Fundamental Applications of Internet of Things

A Thesis submitted in partial fulfilment for the degree of B.Sc
in Electrical & Electronic Engineering

Authors

MD. MONWAR JAHAN CHOWDHURY	**14110021**
MD. FAZLUL HAQUE JESAN	**14310003**
Md. SAIFUL ISLAM MILON	**14321006**

Supervisor

Dr. Saifur Rahman Sabuj

Assistant Professor

Department of Electrical and Electronic Engineering,

BRAC University

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Declaration

We hereby declare that the thesis titled "Fundamental Applications of Internet of Things", submitted to the Department of Electrical and Electronic Engineering of BRAC University in partial fulfillment of the Bachelor of Science in Electrical and Electronic Engineering. This is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

Dr. Saifur Rahman Sabuj

Assistant Professor

Dept. of Electrical and Electronic Engineering.

BRAC University, Dhaka-1212.

Md. Monwar Jahan Chowdhury

Student ID: 14110021

Md. Fazlul Haque Jesan.

Student ID: 14310003

Md. Saiful Islam Milon

Student ID: 14321006

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Abstract

Presently there is a globally growing demand across all industries for small and portable electronic devices which feature Internet connectivity. This is largely due to their ease of use provided by robust interoperability and feasibility in almost any scenario. Internet of Things (IoT) can be a great tool to achieve this goal of connecting people and devices everywhere all the time. IoT is a network of various types of devices connected together to seamlessly data transfer without any computer or human interaction. IoT can be defined as a network consisting of many small sensor nodes whose main purpose is to collect data from surrounding environment and then forward to the base station. Firstly, we develop a theoretical model of physical layer of Wireless Sensor Network (WSN). Next, we derive the energy efficiency expression and solve the optimization problem of energy efficiency under the constraint of Packet Reception Rate (PRR). Two application perspective of IoT such as biomedical and smart home appliance has been proposed. Modeling of WSN using MATLAB to perform simulation of real human body have been analyzed. A model of smart juice maker has also proposed here which can be controlled from mobile apps.

CONTENTS

3 IoT in Biomedical Application

4 Application of Smart Appliance using IoT

LIST OF FIGURES

LIST OF TABLES

List of Abbreviation

4G	Fourth Generation
AWGN	Additive White Gaussian Noise
ARIMA	Autoregressive Integrated Moving Average
BER	Bit Error Rate
BTRC	Bangladesh Telecommunication Regulatory Commission
CIoT	Cognitive Internet of Things
CCI	Co-channel interference
CDC	Continuous data collection
CDMA	Code-Division Multiple Access
DIPS	Dual-Interface Dual-Pipeline Scheduling
ECG	Electrocardiogram
GPS	Global Poisoning System
GA	Genetic Algorithm
HTML	Hypertext Markup Language
HHP	High Hydrostatic pressure
HA	Hybrid Algorithm

HEDS	Health Electronic Data Sheet
IoT	Internet of Things
ITU	International Telecommunications Union
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
IoMT	Internet of Medical Things
ISM	Industrial Scientific and Medical
LCD	Liquid Crystal Display
LTE	Long-Term Evolution
MIMO	Multiple Input Multiple Output
M2M	Machine to Machine
NFAP	Frequency Allocation Plan
OFDM	Orthogonal Frequency Division Multiplexing
PAN	Personal Area Network
PIM	Physical Interference Model
pH	Potential of Hydrogen
PAPR	Peak-to-average power ratio
PRR	Packet Reception Rate
RFID	Radio Frequency Identification
SDRP	Satellite Downlink Preplanning Problem
SIM	Subscriber Identification Module
SRD	Short range Device
SDC	Snapshot or data collection

SNR	Signal to Noise Ratio
UI	User Interface
WSN	Wireless Sensor Network
WBANs	Wireless body Area Networks

Chapter 1

Introduction

1.1 Introduction to Internet of Things

Internet of Things (IoT) is a primitive term which has greatly attracted the attention of researchers and academicians in the past couple of years. The term was first introduced by Kevin Ashton of Proctor and Gamble back in 1999. He proposed the term to use the idea of using radio frequency identification (RFID) to allow computers to manage all individual things [1]. The concept of smart devices connected together was proposed early in 1982 with a modified coke machine at Carnegie Mellon University becoming the first internet connected device [2]. The definition of IoT has changed a lot recently due to contribution of various embedded system, wireless sensor networks, control systems, automation and much more. It has been predicted that the number of devices connected together seamlessly will have thirtyfold increment between 2009 and 2020, thus by the end of 2020 the number of connected device will be approximately 26 billion [3]. There are two law which are greatly increasing the use of IoT driven applications. First one is Moore's law which states that number of transistor in an electronic chip doubles every two years [4]. This has helped researchers to create more powerful computer on a same size chip. Intel, a leading brand in chip industry now has 1.4 billion transistors on a single processor while the number was only 2300 transistor back in 1971 [5]. The number of transistor will surely rise in the future but size will decrease relatively.

Second law is koomey's Law which states number of computations per kilowatt-hour roughly doubles every one and half year [6]. Combining these two idea tells us that we can perform the same amount of computing on an increasing smaller chip but also at the same time little amount of energy is needed, thus making the whole process energy efficient. The final result is more compact energy efficient computer which can perform powerful services more swiftly than ever.

Internet of Things is a recent communication concept that imagines a future world where our daily used objects will be equipped with microcontrollers, transmitter-receivers, sensors, nodes that will be able to communicate with each other and with the corresponding user making an integrated part of Internet. Together, it can be seen as a network of physical devices that can act on their own via surrounding environment and can communicate with other devices or peripherals. IoT is a major breakthrough tool which will digitalize the way we communicate in the next smart world that lies ahead of us making all devices connected to internet to continuously collect and update data as per requirement. The future of our internet will encapsulate a substantial number of devices that will provide data to the end user through various communication protocols and unique addressing schemes [7].

Fig 1.1: Schematic Illustration of IoT (EC 2015), [3].

There are many definitions of IoT that has been given by both academics and industry persons. According to International Telecommunications Union, “A worldwide framework for the data society, empowering propelled benefits by interconnecting (physical and virtual) things in view of existing and advancing interoperable data and correspondence advancements” [8]. The main principle of IoT is connect device to internet and made a system so that they can communicate with each other and also communicate with user of the system. By connecting the physical world with the virtual world this emerging concept bring new idea to connect all devices to internet bringing a tons of new and exciting opportunity. But new possibility can also bring new threats such as security risks, risks of malware attack, information theft and many more. The term Things in IoT has dual meaning, for real world things are what we feel, sense or operate. On the other hand, in virtual world things refer to objects that can be stored or accessed [9].

IoT uses sensors to collect information from the surrounding environment. We are using sensors in our daily life continuously although not aware of it. Smartphone which is the most integrated part of our daily life uses various types of sensors such as GPS, Accelerometer, GPS receivers etc. for performing various functions. In IoT, everything is in virtual world, each person has his own unique RFID tag connected to internet. By the help of this tag, one can easily communicate and locate this person anywhere on the globe. IoT enables us to easily interact with a wide range of devices such as home appliance, security camera, monitoring, sensors, vehicles, display and many more. Thus, it will have a huge impact on the life of user who are connected to it . For a general user, IoT can play an important role in both of his personal and professional life. Smart homes and offices, e-health and assisted living are only a few example which will greatly shape the world in future in which we live now [10]. Canary smart security system is a great example of an ideal IoT device. Previously, motion detected was the most technological used device to keep the house safe from intruders. But now things have changed rapidly. Canary smart security system comprise of video, audio, motion detection, night vision, a siren, and air quality, temperature, and humidity sensors into a single device that you can be controlled from user phone. A user may be far away from his home but he can see who has been entering or leaving his house, locked the main security gate or shut down the electronic appliances by the help of this smart app system [11]. Another example of such devices is kolibree smart toothbrush. A digital toothbrush which connect with user's smartphone and creates a good brushing habit for both kids and adults. Data is stored on the memory card of smartphone which can be later sent to dentist if any problem arises for necessary investigation [12].

1.2 Background to Internet of Things (IoT)

The most important and crucial part of IoT is communication, as the main purpose of IoT is to communicate with various devices connected to the internet. The ability to communicate is important to label a device IoT enabled devices. All through there can be many other features such as sensing, mobility, memory, image processing and many more.

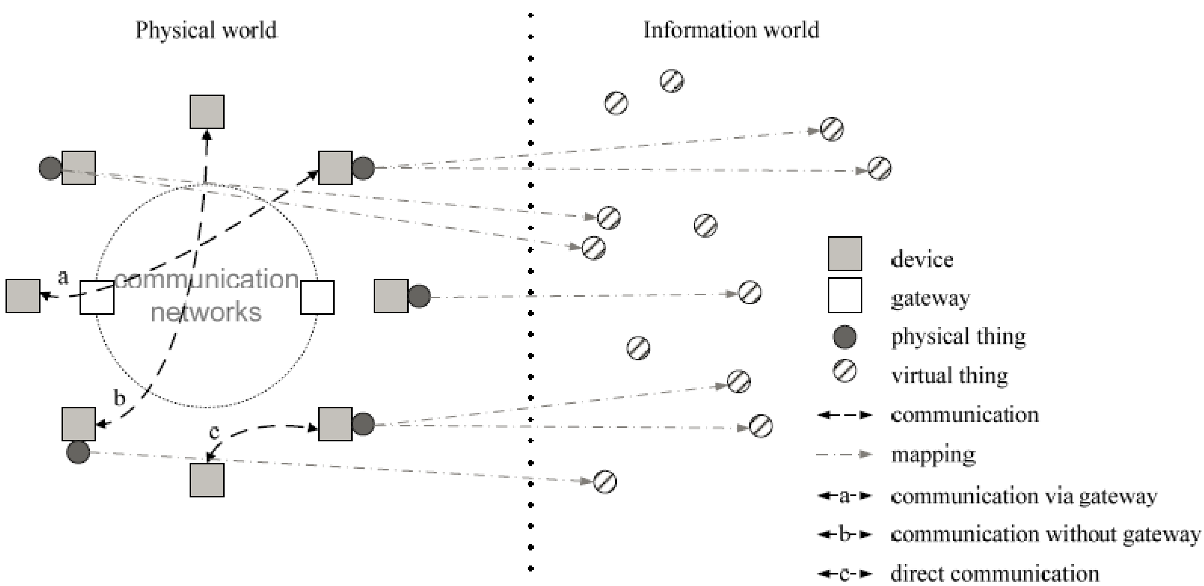

Fig 1.2: Overview of Internet of Things [9].

The following figure is an example of an IoT prototype taken from [9]. From the picture it is evident that devices are not always required to connect to internet for transfer of data between them. If devices are close enough, protocols like Bluetooth and ZigBee can be used to transfer data between devices easily. In case A, a device might communicate via gateway using IPv6 protocol and then afterwards gateway can use another protocol such as IPv4 to communicate with internet. In case B it is shown that two devices can be communicate with each other directly without gateway since they are connected to same network. Not all virtual devices can be called IoT. There are some distinct features of an IoT device. The following table states the fundamental characteristics of IoT as per recommendation of IUT [9].

Table 1.1: Characteristics of the Internet of Things

Characteristics	Description
Interconnectivity	Anything can be connected to the global information and communication highway.
Heterogeneity	Devices in IoT have different network and hardware with in them but still they can communicate with each other.
Dynamic changes	The condition of a gadget can change progressively; in this way the quantity of gadgets can fluctuate. (Device states: connected, disconnected, waking up, and sleeping).
Enormous scale	The quantity of gadgets working and imparting will be bigger than the quantity of gadgets in the present Internet. The vast majority of this correspondence will be gadget to gadget rather than human to gadget.

Things-related Services	Gives things-related administrations inside the limitations of things, for example, protection and semantic consistency amongst physical and virtual things.

1.3 Review of Previous Works and Observation

IoT has become the center of attention for researchers for the last couple of years due to its vast field from home applications to surveillance monitoring for big industries. Various researchers have worked on various sides of IoT such as energy efficiency, optimization battery saving technique, medical health applications, smart home appliances, security of IoT, noise in sensor nodes and many more.

