# Fundamental Application of Internet of Nano Things

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## Declaration

It is hereby declared that

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2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
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# Approval

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Of Summer 2019, 2019 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Undergrad on 25 April, 2019.

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## Ethics Statement

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

# Abstract

The trap of things, or IoT, is a plan of interrelated figuring contraptions, mechanical and electronic machines, things, creatures or individuals that are furnished with unique identifiers (UID) and the capacity to exchange information over a structure without envisioning that human-should human or human-to-PC affiliation. On the other hand, nanotechnology envelops the comprehension of the key material of physics, chemistry, biology and technology in nanoscale devices (between1 nanometer to 100 nanometer). The interconnection of nanosensor and nanodevices with Internet has led to development of next generation standard based on IoT is called Internet of Nano Things (IoNT). It has a huge role in the development of technology because it is being used in medical devices, including micro needles, both for drug delivery and for biosensing. In this paper, we address key components influencing the energy consumption of nanodevices, featuring the impact of the communication scheme utilized. Previously a system model was proposed by some researchers and scientists where ZnO nanowires have been used. It was proved there that because of its straightforwardness, this nanogenerator creation techniquecan possibly be scaled up for the mechanical generation of piezoelectric energy harvesting devices. If the ZnO nanowires used in the protocol are compressed or flexed then current flows through them as a result power transmission occurs. In contrast, in this paper it has been shown that if the system model can be replaced with SWIPT (Simultaneous Wireless Information and Power Transfer) then a good energy harvesting rate and high bit rate can be gained. Here, with different mathematical expressions it has been derived, compared and analyzed how using SWIPT is more fruitful. Based on the expressions and analytical values the result reveals that SWIPT gives a promising outcome. Though the bit rate and energy harvesting rate is of SWIPT is not more than ZnO nanowires but the uses of this model can be easier because SWIPT model does not need any extra device to charge itself whereas the other models require them.

DEDICATED TO OUR PARENTS

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# Table of Contents

## List of Figures

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction to internet of Nano things in health care system

Nano technology is a gigantic field to investigate with the possibility to present new logical developments. Nano innovation imagined much application in the bio medication, mechanical and military fields just as in purchaser and modern products. Here, fundamentally we work with the bio medical parts. The internet is living element and continually changing with new remodel. New application and programming are made persistently. When of developing internet innovation is additionally evolving scene. Broadband associations are more grounded; gadgets are turned out to be all the more dominant and littler. As the sensor and gadgets are really small, we will ready to utilize it in various part and it turns out simpler to utilize the gadget. The internet of things (IOT) is the system of various physical gadgets like vehicles, home application, programming, sensors, and associate this things to gather, trade information making more open doors for the physical world. Fast advancement data and Nanotechnologies change the entire medicinal services framework. It gives the social insurance framework another worldwide world. Internet of Nano things and Nano medication change the establishment of illnesses distinguishing proof, treatment and anticipation. Consistent populace development impacts of human services framework and requirements for refreshed, new and further developed logical arrangement.

Nano innovation implies the art of incredibly little things. It developed colossal potential for social insurance, for conveying drugs all the more viably, determination sicknesses all the more successfully and quickly and counteracted the illnesses all the more delicately. It chiefly includes to control of particles littler than 100 nano meters (one Nano meter is equivalent to one billion of a meter) and the innovation includes building up the gadgets in that measure. For instance a noteworthy test is that the body does not assimilate the whole medication portion which is given to the patient. So on the off chance that they use Nanotechnology the researcher

can guarantee that the medicines are conveyed to the particular region of body with the ideal medication portion. Created and rich nations are putting as much as they can in this part.

## 1.2 Review of previous works and observation

E Cummings et al. (2018)proposed that healthcare data assumes an indispensable job in computerized change of human services area. The combination and association of healthcare administrations, experts and buyers is basic to the acknowledgment of the upgrades guaranteed by computerized healthcare and the optional utilization of the healthcare information prompted earth shattering looks into, disclosures. Increment dependence upon a wide range of computerized prescription has additionally settled healthcare data's as accessible specialization in human services.

Raj Gururajan et al. (2018) have analyzed the tele health literature has grown over the years to be a substantial body of work. They also try to highlight the problems in interacting value from tele health activities. They mainly explain the health literature over the period of 2000 to 2015 which mainly focused on pardons or surprise in the findings.

A Ryan et al. (2018) presented that featuring front line investigate proof, innovation updates and advancements from the computerized change of human services framework covering a wide range of work, enveloping major hypothetical ideas, instances of key utilizations of new advances and significant new improvements in the field of wellbeing data.

MamtaRath et al. (2017) predominantly centered around the urban regions; they asserted that the way of life of people in metro urban territories with the costly volume of populace is likewise impacted by various application and organization outline works. Each one of those are influenced to the human wellbeing framework up to an all-inclusive degree and there are more wellbeing related issues and wellbeing risk worries that can be recognized in urban territory. The primary focal point of this paper is to display an explanatory investigation on different parts of the shrewd human services framework in a keen viewpoint by examining them concerning rising designing advancements, for example, portable system, web of things (IOT), distributed computing, huge information examination and universal registering. They

additionally centered around completed subtleties overview of medical problems and improved arrangements in robotized framework utilizing these innovations.

Louise K Schaperet al. (2017) reported that incorporating and associating care the most recent couple of decades have seen the advanced change of medicinal services with wellbeing data taking the lean in developments which have empowered the area to advance from simple PC based records to expansive scale frameworks taking into consideration intra hierarchical, national and global correspondence and data changes.

Sanjay Bhushan et al. (2017) has dissected the fake medications production network elements pursue an illogical example. In spite of it being focused by law requirement strategies, they proposed a dynamic theory dependent on frameworks approach, scrutinizing the very manner by which the provisions of fake medications have been controlled by utilizing the displaying structure of framework elements (SD). An all encompassing impact model is propounded featuring the common interchange and causality of affecting elements under the fake medications production network biological system. The objective of this exploration was to distinguish the key approaches intercession focuses' basic far basic leadership.

Rui Zhang et al. (2017) have exhibited a systematic model of the terahertz correspondence direct far in vivo Nano arranges by considering the powerful of commotion on connection quality and data rate. The sub-atomic retention commotion model for in vivo Nano systems is created dependent on the physical instrument of the clamor present in the medium which considers both radiation of the medium and the sub-atomic ingestion from the transmitted flag. The flag to clamor proportion (SNR) of the correspondence channel is researched for various power portion plans and the most extreme reachable data rate is concentrated to investigate the possibilities of THZ correspondence inside the human body.

Siyiwang et al. (2017) have displayed the execution of full scale sub-atomic correspondence with sensor purifies time. He considers an atomic dispersion based interchanges connect that passes on data on the full scale. He inferred novel catch likelihood articulation of a limited estimated recipient. At that point presents the idea of time totaled sub-atomic clamor at the beneficiary as an element of proportion at which the sensor can self-rinse. The execution is delicate to the sensor wash down time and speed.

M. Okwori et al. (2016) has presented that a micro scale mobile enabled implantable medical sensor. They investigate the use of magnetic induction-based backs cater communication as an alternative technology. In particular the goal is to provide a practical design for a macro-scale IMD, referred as a bio mate here that can communicate with a wearable or handheld device such as cell phone, tablet or smart watch. Firstly it is demonstrated that communication via magnetic induction can be established between a bio mate and such as external reader. Secondly low power modulation and error- correction coding schemes that can be implemented in micro scale are explored for the mate.

## 1.3 Motivation

In the last few edges, we are blessed a great innovation about the internet of this which is also known as IOT. In medical sector we find an opened and motivational place to research of technological solution and a better result. In this heath care system there is a huge place to research and innovation. This way, the patient who is informed daily about their health can take a very good and active role in health care. IOT is connected many smart devices to a specific network. This way technology can improve services in hospitals, health care center and the practice of home care. IOT is something that is a source of huge inspiration in health care resource field. If IOT is related to the health care system, then the health care process will be faster than before. People need to organize much campaign about IOT base health care system. In this way we can motivate the people about IOT based health care system.

## 1.4 Challenges

Technology is related in every sector like Health care, business, finance, and others. Health care remains the fastest to adopt technological changes in this sector when we talk about IOT based changes it means the effectiveness and quality of service in health care system. Although the IOT is revolutionary in the as well that need to be kept in mind.

## 1.5 Security threats

Mainly the personal health care information stored and conveyed in the device which is connected to the internet while many health care organization make sure that the sensitive data is stored in a secure way not open for all. They must have the control over the safety and security of the health care basis data. This creates significant challenges that the authority can keep proper responsibility of the data which is connected to the network. Security is important because some hackers might be changes the data and state the data. So security threats are the main challenges for IOT based health care system.

