REPUBLIC OF TÜRKİYE

ALTINBAŞ UNIVERSITY

Institute of Graduate Studies

Electrical and Computer Engineering

IMPROVED MAC PROTOCOL BASED ON ENERGY HARVESTING AND WAKE UP DUTY CYCLING TECHNIQUE

Anhar Sami MOHAMMED HASAN

Master's Thesis

Supervisor

Asst. Prof. Dr. Abdullahi Abdu IBRAHIM

Istanbul, 2022

IMPROVED MAC PROTOCOL BASED ON ENERGY HARVESTING AND WAKE UP DUTY CYCLING TECHNIQUE

Anhar Sami MOHAMMED HASAN

Electrical and Computer Engineering

Master's Thesis

ALTINBAŞ UNIVERSITY

2022

The thesis titled IMPROVED EH-MAC PROTOCOL BASED ON ENERGY HARVESTING AND WAKE-UP SLEEP DUTY CYCLING TECHNIQUE prepared by ANHAR SAMI MOHAMMED HASAN and submitted on 15/12/2022 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering.

Asst. Prof. Dr. Abdullahi Abdu Ibraheem
Supervisor

Thesis Defense Committee Members:

Asst. Prof. Dr. Abdullahi Abdu IBRAHEEM	Department of computer Engineering, Altınbaş University	_____
Asst. Prof. Dr. Ayça Kurnaz TÜRKBEN	Department of Software Engineering, Altınbaş University	_____
Assoc. Prof. Dr. Serdar KARGIN	Department of Biomedical Engineering, İstanbul Arel University	_____

I hereby declare that this thesis meets all format and submission requirements of a Master's thesis.

Submission date of the thesis to Institute of Graduate Studies: ___/___/___

I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Anhar Sami Mohammed Hasan

Signature

DEDICATION

Although they are no longer of this world, their memories continueto regulate my life. First and foremost, to my husband's soul Professor Wail Alsaffar whose love for me knew no bounds and, who taught me the value of humanity. Thank you so much "wail", I will never forget you……

I devote and pledge this research work to my supervisor who is salient for guiding me through whole research work as well as my family for always assisting me in my hard times.

This humble piece of work lovingly dedicated to researcher's parent who serves as their inspiration, to my lovely aunts who never left me through my dark times to my friends, to class mates who always make us happy and inspired all throughout this writing. To almighty GOD who serves as guidance and the source of strength and knowledge for without his guidance everything is futile.

PREFACE

First and foremost, I would like to thank my supervisor Asst Prof. Dr. Abdullahi Abdu Ibraheem for guiding and helping me throughout the way in writing this dissertation, discussing my progress, assisting in solving my problems, giving incredible ideas to support my research. offering advice and encouragement with a perfect blend of insight and humor. I'm proud of, and grateful for, my study time under his supervision.

Lastly, my family deserves endless gratitude to my little children who never failed to be there for my mental support throughout my study journey, they supported me in all ways needed. I will never forget the soul of my late husband; I would like to take this opportunity to acknowledge my work and success in this research to his soul. To all my family members; And dear friends I give everything, including this research

ABSTRACT

IMPROVED EH-MAC PROTOCOL BASED ON ENERGY HARVESTING AND WAKE-UP SLEEP DUTY CYCLING TECHNIQUE

Mohammed Hasan, Anhar sami

M.Sc, Electrical and Computer Engineering, Altınbaş University,

Supervisor: Asst. Prof. Dr. Abdullahi Abdu Ibraheem

Date: December/2022

Pages: 67

The aim of this thesis is to devise an improved Mac protocol using Wake-up sleep duty cycle technique and Energy Harvesting technique in general WBAN (IN/ON) of medical application. This can be defined as an organized protocol designed to control the WBAN in the health care system for the desired properties for improvement issue. Especially when time and resources are limited, one must hit the objective on the first attempt with a view to make an effective helpful strategy that takes into account the energy consumption that'll be handled as well as the routes that the suggested algorithm will chose. This study attempts to combine the Energy from multiple sources, and Suggested EH- Mac protocol with the obtained network life time in one algorithm. As soon as the WBAN starts selecting the priority of which data to be treated first, the selection goes to the emergency data the system wake-up because of this signal to take the required action. This is why unveiling a new improved model with specific characteristics (Throughput and Network life time) to Extend the Battery life time reduce the cost and risk of WBAN of changing the batteries. This suggested algorithm was designed to shed the lights on how to increase the Network life time effect based on the results of Energy Harvesting. Investing energy in its various forms and converting it from one state to another has become a basic life

goal. Today, science and various industries are heading in one way or another to how to reduce the cost used to achieve any product. in another way, Using energy for free. Improving the performance of the body's wireless area network is one of the most important aspects that must be fixed at the present time due to its importance in terms of the practical and scientific aspect that constitutes the industrial and medical aspect. In this research, the energy inside the body was exploited, in addition to this feature in harvesting energy, the throughput feature and network life time have been increased.

Keywords: Energy Harvesting, WBAN, Wakeup-Sleep Duty Cycle, Throughput, Network Life Time, MAC Protocol

TABLE OF CONTENTS

Pages

LIST OF TABLES

Pages

LIST OF FIGURES

Pages

ABBREVIATIONS

EH_MAC	:	Energy Harvesting Mac Protocol
WBAN	:	Wireless Body Area Network
THP	:	Throughput
NLT	:	Network Life Time
QoS	:	Quality of service
SN	:	Sensor Node
HP	:	High Priority
NP	:	No priority
LP	:	Low priority

1. INTRODUCTION

1.1 OVERVIEW

An effective Algorithm is a coordinated effort aimed at improving the performance of WBAN to Extend the NLT, and avoid battery replacement. Most desired criteria take place in Every aspect of the suggested algorithm to satisfy WBAN requirements. First and foremost, you must maintain organization in your life. Every attempt must succeed the first time, especially when time and resources are scarce.

An important question on medical applications right before the start of the usage is: How can we make the most of our effective time and long life in WBAN? This thesis works to provide a preliminary model that gives the answer. An alternative interpretation is that the issue is how to reach as longer network life time as possible in the limited time frame, while also utilizing Embedded Energy to increase system's performance. In a WBAN, it is impossible to say exactly how may any algorithm given a specified Mac protocol will perform the best; however, we are aiming to create a model that can live longer depending on exploiting the existed energy within the body and the mac routing protocol for choosing the required path. A strategy for allocating the energy and node programming to work on a certain time in case of need. A further factor to keep in mind is that in a short period of time, it is beneficial to activate the WBAN with such a higher potential qualifications and a higher possibility of success if necessary while keeping the system of rest state when no need for WBAN to be activated." We hope to shed more light on how to use the energy harvesting effect based on previous works results by having to introduce this model.

A continuous cycle of general WBAN in the medical field representatives to the energy harvesting, sensing system and wake up sleep duty cycle, and we apply our model to WBAN in Chapter 3.

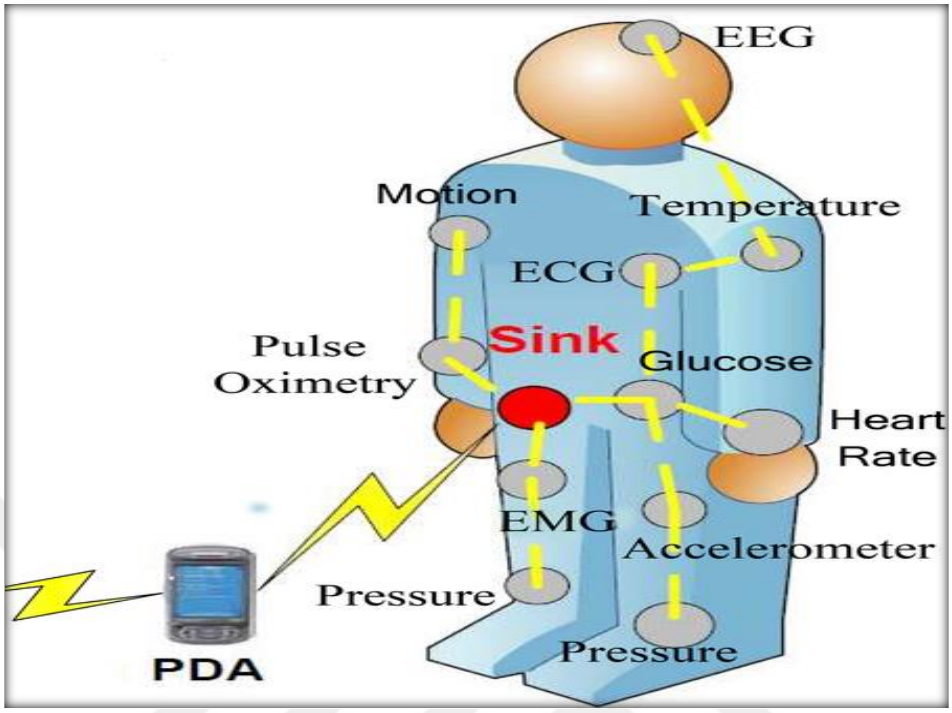

Figure 1.1: A General example for (WBAN) representation [1]

Today the enormous population growth overall the world because of the incremental in birth rate besides to decremental in total death rate and the expansion of the average lifetime of the individuals [2]-[3] Due to the above-mentioned reasons and its role as an effective influence, it is a direct cause of increasing the effective pressure to impede the progress of the medical process, which in turn requires a high degree of flexibility to provide optimal solutions in the process in general [4]. For the purpose of joining the patient's life and before it becomes irreversible , it is necessary to develop a special system to follow up on the detection of the patient's health status through the use of smart improved systems and to develop them periodically and continuously to be sufficient and adequate as possible to provide an effective proactive analysis at reasonable prices [5].furthermore to the flexibility & comfort provided by the sensor network for measuring the patient's health fluctuations while he performs daily life functions without causing what may disturb the patient or negatively affect the psychological state or the movement of the patient in particular [6].The small computers that consist of the body's wireless network of various kinds, whether they are implanted ,wearable ,or close outside the body, such as a smart watch and others networking products [4].Ensuring the quality of the wireless body network is one of the most important specifications of a successful WBAN, as choosing an effective and successful

QoS service by making the most fit decision is one of the methods aimed at achieving quality of service QoS with a high level efficiency, taking into account the conditions of Quality of service [7]-[1].

Because of the limitations of the models produced and applied within the conditions of IEEE standards in the case of the sensor death in the wireless body area network due to a lack of work in the battery or the battery not obtaining power after the end of its life and avoiding changing the battery due to the difficulties that follow changing it or even charging it causing surgical interference Replacing the dead sensor. Because of the solution is that were presented by previous researchers to improve energy management, Quality of Service has become an interesting way to develop our energy in an efficient and distinct manner and harvest energy additionally in addition to serving the efficiency in the wireless body network [8]-[9]-[10].

1.2 INSPIRATION

In today's medical applications, energy harvesting (EH) and an efficient MAC protocol are a necessity. This one has led to serious research from academics because of its importance to the health care system future. WBAN have already dialed with a wide range of issues. Depending on the subject matter, we can divide these studies into two categories. Medical applications and nonmedical applications [8]. The allocation of resources and the exploitation effects of the ambient energy, as discussed in [9], create an inspiration which represents a sparkle that flashed to create improvement that provides more quantitative information within the sensor characteristics specifically and the WBAN generally.

Many studies have focused at how MAC protocol enhance the path selection of the WBAN; however, there has been little research into how to combine between EH and MAC protocol route. As a result of the research gap, we combined the EH and MAC routing problems and came up with a comprehensive WBAN strategy that considers the potential energy(in spite of its type) being studied and how to collect them together and come out with one output . That's why in our research, we present an all-in-one model that considers factors like network life time (NLF) and throughput (THP), the percentage of results shows in the comparison polls by those similar MAC protocols, and other factors like speed and Quality of service, as detailed in [11]. This methodology can be used by others to develop a well-thought-out WBAN strategy.

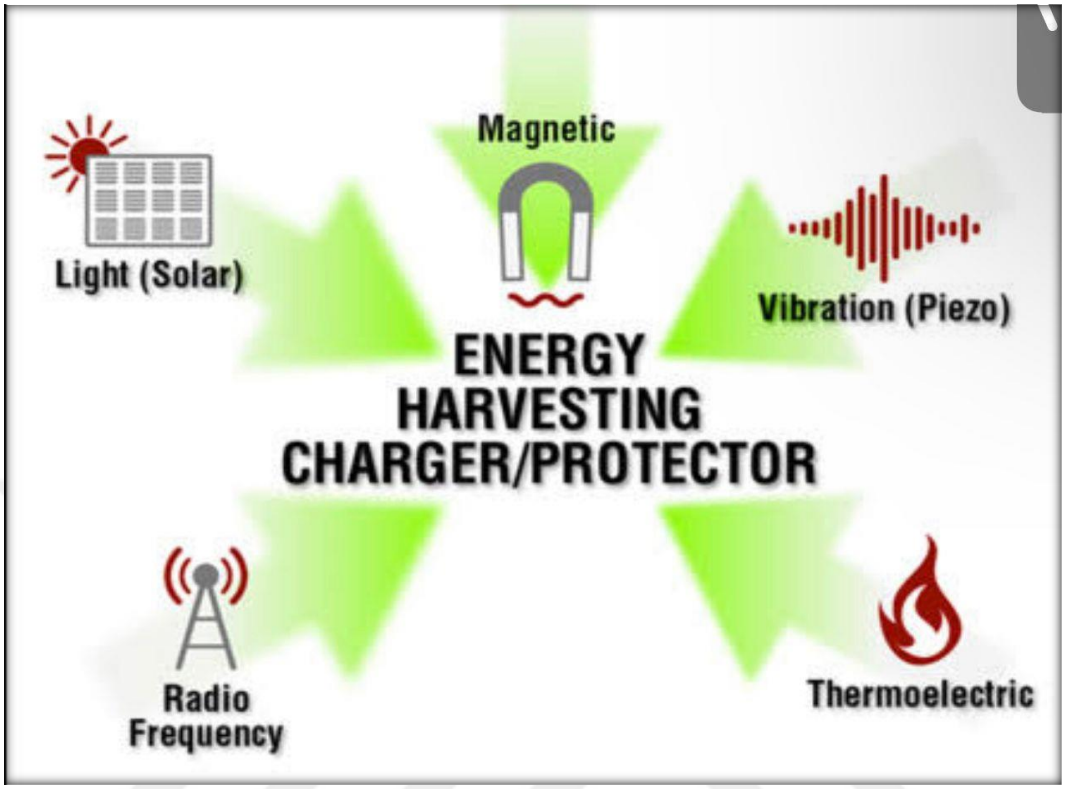

Figure 1.2: Variety of ambient energy resources [10]

Problems with sensor death are a common problem block in WBANs life cycle. It has received little attention from researchers, deny the reality that the body has the potential energy to change the outcome of the NLF [12].researchers created a model to help sink node in to rout signal to minimize packet loss. A remarkable assumption they made was that momentum from the ambient energy could be used to the next round. These signals were transferred by adding a coefficient to the formula that represents the Energy Harvesting that an individual WBAN had previously supported the SN in question. They ensured that the Urgent signal sequence would be transferred by doing this. The harvested energy should be distributed among the SNs as shown in a rule that assumes that perhaps the multitude of most urgent signal at any node should really be considered when emergency occurs.

For any type of energy harvester source there should be a transducer to convert the energy from the that source in spite of its kind to the electrical energy ,a Thermoelectric element Power inverters must be connected to this power source to change the power into a fully controllable electric power source but for a mechanical power source where the nature of the sources is uncontrollable and unpredictable a piezo electric transformer is required for the uncontrolled

solar source but Predictable hearing, photovoltaics required and type of transducer required for the partially controllable nature of this source which is RF energy [13].

Table 1.1: Ambient energy sources [13]

Energy Source	Performance	Notes
Ambient light	100 mW/cm² (direct sunlight) 100 μW/cm² (illuminated office)	Common polycrystalline solar cells are 16–17% efficient, while standard monocrystalline cells approach 20%
Thermal	a) 60 μW/cm² at 5 K gradient b) 135 μW/cm² at 10 K gradient	Typical efficiency of thermoelectric generators is ≤ 1% for ΔT < 313 K a) Seiko Thermic wristwatch at 5 K body heat b) Quoted for a ThermoLife® generator
Blood pressure	0.93 W at 100 mmHg	When coupled with piezoelectric generators, the power that can be generated is on the order of microwatts when loaded continuously and milliwatts when loaded intermittently
Vibration	4 μW/cm³ (human motion-Hz) 800 μW/cm³ (machines-kHz)	Predictions for 1 cm³ generators. Highly dependent on excitation (power tends to be proportional to ω, the driving frequency, and y_ω, the input displacement
Ambient radio frequency	<1 μW/cm²	Unless near a radio frequency transmitter

1.3 PROBLEM STATEMENT

Over the course of WBAN creation, energy harvesting, mac protocols, duty cycling and their issues have been extensively researched. There are numerous connections between the proposed computer formula in this study and energy harvesting effect for specific improved mac protocol, in WBAN theory, and the network life time (NLF), because every sensing result to the sink node activate significantly contribute to the wakeup duty cycle whereas every unurgent signal definitely leads the system into sleep state cycle to the potential benefits. As a result, in this study, we examined the wakeup sleep effect, Energy Harvesting effect from different resources, and effects in WBAN using the network life time (NLT) and throughput (THP).

