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ISTANBUL ALTINBAŞ UNIVERSITY

ELECTRICAL AND COMPUTER ENGINEERING

BASE NODE POSITION OPTIMIZATION FOR OPTIMAL ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORKS

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Istanbul, 2019

BASE NODE POSITION OPTIMIZATION FOR OPTIMAL ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORKS

By

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Electrical and Computer Engineering

Submitted to the Graduate School of Science and Engineering

in partial fulfillment of the requirements for the degree of

Master of Science

ALTINBAŞ UNIVERSITY

2019

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Mays Qasim Jebur

DEDICATION

I dedicate this thesis to my family, classmates and all my friends for the support and encouragement throughout my education and life. Special dedication goes to my supervisor Asst. Dr. safer kurnaz, my sisters and my mother for their support and prayers during my research work.

ACKNOWLEDGEMENTS

I might want to offer my thanks to every one of the individuals who have upheld me all through the regularly extended periods of this voyage. I might want to thank my advisor, Asst .Dr. Sefer kurnaz for being my compass notwithstanding when I believed I was lost and being in extraordinary part in charge of the zenith of this work. I might likewise want to thank my supervisors for their supportive exhortation, which incredibly enhanced the nature of this work. Finally, I thank this institution for hosting me during these years, securely earning its place as my home. I am very thankful to my mom and dad, whose values and education motivate me to keep asking questions; to my siblings and family for their infinitely appreciated love and to my country which, although inanimate, keeps me anchored and offers me an example of resiliency.

ABSTRACT

BASE NODE POSITION OPTIMIZATION FOR OPTIMAL ENERGY CONSUMPTION IN WIRELESS SENSOR NETWORKS

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Date: March /2019

Pages: 45

It is essential to find and optimize the base nodes position for the purpose of optimum energy consumption in Wireless Sensor Networks (WSNs) because of energy restrictions as they run on battery. Also WSNs are prone to sudden changes for example due to node failure or unpredictable topological changes. For us to reduce energy consumption in WSNs the design of routing technique is very key. The purpose of this research work is to design a base node position optimization technique that will reduce the level of energy consumption and increase the network performance by considering three key parameters namely the distance between source node and the gateway, the energy of the sensor node and the amount of data in the queue for the sensor node.In WSNs the nodes which are near the sink or the gateway are used to forward or direct the data for the nodes which are far away from the sink. This means that the nodes closer to the sink will get drained faster in terms of power because they have to send the data of the nodes which are far away from the sink node together with their own data. In order to avoid nodes from failing there is need to design a base node position optimization protocol that is aware of the energy of the sensor nodes, the data in the queue and the distance to the sink node. The sink node is the one that sets up the routes for each sensor node.

The base node position optimization protocol used is based on MA-based technique and wake-up schedule. The use of MA-based technique is to compute the overall cost of each node to the gateway by considering the data load in the node and the energy of the node. The wake-up schedule algorithm is used in this work to find and evaluate the shortest route from the source sensor node to the gateway (sink node) which is determined by the shortest distance. The designed protocol showed an improved performance and a routing balance between the network performance and the network lifetime.

During the last decade, communication protocols have expanded from the TCP/IP protocol stack used in most of the networks around the world, to a more purpose oriented designs such as the ones intended for Wireless Sensor Networks (WSN) protocols. While both designs share the objective of having reliable data transmissions, their designs are intrinsically different by their very nature. For example, protocols designed for wired-link connections are characterized by their low delay, high reliability, and high bandwidth. On the other hand, WSN protocols deal with mobile elements, have a high propagation delay and high error rates. In addition to this problems, WSNs introduce mobility and the requirement of energy efficiency to ensure the devices lifetime.

Keywords: node positioning, routing protocols, MA-based, energy consumption, base station, optimization, wireless networks, network topologies, wake-up schedule.

ÖZET

KABLOSUZ SENSÖR AĞLARINDA OPTİMAL ENERJİ TÜKETİMİ İÇİN BASE NODE POZİSYONU OPTİMİZASYONU

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Tarih: Mart / 2019

Sayfalar: 45

Kablosuz Algılayıcı Ağlarda (WSN'ler), pilde çalıştıkları enerji kısıtlamaları nedeniyle optimum enerji tüketimi amacıyla taban düğümlerinin konumunu bulmak ve optimize etmek önemlidir. Ayrıca WSN'ler, örneğin düğüm arızası veya öngörülemeyen topolojik değişiklikler nedeniyle ani değişikliklere eğilimlidir. WSN'lerde enerji tüketimini azaltmak için yönlendirme tekniğinin tasarımı çok önemlidir. Bu araştırma çalışmasının amacı, enerji tüketimi seviyesini azaltacak ve kaynak düğümü ile ağ geçidi arasındaki mesafe, sensör düğümü enerjisi ve Sensör düğümü için kuyruktaki veri miktarı. WSN'lerde, lavaboya veya ağ geçidine yakın olan düğümler, lavaboya uzak olan düğümlerin verilerini iletmek veya yönlendirmek için kullanılır. Bu, lavaboya daha yakın olan düğümlerin güç açısından daha hızlı boşalacakları anlamına gelir çünkü lavabo düğümünden çok uzakta olan düğümlerin verilerini kendi verileri ile birlikte göndermek zorundadırlar. Düğümlerin bozulmasını önlemek için, sensör düğümlerinin enerjisinin, kuyruktaki verilerin ve lavabo düğümüne olan mesafenin farkında olan bir temel düğüm konumu optimizasyon protokolü tasarlanması gerekir. Lavabo düğümü, her bir sensör düğümü için yolları ayarlayan düğümdür.

Kullanılan temel düğüm konumu optimizasyon protokolü, MA tabanlı tekniğe ve uyanma çizelgesine dayanır. MA tabanlı tekniğin kullanılması, düğümdeki veri yükünü ve düğümün enerjisini dikkate alarak her düğümün toplam maliyetini ağ geçidine hesaplamaktır. Uyandırma programı algoritması bu çalışmada kaynak sensör düğümünden en kısa mesafeyle belirlenen ağ geçidine (lavabo düğümü) giden en kısa yolu bulmak ve değerlendirmek için kullanılır.

Tasarlanan protokol, geliştirilmiş performans ve ağ performansı ile ağ ömrü arasında yönlendirme dengesi gösterdi.

Son on yılda, iletişim protokolleri, dünyanın dört bir yanındaki ağların çoğunda kullanılan TCP / IP protokol yığından, Kablosuz Sensör Ağları (WSN) protokolleri için tasarlananlar gibi daha amaçlı odaklı tasarımlara doğru genişledi. Her iki tasarım da güvenilir veri aktarımlarına sahip olma hedefini paylaşırken, tasarımları doğaları gereği aslında farklıdır. Örneğin, kablolu bağlantı bağlantıları için tasarlanan protokoller düşük gecikmeleri, yüksek güvenilirlikleri ve yüksek bant genişlikleri ile karakterize edilir. Öte yandan, WSN protokolleri mobil öğelerle ilgilenir, yüksek bir yayılma gecikmesine ve yüksek hata oranlarına sahiptir. Bu sorunlara ek olarak, WSN'ler cihazların kullanım ömrünü sağlamak için mobilite ve enerji verimliliği gereksinimi getirmektedir.

Anahtar Kelimeler:düğüm konumlandırma, yönlendirme protokolleri, MA tabanlı, enerji tüketimi, koloni optimizasyonu, kablosuz ağlar, ağ topolojileri, uyanma programı.

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LIST OF ABBREVIATION

AI	Artificial Intelligence
ADC	Analog to digital Converter
AMABIS	Adaptive MA-based Inference System
BPS	Bits per Second
DD	Directed Diffusion
DDDC	Directed Diffusion Data Centric
DV	Distance Vector
GEAR	Geographic and Energy Aware Routing
GSPR	Greedy Perimeter Stateless Routing
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
IOT	Internet of Things
LEACH	Low-Energy Adaptive Clustering Hierarchy
MAC	Medium Access Control
NO	Node Optimization
OSI	Open Systems Interconnection
OSPF	Open Shortest Path First
PAN	Personal Area Network
PSO	Particle Swarm Optimization
QOS	Quality of Service
RIP	Routing Information Protocol
SPEED	Stateless Protocol for End to End Delay
TBF	Trajectory Based Forwarding
WUS	Wake-Up Schedule
WSNs	Wireless Sensor Networks

1. INTRODUCTION

This starting chapter is organized as follows .The first section pertains to the global the me, base node position optimization with the current view of market as well as some statistics, and also mention in gapartnerofthisproject.Section1.2 shows the problem statement of this work, while Section1.3 presents the justification to carry on this work, and Section1.4 describes the objectives of the thesis and project .The last section contains the scope of the thesis

1.1 BACKGRAOUND INFORMATION

WSNs are composed of several sensors which are randomly or deterministically distributed for data acquisition and to forward the data to the gateway for further analysis. WSNs are used in many applications such as in health care for in patient monitoring; in utilities such as electricity grid, streetlights and water distribution in municipalities; in remote monitoring for example to monitor the condition of water, soil or bridges; in industries to monitor the state of equipment and detect any malfunction during normal production activity. In general, WSNs take measurements of the desired application and send this information to a gateway, whereby the user is able to interpret the information to achieve the desired purpose. The main importance of WSNs in area of machine monitoring is that they can be placed in a rotating machinery, or in a place which is unreachable for the engineer to take measurements by hard wired sensors.

WSNs routing protocols are designed to establish routes between the source and destination nodes. What these routing protocols do is that they decompose the network into more manageable pieces and provide ways of sharing information among its neighbors first and then throughout the whole network. The traditional routing protocols which have been in existence are divided mainly into three; network organization routing protocol, route discovery routing protocol and protocol operation routing protocol. However, these traditional protocols do not perform well as compared to Artificial Intelligence (AI) routing protocols. Other routing protocols such as Open Shortest Path First (OSPF) and Distance Vector (DV) have not been considered because they are based on distance only. Since WSNs are limited in energy we need to consider other factors which lead to energy consumption apart from distance only. These factors include the energy of the sensor node and the data in the queue

The importance of using AI techniques to perform routing of WSNs is that the system operation is energy aware, distance aware and data aware. If such a routing algorithm is used in industrial applications, it will lead to energy conservation and efficiency.

1.2 STATEMENT OF THE PROBLEM

The main problem of WSNs is energy limitation. Energy factor is very crucial when designing a routing protocol for WSNs even if the sensor is running on external solar energy or other form of renewable energy. Wireless sensors are designed to run on battery which is not a reliable source and can go on a few days depending on the application in use. For us to avoid sensors from failing out quickly leading to network failure and unreliability an energy aware routing is very essential. The other problem of WSNs is the bandwidth, the data that is transmitted to the sink node is reduced to avoid redundant or unnecessary data transmission which can lead to energy wastage of sensors. Therefore, it is very important to design a routing protocol that will efficiently lead to minimum energy consumption of the sensor nodes.

In this work the applied protocol has used FACO to find the optimal path from source node to the sink node to improve the network lifetime. Generally speaking, various machine learning algorithms have been proposed by different researchers to enable WSNs to perform routing in a dynamic environment. Most of these machine learning algorithms are adaptive and can greatly provide energy efficient communication in WSNs. These machine learning algorithms include Neural Network (NN), MA and Swarm Intelligence (SI) [1][2].

1.3 JUSTIFACTION

WSNs are cheaper in cost and require little or no maintenance once installed hence the need for using them for various applications. For these applications to be efficient and reliable, there is need to design a routing optimization protocol to manage the communication of WSNs in energy aware, data aware and distance aware mechanism.

The designed routing protocol is modified to take extra considerations like the data load on the sensor nodes in addition to the other considerations for example the energy available in the node and the minimum distance between the source node and the destination node. These additional considerations will enhance energy efficiency and reliability for WSNs.

1.4 OBJECIVE

1.4.1 Main Objective

The main objective is to develop an efficient routing optimization protocol for wireless sensor network using wake-up schedule optimization algorithm and MA-based logic technique.

