بسم الله الرحمن الرحيم

Analysis of Energy Efficiency in Wireless and Next Generation Networks

By Fahad Mohammed Bahazaq

**A thesis submitted for the requirements of the degree of
Master of Science [Computer Science]**

Supervised By

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This thesis has been approved and accepted in partial fulfillment of the requirements for the degree of Master of Science [Computer Science]

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Dedication

I would like to dedicate this work to my beloved parents, brother and sisters for their deep love, encouragement, prayers and help throughout the study.

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First of all I thank Allah, who guided me to start this work and gave me the strength accomplishes this work. In completing this thesis I have been fortunate to have help, support and encouragement from many people. I would like to acknowledge them for their help.

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Analysis of Energy Efficiency in Wireless and Next Generation Networks

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Abstract

Wireless network is almost pervasive in many applications, and many types of wireless networks are available for accessing wireless systems used in current organizations. They are used in business, medical, military etc. In all wireless system connected with wireless network, energy efficiency is a challenging problem because it reduces the overall cost and power consumption. Further, reliability of wireless devices is also protected because some devices are overheated by high power consumption. While some efforts have been made towards existing wireless network, challenges still exist and need to be tackled for the latest wireless networks (wireless sensor network) and also in the next generation network based on multiple input and multiple out (MIMO).

Wireless sensor network (WSN) usually consists of many individual nodes that collectively work according to the application of the network. Nowadays most of the research is being done on how or what we have to do in order to preserve energy in WSN. Therefore various steps have to be taken in order to improve the energy efficiency in WSN's. One of the step is designing a proper routing algorithm that takes into consideration the factor of improving the energy efficiency in sending data from source to destination.

In this thesis, a routing algorithm has been developed which is energy efficient for WSN's and a theoretical model for Next Generation Networks has also been build. The simulated results show that the routing algorithm has better energy efficiency in transmitter and receiver when compared to other existing algorithm in terms of distance and energy. Also the results of the Analytical Model based on Pn manifold are presented which shows that increase in the number of feedback bits, the energy consumption approaches constant value.

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WSN	**Wireless Sensor Network**
EE	**Energy Efficiency**
MIMO	**Multiple Input Multiple Output**
ACO	**Ant Colony Optimization**

Chapter I

Introduction

In this chapter an overview on the thesis is given which includes motivation to do the research, objective, scope, followed by methodology. The last section gives how the chapters are organized.

1.1 Motivation

Wireless network is almost pervasive in many applications, and many types of wireless networks are available for accessing wireless systems used in current organizations. They are used in business, medical, military etc. In all wireless system connected with wireless network, energy efficiency (EE) is a challenging problem because it reduces the overall cost and power consumption. Further, reliability of wireless devices is also protected because some devices are overheated by high power consumption. While some efforts have been made towards existing wireless network, challenges still exist and need to be tackled for the latest WSN's and in the next generation network.

These WSN's usually consists of many of individual sensor nodes which work together in a collective manner according to the application of the network.

Nowadays most of the research is being done on how we can preserve the energy in these networks. So various steps are to be taken in order to improve EE in these WSNs. One of the methods would be the designing a routing algorithm which will be energy efficient and consumes less power and also takes into consideration the factor of improving EE in sending data from source to destination.

In this thesis, we will introduce an optimized energy efficient routing algorithm for the WSN. As anticipated results, we will be presenting energy efficient routing path from source to destination in a WSN.

1.2 Objective

The goal/Objective of this research is to develop an energy efficient routing algorithm for WSN's and also designing a theoretical model for energy saving for Next Generation Networks based on Multiple Input Multiple Output (MIMO) technology.

To achieve our goal, the objective of this study would be:

1) Develop an energy efficient routing algorithm which reduces power consumption with low cost technology or gives high EE.
2) Implement and compare the algorithm results with existing algorithm on a simulation software to check out the results.
3) Developing a theoretical model and providing energy efficient solution for the next generation wireless network.

1.3 SCOPE

The study area of this thesis will be related to WSN's and also MIMO technology. Various energy efficient routing protocols have been proposed earlier by various researchers. Our study will analyze these routing algorithms and also develop an energy efficient routing algorithm for the WSN's. Also a theoretical model is developed for saving energy using MIMO technology which is one considered as one of the Next Generation Networks technology. The majority of the research nowadays is based on MIMO concept which is one of the hottest topic in WSN and also in other networks. In order to maximize EE of the wireless networks, efficient algorithms of wireless network or MIMO technology with feedback can be used.

1.4 METHODOLOGY

Following methodology is used to build the thesis.

1) Building background knowledge about various wireless network concepts.

2) Designing/Developing an energy efficient routing algorithm for WSN.

3) Implementing the routing algorithm in MATLAB and checking out the results.

4) Designing of the theoretical model based on proposed routing algorithm will be presented using MIMO technology and initial results are implemented to predict that the designed model is energy saving model for next generation networks.

1.5 THESIS ORGANIZATION

The organization of the thesis is as follows:

Chapter II provides a basic overview about WSN, its characteristics and WSN node architecture. This chapter also contains various energy efficient WSN routing algorithms and brief information about Next Generation Network technology (MIMO).

Chapter III gives us the proposed methods. The first section tells us about the proposed routing algorithm and the second section tells us about the theoretical model developed using MIMO technology.

Chapter IV consists of System design, development and the implementation. This chapter contains the flowchart of routing algorithm and also the necessary steps to calculate the energy of each node in WSN. Also the interface for WSN can be seen in this chapter. The last section in this chapter includes the steps to calculate the energy for the analytical model

Chapter V provides us the results and discussion of both the routing algorithm as well as the Analytical Model developed using MIMO.

Chapter VI includes the conclusion part and also the future work.

Chapter II

Literature Review

In this chapter, we will be discussing a brief introduction about WSN, their characteristics, structure of wireless sensor node. Also various energy efficient WSN routing algorithms have been discussed. A brief information about MIMO which is considered as future technology for the Next Generation Networks has been discussed in this chapter.

2.1 Wireless Sensor Network

There are various definitions of WSNs, given by various researchers, they are:

"A WSN comprises of a large number of low-power wireless sensor nodes spread across a geographical area that can be used to monitor and control the physical environment from remote locations. Each sensor node is battery powered and equipped with integrated sensors, data processing capabilities and short-range radio communications" [7].

"WSN's are composed of many small inexpensive nodes with limited computing and wireless communication capabilities. The main function of WSN is to monitor the physical environment, process the sensed information, and transmit the results to the base station" [8].

"WSN is a wireless computing devices network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, motion, intrusion or pollutants, at different locations"[9].

"WSN's are composed of the huge number of sensor nodes which can monitor the environment by collecting, processing as well as transmitting collected data to the remote sink node through direct or multi-hop transmission. WSNs have attracted lots of attention in recent years due to their wide applications such as battlefield surveillance, inventory and wildlife monitoring, smart home and healthcare etc. [3]."

"A WSN in its simplest form can be defined as a network of (possibly low-size and low-complex) devices denoted as nodes that can sense the environment and communicate the information gathered from the monitored field through wireless links; the data is forwarded, possibly via multiple hops relaying, to ~~a~~ sink that can use it locally, or is connected to other networks (e.g., the Internet) through a gateway [4]."

WSN's are basically based on an equation which are Sensing the data + Computation + Radio Signal = Number of Applications. WSN's, Cellular Networks, WLANs, and ad hoc networks are the most popular technologies for wireless network applications. In addition, many wireless devices are being equipped with existing wireless networks and multiple interfaces. Improvements in the EE should be analyzed because wireless devices between the source and destination are still consuming high power.

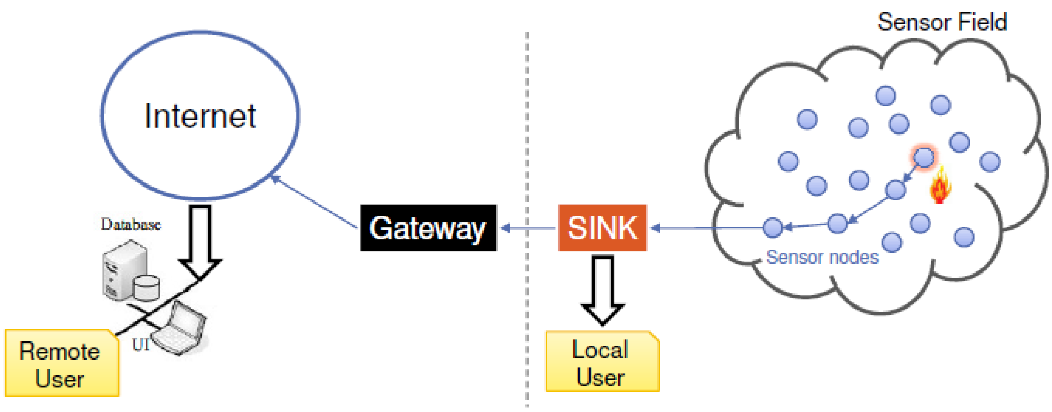

Figure 2.1: WSN Architecture

WSN's usually consists of thousands or millions of sensors which are deployed in the network randomly [1]. Once these nodes are deployed, they are usually inaccessible to the user, so therefore replacing the energy resource will not be a good option. Each node in WSN has limited processing power, limited battery life and also limited view of the environment [43] [44]. Therefore, the main issue is how to design a good energy efficient algorithm for these WSN's in order to increase the life span of the whole network [2].

The sensor nodes usually are powered with the help of battery resources which are limited to the certain extent, so that is why EE is one of the important issue/challenges that need to be addressed for a successful working of WSN. In WSN, the energy is usually consumed in three steps/phases. These can be counted as sensing, processing and then the communication process. But here we are only focusing on the energy consumption part which takes place during the communication process which is important part and also it prevails over the other two phases [3].

In WSN's, the nodes gather the data with the help of sensors and then they process it locally or communicate among the neighbors and then they finally forward the information/data to the end user or to the destination. These nodes tends to have high power consuming factors and also they are wireless. So they consume a huge amount of energy. And to replenish the energy by replacing the batteries for say thousand nodes in the network is not a feasible solution [4]. Hence it is important to conserve the energy in order to maximize the network lifetime. So how to preserve the energy, how to do minimum routing in the network, how to prolong the lifetime of the network are the principle problems that need to be addressed.

