REPUBLIC OF TURKEY
ISTANBUL GELISIM UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

Department of Electrical and Electronics Engineering

PERFORMANCE COMPARISON OF PEGASIS, HEED, AND LEACH PROTOCOLS IN WIRELESS SENSOR NETWORKS

Master Thesis

KAREEM HAMEED ALI AL-GBURI

Supervisor
Asst. Prof. Dr. A. F. M. Shahen SHAH

Istanbul – 2022

THESIS INTRODUCTION FORM

Name and Surname : Kareem HAMEED ALI

Language of the Thesis : English

Name of the Thesis : Performance comparison of PEGASIS, HEED, and LEACH protocols in wireless sensor networks

Institute : Istanbul Gelisim University Institute of Graduate Studies

Department : Electrical and Electronics Engineering

Thesis Type : Master

Date of the Thesis : 5/8/2022

Page Number : 98

Thesis Supervisors : Asst. Prof. Dr. A. F. M. Shahen SHAH

Index Terms : WSN, Mobile sensor, Power Management, Mobility Support, Routing Protocol

Turkish Anstract :

Kablosuz Sensör Ağları (WSN), bilim dünyasında en çok ortaya çıkan ve en hızlı büyüyen alanlardan biridir. Son birkaç yılda WSN, ev otomasyonu, çevre izleme, hedef izleme, boru hattı (su, petrol, gaz) izleme, yapısal sağlık izleme, hassas tarım, sağlık hizmeti izleme, tedarik zinciri yönetimi, aktif yanardağ izleme gibi farklı uygulama alanlarını araştırdı. , ulaşım ve Nesnelerin İnterneti'ne (IoT) yer altı madenciliği. Algılayıcı ağ tasarımıyla en sık ilişkilendirilen kısıtlama, algılayıcı düğümlerin sınırlı enerji bütçeleriyle çalışmasıdır. Tipik olarak, bir sensör düğümünün sınırlı pil gücü, pilini değiştirmek veya yeniden şarj etmek mümkün olmadığında kritik bir sorun haline gelir. Bir sensör düğümünde enerji kaynağının verimli kullanımı, ölçeklenebilirlik ve WSN'nin ömrünün uzatılması için arzu edilen bir kriterdir. Bu nedenle, enerji tüketimini azaltmak için verimli bir yönlendirme protokolü tasarlamak ağdaki önemli konulardan biridir. Son birkaç on yılda çok sayıda yönlendirme protokolü önerilmiştir. En popüler ve enerji açısından verimli yönlendirme protokollerinden bazıları, LEACH (Düşük Enerji Uyarlamalı Kümeleme Hiyerarşisi), SEP (Kararlı Seçim Protokolü), PEGASIS (Sensör Bilgi Sistemlerinde Güç Verimli Toplama), GAF (Geographic Adaptive Fidelity) ve HEED gibi hiyerarşik yönlendirme protokolleridir. (Hibrit Enerji Verimli Dağıtılmış kümeleme protokolü). Bu projede, artıları ve eksileri için çeşitli hiyerarşik yönlendirme protokollerini inceledik. Daha sonra, PEGASIS, HEED, ve LEACH yönlendirme protokollerini kullanışlılıklarına göre seçtik ve aralarında karşılaştırmalı bir çalışma yaptık. Son olarak, bu yönlendirme protokollerinin MATLAB yazılımında çeşitli simülasyon parametreleri ve farklı simülasyon ortamları üzerinde simülasyonları ile Yük Dengeleme, Enerji Tüketimi, Kararlılık Süresi, Ölçeklenebilirlik ve Ağ Ömrü gibi çeşitli metriklere dayalı olarak seçilen protokoller üzerinde karşılaştırmalı bir çalışma yapılmıştır.

Distribution List :

1. To the Institute of Graduate Studies of Istanbul Gelisim University
2. To the National Thesis Center of YÖK (Higher Education Council)

Kareem HAMEED ALI

REPUBLIC OF TURKEY
ISTANBUL GELISIM UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

Department of Electrical and Electronics Engineering

PERFORMANCE COMPARISON OF PEGASIS, HEED, AND LEACH PROTOCOLS IN WIRELESS SENSOR NETWORKS

Master Thesis

KAREEM HAMEED ALI AL-GBURI

Supervisor
Asst. Prof. Dr. A. F. M. Shahen SHAH

Istanbul – 2022

DECLARATION

I hereby declare that in the preparation of this thesis, scientific ethical rules have been followed, the works of other persons have been referenced in accordance with the scientific norms if used, there is no falsification in the used data, any part of the thesis has not been submitted to this university or any other university as another thesis.

Kareem HAMEED ALI

…/.../2022

TO ISTANBUL GELISIM UNIVERSITY

THE DIRECTORATE OF INSTITUTE OF GRADUATE STUDIES

The thesis study of Kareem HAMEED ALI titled as Performance Comparison of PEGASIS, HEED, and LEACH Protocols in Wireless Sensor Networks has been accepted as MASTER THESIS in the department of Electrical and Electronics Engineering by our jury.

Director

Asst. Prof. Dr. A. F. M. Shahen SHAH

(Supervisor)

Member

Assoc. Prof. Dr. Indrit MYDERRİZİ

Member

Asst. Prof. Dr. A. F. M. Suaib AKHTER

APPROVAL

I approve that the signatures above signatures belong to the aforementioned faculty members.

… /…. / 2022

Signature

Prof. Dr. İzzet GÜMÜŞ

Director of the Institute

SUMMARY

Wireless Sensor Networks (WSN) is one of the most emerging and fastest growing fields in the scientific world. WSN has investigated different application regions as of late, including home computerization, climate checking, target following, pipeline (water, oil, gas) observing, underlying wellbeing observing, accuracy horticulture, medical services checking, store network the executives, dynamic spring of gushing lava observing, transportation, and underground mining (IoT). The most widely recognized requirement related with sensor network configuration is that sensor hubs have restricted energy spending plans. Typically, the limited battery power of a sensor node becomes a critical issue when it is not possible to replace or recharge its battery. The efficient use of energy source in a sensor node is a desirable criterion for scalability and prolonging the lifetime of WSN. Therefore, designing an efficient routing protocol for reducing energy consumption is one of the important issues in the network. A large number of routing protocols has been proposed in the last few decades. Some of the most popular and energy efficient routing protocols are hierarchical routing protocols like LEACH (Low Energy Adaptive Clustering Hierarchy), PEGASIS (Power Efficient GAthering in Sensor Information Systems), and HEED (Hybrid Energy Efficient Distributed clustering protocol). In this thesis, various hierarchical routing protocols are studied for their pros and cons. Subsequently, we have selected LEACH, HEED, and PEGASIS routing protocols, based on their usefulness and have done a comparative study among them. Finally, a comparative study on the selected protocols is done based on several metrics such as: energy consumption, stability period, scalability and network lifetime through simulations of these routing protocols in MATLAB on various simulation parameters and different simulation environments.

Key Words: WSN, Mobile sensor, Power Management, Mobility Support, Routing Protocol

ÖZET

Kablosuz Sensör Ağları (WSN), bilim dünyasında en çok ortaya çıkan ve en hızlı büyüyen alanlardan biridir. Son birkaç yılda WSN, ev otomasyonu, çevre izleme, hedef izleme, boru hattı (su, petrol, gaz) izleme, yapısal sağlık izleme, hassas tarım, sağlık hizmeti izleme, tedarik zinciri yönetimi, aktif yanardağ izleme gibi farklı uygulama alanlarını araştırdı. , ulaşım ve Nesnelerin İnterneti'ne (IoT) yer altı madenciliği. Algılayıcı ağ tasarımıyla en sık ilişkilendirilen kısıtlama, algılayıcı düğümlerin sınırlı enerji bütçeleriyle çalışmasıdır. Tipik olarak, bir sensör düğümünün sınırlı pil gücü, pilini değiştirmek veya yeniden şarj etmek mümkün olmadığında kritik bir sorun haline gelir. Bir sensör düğümünde enerji kaynağının verimli kullanımı, ölçeklenebilirlik ve WSN'nin ömrünün uzatılması için arzu edilen bir kriterdir. Bu nedenle, enerji tüketimini azaltmak için verimli bir yönlendirme protokolü tasarlamak ağdaki önemli konulardan biridir. Son birkaç on yılda çok sayıda yönlendirme protokolü önerilmiştir. En popüler ve enerji açısından verimli yönlendirme protokollerinden bazıları, LEACH (Düşük Enerji Uyarlamalı Kümeleme Hiyerarşisi), SEP (Kararlı Seçim Protokolü), PEGASIS (Sensör Bilgi Sistemlerinde Güç Verimli Toplama), GAF (Geographic Adaptive Fidelity) ve HEED gibi hiyerarşik yönlendirme protokolleridir. (Hibrit Enerji Verimli Dağıtılmış kümeleme protokolü). Bu tezde, artıları ve eksileri için çeşitli hiyerarşik yönlendirme protokollerini inceledim. Daha sonra, LEACH, HEED, ve PEGASIS yönlendirme protokollerini kullanışlılıklarına göre seçtik ve aralarında karşılaştırmalı bir çalışma yaptık. Son olarak, bu yönlendirme protokollerinin MATLAB yazılımında çeşitli simülasyon parametreleri ve farklı simülasyon ortamları üzerinde simülasyonları ile Yük Dengeleme, Enerji Tüketimi, Kararlılık Süresi, Ölçeklenebilirlik ve Ağ Ömrü gibi çeşitli metriklere dayalı olarak seçilen protokoller üzerinde karşılaştırmalı bir çalışma yapılmıştır.

Anahtar kelimeler: WSN, Mobil sensör, Güç Yönetimi, Mobilite Desteği, Yönlendirme Protokolü

TABLE OF CONTENTS

CHAPTER ONE

CHAPTER TWO
LITERATURE REVIEW

CHAPTER THREE
ANALYSIS OF RESULTS

ABBREDIVATIONS

WSN	**:** Wireless Sensor Network
CH	**:** Cluster head
MAC	**:** Medium Access Control
QoS	**:** Quality of Service
weC	**:** wireless effects Controller
GUI	**:** Graphical User Interface
IDE	**:** Integrated Development Environment
LEACH	**:** Low energy adaptive clustering hierarchy
PEGASIS	**:** Power-Efficient Gathering in Sensor Information System
HEED	**:** Hybrid Energy-Efficient Distributed clustering
GEAR	**:** Geographic and Energy-Aware Routing

LIST OF TABLES

LIST OF FIGURES

PREFACE

I would like to thank my supervisor, Asst. Prof. Dr. A. F. M. Shahen SHAH, for his encouragement and support in preparing this thesis. I would also like to express my appreciation and thanks to Assoc. Prof. Dr. Indrit MYDERRİZİ, Asst. Prof. Dr. A. F. M. Suaib AKHTER and all the staff of Istanbul Gelişim University, including the knowledgeable professors and colleagues who accompanied us during our academic journey. I also thank my family for being a source of motivation throughout my thesis period.

I dedicate my thesis with appreciation to our homeland Iraq and the lovely Turkey, which embraced our scientific experiment and cooperated in making it possible for me to graduate in such a splendid way.

Kareem HAMEED ALI

INTRODUCTION

The super distant association, known as the "Sound Surveillance System (SOSUS)," was made by the United States military during the 1950s to perceive and follow Soviet submarines. This association used brought down acoustic sensors known as hydrophones that were spread across the Atlantic and Pacific oceans. This distinguishing advancement is at this point elaborate today in extra serene applications like noticing undersea untamed life and volcanic activity. Up until 1980, the United States Defence Advanced Research Projects Agency (DARPA) started research in Wireless Sensor Networks (WSNs) known as "Circulated Sensor Networks (DSN)" to officially investigate the difficulties in executing disseminated WSNs. DSNs were assumed to have a large number of spatially distributed low-cost sensing nodes that collaborated and operated autonomously, with information being sent to the appropriate node for use. Coordinated effort with colleges, for example, Carnegie Mellon University and the Massachusetts Institute of Technology Lincoln Labs permitted DSNs to be incorporated into the scholarly community. Regardless of its uncertainty at that point, WSN innovation immediately tracked down a home in scholarly world and non-military personnel logical exploration.

Late headways in semiconductor, systems administration, and material science advancements empower the far reaching sending of enormous scope remote sensor organizations (WSNs). Together, these innovations have empowered another age of WSNs that offer huge benefits over remote organizations created 5 to quite a while back. Then again, the utilization of Wireless Sensor Networks has detonated in late many years and is as yet developing at a disturbing rate. This is impacting the manner in which we live, as individuals depend on remote network in an ever increasing number of parts of their regular routines.

Wireless Sensor Networks (WSNs) are comprised of countless sensor hubs that are battery-controlled and have restricted memory as well as correspondence and calculation capacities. WSN applications are partitioned into two sorts: occasion discovery (ED) and spatial interaction assessment (SPE) (Buratti et al. 2009). Sensors are conveyed in ED to distinguish an occasion like a backwoods fire, tremor, and so on, while in SPE, WSN plans to screen actual peculiarities like temperature, pressure, etc for a given Region of Interest (ROI). Due to the large number of uses covered by

WSN, sensor network execution measurements are rigorously application explicit.. WSNs can work in unattended unforgiving conditions where human mediation is unsafe, wasteful, and here and there unimaginable (Abbasi and Younis, 2007). Thus, "network lifetime" has turned into a typical presentation metric for practically all WSN applications. The expression "network lifetime" alludes to the time after which an organization becomes inoperable. The hidden WSN's non-usefulness is likewise application subordinate, as a matter of fact. In the event that a sensor network isn't functional, it is supposed to be non-useful.

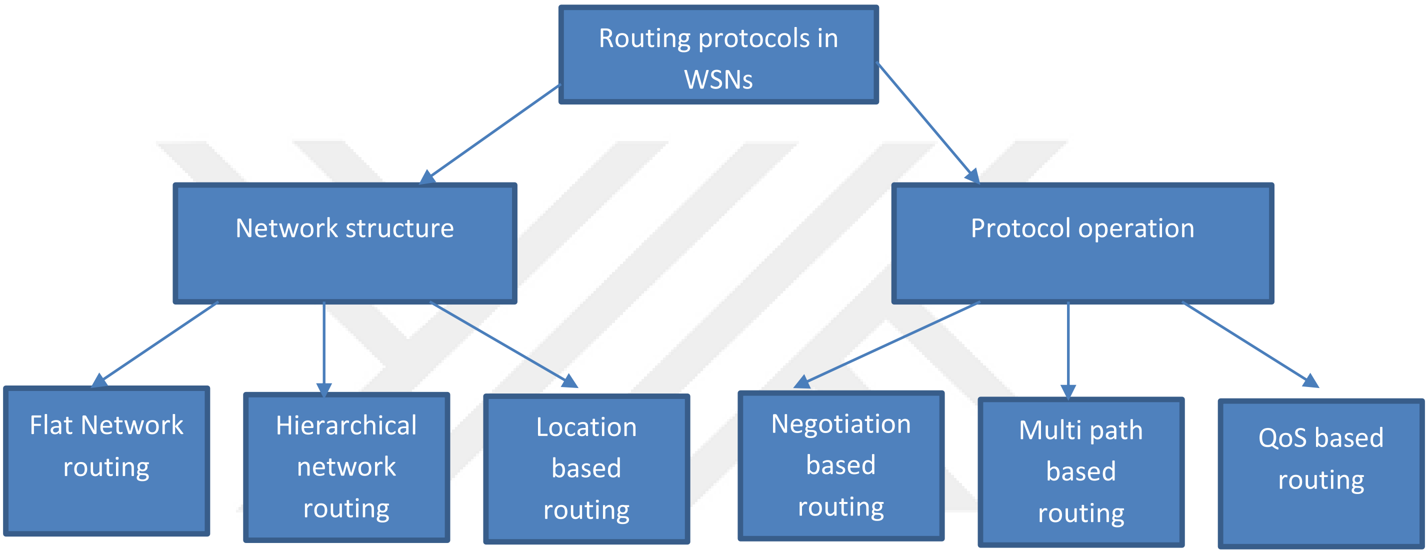


Figure 1. Taxonomy of routing protocols in WSN (Singh, H et al. 2016)

Because of energy limitations, the essential objective of this examination is to work on the usefulness of the static homogeneous organization. The correspondence between hubs overwhelms the energy exhaustion of the WSN organization, bringing about network parcelling. This affects the application's prerequisites because of the absence of information from a particular locale. Notwithstanding, in the event that the hubs are sent in a brutal climate where human mediation is either unimaginable or hazardous, it is difficult to supplant or re-energizing the batteries. Moreover, because of the enormous number of hubs sent in the organization, it is unrealistic to supplant or re-energize hub batteries. Accordingly, WSN conventions should be energy productive.

The organization lifetime is rigorously application explicit and relies upon boundaries like WSN geography (Banerjee et al. Santi, 2013), information conveyance modes (occasion driven, question driven, or crossover) (Akkaya and Younis, 2007), information collection strategies (like concealment, min, max, or normal), MAC calculations (Ramaraju Kalidindi, Kannan, and Iyengar), steering conventions . This study centers around broadening network lifetime using energy-proficient directing conventions with viable bunching systems.

Figure 1 portrays the steering convention scientific classification (Al-Karaki and Kamal,2004). Steering conventions are characterized into three kinds in light of their organization structure: level directing conventions, progressive organization steering conventions, and area based directing conventions. Steering conventions are ordered into discussion based directing, multi-way based directing, inquiry based directing, QoS-based directing, and reasonable put together steering based with respect to their functional usefulness. Various levelled network steering conventions are the focal point of this examination since they are energy productive, adaptable, and decrease geography support above. (Abbasi and Younis, 2007).

CHAPTER ONE

1.1. Background of Sensor Network Technology

Numerous specialists have inspected remote sensor networks as an interesting arising space of profoundly organized frameworks of low-power remote bits with a modest quantity of CPU and memory, with huge related networks for high-goal detecting of the climate. Sensors in a WSN fill an assortment of needs, play out an assortment of capacities, and have many abilities. The field is currently leading the pack because of ongoing innovative advances and the draw of a plenty of likely applications. Radio detection and ranging (RADAR) networks are used to detect the position and location of the objective, airport regulation, the public electrical power lattice, and cross country weather conditions stations to organized over an ordinary geological lattice in the organization there are instances of the early-sending sensor organizations; these sorts of frameworks, be that as it may, utilize particular PCs and correspondence conventions and thusly, are pricey. In right now there is minimal expense of the Wireless Sensor Networks are currently being anticipated novel applications in actual security, medical services, and trade. Wireless Sensor Network (WSN) has provide the many fields areas in the network that are involved, among others, radio and networking, signals processing, artificial intelligence, database management, a systems architectures is designed as operator-friendly environment in infrastructure administration, resource optimization, platform technology (hardware and software, such as operating systems) and power management algorithms. These frameworks' organizing standards, applications, and conventions are still in the beginning phases of advancement. The presence of hubs on the Internet, headways in remote and wire line correspondences advances, network work out (especially in the remote case), IT improvements (enormous (RAM) Random-Access Memory contributes the framework organization, high-power processors, computerized signal handling, and matrix registering), and late designing advances are making the way for minimal expense sensor innovation and actuators in the wired organization. For the control and sensing in the network there is technology is used that is included electric and magnetic field sensors; radio-wave frequency sensors; optical, electro-optic, and infrared sensors; Radars, lasers, area or route sensors, seismic and pressure-wave sensors, natural boundary sensors (e.g., heat, wind, dampness), and biochemical public safety situated Sensors are minimal expense, untethered multifunctional hubs that are consistently homed to a focal sink hub; they are brilliant, minimal expense gadgets with numerous installed detecting components. Remote hubs and sensor gadgets are likewise alluded to as bits (on occasion). An expressed business objective is to foster total sensor frameworks in view of miniature electro mechanical frameworks (MEMSs) with a volume of 1 mm. These sensors are connected by a progression of multi-jump brief distance low-power remote connections (commonly inside a characterized sensor field); they normally utilize the Internet or one more organization for significant distance information transmission to a point (or marks) of conclusive information conglomeration and investigation. WSNs use dispute situated irregular access station sharing and transmission strategies inside the organization's sensor field, which are currently consolidated in the IEEE 802 group of norms; to be sure, these methods were initially evolved in the last part of the 1960s and 1970s explicitly for remote (not cabled) conditions and huge arrangements of scattered hubs with restricted station the board knowledge. Other channel the board methods, nonetheless, are likewise accessible.

Sensors are ordinarily utilized in networks in a high-thickness and enormous amount way: Sensors are legitimately associated by self-sorting out implies in AWSN (sensors sent in short-jump highlight point ace slave pair plans are likewise of interest). Wireless sensor Networks commonly transmit an information from one station to one more station to gather (screen) some or all of the data Wireless Sensor Networks have remarkable qualities, for example, power limitations and restricted battery duration for the WNs, repetitive information obtaining, low obligation cycle, and many-to-one streams. Subsequently, new systems and plans are expected across an assortment of disciplines, including, however not restricted to, data transport, organization and functional administration, classification, uprightness, accessibility, and in-network/neighbourhood handling. There are a few situations where gathering (extricating) information from wireless networks (WNs) can be troublesome on the grounds that availability to and from the WNs can be discontinuous because of a low-battery status (for instance, on the off chance that these kinds of organizations depend on daylight to re-energize) or other WN breakdown. A lightweight convention stack is likewise wanted. As a rule, the framework and the tending to contraption should uphold an enormous number of client units in the organization (say, 64k or more).

