NODAL BIOMEDICAL COMMUNICATION SCENARIO BASED ON WIRELESS BODY AREA SENSORS NETWORK WITH PARAMETERIC CORRELATION

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DECLARATION

I, Shaina hereby declare that the work presented in this thesis entitled **"NODAL BIOMEDICAL COMMUNICATION SCENARIO BASED ON WIRELESS BODY AREA SENSORS NETWORK WITH PARAMETERIC CORRELATION"** in partial fulfillment of the requirement for the award of degree of Master of Engineering (ECE) submitted at Electronics and Communication department. T.I.E.T., Patiala is an authentic record of work carried out under supervision of **Dr. Amanpreet Kaur** (Assistant Professor) Electronics and Communication Department, Thapar University, Patiala from July 2016 to July 2018.

The matter presented in this thesis has not been submitted either in part or full to any other university or institute for the award of any other degree.

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It is certified that the above statement made by the candidate is correct to the best of my knowledge and belief.

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ABSTRACT

In this work, different simulations of Wireless body area sensors network explains random behavior of energy consumption at different nodes, also erratic distribution of energy helps to explore new models on energy, path loss which helps in reduction of energy consumption per node so that the battery life can be expanded. Amount of energy consumed per node helps researcher to reduce efficient cost of complete network. Introduction of a new simulator Castalia for WBASN's which works for low power devices is the novelty of this work. This simulator works on OMNET++ Platform. Further to lower down the consumption of energy at different nodes an innumerable definitive topology designs and furnishing approach for Wireless Body Area Sensors Network is proposed. Different topology designs that takes into account are well designed so that the consumption of energy can be minimized and guaranteeing a reliable and fast data delivery which supports various health applications. So the literature first proposed a 3D coordinate system that is used to calculate the distance between the different nodes in different body postures and movements. System uses a model of a standard human body and some meticulous set of node positions. Next, scrutinize the superlative nodes by calculating the distance between them, and the author try to compare energy, path loss, Probability density Function along with other performance metrics like node degree, diameter, link capacity and bisection width.

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LIST OF ABBREVATIONS

WBAN	Wireless body area network
MATLAB	Matrix Laboratory
NICTA	National Information and Communications Technology
WLAN	Wireless Local Area Networks
WMAN	Wireless Metropolitan Area Networks
WWAN	Wireless Wide Area Networks
WPAN	Wireless Personal Area Networks
BAN	Body Area Network
RTDP	Reliable Topology Design and Provision
ILP	Integer Linear Programming
NOC	Network-on-chip
QOS	Quality of Service
EOCER	Optimized Cost Effective and Energy Efficient Routing
GA	Genetic Algorithm
PER	Parcel Blunder Rate
EEG	Electroencephalography
UWB	Ultra-Wideband
IEEE	Institute of Electrical and Electronics Engineers
CTI	Cross Innovation Impedance
WSN	Wireless Sensor Networks
RLNC	Random Linear Network Coding
NED	Network Description Language
MAC	Media Access Control
AWGN	Additive White Gaussian Noise

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION

In wireless sensor technology different advances have set up various instances in health industry for researchers and developers. Embedded medical surveillance [1] will help to revamp the daily lives of people by giving the diversity in medical body sensors and its technological upgrades leads to new research function called as wireless body area network (WBAN). The main aim is to provide guideline and conveying various specifications to design systematic and logical wireless devices. To detect human body in various conditions a set of frequencies should in sanction with the different communication standards. WBAN is a divulgation standard which is optimized for small and low power devices and different operation on, in and around the person s to serve a lot of applications including health care [2], Electronics gadgets etc. WBAN holds promise to give timely statistics about pivotal parameters and movements.

Although WBAN is designed for medical applications but it serves a lot in various other applications like in sports, security, entertainment, education, military purposes.

1.2 STATE OF ART

A lot of heath diagnosing enginery had been developed so that various health monitoring systems can be developed. Numerous of projects are being carried out in esteemed institutions so that better health facilities can be provided. The target of these projects is to develop number of applications and to prevention of profound diseases, posture recognition, processing of different physiological signals and evaluation of states. Various applications require wide variety of sensors to sense physiological signals like heart beat rate, pulse rate, blood pressure, skin temperature and respiration rate. Recorded signals require different communication standards like Bluetooth, GPRS, etc. With the advent of new techniques a lot of issues regarding technical requirement and designs need hasty consideration of researchers and developers. Parameters including data rate, security, energy efficiency and reliability need special concentration. In today's era consumption of energy becomes an important factor to work on. For this different simulations which explains random behavior of energy consumption at different nodes, also erratic distribution of energy helps various researchers to find best sensors network to reduce energy consumption per node so that battery life can be expand. Amount of energy consumed per node helps researcher to reduce efficient cost of complete network. A new simulator Castalia for WBASN's which works for low power devices has been developed in National ICT Australia (NICTA). This simulator is based on OMNET++ Platform. Developers can use this simulator for testing their algorithms and protocols for their realistic model. This software is highly

parametric and can also calculate different characteristics for different platform. Consumption of energy helps in innovation of low power devices [3]. Our case study with this simulator shows different applications and shows energy consumption at different nodes.

1.3 WHY A NEW SIMULATOR

Different types of simulators are used by different developers to fulfill their requirements in different network. Simulators which use a common processor found in different sensors nodes, some are written in C++ or MATLAB to test distinct properties of various modules. Then we need a new simulator? A person wants to test few communication patterns in simulation so that study can further move to real system. In order to do so, enough radio channels and models are required so that the simulation results help us in our research work. Observation says that modeling works for sensor networks are falling short day by day. For short range and low power communication models which remain simple and real invent this CASTALIA simulator. As for the sake of reliability and speed enhancement OMNET ++ software is also used. Using OMNET++ we can focus on different models and overall designs of complex networks can be emphasized.

1.4 INFRASTRUCTURE

OMNET++ is used as base for Castalia so that a user could have clear understanding of basic Concepts of Castalia. OMNET works for basic modules and messages. Making acceptance of messages execution of code takes place. New messages received and sent when states altered with time. Different modules include in simple and composite helps in construction of other modules.

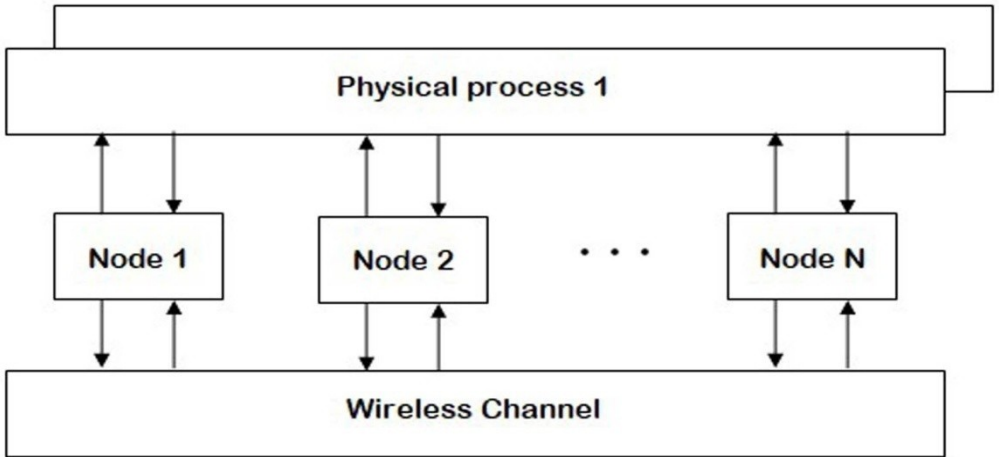

Figure 1.1: Modules and their connections in Castalia

Different nodes connect with themselves with wireless channel modules. These arrows shows message passing from one type of module to another. Different nodes having different packets and decides that which packet will go which wireless channel. Nodes connect themselves through physical

process which they monitor. For each and every physical process one module holds the “truth” on the quantity which the physical process is representing. In space and time nodes sampling process takes place to evaluate their sensor readings. Multiple physical processes shown in Figure 1.1 representing multiple sensing devices can be present which the node has.

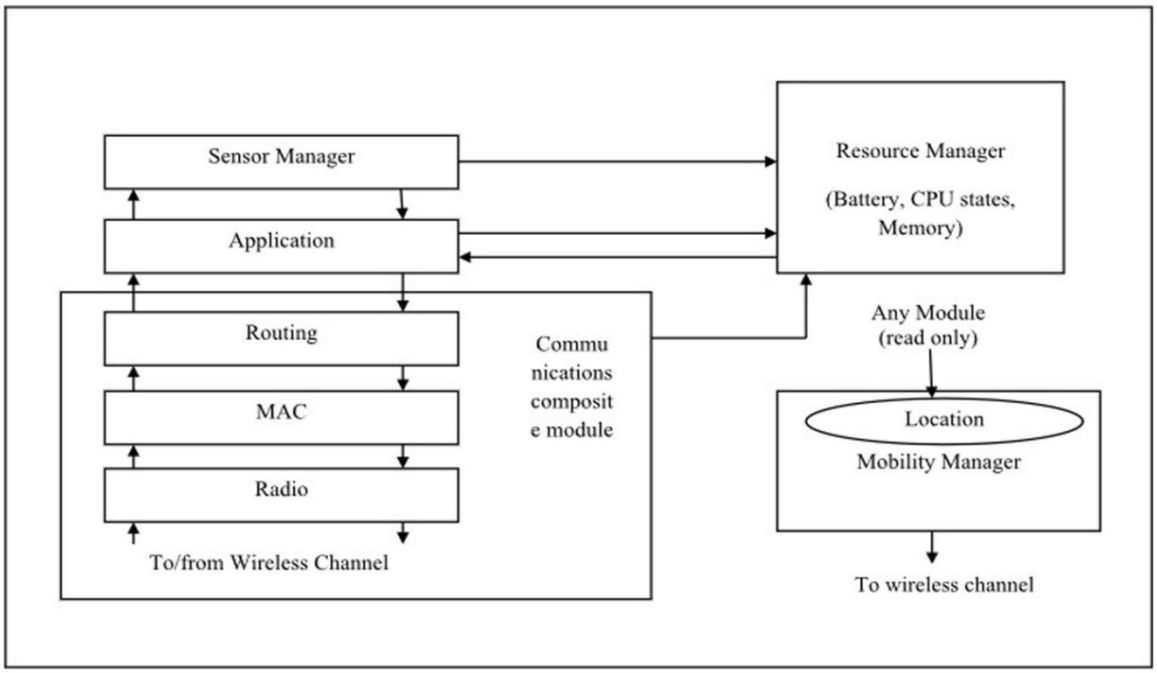

Figure 1.2: Node composite module

Node module bears composite nature. Figure 1.2 depicts the intramural structure of node composite module. Arrows with solid lines implies the message passing and the dashed arrows tells us simple function calling. Almost all of the modules call a function of the resource manager to notify that excess of energy has been consumed. Application module changes according to the user’s need just by creating a innovative new module for an implementation of a new algorithm. Castalia helps us to built one own protocol, application by defining appropriate abstract classes. Almost all existing modules are richly tuneable by many parameters.

1.5 ORIGIN OF WBAN

1.5.1 Wireless Network

Advancements in wireless body area network sensors have consummate remarkable growth [5][6] in medical industry. Radio signals help in communication of different wireless networks so that secure link can be established between different nodes present in a network. Figure 1.3 shows different type of wireless technologies and their advantages in real world are discussed below.

Few advantages of using wireless networks over wired:

- High mobility and flexibility of communicating nodes
- Low communication cost
- Low cost of maintenance
- Upgrade is easy
- Organization of network is easy
- Reliability
- Security

1.5.2 Hierarchy of wireless networks

On the basis of geographical coverage wireless networks are classified into four different categories:

Wireless Local Area Networks (WLANs)

- Wireless Metropolitan Area Networks (WMANs)
- Wireless Wide Area Networks (WWANs)
- Wireless Personal Area Networks (WPANs)

1.5.2.1 Wireless Local Area Networks

This type of network is basically consists of two or more devices which are connected with each other in a small network area with the help of some wireless tool. Mainly it uses an Access point to provide internet connection to the different users. In today's world OFDM technologies and high frequency radio waves allows different users to connect in local network area, without even losing their network connection. It is basically based on IEEE 802.11 standard.

1.5.2.2 Wireless Metropolitan Area Networks

It is a point to point or one point to multi point network which covers large area around 5-10 kilometers of radius in a circular region. It provides suitable connectivity in telecommunication sector. The well-known example of it is WIMAX. It is based on IEEE standard 802.16.

1.5.2.3 Wireless Wide Area Networks

This type of network cover large topographical area like it connects one town to another town, different cities which are few miles away from one another. It provides various types of services to the user through different cellular networks like GPRS, LTE, GSM and use satellite communication for transmission of different types of signals.

1.5.2.4 Wireless Personal Area Networks

It helps in communication over short range, connects various devices like phones, tablets and many

other digital devices. These types of networks are based on IEEE 802.15 standard. It communicates with different technologies like IrDA, Bluetooth etc.

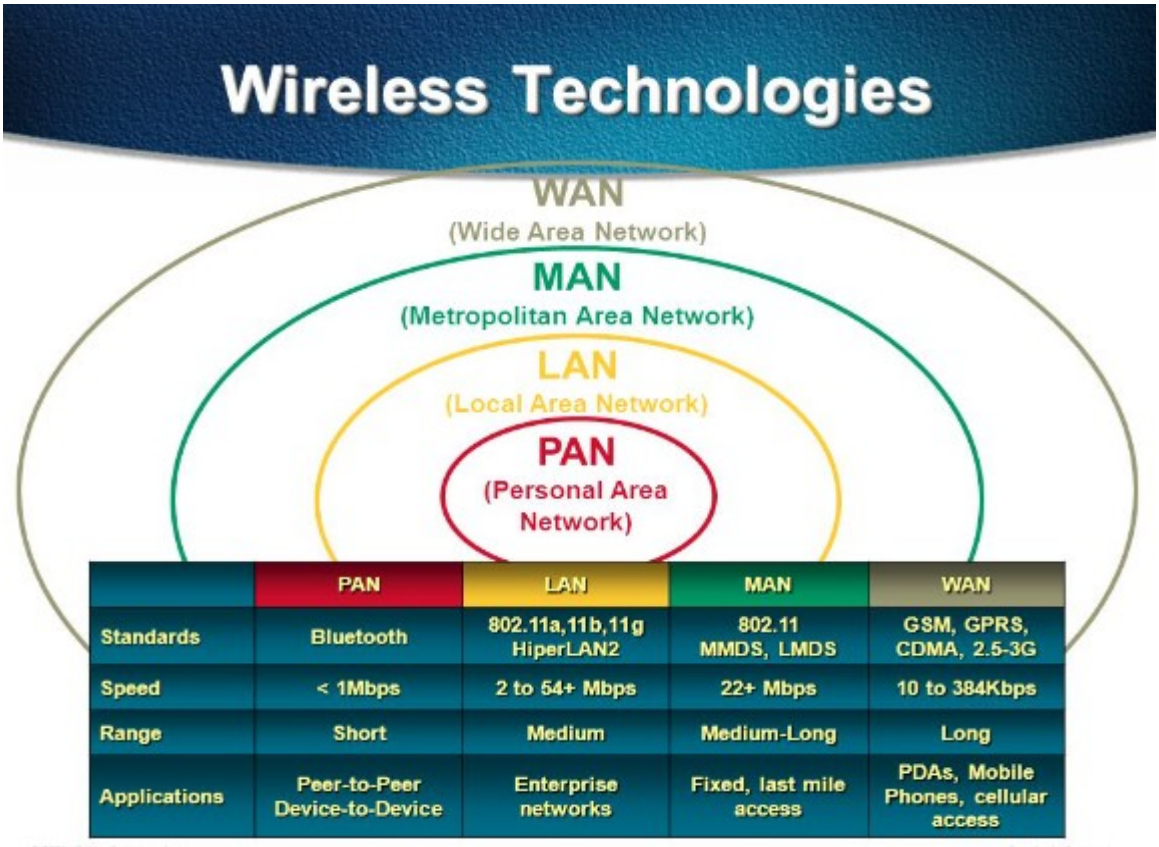

Figure 1.3: Different wireless technologies

1.6 ADVENT OF WIRELESS BODY AREA NETWORKS

Advances in the field of computer science helps in increasing mobility and accessibility to process huge amount of data and high level of connectivity. It is a subset of wireless network family called as PAN. BAN was developed to improve various kind of health conditioning system [4] of medical science but its applications spans from medical to military and other intelligence areas.

1.7 APPLICATIONS OF WBANS

To upgrade health monitoring techniques, the development of WBAN is necessary, not only in medical area, it spans from health to personal or sometimes for military purposes it is very useful. Applications of WBAN in various fields are listed below:

- **Monitoring in Health and Care:** Used in monitoring system, diagnosis and treatment of various diseases like cancer detection, electrocardiogram (ECG), electroencephalogram

(EEG) and helps in detecting cancer.

- **Security and Authentication:** It is used for authentication of physiological biometry and optometry of behavior such as facial pattern, matching of fingerprints, iris identification etc.
- **Sports and Training:** WBAN maintains different logs of movements and various parameters like body posture, mobility, heartbeat rate, weight scale etc.
- **Entertainment Application:** Use of WBAN in gaming and social networking gives new feature to sports industry like in consumer electronics such as mp3, cameras, recognition of gesture, gaming, virtual reality etc.
- **Military and Defense:** Modern features of WBAN help military and defense forces like in battlefield surveillance and in the assessment of soldier fatigue.