The outcome of sensing is heavily influenced by the conduct of the body health. There would have been many more signals which were unsure of their importance if the sensor had to send all sensed signals. The establishment of a WBAN sensors nodes network is predicated on a single objective: to live longer. With the goal of reaching as long as possible network life time and efficient throughput to support the WBAN's goal. Because of this, it is imperative that all these sensor node SN types and their effects on the WBAN and EH carefully considered. There are several studies on the impact of WBAN energy harvesting (EH) on results. Shared perceptions of hopefuls in different suggested WBANs effectiveness were integrated into an official model for sensors in medical applications. As declared this work is interesting, so we'll go into more detail about it now. The model predicts that MAC protocol will behave more desired to SN that are "urgent" or "extra urgent." Most data signal had already classify their priority about the other SN before the WBAN began sending signals and were not swayed by the unnecessary data, according to early research on the WBAN field. To determine whether to harvest more energy resources, it is important to consider the candidates' effectiveness so at times of high effectiveness they may expect increased marginal utility than their rivals.

1.4 CONTRIBUTIONS

With this work, I hope that I can offer a template that answers one of the most important questions on WBANs ' energy harvesting avoiding SN death to increase of the energy life time period:

i. In order to maximize NLT efforts with a high throughput and EH, how can we best exploit the ambient sources?

ii. This problem may leads to think as how to best use conceptual algorithms to shape MAC routing issue how to use the constricted path to reach the most urgent signal first.

iii. It is our goal to create a method that greatly increases the NLF yield by use of the EH energy harvesting allocation of ambient resources and meeting throughput criteria spending with $E_{h\ mac}$ protocol but also Efficiency in the study of WBAN.

iv. Depending on EH allocation within the suggested MAC protocol, the research aims to find a path to conduct mass energy for making a full use of WBAN and compare it with the previous suggested works for discussion.

v. It's better to use energy with a higher request signal and a higher emergency of SN during a constrained network life time (NLT) period, and another factor to consider the fact: is (THG) throughput.

vi. The study intends to shed more light on how to increase the harvesting effect based on ambient energy results with specific available sources by introducing a multi source energy hard ware diagram.

1.5 THESIS CONCERN

This concept can be used by others to develop a thoughtful approach to WBAN. The study's flow is depicted in the diagram below. The challenges surrounding medical WBAN use in general as well as the specific problem under investigation are briefly discussed in chapter one. The opening chapter emphasizes the problem's relevance and uniqueness as the study's motivating factors. Chapter 2 reviews the relevant literature on WBANs, MAC protocols, energy harvesting techniques, and some other criteria in WBAN. This concept can be used by others to develop a thoughtful approach to WBAN. Chapter 3 provides a description of the causal dynamic programming employed in this study, together with information on the usage of ambient energy sources and the Eh MAC Algorithm, as well as the proposed mathematical model. In Chapter 4, findings from several large-scale studies are provided together with a sensitivity analysis and computational findings. A discussion in Chapter 5 explains an alternative method to the model created in Chapter 3, conclusions and future research directions are explored.

2. RELATED WORK

This thesis work is motivated by the goal of overcoming the challenges and difficulties that Energy harvesting or Mac protocols faces during the WBAN lifetime. The difference between algorithm taken before and after the energy harvesting appliance and the results can be used to gauge the impact of the suggested algorithm. Expect this difference to be a result of how much time, money, and other resources are spent on it. It's not uncommon for people to spend less amount of money and get better results. There may be a variety of reasons for these differences, but in this study, we focused on the Energy harvesting technique. Consequently, the objective is to achieve the most effective investment strategy in both energy types and suggested MAC protocol in order to determine the amount of network life time affected by the energy harvesting activities, and network throughput I certain life cycle period.

2.1 LITERATURE REVIEW

Currently, the world is seeing huge population increase due to rising birth rates, falling overall death rates, and longer average life spans for people. Anew protocol named Fair Efficient Location-based Gossiping has been suggested they showed on their work how they spectated the energy among the nodes efficiently with life time increased and less energy consumption [2].

Due to increased birth rates, decreased overall death rates, and increased average life expectancy, there is currently a tremendous population rise around the world. This paper suggested anew Mac protocol architecture for harvesting the energy within the WBAN SN [3].

The different types of small computers that make up the body's wireless network, whether they are implanted, worn, or located nearby outside the body, such as a smart watch and other networking items. In this research they focused on collaborative learning, path loss and link aware with w energy efficient protocol has been presented with a comparison to similar works [4].

It is necessary to develop a special system to follow up on the patient's health status through the use of smart improved systems in order to join the patient's life and before it becomes irreversible. These systems must be developed on a regular basis and continuously in order to be as sufficient and adequate as possible to provide an efficient proactive analysis at affordable

prices. The proposed protocol in the design of the body’s wireless hybrid network using the Internet provides better characteristics than the simple Mac system in terms of epidemic production, and the extent of its timing [5].

Additionally to the adaptability and comfort offered by the sensor network for monitoring the patient's health changes while he goes about his everyday activities without being disturbed or having anything adversely impact his mental state or mobility in specific [5].

Rresearcher presented in his research paper to impose and create a new Mac protocol based on two main components, namely, energy and service efficiency, aiming to reduce the consumed energy and improve the efficiency of the network body by classifying the type of signal in whether it is natural or low and giving priority to the highest for emergency signals and working to implement it by sending it directly for the main basin, power is not provided in particular [6].

In his research paper, Hamed and his colleagues described the energy sources available in our daily life to be employed as a source to supply the body's wireless network and compared the methods of energy harvesting and showed some of its uses in the environments in which the body's wireless networks were used, healthy and unhealthy, and did not specify the use of a specific type of them [14].

As choosing an effective and successful QoS service by making the most appropriate option is one of the approaches targeted at attaining quality of service, ensuring the quality of the wireless body network is one of the most crucial requirements of a successful WBAN. High-level QoS that is efficient while also taking into account the QoS requirements [13].

One of the most crucial requirements for a successful WBAN is ensuring the quality of the wireless body network, as selecting an efficient and successful QoS service by making the best choice is one of the strategies intended to achieve quality of service. Considering the requirements for Quality of service, QoS with a high level of efficiency [7].

In his research paper, Hamed and his colleagues described the energy sources available in our daily life to be employed as a source to supply the body's wireless network and compared the methods of energy harvesting and showed some of its uses in the environments in which the

body's wireless networks were used, healthy and unhealthy, and did not specify the use of a specific type of them [1].

In this research, Marwa and her colleagues focused on the methods of energy harvesting and methods of maximizing it. Exploitation of each layer of the body's wireless network.(physical layer,datalink layer &network layer), and the ambient energy can be harvested in the WBAN, and they were unable to identify a specific source for investing energy [8].

The researcher MD khurram and his colleagues provided a new algorithm represented in choosing the best node most deserving of charging based on its necessity, as well as different properties based on the principle of necessity and sensitivity, and developing the performance of the WPT applied to the class, meaning that the (class b & class c drives) of its efficiency to recharge, but the energy was consumed in a way [9].

Shashwat and co-workers used Zigbee sensors by changing the load using the consumed energy in the standard case using the quadlet 5 0 2 simulator, the use of the personal digital assistant, and the energy analysis. In order to increase the length of the life cycle, less performance is obtained between them. The shorter the life cycle, the better the performance, which leads to energy consumption for the load and service efficiency [10].

In this research, the various applications of the medical wireless body network were reviewed and the corresponding technology for each application was studied and compared between them [15].

This work the researcher designed a power management system through the RMS for Energy harvesting utility in the WBAN system In terms of energy harvesting, power efficiency, energy consumption, and power consumption, this framework's performance will be assessed and verified in this research using both theoretical analysis and testing with a suggested simulator [16].

In this research several low duty cycle MAC protocols were studied . The researchers also note that the asynchronous Mac protocol is more scalable than the a synchronous Mac protocol.However, high energy consumption was observed, in addition to the case of Idle listening & Over Hearing that was encountered [17].

Reference a NEAT routing protocol with single hop and multi-hob issues in WBAN was handled with description of the QoS, and NLT In the actual scenario of forest ecological monitoring, the sender determines the size of the back-off window based on the back-off function, which significantly increases the transmission rate of emergency data packets. Through the wake-up matching mechanism started by the receiver, the RMP-MAC protocol significantly lowers the network's idle listening energy consumption when compared to other protocols in simulated trials. The designed multi-priority factor adaptive backoff method also considers the timely delivery of high-priority data packets, which greatly lowers the average packet delay and average number of collisions and increases network throughput [18].

In this research paper, the researcher provided a general study on the characteristics of the body's wireless network and suggested devices that might diagnose the symptoms and provide treatment for it, in addition to providing information about a patient [11].

Comprehensive study of Mac protocol and different mechanisms for power -efficiency compared but a problem in the suggested protocol was in requiring for a frequent synchronization. They suggested the TDAM because it is much authentic while CCA creates more collisions and CSMA WITH more difficulties [19].

This research paper proposes a security authorization protocol to access the WBAN after being approved by the doctor and patient, but more cost have been done because of the signature and authentication operations [12].

This reference mentioned the duty cycle and compared the traditional S-MAC protocol and VTA protocol with the incremental energy usage to reduce latency and vis versa When monitoring the health of a forest, the sender determines the size of the back-off window using the back-off function, which significantly increases the rate at which emergency data packets are transmitted. By using a wake-up matching process started by the receiver, the RMP-MAC protocol significantly lowers the network's idle listening energy consumption when compared to other protocols in simulated trials. Additionally, the planned multi-priority factor adaptive backoff mechanism considers the timely transmission of high-priority data packets, which greatly lowers the average packet delay and the average number of collisions and increases network throughput [20].

Different optimization techniques has been improved several matters like power consumption, throughput and duty cycle in this reference, The study demonstrates how WBAN optimization methods have been revised to improve a number of important factors, including energy efficiency, power consumption, throughput, dependability, and duty cycle. Patients, healthcare professionals monitoring their care, and hospital employees can all benefit from these optimization algorithms' ability to quickly identify problematic conditions. In a recent article, game theory and cross-layer design optimization were applied. Future work will involve using cooperative communication and game theory to optimize QoS in mathematical models [21].

In this work, the researchers performed analytical simulations with higher productivity and longer network life to conserve energy and control the temperature of the WBAN system due to the damage caused by the body's wireless network implanted inside the body resulting from the heat of the work of the wireless network system [22].

The major goal is to relieve pressure on hospitals and offer effective healthcare remotely. Because it is impractical to monitor patients in their natural environs when devices or sensors are connected by a wire, we employ Wireless Body Area Network (WBAN) to carry out daily activities in an inconspicuous and comfortable manner. These networks use a variety of sensors that are sewn into clothing, implanted on the body, or even affixed to clothing [23].

Discusses the Heart Rate Sensor Node for Embedded Telemedicine System and makes a proposal for its implementation. We will show the embedded telemedicine system's heart rate sensor node, which is intended for use in medical settings. Following a brief overview of the key enabling technologies (such as sensor technology, communication technology, and system analysis and design) that have enabled researchers to implement telemedicine systems, a thorough explanation of the main applications of wearable sensor technology is provided. Applications that concentrate on health and wellbeing, safety, home rehabilitation, evaluation of treatment efficacy, and early disorder detection are among those that are covered in this study [24].

The architecture and functionality of WBANs are briefly introduced in this work. In this effort, we primarily concentrate on energy acquisition, data integration and sharing, and collaboration of WBANs from the viewpoint of energy harvesting development, the social network and

smartphone application in WBANs, and the integration of WBANs and cloud system networks computing to analyze related WBANs issues. We end by offering some suggestions for further research in our concluding remarks [24].

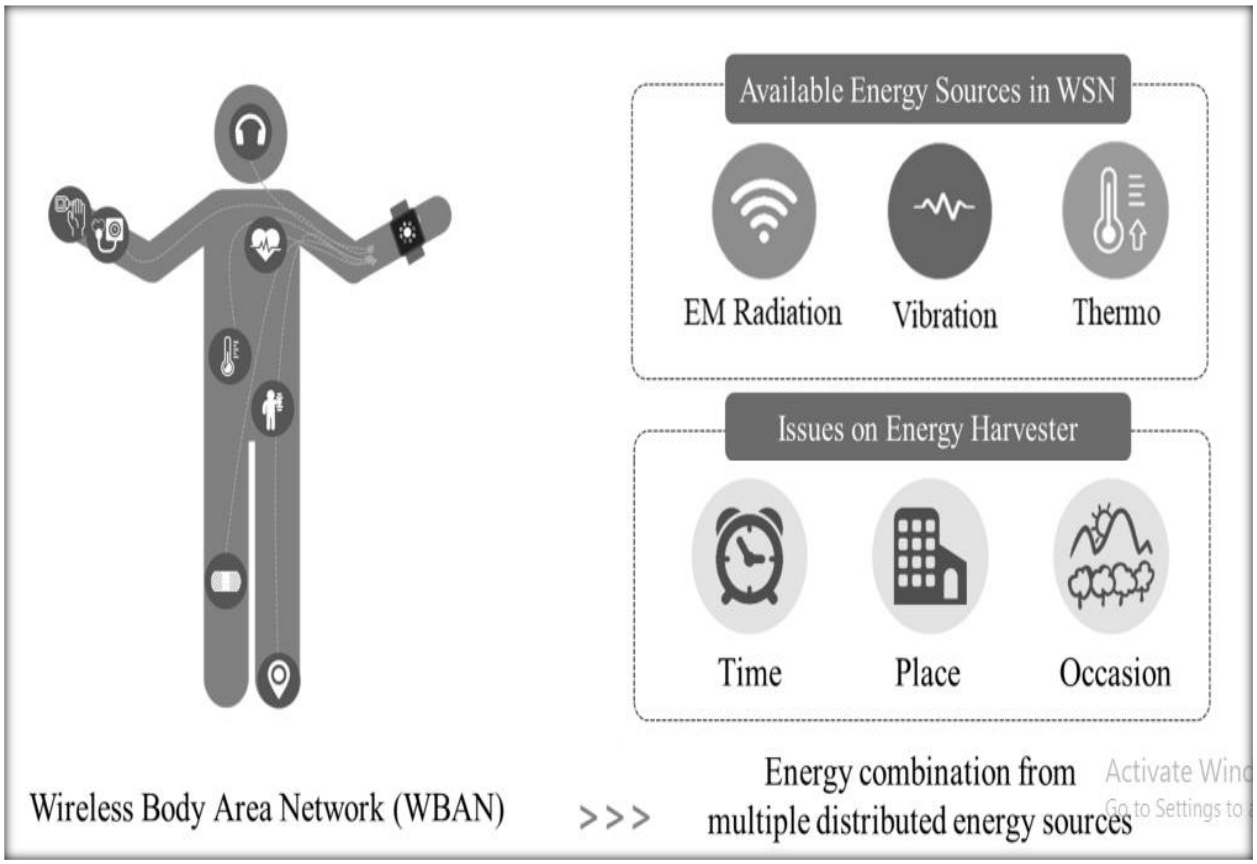

Figure 2.1: Availavle energy sources for wireless body area network [1]

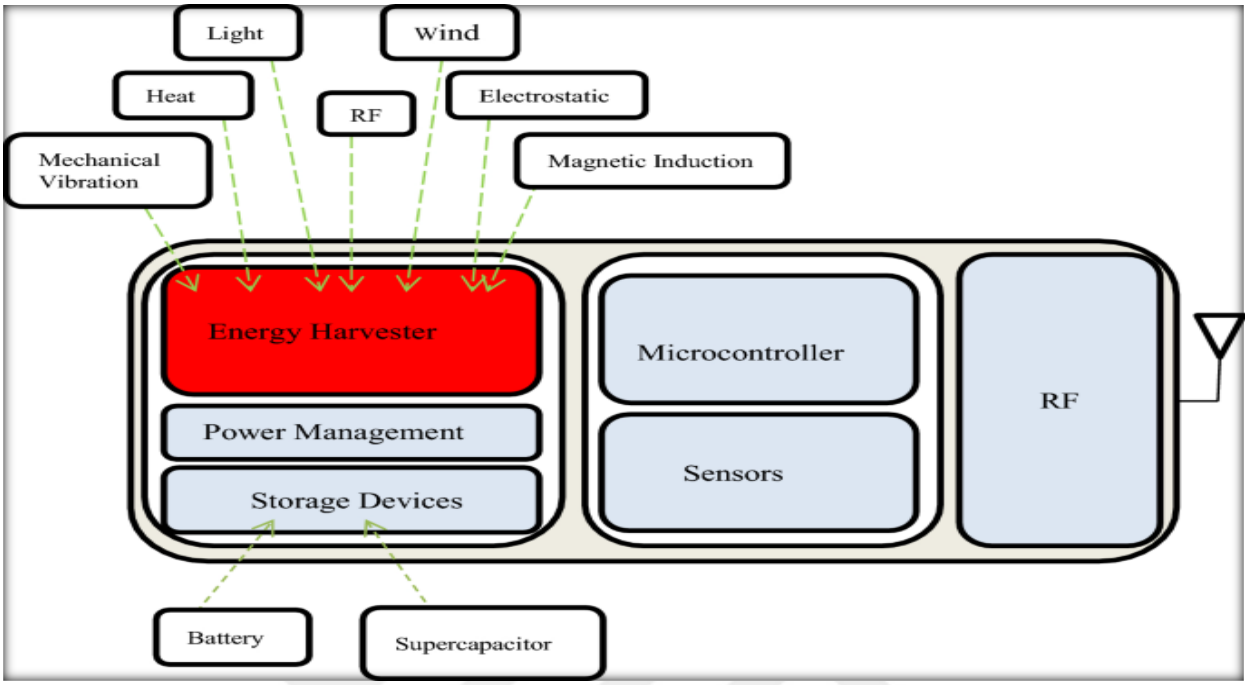

Figure 2.2: The general structure of a sensor node [13]

2.2 ENERGY RESOURCES MANAGEMENT(IN/ON) THE BODY

In WBANs, EH is one of the most important topics because it requires the efficient use of resources in accordance with the WBANs strategic goals. The most difficult part of project management is allocating resources because the resources are spread out (IN/ON) the patient's body of the connected Network, as described in [13]. In order to flexibly of harvested source, these issues can be addressed by computer programs tailored to specific domains of use and expertise.