## 1.6 Multiple device Integration

Multiple device integration is also an obstacle to the successful deployment of IOT base health care system. Today most of the health care devices and equipment which is in the hospitals to be connected to collect data and store them in the internet for the patient. As an example, if one person is suffering from heart diseases he or she might be suffering from blood pressure as well. So if the blood pressure report and heart diseases report is in front of him or her, it will be easy for him or her to consult with the doctor. Through the internet all the data is kept in here and there. So if the authority follows some protocols or standards to restore the data, it will be very helpful for the patient as well as the doctors. Doctors can easily identify the problems of the patient. On the other hand various devices are connected to the network. So it is difficult to identify the actual data. In this case it will turn a complicity one. So it will turn a challenges the network will be faster and easier. For that if all the data follow some protocols and standards then it turn to be easier one and successful implementation is possible in IOT based health care system.

## 1.7 Inferring results from immense data

The process of collecting data and result then is attached to many complexities. Through the new collecting data results can help the patient and doctor to come out conclusion. Coming up with the result from such a significant amount of data is quite challenging. Identifying the actionable and valuable data is critical as most of the specialist find out difficulties to conclude

the data. Sometimes while collecting the data same data would be lost in this case, which is harmful for the patient. For that network will be stronger. Moreover the concern is becoming bigger and bigger, with the growth of some connected devices that continuously collects and generates big data.

IOT will undoubtedly transform the health industry. Not only it will benefit the doctors and the specialist but also the patient who have no knowledge about the basic health facilities. At the last if we overcome this type of challenges then successful implementation is possible in IOT based health care system.

## 1.8 Organization of the Thesis

Chapter 1 is an introductory chapter. It contains internet based health care system or mobile health care system. And have motivation, challenges, security threats, multiple device integration, inferring results from immense data.

Chapter 2 present four parts. Firstly, the perspective of people about internet of nano things in Bangladesh and how it effects in our country. Bangladesh need to more update in this sector. Secondly represents mobile health care system advantages or disadvantages. Thirdly presents the potential benefits, new possibilities and opportunities. At last it shows that Airtel presents health combo pack per minute cost of mobile and also the help line number.

## 1.9 Objective of the Thesis

- To develop mathematical model of Internet of Nano Things.
- To describe mathematical expression of energy harvesting rate and data rate.
- Increasing data transfer rate.

# CHAPTER 2

# Internet of Nano things in Bangladesh

## 2.1 Internet of Nano things in Bangladesh perspective

The idea of Nano things turns out to be progressively well known in this day and age. Fast improvement data and Nano innovation changes the medicinal services framework. It provides for the social insurance framework another world – web of Nano things (INOT) and Nano drug. The fate of INOT framework will make simpler for health monitory, indicative and treatment all the more superbly and auspicious. The examination of the web of Nano things is exceptionally significant for future advancement human services framework. Entomb association of Nano systems to the more extensive web will bring new difficulties. Before we see how web of Nano things effect of our method for living it's imperative to experience its focal points and disservices. The more we realize the data it's simpler for us to take the correct choice. Nanotechnology is a multidisciplinary field that is starting to upset regular daily existence. The Nano world is a strange area where things happen much uniquely in contrast to the typical life.

## 2.2 Mobile Health Care Technology

### 2.2.1 Advantages

The viability of mobile health care innovation is to improve medicinal services administration in conveyance process. Customary consideration and treatment is significant and supportive in improving ailments. Correspondence advances can help in such consideration and backing. By utilizing versatile medicinal services innovation our treatment will be simpler and quicker. On the off chance that one individual is not kidding condition by portable systems administration they can distinguish the diseases and can take prescription. At a specific minute it helps the

most. Since setting off to the medical clinic and taking arrangement for the specialist and sitting tight for the specialist it's too long procedure. In any case, for this situation patient can without much of a stretch or at any minute contact with the specialist. For that innovation ought to be more refreshed. More flawlessness is expected to improve versatile social insurance innovation. Scientist was sought to recognize the control of telephone voice and text message to give legitimate consideration and disease management support in this sector

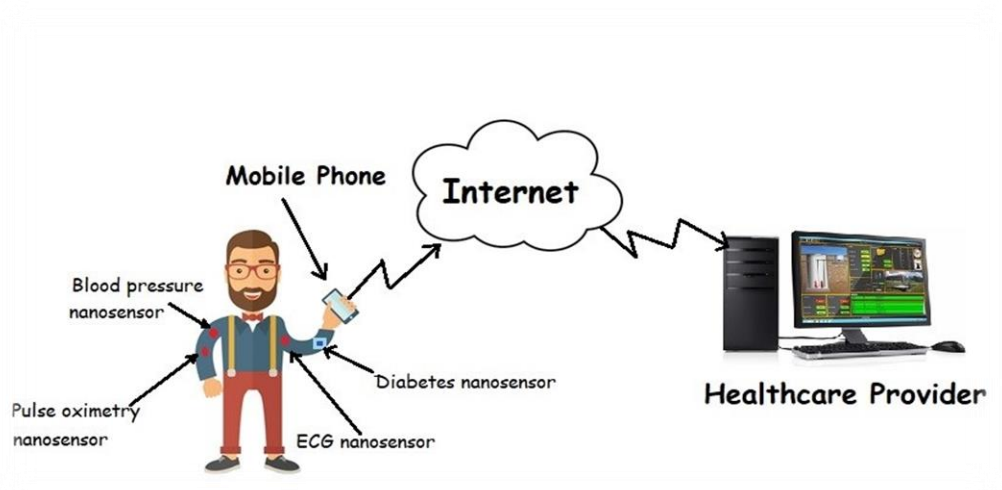


**Fig1: The Internet of Nano things in Healthcare**

Patients additionally would video be able to call to speak with the specialists easily. Patient can get the counsel have they defeated the boundaries and keep up a normal physical movement. Portable advancements are broadly accessible and can assume a significant job in social insurance at the local network and individual dimension in creating nations. Scientist looks at different portable health or e health application and characterizes the dangers and advantages of every division. Be that as it may, positive side is discovered more.

### 2.2.2 Disadvantages

Due to convey through the internet in mobile healthcare innovation there is a gigantic security issue. Mainly patient offer their own information as they should need the exceptionally solid security. So security is basics framework prerequisite. Since patient discharge their own data

over the open remote channels. Here need secure multicast procedure and reliable utilize so patient can convey securely. No bad conduct is permitted in the discussion and it is carefully denied. Another issue is organizing. System will be more grounded as whenever or any strong weather individuals get the mobile healthcare human services innovation effectively.

## 2.3 Potential Benefit

New potential outcomes and open doors for portable health have been emerged by methods for the most recent advances of mobile health care system and innovations. The general population who lived in country region they are the most dismissed patient since they don't have that much chances, they do not get appropriate human services, in light of the fact that in provincial region there don't have enough medical clinic and they don't get refreshed treatment. It is too tough for them to come to city to get the developed treatment. So in this part mobile health care framework can assume an indispensable job. In the event that conceivable rural individuals know the best possible utilization of m-health. This m-health innovation has a few points of interest, for example, minimal effort, proficient, expanded comfort and improved access to administrations as the greater part of the social insurance offices are focused as urban zones. Specialist need to coordinate cooperation with the patient as should be obvious about their issues. We have the web in our grasp so individuals are empowering to get to the web use and advance health data through m-health innovation. So we can utilize computerized innovation for advanced health data. In Bangladesh mobile health care technology charges 15 BDT for the initial three minutes. e-health innovation will resemble proof based medicinal services framework.

## 2.4 My health combo pack

Without precedent for Bangladesh a low every day valued administration of medicinal services tips over SMS, specialist conference on telephone has been presented via Airtel. Airtel paid ahead of time and postpaid endorser both can utilize the administration and the administration is mainly called My health combo pack. For access to this administration clients first need to buy in the mobile number by means of USSD. At that point supporter will social insurance data

by means of SMS. Clients likewise can be known as the administration focus and contact with the specialists for her as well as the individual can counsel the specialists for her entire whole relatives. As they can get health tips by means of cell phone, it is extremely useful for the client. Since they will get fit by pursue the SMS tips. Additionally, they can get free life time protection and emergency clinic money advantage framework. Airtel USSD begin code is 21216 and individuals need to dial *21216*1*1# to buy in the My Health Combo pack. They have to some required data, name, age, candidate name, chosen one relationship, versatile number and so on administration is additionally having auto recharging choice. Before affirm the administration, they have to enroll he /she needs to auto recharging or not.

## 2.4.1 Subscription fee

In the wake of getting the membership affirmation supporter will be deducted the everyday administration charge BDT 2+ VAT. After that they will get health tips through SMS. Health tips SMS will just for once for every day of reasoning. Supporter will have a possibility for moment pay for specialist. Airtel take BDT 28 + VAT for one specialist discussion. It is useful for the client on the off chance that they become wiped out at any minute or any crisis case. Comprehensive VAT and it will charge BDT 34.09. Specialist administration will be accessible from 8 am to 8 pm and 7 days in seven days with the exception of government occasions. Furthermore, patient can counsel with the specialist how much time they need by video call or typical telephone call. On the off chance that specialist would occupy around then there have discussion demand warning. In the wake of getting the counsel demand specialist will be get back to the clients within 60 minutes, amid the administration hours. The meeting demand got between 8 am to 8 pm or any administration occasions will be gotten back to on following day dependent on the necessity sequential. Client will get health tips until they withdrew the administration and the location of Myhealthcare combo pack is twelfth floor, Ambor tower, 99 biruttamakkahndokar, mohalkali c/a, Dhaka 1212 Bangladesh.