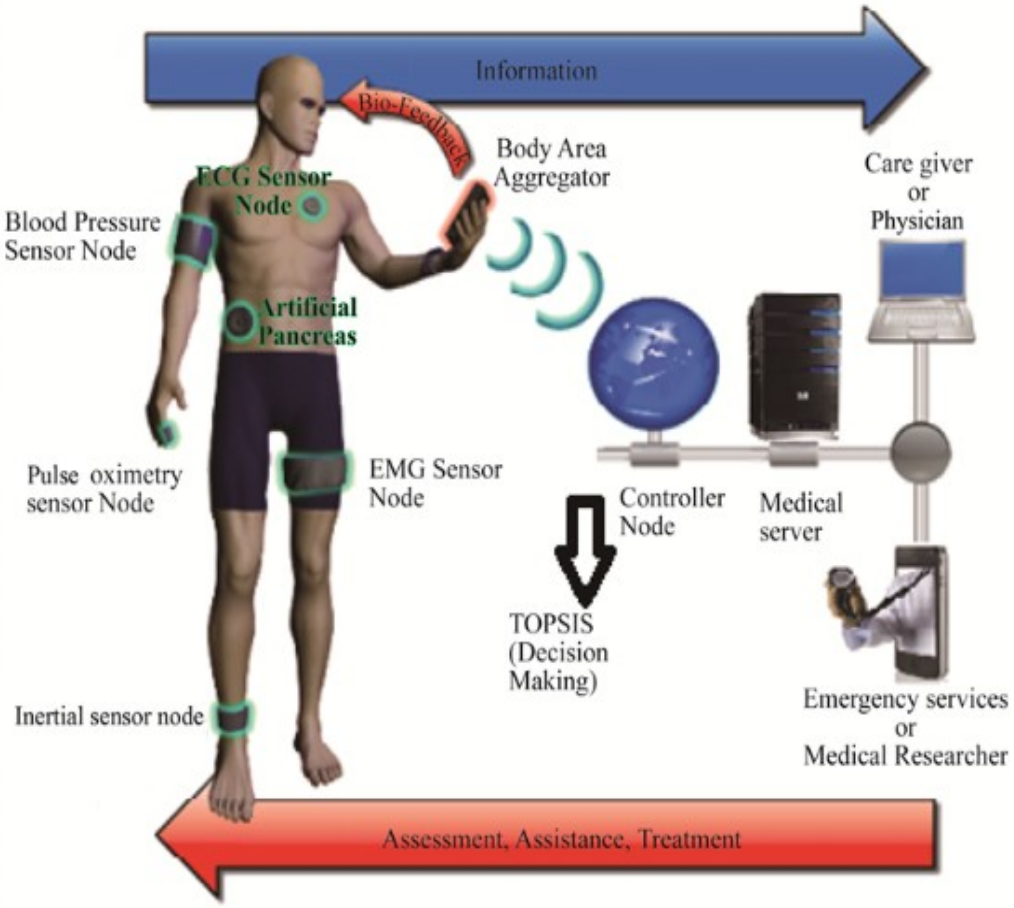

Figure 1.4: Applications WBAN in Medical Science

Figure 1.4 shows how message conveys in Wireless body area sensors network. Sensor [6] senses the movement and passes it to the controller node. Controller node further passes it to the medical supervisor or to any device which shows the absolute results of that particular movement.

1.8 REQUIREMENTS OF WBAN

In WBANs, various sensor devices detect body movements and different parameters and then transmit all the collected information to network coordinator. This data needs a shared medium which requires a lot of specifications like:

- **Energy efficiency**

  It is the most important factor on which all the applications of WBAN are depending, because sensor nodes require long battery life to provide health monitoring for long period as these nodes could not be easily replaceable. So it becomes necessary to lower down the dissipation of energy at the very first level.

- **Bit rate**

  Bit rate basically varies from application to application. Some applications needs bit rate 1kbps like sensing of body temperature but in case of video streaming it can go up to 10mbps.

- **Security and reliability**

  Level of integrity, confidentiality, availability and authenticity of data confirms that the loss of packet or data is absent in a particular transmission. Enhancing data reliability needs good selection of channel access mechanisms, packet size, scheduling techniques and retransmission of packets.

- **Network topology**

  Communication nodes are placed in that way so that it consumes very less amount of energy like hexagonal, star etc.

- **Signal processing**

  Processing of physiological signals needs efficient power-efficient signal processing mechanism. A technique name as compressed sensing method is used to scan analog signal which consume very less amount of energy with no loss of data and information.

1.9 THESIS OUTLINE

In chapter 1, brief introduction of wireless body area sensors is given, need for change, a new simulator's introduction, applications and requirements of wireless body area sensors in different fields is discussed. In chapter 2, research papers are discussed which helps in understanding the general perspective of different types of model and the work done by the different researchers till the date. In chapter 3, related work which had been done in past and how our work is different and implemented through software is explained with its simulation results. In chapter 4, gaps found from

different simulations and previous work is discussed and brief objective of our work is explained. In chapter 5, comparison is done on the basis of different parameters by taking three types of topologies and energy model with proper equations is explained. In chapter 6, conclusion on the basis of all parameters is made with table and scope of future work is also discussed for the benefits of researchers.

CHAPTER 2

LITERATURE SURVEY

Sergio Gonza (2013) *et al.* [1] in "Wireless Body Area Networks: A Survey" discussed several different uses and applications of BAN technology in medical sector. It also covers BAN technology which represents the lower bound of bandwidth and power. It discusses various technologies which surrounds or make use of BAN. A Brief discussion of challenges associated with BANs and some solutions related to it are also included in discussion. Parameters like path loss, signal and few challenges associated with power and communication are also the part of this discussion.

Mohammad Ghamari (2016) *et al.* [2] in "A Survey on Wireless Body Area Networks for eHealth care Systems in Residential Environments" proposed that current advancement in wearable and embedded wellbeing checking innovations can possibly change the eventual fate of human services benefits by empowering omnipresent observing of patients. An average wellbeing checking framework comprises of a system of wearable or embedded sensors that continually screen physiological parameters. Gathered information can handed-off utilizing existing remote correspondence conventions to a base station for extra preparing. This work gives scientists with information to compare the existing low-power communication technologies that can potentially bolster the quick advancement and organization of WBAN frameworks, and essentially centers around remote observing of elderly or constantly sick patients in different situations.

Mónica Vallejo (2015) *et al.* [3] in "Proactive and Reactive Transmission Power Control for Energy efficient On-Body Communications" discussed that the human body importantly affects the execution of the correspondence because of the worldly varieties caused and the constriction of the way misfortune in Wireless Body Area Sensors Network. This actuality proposes that the transmission control must adjust to the present condition of the connection in a way that it guarantees a harmony between vitality utilization and bundle misfortune. In this work, we approve our two transmission control level arrangements (responsive and prescient methodologies) utilizing the Castalia simulator. The mix of our trial estimations in the test system enables us to effectively assess complex simulations, keeping away from the difficulty related with a handy acknowledgment. Our outcomes related to energy demonstrate that erratic of energy distribution need to be considered.

Mark Hanson (2009) *et al.* [4] in "Body Area Sensors network: Challenges and opportunities" discussed that Body area sensors may have novel applications in the field of health and care but research must address different challenges such as cost, size, compatibility, consumption of energy, network capacity, fidelity, throughput and delay required by different applications. Packing and

packaging are also important design considerations because nodes can never be prominent.

Jocelyne Elias (2013) *et al* [5] in "A Reliable Design of Wireless Body Area Networks" provided an introduction on a reliable topology design and provisioning approach for Wireless Body Area Networks (named RTDP-WBAN) that considers the portability of the patient while ensuring a dependable information conveyance required to help social insurance applications' needs. To do as such, this work proposes 3D facilitate framework ready to ascertain the directions of hand-off sensor hubs in various body stances and developments. This framework utilizes a 3D-model of a standard human body and one specific set of hub positions with stable correspondence joins, shaping a virtual spine. Next, examination is done on the ideal transfer hubs situating mutually with the solid and savvy information directing for various body stances and developments. Along these lines, a proposal to utilize of Integer Linear Programming (ILP), that the ideal number and areas of transfer hubs and figure the ideal information directing from sensors and transfers towards the sink is introduced, limiting both the system setup cost and the vitality utilization. We fathom the model in powerful WBAN (Stand, Sit and Walk) situations, and contrast its execution with other handing-off methodologies. Test comes about demonstrated that our reasonable and dynamic WBAN configuration approach basically enhances unwavering quality, vitality utilization and number of transfers sent on the body.

Dheeraj Rathee (2014) *et al* [6] in "Recent trends in Wireless Body Area Network (WBAN) research and cognition based adaptive WBAN architecture for healthcare" explains that Wireless Body Area Network (WBAN) has critically new technical innovation which is fit for giving better strategies for ongoing patient wellbeing checking at clinics, work place and even at their homes. As of now, WBAN has increased extraordinary intrigue and demonstrated a standout amongst the most investigated advances by medicinal services offices in view of its crucial part and extensive variety of use in medical sciences. WBAN include correspondence between little sensor nodes with as often as possible evolving condition, subsequently bunches of issues still should be tended to. A portion of the real issues are Physical layer issues, interoperability and portability issue, unwavering quality, asset administration, ease of use, Energy utilization and QoS issues.

Agustinus Borgy Waluyo (2016) *et al.* [7] in "Middleware for Wireless Medical Body Area Network" discussed that headway in remote sensor innovation have opened up another worldview in the medicinal services industry. Pervasive and implanted restorative observing is not any more a fantasy and this will help enhance the daily lives of the debilitated, elderly, weak, and incessantly sick individuals. The motivation behind this work is to propose such middleware for remote therapeutic body zone arrange. The proposed middleware can bolster: (I) various sensors and applications, (ii) fitting and play highlight, and (iii) asset administration. The middleware has been executed and the

model framework has been assembled. The viable employments of the proposed middleware will be appeared with the medicinal services checking framework running over the middleware.

Jie Ding (2015) *et al* [8] in "Joint optimal relay location and power allocation for ultra-wideband-based wireless body area networks" contemplate the joint ideal hand-off area and power designation issue for single-hand-off helped ultra-wideband (UWB)- based wireless body region networks (WBANs). In particular, to enhance otherworldly proficiency (SE) for single-hand-off helpful correspondence in UWB-based WBANs, methodology looks for the transfer with the ideal area together with the relating ideal power distribution. With proposed transfer area based network models, the SE amplification issues are scientifically defined by thinking about three useful situations, to be specific, along-middle situation, around-middle situation, and in-body situation. Considering practical power contemplations for every situation, the ideal hand-off area and power distribution are together inferred and broke down. Numerical outcomes demonstrate the need of use of hand-off hub for the unearthly and vitality productive transmission in UWB-based WBANs and show the viability of the proposed conspire specifically for the around-middle and in-body situations. With the joint ideal transfer area and power distribution, the proposed conspire can drag out the network lifetime and expand the transmission go in WBANs altogether contrasted with coordinate transmission.

Mohd Kaleem (2014) *et al* [9] in "Energy Consumption Using Network Stability and Multi-hop Protocol for Link Efficiency in Wireless Body Area Networks" propose a base, control proficient and max throughput directing convention for Wireless Body Area Networks (WBANs). We utilize multi-bounce topology to accomplish least vitality utilization and longer system lifetime. This work calculates cost capacity to choose forwarder node, proposed cost work chooses a forwarder node which has high leftover vitality and least separation to sink. Leftover vitality parameter adjusts the vitality utilization among the sensor nodes while remove parameter guarantees effective parcel conveyance to sink. Recreation comes about demonstrate that our proposed conventions expand the system security period and hubs remain alive for longer period. Longer soundness period contributes high packet conveyance to a particular sink which is real enthusiasm for ceaseless patient checking.

Leila Ben Saad (2017) *et al* [10] in "Topology Design to Increase Network Lifetime in WSN for Graph Filtering in Consensus Processes" discussed that Graph filters are considered as the workhorses of diagram flag examination in the developing field of flag preparing on charts, are helpful for some applications, for example, disseminated estimation in remote sensor systems. A large number of these undertakings depend on essential circulated administrators, for example, agreement, which is done by sensor gadgets under constrained vitality supply. To adapt to the vitality requirements, this works on planning the system topology so as to expand the system lifetime and lessen the vitality utilization while applying graph filters. The issue is a complex combinatorial issue and in this work, work is

done to propose two heuristic calculations for fathoming it. Great execution regarding the network lifetime and the overall vitality utilization of energy in the filtering procedure is appeared.

Robert Chepkwony (2015) *et al* [11] in "Energy efficient model for deploying wireless body area networks using multi hop network topology" proposed that Wireless Body Area Network Sensors (WBANs) offers a ton of utilization openings in the region of medical services. Late advancements in sensors and radio correspondence advances have spurred numerous scientists to plan WBAN frameworks for application in medicinal services arrangement. Power utilization is as yet a restricting element in understanding a WBAN with a long lifetime. Subsequently, plan of vitality proficient WBANs is required to upgrade battery life in the meantime guarantee that sensor hubs are sufficiently little to be helpfully worn or embedded in the body. Vitality utilization in WBANs occurs amid detecting, preparing and correspondence. This exploration concentrated on outlining a vitality productive model amid correspondence between sensors. The parameters were recreated and executed utilizing MATLAB and Simulation reproduction programming. The sensors are arbitrarily confined on a plane and separation between them ascertained. The model uses a hand-off between the sensors and the organizer to lessen control utilization by sensors amid flag transmission.

Marek Bykowski (2011) *et al.* [12] in "A Schema for the Selection of Network Topology for Wireless Body Area Networks" discussed that topology oversees the coherent availability between the hubs in the system. Improvement of Wireless Body Area Networks (WBANs) requires applying customized advances to counter measure the impacts of remote spread while fulfilling obliges forced by equipment. Vital piece of this procedure is topology choice as it influences the advancement of the whole system convention stack. For instance, utilization of a star or point-to-point topology evacuates the requirement for utilizing directing as required by different topologies, for example, work. Consequently, in this work we propose a novel strategy for topology choice for BANs that we allude to as a topology choice pattern. The blueprint distinguishes and talks about a wide scope of parameters that ought to be considered in topology choice and afterward proposes a topology determination construction. The composition decides the estimations of those parameters by looking at them against a given arrangement of suspicions on the utilization of the system, e.g. utilize case situation, natural conditions, gadget and activity related parameters. At that point it decreases them into an arrangement of compact parameters, which can be effortlessly used to evaluate the appropriateness of given topologies.

Shuchi A. Parkhani (2016) *et al* [13] in "A Survey of Different Topologies for Network-on-Chip Architecture" discusses that Network-on-chip (NoC) has a basic aspect that decides the execution and power utilization of many-center frameworks. Different topologies have different points of interest

and applications. This work introduces a concise study of different NoC topologies, and their related parameters are compared.

Francesca Cuomo (2009) *et al* [14] in "Performance analysis of IEEE 802.15.4 wireless sensor networks: An insight into the topology formation process" discuss that topology development is a vital issue in a wireless sensor network. Execution parameters, for example, vitality utilization, network lifetime, information conveyance delay, sensors network scope rely upon the network topology. In this work, we dissect the procedure of arrangement of a wireless sensor network as per the IEEE 802.15.4/ZigBee norms. Work is centered around both single-sink situations and multi-sink ones where: (I) portray the topology as far as network profundity and hubs dissemination at various network levels; (ii) break down some network execution as a component of the quantity of sinks; (iii) research is done on the effects of some topology constraints on network performance; (iv) study is done on the impacts of hubs portability on the network arrangement. The entire examination is performed by considering the specific highlights and proposals of the IEEE 802.15.4/ZigBee gauges; along these lines, *our* outcomes can be utilized to configure IEEE 802.15.4/ZigBee methodology and set the related parameters, as a component of the coveted application prerequisites.

Gurwinder kaur Matharu (2012) *et al* [15] in "Energy efficient topologies for wireless sensor Networks" explained that a wireless network is a gathering of spatially scattered specific transducers with a detecting, figuring and correspondence foundation which expects to enable them to detect and record different conditions in an observed domain. They go about as interfaces amongst genuine and virtual universes. They are the most quickly creating data innovations in this day and age because of their tremendous scope of uses. This work gives an outline of wireless sensor networks and gives a situation based correlation with vitality effectiveness between various topologies utilized as a part of these networks.

Aime V. Mbakop (2008) *et al* [17] in "Implementation of a Wireless Body Area Network for Healthcare Monitoring" discussed that the quick development of wireless innovations and individual region networks has empowered the nonstop medicinal services observing of versatile patients utilizing conservative sensors that gather and assess body parameters and developments. These sensors constitute a body region network (BAN) where patients' essential signs are gathered and revealed wirelessly to a base station. Once the information is gotten, it is shown or put away in a database for sometime later. The objective of this venture was to explore the practicality of the reasonable development, and utilization of a BAN. The framework has been effectively tried progressively where information was effectively acquired and shown.

Navneet Kaur (2017) *et al* [18] in "Optimized cost effective and energy efficient routing protocol for wireless body area networks" discussed that the expansion in normal life expectancy and enormous

expenses for wellbeing medications have brought about savvy answers for social insurance administration. Wireless Body Area Network (WBAN) is a promising innovation for conveying quality human services to its clients. Low power gadgets connected to the body have constrained battery life. It is alluring to have vitality productive directing conventions that keep up the required dependability esteem for sending the information from an offered hub to the sink. The present work proposes two conventions: Optimized Cost Effective and Energy Efficient Routing convention (OCER) and Extended-OCER (E-OCER). In OCER, improvement utilizing Genetic Algorithm (GA) is connected to the multi-target cost work with remaining vitality, interface unwavering quality and way misfortune as its parameters for choosing the most ideal course from a given body organizer to the sink. E-OCER broadens crafted by OCER by considering between BAN correspondence.. A correlation of the execution of E-OCER with OCER is made to consider the impact of on-body sensors correspondence on the vitality utilization and throughput of the network. The outcomes demonstrate an enhanced execution of the proposed conventions as far as vitality proficiency.

Ramy Hussein (2015*)* *et al* [20] in "Scalable real-time energy-efficient EEG compression scheme for wireless body area sensor network" proposed that ongoing medical advances in wireless body sensor networks have made it feasible for the advancement of imaginative restorative applications to enhance human services and the personal satisfaction. By utilizing scaled down wireless electroencephalography (EEG) sensors, it is conceivable to perform wandering EEG recording and constant social insurance applications. The customary EEG spilling approach forces in an inordinate power utilization, as it transmits the whole EEG flags wirelessly. In this way, inventive answers for reduce the aggregate power utilization at the recipient are very wanted. This work presents the utilization of the discrete wavelet change and compressive detecting calculations for versatile EEG information pressure in wireless sensors with a specific end goal to address the power and bending requirements. Encoding and transmission control models of the two frameworks are introduced which empower examination of energy and execution costs.

Sidrah Yousaf (2016) *et al* [21] in "Towards Reliable and Energy-Efficient Incremental Cooperative Communication for Wireless Body Area Networks" examined that incremental agreeable correspondence for wireless body territory networks (WBANs) with various quantities of transfers. Vitality proficiency (EE) and the parcel blunder rate (PER) are explored for various plans. Another helpful correspondence conspire with three-organize handing-off and contrast it with existing plans are proposed. Later on, the proposed three-arrange incremental collaboration is executed in a network layer convention; upgraded incremental helpful basic information transmission in crises for static WBANs (EInCo-CEStat). The outcomes additionally uncover that EInCo-CEStat ends up being more solid with less PER and higher throughput than both of the partner conventions.

Jocelyne Elias (2014) *et al* [22] in "Optimal design of energy-efficient and cost-effective wireless body area networks" discussed that Wireless Body Area Networks (WBANs) prove to be the most encouraging methodologies for enhancing the personal satisfaction, permitting remote patient checking and other social insurance applications. The arrangement of a WBAN is a basic issue that effects both the network lifetime and the aggregate vitality devoured by the network. This work explores the ideal outline of wireless body region networks by concentrate the joint information steering and hand-off situating issue, keeping in mind the end goal to build the network lifetime. At the end, a blended whole number direct programming model, the Energy-Aware WBAN Design display, which advances the number and area of transfers to be sent and the information steering towards the sink, limiting both the network establishment cost and the vitality devoured by wireless sensors and transfers is proposed. both practical WBAN situations and general topologies, and contrast the model execution with the most eminent methodologies proposed in the writing.

