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Research and Postgraduate Studies (RPGS) Unit

Enhancing data availability in wireless sensor networks using power thresholds

Submitted By

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December 2020

Declaration

I declare that the information contained in this paper is my original composition and the work has not been submitted for any other academic or professional qualification. I declare that all the work is my mine, except work where contributors have been cited and referenced. All the interpretation in this work is my own understanding and does not appear in other publications.

Simeon Nsabiyumva

Approval

This thesis has been submitted for examination with my approval as the project supervisor, University of Rwanda, College of science and technology.

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Abstract

Sensing devices are installed in places like parking areas, near rubbish bins, on the doors, gates scanners and other security areas like battlefields. These sensing devices interconnect to form Wireless sensor networks (WSNs). Within a fraction of a second, WSNs are able to collect data and share information. Monitoring the activity of a sensor node should be a priority throughout the life of the network. Power management determines the life of a sensor node and also allows for other sensor nodes to easily map with alternate node thus increasing the channel availability. Cluster-based hierarchical protocols have been adopted as the best protocols for decreasing on the possibility of high energy consumption. In our research, Low Energy Adaptive Cluster Hierarchy (LEACH) protocol is used to study the WSN's power implications, paying attention to the forms of sensor node activity and analyzing the power levels at its threshold value. To improve on data availability and data delivery of the WSN we propose an improved routing protocol in this research. We proposed an enhanced data delivery LEACH (EDD-LEACH) protocol where the sensor node selects an alternate path for service sharing with the neighboring node, other than a node whose power levels have reduced. The solution provides possible actions to mitigate the effects of data loss and allows for availability of information. To reduce on the possibility of the sensor node's power draining quickly, we set the minimal operating power basing on the energy dissipated in transmitting a packet and the energy dissipated while choosing the alternate transmission path. Our simulation Results exhibit that, in comparison with LEACH, when the sensor node's power is set to operate above threshold levels and with proper placement of the base station (BS) relative to the field size, there is 4% increase in data packets reaching the base station in EDD-LEACH than LEACH.

List of Acronyms

WSN: Wireless Sensor Network

DDoS: Distributed Denial of Service,

IoT: Internet of Things,

QoS: Quality of Service

ICT: Information Communication Technology

mA: Milliamps

V: Volt

UIDs: Unique Identifiers

CPC: Circuit Power Consumption

PMM: Power Management Module

BS: Base Station

CH: Cluster Head

LEACH: Low Energy Adaptive Clustering Hierarchy

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Definitions

WSN	It is short form for wireless sensor network. It refers to a collection of wireless sensors which have been deployed to collect data about the behaviour of the environment.
Cluster	It is a set of nodes which have been grouped together.
CH	Is short form for cluster head. It is a self-configured sensor node for purposes of collecting data packets of cluster members.
BS	This is a central data collection point for all sensed data packets in a WSN.
Round	A time-frame during which the network system exchanges a data packet from sensor node, CH and BS.

CHAPTER ONE: INTRODUCTION

1.1 Introduction

The implementation of WSN technologies has made it a popular research area in recent years (S. Chakraborty, 2020). New developments have led to the use of wireless sensor networks. Wireless sensors are configured to collect data and communicate in an ad hoc behavior.

Sensor nodes have capabilities such storage, sensing, processing, communication and real-time observation. The deployment of these sensors play a big role in different areas such as health monitoring (Sadiku, 2018), warzones, monitoring of fire outbreaks, surveillance, traffic control (Poor, 2017) and control of buildings or intrusion detection and monitoring of the device coordination in industrial sites or experimentations (Wang W., 2013).

Considering all the tasks these WSNs can accomplish, power constraints and network lifetime becomes a primary area of research. Most of the times, these WSNs are deployed in areas where working conditions are harsh or even unbearable (Jaydip, 2013).

Since most of the sensors in WSN use replaceable batteries (N Yaakob, 2014), locating and replacing these batteries may be difficult. Sensors operate on service sharing experience (N Yaakob, 2014). This requires a sensor node to be up and correctly powered for all the time. Basing on the functions of these WSNs, the security concerns of these sensors should be put to a forefront.

The mission set for these WSNs may fail to be accomplished due to factors like (i) lack of battery power, (ii) limited energy and resources such as slow in processing power in the event of high data transfer rate and data input, (iii) physical attack of the WSN and (iv) node dynamism. It is in this regard that a mechanism should be laid to prevent or limit the occurrence of these failures.

According to Yang et al (2004), security implementations do not come at no cost. In the event of enhancing network sensor performance, availability and scalability, security concerns have to take priority (H Yang, 2004). Ensuring that a WSN has sufficient power to run throughout its life and with a capability to enhance power-saving in the process of self-reconfiguration, helps in ensuring all-time access to data and information. This is worth, keeping other security concerns enhanced.

Today, industries, organizations and government institutions are experiencing a lot of need for data collection and processing (Komanduri, 2016). Sensors can provide a large benefit in terms of greater efficiency and reduced physical labor costs.

In a smart city, for instance, the growth of Information Communication Technologies (ICTs) has seen most of the sophisticated hardware and software being developed (Saraju, 2016). Using these ICTs leads to increased effectiveness of operations (Saraju, 2016). Today, almost all organizations want to embrace these smart technologies to reduce on the labor costs, ensure quick information delivery and coordination of practices.

The overall adoption of sensor networks is being realized as growing with a stead slope (Komanduri, 2016), and modifying features within these sensors is vital in ensuring increasing activity. Ensuring the adaptive power management capabilities helps to improve the efficiency of their services.

1.2 Background

Among the most leading factors for determining sensor capabilities, energy consumption is key (M.A. Matin, 2012) because these sensor nodes rely on battery. The power management schemes are controlled and managed by the sensor's microprocessor. These sensors loose power basically during the states like (i) listening state of a sensor (ii) communication state (iii) waiting time (iv) transmission distance (Figure 1)

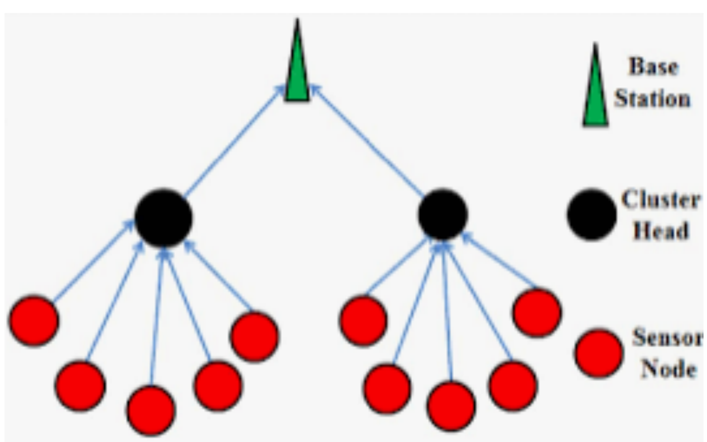

Figure 1: A communication model between SN, CH and BS

In figure 1, a random number of nodes is grouped and one of the group members chosen as a cluster head. The choice for cluster head selection is based on the distance of a sensor node from adjacent nodes in a cluster, energy levels and nearness to the base station.

These nodes can fail due to hardware issues or exhaustion of energy (M.A. Matin, 2012), or even the transmission distance. To overcome this, power saving schemes have to always be improved and monitored throughout the life of a sensor activity.

Devices installed for mission-critical cases like in the battlefield, security at entry points, or related monitoring activity should always ensure battery constraints are given additional priority. The design and implementation of a comprehensive, easy to use and reliable WSN may be a challenging task.

There are also WSN's power implications while searching for nearby ad hoc nodes, paying attention to the forms of insecurity exposed to these devices. Determining the shortest path based of the neighboring node for service sharing with the neighboring node can increase on power saving.

To allow for continued communication and availability of Information, strategies to ensure that in the event of the node's critical low power status, other nodes in the range should detect this effect and hence divert the sharing to other nodes in the range. This would limit on the extent of packet loss, packet retransmission and channel congestion.

The thesis aims at studying the power management schemes, looking at the power thresholds and ensuring that when power levels are below the threshold value, a sensor node cannot transmit its captured data. It is also vital to ensure that the controller has all the information about the power levels of nodes in a network, as well as making sure that data to be sent to the failing node is rechanneled to another node whose power is above threshold.

The proposed solution was to mitigate the failure of a network by developing a network management plan or protocol which would ensure that power failure is not a hindrance to communication. Also in the case of failure information in adjacent nodes is updated and communication is continuous.

1.2.1 Power consumption reviews

Like sensor in sleep mode, an adaptive activation of sensors has led to maintaining the services of the sensor readily available in case of need (Qun Li, 2018). Primarily, any sensor in sleep mode can hardly be detected on the network (Qun Li, 2018). Making sure this sensor is active depends on several factors such as (i) data flow across the network or (ii) the applications. For this case, there is a great deal of energy consumption for the sensor node that is active on the network.

1.2.2 Energy utilization Parameters of the sensors to be used.

Wireless sensors are supplied with power in order to operate. The assumed energy to be used was 0.5J. The minimum operating energy was determined and implemented in our study. The determining parameters for the minimum energy used are energy used to transmit one bit of a packet plus the possible amount of packets that would be transmitted by a single sensor node and the cost of transmission. In the system setup, any power levels below this minimal (threshold) energy would not permit a sensor to operate on a network.

1.3 Problem Statement

The concept of IoT has been looked at as a system of interlinked and interrelated computing devices, objects, animals or people that are provided with unique identifiers (UIDs) and with the capability to transfer data over a network without human-to-human and minimal human-to-computer intervention (IoT Agenda, 2016). Sensors are deployed to collect data from the environment for IoT to process (Trend Micro, 2020). Sensors are able to measure observable occurrences.