There are sensors that reach in actual size by a few significant degrees; they (or, in any event, a portion of their parts) range from nanoscopic-scale gadgets to meso-scopic scale gadgets toward one side, and from miniature scopic scale gadgets to perceptible scale gadgets on the other. The nano-scopic scale (otherwise called nanoscale) alludes to items or gadgets with breadths of 1 to 100 nm; the meso-scopic scale alludes to objects with distances across of 100 to 10,000 nm; the tiny scope goes from 10 to 1000 mm; and the naturally visible scale is millimetre-to-meter. At the low finish of the scale there are natural sensors, little uninvolved miniature sensors (like Smart Dust4), and lab-on-a-chip" gatherings. There are different stages, for example, character labels, cost assortment gadgets, controllable climate information assortment sensors, bioterrorism sensors, radars, and undersea submarine traffic sensors in light of sonars. There are most recent ages of sensors, particularly the scaled down sensors that are straightforwardly implanted in some actual foundation, as miniature sensors. A Wireless sensor network upholds any kind of nonexclusive sensor; all the more barely, organized miniature sensors are a gathering of the overall group of remote sensor organizations. Miniature sensors contain handling and remote connection points that can be utilized to study and screen many peculiarities and conditions in closeness. Sensors can be either single point components or multipoint recognition clusters. Hubs are regularly furnished with at least one application-explicit sensors as well as on-hub signal handling abilities for the extraction and control (pre-handling) of actual climate information. Implanted network detecting alludes to the synergistic fuse of miniature sensors in designs or conditions; installed detecting takes into consideration thick spatial and fleeting checking of the framework viable (e.g., a climate, a structure, a combat zone). Sensors in the organization might be detached or potentially self-controlled; sensors further down the power-utilization chain might require moderately low power from a battery or line feed. A few sensors at the high finish of the power-usage range might require incredibly high power takes care of (e.g., for radars). Sensors in the organization aid the instrumentation and control of processing plants, workplaces, homes, vehicles, urban areas, and the climate, especially as business off-the-rack innovation opens up. Boats, airplane, and structures can self-identify primary shortcomings utilizing sensor network innovation (explicitly, inserted arranged detecting) (e.g., exhaustion instigated breaks). Spots of public gathering can be utilized to distinguish airborne specialists like poisons and to find the wellspring of pollution, in the event that any is available (this should likewise be possible underground and ground circumstances). There are seismic tremor sensors in structures that can identify likely survivors and assist with evaluating underlying harm; wave cautioning sensors are helpful for nations with long shorelines. Sensors are additionally broadly involved on the combat zone for investigation and reconnaissance. We feature the development of open guidelines on the side of WSNs; normalization drives innovation commercialization. "New things" every now and again start as cutting edge research projects led at government as well as scholastic labs. As a rule, unadulterated or applied research consumes a large chunk of the day. Specific, unique, complex, and useful models, pilots, or arrangements are normal at this beginning phase. At last, assuming another innovation is to become universal, business level open principles, chipsets, and items that meet business administration and functional level arrangements concerning dependability, cost, convenience, strength, and straightforwardness are required. In light of a delegate test of late logical WSN articles, the accompanying example order of examination points by recurrence of distribution has been created.

In the last few decades, WSN has come into prominence because WSN has the attributes to change the living standards using monitoring, automation, and management of applications. WSN is a collection of tiny computers. These tiny computers are called sensor nodes. WSN is used basically for the monitoring the environment, field area, machines, etc using sensing the activities. For designing, implementation, and operation of a sensor network, care should be taken of signal processing, routing, protocols, data management etc (Wang, J. et al. 2018). Four basic components of the sensor network are the assembly of sensors which are distributed or localized, connect to another network, collection of information at a center point, resources that handle data collection and mining. WSNs have some general properties and assumptions. These properties make WSN different from others.

1. Limited resource of single sensor

2. Connections between nodes are not planned; the only assumption is that nodes will detect its neighbors.

3. Sensor nodes only sensed and send the data. No other moderation is operated.

The WSN is a system for communication, which senses data and collects the data from a explicit area and passes on that information to the main area. For such kind of network should be competent, safe, easy to handle and consistent. The wireless sensor network is valuable for military applications, monitoring in farms and forests (Ali Newaz Bahar Shamim Sardar et al.2015) . Wireless sensor network applications provide benefits to the environment. Figure 1 describes the basic arrangement of the wireless sensor network.

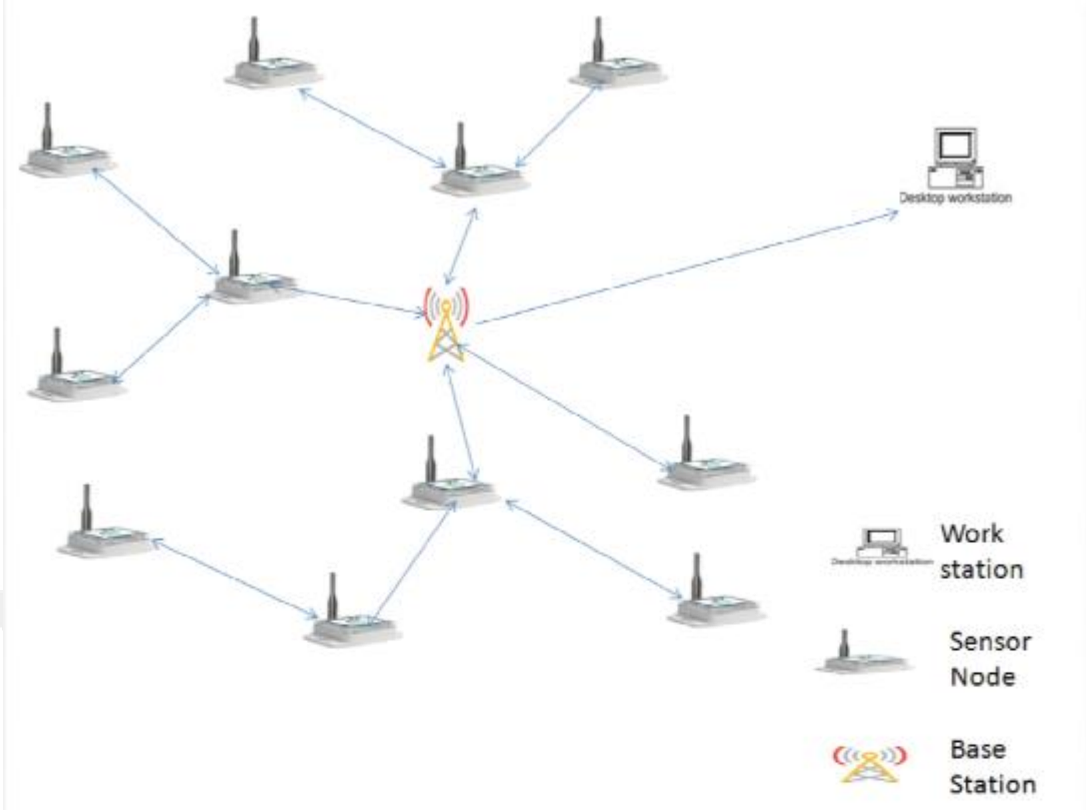


Figure 2. Arrangement of Wireless Sensor Network (Ali Newaz Bahar Shamim Sardar et al.2015)

1.2. Wireless Sensor Network Architecture

Coming up next are the fundamental components and configuration focal point of sensor networks in remote sensor organizations. These peculiarities and plan standards should be viewed as with regards to the WSN sensor network climate, which is portrayed by a lot of people (in some cases) the accompanying variables as a whole: a huge sensor populace (e.g., at least 64,000 client units should be upheld by the framework and the tending to device), enormous floods of information, fragmented/unsure information, high potential hub disappointment; high potential connection disappointment (impedance), electrical power restrictions, (Some, yet not all, C2WSNs have constraints.). Sensor network progressions are reliant upon headways in detecting, correspondence, and registering (information taking care of calculations, equipment, and programming). As recently expressed, energy-mindful steering conventions for WSNs are expected to enough oversee interesting WSN assets. The concentrated information directing and handling in the organization are basic ideas that are inseparably connected with sensor organizations. Start to finish directing plans for versatile impromptu organizations are not suitable for WSNs; information driven advancements that act in-network information accumulation are expected to yield energy-productive dispersal.

Wireless Sensor Networks (WSNs) stand out in scholarly world and industry as of late. In view of their minimal expense, transportability, simplicity of sending, self-association, and reconfigurability, WSNs enjoy various upper hands over customary wired networks. They can be performed on anything, from the human body to being profoundly implanted in the climate. Remote Sensor hubs can be effortlessly sent in enormous regions with fundamentally less intricacy and cost than wired hubs. Remote hubs can likewise self-coordinate to shape directing ways, team up on information handling, and structure progressive systems. The WSN can likewise be effectively reconfigured by adding and eliminating sensor hubs. As shown in Figure 3, the equipment setup of a remote sensor hub comprises of five essential kinds of assets: registering, capacity, correspondence, detecting and impelling, and battery (Ali Newaz Bahar Shamim Sardar et al.2015)

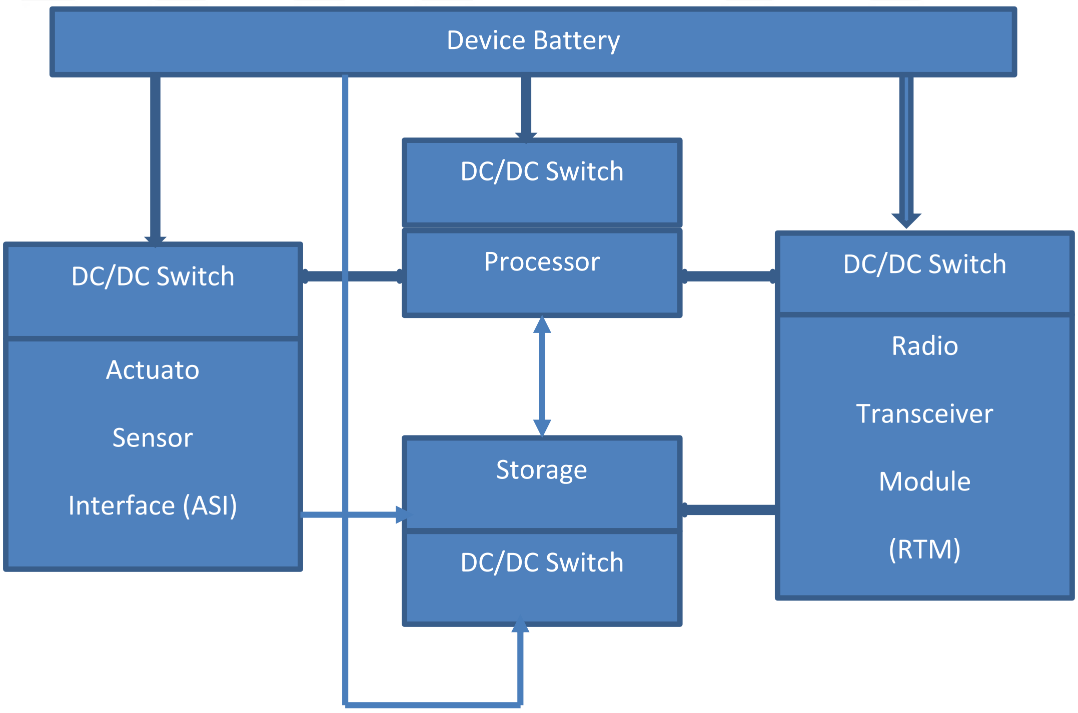


Figure 3. Hardware configuration of wireless sensor node (Ali Newaz Bahar Shamim Sardar et al.2015)

Remote sensors interface the physical and computerized universes by catching and uncovering certifiable peculiarities and changing over them into information that can be handled, put away, and followed up on. Figure 2 portrays an illustration of the means taken by a sensor hub during information securing and incitation. A sensor gadget notices peculiarities in the actual world. Since the caught electrical signs are not generally prepared for guaranteed handling, they should go through a sign melding stage. An assortment of tasks can be performed on the sensor signal here to set it up for signal handling. Signals, for instance, much of the time require intensification (or weakening) to change the size of the sign to all the more likely match the scope of the accompanying analogous-advanced transformation. The sign is then presented to various stations to dispose of unwanted upheaval inside unambiguous repeat ranges (e.g., high-pass stations can be used to wipe out 50 or 60 Hz noise got by incorporating electrical links). Following this, the straightforward sign is changed over totally to a mechanized sign using an Analog to Digital Converter (ADC). The sign is by and by electronic and ready for extra dealing with, amassing, or portrayal.

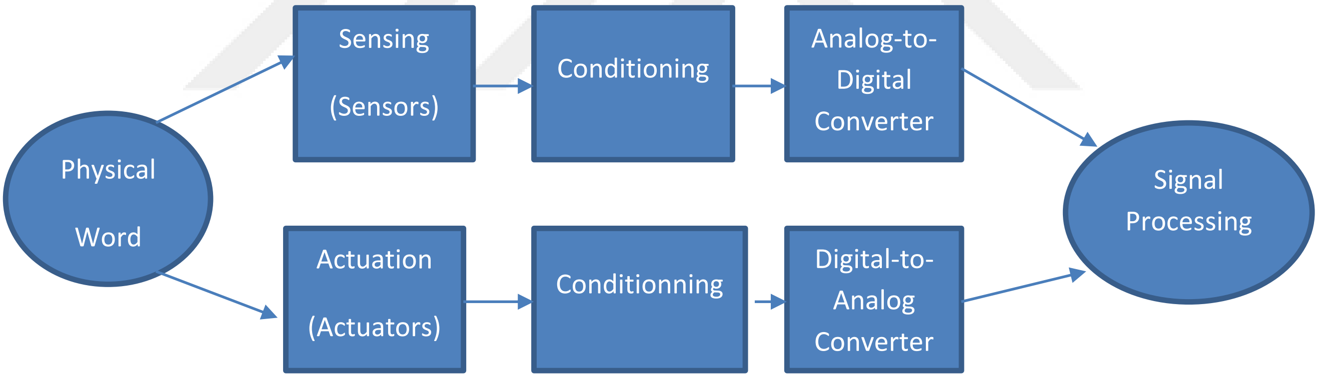


Figure 4. Processing steps of data acquisition and actuation (S. Lindsey et al. 2002)

Different far off sensor networks interface actuators, permitting them to control this present reality obviously. A valve that controls the development of boiling water, an engine that opens or shuts an entryway or window, etc are instances of actuators. A distant sensor and actuator affiliation (WSAN), as displayed in Figure 4, takes orders from the microcontroller gadget and converts them into input signals for the actuator, which then connects with a genuine cycle.

1.3. Typical Applications of WSNS

The developing interest in remote sensor networks as of late has extraordinarily extended their applications in an assortment of fields. Figuring out these application situations and their particular prerequisites/attributes is basic for remote sensor network plan. This part gives an outline of five kinds of run of the mill WSNs applications.

1.3.1. Medical and Health Care

WSNs are being utilized in the medical care space, which is one of their arising applications. With propels in scaled down electronic gadgets bringing about more modest battery, information handling, detecting, and remote correspondence advances, every sensor bit in the organization can be intended to be worn on or embedded into the human body for the estimation and checking of comparing physiological signs. Patients can be observed with such gadgets in the medical clinic or at home because of their little aspects and light weight. They can move unreservedly without impeding everyday exercises, and the gathered information can be naturally communicated to clinical staff to support the assessment of patients' circumstances. An assortment of sicknesses have profited from this sort of checking.

The Mercury wearable framework (M.A. Matin et al. 2012), created by Harvard University analysts, was planned to screen and break down the development execution of patients experiencing Parkinson's infection, epilepsy, and strokes.

Implantable glucose sensors were embedded in the subcutaneous tissue of 15 grown-up patients' midsections to constantly screen their glucose levels in the expectation of tracking down fitting answers for lessen hypoglycaemia. Glucose levels were estimated like clockwork in the clinical examination, and glucose information was radio sent to the collector at regular intervals. The last exploratory outcomes showed the way that this framework could meet the prerequisite of ongoing ceaseless blood glucose checking while likewise assisting with diminishing hyperglycaemia trips in type 1 diabetes patients. Moreover, the utilization of WSNs in such constant and expanded medical services observing can be found in fields, for example, hypertension checking, asthma observing, and Alzheimer's illness checking;

1.3.2. Environment and Ecological Monitoring

In 2005, Werner-Allen et al. directed a spring of gushing lava checking project Thakkar, A et al. 2014) that sent a TMote Sky hub (C.Reed D et al. 1998) put together organization with respect to Vulcan Reventador in northern Ecuador to gather seismic and acoustic information from dynamic fountains of liquid magma. The organization is comprised of 16 TMote Sky hubs with a typical distance of 200400m between them. The organization was continued running by utilizing multihop information transfer from the source hub to the door hub to gather information, which was then communicated to a PC at the base station for capacity and later assessment. Researchers effectively caught 230 volcanic related occasions after over three weeks of field tests.

Lancaster University specialists proposed involving WSNs in a flood advance notice framework (Sohn, I et al.2016) .The notable ZebraNet (Taheri, H et al. 2012) convention was utilized to concentrate on zebra conduct by joining exceptional GPS prepared collars (hubs) to them. These hubs can utilize a shared organization to follow the creatures across a huge wild region and convey the logged information to specialists. As per the scientists, a 30-hub ZebraNet framework was wanted to be sent at the Maple Research Centre in focal Kenya. Essentially, the Great Duck Island project (Nayak P et al. 2017) was intended to concentrate on creature conduct by checking ocean bird settling conduct. In horticulture, a picture upheld remote sensor network was sent for grape plantation observing (Noman Shabbir et al. 2017) where information is gathered and broke down to give a reasonable finding to the plants, for example, insect poison and manure selection.

1.3.3. Home and Building Automation

Wireless sensor hubs, because of their little size and expanding information handling power, can be effectively coordinated into different home machines or introduced in brilliant structures for control and observing assignments. For instance, the I Power energy preservation framework was intended for use in savvy structures and was focused on naturally changing and specifically switching off electric machines to meet energy saving prerequisites. Micas bits were utilized to gather detecting information from their environmental elements, like light, sound, and temperature. In this framework, one transmitter was connected to a control server by means of a RS-232 connection point to send explicit orders to every free hub (with a novel location for every hub). The framework was assessed utilizing a savvy work area situation, which uncovered that utilizing the I Power framework saved roughly 16.5 percent 46.9 percent energy. Besides, the New York Times base camp is viewed as a shrewd assembling that consumes 30% less energy than standard office tall designs while stretching out client solace because of the utilization and combination of exact environment sensors, air quality sensors, and inhabitancy sensors (Padmalaya Nayak et al. 2016).

1.3.4. Design Challenges of WSNS

The most serious issue with WSN organization, because of its little aspects and battery-fuelled highlights, is the restricted energy supply, which is every now and again underscored by analysts. The primary plan model is to lessen energy utilization for longer lifetime without compromising other sensor network application-explicit measurements. WSN configuration should track down a trade-off answer for the accompanying difficulties:

1.3.5. Quality-of-Service (QoS)

In spite of contrasts in QoS necessities and determinations between applications, the two fundamental QoS measurements are unwavering quality and idleness. To guarantee network dependability and usefulness, the pace of fruitful information trade between source hubs and sink hubs should regularly be more prominent than a specific edge. The dependability can be worked on further, however to the detriment of expanded energy utilization. Subsequently, a trade-off is required. With regards to idleness, a few applications require the gathering of detected information at the sink hub to be completely planned, so lengthy dormancy information might cause break issues and lead to wrong choices, especially in modern observing applications.

1.3.6. Security and Privacy

Since sensor hubs are here and there conveyed in open regions, they are powerless against specialized impedance or human interruption, bringing about security and protection issues. In this manner, to safeguard the whole organization from different goes after like detached assaults, dynamic assaults, and outer disavowal of-administration (DoS) assaults, powerful calculations for information encryption, verification components for security assurance, and secure directing for information hand-off are required (Atalik et al. 2010).

1.3.7. Resource limitation

It is hard to further develop the energy supply and memory stockpiling because of the restricted actual size. The utilization of 8-cycle and 16-digit microcontrollers limits information handling ability. Due to the low result transmission power, the short correspondence reach and limited inclusion are inescapable. MICA2, for instance, has a 8-digit AVR RISC-based microcontroller (ATmega128), 4KB of RAM, 128KB glimmer memory, and an optimal radio correspondence recurrence of 916MHz. Moreover, cost viability is a significant component to consider, as engineers are continuously searching for ways of expenditure less cash on the best ideal designs.

1.3.8. Adaptability

WSNs should be intended to be versatile and adaptable enough to be sent in a wide scope of use situations. The whole organization ought to be kept functional, whether or not there are hundreds, thousands, or a couple of hubs. The general geography of the organization changes because of the versatility of sensor hubs and noticed occasions, as well as the chance of failing sensor hubs inside the organization. Thus, WSN configuration should be canny and hearty enough to manage these powerful geography situations.

1.3.9. Energy

Quite possibly the most genuine concern is that the sensor hub's life expectancy not entirely settled by how much energy accessible and the pace of energy utilization (for example the typical power utilization). Since further developing the energy limit of little aspect batteries actually requires huge exertion, accomplishing the objective of a long lifetime by expanding how much energy accessible is troublesome. Subsequently, the advancement of energy-productive MAC conventions, correspondence procedures, working frameworks, and energy-saving directing instruments gives compelling method for broadening the hub's lifetime. Lately, the utilization of energy gathering advancements for sensor hub power supplies has likewise given another option.