Elisabeth Reusens (2009) *et al* [23] in **"**Characterization of On-Body Communication Channel and Energy efficient Topology Design for Wireless Body Area Networks" discussed that Wireless Body Area Network Sensors (WBANs) offer numerous promising new applications in the zone of remote wellbeing checking. A vital component in the advancement of a WBAN is the portrayal of the physical layer of the system, including an estimation of the defer spread and the way misfortune between two hubs on the body. This work examines the spread channel between two half-wavelength dipoles at 2.45 GHz, set close to a human body and introduces an application for cross-layer configuration keeping in mind the end goal to advance the vitality utilization of various topologies. Engendering estimations are performed on genuine people in a multipath situation, considering diverse parts of the body independently. A period space examination is performed and models are exhibited for the mean over abundance delay and the defer spread. As a cross-layer application, the proposed way misfortune models are utilized to assess the vitality of single-bounce and multi hop topologies.

Yinglong Wang (2017) *et al* [24] in "Stochastic Geometry Analysis of Throughput for Wireless Body Area Networks" discussed that Wireless Body Area Network (WBAN) concurrence is an extremely difficult issue, bringing about exceptionally solid obstruction among them, which genuinely influences the unwavering quality of correspondence. The obstruction is the primary execution constraining component in wireless networks conjunction, and hence it is pivotal to alleviated. The objective of this work is to diminish between WBANs impedance and to expand the transmission achievement likelihood or throughput. In this work, the effect of channel detecting reach to IEEE 802.15.4-based coinciding WBANs is dissected and is improved by the closest hub's separation. Likewise, we show the framework embracing the stochastic geometry Poisson point process and break down the effect of monitor zone size to networks execution. Besides, the throughput proficiently

accomplishes higher through streamlining the extent of monitor zone. The vitality and ghostly proficiency, also, have been moved forward.

Hongyao Luo (2015) *et al* [25] in "A Survey on Spectrum Utilization in Wireless Sensor Networks" surveyed that the mechanical, logical, and restorative (ISM) groups have been seriously imparted to unlicensed wireless interchanges applications, for example, wireless sensor networks (WSNs). With prospering fame of sensor gadgets and expanding establishment of wireless sensor nodes, the cross innovation impedance (CTI) has turned into a significant genuine issue. Broad methodologies have been proposed to investigate range usage in WSN. This work introduces an exhaustive review on range use in WSNs. To accomplish this objective, initially delineate the foundation of WSN and range use is discussed. Later, the significance of productive range usage is shown. Inevitably, through grouping and outline of late related works, a fundamental structure of research in titled field and point by point scholarly merits of distributed works is given.

Hongyun Zhang (2017) *et al* [26] in "Measurement-based characterizations of on-body channel in the human walking scenario" examined that Wireless Body Area Networks (WBANs), on-body channels experience transient varieties prevalently in light of the body movement and shadowing of tissue. This work is based on a typical human movement, strolling, to investigate the attributes of the dynamic on-body proliferation channel. A modified compact wireless sounder is manufactured and used to gather the first on-body channel information both for the indoor and open air situations. Investigating the second-arrange insights of the channel pick up variety amid strolling, including the transient autocorrelation, the cross-relationship and the channel pick up inconsistency between the two associated joins is done. This channel portrayal encourages more productive outlines and assessments of WBAN frameworks, including more proficient network asset designation and more effective arrangement of helpful correspondence.

Yung-Fa Huang (2009*)* *et al* [27] in "Equalization of Energy Consumption at Cluster Head for Prolonging Lifetime in Cluster-based Wireless Sensor Networks" explained that in group based wireless sensor networks (WSN), the greater part of vitality is expended in bunch head which performs information accumulations and handing-off. The lifetime in group based WSN is subjected by the lifetime of bunch heads. After leveling, the length of sides of group zone is acquired. Numerical outcomes demonstrate that the length of far site group is shorter than the closest bunch to perform evening out for every one of the three directing plans. In addition, recreation comes about demonstrate that the three-bounce plan can acquire the most vitality productivity than other two plans.

.**Hisham Alshaheen (2017)** *et al* [28] in "Improving the Energy Efficiency for the WBSN Bottleneck Zone based on Random Linear Network Coding" discussed that the decrease of vitality utilization and the fruitful conveyance of information are critical for the Wireless Body Sensor Network (WBSN).

Numerous investigations have been proposed to enhance vitality effectiveness, however the greater part of them yet not focus on the biosensor hubs in the WBSN bottleneck zone. Every single biomedical bundle is amassed through these hubs framing a bottleneck zone. This work proposes a novel numerical model for body zone network (BAN) topology to clarify the arrangement and association between biosensor hubs, straightforward hand-off hubs, network coding hand-off hubs and the sink hub. In this manner, this work is devoted to investigating both the vitality sparing and conveyance of information if there is a disappointment in one of the connections of the transmission, which identifies with the proposed Random Linear Network Coding (RLNC) show in the WBSN.

Suraiya Tarannum (2010*)* *et al* [29] in "Energy Conservation Challenges in Wireless Sensor Networks: A Comprehensive Study" explained that a Wireless Sensor Network (WSN) comprises of countless sent sensor nodes. These sensor nodes arrange themselves into an agreeable network and play out the three essential elements of sensing, calculations and interchanges. Research in WSNs has turned into a broad explorative territory amid the most recent couple of years, particularly because of the difficulties offered, vitality requirements of the sensors being one of them. In this work, an intensive thorough investigation of the vitality preservation challenges in wireless sensor networks is completed. The requirement for viable use of constrained power assets is likewise underscored, which moves toward becoming pre-famous to the Wireless Sensor Networks.

Ziyad Khalaf (2015) *et al* [30] in "Performance Comparison among (Star, Tree and Mesh) Topologies for Large Scale WSN based IEEE 802.15.4 Standard" examines the pertinence of star, tree and work topology plans for vast scale Wireless Sensor Network (WSN) consenting to IEEE 802.15.4 standard. The fundamental focal point of this survey is to assess the execution of such system through recreation which is completed by means of the discrete occasion OPNET test system (variant 14.5). The execution measurements of intrigue incorporate throughput, end to end postpone and bundle drop rates. Execution correlation and investigations of various topologies have been made, and it is presumed that the choice of topology plot relies upon the application setting.

Anas Bouayad (2015) *et al* [31] in "Modeling and Simulation of a Wireless Body Area Network for Monitoring Sick Patient Remotely" signifies that advance has been made in the restorative field to coordinate correspondence and data innovation particularly the Wireless Body Area Networks (WBANs) in human services frameworks for remote checking. WBANs have indicated incredible potential in enhancing human services quality. WBAN works in close region to, on, or inside a human body and supports an assortment of therapeutic applications. These kinds of utilizations can be additionally upgraded by incorporating distributed computing innovation for putting away sensors' information. The data put away winds up accessible in the "cloud" from where it can be handled by master frameworks as well as appropriated to restorative staff. In this work we are occupied with

displaying and recreation of a remote sensor organize based arrangement permitting circulated sensor hubs to speak with each other in an ideal path adjusted to the particular limitations.

Rim Negra (2016) *et al* [32] in "Wireless Body Area Networks: Applications and Technologies" discussed that the expanding utilization of wireless networks and the consistent scaling down of electrical intrusive/non-obtrusive gadgets have empowered the improvement of Wireless Body Area Networks (WBANs). A WBAN gives a persistent wellbeing checking of a patient with no imperative on his/her ordinary day to day life exercises. Numerous innovations have demonstrated their proficiency in supporting WBANs applications, for example, remote observing, biofeedback and helped living by reacting to their particular nature of administration (QoS) prerequisites. Because of various accessible innovations, choosing the fitting innovation for a therapeutic application is being a testing undertaking. In this work, the distinctive therapeutic applications are introduced. The most well-known advances utilized as a part of WBANs are featured. At long last, a coordinating between every application and the comparing appropriate innovation is examined.

Mourad Ouadou (2015) *et al* [33] in "Minimum Spanning Tree Topology in Real Zigbee-Arduino Sensor Network" exhibits a genuine indoor application for enhanced "Cluster Tree" arrange utilizing Zigbee sensor hubs coordinated with "Arduino" microcontrollers where the fundamental objective is to consider the efficiency of our enhanced grouping topology in light of Minimum Spanning Tree (MST) development under genuine conditions. It depends on numerous sensor sensors conveyed everywhere on a working to screen temperature and dampness and identify any severe temperature increment. These nodes depend on basic effectively customized gear. while a few recreations utilizing NS-2 and different test systems has been directed in numerous different attempts to contemplate the efficiency of a system in view of MST, different application tests this topology in genuine conditions to guarantee it effectiveness in a Zigbee organize. This work likewise shows a few exhibitions of this talked about topology got by genuine conditions tests.

.**Kavitha (2016)** *et al* [34] in "Energy efficient transmission path for wireless body area network applications" examine that Wireless Body Area Network, a wireless network with number of little shrewd gadgets (Sensors, Actuators,) that are joined in the pieces of clothing, on the human body or under the skin of the individual which is equipped for transmitting information through the wireless medium and topology of the network depends on the position of nodes in the human body. The primary goal of WBAN is to enhance medicinal services and personal satisfaction. Applications of WBAN incorporate human social insurance monitoring (in clinic/home/different places), sports, home automation (poison/gas detection), electronics (music player, head mounted gadgets, games). This work outlines a proficient and solid transmission way for information spill out of source to sink hub.

Utilizing this system we need to enhance the throughput and lifetime of the hubs in network. Reproductions are performed by means of NS-2 instrument.

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CHAPTER 3

RELATED WORK AND IMPLEMENTATION

3.1 RELATED WORK

This new simulator has been deployed around for a number of years. Castalia have managed to adapt to the changing properties of the wireless network by reordering sensors nodes and their different modules in order to adapt wireless link reliability [7] [8] [9], however they do not link with any of the specific protocols for sensors network [10] nor the detail of the low level wireless protocol, as they both depicts the most important aspects in the sensor network.

In Castalia users can plot graphs of energy consumption for different nodes in gun plot. From that different developers can estimate total energy and consumption, which helps in innovation of low power devices. Random fashion of energy consumption gives an idea of moving to configure different topologies [11] that can lowers down the sensor's consumption.

Different structure depicts in related networks have been accomplished through Castalia with the use of the OMNET++ NED language. With the use of this language, different modules name, module parameters and module interface (gates in and gates out) and module structure (if this is a composite module) can easily be defined. Each file with the suffix ".Ned" contains NED language code. The structure of Castalia reflects in the hierarchy of directories in the source code. Each module pointed to a directory which always contains a .Ned file which clearly defines the module. Composite module reflects presence of sub modules in it and simple module reflects C++ code (.cc, .h files) to expound its behavior. The overall structure of the Castalia simulator is defined by .Ned files. These are dynamically loaded files and processed so that no need of recompilation of Castalia is required. With Castalia 3.0, two scripts may help with running different simulations and interpreting results and called as Castalia and Castalia results respectively. They all stored in Castalia bin.

3.2 IMPLEMENTATION

This section shows the different type of simulations and their energy consumption at different nodes. These simulations run only on the simulator and help the researchers to model the future network scheme. List of different types of simulation as follows:

A. Radio test

B. Ban test

C. Value propagation

D. Simple aggregation

E. Value reporting

Firstly open the directory of OMNET 4.6 (mingwenv) and then follow the path

Castalia-3.2/Castalia /make/Simulations/ radio test.

In the next step, particular simulation run with Command (.../.../CastaliaBin.exe –c General).The use of –c switch is to choose a configuration with in that particular file. Also do not mind for running the help-text mentioning in which list of all configurations can be given. 'General' which is always present in an OMNET pp .in and this is considered as welsh configuration. One file should include that omnetpp.ini.

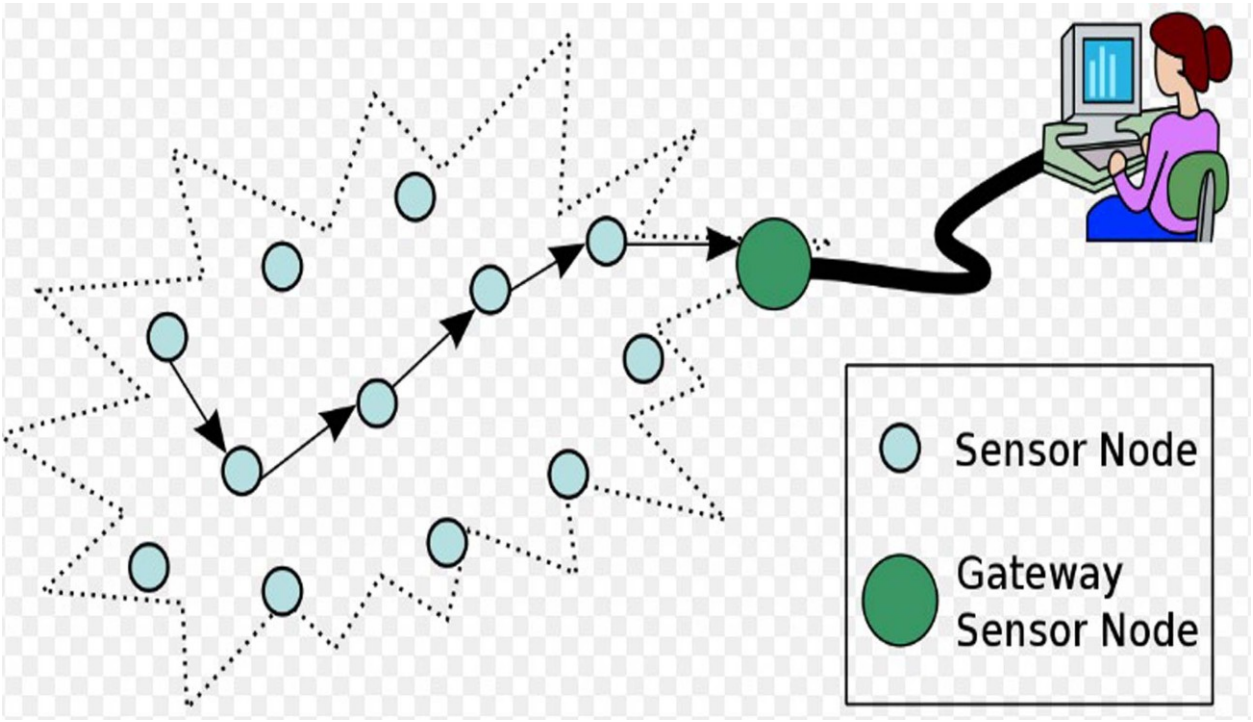


Figure 3.1: Nodes connection

WSN Typically consists of nodes, as above Figure 3.1 shows that, from a few to several hundreds or even thousands, on the other side these nodes have connection to some sensors. Each sensor network is further connected to several parts: a radio transceiver with an antenna or some connection to external antenna. Different topology varies from unadorned star network to multi-hop wireless mesh network. Different propagation technique used in hops can be routing or flooding.

3.2.1 Simulation results and their erratic energy behavior

In the following, we demonstrate our simulation results when different nodes interact with each other in an irregular fashion.

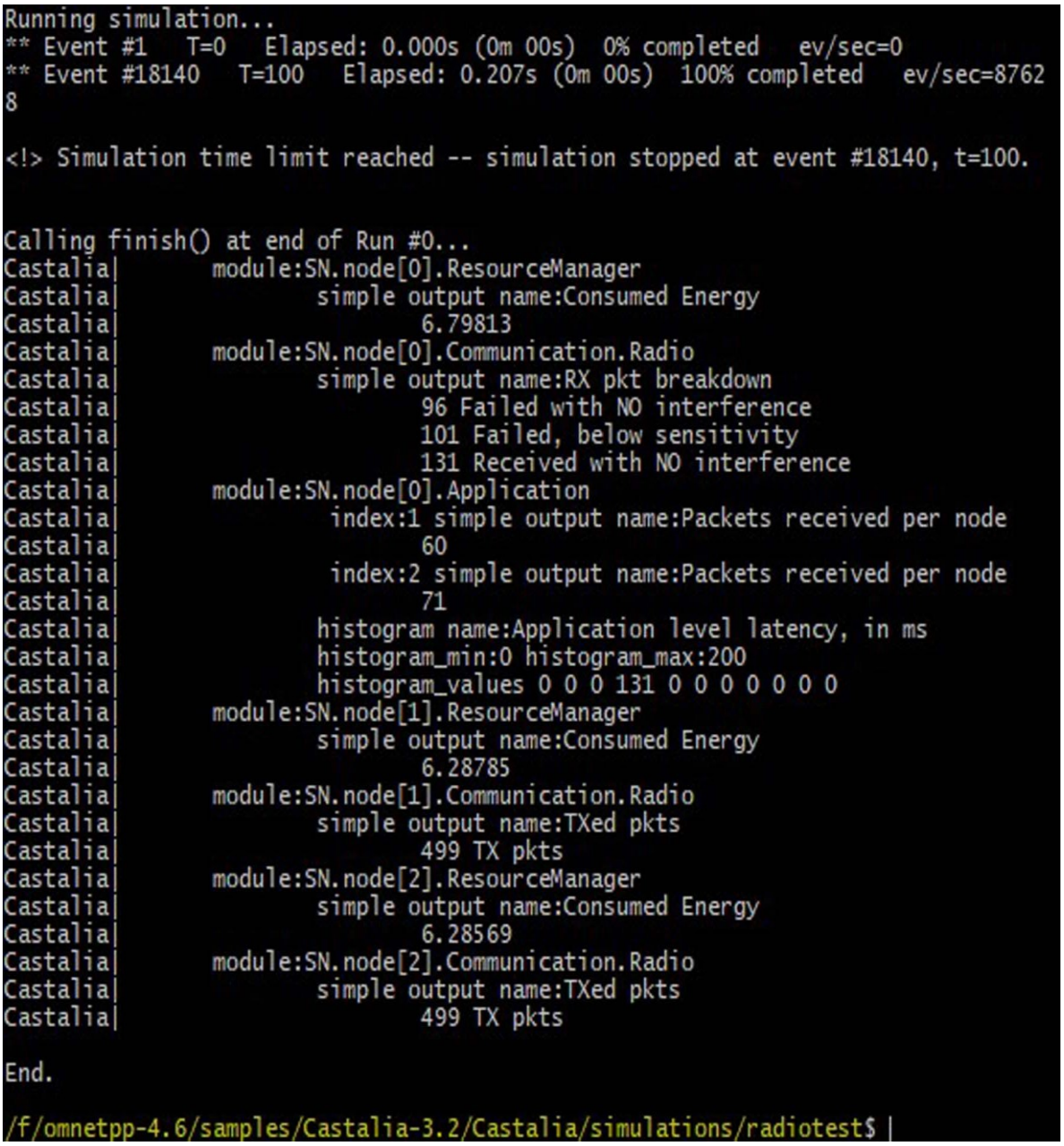


Figure 3.2: Simulation result for Radio Test

Figure 3.2 shows the snapshot of Radio test followed by the Figure 3.3 which is plotted in gun plot (the plot which is supported by Castalia 3.2) shows energy consumption with respect to different nodes. Each and every line shows a different trace event. The first term in the line depicts simulation time on which that event happened. Second term shows the full name of the module which produces the particular trace event. In all of the above examples, all the lines produced by the Application module of node 0. Finally, the last term shows the trace message itself. The example above shows that most messages notify users of packet received by node and also depicts the packet's serial number. The creation of radio test simulation scenarios has been stimulated so that different users can have the idea of realistic model and can also see some of Castalia's features in action.

