comparison of range of energy consumption by all sensor nodes between existing and proposed methodology. Comparison is done for all three set of nodes as explain above. We can clearly see that proposed approach is giving much better results in comparison to existing approach as we can see that in proposed approach all sensor nodes consuming very less amount of energy in comparison to existing approach and are utilizing energy very efficiently.

| Number of Transmissions | Energy consumed by all IOT Sensors | | | | | |
|---|---|---|---|---|---|---|
| | N = 50 | | N = 100 | | N = 150 | |
| | Existing | Proposed | Existing | Proposed | Existing | Proposed |
| 001 | 0.04 ~ 0.14 J | 0.02 ~ 0.021 J | 0.04 ~ 0.14 J | 0.04 ~ 0.042 J | 0.08 ~ 0.25 J | 0.0605 ~ 0.0625 J |
| 500 | 0.04 ~ 0.14 J | 0.02 ~ 0.021 J | 0.04 ~ 0.14 J | 0.04 ~ 0.042 J | 0.08 ~ 0.25 J | 0.0605 ~ 0.0625 J |
| 1000 | 0.04 ~ 0.14 J | 0.02 ~ 0.021 J | 0.04 ~ 0.14 J | 0.04 ~ 0.042 J | 0.08 ~ 0.25 J | 0.0605 ~ 0.0625 J |
| 1500 | 0 | 0.02 ~ 0.021 J | 0 | 0.04 ~ 0.042 J | 0.08 ~ 0.25 J | 0.0605 ~ 0.0625 J |
| 2000 | 0 | 0.02 ~ 0.021 J | 0 | 0.04 ~ 0.042 J | 0 | 0.0605 ~ 0.0625 J |
| 2500 | 0 | 0.02 ~ 0.021 J | 0 | 0.04 ~ 0.042 J | 0 | 0.0605 ~ 0.0625 J |
| 3000 | 0 | 0.02 ~ 0.021 J | 0 | 0.04 ~ 0.042 J | 0 | 0.0605 ~ 0.0625 J |
| 3500 | 0 | 0.02 ~ 0.021 J | 0 | 0.04 ~ 0.042 J | 0 | 0.0605 ~ 0.0625 J |
| 4000 | 0 | 0.02 ~ 0.021 J | 0 | 0 | 0 | 0.0605 ~ 0.0625 J |
| 4500 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table (4): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

### 7.2.5 Average Energy Consumption by IOT devices

Simulation results for Average energy consumption by all nodes are checked with number of increasing transmissions for different sizes of WSN by varying number of nodes to 50, 100 & 150. But Simulation results proves that proposed approach shown improved results as for each case Average energy consumption by all nodes with increasing transmission in proposed approach is found much lower that Average energy consumption by all nodes in existing approach.

For Number of nodes= 50, In Existing approach Average Energy Consumption by all nodes over ~ 1200 transmissions is ~ 11.2 J while in proposed approach Average Energy Consumption by all nodes over ~ 4600 transmissions is just 4.1 J which is quite lower and impressive in comparison to existing approach.

In below plot illustrated that lower average energy consumption in proposed approach is reason that all IOT devices or node are staying for longer period in comparison to life time of all nodes in existing approach. Further it is constant over 4000 transmission.