1.4.2 Specific Objectives

- To develop a model of routing for wireless sensor network.
- To simulate the model in Matlab using wake-up schedule algorithm and MA-based logic to achieve minimum energy usage within the nodesand to use the optimum shortest path possible from source to the sink node.
- To analyze the performance of proposed routing protocol and compare with other related existing routing protocol.

1.5 SCOPE OF STUDY

This study focused on performing a node position optimization for WSNs. The main aim is to apply MA-based and wake-up schedule algorithms for the creation of base station and to improve the communication performance and reliability of WSNs with less energy used. The issue of concern in this research is the battery life for WSNs. To increase the battery life of WSNs, the routing protocol is designed to allow sensors with the highest score to be allowed to transmit data while the sensors with a lower score are allowed to stay on standby for the next round of sending information to the sink node.

The proposed routing technique and base station creation uses MA-based and WUS.This research focused on designing a routing protocol that is energy efficient considering three factors namely; total energy of the sensor network; minimum distance; and data load on nodes. The routing protocol was written in Matlab and Python code and the results simulated. No physical implementation was done because the time frame and resources did not allow both simulation and hardware implementation.

2. BACKGROUND

The information contained in this chapter represents the basis fall the work developed throughout this thesis and project, in two distinct areas : abase node position optimization through the vast use of base station and second the use of proposed algorithm in the domain of wireless sensor networks.

2.1 INTRODUCTION

In the world of today a key interest is focused on industrial automation. Wired sensors are being replaced by WSNs because wireless sensors are portable and cheaper as compared to their counterpart. It is seen that in the 20th century the technology of WSNs did not exist as much but over the years in the 21st century, they have been used to solve engineering problems in the areas of academics and in the industry. The following are the evolutions of wireless sensors: The University of California Los Angeles. In the case of WSNs with ZigBee technology the battery life duration is limited to three years [1].

The technological improvement of wireless sensors over the years will combine in the future to make the nervous system of the Internet of Things (IOT). For this reason, also the market share will increase with the number of applications and the life of human beings will be greatly improved by reducing the man power required to perform various operations. WSNs are built on several of mobile Internet Protocol (IP) standard [2].

Figure 2.1 illustrates a model of a sensor network. WSNs have several sensor nodes which are embedded in the sensor field to capture the required data which is forwarded to a common gateway or a sink node (base station). The data from the gateway is forwarded to the observer remotely via the internet. The sink node is the network controller and it is responsible for setting up the routes for each sensor node. It also acts as a gateway (destination) for WSNs to collect all the data from the network [3].

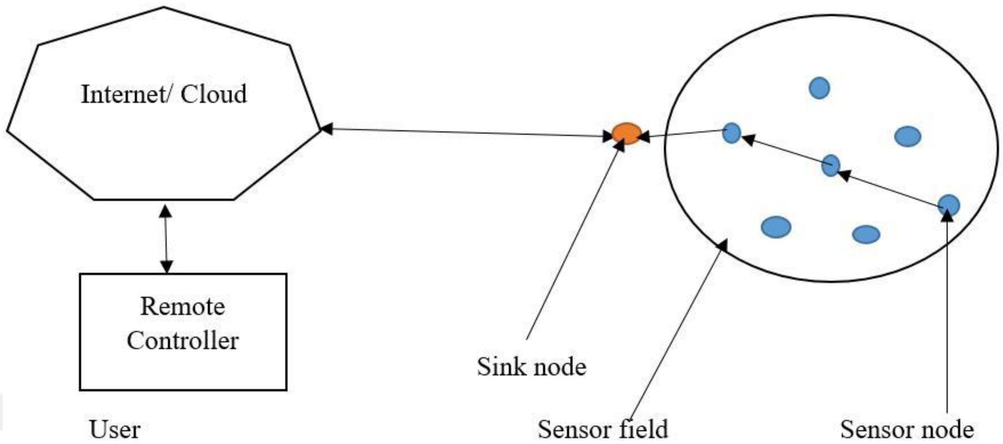

Figure 2.1: Model of a sensor network

Figure 2.2 shows a sensor node comprised of several parts which are: a unit used for sensing and actuation, it is composed of one or more sensors; a unit for processing, which forms the memory of the sensor; a unit for communication, which is comprised of transceiver with an internal and external antennas for purpose of data transmission ; a unit for power, which includes the battery; and other units for other applications which include the Location finding system, power generator and an actuator [4] [5].

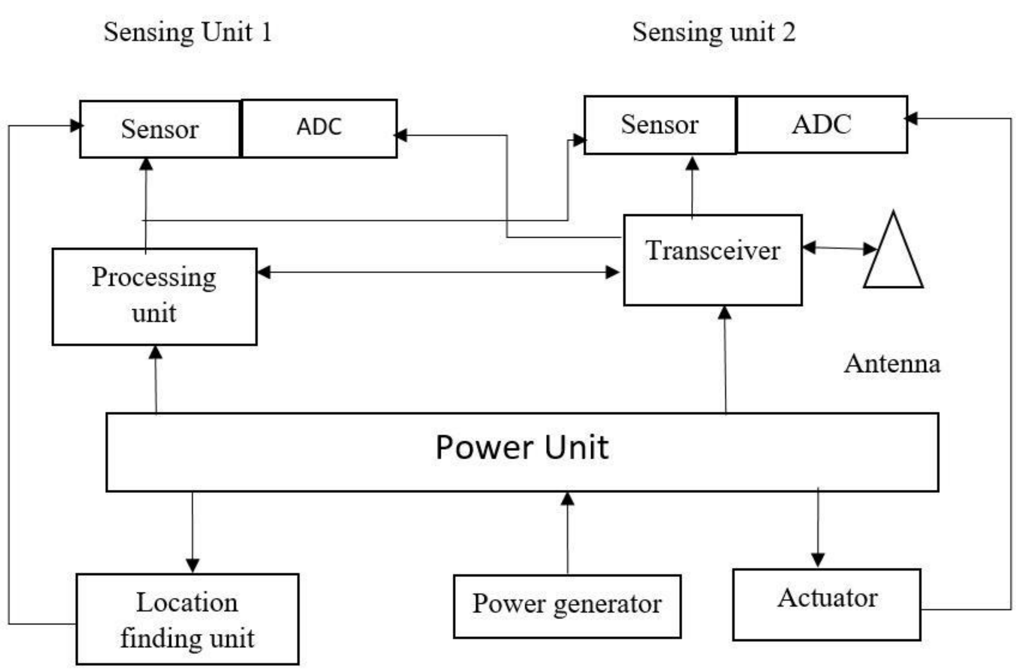

Figure 2.2: Various parts of a sensor node for measuring pressure

A sensor node has an in built radio transceiver with an internal antenna to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source which is a battery and a platform for allowing external energy supply if required especially for the sink node. Industries manufacturing WSNs are looking forward to produce complete Micro-electromechanical Systems (MEMS) based sensor systems at a volume of 1 mm^3. Wireless sensors are relatively inexpensive but the cost will depend on the application and other factors like the memory of the sensor, the energy of the sensor, the operating speed of the sensor as well as the size of the sensor [5].Figure 2.3 shows a worldwide survey that was done to show the increase of wireless sensors installed by the year of 2016. WSNs have increased its market in the industry applications by over 20% and other market for new applications that do not rely on hard wired sensors with a share of 60% [6] [7]. From the survey shows there has been and still is an increase in the number of installed industrial wireless sensors over the years.

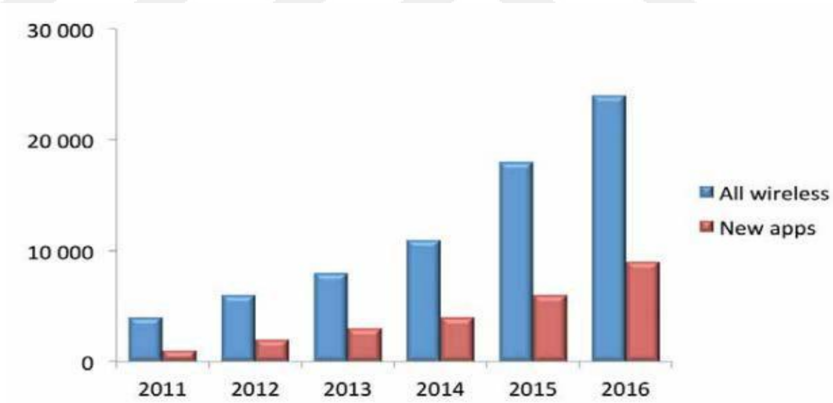

Figure 2.3:Industrial wireless sensors that have been installed in the world over the years

2.2 COMMUNICATION PROTOCOLS FOR WSNs

Several researches have been done by different authors to save energy usage of WSNs. The researchers have focused on routing protocols because these protocols may be different from the traditional networks [8;11].

Table 2.1 shows a reference communication protocol which is in reference to the Open Systems Interconnection (OSI) reference model used to describe the communications in WSNs. The upper layers (application, presentation and session) in the network are the ones used for communication purpose and they include the application processing, data aggregation, external query processing and external database. The other layers in the communication protocol are; Layer 4 which is the transport layer and its work is to provide error correction and to work with other layers to enable packets to be send and received without errors; Layer 3 is the networking layer and its work is to forward packets and perform routing; Layer 2 is the data link layer and is concerned with delivery of frames between devices connected on the same Local Area Network (LAN), the data link layer also includes channel sharing Medium Access Control (MAC), timing; and Layer 1 is the physical medium which is the communication channel for sensing, actuation and signal processing [12].

Table 2.1: Communication protocol for WSNs

Application Layer-Layer 7
Presentation Layer-Layer 6
Session Layer-Layer 5
Transport Layer-Layer 4
Network Layer-Layer 3
Data Link Layer-Layer 2
Physical Layer-Layer 1

2.3 NETWORK TOPOLOGIES FOR WSNs

Figure 2.4 displays the most commonly used WSNs topologies which are star, cluster tree or mesh network topologies. The star topology is one where each node is connected directly to the sink node. The cluster tree network forms a cluster head to represent each cluster, the cluster head then connects to a node which is higher in the tree and then to the sink node. Mesh topology is one where each node is connected to several nodes by forming several paths to the sink node. Mesh topology is also called a router [13].

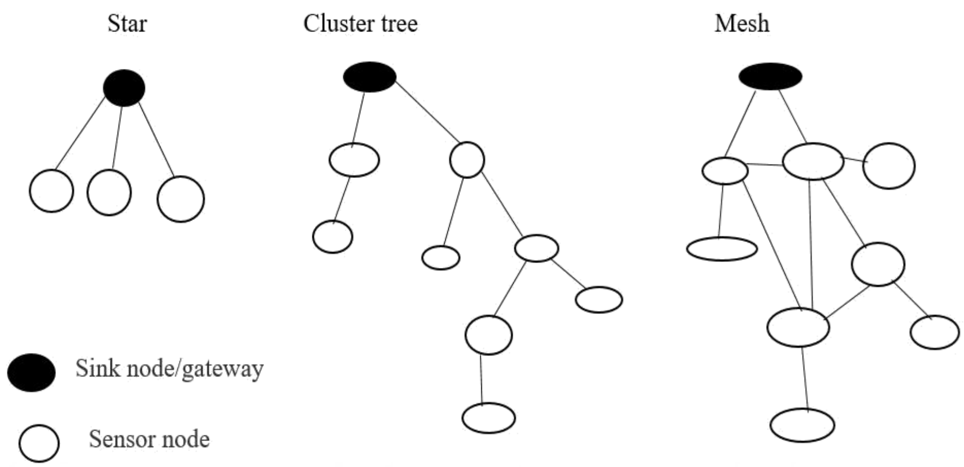

Figure 2.4: WSNs network topologies

2.3.1 Star Topology

A star topology is one in which the nodes are connected to a centralized hub or a gateway. The transmission of information is routed through the gateway. This is done by naming the nodes as clients and the gateway as the router. Reference [14] proposed a routing technique for WSNs to improve the life of a battery using MA and an A-star algorithm. It used a star topology in the algorithm.