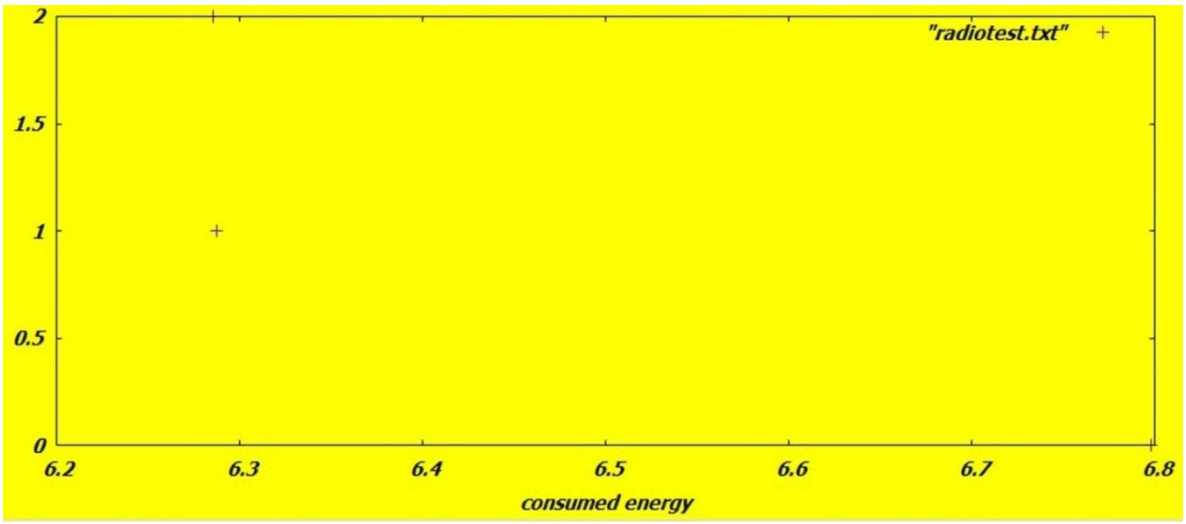


Figure 3.3: Gun plot for Radio Test

```
Castalia|        module:SN.wirelessChannel
Castalia|                histogram name:Fade depth distribution
Castalia|                histogram_min:-50 histogram_max:15
Castalia|                histogram_values 0 0 4 8 16 27 60 154 287 422 388 121 7
0
Castalia|        module:SN.node[0].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.158026
Castalia|        module:SN.node[0].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        28 Failed, below sensitivity
Castalia|                        213 Received with NO interference
Castalia|        module:SN.node[0].Application
Castalia|                 index:3 simple output name:Packets received per node
Castalia|                        213
Castalia|                histogram name:Application level latency, in ms
Castalia|                histogram_min:0 histogram_max:600
Castalia|                histogram_values 213 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0
Castalia|        module:SN.node[1].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.1581
Castalia|        module:SN.node[1].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        8 Failed, below sensitivity
Castalia|                        241 Received with NO interference
Castalia|        module:SN.node[2].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.158001
Castalia|        module:SN.node[2].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        17 Failed, below sensitivity
Castalia|                        228 Received with NO interference
Castalia|        module:SN.node[3].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.157937
Castalia|        module:SN.node[3].Communication.Radio
Castalia|                simple output name:TXed pkts
Castalia|                        249 TX pkts
Castalia|        module:SN.node[4].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.158066
Castalia|        module:SN.node[4].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        4 Failed, below sensitivity
Castalia|                        244 Received with NO interference
Castalia|        module:SN.node[5].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.158092
Castalia|        module:SN.node[5].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        39 Failed, below sensitivity
Castalia|                        197 Received with NO interference

End.

/f/omnetpp-4.6/samples/Castalia-3.2/Castalia/simulations/BANtest$ |
```

Figure 3.4: Simulation result for Ban Test

Figure 3.4 shows the snapshot of BANTEST which explains that, for node 0 to 5 different resource managers consumes different energy. The graph in Figure 3.5 has been drawn using gun plot to show

the erratic behavior of energy at different nodes. Ban test drag wireless communications protocols which allow low powered sensors to communication with each other. It can also transmit data to remote areas like local base station and hospitals.

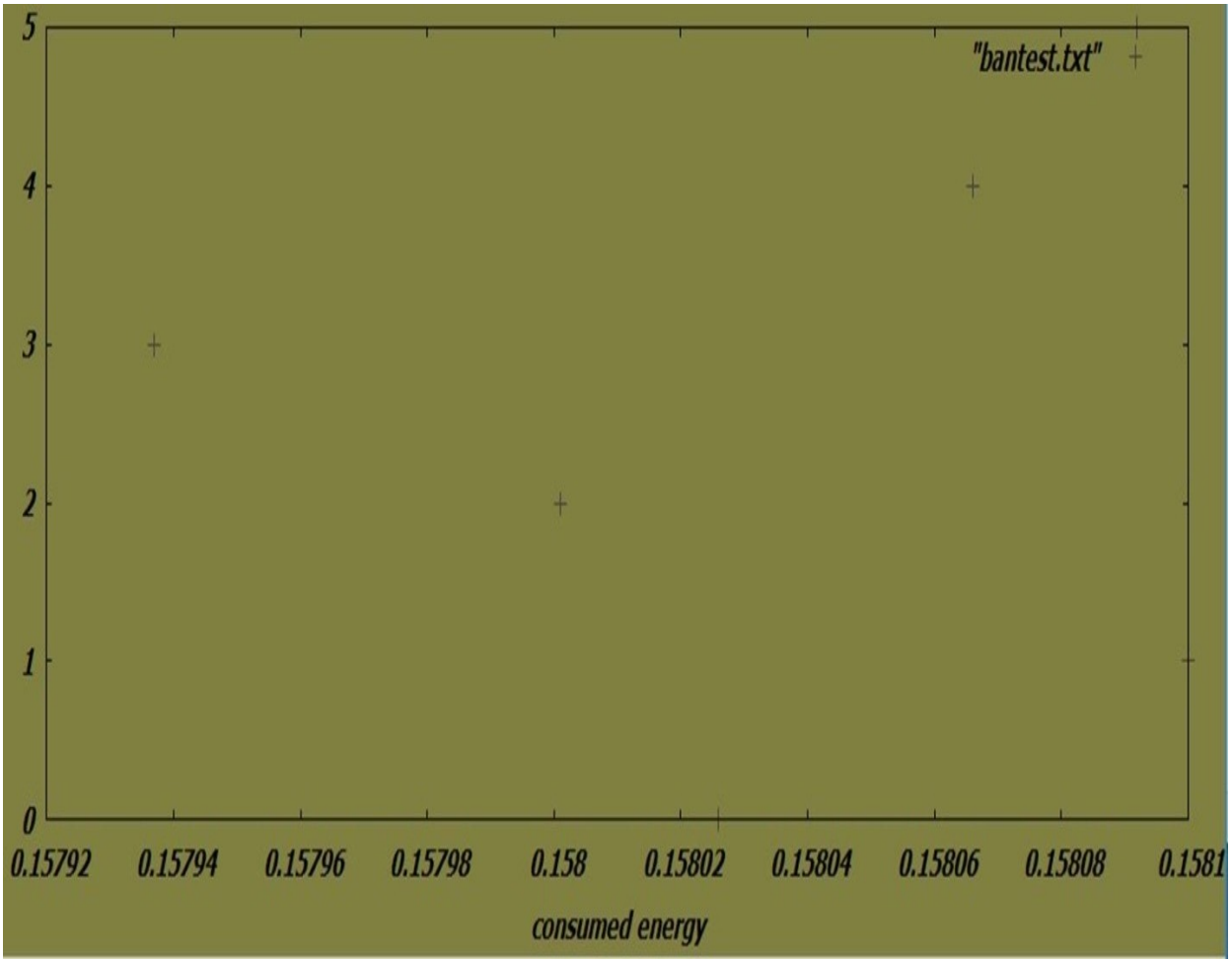


Figure 3.5: Gun plot for Ban Test

Figure 3.6 shows the Simulation result for Value propagation which gives user an idea of that how beacons are travelling and whether they are accepted if YES then how much energy it is consuming for particular node by different resource manager and if they are rejected that is NO then what other node is going to interact with. Here 0-15 nodes are taking part in simulation. Figure 3.7 drawn here depicts the energy plotting of those different nodes so that the user can provide sufficient input at the external level. In value propagation user combine 3 configurations i.e. vary duty cycle, vary beacon, transmission power. Total energy consumed here is graphically shown using gun plot.

```
Castalia|        module:SN.node[14].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.138658
Castalia|        module:SN.node[14].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        4 Failed with NO interference
Castalia|                        1 Failed with interference
Castalia|                        7 Failed, below sensitivity
Castalia|                        284 Failed, non RX state
Castalia|                        3 Received with NO interference
Castalia|                simple output name:TXed pkts
Castalia|                        23 TX pkts
Castalia|        module:SN.node[14].Communication.MAC
Castalia|                simple output name:TunableMAC packet breakdown
Castalia|                        1 Received from App
Castalia|                        3 received data pkts
Castalia|                        22 sent beacons
Castalia|                        1 sent data pkts
Castalia|        module:SN.node[14].Application
Castalia|                simple output name:app packets received
Castalia|                        3
Castalia|                simple output name:got value
Castalia|                        1 yes/no
Castalia|        module:SN.node[15].ResourceManager
Castalia|                simple output name:Consumed Energy
Castalia|                        0.143529
Castalia|        module:SN.node[15].Communication.Radio
Castalia|                simple output name:RX pkt breakdown
Castalia|                        2 Failed with NO interference
Castalia|                        2 Failed with interference
Castalia|                        11 Failed, below sensitivity
Castalia|                        259 Failed, non RX state
Castalia|                        25 Received with NO interference
Castalia|                simple output name:TXed pkts
Castalia|                        23 TX pkts
Castalia|        module:SN.node[15].Communication.MAC
Castalia|                simple output name:TunableMAC packet breakdown
Castalia|                        1 Received from App
Castalia|                        21 received beacons
Castalia|                        4 received data pkts
Castalia|                        22 sent beacons
Castalia|                        1 sent data pkts
Castalia|        module:SN.node[15].Application
Castalia|                simple output name:app packets received
Castalia|                        4
Castalia|                simple output name:got value
Castalia|                        1 yes/no

End.

/f/omnetpp-4.6/samples/Castalia-3.2/Castalia/simulations/valuepropagation$ |
```

Figure 3.6: Simulation result for Value Propagation

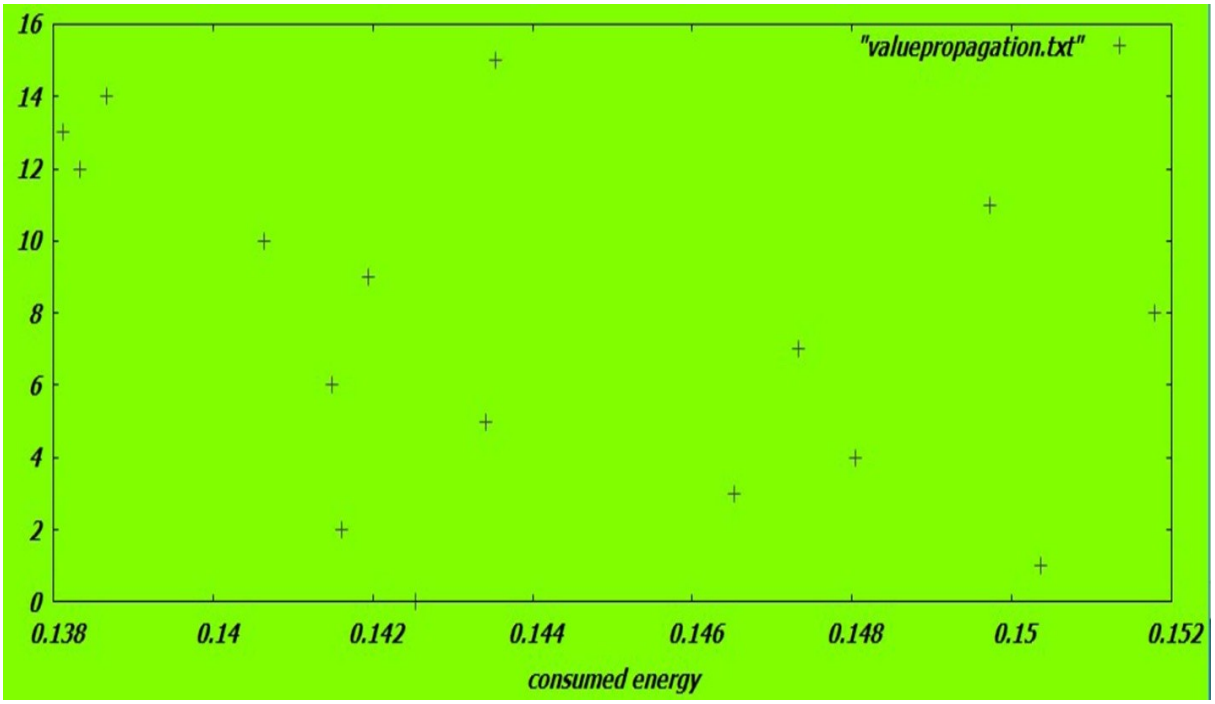


Figure 3.7: Gun plot for Value Propagation

Figure 3.8 depicts the snapshot of Simple aggregation which informs the user that energy is simply transmitting from resource manager to nodes in random fashion. It is more for some nodes and less for the others. Graph shown in Figure 3.9 shows that energy for 0-15 modules /nodes, this energy is increasing and decreasing without any constant factor. So that different networks can be formed to lower its value.

```
Calling finish() at end of Run #0...
Castalia|       module:SN.node[0].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79819
Castalia|       module:SN.node[1].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79982
Castalia|       module:SN.node[2].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79766
Castalia|       module:SN.node[3].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79721
Castalia|       module:SN.node[4].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79907
Castalia|       module:SN.node[5].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79965
Castalia|       module:SN.node[6].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79833
Castalia|       module:SN.node[7].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79813
Castalia|       module:SN.node[8].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79703
Castalia|       module:SN.node[9].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79858
Castalia|       module:SN.node[10].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79702
Castalia|       module:SN.node[11].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.8
Castalia|       module:SN.node[12].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79964
Castalia|       module:SN.node[13].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79993
Castalia|       module:SN.node[14].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79936
Castalia|       module:SN.node[15].ResourceManager
Castalia|               simple output name:Consumed Energy
Castalia|                       6.79922

End.

/f/omnetpp-4.6/samples/Castalia-3.2/Castalia/simulations/simpleAggregation$ |
```

Figure 3.8: Simulation result for Simple Aggregation

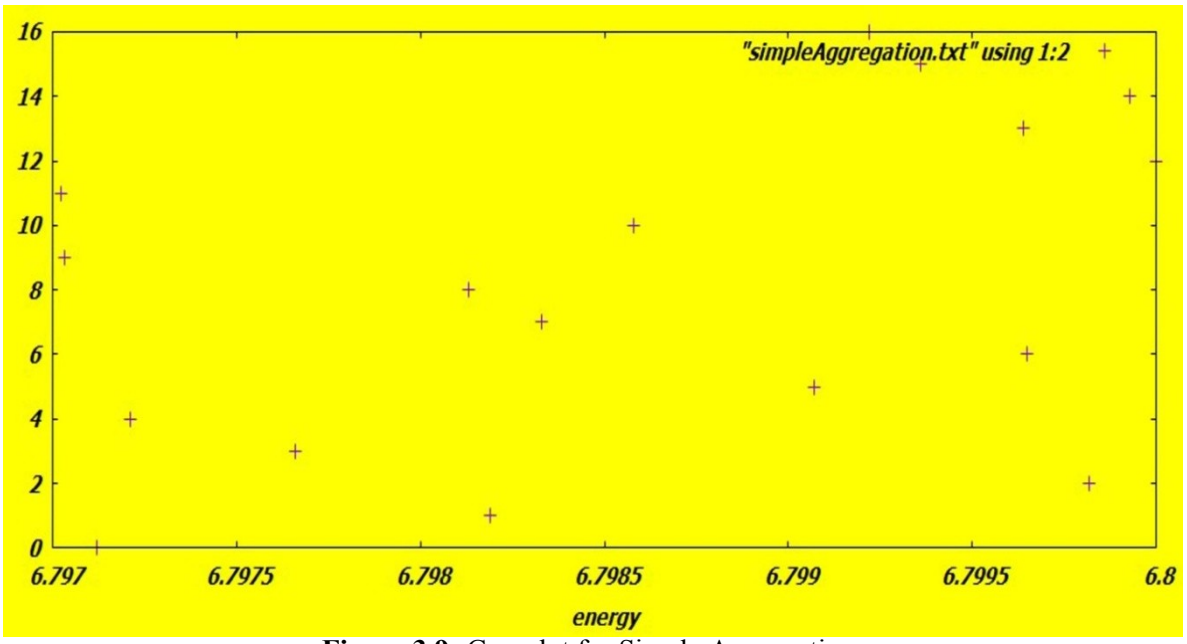


Figure 3.9: Gun plot for Simple Aggregation

```
castalia|        module:SN.node[33].ResourceManager
castalia|                simple output name:Consumed Energy
castalia|                        5.854
castalia|        module:SN.node[33].Communication.Radio
castalia|                simple output name:RX pkt breakdown
castalia|                        72 Failed with NO interference
castalia|                        150 Failed with interference
castalia|                        793 Failed, below sensitivity
castalia|                        15 Failed, non RX state
castalia|                        89 Received despite interference
castalia|                        881 Received with NO interference
castalia|                simple output name:TXed pkts
castalia|                        100 TX pkts
castalia|        module:SN.node[33].Communication.MAC
castalia|                simple output name:Sent packets breakdown
castalia|                        100 SYNC
castalia|        module:SN.node[34].ResourceManager
castalia|                simple output name:Consumed Energy
castalia|                        5.85561
castalia|        module:SN.node[34].Communication.Radio
castalia|                simple output name:RX pkt breakdown
castalia|                        236 Failed with NO interference
castalia|                        155 Failed with interference
castalia|                        886 Failed, below sensitivity
castalia|                        24 Failed, non RX state
castalia|                        82 Received despite interference
castalia|                        717 Received with NO interference
castalia|                simple output name:TXed pkts
castalia|                        100 TX pkts
castalia|        module:SN.node[34].Communication.MAC
castalia|                simple output name:Sent packets breakdown
castalia|                        100 SYNC
castalia|        module:SN.node[35].ResourceManager
castalia|                simple output name:Consumed Energy
castalia|                        5.75972
castalia|        module:SN.node[35].Communication.Radio
castalia|                simple output name:RX pkt breakdown
castalia|                        193 Failed with NO interference
castalia|                        116 Failed with interference
castalia|                        790 Failed, below sensitivity
castalia|                        35 Failed, non RX state
castalia|                        40 Received despite interference
castalia|                        537 Received with NO interference
castalia|                simple output name:TXed pkts
castalia|                        100 TX pkts
castalia|        module:SN.node[35].Communication.MAC
castalia|                simple output name:Sent packets breakdown
castalia|                        100 SYNC

End.

/f/omnetpp-4.6/samples/Castalia-3.2/Castalia/simulations/valueReporting$ |
```

