OPTIMIZATION OF SELF-ORGANIZING NETWORK (SON) IN NEXT GENERATION NETWORKS

BY

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DECLARATION

I, ***Sunya Suhail***, certify that the work included in the thesis named "**OPTIMIZATION OF SELF-ORGANIZING NETWORK (SON) IN NEXT GENERATION NETWORKS**" in relation to my own findings was produced by me in accordance with the research I conducted.I endorse that:

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3. Each time I have consulted someone else's published work, it has been explicitly cited.

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DEDICATION

This article is dedicated to everyone who assisted me in gaining the technical understanding of my accomplishment. A special word of thanks goes out to my parents and my husband, who saw the importance of my effort and provided me with unwavering support throughout the process.

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ABSTRACT

For centuries of years, the telecommunication industry has been working in the harmony of flourishing adequate and effective communication services to the people in world but still faces several disruptions and issues which have not been addressed up till now. One of the major issues and difficulty which is found is the lack of an optimized network management system in the domain of telecommunication sector. Moreover, the number of cellular users are increasing day by day and with the advancement of IoT, the introduced heterogeneity in the network has drastically increased the amount of network equipment resulting in more energy consumption and overall increase in the cost of network deployment. Therefore the development of a more optimized self-organizing network leading to the development of an adequate disaster management system would be beneficial in this regard. The development of an optimized self-organizing that is capable of adjusting its working parameters and performance according to the defined needs of the network will lead to the basis of an advanced disaster management system.

The main goal that lies behind the idea of an optimized SON is to provide communication & connectivity anywhere anytime. Therefore, in this regard a combined approach using Low energy adaptive cluster hierarchical protocol of wireless sensor network is integrated with five user-collaborative codes to build a network that can meet the demands of increasing users and facilitate them every time. The proposed approach is capable of accommodating increased number of users on shared medium which will leads towards efficient bandwidth utilization. It has proven to be energy efficient in terms of user’s energy utilization thus increasing the overall life time of network making it more scalable.

CHAPTER ONE

1 Introduction

Self-organized networks is a system of networks that is capable of adjusting its working parameters and performance according to the defined needs of the network. These networks are equipped with advanced processors that are autonomous in planning, organizing, configuring, managing and optimizing a cellular network [1]. The term self-organized has been devised in the past few years in the need of developing a self-sustainable system that can assist the network operators in order to improve the overall efficiency of the network.

From the time when the cellular system was initiated in the late 1970s, cellular wireless communication has grew from analog voice calls to present modern technologies proficient of providing prime quality cellular broadband services with end-user data rates of several megabits per second over wide areas and tens, or even hundreds, of megabits per second in the vicinity[2]. The advancement in terms of capability of cellular communication networks, along with the commencement of new forms of cellular devices such as smart phones and tablets, have formed an outbreak of new applications which will be used in cases for cellular connectivity and a subsequent exponential growth in network traffic. The main idea that lies behind the development of an optimized SON system is to eliminate the human intervention in the deployed network such that it can effectively upgrade, configure and heal on its own based upon the substantial requirements of the system.

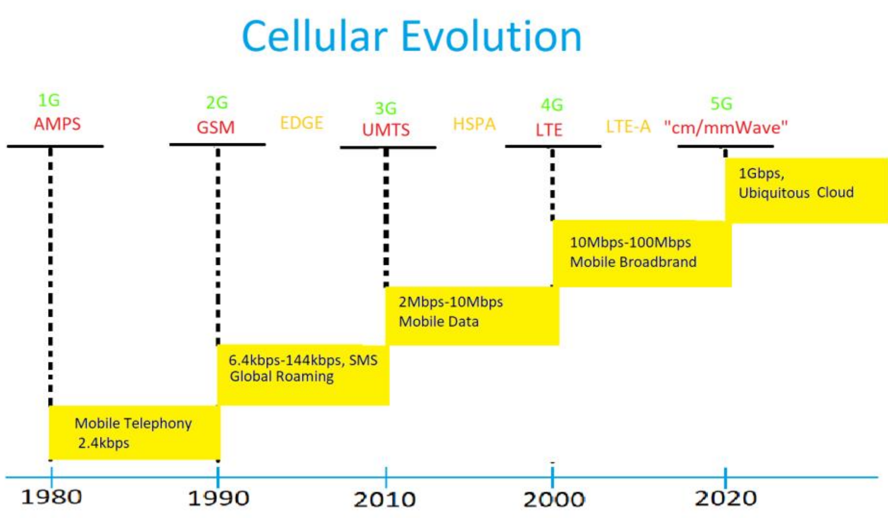


Fig 1. Evolution of Wireless Technology (picture credits to medium.com)

1.1 Motivation & Outline

With the emergence of the different wireless technologies, and heterogeneity in networks a significance increase in the amount of cellular users as well as smart devices has been observed which are predicted to be twice of the world's population. Therefore the service providers needs to enlarge their existing architecture to accommodate such an enormous amount of users as well as to provide enhanced quality of service in terms of connection and communication both. This requires more network equipment deployment thus resulting in more power consumption and large area coverage. In today's fast moving world, one has no time to look into the issues of configurations of devices or different multiple connection problems of networks. Moreover the management of heterogeneous network itself is a huge issue to be taken into consideration, as for the future generation networks, heterogeneity is the essential element of network. . The vision of future generation networks depicts a cellular network with limitless access to information and sharing of data which is accessible for everyone everywhere and every time. To initiate such a vision, new technology constituents need to be reviewed for the advancement of prevailing wireless based technologies. Current wireless based technologies, like the 3rd Generation Partnership Project (3GPP) LTE technology, HSPA and Wi-Fi, will be adapting themselves with new technology constituents to meet the future aspects of network. However, there will be certain scenarios (like catastrophic events) that may not be effectively addressed with the existing ongoing progress of network technologies.

As most of the researchers is working in the domain of predicting the disasters and providing an early warning, there is a need to develop a robust self-adaptable heterogeneous network. This network should be intelligent enough to organize and optimize itself according to the runtime needs of the spanning area. This network should provide self-reconfiguration and self-fault assistance such that network services are not lost or disrupted at times of such catastrophic events.

1.1.1 Drawbacks of Today's Wireless Cellular Network

The today's wireless cellular network is no doubt providing the adequate quality of service along with accommodation to millions of people but this may no longer seems to be providing with the same, as with the increase in the number of years the number of smart devices will also increase with the advancement of IoT, which in turn will require broader spectrum as well as heterogeneous processing network. Also when the number of users will increase their service allocation will require more network equipment which will increase the capital expenditure as well as the cost of maintenance engineer as well. As to manage and maintain the whole network more people will be required since the network cannot be configured on its own, these are some limitations which have become hurdles in the growth of wireless technologies.

Moreover, the telecommunication industry has so far developed versatile technologies for communication over long distances but fails to deliver the service in times of natural and catastrophic disasters. These disasters either man made or natural may occur at any time anywhere furnishing very outrageous results which comprises of huge unpredictable losses including loss of habitat and life as well. These disasters can cause several communication disruption over large scale telecom networks resulting in deprivation of the people from essential network services for a long period of time

1.2 Effects of Catastrophic Disasters All Over the World

Natural disasters are those inimical events which are generated from the natural processes of earth. The examples of such disasters include earthquakes, hurricanes, tsunamis and floods etc. On contrary, there some man-made disasters as well which includes bombing, terrorism, wars etc. The Earth in the past few years has undergone through an enormous number of catastrophic events as shown in figure (1,2). These events not only resulted in the loss of habitat and lives but also the people living in the areas of these events were deprived off from the essential service of cellular technology [3]. At such times of these disasters, the most required platform is communication, with the era of cellular wireless technology it is just a blink of eye to contact someone but when these catastrophic events occur they also damages the base stations and cellular sites as well resulting in loss of connectivity.

Fig2. Earthquake & Tsunami in Japan 2011(photo credits to Encyclopedia Britannica)

Fig 3. Earthquake in Turkey and Syria (Photo credits to BBC News)

1.2.1 How these Disasters Affect Cellular Communication?

All these disasters affect the communication link all over the world, these are mostly derived from the failure of infrastructure which may occur due to following reasons.

1. Destruction of physical network components, such as base stations, RF-antennas, baseband units.
2. Interruptions in network services, such as power failures, maintenance down-time
3. Congestion due to network traffic

Therefore cellular wireless technologies must be designed in such a way that they must provide connectivity as well as communication at times of such events.

1.2.2 Current Disaster Management Systems

The current disaster management systems are merely relying on reconstruction and repair mechanism. All the developed and under-developing countries are spending money on creating a more efficient emergency responses, focusing on the reconstruction and restoration of destroyed equipment in lesser time, making teams of operating engineers that can visit the affected area and adjust mechanism to tackle the network traffics and thus releasing the network services by providing physical support to network infrastructures.

Besides this, the non-advancement of under developing countries have already left them behind in the race of vigorously growing wireless technology. Due to their nature of lacking in the advancements, they are the one which suffers the most in these catastrophic events, and due to unsustainable economy and crises they bear the aftermaths for over years and decades.