1.4. General Scenario of WSN

WSN contains hundreds or countless those sensor center points and these sensors can give either among each other or expressly to an external BS. A more noticeable number of sensors contemplate recognizing over more noteworthy land districts with more indisputable accuracy. Essentially, every sensor center contains recognizing, arranging, transmission, gather, position tracking down framework and power units (a piece of those parts are discretionary especially like the initiate). Sensor center points are consistently scattered during a sensor field, which could a be a region where the sensor centers are conveyed. Sensor center points coordinate among themselves to pass on all out data about the real environment. Those scattered sensor habitats can collect and course data either to various sensors or back to an external BS. A BS could similarly be a settled or reduced center fit joining the sensor association to a present exchanges foundation or to the web where a client can have area to the itemized information. Inside the past numerous years obsession examination that watches out for the capacity of joint effort among sensors in information gathering, planning, coordination and organization of the it was coordinated to distinguish development. In numerous applications sensor hubs are obliged in energy supply and correspondence information transmission.

1.5. Energy-Efficient Routing Algorithms

Energy effective steering algorithm (Satish Kannale et al. 2015) can be ordered as follows: information driven routing (D. Dudgeon et al. 1994) calculation, area based directing calculation (C.Reed D.Chen K.Yao et al. 1984) and progressive directing calculation . Information driven steering calculation utilizes meta information to track down the course from source to objective before any genuine information transmission to dispose of repetitive information transmission Location based directing calculation requires real area data for each sensor hub. Various levelled steering algorithm separates the organization into bunches. Group head (CH) is chosen in each bunch. (O. Younis et al. 2004) gathers information from its individuals, totals the information and ships off sink. This approach is energy proficient however generally complex than different methodologies.

1.5.1. Data centric

Information driven protocols (C.Reed D.Chen K.Yao et al. 1984) are question collected and they depend with respect to the naming of the best information. Reliant upon the solicitation, sensors gather a specific information from the area of interest and this specific data is essentially expected to pass on to the BS and henceforth diminishing how much transmissions. for example Turn was the key information driven show.

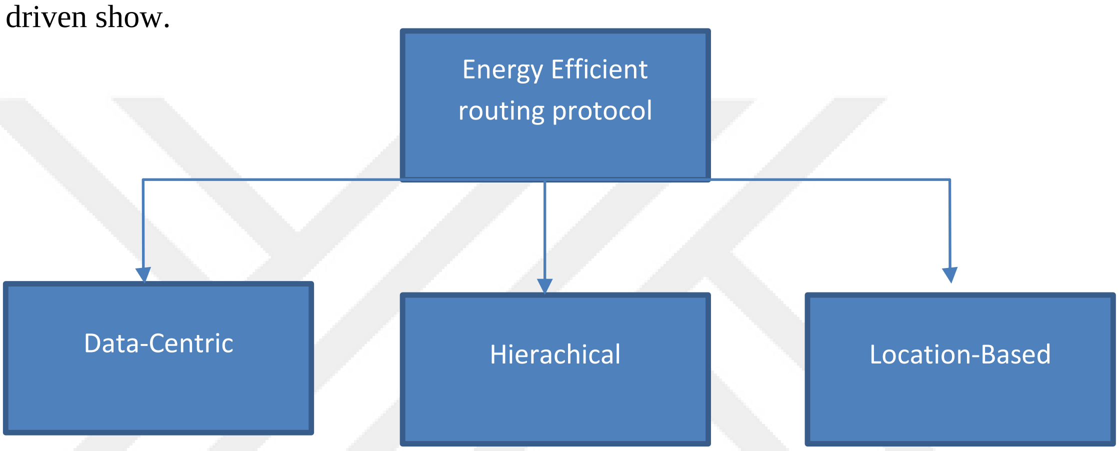


Figure 5. Classification of Routing in WSNs (Yuanchang Zhong et al. 2014)

1.5.2. Hierarchical

Hierarchical routing in WSN involves the arrangement of clusters in form of hierarchy when sending information from the sensor nodes to the base station. Hierarchical routing efficiently reduces energy consumption by employing multi-hop communication for a specific cluster and thus performing aggregation of data and fusion in a way that decreases the number of data carried across the network to the sink. Cluster formation is based on residual energy in the sensor nodes and election of a CH (Ali Newaz Bahar Shamim Sardar et al.2015). A very good example of an hierarchical routing protocol is low-energy adaptive clustering hierarchy (LEACH) (Ali Newaz Bahar Shamim Sardar et al. 2015).Location Based

Area based sorting out shows need some district information of the sensor places. Area information can be gotten from GPS (Global Positioning System) signals, got radio transmission strength, and so on. Utilizing district data, an ideal way can be illustrated without utilizing coding strategies. for instance, Geographic and Energy-Aware Routing (GEAR).

1.6. Problem Formulation

Like different kinds of remote gadgets, the sensor hubs experience the ill effects of numerous limits like untrustworthy correspondence joins, restricted recurrence groups and security issues. Another test for sensor hubs is that since the sensor hubs ought to be cheap, little and light, the memory limit, CPU power and particularly battery size is incredibly restricted. Likewise, in numerous situations like climate checking and military applications, the sensor hubs are not open for quite a while. Experiencing the same thing, the battery substitution (on the off chance that certainly feasible), is extremely challenging. Subsequently, planning an energy effective correspondence convention for WSNs is inescapable.

From the above discussion, it can be inferred that enhancing the network lifetime remains to be the primary objective while designing routing protocols for WSNs. Energy efficient routing plays an important role in achieving this objective. Although many energy-efficient clusters based routing protocols have been proposed in the literature, still following are the open issues that need due consideration:

1. An efficient selection of cluster head is required for increasing the network lifetime.

2. The location of the cluster head for multi-hop data transmission should be revised.

3. Cluster boundaries need to be computed carefully to reduce the interference between clusters. Unbalanced clusters may put an overhead and hence increase the energy consumption.

5. Most of the routing protocols consider sink as well as sensor nodes as stationary. However, for many of the WSN applications, it is desirable to have mobile nodes in the network. It becomes challenging to design energy efficient routing protocols for frequently changing network topology.

Inspired by the need of issue analysis in remote sensor organizations, the deficiencies of this issue finding method and focusing on the examination headings, it's been understood that there exists sufficient extension to upgrade the conclusion execution. During this proposition, the proposed conclusion calculations lessen the analysis upward while keeping up with high location precision, low admonition rate, low finding idleness and low correspondence and energy upward.

1.7. Motivation

Recent advancements in wireless technology have resulted in the creation of mobile wireless sensor networks. Aside from sensor mobility, sensors in the network are low-cost and have a limited battery life. They are more material with regards to the central attributes of these organizations. These organizations have an assortment of uses, including search and salvage tasks, wellbeing and ecological observing, and canny traffic signal frameworks. As per the application necessities, portable remote sensor hubs are energy restricted gear, so saving energy is quite possibly the main issues in the plan of these organization. Alongside each of the difficulties brought about by the versatility of the sensor hubs, we can note to the directing and dynamic grouping. Concentrates on show that group models, which have customizable boundaries have critical effect in limiting energy utilization and broaden the lifetime of the organization. Subsequently, the principal objective of this examination is to present and choose the shrewd way involving transformative calculations for grouping in portable remote sensor networks for expanding Lifetime of the Network and right conveyance of bundles.

Considering the design issues in WSNs and the sheer number of protocols available to tackle them, it is very difficult to find a routing protocol which suits a specific purpose or fulfills certain requirements with better results as compared to other protocols.

Moreover, there are many surveys such as (Bhanu Pratap Singh Jyoti Singh et al.2014), (Ali Newaz Bahar Shamim Sardar et al. 2015) and (A.E.Narayanan C.Narmadha et al. 2018) on energy-efficient hirerchiral routing protocols analyzing their strengths and weakness depending upon their impale- mentation, but none of them focused on their performance in energy-efficiency and prolonging network lifetime for large scale WSNs. That is, the scalability of a network is also an important criteria in deciding which routing protocol is more energy-efficient than the other.

This motivated us to work on this project, where we select three known hierarchical routing protocols, LEACH, PEGASIS and HEED and do a simulation for 100 to 1000 nodes over a network area of (100 X 100) to (1000 X 1000) square meters and compare them on metrics such as load balancing, average energy consumption and lifetime of the network.

1.8. Research Aim

As it is widely indicated from the present research works, existing solutions destined to scale back power consumption during a sensor environment might not suit the wants of another sensor environment. This research work aims at improving the lifetime of a sensor network from the energy perspective. The scope of the research work ascends from lack of generalization and obscurity in performance objectives. Unlike traditional ad-hoc networks, WSNs place many complex scenarios and encourage novel research ideas to emerge. Dynamic nature of the sensor application requirements makes many existing solutions obsolete and triggers the necessity for tuning and redefining these solutions.

The goal of this project is to find out which among these three protocols: LEACH, PEGASIS and HEED, is better in terms of energy-efficiency, stability period, network lifetime and scalability. It also discusses the challenges faced by the existing routing protocols and wireless sensor networks as a whole and what can be done to create a better and energy-efficient wireless sensor networks that can be utilized at a greater scale in the existing scientific and industrial areas in the real world.

1.9. Contribution

Wireless sensor networks (WSN) play an important role in today's world. It is a useful technology for sending and receiving data from various parts of the system via mini sensor nodes spread across a large area. These nodes can perform a variety of data operations such as sensing the environment, gathering and processing data, and so on. The batteries embedded in these nodes provide the necessary energy for these processes. In many applications, sensor nodes are small and equipped with a small, low-energy battery. It is critical to reduce energy consumption and extend the network's lifetime as much as possible (W. S. Email et al. 2013) .

• This work includes simulation of network for various simulation parameters such as number of nodes, network area, initial energy, location of base station, crossover distance, electronics energy per bit, aggregation energy per bit, length of packets.

• Then the LEACH, PEGASIS and HEED are simulated as directed in their original paper and run these protocols over the above-mentioned simulated network.

• After that, the statistics are stored such as residual energy of network per round, dead nodes per round, average residual energy of a node per round, variance of residual energy per round for each protocol in different simulation environments.

• Finally, the conclusion was drawn after analysing the statistics obtained by plotting the graphs for each protocol after every simulation.

1.10. Thesis Organization

The rest chapters of the thesis are prepared as follows:

Chapter 2: This chapter presents detailed review of literature of some existing methods explained in the fault diagnosis WSNs.

Chapter 3: This chapter gives the detailed overview of proposed algorithm to diagnose hard faults. This chapter also gives the implementation a comparison of LEACH, PEGASIS and HEED protocols.

Chapter 4: This chapter present Experiment results and performance analysis of the three protocols.

Chapter 5: This Chapter highlights this thesis's research findings as well as key contributions, and examines the future prospects.

CHAPTER TWO

LITERATURE REVIEW

Wireless sensor systems (WSNs) frequently contain numerous sensor nodes which can be sent to deploy in generally harsh and complex situations. In viewpoints on equipment gear cost, sensor hubs reliably get reasonably modest chips, which cause these center points to turn out to be dead skewed or defective inside the course of their development. Ordinary factors and electromagnetic check could in like way influence the presentation of the WSNs. Precisely when sensor centers become faulty, they'll have died which recommends they cannot communicate with different individuals' nodes inside the wireless system, they'll be as yet alive yet produce wrong information, and they'll be temperamental hopping between ordinary state and broken state. To build up information quality, reduce reaction time, strengthen network security, and increase system life expectancy, numerous examinations have concentrated on fault diagnosis (Ahlawat Manoj 2013).

.

2.1. Energy Consumption in Sensor Networks

Since sensor hubs are ordinarily battery-controlled gadgets, and the size of activity shifts from research facility testbeds to useful arrangements, it is a higher priority than any time in recent memory to ration energy to follow through with given responsibilities. This is particularly obvious in consistent checking situations where (continuous) battery changing and re-energizing could upset and discredit the assignment. Regardless, energy is an important asset that should be utilized carefully to broaden the life expectancy of the sensor hub and organization. The energy utilization of sensor networks is analysed in this part from the hub and organization (MAC layer) levels. Then, we'll go over some new and arising energy-saving methods.

2.1.1. Energy Consumption at Node-Level

Since sensor focuses are part-based, the energy utilization of typically elaborate equipment parts in the sensor community point, for example, a microcontroller, radio chip (handset), memory, and sensors, is being inspected at the middle point level.

Microcontroller (MCU): Each sensor community point's MCU consumes energy for information handling and control undertakings. As a general rule, different working states are executed in present day MCUs to save energy. Dynamic voltage scaling (DVS) (Ahlawat Manoj 2013) is a well-known energy-saving strategy utilized in MCUs that can progressively adjust the stock voltage worth to guarantee processor task execution while staying away from superfluous power utilization. More power data about different MCUs can be gotten from current utilization (Ahlawat Manoj 2013).

2.1.2. Radio (Transceiver)

A radio handset is responsible for bundle transmission and gathering over the air. In light of the intricacies of remote correspondence, the handset should incorporate numerous useful modules (modules for tweak, de-regulation, recurrence combination, recurrence change, sifting, and different capacities) furthermore, will consume an enormous piece of the hard and fast energy in a sensor center point. The most major energy-saving framework is to turn off the handset whatever amount as could sensibly be anticipated and conceivably turn it on when required. The famous CC2420 handset (Abdelzaher, T et al. 2014) has a run of the mill power utilization of 52.2 mW in transmission (TX), 56.4 mW in gathering (RX), and 3 W in rest mode. The MRF24J40 (Vishal Krishna Singh et al. 2019) consumes more energy in every one of the three states as an upgraded handset coordinated with the IEEE 802.15.4 norm: 69 mW in TX mode, 57 mW in RX mode, and 6 W in rest mode.

2.1.3. Sensor

A sensor hub regularly comprises of four essential parts, as displayed in Figure 6: a detecting unit, a handling unit, a correspondence unit, and a power unit. This figure is gotten from.

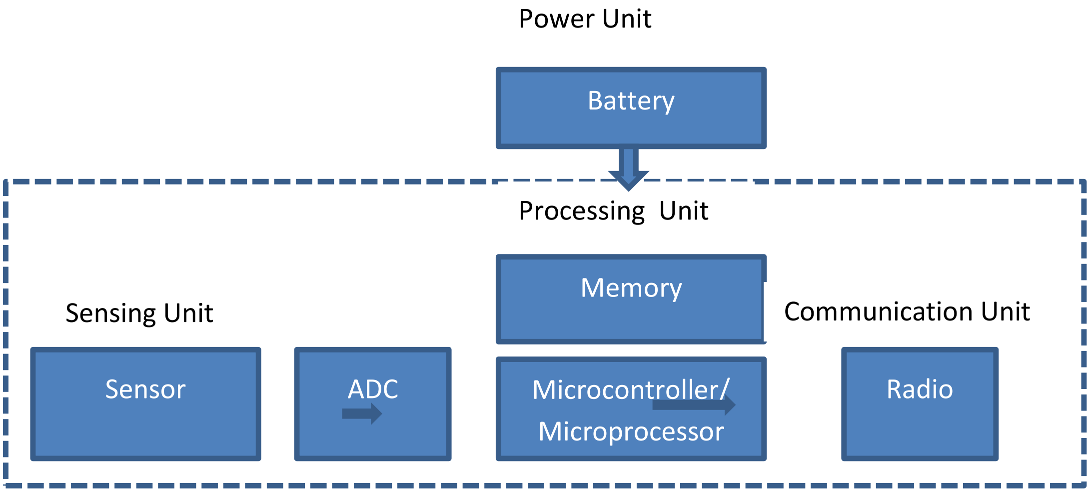


Figure 6. Sensor Node Structure (Abdelzaher, T et al. 2014)

In any case, the energy scattered by the correspondence unit, for example radio, is fundamentally more noteworthy than the energy disseminated by the Sensing Unit or Processing Unit. Thus, to expand the organization lifetime of WSNs, radios ought to be kept in low power mode, for example rest mode, however much as could reasonably be expected. Besides, energy use is relative to the square or quad of the distance. To augment network life span, significant distance correspondence ought to be stayed away from however much as could reasonably be expected. Moreover, energy utilization is corresponding to the quantity of parcels communicated or got through radio. Subsequently, information collection methods (like Min, Max, or Avg) ought to be utilized to decrease radio energy utilization.

2.2. Clustering Advantages

2.2.1. Extending Scalability

Sensor nodes in a WSN are split into groups and each group is called a cluster, with different allocation rates of routing protocols for each cluster. Aggregation of data, dissemination of information and maintenance of networks are some of CH's responsibilities. The routing table information is stored by the sensor nodes. Clustering increases the level of scalability and topology control over the network.

2.2.2. Minimal Load

As sensors can produce critical redundant data, the consolidation or fusion of information in WSNs is a basic principle and target of CHs. A rich and multidimensional view of data to redundant data transmission is provided by the information aggregation or fusion method. Throughout clustering, the CH conducts the process of consolidation and fusion of the data transmitted by the cluster participants, thereby improving the efficacy of data transfer and energy usage. The sensor nodes store the routing table size which can be limited by choosing best routing protocols. Hence, the load in all the sensor nodes is limited to a specific amount (Salayma, M et al. 2019).

2.2.3. Minimal Energy

Once clustering is done, transfer of CH information into the Sink requires more energy than the reception of BS data. Cumulative data and blended data enable perfect data transmission, reducing power consumption. Such clustering improves networking between intra-cluster and inter-cluster communication. For minimizing energy consumption cluster communication uses very few sensors to transmit data to long communication.

2.2.4. Robustness

For network topology management efficient cluster routing protocols makes CHs suitable. Accumulation of nodes, unannounced node failures and node quality are easier to account in network changes. For the network to get strengthened and to become suitable for management, any clustering schemes should follow the above modifications among individual clusters. To distribute duties of CHs and to avoid failure of CHs, CHs responsibilities are usually rotated among all these member nodes.

2.2.5. Latency Reduction

At the point when the WSN is splitted into groups, just CHs execute the job of communicating information. The information transmission method of the group assists with keeping away from hub impacts and diminishes inactivity. Hop-by-hop data, in comparison, is transferred in flat routing topology without considering of the data flooding. In the cluster routing method, CHs play the role of data transfer, which essentially decreases the delay and the distance from the CH to the BS consequently.

2.2.6. Resolving Energy Hole Issues

Data collection of Sink node in WSN is done either directly from the member nodes in the cluster or through many intermediate nodes. All sensor nodes in a cluster produce both traffics by themselves and by relayed traffic. Usually, Sink node forwards more number of data packets to its nearer sensor nodes than to the distantly located nodes. Because of nodes being close to the Sink depletes more energy quickly and dies vastly. So a vacant space is created closer to the Sink and this vacant space is called Energy Hole (EH). EH splits the network and does not allow any data from external nodes to Sink. The external Outer most nodes have high battery power (Salayma, M et al. 2017). By introducing proper load balancing, viable node deployment, and prioritizing the node energy are the efficient balancing techniques to reduce power conservation used to avoid the EH nearer to the Sink.

Utilizing these plans, the close by hub and the farthest hub to the BS are distinguished. The nearer hubs to the Sink use low energy while the farther hubs which are far off from the Sink use high ability to convey the information among between bunch organizations (Padmalaya Nayak and al. 2016). Calculating the distances from the Sink and to analyse the power balancing process of the nodes is a very critical task

2.2.7. Lifetime and Power consumption of Network

The environmental technology concerns include processing efficacy, data transfer energy and communication network latency. In WSN, however, the amount of networking time (lifetime) is a major concern. In the intra-cluster CH data transfer network, it is most essential to decrease energy consumption. In addition, greater chances of becoming CHs for more sensor nodes are widely or heavily scattered in the cluster. Identifying the best shortest route for the inter-cluster data transmission with a high safeguard capacity reduces energy consumption and increases the network lifetime.

2.3. Classification of Routing Protocols in WSNS

This segment momentarily examines a couple of significant remote directing conventions connected with WSN. We can partition steering conventions into four significant classes: • Flat directing conventions • Hierarchical steering conventions • Location-based directing conventions • Quality-of-Service (QoS) steering conventions.

A few conventions might fall under more than one classification. Table 1 gives a concise outline of this order. Essentially, Table 2 looks at a couple of various leveled steering conventions.

Table 1. Arrangement of the directing conventions utilized in WSN (Amar Kurmi, Jaya Dipti Lal, 2015)

Routing	Flat	Location based	QoS
SPIN	Yes		
Directed Diffusion	Yes		
LEACH		Yes	
PEGASIS		Yes	
TEEN, APTEEN		Yes	
MECN		Yes	
SPAN		Yes	
GEAR		Yes	
GAF		Yes	
VIBE		Yes	Yes
SAR	Yes		Yes
SPEED	Yes		Yes
MERR		Yes	
DSC		Yes	

2.4. Survey Based on Model of Clustering

WSN configuration is muddled in more ways than one. The key intricacy is to augment network security and lifetime. It is hard to supplant the batteries in hundreds or thousands of remote sensor hubs that are sent in the field. Hub grouping is a progressive option in contrast to level network. Bunching is a procedure where sensor hubs are gathered progressively founded on their vicinity to each other. The progressive course of action jklkkguarantees that information gathered by sensor hubs is directed really and dependably to the BS. Sensor hub bunching supports decreasing directing table size. Grouping can likewise save correspondence data transfer capacity by collecting it prior to sending it. The organization is separated into a few bunches (gatherings). Each group will have one Cluster-Head; any remaining hubs in the bunch will speak with the Cluster-head; and the Cluster-head will speak with the Base Station (Sink Node). Thus, the hubs that have a place with a particular bunch head are its one-jump neighbors. Scientists' generally proposed bunching strategies increment both lifetime and adaptability. Many grouping conventions exist to make various levelled structures that diminish in general transmission costs/energy while speaking with the base station (X. Liu, 2012).