Figure 3.10: Simulation result for Value Reporting

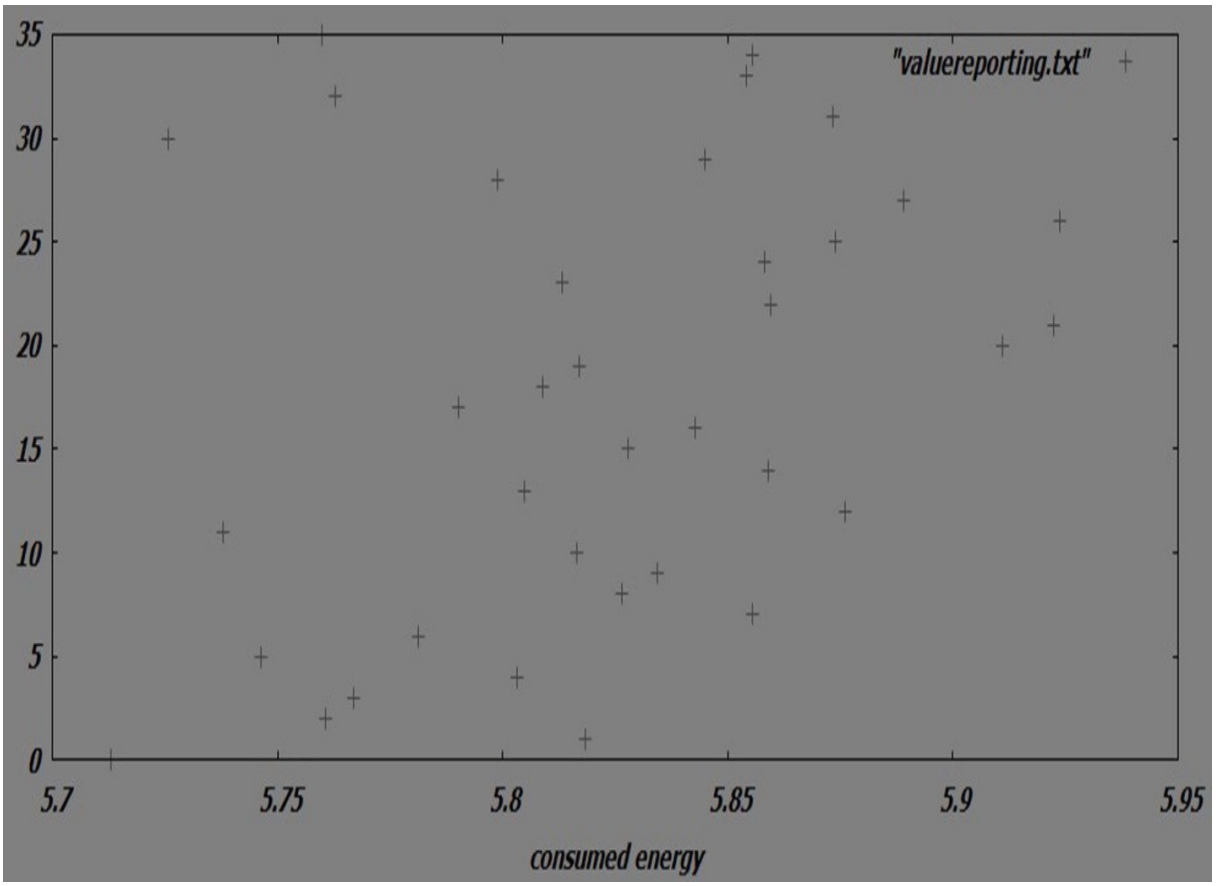


Figure 3.11: Gun plot for Value Reporting

Figure 3.10 revealing the snapshot of Value reporting which reports that energy consumption takes place at two levels whether it is taking place with radio or MAC protocol and when packet breakdown is there, or when it is received then how much energy is actually consumed. This simulation takes place for 0-35 nodes and the graph shown in Figure 3.11 depicts consumption of energy for all those nodes. This energy graph also follows the random fashion and can be plotted in gun plot.

Castalia has now moved to new territories and give privilege to the researcher to create your own simulation in OMNET++ directory so that he can compare different functionalities in other software.

CHAPTER 4

PROBLEM STATEMEMT AND OBJECTIVE

4.1 PROBLEM STATEMENT

Huge amount of energy is consumed when data transmits from human body to the main central server. Few amount of energy get wasted due to path loss factor and some get consumed in relay nodes. So the overall energy we get at the output is too less than required. So, there is need to reduce overall consumption of energy in any wireless system. As need of energy upgrades results increase in overall cost of system.

While designing a network, energy consumption considered to be the most important factor. So, considerable work has been done just to explore the erratic nature of energy in different type of simulations for wireless body area sensors network and in their architecture. In between communicating nodes wireless networking involves positioning of different types of topologies having indefinite number of sensor nodes. As the number of nodes increases in any wireless body area sensors network, consumption of energy also increases. So, different parameters are examined by keeping an aim to achieve maximum throughput, controlling the major sources of energy dissipation, node degree should be balanced, capacity of network and bisection width should be symmetrical.

4.2 OBJECTIVE

In biomedical research, immeasurable attention is given to reduce power consumption between different sensors nodes, so that the battery life of complete system can be increased. For that the nodal structure so designed, which is worn or implanted on the body structure can get small amount of energy from their surroundings. Thus to escalate the life of the network, different mechanisms are adopted like variation in topology, which can further be compared on the basis of different parameters. While adopting this method, we want to prove technically or practically, that for large network areas, specifically for body sensors this parametric comparison on various topologies will work efficiently and will be more beneficial for researchers for their future research work.

In past few years, researches have been done on various protocols, integration of circuits, network on chips, different algorithms on single type of topology but in this research different topology formation with some parameters are selected to carry out the work in an effective manner. Types of topology have variation in their nodal structure gives different distance and energy consumption. These topologies varied in shape, number of nodes and dependent on distance if transmission and receiver energies are same in all the three cases (elementary, hexagonal, mesh). These parameters are decided so that it can cover all the basic requirements of any wireless connection to reduce overall system cost.

CHAPTER 5

PARAMETRIC COMPARISON OF DIFFERENT TOPOLOGIES IN WIRELESS BODY AREA SENSORS NETWORK

Wireless body area network tries to connect independent nodes that are sometimes implanted under the skin of human body or sometimes lie on the body. This type of network typically prolonged over the whole human body or sometimes covers few organs of human body and the different nodes are connected with each other through wireless communication channel. According to the implementation, these nodes are placed in random, hexagonal and in elementary manner to build different types of topologies.

Energy consumption plays important role in deployment of WBANs, therefore it is magisterial that the demand of energy in network should as small as possible. WBAN consumes energy in various operations like in sensing, communicating and data processing. Most of the energy consumption takes place during communication when different nodes are actually transferring data from one node to another. In the last few years, number of techniques and different type of chips were made for low power consumption in authentic devices which attracts a great deal of attention for future developers and researchers.

WBAN consist of dissimilar components which work together to store, process and dispatch data from human body to particular points of body where data is required at that particular of time for any emergency response. Figure 5.1 shows main components which includes sensors nodes, control center and gateway which helps in connecting the sensors to the main network.

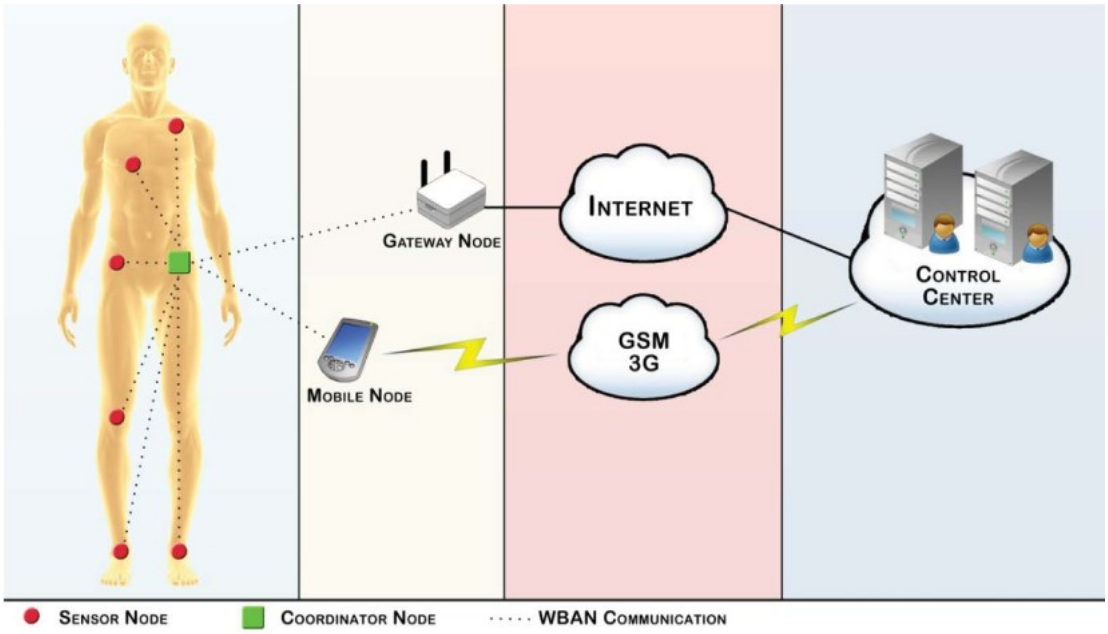


Figure 5.1: Main Components of wireless body area sensors network

5.1 CONCEPTUAL DESIGN

This conceptual model is actually garrison on a archetypal WBAN for different and specific type of applications, which focus on the factors that affect consumption of energy during communication between relays, node and sink. Figure 5.2 shows the model layout [11] 12] is so designed so that the relations between components, attributes and interfaces can be emphasized**.**

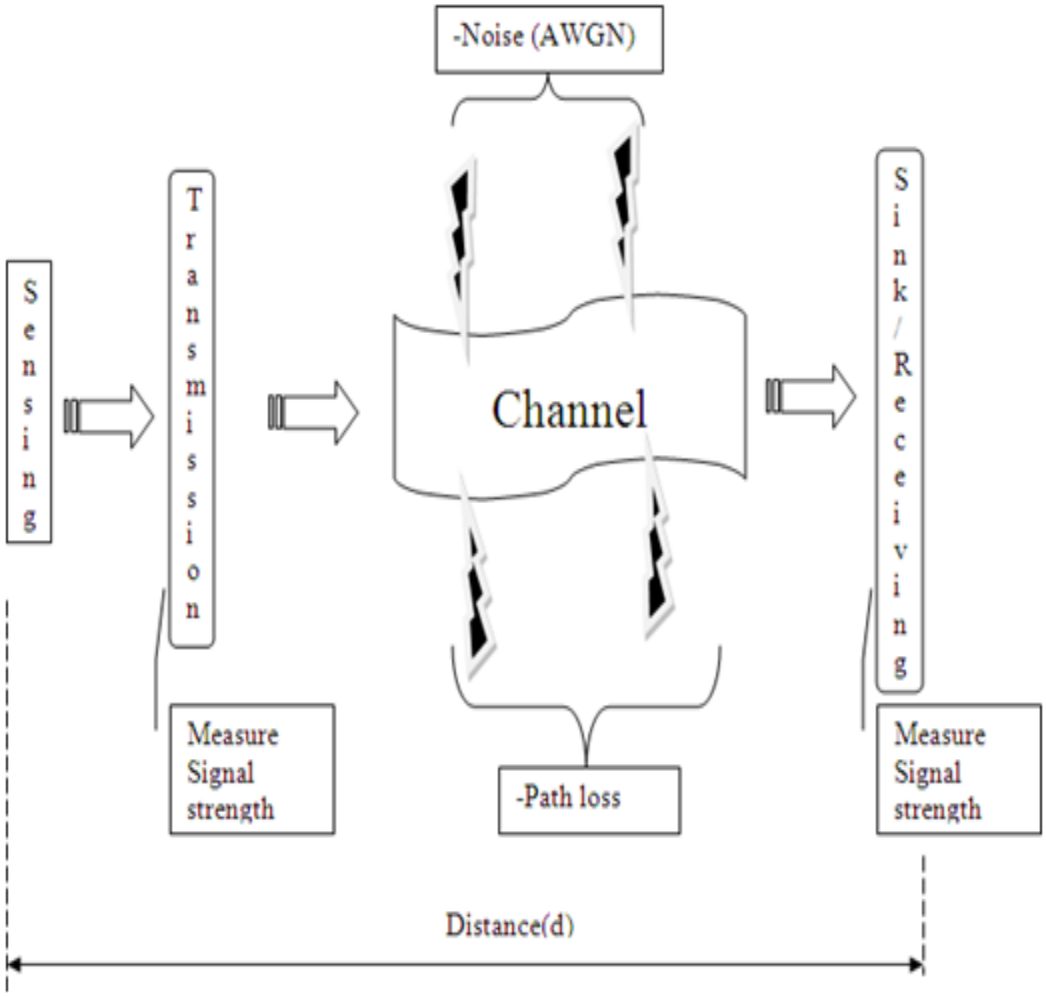


Figure 5.2: Model layout

5.2 CONCEPTUAL MODEL COMPONENTS

1. Sensing unit

It carries the sensors which collect information in the form data from various parts of body. Sensors collect different physical signals like body movement, pressure, temperature and other physical disturbances happens in our body. Sensors collect these analog signals which then transferred by the transmitter.

2. Transmission unit

It helps in collecting data from sensor node and delivers it to receiver node. Distance and signal strength plays most important role in relaying of signals. Distance is basically defined as the separation between transmitter and receiver which is used to calculate minimum power required to send the signal. The strength of signal is first measured at the transmitter and then at receiver end so that we can establish the optimal distance between them.

3. Channel

To describe the parameters between the transmitter and receiver, distinct type of channel [13] parameters are used, so that the capacity of wireless link can be accurately estimated.

Parameters like channel capacity, noise, path loss will influence the transmission of signal.

Noise: Any interference from environment can affect the signal strength or signal itself which is going to transfer between the transmitter and receiver node. In this model that kind of noise is represented as Additive White Gaussian Noise (AWGN).

Path loss: This component is also highlighted in this model. Path loss is basically affected by the distance between the nodes and body movement. It varies because it depends upon line of sight that is whether the communication takes place is of line of sight or non line of sight.

4. Node location

Placement of nodes is accomplished by using a MATLAB code to generate node positions on 150cm plane/graph. The choice of 150 cm is astute because an average height of person is 150cm.

So, this placement of nodes [14] can be deployed on various types [15] of topologies. Here the nodes are randomly placed on all the three graphs of different topologies [16] and then the distance between them is calculated by taking one of the reference node and all others are (sink) nodes. The x and y coordinates of different nodes are calculated to measure the accurate distance between them by applying the Pythagorean Theorem. For all node pairs, distance between nodes taking reference as n_i, n_j and reference point

$X = \text{abs}(x_i - x_j)$

$Y = \text{abs}(y_i - y_j)$

$\text{Distance} = \text{sqrt}(X^2 + Y^2)$

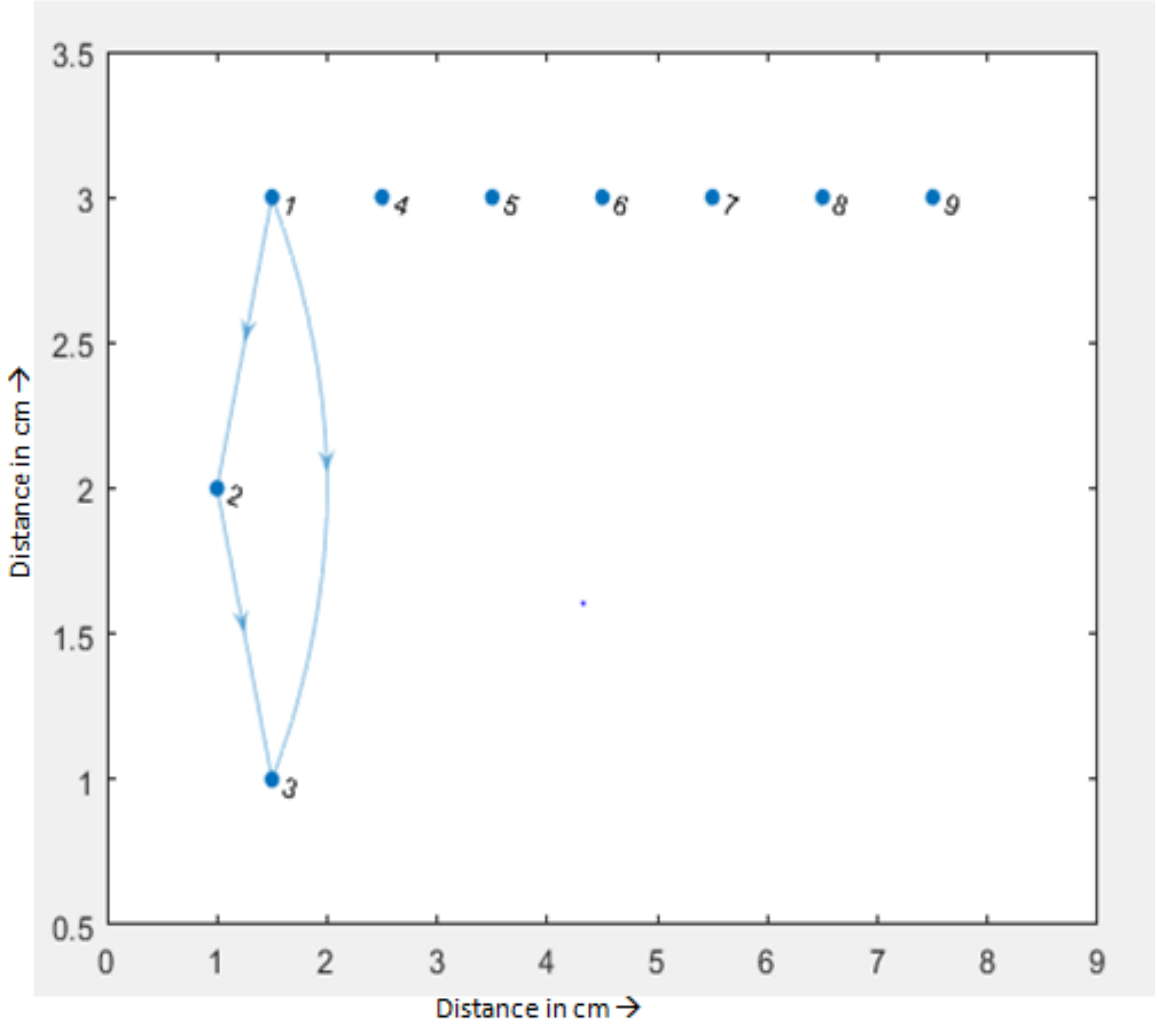


Figure 5.3: Random placement of nodes for Elementary type of topology

Table 5.1: Data for nodes Vs distance for Elementary topology

Node Pairs	**Distance (cm)**
1-2	**1**
1-3	**2**
2-3	**1**

Figure 5.3 shows elementary kind of topology in which by taking node 2 as reference distance is calculated between node 2 and 1, node 2 and 3. Table 5.1 shows the nodes combination and corresponding distance between them.