## 2.4.2 Terms and condition

•My healthcare combo pack is accessible day by day from 8 am to 8 pm aside from government occasions.

•For booking meeting demand and other helpline my healthcare combo pack is accessible all day, every day.

•Service is for both paid ahead of time and postpaid clients.

•Customers will get healthcare tips or essential interview by Myhealthcare combo pack administration.

Specialist's discussion is just for them whose relative buys in Myhealthcare combo pack administration and the endorser must be 18 years age or beneath 60 years.
The most significant thing is that they have to buy in the administration. Just enrolled endorser will get the administration. It is useful administration in any crisis case. Individuals will get a major hand for help. When enrolled under the administration endorser isn't permitted to change the harmed life subtleties. Be that as it may, candidate name can be changed after the membership and above all the assistance line number is 21216.

# CHAPTER-3

# Piezoelectric Model and SWIPT Model

## 3.1 Introduction

Nanotechnology is one of the part of technology and innovation that bargains with measurements and tolerances of less than 100 nanometres; particularly it controls individual molecules and atoms. It is the investigation and use of minute things which can be utilized over

the various science fields. For instance, material science advancement in the territory of nanotechnology is pushing for new correspondence procedures to organize various nanoscale devices. And wireless nanosensor network systems (WNSNs) comprise of nanosized conveying gadgets, which can identify and measure new sorts of occasions at the nanoscale. These alleged nanodevices would have the capacity to accumulate physical parameters at the nanoscale, checking and following up on any situations that is yet unexplored. The motivation for wireless power originates from wires being messy and untidy. With the various numbers of nanodevices that we utilize today, there is a colossal interest for comfort in supervision of their capacity supplies. Wireless communication has made a huge advancement in Internet-of-Thing (IoT) gadgets. WNSNs are the empowering innovation for extraordinary applications, for example, intra body medicine delivery system frameworks or inspection systems for chemical attack prevention. They also can measure blood cholesterol level.

To add with, those wireless nanodevices would empower incomprehensible applications in numerous fields, for example, prescription (e.g., recognizing dangerous cells or focused on medication carriage), natural science (e.g., estimation of environment parts) or industry (e.g., basic nanofractures recognition in machines or structures). By and by, attributable to their restricted size, nanodevice assets are seriously constrained because they are unable to meet their working ability as independent gadgets due to less power transmission. Consequently, the capacity to complete valuable applications viably depends on an agreeable exertion among nanodevices, setting up wireless nanosensor systems (WNSN). Logical writing uncovers how electromagnetic (EM) nanodevices ought to impart, proposing creative correspondence systems for media get to control, synchronization or tending to which are adjusted to the unlikely imperatives of nanodevices (low registering assets, transmission in the THz band, short correspondence range or high number of hubs, among others). Our target is to contribute by propelling and recommending profitable advances in WNSN. Nonetheless, there is a noteworthy constraining element to be investigated more completely, which is energy limitation. It directly affects the achievability of an operational WNSN. So it can be stated that one of the real bottlenecks in WNSNs is presented by the limited energy that can be put away in a nanosensor. In such manner, the researchers in [1] proposed the principal energy test for nanonetworks, presenting a controlling nanosystem made out of a piezoelectric nanogenerator and a nanocapacitor. The energy harvesting process is because of the correspondence among nanosensor bits in the terahertz band (0.1-10 THz).It converts mechanical energy into electrical

while the last stores the energy created. With these instruments, WNSN can conquer their energy bottleneck and even have infinite lifetime (perpetual WNSN), gave that the energy harvesting is structured. Here, a scientific structure is produced to acquire the likelihood dispersion of the nanosensor to examine how the power transmission rate of the WNSNs can be improved. In view of this nano system, with decided determinations we catch the nanonetwork fiery conduct. To this impact, a probabilistic investigation of the system movement and impedances between hubs is produced to get a dissemination of the energy accessible in every hub. The energy harvesting expected in [1] for correspondence is consistent and settled to a certain power for transmission and another fixed energy in the harvesting of a heartbeat, paying little respect to the medium in which hubs are sent. From an alternate methodology yet dependent on the equivalent fueling arrangement (piezoelectric generator together with a capacitor), this paper expects to explore the energy shortage issue in WNSN from a more reasonable point of view, investigating those elements that ought to be considered in an energy achievable WNSN. This investigation is persuaded by the high transmission controls that have been expected by various effectively distributed correspondence plans to beat the colossal way misfortune at terahertz frequencies when the nanonetwork is conveyed in a lossy medium (e.g., the human body). As a rule, these transmission forces may be unreasonably expensive for nanodevices. To this end, we focus on the effect of tuning an arrangement of various factors on the conduct of a nanonetwork, not being obliged to explicit estimations of, for example, the region or transmission power treated in confinement [1]. We assessed how the expansion in both power (control) transmission and gain of a WNSN. Likewise, the impact of various key parameters engaged with a WNSN, (for example, generator and capacitor territory or energy source) break down towards the structure of a legitimate and achievable arrangement relying upon the application. As such, the paper's association and its principle commitments can be outlined as pursues.

There are a few elements affecting on the vitality utilization of EM-based WNSN, which ought to be legitimately tuned relying upon the application. In this area, we recognize and survey the most essential, featuring their fundamental highlights. For a low transmission control, the level of power is very much lower compared to the total power. It is an imperative worry for nanodevices when the energy per beat turns out to be too high. We should take a note that low-weight signals for WNSN have been proposed to advance the likelihood of sending a '0' and afterward diminish the quantity of heartbeats transmitted [2]. Nevertheless, this enhancement

relies upon the channel and system conditions, so for effortlessness, an evenhanded circulation of '1' and '0' has been considered. The EM communication envisioned for WNSN is based on the exchange of electromagnetic pulses. System topology impacts on two key issues: the distance among nanonodes and the essential communication method [3]. In this kind of system, the EM achieves huge values because of the absorption loss working in the THz band [3].This path loss can achieve values up to a huge level for each millimeter in high-glossy mediums (e.g., blood). Along these lines, the distance between nanodevices with the WNSN is an urgent factor that decides the transmission control expected to guarantee a satisfactory power transmission at the receiver. Then again, the correspondence conventions utilized in a WNSN will be liable to the system topology, which straightforwardly influences the energy consumption. To outline the two inquiries, the most widely recognized topologies proposed in the writing for WNSN are investigated, handling their steering plan from the energy consumption perspective. A promising answer for WNSN that are in consistent development (e.g., a WNSN moving through the circulation system) is a foundation topology motivated by regular portable systems. In this system, nanorouters are deliberately put at settled purposes at the gateway. On the other hand, nanonodes travel through the medium. In this manner, nanonodes are not for all time related to a nanorouter, but rather they transmit data to the nearest nanorouter in the circuit if and when they are on its coverage range, making this topology a reasonable answer for body area nanonetworks (BANN), as proposed in [4]. Finally, nanorouters dispatch every one of the information gathered from nanonodes to the door. The piezoelectricity of nanomaterials pulls in a lot of consideration because of its expansive application, including the receiving of surrounding mechanical energy to control little gadgets. We report here a basic technique to create piezoelectric nanogenerators comprising of systems of ZnO nanowire developed on aluminum (Al) foils, where the Al goes about as both a substrate for development and as an anode reaching the ZnO arrange. To create piezoelectricity, a top electrode was rubbed against the ZnO nanowire. [4] Because of its straightforwardness, this nanogenerator creation technique can possibly be scaled up for the mechanical generation of piezoelectric energy harvesting devices. If the ZnO nanowires used in the protocol are compressed or flexed then current flows through them as a result power transmission occurs.