WSNs as one of the major IoT components capture electric pulse and pass it to the IoT system (EDUCBA, 2020).

During the process of transmission of data, sensors use reasonable amounts of battery power. As more and more data capture and transmission occurs, power levels of these sensors are greatly lowered. Power thresholds do not allow for the sensor node to get rid of its saved contents before it can go off. Data coming from adjacent nodes shouldn't be lost or dropped. Sensor nodes in the range are not configured with a mechanism to detect the low levels of another node and determine alternate paths. This should be in coordination by the controller.

Currently, sensor nodes are configured to save power. They also have an adaptive mechanism where they can change state from sleep mode to active state depending on the incoming signal or application. Sometimes it takes time to realize that a sensor node has run out of power, and this means that the sensor went off with some data captured. This does not only affect the functionality of the node, but also affects the security of data.

New adaptive capabilities need to be configured to mitigate data loss or loss of service. Designing standards with a self-reconfiguration mechanism requires power constraints put in consideration.

Much as there are similar studies and implementation plans already in place, the issue of determining the action when power levels go below the minimum required levels were given less attention. This research seeks to assess how the current measures can be improved.

1.4 Objectives of the research

Most Sensing devices are setup in harsh environments. Recent research from different scholars about factors affecting WSNs have been discussed. While it is important to enhance the network lifetime by implementation of low energy consumption strategies, it is also important to evaluate how much data can be collected if the already existing energy constraints are analyzed and then compared with our suggested energy values.

1.4.1 Main Objective

The main objective is to evaluate the adaptive behaviours and apply improved energy strategies to mitigate data losses due power loss.

1.4.2 Specific objectives

The specific objectives to this research was but not limited to

i. Assess the current WSN power configurations.

ii. Identify the power critical levels in the existing configurations of the wireless sensor.
iii. Assess causes of data loss.
iv. Define requirements for updating the current power schemes to determine critical power levels.
v. Implement an algorithm that mitigates data loss and ensure critical data recovery.
vi. Analyze the new scheme of power monitoring.

1.5 Research Questions

To accomplish the objectives stated above, the following research questions served as guidelines for this present work.

i. What are the current power configurations in the sensor node?
ii. What changes do take place in the current WSNs due to critical power levels or power exhaustion?
iii. How should we detect that the other node is broken down?
iv. How do we ensure availability of service ensuring that data on a node in study is not lost?
v. How will the solution look like?

1.6 Justification of the study

This research aimed at ensuring limited data losses due to sensor node power exhaustion. The research results contributed to enhancing the operational capabilities of the sensor.

The research examined power levels during the active process of a sensor. Gaps realized during the analysis stage of these power schemes were addressed. This thesis consists of both the academic and strategy propositions. Findings from this study are to be proposed to industrial standards so that new upcoming devices have enhanced power management capabilities.

1.7 Limitations of the study

This research was conducted using MATLAB simulation platform. Modules required to use in these simulation packages were to be acquired at a relatively cheap cost.

1.8 Research proposal structure.

This research proposal is sequenced in three main chapters

(i) The general introduction to research, thoughts about the intended work, problem statement, and objectives of carrying out the research and limitations.

(ii) The review of related literature, the existing systems and their gap.

(iii) The methodology used in carrying out research; listing the tools to be used, methods of collecting data, and sampling methods plus the research design.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Energy enhancement in WSNs is an important factor that ensures data availability and sensor lifetime. Different Energy schemes have been proposed to ensure that the sensor battery is always monitored and the results of the falling energy intervals communicated to the BS.

Energy conservation protocols have been suggested. Santosh et al**.** (Purkar Santosh V, 2018) proposed a protocol that takes into account for the formation of Cluster Heads (CH) based on the node's residual energy, the distance between the adjacent nodes and the initial energy.

Min Xiang et al. (Min Xiang, 2010) proposed a clustering algorithm to reduce energy consumption and an enhanced system time. He used an analytical model of a single-hop distance and clustering angle. Formation of a cluster head to continue working as a control centre for all nearby nodes is what was implemented.

A. Chandanse et al. (Chandanse Akash, 2019), said that transmission of data by sensor nodes consumes battery. Efforts to reduce energy consumption was proposed by use of suitable algorithms. In his analysis, the implementation of LEACH protocol was proposed to be the best energy saving Adaptive clustering technique. Years before this, Alka Singh et al. (Alka Singh, 2016), also proposed LEACH as a routing method for multi-hop network designs to reduce on energy dissipation from clusters to base stations. LEACH relies on time division multiple access (TDMA) technique to transmit data from sensor nodes to the base station. With LEACH, there is localized integration and concentration of data to a CH, which is then sent to the Base station.

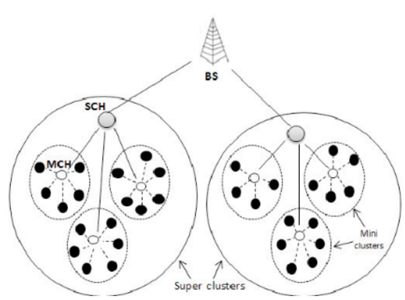

Figure 2: A randomised formation of clusters, cluster heads using LEACH protocol

In LEACH protocol, clustering works on a randomized (Figure 2), self-configuring and adaptive standard (Wafa Akkaria, 2015). Hinzelmann also suggested a hierarchical method for WSN communication (Zahabi, 2015). Here, specific number of nodes are randomly picked and their energy checked. After this step a CH from these nodes is formed to receive and transmit other sensor nodes' packet to the BS. This study did not tackle other important parameters required for clustering and transmission.

LEACH-B is an improved LEACH protocol (Li & Wanyuan Jiang, 2017). Research approved that LEACH-B routing protocol saves more energy and ensures a balanced cluster. In their research, C. Prajapati et al (Prajapati, 2014) worked on a system to reduce the number of CHs per round and ensured that each CH builds its TDMA plan and broadcasts it across all other sensor nodes. This system allows for a balanced energy saving and CH formation. Each CH has a specific time to collect and transmit packets before another sensor node takes up the role.

Jin Wang et al. (Jin Wang, 2018) proposed and analyzed a PEGASIS (Power-efficient gathering in sensor information systems) algorithm and called it "An Enhanced PEGASIS Algorithm". In his algorithm (Jin Wang, 2018), he determined an optimal distance to reduce energy consumption. He also proposed setting minimal energy for a node for continued efficiency. PEGASIS is a power gathering technique that helps in making sure that sensors in communication learn about the Energy levels of the nodes in the range. PEGASIS ensures that a node communicates only with a closest node to reduce power consumption.

The power management module (PMM) was proposed in 2015 (Z. J. Chew, 2015) to harvest energy from the strain energy harvester (SEH) regardless of the vibrational frequency (Zhu, 2016). These practices involve addition of more devices to an already exiting sensor node thus making it heavily weighed.

Li (Li Q. a., 2003), presented an idea about adaptive activation of sensors. In their research, sensor nodes that are not in activity are put to sleep mode. Their algorithm ensured that a sensor in sleep mode does not participate in the network by receive any incoming communication or transmitting collected packets. Activation of sensors from sleep mode was based on the type of application communicating. This is problematic if other sensors on the network face a critical security flaw and require the services of the node in sleep mode. A technology to interrupt the sleeping node in case another node wants to communicate to it would have been developed.

Mujun Qian et al (Qian, 2016), studied the implementation of circuit power consumption (CPC) in cooperative beamforming. In this technique, relay node placement helps in ensuring improved received signal to noise ratio. CPC was introduced to cater for the distance-power ratio. Dense distribution of power allows for low power wattages. This solution does not cater for a failing node. This means that in case of power loss, data collected remains with the failed Node.

R. Chéour et al (Chéour, 2017), designed a Scheduling and energy harvesting model using Dynamic Power Management (DPM) and Dynamic Voltage and Frequency Scaling (DVFS). Studies in WSN have realized that energy harvest is a best technique to improve efficiency (J. Amaro, 2015). These parameters however, do not cater for the changes in applications or the frequency of transmission. The environments in which these nodes are deployed is a determining factor for the frequency variations.

H. Zhang et al (Zhang H. a., 2020) proposed a quick precoding scheme in clustering based on a sub-connection structure. This structure works on a principle that each RF channel is connected to a phase shifter and the number of phase shifters is equal to the number of Antennas in the range. The Multi-antenna setup is not cost effective and involves more devices in the data collection communication process. Network channels reduce competition but increases device congestion and decision complexity.

A LEACH algorithm was designed to improve the network lifetime. This protocol was designed to solve power restrictions issues in WSN. It worked on the principle of sub-dividing a network into layers (by comparing the distance from the base station and a sensor node plus the distance between two layers) before the clustering process takes effect (Sedighimanesh, 2016). Results from this research proved to have a better performance lifetime of sensor nodes that the known LEACH protocol. However energy levels were simulated without the threshold energy in mind.

In their research, Zhang, et al (Zhang Z. a., 2020), studied an intelligent algorithm of data transmission in agricultural IoT. They suggested a corrected recirculating wireless sensor network (CR-WSN) routing mechanism to mitigate fault-tolerance. When compared with cell corrected recirculating aquaculture system (CRAS). Their findings proved that cluster head selection is based on the sensor node with the highest energy levels. When they compared their results with concurrent read exclusive write (CREW), the difference in their findings was the energy exhaustion levels. CREW proved to have a considerably lower consumption as compared to CRAS protocol. However, their study did not involve threshold energy values and also did not study amount of transmissions to the base station. It only covered the CH capacity.

Chen L et al (Chen, 2020) did a comparison of the traditional protocols used in WSN. They laid down the advantages and disadvantages of each protocol and suggested improvement measures for protocol optimization to increase the network lifetime. Their findings were that LEACH protocol was the most reliable in that it increases the network lifetime at a reduced energy consumption. Their research put that cluster heads in LEACH are evenly distributed and cluster formation is done in a specified location to avoid energy losses during connectivity. CH formation and range of CH communication was not taken into consideration. The energy levels to data transmission was not taken into consideration.