Star topology is able to simplify the network because it has minimum networking issues, but its biggest challenge is the issue of scalability. Nodes deployed far away from the gateway or the hub will have bad quality connection with the hub. Therefore, star topology is used where the coverage area is small or within the range of radio transmission.

2.3.2 Cluster Tree Topology

Cluster topology is mainly used in applications for larger WSNs. In this topology the devices in the lower tier send their information to a local cluster head and in turn thecluster head sends the information to the gateway in the upper tier. The main advantage of cluster tree topology is that it partitions the entire network into small clusters where information is routed to a cluster head locally. The cluster head is the one that is responsible for transmitting the data to the sink node. According to [15] the proposed method makes use of cluster topology in WSNs to increase the network battery and also use of Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol, which is one of traditional routing protocols for WSNs. The LEACH protocol uses a local cluster head that is able to distribute the energy evenly in the WSNs. The limitation of LEACH protocol is that it only considers one parameter for routing which is the energy of a sensor node.

2.3.3 Mesh Topology

In mesh topology data can be sent via several paths from source node to the gateway. This topology has the ability to keep the list of nodes that have been given the access to use the network. When the node wakes up the radio is turned to ON state and is able to scan the network, locate the sink node in order to join the network and begin taking the required measurements. For the reason that each node is joining the network upon its wake up, there is a possibility of finding an alternative path to the sink node in case some paths are not available for data transmission.

The main advantage of this topology is that it is fault tolerant in case of a failure of one link an alternative link can be established to route information to the gateway. However, this topology disadvantage is that the network performance may decrease because each node must hop to get its messages back to the gateway.

2.4 ROUTING PROTOCOLS FOR WSNs

The aim of WSNs is to perform sensing and to acquire the desired information from a source node, process the information and send it to a gateway for analysis depending on the kind of application in use. In order to perform these tasks efficiently and appropriately there is need for a routing protocol that is energy aware, data aware and distance aware so as to establish optimum routes between source sensor nodes and the sink node. This route selection is referred to as routing and must be done in a way that WSNs battery life is extended in an optimum way. One of the main challenges of the sensor network is energy limitation within the operating environment making the routing problem very challenging. A reliable design of routing protocols for WSNs should consider that the power in these sensors is limited and so energy factor must be considered in their designs [16].

The choice of a routing protocol in WSNs is generally made based on the following factors; sensor node physical placement, energy in the sensor node, data delivery model, fault tolerance, scalability, network dynamics, transmission media, connectivity, coverage, data aggregation/converge cast and quality of service. In node placement, the physical placement of sensors depends on the type of application in use. This sensor placement can be deterministic or random depending on where exactly the measurements are to be taken. Deterministic sensor placement method allows the engineer to manually place the sensors through established or pre-determined routes. Random node placement allows the engineer to randomly place the sensors in the desired area of sensor measurement. In the case of the energy in the sensor network nodes in the network can drain their energy when doing computations and sending datato the gateway which may be located a bit far from its area of physical connection. In order to conserve this limited energy, the ways of communication and computation are important. For the case where a sensor node has several hops to the sink node, the sensor node will perform both the dual role of data acquisition and data sender. In the event that a sensor network might fail due to energy depletion, there can be a significant topological change which might result in rerouting of packets and reorganization of the network [15].

Figure 2.5 shows the routing protocols for WSNs; Flat routing include Sensor Protocols for Information via Negotiation (SPIN) and Directed Diffusion (DD); Hierarchical routing include LEACH (Low-Energy Adaptive Clustering Hierarchy) protocol, and PEGASIS (Power-Efficient Gathering in Sensor Information Systems) ;Location based routing include GEAR (Geographic and Energy Aware Routing) protocol and GPSR (Greedy Perimeter Stateless Routing); Negotiation based routing include SPIN; Multi-path network routing include DD (Directed Diffusion); Query based routing include DDDC (directed-diffusion- Data Centric routing); QOS based routing include TBP (Trajectory Based Forwarding) and SPEED (Stateless Protocol for End to End Delay); Coherent based routing include DD (directed diffusion); The proactive strategy is the strategy where routing information is forwarded periodically so as to keep accurate and consistent routing tables. Flat proactive routing strategies are used to find optimal paths. Reactive routing strategies determine paths to a limited number of destinations. Hybrid strategies base their routing technique on the structure of the network to gain scalability and stability for large networks. A hybrid routing strategy can be used but proactive routing is adopted in a cluster while a reactive routing is adopted across clusters [18].

Other traditional routing protocols include Open Shortest Path First (OSPF), a protocol which is based on the open shortest path first. Distance Vector (DV) routing protocol manipulates vectors of distances to other nodes in the network.

The above traditional routing protocols are not effective since they consider only one factor in evaluating the shortest distance between the source node and the sink node. For example, OSPF and DV consider the distance only, LEACH protocol considers the energy only, and GEAR protocol considers only the locality of the sensor node. Other routing mechanisms which are more advanced as compared to the methods above are based on machine learning. The routing mechanisms that can be used are in AI and can perform better in relation to above traditional routing techniques. They include; MA, NN and SI algorithms [17]- [21].

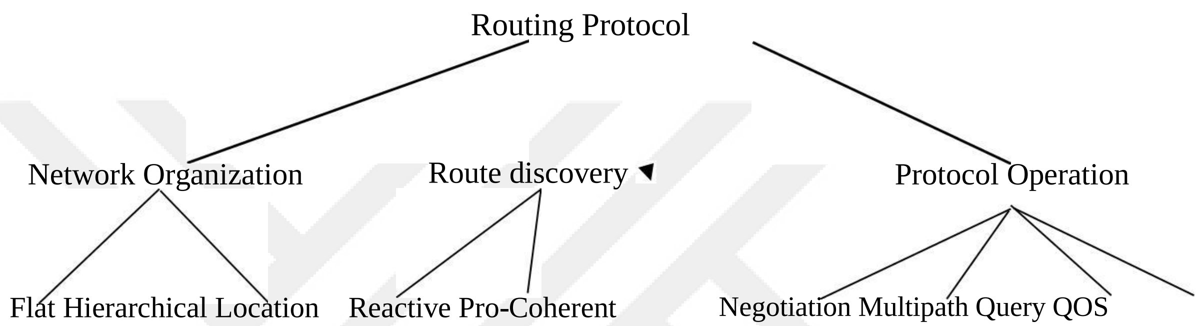

Figure 2.5: Routing protocol categories

In Figure 2.6, for communication to be established between two sensors the energy usage during information transmission (E_{TX}) is calculated by first order radio model from equation (2.1) [22] [20] [24].

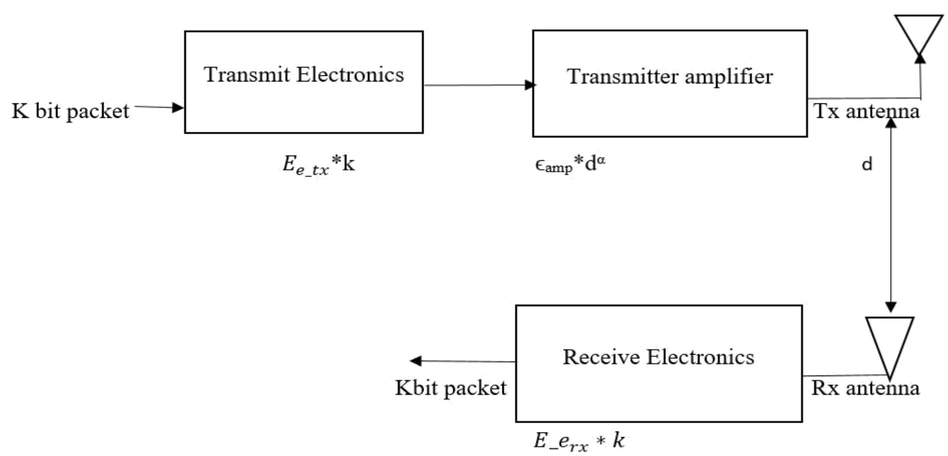

Figure 2.6:First order radio model for WSN

$$E_{TX} = *k+\epsilon_{amp}*d^{\alpha} \quad (2.1)$$

In the above equation K represents the number of data bits that have been sent; α is a constant value that is between 2 and 5; d is the distance between two sensor nodes; ϵamp is the amplification coefficient that enables minimum bit error rate; and is the amount of dissipated energy to operate the transmitter, it is shown in equation (2.2).

$$Vcc= *ITP+\epsilon amp*Kdata \quad (2.2)$$

Vcc represents the working voltage, ITP represents the transmission current, and Kdata _ rate represents the information transmission rate. The energy usage for information reception is given by equation (2.3).

$$E_{RX} = E\_e_{rx} * k \quad (2.3)$$

If the distance is fixed, then the energy usage is directly proportional to the number of data bit, this is from equation (2.1).

2.5 RELATED WORK AND SUMMARY OF RESEARCH GAPS.

The major challenges of WSNs is energy efficiency, responsiveness, robustness, self-configuration and adaptation. Research has been done within the past years to determine the optimal path for a WSNs minimizing energy consumption between the source node and destination node. However, the challenge has been to create a good routing algorithm taking into consideration the major challenges mentioned above.

Reference [14] proposed a routing optimization design of WSNs based on the residual energy of the sensor node, minimum hop counts; and data burden on nodes. The algorithm was LPA-star algorithm (Lifelong planning star search algorithm) combined with MA. The algorithm employs LPA star algorithm to find the route between the source node and the destination node in a dynamic environment. The algorithm used does not perform well because it uses a star topology meaning nodes deployed far away from the sink node will have bad quality connection to the sink node.

Reference [25] designed a leakage detection system that used WSNs in a pipeline that allowed a number of sensors running on low power to be used to check a leakage in the pipeline as well as determine the size of the leakage. The model was able detect small leakage and estimate the size of the leakage, and also train the system. The algorithm used reduces the overall communication cost because the sensors only send data about leakage status to the gateway. The algorithm used a pattern recognition to enable the WSNs to learn and adopt to new changes in the environment of leakage in the pipeline. The algorithm used here only considers the amount of energy in a sensor node to determine which route will be used. Reference [26] conducted a research by placing wireless sensors at the contact points of distribution transformer. The author compared WSNs technology with other technologies which include; fiber-optic thermometry technology which utilizes an optical temperature sensor on optical fiber to measure temperature, a thermal infrared detector technology which makes use of; a thermal infrared measuring device, traditional contact measurement and the use of color chip to measure transformer status. The routing algorithm used here only considers the shortest distance between source node and destination.

Reference [27] discussed the reason why WSNs deployment in industry is essential for improving the efficiency at industries. The discussion is how the placement of sensors in the industry for control purpose is important. Further, the sensors can be placed on a rotating machinery to monitor the status while at the same time the machine is in normal operating mode. The author insists how this can improve the productivity and efficiency of a company by avoiding unnecessary downtime of a machine.

Reference [28] provided a critical analysis of various Machine Learning for Wireless Sensor Network used to transmit information to the sink node in a way that extends the battery lifetime and improve the network reliability. The authors also provide a review of the known possible algorithms, their challenges and applications. The mentioned techniques include MA, NN and SI. The author further recommends machine learning techniques to optimize WSNs.

Reference [29] proposed ACO to enhance the accuracy of the best path selection. The ACO algorithm the author proposed consist of three type of nodes, namely the frontward node, the B-frontward node and the backward node. The frontward node is used to find the best and shortest path by looking up the information on neighboring nodes from the routing table. A backward node is used for the same path back as frontward node, while using the algorithm to adapt to the network changes. The last node which is Frontward node and was used to enhance the ability to predict the cost of selecting the next node as a path to send data for the next level of transportation. The limitation of this protocol is that it considers only the shortest distance between source node and the sink node.

Reference [30] used a termite hill algorithm for routing, this termite hill algorithm is also known as wake-up schedule optimization algorithm. In this routing algorithm the only factors of consideration are the energy of the sensor network and the distance between the source and the sink node.