In the field of WSN, the hottest topic for research is how to reduce the energy consumption of the network and improve the network lifetime. The sensor nodes are small in size and they use tiny batteries. So the chances are that they deplete in energy fast [5]. The lifetime of the network is defined as either the time for the first/initial node or that a certain percentage of network nodes to run out of power supply [6]. The main responsibility of the sensor node is that they systematically gather the data and deliver that data to the base station. Because these nodes consume a huge amount of energy, so the communication that takes place between the sensor nodes and the base station should be made in a very energy efficient manner [4].EE can be enhanced without increasing complexity which depends on the optimization of routing algorithms and optimum design of WSN.

2.2 Characteristics of WSNs:

Various characteristics of a WSN are:

- Communication failures
- Heterogeneity of nodes
- Their ability to withstand extreme climatic conditions.
- Easy to use
- Mobility of the nodes
- Scalability to large scale of deployment area.
- Cope up when nodes fail.

Wireless Sensor nodes are small computers which have basic interfaces and components. These nodes consists of computation unit. They have limited power and less memory. It also contains a radio like transceiver which is responsible for communication purpose and a small battery [10].

2.3 Wireless Sensor Node Architecture:

WSN node contain different components as shown in Figure 2.2.

1- **Controller**

   The main responsibility of the controller is to perform the tasks in the network. It also process the data. A microcontroller is often used in many systems like especially the embedded systems as sensor nodes .The reasons behind using the micro controller in sensor nodes is because it has of its low cost, easily programmable, low power consumption and the flexibility to connect to other devices.

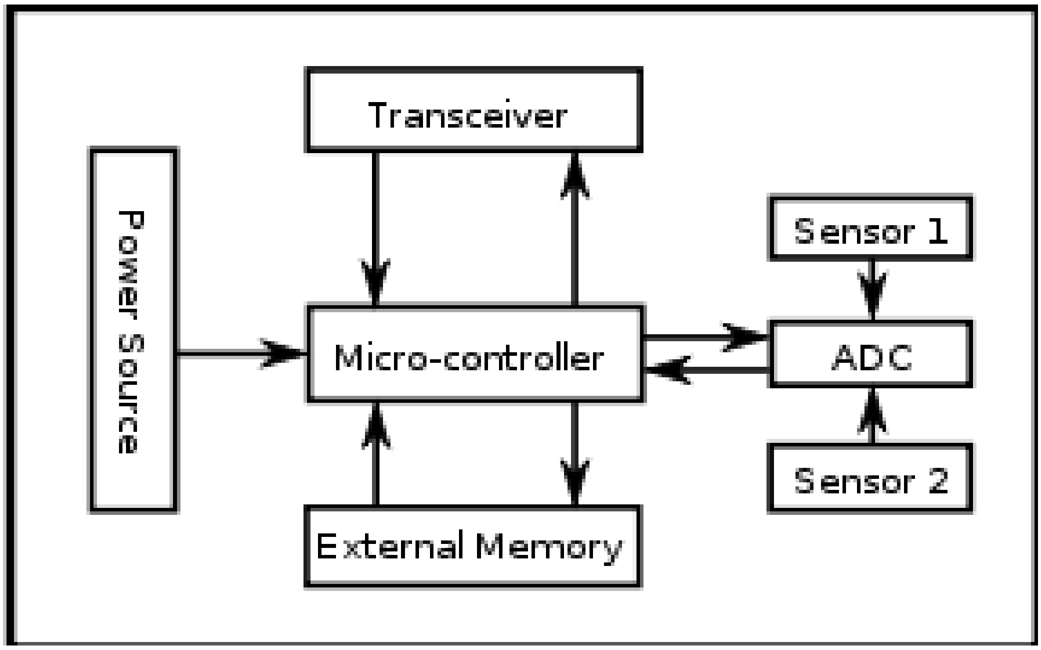

Figure 2.2: WSN Node Architecture

2- Transceiver

Sensor nodes in WSN’s often make use of the Industrial, scientific and medical band, which gives them global availability, free radio transmission and also availability of spectrum. For the wireless transmission, the best media available are radio frequency (RF), optical communication (laser) and infrared. These lasers requires less amount of energy, but the disadvantage is that they require line-of-sight for communication and are also they are sensitive to the atmospheric conditions. These infrared media requires no antenna but they are limited to their broadcasting capacity. The Radio frequency-based communication is considered to be the most appropriate for WSN applications. WSNs uses free communication frequencies. Transceiver are the combination of both transmitter and the receiver in a single device. Their states are receive, transmit, sleep, and idle

3- External memory

Microcontroller and Flash memory are the most relevant kinds of on-chip memory to be used from an energy perspective. Flash memories are especially used because of their low cost and good storage capacity. Memory requirements depends upon the application. There are two categories of memory: user memory that is used to store data related to application or even personal data, and another is the program memory which is used for functioning the device in a programmable manner.

4- Power source

A wireless sensor node is a good solution when we find it difficult or impossible to run a main supply to the sensor node. These sensor nodes is often placed in locations that are hard to locate. Therefore to change the battery again and again is a tedious task. The most important step for proper functioning of wireless sensor node is that it should get adequate power supply. Generally these sensor node consumes the power for communicating, sensing and data computation. Majority of the energy is required for data communication when compared to other process. Power is generally stored either in batteries or in capacitors. The main source of power supply is the batteries which supply power to these sensor nodes.

5- Sensors

Sensors are hardware devices that produce an output to a slight change in pressure or temperature. These sensors take the measurements of physical data of the parameter that is to be fetched or monitored. The continuous analog signal which are produced by these sensors are then digitized by an analog-to-digital converter and are sent to these controllers for further processing. These nodes are usually small in size. The good characteristics of sensor nodes is that they should consume less energy and operate on high densities. They should be produce correct results even though if they are unattended, and should be adaptive to any sort of environmental conditions.

2.4 Energy Efficient Routing in WSN

WSN, Cellular Networks, WLANs, and ad hoc networks are the most popular technologies for wireless network applications. In addition, many wireless devices are being equipped with existing wireless networks and multiple interfaces. Improvements in the EE should be analysed because wireless devices between the source and destination are still consuming high power. Many of the energy efficient routing algorithms have been proposed for WSN in recent years [45] [46]. A new WSN protocol [13], which preserves energy through balance clustering was proposed. This protocol uses Gaussian elimination algorithm to calculate the combinations of nodes which has be chosen as cluster heads in order to extend the lifetime of the network. This protocol uses efficient way to choose the cluster heads.

The authors have proposed an algorithm for WSNs which achieves both EE and also balancing from hop number and distance [3]. Given the distance between the source to the destination node, the multi hop number is calculated. Also the individual distance is calculated between the source and sink node. During the routing process, the authors have considered the two important factors which are distance and hop number as their primary factor and the secondary factor is residual energy.

There is another research which is given in [9]. The authors have stressed on energy efficient routing. The authors have made an efficient routing and also taken into consideration about the maximizing network lifetime. The authors have made both cost and also the convergence time low for the proposed algorithm when it is compared with other algorithms.

The authors have designed a common key cryptographic security algorithm [14] which is for scalable wireless networks. It is used to provide an energy efficient secure dynamic address routing protocol WSN's. The RAC algorithm consumes less power and provides more security than other well-known security algorithms.

In this paper [15], the authors have proposed another energy saving routing protocol. The authors proposed to split the lifetime of a WSN into the equal amount of time referred to as rounds and designed the energy constrained routing during a round as a polynomial-time solvable flow problems. The flow of information from an optimum solution to a flow problem is then used as a basis for an energy-efficient routing protocol. The results have proven that this algorithm saves lot of energy also sends the packet through shortest distance.

This paper is about an energy saving project [16] which aims in developing new energy and power saving methods and solutions. The main objective EARTH's project is to bring awareness about the challenges that the globe faces by identifying the effective procedure to reduce the energy wastage and also to improve EE of various mobile communication systems.

In these articles [47] [48] [49], the authors have studied the energy consumption by studying in terms of transmission of data which had proved to be more effective.

In this paper the authors have proposed an energy efficient protocol [7] that is cluster based and hierarchical. The Base Station nominates the Cluster Heads (CH) and this procedure is carried out in two different stages. The first stage, all the candidate nodes that have to become CH are listed based on different parameters. The Cluster Head now gives two commands for its cluster members which are TDMA based Transmit and Sleep. The data transmission from the CH to BS takes place in a multi-hop fashion. This session ends when Cluster Head energy reduces to half of its initial energy amount.

In this paper [4], the authors have made an approach to balance network energy consumption and prolong network lifetime. This algorithm improves EE by changing the activity of energy model, sensor node and transition state of sensor nodes.

This article proposed an energy efficient cluster routing algorithm [8]. Firstly the technique involves that this algorithm divides the nodes which are there in the WSN's into clusters. Then by using an improved neighbor algorithm a chain is formed in each cluster. Lastly, to transmit the data from cluster head to BS, multi hop transmission is used.

In this article [17], the authors have proposed two energy efficient geographic routing algorithms for WSN's. These algorithms are based on the existing geographic routing algorithms which take into consideration computing cost of routing, signal interference and routing distance into account. In the first algorithm the authors have combined the interference into the routing cost function and then they have used it to find routing decision. In the second algorithm they have transformed the problem into a optimization problem and then solving it by searching the optimal discretized interference level. The authors have integrated four different geographic routing algorithms which are mentioned in their article. In [50], the authors have presented a program for energy efficient routing in WSN with multiple mobile base stations.

In this paper the authors have proposed an energy-efficient clustering for WSN's [2]. This paper talks about distributed nodes clustering, inter-cluster routing selection and dynamic cluster head rotation.

In the paper [1], the authors have proposed a load-balanced and energy-efficient routing protocol. The main features of this algorithm are: low energy consumption, localized coordination, self-configuration, cluster head with maximum energy, hierarchical level of forwarding, and load balancing.

Another Cluster-based Algorithm in WSN which is energy saving has also been proposed [18]. Its concept is based on cycle-switching cluster head. It improves energy of the node and also makes consumption of energy in a balance way. This algorithm is based on cluster-head prediction and power control.

A dynamic multi hop routing technique is proposed [19]. The authors have used the residual energy based clustering algorithm in order to prolong node as well as lifetime of the network. The clusters are constructed using various parameters .Once after collecting all the required data within a cluster, now the cluster heads increase their transmission range till they find a high sufficient energy based adjacent cluster heads to forward the data to the base station.