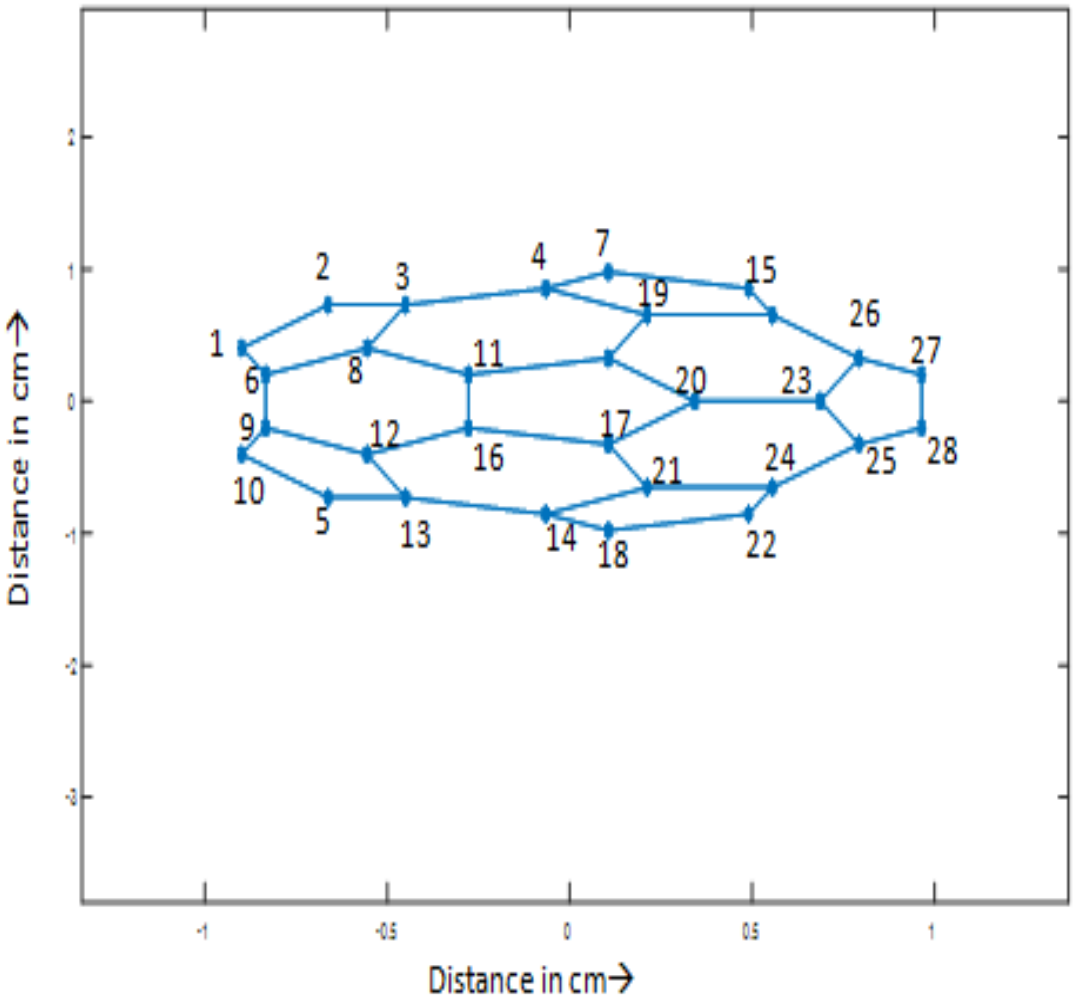


Figure 5.4: Random placement of nodes for Hexagonal type of topology

Table 5.2: Data for nodes Vs distance for Hexagonal topology

Node pairs	**Distance (cm)**
6-8	**0.3**
8-11	**0.35**
11-16	**0.4**
16-12	**0.25**
12-9	**0.26**
9-6	**0.5**

Figure 5.4 shows hexagonal type of topology in which different hexagons are formed. By taking one (the left most in the middle) hexagon into consideration we calculate the distance between corresponding nodes. Table 5.2 shows the combination of different nodes structured in hexagon and the distance between them.

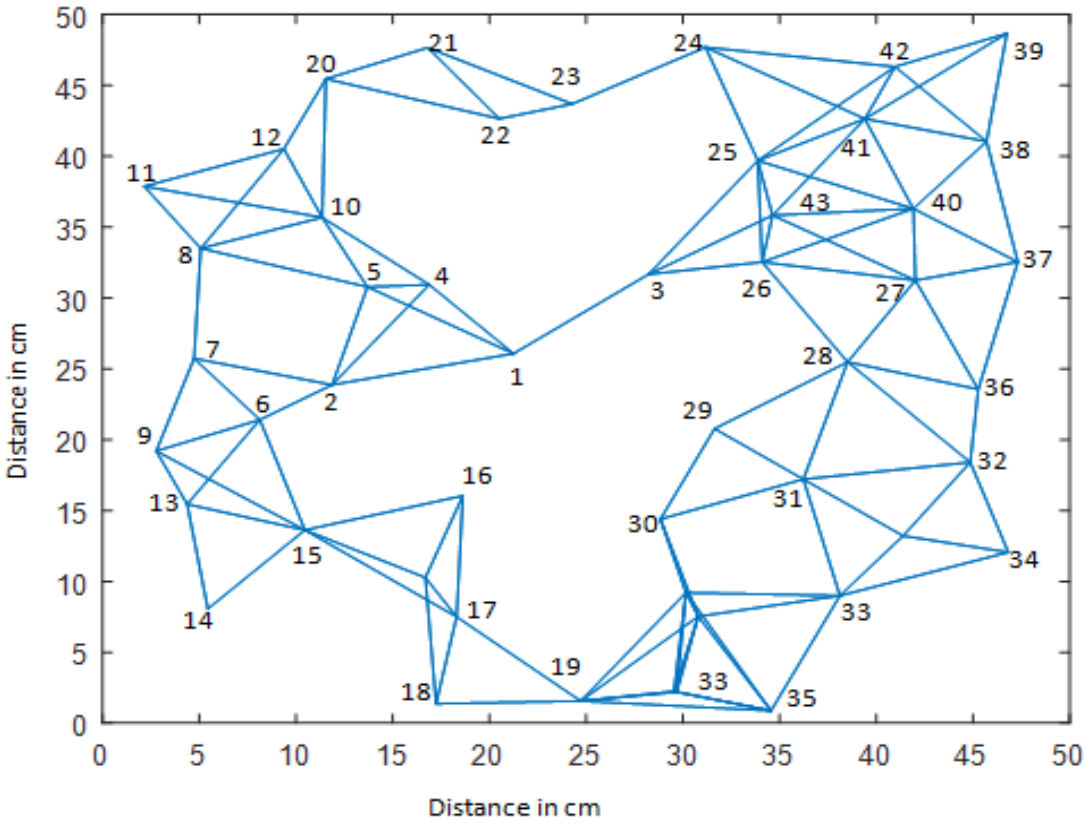


Figure 5.5: Random placement of nodes for Mesh type of topology

Table 5.3: Data for nodes Vs distance for Mesh topology

Node pairs	Distance (cm)
1-2	9.5
1-3	5.5
1-5	8
2-5	8.5
4-5	3.5
1-8	16.7
8-10	7
25-39	11.5
25-40	8
42-38	5
40-38	6.2

Figure 5.5 shows Mesh topology in which we consider large amount of nodes are placed in a random manner. By taking one section (uppermost left section) we calculate the distance between different nodes and corresponding energy consumes by each node. Table 5.3 shows the all the nodes pairs and

corresponding distance [18] between them so that energy can be calculated. Now the question is how energy is related to distance.

To answer that, we propose an [19] [20] efficient Radio Propagation Energy Model. This model helps in calculating total energy consumed when different nodes are far apart at some distance, present in any network area. Now, how this energy varies according to distance is explained in next paragraph.

5.3 RADIO PROPAGATION ENERGY MODEL

To calculate consumption of energy in wireless body area sensors network, Radio Propagation Model has been proposed. This model was proposed by Reusens E. et al in 2009). Model uses the distance (d) between source node and destination node and assumes that loss of energy [21] due to transmission is d^2. Equations included in this model are shown below:

$$E_{Tx}(k,d) = E_{Tx-elec}(k) + E_{Tx-amp}(k,d) \quad (1)$$

$$E_{Tx}(k,d) = E_{Tx-elec} \times k + E_{amp} \times k \times d^2 \quad (2)$$

$$E_{Rx}(k) = E_{Rx-elec}(k) E_{Rx}(k) = E_{Rx-elec} \times k \quad (3)$$

$$E_{Rx}(k) = E_{Rx-elec} \times k \quad (4)$$

Where,

E_{Tx} is transmitted energy in (Joules)

E_{Rx} is energy consumed by the receiver in (Joules)

$E_{Tx-elec}$ is energies required by the transmitter and receiver in nJ/bit. E_{amp} is the energy required by the amplifier in J/bit.

k = size of packet in bits.

Suppose E_{Tx} and E_{Rx} are same for all nodes because we are providing same input energy to each node as we are testing difference in topologies, so receiver and transmitter both consume and emit same amount of energy. Difference is basically counted on the basis of distance parameter. Also we consider the size of packet that is k is constant for each transmission.

According to Table 5.1, 5.2 and 5.3 we calculated distance between the nodes from which further energy which is the square to the distance between nodes can be calculated.

The following Figures numbered 5.6, 5.7 and 5.8 demonstrate here shows mathematical representation of energy consumption [22] of all the three types of topologies. All the three graphs show different form of nature and deviation to the axis. These plots may help many researchers and developers to explore many more simulations of different types in Wireless body area sensors network.

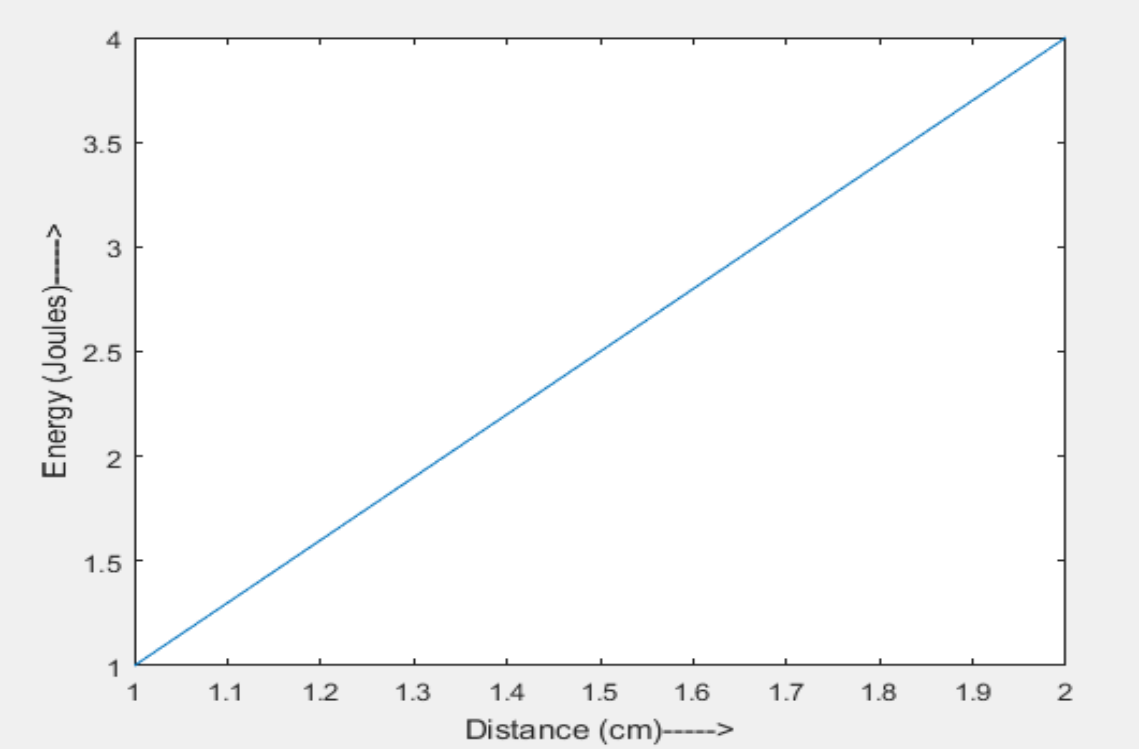


Figure 5.6: Consumption of energy for Elementary topology

Figure 5.6 shows straight line which means distance is linearly vary with energy and directly proportional to it in case of elementary topology. Energy consumption for 2 to 3 nodes in this type of topology goes to 4 joules.

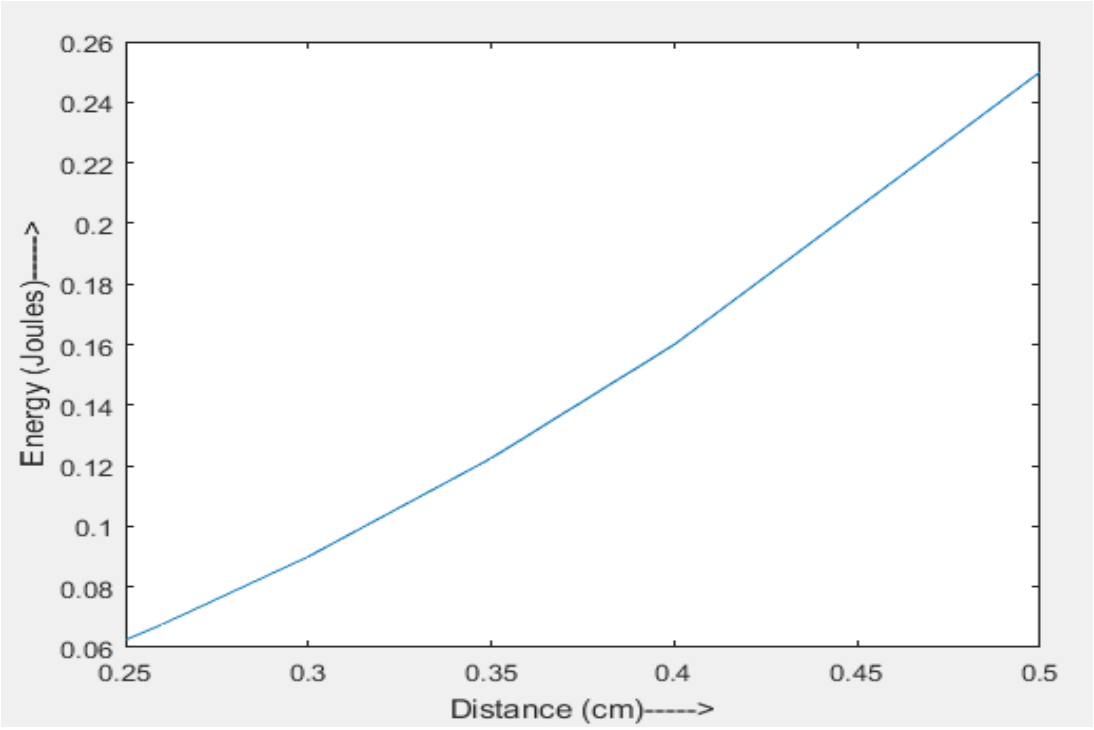


Figure 5.7: Consumption of energy for Hexagonal topology

Figure 5.7 shows a curve of total energy consumed by each node when placed in hexagonal structure separated by some distance. This curve is somehow deviated from linearization but the consumption of energy in case of hexagonal is very less with 6 nodes in a particular hexagon it consumes only 0.25 joules approximately.

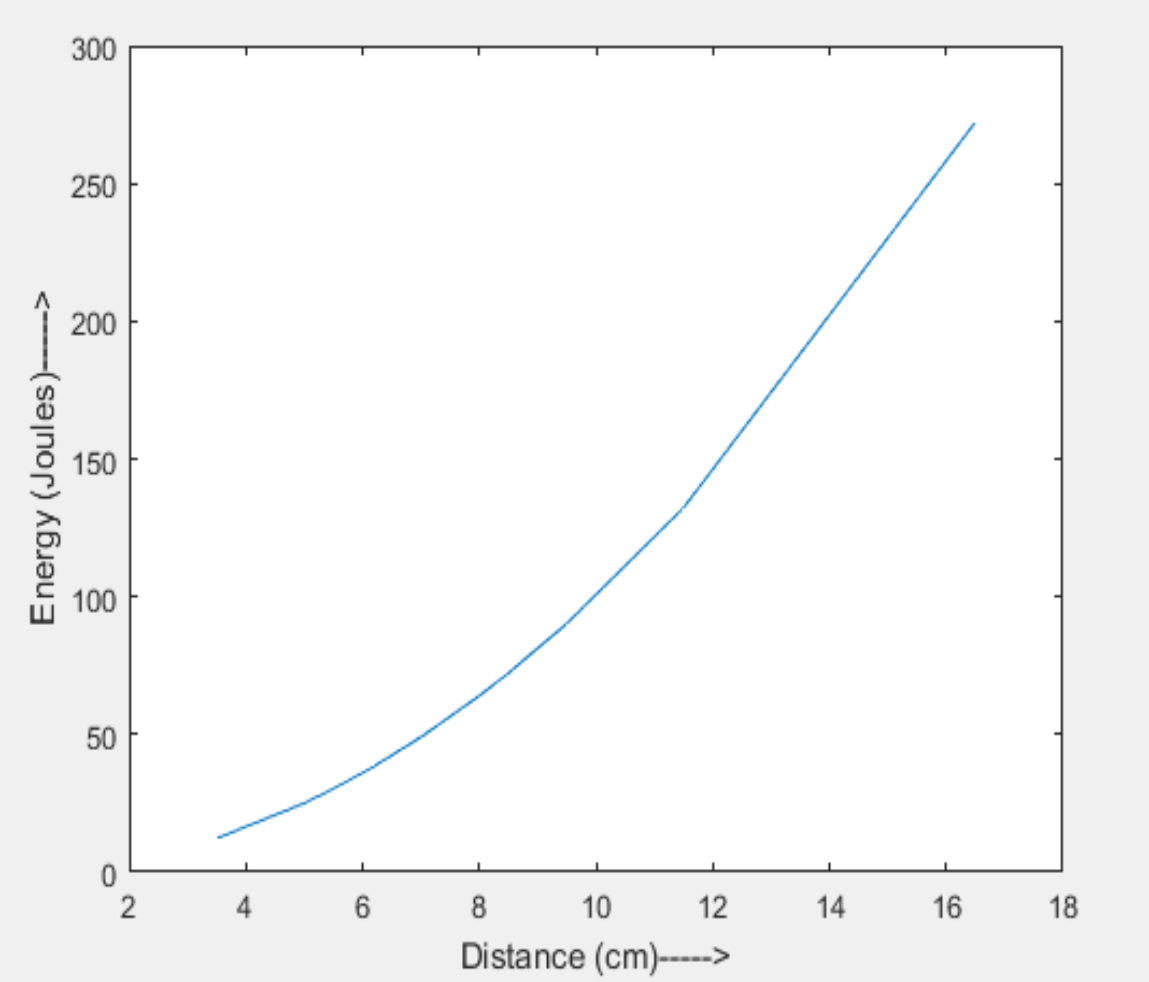


Figure 5.8: Consumption of energy for Mesh topology

Figure 5.8 shows a curve of total energy consumed by each node when placed randomly in any network area separated by some distance consume more energy than required. This more deviated curve shows that energy level raises to 280 joules in case of mesh topology which is not the requirement of any network in any kind of medical sector.