From the above related work, we can deduce that the existing routing protocols are using a single routing criteria for example some authors have considered the energy level only, while others have considered only the hop count. This type of approach can overload sensor nodes or drain energy in some nodes leading to unbalanced energy levels in the sensor nodes. Therefore, there is need to design a routing algorithm that is aware of the data congestion, the energy level and the distance for reliable and energy efficient communication of sensors for industrial applications. However other techniques for example Adaptive Neuro-MA-based Inference System (ANFIS) have not been considered because they are not search based and therefore they cannot be used alone to establish the shortest path between the source node and the sink node.

The proposed routing algorithm is modified to take extra considerations which include the data in the queue on the sensor nodes in addition to other considerations like the energy available in the node and the minimum distance between the start node and the sink node. The design uses MA and a heuristic search based algorithm ACO to enable efficient data transmission, utilize the energy in the network, extend the WSNs lifetime and hence increase their communication performance.

In this research ACO was chosen to perform routing optimization instead of other SI techniques such as cuckoo search, particle swarm Optimization (PSO), Genetic Algorithm (GA), Artificial Bee Colony (ABC) and other SI techniques. This is because ACO gives better performance, has faster convergence and can automatically adjust to an environment that dynamically changes over time [31]. Other authors who have used wake-up schedule optimization alone for routing in wireless sensor networks are [32]. ACO together with the hybrid of MA-based is designed to take the extra important network considerations mentioned above.

3. METHODOLOGY

This chapter will present a selection of research papers about base node positioning and optimization, divided into different categories. Our work fits into categories, but to the best of our knowledge, this was never attempted. The first section introduce to the statistical studies, and none of the authors try to use base station sinking for the position and optimization of nodes to reduce the use of energy. On the other hand, the articles in the second section deal with prediction as an atomic events of nodes representation. Nevertheless, these show some of the applications of base station techniques to the study of reducing the use of energy in the domain of wireless sensor networks.

3.1 INTRODUCTION

The aim of this research is to perform optimal routing for WSNs from source node to sink node. The developed algorithm has considered several parameters which include; the total energy of the sensor network, the distance and the data load in the queue. Due to the reason that WSNs are limited in energy the nodes need not to know about their geographic location if the routing protocol used is not location based. In this case the protocol is not location based and the sensor nodes do not know about the locality of the other nodes.

3.2 DESIGN AND ROUTING MODEL

The design used here is simulation research design in Matlab. The sensors have been randomly deployed and the routing protocol used is a hybrid of MA-based and WUS for WSNs.

3.2.1 MA-based Algorithm

Figure 3.1 illustrates the MA system design. The network controller is the sink node. It is the one that sets up the routes for each sensor node, and also it acts as a gateway (destination) for WSNs to collect all the data from the network. The sink node is the one that evaluates the cost of each sensor node to the gateway and sets up the optimum route for each sensor node and broadcasts the route schedule to the sensor nodes.

MA-based system is a very important tool because we can incorporate the human way of reasoning to operate systems efficiently. This research has used MA to incorporate important parameters that will determine the overall cost for a packet to be sent from source sensor node to the gateway. MA is used to evaluate the node cost with the input parameters being the energy of the sensor network and the data load in the queue.

WUS is very important search heuristic algorithm. It is in the class of SI and it is inspired by the process of nodes searching the shortest paths between the nest and the food source. In this research WUS is used to calculate the shortest path that will be used after MA has calculated the node cost.

It queries all the sensor nodes to send the information about their energy status and the data status. The cost of the link is evaluated by the inputs of MAC being the transmission energy and the data. Once the cost of all the possible links to the sink node is computed the route will be determined using the shortest path algorithm for optimum route selection. This shortest path algorithm is WUS. Once the optimum path has been calculated the sink node is the one that broadcasts the routing schedule to each sensor node.

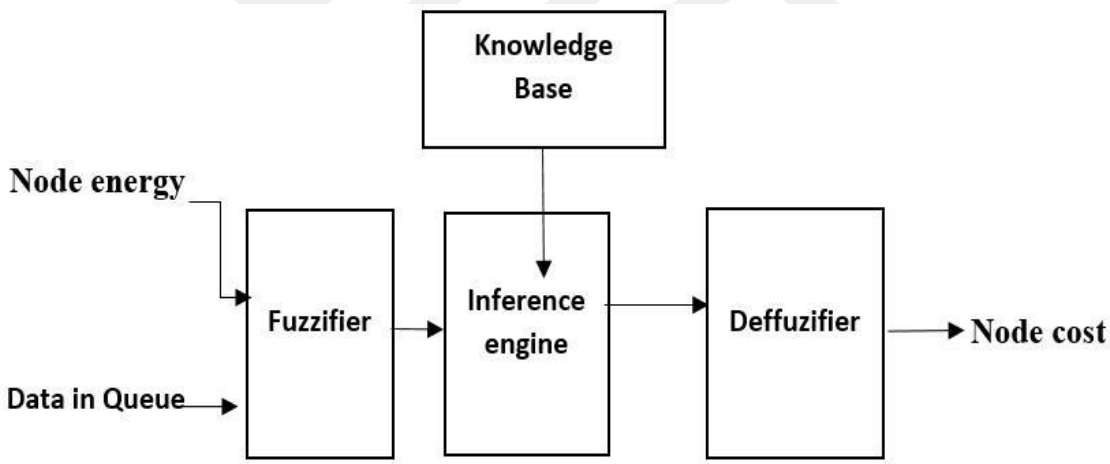

Figure 3.1: MA-based system for calculating the node cost

- **Fuzzier**

Fuzzier scales and maps input variables to MA-based sets. It is the establishment of the fact base of the MA-based system. It identifies the input and output of the system, defines appropriate IF THEN rules and uses raw data to derive a membership function. The engineer determines membership functions that map the crisp values of interest to MA-based values [33].

- **Inference Engine**

Inference engine is used for approximate reasoning and it deduces the control action, evaluates all rules and determines their truth values. If an input does not precisely correspond to an IF THEN rule, partial matching of the input data is used to interpolate an answer [34].

- **Knowledge Base**

Knowledge base is the storage of all rules, the IF THEN rules. It assists the inference engine by providing the rules which determine the output of the MAC.

- **Defuzzifier**

Defuzzification is the process used to convert MA-based output values to control signals. It involves conversion of the MA-based value obtained from composition into a "crisp" value. It is necessary since controllers of physical systems require discrete signals [35].

3.2.3 MA-based inputs

a) Energy

The energy of WSNs is limited since these sensors rely on battery. To minimize energy consumption, this input is a variable that is used to determine the best node to be chosen in terms of the cost of the node. The energy limits are between 0 and 5 joules, with MA-based variables low, medium and high. The energy model is based on first order radio model. The purpose of including first order radio model is to give priority to nodes with the highest energy. When a packet K is being transmitted from source node to destination node through the selected nodes, energy is consumed and some of the nodes may be dead (may fail) depending on the number of simulated cycles.

b) Data

The number of packets K in the queue will determine how long it will take to empty the queue before a packet can be sent from source node to destination. In route selection the node with less data will have a high possibility of being picked because the data in the queue is minimized. The data limits are between 0 and 10 in bits with MA-based variables low, medium and high.

3.2.3 MA-based output

Node cost

The output of the MA-based system is the cost of each node. The node with the highest score will be selected, which is based on the highest energy and the least data. The cost limits are between 0 and 10. Once the nodes have been selected based on cost WUS is used to determine the optimum route to be used based on the shortest distance.

The limits of the MA system have been chosen based on the expert knowledge that, the nodes with the lowest data and highest energy will have the highest score and will be chosen to transmit or route data to the sink node.

3.2.4 Wake-up schedule Algorithm

WUS is very important search heuristic algorithm. It is in the class of SI and it is inspired by the process of nodes searching the shortest paths between the nest and the food source [38] [39]. In this research WUS is used to calculate the shortest path that will be used after MA has calculated the node cost.

3.2.5 Description of WUS Algorithm for WSNs

Forward node in creating solution: probabilistic process

Nodes operate in two different ways either in forward or backward way. In forward direction, nodes move from source node to destination node, while in backward direction nodes are moving from destination node back to source node. For a given graph G = (N, D),two sensor nodes x, yϵN are neighbor's if there exists an arc (x, y)ϵD.The choice is probabilistically determined by the amount of pheromone trails that were deposited by other nodes.

Backward nodes in pheromone update: deterministic process

The backward node retraces the route it followed when finding the destination node. The backward node leaves pheromone on the arcs they pass through while moving in the backward direction.

Pheromone updates in relation to the quality of the solution

Node colonies are intelligent as they know the nodes they had visited in the forward direction and also the cost of the arcs traversed. The cost determines the amount of pheromone they deposit while in the backward mode. More pheromone is deposited on short paths.

Pheromone evaporation

For a period of time the amount of pheromone that was deposited reduces because of the effect of evaporation. The purpose of pheromone evaporation is to decrease the effect of the amount of pheromone that was deposited in the initial stages of path finding.

//*WSNs initialization for base node optimization*

∀ edges D ϵ G(N,D)

Assign the initial energy to each node
Initialize the transmission distance between two sensor nodes.
Assign the amplification coefficient that allows minimum bit error rate.
Calculate the amount of dissipated energy to operate the transceiver.
//*MA-based logic*

Assign membership function values to each node for each input parameter and the output
Compute the cost of each node to the sink node based on energy used and the data.

//*Route finding*

Begin

Initialize node's information
Number of nodes k
Evaporation co-efficient(e)
Number of cycles
Effects of node's sight (α)
Traces effect(β)
While stopping criteria not satisfied do
Set each node at the source node
Repeat
For each node do
Apply probability rule
Move to choose the next node
Apply pheromone update
End for
Until every node has built a solution
Locally optimize the solution
Find best solution
Update global pheromone
Output optimum route