1.2.3 Highlighted Challenges & Issues

i. ***Reliability-*** Reliability in the domain of telecommunication industry have always been an unresolved issue. Most of the service providers in the world are still in search for an absolute solution to address this problem. The most important thing that comes in mind when we talk about cellular system is reliability, everyone in this world requires a reliable service such that anyone can access the service whether it is a voice message or data communication whenever it is required without being taking the circumstances such as (weather situations, catastrophic disasters) into consideration

ii. ***Communication & connectivity-*** The other main important challenge is connectivity and communication. Today we live in a fast moving world which requires ubiquitous communication, which simply means that anyone anywhere at any time can connect and establish communication with anyone they want which is far more affected at times of natural and catastrophic disasters. This disasters not only results in loss of habitat and life but also severely affects the cellular communications. The telecommunication industry instead of focusing on the development of a robust network, primarily relying on the maintenance and repair mechanism at times of such disaster which could take weeks or months and till that period the people in affected areas remains unprivileged in terms of cellular services.

iii. ***Heterogeneity-*** The introduction of IoT in devices, along with advancement of 5G has coined the term of a heterogeneous network, such that the smartness will not remain limited to the cellphones, laptops or tablets but will cover each and almost every electronic device such as (refrigerators, air conditioners, lights, fans, ovens, television etc.) in such a way that you control all these devices remotely. So for such development and to provide connectivity among them, there must be a heterogeneous backbone network supporting all the communication standards whether it is cellular, IEEE 802.11(WIFI), or 802.15.4(ZIGBEE).

iv. ***Energy optimization-*** With the increasing number of cellular users, the accommodation factors are also increasing which has given rise to the problem of energy consumption. As we know that energy is the basic driving element for any service and with the exponential growth of users, the requirement of network equipment has also increased which in turn has influenced the demand of energy resources which are to be optimized such that it does not affect the overall cost of the architecture.

v. ***CAPEX (capital expenditure of network equipment)-*** One of the major concerns of the Cellular service providers is the capital expenditure of the network, there is a defined budget for every service provider for the deployment of the network, which is increasing along with the increase in the user, more network equipment is required which has become a biggest challenge. Moreover at times of natural disasters, the company has to rebuild the structure again (including damaged cell sites, baseband units, antennas) which adversely affects their budget so a robust architecture with less capital expenditure and sufficient reliability is required in this regard.

1.3 Proposed Network Architecture

Although several forms of cellular networks will govern in the 2020's, there are also countless challenges to be addressed which are discussed above. Though until recently the research in the telecommunication sector was done in harmony of providing ways for the development of optimized network which comprised of adequate resource allocations, power saving base stations. On the contradictory the disaster events have raised a question towards the researchers of providing a self-sustainable network [4,5]. The disasters either man-made or natural tends to affect the communication sector in the same way it affects the habitat. As we all know the world of today has no meaning and purpose without communication, all we are connected together is by means of communication. An important and crucial part of life has been dictated by the word "communication" and this is the instrument which is severely required at times of occurrence of disasters. The telecommunication industry has so far focused on the reconstruction and restoring of the cell sites damaged in these events, which may take days and months to be restored. However, the idea of an optimized self-organized network with least physical devices may result in a beneficial outcome such that individuals residing in the place of incident will not be deprived off from the communication services and can even contact the respective individuals in order to save their lives on time.

In today's world one may forgot to take his or her wallet or keys on the go but remembers the cellphone as the society in which people live today runs on the commands of smart devices, such as starting up the AC of car, reserving a parking lot for the car, checking the least distance route to the destination. These are some of the tasks which are highly accomplished through cellphone. The disasters such as an earthquake or a blast does not come with an early warning, like hurricane, so for the case of occurrence of such events keeping the general observation in mind that the individuals of this society keep their cellphone along with them all the time can save their lives as well on adequate time.

The main purpose is to design such a system that provide ubiquitous connectivity, communication and connectivity anywhere anytime. The term self-organized network or SON has been introduced in past few years, but its real placement is in the Today's and the future wireless communication technology. Based on the above challenges, a most appropriate solution has been devised which allows to accommodate additional number of users on the same network in all circumstances. The designed network will be able to adjust itself according to the number of available resources.

To overcome above mentioned challenges of service deprivation and power optimization that are initiated due to such disaster threats both algorithm LEACH and collaborative codes are explored to develop an integrated architecture of network which incorporates the benefits of both, thus providing a more optimized self-organizing network which will provide basis for next generation networks. The proposed system will be capable of managing and catering a heterogeneous network which will be incorporating all the developed wireless communication technologies used today and in the future as well such as cellphone communication network, device to device communication network, IoT wireless communication network based on WIFI (802.11) and Bluetooth Low Energy (802.15.1) and wireless sensor network (802.15.4) as shown in figure 5.The decisions to be taken by the network itself based on the configuration and real time scenarios network must adapt itself accordingly such as if the one or two cell sites suddenly goes down which can happen due to uncertain circumstances so in such situations the network may shift its traffic and parameters to the other nearby cell sites covering that particular area such that the communication may not be disrupted. This task should be done by the network itself without the involvement of any physical entity or operator. An optimized self-organizing network will be able to do such job on its own.

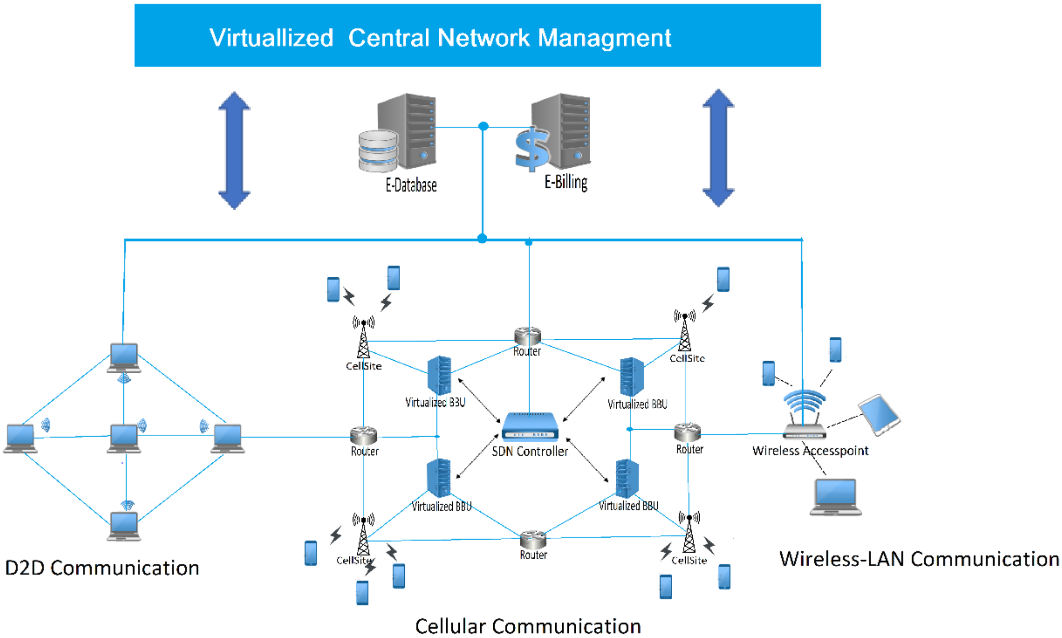


Fig 4. Proposed SON Architecture

CHAPTER TWO

2 Background

The rapid expansion of bandwidth-hungry apps like video streaming and multimedia file sharing will cause a significant shift in user behavior that will define the future of wireless cellular communication infrastructure. The demand for mobile broadband is increasing at an unprecedented rate, particularly with the introduction of numerous smart handheld gadgets. This change in user behavior puts cellular communication systems under a lot of strain in terms of capacity, Quality of Service (QoS), and energy efficiency.

The number of nodes in future cellular systems will be too large to be configured and maintained for routine operation with traditional and field trial based design approaches due to the recent introduction of femtocells and the increasing deployment of outdoor relays or Pico cells in the search for capacity and QoS [6]. This is especially true for femtocells because they will be set up on-the-fly with plug-and-play capabilities and may, if not given self-organizational skills, cause serious interference and degrade the performance of nearby macro cells.

2.1 Self-Organizing Networks

As cellular networks becoming denser and more varied, self-organization becomes a crucial component. Self-configuring, self-optimizing, and self-healing are all capabilities of self-organizing networks (SONs). These activities may include simple chores like setting up a recently installed base station (BS), managing network resources, and managing network faults [7].

Configuring the transmit power at various small BSs to manage interference is one of the key duties of SONs. In actuality, a small BS must set its transmit power before connecting to the network (as self-configuration). So, while operating in the network, it must dynamically manage its transmit power (as self-optimization). We take into account a macrocell network with small cells overlay in order to handle these two problems. We concentrate on autonomous distributed power control, a crucial component of self-organization because it increases network throughput [8,9] and reduces energy consumption [10,11]. We build an optimized SON framework that can continuously enhance the aforementioned performance metrics by using LEACH algorithm and collaborative codes.

2.1.1 Wireless Sensor Network

In recent years, wireless sensor networks (WSNs) have drawn attention from all over the world, in part because of the widespread use of Micro-Electro-Mechanical Systems (MEMS) technology, which has eased the creation of smart sensors. In comparison to conventional sensors, these sensors are less expensive, smaller, and have less processing and computational power. These sensor nodes have the ability to sense, quantify, and gather data from their surroundings. Based on a local decision-making process, they can then relay the perceived data to the user. Low power devices called smart sensor nodes come with one or more sensors, a processor, memory, a power source, a radio, and an actuator. To detect environmental characteristics, a sensor node may be equipped with a range of mechanical, thermal, biological, chemical, optical, and magnetic sensors. A radio is implemented for wireless communication to transport the data to a base station (such as a laptop, a personal handheld device, or an access point to a fixed infrastructure), as the sensor nodes often have limited memory and are placed in challenging-to-reach locations. A sensor node's main power source is a battery. Depending on how suitable the environment is for the deployment of the sensor, a secondary power source that draws energy from the environment, such as solar panels, may be added to the node. Actuators may be built inside the sensors, depending on the application and the chosen type of sensor [12]. Security, industrial automation, remote exploration, and medical monitoring are just a few of the applications that will be made possible by low-cost links between the real world and telecommunications networks made possible by wireless sensor networks.