Conversely, SWIPT is a process which create high electromagnetic fields, for example, TV signals, remote radio systems and wireless towers, yet through power producing circuit connected to an accepting reception apparatus, caught and changed over into usable DC

voltage. Portable correspondence, radio and TV towers, satellites circling earth and even the mobile phones are consistently transmitting SWIPT waves. This colossal measure of energy source around us is un-used and with the utilization of fitting innovation it could be used to control up little independent applications. Most usually utilized as an application for SWIPT identification labels in which the nano detecting gadget remotely sends a EM wave to a receiver which supplies enough capacity to the generator. The circuit design gets the recognized rectenna that can change over the proliferated electromagnetic waves to low voltage DC control at a distance up to 100 meters. It is contingent on the concentration levels which can contrast as the day progressed, the power change circuit might be joined to a capacitor which can separate a steady required voltage for the sensor and circuit when there is certainly not an adequate supply of approaching energy. A floating transistor is deployed as the diode changes over the AC current into produced power. So it is now referenced that SWIPT signals are fit for gathering power. The exchanged power can be used for empowering low power devices, for example, remote sensors, Internet-of-Things (IoT) devices and nanodevices. This alongside the development of low energetic devices mainly the nanodevices has made a critical consideration towards the investigation of Power Transfer designs [5]. The basic tradeoff of the transmitted power was first concentrated in [6] by Varshney, where a portrayal of the limit control work for a point-to-point discrete memory less channel is achieved. With the end goal to structure this proficient power system, it is extremely vital to show the energy harvester (EH) with an abnormal state of accuracy. The EH comprises of a rectenna, which is made out of a receiving wire pursued by a rectifier. The rectifier is utilized to change over the SWIPT control into DC current with the end goal to charge gadgets. Albeit the greater part of the outcomes in the writing received a straight trademark work for the rectifier, by and by, because of the nearness of a diode in the rectifier, the output of the EH is a nonlinear capacity of its input [7,8]. Because of the nonlinearity of the diode features, the SWIPT to DC change proficiency of the EH is very reliant on the power. Perceptions dependent on test results uncover that signals with high Peak-to-Average Power Ratio result in high communicated DC control contrasted with different signs [8]. Spurred by this perception, in [5], a logical model for the rectenna is presented and a joint improvement over the stage and a huge deterministic result is examined. It is reasoned that not at all like the straight EH display that support a solitary bearer transmission, a nonlinear model supports a multicarrier transmission. In Simultaneous Wireless Information and Power Transfer (SWIPT) frameworks, the objective is to structure waveforms that expand the DC control at the yield of the EH, though which is generally alluded as

augmenting the rate-control (RP) district. Dissimilar to the vast majority of the SWIPT frameworks with the straight model suspicion for EH, for SWIPT frameworks with nonlinear EH, there exists a tradeoff between the rate and communication control [5]. Because of the nearness of nonlinear segments in EH, getting the correct ideal tradeoff diagnostically has so far been unsuccessful. Be that as it may, subsequent to making some improving suspicions, some fascinating outcomes have been inferred here.

However, in section 2 of this chapter we have explained the system model of both ZnO nanowires and SWIPT. How power is transmitted by both ZnO nanowires, their circuit models are explained here.

Therefore, in section 3, the mathematical discussion of the models of ZnO nanowire has been emphasized. All their equations have been stated properly for reference.

Moreover, in section 4 the results, graphical representation and a discussion has been expressed.

## 3.2 System Model

The designs and the models of ZnO and SWIPT of the system have been represented in this part. At first, how using ZnO nanowires in piezo-electric nanogenerator can help in transmitting more energy is represented. And after that, it has been examined that using radio frequency (RF) in those nanogenerators can be more fruitful which means it will produce more power. So basically, the power transmission rate will be higher rather than the first case.

### 3.2.1 System Model of using ZnO in nanogenerator

Due to the miniature size of the nanodevices replacement or change of battery is kind of implausible. To solve the power transmission issue on each nanodevice a piezo-electric generator has been implanted so that it might intake energy from the environment [1]. The equipment that has been used in this power system is a series of zinc oxide nanowires, a nanocapacitor, a rectifier circuit and a resistor.

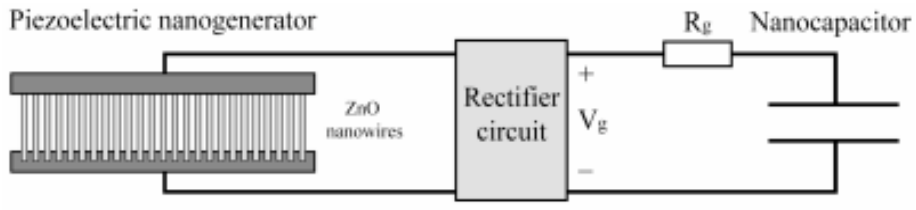


**Fig3.1 : Piezoelectric powering nanosystem diagram**

When a nanowire is flexed or squeezed an electric current occurs at the edge of the nanowire and it charges the nanocapacitor. An electric current in the opposite direction is produced and charges the nanocapacitor one more time after rectification as the nanowires get released. The solution of this issue is convenient vas capacitor and the piezoelectric generator as both are available in tiny size and the energy storing capacity is almost same though a bit of lacking might happen.

To elaborate the features of this powering nanosystem we are going to examine the gained results. As an example, a capacitor can hold maximum 800 pJ energy and if the capacitor gets recharged up to 95% of its total capacity at least 50s or 42 minutes time will be needed which is basically dependent on the vibration that is contemplated by the frequency.[2] It is already known that nanodevices are not dependent on anything for power which means they are self-powered. As the charge and discharge cycles of the force repeats frequently it becomes really difficult to design the power scheme because the charging time relied on the specific energy source changes continuously. In this issue, air-conditioning gaps and the bloodstreams are proposed which might have vibration frequencies of for example 50 and 1 Hz accordingly. [3] As nanodevices are measured in nanoscales so these measurements are valid for a nanodevice which has a certain area. If the values are not noteworthy for a nanodevice and if it does not go with the features of a nanodevice then those values could be more limited.

This solution has been used in many works. It was particularly outlined for a power transmission system. In some cases, if the rise in transmission power happens or the area of the nanodevice becomes smaller, the blueprint of the nanosystem have to be modified. For instance, the reserved energy is going to be very negligible if a definite per pulse energy is contemplated as number of transmissions without recharging the capacitor. Consequently, three important factors mainly have direct effect on the performance of a piezoelectric

nanogenerator as the powering element for nanodevices which are the area, technology and energy source accordingly [3].

An electric current occurs each and every time when a ZnO nanowire is flexed or twisted. If the number of ZnO nanowires becomes more, in every press-release cycle the produced charge will become more. The total area of a nanogenerator regulates the number of ZnO nanowires that can be merged because nanowires have almost alike diameter which is between 50nm to 150nm. Reviewing the previously mentioned nano generator, the charge produced per unit area is directly proportional to the area of the piezoelectric nano generator [3]. For assessing the effect of the area of a nanogenerator on the energy rate, the nanogenerator has been represented as a voltage source for obtaining the expression and for it the procedure has been followed is mentioned in [1].

A ZnO nanowires built nanogenerator is such an auspicious automation in the developing era of nanodevices. In contrast when the area of this nanogenerator becomes smaller the energy harvesting becomes restricted which is a noticeable problem. So for further improvement some modified solutions should be found so that the charging time of the nanodevices can be reduced. Moreover, the nanocapacitor technology states that the maximum ability of storing energy in a nanocapacitor mostly relies on its capacitance. For instance, an onion-like carbon electrode is represented by Jornet and Akyldiz. It can give a capacitance of 9 nF for an area of1000 μm^2, so the capacitance per unit area of it becomes 9 pF/μm^2 [1]. In [4] an alleged super capacitor is proposed and manufactured with a capacity of 400 pF/ μm^2, which is much greater than the previous one. This expansion in capacitance implies multiple times more vitality putting away limit with regards to a similar territory. This is simply a case of the capability of novel capacitor innovations, which ought to be looked into for future research with the end goal to adjust correspondence methods for WNSN to the vitality putting away limit accessible.

Two important sources have been recommended for WNSN so far [1, 4], both saddling the piezoelectric nature of the nanogenerator, changing over mechanical vitality into power. One of the solutions for this issue is vitality can be collected from environment. This arrangement is visualized for WNSN sent in unique situations, where the mechanical powers incited by the medium create vitality enough to control nanodevices. In any case, to the best of our insight, no vitality show for nanodevices has considered how the vitality gathering rate shifts for various situations as far as strain size and recurrence. In this regard, more exertion is required to gain sensible data. Another arrangement can be Wireless power exchange (WPT) with

ultrasound utilizing WPT, the piezoelectric nanogenerator vibrates at the ultrasound recurrence, creating compress– discharge cycles paying little respect to the earth. This outside power supply guarantees that the vitality collecting rate is consistent and regardless of the explicit ecological conditions.

### 3.2.2 System Model of nanodevices using SWIPT (Simultaneous Wireless Power & Information Transmission)

On the other hand, the corresponding framework is mainly dependent on the streamlining of individual parts of the transmitter and the receiver. In numerous situations, it is unclear whether this methodology is the ideal conceivable plan. Arisen by this, we go for using SWIPT to empower enhancement of power system for end-to-end execution, without the requirement for separating the transmitter and receiver beneficiary into various areas. So with the end goal is to structure more capable Wireless Power Transfer (WPT) design it is pivotal to show the energy harvester (EH) with abnormal state of precision. For more exactness we have utilized SWIPT rather than ZnO nanowires on the grounds that the power transmission rate will be higher for this situation. Here, it is demonstrated how the power transmission of SWIPT is higher than that of ZnO nanowires.