End while

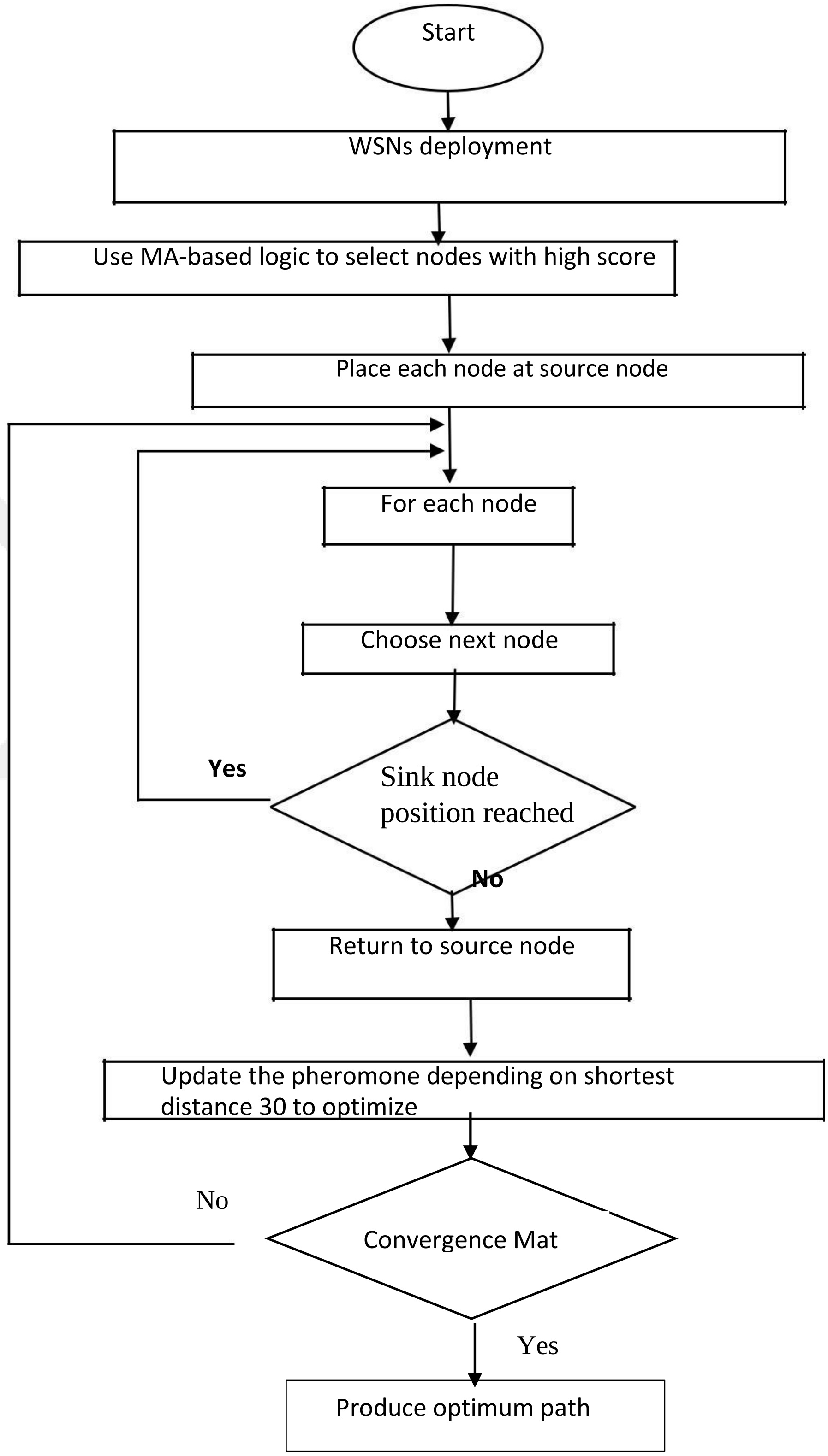

Figure 3.2: System architecture for routing of base node position optimization

3.3 ROUTING MODEL FOR POSITION OPTIMIZATION

The first objective was to develop a routing model for WSNs. This model was used in the simulation to perform routing optimization for WSNs. The developed routing model is energy aware, distance aware and data aware. This model proved to be effective and reliable in terms of energy level, number of dead nodes and packet delivery. The cost of sensor nodes was calculated using MA. The nodes with the highest score were used for selection of the best route using WUS.

Table 3.1 describes the routing model for WSNs, it illustrates results and observations obtained from the first objective.

- Wireless sensors were randomly deployed in the desired region. For industrial applications the sensors are deployed in the target area for example in power transformer to measure temperature, humidity and oil level for transformer protection.
- The cost of each node to the sink was evaluated using MA. Every sensor node sends its details to the sink node where the cost is calculated. The parameter values sent to the sink node are the energy of each node in joules and the amount of data in the queue. The energy was calculated using first order radio model for WSNs.
- The sensor node with the highest score was considered for routing. The node with the highest energy and the least data in the queue has the highest score. The highest score in this research work refers to the good nodes, nodes with a lower score are referred to as bad nodes and were not considered for routing until the next cycle.
- Several nodes with high score were selected for routing. Once the nodes were selected for routing, WUS evaluated the optimum path to the sink node based on the shortest path. WUS evaluated the shortest path by applying more pheromone trails along the arcs with the highest score (good nodes) as well as pheromone evaporation to clear trails in the least score paths (bad nodes). The shortest path with the minimum distance was established in the good nodes.
- The sink node acted as the gateway where information or packets were delivered. For industrial application in the case of power transformer monitoring, if the temperature exceeds the set limits or the oil level is below the minimum value, various control measures will be set based on the information sent to the sink node.

Table 3.1: Optimization parameters consumed by nodes [37].

Parameters	**Value**
X*Y simulation area	100*100 m^2
Number of nodes (N)	100
Sink node location	50*175 m^2
Node initial energy	5 joules
Number of Maximum data load	10 bits
Packet length	6400 bits
Distance between nodes (d)	50 meters
ϵamp	50 nJ/bits

Table 3.1 displays the simulation parameters which are the same as the parameters chosen for the author in reference [29] who used WUS to perform base node position optimization for WSNs. This research has combined a hybrid method of MA-based and WUS.

4. SOLUTION

This chapter presents the implementation and solution used in this thesis. The first section describes the algorithm characterization used in this work, while the other two present implementation details, techniques used to position and optimize the need of energy in the wireless sensor network, namely the plan for the handling of incomplete records and the construction of a model respectively.

4.1 WSN's PROTOCOLS CLASSIFICATIONS FOR OPTIMIZATION

There are multiple surveys papers that classify Wireless Sensor Protocols (WSN) for optimization of base node positioning from different perspectives. One of such classifications is based on the network structure and type of applications in which they are used. Using these metrics, WSN protocols are commonly classified in *data-centric* (often called flat protocols), *location-based* and *hierarchical*. WSN hierarchical based routing protocols. Hierarchical routing protocols make use of the concept of node groups called clusters. Each one of these clusters have one or more cluster heads (CH). It is this way that different levels or hierarchies are formed in the network. The selection process of the CH differs from protocol to proto-col, as well as the parameters used in its selection. Regardless, all hierarchical WSN protocols main aim is saving the residual energy of each sensor node and extending the network lifetime. For this reason, hierarchical protocols are arguably the most used and developed among the WSN routing protocol types. Some of the most popular hierarchical WSN protocols are LEACH, PEGASIS, TEEN and HEED.

4.2 HIERARCHICAL WSN PROTOCOLS FOR OPTIMIZATION

4.2.1 Leach

In the Low energy adaptive cluster hierarchy (LEACH) protocol, a hierarchical clustering is done based on information received from the base station (sink node). Each node in every cluster generates a random number between 0 and 1. A threshold is set and the generated random number is compared to it. If the number is less than the threshold, the node is selected as the CH. Both, cluster membership and the cluster heads change periodically (random rotation of the CH) in "rounds” to conserve energy. The communications in LEACH are single hop. In other words, only the CH communicate with the sink and nodes only communicate with their CH (Figure 4.1).

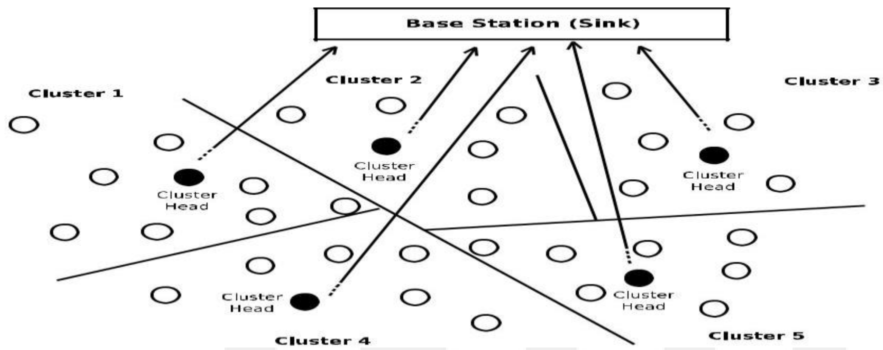

Figure 0.1: The LEACH protocol of Base Station

In the solution, LEACH is by far the most popular protocol and it has inspired a lot of variants. Some examples are: DE-LEACHU-LEACH,LEACH-B,LEACH-C. In fact, its variants areso diverse that there are multiple surveys classifying LEACH-based protocols alone. LEACH variants use a wide range of parameters that influence the selection of the CH (remaining energy, load balancing, data aggregation, overhead) and can be classified in two: those variants that support a single hop communication as the original or multi-hop communication as its most advanced variants.

4.2.1 Pegasis

The key idea in the Power-Efficient Gathering in Sensor Information Systems (PEGASIS) protocol is to form a communication chain between the nodes in the network. That is, each node in the network only receive or transmit information from a close neighbor. The construction of the communication chain is done by using a greedy algorithm. Different to the LEACH protocol, there are no clusters and only one node is chosen to transmit data to the sink. This leader node is randomly selected and change in intervals of time (rounds). When data is received in a node it can be aggregated, in this way transmissions of packets can be reduced and therefore, the amount of energy consumed. If at any moment a sensor dies, the chain is reconstructed using the greedy approach and bypassing the dead sensor. Figure 4.2 shows an example of the chain of nodes created in PEGASIS.

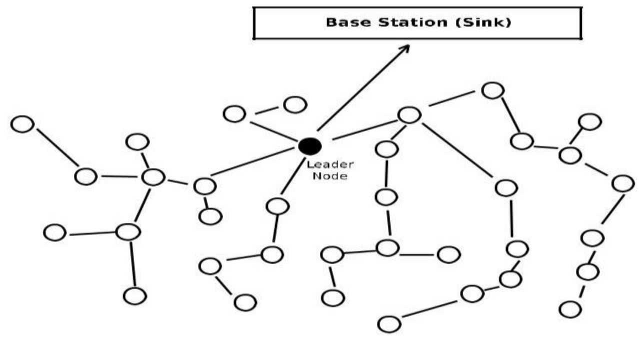

Figure 0.2: The PEGASIS protocol of Base Station.

4.2.1 Teen.

The Threshold sensitive Energy Efficient sensor Network (TEEN) protocol enhance some ideas introduced in the LEACH protocol. Similar to LEACH, the TEEN protocol model use a hierarchical clustering scheme, but TEEN protocol is a reactive protocol, one of the first protocols of its kind. As shown in Figure 4.3, TEEN protocol have 2 levels of hierarchy. In the first level, multiple nodes form a cluster with one of these nodes selected as a cluster head (CH). Nodes can only transmit information to its CH. At the same time, multiple CH form another cluster with one of these CH selected as the second level CH. Before first level CHs send the information to the second level CHs, data is gathered and aggregated. After that, second level CHs collect data from its first level CHs and send it to the base station (sink). The cluster transmissions to its member nodes are based on the sensed threshold value of a given attribute.

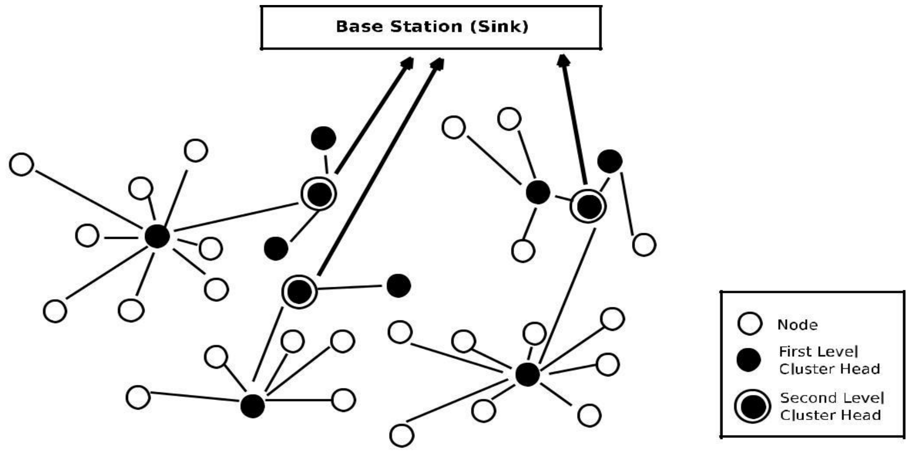

Figure 0.3: The TEEN protocol of Base Station**.**

4.2.1 Heed

The main objective of the Hybrid energy efficient distributed (HEED) protocol is to prolong the network lifetime. Similar to LEACH, the network is organized in clusters. One of the key characteristics of HEED is that the selection of the cluster heads is done periodically using the residual energy and intra-cluster communication cost values as parameters. Member nodes communicate only with their CH (1 hope communication), while CH are able to communicate with each other to relay data to the sink (multi-hop communication). A general idea of the HEED protocol distribution can be observed in Figure 4.4.