A WSN differs from conventional networks in that it has its own design and resource limitations. Constraints on resources include a limited energy, constrained processing and storage capacity in each node, constrained bandwidth, and short communication range. Design restrictions rely on the application and are based on the environment that is being watched. The environment is a major factor in deciding the network's size, deployment strategy, and architecture. The network's size changes depending on the environment. When the environment is inhospitable to people or the network has hundreds to thousands of nodes, an ad hoc deployment is preferred to a pre-planned deployment. Environmental obstacles can also restrict communication between nodes, which has an impact on the network's connection (or topology).

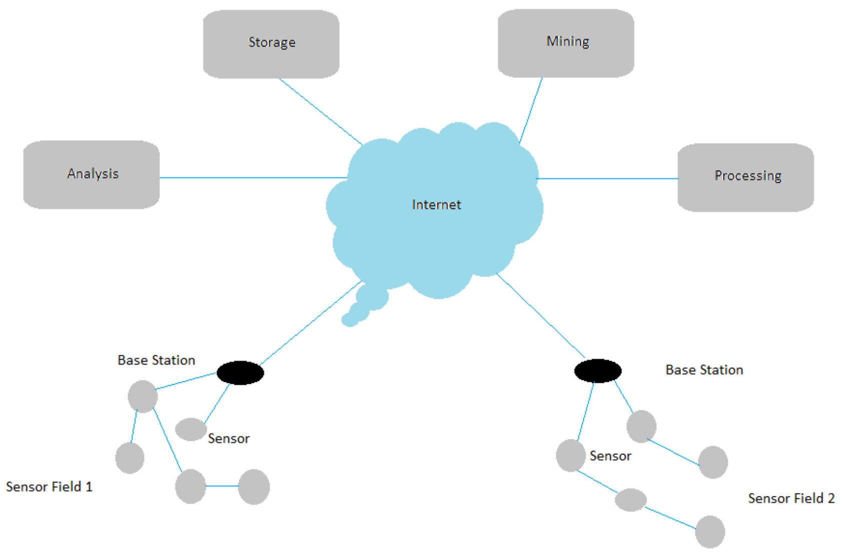


Fig 5. Architecture of wireless sensor network (WSN)

In order to address the aforementioned constraints, research in WSNs employs novel design ideas, brand-new protocols, updated protocols, new applications, and novel algorithms. This chapter presents a top-down assessment of various protocols and algorithms proposed in recent years.

2.2 WSN Routing Protocols

WSN offers a wide range of potential applications, including monitoring habitat and temperature, managing disasters, and conducting military reconnaissance, security monitoring, among several other things. The majority of the time, battery-powered sensor nodes are randomly dispersed. Although battery replacement for sensors frequently is not possible, the routing method utilized in these types of networks should assure minimal energy use. In accordance with Nikolaos et al. [14], there are four categories into which routing protocols can be sorted: Network Structure Scheme, Topology Based Scheme, Communication Model Scheme, and Reliable Routing Scheme. The network structure schemes can further be classified into two types based on the placement of nodes in the network: Flat routing and Hierarchical routing. While considering architecture of both routing schemes, flat routing has a scalability issue and is therefore only preferred for small area networks while hierarchical routing is energy efficient and it has a larger scalability as compared to flat routing protocol. In a hierarchical routing scheme, nodes are chosen to act as special nodes based on pre-set criteria once the network has been divided into clusters. These unique nodes, referred to as cluster heads (CHs), gather, assemble, and compress the data received from neighbouring nodes before transmitting the compressed data to the BS. The CH uses more energy than other nodes in the cluster because it offers extra services to other nodes in the cluster. A popular strategy used to balance energy loss inside a cluster is cluster rotation. Typical hierarchical routing protocols include threshold-sensitive energy-efficient sensor network (TEEN) protocol, power-efficient gathering in sensor information systems (PEGASIS), low-energy adaptive clustering hierarchy (LEACH), and hybrid energy-efficient distributed (HEED) clustering approach. These protocols can group nodes into clusters to form a particular hierarchy. Since we have focused on the development of an optimized SON network therefore we have taken LEACH and its versions into consideration.

2.2.1 LEACH

Heinzelman et al. [15] proposed the first hierarchical routing protocol, called LEACH. The Low Energy Adaptive Clustering Hierarchy (LEACH) MAC protocol is based on TDMA. By reducing the energy consumption needed to establish and maintain Cluster Heads, this protocol's major goal is to increase the longevity of wireless sensor networks. The LEACH protocol's functionality consists of multiple rounds, each with two stages set-up stage and steady stage. The major objective of the setup stage is to combine the sensor nodes into clusters and choose the cluster leader for each cluster by selecting the sensor node with the most energy. Steady Phase, which lasts longer than set-up in comparison, focuses on data aggregation at cluster heads and transmission of aggregated data to the base station (sink node).The main characteristics of LEACH are as follows:

i. For cluster setup and operation, localized coordination and control are required.
ii. Rotation of cluster's "base stations" in a random order.
iii. To cut down on global transmission by using local compression.

2.2.2 Drawbacks of LEACH Algorithm

vi. **Number of Cluster Heads-** LEACH does not give any accurate number for the cluster heads.

vii. **Reliability-** One of the main drawbacks of LEACH is that if the Cluster Head dies for any reason, the Cluster would be rendered worthless because the data collected by the Cluster Nodes will never reach the Base Station.

viii. **Energy Deprivation-** Since the nodes are randomly distributed, there is also a chance of uneven distribution of nodes to cluster head. For instance, some clusters have more nodes than others. Some cluster heads may be in the heart of the cluster, while others may be on the edge; this occurrence can increase energy consumption and have a significant impact on how well the network functions as a whole.

2.2.3 LEACH-C (Centralized LEACH)

All choices in the centralized LEACH-C protocol, which determines the CH, cluster formation, and information distribution across the network, are made by the BS. LEACH-C makes excellent clusters by dispersing the CH across the sensor network. Since the steady state phase is entirely implemented at the BS, there is no overhead for sensor nodes during cluster formation. The setup process for LEACH-C with the LEACH approach is identical. In the case of centralized LEACH, the BS determines the average energy of all the sensor nodes in the network, and if their level of energy is lower than the average energy, those nodes are not permitted to take part in the CH selection process for that round. Using a simulated annealing algorithm, the BS creates K optimum clusters from the sensor nodes whose average energy is higher than average energy [18]. This is how the average energy is determined:

$$\boldsymbol{E_{avg} = \frac{\sum_{i=1}^{N} E_i}{N}} \tag{1}$$

Where E_i is the residual energy of i^{th} node and N represents the number of nodes present in the entire network. The cluster formation equation is given below:

$$\boldsymbol{\sqrt{\frac{N\epsilon_{fs}}{2\prod\epsilon_{mp}}}\ \frac{M}{d_{toBS}^2}} \tag{2}$$

Where d_{toBS} represents the distance between CHs and BSs. The ε_{mp} and ε_{fs} are representing the circuit of transmission reception in free space and multipath fading. Once the process of CH selection is over the BS broadcast the message to all sensor nodes and the rest of the steady state phase is similar to LEACH algorithm but sue to centralized management it is less scalable.

2.2.4 Sec-LEACH (Security LEACH)

The primary defence against attacks like sinkhole and selective forwarding assaults is the security-based LEACH protocol Sec-LEACH [19]. When Sec-LEACH is deployed, a large number of key pools and their IDs are created. A ring of key pools is pseudo-randomly assigned to each node when using pair-wise key sharing with the BS. The CH selection broadcasts the IDs and a special identifier for the chosen CHs, similar to LEACH. The other sensor nodes calculate the IDs of the CHs, select the CH that is nearest, and then send a join request message. CHs transmit a TDMA schedule to each member of their cluster. The join request message generated by MAC is encrypted with the same shared key that secures transmission between sensors and the CH. Using a value obtained from the unique identifier, the reply including reporting cycle is stopped. The CH combines the message that has been decrypted and sends it to the BS using a symmetric key that is shared for security. In terms of preserving network security overall, Sec-LEACH has done better than average, however because of the extra security measures and IDs required, network lifetime has been reduced.

TB-LEACH (Time Based LEACH)

A protocol in which the CH is chosen on threshold based on time interval known as time based LEACH was proposed by Junping et al. [20]. In the race to become the CH, the nodes with the shortest time interval triumph. There is a counter that can be used to obtain the given constant value for CHs. Each node generates a random number at the beginning of each round. The node proclaims itself to be a CH and broadcasts a CH advertisement message using the CDMA MAC protocol if the number of CHs in the advertisement message is less than the constant value of CHs. The remaining steps are comparable to LEACH when the CH is chosen. As it doesn't need global knowledge to construct clusters, it is a completely distributed method. It has significantly increased the network lifetime but due to distributive nature it does not have the ability to support large scale network.