Oring [1] circuit is the most simple traditional and easy architectural device to combine more than one energy harvested sources it is possible to collect the harvested energy from multiple sources one ,two or three or even more ,each one of these harvested energy in spite of it's type change energy from it is a condition to be turned into an electrical energy to be able to be used within the WBAN. a schema of dual load has output of power path with two ways low & high, this is because of the energy harvesting amount changes according to the unstable environmental changes (wide energy levels) In the architecture, a load is provided for the low-power path, and the high-power path has a storage component like a rechargeable battery. Harvested energy is often sent straight to a load. When a harvester's energy output is more than the energy used by a

load, the surplus energy is stored in a storage element. The excess power can later be used in the load by being stored in a storage element.

This architecture's capacitance is a key component that affects the operating clock frequency. This has an impact on the circuit's power usage. The capacitance should be carefully taken into account because a circuit with a high operational clock frequency uses more power. The formula for calculating capacitance is deduced below.

From our own point of view, we suggest using any ambient energy sources as an additional source of the harvested energy to be obtained from the ambient energy to achieve the efficiency of the proposed system, in addition to our suggestion in the way the system works through the proposed algorithm. Surrounding the body, the important role in employing the network architecture by providing a very important collecting part, which is the Oring circuit that was proposed in [1]. This power through the use of the proposed network architecture and the employment of the merging feature stemming from the use of Oring Gate will achieve a breakthrough in the world of body networks WBANs.

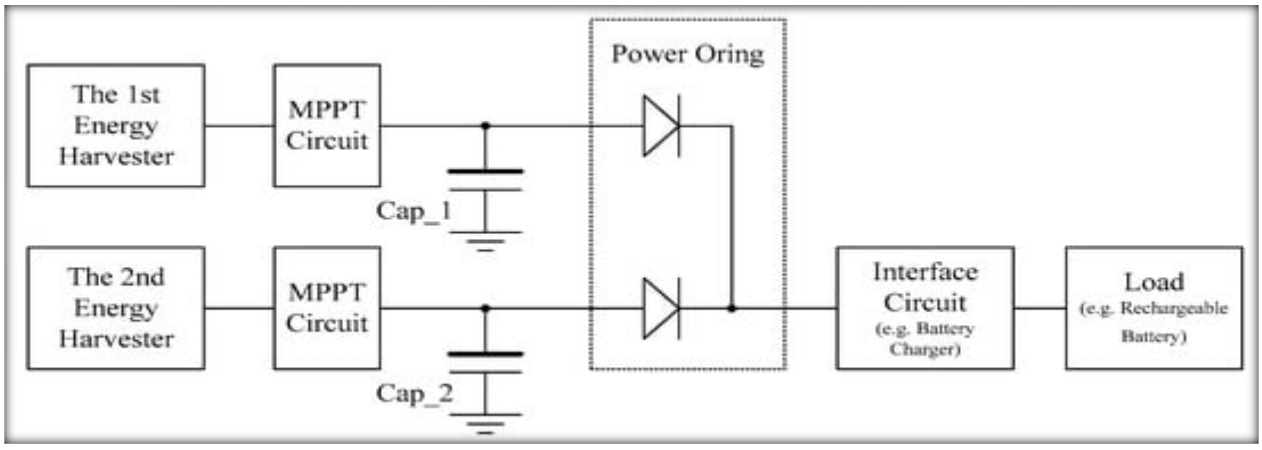

Figure 2.3: Single circuit multisource energy harvesting diagram [13]

Availability with resources plurality is a strong basement block in WBANs EH preparation. It has received little attention from researchers, deny the reality that everyone has the potential to change the outcome of the network life time.in this circuitthe capacitor provides important criteria and make it more deterministic to operate the clock frequency To help WBAN in reducing power consumption [1], researchers created a model that aims to maximize the NLT of

available resources. A remarkable assumption equation of sizing clock frequency controller of sizing capacitance is shown below:

Where **Q** is the charge quantity, **C** is the capacitance size ,**V**is the voltage , $\frac{dQ}{dt}$is the charge quantity differentiation with time, and $\frac{dV}{dt}$ is the voltage quantity differentiation with time [1].

$$Q = C.V \tag{2.1}$$

$$\frac{dQ}{dt}(i) = C.\frac{dV}{dt} \tag{2.2}$$

Equation (1) defines Q as the amount of charge, C as the capacitance's size, and V as the capacitor's voltage. According to Equation, the current can be defined as the sum of the capacitance size and the voltage change when Q is varied with time (2). The capacitor's voltage change rate and current flow are both inversely correlated. The capacitor's voltage increases as current is gathered in the input stage. The capacitance controls how quickly the voltage changes in the capacitor. The integrated circuit (IC) should monitor the capacitor voltage more frequently if it fluctuates quickly [1].

As a result, there is a strong correlation between capacitance and IC operating frequency. Equation (2) also depicts the relationship between capacitance and the amount of current used during the load stage. The voltage of the capacitor starts to drop as soon as electricity is used during the load stage. The size of the capacitor and the operation frequency of the IC should be properly maintained to avoid the voltage of the capacitor dropping below the threshold voltage.

Large capacitance is preferred to lower the working clock frequency. Energy extracted from an energy source kicks off the process. When energy is harvested, it is stored in a temporary storage capacitor, C, raising the voltage of C. The switch in the low-power path is activated, supplying

the load with the energy stored in C via the low-power way. The voltage of C will drop if the power gathered is less than the power used by the load, and the switch on the low-power line will become inactive. In the absence of such, C's voltage keeps rising. The switch for the low-power

path then closes, while the switch for the high-power path opens. The battery is connected to the energy stored in C via the high-power line rather than the load via the low-power path. The harvester power is used to charge a battery as a result when the harvested power is more than the load power.

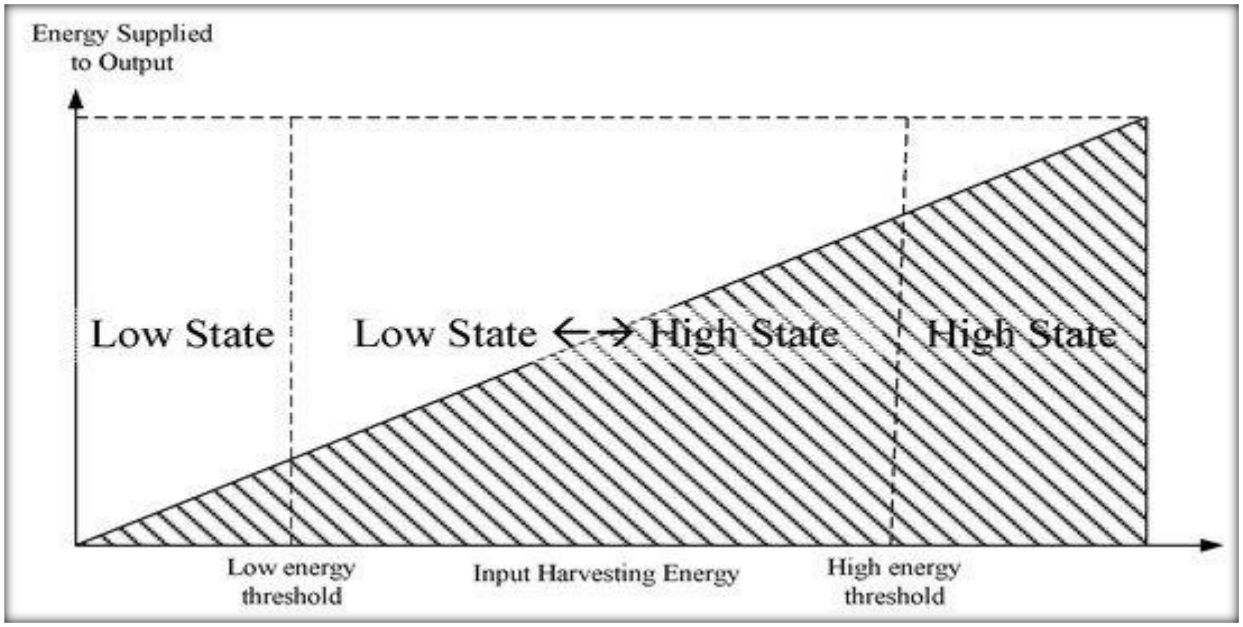

Figure 2.4: State classification of input energy harvesting signal [1]

The capacitor's voltage change rate is inversely correlated with the current flowing into it. The voltage of the capacitor increases as current is gathered in the input stage. The capacitance controls how quickly the capacitor's voltage changes. The integrated circuit (IC) should check the voltage more frequently if the voltage in the capacitor varies quickly. As a result, there is a strong correlation between capacitance and the IC's operating frequency [1]. The relationship

between capacitance and the current used at the load stage is also shown in equation (2.1). The voltage of the capacitor starts to decrease as electricity is used at the load stage. To keep the capacitor's voltage from dropping below the threshold voltage, the size of the capacitor and the operating frequency of the IC should be controlled appropriately [1]. To slow the operating clock frequency, large capacitance is preferred. The operation starts with the energy harvested from an energy source. When the energy is harvested, it is stored in a temporary storage capacitor, C, which rises the voltage of C [1]. The voltage of C is periodically checked by internal comparators whether the voltage of C is higher than threshold voltage, Vth, or not. If the voltage

of C is higher than Vth, the switch in the low-power path turns on, and the stored energy in C is supplied to a load through the low-power path. If the harvested power is less than the power consumed by the load, the voltage of C will decrease, and the switch on the low-power path turns off [1]. If not, the voltage of C keeps increasing. Then, the switch on the low-power path turns off, and the switch on the high-power path turns on. The energy stored energy in C is connected to the battery through the high-power path instead of to the load in the low-power path. Thus, when the harvested power exceeds the load power, the harvester power is used to charge a battery. By adopting dual output paths, a wide range of input energy can be handled [1].

2.3 CONVENTIONAL STRUCTURE

The OR-ing circuit should also be enhanced next. One disadvantage of the diode-based power.

OR-ing circuit is the unintended power consumption brought on by the diode's forward voltage drop. With a low forward voltage diode, such as a Schottky diode, the forward voltage drop can be reduced to a minimum. But employing the diode-based power OR-ing method will inevitably result in power waste because of the forward voltage drop. The diode can be replaced with a metal-oxide-semiconductor field-effect transistor (MOSFET) switch to prevent this power wastage. Power consumption is needed to drive the MOSFET-based power OR-ing circuit as well. However, a circuit's power consumption is continuously reduced as the integration process moves forward [1]. One other problem unites diode-based power OR-ing circuits and MOSFET-based power OR-ing circuits, in addition to the undesirable energy loss in a typical OR-ing stage. Energy streams from the other harvesters are rejected by the power OR-ing method when one energy harvester produces more energy than the others do. As a result, low energy harvesters are unable to supply energy to a load device. For instance, on a sunny day, the PV transducer produces significantly more energy than the PZ transducer when two harvesters are, respectively, photovoltaic (PV) and piezoelectric (PZ). Energy stored in the PV capacitor has a higher voltage than energy stored in the PZ capacitor [1].Through the interface circuit, PV harvester energy can be delivered to the load. The energy captured by the PZ transducer has no possibility of being connected to a load until the voltage of the energy stored in the PV capacitor decreases below the voltage of the energy stored in the PZ capacitor. Due to the temporary storage's leaking properties, the harvested energy may vanish while the energy in the PZ only waits to be linked.

The energy that has been captured needs to be carefully stored for low power applications like WBANs. It is never advisable to completely exclude any of the harvesters [1]. The amount of energy in each harvester should be transferred to storage in order to prevent the exclusion of a particular harvester, and the magnitude of energy in all harvesters should be routinely monitored.

Additionally, if the harvester produces more energy than the load consumes, the temporary storage capacitor's voltage keeps rising. Then, the extra energy that was gathered is not used to power the load, and the circuit could be harmed by the rising voltage of the temporary storage. Therefore, when the harvester produces more energy than is used at the load, alternative use for the surplus energy should be taken into account.

2.4 ENERGY MANAGEMENT

Using a 0.13 m TSMC CMOS technology, the suggested dual output energy management circuit was designed and constructed. Figure 9 displays a layout and a die micrograph, with a 960 910 m die size. To save energy, an I/O pad with minimal capacitance and leakage power was chosen. The recently created IC was housed in a quad-flat no-leads (QFN) package measuring 4 mm by 4 mm and had 24 leads. The power consumption of the packaged IC was under 1.5 W with 1.2 Vdd while all input ports were active. The internal oscillator had a frequency of 32 kHz, and every 125 s, the digital control circuit examined the input harvester's condition. An evaluation board with three input ports was created to test the newly developed IC's functionality. Each harvester had a power supply built into the model. Each input had a 10 nF capacitance. A resistor that can consume 55 W of electricity was used to mimic the load in a low-power way. A battery was charged by the supply of more than 55 W of electricity to a high-power route. A modest size resistor was used to simulate the battery in a high-power path such that it would use significantly more power than the load in a low-power path. In this experiment, the load's low-power path load (275 W) had its power consumption set at five times the battery's high-power load.

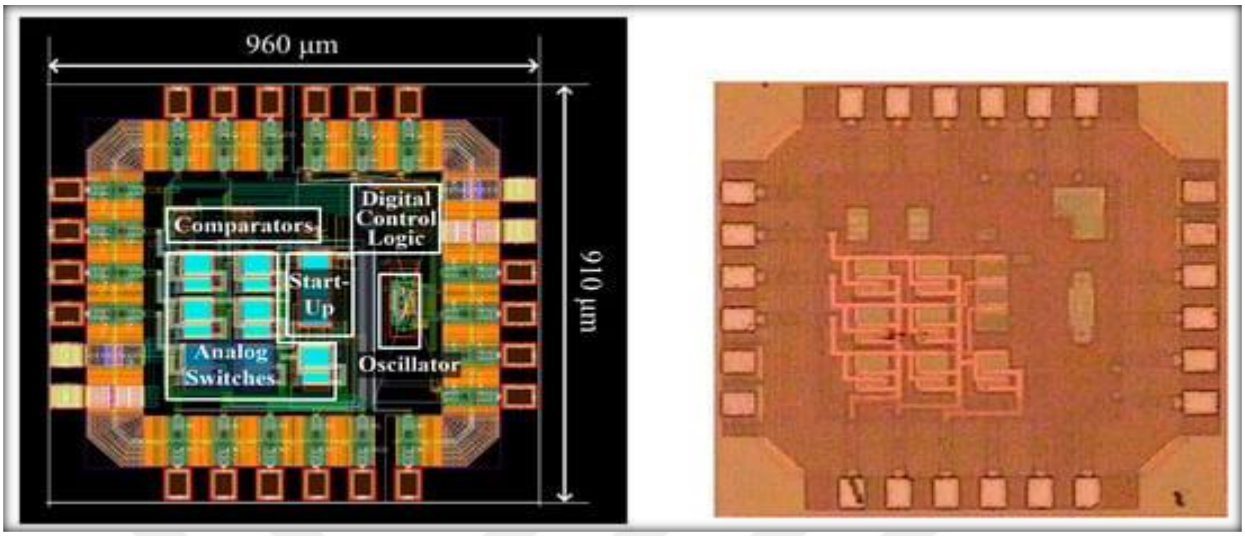

Figure 2.5: Layout and die micrograph of ic energy management [1]

Three different types of experiments were run to test the energy management circuit described in the previous section, and the waveforms were recorded using a four channel digital oscilloscope. In the first experiment, an energy harvester was used to demonstrate the IC's internal operational waveforms. The second experiment displays the waveforms of dual outputs in relation to the quantity of energy harvested from multiple sources. In the most recent experiment, the produced IC's energy-combining efficiency from multiple energy harvesters and the power-distribution ratio between low- and high-power paths are represented as the size of the input harvesting energy. One energy harvester was used in the initial experiment. Figure 10a displays the waveforms used in the experiment. The input capacitor's voltage rises to the threshold voltage, Vth, when an input energy harvester in the low state begins to produce energy. By adjusting the bias voltage with an external resistor, an internal oscillator's frequency can be adjusted. In this experiment, a 10 M bias resistor was used to make the internal oscillator produce a 32 kHz clock signal. The digital control logic, using a 32 kHz internal clock, monitored the input capacitor voltage every 125 s. The digital control logic disabled the low-power path switch if the input capacitor's voltage exceeded Vth.

As a result, their findings endorsed on energy harvesting which claimed that energy consumption influenced the coverage the shortage by the Oring technique and Mac protocol. Misusing the fixed effects model, and generalizing a study based on only presidential elections, the researchers' work of being imprecise in making the argument that their trying to find the best

algorithm did nothing to shape algorithm defects was unconvincing. and a low-power channel was used to deliver the input capacitor's energy to a load. The input capacitor discharges as it transfers energy from the capacitor to the load. As a result, the input capacitor is frequently charged and discharged close to the Vth level, and occasionally, the harvested power is available at the load stage. The duty rate during a load stage may vary based on the size of the input power gathered. The on-time for a switch increases with high harvest power, whereas it decreases with low harvest power.

2.5 ENERGY HARVESTING

Multi source energy harvesting The stored temporary energy is constantly increasing, and its increase may cause damage to the electrical circuit of the body's wireless network. Moreover, if the harvested energy produces more energy than the energy it needs to consume with the load, the temporary energy stored will increase when the energy generated is greater than the energy actually consumed in the load. This phenomenon is the reason for the failure of the circuit.

The first source of the harvested energy can be added. A second source can be added, as well as a third additional source of energy. Any specific surrounding energy is transformed from its own kind to the type of electrical energy to move and stimulate the electrical circuit of the body’s wireless network, which is adapted by the MPPT circuit.