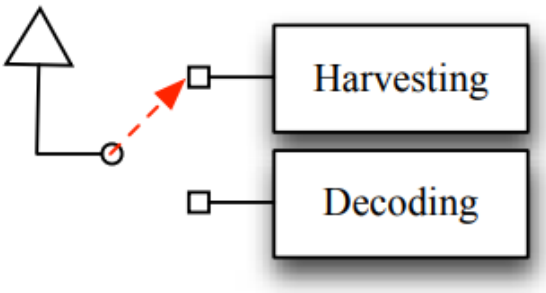


**Fig3.2: SWIPT transmission technique on time domain**

Though Simultaneous Wireless Power Transfer is theoritically proved, but it is practically impossible to imply. For practical uses, the signal that will be received gets splited in two distinct parts which are for energy harvesting and information decoding accordingly.For our model one of the most important domain for splitting the parts are time switching [5].
In fig3.2 when time switching is employed ,at first the reciever recieves a signal. Then the reciever continues switching in time between information decoding and energy harvesting [16].

For this situation, the signal splitting is performed in the time space and hence the wholesignal received in one time slot is utilized either for datadecoding or power transmit (Fig3.1) The TS method takes into consideration a basic equipment usage at the recipient however requires exact time synchronization andinformation/energy scheduling [5].

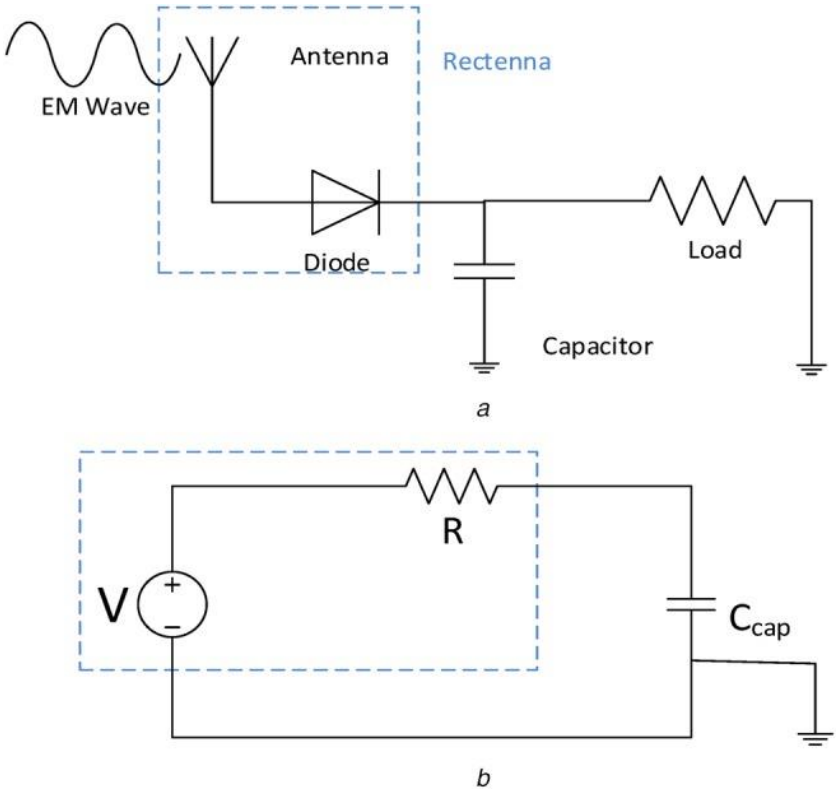


**Fig3.3: The Schematic diagram of a (a) Rectenna and (b) Simplified system equivalent RC circuit**

In fig3.3(a) a rectenna, appeared schematically which is a mix of an antenna and a rectifying device which is usually a diode.With the end goal ofharvesting energy in nano-the EM waves are gotten by a nano-reception apparatus and afterward coupled to a rectifier to finish the rectenna arrangement. Hence, the center parts of a nano-rectenna are ahigh-speed rectifier (diode) and a nanoscale antenna,which can be utilized for gathering energy from THz bandnand higher frequencies [6]. As nano-sized radio wires work in the THz band, their related amending diodes need a quick reaction with the goal that they can respond fittingly to the approaching THz signal and deliver a DC signal. The nano-antenna gathers high-frequencyunreservedly engendering EM which it changes over into AC current to the ultrafast diode, which at that point changes over this current to DC [6].

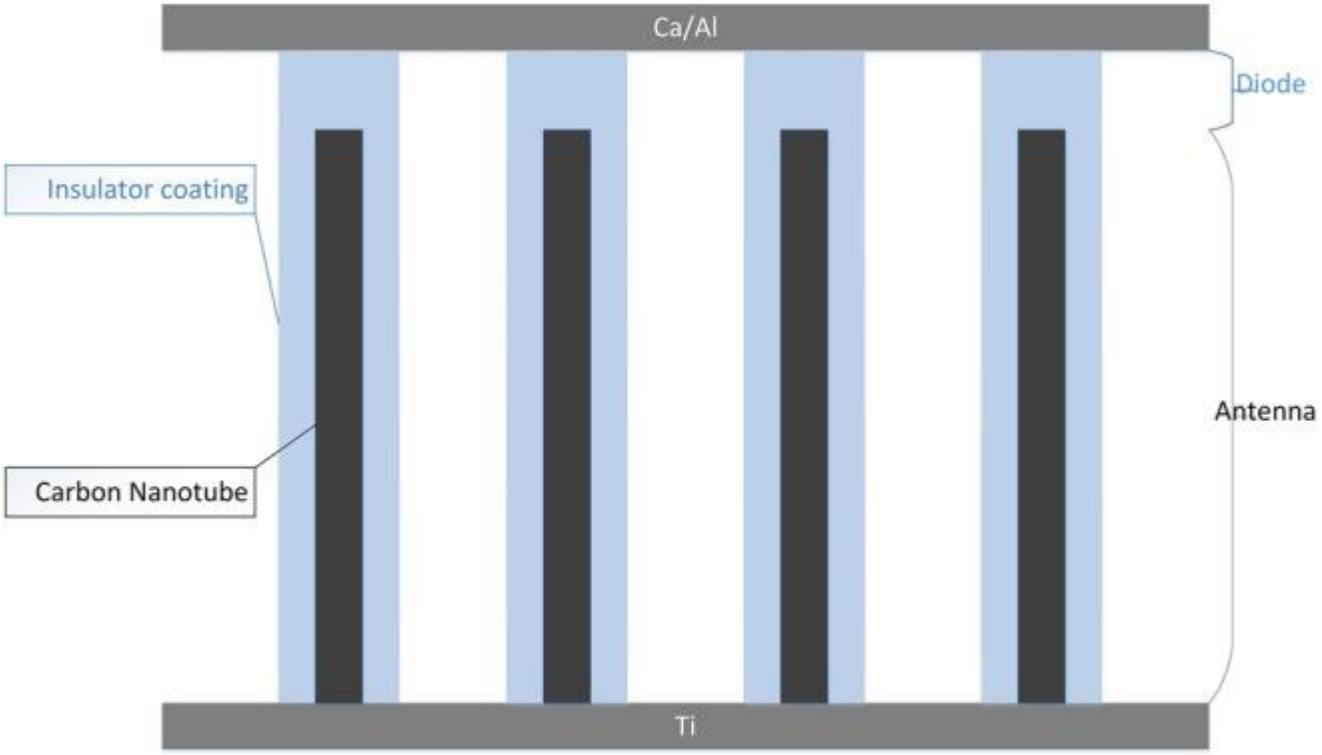


**Fig3.4: Schematic diagram of CNT rectenna**

In fig3.4, we have represented the nano-arrange energy harvesting design utilizing a CNT nano-rectenna. As expressed above, since customary energy harvesting plans are not accessible for body-driven nano-systems a rectenna-based plan is promising. In the event that we treat the rectenna as a nano-generator.it comprises of the nano-rectenna, for example a nano tube rectenna and a ultra-nanocapacitor. The rectenna is represented by its series resistance R and output voltage V (from an EM wave) and it is rectified by the diode to supply a DC charging current to an ultra-nanocapacitor Ccap.

From fig-3.4 it can be stated that the CNTs act as receiving wires with their little tip zones going about as rectifying diodes [7]. At the point when the CNTs assimilate EM radiation, a DC current will be created after correction by the tip region. This changed over current is utilized to charge a capacitor [8]. The transformation procedure keeps utilizing the THz motion inside the framework and surrounding free EM so the energy source of such a nano-rectenna generator needs no other explicit outer power source.

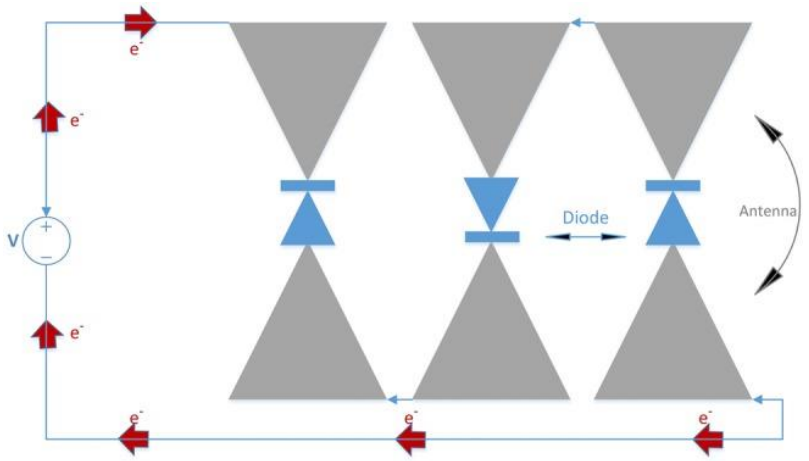


**Fig3.5: Schematic diagram of bowtie nano-rectenna array**

In fig3.5 bowtie dipole nano-rectennas have been proposed which are created in gold with lengths of 5– 6 μm with two 2– 3 μm triangular segments. The antenna thickness is 100 nm, and the nano-diodes, produced using graphene [9] or MIM [10], are situated amidst the bowtie bowtie antenna gap area, creating the rectenna activity. A progression of these rectennas can be associated with structure a nano-rectenna exhibit appeared in fig.3.5. The bowtie dipole gets EM radiation and changes over to AC current stream to the nano-diode. The diode at that point converts the AC current flow to DC current flow. At the point when associated with a ultra nanocapacitor, the DC electricity can be collected and utilized by nanosensors.