2.2.5 LEACH-H (LEACH Hybrid)

Two protocols centralized LEACH and LEACH were explored in order to build a hybrid algorithm that incorporates the functionalities of both. Wang et al. [21] proposed this hybrid protocol which solved the problem of formation of indeterminate number of CHs each round. This protocol favours the fixed number of CHs for each round. It is based on iterative CHs selection process and consist of collection c, which is used to represent CH list and ć which represents new CH list. The succeeding CH is selected on the basis of following equation:

$$P_k = \begin{cases} e^{\frac{-\left(f(c')-f(c)\right)}{\alpha_k}} & : if\ f(c') \geq f(c) \\ 1 & : if\ f(c') \leq f(c) \end{cases} \tag{3}$$

Where P_k is the probability of CH list selection, while f(c) and f(ć) represents energy consumption of network and α_k are controlling parameters to guarantee the CH convergence. The enrgy consumption of network whose CH list collection is c can be calculated by the given formula below:

$$f(c) = \sum_{i=1}^{N} mid\ d^2(i, c) \qquad (4)$$

This protocol has shown to have longer network lifetimes in large networks, however it has more overhead because current CHs choose new CHs lists.

2.2.6 MOD-LEACH (Modified LEACH)

Mahmood et al. [22] have developed a new variation of the LEACH methodology called Modified LEACH (MOD-LEACH) to address its flaws. This protocol makes use of two different methods for signal amplification for intra- and inter-cluster communication. When communicating internally, a low-amplified signal is employed, and when communicating externally, a high-amplified signal. This approach can conserve a lot more energy than LEACH, which use the same signal amplification for both intra- and inter-communication. MOD-LEACH has altered two of LEACH's key weaker areas: Each round's CH is different, but both intra- and inter-round communications use the same amplification signal. It performs better in terms of energy consumption and network lifetime when compared to LEACH. This protocol has several problems, two of which are the amplification of signals in two different modes and their synchronization.

2.2.7 V-LEACH (Vice Cluster Head LEACH)

In the fundamental LEACH algorithm, the CH is chosen using a probability without taking into account the power of nodes. This results in a bad choice of CH because certain CHs may pass away owing to extremely low energy before the end of the current round. In order to solve this issue, Sasikala et al. [23] proposed the concept of a vice CH, who takes over as CH in the event that the original CH passes away before the end of the current round. Similar to the basic LEACH process, the sensor node with the most energy stored is chosen as the original CH, and the vice CH is chosen using the same manner. As a result, each cluster in the V-LEACH protocol has three different kinds of sensor nodes: the CH (which receives data from member nodes), the member nodes (which sense the environment), and the vice CH (which takes the CH's place in the event that the original CH dies). The steady state phase of V-LEACH and the basic LEACH approach are the same. This protocol uses two CHs as compared to one in LEACH, which improves data transfer efficiency. This protocol has overhead and scalability problems because there is a second CH and only one hop in communication between the CH and the BS, respectively.

2.2.8 Comparative Analysis

Table format is used to offer a comparative study of all the aforementioned LEACH versions. These clustering protocols are examined based on a variety of criteria, including routing type, energy efficiency, location data, mobility, scalability, overhead for cluster creation, and approach for cluster formation (distributed or centralised or both (Hybrid)). The basic LEACH has some important limitations even though it is energy-efficient, as was already mentioned. More effective LEACH successors have been created, which are covered above, to address these problems. In a number of areas, including energy efficiency, scalability, CH selection, and cluster formation, these protocols outperform basic LEACH. Since sensor nodes are energy-constrained, the majority of LEACH variant protocols are created to consume as little energy as possible. However, several aspects, such as cross-layer approaches, optimization, data transfer, duty cycle, etc., are not completely investigated in LEACH variations.

Table:1 Comparative analysis of LEACH protocol and its variants

LEACH and its variants	Year	Energy efficient	Approach	Overhead	Load Balancing	Difficulty	Procrastination
LEACH	2000	Moderate	Distributed	High	Bad	Low	Shorter
LEACH-C	2002	High	Centralized	Low	Moderate	Moderate	Shorter
Sec-LEACH	2006	Low	Distributed	Very high	Moderate	Very High	Shorter
TB-LEACH	2008	Moderate	Distributed	High	Good	High	Shorter
LEACH-H	2009	High	Hybrid	High	Moderate	High	Longer
MOD-LEACH	2013	High	Distributed	Low	Good	High	Shorter
V-LEACH	2015	Very High	Distributed	High	Good	Very High	Longer

Nevertheless, the following are the primary goals for creating LEACH variations protocols for WSNs:

a. WSN communications that use little energy.
b. An increase in scalability.
c. Enhancing WSN security.
d. Reduction of network latency.
e. A decrease in complexity.
f. Context-specific connectivity assurance.
g. An even distribution of load over the whole network.
h. An improvement in WSN's general performance.

The researched literature and the table that are shown unmistakably show that the development of an appropriate self-optimizing protocol largely depends on the network requirement.

CHAPTER THREE

3 Proposed Network Architecture

In the previous chapter we have reviewed different variants of LEACH algorithm and their advantages in accommodating users, maintaining energy reservoir for nodes as well. But with increasing traffic and advanced demands of users it is still a universal issue to allocate the same bandwith to the increasing number of users keeping the network structure optimized. In this regard we have also studied the collaborative codes and their uses in multiple medium access channels as they provide far better results than the novel TDMA schemes. To address the issue of engaging increased number of users on a single network along with reserving the energy we have developed an integrated architecture of two major medium access algorithm that will provide significantly better results in terms of network efficiency and optimization. The low energy adaptive cluster hierarchical protocol is combined with collaborative codes to ensure a more scalable and energy constrained network. This chapter presents the detail of collaborative codes and the integrated architectural network of LEACH and collaborative codes.

3.1 Collaborative Codes

The term collaborative codes are not new, they were first introduced in 1978 by Wolf JK [24]. More users (U) each time step may access a communication channel using the collaborative coding multiple access (CCMA) technique. Many codes are available in the open literature, including: 2 user codes, 3 user codes, and 5 user codes [25, 26, 27]. Each user is given a special code that it uses to encrypt its data. Code words are sent simultaneously on the channel by many users, where they add up. The decoder (or decoders) can extract the information sent by each user and transmit it to its intended destination because each of the channel sums is distinct. As opposed to TDM or FDM (time or frequency division multiplexing), a CC allows numerous users to use the channel at once, resulting in a higher bit/channel utilisation. Before transmission, the channel codes the signals from each user. When communicated simultaneously, the coded symbols total up to the direction.

3.2 Integration of LEACH and 5-User CCs

In the era of this fast moving world, more heterogeneity will be introduced in the network along with micro and Pico cells infrastructure in the upcoming time which will simultaneously increase the number of users, since every household device will move towards AI and smartness. To accommodate such huge number of user a network infrastructure must be strong enough to support the respective users and provide them adequate quality of service. In conditions of any natural or catastrophic disasters, along with human fatality rate and loss of habitat, we as a developing and struggling country also suffers from damages of cellular infrastructure which affects overall connectivity. Therefore, we have presented our study in this regard.

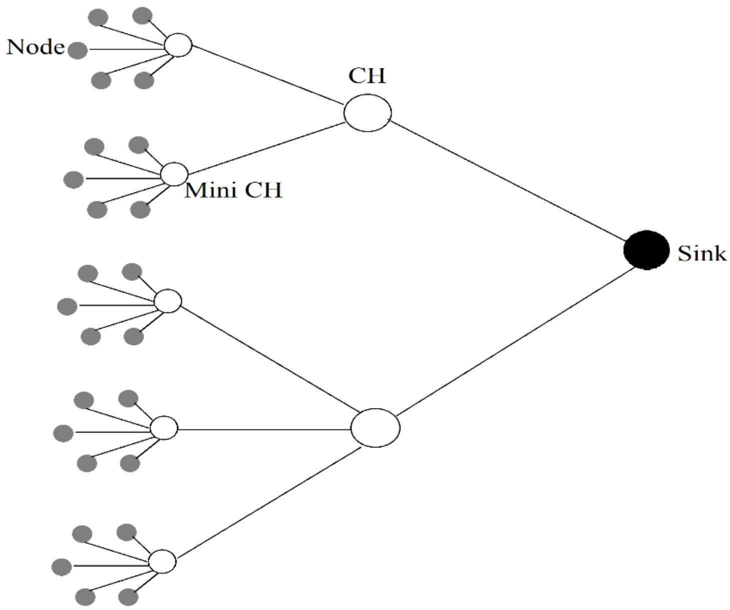


Fig 6. Integrated network architecture

Our algorithm is based on the benefits of both LEACH and CCs. LEACH algorithm is itself a TDMA based protocol which is used to improve the lifespan of wireless sensor network by constraining the energy consumption. As discussed in previous chapter about LEACH , our algorithm has two phases.

i. The set-up phase
ii. The steady-state phase

3.2.1 The set-up phase

In setup phase, the number of nodes and respective rounds are initialized and an average of energy is calculated. The average energy is set as a threshold level for each node to become a cluster head After energy calculation, the number of nodes participate in the pooling of becoming a cluster head. |The number of nodes whose energy is more than the threshold level becomes the cluster heads and the neighboring nodes connect to their nearest cluster head. In addition to this we have also created mini cluster heads for each of the five nodes. The duty of mini cluster heads is to combine the data received from each of the five nodes using 5-user CCs and transfer it to cluster heads which then will combine the data and forward it to sink node or base station. In this way the number of nodes which was transmitting the data in actual LEACH algorithm will now transmit five times the original data which will increase the over all scalability of the network.