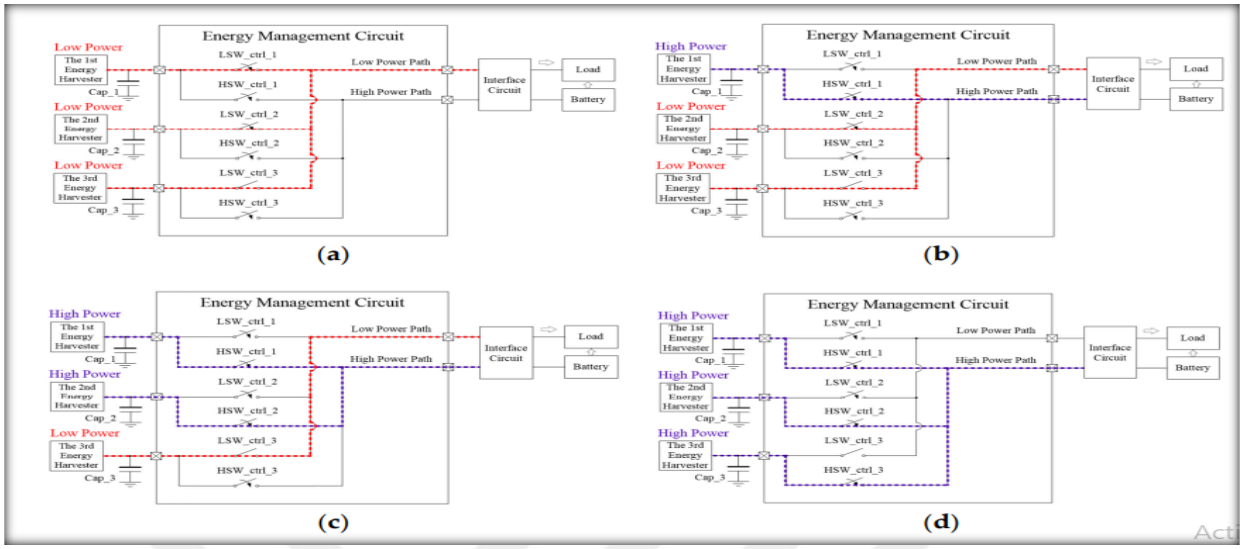

Figure 2.6: Magnitude of energy harvested in proposed energy magnitude circuit the energy flow [1]

The load schema is dual in this simplified energy management harvesting application to support the system comprehension of operational algorithm for the energy harvesting idea.

This is due to the instability of the amount of harvested energy resulting from the difference in the nature of the saved energy source, which will be used later in the operation of the management of this system. It follows two methods, which are the low power path and the high power path, which changes according to the environment, so it accepts wide energy levels. Where different types of cells are connected in the circuit to convert the energy in question into electrical energy, for example including photovoltaic cells (PV) and piezo cells (pz).

A combinatorial software and hardware solution for the problem is being suggested, it is an integer programming problem. MAC protocol is used to determine the most efficient route for a sensor node to achieve to a group of data. Initially, an analytic approach was used for the delivery of signal [10].

Using MAC protocol, delivery packets can answer the question of how to distribute energy from one or more sensor node using a fleet of protocol and a different of ambient energy sources which can travel across any network channel segment to deliver signal to the sink node. To put it another way, sensor node seeks out the set of routes with the highest total energy for each

individual signal. While doing this, deployment constraints and WBAN system requirements (such as scheduling or amounts) still need to be met. Depending on the use, a EH-MAC's primary objective and internal structure can diverge significantly. A "Wake-up-sleep" and a "EH" are the only two entities that appear in our problem. Furthermore, the sink node's capacity reveals the constraints of "energy and distance.".

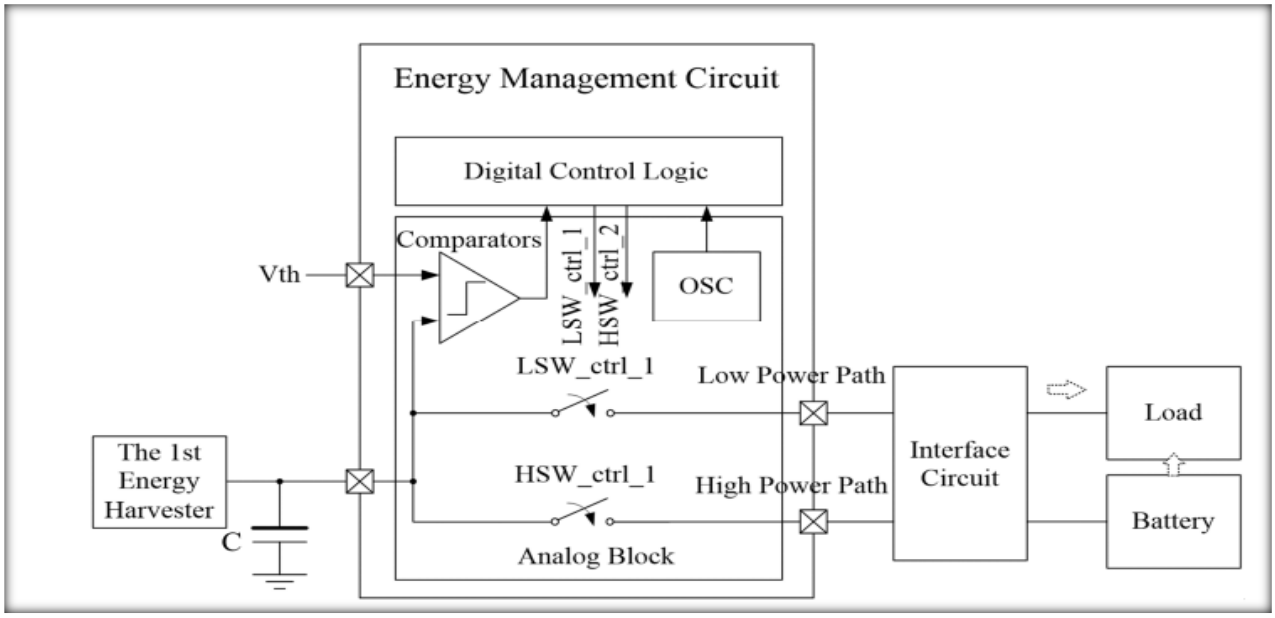

Figure 2.7: single EH simplified circuit [1]

2.6 MULTI-SOURCE HARVESTERS FOR ENERGY MANAGEMENT

Two output ports and three input ports combine to make up the proposed energy management circuit. The circuit can sustain two loads and up to three energy harvesters linked together. Energy streams from several harvesters may occasionally be routed to two output ports, or they may occasionally be integrated into one output port by sharing time, depending on the condition of the gathered energy.

The situations in which energy is gathered fall into four basic categories. Figure describes the four various input conditions situations.

All three energy harvesters provide minimal power in the scenario shown in Figure 4a. The three harvesters, which are linked to the low-power channel, distribute energy to a load over time. This is different from the power OR-ing way of combining energy in that each of the three harvesters is watched over and given the opportunity to be linked to the low-power channel. This stops the already-harvested energy from fading away while it is being temporarily stored.

Similar to the first instance, the first harvester's energy is examined before being linked to a low-power path. The voltage in Cap 1 remains higher than the threshold voltage, Vth, if the first energy harvester's power is greater than the load's power consumption. After that, the first harvester is switched to a high-power path after the subsequent check is finished.

When the first harvester begins to charge a battery, Cap 1's voltage begins to drop. The first harvester is once more linked to a low-power path at the time of the subsequent inspection. The other harvesters continue to successively deliver energy to the low-power channel as they did in the first instance.

In the scenario depicted in Figure 4b, the first harvester's power is high while the power of the other harvesters stays low.

Energy flow is dependent on how much energy is captured in the suggested energy management circuit.

Three low powers (a), two low powers and one high power (b), one low power and two high powers (c), and three high powers (d).

Only the third harvester is producing little power in the scenario shown in Figure 4c, whereas the second harvester is yielding significant energy.

The first and second harvesters alternately provide energy to a load and the battery, and the third harvester only provides energy to a load.

The last example, Figure 4d, shows that all three harvesters create a high amount of energy and simultaneously deliver energy to a load and a battery.

Energy from all three harvesters is used to recharge the battery. Energy from all three harvesters is used to recharge the battery.

The charged battery's energy can be used by the load through a diode or an extra switch if harvest energy is not flowing to it. The amount of energy harvested determines the energy output path for a harvester.

According to the energy threshold values shown in Figure 5, there are three output-path states.

The energy consumed in the low-power path determines the low energy threshold, whereas the energy consumed in the high-power path determines the high energy threshold.

The harvester always provides energy to a low-power channel when the amount of energy captured falls below the low energy threshold.

When the amount of captured energy falls between the low and high energy thresholds, it is alternately sent to the low and high power channel within a set time frame. A harvester only supplies energy to the high energy threshold when the amount of harvester energy exceeds it.

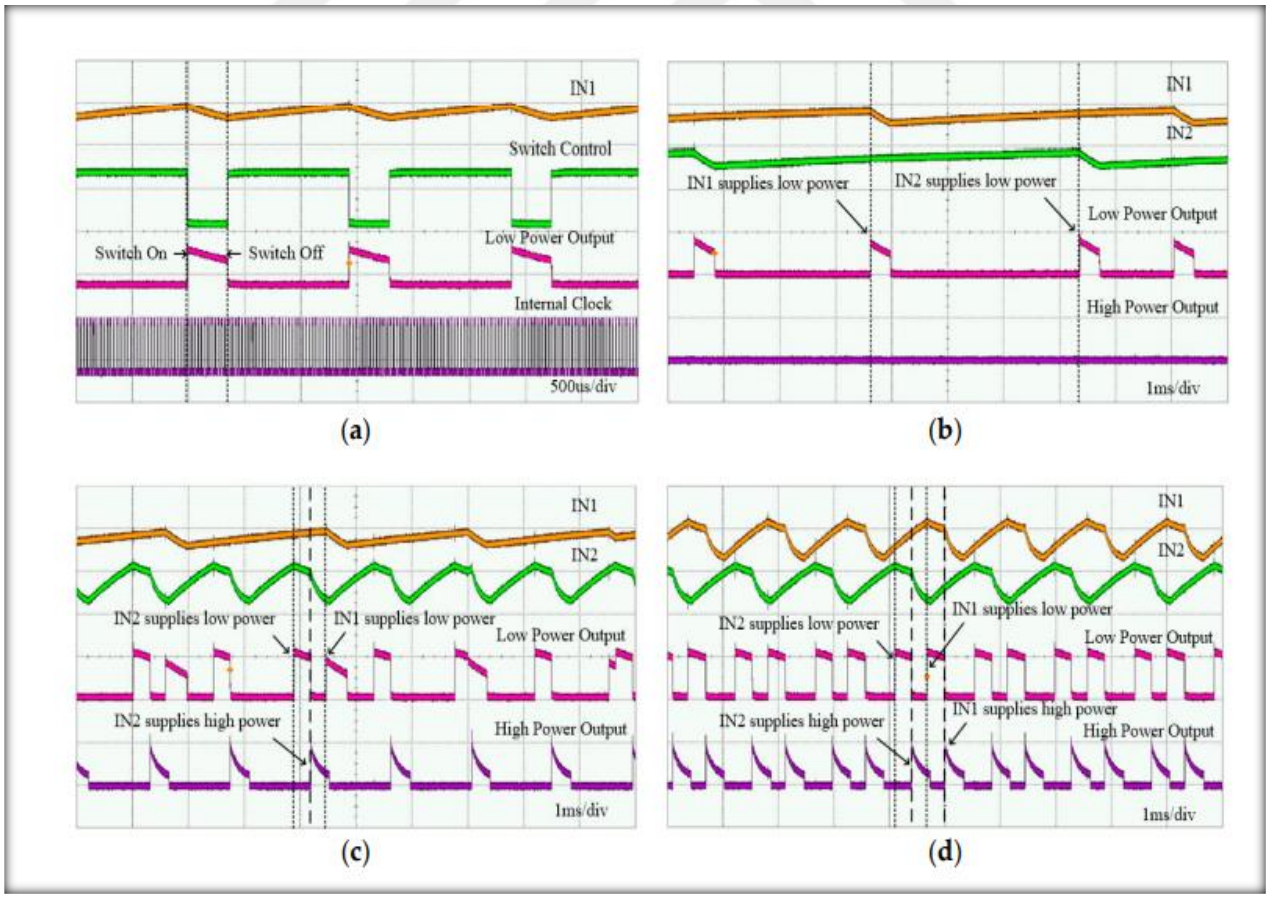

Figure 2.8: Waveforms energy management of IC sample [1]

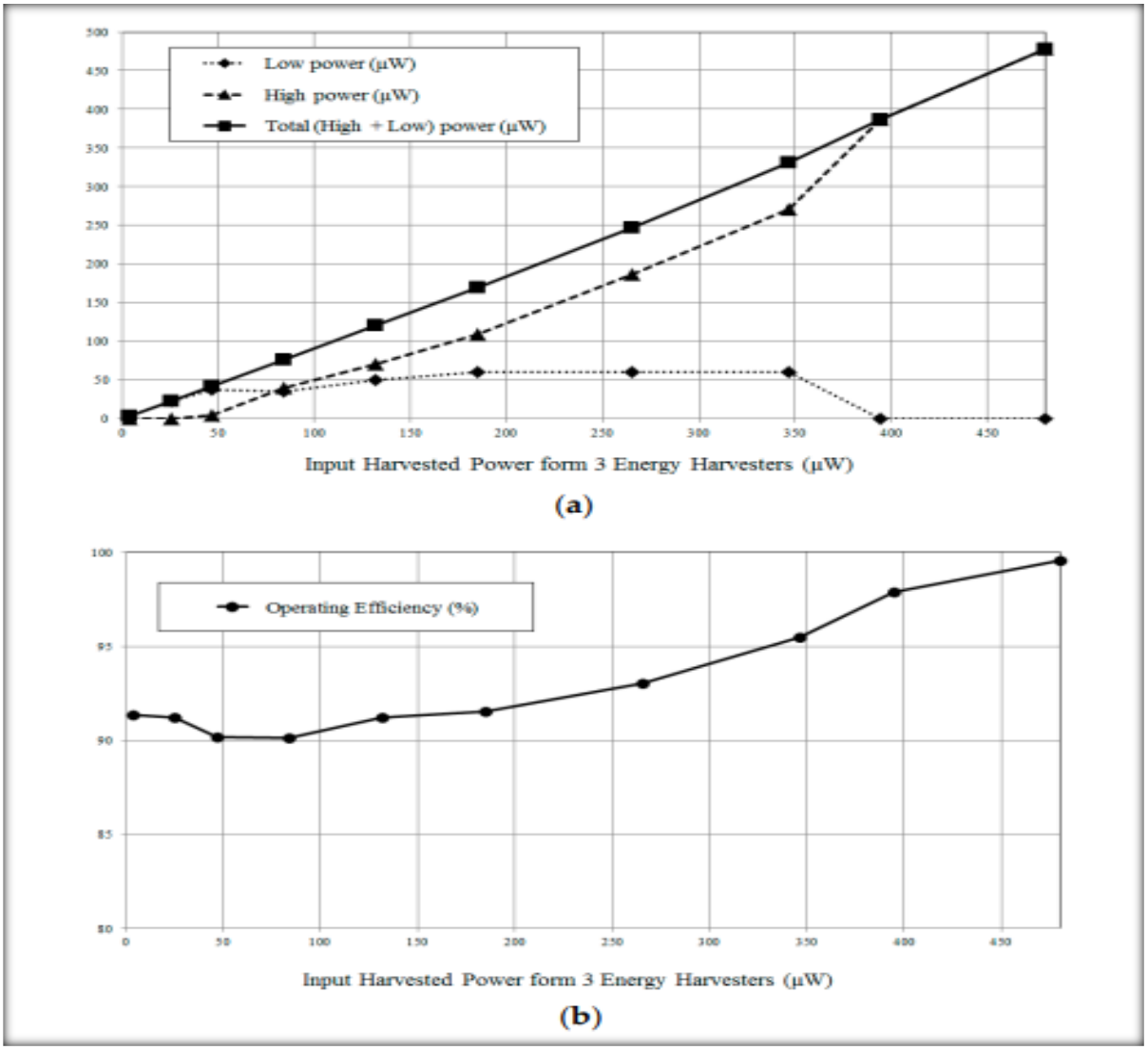

Figure 2.9: Harvested energy from three different sources [1]

The goal of EH-MAC protocol is to find an Energy plausible when a battery of the sensing system which must be consumed only by harvesting the natural and artificial sources and the loop must be completed before consuming the energy.

2.7 STANDARD IEEE MAC -SUPER FRAME

Available possible topologies were used by researchers in [17] to generate every possible WBAN procedure which are peer to peer network and cluster tree network. Using the IEEE 802.15.4 with duty cycle mechanism adjusting the formation of scheduled and-based and contention-based this combination of the IEEE standard protocol of 802.15.4.

Topology of peer to peer the cluster tree network has been performed in an extensive method in active and inactive parts. ZigBee TG5-task group5 IEEE 8.15 standard which represents the second type of topology Mesh topology.

FFD (is full function device which defines double assignment address which is the same as for RFD (Reduced Function Device)triple different roles can be handled by the FFD as a PAN coordinator and the coordinator and the RFD where it can work only as an equipment [17],this means adjusting the life cycle by controlling the time slot of active and inactive periods .where the coordinator is the PAN the possible used topology is the peer to peer and the mesh topology. The most fit topology is the star topology for the sensitive applications and the small coverage ones, but for large networks the peer to peer topology is much more recommended for the reasons of needing multi hop criteria with high estimation of network latency.

Beacon mode where synchronization measures and Non Beacon mode where asynchronization measure is provided ,the two modes which had been classified by the standard of IEEE 802.15.4 of the network feature [17].

Typically the first slot to be transmitted is the Beacon frame followed by two other parts which are CAP & CFP or GTS (where CAD stands for contention access period but F in GTS stands for the Free, and the guaranteed time slot) which already require 7 time slots the super frame ,which is defined by the IEEE standard form 802.15.4 structure .The structure shown bellow illustrate the organization channel access and data exchange which is the super frame structure .