In Sensor Protocols for Information via Negotiation (SPIN) each and every node plays the same role. It distributes the information among all the nodes in the network assuming that all nodes as base stations. So the user will ask a query to any node in the network and it will get a quick reply from the node. There is even the distribution of data in all the nodes [20]. Directed Diffusion is another routing algorithm that has been proposed to EE in WSN [21].

There are various path establishment protocols which are divided into Proactive, Reactive and Hybrid. Proactive routing maintain accurate information and routing tables of all networks. This type of protocols are mainly used in flat as well as in hierarchal structures. Flat routing are advantages in calculating the optimal path quickly. But for large ad hoc networks, hierarchal proactive structures are used [22-23]. Reactive routing is used to establish ~~the~~ a route between the source and destination on demand by dynamic search. In order to establish ~~the~~ a connection between the source and destination we need to supply this routing protocol with a route discover the query and also the reverse path to get the path from source to destination. Firstly a route selection has to be submitted on demand by using any route query to get the path from source to destination [23].

Hybrid Protocols are applied to large networks. It uses the concept of both proactive and Reactive protocols. This protocol uses clustering technique to make the network more scalable and also stable. The network is divided into clusters so any node added or removed is maintained. Proactive technique is used when routing is made within the clusters and reactive technique is used when routing is made across the clusters [22].

There are various Network Based Protocols. These protocols are [24] Flat Based Routing, Hierarchical Based Routing and Location Based Routing. Flat Based Routing are used when the network is very large. Since the network is large, to assign different ids to each sensor node is difficult. So the base station sends the query to each and every node in the network by a data centric routing and waits for the response [22] [25] [26].Examples of this protocol are in [23].

Hierarchical Based Routing is best used when efficient communication and also network scalability are needed. It is also called as Cluster based routing. This type of protocol is needed where the high energy sensor nodes are selected for processing and communication purpose whereas low energy sensor nodes are used for sensing and sending the information [22] [25] [26].Examples are mentioned in [23].

In Location Based Routing type of protocols the sensor nodes are scattered randomly around the area. These sensor nodes are located with the help of GPS. Distance between each node are determined with the help of signal strength and coordinates are determined with the help of information exchanged between those nodes [22] [25] [26]. Examples of this type of routing protocols are mentioned in [23].

There are also various Operation Based Routing Protocols. Multipath Routing Protocols are the protocols that send the message to the destination from a selected path made from multiple routing paths. This decreases delay and increases network performance [22].Examples of Multipath Routing protocols are: Multi path and Multi SPEED (MMSPEED), Sensor Protocols for Information via Negotiation (SPIN).

Query Based Routing Protocols provides mechanisms for sending and receiving queries for the data [22]. Various examples of this type of protocols are mentioned in [23].Negotiation Based Routing Protocols uses data descriptors which are used in order to eliminate data which is redundant and sends specific data which is required to the destination. These data descriptors are high level. They make intelligent decisions based on for example how much available the resources are available [22]. Examples of this type of routing protocols are mentioned in [23].In Quality of Service Based Routing Protocols, the network application should consider QoS when communicating to either base station or to another networks. Examples of this type of networks are mentioned in [23].

Data Processing Routing Protocols are classified into two types, Coherent and non-Coherent. In Non-Coherent nodes process the data locally and send it to other node. Aggregators are the nodes that process the data further [23].

In coherent first the data is forwarded to aggregators first. There is a minimum processing which includes tasks like duplicate suppression, time management etc.

Reinforcement learning based routing protocols is an area of machine learning techniques that uses computer programs in order to rules from various sets of data. This type of study deals with behavior/actions of the agent in a particular environment to make the agent have a long term success. The agent starts exploring its environment. Then it has to try a different combination of the knowledge it has to go to next step. It selects some of the possible action for a particular state and receives the success from the environment [23].Q-Routing technique is one of the early techniques that has been done in routing by with the help of machine learning concepts. The logic of this protocol is that it takes the minimal times in order to deliver the best paths in the network. Other Reinforcement based routing protocols are given in [27].

The ant colony optimization (ACO) algorithm based on the behavior of ants and how they communicate with each other through pheromone. This pheromone is a substance released by the ants which helps them in making moving decisions. While walking the ants lay this pheromone. At the initial stage, there is no pheromone laid on the routing path and ants do not have any idea of the path length. Once these ants get the shortest path, they receive the pheromone at high rate than the one which is the longer path. The more the pheromone the ants leave on the path, it will be a larger probability that these ants will visit this path next time .Example of ACO based routing algorithms are given in [27].

There are various algorithm based on fuzzy logic [28]. Generally fuzzy logic is a field of mathematics concepts. Its concept is based on approximation reasoning based on human reasoning. Examples of Fuzzy logic based routing protocols are FCH, Fuzzy multi-objective routing algorithm (FMO).

Genetic Algorithms can be used to build clusters for WSN's with medium or large size. These algorithms uses Genetic Algorithm technique that generates an aggregation tree that helps spanning of all the sensor nodes in the network. It also improves the lifetime of the network when it is compared to any single best tree algorithm [29].

2.5 Energy Efficiency in MIMO

MIMO system has proven to be able to provide high spectral efficiency and also increase the channel capacity through multiple spatial channels without the need of any additional spectrum. With the help of multiple antennas at the transmitter and/or the receiver, a MIMO system takes the advantage of multiplexing to simultaneously transmit multiple data streams in order to increase wireless data rate and diversity to optimally combine signals from different transmission streams to increase transmission reliability and range. Nowadays more and more wireless devices are equipped with multiple antennas to meet the high data rate requirements. MIMO is considered as a technology for next generation wireless systems such as IEEE 802.16, IEEE 802.11n, and the third and also the fourth generation cellular systems.

From a network layer's perspective, MIMO nodes provide different transmission/receiving capabilities from single-antenna nodes. A node which is equipped with multiple number of antennas could possibly transmit/receive more downlink/uplink streams. It can add significant impact for determination of optimal routes for traffic transmission. Moreover, the option of different MIMO strategies like spatial multiplexing or diversity with different levels of degree of freedom, could also increase the flexibility of routing decisions in a network with the help of MIMO nodes. Therefore, it is important that the routing scheme to be MIMO-aware in order to have the benefits brought by MIMO into wireless networks. The EE of MIMO transmissions in WSN is analyzed considering the trade-off between diversity and multiplexing gains. Various MIMOs are studied with non-cooperative, half-cooperative or cooperative realizations [51].

An Energy Efficient Channel Estimation in MIMO Systems has been studied. The objective is to minimize the energy spent during the channel estimation phase, which tells us about the transmission of training symbols, then storage of those symbols at the receiver, and channel estimation at the receiver. A model has been developed that is independent of the hardware or software used for channel estimation which uses divide and conquer strategy to minimize the overall energy consumption [52]

2.5.1 MIMO involvement in next generation network

The EE is the one of the feature of MIMO which increases the overall EE performance and cost of next generation network.

Table 2.1: Standards for Wireless Networks

Standards	Techniques used in Wireless networks
WiMAX 802.16 2004	OFDM/OFDMA
3GPP Release 7	WCDMA
WLAN 802.11n	OFDM
WiMAX 802.16e	OFDMA
3GPP Release 8 (LTE)	OFDMA
802.22	OFDM

As mentioned in the table 2.11, next generation network will be considered with some selected wireless networks from the Standards which allow us to increase the EE through the protocols that we have studied in this project. The above standards compiled with MIMO are applied to next generation networks to increase the EE.

MIMO is a technology of using multiple antennas in order to simultaneously transmit multiple streams of data in a wireless communication systems. In MIMO technology, antennas transmit multiple streams of data simultaneously in wireless communication systems. This technology provides wire like speed to the end user. MIMO technology combines both multiple send and receive antennas, and multiple streams of data being transmitted at the same time. Unlike the single-input and single-output (SISO), MIMO technology is used to increase the throughput by increasing the number of radio transmit and the receive chains. A client/AP may have up to four transmit and four receive chains. It is possible that it can have a different number of transmit and receive chains. Figure 2.3 shows the difference between a SISO and MIMO transmission.

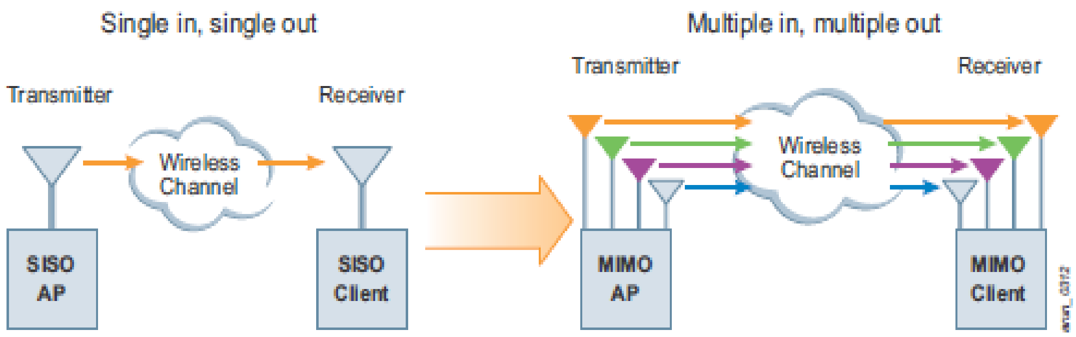

Figure 2.3 SISO vs MIMO

MIMO generally uses spatial streams of data which has the ability to transmit and receive on multiple transmissions. More number of transmitters and receivers allow the access point to send independent streams of data. Adding additional lanes to the road allow the traffic to move smoothly, similarly multiple spatial streams allow the wireless AP to transmit more data simultaneously. Spatial streams split data into multiple parts and forward them over different radios, and the data takes different paths through the air. Figure 2.4 demonstrates the concept of multiple spatial streams of data.