Qin *et al.* (2018) have proposed a Dual-Interface Dual-Pipeline Scheduling (DIPS) method to enable energy efficient multi-hop data delivery in IoT. As the number of devices connected to IoT is increasing rapidly, energy consumption is also rising. Various simulation and experiment have been done to reduce the energy consumption of connected devices. From the experimented result, it has been shown that energy consumption of DIPS is 92.8% lower than IEEE 802.11 power saving scheme [13].

Song *et al.* (2018) have shown the relationship of satellite resources to the internet connection of growing IoT devices. Satellites can play a very important role in data transmission of IoT devices connected anywhere on earth. Genetic algorithm (GA) for a satellite downlink preplanning problem (SDRP) was analyzed here. It has been proved that proposed hybrid algorithm (HA) performed slightly better than other running algorithms [14].

Lunardi *et al.* (2018) has researched about the security of IoT devices and how to secure them from unwanted malicious attacks. There has been a growing concern of security of IoT devices as they are connected to internet, hackers can steal important data from devices via cyber-attacks Many researchers have introduced the concept of blockchain to prevent security threats but it's performance on device hardware is not yet fully examined. Due to device hardware limitation, blockchain cannot be implemented on all IoT devices. To solve this problem, they have proposed an IoT ledger based architecture to maintain control on independent conditions. Arduino, Raspberry Pie has been tested by this model. Performances of IoT devices on local network [15].

Tao *et al.* (2018) has proposed a faster protocol for ZigBee controlled IoT devices. IoT devices are now used from home appliances to big automation industry. As the number of IoT devices increases, speed and access control can be a concern issue here. ZigBee module within a registered IoT devices can connected to a Personal Area Network (PAN) and access the desired ZigBee network for faster and reliable data communications. A prototype has been designed and it has been tested against the other existing methods to show a slight better result [16].

Lee *et al.* (2018) investigated the usefulness of energy efficiency of massive MIMO-OFDM systems of battery powered IoT networks. This paper presented the uplink reference signal power control and peak-to-average power ratio (PAPR) reduction of the OFDM signal for downlink transmitter power control. Theoretical closed-form approximations of spectral efficiency and energy efficiency have derived here. Numerical result verifies with the theoretical results and this model can be helpful to improve energy efficiency of IoT devices [17].

Maldonado *et al.* (2018) have analyzed the use of IoT in e-health sectors. IoT is now used in medical service to remotely monitor patient's temperature, blood pressure, call a specialist doctor if there is any emergency, data collection and real time analysis, pharmacy inventory management and many more. The whole process is now called Internet of Medical Things (IoMT). This paper has presented Health Electronic Data Sheet (HEDS) design that aimed to provide a standardized framework in smart sensors. Baseline sensor failure detection, parameter identification with the HEDS system, algorithm execution and integration has carried out on this paper [18].

From the above literature review, it's been evident that many research has done on energy efficiency, communication protocols, medical health applications, security of IoT devices. Too much access, privacy policy, security of devices, number of connected devices on a network, these are the concerns of IoT that has not yet fully analyzed and tested. There is also no analytical expression of energy efficiency of sensor nodes, optimization technique to reduce transmission power, energy of sensors in e-health etc. There is not enough real world application of IoT which is both power consuming and user friendly. Many methods which connect both IoT and health has been devolved by many researchers over the time but every system has some limitations. So, it's essential to build an analytical modeling of WSN networks and introduce an optimization technique to reduce transmission power in order to save energy of IoT devices. A smart home appliance is also proposed which takes much less power than conventional IoT devices. Lastly, Biomedical simulation in cognitive IoT is demonstrated here for better health care monitoring system by the help of IoT

1.4 Motivation

Since the invention of IoT, energy efficiency of IoT connected devices has been a concern for both researchers and inventors of this field. As the number of devices connected to internet is rising day by day, providing enough energy to all these devices has become a challenging issue. Many researchers have proposed various energy efficient scheme to tackle this problem. As our energy is limited and number of digital devices are increasing in manifold, it is necessary to think about a realistic approach that can make these smart devices power saving and energy efficient at the same time. IoT is now playing an important role in our day to day life. From smart wearables which can detect our fitness statistics to smart home, IoT is vibrant everywhere. Integration of IoT on our home appliances can make our life much more safe and smooth. For example, if a smart juice maker can prepare our juice with proper nutritious value or warn us against any harmful element in the juice then it can be a crucial element of daily lifestyle. Another important application of IoT is in health sectors. Nowadays, doctors can track the patient's heartbeat, pulse, temperature etc. just from his smartwatch. Sensors built in the machine which is tracking patient's statistics continuously sending the signal to both nurse and doctors, they both are always updated with patient's condition. All these miracles are only possible by the help of IoT. An analytical model to reduce transmission power to making devices energy efficient has been developed here. Alongside that, a smart juice maker model and a simulation of WSN with respect to real human body has been analyzed here.

1.5 Objective of the Thesis

The objective of this thesis is to study different aspects of IoT including its applications, a new energy efficient technique, optimization solution and application of IoT in medical service. To meet this goal, the following objectives are set:

1. To develop an energy efficient technique for WSN.
2. To adopt an Optimization technique for reducing transmission power.
3. To develop MATLAB Simulink health model using IoT.
4. Build a model of IoT based smart home appliance.

1.6 Organization of the Thesis

This thesis is organized in five chapters as follows:

Chapter-1 is an introductory chapter. It contains the background history of IoT and various important previous work done by researchers in this field.

Chapter-2 contains two sections. In the first part, an energy efficient model of single and two-slope pathloss for WSN has been introduced. Performance of Packet reception rate (PRR) with respect to energy efficiency has been studied here. In second section, an Optimization technique has been proposed in order to increase the energy efficiency in WSNs. We find out the optimal transmission power and frame length, hence minimizing the transmission power which brings energy efficiency enhancement to WSNs. Finally, we evaluate the performance of optimization problem.

Chapter-3 contains our work on medical application based on IoT. We have model wireless sensor network with Simulink (a MATLAB based simulation program) in order to perform the simulations which correspond to real data of human body. We have done Biomedical simulation in cognitive IoT. Circadian rhythmicity is also observed in digital form.

Chapter-4 presents a model of IoT based smart home appliances system. We have created a juice maker that will tell us if our juice is contaminated or not by measuring the data taken from pH sensor and temperature sensor and will measure value by water flow sensor. We have created the connection between IoT and user as our smart juice maker can be controlled by mobile or smartwatch.

Chapter-5 contains the conclusion part and highlights some conceivable promising roads of further improvement.

Chapter 2

Energy Efficiency Model & Optimization Technique

2.1 Introduction

IoT is one of the most recent innovations of modern engineering and a very important field of research. The full utilization of this technology can greatly benefit industrial production, medical services, office productivity and even simple personal use at home. Regarded as the future of the Internet, IoT is a result of millions of Internet protocol (IP) enabled devices (e.g. television, security camera, medical equipment, access cards) connecting together to share data. One aspect to note however is the fact that most of our electronic devices are slowly getting more compact and portable, meaning that wireless connectivity is of utmost importance when it comes to establishing this technology. These wireless devices are collectively referred to as WSN since they are typically a collection of sensors, each with its own transceiver that communicates with a central sink connected to the Internet. The use of WSN enables us to very easily and quickly deploy any type of sensor wherever needed, making sure that the most up to date technology is being used. The application of WSN is one of the key innovations within IoT. An important factor that arises from using WSN however is the battery life expectancy. A piece of equipment which is meant to share important data at a continual pace is not very practical if it has to be constantly recharged or if the stored energy falls to a point where said device cannot function properly. WSN uses a technique known as mesh networking in order to pass on data to the central sink, meaning that for a majority of the time almost every node is actively receiving and transmitting data, particularly those closest to the sink. If even one of these nodes run out of battery that means the network would need to reroute to other nodes, exponentially decreasing the energy efficiency of the whole WSN. Going back to the example of body sensors for medical purposes, a low battery life could possibly fail to transmit data to the doctor's node when there is an emergency, effectively making the device useless; there is also the likelihood of a low power level causing the device to transmit incorrect data, which may lead to misdiagnoses by doctors leading to life threatening situations. When using sensors on high end machinery for maintenance, it is also possible that a failure of the device to inform the manager of any form of malfunction can harm the user, or send false alarms necessitating in more repair work than what is actually needed thus raising expenses. In this chapter, energy efficiency model of single and two-slope for the WSN has been proposed which evaluates the performance of packet reception rate (PRR) and energy efficiency. Along with that, introduction of an optimization technique in order to increase the energy efficiency in WSNs has been developed here. We find out the optimal transmission power and frame length, hence minimizing the transmission power which brings energy efficiency enhancement to WSNs. Finally, we evaluate the performance of optimization problem.

2.2 Related works

Different pathloss models for both indoor and outdoor applications have been proposed by researchers over the time. In [19], sensor nodes were used to study WSN in a field covered by snow for various heights. Results were checked with two ray pathloss model and ray tracing model indicating important dissimilarity. The proposed models got compared with current pathloss models to show their efficiency for sensor nodes used in WSN. In a related case, various pathloss models such as two ray model, log-distance pathloss model, log-normal shadowing, free space outdoor model and WSN constraint are discussed in [20].

Authors in [21] have conducted research work to find out the reasons behind failures in packet reception. Performance gains provided by multi-radio mobile sinks have been analyzed here. It is stated that use of multiple receiver radios can improve PRR and obtain required PRR with few retransmissions. The study in [22] presented a meaningful representation of the expected interference levels at a target location by measuring the probability distribution function of idle period lengths, and used this to estimate PRR before network deployment. It is also shown that probability distribution function of idle period lengths can be measured using off-the-shelf sensor nodes. Reference [23] is a survey paper which presented details on radio link quality estimation for different quality measurements. Similarly, a study in [24] describes the technique to generate link layer model in WSN. link layer model for various condition and radio models were presented here.

The study in [25] proposed a decoding technique that exploits the correlation knowledge of the sensing data to be transmitted from each sensor to the fusion center. The authors have derived an algorithm to estimate the observation error probabilities, representing the correlation of the links between the sensing object and sensors. The Bit Error Rate (BER) of two cases is also made here. Similarly, the authors in [26] have analyzed the effects of Co-channel interference (CCI) on the BER performance of WSN under the CCI source within the vicinity of a sensor node. Both Nagakami distribution and space division with maximal-ratio-combining have been used to analyze WSN with multiple antenna at receiver side. The authors in [27] have examined the properties of information gathering in remote sensor systems, in terms of both capacity and power distribution procedure. They derived the data collection, in coherent and media access control, model using minimum mean square error estimator. Capacity is derived for both equal power allocation and optimal power allocation of both models. BER of WSN using Rayleigh and Nakagami-m fading channels is analyzed in [28]. At a related case, the authors of [29] have assessed the performance of CDMA based WSN with respect to outage probability and BER. A correct model for the interference power, outage and BER are presented for single hop communication along with detection probability evaluation. In [30], authors have studied the snapshot or continuous data collection (SDC/CDC) problem under the physical interference model (PIM) for randomly deployed dense WSNs. Cell-based path scheduling algorithm and novel segment-based pipeline scheduling algorithm have been proposed for SDC and CDC respectively. As a measure of reliability of such systems, outage probability of WSN in distinct condition of random sensing where sensors' readings are affected by spatial correlation and channel fading has been studied in [31]. In [32], authors have considered the issue of state computation for L-sensor in linear dynamic systems. The paper presents a fuzzy model for measurement condition estimation and a designed Kalman filter to find information on moving target tracking in WSN. The proposed scheme achieves superior performance over traditional methods where moving target tracking in WSN is considered. An application driven extension to routing protocol which increases the WSN lifetime by reducing the routing and sending activity of the network to nodes running the same application is proposed next [33]. A synchronization mechanism is also introduced here which proves the model provides lower energy consumption and lower number of packets exchanged than conventional ones where PRR is high

2.3 System Model

2.3.1 Path Loss Model

Path loss model predicts signal attenuation between transmitter and receiver as a function of propagation distance and other factors. One of the most commonly used path loss model is log- normal shadowing, which predicts pathless of a desired signal as it propagates through a medium. Both single-slope and two- slope models which are derived from log-normal model were used to calculate path loss in a simulated outdoor environment. The standard log-normal model is defined as a single-slope pathless model. In a two-slope model, two different path loss exponents are used and critical distance can be between 1 m and 100 m.

a) Single-Slope: In order to simulate wave propagation loss for any particular path we used the log-normal model. This can be considered to be applicable for a very wide range of real world environments, and is generally expressed as:

$$P\,L(d) = P\,L(d_0) + 10n\log10(d) + \sigma \quad (2.1)$$

where P L(d_0) denotes the path loss at a reference distance of d_0, the path loss exponent is n, and the σ is a zero mean Gaussian distributed random variable in dB.