CHs are assigned as bunch pioneers. Bunch heads are entrusted with extra errands, for example, information accumulation and information steering from individuals to the base station. While getting, conglomerating, and communicating information to BS, bunch heads with additional hubs have a higher burden than group heads with less hubs. Subsequently, the job of CH is turned to appropriate the heap and further develop hub lifetime. In an irregular determination process, a hub is chosen as group head in view of the probability of not becoming bunch head previously. This diminishes the traffic load on some random hub while likewise stretching out CH usefulness to all sensor hubs. The group head is turned consistently. CH can likewise be turned when its leftover energy level falls under a specific limit. This turn of CHs will bring about an even appropriation of the sensor organization's general energy utilization. Another methodology is to think about the distance to BS. The amount of good ways from CH to BS is limited utilizing this technique. Sending information from sensor hubs to base station by means of the CH lessens transmission distance and in this way correspondence energy. The size of a group is a significant component in WSN energy streamlining. Little bunches can save power in intra-group correspondence, yet the spine network turns out to be more mind boggling. Subsequently, the quantity of groups in an organization is a similarly significant consider energy reserve funds.

The multi-bounce transmission lessens energy utilization. This can be utilized for intra-group correspondence as well as CH-BS correspondence. For this situation, the most energy consumed by any hub is the base transmission energy expected to arrive at an adjoining sensor hub. Sensor hubs isolated by significant distances don't have to straightforwardly communicate. These hubs can utilize adjoining hubs to hand-off information to the Base Station. It has the detriment of being more slow than direct transmission. Nonetheless, in the event that start to finish delay isn't a limitation, multi-jump gives preferred execution over single-bounce at times. Table 2 shows an examination of progressive grouping conventions normally utilized in WSN (Bhanu Pratap Singh Jyoti Singh, 2014).

Table 2. Correlation of progressive grouping conventions of Wireless Sensor Network Bhanu Pratap Singh Jyoti Singh, 2014)

Features	LEACH	TEEN	APTEEN	DSC	CPEQ	LESCS
Single hop (CH-BS)	y	x	x	y	x	x
Multi hop	x	y	y	x	y	y
Cluster is formed by BS	x	y	y	y	x	y
CH sends aggregated data toBS	y	y	y	y	x	x
CHs relay event notification to BS	y	y	y	y	x	x
Periodic, event,	y	x	y	x	y	x

Clustering is an energy saving and the network lifetime extension effective method of energy constraint WSNs. Generally, the residual energy of individual nodes (Low Energy Adaptive Clustering Hierarchy (LEACH) based method is used for clustering. Another similar method is Hybrid Energy Efficient Distributed clustering (HEED). CH selection has been taking place in LEACH randomly and few nodes act as cluster heads, the formation of the role of cluster head nodes are rotated to balance the energy loss of the sensor nodes to sustain in the network for longer period.

The information collection and combination of information are finished by group heads hubs CHs that show up from hubs that have a place with the separate bunch. Sink gets the collected information from the CHs simply to decrease how much information and to keep away from the copied information transmission. Sink becomes the data collection center and executed periodically. The two phases of LEACH protocol are the one set-up phase and the next steady-state phase. Cluster head selection and organization of clusters takes place over the first phase. The actual data transmissions takes place to the sink occurs in the second phase, steady- state phase.

The cycle gets repeated after the steady-state.(Fan Wang et al. 2016) conducted a survey on clustering algorithms which depicts that based on clustering attributes like properties of clusters, capabilities of cluster head, process of clustering etc. With reference to the homogeneous wireless sensor network architecture, the following parameters are described node deployment and capabilities, in-network data processing, clustering objectives like load balancing and fault-tolerance, minimum cluster count, reduced delay, increased connectivity, and maximal network longevity.

The WSN LEACH-C protocol as an extension of LEACH and it was based on a simulated annealing centralized algorithm. The lifetime of the network is improved by ensuring the survival of some clusters with nodes in the network. Due to the probabilistic nature, the standard LEACH algorithm not promises identical number of cluster heads in every round. A multi-hop routing protocol proposed by (Thakkar, 2014), employs same amount of equal grid area forming clusters which increases the lifetime of network and energy efficiency. Also, an energy- balancing clustering protocol proposed by (Sohn, et al. 2016) forms clusters of smaller size adjacent to the sink as comparing the ones which are farthest from the sink to improve the lifetime network yield better outcomes. (Taheri, H et al. 2012) has given importance in selecting the cluster quantity for improving the lifetime of a Wireless Sensor Network (WSN) locating the base station (BS) with respect to inner and outer of the sensor field.

They represent a family of research algorithms inspired from species' biological evolution, such as: natural selection, mutation, reproduction, and recombination. Evolutionary algorithms idea is too simple. In a first step, a set of point called initial population is randomly built in a predefined search space. Each point or individual possesses a performance degree that measures its adaptation level to the target objective.

A transformative calculation step by step advances the populace creation while keeping up with its consistent size through progressive cycles or ages. The general objective is to work on individual execution across ages. In every age, a progression of administrators are applied to populace people to create another populace. Every administrator utilizes at least one populace individuals, known as guardians, to create new up-and-comers, known as posterity. A transformative calculation normally contains three key administrators: determination, hybrid, and change. The determination administrator leans toward the spread of improved arrangements inside the populace while saving hereditary variety.

A crossover, game hypothesis based, and conveyed bunching convention for remote sensor organizations, , internet Clustering has for some time been perceived as a compelling technique for decreasing energy dissemination and expanding network lifetime in remote sensor organizations. Game hypothesis has as of late been utilized to demonstrate the grouping issue in a remote sensor organization. Every hub in the framework network is displayed as a player who can pick the decision about whether to be a group head (CH). Furthermore, by playing a restricted bunching game in the organization, it gets a harmony likelihood of being a cluster head (CH), permitting its result to stay stable. In this paper, we present a grouping convention called Hybrid, which depends on game hypothesis and disseminated bunching. In this convention, we explicitly characterize the result for every hub in the framework while choosing various procedures, considering both hub degree and distance to base station. For this situation, every hub in the framework network gets its balance likelihood by partaking in the game.

(Rama Shankar Yadav and Sarika Yadav 2010) A gander at energy-saving conventions in remote sensor networks Springer Science and Business Media New York, 6 August 2015, distributed web-based Wireless sensor networks certainly stand out of specialists, producers, and clients over the course of the past ten years for remotely observing undertakings and viable information assortment in an assortment of conditions. Since remote sensor hubs are little battery-fuelled gadgets with restricted lifetime, the essential concern while planning conventions and applications for life span and unwavering quality is limiting energy utilization and amplifying network lifetime.

In this sdudyr, the authors plan the main pressing concerns in light of the remote sensor network model: structure free and organized for information assortment and total, where the job of grouping and directing for energy preservation and organization lifetime is examined. From an energy-saving stance, these plan systems are the groundwork of any systems administration convention. There is a thorough even outline of various methodologies for information assortment, conglomeration, bunching, and directing in structure free and remote sensor networks gave main points of contention.

Springer Science and Business Media New York, August 18, 2015 Wireless sensor networks represent a critical test for information directing as a result of their promising utilization of gathering data from remote or distant areas. The writing portrays different sorts of group-based energy mindful directing conventions for boosting the existence season of sensor hubs in a remote organization. Thus, in this paper, an energy-productive bunching component in light of a fake honey bee state calculation and factional math is proposed to boost network energy and hub life time by ideally choosing group head. The multi objective fragmentary fake bumble bee state creamer improvement estimation was made to control the association speed of ABC with an as of late arranged wellbeing work that thought about three focuses, for instance, energy usage, distance journeyed, and deferrals to restrict the overall objective. In this survey, the association's proposed FABC-based bunch head decision is diverged from PSO, LEACH, and ABC-based coordinating using life speculation.

The sensor network consumes more energy during information transmission and handling, making it be in an ideal state. Low Energy Adaptive Clustering Hierarchy (LEACH) is a notable moderate coordinating show in WSN that is liable for energy limit in centers. In standard system strategies, the waiting energy and distance between the base station and center are not considered while picking the gathering head. A cross layer-low energy adaptive clustering hierarchy model (CL-LEACH), a powerful guiding show to extend the lifetime of the battery, is utilized in this examination work to dissect network life time. CL-LEACH represents leftover energy and group head determination, and it gives an energy effective transmission conspire for WSN. This cross-layer configuration gives versatile balance by utilizing intersegment conditions across the Medium Access Control, Physical, and Application layers. Besides, there is CL-LEACH uses the leftover energy of the hub in the organization for group head choice which safeguards the general energy.

(Padmalaya Nayak, e al. 2016) Hybrid routing and load balancing protocol for wireless sensor Network‖ Published online: 18 November 2015, Springer Science and Business Media New York 2015 At the point when the hubs in a remote sensor network are portable, the organization structure changes powerfully, as new hubs join the organization and old individuals leave. Subsequently, the way from one hub to the next hub changes over the long run. On the other hand, on the off chance that the heap on a particular piece of the organization is high, the framework's hubs will not be able to communicate information. Thus, information conveyance to the objective will fizzle. Moreover, the organization portion associated with information transmission ought not be over-burden. To resolve these issues, this paper examines a crossover directing convention and burden adjusting procedure for versatile information gatherers that guarantees the way from source to objective before information transmission. To further develop slope based directing conventions for low power and misfortune organizations, a half breed steering convention that joins the proactive and responsive methodologies is utilized. This convention can deal with the development of various sinks in the organization productively. At last, load adjusting is utilized across different portable components to adjust the heap on sensor hubs.

2.5. Survey Based on Clustering Routing Protocol

(Amar Kurmi et al. 2015) Cluster Based Routing Protocol for Mobile Nodes in Wireless Sensor Network‖ Published online: 23 May 2010, Springer Science and Business Media, LLC. 2010 Mobility of sensor nodes in wireless sensor. One of the fundamental difficulties that shows up with energy utilization is parcel misfortune brought about by sensor hub portability. To resolve these issues, we utilize cross-layer plan between the medium access controls (MAC) and organization layers in this paper. The bunch based directing convention for portable sensor hubs (CBR-Mobile) is proposed. CBR-Mobile is a portability and traffic adjusting convention. The organization timeslots are utilized to reassign versatile sensor hubs that have moved out of the bunch or don't have information to ship off approaching sensor hubs inside the group locale. There is a convention that brings two basic data sets into the organization to accomplish versatile portability and traffic. This convention is utilized to productively send information to bunch heads in view of gotten signal strength. CBR-Mobile convention is a group based directing convention that works with a mixture MAC convention to help sensor hub versatility.

Helpful Space-Time Block Codes for Wireless Video Sensor Networks, Marcelo Portal Sousa, Ajey Kumar, Rafael F. Lopes, Wilson T. A. Lopes, Marcelo Simpatico de Alencon Springer Science and Business Media, LLC distributed the article online on January 28, 2012. Remote video sensor organizations (WVSNs) are turning out to be progressively famous because of their large number of expected applications, including video observation, natural and territory checking, etc. The organization framework effectiveness is expanded by utilizing a huge scope remote video sensor network on the grounds that the sink hub isn't close enough to any remaining hubs, requiring a multi-jump activity. This study proposed a clever helpful framework that utilizations space time-block codes to work on the exhibition of multi-jump remote video sensor organizations. There is a plan in the organization that depends for huge scope WVSNs, by changing the group size and expanding the participation between the bunch heads. Stable-Aware Evolutionary Routing Protocol for Wireless Sensor Networks, Enan A. Khalii and Bara's A. At tea Springer Science and Business Media, LLC distributed the article online on May 19, 2012. In reality situation for remote sensor organizations (WSNs) in 2012, energy heterogeneity among sensor hubs because of lopsided territory, network disappointment, and bundle dropping is a basic figure creating powerful and solid directing conventions in the framework. At the point when the primary hub kicks the bucket, time is expanded; the soundness time frame is a basic condition for some applications that require dependable input from the WSN. Low Energy Adaptive Clustering Hierarchy (Endlessly filter like conventions are fundamental and well known grouping conventions for overseeing framework energy and hence expanding network lifecycle. These organizations expect an ideal energy homogeneous framework where hub disappointment, seepage, and recharging are ordinarily not thought of. A Stable Election Protocol (SEP) considers something contrary to the past convention, which is energy heterogeneity, and appropriately uses the additional energy to guarantee the organization framework's steady and dependable presentation. Albeit developmental calculations (EAs) certainly stand out as of late to address different WSN difficulties like hub organization and confinement, information combination and collection in the framework, security and directing in the organization, they didn't (supposedly) investigate the chance of keeping up with the heterogeneous-mindful energy utilization that is give the dependable and robust. The stable-careful extraordinary directing show (SAERP) is proposed in this paper to ensure most prominent relentlessness and least shakiness periods for both homogeneous and heterogeneous WSNs. SAERP is a ground-breaking showing show that is indispensable., where the bunch head political decision likelihood turns out to be more effective, to well keep up with balance. LLC is the Energy constrained remote sensor organizations (WSNs) have been broadly proposed for observing and reconnaissance purposes in 2012. The battery duration of the framework is a basic boundary for sensor hubs (SNs) in the organization. Work on an energy-proficient convention that gives another technique for making conveyed bunches in this paper. This convention is a changed form of the Low Energy Adaptive Clustering Hierarchy (LEACH) convention demonstrating, which is a basic convention. The reproduction result shows that the LEACH convention beats when both the lingering energy at every SN and the distance between the SNs are considered. A Centralized Balance Clustering Routing Protocol for Wireless Sensor Networks, Jian Chen, Zhen Li, and Yong-Hong Kuo Springer Science and Business Media New York 2013, distributed on the web: 1 February 2013. Directing conventions assume a significant part in remote sensor network execution (WSNs). In this paper, a concentrated equilibrium bunching steering convention in view of area is proposed for WSN with irregular dissemination. We plan a fundamental bunching calculation to adjust the organization's lifetime and adjust to the non-uniform dispersion of sensor hubs because of the grouping method. A calculation is intended to decide the organization's bunch in light of the framework and change the hexagonal grouping results to adjust the quantity of hubs in each bunch. The subsequent point is that it chooses the group heads, in each bunch in view of the energy and circulation of hubs, and enhances the bunching results to limit energy utilization. At last, it appoints fitting schedule openings for transmission to stay away from crashes. The re-enactment consequences of this examination demonstrate the way that the proposed convention can essentially further develop network throughput and lifetime while adjusting energy utilization. bunching calculation.

2.6. Methods Of Energy Saving

Reviews of a few late and arising energy preservation conspires that can address and lighten energy utilization challenges are introduced in this part.

2.6.1. Hierarchical Sensor Node Architecture

Since the sensor hub equipment consumes energy, the advancement of an energy-effective hub stage fills in as the establishment for significant level energy protection techniques (e.g., conventions, systems, programming). Subsequently, (Annie Selina et al. 2012) proposes a progressive hub design. A two-layered engineering is utilized in a reconnaissance application situation. A low-end microcontroller (e.g., ATmega128L in MICA2/z) is utilized in the occasional 'low responsibility' based gate crasher recognition stage for two reasons: I super low power rest mode, in light of the fact that the hub invests the vast majority of the energy in rest mode during this stage, and (ii) quick wakeup time to decrease the above in the continuous rest dynamic activity. After the presence of the gate crasher is distinguished, a very good quality implanted processor (e.g., Intel PXA-255 in Stargate (Salayma, M et al. 2017) is utilized. The processor stays in dynamic mode during this 'high responsibility' stage to perform calculation and correspondence for gate crasher following and following. In this calculation-based process, a top of the line implanted processor consumes definitely less energy. Thus, the plan of this heterogeneous and progressive engineering gives a trade-off in energy discussion.

2.6.2. Energy Harvesting

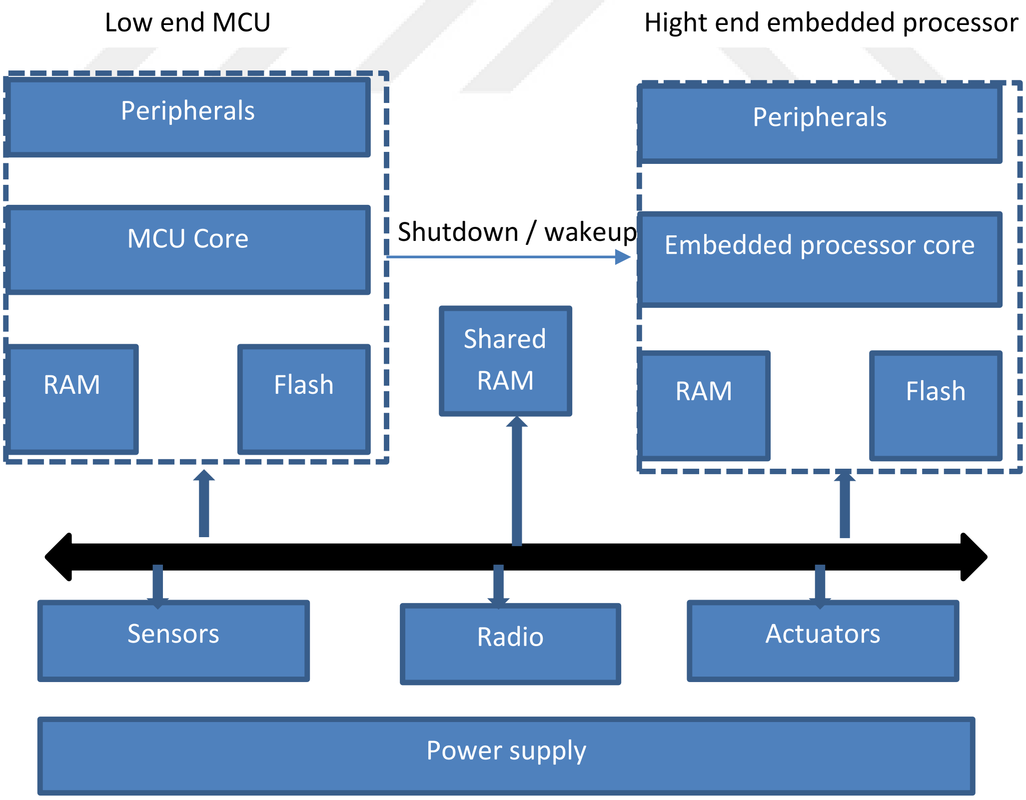


Figure 7. Sensor node architecture with two tiered processors (Guo, P et al. , 2012)

Since how much energy put away in the battery is restricted, the sensor hub/organization's lifetime is additionally restricted. As opposed to zeroing in on the equipment stage or the product that sudden spikes in demand for it, researchers have dynamically cantered around the energy supply structure. As an emerging advancement, the usage of such methods in WSNs has filled in omnipresence recently, owing to their ability to decrease or attempt to kill battery dependence for individual sensor center points. One of the critical hardships is the issue of energy storing for in a little while. While considering a sunlight based controlled stage, additional energy should be put away to keep the stage functional around evening time or in low-light

2.7. WSN Energy Routing Protocols: Related Works

2.7.1. A Chain-Based Routing Protocol

To expand the life expectancy of a WSN, the creator (H. Guyennet M. Hadjila et al. 2013)proposed a calculation that frames various chains toward the sink, each with a pioneer hub that is the last and nearest hub to the sink. Information is communicated from one hub to another, with the last hub sending straightforwardly to the sink. A superior plan of this last option involves framing a fundamental chain gathering the pioneer hubs, as displayed in figure 8, and further decreasing the organization's energy utilization

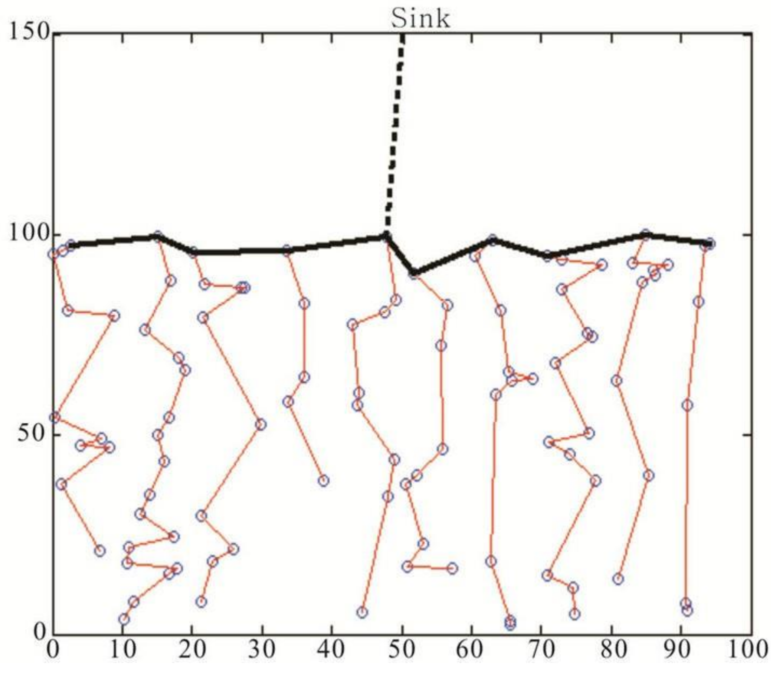


Figure 8. Multiple Chain Formation in WSN (H. Guyennet M. Hadjila et al. 2013)

The simulation results revealed that the improved algorithm reduced the energy consumption as compared to the former chain schemes and consequently maximized the lifetime of the WSNs.