2.2 Summary table for a list of related Literature.

Author	**Topic/title**	**Strength**	**Area of improvement**
Haisen Zhang, Haijun Zhang, Wei liu, Keping long, Jiangbo Dong, Victor C. M. Leung (May 3, 2020)	Energy Efficient User Clustering and Hybrid Precoding for Terahertz MIMO-NOMA Systems	This paper studied the energy complexity and consumption schemes in THz-NOMA-MIMO systems. After implementing a sub-connection scheme, their results showed an improvement in convergence and high energy efficiency. System design accounts for inter cluster interference and attenuation.	• Sensor energy has no threshold value. • The effect of data transmission in relation with energy efficiency was not given priority.
Zihong Zhang, Rui Luo & Wei Fu (July 27, 2020)	Energy Saving Algorithm of Wireless Network Nodes in Cluster	Proposed a CREW routing algorithm. Cluster selection is based on the SN with high energy. Simulation results show an improvement in power saving that in CRAS.	• Result compare the capacity of the CH with the number of clusters in a network.

		Energy consumption in CREW is limited as compared with CRAS	• Data collected at the BS is not referenced. • The relationship between energy and data collected is not reflected in the results • No energy levels are assumed for any SN
Chirag Prajapati & Nimit Modi (May 5, 2015)	Energy Efficient Cluster Head Selection in Wireless Sensor Networks	Used LEACH-B protocol to analyze power consumption. Their proposed system ensured reduced formation of CH and replacement costs. BS advertises the CH IDs for the SN to join the cluster. CH builds and advertises it's TDMA to other sensor nodes before transmission commences. Node sends data within the allocated time.	• Energy thresholds not declared, a factor that nodes can operate at any energy levels. • Impacts of time and amount of packets transmitted not analyzed.
N. Kumar, J. R. Desai, Annapurna D (November 02, 2020)	ACHs-LEACH: Efficient and Enhanced LEACH protocol for Wireless Sensor Networks	Proposed a modification of LEACH and M-LEACH to form ACHs-LEACH. This protocol performs power consumption metrics, data loss and data delivery. It works on the principle of CH and assistant cluster head (ACH) election to cut down the amount of energy exhaustion. The system implements the concept of eliminating malicious nodes that may affect data integrity.	• Strategy for sensor nodes near the BS to forward directly to the BS is not configured.
Vasudha Bahl, Anup Bhola (2018)	Enhanced Energy Efficient Cluster Head Selection Algorithm for Improvement in Network Lifetime for Wireless Sensor Network	Proposed a mathematical model for an improved LEACH model called WLEACH. In this protocol, CH selection is based on residual energy of a sensor node.	• Considerations for a node to be dead is when its energy is zero. • Packet size and energy use to transmit it is not

			clearly taken into account.
Shriya Sinha, M. P. Parsai (July 22, 2020)	Cluster Head Selection in Leach with Minimum Risk of Failure	Did a survey on the existing LEACH protocol and implemented CH load balancing, where a sensor node with the highest load of packets cannot be selected as CH; a mechanism to combat early death of a node. This was one way of ensuring data availability.	• Analysis results show probabilities of CH formation and not about the amount of packets at the receiving end.
WooSuk LEE, Kye-Dong Jung and Jong-Yong Lee (November 20, 2017)	Improvement of cluster head selection of LEACH Protocol	Implemented the LEACH protocol to improve the CH selection based on the residual energy of a sensor node. The residual energy thresholds of the sensor node changes basing on the residual energy of the alive node.	• Impacts of residual energy implementations were not compared with packet transmission.
JinWang , Yu Gao, Xiang Yin, Feng Li,1 and Hye-Jin Kim (December 3, 2018)	An Enhanced PEGASIS Algorithm with Mobile Sink Support for Wireless Sensor Networks	Proposed EPEGASIS to specify optimal communication distance, reduce energy consumption and adjustment of communication range when BS distance is far from the node. Their model implemented threshold energy number of neighboring sensor nodes and current sensor node's energy. Their model safeguards communicating nodes from failing at early stages.	•

Table 1: A table listing related literature, their strength and areas of improvement.

Recent research made and protocols proposed were mainly aimed at increasing the network life time and reduction of energy consumption.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

The modeling process involves laying down and setting up theoretical approaches to use in the research process (Mentzas, 2001). This chapter highlights all workflow elements, tasks, human skills, information communication technologies and so on. This part of our research involves designing algorithms, methods, qualitative and quantitative modeling techniques.

3.2 System model.

In the proposed protocol, a clustered node map was used to implement the idea. In this case, the network model involves having a group of nodes forming a cluster. The formation of clusters is based on the relative distance from nodes. Data transfer from a cluster to a base station is done by a cluster head. Energy consumption in this communication model is relatively low. Clustering helps in quick discovery of routes because only cluster heads do communicate with the base station.

The illustration below shows how the communication in the cluster. It is a single-hop node-to-cluster communication.

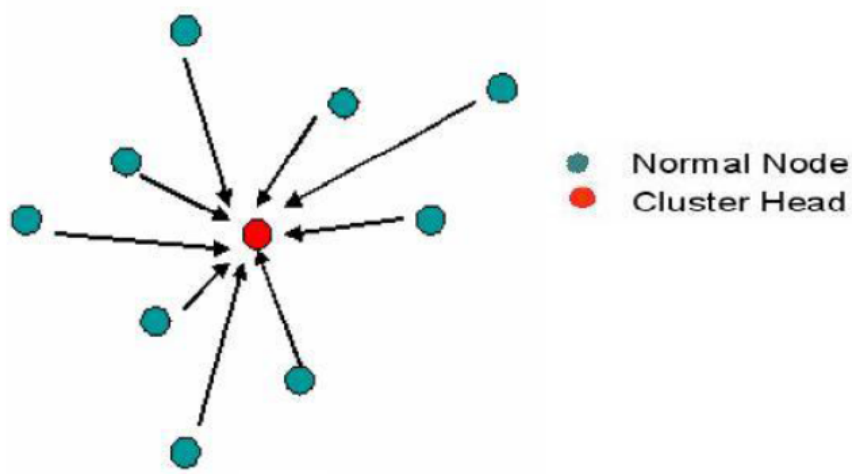

Figure 3: Transmission between sensor nodes and cluster head.

In the proposed communication model, we have used a single hop cluster-to-base station transmission hierarchy. Data collected by the cluster head are sent directly to the base station as shown in the figure below.

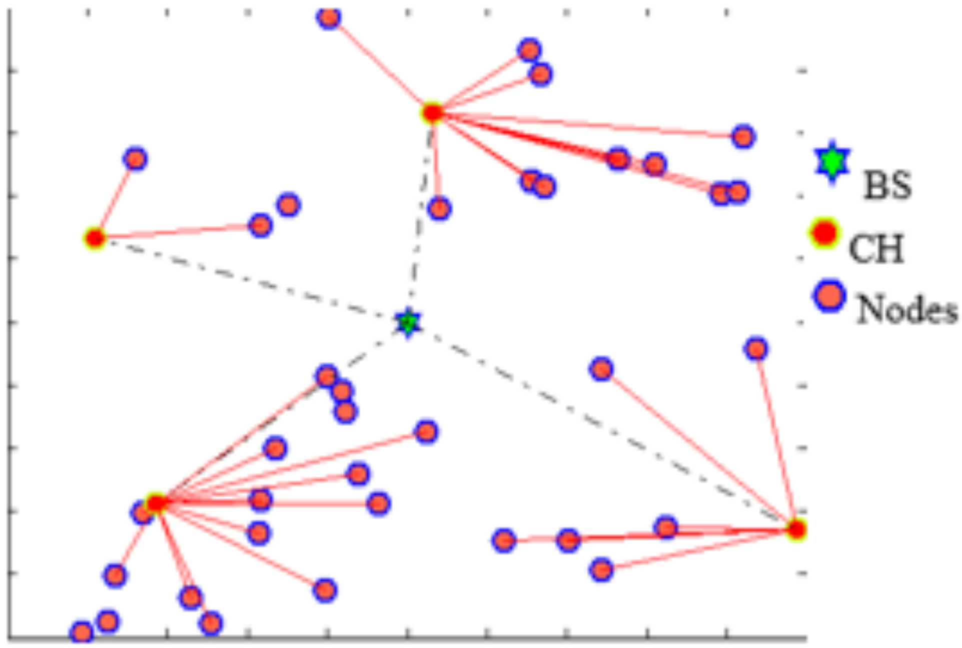

Figure 4: Transmission of data from sensor nodes to CH and from CH to BS

Referring to figure 4, a group of nodes forward collected data to the cluster head. The cluster head then forwards all the cluster members' data to the base station.

The condition for a node to be configured as a CH is based on its power level, and distance between the neighboring nodes. Node communication follows a fact that, in a single round, sends its collected packets to a cluster head, and a cluster head forwarding it to the BS. For any failing node, the route design strategy is forwarded based on the sub-clustering approach.

3.3 Proposed scheme and Algorithm

In the proposed system, each sensor node in the network is assigned with a power threshold. A random number of nodes are selected to form a cluster. Among these nodes, one node acts as a CH. All data packets sensed by each node are sent to a CH in the range. The cluster range is an assumed value. All packets arriving at the CH are then forwarded to the base station. The sink has a capability of recording power levels of the nodes in the network. Any node whose battery power is getting below the minimum required power is removed from the network until the next recharge. The activity of the node is monitored by the base station, which is responsible for other distance between nodes and capability of a node to become a CH.

3.4 Energy Model of a sensor node.

A sensor node dissipates energy every time it sends packets or receives them. In addition, power is lost when the sensor is searching for the nearby CH to transmit its packets to.