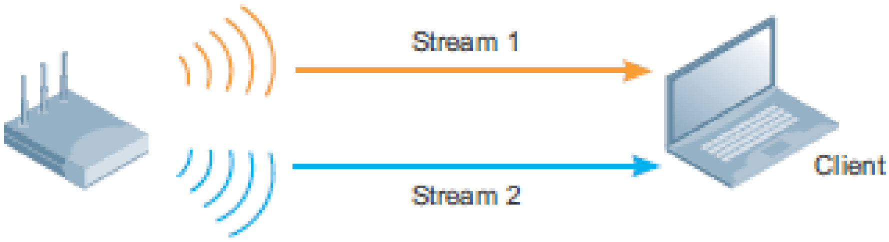

Figure 2.4 A MIMO transmission with two spatial streams of data

Overall MIMO is an enabler for the development of future broadband (fixed and mobile) networks which will be energy-efficient, secure, and robust, and will use the spectrum efficiently. It is an enabling technology for the next generation networks that will connect the Internet of people, Internet of things, with clouds and other network infrastructure.

2.5.2 Advantages of MIMO in next generation network

MIMO in cellular systems brings improvements on four fronts:

• Improved data rate: More the number of antennas, the more independent data streams can be sent out.

• Improved reliability: More the number of antennas the more possible paths that the radio signal can easily propagate over.

• Improved EE: The base station can focus its emitted energy into the spatial directions where it knows that the terminals are located.

• Reduced interference: The base station can purposely avoid transmitting its signals into directions in which spreading interference would be harmful.

Chapter III

Proposed Methods

In this chapter, we will be discussing about the proposed methods done in our research. The first section tells us about the proposed energy efficient routing algorithm for WSN. It gives us the step by step procedure of our proposed routing algorithm. The second section presents our Analytical Model that is developed for Next Generation Networks using the MIMO technology with the help of Pn-manifold concept.

3.1 Proposed Energy Efficient Wireless Sensor Routing Protocol

The optimized routing algorithm uses ACO concept for getting the shortest path between the source and destination. ACO algorithm is a technique for solving various computational problems which can be reduced by finding good paths thorough graphs. There are various applications where ACO is used like finding optimal path in Travelling Salesman Problem, Network Model Problem, Quadratic Assignment Problem and Vehicle Routing Problem.

The ACO algorithm based on the behavior of ants and how they communicate with each other through pheromone. This pheromone is a substance released by the ants which helps them in making moving decisions. While walking the ants lay this pheromone. At the initial stage, there is no pheromone laid on the routing path and ants do not have any idea of the path length. Once these ants get the shortest path, they receive the pheromone at high rate than the one which is the longer path. The more the pheromone the ants leave on the path, it will be a larger probability that these ants will visit this path next time. It will be shortest path and the best path as the ants tend to get the food which is shortest and best path.

The proposed optimized routing algorithm consists of Seven Phases:

First Phase: The user defines the number of nodes and the destination node in a network.

Second Phase: The nodes in the network will be deployed as per the topology that is defined by the user. Then initialize the node properties which are sender or receiver, distance between nodes, sending the packet, receiving the packet, radio, and id. And now the distance between each node is taken.

Third Phase: In this phase nodes will be checked for their radio which are ON. Sender and receiver are found in this phase. After finding the sender, receiver will be selected based on the shortest path based on ACO with whose nodes radio is 'ON'. Then after finding the sender and the receiver, all other nodes radio are turned 'OFF' which is important for energy conservation.

Fourth Phase: Since we got the sender and receiver, we set the properties of sender so that it sends the packets to the receiver .Now when the receiver starts receiving the data we also set its properties. We check the transmission time, if the time of reception is less than transmission then the data is sent successfully otherwise retransmit the data for specified number of times .Now check if the reception time is less than among the specified number of times then the data is transmitted successfully otherwise data cannot be read. So, now nodes are checked again for the radio 'ON' and above phase is repeated until sender and receiver are obtained.

Fifth Phase: Now since we got the sender and receiver, put their radio 'OFF' and put them in a path file.

Sixth Phase: Repeat the phases from 3 to 5 .The last element in the path now will act as sender. This process is repeated until the destination node is obtained which is given by the user.

Seventh Phase: We get the complete path from source to destination among the whole topology.

The implementation of the routing algorithm and its results are discussed in the Chapter 4 and Chapter 5 respectively.

3.2 Proposed Analytical/Theoretical Model for Energy Saving in Wireless Sensor Networks

In this section we will be showing the proposed Analytical Model based on Pn-manifold technique which is useful for energy saving in future generation networks (MIMO).

There are various applications in wireless networks and their demands are increasing daily because of the basic facilities have made their impact in our daily life's. Here we propose an energy saving model using the future MIMO technology which helps us save energy for the future wireless applications that are based on WSN's. The proposed model can be utilized to enhance the EE in WSNs and also in other wireless networks. Here we have used the concept of Pn-manifold in designing the model .Pn-manifold minimizes the dimensions of the channel matrix that is used in MIMO system. Usually Manifolds are applied in MIMO systems in order to increase the efficiency of the communication channel. It also consumes less energy which reduces the overall cost in our proposed energy saving model.

There are many researches made on manifolds techniques used in MIMO systems. According to [34] [35] when the base station have more antennas than the users involved, MIMO is improved. In another research which is [38] [39], the basic differences between the MIMO and basic MIMO are compared. There are other researches made in [43] [44] based on MIMO in order to analyse the EE of MIMO transmission in various wireless networks. In our research the greatest challenge in the MIMO system involves with the feedback and Pn-manifold.

While designing the applications for WSN proper routing protocols should be implemented [9] [36]. In our research ACO algorithm is considered with combination of link quality, congestion and energy [37]. In WSN sensor nodes consume a lot of energy to process the data from source to destination. Therefore the communication between the base station and the sensor nodes should be carried out in an energy efficient manner [40].

In designing the analytical model, four main aspects are identified namely energy required in each node during the transmission, routing protocols for energy saving, MIMO design for EE communication and the utilization of manifolds with EE factor based on the feedback bits [41].In our research, energy saving wireless routing algorithm along with the manifold technique is used to design the analytical model. As shown in figure 3.1 sensor may be distributed on the manifold. Here we are considering 3D topology [42] in WSN as 2D is not that efficient in real time applications.

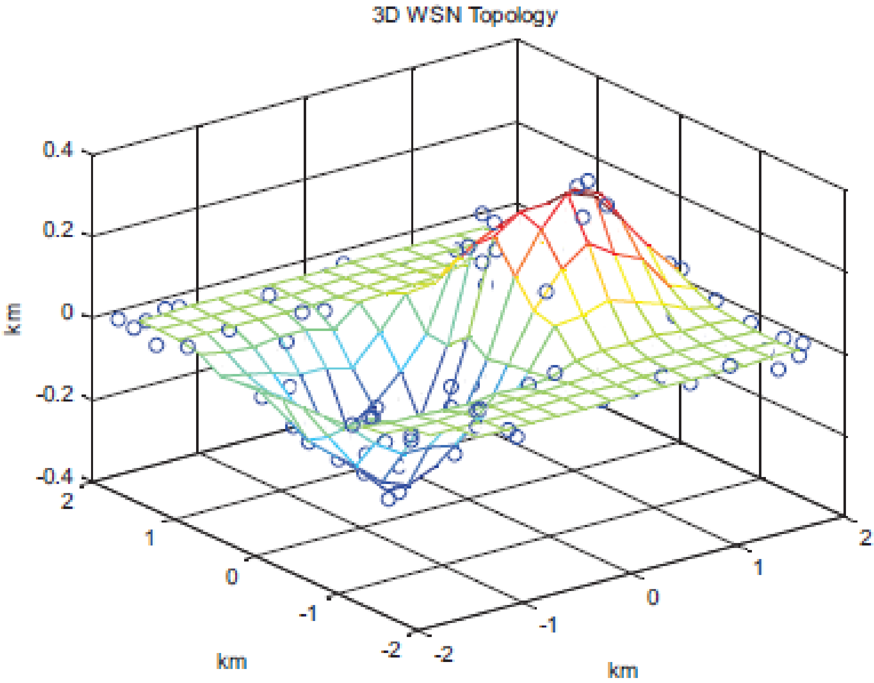

Figure 3.1: 3D WSN Topology

3.2.1 Proposed Analytical Model

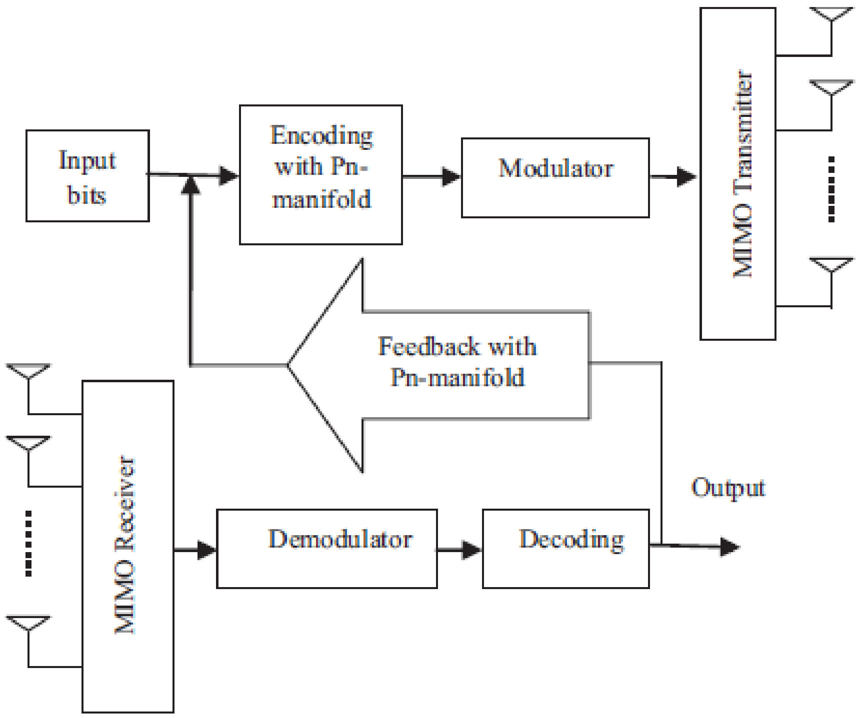

Figure 3.2: Analytical Model Architecture

As shown in Figure 3.2, the proposed analytical model is developed. This model can be applied for calculating necessary parameters used in energy saving approaches of WSN. In this research, we show that capacity is changed through the manifold, is controlled by MIMO technology, which uses Pn-manifolds. As mentioned in [35], sets of positive semi-definite matrices are considered in order to identify the Pn-manifold with various trace and ranks that optimize the overall problems. As in equation (1), general Pn manifolds can be written as:

$$Pn(p, \mathbb{F}, Tr(Q) \leq \rho^2, Rk(Q) = s) \qquad (1)$$

To increase the EE, dimension of channel matrix can be reduced and optimized using Pn-manifolds which take different forms according to the environments.