3.2.2 The steady-state phase

After the selection of cluster heads, the number of nodes are now ready for transmission. In steady state phase, the sink first synchronize the number of nodes by broadcasting a hello message. Once the nodes are synchronized then it starts to send data. Firstly each of five nodes sent their data packet to mini cluster heads. The mini cluster heads then combine the data using the five user collaborative codes and forward it to cluster heads, which in turn receives data from multiple mini cluster heads and aggregate the data and send it to sink node where the data is received and decoded. The flow chart of proposed network architecture is given below.

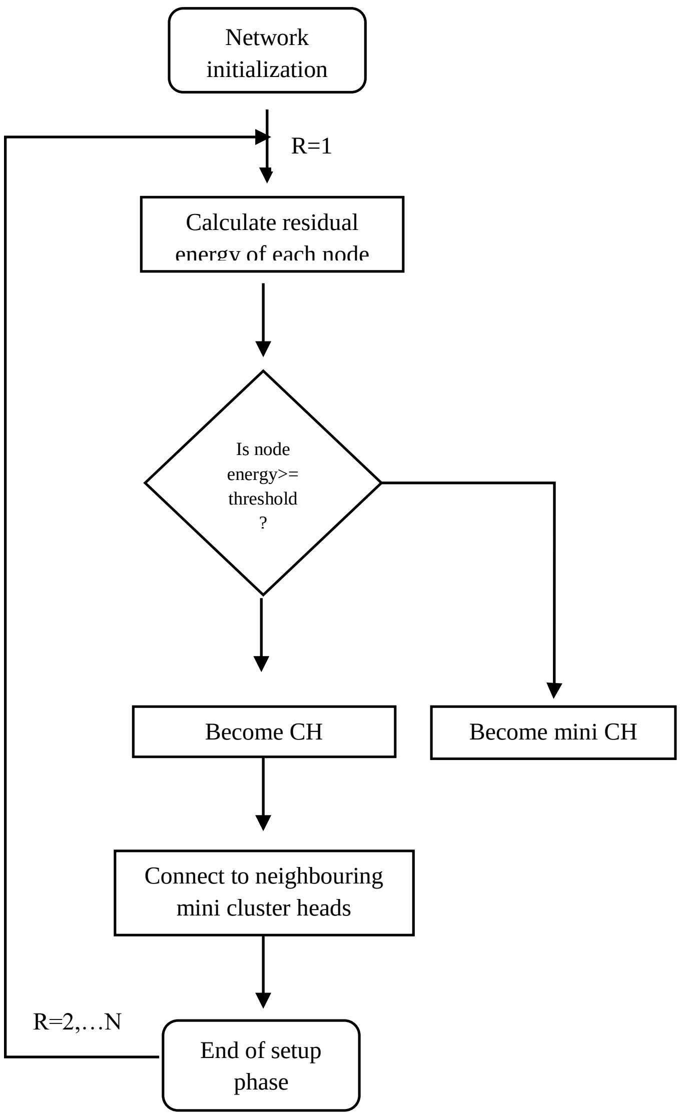


Fig 7. Flowchart of set-up phase

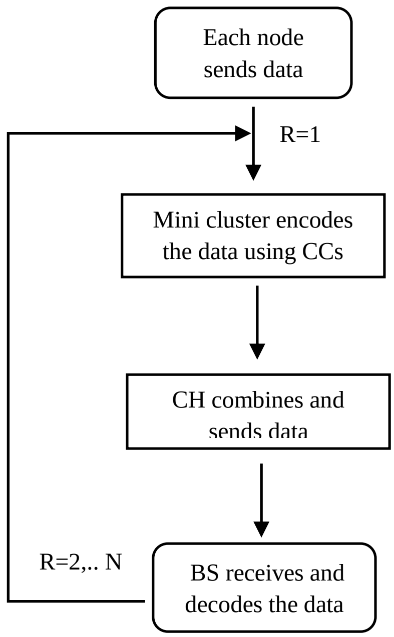


Fig 8. Flowchart of steady-state phase

The number of nodes in LEACH were only capable of transmitting a limited data and each Cluster head take single timeslot for sending data while in integrated approach using collaborative codes each mini cluster is able to transmit data of five nodes in single timeslot thus saving the energy resources and time slots as well along with providing an increase in number of data packets. Thus, overall network efficiency is approved along with maintaining a high data rate. The integration of 5-user collaborative code has increased the network throughput to five times of the original one. The next chapter presents simulation results and graphs.

CHAPTER FOUR

4. Mathematical Modelling

The fundamental mathematical model that was used to create the integrated system is laid forth in this chapter. All the steps required to simulate a program or a system are incorporated in a mathematical model. Additionally, it partially validates the system and aids in troubleshooting any problems. Our system, as we've already mentioned, combines two fundamental algorithms. The LEACH algorithm comes first, followed by CCs. We all know that WSN networks are made up of low power devices, thus they are energy constrained, and hence the goal behind the addition of CCs to the revolutionary LEACH algorithm is to expand the number of users while also making the system more energy efficient. Our system like LEACH is divided into two phases;

i. Node initialization phase
ii. Constant phase

.

4.1 Node Initialization

In the first stage, the senor nodes are initialized with a random number (250 nodes for our case). Then the initial energy for each node is set. After setting the initial energy, the average residual energy is calculated for cluster formation. The main goal of the current stage is to organize the sensor nodes into clusters, with each cluster's cluster head being the sensor node with the most energy.

There are three essential steps in this phase:

i. Advertisement for cluster heads
ii. Deployment of cluster
iii. Setting up communication timetable

The cluster head informs the cluster nodes during the first stage that they have taken over as the cluster head by sending an advertisement packet, as per the aforementioned formula. X could be chosen at random from 0 to 1. Where G denotes the collection of nodes that did not serve as cluster heads in the previous round, r denotes the current round, n denotes the given node, p denotes probability, and T(n) denotes the Threshold [16].

$$T(n) = \begin{cases} \frac{P}{1-P\left[r*mod\left(\frac{1}{P}\right)\right]} & if\ n \in G \\ 0 & otherwise, \end{cases} \quad (1)$$

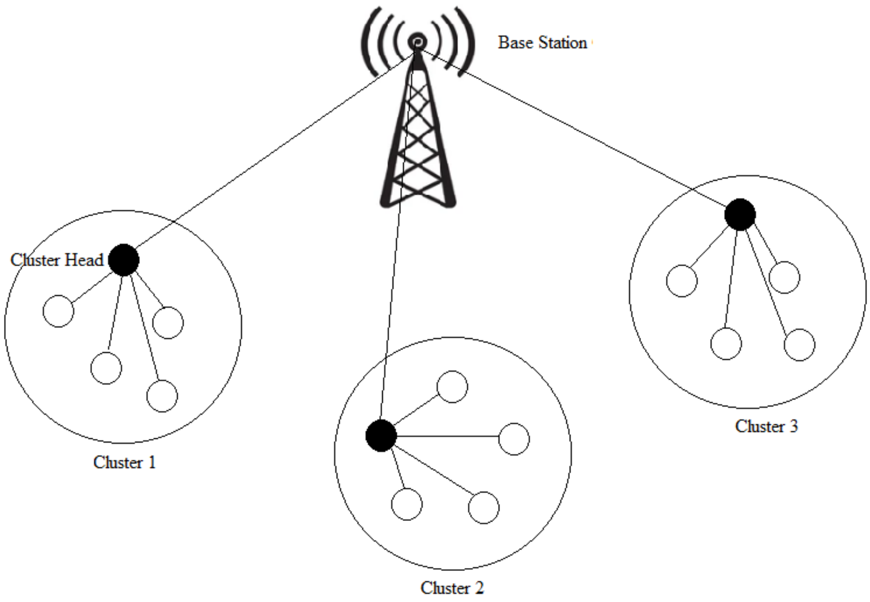


Fig 9. Formation of clusters in LEACH

The node is chosen as the cluster head for the current round if the value is less than threshold T(n). Once a node has been elected to act as the cluster head, that node cannot be chosen to fill that role once more until all of the cluster's nodes have done so. The outcome is a balanced use of energy. The non-cluster head nodes continue by sending the cluster head a join request informing them that they have become a part of the cluster under that cluster head upon acquiring the cluster head advertisement, as shown in Fig. 9 [17]. These non-cluster head nodes save a large amount of energy by primarily shutting off their transmitter and only turning it on when they have data to relay to the cluster head. Each node functions as a miniature cluster head that combines the advantages of cooperative codes. The data from each node is coded by the small cluster head before transmission. The encoded symbols are transmitted all at once, adding up in the channel. The choice of CC codewords ensures that every combination of sent symbols is unique. The receiver can then decode this combined message to reveal its individual codewords. A two user code is given as an example in the following table.