## 3.3 Mathematical Model

### 3.3.1 Powering Nanodevices with Piezoelectric Nanogenerator

Since bending a ZnO nanowire generates power, increasing nanowires will generate greater power with every time it is compressed or released. Due to the similarities in diameter of each nanowire, number of nanowire can be determined with the area of a nanogenerator. Therefore, the charge generated per compress-release cycle per unit area is $\Delta Q_g$ and the area of a nanogenerator is $A_g$. Which determines the charge generated in each cycle of the nanogenerator is $\Delta Q = \Delta Q_g A_g$. Evaluation of how area affects energy harvesting rate (denoting it as $\lambda$) can be modeled by assuming the generator as voltage source (denoting it as $V_g$) and a resistor in series (denoting it as $R_g$). As a result, if $I_g$ is the average generator

current in each cycle, $R_g = V_g/I_g$. Here $I_g$ equals $\Delta Q$ multiplied by $f_g$, where $f_g$ is considered to be the strain frequency [3]. Thus, charge stored with respect to time is:

$$Q(t) = CV_g\left(1 - e^{\left(\frac{-t}{R_g C}\right)}\right) = CV_g\left(1 - e^{\left(\frac{-t\Delta Q_g A_g f_g}{V_g C}\right)}\right) \quad 3.1$$

Here, C = capacitance of the device nanocapacitor. Now, if the stored energy in C is stated as $E_c$, then $E_c = Q^2/2C$. Assuming the capacitor is empty at the beginning the equation becomes:

$$E_c(t) = \frac{CV_g^2(1 - e^{\left(\frac{-t\Delta Q_g A_g f_g}{V_g C}\right)})^2}{2} \quad 3.2$$

The energy harvesting rate can be determined by differentiating the aforementioned equation as it is the change in stored energy with time. The equation is as followed:

$$\lambda(t) = \frac{dE_c(t)}{dt} = \Delta Q_g A_g f_g V_g\left(1 - e^{\left(\frac{-t\Delta Q_g A_g f_g}{V_g C}\right)}\right)e^{\left(\frac{-t\Delta Q_g A_g f_g}{V_g C}\right)} \quad 3.3$$

By examining this equation, it is clear that with the increment of $A_g$ the energy harvesting rate $\lambda$ increases which means that larger area leads to faster nanocapacitor charge. However, the area of a nanocapacitor also influences the capacitance, which determines the maximum energy stored (denoting it as $E_{max}$). As a result, $E_{max} = \frac{{V_g}^2 C}{2}$

If the capacitance per unit area is $C_c$ and the area of a nanocapacitor is $A_c$, the max energy stored is proportional to the area of a nanocapacitor. Nonetheless, increasing the nanocapacitor area also increases the time to charge a capacitor.

To emphasize this, isolating t from equation 3.2 will help us to determine the time needed to store the energy given. The equation is as follows:

$$t(E_c) = -\frac{C_c A_c V_g}{\Delta Q_g A_g f_g}\ln\left(1 - \sqrt{\frac{2E_c}{{V_g}^2 C_c A_c}}\right) \quad 3.4$$

If $E_c = E_{pulse}n_{pulse} + P_{dev}\, t_{on}$, then the idle charging time (denoting it as $t_{charge}$) corresponds to:

$$t_{charge} = -\frac{C_c A_c V_g}{\Delta Q_g A_g f_g}\ln\left(1 - \sqrt{\frac{2(E_{pulse}n_{pulse} + P_{dev}t_{on})}{{V_g}^2 C_c A_c}}\right) \quad 3.5$$

Here, $E_{pulse}$ is the energy stored per pulse, where number of pulses is $n_{pulse}$. In addition, $P_{dev}$ is the power developed at the times $t_{on}$. WE are assuming that the capacitor is initially empty as we are trying to determine the influence of nanocapacitor area on charging time. Hence, the expression of data transfer rate R after the communication has started and after a time $t_{charge}$ is:

A`1

$$R = \frac{n_{bits}}{t_{charge}} = -\frac{n_{bits}\Delta Q_g A_g f_g}{C_c A_c V_g \ln(1 - \sqrt{\frac{2(E_{pulse} n_{bits} p_{pulse} + P_{dev} t_{on})}{{V_g}^2 C_c A_c}})} \quad 3.5$$

Here, $n_{bits}$ is the number of bits transmitted per charge and $n_{pulse} = n_{bits}p_{pulse}$. Where, $p_{pulse}$ is the probability of a pulse reaching correctly [3]. Nonetheless, from the equation mentioned above, we can justify our claim that increasing nanocapacitor area will decrease the rate of transferring data.

## 3.3.2 Powering Nanodevices with Simultaneous Wireless Information and Power Transfer:

The bowtie nanorectenna can be treated as a nano-generator represented by a series resistance $R_r$ and an output voltage of $V_r$. The voltage is rectified by a diode to provide charging current to an ultra-capacitor. The system uses a THz signal so that it does not need any external power source. The DC current created by the induced Electro Magnetic radiation power over the rectenna defines the response of the device. For a specific input AC electromagnetic power, induced DC current can be calculated as follows [19],

$$\beta = \frac{I''(V_{bias})}{2\, I''(V_{bias})} \quad 3.7$$

It is the ratio of second to the first derivative of the current. Here, the current generated by the rectenna can be calculated depending upon the input power:

$$I_r = P_{in} A_{eff} \eta_a \beta \eta_c \quad 3.8$$

Where, $P_{in}$ is the input electromagnetic wave power, $A_{eff}$ is the effective area, $\eta_a$ is the absorption efficiency, $\eta_c$ is coupling efficiency of the rectenna.

Moreover, the DC voltage generated from the nano-generator can be calculated as follows:

$$V_r = -\frac{1}{2}\beta V_{opt}^2 \quad 3.9$$

Where $V_{opt}$ is the output AC voltage from the rectenna.

Considering equation 3.8 and 3.9, we can determine the resistance of the rectenna as given below.

$$R_r = \frac{V_r}{I_r} = \frac{-\frac{1}{2}V_{opt}^2}{P_{in}A_{eff}\eta_a\eta_c} \quad 3.10$$

Charge stored in a capacitor as a function time is as follows:

$$Q_R(t) = CV_r(1 - e^{\frac{2tP_{in}A_{eff}\eta_a\eta_c}{CV_{opt}^2}}) \quad 3.11$$

The energy stored in the capacitor is calculated as follows:

$$E_{R_C}(t) = \frac{1}{2}C{V_r}^2(1 - e^{\frac{2tP_{in}A_{eff}\eta_a\eta_c}{CV_{opt}^2}})^2 \quad 3.12$$

By taking the derivative of $E_{R_C}(t)$, we obtain the energy harvesting rate which is the variation of energy stored in a capacitor as a function of time:

$$\lambda_R(t) = \frac{dE_{R_C}(t)}{dt} = \frac{2P_{in}A_{eff}\eta_a\eta_c{V_r}^2}{V_{opt}^2}(e^{\frac{2tP_{in}A_{eff}\eta_a\eta_c}{CV_{opt}^2}} - 1)e^{\frac{2tP_{in}A_{eff}\eta_a\eta_c}{CV_{opt}^2}} \quad 3.13$$

To calculate the time required to accumulate a specific energy, we need to find the expression of t in terms of energy. Hence, isolating t from equation 3.13

$$t_{charge,R} = \frac{CV_{opt}^2}{2P_{in}A_{eff}\eta_a\eta_c}\ln(1 - \sqrt{\frac{2(E_{pulse}n_{pulse} + P_{dev}t_{on})}{CV_r^2}}) \quad 3.14$$

We are assuming that the capacitor is initially empty as we are trying to determine the influence of nanocapacitor area on charging time. Hence, the expression of data transfer rate $R_{rectenna}$ is

$$R_{rectenna} = \frac{n_{bits}}{t_{charge,R}} = \frac{2n_{bits}P_{in}A_{eff}\eta_a\eta_c}{C_cA_cV_{opt}^2\ln(1 - \sqrt{\frac{2(E_{pulse}n_{bits}p_{pulse} + P_{dev}t_{on})}{C_cA_cV_r^2}})} \quad 3.15$$

As mentioned before in section 3.3.1, $n_{pulse} = n_{bits}p_{pulse}$, which determines the number of pulse that incorporates the probability of sending a pulse and the number of bits per charge.