(b)Two-Slope: Based on [20], two-slope model can be expressed as:

$$PL\,(d) = PL\,(d_{01}) + 10n_1\log\,(d) + \sigma 1 \qquad \text{if } d \geq dc \quad (2.2)$$

$$PL\,(d) = PL\,(d_{02}) + 10n_2\log\,(d) + \sigma 2 \qquad \text{if } d \leq dc \quad (2.3)$$

Here dc is used to imply the critical distance and for simulation purposes we considered n_1 and n_2 to be 2.09 and 4.01 respectively. We also considered PL (d_{01}) and PL (d_{02}) to be 33 dB and 23 dB respectively, while σ1 and σ2 are 0.28 dB and 0.67 dB respectively. The values used here were taken from the real life experiment presented in [20] which was done in a grassland

2.3.2 Packet Reception Rate

PRR is defined to be the percentage of nodes that successfully receive a transmitted packet from the desired node which is within the transmission range [34]. Based on this we can consider the connection quality to be good when PRR is high and vice versa. To calculate it we are used a link layer model derived from [32] and [33] for a specific distance d, which can be expressed as

$$P_{RR} = \left[1 - 0.5 * \exp(-\frac{\gamma}{2})\right]^{8*F} \quad (2.4)$$

where F is the frame length and is the signal to noise ratio which is calculated by using the following equation:

$$\gamma = P_t - PL(d) - P_n \quad (2.5)$$

Here P_n denotes noise floor, which is the thermal noise that has been generated from radio components (i.e. transmitter and receiver) and P_t is the transmitted power.

2.3.3. Energy Efficiency

Sensor nodes are a vital part of WSN and thus the battery optimization of these nodes for prolonged usage is a major challenge in the development of this technology for mass use. Reference [32] suggests that data communication has a big impact on the node's battery life as radio transceivers have high power consumption rates. Apart from this, channel noise and collisions amongst some other factors significantly attribute to the battery life of a node. A dead node in the WSN may cause drastic change in the routing of data in the network. The typical energy consumption of a WSN node can be modeled from the following equation:

$$E_c = P_m t_m + P_a t_a + P_t t_t + P_r t_r + \sum_{i=1}^{m} \left(P_{c(i)} t_{c(i)}\right) \quad (2.6)$$

where Pm is the power consumed by the microprocessor while it is running for the time $t_m$in active mode. P_a is the power consumed by microprocessor in low active mode, P_t is expressed as power dissipation at transmit mode and P_r is defined as power dispersion of microcontroller in receiver mode with respect to time t_r. Power consumption of other miscellaneous components of node (e.g. LED, ADC) is denoted by P_c and lastly the supplied voltage for every component is denoted by V .

From eq. (6) we can derive the total energy consumption of a WSN node to be as follows:

$$E_c = E_m + E_a + E_t + E_r + E_{tc} \quad (2.7)$$

where E_m is the energy consumption for the microprocessor, E_t is total energy consumption while sending packets, E_r is energy utilized when receiving packets, E_a is the energy usage in low active mode, and E_{tc} is the energy consumption due to miscellaneous components in the node.

Energy efficiency is defined as the ratio between successful packet delivery rate to the total energy consumption of a system. For WSN the overall efficiency of the network can be given by the following expression:

$$EE=\frac{PRR}{E_c} \tag{2.8}$$

2.3.4 Optimization Problem

In this section, our objective is to maximize energy efficiency under the constraint term in the expression of PRR. In optimization problem, we determine the transmission power and frame length that maximize energy efficiency subject to PRR, when PRR is greater than the prespecified constant PRR_{max}. The corresponding optimization problem can be formulated as:

$$\max \quad EE(P_{t,}f) \tag{2.9a}$$

$$\text{s.t } P_{RR} \geq PRR_{max} \tag{2.9b}$$

$$F \geq F_{max} \tag{2.9c}$$

$$P_t \geq 0 \tag{2.9d}$$

where $EE(P_{t,}f)$ is defined in eq. (8), P_{RR} in eq. (4) and PRR_{max}denotes the minimum required P_{RR}. We point out that (9b) can be viewed as a P_{RR} constraint and that (9c) can guarantee that the optimal solution of F, which is greater than F_{max} and that (9d) can guarantee that the optimal solution of P_t, that is equal to 0.

2.3.5 Theorem

The maximum energy efficiency $EE(P_{t,}f)$ can be expressed as

$$EE(P_{t,}f) = \frac{\left[1-0.5*\exp(-\frac{\gamma}{2})\right]^{8*F}}{P_m t_m + P_a t_a + P_t * t_t + P_{tc} t_{tc}} \tag{2.10}$$

The optimal solution of P_t^* and F* are presented as

$$P_t^* = PL(d) + P_n - 2\ln\left[2 - 2(PRR_{max})^{\frac{1}{8}*F}\right] \tag{2.11}$$

$$F^* = F_{max} \tag{2.12}$$

Proof: The proof is given in appendix A

2.3.6. Simulation Results

In this section we simulate both single-slope and two-slope log-normal modeling in order to compare multiple aspects of the performance of these two models. The simulation has been carried out using MATLAB with the input values for the simulating expressions having been taken from a real life experiment done in [20]. These parameters are given in Table 2.1.

Table 2.1: Simulation parameters

Parameter name	**Value**
Single-slope	
Pathloss exponent (n)	3.69
Gaussian noise (σ)	1.42 dB
Reference distance pathloss ($P\ L(d_0)$)	31 dB
Two-slope	
Pathloss exponent ($n1$)	2.09
Pathloss exponent ($n2$)	4.01
Gaussian noise ($\sigma1$)	0.28 dB
Gaussian noise ($\sigma2$)	0.67 dB
Reference distance pathloss ($P\ L(d_1)$)	33 dB
Reference distance pathloss ($P\ L(d_2)$)	23 dB

Energy consumption	
Microprocessor power P_m	9 *mW*
Microprocessor time t_m	1197.43 *sec*
Active mode power P_a	1.825 *mW*
Active mode time t_a	597.43 *sec*
Transmitting mode time t_t	600 *sec*
Miscellaneous components power P_{tc}	29 *mW*
Miscellaneous components time t_{tc}	1197.43 *sec*

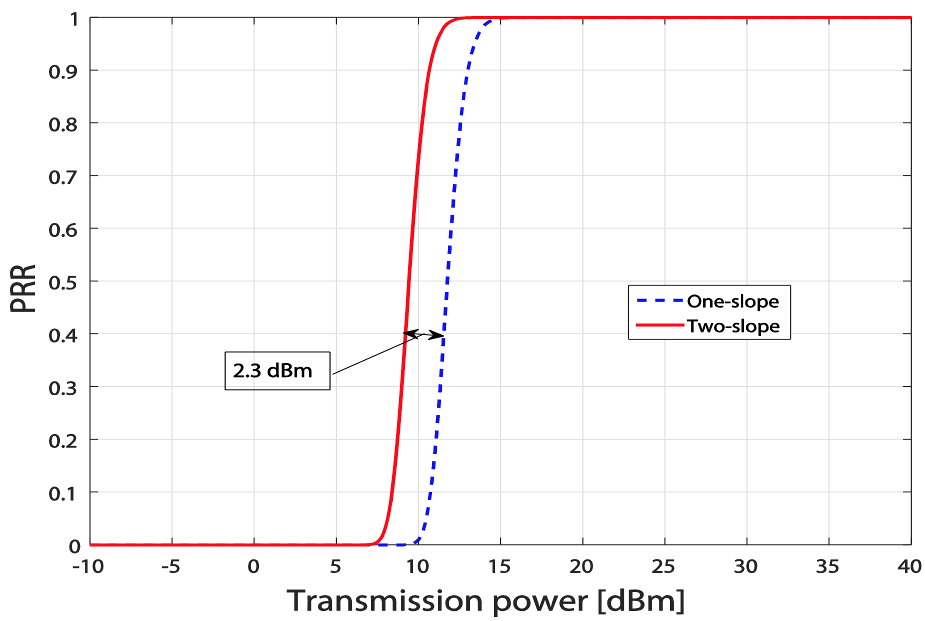

Fig 2.1: PRR vs. Transmission Power.

Our first simulation shows the variance of PRR with respect to change in transmission power for single-slope and two-slope models. Both curves are shown together with a legend for proper indication. It can be observed in Fig. 2.1 that that PRR stays at zero up until a certain point, different for each curve, then PRR rises dramatically and remains constant at its peak value for the rest of the simulated transmission power increments. Based on the two curves present it is quite evident that the sharp rise of PRR occurs at a lesser transmission power for the two-slope model and the peak PRR is also reached proportionally early. And at the illustrated data point we have observed a 20% lower transmission power for the two-slope model. Further we have carried out four simulations comparing the energy efficiency and optimal power of single-slope and two-slope models. We have carried out our tests against each of the following factors: transmission power, PRR and pathloss distance. In terms of the transmission power we can observe in Fig. 2.2 that when the power is negative or very low the energy efficiency is extremely low, however at a certain point it rises sharply, and once reaching the peak the efficiency drops at a more gradual rate. From comparing the two curves it can be seen that the efficiency of two-slope model is proportionately higher than the single-slope during the sharp rise phase of the curves, whilst at other points both are the same. At the given point on the figure we have observed 21:1% lesser transmission power for the two-slope model than single-slope at the same energy efficiency. Most importantly however is that the peak efficiency of the two-slope model is higher and possible at a lesser transmission power than what is the case for single-slope (i.e. 11:6 dBm against 13:8 dBm).

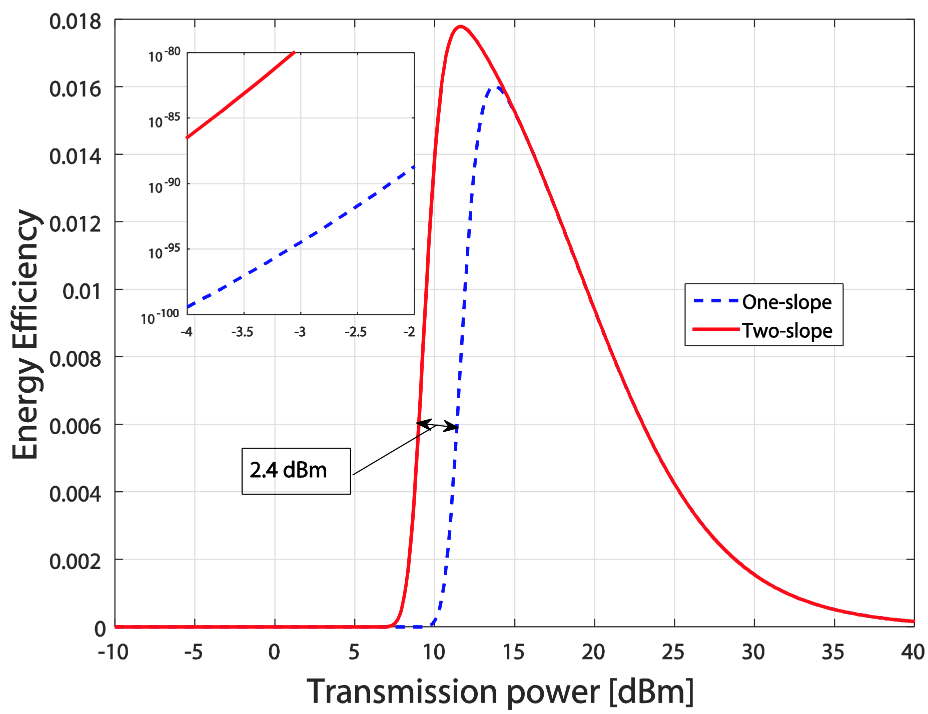

Fig 2.2: Energy Efficiency vs. Transmission Power.