5.4 TOPOLOGY PARAMETER WHICH AFFECTS ENERGY CONSUMPTION

Certain others parameters [24] are used to characterize the different topology. These parameters are used to descry different topology. These parameters are discussed below:

5.4.1 Node Degree

It is defined as the number of links connected to a particular node. If we consider a wireless network where all nodes are having the same node degree that network is called as regular. Here hexagonal topology can be called as regular network where all hexagonal structures are having six degree, whereas elementary kind of topology [25] is irregular. A network consist of small node degree indicates that it consumes less energy and so less hardware cost is required.

5.4.2 Diameter

It is defined as the maximum shortest distance between all pair of nodes. If the distance between particular node pair is less, the energy it consumed is assumed to be less and vice-versa.

Farther the pair more will be the delay and consumption of energy will be more.

5.4.3 Link Capacity

In a particular topology, the total number of links present is called as Link complexity. It is directly proportional to the growth of topology. By adding number of links in the topology we can reduce the diameter. But it also increases the hardware complexity of network and area overhead.

5.4.4 Bisection width

Total number of links required to be eliminate to bisect the topology into two different networks of almost equal size is called as Bisection width.

5.4.5 Probability density function

It is used to specify the probability of random variables (nodes) falling with in particular range of values. This probability [26] is calculated by determining area under the density function but it is observe that area above the horizontal axis is counted and also between the lowest and greatest values of the range.

Probability density function is nonnegative and over the space its integral is equal to one.

So, different topologies are compared on the basis of probability density function by using different codes in MATLAB.

Figure 5.9 shows graph for elementary topology in which values lies between 0.25 & 0.3. That means mean number of nodes per level in elementary type of topology is having probability density function is around 0.29.

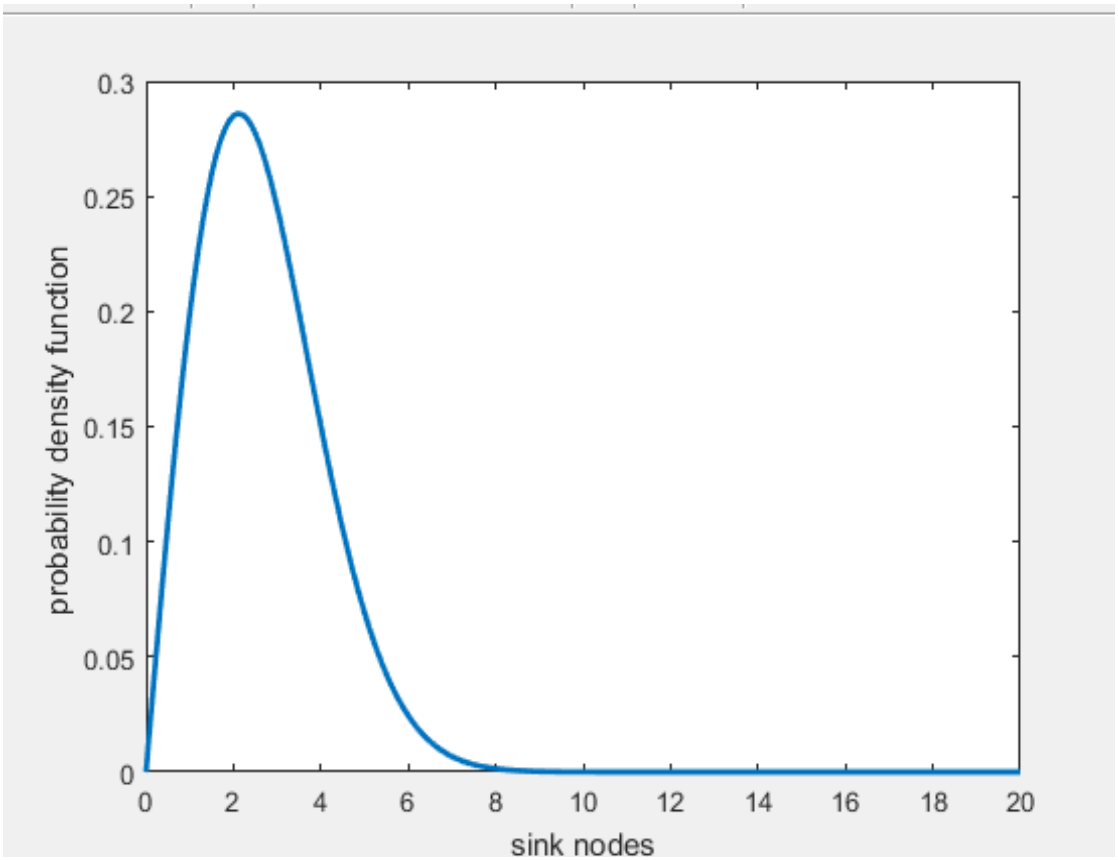


Figure 5.9: Density graph for Elementary topology

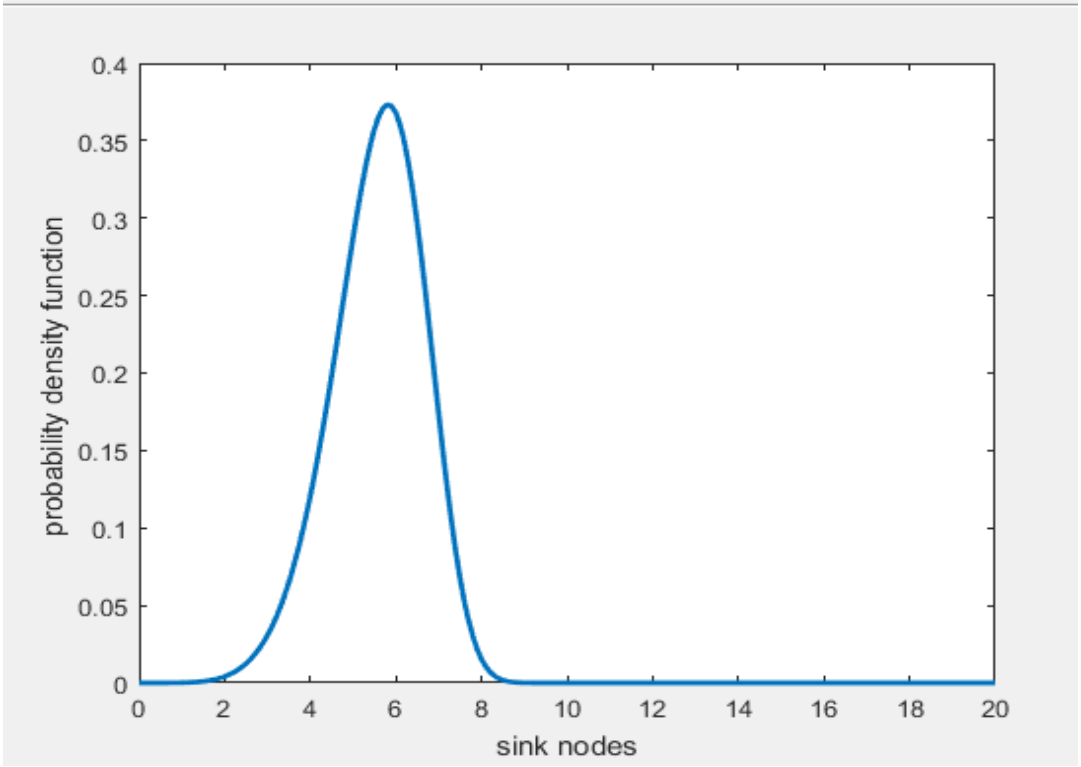


Figure 5.10: Density graph for Hexagonal topology

Figure 5.10 shows graph for hexagonal type of topology in which values lies between 0.35 and 4. It shows that mean number nodes per level that is nodes connected in that particular hexagon is having probability density function as 0.38.

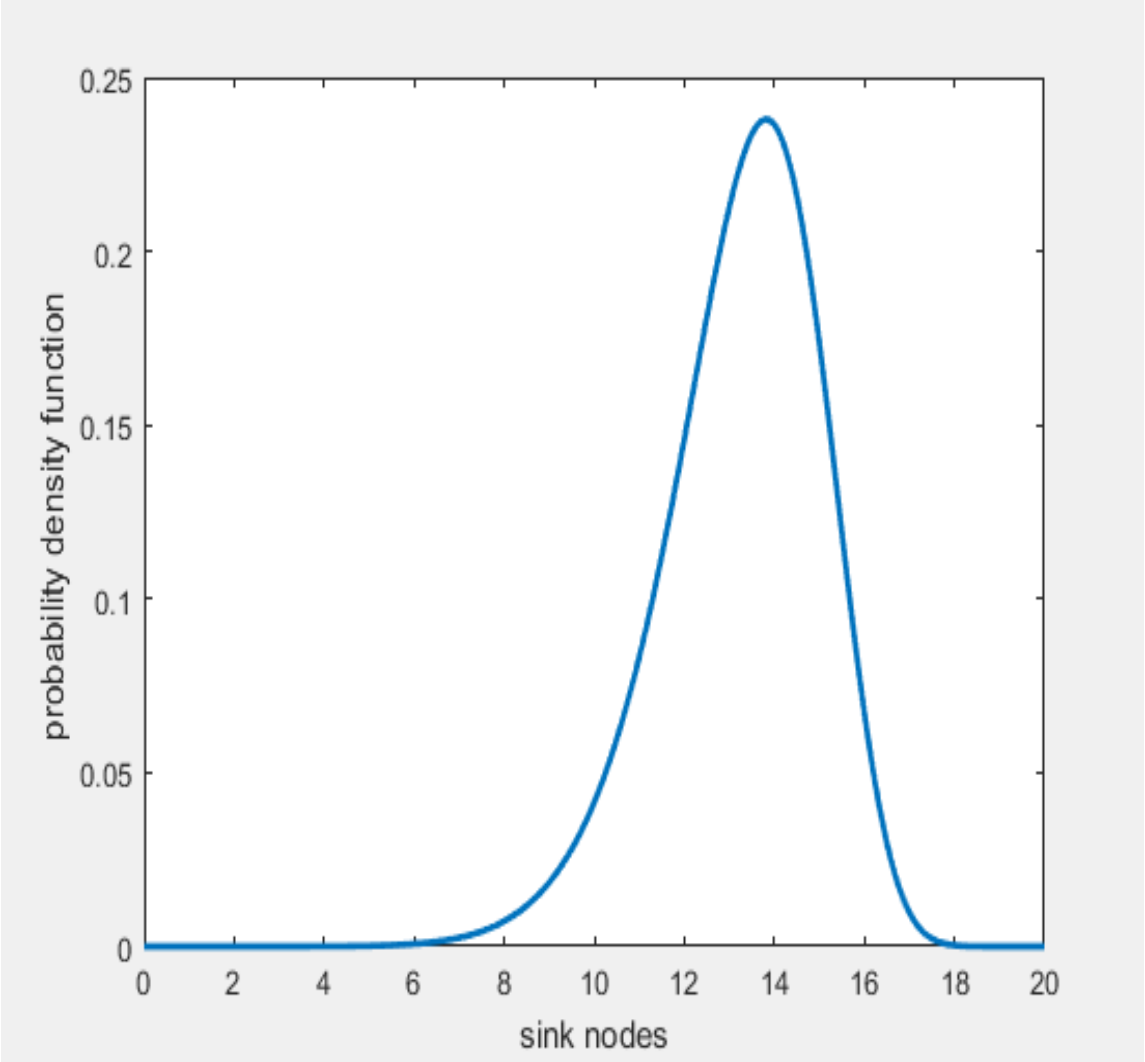


Figure 5.11: Density graph for Mesh topology

Figure 5.11 shows graph for mesh type of topology in which values for probability density function lies between 0.2 and 0.25. It means mean number of nodes connected in that particular area having probability density function as 0.24.

5.4.5.1 Comparison of all three topologies on the basis of probability density function

In Figure 5.12 we can clearly observe that curve with red color shows Hexagonal type of topology which have highest peak than other two because mean number of nodes are distributed in well manner and also number of child node attached with parent node are very well distributed in case of hexagonal while in case of mesh topology it is somehow of tangled nature or we can say it is acrimonious. Yellow colored

graph shows Mesh topology which has lowest peak in all of the three topologies shows that distribution of parent node with respect to child node is not a compact structure and hence consume more battery which gives more cost and less input.

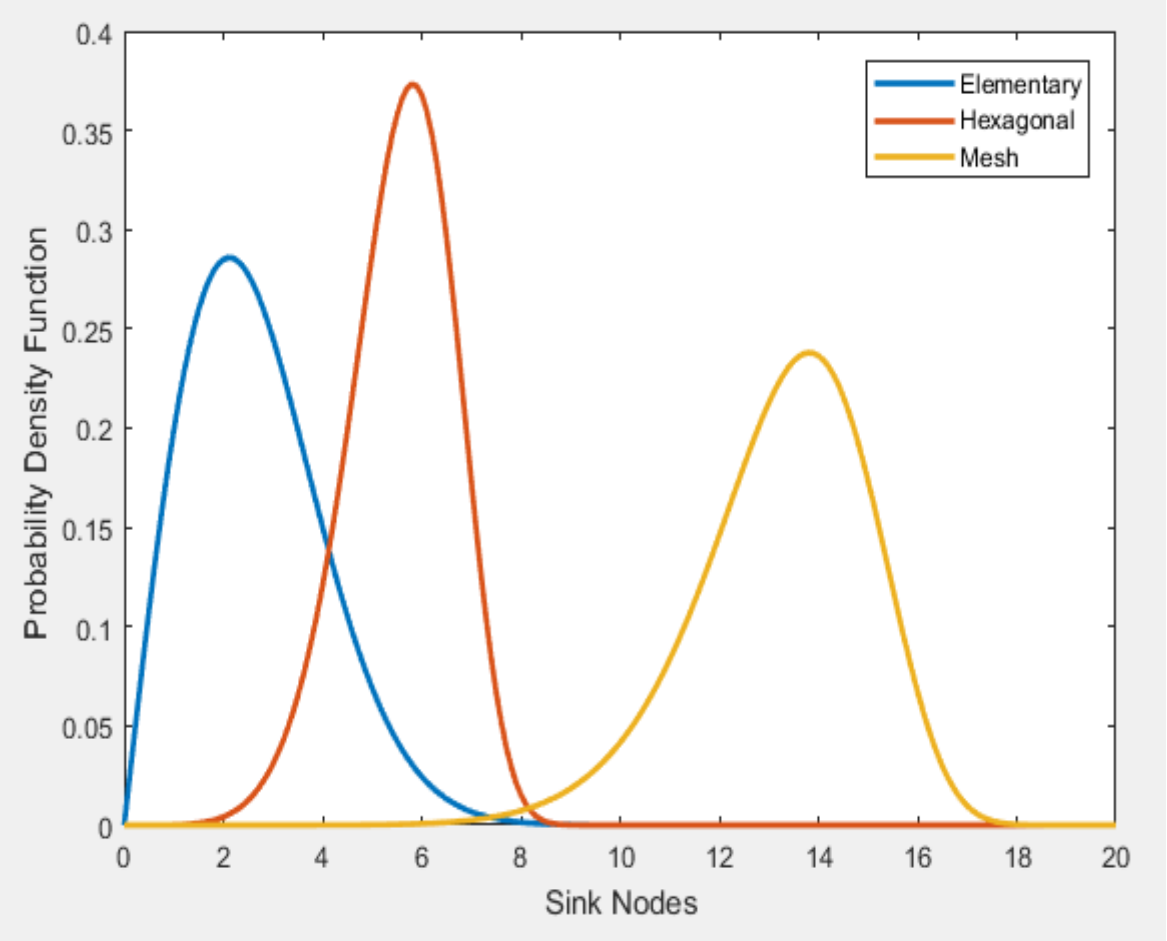


Figure 5.12: Comparison between Elementary, Hexagonal and Mesh on the basis of Density Function

After heaxogonal we will say elementary topology is having well distributed probability density function. And at rank 3 mesh topology because the mean number nodes are not so well dispersefrom which graph lies between 0.2 to 0.25.

5.4.6 Path loss

Path loss [27] is calculated to measure the transmitted energy between two nodes, for instance, power is caluculated between sending node and receiver node for different forms of networks.

It is calculated between the sending and receiver node [28] and is a function of distance parameter. Using this formula we can calculate path loss for any pair of nodes. This formula is shown above:

$$PL\ (d) = PL_0 + 10n\log_{10}(d/d_0) \quad (1)$$

It can also be calculated as a function of both frequency and distance using the formula

$$PL = 20\log_{10}(4\pi df/c) \quad (2)$$

Where f is the frequency, d is the distance between the transmitting node and receiving node and c is the speed of light. In free space, n is used as 3.38. But in WBAN [29] n varies from 3 to 4 for line of sight communication, and it varies from 7 to 8 for non line of sight communication.
In our analysis the 2.4 GHz frequency is used because it is freely available and gives many choices to different researchers in designing of WBAN. The path loss [30] exponent in free space is assumed to be two (2).

MATLAB is used to generate random sensor nodes which further set into three different topologies as shown in figure 18, 19 and 20 i.e. elementary, hexagonal [31] and mesh. From formula 1, path loss for each node pair has been calculated and plot for all the three topologies are shown below in figure 28, 29, and 30.

In this work we want to calculate path loss for each node pair taken into account, but it is difficult in theory not only for perfect analysis but also for practical implementation in real life [33] wireless system deployment [32]. For the sake of simplicity, distance is taken as main parameter. For each node pair, distant apart we get some value of path loss. As it is inversely proportional to the stability of network so it should be as low as possible. Increase in path loss leads to data loss which is not desirable in wireless networks.

As in the case of Elementary topology, Table 5.4 shows that path loss upgrades as the distance increases which further consumes more input energy and overall cost of any network structure composition increases. Following are the results of path loss for different type of topology [34] in figure 5.13, 5.14 and 5.15.