In the next section, we discuss the benefits and drawbacks of both systems, implemented with nanogenerator versus wireless power transfer.

## 3.4 Result and Discussion

The performance of the two systems largely depends on the energy harvesting rate of the system. Using MATLAB, we generated the graphs for both the systems with the following fixed parameters, as it is important to properly determine the harvesting rate with the difference in system models to power the nanodevices. The parameter values for $\Delta Q_g$, $f_g$, $A_g$, $V_g$ and $C_c$ are assumed as 6fC/μm$^2$, 1Hz, 1000μm$^2$, 0.42V and 9nF respectively for the system with nanogenerator. On the other hand, $A_{eff}$, $P_{in}$,$V_{opt}$, $\beta$,$\eta_a$ and $\eta_c$are assumed1μm,0.01W, 68mV, 0.4, 0.001 and 0.001 respectively for the system with WPT. The obtained results are given below.

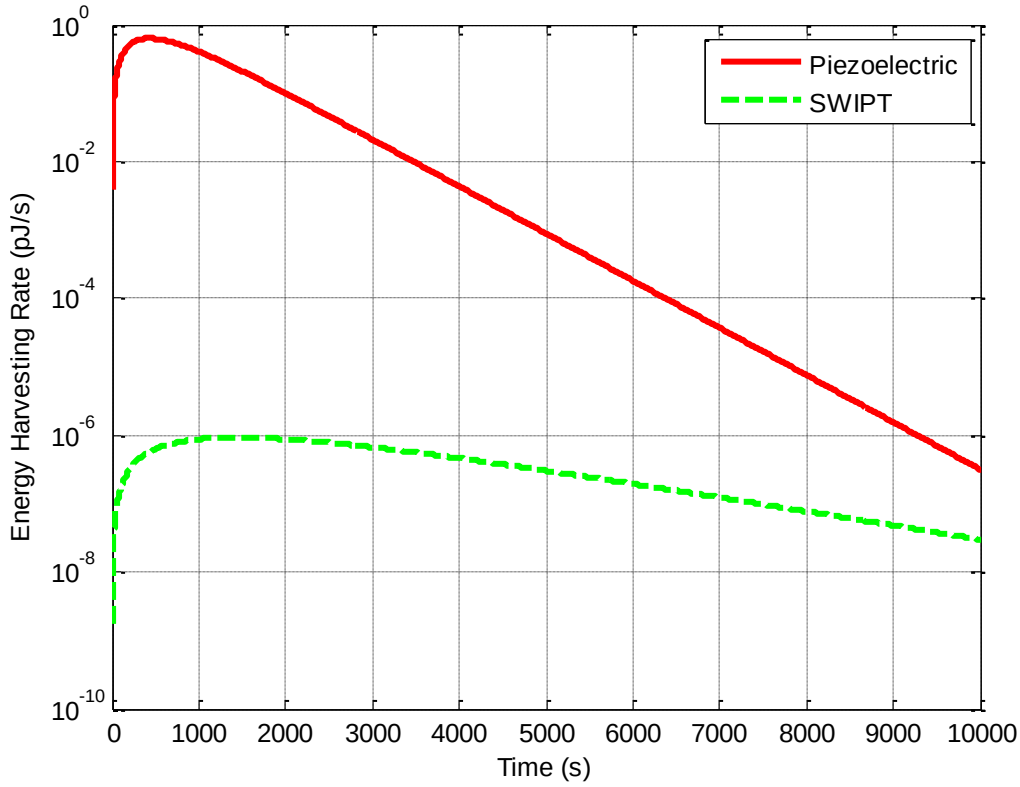


**Fig 3.7: Energy harvesting rate of both models.**

Here, we can observe from the graph that the nanocapacitor energy harvesting rate increases gradually with time and it decreases once the nanocapacitor reaches its maximum charge storing capacity. The nanogenerator can harvest energy both from the environment and through wireless power transfer with ultrasound. The mechanical forces generated by the medium generate sufficient energy to power a nanodevice. With the help of ultrasound, it generates compress-release cycle no matter how the environment is. This means that the energy harvesting rate is persistent notwithstanding the conditions of the environment.

On the contrary, the energy-harvesting rate with SWIPT is almost $10^6$ times lower than the piezoelectric model, if the peak value is considered. The result is such that because we are considering the values of effective antenna area, input power, absorbing and coupling efficiency to be very low.

Another area that needs emphasization is the bit rate of the models. Superior energy harvesting will not come to use if the bit rate is low. Hence, we also generated graphical representation of the bit rate equation with MATLAB, with the following parameters employed with practical life assumption of the values. The presumed values $E_{pulse}$, $n_{bits}$, $p_{pulse}$, $P_{dev}$, $t_{on}$, $V_g$, $C_c$, $Q_g$, $A_g$ and $f_g$ are 1pJ, 169 bits, 0.5, 240 nW, 1 ms, 0.42 V, 9 pF/µm$^2$, 6 fC/µm$^2$, 1000 µm$^2$ and 1 respectively. The graphical representation is given in Figure 3.8. The values were set preserving the consistency of the study. The obtained result speaks for itself, indicating that the piezoelectric model is superior again with the maximum value 0.3 bps whereas the maximum value for the SWIPT model is 0.03 bps. This illustrates that the piezoelectric model is better for transferring power to nanodevices.

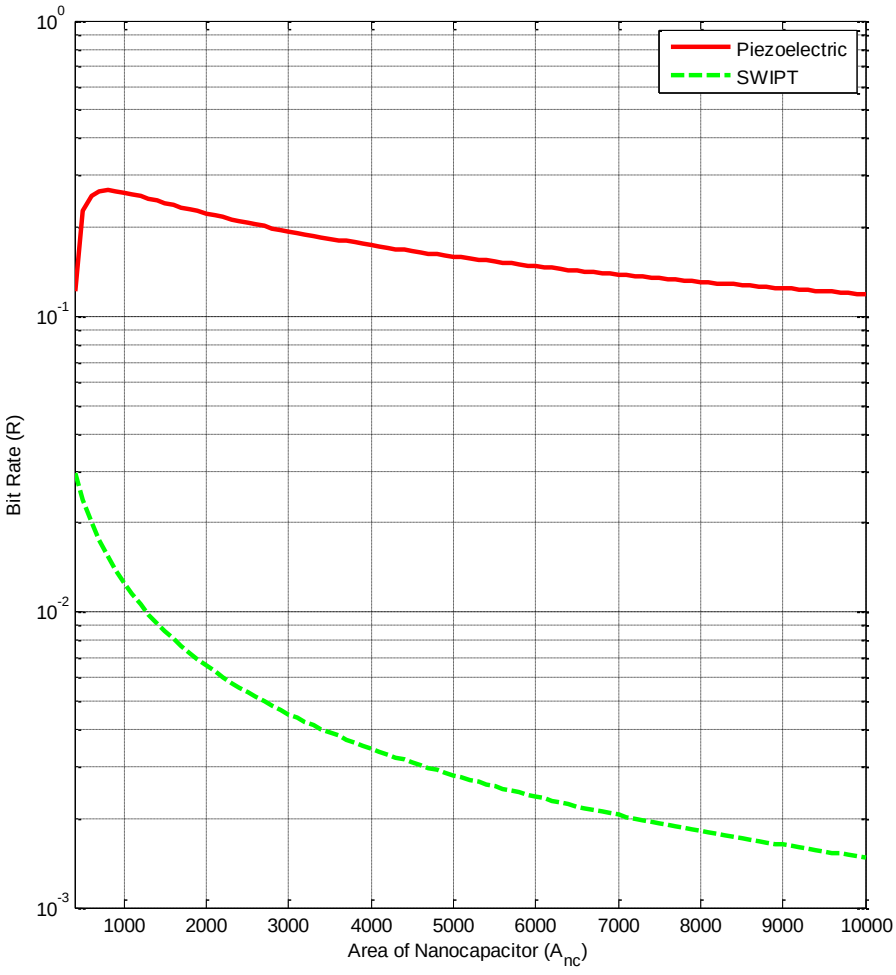


**Fig 3.8: Bit rate as a function of nanocapacitor area**

However, it has to be considered that with piezoelectric model we need ultrasound just for powering the nanodevice. On the other and, SWIPT model simultaneously sends power and information at the same time which means that the data we are transferring can power the nanodevice at the same time. This is more convenient as we do not need a separate method for powering and transferring data unlike the piezoelectric model. Moreover, if we increase the rectenna effective area to 37.5$\mu m^2$, which in turn increases the input power to 0.049$Wmm^{-2}$ then the bit rate for SWIPT increases drastically.