The results of our simulation over the variance of optimal power with respect to increase in distance of pathloss can be seen in Fig. 2.3. This shows the curve for both single-slope and two-slope models as indicated by the legend. Here we can observe that there is a somewhat linear relation between optimal power and pathloss distance, however the two-slope model has a constant lesser optimal power value across all the simulated distances of pathloss. From the data point shown in the figure we have observed a 46% decrease in the optimal power for the two-slope model. For the energy efficiency curve against the pathloss distance in Fig. 2.4 (i.e. the distance between transmission and receiving nodes) we have observed that for the first time, the relative improvement of our two-slope model is exponential to the single-slope performance. Here, both curves show a drop in energy efficiency as the pathloss distance increases, however the drop is significantly steeper for the single-slope model. Initially both curves start out the same as having very high energy efficiency at 0m pathloss distance.

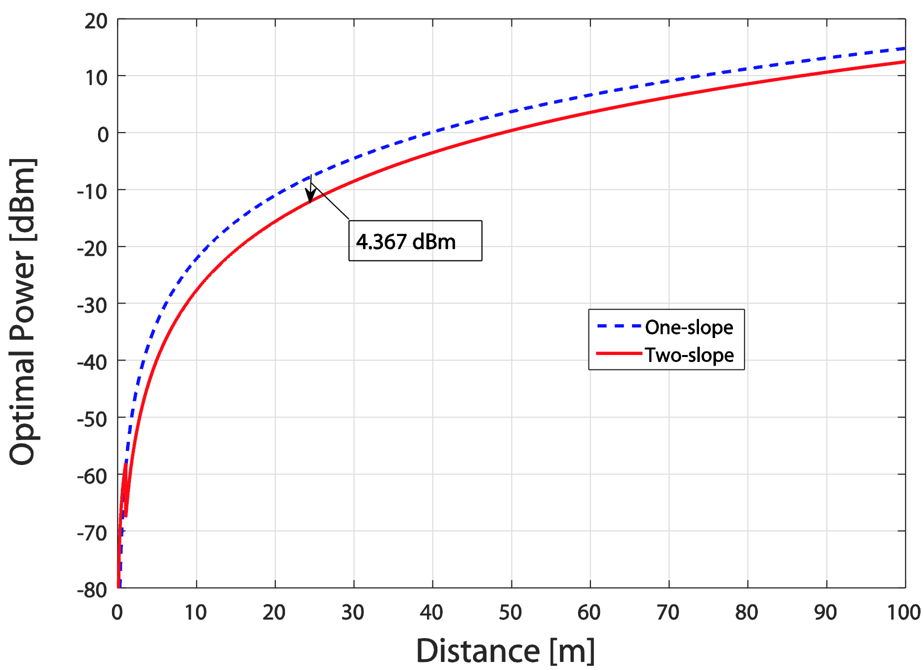

Fig 2.3: Optimal Power vs. Distance.

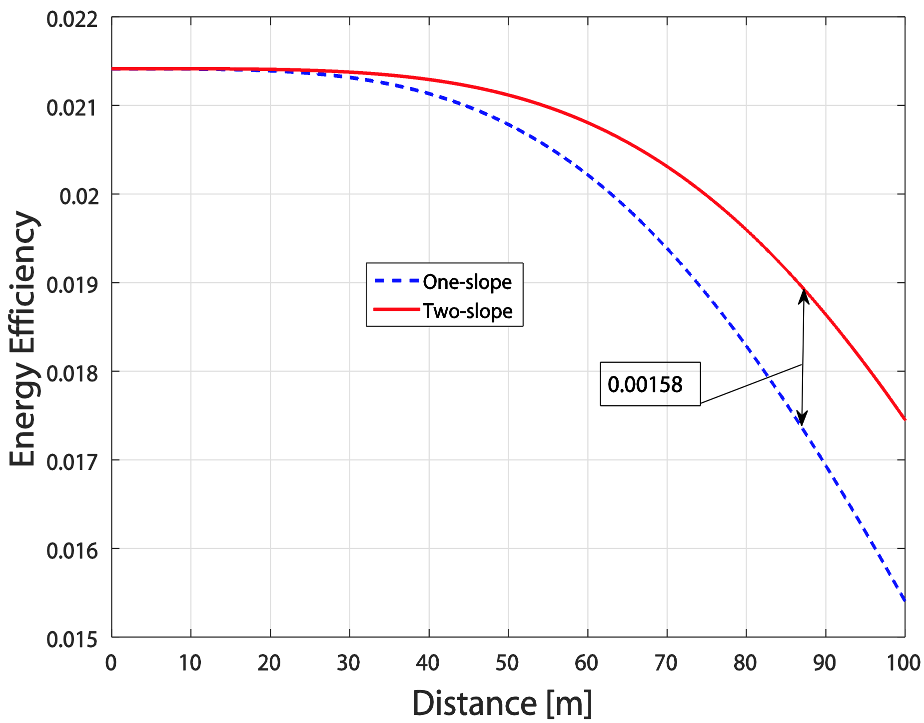

Fig 2.4: Energy Efficiency vs. Distance

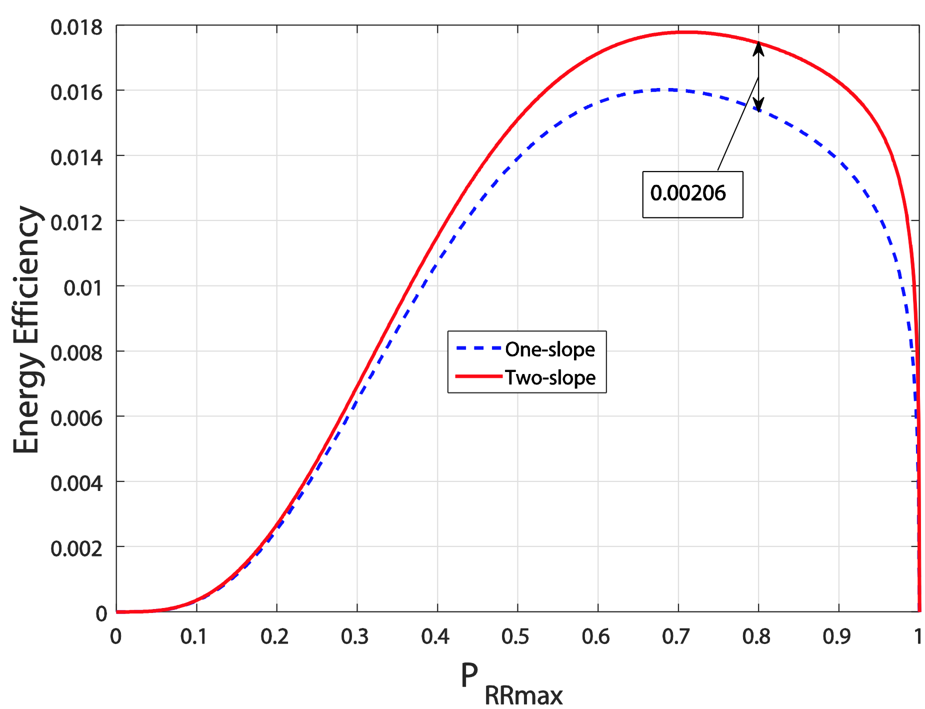

Fig 2.5: Energy Efficiency vs. PRR_{max}

However, as the two curves start to drop it is quite obvious that the rate of fall in efficiency for single-slope is much greater than that of two-slope. At the point marked on the figure we have observed a 9:1% difference in energy efficiency. When considering the energy efficiency during variation of PRRmax, a similar situation is observed in fig. 2.5. Here the two lines start off with the same efficiency of zero when PRRmax is at nil, however as PRRmax rises we see that the rate of increase for two-slope model is greater than that of single-slope. We observe that the energy efficiency in terms of PRRmax peaks for both models at the same value of 0:7 PRRmax, however the efficiency of two-slope model is significantly greater at that point. After this however both curves slowly converge again, dropping their energy efficiency to an eventual zero when we reach the absolute PRRmax. In the point shown on the figure we observe that the relative improvement of our two-slope model is 11:8%.

2.4 Conclusion

In this chapter we have proposed the usage of certain energy efficient consumption techniques for use in WSN nodes. Further, we have gone on to extensively test our findings using single-slope and two-slope log-normal modeling for simulation of different aspects of wireless performance. The two specific features of log-normal modeling, single-slope and two-slope modeling, are both industry standard models for these forms of simulations. From out tests we have observed significant improvements on the efficiency, 9:1% as observed at a certain point in the case of variation in pathloss distance. This was achieved through the use of our battery power optimization techniques, which have also been observed in simulations to not cause any loss in connection quality (i.e.PRR).

Chapter 3

IoT in Biomedical Application

3.1 Background

The Internet of Things (IoT), originated at first by Kevin Ashton as the title of a presentation in 1999[1], is a technological regime change which is bringing the world into a new ubiquitous era of communication, computing, connectivity and automation. IoT is a worldwide network where all the objects are addressable based on a protocol and accepts people or things to be connected from Anywhere, Anyone and Anyplace via any network [35]. As a booming network, Internet of Things (IoT) can use each and every sector of modern technology. For this reason, it is important to upgrade the features of IoT gradually. Now, the improvement of IoT depends on progressive technical innovations in a number of fields like the WSN to Nanotechnology [36]. In the past decades, we have observed the hard work from network architecture, service provider, academic community and intelligent features for getting the ideas to specific applications [37], [38]. Basically, connectivity, communication and computing was the most focussed field which was really important. However, without the comprehensive cognitive capability and the disagreement between the offered service and expected application requirement, we believe that IoT is nothing but a human body without the nervous system. To solve these gradual growing challenges, we have to take cognitive capability under consideration and furnished IoT with improved intelligence [39]. Therefore, we propose an improved IoT concept which is Cognitive Internet of Things (CIoT) and investigate the key techniques.

3.2 Internet of Things in the Perspective of Bangladesh

Arrival of Internet of Things (IoT) has opened the door of new era to solve several types problem in our every day's life. To keep pace with the modern technology, Bangladesh has already started so many projects based on IoT. Study says, within 2020 almost 30 billion objectives will be under Internet of Things (IoT) [40]. Bangladesh is dreaming to be a part of this new system and solve countless problems and touch the dream of 'Digital Bangladesh'. As, we know that IoT devices use Subscriber Identification Module (SIM) based sensor or Non SIM Based sensor to collect the data of mobile operators. They also use Short Range Device (SRD) and Industry

Scientific and Medical (ISM) frequency. According to National Frequency Allocation Plan (NFAP) and for maintaining the echo-system of IoT devices around the world, Bangladesh government considers the following bandwidth for IoT device:

433.05-434.19 MHz

866-868 MHz

922-925 MHz

2400-2483.5 MHz

5'725-5875 MHz

This allocation will be reconsider with the increase use of IoT devices. The maximum power output of the IoT devices will be 1~ 2 Watt/30~33.01 dBm. One possible interference can be, if any other allocated bandwidth frequency face any types of obstacle due to excessive use of IoT devices then IoT devices will be remain close until getting the permission from Bangladesh Telecommunication Regulatory Commission (BTRC).

3.3 Cognitive Internet of Things: An Overview

A CIoT is an Iot with the knowledge of cognitive and cooperative mechanisms. It is integrated for promoting performances and achieving intelligence [41]. It is a network where everything like things or objects are connected with each other and acts like one without any types of intervention [39]. This network works as a cycle and establish the connection with environment and social network and gather all the knowledge as database for taking the effective decision later. For improving energy efficiency, cognitive radio networks are now showing the interest to enormous power consumption to wireless networks [42]. The focus has been also shift to wireless radio frequency harvesting in battery-operated device to cognitive radio networks [43].

3.3.1 Internet of Things to Cognitive Internet of Things

In today's world, we see that most of the systems are being controlled by IoT and the number of IoT controlled system is increasing day by day. One of the main reason of this success is the inter connectivity among different systems. But, let's give a close look of existing IoT systems, we will see that most of these applications are controlled by human beings cognition process. This is one of the main reason of the introduction of 'Cognitive Internet of Things'. Here, all the parts of any applications will be inter-connected by using physical/social network with the minimum intervention of human. Basically, CIoT will furnish the IoT with new system design by reducing human contribution. The outcome will be increasing resource efficiency, saving time and effort, reducing cost, increasing service quality and so on.