2.7.2. Energy-Efficient Routing Control algorithm in large- scale WSN

An ordinary illustration of huge scope remote sensor network research is the utilization of remote sensor networks for water climate checking in the Three Gorges Reservoir region (Yuanchang Zhong et al. 2014). It likewise has the ordinary elements of zonal conveyance and a huge inclusion region. The creator's exploration depends on past achievements and an intensive assessment of existing steering calculations, for example, the LEACH (W. R. Heinzelman et al. 2000) calculations, with an emphasis on the energy-saving directing calculation for enormous scope WSN. Accordingly, a better energy-saving steering calculation in view of greatest energy-government assistance bunching has been proposed. The significant upgrades are separated into three classes:

• To begin, when selecting cluster heads, both remaining energy and node distance from base station were taken into account. As a result, it is more reasonable.

• Second, the group heads change and bunching enhancement in view of further developed most extreme energy-government assistance made the bunch head circulation more uniform, and the organization's energy utilization was effectively adjusted.

• Third, in the bunching directing development, factors, for example, way costs, remaining energy, and point deviation among hub and base station were considered, expanding hub energy effectiveness.

2.7.3. SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks

In this paper, the creator expects that the sink isn't energy restricted and that the sink organizes and field aspects are known. They likewise expect that the hubs are circulated consistently across the field and are not portable. In this model, they propose SEP, another convention for choosing bunch heads in two-level progressive remote sensor networks in a disseminated design. Dissimilar to past work, SEP is heterogeneous-mindful as in political race probabilities are weighted by a hub's underlying energy comparative with different hubs in the organization, for example it works on the steady district of the bunching ordered progression process by using heterogeneous trademark boundaries, to be specific the small portion of cutting edge hubs (m) and the extra energy factor among cutting edge and typical hubs (a). This drags out the time stretch before the passing of the primary hub (alluded as dependability period), which is critical for some applications where the input from the sensor network should be solid.

SEP outflanks current grouping heterogeneous-negligent conventions concerning solidness and normal throughput. The creators additionally examined the SEP (Georgios Smaragdakis et al. 2004) convention's aversion to heterogeneity boundaries catching energy lopsidedness in the organization. It has been shown that SEP is stronger than LEACH (W. R. Heinzelman et al. 2000) with regards to prudently consuming the additional energy of cutting edge hubs. SEP brings about a more extended solidness period for higher upsides of additional energy in the organization's high level hubs.

The creators of (Heinzelman, Chandrakasan, and Balakrishnan, "Energy-productive correspondence convention for remote microsensor networks") showed the presentation of the LEACH convention with a homogeneous organization, where all hubs have a similar measure of energy. The creators of Stable Election Protocol (SEP) (Smaragdakis, Matta, and Bestavros) exhibited that conventional conventions, for example, LEACH can't exploit network heterogeneity. Network heterogeneity is accomplished by dispensing more energy to a subset of all out hubs. These are known as cutting edge hubs, while the excess hubs are known as would be expected hubs. The ideal likelihood of being bunch head as an element of spatial thickness has been concentrated mathematically or logically (Bandyopadhyay and Coyle, "An energy productive various leveled grouping calculation for remote sensor organizations" "Limiting correspondence costs in hierarchically clustered organizations of remote sensors") When energy utilization is equitably disseminated across all sensors and all out energy utilization is low, this grouping plan is ideal.

In SEP, every hub picks an irregular number somewhere in the range of 0 and 1, and in the event that the picked irregular number is not exactly the edge, the hub is chosen as CH. Since SEP utilizes a heterogeneous organization, the limit values for typical and high level hubs contrast.

One of the main issues in Wireless Sensor Networks is energy proficiency, and bunch based steering procedures can assist with further developing organization lifetime. Moreover, the dispersed grouping plan is ideal since it takes into consideration versatility. Despite the fact that they are energy productive, the bunched directing conventions examined in this part can be advanced further. Methods for expanding the organization lifetime of Wireless Sensor Networks have been distinguished and are being considered for execution.

2.7.4. Design of a Distributed Energy-Efficient Clustering algorithm for heterogeneous wireless sensor networks

The bunching calculation is a sort of key procedure used to decrease energy utilization. It can expand the versatility and lifetime of the organization. Energy-proficient grouping conventions ought to be intended for the trait of heterogeneous remote sensor organizations.

The creator proposed and assessed DEEC, another conveyed energy-proficient bunching plan for heterogeneous remote sensor organizations. DEEC, similar to LEACH, permits every hub to consume energy consistently by turning the bunch head job among all hubs. In DEEC, bunch heads are picked utilizing a likelihood in light of the proportion of every hub's lingering energy to the organization's typical energy. Therefore, DEEC requires no worldwide information on energy during every political race round. The round number of the turning age for every hub differs with its underlying and leftover energy, suggesting that DEEC adjusts the alternating age of every hub to its energy. The hubs with the most elevated introductory and remaining energy have a superior possibility becoming bunch heads than the hubs with the least starting and lingering energy. In this manner, by utilizing a heterogeneous-mindful bunching calculation, DEEC can expand the organization lifetime, especially the strength period.

2.7.5. Enhanced LEACH Multi-path Based Energy-Efficient Routing for wireless sensor network

The creators of this paper proposed a multi-way LEACH convention in light of LEACH. The essential objective of this convention is to give energy-productive and vigorous correspondence. The multi-way procedure takes care of the issues that solitary way or multi jump steering calculations have. Obviously, in a sensor organization, different ways exist between the sensor hub and the base station. This demonstrates the distance between the bunch head and the detecting hub. This data is helpful for finding the closest group head hub. This recoveries energy and decreases the quantity of jumps expected to impart between the group head and the sensor hub. Simulation results show that multi-path LEACH protocol performs better than LEACH in terms of energy-efficiency and prolonging the lifetime of the network.

Following bunch development, the Cluster Head (CH) gets information from its part hubs (to keep away from significant distance correspondence by the part hubs), totals the information (to diminish the quantity of pieces expected to be sent by CH), and sends it to the Base Station (BS). Accordingly, CHs consume more energy than non-CH hubs. To accomplish uniform energy exhaustion, the CH should be picked on a rotational premise. One conspicuous bunch based convention that works in adjusts is Low Energy Adaptive Clustering Hierarchy (LEACH) (Heinzelman, Chandrakasan, and Balakrishnan, "Energy-productive correspondence convention for remote microsensor networks"). The round is the timeframe during which a hub chooses itself as CH and serves different hubs. Each round has two stages: I Cluster Setup Phase and ii) Steady State Phase. CHs plan TDMA plans and inform part hubs subsequent to getting join messages. During the Steady State Phase, part hubs send information as per the TDMA plan. In the wake of getting information from part hubs, CHs total it and send it to BS.

2.8. LEACH Protocol

Drain (Low-Energy Adaptive Clustering Hierarchy) is a straightforward TDMA-based steering convention utilized in WSNs and is one of the most established and first various leveled conventions. Heinzelman (W. R. Heinzelman et al. 2000) proposed it in the year 2000. This group based convention arose as an energy-proficient correspondence convention for remote miniature sensor networks that utilizations randomized revolution of nearby bunch base stations known as group heads to appropriate energy load consistently among sensor hubs in the organization.

The key features of LEACH are:

- Localized coordination and control for cluster-set up and operation.

- Randomized rotation of the cluster heads and the corresponding clusters.

- Local compression to reduce global communication

Filter (S. Lindsey, et al. 2002) is a various levelled directing convention that is ordinarily utilized in WSNs. The idea proposed in LEACH has enlivened the advancement of a few comparable various leveled steering conventions. Sensor hubs in LEACH put together themselves as nearby groups, with one hub going about as the Cluster Head (CH) and different hubs as straightforward individuals from that bunch. Drain utilizes randomized group head pivot to appropriate energy utilization uniformly among hubs. The bunch heads get information from their group individuals and total it to lessen the quantity of messages shipped off the Base Station (BS). In each round, the sensor hubs freely choose themselves as group heads with a foreordained likelihood. To decrease above in group head foundation, every hub pursues a political race choice that is autonomous of different hubs. The organization runtime is separated into adjusts. In each round, every hub chooses an irregular worth somewhere in the range of '0' and '1'. Assuming the arbitrary worth is not exactly the ongoing round's limit, the hub turns into the group head:

$$T(n) = \begin{cases} \frac{p}{1-p(r \; mod \; \frac{1}{P}} \; if \; n \; \in G \\ 0 \;\; otherwise \end{cases}) \qquad (2.1)$$

Where n addresses the given hub, p addresses the predefined level of hubs that can be bunch heads, r addresses the ongoing round, and G addresses the arrangement of hubs that didn't become group heads in the past 1/p adjusts. Drain's execution time is separated into adjusts. Each round comprises of:

Drain convention execution is partitioned into adjusts. At the point when a hub chooses to turn into a bunch head, it communicates a message with its hub ID. For this transmission to the whole organization, it utilizes a non-industrious transporter sense different admittance (to dispense with impacts) MAC convention. The message is kept little in size. It further develops broadcast productivity and guarantees that bundles arrive at all hubs in the organization. K hubs with higher probabilities are picked as Cluster Heads from among these hubs. All leftover hubs pull out from the opposition. The Cluster Head then, at that point, communicates a message (ADV) declaring its political decision as CH. Non-CH hubs (otherwise called part hubs) decide to join the group head with the most grounded signal. Then, at that point, utilizing CSMA, each non-CH sends a join-solicitation to the chose CH, including its ID. All each Cluster Head hub makes a TDMA plan that its individuals should follow for information transmission and broadcasts. This is otherwise called the bunch arrangement stage.

LEACH is considered to be a self-organizing protocol in which the sensor nodes organize themselves to form clusters and one node is chosen as a cluster head (CH). The CH acts as a local Base Station (BS) in a way that data is transmitted by each sensor node to its corresponding cluster head. The cluster head position is rotated among different sensor nodes within the cluster to ensure that just a single node does not die out due to loss of its whole energy. The rotation is done in a random manner. The CHs also compress the data received by it from the other nodes before sending it to the base station to ensure less energy dissipation in the network. When the CHs are picked, they broadcast their situation or status to other sensor hubs inside the organization. Every sensor hub then, at that point, ascertains how much energy expected to convey information to the CHs and picks the one with least. In this manner the bunches are framed. The CHs then, at that point, make plan for its sensor hubs to send the information and the hubs stay switched off until their chance for communicating information comes. This saves a lot of energy disseminated by every sensor hub. In the wake of gathering information from every hub inside the group, the CH then totals it and sends it to the BS.

2.9. PEGASIS Protocol

The convention PEGASIS (Power-Efficient Gathering in Sensor Information Systems) was supportive of presented by Lindsey and Raghavendra in which a chain of sensor hubs is framed and every hub discusses just with its nearby neighbors. Data transmission is done from node to node and only a designated node sends it to the BS.

The leader node responsible for transmission changes turn by turn. The chain formation is either determined by the BS or the nodes themselves form chain using greedy algorithm. While data gathering, each node gathers data from its neighbor and further transmits it to next neighbouring node after fusing it with its own sensed data. To make the scheme robust, the sensor nodes die out at random locations. This is achieved by changing the data transmission leader in each communication round.

2.9.1. PEGASIS Algorithm

The chief idea behind PEGASIS is for each center point to get from and convey to nearby neighbors, and for each center point to substitute being the trailblazer for transmission to the BS. This system will fitting the energy load impartially among the association's sensor centers.

2.9.2. Formation of a Chain

Firstly, a chain is formed before the start of any data communication using a greedy approach among the nodes.

The furthest node from the sink or BS is chosen as a starting point for the chain in order to make sure that the nodes farther from the BS have close neighbors.

As in the avaricious calculation the neighbor distances will increment bit by bit since hubs currently on the chain can't be returned to. Subsequently few out of every odd hub in the chain will have the nearest neighbor among every one of the hubs in the environmental elements.

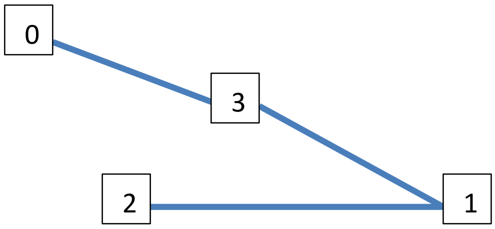


Figure 9. Chain Formation in PEGASIS (S. Lindsey et al. 2002)

In Figure 9, hub 0 is associated with hub 3, hub 3 is associated with hub 1, and hub 1 is associated with hub 2. At the point when a hub kicks the bucket, the chain is remade similarly to stay away from the dead hub.

2.9.3. Data Transmission

For social event data in each round, each center gets data from one neighbor, wires with its own data, and ships off the following neighbor on the chain. See that middle I will be set up j on the chain arbitrarily. Center points convey to the BS in changes, with center number I mod N (N tending to the amount of centers) shipping off the BS in round I. In this manner, the precursor in each round of correspondence will be at a sporadic circumstance on the chain, which is huge considering the way that centers fail miserably unpredictably puts. The objective of colouring hubs at arbitrary areas is to make the sensor network stronger to disappointments. In some random round, the pioneer can utilize a straightforward control token passing way to deal with start information transmission from the chain's finishes. Since the symbolic size is so little, the expense is negligible.

PEGASIS performs information combination at each hub in the chain aside from the end hubs. Every hub will consolidate its neighbors' information with its own to make a solitary bundle of a similar length, which it will then, at that point, send to its other neighbor (in the event that it has two neighbors).

$$c0 \rightarrow c1 \rightarrow c2 \leftarrow c3 \leftarrow c4 \qquad (2.2)$$

Figure 10. Token Passing Approach in PEGASIS (Wang, J., et al. 2018)

In figure 10, hub c2 is the pioneer, and it will pass the token along the chain to hub c0. Hub c0 will pass its information to hub c1. Hub c1 wires hub c0s information with its own and afterward sends to the pioneer c2. After hub c2 gets information from hub c1, it will pass the token to hub c4, and hub c4 will pass its information correspondingly towards hub c2.

At last, hub c2 sends one message to the BS. In this way, in PEGASIS every hub will get and send one bundle in each round and be the pioneer once every 'N' (N is the quantity of leftover hubs in the chain) adjusts.

2.10. HEED Protocol

The essential presumption in HEED (Hybrid Energy-Efficient Distributed grouping) is that every sensor hub is fit for controlling its transmission power level however they are area un-mindful. It was proposed by Younis and Fahmy in 2004, this method was created as a disseminated and energy proficient group development. Notice utilizes a blend of two unique boundaries for CH determination for example remaining energy of every hub and hub degree. A hub can be chosen as a CH relying upon its lingering energy along with some likelihood. The group arrangement happens when different hubs in the organization pick their separate CHs keeping up with least expense of correspondence. The fundamental goal of HEED is to draw out network lifetime as well as supporting versatile information conglomeration.

The two clustering parameters which are used in the algorithm are Residual Energy of the node as a primary parameter and Intra Cluster Communication Cost as a secondary parameter. Higher the residual energy of the node, higher the probability of that node to become a cluster head (CH)

2.11. Literature Review Summary

The writing study offers a comprehension of Wireless Sensor organizations and various approaches to improving the functional season of the organization. The ordinary energy safeguarding techniques have upward in message transmission and intricacy in bunch development and update exercises. The proposed strategies limit message transmission upward utilizing AI methods. They work on the development of bunches and improve the replastering of the organization utilizing the update cycle determined with the assistance of fluffy derivation framework. The proposed techniques additionally broaden the lifetime of Wireless Sensor Networks by joining rest booking as an energy saving system.

CHAPTER THREE

ANALYSIS OF RESULTS

Today, the greater part of the exploration is done to create efficient WSN which is just conceivable provided that the general organization lifetime increments, energy utilization (O. Younis et al. 2004) diminishes and the organization run with high security and unwavering quality. To accomplish this, numerous calculations have been executed. They are called energy-productive calculations. These calculations in their fundamental structure have previously been carried out on different organization conventions including LEACH, PEGASIS, HEED and so on. Be that as it may, these calculations need further examination for expansion in network lifetime, energy productivity and so forth. So, the proposed algorithm is one of the energy productive conventions intended to build the organization lifetime.

3.1. MATLAB Environment

The diversion (Satish Kannale Gaikwad Ranjitkumar Sharnappa, et al. 2013) is done remembering Custom Built Iterative Based Simulator for MATLAB 8.2.0.701 (R2017a) which duplicates the sending, getting, dropping and information sending, and so on. MATLAB is an enormous level explicit selecting language and intuitive climate for calculation movement, information insight, information evaluation, and numeric assessment. Utilizing the MATLAB thing, specific enrolling issues can be settled quicker than with conventional programming vernaculars, like C, C++ and Fortran. It is used in a wide extent of purposes, including sign and picture dealing with, trades, control setup, test and assessment, money related showing and examination. Add-on apparatus stash (collections of explicit explanation MATLAB limits, open freely) loosen up the MATLAB environment to deal with explicit classes of issues in these application areas. MATLAB gives different features to story work. MATLAB code can be composed with various vernaculars and applications, and gives out various new computations and applications. Network parameters and assumption

3.1.1. Assumptions

The network is homogeneous i.e. all nodes have equal initial energy at the time of deployment.

-The network is static and nodes are distributed randomly.

-There exists only one static base station which is positioned depending upon the environment (described later) chosen.

-The energy of sensor nodes cannot be recharged after deployment of network. i.e. the sensors are not reusable.

-Sensor nodes are not equipped with GPS so they are location unaware.

-No power and computational constraints on Base Station (BS).

-Deployed nodes can use power control to vary the amount of transmission power, which depends on the distance to the receiver.

-we assume all sensors are sensing at a fixed rate and thus always have data to send to base station.

The simulation of LEACH, PEGASIS and HEED was done in MATLAB. Some simulation plots have been shown in figures below. Here, we are going to describe some of the important aspects of the simulation like assumptions, simulation parameters, simulation network environments and energy dissipation model.

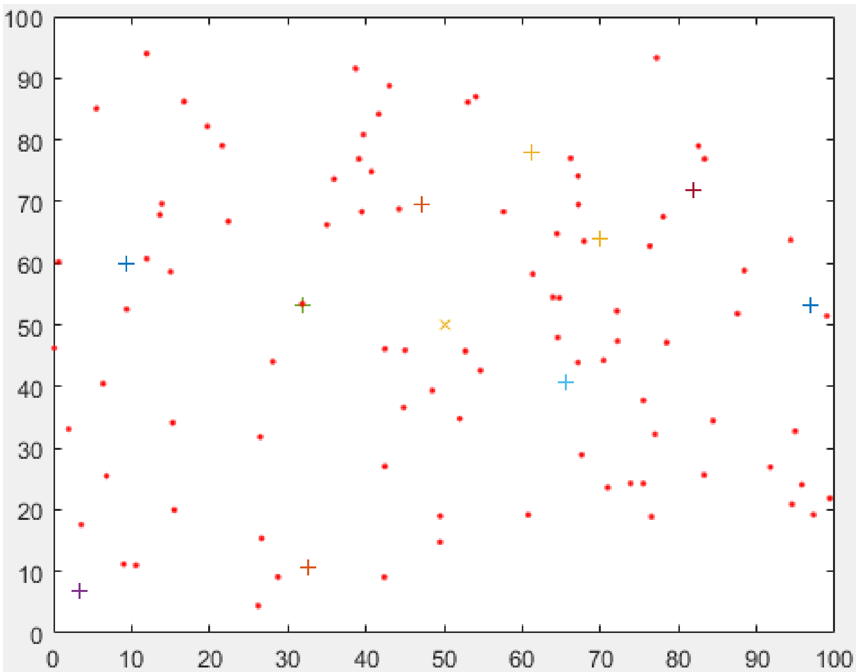


Figure 11. LEACH plot for 100 nodes at round 1334, dead nodes 20, cluster heads 6

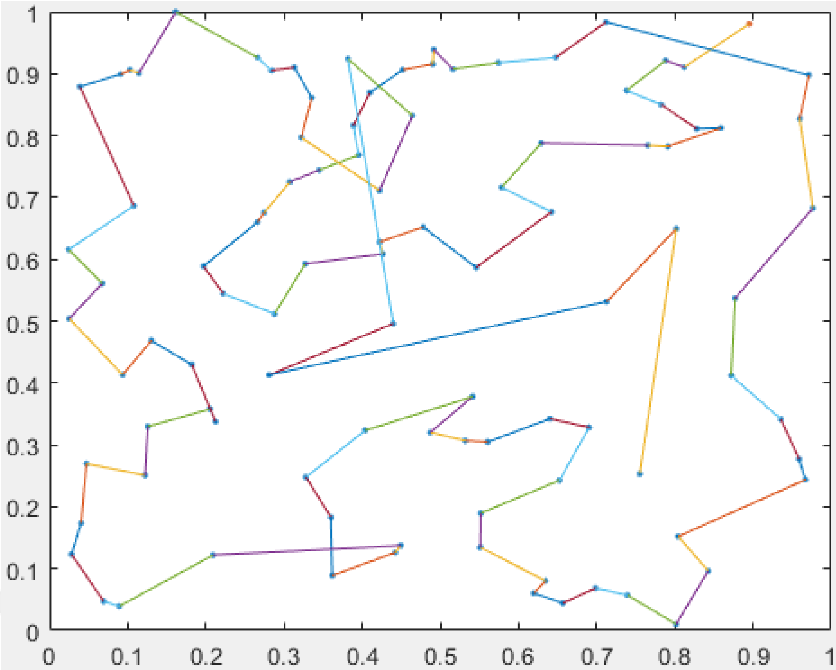


Figure 12. Chain formation in PEGASIS for 20 nodes

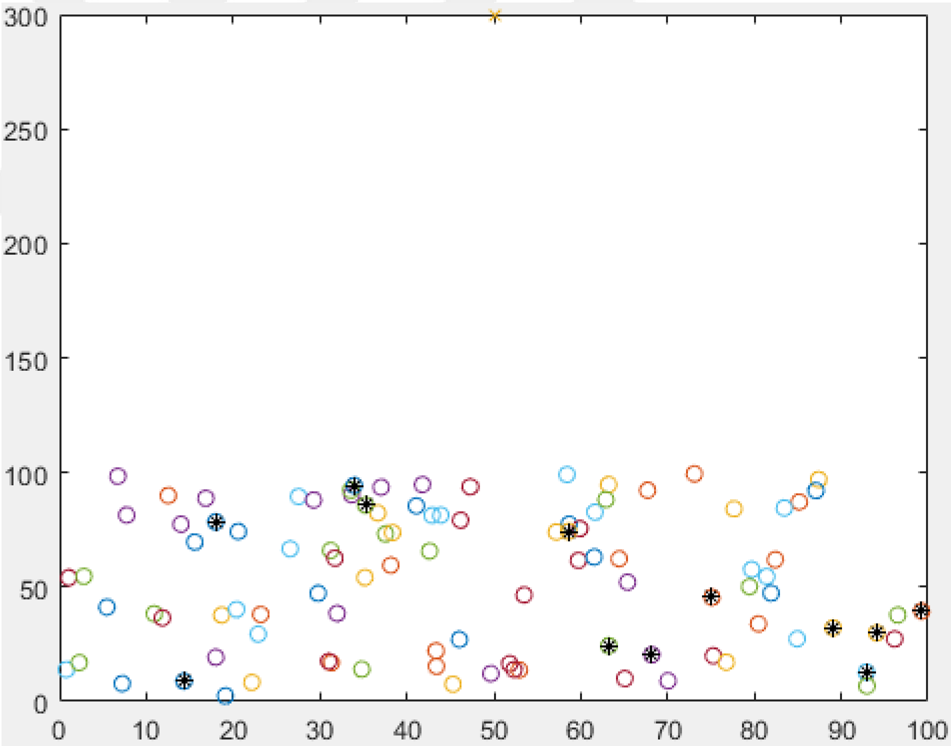


Figure 13. Chain formation in HEED for 200 nodes

The simulation parameters which were used in our simulation are described below in table 3.