3.2.2 Various Categories of Pn-manifolds

The classification of 8 different manifolds that are obtained from covariance matrices can be considered as Pn-manifolds. However, depending on the system constraints, we classify the space of non-negative matrices into four categories as in [35].

Pn-manifolds can be categorized as follows:

First category

1. Matrix size (positive integer)

Second category

2. Elemental field (obtained from the field F)

3. Elemental field (real values R)

4. Elemental field (complex values C)

Third category

5. Trace constraint $Tr(Q) \leq \rho^2$(Power is given as ρ)

6. Trace constraint $Tr(Q) = \rho^2$

Fourth category

7. Rank constraint $Rk(Q) \leq s^2$ (here s should be s ≤ N_t)

8. Rank constraint $Rk(Q) = s^2$

The energy calculation part and the results for the Analytical Model is discussed in Chapter 5 and Chapter 6.

Chapter IV

System Design Development and Implementation

This chapter includes the System Design Developments and how the implementation is done. The proposed routing algorithm is implemented in MATLAB. The Graphical User Interface (GUI) designed asks the user to enter number of nodes and the destination node. The GUI consists of buttons called topology which creates the topology and the routing button implements the proposed energy efficient routing algorithm. The axis shows the complete path from source to the destination node. The node in red denotes the destination node, the node in green denotes the source node and intermediate nodes are denoted in magenta. Energy calculations for each node in the network is discussed in section 4.1 and energy calculation for Analytical model is discussed in section 4.3.

As shown in the figure 4.1, the user defines the number of nodes and the destination node in a WSN. Then in the next step the nodes in the network will be deployed as per the topology defined by the user. Then initialize the node properties which are sender or receiver, distance between nodes, sending the packet, receiving the packet, radio, and id. And now the distance between each node is taken. The nodes will be checked for their radio which are ON. Sender and receiver are found in this phase. After finding the sender, receiver will be selected based on the shortest path based on ACO with whose nodes radio is ‘ON’. Then after finding the sender and the receiver, all other nodes radio are turned ‘OFF’ which is important for energy conservation. Since we got the sender and receiver, we set the properties of sender so that it sends the packets to the receiver .Now when the receiver starts receiving the data we also set its properties. We check the transmission time, if the time of reception is less than transmission then the data is sent successfully otherwise retransmit the data for specified number of times .Now check if the reception time is less than among the specified number of times then the data is transmitted successfully otherwise data cannot be read. So, now nodes are checked again for the radio ‘ON’ and above phase is repeated until sender and receiver are obtained. Now since we got the sender and receiver, put their radio ‘OFF’ and put them in a path file. Repeat the above mentioned steps .The last element in the path now will act as sender. This process repeats until the destination node is obtained which is given by the user. We get the complete path from source to destination among the whole topology.

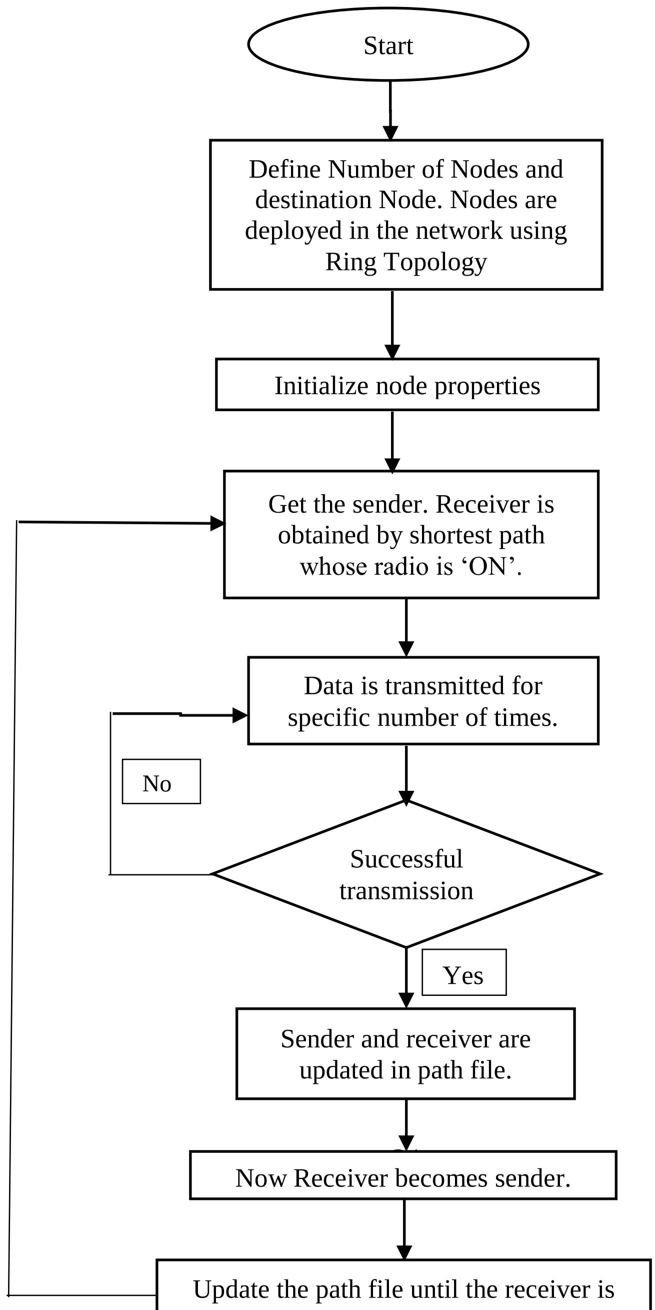
Start
Define Number of Nodes and destination Node. Nodes are deployed in the network using Ring Topology
Initialize node properties
Get the sender. Receiver is obtained by shortest path whose radio is 'ON'.
Data is transmitted for specific number of times.
No
Successful transmission
Yes
Sender and receiver are updated in path file.
Now Receiver becomes sender.
Update the path file until the receiver is

Figure 4.1: Flowchart for WSN Routing Algorithm

4.1 Steps for Energy Calculation for Each Node

Following block diagram will represent the transmitting nodes and receiving nodes of either in 2D or 3D WSN. Although we know that the energy calculations depends on the individual node and their link quality which influences under various environmental conditions, the proposed routing protocol plays an important role with the distance (PQ=d) as shown in Figure 4.2.

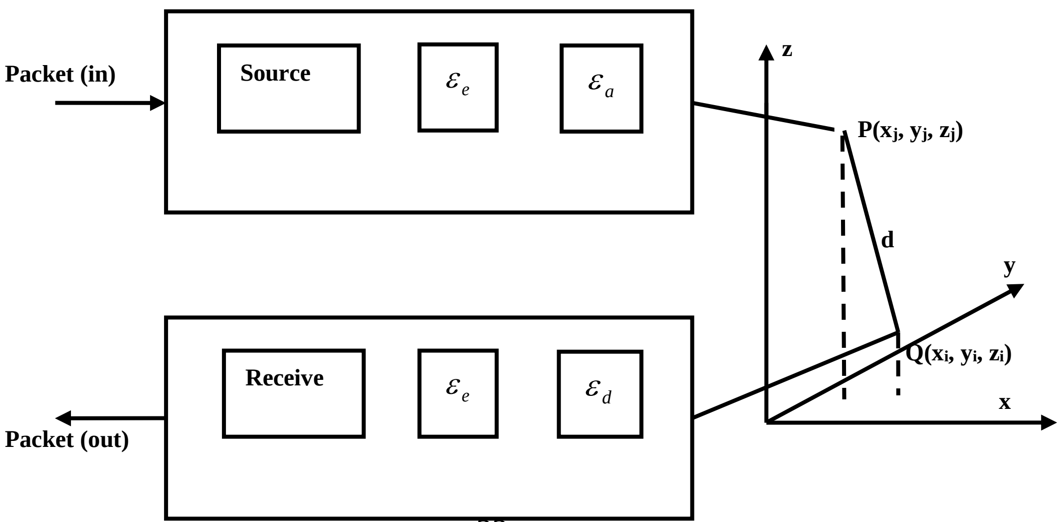

Figure 4.2: Energy Calculation for Each Node

In figure 4.2, the energy consumption is obtained from the equations (2) and (3) respectively when m-bit packet holds the data between the two wireless sensor nodes[27]. In the following energy calculations, d is the actual distance between the nodes.

Here assuming m = 2000 kb, $\mathcal{E}_e$= 50nJ/bit, d = 5km, $\mathcal{E}_a$=$\varepsilon_b \times d^2$,

$$E_{tx}(m, d) = \mathcal{E}_e m + \mathcal{E}_a m \qquad (2)$$

Where $E_{tx}(m, d)$ is the transmitter energy consumption, and $E_{rx}(m, d)$ considered with electronic circuits and decoding is the receiver energy consumption given below.

$$E_{rx}(m, d) = \mathcal{E}_e m \qquad (3)$$

The electronic circuits that are employed in both the transmitter and the receiver, consume energy $\mathcal{E}_e$ in each of these cases. In the transmitter node, $\mathcal{E}_a$ is the circuits of amplifier energy that needs to be set with distance. To calculate the transmission energy in each node, following conditions (4) can be used in (2)

$$\varepsilon_a = \begin{cases} \varepsilon_b \times d^2, when \quad d < d_0 \\ \varepsilon_c \times d^4, when \quad d > d_0 \end{cases} \qquad (4)$$

where d_0 is a threshold value. If the distance d is less than that of d_0, the free-space which is the noise free propagation model can be applied. Otherwise, the model will be considered with the multipath and fading channels which need more energy during the transmission [27]. Energy parameters ε_b and ε_c are influenced to adjust the amplifier energy with distance. According to [27], ε_b is set as 10 pJ/bit/m² and ε_c is set as 0.0013 pJ/bit/ m^4 in this research. When many nodes are allocated in the WSNs, average distance as in (5) is calculated to determine the total energy [27].