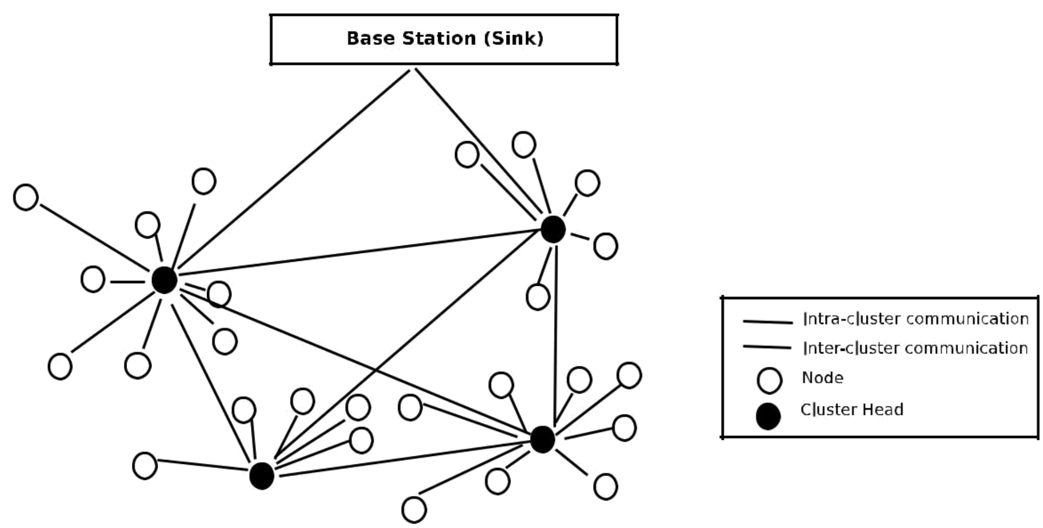

Figure 0.4 : *The HEED* protocol of Base Station

4.3 Hierarchical Mobile WSN protocols

In the previous section, a brief explanation of the most popular a some of the first hierarchical WSN protocols for optimization. Regardless the different type of parameters, the protocols described share one in common, the nodes are all static. A natural evolution of the WSN protocols lead to the development of protocols that consider one or more mobile nodes. Adding mobile nodes to the design of the net-works also added problems to the existent one in networks than used static nodes exclusively. Figure 4.5 shows a simplified taxonomy of some of the most notable categories found in mobile hierarchical WSN protocols for optimization of nodes position. The metrics we used in this classification are: Mobile element, mobility pattern, route establishment, protocol goals and application type.

4.3.1 ENERGY EFFICIENTMOBILE ELEMENT

- Mobility is one of the biggest changes introduced in modern networks, and often protocols design revolve around this challenge. Mobility can be applied to one or more nodes in the network.
- Sink. A mobility of the base station that receives all the data packets.
- Sensor node. A mobility of one or more nodes that form the network but with a static base that receives the data packets.
- Sink and sensor nodes. Mobility in all parts of the network.

4.3.2 Energy Efficient Mobility pattern

- The path that nodes follow have important implications in the general performance of the protocol. Depending on the requirements of the applications, some patterns might be more effective than others to collect information with the least amount of resources.
- Predefined mobility. In this pattern, a mobile node moves along a predefined path for a pre-defined amount of time. Stop positions are also programmed in advance and can play a role in the node tasks.
- Random mobility. In this kind of pattern, one or more mobile nodes move randomly within an area.
- Controlled mobility. In this pattern, the mobility behavior is subjected to the needs of the routing protocol. Attributes such like remaining energy, connectivity, etc. influence the mobility of the nodes (both speed and trajectory).

4.3.3 Energy Efficient Route establishment

The path data packets must follow to reach their destination. Multiple mechanisms are used to discover routes or react to sudden route changes.

- **Proactive.** Protocols that generate they routes in advance before the transmission of the first data packet in the network. This types of protocols are often called table-driven because nodes contain tables with the necessary cost (hop cost) to reach another destination. Proactive protocols are designed for applications that do not require intensive transmission of information or immediate response.
- **Reactive**. In this type of protocols routes are created as they are needed. The protocols are capable of reacting to changes (communication holes, low energy nodes, etc) occur in the network and reconstruct the routes as they are needed.
- **Hybrid**. These protocols react to sensed events like reactive protocols and also, keep updated status with neighbor nodes by sending periodic updates.

4.3.4 Energy Efficient Application type

- Protocols are often designed to give a solution to a specific problem. Protocols applications often have a profound impact on the general design and its shortcomings.
- Time driven. In this type of applications, data is generated and transmitted in intervals of time. These applications are used for tasks that do not require an immediate response. Examples of such of applications are environmental monitoring applications and agricultural applications.
- Event driven. In this type of applications, nodes are mostly inactive waiting for an external event to occur. When the event occurs, it is immediately reported to the sink.
- On demand. In this type of protocols updates of the status from different parts of the net-work are requested by using queries.

4.3.5 Energy Efficient Protocol Goals

- Besides achieving data transmission by overcoming constraints, protocols aim to improve the general performance by enhancing some aspects of its operation.
- Lifetime extension. Protocols are often deployed in remote areas and must be able to operate for extended periods of time without supervision or energy supplies replacement.

- Load balancing. Protocols must ensure that there is not extreme disparities in the routes usage. An excessive use of a route can lead to variance in the nodes energy creating communication holes.

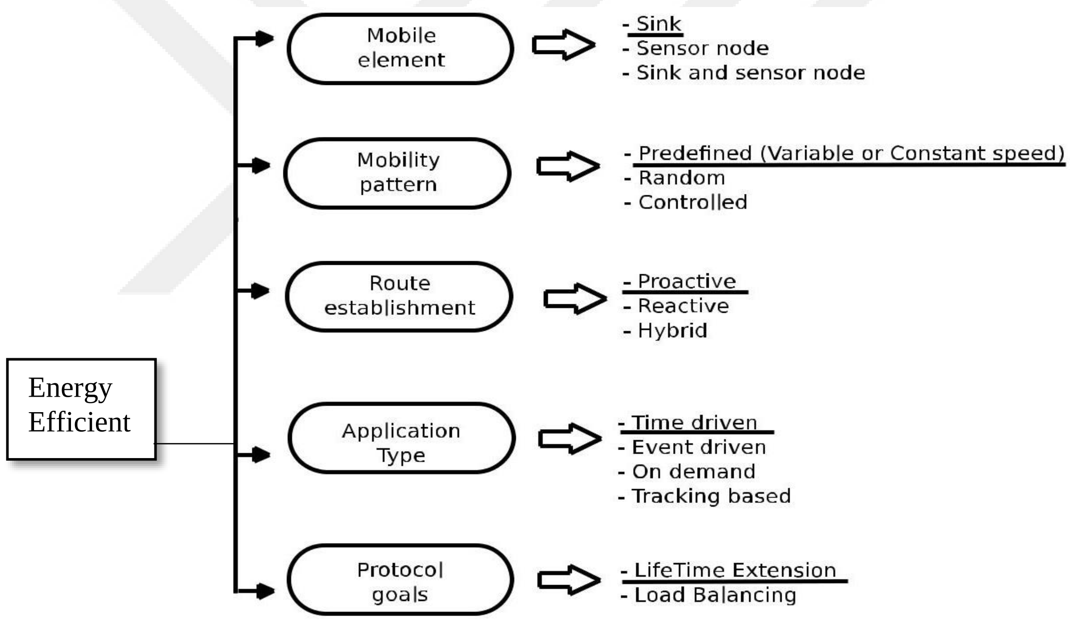

Figure 0.5: Energy efficiency taxonomy criteria of WSN's for the Base Station.

4.4 PATH CONSTRAINED SINK WSN PROTOCOLS

Protocols with path constrained sinks have been around since the beginning of mobile WSN. Con-strained path sinks help to balance the energy consumption of the network and introduce some predictability to the system that can be exploited. For example, in protocols that used constrained path sinks is possible to predict the route changes in advance and transmit data packets to the latest locations of the sink. Other exploits include the use of duty cycling mechanism to save energy and reduction of the controls packets to form the routes of the networks. The protocols OTABP is an example of hierarchical WSN protocols that use path constrained sinks for positioning of node in the sink or base station.

4.4.1 OTABP.

In the Optimal Terminal Assignment based Path (OTABP) protocol for position optimization one or more node sinks move collecting data from clusters or "subsinks". Subsinks are located along the path of the mobile sink (at any given moment, in direct communication with the mobile sink). Each one of those subsinks have a number of member nodes assigned to them based on their distance (Figure 4.6).

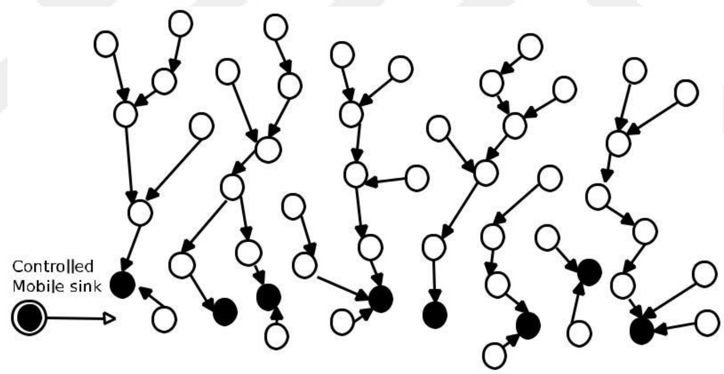

Figure 0.6:The OTABP protocol for position optimization.

To optimally assign the number of nodes to each sub-sink, OTABP requires that every node in the network is aware of their own location. When mobile sinks collect data, they can increase or reduce its speed based on the amount of data in the sub-sink queue and remaining energy (controlled sink movement).

MA-based rules

The MA-based rules form the knowledge base for inference engine. The MA-based rules maybe formed among the following statements.

- **Assignment statements**

  They are used to restrict the value of a variable to a specific quantity. For example energy is Low(LW).

- **Conditional statements**

  They form both the assignment statement and the consequent statement, with If …..Then statements. For example, IF energy is Low and data is Low THEN the node cost is Medium

- **Unconditional statements**

  These statements exclude the IF clause for example turn the pressure lower.

5. RESULTS

There were several implementation steps in the course of this thesis. This chapter covers all of them, presenting the actual results of the experiments already described. In the next sections, the results of base node positioning, Imputation and optimization, and Classification will be considered using the base station sinking and proposed algorithms to reduce the usage of energy consumed by nodes in the wireless sensor networks.

5.1 DERIVED RESULTS

The statements used in this simulation are conditional statements because they are the most appropriate statements for MA-based reasoning.

Table 5.1 illustrates the MA-based rules used to assist the inference engine to perform deductive reasoning. The Rules are nine and are IF… THEN rules.

If energy is low and data low, then the cost is medium.
If energy is medium and data is low, then cost is large.
If energy is high and data is low, then cost is large.
If energy is low and data is medium, then cost is small.
If energy is medium and data is medium, then cost is medium.
If energy is high and data is medium, then cost is large.
If energy is low and data is high, then cost is small.
If energy is medium and data is high, then cost is small.
If energy is high and data is high, then cost is medium.

Table 5.1:MA-based rules in tabular form

Energy	Data	Node cost
low	Low	Medium
medium	Low	Large
high	Low	very large
Low	medium	Small
medium	medium	Medium
High	medium	Large
low	high	very small
medium	high	Small
high	high	Medium

5.1.1 Fuzzification

The fuzzifier is the brain of the MA-based engine it does approximate reasoning in order to come up with a decision. When a wireless sensor sends values of energy and data to the sink node they are mapped based on their membership functions to their respective MA-based regions that they belong to. For example, when energy is at 1.5 joules and data is at 7 bits their corresponding membership values and associated MA-based regions are as shown in Table 5.2.

Table 5.2:MA-based energy level representation

Parameter	MA-based region	Membership function
Energy	Low(LW), Medium(MD)	0.3, 0.4
Data	Medium(MD), High(HG)	0.2, 0.1

5.1.2 Defuzzification

In MA-based de-fuzzification, converted the MA-based outputs Small(SM), Medium (MD) and Large (LG) to a single crisp value which is to be used to choose the best sensor node. The commonly used defuzzification method is centroid and is applied in this simulation because it is easier to use and accurate as compared with other methods.