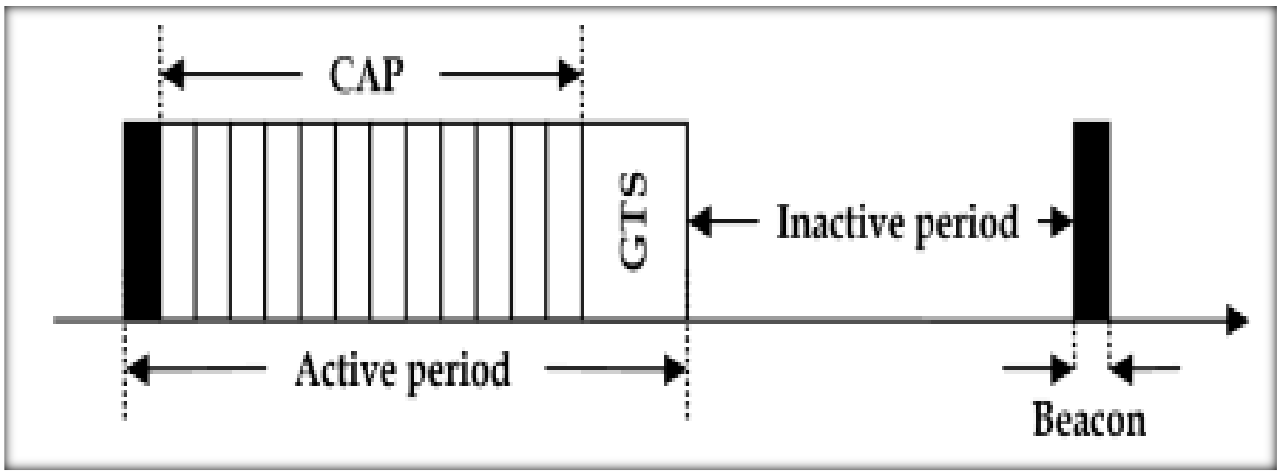

Figure 2.10: Beaconed mode super frame structure [17]

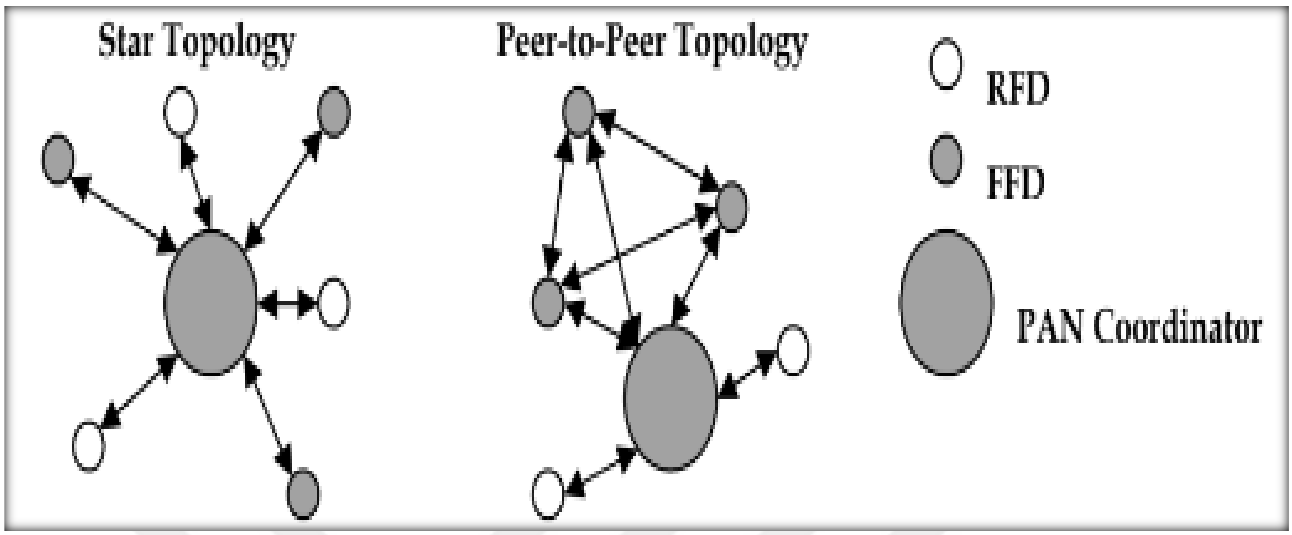

Figure 2.11: topology configuration [17]

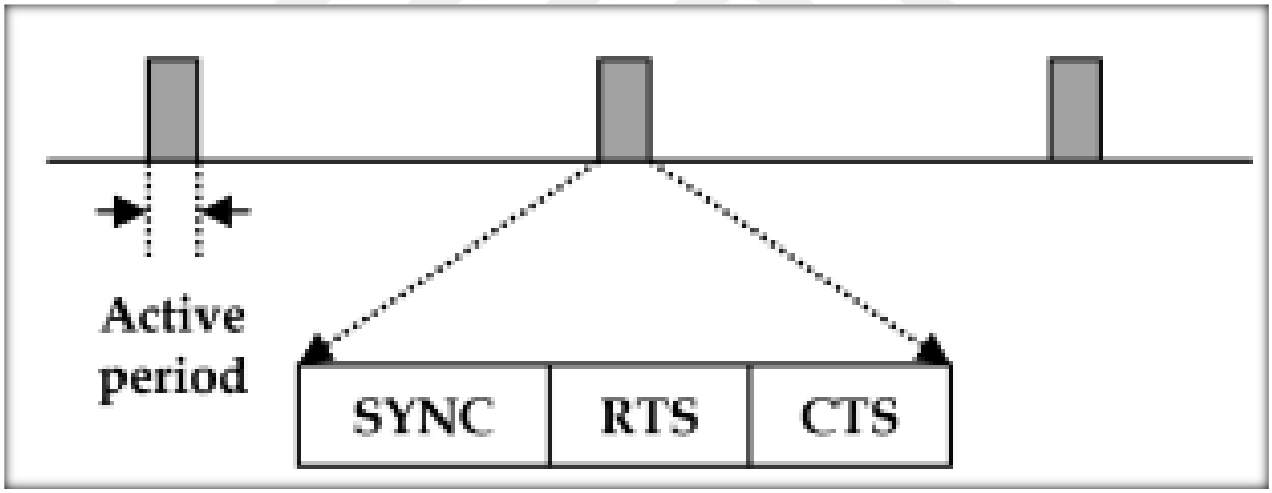

Figure 2.12: Wake-up schema [17]

2.8 MAC PROTOCOL AND ACTIVITIES

According to this study [17], one activity of putting the SN in sleeping status , this is the idea of low duty cycle protocols which is used to reduce the period of time in idle status and /or overhearing status . In addition to being less time usage, it also said to be as a means of (most idle) status. The periodic working style for the SN transmitting and receiving signals to neighbor SN can be a clear description for this periodic (wakeup period) cycle, Also there is the (listening

period) of these SN MAC protocol is listen to the channel if any available activity is happening. However, no channel activity shows the (sleeping period) [17]. the ratio of the listening period length called (Duty cycle measurement) it is said to be (How long dose the listening period take?). To avoid the period of idle listening and overhearing, then mostly the node should be asleep [17].

A clear variation in low duty cycle protocol. There are a variety of Sn are sharing the same wake up phase beacon frames are being sent by each node to its neighbor, including ways to communicate like pending packets for transmitting, or to inform the neighbor about the schedule of wake up cycle.

The majority of synchronized low duty cycle MAC protocols have predetermined periodic wake-up schedules for data exchanges that include a sleep period Tsleep and an active period Tactive repeated at T wake-up period intervals [17]. An ordinary illustrates the operation of synchronized low duty cycle MAC protocols. Frequent beacon frame broadcasts are used to achieve synchronization [25]. Once a node enters the active period, it transmits its beacon frames to tell its neighboring nodes of its current schedule and condition.

All the nodes can then utilize this information for data transfer to learn about the schedules of their neighbors. Think of a scenario where a node needs to send a data packet. When the target node's active period begins, the node awakens and sends its data packet. We can plainly see that the ability to operate data transmission in such a manner results from the destination node's superior timing knowledge, which was acquired by numerous beacon frame broadcasts.

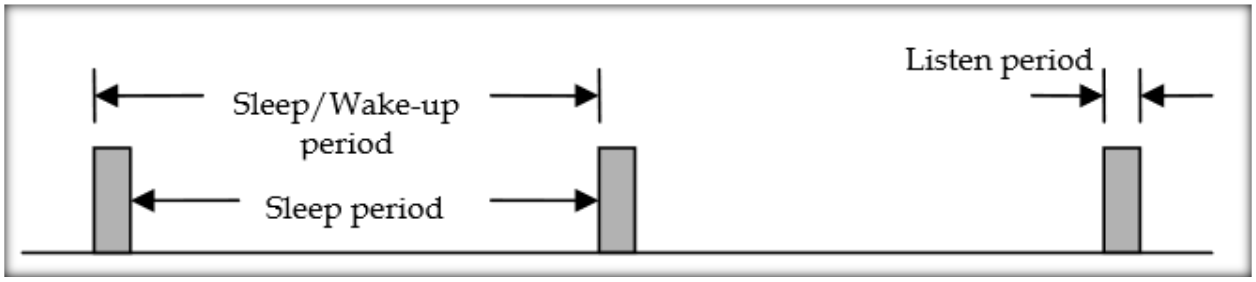

Figure 2.13: Periodic wake-up schema [17]

Due to the difficulty of maintaining global synchronization in a large scale WSN deployment as well as to guarantee high scalability, synchronization is often only maintained within a local

group or cluster. In the subsections that follow, we look at the most significant synchronous low duty cycle MAC protocols that have been put forth in the literature and are directly related to the chapter's direction.

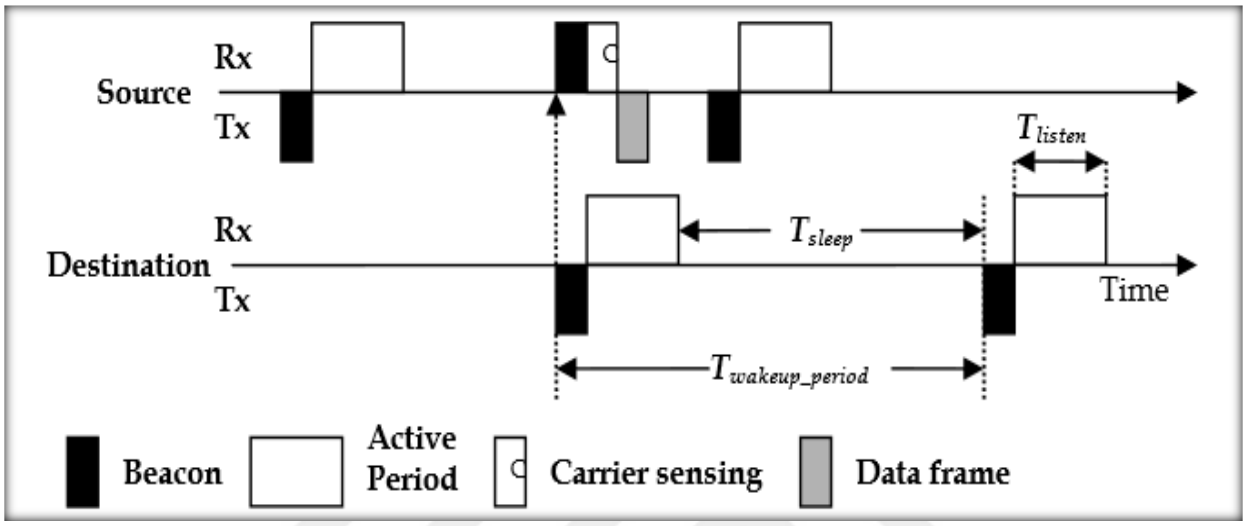

Figure 2.14: Asynchronous wake-up schema [17]

2.9 DESIERD WBAN CRITERIA

The main desired criteria in WBAN characteristics, is the small size, and long life battery, long network life time and a high throughput, Avoidance of battery changing, now lithium batteries earns longer life time may last for fifteen years in some applications [14]. The SN performs many tasks it's job is simply harvesting ,storing sensing controlling and transmitting because it is simply containing the followed parts a transmitter receiver , data controller, microcontroller and sensor [14] as shown in the diagram() below, different topologies are able to construct the SN due to the body movement mesh topology and star topology are the most common used topologies because of their structure .the power supply is inaccessible and difficult to be changed in an implanted type .the power demand is like to be low, and energy supply is ,more difficult [14].

The demands of a telemedicine setup are determined by the factors listed below:

High-quality contributes to a positive patient experience.

The doctor is not confined to a specific location thanks to his laptop and internet. integrated with patient gear, such as a digital stethoscope, blood pressure, electrocardiogram, etc. — much more than just a video conference.

• Integrated with a teleradiology platform that enables the transmission of the patient's X-rays, CT scans, and other imaging data to the treating physician.

Ideal for rural areas because it uses low bandwidth (512 kbps). There are two different kinds of hardware devices needed for BAN.

Wearable gadgets are utilized on the human body's surface, and medical implants are placed inside the body. A crucial piece of technology in the shift to more preventive and inexpensive healthcare is wearable equipment for continuous health monitoring. They make it possible to keep a patient's diagnostic status under review and offer comments in order to improve their treatment and help them maintain good health. There are three types of WBAN traffic. The data flow we employ to monitor a patient's normal condition—one devoid of any emergencies or urgent situations—is referred to as normal traffic. In order to obtain specific information for diagnostic purposes, the doctor or consultant will start an on-demand traffic flow. When nodes reach a certain threshold, they start an emergency flow of traffic that needs to be handled right away. Such traffic is completely unpredictable [23].

This technique enables discreet and regular patient health monitoring, for the therapy of numerous other illnesses. All information gathered via the body network coordinator.

2.10 SENSOR NODE

Using sensor nodes put in or near the body, (WBAN) is a popular topic today for tracking a patient's health and movements. Body tissue has sensor nodes that are implanted there. The primary function of sensor nodes is to transmit collected data to back-end servers connected via wireless local area networks for patient health evaluation and to the main servers for overall data analysis (WLAN).

Electrooculography (EOG), Electromyography (EMG), Electrocardiography (ECG), and Electroencephalography (EEG) are a few of the several sorts of signals that are transmitted from

the nodes. These signals also sense the skin's conductivity and temperature. Send this info to at the appropriate times.

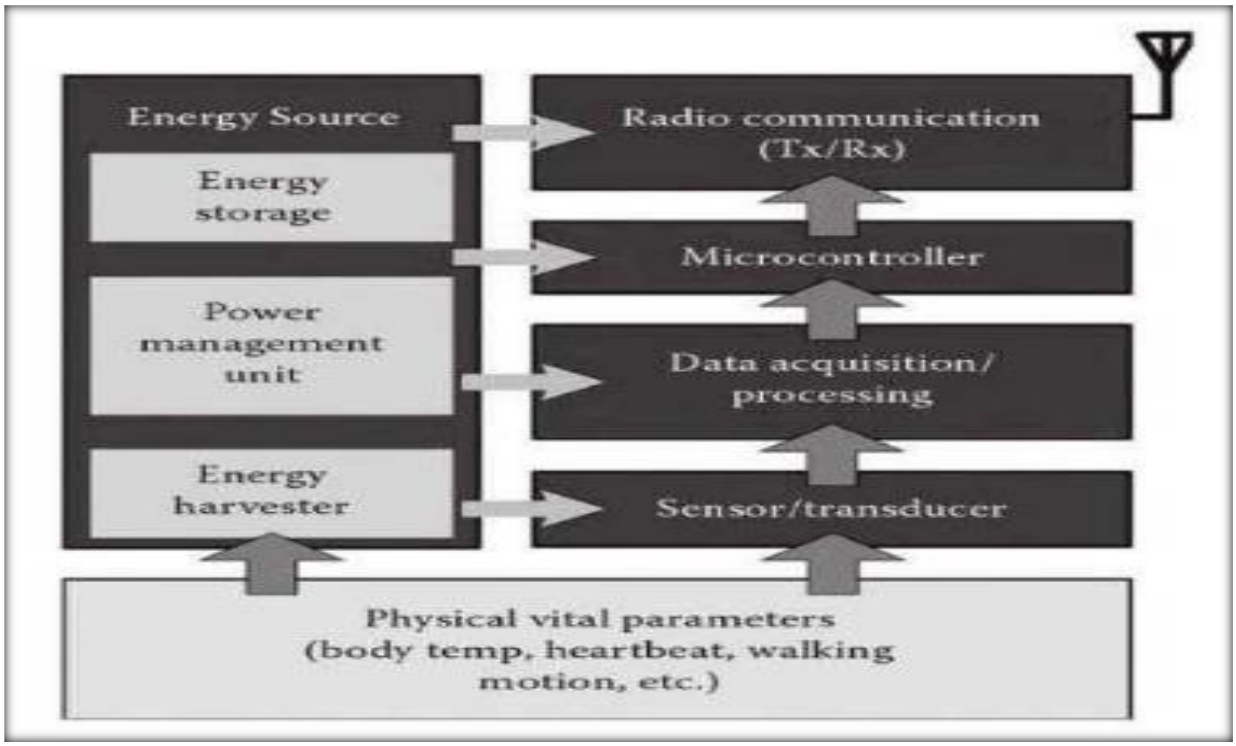

Figure 2.15: Sensor node block diagram [14]

Using sensor nodes put in or near the body, (WBAN) is a popular technology nowadays for tracking a patient's movements and health. The purpose of sensors is to collect data on the many bodily parameters at various points in time and communicate it to actuators. Using WAN or other channels, these actuators transmit this data to the servers. We face a variety of obstacles while designing sensor nodes for WBAN, including weight and performance issues. Long battery life is crucial because nodes are powered by batteries.