3.3.2 System Model of Cognitive Internet of Things

Cognitive Internet of Things (CIoT) acts like a connection bridge between physical world (like virtual things, automation, resources, objects and so on) and social world (social character, public demand, mass people's reaction and so on). Taking everything under consideration, a system can consider which is intelligent physical-cyber - social (iPCS) system. This model consists four major layers:

- Data Observation Step: The task of this step is to make the direct interaction with physical environment. Here, by processing the incoming stimuli and feedback observations the preceptor sense the environment. For controlling the perceptors via environment, the actuators act like that.
- Data study step: The task of this step is to analyze the sensing data so that it can form handy semantic and knowledge.
- Resolution step: This step completes several types of task. First of all, it uses the semantic and knowledge which is engrossed from the lower layer for enabling multiple or even enormous interactive emissaries to reason, plan and selection. Along with, the most suitable action with dual functions for supporting services for social or human networks and vivifying to physical environment.
- Action assessment step: The function of this step is to sharing valuable interfaces with social networks. By doing this, we can know the on-demand provision which is

provided to social networks. Novel performance matric are designed for the assessment of the provisioned services along with the feedback evaluation result in cognitive process.

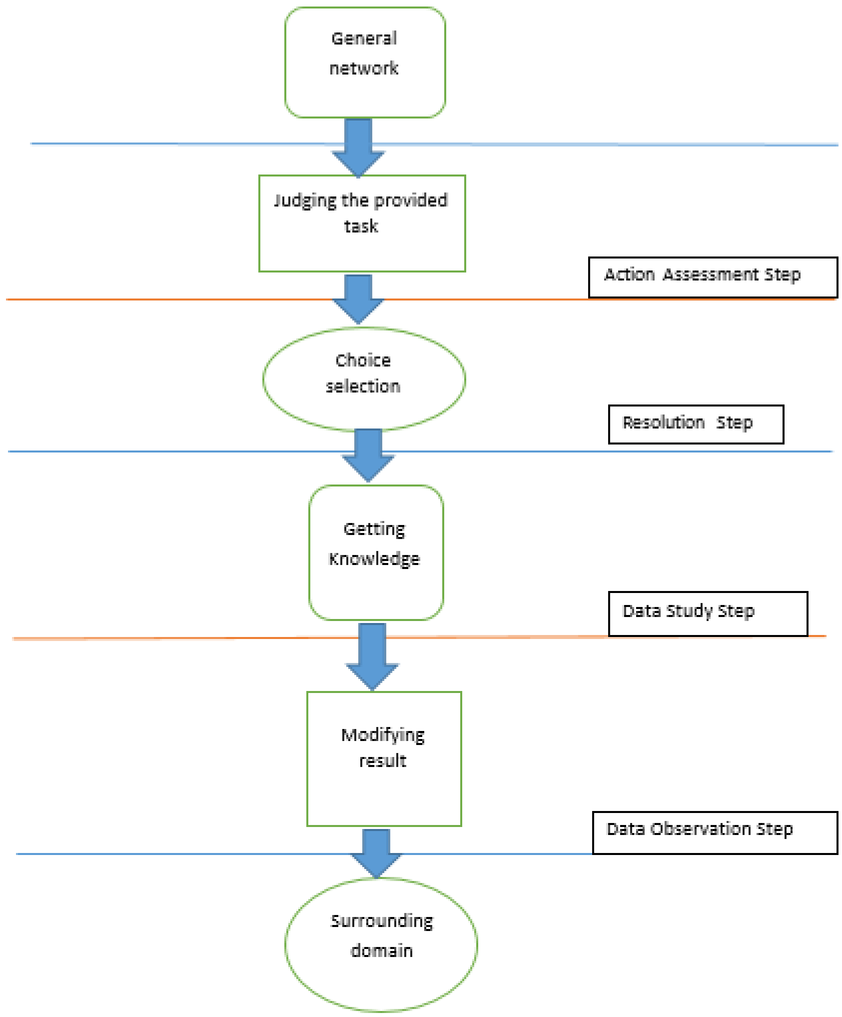

Fig 3.1: System Model of Cognitive IoT

Consisting a clear imitating methodology 'learning by understanding' which is in the middle, the framework of Cogntive Internet of Things (CIoT) has five fundamental cognitive tasks. Those tasks are Perception-action cycle, Massive data analytics, Semantic deviation and knowledge discovery, Intelligent decision making and On-demand service provisioning [39]. We can discuss the function of these tasks in short. First of all, perception cycle is the most antediluvian cognitive tasks in CIoT. It takes perception as input from the physical environment and action as output. Instead of taking perception, on-demand service provisioning directly supports various services (e.g., Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), Sensing-as-a-Service (SaaS) and Everything-as-a-Service (EaaS) [44] to human or social networks. This concept is investigated recently (in [45] - [47]).

3.4 Spectrum Shortage

In our everyday life we use our smartphone or app for communication. We connect to the wireless data network via spectrum. The wireless channels are constructed by spectrum to link our smartphone with the wireless data network. Demands of spectrum have been increasing day by day with a rapid speed. In 2001, the mobile cellular subscriptions were 15.5 for every 100 people, in 2013 it became 96.2 [36]. Before 2008, there was not that much use of Mobile Broadband Internet service on smartphone. In 2013, it became 78.8 mobile broadband subscriptions per 100 people in the first world countries and 29.5 over 100 in the world as a whole [41]. The most beneficiary of the wireless revolution is the developing countries or the developing worlds. The exorbitance of enabled electronic devices, sensors is increasingly accessible over the Internet of the arising Internet of Things (IoT) [48] will exaggerate the whole situation. All the latest applications because of IoT may have the implications in different traffic models which will eventually cost the redistribution of spectrum resources between uplink versus downlink.

3.5 Spectrum Shortage in the Perspective of Bangladesh

According to Bangladesh Telecommunication Regulatory Commission (BTRC), the number of mobile subscribers in Bangladesh was 45.21 million in February, 2009. In May 2018, it became 150.727 million [49]. Within nine years, the number of users has increased almost four times. This rapid growth of users may good for the economy but it creates the problem of spectrum shortage. Because of the users, we have to redistribute our existing spectrum range or have to increase the spectrum frequency.

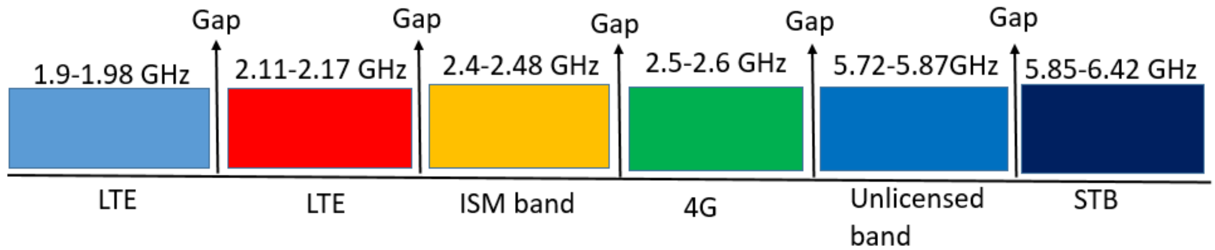

Fig 3.2: spectrum allocation in Bangladesh (collected from BTRC website [http://www.btrc.gov.bd/content/mobile-phone-subscribers-bangladesh-may-2018])

From the above figure we can see that Long-Term Evolution (LTE) which is a high sped wireless communication for mobile devices has two different frequency range which is 1.9-1.98 GHz and 2.11-2.17GHz. After that, we see Industrial, Scientific, Medical (ISM) band has the frequency range of 2.4-2. 17GHz. Also, Fourth Generation (4G) of broad band cellular network has its own frequency range 2.5-2.6GHz. Along with that, we have an Unlicensed band (5.72-5.87 GHz) and Set-Top Box (STB) which is an information appliance device generally contains TV tuner input has its frequency range of 5.85-6.42 GHz. If we give a close look, we can understand that it is tough to provide the greatest service to the excessive number of subscribers with only two frequency range band (LTE and 4G). It might be possible in the last decade but it is not possible in this decade especially when spectrum scarcity is getting high and high. If we give full concentration on this topic, we can solve this problem. First possible solution can be the redistribution of spectrum management where we will emphasize more to the spectrum shortage problem in mobile communication which is obviously a costly step. After that, we can also solve this scarcity in our existing system. For instance, LTE and 4G are remain busy in 24 hours a day but Set-Top-Box (STB) which is TV tuner is remain quite free in day time. Also, majority industry and scientific activity operates at day time but stay close at night. Therefore, if we can use their frequency as a cognitive user when they don’t operate much then we can solve this problem within our existing system which will be cost effective. For doing this, we have to detect which frequency range which remains free according to our expected time. In addition, with that, we need their permission so that we can use their frequency as secondary user which will be a priority base process.

3.6 System Model

Wireless body Area Networks (WBANs) which is based on radio frequency wireless networking technology can collect human body health information [50]. Those information consists patients' blood pressure, body temperature, electrocardiogram (ECG) signals, heart rate etc. Data are collected by the sensors which are located in or around the human body. This WBAN should design by taking few criteria under consideration like patient's mobility and the reduction of public health cost. Those collected data may be sent to several clinical personnel to observe patients remotely. They can also use in telemedicine or tele surgery etc. Now, transferring these data to several receivers within the present WSN system is a challenge because of interference problem which we should avoid at any cost. In addition, with that, in the new scenario higher data rate is not the requirement of mobile network. IoT and other e-health applications demand other requirements than high rate data transfer [51]. Using the concept of Internet of Things (IoT), we can solve all types of interfacing and other challenges. In our every day's life human body disclose circadian rhythmicity. Under ambulatory condition, because of several environmental factors and our physical effort can improve or worsen the rhythms. We have three most common vital signs which is blood pressure, heart rate and body temperature which can vary at day time because of many different activities. The purpose of this study is to model wireless sensor network with Simulink (a MATLAB based simulation program) in order to perform the simulations which correspond to real world human body area network [52].

3.7 Systolic Blood Pressure

Fig 3.3 shows the simulation model systolic blood pressure which is done by using MATLAB Simulink. This proposed model shows how a user can get expected data from any random source and using data conversion in systolic BP block. After that, the received output transmitted in transmitter block and mixed with additive white Gaussian noise in AWGN block. Then, it goes to receiver and finally, data comes into systolic BP block and we get out expected result.

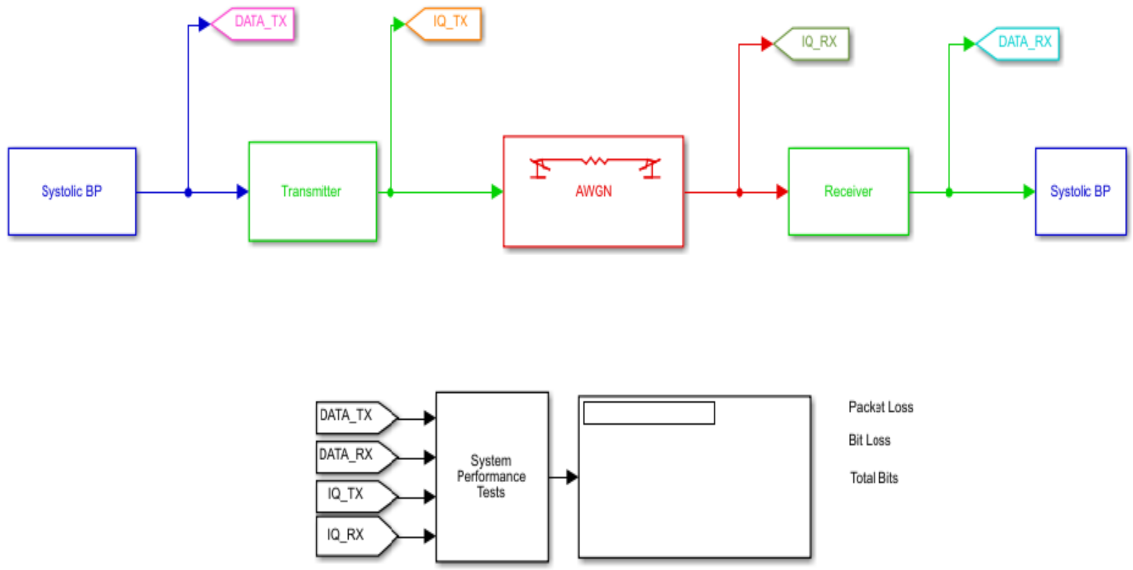

Fig 3.3: Systolic Blood Pressure Block

The following figures show the sub blocks of the Systolic Blood Pressure Simulink model:

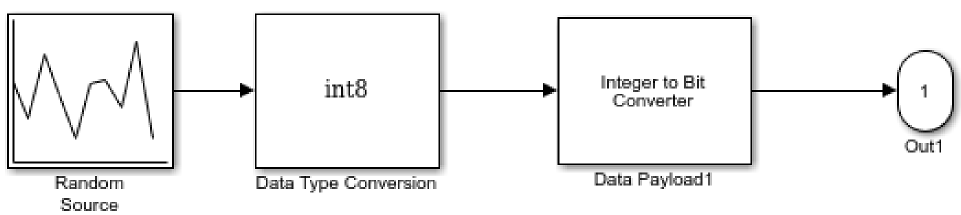

Fig 3.4: Sub Block of Systolic BP

Figure 3.4 is the sub block of Systolic BP which is the starting of this model. Here, we took the Random source which set output repeatability to no repeatable. We know the systolic BP of human body is low 85(mm Hg) and high 135(mm Hg).Therefore, parameters will be:

Source type: uniform, Minimum: 85, Maximum: 135, Sample time: 0.1

Then, we took data type conversion which convert the input to the data type and scaling the output. After that, the signal will go to integer to bit converter where the number of bits per integer will be 8.