Table:2 Channel sum for a 2-user collaborative code scheme

User Bits	**Code word U_1**	**Code word U_2**	**Channel sum**
00	00	01	01
01	00	10	10
10	11	01	12
11	11	10	21

For communicating their respective "0" and "1" bits, users 1 and 2 are given the code words (00, 11) and (01, 10) respectively. Since two encoded bits are transferred for every user bit, the individual coding rate is 0.5 and the overall rate is 1. Although no code gain is realized in this case, the two-user code is a nice illustration of how collaborative codes work in their most fundamental form. While employing CC, each user's bits are individually encoded before being delivered simultaneously into the channel, where the associated code words from every user come together to create a single multi-symbol multi-level CC code word. Each set of transmitted symbols is uniquely combined thanks to the way the CC code words are chosen. This combined message's individual code words can be decoded by the receiver and sent to the appropriate users. A K-user CC is created mathematically to meet the following requirements:

$$sum(i) = \sum_{j=1}^{K} c_i \qquad i = 0, \dots, n, m, \dots . N-1 \tag{6}$$

$$sum(m) \neq sum(n) \forall m, n \qquad m = 0,1,2, \dots \dots, N-1$$

$$n = 0,1,2, \dots \dots, N-1$$

where sum I is the symbol-by-symbol addition of the N possible combinations of the binary codewords of the T-users, and $N=2^K$ is the number of input combinations available. C_j represents the equivalent multi-bit binary code word for sending a '0' or a '1' from each of the K-users. These N sums I are all multi-level, multi-symbol CC code words. In comparison to Chang and Weldon's codes [27], two codes are described that utilize less power to transmit information and have a lower probability of error. The list in the table 3 is given for conversion of data of five users whether they have sent ‘0’ or ‘1’.

Table:3 Group of 5-user codes

S.No	User Data #1		User Data #2		User Data #3		User Data #4		User Data #5	
	0	1	0	1	0	1	0	1	0	1
1	0	1	0	2	1	6	3	4	7	2
2	0	1	0	2	2	5	4	3	1	7

Table:4 Code word symbols

User Data(U_1,U_2,U_3,U_4,U_5)	**Code word**
00000	123
00001	022
00010	212
00011	111
00100	232
00101	131
00110	321
00111	220
01000	133
01001	032
01010	222
01011	121
01100	242
01101	141
01110	331
01111	230
10000	124
10001	023
10010	213
10011	112
10100	233

10101	132
10110	322
10111	221
11000	134
11001	033
11010	223
11011	122
11100	243
11101	142
11110	332
11111	231

Table 4 comprises the 32 potential combinations of the two codes from 00000 to 11111, listed in order, of the summations of the symbols that indicate the channel outputs. This 5- user CC has an overall code rate of 1.67 which is far better than any other codes presented in previous years. The next step involves the creation of a transmission schedule by each of the selected cluster heads for the nodes that make up their cluster. TDMA schedules are developed based on the cluster's node count. After that, each node broadcasts its data according to the scheduled time.

4.2 Constant Phase

In this phase, Cluster nodes continuously transmit the coded data to the cluster head. Each sensor cluster's member sensors are only able to send a single hop transmission to the cluster head. The cluster head compiles all the gathered data and delivers it to the base station either directly or via another cluster head, along with the static route provided in the source code. After a predetermined period of time, the network moves back to the node initialization stage.

CHAPTER FIVE

5 Simulation & Results

This chapter compares and validates the suggested integrated LEACH and CCs scheme. Firstly, we designed and implemented a simulation of wireless sensor network by using MATLAB tool. Software like MATLAB offers comprehensive coverage for all disciplines, including wireless sensor networks. The allocation of resources and utilization of energy was observed. Lastly, a comparison of the suggested method with the wireless sensor network's LEACH algorithm is carried out.

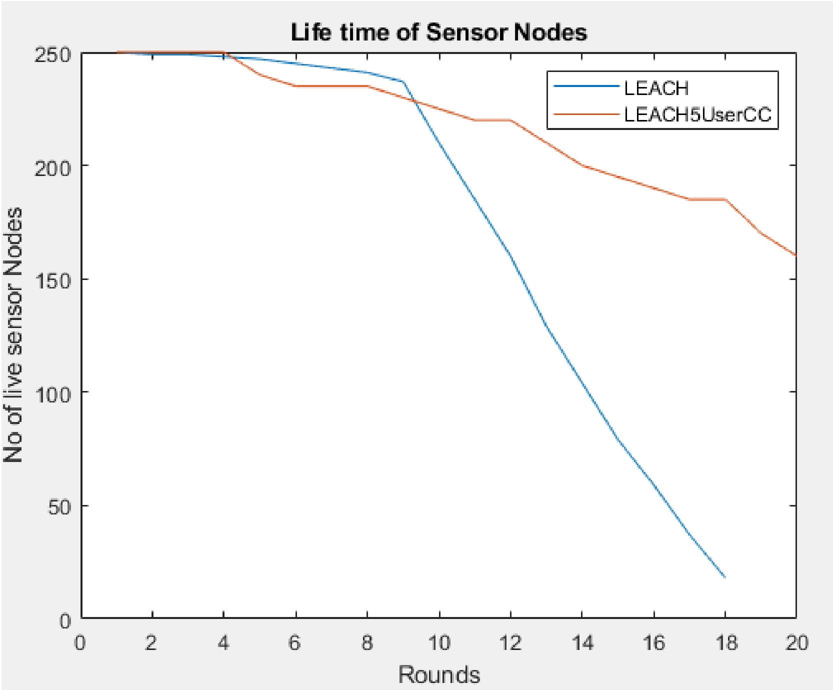
5.1 Experimental Results

We take into account 100 nodes in our simulated WSN. The distribution of the nodes is random. Table 5 lists the parameters of the simulation experiments. It allows us to observe a sensor's metrics and behaviour and assesses how well the suggested schema performs.

Table:5 Simulation Parameters

Parameters	**Values**
Number of sensor nodes	250
Area of simulation (in meters)	1000 x 1000
Probability of a node for CH selection	0.1
Initial energy of node	2 Joules/node
Protocol	Integration of LEACH and CCs

We have simulated the integrated scheme of LEACH and CCs for wireless sensor network and then compared the results with the novel LEACH algorithm [27]. Since nodes in wireless sensor networks are energy-constrained and hence unable to extend their lives, node life is a key component. As can be seen in figure 10, the combined strategy has so far produced noticeably better results than the innovative LEACH algorithm. The figure clearly shows that the number of dead nodes in novel LEACH algorithm was more as compared to the combined approach. This means that the energy utilization in LEACH was more than this one. Our algorithm has significantly achieved better results as the number of live nodes has decreased drastically in LEACH algorithm while it has a stable condition in combined approach.



. *Fig 10. Life time of alive sensor nodes of LEACH and 5-user CCs*

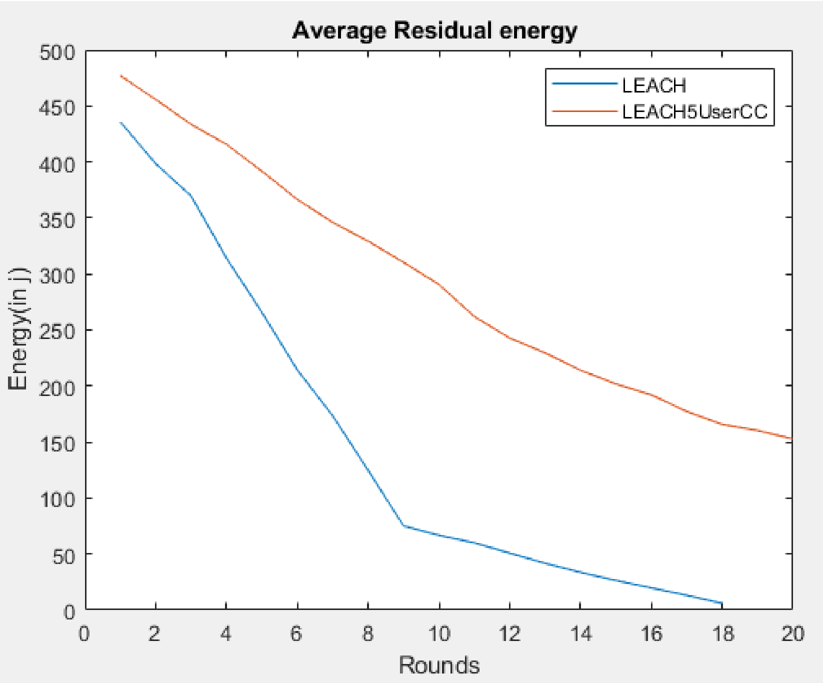


Fig 11. Average Residual energy of nodes

In figure 11, the average residual energy of node is calculated for each round. The proposed scheme has shown improved effectiveness in terms of energy usage. The combine approach has provided better energy conservation rather than the novel LEACH algorithm in which nodes are dropping their energy at a very fast rate. In the novel LEACH, a single node transmits data for a single time slot, consuming a lot of energy, whereas in the combined approach, a single hop consists of the data from precisely five nodes, increasing its capacity and energy efficiency. We merged our data transmission statistics as well, and the results we got in terms of data transmission were noticeably better. Our combined approach allows nodes to send their data packets while also conserving energy, whereas the novel LEACH algorithm on average for 250 nodes was able to send 250 data packets for each round. However, as the nodes die out due to energy drain, they are unable to participate in the steady-state phase and as a result, the count of data packet is declined to a very low number.

In addition, although LEACH requires 5 time slots for the transmission of 5 bits, our system can only accomplish this with the aid of a single time slot and CCs. Our system uses an encoding method specified by CCs to transmit the bits; as a result, there are more data packets transmitted in our combined approach than in the LEACH algorithm. Figure 12 compares the data packet transmission between the two systems.