In our study, a radio Model (Fig 5) was adopted. The model was proposed by W. R. Heinzelman et all (W. R. Heinzelman, 2000) and adopted by many scholars doing their research in the WSN technology. This Model helps us to evaluate the energy dissipated while transmitting or receiving packets of data.

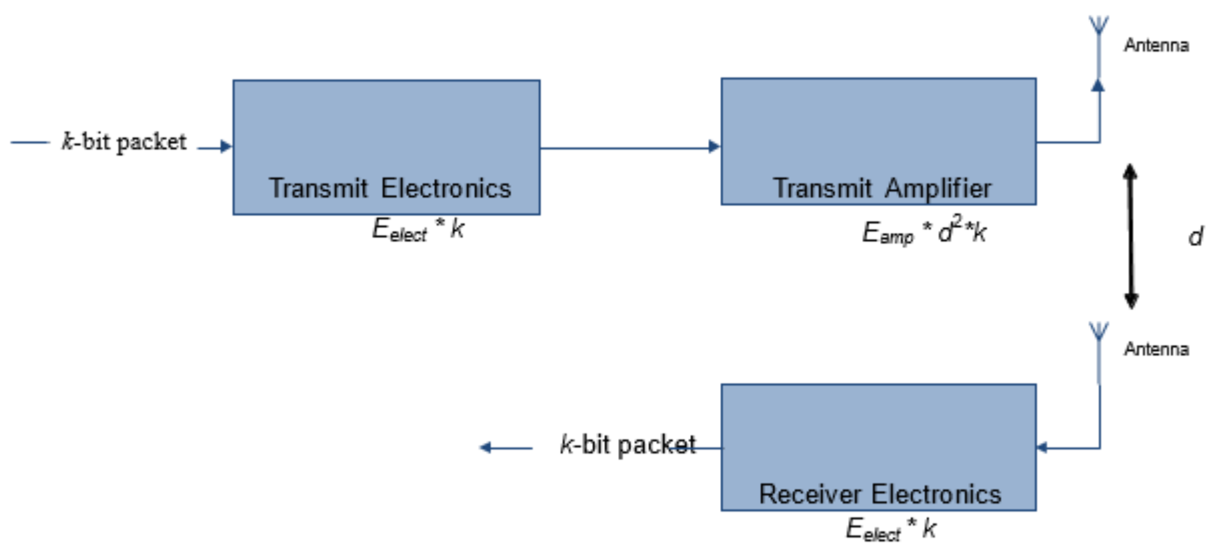

Figure 5: Structure of the first order Radio Model

When a packet of $\boldsymbol{k}$ bits is being transferred to a distance $\boldsymbol{d}$**,** the energy needed for the sensor to accomplish this task is given by;

$$E_{Tx} = E_{elec} * k + E_{amp}.d^2 * k \qquad (1)$$

Where;

E_{Tx} is the energy to transmit $\boldsymbol{k}$ packets to a distance $\boldsymbol{d}$

E_{amp} is amplification energy

E_{elec} the amount of energy used to transmit or receive a single data packet.

$\boldsymbol{k}$ data packets in bits

$\boldsymbol{d}$ the distance between the sensor to the CH or CH to base station.

Likewise, there is an amount of energy dissipated by the receiving node (CH). This energy is calculated as;

$$E_{Rx} = E_{elec} * k \tag{2}$$

Therefore, for any single-hop transmission system in sensor communication, total energy dissipated is given as shown in **(1)** above, where;

E_{Rx} is energy used to receive $\boldsymbol{k}$ packets

In the proposed algorithm, we involve components and constraints to determine contributing factors to energy dissipation. We looked at neighboring sensing nodes (SN), CH, base station (BS), distance from node to node (d_{is}), Energy level of a node (E_0) before it becomes a CH.

For purposes of controlling the sensing nodes from energy exhaustion, we set a threshold energy for each sensing node. This helped the node to determine when to forward its data before it goes down or when to be selected as CH. The threshold energy was determined from the formula;

$$E_{thr} > E_{elec} * k \tag{3}$$

Setting a threshold power level safeguards a node from unmonitored exhaustion. Sensor nodes with power close to the threshold value can use the remaining power to transmit sensed data. **Figure 6** below show how the proposed flow of decisions.

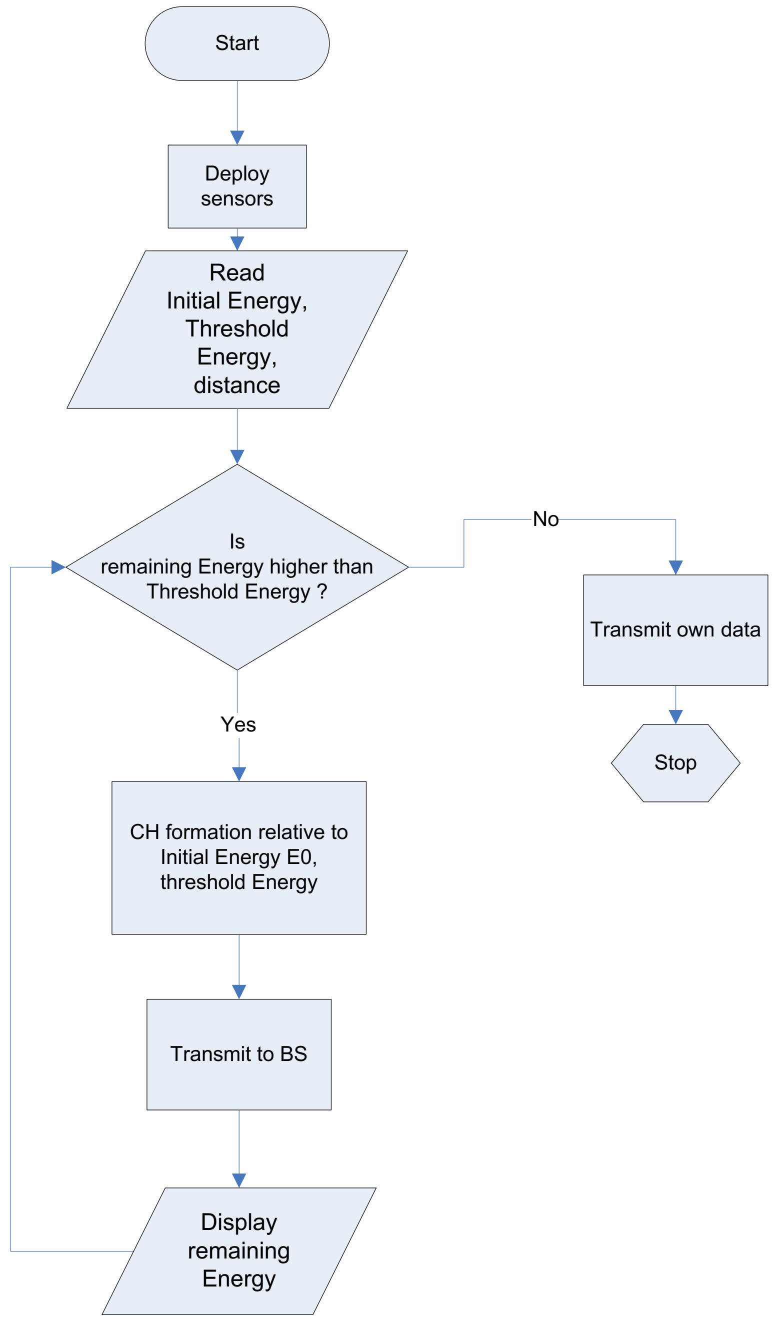

Figure 6: Diagram for sensor node activity for the proposed Protocol

Figure 6 describes the wireless sensor deployment process and criteria for a sensor node to collect data and transmit it. Sensor nodes are deployed with the same initial energy. Energy levels are first determined before a sensor node can become a CH or before it can transfer collected data. The flowchart implements the setting of threshold energy levels and ensuring that when the sensor node power level is below threshold, the sensor node does not participate in the network, The following features are key in the simulation.

i. Determining the level of node Battery E_o
ii. Setting threshold energy
iii. Selection of a CH
iv. Distance (d_{is}) between a node and the nearby CH and BS
v. Determine the Energy required to transfer data (based on the distance of a node to the CH and the packet size) or higher level CH using the formula: $E_{amp}.d^2 * k$
vi. Connection of nodes to the CH based on their Energy level
vii. Estimate the Energy after the first round of transmission and determination of the next CH specified using the formula: $E_o - E_{amp}.d^2 * k$

The following is the algorithm for EDD-LEACH

i. X and Y field measurement
ii. Number of nodes (N), rounds (r)
iii. Initialize network parameters for the WSN
iv. Randomly deploy the sensor nodes in the field
v. Deploy the BS in the field
vi. Start of node pairing
  a) for i=1:n
  b) neig_distance=inf;
  c) if(SN(i).E>thr && SN(i).neighbour_flag==0)
  d) distance between CH and SN calculated
vii. Start of CH formation
  a) if(SN(i).E>thr)
  b) if(cluster<=p*alive)
  c) Plot the CH
viii. Start of packet forwarding to CH and to BS (round of packet collection) and update energy for all nodes
  a) if (SN(i).E<thr)
  b) mark node as dead

3.5 System simulation

The study requires the use of a simulation platform. We used code from published research and modified it to reflect the requirements of our research (mehmetkalayci, 2018). Energy efficient protocols in Wireless Sensor Networks (WSN) Simulation. Data analysis was mainly done using simulation platforms and graphical interpretation of the current mechanisms and systems in use. The aim of this analysis was to help us record and comprehend "as is" the state of the current WSNs set-up and environment. **MATLAB** was used to simulate network topologies. Datasets from the simulation were interpreted in MATLABv14.