Table 5.4 shows path loss value for elementary kind of topology in which an observation says that as distance [35] upgrades path loss also increases. For all the three node pairs, path loss is calculated and graph of path loss vs distance for elemnetary topology is shown in Figure 5.13. For this type of topology graph gives a straight line. This shows that as distance increase path loss also upgrades which is not desirable in wireless type of networks.

Table 5.4: Data for node Vs Path loss for Elementary topology

Node Pairs (distance in cm)	Path loss
1-2 (1)	0.0415
1-3(2)	6.062
2-3(1)	0.0415

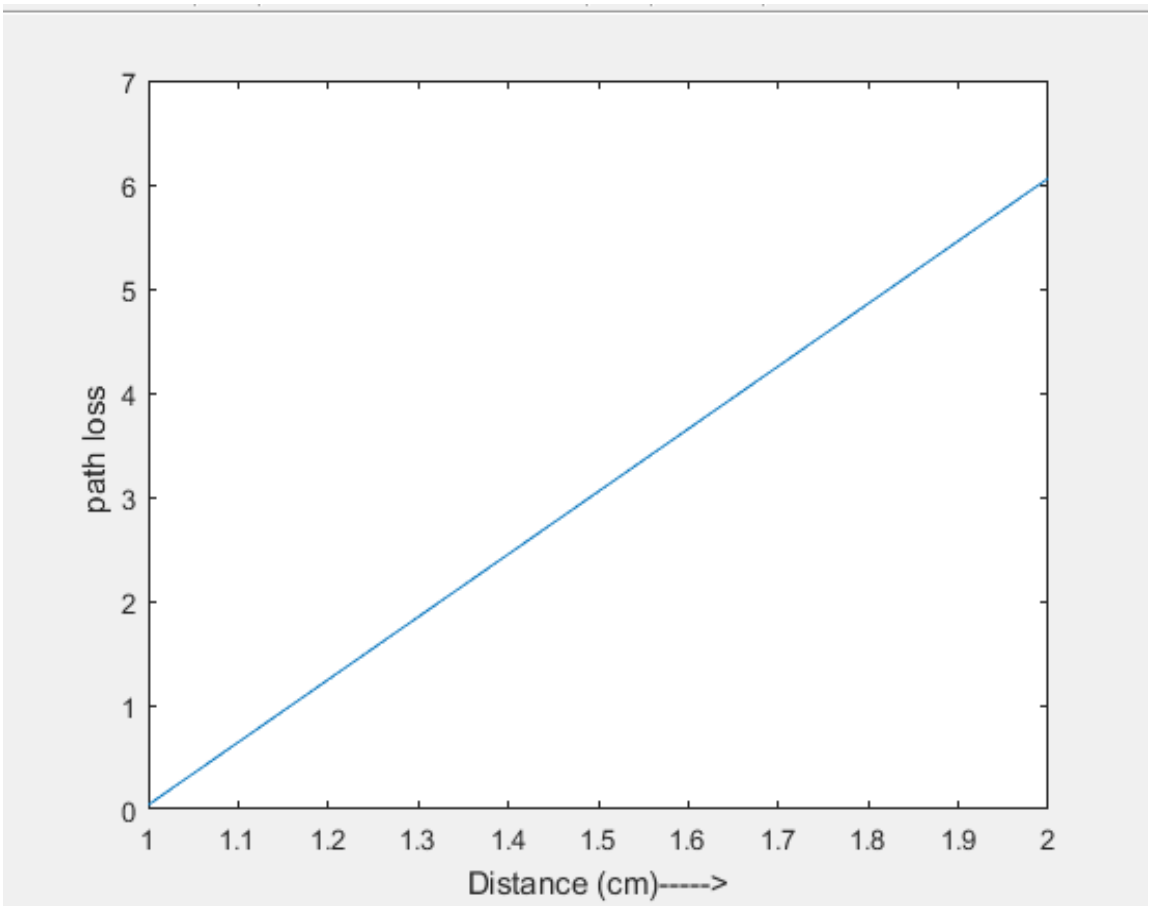


Figure 5.13: Path loss for Elementary topology

Table 5.5 shows path loss value for hexagonal type of topology in which our observation says that as distance upgrades path loss also increases. For all the node pairs, path loss is calculated and graph of path loss vs distance foe hexagonal type of topology is shown in Figure 5.14. For this type of topology graph gives a small curve and values of path loss are in non negative in nature for small distance and compact structure which is the basic need of wireless systems.

Table 5.5: Data for node Vs Path loss for Hexagonal topology

Node pairs (distance in cm)	Path loss
6-8 (0.3)	-10.4159
8-11(0.35)	-9.077
11-16(0.4)	-7.917
16-12(0.25)	-11.99
12-9(0.26)	-11.6589
9-6 (0.5)	-5.979

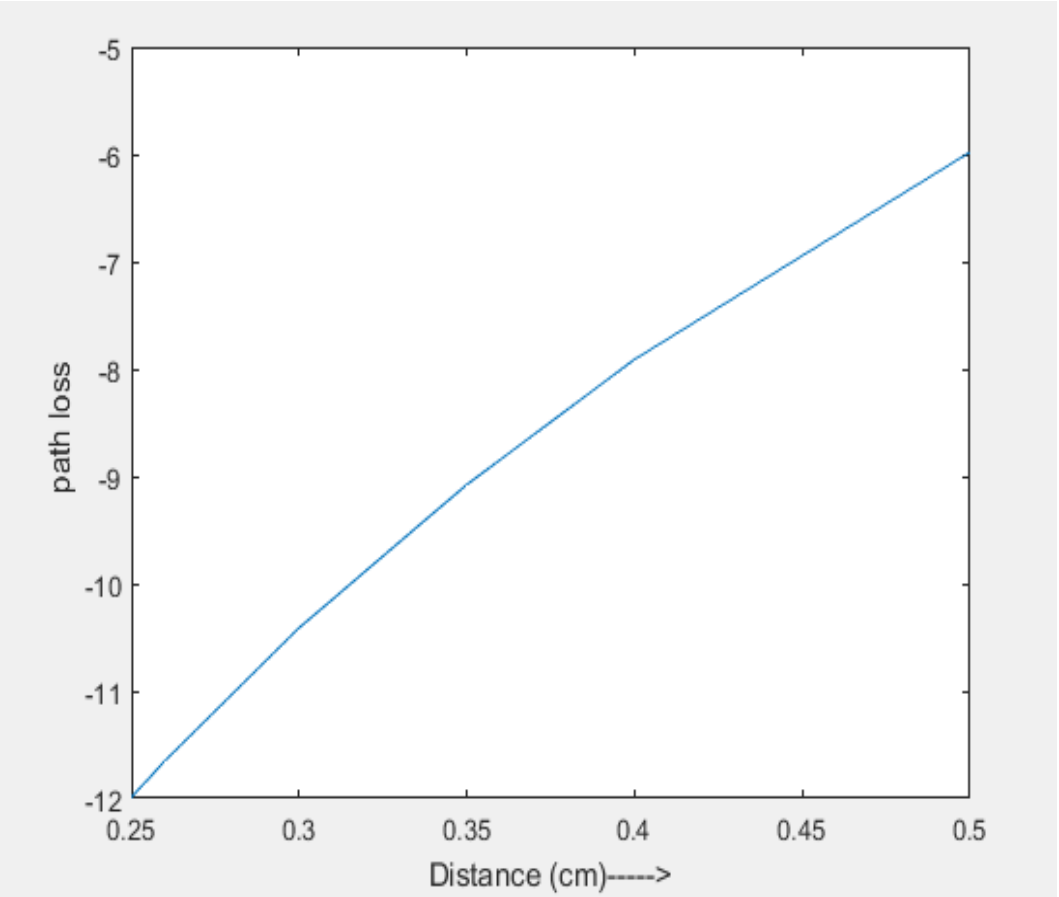
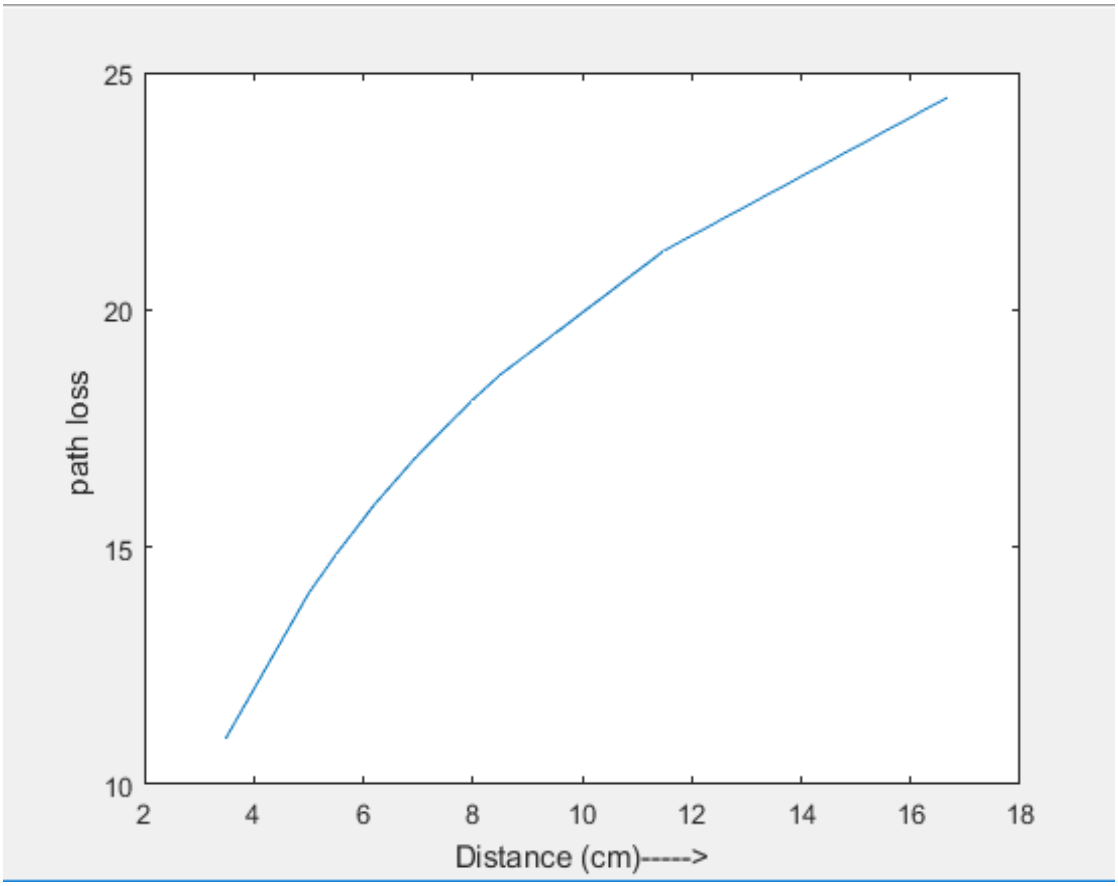


Figure 5.14: Path loss for Hexagonal topology

Table 5.6 shows path loss for mesh kind of topology in which an observation says that as distance upgrades path loss also increases. For all the node pairs in a particular region, path loss is calculated and graph of path loss vs distance for mesh [36] type of topology is as shown in Figure 5.15. For this type of topology graph gives a curve which is bent inwards and values for path loss is very high is very high. As it goes upto 24.49 for 16.7 cm distance. For large networks these type of topologies are not preferred

Table 5.6: Data for node Vs Path loss for Mesh topology

Node pairs(distance in cm)	Path loss
1-2(9.5)	19.5
1-3(5.5)	14.84
1-5(8)	18.103
2-5(8.5)	18.629
4-5(3.5)	10.922
1-8(16.7)	24.49
8-10(7)	16.943
25-39(11.5)	21.25
25-40(8)	18.103
42-38(5)	14.020
40-38(6.2)	15.889



5.4.6.1 Comparison between elementary, hexagonal and mesh topologies on the basis of path loss

Comparison [37] [38] [39] [40] is made to differentiate all the three topologies on the basis of path loss value. For each node pair path loss is different but follows the same fashion that it upgrades as distance

between nodes increases. For mesh toolpogy the graph (Figure 5.16) has more path loss value than hexagonal or elementary type of topology which is not required by any type of wireless body area sensors network.

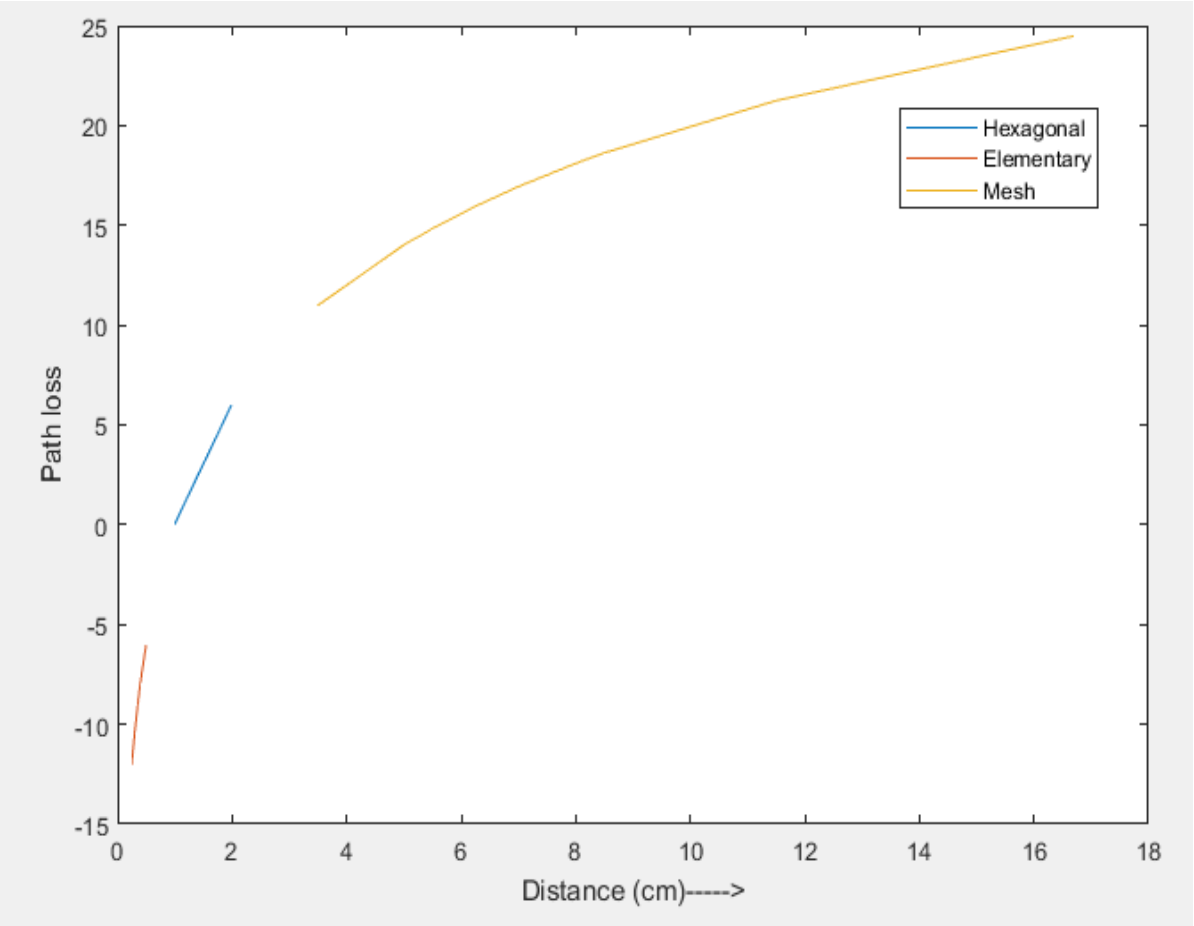


Figure 5.16: Comparison between Elementary, Hexagonal and Mesh topology on the basis of path loss

In Elementary type of topology nodes are limited and arranged in random fashion which takes lot of network area and if distance increase then path also increases which again gives fault in our network. So, next we consider hexagonal type of topology in which there is hexagonal type of compact structure [38] is formed and distance between nodes is also less and gives less path loss value. Blue colored line shows hexagonal type of topology, orange shows mesh topology and red color line at the very initial point shows elementary type of topology. Considering all the parameters of path loss, distance, probability density function, bisection width, node degree, diameter, [39] network area, we preferred hexagonal as best of all.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

In this work, we have provided with ingenous analysis of the WBAN which further emphasise on different parameters on the basis of different topologies. A new software CASTLIA is discussed with five different simulations techniques and their energy grpahs (chapter3). These graphs shows erratic type of behavior which motivates us to find any particular type of network in which total consumption of energy is as low as possible. To reduce overall consumption of energy, this work tries to include an efficient energy model tested for different topologies. The model uses distance as a main factor which affects the consumtion of energy. Different parameteric analysis like node degree, diameter, link capacity, bisection width, probability density function are also discussed and decision for best topology is being taken by considering all of them together.

Table 6.1: Parameteric Comparison topologies

Parameters	**Elemntary topology**	**Heaxagonal toplogy**	**Mesh topology**
Energy consumption	**Low**	**Low**	**High**
Node degree	**Low**	**Moderate**	**High**
Diameter	**Low**	**Low**	**Low**
Link capacity	**Low**	**High**	**High**
Bisection width	**Low**	**High**	**Low**
Probability density function	**Low**	**High**	**Moderate**

After analysis of all the Energy graphs whether it is being compared on the basis of distance between nodes, probability density function, path loss model and the parameters like node degree, diameter, link capacity, bisection width, we conclude that for hexagonal type of topology, energy consumtion is very less, graph is more sharp in case of probability density function and less loss of data in case of path loss, node degree is moderate, diameter is not so high, bisection width is good. Considering all of them together, the topology with compact structure, more network area capacity, moderate node degree number, high link capacity and symmetric bisection width [41] is preferred. That means, when there is more number of nodes arranged in hexagonal pattern gives good link capacity, more throughput and consumes less energy. Loss in data degrades which further reduces the risk of noise and attenuation in any kind of network area. Efficiency in energy enhances quality of life, improves national security, overall economy and sves overall economy of any organisation.

6.2 FUTURE SCOPE

Radio innovation for WBANs can be settled on a view of the specific prerequisites of a WBAN application and at which level of the design it will be conveyed, designed, fitted and used. Work on noise in different relay modes, channels variation can be the point of more research work in future. Recent advacnes in military sensing, traffic surveillance, target tracking, environment monitoring can become the most interesting areas of research in future time.

Here Path loss is used to compare different topologies but for large number of nodes in any particular network area where region is more wide, it will definately increase. So new techniques can be invented to reduce overall loss of a system. Work on network chips, ICs designing with dedicated point-to-point connections, nanometer CMOS technology should combine with sensors parameters to reduce overall cost of system. Future WSNs will combine to form the nervous system of the IoT, when combined with cloud computing and big data processing. Lives will be saved with continuous in-home medical monitoring systems. In short, the coming years are an exciting time in the world of wireless sensor networks.

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