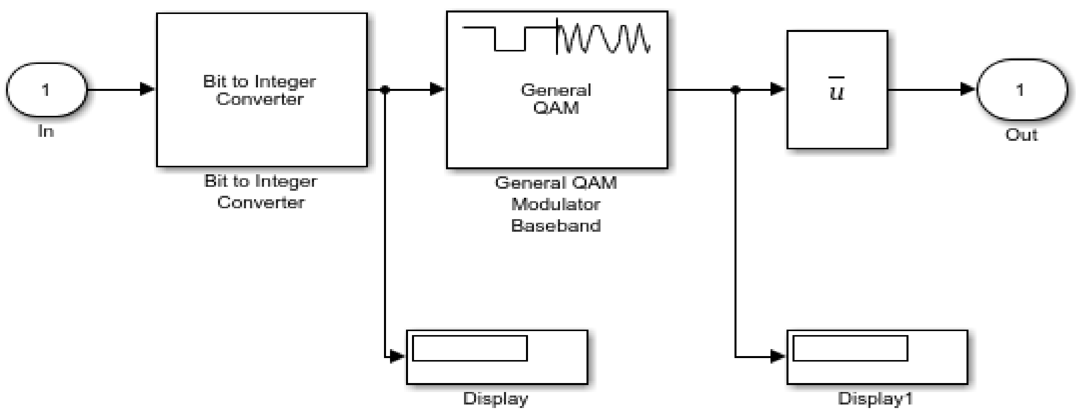

Fig 3.5: Sub Block of Transmitter

Figure 3.5 is the transmitter block where signal will first go to bit to integer converter. Then, signal will go to general QAM modulator baseband where signal will be modulated by using the quadrature amplitude modulation. After that, we took a mathematical function which basically corresponds to the top input port and will pass the signal to next block.

Now, signal will pass through the AWGN channel which will add white Gaussian noise to input signal. During the simulation time, for getting expected data, we have to change the SNR 0 dB to 40 dB. Therefore the parameters will be:

Initial seed: 1, Mode: Signal to noise ratio (SNR), SNR (dB): [0, 2, 4,……40]

After that signal will go to receiver block.-

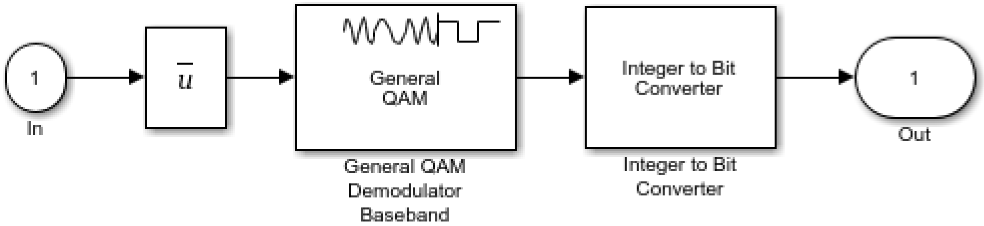

Fig 3.6: Sub Block of Receiver

Figure 3.6 is the receiver block where signal will go to the mathematical operations. In the general QAM, we have to set 'Output type' parameter as 'Integer' because of getting the proper demodulated signal. Then, signal will convert from integer to bit and pass the signal to the next block.

Fig 3.7: Sub Block of Systolic BP

Figure 3.7 is the final block of the system where signal converts for the final time from bit to integer and give the resulting signal using terminator.

Table 3.1: Systolic BP Table

Systolic BP			
SNR	Packet loss	Bit Loss	Total Bit
0	0.44318	390	880
2	0.41477	365	880
4	0.38977	343	880
6	0.39204	345	880
8	0.35681	314	880

10	0.35227	310	880
12	0.32386	285	880
14	0.32840	289	880
16	0.28181	248	880
18	0.26704	235	880
20	0.24431	215	880
22	0.22272	196	880
24	0.18863	166	880
26	0.19659	173	880
28	0.15909	140	880
30	0.13636	120	880
32	0.10340	91	880
34	0.07386	65	880
36	0.04659	41	880
38	0.02727	24	880
40	0.01136	10	880

3.8 Heart Rate

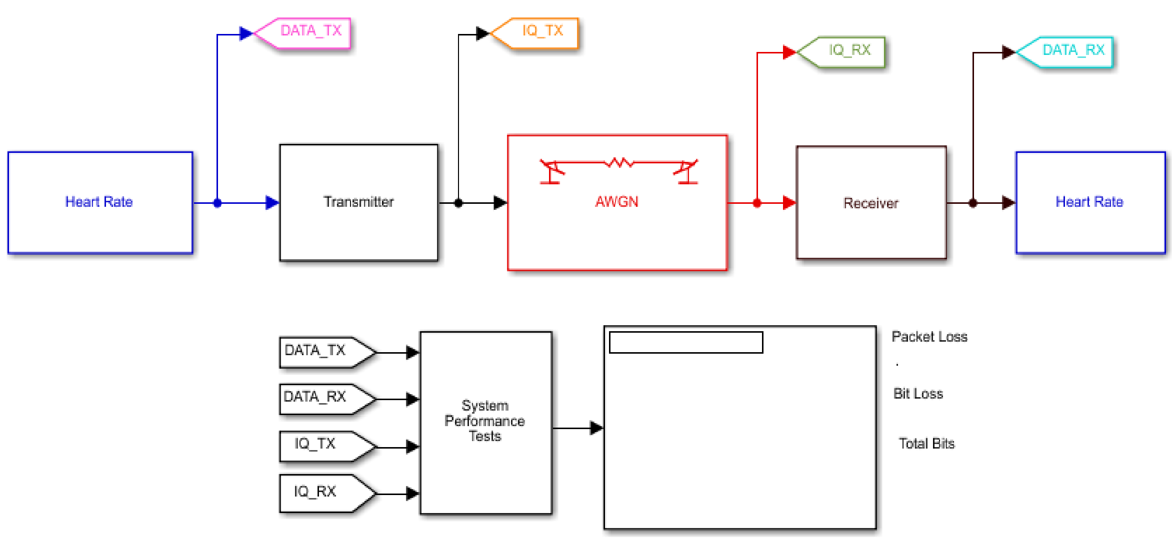

Fig 3.8: Heart Rate block

Fig 3.8 shows the simulation model heart rate which is done by using MATLAB Simulink. This proposed model shows how a user can get expected data from any random source and using data conversion in heart rate block. After that, the received output transmitted in transmitter block and mixed with additive white Gaussian noise in AWGN block. Then, it goes to receiver and finally, data comes into heart rate block and we get out expected result.

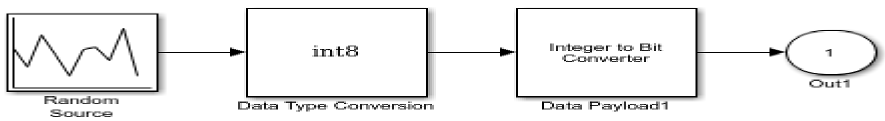

Fig 3.9: Sub Block of Heart Rate

Figure 3.9 is the sub block of heart rate which is the starting part of this model. Here, we took the Random source which set output repeatability to No repeatable. We know the heart rate of human body is low 45 (bpm) and high 95(bpm). Therefore, parameters will be:

Source type: uniform, Minimum: 45, Maximum: 95, Sample time: 0.1

Then, we took data type conversion which convert the input to the data type and scaling the output. After that, the signal will go to integer to bit converter where the number of bits per integer will be 8. Rest of the process has followed the previous model of 'Systolic Blood Pressure'.

Table 3.2: Heart Rate Table

Heart Rate			
SNR	Packet Loss	Bit Loss	Total Bit
0	0.44318	390	880
2	0.42159	371	880
4	0.34809	338	880
6	0.37727	332	880
8	0.37386	329	880
10	0.35568	313	880
12	0.33863	298	880
14	0.33409	294	880

16	0.30454	268	880
18	0.27613	243	880
20	0.25340	223	880
22	0.22727	200	880
24	0.19772	174	880
26	0.18636	164	880
28	0.18522	163	880
30	0.18295	161	880
32	0.14204	125	880
34	0.11590	102	800
36	0.07954	70	800
38	0.03295	29	880
40	0.02159	19	880

3.9 Body Temperature

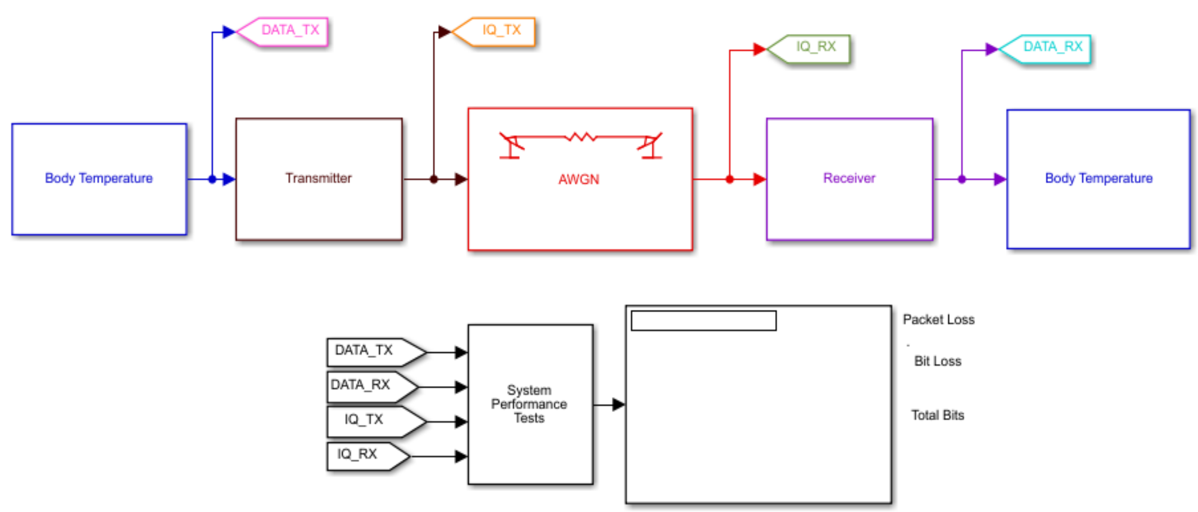

Fig 3.10: Body Temperature Block

Fig 3.10 shows the simulation model body temperature which is done by using MATLAB Simulink. This proposed model shows how a user can get expected data from any random source and using data conversion in body temperature block. After that, the received output transmitted in transmitter block and mixed with additive white Gaussian noise (AWGN) block. Then, it goes to receiver and finally, data comes into body temperature block and we get out expected result.