3.6 Population of the study

In this research, a topology of 100 sensor nodes were used in simulation and data mapping. CHs were formed to ensure nodes in the range can transmit their data to that CH. The node would only transmit when it has new data. An algorithm was updated after every round where, a new CH would be formed. The protocol responsible for power management was also studied and modified to adapt changes in the failing node.

CHAPTER FOUR: NUMERICAL ANALYSIS AND RESULTS

4.1 Introduction

In our research, we proposed EDD-LEACH protocol which implements wireless sensor packet transmission and forwarding to the base station basing on the threshold energy. There are a variety of simulation platforms which can help us model wireless sensor behavior (Fall, 2008) (CC-BY-SA, 2011) (Andras, n.d.). In this research, our system used MATLAB for simulating the WSN patterns and performance. We used the existing LEACH protocol to compare and assess the performance of our proposed EDD-LEACH protocol.

4.2 Simulation structure

The table below, summarizes primary values and initial plot values

Parameter	Value
Field size (in meters)	$10000m^2$
Number of nodes(n) deployed	100
Initial energy(E_0) of the node (measured in Joules)	0.5
Size of the packet (k) in bits	4000
Threshold energy (E_{thr}), (in Joules)	$0.0001*E_o$
Energy (E_{elec}) used to transmit or receive a single data packet (in Nano Joules per bit)	50nJ/bit
Energy (E_{amp}) dissipated by the amplifier to transmit bits (in J/bit/m^2)	1.3*10^(-15)
Base station (BS) coordinate assumed as (L, L)	(50m,50m)

Table 2: A table summarizing input parameters for our simulations.

This analysis starts with WSN deployment. Deployment is done in a field measure of 100x100 (m). Sensor nodes are randomly deployed. Figure 7 below represents a simulated deployment process. Axes X and Y are measured in meters (m).

The following assumptions were made during the deployment process.

- All sensor nodes follow a random deployment process.
- All sensor nodes have the same initial energy values. For experimentation purposes, initial energy has been set to 0.5J. An increase in sensor energy values provides for an increased sensor lifetime. This is because, when we increased the amount of energy, it would take a sensor more time before its power gets depleted. The assumed energy value above helped us to get quick simulation results and reduce on the simulation time.
- The BS has an assumed fixed position of (50, 50).

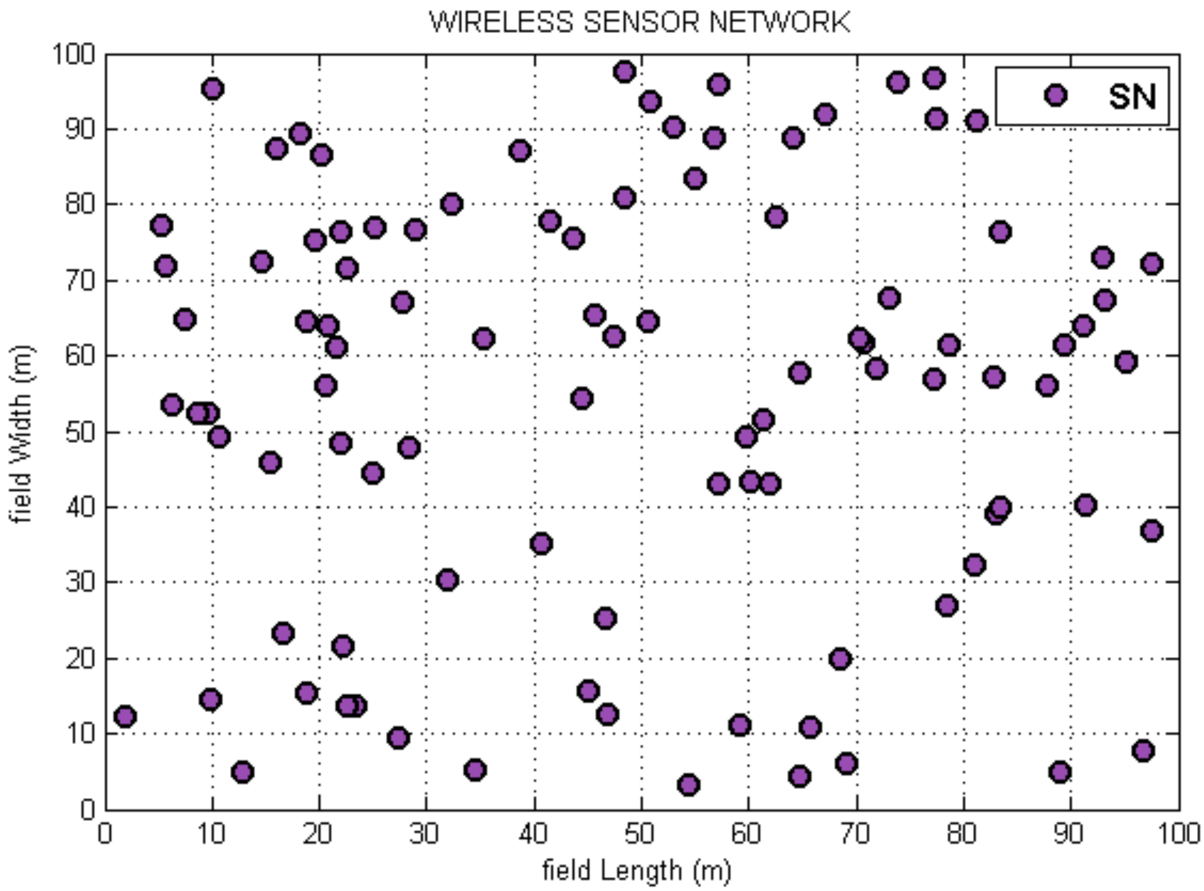

Figure 7: Wireless sensor deployment (100 node network)

Next, we deploy a base station (BS) where all the data from the sensor nodes would be stored. This BS was deployed in the field center to reduce on the channel distance during the cluster-head to BS communications. Figure 7 below show a sensor node deployment together with the BS.

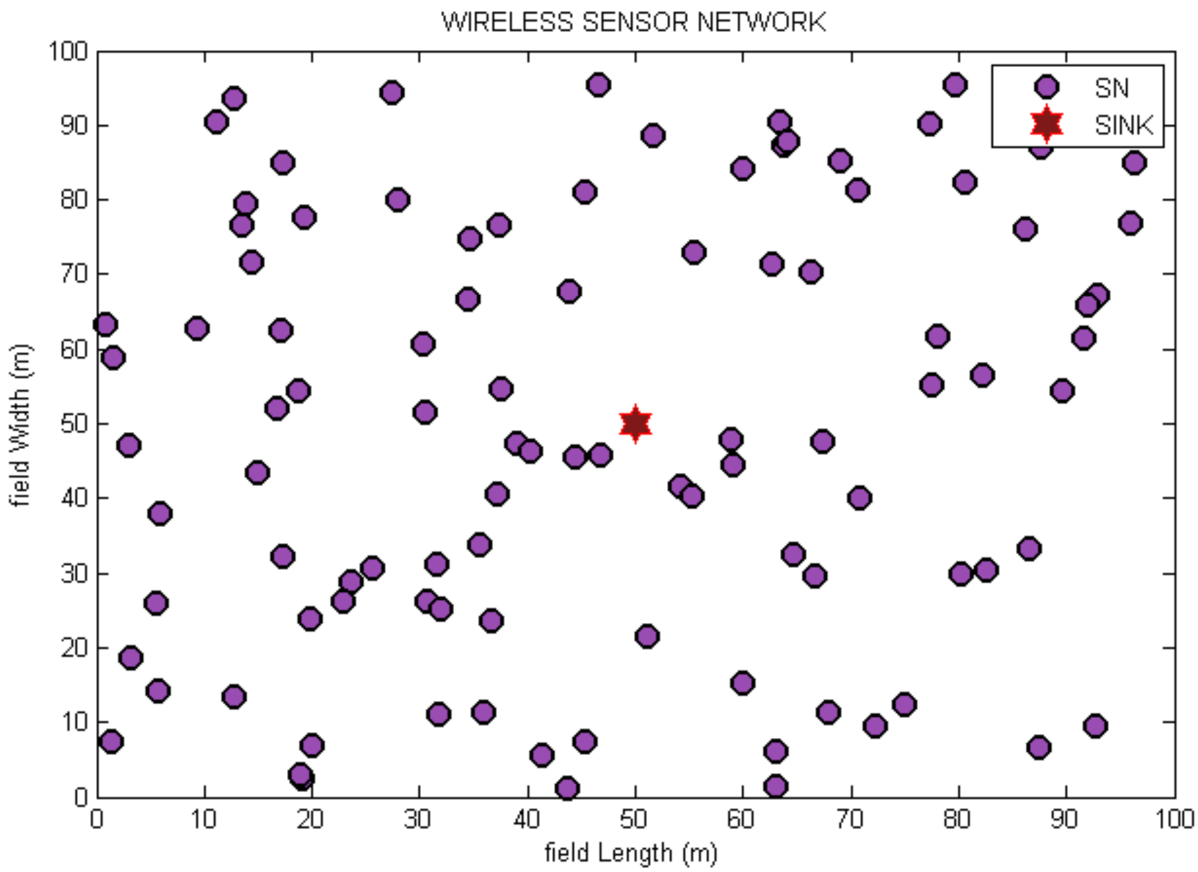

Figure 8: SN deployment together with the BS

The next scenario is a CH formation process. Since the sensor node followed a random deployment procedure, the same applied to the CH. the remaining conditions for the formation of CHs are; Range of CH from dependent sensor nodes, sensor energy (if it's above the threshold and can receive all packets from the neighbour SN without being drained). Figure 8 below represents a simulated output of the topology in figure 7 with CHs added.