Additionally, use various methods to charge these batteries with various technologies. The majority of research nowadays focuses on improving battery timing and energy harvesting with little power consumption. Energy harvesting techniques are employed for extended periods of time without battery recharging to address these problems. These methods extend the sensor nodes' battery life by making advantage of body heat, light, and movement. Our primary goal is to identify methods for obtaining energy from human body movements and blood circulation to power sensor nodes. The many methods of energy harvesting are described in by the authors.

Models that extract the gathered energy were suggested by the authors as stationary and generalized. Researchers have also presented energy harvesting methods that integrate the models that have been previously put out in order to improve data flow and energy harvesting. The many tasks that the sensor nodes are capable of doing are categorized into distinct power consumption categories.

Numerous publications have provided detailed descriptions of the nodes' architecture [7]. Fig 2.12 presents all the components of the sensor node using the energy harvesting technique. Not every node's component is the same for every sensor node. It is very challenging to determine which element of the sensor node consumes more power when considering how they are used. WBAN specifications are provided in the Table 1.

To recharge sensor nodes in wireless body area sensor networks so they can function flawlessly inside the human body, many energy harvesting techniques are employed. The sensor nodes can be charged using a variety of harvesting techniques, including those that use radio frequency, blood pressure, body movement, thermal energy, sunlight, thermal energy from the body, thermal energy from the sun, and thermal energy from thermal energy. The sensor nodes are recharged using these energy harvesting techniques, which also lessen the requirement for batteries in WBAN and other energy-hungry devices by allowing them to more readily capture energy that is directly obtained from the surrounding environment.

3. METHODOLOGY

In a WBAN, receiving as many packets as possible in the shortest amount of time and with the least usage of Energy is the goal. Network life time and throughput are two of the most common ways to compare with the similar WBAN protocols and moreover their Energy consumption is in the front of them on a regular basis. It's all about getting the best possible WBAN effectiveness based on previous performance.

In this thesis, we devise a method for harvesting Energy and add extra energy sources in the highly useful way possible. EH-MAC for this purpose will be compared in order to find the best possible algorithm.

Additionally, we propose multiple Energy sources to perform efficient protocol and the best of suggested algorithm to exploit under period the Wake-up -sleep duty cycle. As a result, the model prioritizes emergency data that are most likely to be treated first to activate the certain alarm, for announcement issue. Our study differs from others in the field because it tackles both the MAC protocol and supply Energy harvesting at the same time.

A default case has also been examined in this work. The sink node will be the controller of the WBAN application can take an action in each case, despite the fact that they may vary and collide. The SNs typically begin their sensing operation in case of emergency data otherwise, they keep their status in sleep duty cycle mode.

Mostly two separate SN modes on the same time, but working in isolate case holding those different modes along the way. Each case mode is assumed to begin with a important information being sensed by the sensor from the changes in its measurement and ending with an arrival to the end destination in sink node. High priority data sensed by more than one sensor need not be synchronized, and the prime objective is to get the most urgent possible within the constraints of its priority.

A moderate case suggestion idea is the normal changing in data sensing results which is not highly to be emergency just to be announced. Since Low priority data case are assumed to be ineffective by the strategies of our assumptions, this model assumes there is no competitive pressure between SNs to alarm emergency (high priority data). The only goal is to get as many

packets as possible via executing a plan that extend NLF plan distribution amongst wake-up-sleep duty cycle and energy harvesting while in addition providing the finest path to go behind for a less usage of battery, by using the harvested energy. Iteratively solving a problem in this way, which invest and spare energy of each suggested source after extracting them from the capacitor unit which they were supposed to be stored after receiving them as one additional source which had been collected by Oring circuit unit and had been sent state to be used solutions, is the approach we propose as a solution.

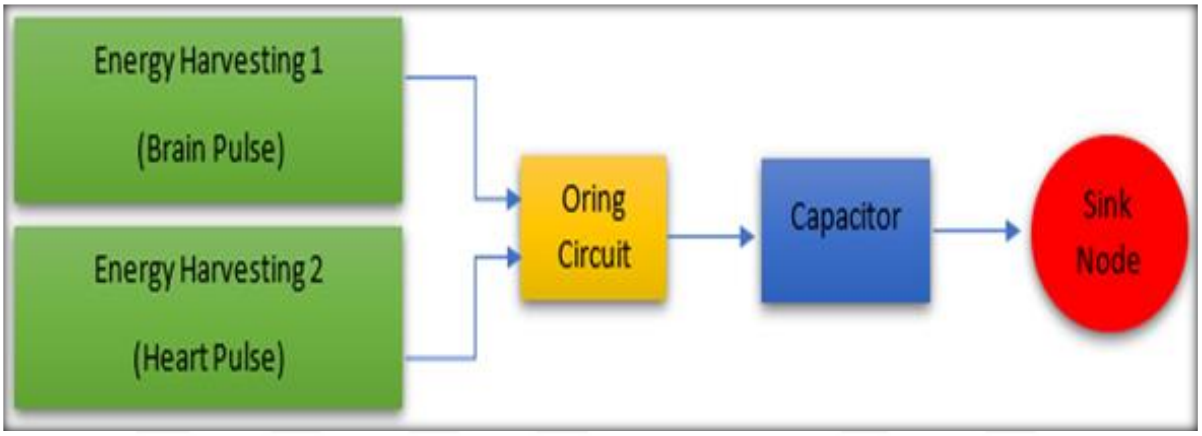

Figure 3.1: A hybrid virtual-inspired (WBAN) sensor circuit algorithms

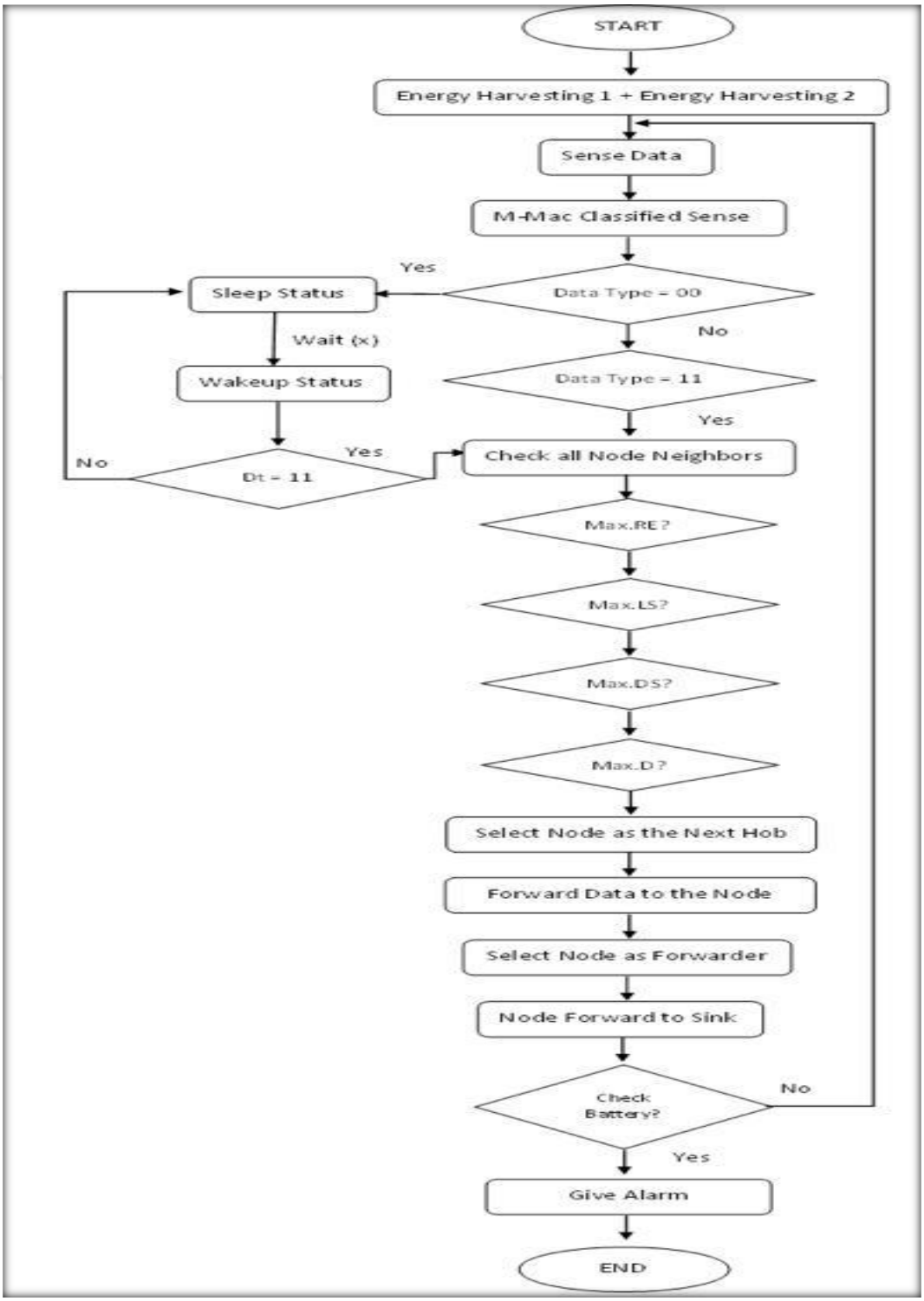

Figure 3.2: The flowchart approach of prposed EH-MAC protocol

3.1 HOW DOES THE EH-MAC PROTOCOL WORK

After integrating the energy extracted from different sources and storing it in an important part called the capacitor, the circuit activates and starts to work. Using the existing energy harvested around the body (from ambient sources), it is invested in activating the sensor nodes. After classifying the type of each signal sensed by the SN leaving the sensor in processing mode and the last necessary procedure, If its priority is low the system entering the sleep status, but if it is of high priority, the system will be activated and then the procedure will be checked to complete the necessary action and send a direct acknowledgment to the sink node.

The system enters the active status testing if the available value is normal priority NP. According to this experiments, the next hob is selected and the normal emergency data obtained and transferred to these neighboring nodes, and the nodes in turn send the important information to the network controlling which is the sink node to acknowledge the emergency message.

In the end of the algorithm procedures, the efficiency of the battery is being examined. If it is in in high condition, the network will continue to work and return to after the start period. If the battery is low, a warning alarm will be issued about its weakness and the system will be taken the necessary action from the controller for termination.

After the end of the situation, the efficiency of the battery has being tested, If it is in good condition, the network will continue to work and return to after the start period. If the battery is low, a warning will be issued about its weakness and waiting for the necessary action from the controller to terminate.

So the question is if normal data is received what is the algorithm decision?

this is the healthy case of the patient **NP**(00), where the algorithm ignores the receiving signal, data will no need to be transferred anymore . As an example The blood pressure is stable equals to (120/ 80 mmHg). Moreover when the signal is received and it is **LP**(01), it means that it is a bit more necessary than to be ignored, as an example the blood pressure is (120/139 mmHg)The routing will happen according to the selection of best next neighbor made by an equation, where the next best decision node is best of energy and closeness to the sink node. the equation below

where **Wx** is the node (**x**) weight value, **REx** is the energy of residual node, **LSx** is the link stability, **DS** is x distance to the sink node and delay **Dx**.

$$W\,x\; =\; (RE\,x\; +\; LS\,x) -\; (D\,x\; +DS\,x\,) \qquad (3.1)$$

3.2 CALCULATION AND MODELING

In a variable factor planning for (Energy harvested and -battery suupported) constraints in multi-source systems was demonstrated as follows:

$$E_{TOTAL} = (\,Eh_1\; +\; Eh_2) +\; BE) - (\,E_{SN} + E_{tx} + E_{SP} + E_{ED} + E_{rx}) \qquad (3.2)$$

Where E_{Total} represents the total energy will be obtained from the different sources

The E_{h1} is considered as the first ambient source,

The E_{h2} is considered as the second ambient source,

The E_{sn} is considered as the sensor node energy,

The E_{tx} is considered as the transmission energy of the node,

The E_{sp} is considered as the sleeping period energy,

The E_{ED} is considered as the energy dissipated within the overall transmission operation,

The E_{rx} is considered as the receiving energy on the receiving end ,

The E_{h2} is considered as the second ambient source,

While the BE is considered as the battery source energy.

So a hybrid idea of combining between the ambient different energy sources and the battery energy source. For each WBAN's node it requires (1100ms), T sensor for starting the lifetime of the sensor, sampling and gathering data, if the sensor is sampling the data each Ts minutes, the sampling rate can be calculated as follows [9]:

$$R_s = \frac{1}{T_s * 60} \qquad (3.3)$$

Taking the consideration the network conditions and the application requirements the sample rate is chosen, the sensor energy is calculated to sampled data as the equation shown below [9]:

$$Td = T_{senspr} * r_s \quad (3.4)$$

Where Td is the sample of data frequency C sensor is the consumed energy through the current time of the sampling data , V is the voltage for supplying the sensor sampling time .where

E sensor is the sample data energy. N preamble is the sample length of preamble packet , while packets of the Data rate is Ndata, Ttx is the packet transmission frequency, Ctxb is the current consumption if 1byte is being transmitted Trx is the receiving time, Trinit for radio initialization , Tron time that is used for turning the radio on and the oscillator that is concerned to it, Trx/tx is the switching time from transmit to receive, Tsr is the channel sampling time Npreamble The energy that is consumed during the transmission time is simply the preamble packet length, Ndata is the data packet ,by the multiplication of the sum of both previous variables multiplied by the sample rate rs we obtain the frequency of packet transmission T txb.

$$E_{sensor} = T_d . Csensor\ V \quad (3.5)$$

$$T_{tx} = r_s * (Npreamble + Ndata\ ). Trxb \quad (3.6)$$

$$E_{tx} = T_{tx} * crxb * V \quad (3.7)$$

$$T_{rx} \leq n * r_s * (Npreamble + Ndata\ ). Trxb \quad (3.8)$$

$$E_{rx} = Trx\ . crxb\ V \quad (3.9)$$

$$Npreamble >= \left[\frac{T_i}{Trxb}\right] \quad (3.10)$$

$$Elisten <= Esample * \left[\frac{1}{T}\right] \tag{3.11}$$

$$T_{listen} = \left(Trinit + Tron + \frac{T_{rx}}{t_x} + T_{sr}\right) * \frac{1}{T_i} \tag{3.12}$$

$$T_{transien} = T_{rinit} + T_{ron} + \frac{T_{rx}}{t_x} \tag{3.13}$$

$$Tsleep = 1 - Trx - Ttx - Td - Tlisten \tag{3.14}$$

$$Esleep = Tsleep\,.csleep\,V \tag{3.15}$$

Simply put, C sleep is the consumption during sleep of the specialist in the present moment, which means that the sensor node is in a state of sleep. When you are in a state of sleep, the algorithm will provide flexibility to the next level better as it allows a very important variable to improve its work like rs The benefit of sleep here is that it gives way to the level .The subsequent achievement of high flexibility so that the parameter like rs works due to the change in the circulating conditions, but on the other hand it will increase the traffic, which causes the phenomenon of excessive listening. Clearly, the difference in the relationship must be taken into account before any change in the parameters

3.3 FUNDAMENTAL STATEMENTS

i. The goal is to forward as many packets as possible septically during emergency data within the WBAN with less energy consumption.

ii. II In light of our various ambient energy resources, we are only interested in the impact of vibration and thermal and of all EH.

I. Between the energy of battery rallies and the harvested energy WBAN with such scenarios are lived longer.

II. The higher signal priority receives the higher possibility to transmit since for the prioritizing they classified to be treated.

III. In order to determine the energy consumption for a specific SN on a specific transaction moment, we need to know two things:

1. Energy which is available in WBAN considering the Energy Harvesting in the SN
2. Energy which is consumed in the WBAN Within each time slotting.

IV. sink node with differing multiple high emergency results (prior decision taking gain as collision) might not be considered in this model. Algorithm scenario in any WBAN MAC-protocol can help sink node making the best decision.

V. This issue will be considered in the future work. In our model, priority type of a node has no negative influence on results since we only look at THG & NLT effects, not every element.

VI. The priority selection are well-handled instead of the battle naïve transferring.

VII. Due to distance to the sink node and next hob selection, algorithm can only visit one neighbor per a search iteration.

VIII. Not all neighbors must be visited. Time of the distance to the sink node limits dictate which nodes are visited.

IX. Wake-up time slots spends more time that yield more energy consumption.

X. For the IEEE 802.15.6 model considered a slot duration spends one second are the same for all activities, however wake up expenditures are four time slots.

XI. On each transmission, any five packets may travel no more, this is called transmission rate.

XII. On WBAN Transmission power 10 mW, Transmission energy consumption 3.1.

XIII. A Packet size is 2 Kb and MAC header length is 32 bit with single sink node.

XIV. Data rate is 1024 and Number of super-frame slots is 16 with Bandwidth 20 MHz.

The mathematical model is predicated on the consumption that each node is allocated a specific type of data. The data that is sent can be based on the priority of the information that can be sent with each sensor, directly or indirectly to the sink node. The mathematical formalism is built on the basis of these assumptions, and the model footnotes that are employed in this optimization are as follows.

3.4 DATA DESCRIPTION

For data classification , each vector represents a new observation, and each section offers a new variable. This data can be either qualitative (categorical) such as high priority HP and normal priority NP; or quantitative (numeric) such as the no priority in the particular sensor when the ideal case is. Again, and as said before depending on the type of data the approach used to the analysis may vary, because is no treated the same way numeric and categorical data. a dataset holds been obtained as of the free-source report: The size of this dataset is relatively manageable due to mainly three facts.

a) The number of nodes that are a small amount accounting for different sub-broadband networks for WSN during priority checking.

b) The measurements period is in most of the length of packet around transition operation in the WBANs.

c) The data was aggregated during the Sn activation time, fact that reduced the final number of observations and therefore the dataset's size is not huge.

d) Determination of routing protocol result based on measured NLT and THG.