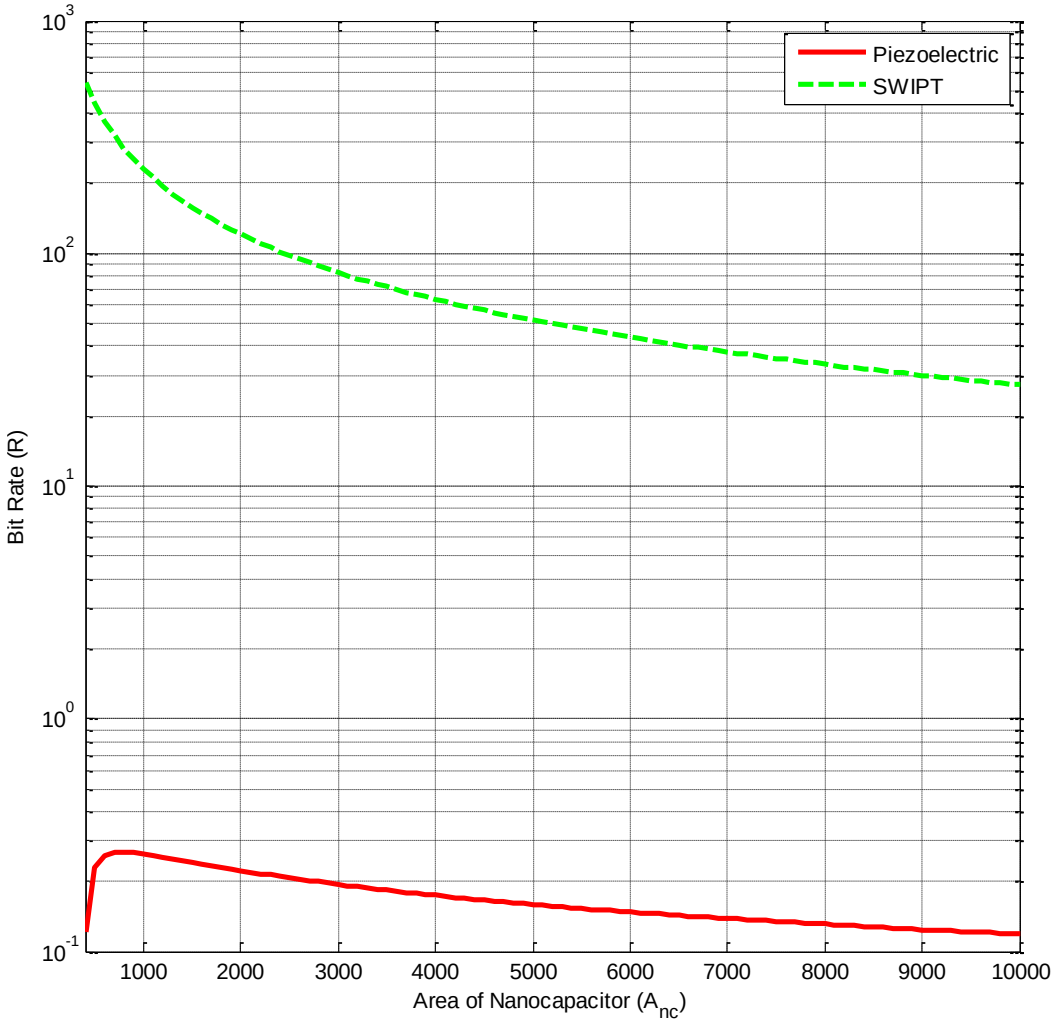


**Fig 3.9: Bit rate as a function of nanocapacitor area after increasing effective rectenna area**

This further proves the fact that even if the energy harvesting rate is lower for SWIPT when compared to piezoelectric, the rate is tweakable. Considering the ability of transferring both power and information at the same time for SWIPT, the model is superior to the piezoelectric model in this case. This paper analyzes the management of energy, as it is a crucial topic for designing wireless nanodevices. Low control esteems are utilized for WNSN sent in low-loss situations (e.g., the air) and

micro range communications (which relies upon system topology). On the other hand, regardless of whether the medium shows high water content (e.g., natural tissues) or the communication range increases (couple of millimeters), more prominent power values are required to beat the high path loss resulting from working at THz radiation frequencies. Despite the fact that the pulse duration is short to a great degree, these transmission powers involve critical energy consumption when contrasted with the energy consumption of the rest of the parts of the nanodevices. For a low transmission power, the level of power compared to the total power is lower than 1%, while for a higher transmission power this value ascends to 99%. In the last case, communication among nanodevices represents a genuine test that must be precisely examined when building up a correspondence convention for WNSN. At long last, nanorouters are typically joined to the alleged door which is endowed with the gate-way of the WNSN with a (macro) gadget, for example, a cell phone or a PC. The task of system locations can be improved by separating them into sub ranges, every one assigned into one group, which would go about as a subnanonetwork. This topology bolsters the structure of energy proficient correspondence conspires in which each nanonode fits the vitality required to send a parcel by tuning, in every transmission, distinctive correspondence parameters, for example, control transmission or the quantity of bounces to come to the nanorouter. Be that as it may, this engineering presents issues when the WNSN isn't static, since bunches would change ceaselessly. This fluctuation involves the reconfiguration of the WNSN tending to too much of the time, which would result in an over the top misuse of vitality for nanodevices. Regardless, this designing presents issues when the WNSN isn't static, since packs would change reliably. This changeability includes the reconfiguration of the WNSN watching out for a lot of the time, which would result in an over the top misuse of vitality for nanodevices.

# CHAPTER-4

# Conclusion and Future Work

## 4.1 Conclusion

This paper breaks down why IOT is imperative in everyday life. Moreover, it investigates energy management as a basic issue to be considered in future WNSN structures. We initially talk about the necessity of IOT in the advancement of technology. Here it is discussed how IoT develops nano gadgets providing the capacity to gather and convey information to gadgets having the capacity to process data and make decisions. IOT is so imperative since it discover an answer for each issue. The Internet has additionally made access to data and communication far less demanding. Moreover, in this paper we have discussed the primary variables impacting the energy consumption in WNSN, featuring the significance of the energy required for data transmission. At that point, we audit the most significant parameters affecting the working of a powering nanosystem, looking at the most acknowledged answer for nanodevices, and assessing its performance under various conditions. Since twisting a ZnO nanowire produces power, expanding nanowires will help us create more prominent power with each time it is packed or discharged. Further, after mathematical examination, results uncover some principle ends like numerous officially distributed works utilized high transmission powers (even peak of kilowatts) imprudent for a nanogenerator with the technology and innovation proposed in [1], the WNSN bit rate can be enhanced for an explicit application by structuring nanodevices with a decided nanocapacitor area. Moreover, we have observed that the nanocapacitor energy harvesting rate increases gradually with time and it will decrease once the nanocapacitor reaches its maximum charge storing capacity. The nanogenerator can gather both from the environment and through wireless power transmission with ultrasound. The mechanical powers produced by the medium create adequate energy to control a nanodevice. But for the compress-release cycle of ZnO nanowires it needs to be vibrated to continue the cycle. So, for the vibration it needs ultrasound. For which a different device has to be attached with human body when the ZnO nanogenerator is inserted in a body for gathering different information. Then again, SWIPT implies the energy harvesting rate is relentless despite the states of the environment. Despite when we replace the model with SWIPT it also gives a promising

outcome though the energy harvesting rate is less this time. The maximum energy gathered by the nanogenerator model is 0.6 pJ/s, whereas the maximum energy gathered by the WPT model is $10^{-6}$pJ/s. Further, we can also see that the bit rate or information transferring rate is much higher in piezoelectric rather than SWIPT model. But just for powering the piezoelectric model it needs some extra devices. For some situations, when a nanosensor will be inserted in a body for collecting different information, piezoelectric nanogenerator will be implied then it will need some other devices for creating ultrasound. But ultrasound cannot be reached in all parts of the body especially the inner organs of the body like heart. It can only reach the skin. In contrast, SWIPT does not need any device for getting powered rather it creates power and information simultaneously. Be that as it may, a piezoelectric energy harvesting system is constrained to certain pieces of the body in light of the fact that the power wellspring of this method is mechanical pressure or vibration. In conclusion, in spite of having some limitations and restrictions, we can see from the model that using RF configuration is much more fruitful rather energy harvesting system requires outside controlling, for example, ultrasound which isn't a piece of THz correspondence nano-systems. Interestingly, remote power exchange components dependent on wireless power transfer mechanisms based on rectifying antennas (rectennas) offer another promising strategy for fueling nanodevices in the nano-arrange [10]. Dissimilar to customary photovoltaic than using ZnO nanowires in nanodevices energy harvesters which depend completely on daylight, rectenna can work at THz and microwave frequencies, which empowers them to work amid the night. Since EM waves convey data as well as energy [11], nano-rectennas can along these lines share a similar signal that is utilized for transporting data inside nano-systems. Simultaneous wireless information and power transfer (SWIPT)become a crucial strategy for driving nano-organizes and are a promising answer for energy bottlenecks. Thus, this implementation can solve the energy management issue in nano-sensor to some extent.

## 4.2 Future work

- In future, we investigate energy efficiency analysis of cognitive Internet of nano things.
- We investigate OFDM based internet of nano things.

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