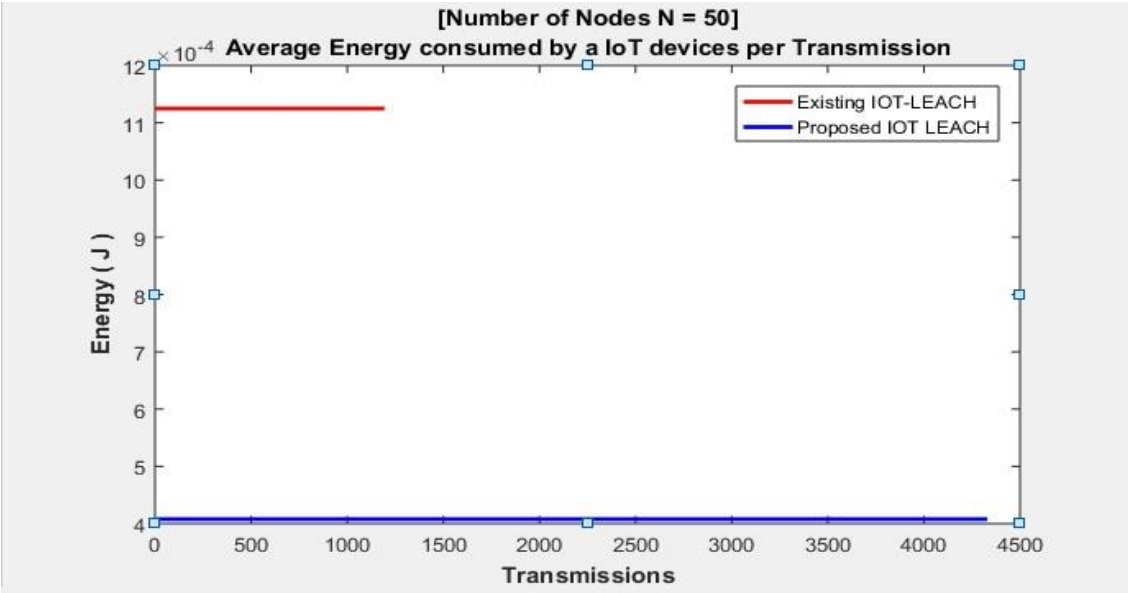


*Figure (20): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

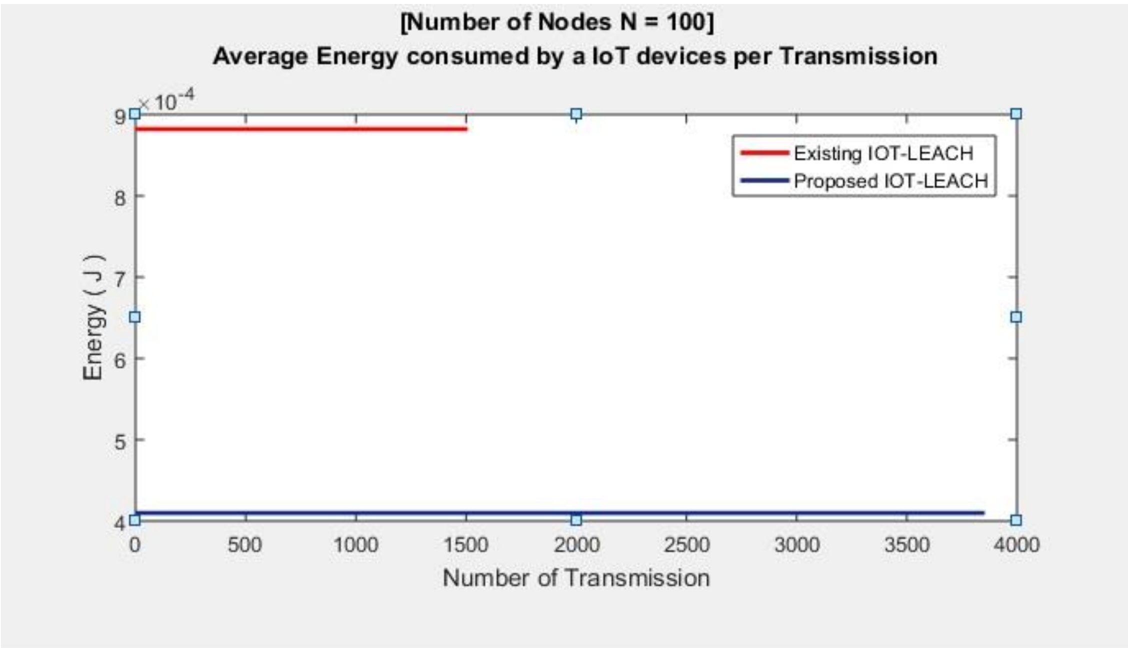


*Figure (21): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

Similarly, for Number of nodes= 100, In Existing approach Average Energy Consumption by all nodes over ~ 1500 transmissions is ~ 8.8 J while in proposed approach Average Energy Consumption by all nodes over ~ 3800 transmissions is just 4.1 J which is quite lower and impressive in comparison to existing approach.