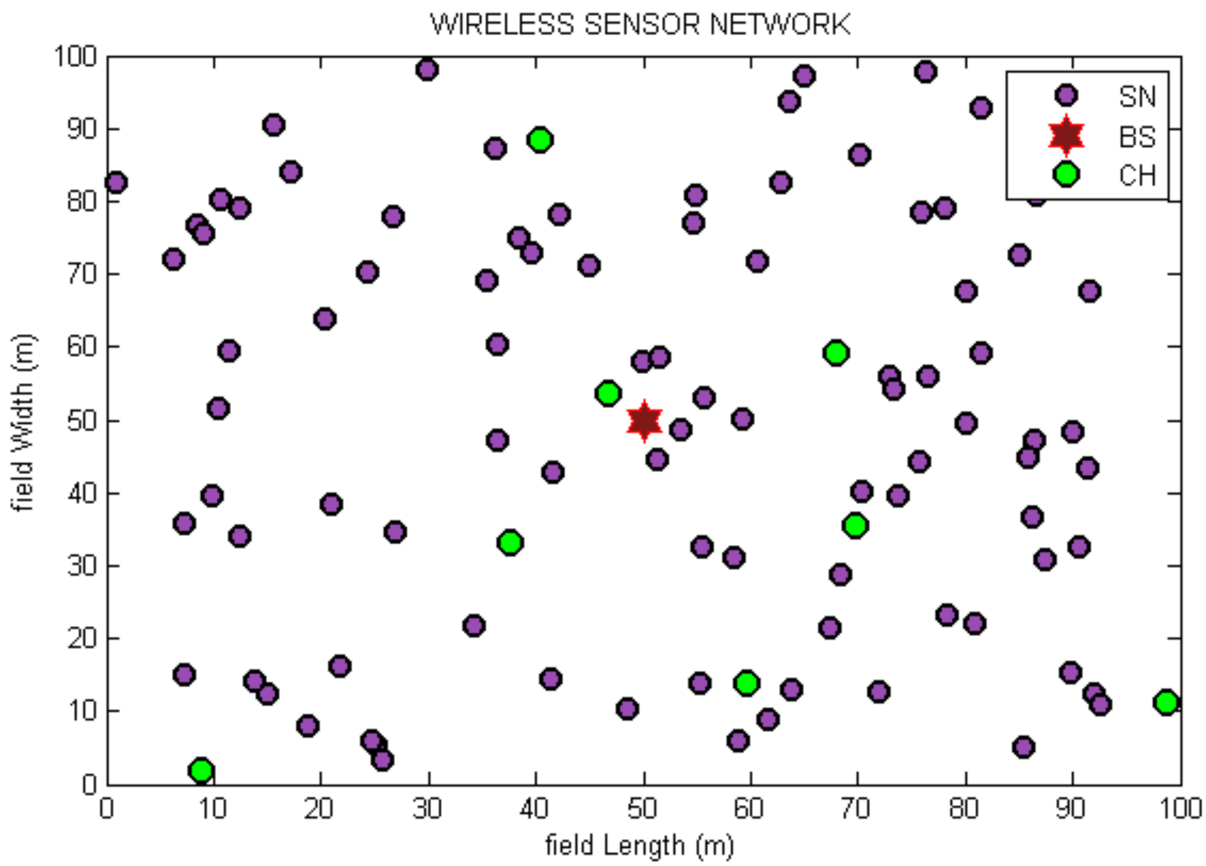

Figure 9: Formation of CHs from sensor nodes.

Within MATLAB, sensor nodes were randomly deployed in a field measuring 10,000m^2 as indicated in figure 6, together with the BS deployed at the centre of the communication field as shown in figure 7. All nodes were deployed with the initial energy equal to 0.5 Joules. For packet to be received or forwarded, energy is dissipated. In addition, the channel in which the packet is to traverse may also contribute to delay thus causing power loss by a sensor node. Due to these factors, we assumed the following;

- Value for the energy required to receive or transmit a single packet is equal to E_{elec}=5*10^-10 J/bit
- Size(k) of a single data packet equal to 4000 bits
- E_{amp}=1.3*10^-15J; Energy dissipated by the amplifier to transmit bits (J/bit/m^2)
- E_{fs}=1*10^-10J; free space loss (J)

We used the energy required to transmit or receive a single bit (E_{elec}) and the size of the packet to assume the threshold value of energy. In this case, threshold energy (E_{thr}) is a value greater than $E_{elec} * k$ (i.e. $E_{thr} > E_{elec} * k$). The threshold value (E_{thr}) is 0.0001*E_0.

In our system, the WSN is subdivided into clusters. Each cluster selects a node to be a CH that is responsible for receiving aggregating and sending collected packets to the BS. To cut down on energy consumption, a single CH is formed per cluster. CHs are formed on a rotational basis (Liu, 2019), (Sadeer Rasheed Ahmed, 2019). The CH packet collection is based on the inability of other sensing nodes to have optimal resources (Sadeer Rasheed Ahmed, 2019). CHs that receive data from individual sensor nodes transmit what they receive to the BS. During the life of a network and to avoid overloading a CH, data forwarding strategy does not allow for a CH to collect packets from another CH.

4.3 Simulation results

A cluster has an assumed communication range, sensor energy and cluster-to-SN distance are the parameters that contributes to cluster-sensor node communication.

The major metrics we used to evaluate the performance of the algorithm are:

Network stability phase: The time frame from the start up to when the first sensor node leaves the network.

Network lifetime: The period from the start of the network up to when the nodes cannot collect, transmit packets or cannot reconfigure to form clusters.

Number of Packets transmitted: This is the sum of all data collected and sent by both CHs, sensor nodes in the WSN to the BS.

4.3.1 Network lifetime and stability phase

Using 100 random nodes and the equations (1) and (2), results from our simulations (fig 10 and fig 11) display the network lifetime plus how long it took before the first node left the network. Results display the network lifetime for EDD-LEACH compared with LEACH. From the graph (fig 10), it is very clear that the first node died in the 1822 round and 2099 round for LEACH and EDD-LEACH respectively. These sensor nodes leave the network due to power limitations.

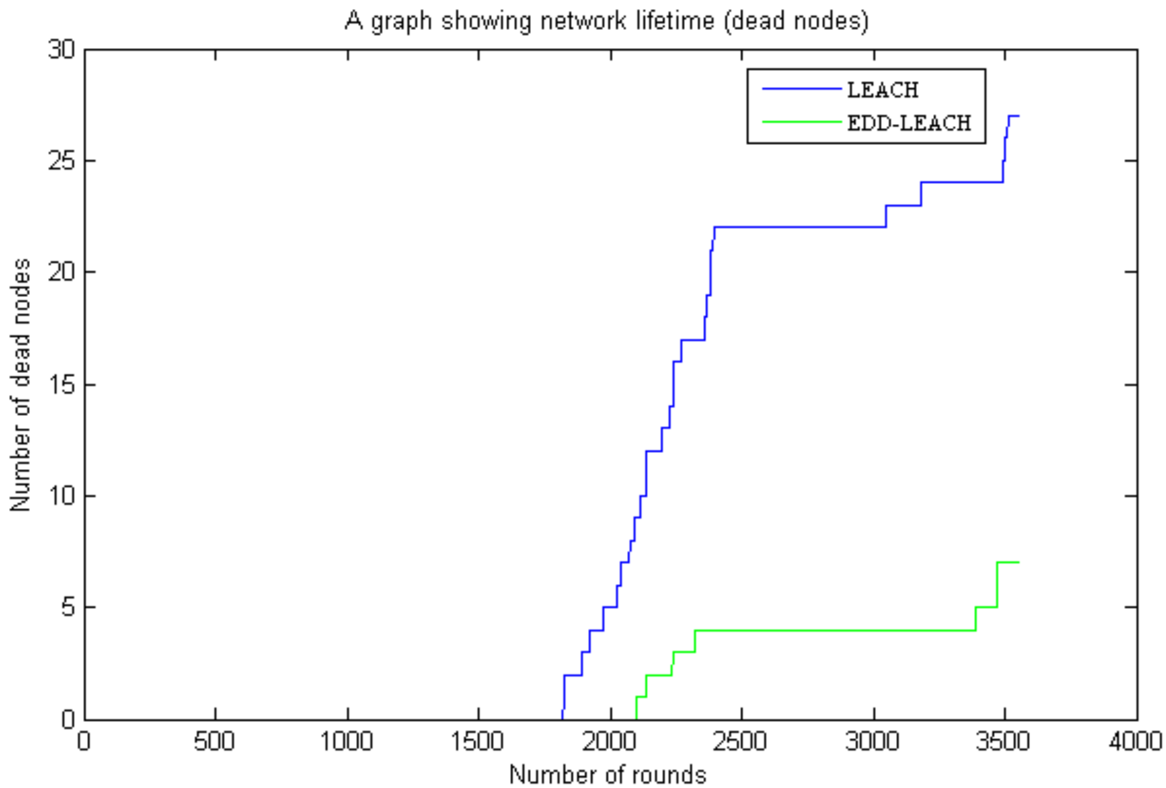

Figure 10: Graph showing network lifetime (dead nodes in a given number of rounds)

Statistics from figure 10 above indicate that sensor nodes start to get depleted of power and leaving the network in the 1822nd round for LEACH protocol and 2099th round for EDD-LEACH protocol.

To generate better performance statistics, we also get values for the live nodes after a certain number of rounds as shown in the graph (figure 11) below.