3.5 MULTI SOURCE FUNCTION AND SENSOR

In order to overcome this obstacle of sensor life time, we propose a type of searching EH-MAC protocol based on multiple Energy harvesting types, which is especially helpful when dealing with problems made up of a large number of interrelated smaller subproblems. In this approach, a scientific method is provided for determining the overall best response to a group of secondary options that are merged. Dynamic programming approaches the problem after segmenting it into smaller components (stages). When the algorithm discovers the emergency information for either

the final or first subproblem, it extends the problem step by step until it has solved it. As can be seen, there are occasions when a top-down approach is employed and times when a bottom-up approach is used to build a later stage optimum on top of a prior stage ideal. In this instance, the future reference is to the next subproblem. The calculating time is greatly reduced by this method since it preserves the results of each step, but the transmission time investments resulted in a higher memorial utilization. Memory development is referred to as memorizing in computing, and it is a special quality that is not taken into account by exhaustive enumeration techniques. Additionally, unlike with linear programming, there is no standard way to formulate a problem in dynamic programming languages, therefore any can change equalities to match the SN varying on the extent of one's previous experience to static programming applications.

Although EH-MAC protocol is an extremely successful solution approach for longer NLT network life time issues in short term system matters, mathematics, pc science, and executives' arts, it can barely be employed to situations that match a specific set of conditions. These criteria include the following: For a problem to be classified as a nonlinear control problem, the fundamental structure of something like the problem must exhibit the criteria listed below:

1. The issue need to be amenable to segmentation.

The most notable feature of dynamic programming problems is said to be their ability to be divided into smaller steps that, when taken one at a time, lead to a general explanation of the entire problem. Each response in the series helps to determine the characteristics of the following one-stage problem. These 1-step cleaner types of problems are handled in the same way as other WBAN problems.

The stages in the model can be utilized to represent the different time periods because the great majority of time consumption problems call for the usage of many timeframes to make sub decisions based on data. Other problems with it include the fact that the stages can really be interpreted in terms of time. These kinds of issues can still be expressed as dynamic programs, but doing so requires more comprehension and insight. In our example, the time intervals t, which are known as promotion preparatory times in the context of the transmission protocols, indicate the phases.

2. During this time frame, many actions are taken.

In our problem, the action indicates the amount of energy that will be harvested to each sensor. The following actions are generated in a systematic manner and displayed:

$$a = [a_1, a_2]$$

The acceptable provision rates for energy and consumption are a1 and a2, respectively. Many various energy harvesting and routing possibilities were found throughout the investigation, from which the model would select the one with the most potential energy based on a comparison of the results. These options included multiple possible energy sources for WBAN and extended life times. As can be inferred, during the listening phase, the first action to take is a. As a result, this activity is carried out throughout the transmission period regardless of the time t.

Based on the total energy obtained from all available energy sources, the best course of action is determined by a* = [a1*, a2*].

3. Each stage has a predetermined or quantity of sensing information can be received.

To each slot of the transmission relates to a finite number of possible states. Information about future consequences of the current choice is provided by the sensor node.

Dynamic programming design relies heavily on the detection of the problem states. It is usually acknowledged like art form that necessitates a great level of originality combined with acute perception of the trouble. EH-MAC protocol selection is influenced by several factors, including.

i. In order to offer proposals for the future, it is not necessary to understand how the organization came to be in the position it is in.

ii. Each stage shouldn't have any more next hobs than necessary; otherwise, the computational effort would take longer and the stage would become less effective.

iii. The effectiveness of dynamic programming techniques in practical settings is constrained.

Sn's exist in our model that want also be transmit to at the moment in time t. The system selects the next best hob with a greatest amount of energy from the other SN in accordance with the constraints of the LP data.

4. There is a change from one state to the next at each stage t.

Energy Harvesting resources variations for each sensor make up the action 'a' in our model, and these are randomly picked. The algorithm chooses the sensor node with the greatest amount of energy totals after performing action 'a,' which includes calculating how much energy should be spent on transmission preparations. At the conclusion of each period, the energy is reduced, and the sensor node with the most remaining benefit is chosen as the new Sn+1. In this case, the initial action 'a' has a serious influence on this transition. Being within next phase during time t+1 is advantageous.

$$v_{t+1}(S_{n+1}) = max_{a\in A}[C(S_{n+1}, a) + v_t(S_n)] \quad (3.16)$$

$$S_{n+1} = f_t(S_n, a) \quad (3.17)$$

Transition function is defined as: ft (SN), while immediate contribution is defined as: C (a).

A left-to-right-hand flow involves that the goal exists to move from one government to another, as shown above. Future states are created when we act. As a result, a stochastic optimization trouble tin can be conceptualized like a net, with each point contributing to the optimal solution in some immediate way.

For each stage, dynamic programming provides alternative solutions in the event that the overall optimization algorithm cannot be followed due to an unforeseen event. To perform a sensitivity analysis with greater freedom.

The principle of optimal solutions in nonlinear control difficulties involves that the optimum for subsequent steps be separate of the optimum for earlier steps.

$$v_{n+1}(S_{n+1}) = max_{a\in A}[C(S_{n+1}, a) + v_t(S_n)] \quad (3.18)$$

We can see from the equation above that the next move can't be limited by the previous optimal given the current state. All values are then compared to determine which neighbors are the best, armed with the most existed energy of the preceding stage's optimal value., and dynamic programming won't work if a problem doesn't meet this requirement.

7. Initiating a solution procedure from either the final or first stage is possible.

$$v_t(S_n) = max_{a \in A}[C(S_n, a) + v_t(S_n)] \quad (3.19)$$

$$S_{n+1} = f_t(S_n, a) \quad (3.20)$$

Both forward and back induction are acceptable methods of reasoning. Even though we conducted this study by using forward induction, we might well however find the results even condition we treated retrograde induction in the same way.

8. It's possible to derive the optimal rule meant for phase t+1 first after most favorable policy for show t because of the recursive nature of the relationship between the two stages.

sensing from nodes that have been checked up and also where high energy have been found are used to calculate the value for being in sensor node Sn+1, vt+1(Sn+1).

$$v_{t+1}(S_{n+1}) = max_{a \in A}[C(S_{n+1}, a) + v_t(S_n)], \qquad t = 1, \ldots, T \quad (3.21)$$

At the time of this writing, the instant benefit function C (Sn +1 Sn, a) defines the amount of elects procured since nation Sn+1 when it journeys from public Sn below legal action a.

A*, which is the distribution of funds circumstance that receives the most votes, was chosen as a final decision because it maximizes the value function. Distribution of funds decision a* dictates the cities in which advertising and mass meetings are to take place.

The EH-MAC protocol methodology can be broken down into two categories: deterministic and probabilistic. There is a probability distribution for what the next state will be in problems involving probabilistic dynamic programming; however, the supply is however entirely affected via an actual energy and decision. This means that the situation at the next point is not just dependent on the public and judgement. To solve our problem, we used deterministic dynamic programming, which is a type of dynamic programming.

3.6 EH-WBAN VS BT-WBAN BY NODES

In this section, the implementation of EH-WBAN and BT-WBAN into one deterministic problem for medical application is presented in part. Deterministic energy problems are those in

which the affect our cognitive process in our WBAN is resolved solely by the recent condition EH energy harvesting Oring technique.

As a result, the network life time NLT is obvious difference in the figure shown below comparing the SN life time with battery powered case and energy harvesting case play a role at SN as well as the functional form procured from Energy combine to form the utility function Energy harvesting E_{total} has been mentioned in equation (3.1). For each subsequent stage of computation, we must first determine the weighted SN energy for the whole operation of transmitting channel for each time slot sending and receiving packets through the channel. would also be made at stage t+1 by the next sensing operation within the SN It is gained by properly combining these two energy forms and moving on to the next step. As a result, the function is streamlined to focus on adding energy harvesting, which provides the most NLT.

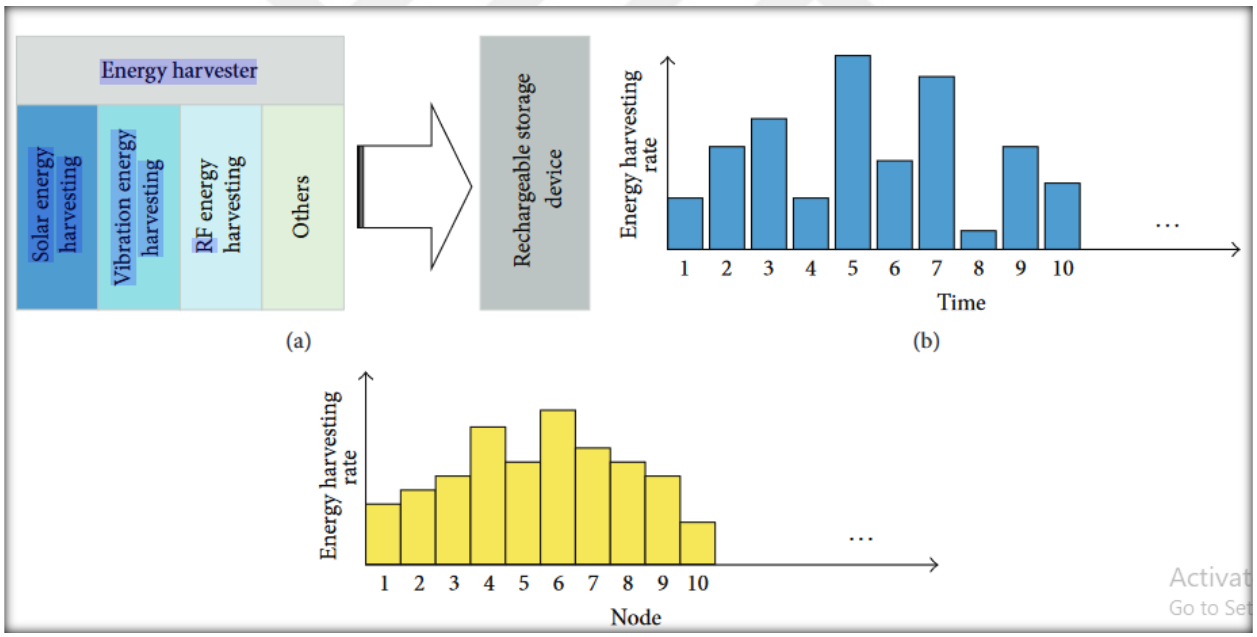

Figure 3.3: The comparison between the performance of EH-WBAN and battery powered WBAN [3]

In this model, now next state is determined entirely by the priority condition and the existing regulatory choosing to use the next hob. So knowable the suggested Duty cycling is the solution to our problem. WBAN usually aim to reduce energy consumption of individual SN contributions or max a total of energy sources contributions. The nature of the NLT in stages can also help determine EH-WBAN and duty cycle. WBAN can be allowed to treat as deterministic nonlinear control problems if they have discrete or continuous network topology, or a WBAN

topology with multiple sink node. Despite the apparent differences, the fundamental structure is largely the same.

3.7 ENERGY HARVESTING MAC PROTOCOL (EH)

During transmission, the Energy harvesting (EH-MAC) classifies different perspectives. The EH protocol utilize algorithms of provide especially exact best sensor node to decide the next hob. This algorithm is both efficient and practical. The EH algorithm is accurate and simple, especially in the unplanted SN, but it requires wireless connection or a wired connection between the ambient energy source and the WBAN system. Unlike the implanted WBAN system, the multiple EH-MAC wake-up sleep duty cycle methodology is increasingly working but does not involve physical contact. This method tracks instinctual energy existence patterns without requiring more information to be informed by as well as hold any request-related demands. Famous passive based approaches include MAC protocol algorithms. When using EH-based methods, the WBAN must be in a critical measurement environment. The EH-based algorithm captures the SN sensor node energy using a predetermined examining steps. Then each SN is processed and broken down into a feature set. This type of modulation produces a signal whose frequency changes linearly with time. When the listening period is prolonged, the hearing range is exceeded. When more people ask for the best next hob, SN energy will start to run out. The benefits of this signal type for series recognition are numerous. They start off with a transmission channel. They're perfect for ranging applications due to their excellent time resolution, which is number two. The typical need for study is for a brief signal to be somewhat close to a sensing impulse. It uses the same kind of occurrence information as an impulse, but not the same phase modules. The EH algorithm has the ability to disregard irrelevant sensor data. The temporal posture of each emergency frame is then established. By examining the chronological order of time positions and teaching a classifier about which series, we can categorize the type of data that was produced.

Energy harvesting designation is anticipated in many WBANs that do not tolerate low giving out authority, so a spanning structure requiring little initial complexity was ultimately required.

There are limited methods to estimate a wireless channel's impulse response. This section presents a mathematical model for received signal response estimation method using wake-up

sleep duty cycle. The range for different types of sensing is then estimated using the approach. Getting a rough idea of the transmission time range and received signal strength is one way for sensing integrator categorization. Many methods could be used to estimate range using the time of the non-emergency signal. Sensing can detect series occurrence by evaluating the strength of the incoming signal. Range estimate can be used to classify a series' kind. This method is applied in this investigation, and the ambient multiple energy harvesting outcomes are outstanding. According to the diagram, the sensor consists of many pieces of different lengths. Each hop possesses a certain quantity of energy that was first harvested using a unique technique. While sensing connected to an even index decreases efficiency, sensing associated with extremely strange indexes increases efficiency. The first base is rising, the second base is falling, and the third base is rising. This enables numerous energy harvesting sources to operate at once. Compared to techniques that rely on the Battery type, it consumes less power. Series acknowledgment that uses ambient energy harvesting is quicker than only battery-based algorithms. Additionally, it protects user privacy when sending and is unaffected by ambient energy harvesting. A cheap ranging system is necessary since many underdeveloped WBANs need to be classified for energy harvesting. The impulse response of an EH channel can be calculated using inexpensive techniques. The statistical equation for the deep learning received signal response estimator is presented in this section. The range for various movements is then estimated using the approach.

$$EH = \{EH_1, EH_2, Eh_3, \dots, EH_n\} \tag{3.22}$$

$$EH1 = \{EH_i^1, EH_i^2, EH_i^3, \dots, EH_i^n\} \tag{3.23}$$

$$EH2 = \{EH_{i,1}^j, EH_{i,2}^j, EH_{i,3}^j, \dots, EH_{i,d}^j\}^T \tag{3. 24}$$

The Energy Harvesting type, or "EH," is employed to improve the rate of energy during the operations of the WBAN. And "T" is the total number of iterations because all of the proposals from the sensor nodes must be filtered in our conditions, where research wanted the beat interval to be as long as possible. In order to allow for increased energy during the transmission period, the EH algorithm sets the current heartbeat maximum for a WBAN equal to the preceding pulse. In other words, because they are sensing, the reflections from the previous pulse won't affect the

expressions from the current beat. This guarantees that the EH algorithm receives the information it needs to decide on the next hob. This issue can be solved by employing the EH algorithm wake up sleep duty cycle. In order to cover the WBAN network life time, the EH algorithm has an improved flexible range than other algorithms with a single decision of choosing the next hob. Due to the fact that the energy is dispersed over a wider range of frequencies, they are also more resistant to noise.

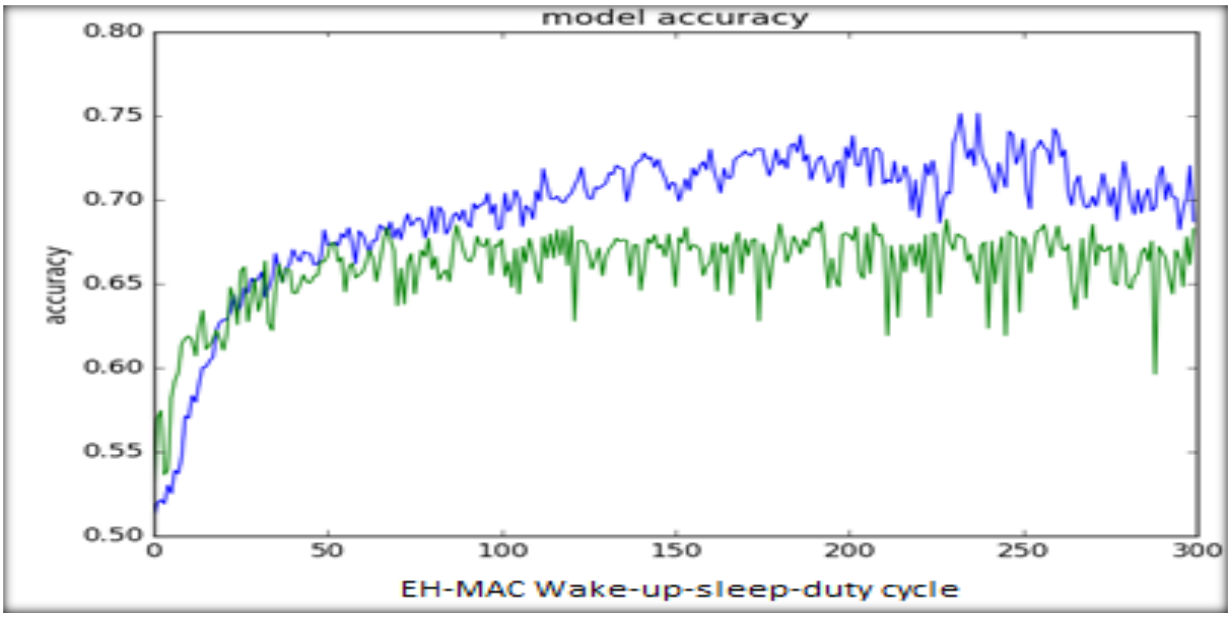

Figure 3.4: The training and testing of EH-MAC algorithm

As long as Network life time and throughput estimating modulation has been used to produce general Mac protocol, the EH-MAC protocol Wake-up sleep duty cycle methodology has been in operation. Linearly increasing or decreasing frequencies can be generated by using this multiple energy harvesting modulation. Routing protocol with confidence is often referred to as "harvesting ambient energy," while sensor with harvested energy with a decreasing network life time low throughput is referred to as "un-optimized routing with EH-MAC algorithm." The use of this kind of method in applications for series recognition has many benefits. They make use of channel space first and fore most. Energy harvesting are also a fantastic option in this context due of their high time-resolution capabilities. Energy harvesting systems should be enhanced using the EH-MAC algorithm approach to be as succinct as feasible in order to move closer to an emergency routing. The components of a transmission signal known as the next hob taking

decision and sending to the sink node vary depending on the suggested protocol, but they share the same fundamental structure as a category.