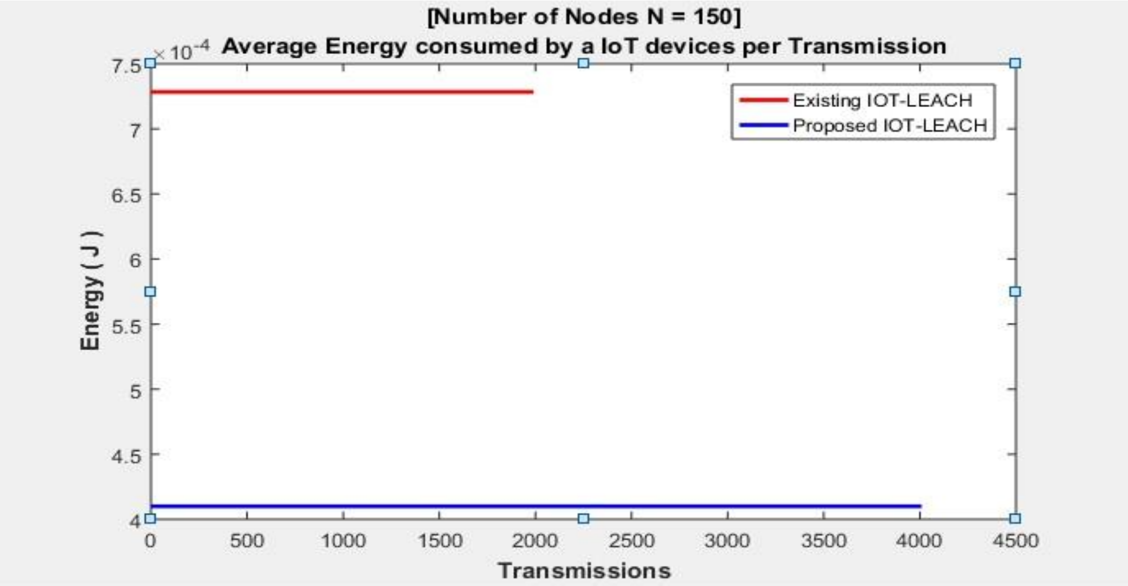


*Figure (22): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

Similarly, for Number of nodes= 150, In Existing approach Average Energy Consumption by all nodes over ~ 2000 transmissions is ~ 7.3 J while in proposed approach Average Energy Consumption by all nodes over ~ 4000 transmissions is just 4.1 J which is quite lower and impressive in comparison to existing approach.

Like Energy consumption analysis done above for all sensor nodes in above table, below Table shown comparison of average energy consumption by all sensor nodes between existing and proposed methodology. Comparison is done for all three set of nodes in similar fashion as explain above. We again can clearly see that proposed approach is giving much better results in comparison to existing approach as we can see that in proposed approach all sensor nodes consuming very less amount of average energy in comparison to existing approach and again showing that utilizing energy very efficiently.

| Number of Transmissions | Average Energy Consumption by all IOT devices | | | | | |
|---|---|---|---|---|---|---|
| | N = 50 | | N = 100 | | N = 150 | |
| | **Existing** | **Proposed** | **Existing** | **Proposed** | **Existing** | **Proposed** |
| 001 | 11.3 J | 4.15 J | 8.8 J | 4.15 J | 7.3 J | 4.15 J |
| 500 | 11.3 J | 4.15 J | 8.8 J | 4.15 J | 7.3 J | 4.15 J |
| 1000 | 11.3 J | 4.15 J | 8.8 J | 4.15 J | 7.3 J | 4.15 J |
| 1500 | 0 | 4.15 J | 0 | 4.15 J | 7.3 J | 4.15 J |
| 2000 | 0 | 4.15 J | 0 | 4.15 J | 0 | 4.15 J |
| 2500 | 0 | 4.15 J | 0 | 4.15 J | 0 | 4.15 J |
| 3000 | 0 | 4.15 J | 0 | 4.15 J | 0 | 4.15 J |
| 3500 | 0 | 4.15 J | 0 | 4.15 J | 0 | 4.15 J |
| 4000 | 0 | 4.15 J | 0 | 0 | 0 | 4.15 J |
| 4500 | 0 | 0 | 0 | 0 | 0 | 0 |

*Table (5): Energy consumed by IOT devices per Transmission-Existing vs Proposed IOT LEACH*

# CHAPTER 8: CONCLUSION AND FUTURE WORK

Here problem of mobile IOT sensors-based applications i.e. Military based application as taken here has successfully addressed and solution is successfully implemented in WSN using LEACH protocol for MANET. Also, a new methodology or approach for implementing WSN with modified LEACH Protocol has been used for an IoT based system.

This new methodology for improving WSN network stability by improving energy efficiency has been done successfully for IOT based application considered here. This new approach of implementing new threshold value formula by considering residual energy ratio and giving weightage to it along with percentage of Cluster head required is done in very specific and new way has proven a considerable improvement in energy efficiency, energy utilization and prolonging network life time.

Along with improved LEACH protocol, muti-hop transmission methodology has been implemented successfully in existing approach to improve energy utilization in even better way by saving energy which has been consuming very fast in case of single hop transmission of aggregated data by Cluster head to base station or server destination.

The comparative results obtained after simulation of proposed methodology for different size of WSN networks proved that the proposed algorithm is a more effective and more energy efficient technique if we are implementing WSN – LEACH based routing algorithm for IOT applications. Including residual or remaining energy ratio in specific manner as given in proposed methodology has been giving better results as we have seen in above implementation. Therefore, giving a solution which can be a real help to the WSN deployed for sensitive IOT based applications.

**Future Scope**

Our proposed IOT-LEACH methodology has been implemented successfully for MANET for mobile IOT sensors. Improved Cluster Head selection process by involving residual energy ration of sensor nodes and concept and benefits of Multi-hop communication has been implemented successfully. We can further improve Cluster

Head selection process by doing improvement in many areas like special attention to isolated nodes which hasn't been addressed here so far. Current algorithm addresses cluster head selection for sensor nodes which are distributed uniformly or randomly in space but assumption is that all nodes are connected to at-least one other sensor node in network that means there is no isolated node in WSN.

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