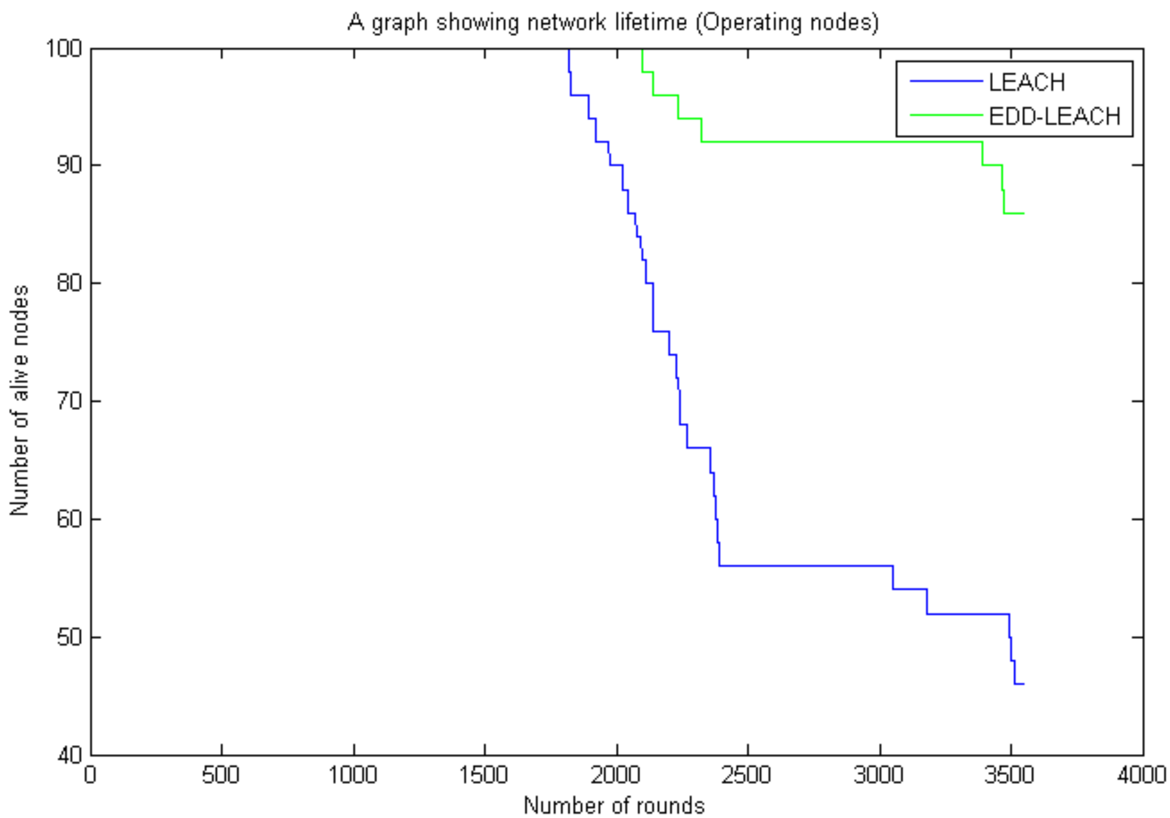

Figure 11: Graph showing network lifetime (live nodes in a given number of rounds)

4.3.2 Number of packets transmitted to the BS

In this part, we used the same input parameters and the same node deployment techniques like those used to generate the results for network lifetime. The sum of all packets reaching the base station is determined by the total number of nodes participating in the network per round. From the results, the performance of EDD-LEACH is far better than LEACH in terms of information delivery.

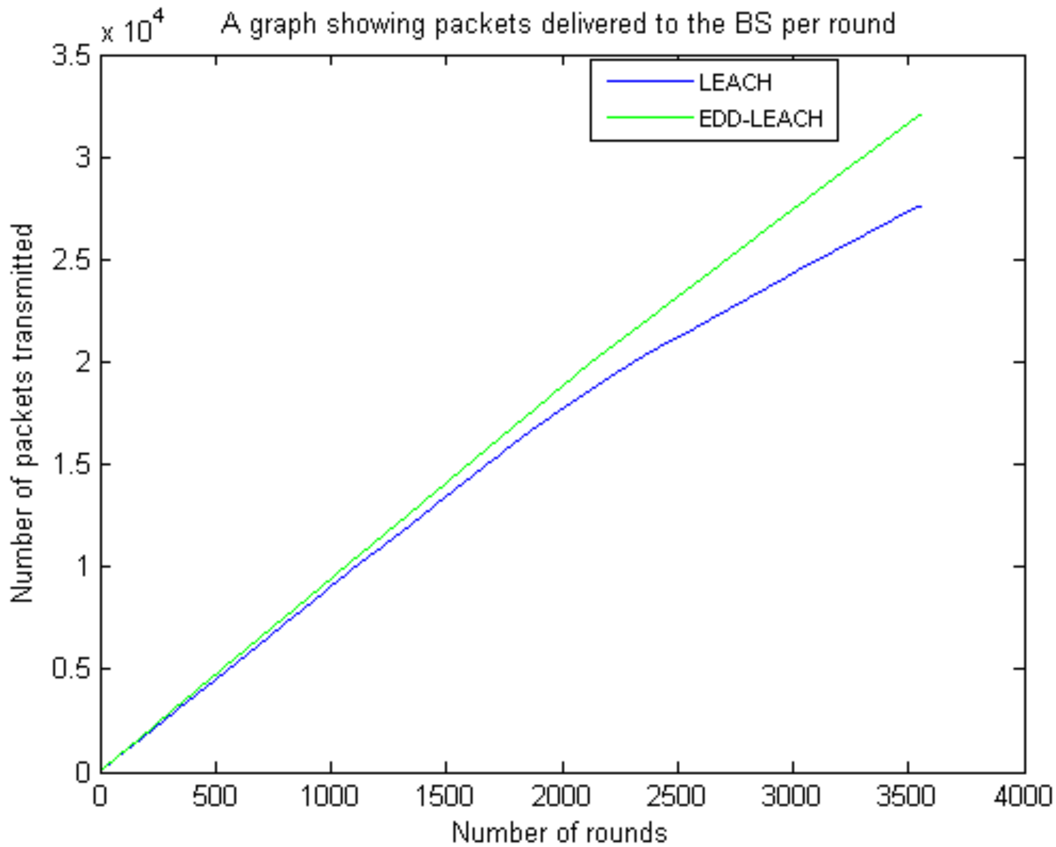

Figure 12: A graph showing packets transmitted to the BS.

Figure 12 above gives the statistics of the total packets delivered to the BS after 3550 rounds. By comparing the results from LEACH protocol with those of EDD-LEACH protocol, the throughput of EDD-LEACH protocol is higher approximately 4% higher than that of LEACH protocol.

Results Table

Protocol	1st node dead	dead nodes after 3550 rounds	Packets delivered to the BS after 3550 rounds
LEACH	1804	27	31619
EDD-LEACH	2099	7	38273

Table 3: Performance comparison between LEACH and EDD-LEACH in a 100mx100m field

4.3.3 Simulation results with varying field sizes and input parameters

We increased the field size to 300mx300m, randomly deployed 100 sensor nodes and also adjusted the BS deployment strategy by making sure that it is in the center of the field. The network lifetime was greatly affected, where the first node died in the 274th round for EDD-LEACH protocol and 201th round for LEACH protocol. This greatly affected the total number of packets collected by the BS. It is observed that only 18117 packets were collected at the BS after 3550 rounds for EDD-LEACH protocol and 16315 packets for LEACH protocol. The plot (fig 13) below shows the number of packets arriving at the BS per round.

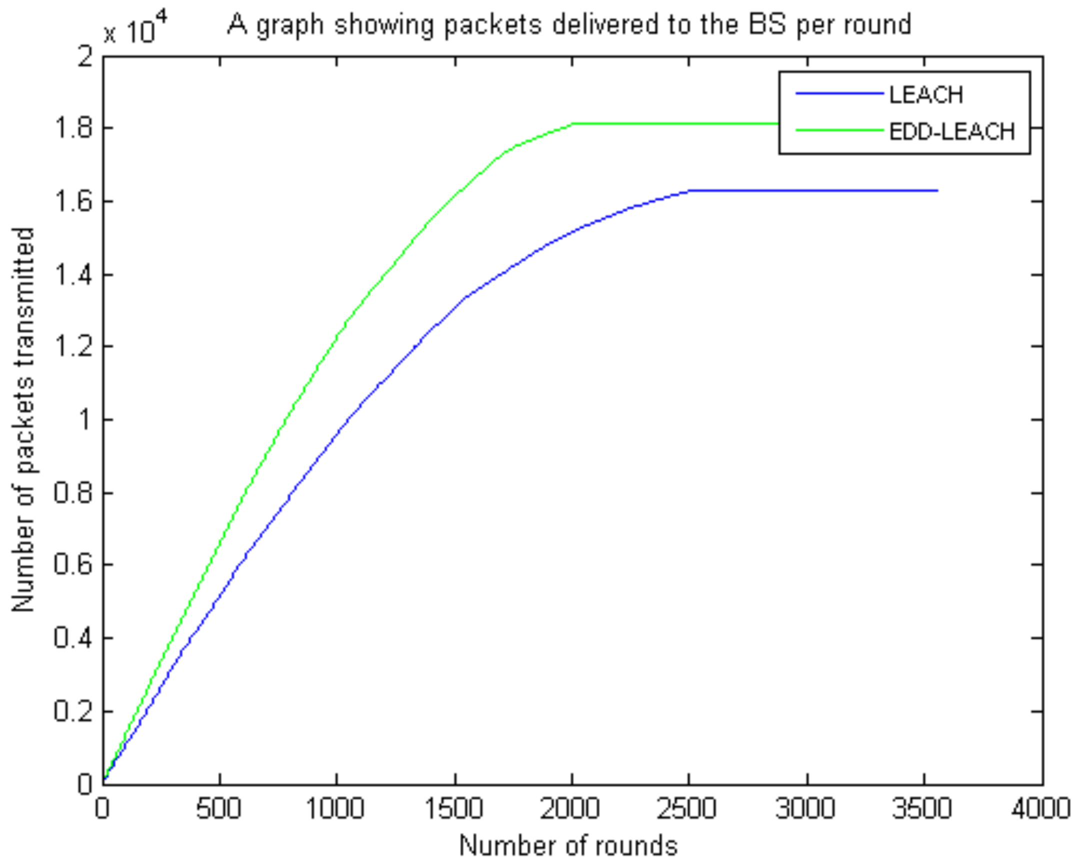

Figure 13: A graph of packets sent to the BS in a 300mx300m field

Because of a random deployment and large field of WSN, sensor nodes may be scattered away from the CH. This may require the receiving CH to dissipate more power to receive packets from distant nodes and more power for these sensor nodes to forward their collected packets to the CHs. Sensors nodes scattered far from the CH or CHs away from the BS will use considerable amounts of power in order to deliver sensed packets. Also, results from our simulations clearly indicate that the big size of the sensor field and number of sensors deployed do not necessarily lead to high throughput. Smaller WSNs with a smaller number of sensor nodes deployed achieve the best results in terms of packets collected at the BS. To prove this, we modified the parameters by deploying 200 nodes in a 300mx300m field. Results from our simulation indicate that, after 3550 rounds, only 28 nodes remained on the network (with 172 sensor nodes dead) and the average number of packets arriving at the BS reduced to 38608 for EDD-LEACH protocol and only 26 nodes remained on the network (with 174 sensor nodes dead) and the average number of packets arriving at the BS were 36607 for LEACH protocol. The round at which the first node left the network was 327 and 227 for EDD-LEACH and LEACH respectively.