As shown in figure 4.2 node i and node i+1 are final sender and final receiver and "d" is the distance between them. Before sending the data to final sender, the packets are sent to different nodes and then after collecting the complete packet, it is transmitted to final node or manager node. The manager node then sends that packet to final receiver. We assume that average distance (d_{avg}) between the nodes and the distance between the final sender and final receiver which is "d" is same.

Average distance of nodes $d_{avg} = \frac{\sum_i^n a_i}{n}$ (5)

In (5), n is the total number of nodes and $a^i$is the i^{th} node in the WSN.

4.2 Implementation

The proposed algorithm has been implemented in MATLAB 2013. Following are the step by step procedure of screen shots of the implementation.

First the User enters the number of nodes and the destination node as shown in (Figure 4.3) below.

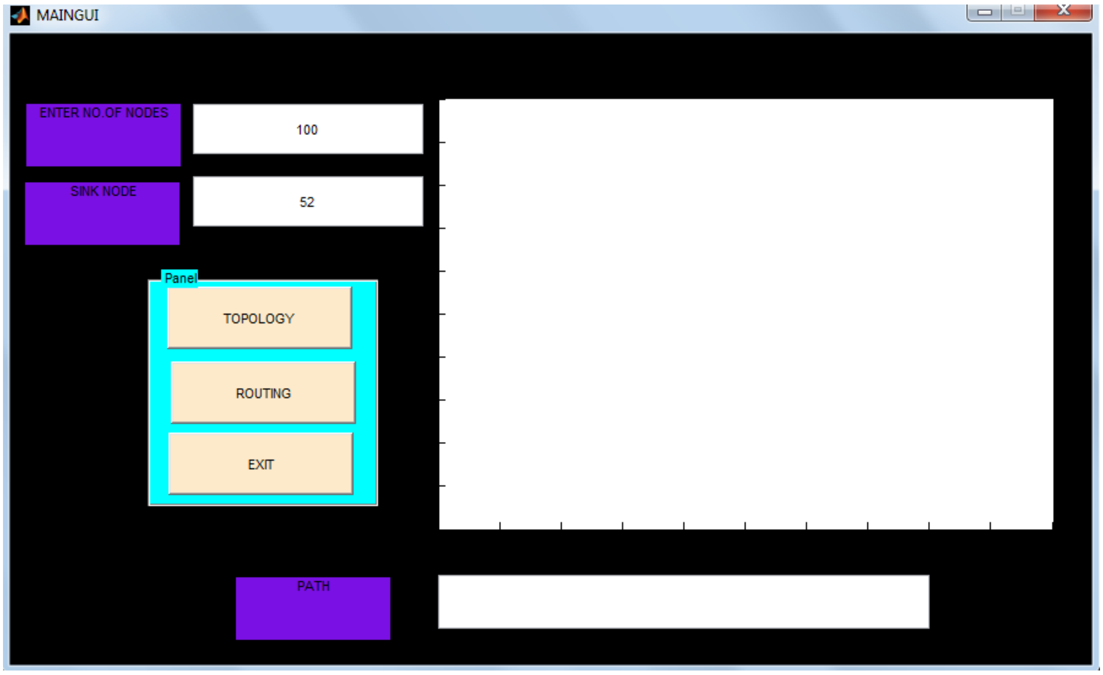

Figure 4.3: Implementation Screen 1

Next the user clicks on topology tab and the ring topology is created. The source node or the first is denoted in green and is separated from the topology as shown whereas the sink node or the destination node the denoted by red and is among the nodes in the topology as shown in Figure 4.4. The intermediate nodes will be denoted in magenta in figure 4.5.

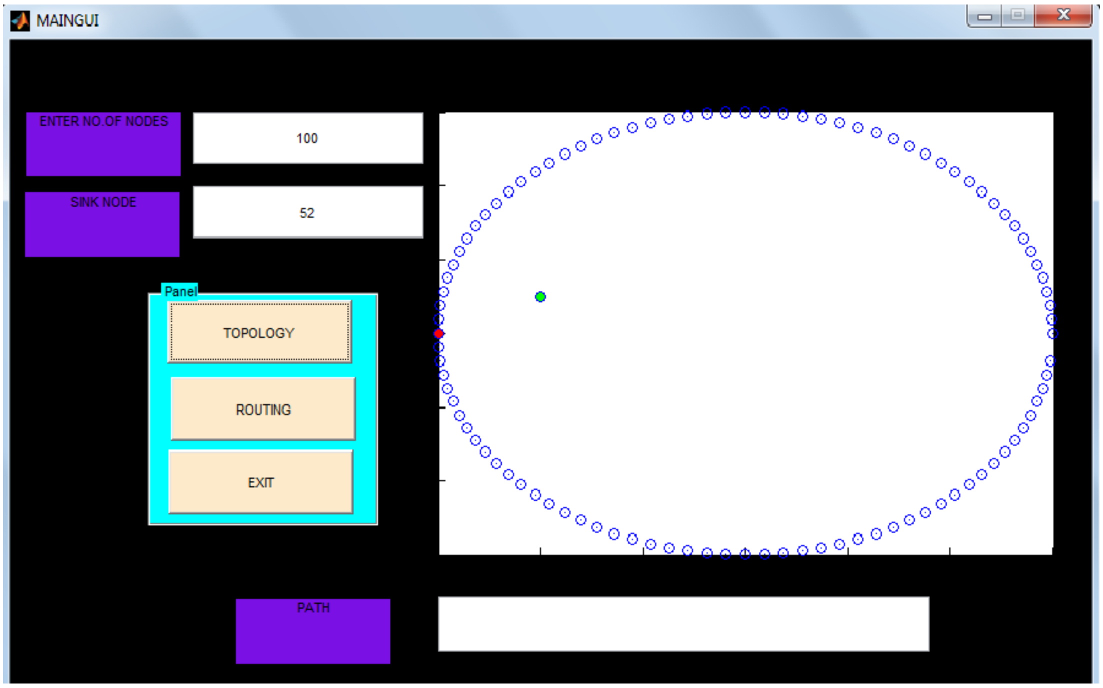

Figure 4.4: Implementation Screen 2

The next step is that the user will click on routing tab and the proposed routing algorithm will be executed. Also seen are the intermediate nodes and the destination node.

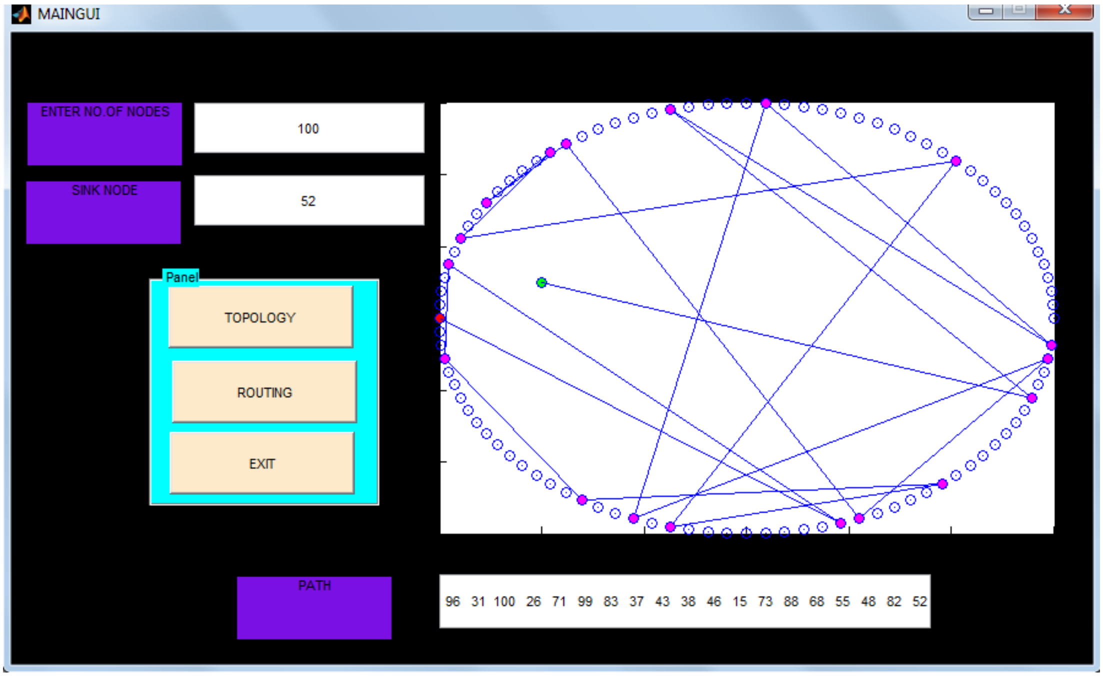

Figure 4.5: Implementation Screen 3

As we can see in the above figure 4.5, the complete path from the source to the destination has been given as an output. Out of the 100 nodes used, 20 nodes have been used to transfer the data from source to destination.

4.3 Energy Calculation for Analytical Model

In the MIMO, short-term energy constraint (STEC) and long-term energy constraint (LTEC) are considered with manifolds, which optimize the energy through the finite-rate feedbacks. In LTEC case, code words are allocated in b blocks. Hence, the average energy constraint is given by

$$E/t = P = \frac{1}{b}\sum_{i=1}^{b} |x[i]|^2 \qquad (6)$$

Where $x[i]$ is the signal transmitted in the i-th block. In this research, random quantization is used over the 3D WSN topology which can be assumed as Pn-manifold [34].

$$\mu \geq 1 - \mathrm{k} \times (2^{-\frac{N_f}{N}}) \qquad (7)$$

Power efficiency factor (7) depends on the "k" which have been obtained from channel matrix [34].

$$k = e_c \left[\frac{E_H(\sqrt{tr[(H\,H^H)^2\,(1+HQ_fH^H)^{-2}]}}{E_H(tr[(1+HQ_fH^H)^{-1}\,HQ_fH^H]} \right] \qquad (8)$$

In this research, random quantization technique is employed to calculate the e_c , which is a constant used in equation (8) [34].

$$e_c = \Gamma\left(\frac{1}{N}\right)(C)^{\frac{-1}{N}} \qquad (9)$$

In equation (9), c is the code word created from the random quantization [34]. When EE is, maximized without reducing the numbers of antennas used in MIMO, Pn-manifold that contains best suitable dimension and low-rank matrices can be used. The results obtained through these equations are discussed in the Results and Discussion chapter.