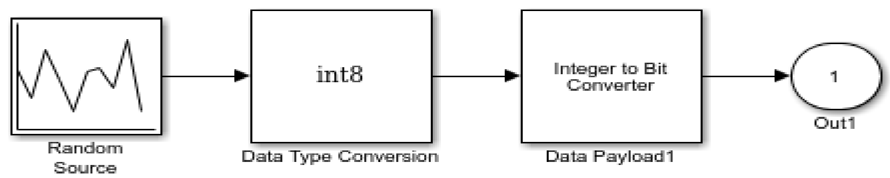

Fig 3.11: Sub Block of Body Temperature

Figure 3.11 is the sub block of body temperature which is the starting part of this model. Here, we took the Random source which set output repeatability to No repeatable. We know the heart rate of human body is low 96.4^0 (F) and high 99.9^0 (F).Therefore, parameters will be:

Source type: uniform, Minimum: 96.4, Maximum: 99.9, Sample time: 0.1

Then, we took data type conversion which convert the input to the data type and scaling the output. After that, the signal will go to integer to bit converter where the number of bits per integer will be 8.

Rest of the process has followed the previous model of 'Systolic Blood Pressure'.

Table 3.3: Body Temperature Table

Body Temperature			
SNR	Packet Loss	Bit Loss	Total Bit
0	0.40795	359	880
2	0.39886	351	880
4	0.36704	323	880
6	0.35568	313	880
8	0.35340	311	880
10	0.34772	306	880
12	0.33181	293	880
14	0.32045	282	880
16	0.31931	281	880
18	0.30113	265	880

20	0.27272	240	880
22	0.25454	224	880
24	0.22386	197	880
26	0.20454	180	880
28	0.18181	160	880
30	0.16363	144	880
32	0.12272	108	880
34	0.09090	80	880
36	0.05454	48	880
38	0.02613	23	880
40	0.01022	9	880

3.10 Result and Discussion

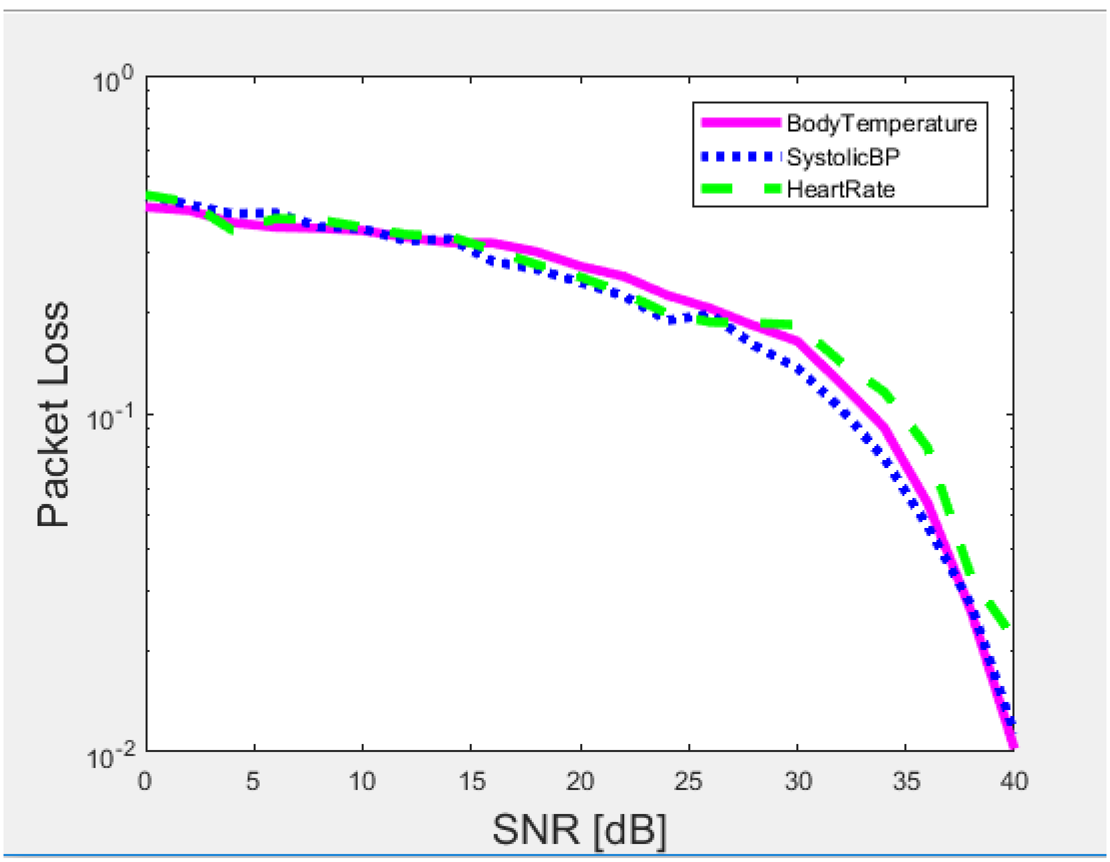

Fig 3.12: Packet Loss vs. SNR for Temperature, Heart rate and Systolic BP.

In figure 3.12 we can see the three different wave shape for Blood pressure, heart rate and body temperature. From the behavior of these wave shape we can say that, when SNR (dB) value increase, packet loss value decrease. When SNR (dB) value decreases, packet loss value increases.

We will take two values for percentage improvement,

For systolic BP: For SNR 0 dB, X_1= 0.44318 and for SNR 2 dB, X_2= 0.41477

Percentage improvement = $\frac{X1-\mathrm{X2}}{X1}$

$$= \frac{0.44318-0.41477}{0.44318} \times 100$$

$$= 6.410\%$$

For heart rate: For SNR 0 dB, A_1= 0.44318, and for SNR 2dB, A_2= 0.42159

Percentage improvement = $\frac{A1-\mathrm{A2}}{A1}$

$$= \frac{0.44318-0.42159}{0.44318} \times 100$$

$$= 4.871\%$$

For Body Temperature: For SNR 0 dB B_1= 0.40795 and for SNR 2dB, B_2= 0.39886

Percentage improvement = $\frac{B1-\mathrm{B2}}{B1}$

$$= \frac{0.40795-0.39886}{0.40795} \times 100$$

$$= 2.228\%$$

3.11 Conclusion

In this chapter, we analyze, the performance of biomedical applications in CIoT. In our model, we consider three biomedical vital body symptoms like BP, Heart rate, Body temperature for the performance analysis of wireless sensor network. Three signals have been generated and transmitted through to wireless medium. Finally, we evaluate the packet loss with respect to signal to noise ratio and our result reveals that systolic BP improves 6.410%, heart rate improves 4.871% and body temperature improves 2.228%.Therefore, clearly we can say that systolic BP improves more than heart rate and body temperature. Also, we discussed about the CIoT and its structure. Along with that, we showed the spectrum shortage problem and the possible solution of spectrum shortage.

Chapter 4

Application of Smart Appliance

4.1 Introduction

As technology makes progress the devices we use in everyday lives are getting more and more sophisticated, and thus becoming complicated to use for many. Due to this there is a trend of making our electronics ‘smart’, as in making the devices capable of setting the proper configurations and changing them when required on their own without any human intervention, generally using an array of different sensors. Although smart devices are being used in many areas such as manufacturing and automobiles, here we are focusing on their use in households.

Another big trend in current technology is Internet of things (IoT), which effectively means the connection of all electronic devices to the Internet in order to achieve better control, monitoring and automation. In terms of household appliances these features can be used to bring a significant improvement to our lives be alleviating many tasks which are rather tedious and time consuming (i.e., cooking, washing clothes, etc.). The usage of IoT and smart appliances can make these tasks much easier and add greater amount of leisure time to people or simply allow them to be more productive at home. These technologies can be broadly applied to almost every home electrical device, but for the purposes of this research we have focused on one particular appliance, which is the juice maker.

4.2 Related Works

IoT enables electrical devices designed for home use is an area which is being widely researched and facing continual development. The addition of IoT has the potential to bring a significant improvement in the general livelihoods of people. However, due to the core nature of how IoT works we require easy device interoperability and interfacing, and for that we re-quire well developed network architectures specially designed for this purpose along with the proper network protocols. Much work has already been carried out to this regard, several different architectures each with its own pros and cons as established in survey paper [53], whilst the communication part, commonly referred to as machine to machine (M2M) communication has been covered in the survey paper [54]. Much practical work has also been carried out towards the introduction of IoT enabled or interfaced devices in homes. Many of these projects focus on adding IoT functionality towards existing electrical devices to enable remote control and sometimes monitoring. The user generally accesses the IoT functions through smartphones as seen in [55] or through a webpage user interface like in [56], whilst [57] made its own micro-controller based device for remote control. In case of [58] we observe the same functionality with webpage user interface, however with an additional focus on affordability and a more graphical user interface through the use of HTML5.

Other projects, while having remote control functionality, have focused in on the security capabilities of IoT systems as well. In [59] we observe the use of open source software tools to add security to an IoT system where a Raspberry Pi is used as the server, and in [60] they have used sensors of sorts to detect robberies.

Monitoring is also a common application of IoT systems, as seen in [61] which uses IoT to network security requirements by developing a secured platform driven by triangle based security algorithm. A lot of work show the aspect of power efficiency, which is something that adds to the practicality of IoT devices, through having portable wireless network nodes with batteries which last longer. However, power efficiency can also be tackled through monitoring of the power usage of other electrical devices and switching them on or off in an intelligent manner as seen in [62] [63]. In case of [64] they take it a step further with a system not only capable of monitoring power usage for greater efficiency, but also the capability to generate electricity bills. The system being targeted towards disabled people, also has the functionality of temperature monitoring. And lastly [65] has developed a relatively unique IoT node which is designed to develop reliable, efficient, flexible, economical, real-time and realistic wellness sensor networks for smart home systems.

Some papers put more emphasis on establishing the current. Smartphone status of IoT systems to lay a solid foundation and then go on to develop on top of that. Reference [66] and [67] presents the current architectures which are in use for IoT and then continues to present a prototype model of adding IoT functionalities to existing devices in case of [66], whilst the latter explores the current problems which are faced in the industry and suggests to provide solution them. Lastly we find [68] which explains the potential of IoT to significant improvement in life quality through adding features such as remote control, security and automation through M2M technology. [70] did a research analysis regarding the effectiveness of high hydrostatic pressure (HHP) and carbon dioxide (CO_2) for the pasteurization process for fruit juices of various pH levels; ending with the conclusion that the HHP process is very successful for high pH value juice, even at relatively low pressures, whereas for fruit juice lower pH value HHP on its own is quite acceptable, but its effectiveness increases exponentially with the addition of CO_2.Meanwhile the researchers in [69] did a similar analysis on pasteurization, however they instead based their analysis on all existing published papers which were freely available to carry out a meta-analysis with the goal of formulating a linear model based on basic bigelow equation. The process of pasteurization at focus was heat treatment, and the research concluded in having made a successful model for predicting the effectiveness of heat treatment against Alicyclobacillus acidoterrestris that is found in fruit beverages. Some researchers such as in [71] studied the effects of packaging and long term storage on the fruit juice. Here the particular juice studied was Roselle-mango juice blend which had its various attributes measured (e.g. anthocyanin's, vitamin C, total phenols) whilst in a variation of conditions (glass or plastic storage, and low or high temperature). Their conclusion was that the use of plastic or glass for storage made no difference, but cold storage served much better for keeping the various elements of the drink intact (e.g. vitamin C and anthocyanin's). Apart from these researches have also looked into the effect of fruit beverages on our dental health. Both [72] and [73] have studied the matter using samples of 20 children who have had the pH level of them

dental plaque measured at different time intervals. The main objective was whether the fruit juices caused the pH level of plaque to fall below a certain threshold in which case the teeth gets damaged. Based on the study of [73] which involved two fresh juices and two ready-made ones, no such danger was observed as the pH level of the plaque never went below the threshold. However, [73] made an additional note from their similar research based on mango juice exclusively, that commercially available mango fruit juice is more likely to harm dental health than fresh juice.