The graphs for network stability and packets sent to the BS when the number of nodes is 200 in the field size measuring 300mx300m is shown in figures 14 and 15 below.

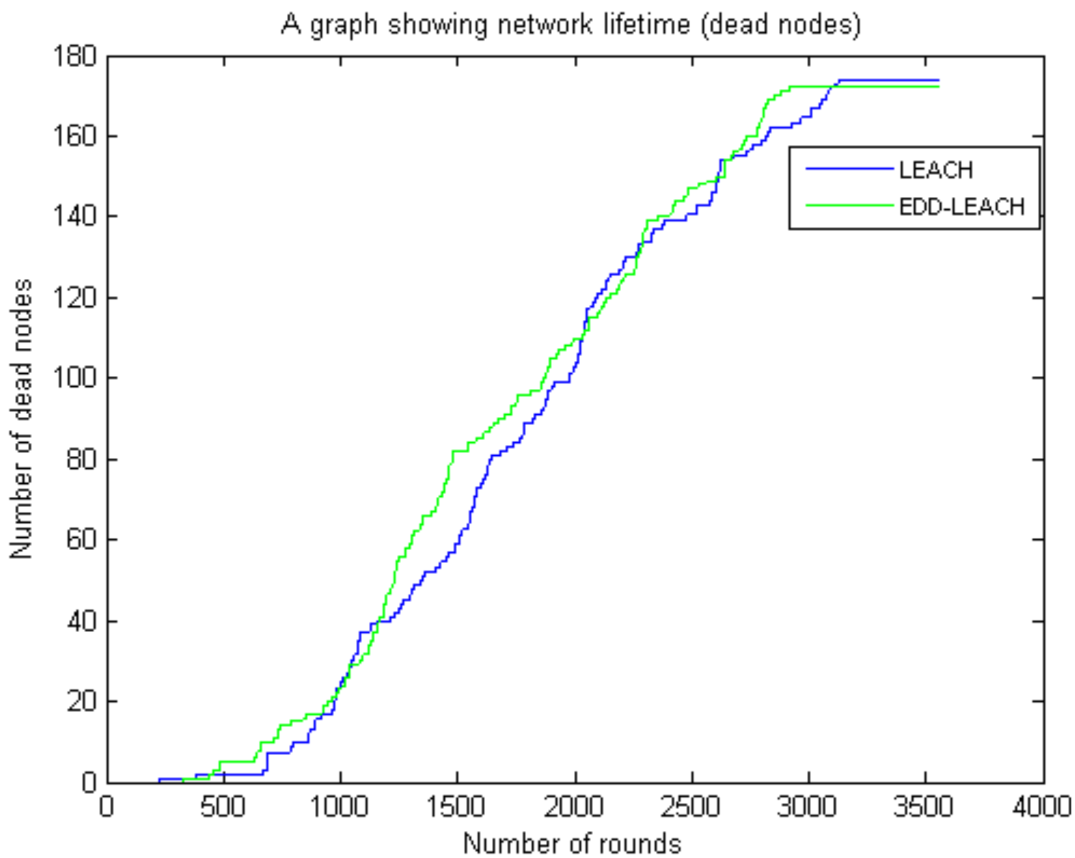

Figure 14: A comparison of the network stability and network lifetime for a large sensor field

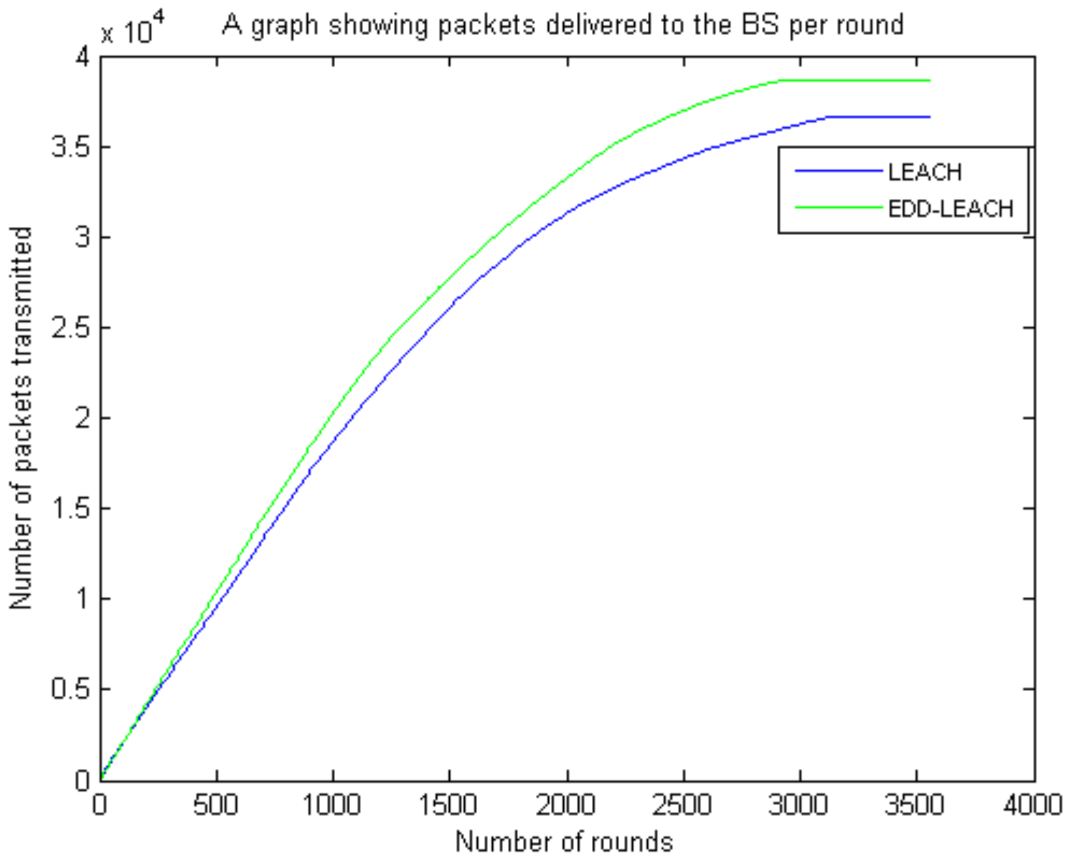

Figure 15: A comparison of packets sent to the BS for a large sensor field

Results shown above (figure 13, 14 and 15) were generated when the field size was assumed with varying parameters and a varying number of nodes. Results indicate that when we assume a random field, the probability of having more nodes scattered with reduced CH formation and less data reaching the Base station is relatively high. This can leads to power problems when it comes to nodes that are scattered far from each other.

For accurate values and ensuring more packets are delivered with a limited power dissipation rate, the location of the BS was set to be in the centre of the field, ensuring its position varies with change in field size using sink.x=0.5*xm for the horizontal position and sink.y=0.5*ym for the vertical position. Where sink.x and sink.y is the horizontal and vertical position of the base station, xm and ym is the x and y field measurement.

CHAPTER FIVE: CONCLUSIONS

This research focused on determining the effects of sensor energy in data collection and transmission. One of the best considerations during WSN simulations is the threshold energy. All sensor node operation procedures should be set with respect to the threshold values. For accurate simulation values, we set power thresholds by taking into account the amount of power required to transmit a single packet of data. Considering that sensor nodes lose energy basing on a certain number of packets they send to the CH and also the distance constraints from the CHs, setting the threshold should be above the minimum energy required by a sensor to transmit.

Our research proposed a routing protocol named EDD-LEACH. Our method applies a random deployment of sensor nodes. This research studies the possibility to improve data delivery to the BS. With power threshold (E_{thr}) implemented, results from our simulation were compared with LEACH protocol, indicate that EDD-LEACH protocol increases the network lifetime, and ensures a greater throughput in terms of packet forwarding to the BS.

RECOMMENDATIONS

For future researchers, the key areas of concentration should be on making sure that CH formation be based on the time spent by the CH in transmitting data, configure a mechanism for reuse of residual energy and adding parameters that lead to self-recharge. There should also be consideration about mobility of sensor nodes and base station as a means of ensuring security of the WSN. We recommend that future researchers study the impacts field sizes and shapes can cause on the life of the network. An observation was made that, in the last rounds of simulation, sensor nodes close to the BS do remain in the field and not forwarding data packets to the BS. Further research on how to ensure that sensor nodes close to the BS forward their data packets directly to the BS and reduce on the cost of forwarding data to the CHs.

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