Generally speaking, wireless body area networks tend to fit the data better than feedforward networks. Second, the plot shows that layers that were retrained for the energy harvesting Mac procedure had fewer training damages than layers that were retrained only once. There are numerous approaches to address this issue. The simplest techniques involve adding additional data and including obscured image types in the training dataset. More complicated subsystems for segmentation, depth detection, and other routing protocol duties are included in modular systems created by machine learning engineers.

Another option was to draw inspiration from multi source harvesting using or-ing technique. As routing protocols studies have shown, the acknowledgment of partially occluded channel totals takes longer than the recognition of unobstructed transmission results. It is possible that a repeated coatings offer is extremely large examination space out, letting a simulation to around, thus losing a little reward that they would have on or after their element seek breathing space for sink node a small reward that they would receive during or after their element searches for a sink node with breathing room. The finding that lower standard failures are still connected with an improvement in seeing at does not support the overfitting hypothesis, although training assessments can be helpful in this regard.

As a result, these gadgets are expensive. Due to the high efficiency and complexity of active period life time, active period demands quick contact between the sensor and the sink node, which can be uncomfortable for some emergency data. Sleeping period requirements might only demand very little processing power, but because they don't require direct data transfer, they are better suited to routing policies than active signal channel devices. WBAN networks tend to better linear model than feedforward networks, as can be seen in general. Second, the plot shows that connections that already had layers retrained for democratic optimization had low variable losses than networks that had one layer retrained.

4. RESULTS

Figure (4.1) shows the throughput comparison of the proposed algorithm with multiple EH sources and also our proposed work EH-MAC protocol with M-MAC's work and with a plain transmission style where no algorithm has achieved. It is evident from the figure that our algorithm achieves higher throughput. Because plain transmissions uses its energy quickly and cannot transfer any data to the sink node, it has the lowest throughput. While M-MAC's algorithm achieves better network throughput compared to No-algo, it's throughput is significantly lower than the rest because of the large number of packet loss. Even though EH-MAC-WBAN protocol attained a throughput of around 88 kbps, our proposed technique outperforms it due to it limited packet drop. The results above demonstrate that, in terms of delay, network lifetime, energy consumption, packet drop, and throughput, the proposed EH-MAC-WBAN protocol greatly surpasses state-of-the-art methods.

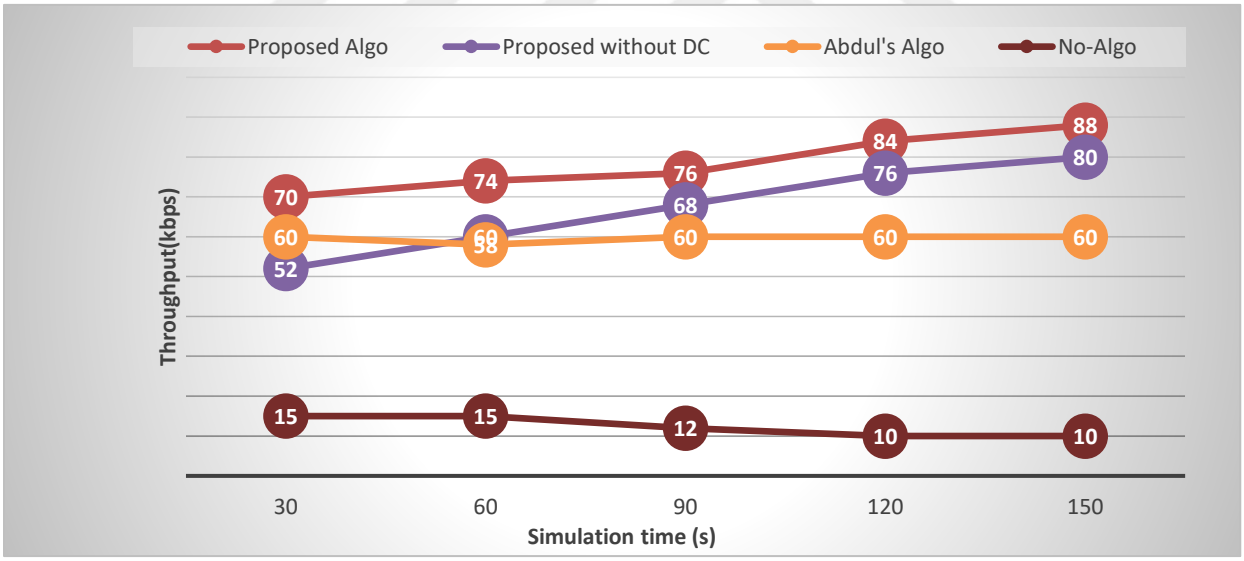

Figure 4.1: Throughput

Hence, it can be concluded that our hybrid architecture with Energy harvesting-MAC protocol, and sleep-wake-up duty cycle are efficient enough to increase the total performance of the network. This proves that if our work is applied in real time scenario, it will attain similar results.

$$Throughput = \frac{Packet\ size}{Transmission\ time} \tag{4.1}$$

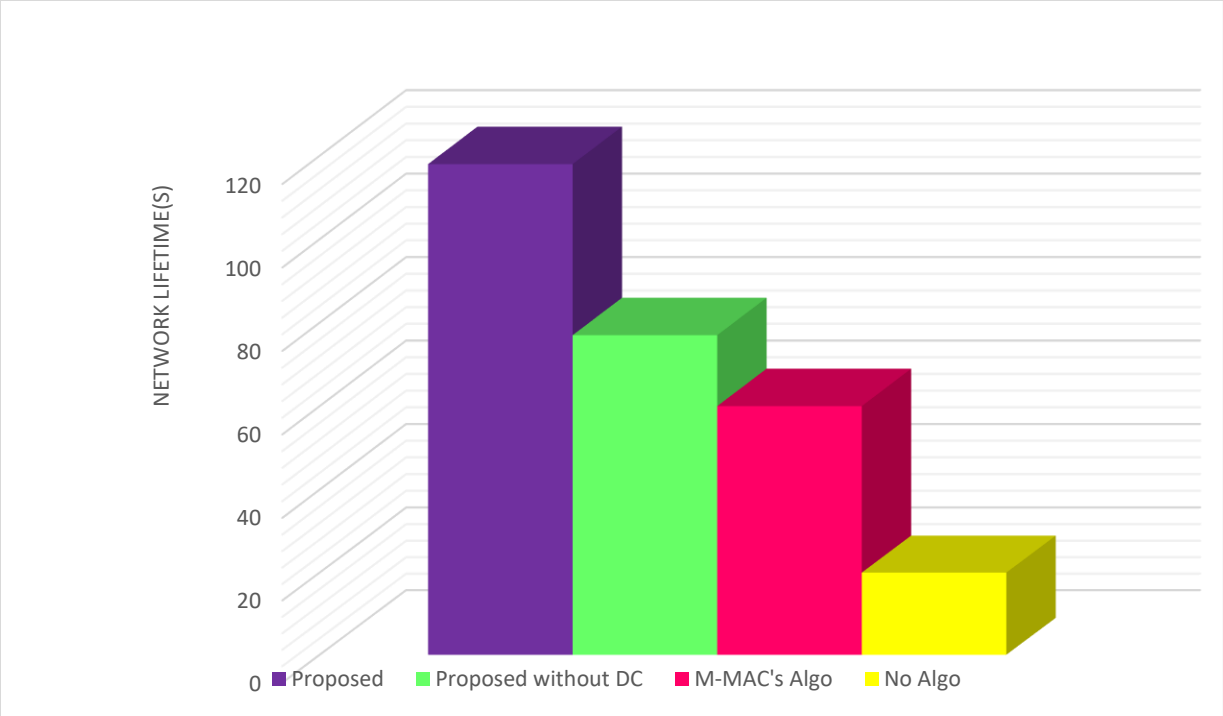

Figure 4.2: Network lifetime

In figure 4.2, the network lifetime of the proposed EH-MAC-WBAN was compared with similar state-of-art algorithms. In plain mode status algorithm, its network lifetime is only 8s, this is because nodes are transmitting without following any algorithm. In M-MAC's work, it achieved a lifetime of 60s because of the inefficient selection of intermediate node. While in the case of EH-MAC-WBAN, a better network lifetime of 96s was realized though lower than our algorithm. This is because complexity of plain algorithm and transmission of duplicate and non-critical data. This is a result of the M-MAC's algorithm complexity and the transmission of redundant and irrelevant data. The implementation of the proposed work results in a much longer network lifetime. and Sleep wake duty cycle algorithms.

For a study in the WBAN we analyzed the results of the proposed model. Energy on the WBAN has been gathered from a variety of sources. We utilized data since the Ultimate Vote Commission to the WBAN to the group of sensors SNs in elections in every WBAN application we preferred to compare & analyze the percentage of the throughput moreover the network life time. To get a sense of the real packet sending, we chose four statues that were diverse in both NLT and throughput. We made certain, however, that the WBAN requirement are varying

because of the purpose behind the usage, but the most important factor that must present in all those WBANs application is the EH energy harvesting. For the purposes of this study, the WBAN NLT& THG in were chosen based on their importance, the previous mac protocols compared to our work, and the proportion of comparison in each case before and after adding the EH criteria. which is shown in Table (1).

Table 4.1: Proposed algorithm EH-MAC protocol with network life time and throughput

WBAN Algorithm	**NLF (seconds)**	**THG (kb/second)**
Proposed Work With Sleep-Wake-Up Duty Cycle	96 s	88
Proposed Work Without Sleep-Wake-Up Duty Cycle	80s	80
M-MAC Work	60 s	60
Plain Algorithm	6 s	10

5. CONCLUSION

Using a proportional WBAN system, this study combined EH from multiple sources and wake up -sleep duty cycle -MAC protocol to produce a plausible working algorithm plan. There were two issues: Throughput and Network life time To promote the hybrid model, many comparison were made. The model provided an EH and a fitness-based MAC routing where the SN never dies due to the uninterrupted harvesting and the efficient MAC protocol . The findings experimented for MAC protocoled and non-MAC protocoled algorithm comparisons. Theoretically Special estimated costs are expected, by comparing the long-lived sensors SN, due to the EH criteria, effectiveness rates were all subjected to a sensitivity analysis, to enhance the impact. Each analysis identified a model's strengths and potential areas for improvement. In one scenario, the proposed work EH without Wake -up Sleep duty cycle was less fitness valued due to a lack of sent packets. While in the scenario, the proposed work EH with Wake -up Sleep duty cycle was more fitness valued due to an efficiency of Energy usage. Finally, this model can assist WBAN researchers by providing holistic solutions.

5.1 FUTURE RECOMMANDATION

This section discusses possible research directions. Although the developed EH criteria is suitable for long life applications, it could be improved to make it more accurate. In order to obtain more realistic results, the model can be updated to avoid the possible **collision** which happens in the same time. Different scenarios are used to verify the model's validity, although more exact data will provide clearer insights. Here, research-related topics are discussed. We believe the mathematical model can be improved for being more compactable to a good WBAN requirements. for the future work we aim to make the SN self-powered with integrated batteries to achieve energy harvesting within the WBAN Desired Characteristics. We propose to achieve a fully supported network by doubling the number of sensors and the main controller as well as the system and the presence of parts as accompaniments and matching the original sensor to provide support in the event of a malfunction and to perform any part of the procedure regardless of the high cost because the main goal is the quality that may relate to the life of the user.

REFERENCES

[1] S.-E. Kim *et al.*, "Energy management integrated circuit for multi-source energy harvesters in WBAN applications," *Appl. Sci.*, vol. 8, no. 8, p. 1262, 2018.

[2] M. Dhurgadevi and P. Meenakshi Devi, "An analysis of energy efficiency improvement through wireless energy transfer in wireless sensor network," *Wirel. Pers. Commun.*, vol. 98, no. 4, pp. 3377–3391, 2018.

[3] X. Qi, K. Wang, A. Huang, H. Hu, and G. Han, "MAC protocol in wireless body area network for mobile health: a survey and an architecture design," *Int. J. Distrib. Sens. Networks*, 2015.

[4] K. Guo and S. A. S. Syed, "Energy efficiency based lifetime improvement for wireless body area network," *IET Commun.*, vol. 16, no. 7, pp. 795–802, 2022.

[5] M. Ezziyyani, Ditzinger, and Ezziyyani, *Advanced Intelligent Systems for Sustainable Development (AI2SD'2019)*. Springer, 2020.

[6] A. A. Ibrahim and O. Bayat, "Medium access control protocol-based energy and quality of service routing scheme for WBAN," in *2020 international congress on human-computer interaction, optimization and robotic applications (HORA)*, 2020, pp. 1–6.

[7] A. Kozłowski and J. Sosnowski, "Energy efficiency trade-off between duty-cycling and wake-up radio techniques in IoT networks," *Wirel. Pers. Commun.*, vol. 107, no. 4, pp. 1951–1971, 2019.

[8] M. Boumaiz *et al.*, "Energy harvesting based WBANs: EH optimization methods," *Procedia Comput. Sci.*, vol. 151, pp. 1040–1045, 2019.

[9] M. K. M. Rabby, M. S. Alam, and M. S. T. S. A. Shawkat, “A priority based energy harvesting scheme for charging embedded sensor nodes in wireless body area networks,” *PLoS One*, vol. 14, no. 4, p. e0214716, 2019.

[10] S. Pathak, M. Kumar, A. Mohan, and B. Kumar, “Energy optimization of ZigBee based WBAN for patient monitoring,” *Procedia Comput. Sci.*, vol. 70, pp. 414–420, 2015.

[11] C. A. Tavera, J. H. Ortiz, O. I. Khalaf, D. F. Saavedra, and T. H. H. Aldhyani, “Wearable wireless body area networks for medical applications,” *Comput. Math. Methods Med.*, vol. 2021, 2021.

[12] J. Zhang, Q. Zhang, Z. Li, X. Lu, and Y. Gan, “A Lightweight and Secure Anonymous User Authentication Protocol for Wireless Body Area Networks,” *Secur. Commun. Networks*, vol. 2021, pp. 1–11, 2021.

[13] A. K. Sagar, S. Singh, and A. Kumar, “Energy-aware WBAN for health monitoring using critical data routing (CDR),” *Wirel. Pers. Commun.*, vol. 112, pp. 273–302, 2020.

[14] S. Al-Janabi, I. Al-Shourbaji, M. Shojafar, and S. Shamshirband, “Survey of main challenges (security and privacy) in wireless body area networks for healthcare applications,” *Egypt. Informatics J.*, vol. 18, no. 2, pp. 113–122, 2017.

[15] R. Negra, I. Jemili, and A. Belghith, “Wireless body area networks: Applications and technologies,” *Procedia Comput. Sci.*, vol. 83, pp. 1274–1281, 2016.

[16] A. Mahmoud Olayan, E. Shaaban, S. Ghoniemy, and K. Emara, “Proposed Energy Efficiency and Power Management Framework for Energy Harvesting–Wireless Body Area Network,” in *2021 10th International Conference on Software and Information*

Engineering (ICSIE), 2021, pp. 1–9.

[17] M. R. Ahmad, E. Dutkiewicz, and X. Huang, "A survey of low duty cycle MAC protocols in wireless sensor networks," *InTech Emerg. Commun. Wirel. Sens. Networks*, p. 69, 2011.

[18] A. A. Ibrahim, A. T. Salawudeen, O. N. Uçan, and P. U. Okorie, "A novel energy-conscious threshold-based dAta Transmission routing protocol for wireless body area network (NEAT)," in *2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*, 2020, pp. 1–5.

[19] S. Ullah, B. Shen, S. M. R. Islam, P. Khan, S. Saleem, and K. S. Kwak, "A study of MAC protocols for WBANs," *Sensors*, vol. 10, no. 1, pp. 128–145, 2009.

[20] M. U. Rehman, I. Uddin, M. Adnan, A. Tariq, and S. Malik, "VTA-SMAC: variable traffic-adaptive duty cycled sensor MAC protocol to enhance overall QoS of S-MAC protocol," *IEEE Access*, vol. 9, pp. 33030–33040, 2021.

[21] D. A. Hammood, H. A. Rahim, A. Alkhayyat, and R. B. Ahmad, "Optimization algorithms in Wireless Body Area Networks," in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 745, no. 1, p. 12054.

[22] M. Javed, G. Ahmed, D. Mahmood, M. Raza, K. Ali, and M. Ur-Rehman, "TAEO-A thermal aware & energy optimized routing protocol for wireless body area networks," *Sensors*, vol. 19, no. 15, p. 3275, 2019.

[23] H. Fouad, "Continuous health-monitoring for early detection of patient by web telemedicine system," in *International Conference on Circuits, Systems and Signal*

Processing, 2014, pp. 23–25.

[24] H. Fouad, "Sensor node design for IoT telemedicine embedded system," *Int. J. Internet Things Web Serv.*, vol. 2, 2017.

[25] X. Xu, L. Shu, M. Guizani, M. Liu, and J. Lu, "A survey on energy harvesting and integrated data sharing in wireless body area networks," *Int. J. Distrib. Sens. Networks*, vol. 11, no. 10, p. 438695, 2015.