Table 3. The simulation parameters

Sr.no.	Simulation Parameters	Values
1	E_{elec} (Electronics energy loss per bit)	50 nJ
2	E_{fs} (Free space energy loss per bit per m^2)	10 pJ
3	E_{mp} (Multi-path fading energy loss per bit per m^4)	0.0013 pJ
4	E_{aggr} (Data Aggregation energy loss per bit)	5 nJ
5	Packet length (bits)	2000
6	P (Desired fraction of cluster heads in LEACH)	0.05
7	P_{min} (Minimum probability to be a cluster head inHEED)	$5*10^{-4}$
8	C_{prob} (Initial probability to be a cluster head in HEED)	0.05

3.1.2. Network Environments

We selected four network environments and simulated the above mentioned routing protocols in these environments. They are described below in table 4. Also, the nodes were given randomized locations each time the network was initialized.

Table 4. Four kinds of simulation environments

Environment	Number of nodes	Area (m^2)	Base station location(m)	Initial energy(J)	Cluster Range (For HEED)(m)
1	100	100 X 100	(50 , 200)	0.5	25
2	200	200 X 200	(100 , 400)	1	50
3	500	500 X 500	(250 , 1000)	5	125
4	1000	1000X1000	(500 , 2000)	10	250

3.2. Result Analysis

3.2.1. Result of the Simulation

The simulation results obtained from the 4 network environments shows the overall relative behavior of LEACH, PEGASIS and HEED and is compared on metrics such as Load Balancing, Network Lifetime, Energy Consumption, and Scalability. The table 6 shows a summarized result of nodes death and the number of rounds of each protocol in each environment for comparing their behavior.

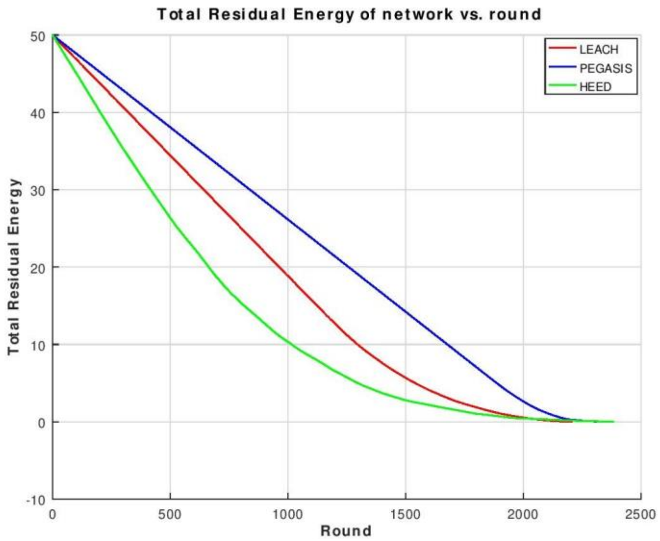
Table 5. Dead Nodes vs. Number of Rounds

Environment No.	Protocols	No. of rounds		
		First Node Dies	Half Node Dies	Last Node Dies
Env.:1	LEACH PEGASIS HEED	1165 1877 207	1611 2090 947	2209 2362 2384
Env.:2	LEACH PEGASIS HEED	255 1236 63	669 2663 498	1729 3600 1867
Env.:3	LEACH PEGASIS HEED	22 507 6	114 1919 192	432 3412 673
Env.:4	LEACH PEGASIS HEED	1 1 1	17 324 59	80 882 236

3.3. Graph Plots of LEACH, PEGASIS and HEED

The graph plots obtained from the simulation describes the performance of each protocol in the simulated environment and can be interpreted on the following metrics:

Figure 15, 16, 17 and 18 shows the graph of each protocol in the 4 environments. Each figure has 4 sub plots describing the total energy, dead nodes, average energy and variance of nodes energy in the network vs. number of rounds of protocol operations.



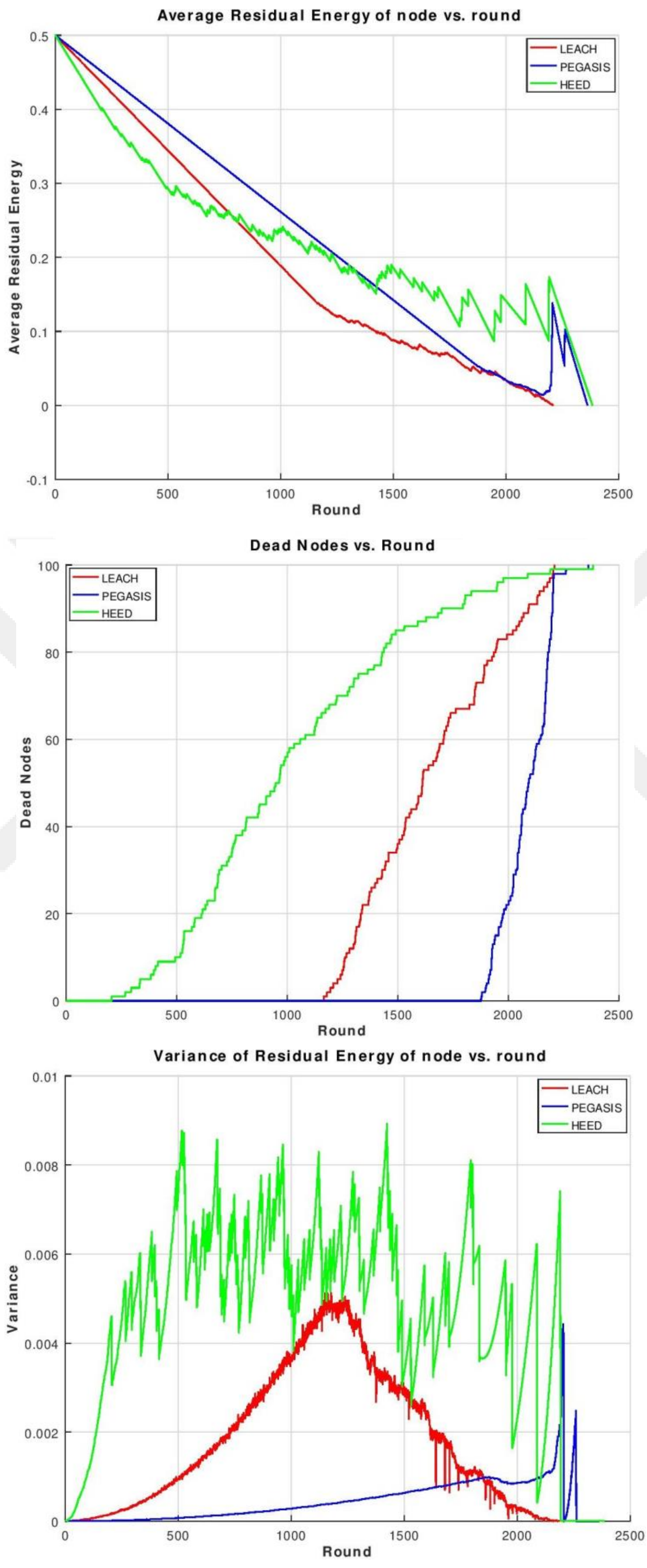
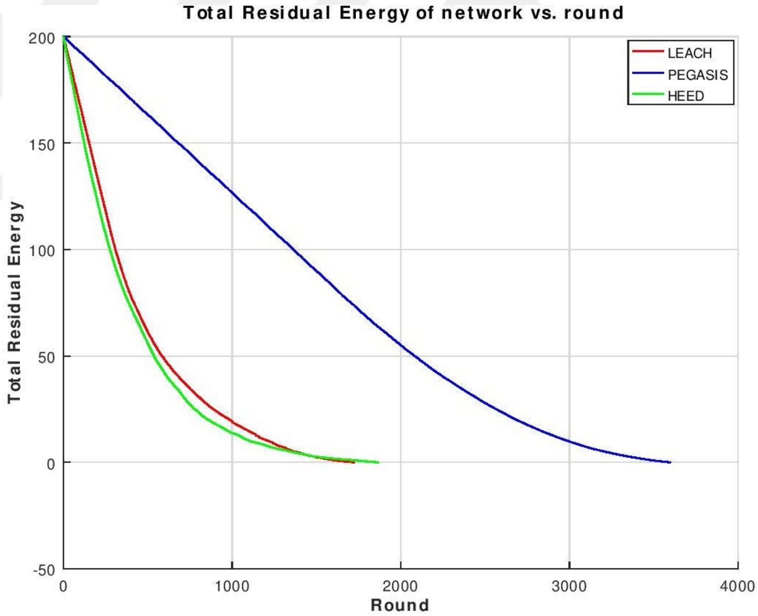


Figure 14. Graphs for Environment: 1

3.4. Interpretation of the Result

The graph plots obtained from the simulation describes the performance of each protocol in the simulated environment and can be interpreted on the following metrics.

Energy Consumption: The higher the total residual energy of the network for any pro- tocol at any given round, the lower the energy consumption and higher the energy efficiency of the protocol. From the sub plots of Total Residual Energy vs. Round, we can observe that the PEGASIS residual energy curve is above the other two curves in every environment, even when the size of network was increased to 1000 nodes and the network area to 1000 X 1000 m^2, so it is highly energy efficient as compared to other two protocols. LEACH on the other hand is better than HEED for smaller network like Environment 1 and 2 but, as the network size increases, HEED becomes better than LEACH as we can observe in graph plots of Environment 3 and 4.



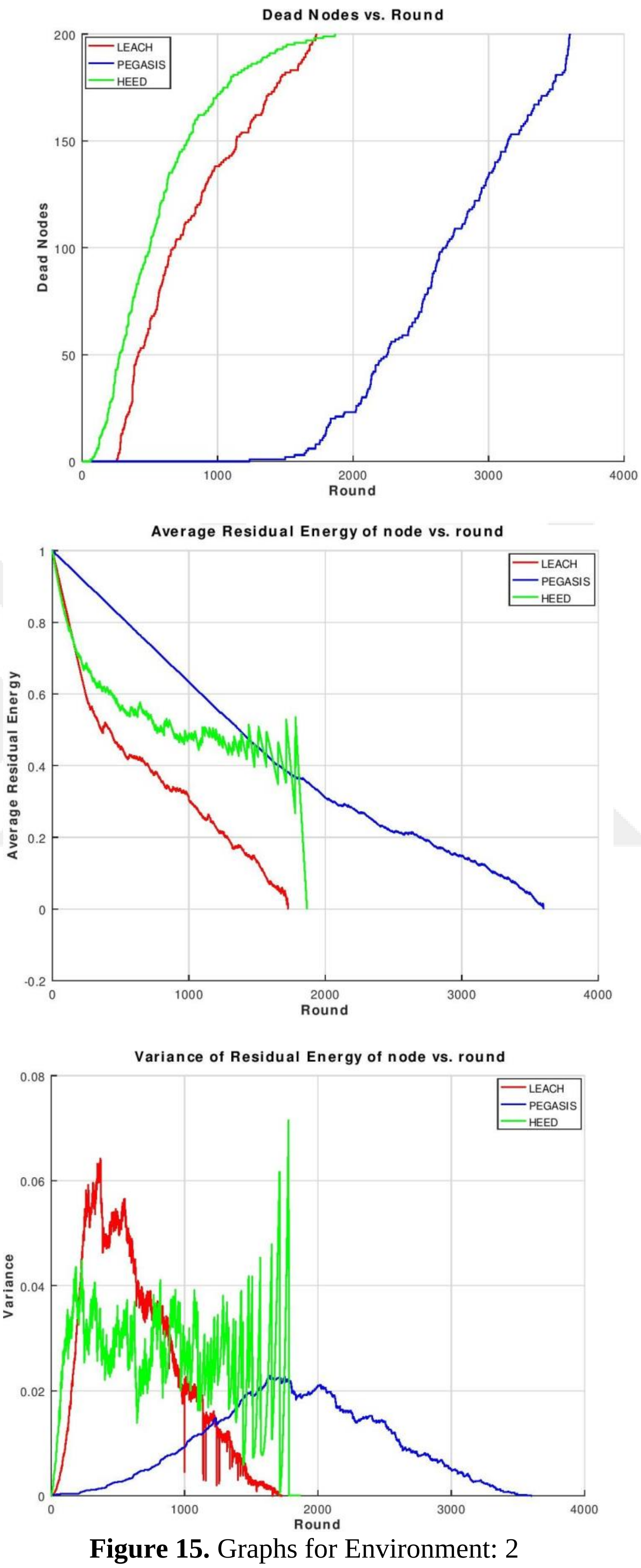
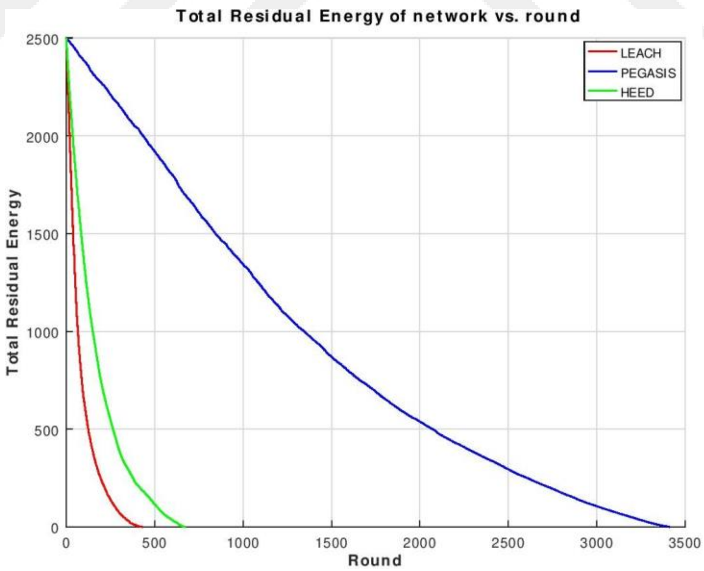


Figure 15. Graphs for Environment: 2

Load Balancing: Load balancing in WSN is the act of balancing the network traffic load on the entire network such that most of the nodes survive longer and consume similar amount of energy in transferring of data from one point to the other. From the sub plots of Average Residual Energy vs. Round and the Variance of the Nodes Residual Energy vs. Round, we can observe that the average residual energy of the nodes at any given round is higher in PEGASIS and the variation in each nodes' residual energy is lower, than in LEACH and HEED in every environment i.e. PEGASIS balances the network load better than other two protocols in every environment.

Stability Period: It is defined as the number of rounds from the starting round after which the first node dies (Georgios Smaragdakis et al. 2004). For many applications, the stability period should be higher to cover the entire network for most of the rounds to get better quality of service from the network. From the data shown in table 5.1 and the sub plots of Dead Nodes vs. Round of each environment, we can observer that the stability period of PEGASIS is far better than the other two protocols.



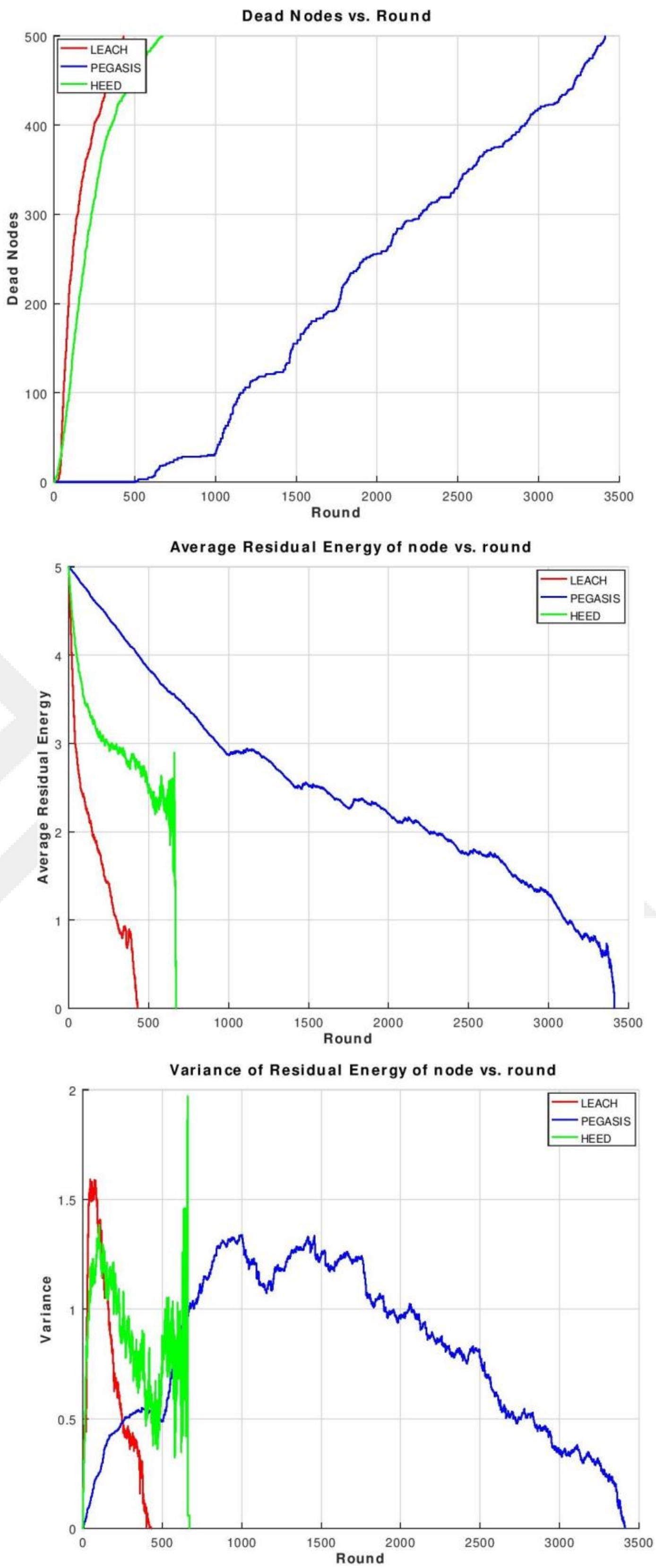
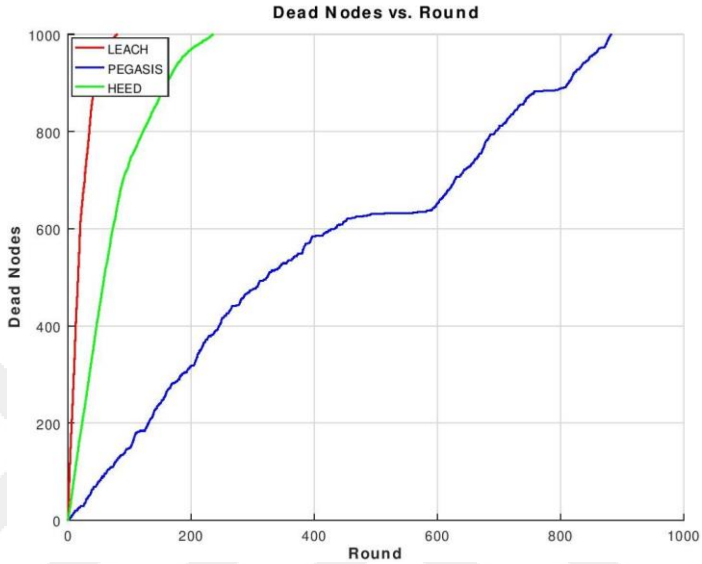
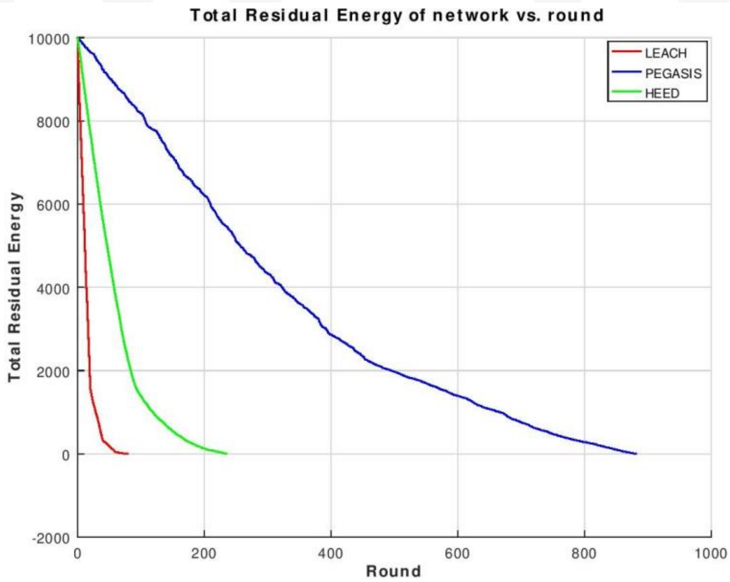


Figure 16. Graphs for Environment: 3

Network Lifetime: It is defined as the total number of rounds for which the protocol runs until the last node dies . From the sub plots Dead Nodes vs. Round in every graph, we can observe that PEGASIS has the highest network lifetime, followed by HEED and the lowest network lifetime is for LEACH in every environment.