Chapter V

RESULTS AND DISCUSSION

5.1 Results for Wireless Sensor Algorithm

Here, 2D and 3D WSNs are considered with less complex topology and energy-efficient routing protocols. Using Matlab, proposed ACO is simulated and compared with conventional ACO.

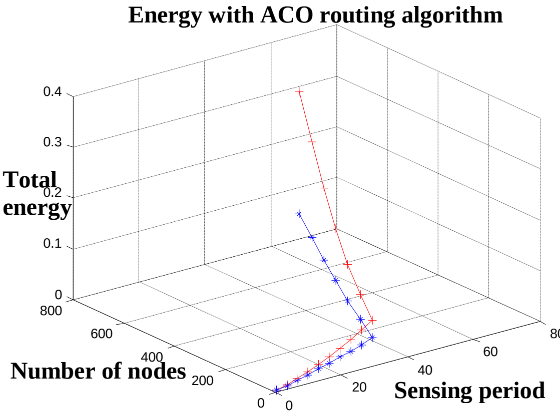

Figure 5.1: Comparisons of Total Energy

In figure 5.1, total energy is considered with sensing period, which allows us to calculate the EE. We can see that within the selected time, proposed and minimum energy can be obtained. The following table 5.1 shows the results for the WSN routing algorithm:

Table 5.1: Results for WSN Routing Algorithm

No. of nodes in topology	No. of nodes used in topology	Destination node	Total path
10	3	3	1,2,**3**
20	4	5	1,2,8,**5**
30	11	10	1,5,28,17,21,27,26,30,25,23,**10**
40	18	11	1,2,8,17,33,26,31,9,19,39,40,15, 7,14,28,27,23,**11**
50	20	13	1,2,11,26,28,15,20,44,16,7,19,48,

			46,8,34,4,6,38,12,**13**
60	20	30	1,2,6,16,22,14,42,52,59,31,29,34,25,36, 30,26,43,40,46,**30**
70	30	25	1,22,45,56,49,39,29,69,62,66,60,5,65,23, 18,26,12,3,6,2,57,55,61,21,51,4,14,34,44, **25**
80	37	45	1,72,11,47,46,29,26,10,17,51,75,79,49,12,74,14, 4,2,9,48,38,56,63,69,93,19,22,27,30,18,59,82, 90,95,102,109,**45**
90	42	46	1,2,5,75,18,24,4,63,80,85,36,48,89,29,43,50,39, 45,88,16,7,69,49,66,79,33,27,76,90,**46**
100	51	62	1,96,31,100,26,71,99,83,37,43,38,46,15,73,88,68, 55,48,82,52,39,3,5,60,4,7,33,13,10,32,95,65,85,40, 19,41,56,6,29,74,20,25,53,77,30,86,23,27,21,2,**62**
200	60	100	1 12 123 180 165 59 21 19 169 78 157 65 102 55 114 13 94 22 58 124 184 143 195 199 41 89 71 52 51 67 127 37 177 183 31 34 50 93 76 196 141 200 40 3 2 81 171 173 7 16 45 53 158 193 4 172 162 73 198 100
300	66	100	1 123 254 300 80 9 114 298 294 134 296 105 6 5 263 290 284 2 152 219 267 256 119 63 122 160 231 8 283 260 235 110 143 292 230 168 170 186 93 43 106 15 25 16 67 196 51 61 101 57 30 54 73 50 85 174 7 29 59 17 184 269 92 49 18 100
400	91	210	1 28 102 386 399 264 34 285 16 237 221 228 75 43 62 316 309 273 57 76 138 89 74 187 331 398 55 397 361 287 110 78 66 93 32 9 13 59 92 108 50 155 38 23 81 350 219 395 211 14 306 268 107 98 191 400 344 220 83 124 97 164 311 317 87 172 259 328 375 73 154 359 179 116 169 184 111 180 266 175 47 72 308 136 3 254 213 11 392 235 210
500	112	360	1 123 214 307 148 68 52 47 44 78 43 224 65 32 57 466 278 23 259 94 444 176 180 89 85 428 442 119 391 165 379 199 458 127 434 495 350 494 433 497 211 206 417 336 4 188 316 77 233 479 11 254 125

			340 274 218 482 267 87 382 53 446 54 96 300 498 169 83 348 263 189 82 271 117 443 430 294 467 246 2 3 36 408 204 58 9 213 241 448 317 351 195 302 304 131 209 499 281 326 205 228 217 361 261 438 463 216 76 472 352 496 360
600	146	430	1 99 139 578 458 204 385 251 388 514 266 332 594 233 341 269 209 131 392 600 515 187 36 4 174 450 159 144 79 352 526 116 78 171 121 226 179 3 317 176 229 80 596 206 587 63 223 398 10 307 478 286 582 336 318 138 52 487 524 502 170 135 390 297 69 569 128 9 59 363 337 574 188 470 72 216 425 108 215 592 62 107 103 503 100 518 105 31 224 181 597 96 104 573 595 296 397 89 213 151 122 145 67 70 481 16 2 371 111 585 500 7 241 445 313 591 28 192 73 556 259 220 441 14 83 468 377 319 403 358 15 575 598 589 521 457 564 57 191 102 5 25 97 382 536 430
700	156	565	1 3 10 18 156 609 103 154 650 699 333 354 531 534 281 107 85 121 75 124 343 233 291 223 553 697 555 202 358 686 605 2 84 171 563 4 6 11 288 318 385 122 261 91 203 524 499 253 433 690 653 569 585 558 696 522 658 21 24 16 369 225 613 561 688 414 290 401 126 444 572 676 680 466 66 556 689 128 39 495 526 668 615 349 543 227 336 692 436 113 95 452 390 592 430 434 46 19 7 13 92 208 158 271 183 108 700 479 277 142 272 197 186 678 698 181 187 31 51 226 82 649 199 79 130 177 41 34 192 133 477 332 404 112 26 408 33 47 206 40 301 264 577 5 90 274 373 8 28 426 391 207 150 262 254 565

5.2 Analysis of EE

EE (E) can be defined as in equation (10) with minimum energy E_{min} used in WSN and selected scheme E_{sel} involved with specific design and routing protocol.

$$E\eta = E_{min} / E_{sel} \qquad (10)$$

Here, selected scheme is considered as a proposed method, which is simulated for measuring the used energy in transmitter and receiver of WSN. Following Figure 5.2 and Figure 5.3 are simulated using the equations (2) and (3).

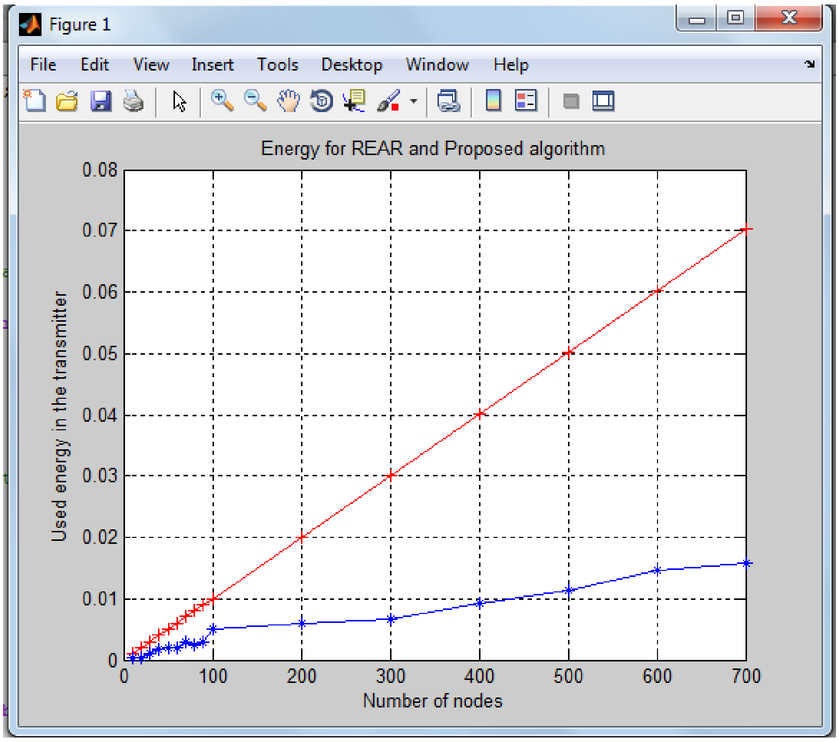

Figure 5.2: Comparisons for used energy for Transmitter

As shown in figures 5.2 and 5.3, energy difference between the transmitter and receiver is very small because selected topology had less complexity. It means Computational Topology is very small because path selection using proposed algorithm is very efficient.

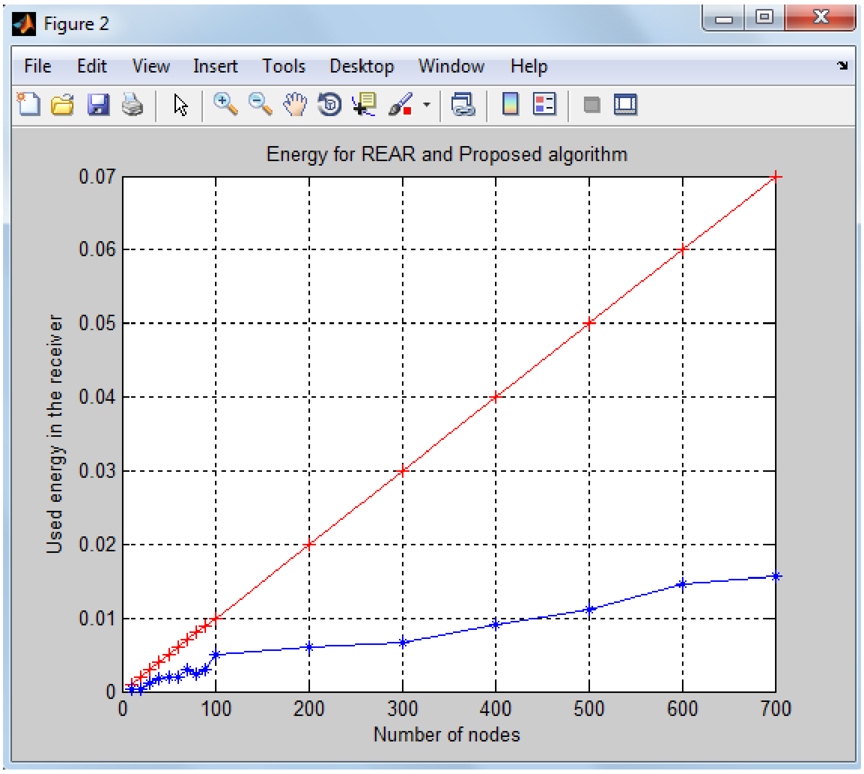

Figure 5.3: Comparisons for used energy in Receiver

Using the above simulations, EE can be calculated using equation (10) where minimum energy from existing scheme and also selected energy from the proposed scheme should be used. Both cases, fixed time and same topology must be considered.