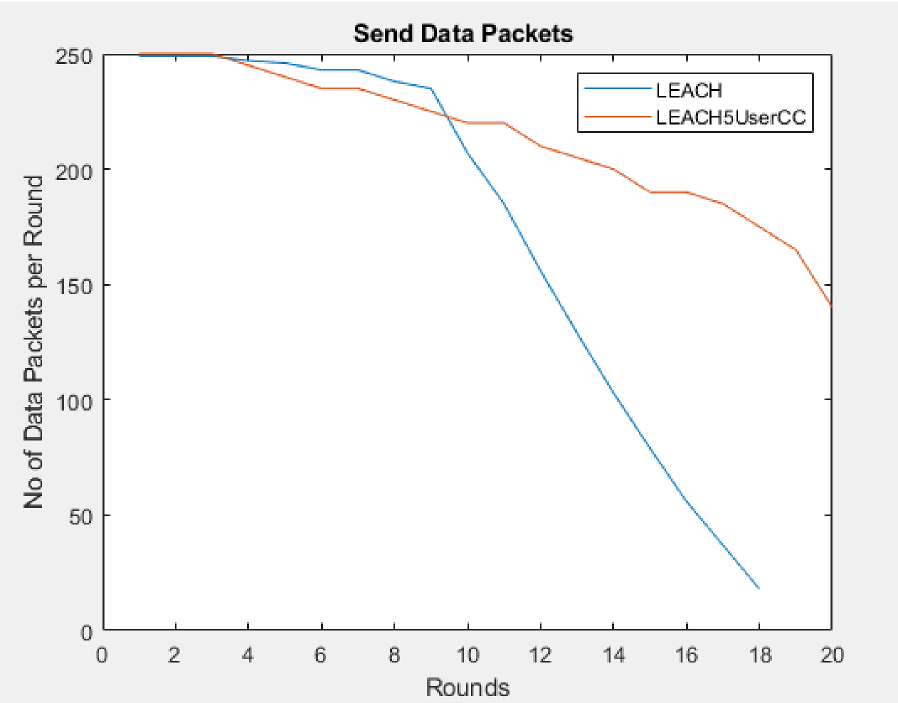


Fig 12. Number of data packets sent over each round

5.1.1 Validation of resource allocation

Resource distribution has always been a difficult task in WSN. It is difficult to increase the number of users on a shared bandwidth while maintaining QoS. This has been partially accomplished by the LEACH algorithm, but it still has certain limitations. Our merged strategy has proved to be essential in helping us accomplish this goal. With this integrated system, we can allocate resources up to five times more efficiently than with the cutting-edge LEACH algorithm. Combining LEACH and 5-user CCs has shown to be a very efficient resource allocator.

5.1.2 Validation of Energy efficiency

In the modern world, when energy conservation is becoming progressively more important, having an energy-efficient network is crucial. It is clear from the results above that the combined strategy greatly conserves node energy because it transmits the data in less time, which saves the energy of the node as compared to the novel LEACH algorithm. Both strategies are carefully implemented in order to achieve effective energy utilisation for the entire network. Our primary objective was to increase energy efficiency, which we did by using a combination of strategies.

CHAPTER SIX

6 Conclusion

Most of the under developing and developed countries have been focusing on the repair mechanism of cell sites and service issues. Yet another solution has been proposed such that which will facilitate the users all time including uncertain circumstances as well.. For repair mechanism, the service providers have to send a team of maintenance and operating engineers physically to the site along with the network equipment which was far more costly and time consuming. The advent of such system will not only provide benefits to the service providers but also to the users in such a way that service will not be pulled-down and the need of sending a physical team will be eliminated because the deployed network is based on the novel term of self-organizing network which simply implies that it is self-adapting, self-healing and self-localizing.

Along with the introduction of a heterogeneous network which is a mixed composition of cellular network, wireless sensor network and IoT network, more robust network infrastructures are required therefor the integrated approach of LEACH and five user CCs will provide a significantly more strong network. It will be a perfect match of more power optimizing yet centrally controlled network. It will also permit to shift more users on shared bandwidth at times of these damaging events.

The proposed integrated system when compared to novel LEACH algorithm has outperformed in every domain including energy conservation as well. But the system still can be more optimized by integrating with different variants of LEACH algorithm.

6.1 Future advancements

As defined above few challenges have been addressed with the proposed system, the robustness is increased in times of disasters, and moreover the heterogeneous networks are also manageable with this approach. The overall capital expenditure involved in the network equipment is also reduced due to low power devices hence become more optimized. The major issues of service deprival at times of catastrophic disaster has been resolved to some extent as the self-organizing network will adapt its priority of services and connectivity along with the needs of the network such that the service may suffer less affect due to catastrophic events.

With the advancement of technology more robust network will be the foremost requirement in terms of reliability and communication, high processing speed virtual network elements will be required to tackle the huge amount of data such that less congestion occurs. A more focus in this regard will be required in future times, due to the fact that there will soon be twice as many devices as people on the planet, it will be necessary to store more data in virtual databases and offer the necessary services at all times and in all circumstances.

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Coding

Functions

```
function [Area,Model]=LEACH_setParameters(n)


%%%%%%%%%%%%%%%%%%%%%%%%% Set Inital PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%
%Field Dimensions - x and y maximum (in meters)
Area.x=1000;
Area.y=1000;

%Sink Motion pattern
Sinkx=0.5*Area.x;
Sinky=Sinkx;

%Optimal Election Probability of a node to become cluster head
p=0.1;

%%%%%%%%%%%%%%%%%%%%%%%%% Energy Model (all values in Joules)%%%%%%%%%%
%Initial Energy
Eo=2;

%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;

%Transmit Amplifier types
Efs=10e-12;
Emp=0.0013*0.000000000001;

%Data Aggregation Energy
EDA=5*0.000000001;

%Computation of do
do=sqrt(Efs/Emp);

%%%%%%%%%%%%%%%%%%%%%%%%% Run Time Parameters %%%%%%%%%%%%%%%%%%%%%%%%%
%maximum number of rounds
rmax=20;

%Data packet size
DpacketLen=4000;

%Hello packet size
HpacketLen=100;
```

```
%Number of Packets sended in steady-state phase
NumPacket=10;

%Radio Range
RR=0.5*Area.x*sqrt(2);
%%%%%%%%%%%%%%%%%%%%%%%%% END OF PARAMETERS %%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%% Save in Model %%%%%%%%%%%%%%%%%%%%%%%%%%%%
Model.n=n;
Model.Sinkx=Sinkx;
Model.Sinky=Sinky;
Model.p=p;
Model.Eo=Eo;
Model.ETX=ETX;
Model.ERX=ERX;
Model.Efs=Efs;
Model.Emp=Emp;
Model.EDA=EDA;
Model.do=do;
Model.rmax=rmax;
Model.DpacketLen=DpacketLen;
Model.HpacketLen=HpacketLen;
Model.NumPacket=NumPacket;
Model.RR=RR;

end
function [CH,Sensors]=LEACH_selectCH(Sensors,Model,r,)

    CH=[];
    countCHs=0;
    n=Model.n;

   for i=1:1:n
        if(Sensors(i).E>0 )
            temp_rand=rand;
            if (Sensors(i).G<=0)
                %Election of Cluster Heads
              if(temp_rand<= (Model.p/(1-Model.p*mod(r,round(1/Model.p)))))

                    countCHs=countCHs+1;
                    CH(countCHs).id=i; %#ok
                    Sensors(i).type='C';
                    Sensors(i).G=round(1/Model.p)-1;

           end
        end
    end
end

function Sensors=LEACH_configureSensors(Model,n,GX,GY)


%% Configuration EmptySensor
```

```
EmptySensor.xd=0;
EmptySensor.yd=0;
EmptySensor.G=0;
EmptySensor.df=0;
EmptySensor.type='N';
EmptySensor.E=0;
EmptySensor.id=0;
EmptySensor.dis2sink=0;
EmptySensor.dis2ch=0;
EmptySensor.MCH=n+1;    %Member of CH

%% Configuration Sensors
Sensors=repmat(EmptySensor,n+1,1);

for i=1:1:n
    %set x location
    Sensors(i).xd=GX(i);
    %set y location
    Sensors(i).yd=GY(i);
    %Determinate whether in previous periods has been clusterhead or not? not=0 and
be=n
    Sensors(i).G=0;
    %dead flag. Whether dead or alive S(i).df=0 alive. S(i).df=1 dead.
    Sensors(i).df=0;
    %initially there are not each cluster heads
    Sensors(i).type='N';
    %initially all nodes have equal Energy
    Sensors(i).E=Model.Eo;
    %id
    Sensors(i).id=i;
    %Sensors(i).RR=Model.RR;

end

Sensors(n+1).xd=Model.Sinkx;
Sensors(n+1).yd=Model.Sinky;
Sensors(n+1).E=100;
Sensors(n+1).id=n+1;
end


function Sensors=joinToNearestCH(Sensors,Model,TotalCH)


n=Model.n;
m=length(TotalCH);
 D=zeros(m,n) ;
if(m>1)

    for i=1:n
        for j=1:m
            %(j,i)=dist(Sensors(i),Sensors(TotalCH(j)),'Euclidean');
           D(j,i)=sqrt((Sensors(i).xd-Sensors(TotalCH(j).id).xd)^2+ ...
                (Sensors(i).yd-Sensors(TotalCH(j).id).yd)^2);
```

```
           %%if(D(j,i)==D(j,30))
             %   j=j+1;
           %end
          end

        end


    end

    [Dmin,idx]=min(D);




    for i=1:n

        if (Sensors(i).E>0)
            %if node is in RR CH and is Nearer to CH rather than Sink
            if (Dmin(i) <= Model.RR && Dmin(i)<Sensors(i).dis2sink)
            %if(histcounts(idx(i)==5))

                Sensors(i).MCH=TotalCH(idx(i)).id;

                Sensors(i).dis2ch=Dmin(i);


            else
                Sensors(i).MCH=n+1;
                Sensors(i).dis2ch=Sensors(i).dis2sink;
            end

        end

    end
    end
```