5.2 POSITIONING AND OPTIMIZATION

Proposed algorithms computes the optimum shortest route from source node to the sink node. The procedure is to initialize the coefficients for node algorithm, these coefficients are given in Table 5.3.

Table 0.1: Wake-up schedule parametric output.

Parameter	**Value**
Number of nodes (m)	100
Evaporation coefficient(e)	0.1
Number of cycles	50
Effects of nodes sight (α)	1
Traces effect(β)	5

After parameter initialization the nodes are placed at the initial sensor node where they move through neighboring nodes to the sink node while searching for the shortest route that remains in the node after data transmission. The energy level has dropped from 50 Joules to 5 Joules in 600 cycles exponentially. For more cycles more nodes will fail since most of the energy will be consumed when information is sent from source node to the sink node.

Table 0.2: Performance comparison of MA-based and WUS on network lifetime.

Parameter	**WUS**	**FACO**
Number of packets delivered to the sink node at cycle 50	170 bits	201 bits
Energy level at cycle 20	1.4 Joules	2.8 Joules
Number of dead nodes at cycle 50	45	27

Table 5.5 shows comparison of proposed techniques. The proposed technique outperforms the other methods in Type1 and 2for position optimization for WSNs.

Table 0.3: Performance comparison of proposed techniques.

Approach	MA-based Optimization Type-1 ref[23]	MA-based Optimization Type-2 ref[21]	WUS-based Optimization Type-1 ref[31]	WUS-based Optimization Type-2 ref[32]
Number of packets delivered to the sink node for 50 cycles (bits)	180	187	170	201
Energy level for 20 nodes (joules)	1.6	1.9	1.4	2.8
Number of dead nodes for 50 cycles	41	38	45	27

Structure formed MA-based and wake-up schedule are used to place the cluster heads (CH). CH are in charge of collecting data from its cluster members and delivering it to the mobile sink using shortest path tree paths. CH are also used to decide which node routes are necessary to be adjusted in case of the sink mobility.

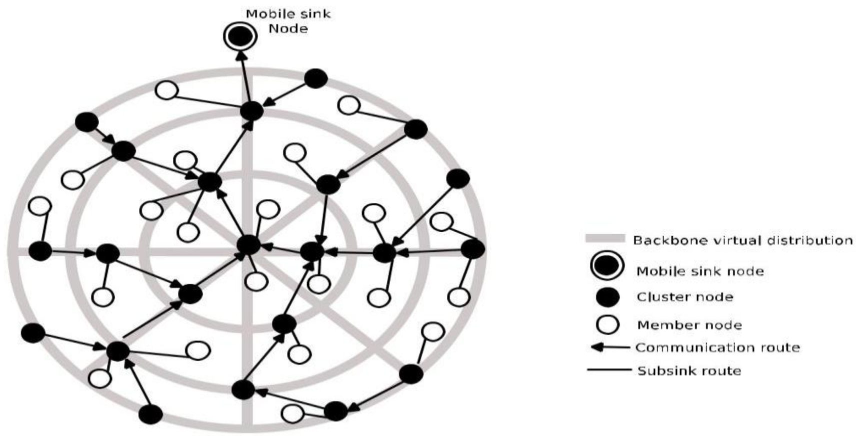

Figure 0.1: Nodes positioned in base station due to virtual distribution of energy.

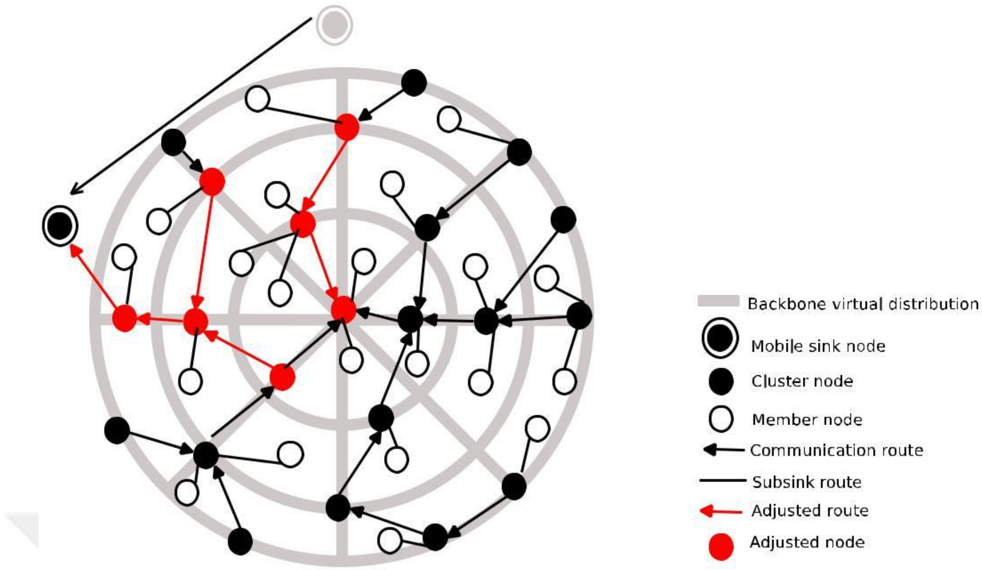

Figure 0.2:Nodes positioned and adjusted in base station due to virtual distribution of energy.

The Node would be positioned at the center for the optimization and sub sinks arena enhanced version or regular member nodes with higher storage capabilities and are deployed at equal distances along the mobile sink trajectory. Routes to the sub sinks are established by broadcasting *Establish Path* message with the sub sink ID. The nodes receiving this message set origin node as its next hop. If a sensor receives multiple Establish Path messages, it selects the node with the highest signal intensity. The process repeats in another time slot to form a multi-hop path is found at the same sink or sub sinks of nodes (Figure 5.3).

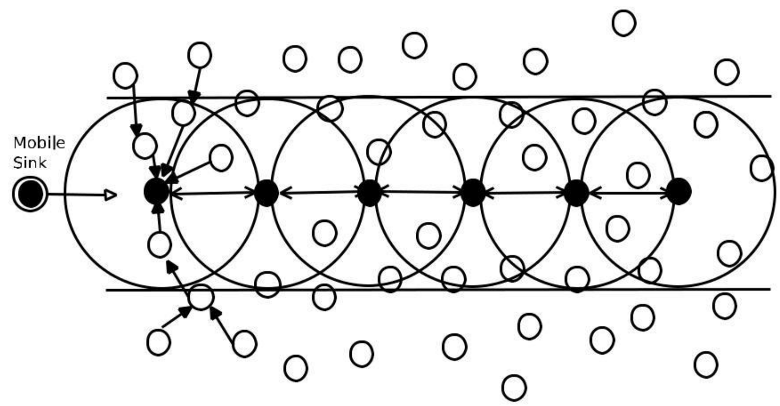

Figure 0.3: Nodes positioned at the center of sink for optimization.

The sink nodes are the only nodes that have capabilities, both sub-sinks and member nodes are static nodes. Figure 5.4 shows a general concept of all the type of nodes involved in energy shifting in the cycles of sink. The node positioning is divided into two phases: *The discovery phase* which works as a way to set all the routes and organize the network and the *data collection phase*, used to collect the information from the applications set in each node (sensors information).

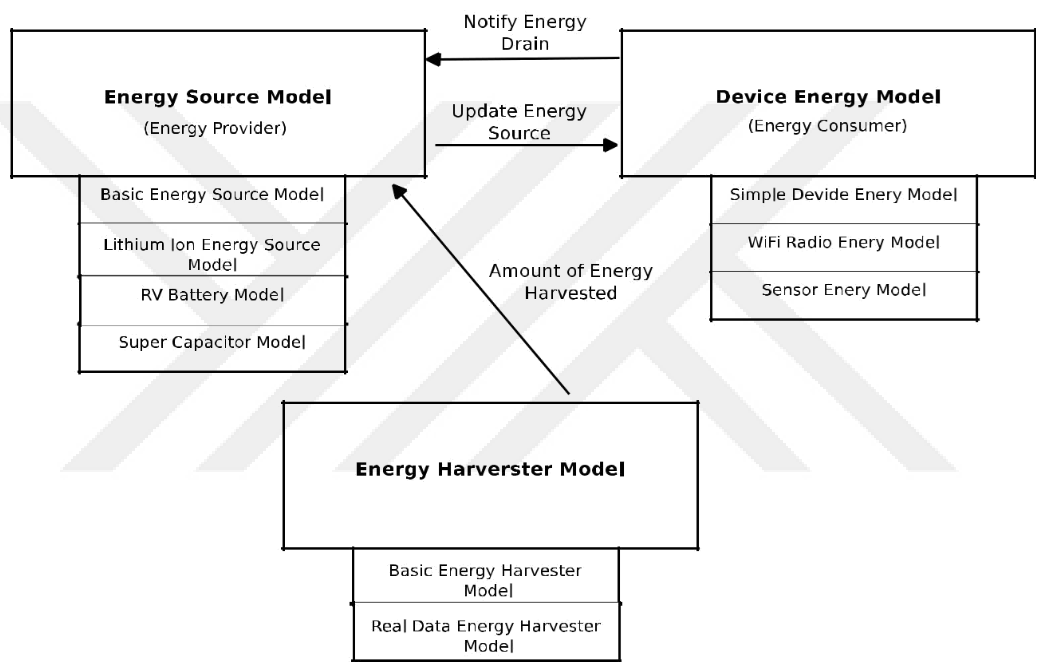

Figure **0.4:** A sink node moves energy to the other nodes in the cycle and shifts that energy more efficiently than the member nodes outside the cycles of sink nodes.

Energy framework (Figure 5.5) consists of an energy source model that provides the efficient energy to the nodes that are positioned in the base station and the device energy model which consume the energy from that source. Optionally, it is possible to use the energy harvester model to feed an energy source with less energy.

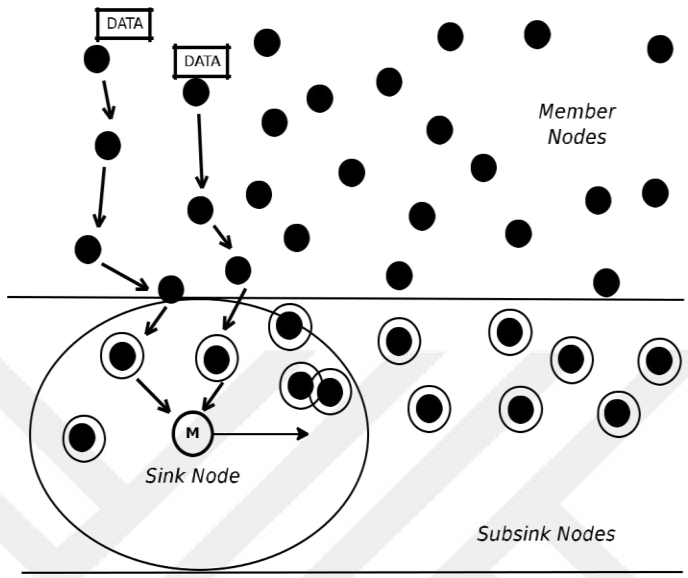

Figure 0.5: General Energy harvest model that consumes comparatively low energy because the nodes are positioned at the base station and sources are updated.

6. DISCUSSION

This section of thesis will discuss the results of the base node position optimization in WSN's with other WSN's techniques applied on physical networks already in existence. All of the following modules were developed in Matlab and Python, as it has a wide open source community, with a number of machine learning packages available, already optimized for the purpose of this work based on implementation parts

In the last two decades, networks had grown exponentially. Consumption of energy by nodes in the wireless sensor networks such as the ones designed for the popular TCP/IP model cannot keep up with the requirements of modern networks. This has brought the emergence of specialized networks such as the Wireless Sensor Networks (WSN). WSN deal with unstable links, high propagation delays and because of their intrinsic mobile nature, they are prone to transmission errors. This research focus in the implementation and description providing the base station nodes that consumes less energy than member nodes in wireless sensor networks of different protocols designed for WSN. The protocols are designed to work in WSN that have at least one sink node with mobile capabilities. The mobile sink or base station of nodes are constrained to follow a specific path and move at a constant speed to reduce the energy consumption. These characteristics can be exploited to improve the performance of the network in the different protocols of wireless sensor network. The protocol shares with the other network protocol the use of mobile sinks and the constant speed. However, it improves upon these concepts and introduces a duty cycling mechanism to save energy.