5.3 Results for Proposed Analytical Model

In this section, power efficiency factor is calculated using MIMO channel matrix. To save the energy in WSN, link quality which depends on the routing protocol should be efficient to deliver the data or packet from the source node to base station (sink node) or receiver node that is on its shortest path. Even though MIMO directly involved in the physical layer, link quality indirectly involved with this layer. If link quality is efficient, total energy during the data transmission can be saved in WSN.

As a preliminary result in this research, power efficiency factor is analysed using Mat-lab. As we studied the manifold concept, Pn-manifold is employed to determine the “k” as in equation (7). As shown in figure 5.4, power efficiency factor is compared with different “k” values. From this factor, we can calculate the EE which helps us to save the energy through our analytical model. Assume fixed number of nodes is considered for simulation sensors randomly deployed over the region.

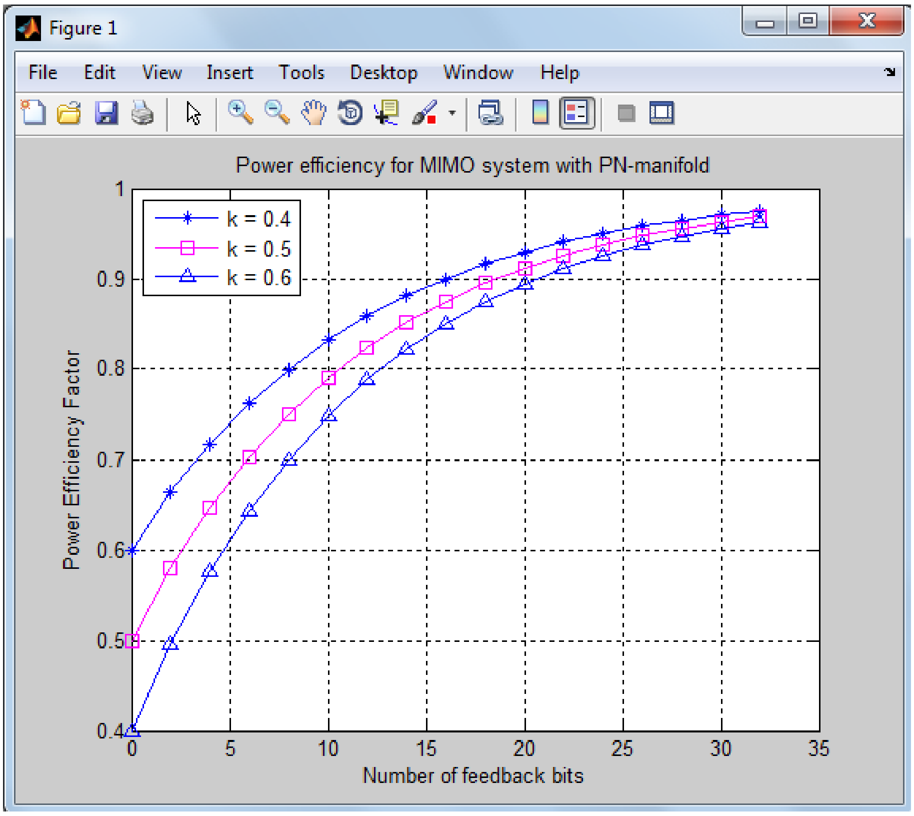

Figure 5.4: Energy Saving in WSN using different d values

Dimension of Pn-manifold is given as $N = \dim(M_f)$, where N and M_f are dimension and Pn-manifold. In order to define dimension for the real case of $M_f = Pn(p, \mathbb{R}, \leq \rho^2, = s)$, the following formula (11) can be used [34].

$$N = 0.5s(2p - s + 1) \qquad (11)$$

Figure 5.5 is simulated using equations (7), (8) and other necessary parameters obtained from [33]. In this simulation, a number of transmitting antennas is varied to analyse the power efficiency factor, which is very useful to determine the energy saving in WSN.

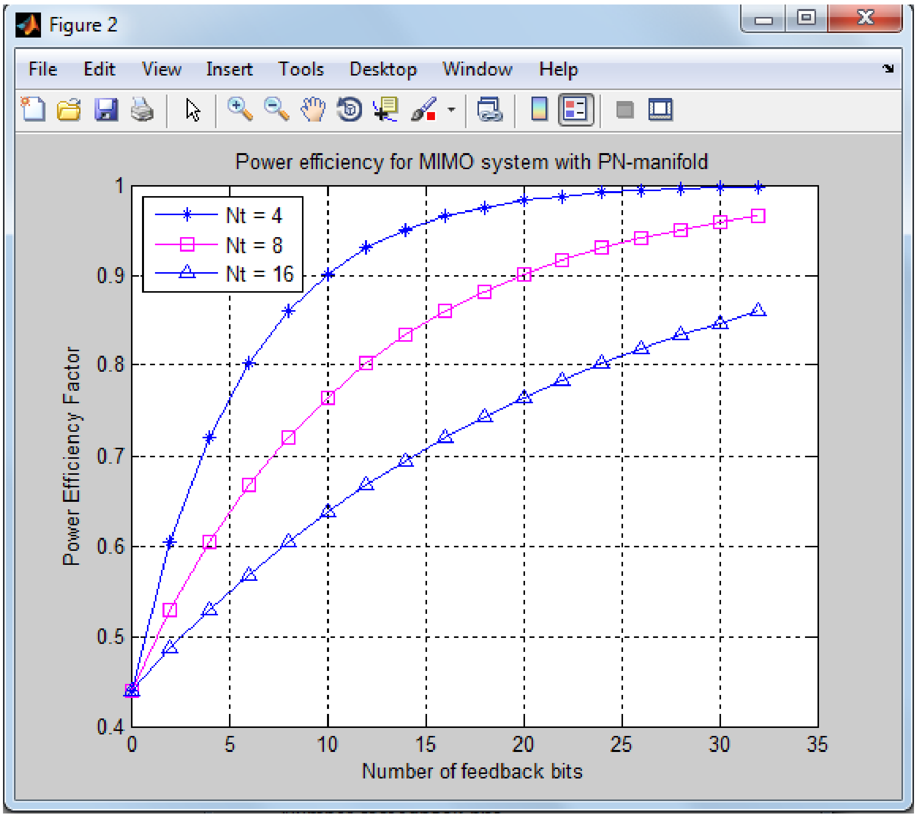

Figure 5.5: Energy Saving in WSN with different dimensions

Most modern communication systems have feedback channels. From this research, advantage of the feedback channels to increase spectral efficiency and decrease complexity, which is important to battery powered mobile applications. Regarding EE factor, rate, capacity and other important key terms used in massive MIMO are dependant. Since the EE is a ratio between the rate and power, the EE gain between two systems can either be the result of a system providing a better rate for a fixed transmit power. Also, lower power consumption for a fixed rate than the other system for the same noise power should be considered. In other word, the EE gain is either due to an increase of spectral efficiency or a decrease of consumed power. When base station has more antennas than allocated users, total EE will be reduced because spatial correlation (SC) and mutual coupling (MC) between antennas takes and wastes the energy unnecessarily. MIMO enables a significant reduction of latency on the air interface. Since the EE is a ratio between the rate and power, the EE gain between two systems can either be the result of a system providing a better rate for a fixed transmit power, or lower-power consumption for a fixed rate than the other system for the same noise power. In other word, the EE gain is either due to an increase of SE or a decrease of consumed power.

Chapter VI

CONCLUSION

6.1 Conclusion

Routing in WSN is now a new area of research. In this research, we have designed an energy efficient routing algorithm which combines both features which are energy efficient routing and shortest distance routing for WSN's. As we have seen that we have analysed the EE using the existing and proposed routing protocol used in WSN. From the results, we have seen that proposed algorithm has achieved better energy performance in both transmitter and receiver nodes when compared to the existing protocol of the WSN. Since the energy consumption is reduced and also the distance is optimized so the proposed algorithm is cost effective. While designing this routing algorithm some points are taken into consideration. Firstly, the nodes only listens to the data whose radio is "ON", therefore idle listening is reduced. Secondly, after making the selection of sender and the receiver all other nodes except them are turned "OFF" till the transmission takes place. Thirdly, the status of nodes is kept "ON" randomly so that energy consumed in all nodes are balanced.

Also in this research, we have developed an energy efficient analytical model for next generation networks based on MIMO technology. The expectation from the next generation networks is to be able to handle much higher data rates with the higher capacity. MIMO techniques are heavily exploited and integrated into many wireless standards like 3G, 4G, WLAN's etc. Multiple-Input Multiple-Output (MIMO) based

Wireless communication systems have increased spectral efficiency for a given total transmit power and also it has increased capacity by introducing additional spatial channels that are exploited by space-time coding. This proposed model can be utilized to maximize EE in wireless as well as in other networks. As we have seen that Pn-manifold is used as a method which helps in reducing the dimensions of channel matrix that uses MIMO technology. Manifolds are applied in MIMO system, which enhances the efficiency of communication channel. Also, it provides less energy consumption, which reduces the overall cost in energy saving model. The Pn-manifold in MIMO applications provides better results, and we can see that EE factor is constant when feedback bits are approached infinity.

6.2 Future Work

As future work, the external environments conditions, traffic (congestion) problems with different types of delays can be used during the processing and link establishments in the routing algorithm. Since our proposed algorithm is based on ring topology, we can extend our proposed algorithm to other topologies like bus, star etc. In the analytical model, we can increase the number of antennas at the transmission or we can increase the number of antennas at the receiving side or we can increase the number of antennas at both transmitter and receiver and check out the power efficiency factor. Also we can implement the analytical model with different types of manifolds and check out the EE factor.

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