Main Code

```
%% Standard Leach Developed by Amin Nazari
%   aminnazari91@gmail.com
%   0918 546 2272
%% Improved Leach Developed by Hritwik Singhal and Nishita Agarwal

clc;
clear;
close all;
warning off all;


%% Create sensor nodes, Set Parameters and Create Energy Model
%%%%%%%%%%%%%%%%%%%%%%%%% Initial Parameters %%%%%%%%%%%%%%%%%%%%%%%
n=100;
```

```
%Number of Nodes in the field
 [Area,Model]=LEACH_setParameters(n);              %Set Parameters Sensors and
Network

%%%%%%%%%%%%%%%%%%%%%%%%% configuration Sensors %%%%%%%%%%%%%%%%%%%%
createRandomSen(Model,Area);            %Create a random scenario
load Locations                          %Load sensor Location
Sensors=LEACH_configureSensors(Model,n,X,Y);
LEACH_plotter(Sensors,Model);                  %Plot sensors

%%%%%%%%%%%%%%%%%%%%%%%%%% Parameters initialization %%%%%%%%%%%%%%%%
countCHs=0;         %counter for CHs
flag_first_dead=0;  %flag_first_dead
deadNum=0;          %Number of dead nodes

initEnergy=0;       %Initial Energy
for i=1:n
      initEnergy=Sensors(i).E+initEnergy;
end

SRP=zeros(1,Model.rmax);    %number of sent routing packets
RRP=zeros(1,Model.rmax);    %number of receive routing packets
SDP=zeros(1,Model.rmax);    %number of sent data packets
RDP=zeros(1,Model.rmax);
%number of receive data packets

Sum_DEAD=zeros(1,Model.rmax);
CLUSTERHS=zeros(1,Model.rmax);
AllSensorEnergy=zeros(1,Model.rmax);

%%%%%%%%%%%%%%%%%%%%%%%%% Start Simulation %%%%%%%%%%%%%%%%%%%%%%%%%
global srp rrp sdp rdp
srp=0;          %counter number of sent routing packets
rrp=0;          %counter number of receive routing packets
sdp=0;          %counter number of sent data packets
rdp=0;          %counter number of receive data packets

%Sink broadcast start message to all nodes
Sender=n+1;     %Sink
Receiver=1:n;   %All nodes
Sensors=sendReceivePackets(Sensors,Model,Sender,'Hello',Receiver);

% All sensor send location information to Sink .
 Sensors=disToSink(Sensors,Model);
% Sender=1:n;     %All nodes
% Receiver=n+1;   %Sink
% Sensors=sendReceivePackets(Sensors,Model,Sender,'Hello',Receiver);
%Save metrics
SRP(1)=srp;
RRP(1)=rrp;
SDP(1)=sdp;
RDP(1)=sdp;
```

```
tic
x=0;
%% Main loop program
for r=1:1:Model.rmax


%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Initialization %%%%%%%%%%%%%%%%%%%%%%%
    %This section Operate for each epoch
    member=[];              %Member of each cluster in per period
    countCHs=0;             %Number of CH in per period
    %counter for bit transmitted to Bases Station and Cluster Heads
    srp=0;          %counter number of sent routing packets
    rrp=0;          %counter number of receive routing packets
    sdp=0;          %counter number of sent data packets to sink
    rdp=0;
    sap=0;
    rap=0;
    dpr=0;%counter number of receive data packets by sink
    %initialization per round
    SRP(r+1)=srp;
    RRP(r+1)=rrp;
    SDP(r+1)=sdp;
    RDP(r+1)=rdp;
    pause(0.001)    %pause simulation
    hold off;       %clear figure

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    Sensors=resetSensors(Sensors,Model);
    %allow to sensor to become cluster-head. LEACH Algorithm
    AroundClear=10;
    if(mod(r,AroundClear)==0)
        for i=1:1:n
            Sensors(i).G=0;
        end
    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%% plot sensors %%%%%%%%%%%%%%%%%%%%%%%%
    deadNum=LEACH_plotter(Sensors,Model);

    %Save r'th period When the first node dies
    if (deadNum>=1)
        if(flag_first_dead==0)
            first_dead=r;
            flag_first_dead=1;
        end
    end

%%%%%%%%%%%%%%%%%%%%%%%%% cluster head election %%%%%%%%%%%%%%%%%%%%
    %Selection Candidate Cluster Head Based on LEACH Set-up Phase
    [TotalCH,Sensors]=LEACH_selectCH(Sensors,Model,r);

    %Broadcasting CHs to All Sensor that are in Radio Rage CH.
    for i=1:length(TotalCH)
```

```
        Sender=TotalCH(i).id;
        SenderRR=Model.RR;
        Receiver=findReceiver(Sensors,Model,Sender,SenderRR);
        Sensors=sendReceivePackets(Sensors,Model,Sender,'Hello',Receiver);

    end

    %Sensors join to nearest CH
    Sensors=joinToNearestCH(Sensors,Model,TotalCH);

%%%%%%%%%%%%%%%%%%%%%%% end of cluster head election phase %%%%%%

%%%%%%%%%%%%%%%%%%%%%%% plot network status in end of set-up phase
%%%%%%%%%%%%%%%%%%%%%%% this will draw lines from every node to its CH

    for i=1:n

         if (Sensors(i).type=='N' && Sensors(i).dis2ch<Sensors(i).dis2sink && ...
                 Sensors(i).E>0)

             XL=[Sensors(i).xd ,Sensors(Sensors(i).MCH).xd];
             YL=[Sensors(i).yd ,Sensors(Sensors(i).MCH).yd];
  hold on
            line(XL,YL)

         end

    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% steady-state phase %%%%%%%%%%%%%%%%%
    NumPacket=Model.NumPacket;
    for i=1:1:1%NumPacket

        %Plotter
        deadNum=LEACH_plotter(Sensors,Model);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% All sensor send data packet to  CH

for j=1:length(TotalCH)

            Receiver=TotalCH(j).id;
            Sender=findSender(Sensors,Model,Receiver);

Sensors=sendReceivePacketss(Sensors,Model,Sender,'Data',Receiver,sap,rap,sdp,rdp);

        end

    end


%%%%%%%%%%%% send Data packet from CH to Sink after Data aggregation
    for i=1:length(TotalCH)
```

```
        Receiver=n+1;               %Sink
        Sender=TotalCH(i).id;       %CH

Sensors=sendReceivePacketss(Sensors,Model,Sender,'Data',Receiver,sap,rap,sdp,rdp);

    end
%%% send data packet directly from other nodes(that aren't in each cluster) to Sink
    for i=1:n
        if(Sensors(i).MCH==Sensors(n+1).id)
            Receiver=n+1;               %Sink
            Sender=Sensors(i).id;       %Other Nodes

Sensors=sendReceivePacketss(Sensors,Model,Sender,'Data',Receiver,sap,rap,sdp,rdp);
        end
    end


%% STATISTICS

    Sum_DEAD(r+1)=deadNum;

    SRP(r+1)=srp;
    RRP(r+1)=rrp;
    SDP(r+1)=sdp;
    RDP(r+1)=rdp;

    CLUSTERHS(r+1)=countCHs;

    alive=0;
    SensorEnergy=0;
    for i=1:n
        if Sensors(i).E>0
            alive=alive+1;
            SensorEnergy=SensorEnergy+Sensors(i).E;
        end
    end
    AliveSensors(r)=alive; %#ok

    SumEnergyAllSensor(r+1)=SensorEnergy; %#ok

    AvgEnergyAllSensor(r+1)=SensorEnergy/alive; %#ok

    ConsumEnergy(r+1)=(initEnergy-SumEnergyAllSensor(r+1))/n; %#ok


    En=0;
    for i=1:n
        if Sensors(i).E>0
            En=En+(Sensors(i).E-AvgEnergyAllSensor(r+1))^2;
        end
    end

    Enheraf(r+1)=En/alive; %#ok
```

```
    title(sprintf('Round=%d,Dead nodes=%d', r+1, deadNum))

   %dead
   if(n==deadNum)

       lastPeriod=r;
       break;

   end

STATISTICS.Alive(r+1)=(n-deadNum);
STATISTICS.Energy(r+1)=(SumEnergyAllSensor(r+1));
STATISTICS.SDP(r+1)=SDP(r+1);

x=r+1;
end % for r=0:1:rmax
sdpx=sum(SDP)

toc
r=1:x-1;
openfig('Alive.fig');
hold on
plot(r,STATISTICS.Alive(r+1));
xlabel 'Rounds';
ylabel 'No of live sensor Nodes';
title('Life time of Sensor Nodes')
legend('LEACH','LEACH5UserCC')


openfig('Energy.fig');
hold on
plot(r,STATISTICS.Energy(r+1));
xlabel 'Rounds';
ylabel 'Energy(in j)';
title('Average Residual energy ');
legend('LEACH','LEACH5UserCC')


openfig('Dp.fig');
hold on
plot(r,STATISTICS.SDP(r+1));
xlabel 'Rounds';
ylabel 'No of Data Packets per Round';
title('Send Data Packets ');
legend('LEACH','LEACH5UserCC')
disp('End of Simulation');



disp('Create Report...')
filename=sprintf('leach%d.mat',n);
%% Save Report
save(filename);
```