One of the first contributions of this research is the recreation of the base station in which the member nodes are distinguished with the sink node to save energy, protocol implementation in the network simulator. The original implementation of node optimization was created using Matlab and python. While often cited as a simulator, is a framework to create simulations but not a computer network simulator in itself. The precision of its simulations created in our research often depends on the modules involved in their creation. The description of the research offered by Gao et al. [34] provide general descriptions of the functions and purpose of base node positioning, but their descriptions do not provide any implementation details.

In this research, the base node positioning and optimization protocol descriptions are given from the point of view of the practical implementation in the network simulator. Simulator is regarded for closely following the Linux network architecture and its emulation capabilities which allow simulations to be more easily ported to real implementations of base node positioning in the network. Descriptions detailing an implementation of an energy saver wireless sensor network are greatly found in the literature.

6.1 DATA ANALYSIS

The data analysis of different to Maximum Amount Shortest Path, Zone based Energy-Aware Data Collection also has the ability to discard the least optimal sub-sinks. The reduction of the right amount of sub-sinks can decrease the packet congestion in the routes during the Setup phase and avoid the creation of routes that are rarely used. The second contribution in Zone based Energy-Aware Data Collections the introduction of a duty cycling mechanism. Most of the recent WSN protocols are cross-layer implementations, however, Zone based Energy-Aware Data Collection favors a layer model design instead. Its duty cycling mechanism works along the protocol in the network layer. Because Zone based Energy-Aware Data Collection uses a layered design, it is possible for Zone based Energy-Aware Data Collection to take advantage of the perks in lower layers.

The experiments also demonstrated that Zone based Energy-Aware Data Collections able to greatly reduce the average energy consumed in the network by introducing a duty cycling mechanism in its Data collection phase. The duty cycling mechanism creates some energy variance between different zones but it remains relatively close be-tween the member nodes that belong to the same zone to reduce the usage of energy by nodes of base station.

7. CONCLUSIONS

This final chapter summarizes the work developed during this thesis, showing a glimpse of the paths this study may lead to the positioning and optimization of node in the base station to reduce energy usage in wireless sensor networks

WSN are limited in energy because they rely on battery and hence there is need for energy efficient routing protocol. The designed base station for node positioning and optimization is energy aware, distance aware and data aware. The results have shown improved performance in terms of the number of packets delivered to the sink node with less energy usage, the energy level in the node and the number of dead nodes. MA-based and wake-up schedule algorithms have shown improved lifetime of WSNs as compared to the performance of other routing techniques and so it can be applied in industrial applications to enhance reliability and efficiency of the system.

- The developed base station model satisfactorily lead to energy conservation of WSNs as they rely on battery as their source of energy. The optimization of the base node in base station sink model using MA-based and wake-up schedule lead to development of energy efficient model.
- The simulation from Matlab and Python code showed enhanced wireless sensor network lifetime by providing a balance between the energy level, number of packets delivered to the sink node and the number of dead nodes.
- The results from simulation showed an improved performance of WSNs based on proposed algorithms as compared to other existing algorithms. The parameters considered were number of packets delivered to the sink node, the energy consumption and the number ofdead nodes in the queue. The number of packets delivered increased by 18.25 %,the number of dead nodes decreased by 40 % meaning more nodes were available for data transmission and the energy level increased by 100% for proposed algorithm as compared to existing algorithms and routing protocol.
- The routing protocol is expected to provide increased reliability and efficiency if used for WSN in industrial applications.

In both cases is possible to observe the sub-sinks selected along the mobile sink path (sub-sinks are the nodes with a black circle around them). Naturally, the changes in the mobile sink path have created a different zone distribution and sub-sinks locations. The only distributions using the proposed techniques protocol, however, similar distributions are created using the routing protocol for more efficient usage of energy.

7.1 RECOMMENDATION

The analysis done on this thesis was based on three parameters for WSNs which include the energy of the node, the data in the queue and the distance from source to sink node. The possibility of including other parameters that affect the energy consumption of WSNs can be analyzed and investigated. These parameters to be investigated are transmission time and number of retransmitted packets to avoid collision.

REFERENCES

[1] Mohammed Alsheik, Shaowei Lin, Dusit Niyato et al, Machine learning in wireless sensor networks algorithms,strategies and applications, vol. 4, IEEE communications & surveys & tutorials, 2014.

[2] Silicon Labs Report, "Evolution of wireless sensor networks", Silicon laboratories Inc., 2013.

[3] Yingshu Li and My T. Thai, *Wireless sensor network applications*, Springer, 2008, pp. 456-687.

[4] Kazem Sohraby, Daniel Minoli and Taieb Znati, *wireless sensor networkstechnology, protocols and applications*, John Willey and sons, 2007, pp. 203-209.

[5] Waltenegus Dargie and Christian Poellabauer, *Fundumentals of wireless sensornetworks theory and practice*, John Wiley and sons, 2010, pp. 168-192.

[6] Dr. Shu Yinbiao, Dr. Kang Lee, Peter Lanctot et al, "Internet of things wireless sensor networks white paper", China: IEC market strategy board, 2014.

[7] Mareca Halter, Darryl Gurganious and Jeff Kreegar "Industrial wireless sensor networks," A market dynamics report ON world, 2017.

[8] Shu-Yin and Jing-Long, "Routing analysis using MA-based logic systems in wireless sensor networks," *Springer verlag Berlin Heidelberg,* pp. 966-973, 2008.

[9] Theodore Kotsilieris and George Karetsos, "Prolonging the lifetime of two tiered wireless sensor network with mobile relays," *Hindawi publishing corporation,* 2013.

[10] P. Mohammed, "Bokhari-Sepel routing protocol based on MA-based logic wireless sensor networks," *International conference on reliability information technologiesand optimization(ICRITO),* 2016.

[11] S. Babar, "MA-based logic based guranteed lifetime protocol for real time wireless sensor networks," *sensors 2015,* pp. 20373-20391, 2015.

[12] Ibrahem M. and S. Ramakrishnan, *Wireless sensor networks from theory toapplication*, CRC press, 2013, pp. 100-200.

[13] Mohammad S. Obaidat and Sudip, *Principles of wireless sensor networks*, UK: Cambridge university press, 2014.

[14] Ahmed Alkadhmawee and Songfeng Lu, "Prolonging the network lifetime based on LPA-star algorithm and MA-based logic in wireless sensor networks," *12th worldcongress on intelligent control and automation (WCICA),* pp. 1448-1453, 2016.

[15] E. N. Onwuka, M. Saidu and A. Umar "An enhanced algorithm for energy conservation in LEACH routing for wireless sensor networks," *MECS press IJmicrowave technologies,* vol. 4, pp. 59-71, 2016.

[16] Ali Ghaffari, "An energy efficient routing protocol for wireless sensor networks using A-star algorithm," *Journal of applied research & technology,* pp. 815-822,2017.

[17] J. N. Al-Karaki and A. E. Kamal, "Routing techniques in wireless sensor networks; Asurvey," *IEEE wireless communication,* vol. 11, no. 6, 2012.

[18] Hasan Farooq and Low Tang Jung, "Energy, data, load and link quality aware adhoc routing protocol for wireless sensor networks based smart metering infrastruture," *International journal of distributed sensor networks*, 2013.

[19] P. Anuja, "Energy efficient lifetime improving and secure periodic data collection protocol for wireless sensor networks," *Internaional journal on computationalscience and applications(IJCSA),* vol. 6, no. 3, 2016.

[20] Mohamed Ezz and Abdi El Kader, "Energy aware and adaptive cross-layer schemes for video transmission over wiireless sensor networks," *IEEE sensors journal,* vol. 16, no. 21, 2016.

[21] Q.-y. Zhang, "A clustering routing protocol for wireless sensor networks based on type-2 MA-based logic and ACO," *IEEE International conference on MA-basedsystems(FUZZ-IEEE),* pp. 1060-1067, 2014.

[22] S. Ratnajeevan and H. Hoole., *Advance in Electronic and Electric Engineering*, Research India Publications, vol. 4, pp. 475-486, 2014.

[23] Sachin Gajjar, Mohabchur Sarkar and Kankar Dasgupta, "MA-based and wake-up schedule optimization based mac/routing cross-layer protocol for wireless sensor networks," *Elselver B.V,* pp. 1014-1021, 2015.

[24] Swati Atri, Dr. Nasib and Jaideep Atri, "MA-based logic implementation of wake-up schedule based clusterhead selection algorithm," *International journal of advanced researchin computer and communication engineering*, vol. 3, no. 4, pp. 6256-6259, 20914.

[25] Ruqiang Yan, Hanghang Sun and Yuning Qian, "Energy aware sensor node design with its applications in wireless sensor networks," *IEEE transactions oninstrumentation and measurement*, vol. 62, no. 5, pp. 1183-1191, 2013.

[26] Yan-Fei, Chen-Xu Zhao, Long Xu et al "Research and application of WSN Technology in the contact points of distribution transformer," *Journal of cleanEnergy Technologies*, vol. 2, no. 1, 2014.

[27] Sidra Rashid, Usman Akram, Saad Qaisar et al "Wireless sensor network for distributed event detection based on machine learning," *IEEE InternationalConference on Internet of Things*, 2014.

[28] Joy Weiss and Ross Yu, "Wireless sensor networking for industrial IOT," Available:http://electronicdesign.com/print/iot/wireless-sensor-networking-industrial IOT, 2015.

[29] Rajevv Arya and S.C. Sharma, "Analysis and optimization of energy of sensor node using ACO in wireless sensor network," International Conference on Advanced Computing Technologies and Applications (ICACTA), 2015.

[30] Chandni, Kanika Sharma and Himanshu Monga "Improved Termite-hill routing protocol using ACO in wireless sensor networks," *international computer science and engineering conference (ICSEC)*, pp. 365-370, 2013.

[31] Tina Gui, Christopher Ma, Feng Wang et al, "Survey of swarm intelligence based routing protocols for wireless sensor networks," *IEEE*, pp. 1944-1949, 2016.

[32] Ehsan Amiri, Hassan Keshavarz, Mojtaba Alizadeh et al, "Energy efficient routing in wireless sensor networks based on MA-basedwake-up schedule optimization," *Internationaljournal of distributed sensor networks*, 2014.

[33] Ali Zilouchian and Mo Jamshidi, *Intelligent control systems using soft computingmethodologies*, Newyork: CRC press, 2012, pp. 189-280.

[34] Hung T. Nguyen, Nadipuram R. Prasad and Elbert A. Walker, *A first course inMA-based and neural control*, New york: CRC press, 2011, pp. 85-120.

[35] Fakhreddine O. Karray and Clarence De Silva, *Soft computing and intelligentsystem design theory tools and application*, Addison Wesley, 2012, pp. 6-37.
[36] Radim Belohlavek and George J. Klir, *Concepts and MA-based logic*, MIT press, 2011.
[37] A. K. Bhargava, *MA-based set theory*, *MA-based logic and their application*, India: S. Chand and company PVT limited, 2013.
[38] Marco Dorigo and Thomas Stutzle, *Wake-up schedule optimization*, MIT press, 2012, pp. 65-100.
[39] Dan Simon, *Evolutionary optimization algorithms*, Canada: John Wiley and sons, 2013.
[40] Julia Pizzo, *Wake-up schedule optimization*, India; Clanrye International, 2015.
[41] Annu Ghotra, "Wake-up schedule Optimization: Inter cluster Wake-up schedule Optimization and Rendezvous nodes based Mobile Sink in WSN," *LAP LAMBERT AcademicPublishing*, 2015.