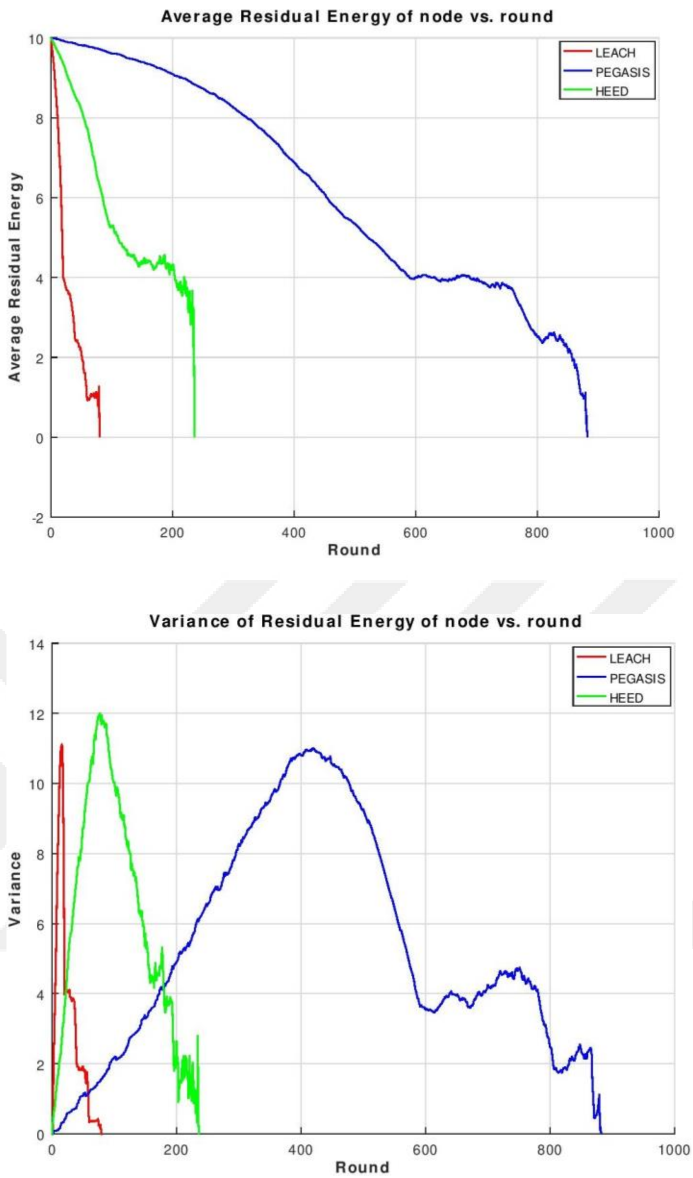


Figure 17. Graphs for Environment: 4

Scalability: Scalability is the property of a system to handle a growing amount of work by adding resources to the system . In WSN, increasing the network size should not reduce the effective performance of the network. From the graph, we can observe that although the total rounds decrease as size increases, but the gap in performance of all the protocols becomes more noteworthy. PEGASIS is scalable as compared to other two protocols as their total rounds decreases heavily and could not withstand higher network sizes.

3.5. Conclusion

From the simulation results, it is ovbious that PEGASIS is highly energy-efficient protocol as compared to LEACH and HEED when scalability is also one of the factors or design issues of WSN. Finally, a comparative study on the selected protocols is done based on several metrics such as: load balancing, energy consumption, stability period, scalability and network lifetime through simulations of these routing protocols in MATLAB on various simulation parameters and different simulation environments.

CONCLUSION AND RECOMMENDATIONS

Conclusion

From the simulation results, it is noticiable that PEGASIS is highly energy-efficient protocol as compared to LEACH and HEED when scalability is also one of the factors or design issues of WSN. This is because PEGASIS has two main objectives. First, reduce the power required by each node to transmit data per round by using collaborative techniques and spread the power draining uniformly over all nodes. Second, permit just neighbourhood coordination between hubs that are near one another so the transmission capacity consumed in correspondence is diminished. Additionally, the collected information is shipped off the base-station by just a single hub in the chain and each hub in the chain alternates in sending the information to the base-station. Not at all like, LEACH and HEED, it dodges bunch arrangement and in this manner lessens grouping overheads as well. Hence, PEGASIS performs better on all the metrics in consideration i.e., load balancing, stability period, network lifetime and scalability. Although more mature results can be found out if the analysis was done on the field sensor networks instead of simulation. Furthermore, WSN routing protocols is still a vast field of research and more scalable and energy-efficient protocols is needed for data gathering in wireless sensor networks.

Future Works

There are many potential applications in the field of wireless sensor networks and a number of directions for future work.

One possible future work is to analyses the contention and schedule based protocols at MAC layer when the deployment of the sensor nodes are randomized for a delay constrained, reliable, high throughput and energy-efficient wireless sensor network protocols.

Another possible work is to analyse the localization algorithms in WSN so that local location information can be found out without the use of GPS on energy-constrained sensors and use it to develop a better, energy-efficient and low latency routing protocols to expand the life expectancy of organization hubs in brutal conditions like oil fields, gas fields, woodlands, synthetic processing plants and underground mines and so on, and how to track down the place of portable hub with Distributed, Range-based and Beacon-based confinement procedure in unforgiving conditions which can additionally build the nature of administration given by remote sensor organizations.

One can also work on analysis of security issues and their possible solutions in WSN as with the increasing development of ubiquitous computing, the demand for WSN and their possible applications will also increase, which will then demand the security of such applications.

REFERENCES

Abdelzaher, T., Blum, B., Cao, Q., Chen, Y., Evans, D., George, J., George, S., Gu, L., He, T., Krishnamurthy, S. and Luo, L. (2014). 'Enviro-track: Towards an Environmental Computing Paradigm for Distributed Sensor Networks', 24th International Conference on Distributed Computing Systems Proceedings-IEEE, ISSN: 1063-6927, pp. 582-589.

Abdulaal, A. H., Shah, A. F. M. S., & Pathan, A. S. K. NM-LEACH: A Novel Modified LEACH Protocol to Improve Performance in WSN.

Adnan, M.A., Razzaque, M.A., Ahmed, I. and Isnin, I.F. (2016). 'Bio-mimic Optimization Strategies in Wireless Sensor Networks: A Survey', Sensors, MDPI Journal, Vol-14(1), ISSN:1424-8220, pp.299-345.

Ahlawat Manoj (2013). Wireless Sensor Network- A Theoretical Review International Journal of Wired and Wireless Communications vol.1, no.2, pp. 11-19.

Akyildiz, I. F. Su, W., Sankarasubramaniam, Y. and Cayirci, E. (2002). "Wireless sensor networks: a survey," Comput. Networks, vol. 38, no. 4, pp. 393–422.

Ali Newaz Bahar Shamim Sardar, Angona Sarker. Hierarchical routing protocol in wireless sensor network a survey. International Journal of Scientific & Engineering Research, 6(2), FEB 2015. ISSN 2229-5518.

Amar Kurmi, Jaya Dipti Lal, Charhate, SV & Sumit Ganvir (2015). Review: Cluster Head Selection using Fuzzy logic in Wireless Sensor Networks International Journal of Innovations in Engineering and Technology (IJIET), vol. 5, no. 1, pp.283-290.

Anasane, A. A. and Satao, R. A. (2016). "A Survey on Various Multipath Routing Protocols in Wireless Sensor Networks," Procedia Comput. Sci., vol. 79, no. 20, pp. 610–615.

Annie Selina, D. An Energy Efficient Self-Healing Sleep/Wakeup Scheduling Against Denial Of Service Attacks For Long Life Wireless Sensor Networks International Journal of Science, Engineering and Management, vol. 2, no. 12, pp.10-16.

Arampatzis, T., Lygeros, J. and Manesis, S. (2005). "A Survey of Applications of Wireless Sensors and Wireless Sensor Networks," Proc. 2005 IEEE Int. Symp. on, Mediterrean Conf. Control Autom. Intell. Control. 2005., pp. 719–724.

Arce, P., Guerri, J.C., Pajares, A. and Lázaro, O. (2017). 'Performance Evaluation of Video Streaming Over Ad-hoc Networks Using Flat and Hierarchical Routing Protoc', Mobile Networks and Applications Journal-Springer, Vol- 13(3-4), ISSN: 1383-469X, pp.324-336.

Arghavani, M., Esmaeili, M., Esmaeili, M. and Mohseni, F. (2017)."Ad Hoc Networks," vol. 65, pp. 91–98.

Atalik, G. For Parameter Estimation In Fuzzy Logistic Regression Iranian Journal of Fuzzy Systems, vol. 15, no. 1, pp. 91-102.

Bhanu Pratap Singh Jyoti Singh and Subhadra Bose Shaw. A survey on leach-based hierarchical routing protocols in wireless sensor networks. International Journal of Engineering Research & Technology (IJERT, 3(6), JUNE 2014. ISSN 2278-0181.

Bocchiaro, P. and Zamperini, A. (2016).“World â€TM s largest Science , Technology & Medicine Open Access book publisher c,” RFID Technol. Secur. Vulnerabilities, Countermeas.

Chen, Z., Xiao, Y., Li, X. and Li, R. (2013).“A Clustering Protocol for Wireless Sensor Networks Based on Energy Potential Field,” vol. 2013.

D. Kohanbash, A. Valada, and G. Kantor, “Base Station Design and Architecture for Wireless Sensor Networks.”

Dong, Q. and Dargie, W. (2013). A survey on mobility and mobilityaware MAC protocols in wireless sensor networks. IEEE communications surveys & tutorials. 15(1): 88-100.

Dudgeon, D. and Mersereau, R. (1984). In Multidimensional Digital Signal Processing, chapter 6. Prentice-Hall, Inc.

Enam, R. N., Imam, M. and Qureshi, R. I. (2012). “Energy Consumption in Random Cluster Head selection Phase of,” vol. 30, no. May, pp. 38–44, 2012.

Fan Wang, Sining Wu, Kunpeng Wang & Xiaopeng, Hu (2016). EnergyBased on Data Change Rate for Wireless Sensor Networks IEEE Sensors Journal, vol. 16, no. 13, pp. 5471-5480..

Fateh Benazir & Manimaran Govindarasu (2015). Joint Scheduling of Tasks and Messages for Energy Minimization in Interference-Aware Real-Time Sensor Networks IEEE Transactions on Mobile Computing, vol.14, no.1, pp. 86-98.

Geetha, V., Kallapur, P. V. and Tellajeera, S. (2012). “Clustering in Wireless Sensor Networks: Performance Comparison of LEACH & LEACH-C Protocols UsingNS2,” Procedia Technol., vol. 4, pp. 163–170.

Georgios Smaragdakis, Ibrahim Matta, and Azer Bestavros (2004). Sep: A stable election protocol for clustered heterogeneous wireless sensor networks.

Giacomin, J. C., Correia, L. H. A., Heimfarth, T., Pereira, G. M., Silva, V. F. and De Santana, J. L. P. (2010). “Radio channel model of wireless sensor networks operating in 2.4 ghz ism band,” INFOCOMP J. Comput. Sci., vol. 9, no. 1, pp. 98–106.

Guo, P., Jiang, T., Zhang, Q. & Zhang, K. (2012). Sleep scheduling for critical event monitoring in wireless sensor networks IEEE Transactions on Parallel Distributed Systems, vol. 23, no. 2, pp. 345 352.

Guyennet, H., Hadjila, M. and Feham, M. A chain-based routing protocol to maximize the lifetime of wireless sensor networks. Wireless Sensor Network, 5(5):116–120, 2013. doi: 10.4236/wsn.2013.55014. URL http://www.scirp.org/journal/ PaperInformation.aspx?PaperID=31780.

Hasn, Y. M. and Hussein, S. A. (2016). “Energy Efficient Routing Protocols for Wireless Sensor Networks Abstract: Designing An Energy Efficient Routing Protocol For Wireless Sensor Network (WSN) Has For,” IOSR J. Electron. Commun. Eng., vol. 11, no. 2, pp. 2278–2834.

Heinzelman, W. R., Chandrakasan, A. and Balakrishnan, H. Energy-efficient communication protocol for wireless microsensor networks. In Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, volume 2, page 10, Jan 2000. doi: 10.1109/HICSS.2000.926982.

Jin-Shyan Lee & Wei-Liang Cheng (2012). Fuzzy-Logic-Based Clustering Approach for Wireless Sensor Networks Using Energy Predication IEEE Sensors Journal, vol. 12, no. 9, pp. 2891-2897.

Kumar, V., Dhok, S. B., Tripathi, R. and Tiwari, S. (2014). “A Review Study of Hierarchical Clustering Algorithms for Wireless Sensor Networks,” vol. 11, no. 3, pp. 92–101.

Li Qing, Qingxin Zhu, and Mingwen Wang. Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks. Computer Communications, 29(12):2230 – 2237, 2006. ISSN 0140-3664. doi: https://doi.org/10.1016/ j.comcom.2006.02.017.

Lindsey, S. and Raghavendra, C. S. Pegasis: Power-efficient gathering in sensor information systems. In Proceedings, IEEE Aerospace Conference, volume 3, pages 3–3, March 2002. doi: 10.1109/AERO.2002.1035242.

Liu, X. (2012). A survey on clustering routing protocols in wireless sensor networks, vol. 12, no. 8.

Massad, Y. E., Goyeneche, M., Astrain, J. J. and Villadangos, J. (2008). “Data Aggregation in Wireless Sensor Networks,” 2008 3rd Int. Conf. Inf. Commun. Technol. From Theory to Appl., vol. 2, no. June, pp. 1040–1052.

Matin, M. A. and Islam, M. M. (2012). “Overview of Wireless Sensor Network,” Wirel. Sens. Networks - Technol. Protoc., pp. 3–24.

Matin, M.A. and Islam, M.M. Overview of wireless sensor network. In Mohammad A. Matin, editor, Wireless Sensor Networks, chapter 1. IntechOpen, Rijeka, 2012. doi: 10.5772/49376. URL https://doi.org/10.5772/49376.

Mazinani, S.M. and Safari, M. (2015). Secure Localization Approach in Wireless Sensor Network. International Journal of Machine Learning and Computing. 5(6).

Mhatre, V. and Rosenberg, C. (2004). “Homogeneous vs heterogeneous clustered sensor networks: a comparative study,” 2004 IEEE Int. Conf. Commun. (IEEE Cat. No.04CH37577), vol. 6, pp. 1–6.

Migabo, M.E., Djouani, K. Kurien, A.M. and Olwal, T.O. (2015). Gradient-based Routing for Energy Consumption Balance in Multiple Sinks-based Wireless Sensor Networks. Procedia Computer Science. 63: 488-493.

Migabo, M.E., K. Djouani, A.M. Kurien and Olwal, T.O. (2015). Gradient-based Routing for Energy Consumption Balance in Multiple Sinks-based Wireless Sensor Networks. Procedia Computer Science. 63: 488-493.

Mohammad Abu Alsheikh, Shaowei Lin, Dusit Niyato & Hwee-Pink Tan (2014). Machine Learning in Wireless Sensor Networks: Algorithms, Strategies, and Applications IEEE Communication Surveys & Tutorials, vol. 16, no. 4, pp. 1-24.

Narayanan, A.E., Narmadha, C., Marichamy, P. (2018). A survey on hierarchical-based routing protocols for wireless sensor networks. International Journal of Pure and Applied Mathematics, 119(16), ISSN 663-3676.

Nayak, P. & Vathasavai, B. (2017). Energy efficient clustering algorithm for multi-hop wireless sensor network using type-2 fuzzy logic IEEE Sensors Journal, vol. 17, no. 14, pp. 4492 4499.

No, I. and Majhi, S. (2014). “Available Online at www.ijarcs.info 3D Localization in Wireless Sensor Networks,” vol. 5, no. 6, pp. 66–71.

Noman Shabbir and Syed Rizwan Hassan. Routing protocols for wireless sensor networks (wsns). In Philip Sallis, editor, Wireless Sensor Networks, chapter 2. IntechOpen, Rijeka, 2017. doi: 10.5772/intechopen.70208. URL https://doi.org/ 10.5772/intechopen.70208.

Padmalaya Nayak & Anurag Devulapalli (2016). A Fuzzy Logic-Based Clustering Algorithm for WSN to Extend the Network Lifetime IEEE Sensors Journal, vol. 16, no. 1, pp.137-144.

Pu-Tai Yang and Seokcheon Lee. A distributed reclustering hierarchy routing protocol using social welfare in wireless sensor networks. International Journal of Distributed Sensor Networks, 8(4), 2012. doi: 10.1155/2012/681026. URL https://doi.org/ 10.1155/2012/681026.

Reed, C., Chen, D., Yao, K., Hudson, R. and Lorenzelli, F. (1998).Blind beamforming on a randomly distributed sensor array system. In Proceedings of SiPS, Oct.

Sadananda, P., W. Trojet and Mouzna, J. (2013). Multicast Authentication Framework for Hierarchical Networks using Chinese Remainder Theorem. International Journal of Computer Applications,82(11)..

Salayma, M., Al-Dubai, A., Romdhani, I & Nasser, Y. (2017). Wireless body area network (WBAN): A survey on reliability, fault tolerance, and technologies coexistence ACM Computing Surveys, vol. 50, no. 1, pp. 1 35.

Satish Kannale Gaikwad Ranjitkumar Sharnappa and Vireshkumar Swamy. Enhanced leach multipath based energy efficient routing for wireless sensor network. International Journal of Advanced Research in Computer and Communication Engineering, 4(6):6, 2015. ISSN 2278-1021. doi: 10.17148/IJARCCE.2015.4613.

Sohn, I., Lee, JH. & Lee, SH. (2016). Low-energy adaptive clustering hierarchy using affinity propagation for wireless sensor networks IEEE Communication Letters vol.20 no.3, 558 561

Song Yang, Chi Zhang & Yuguang Fang, (2010). Minimum Energy Scheduling in Multi-Hop Wireless Networks with Retransmissions IEEE Transactions on Wireless Communications, vol.9, no.1, pp. 348-355.

T. Of, “a Comparative Study of Clusterhead Selection Algorithms in Wireless Sensor Networks,” Int. J. Comput. Sci. Eng. Surv., vol. 2, no. 4, pp. 153–164, 2011.

Taheri, H., Neamatollahi, P., Younis, M., Naghibzadeh, S. & Yaghmaee, MH. (2012). An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic Ad Hoc Networks, vol. 10, no. 7, pp. 1469 1481

Tandel, R. I. (2016). “Leach Protocol in Wireless Sensor Network : A Survey,” vol. 7, no. 4, pp. 1894–1896.

Thakkar, A. & Kotecha, K. (2014). Cluster head election for energy and delay constraint applications of wireless sensor network IEEE Sensors Journal, vol. 14, no. 8, pp. 2658 2664.

Uma, J. S. S. (2015). “Human Interaction Pattern Mining Using Enhanced Artificial Bee Colony Algorithm S.,” Int. J. Innov. Res. Comput. Commun. Eng., vol. 3, no. 10, pp. 10131–10138.

Vasundhara, V. Ghate & Vaidehi Vijayakumar (2018). Machine Learning for Data Aggregation in WSN: A Survey International Journal of Pure and Applied Mathematics, vol. 118, no. 24, pp. 1-12.

Vishal Krishna Singh, Manish Kumar & Shekhar Verma (2019). Accurate Detection of Important Events in WSN IEEE Systems Journal, vol. 13, no. 1, pp. 248-257.

W. S. Email, “Data-centric routing in a wireless sensor network NETWORKS OF SENSOR,” vol. 2, no. 2, pp. 468–473, 2013.

Wang, J., Li, B., Xia, F., Kim, C.-S. and Kim, J.-U. (2014). “An Energy Efficient Distance- Aware Routing Algorithm with Multiple Mobile Sinks for Wireless Sensor Networks,” Sensors, vol. 14, no. 8, pp. 15163–15181.

Wang, J., Gao, Y., Yin, X., Li, F., & Kim, H. J. (2018). An enhanced PEGASIS algorithm with mobile sink support for wireless sensor networks. *Wireless Communications and Mobile Computing*, *2018*.

Wang, X. and A. A, (2004). "Wide-Band TD-CDMA MAC With Minimum-Power Wireless Multimedia Networks," Computer (Long. Beach. Calif)., vol. 12, no. 1, pp. 103–116.

Yadav, L. and Sunitha, C. (2014). Low Energy Adaptive Clustering Hierarchy in Wireless Sensor Network (LEACH). International Journal of Computer Science and Information Technologies. 5(3): 4661-4664.

Younis, O. and Fahmy, S. Heed: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Transactions on Mobile Computing, 3(4): 366–379, Oct 2004. ISSN 1536-1233. doi: 10.1109/TMC.2004.41...

Yuanchang Zhong, Lin Cheng, Liang Zhang, Yongduan Song, and Hamid Reza Karimi. Energy-efficient routing control algorithm in large-scale wsn for water environment monitoring with application to three gorges reservoir area. The Scientific World Journal,. 2014:9, 2014. doi: 10.1155/2014/802915.

Zhang, Y., Chen, W., Liang, J., Zheng, B. & Jiang, S. (2015). A network topology control and identity authentication protocol with support for sensor nodes.

Zhong, C., Eliasson, J., Makitaavola, H. and Zhang, F. (2010). A clusterbased localization method using RSSI for heterogeneous wireless sensor networks. In Wireless Communications Networking and Mobile Computing. 6th IEEE International Conference on. 1-6.

APPENDIXES

APPENDIX - 1. HEED Protocol Code

```
clear;
%Field Dimensions - x and y maximum (in meters)
xm = 100;
ym = 100;
sink.x=50;
sink.y=300;
%Number of Nodes in the field
n = 100;
%Optimal Election Probability of a node to become cluster head
p=0.05;
packetLength =2000;

%Energy values in Joules
%Initial Energy
Eo = 1;
%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=10*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;

INFINITY = 999999999999999;
%maximum number of rounds
rmax=5000;


%Computation of do
do=sqrt(Efs/Emp);
figure (1);
%Creation of the random Sensor Network
for i=1:1:n
    S(i).xd=rand(1,1)*xm; %random x coordinates
    XR(i)=S(i).xd; %assign it to XR vector
    S(i).yd=rand(1,1)*ym; %random y coordinates
    YR(i)=S(i).yd; %assign it to YR vector
    S(i).G=0;
    plot(S(i).xd,S(i).yd,'o');
    %initially there are no cluster heads only nodes
    S(i).type='N'; %N denotes "Not a Clusterhead" while C
denotes "Clusterhead"
    S(i).E=Eo; %all nodes have initial energy Eo=0.5J
    S(i).ENERGY=0;
    hold on;
end
% The 101st node is the sink
S(n+1).xd=sink.x;
```

```
S(n+1).yd=sink.y;

%First Iteration
figure(1);
%counter for CHs
countCHs=0;
%counter for CHs per round
rcountCHs=0;
cluster=1;

countCHs;
rcountCHs=rcountCHs+countCHs;
flag_first_dead=0;

for r=1:1:rmax %?,ÿ1
  r
  %Operation for epoch
  if(mod(r, round(1/p))==0)
     for i=1:1:n
        S(i).G=0;
        S(i).cl=0;
     end
  end

hold off;

%Number of dead nodes
dead=0;

%counter for bit transmitted to Bases Station and to Cluster
Heads
packets_TO_BS=0;
packets_TO_CH=0;
%counter for bit transmitted to Bases Station and to Cluster
Heads per round
PACKETS_TO_CH(r)=0;
PACKETS_TO_BS(r)=0;
figure(1);

for i=1:1:n
    %checking if there is a dead node
     if (S(i).E<=0)
         plot(S(i).xd,S(i).yd,'red .');
       dead=dead+1;    %if energy is less than 0 then the node
is dead.
       hold on;
     end
     if (S(i).E>0)
        plot(S(i).xd,S(i).yd,'o');
        S(i).type='N'; %if energy is more than 0 then it is
not a clusterhead
        hold on;
     end
end
```

```
plot(S(n+1).xd,S(n+1).yd,'x');

% if (dead == n)    %if no. of dead nodes is equal to total
no. of nodes then the whole network is dead.
%    break;
% end

STATISTICS(r).DEAD=dead;
DEAD(r)=dead;

%When the first node dies
if (dead==1)
    if(flag_first_dead==0)
        first_dead=r;
        flag_first_dead=1;
    end
end

countCHs=0;
cluster=1;
for i=1:1:n
   if(S(i).E>0)
     temp_rand=rand;
     if ((S(i).G)<=0) %ý???
        %Election of Cluster Heads
        if(temp_rand <=(p/(1-p*mod(r,round(1/p)))))
            countCHs = countCHs+1;

            S(i).type = 'C';
            S(i).G = round(1/p)-1;
            C(cluster).xd = S(i).xd; % C is a vector storing
details of all the clusterheads
            C(cluster).yd = S(i).yd;
            plot(S(i).xd,S(i).yd,'k*');
            distance=sqrt((S(i).xd-(S(n+1).xd))^2 + (S(i).yd-
(S(n+1).yd))^2);%sink?

            C(cluster).distance = distance;
            C(cluster).id = i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;
            %Calculation of Energy dissipated
            distance;
            if(distance>=do)
                 S(i).E = S(i).E-((ETX+EDA)*packetLength+
Emp*packetLength*(distance*distance));
            else
                 S(i).E = S(i).E-((ETX+EDA)*packetLength+
Efs*packetLength*(distance*distance));
            end
            packets_TO_BS = packets_TO_BS+1;
            PACKETS_TO_BS(r) = packets_TO_BS;
        end
```

```
      end
    end
end

STATISTICS(r).CLUSTERHEADS = cluster-
1;%??r???,r?0?,?1;cluster?-1,?1
CLUSTERHS(r)= cluster-1;

%Election of Associated Cluster Head for Normal Nodes
for i=1:1:n
   if (S(i).type=='N' && S(i).E>0) %??
    % min_dis = sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-
S(n+1).yd)^2 );%???sink?
     min_dis = INFINITY;
     if(cluster-1>=1)%??
         min_dis_cluster = 1;
         %??
         for c = 1:1:cluster-1 %??cluster-1
            %temp = min(min_dis,sqrt( (S(i).xd - C(c).xd)^2 +
(S(i).yd - C(c).yd)^2 ) );
            temp = sqrt((S(i).xd - C(c).xd)^2 + (S(i).yd -
C(c).yd)^2);
            if (temp<min_dis)
                min_dis = temp;
                min_dis_cluster = c;
            end
            %????

         end

         %Energy dissipated by associated Cluster Head?????,??
         min_dis;
         if (min_dis > do)

             S(i).E = S(i).E - (ETX*(packetLength) +
Emp*packetLength*( min_dis * min_dis)); %??
         else

            S(i).E = S(i).E -(ETX*(packetLength) +
Efs*packetLength*( min_dis * min_dis)); %??
         end


         %Energy dissipated %?????,??????
         if(min_dis > 0)
            S(C(min_dis_cluster).id).E =
S(C(min_dis_cluster).id).E - ((ERX + EDA)*packetLength );
%????


           PACKETS_TO_CH(r) = n - dead - cluster + 1; %??????
         end

         S(i).min_dis = min_dis;
```

```
        S(i).min_dis_cluster = min_dis_cluster;

    end
  end
end
%hold on;

countCHs;
rcountCHs = rcountCHs + countCHs;
if dead==n
    break;
end
end

x=1:1:r;
y=1:1:r;
%z=1:1:r;

for i=1:1:r;
    x(i)=i;
    y(i) = n - STATISTICS(i).DEAD;
    %z(i)=CLUSTERHS(i);
end
%plot(x,y,'r',x,z,'b');
figure(2);
plot(x,y,'r');
hold on;
title ('ALIVE NODES vs ROUNDS');
xlabel ('number of rounds');
ylabel ('number of alive nodes');
hold on;
figure(3);
hold on;
plot(x,DEAD,'r');
hold on;
xlabel ('number of rounds');
ylabel ('number of dead nodes');
title ('DEAD NODES vs ROUNDS');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%   STATISTICS
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%  DEAD  : a rmax x 1 array of number of dead nodes/round
%  DEAD_A : a rmax x 1 array of number of dead Advanced
nodes/round
%  DEAD_N : a rmax x 1 array of number of dead Normal
nodes/round
%  CLUSTERHS : a rmax x 1 array of number of Cluster
Heads/round
%  PACKETS_TO_BS : a rmax x 1 array of number packets send to
Base Station/round
%  PACKETS_TO_CH : a rmax x 1 array of number of packets send
to ClusterHeads/round
```

```
%  first_dead: the round where the first node died
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%
%??sink(50,175) ,ctrPacketLength=200,packetLength=4000,Eo=2J.
```

APPENDIX – 2. Protocol

```
 %LEACH
clear;
%Field Dimensions - x and y maximum (in meters)
xm=100;
ym=100;

%x and y Coordinates of the Sink
sink.x=0.5*xm;
sink.y=0.5*ym;

%Number of Nodes in the field
n=100;

%Optimal Election Probability of a node
%to become cluster head
p=0.02;

%Energy Model (all values in Joules)
%Initial Energy
Eo=0.5;
%Eelec=Etx=Erx
ETX=50*0.000000001;
ERX=50*0.000000001;
%Transmit Amplifier types
Efs=10*0.000000000001;
Emp=0.0013*0.000000000001;
%Data Aggregation Energy
EDA=5*0.000000001;

%Percentage of nodes than are advanced
m=0.1;
%\alpha
a=1;

%maximum number of rounds
rmax=3499;

%%%%%%%%%%%%%%%%%%%%%%% END OF PARAMETERS
%%%%%%%%%%%%%%%%%%%%%%

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

```
%Creation of the random Sensor Network
figure(1);
for i=1:1:n
    S(i).xd=rand(1,1)*xm;
    XR(i)=S(i).xd;
    S(i).yd=rand(1,1)*ym;
    YR(i)=S(i).yd;
    S(i).G=0;
    %initially there are no cluster heads only nodes
    S(i).type='N';

    temp_rnd0=i;
    %Random Election of Normal Nodes
    if (temp_rnd0>=m*n+1)
        S(i).E=Eo;
        S(i).ENERGY=0;
        %%plot(S(i).xd,S(i).yd,'o');
        hold on;
    end
    %Random Election of Advanced Nodes
    if (temp_rnd0<m*n+1)
        S(i).E=Eo*(1+a);
        S(i).ENERGY=1;
        %%plot(S(i).xd,S(i).yd,'+');
         hold on;
    end
end

S(n+1).xd=sink.x;
S(n+1).yd=sink.y;
%%plot(S(n+1).xd,S(n+1).yd,'x');


%First Iteration
figure(1);

%counter for CHs
countCHs=0;
%counter for CHs per round
rcountCHs=0;
cluster=1;

countCHs;
rcountCHs=rcountCHs+countCHs;
flag_first_dead=0;

for r=0:1:rmax
    r

  %Election Probability for Normal Nodes
  pnrm=( p/ (1+a*m) );
  %Election Probability for Advanced Nodes
  padv= ( p/(1+a*m) );
```

```
  %Operation for heterogeneous epoch
  if(mod(r, round(1/pnrm) )==0)
    for i=1:1:n
        S(i).G=0;
        S(i).cl=0;
    end
  end

 %Operations for sub-epochs
 if(mod(r, round(1/padv) )==0)
    for i=1:1:n
        if(S(i).ENERGY==1)
            S(i).G=0;
            S(i).cl=0;
        end
    end
  end


hold off;

%Number of dead nodes
dead=0;
%Number of dead Advanced Nodes
dead_a=0;
%Number of dead Normal Nodes
dead_n=0;

%counter for bit transmitted to Bases Station and to Cluster
Heads
packets_TO_BS=0;
packets_TO_CH=0;
%counter for bit transmitted to Bases Station and to Cluster
Heads
%per round
PACKETS_TO_CH(r+1)=0;
PACKETS_TO_BS(r+1)=0;

figure(1);

for i=1:1:n
    %checking if there is a dead node
    if (S(i).E<=0)
        plot(S(i).xd,S(i).yd,'red .');
        dead=dead+1;
        if(S(i).ENERGY==1)
            dead_a=dead_a+1;
        end
        if(S(i).ENERGY==0)
            dead_n=dead_n+1;
        end
        hold on;
    end
```

```
    if S(i).E>0
        S(i).type='N';
        if (S(i).ENERGY==0)
        plot(S(i).xd,S(i).yd,'o');
        end
        if (S(i).ENERGY==1)
        plot(S(i).xd,S(i).yd,'+');
        end
        hold on;
    end
end
plot(S(n+1).xd,S(n+1).yd,'x');


STATISTICS(r+1).DEAD=dead;
DEAD(r+1)=dead;
DEAD_N(r+1)=dead_n;
DEAD_A(r+1)=dead_a;

%When the first node dies
if (dead==1)
    if(flag_first_dead==0)
        first_dead=r;
        flag_first_dead=1;
    end
end


if (dead>=19 && dead<=21)
    dead_20=r;
end

if (dead>=48 && dead<=52)
    dead_50=r;
end

countCHs=0;
cluster=1;
for i=1:1:n
   if(S(i).E>0)
   temp_rand=rand;
   if ( (S(i).G)<=0)

 %Election of Cluster Heads for normal nodes
 if( ( S(i).ENERGY==0 && ( temp_rand <= ( pnrm / ( 1 - pnrm *
mod(r,round(1/pnrm)) )) ) )  )

            countCHs=countCHs+1;
            packets_TO_BS=packets_TO_BS+1;
            PACKETS_TO_BS(r+1)=packets_TO_BS;

            S(i).type='C';
            S(i).G=100;
            C(cluster).xd=S(i).xd;
```

```
            C(cluster).yd=S(i).yd;
            plot(S(i).xd,S(i).yd,'k*');

            distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 +
(S(i).yd-(S(n+1).yd) )^2 );
            C(cluster).distance=distance;
            C(cluster).id=i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;

            %Calculation of Energy dissipated
            distance;
            if (distance>do)
                S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*(
distance*distance*distance*distance ));
            end
            if (distance<=do)
                S(i).E=S(i).E- ( (ETX+EDA)*(4000)  +
Efs*4000*( distance * distance ));
            end
        end



 %Election of Cluster Heads for Advanced nodes
 if( ( S(i).ENERGY==1 && ( temp_rand <= ( padv / ( 1 - padv *
mod(r,round(1/padv)) )) ) )  )

            countCHs=countCHs+1;
            packets_TO_BS=packets_TO_BS+1;
            PACKETS_TO_BS(r+1)=packets_TO_BS;

            S(i).type='C';
            S(i).G=100;
            C(cluster).xd=S(i).xd;
            C(cluster).yd=S(i).yd;
            plot(S(i).xd,S(i).yd,'k*');

            distance=sqrt( (S(i).xd-(S(n+1).xd) )^2 +
(S(i).yd-(S(n+1).yd) )^2 );
            C(cluster).distance=distance;
            C(cluster).id=i;
            X(cluster)=S(i).xd;
            Y(cluster)=S(i).yd;
            cluster=cluster+1;

            %Calculation of Energy dissipated
            distance;
            if (distance>do)
                S(i).E=S(i).E- ( (ETX+EDA)*(4000) + Emp*4000*(
distance*distance*distance*distance ));
            end
            if (distance<=do)
```

```
                S(i).E=S(i).E- ( (ETX+EDA)*(4000)  +
Efs*4000*( distance * distance ));
            end
        end

    end
  end
end



STATISTICS(r+1).CLUSTERHEADS=cluster-1;
CLUSTERHS(r+1)=cluster-1;

%Election of Associated Cluster Head for Normal Nodes
for i=1:1:n
   if ( S(i).type=='N' && S(i).E>0 )
     if(cluster-1>=1)
       min_dis=sqrt( (S(i).xd-S(n+1).xd)^2 + (S(i).yd-
S(n+1).yd)^2 );
       min_dis_cluster=1;
       for c=1:1:cluster-1
           temp=min(min_dis,sqrt( (S(i).xd-C(c).xd)^2 +
(S(i).yd-C(c).yd)^2 ) );
           if ( temp<min_dis )
               min_dis=temp;
               min_dis_cluster=c;
           end
       end

       %Energy dissipated by associated Cluster Head
            min_dis;
            if (min_dis>do)
                S(i).E=S(i).E- ( ETX*(4000) + Emp*4000*(
min_dis * min_dis * min_dis * min_dis));
            end
            if (min_dis<=do)
                S(i).E=S(i).E- ( ETX*(4000) + Efs*4000*(
min_dis * min_dis));
            end
        %Energy dissipated
        if(min_dis>0)
            S(C(min_dis_cluster).id).E =
S(C(min_dis_cluster).id).E- ( (ERX + EDA)*4000 );
         PACKETS_TO_CH(r+1)=n-dead-cluster+1;
        end

       S(i).min_dis=min_dis;
       S(i).min_dis_cluster=min_dis_cluster;

   end
 end
end
hold on;
```

```
countCHs;
rcountCHs=rcountCHs+countCHs;


%Code for Voronoi Cells
%Unfortynately if there is a small
%number of cells, Matlab's voronoi
%procedure has some problems

%[vx,vy]=voronoi(X,Y);
%plot(X,Y,'r*',vx,vy,'b-');
% hold on;
% voronoi(X,Y);
% axis([0 xm 0 ym]);

end

x=1:1:r;
y=1:1:r;
%z=1:1:r;

for i=1:1:r;
    x(i)=i;
    y(i) = n - STATISTICS(i).DEAD;
    %z(i)=CLUSTERHS(i);
end
figure(2);
plot(x,y,'k');
hold on;
title ('ALIVE NODES vs ROUNDS');
xlabel ('number of rounds');
ylabel ('number of alive nodes');
xb=[x 5000];
figure(3);
plot(xb,DEAD,'k');
hold on;
xlabel ('number of rounds');
ylabel ('number of dead nodes');
title ('DEAD NODES vs ROUNDS');

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%   STATISTICS
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%
%
%  DEAD  : a rmax x 1 array of number of dead nodes/round
%  DEAD_A : a rmax x 1 array of number of dead Advanced
nodes/round
%  DEAD_N : a rmax x 1 array of number of dead Normal
nodes/round
%  CLUSTERHS : a rmax x 1 array of number of Cluster
Heads/round
%  PACKETS_TO_BS : a rmax x 1 array of number packets send to
Base Station/round
```

```
%  PACKETS_TO_CH : a rmax x 1 array of number of packets send
to ClusterHeads/round
%  first_dead: the round where the first node died
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%
```

APPENDIX – 3. PEGASIS

```
%pegasis·¨
clc
clear
energy=zeros(1,100);
receive_factor=512*50*0.0001;
 send_factor=512*12*0.001;

no=100;
node_x=rand(1,no);
node_y=rand(1,no);
figure(2);
plot(node_x,node_y,'.')
hold on
%plot(node_x(1),node_y(1),'.r')
hold on
%plot([node_x(1) 0],[node_y(1) 0])
hold on

p=0.15;n=fix(1/p);
for round=1:n

distance=zeros(1);
max_distance=0;
max_node=0;
for i=1:no,
    distance(i)=sqrt(node_x(i)^2+node_y(i)^2);
    if max_distance<distance(i),
        max_distance=distance(i);
        max_node=i;
    end
end
plot(node_x(max_node),node_y(max_node),'.')
average_distance=sum(distance(:))/no;

connect_distance=zeros(1,no);
connect_node=zeros(1,no);
connect_node(1)=max_node;
connect_distance(1)=average_distance;

for i=2:no,
    temp_node=0;
    temp_min_distance=1.5;
```

```
    for j=1:no,
        b=0;
        for k=1:(i-1),
            if j==connect_node(k),
               b=1;
               break
            end
        end
        if b==0,
           distance=sqrt((node_x(connect_node(i-1))-
node_x(j))^2+(node_y(connect_node(i-1))-node_y(j))^2);
           if temp_min_distance>distance,
              temp_min_distance=distance;
              temp_node=j;
          end
        end
   end
    connect_distance(i)=temp_min_distance;
    connect_node(i)=temp_node;
    plot([node_x(connect_node(i-1))
node_x(connect_node(i))],[node_y(connect_node(i-1))
node_y(connect_node(i))],'-');
    hold on
    energy(connect_node(i-1))=energy(connect_node(i-
1))+connect_distance(i)^2*send_factor+receive_factor;

energy(connect_node(i))=energy(connect_node(i))+receive_factor
;
end

t=fix(rand(rand(1,1))*100)+1;
energy(t)=energy(t)+average_distance^2*send_factor+receive_fac
tor;

end

receive_factor=512*50*0.0001;
receive_consumption=100*receive_factor;
energy_consumption=zeros(1,no);
send_factor=512*12*0.001;

for i=1:no,

energy_consumption(i)=connect_distance(i)^2*send_factor+receiv
e_factor;
end
consumption=receive_consumption+sum(energy_consumption(:))

figure();
plot(1:100,energy,'.')
hold on
```

RESUME

Personal Information

Surname, name	:	KAREEM HAMEED ALI
Nationality	:	Iraqi

Education

Degree	Education Unit	Graduation Date
Master	Istanbul Gelisim University	2022
Bachelor	Electrical engineering	2005-2006
High School	Siat Al-madaen	1987-1988

Work Experience

Year	Place	Title
2000-2022	Baghdad-Iraq	Electrical engineering

Foreing Language

Arabic-Engilish