4.3 Proposed Model

The proposed system model of smart appliance is based on the usage of IoT in order to enable remote control and monitoring over the devices using various smart gadgets (e.g. smartphone, tablet, smart watch, smart television). These gadgets, along with the device we intend to control, utilize their Internet connectivity to establish a localized IoT network, which enables us to send instructions and monitor progress. As most of the smart gadgets is using android operating system, and android application is developed so that it user can send juice mixing order from anywhere. The device that is build upon raspberry pi gets request and implement it with fix amount, chosen juice and sugar level. To insure the juice quality, pH sensor and temperature is always monitor remotely and an ARIMA based model is built for predicting the pH values according to temperature.

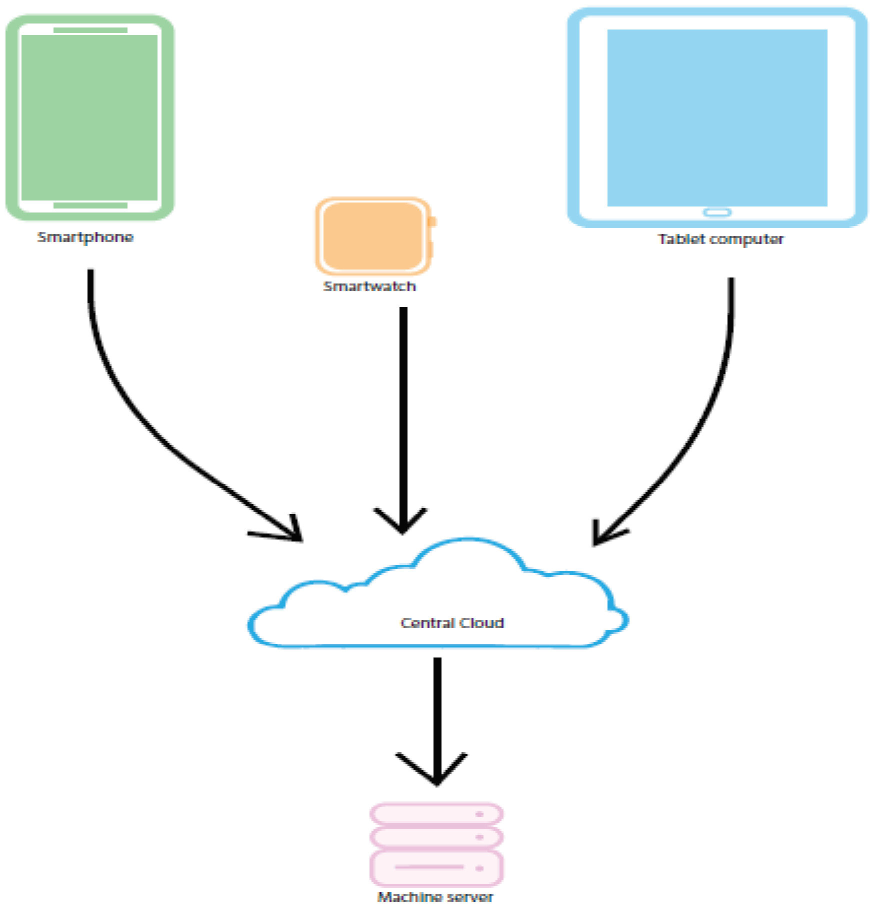

Fig. 4.1: Proposed system model

4.4 Experimental Setup

4.4.1. Hardware Implementation

The hardware setup is formed using 4-channel relay, pH sensor, DS18b20 digital temperature sensor, water flow control module, four mini water pumps, DC motors, display, power source and raspberry pi-3. These four mini water pump consisting of dc motor with water flow control module are used for flowing juice based on user requirement. A 5V four-channel relay module was connected to the Raspberry pi and to the different pumps, one wire for each connection to the pumps. The positive end of the battery, connected to each of the relay channels, was in turn connected to the four relay boards in parallel. When input is given and the power is turned on, the switch in a relay channel would turn on, which further turned the DC motor of the water pump on. When input was given, the water pump takes liquids in from two of the four bottles and discharged the liquids to a glass. pH sensor which is used for gaining threshold hydrogen-ion activity, either acidity or alkalinity. DS18b20 digital temperature sensor is implemented for monitoring the temperature of juices. pH sensor shows values with the respect of temperature and this concept is used for juice quality monitoring as fixed kind of juice has a pH range and if this

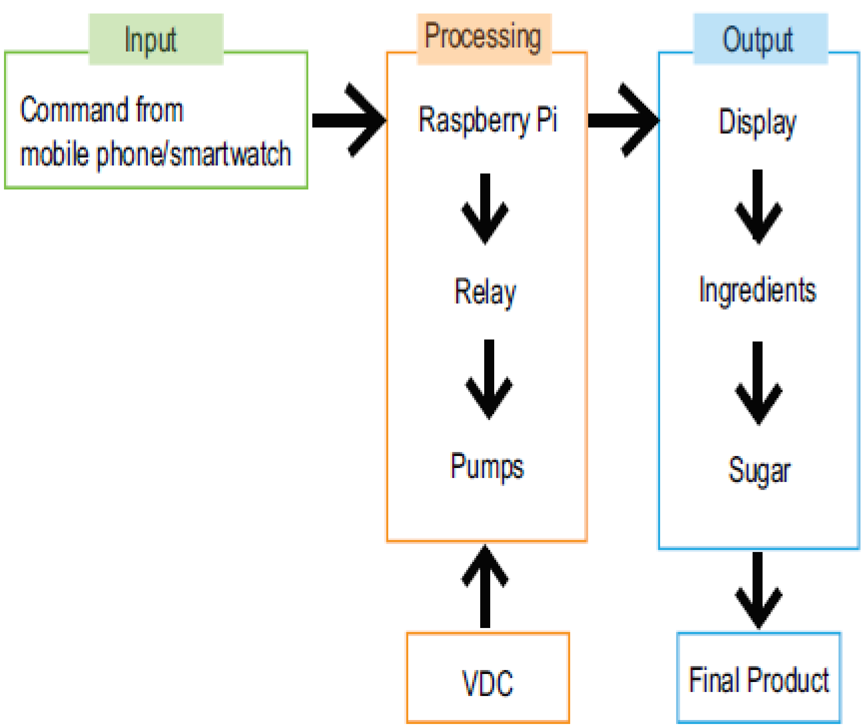

Fig 4.2: System design for automated juice maker

threshold is not fulfilled then taste may hamper or indicates that the sample juices are not fully pure according to that time. Further, all modules and sensors are then configured with raspberry pi which is shown in fig 5. Raspberry pi doesn't support analog sensor, so all analog sensors which generate analog value (DS18b20 and pH sensors) is connected with ADC converter board

Fig 4.3: Android software UI

to convert analog values in digital. Raspberry pi-3 has built in Wi-Fi sensors and connecting with internet it gets command from MySQL sever and then it turns on the relay based on the selected juice. The pump will flow water along with the water flow sensor's given amount to flow. While the processing is going on, the LCD screen show which juice selecting. In the case of adding the sugar and flavoring, we use concentrated syrups since our experimental setup had no hardware for mixing soluble. The syrup is pumped into the glass using one of the 4 pumps, which is dedicated for this purpose only, in the same manner as the water.

Fig 4.4: Juice maker experimental setup

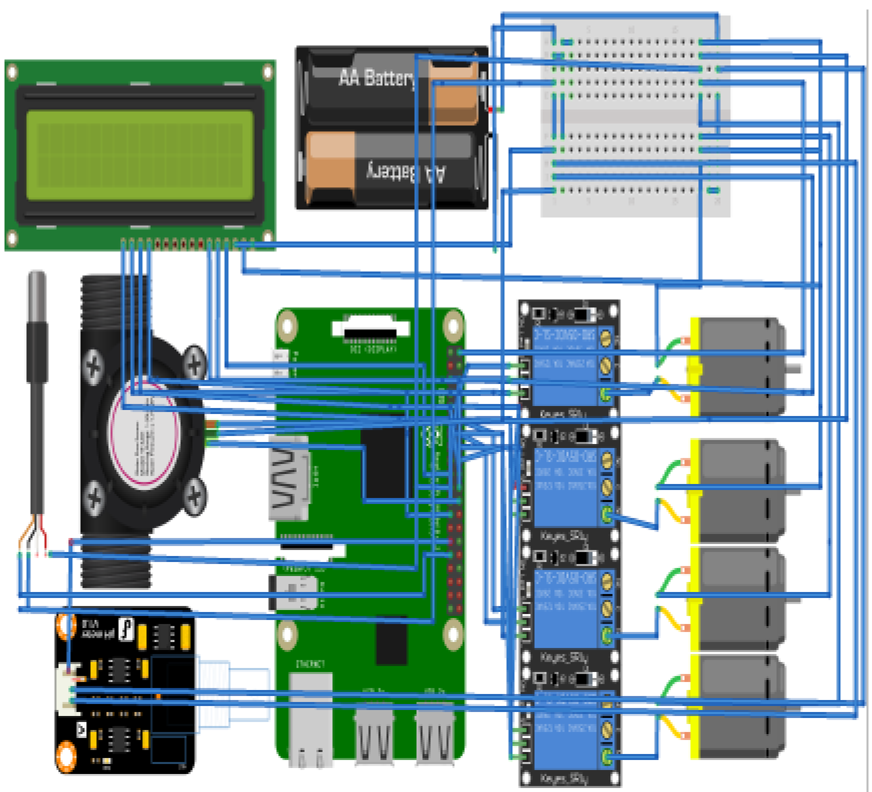

Fig 4.5: Circuit diagram for juice maker

4.4.2 Software and Communication System Implementation

The software implementation part is divided in three major areas - python programming for sensing and giving out, an android application for sending order request based on the concept of IoT and php backend programming for sever side processing. Python is the core programming language for raspberry pi as it is Linux based operating system. The coding architecture is drawn based the GIPO pins of raspberry pi and android application is developed as most of the smart devices like smart phones, tablets, watches and televisions are having android as operating system. Each of button of the application consist of a url which contains the juice's code, amount, sugar level in percentage (e.g. iotjuicemaker. com?order.php?juice='2'+amount='350'+sugar='20') . Now, php backend is applied which handle the url request. It handles the request, then split it and post it to the mysql database with that it is connected. Now, raspberry pi fetches data whenever a new row is inserted with a valid value for order. It has combined with mysqldb library and it is connected with that served the same way php program connected. Moreover, the proposed algorithm is now applied that is shown in table 4.1, and relay will be on based on the values, requested from mysql and android application.

4.4.3 ARIMA Based Prediction System

As the value of pH effects on taste, quality or freshness of juices, so pH value according to temperature is measured with five second interval. With this stationary data, ARIMA that stands for autoregressive integrated moving average is applied. The model has three combined part ARIMA which is denoted by p,d,q that refers lag order, degree of differencing, order of moving average. The system is fitted by an ARIMA (3,1,0) with lag value to 3 for performing auto regression, model that is gained by trial error process as it shows the least mean square errors. The value of d means it is time series stationary and moving average is choosen 0. After the model is prepared fitting the function, the prediction is done by prebuild predict () function. To evaluate the function, training set is processed with ARIMA and cross validates with testing set, accuracy is gained from these cross validation checking.

Juice maker algorithm

Function Insert (flavor, sugar syrup, amount, user info [ ])

Form url of insertion;

Send→ http request;

begin php

Connect with database;

Handle http request;

Split column wise;

Send→ Database;

end php

begin get Request (flavor, sugar syrup, amount, user info[ ])

Quantity ← waterflow sensor();

while (Quantity amount)

if (flavor == n)

relay switch = select (n);

motor_n = ON;

end if

if (sugar syrup == m)

m← to.convert(time)

for (time =1; time m; time++)

relay switch = select (m);

motor m = ON;

end for

end if

end while

end getRequest

Total_Quantity = Total_Quantity-amount;

Juice temp = temp( );

pH = pH( );

urllib (Total_Quantity, Juice temp, pH);

Function end

4.5 Results and Discussion

The average pH threshold value of our sample fresh juices from three different temperatures are apple 4.1 to 5.21, Orange 3.98 to 4.8, blueberry 3.6 to 4.07, and lemon is 3.3 to 3.96. These value are gained from 10°, 20°, 25° temperatures and within 3 hours after freshly made. Crossing the threshold value may affect the quality or refers impurity of the juices. The figure 4.6,4.7,4.8 shows the predicted system obtained from ARIMA model. The accuracy depends on how less the mean square error is. Table 4.1, 4.2, 4.3 show the mean square error of the predicted system based on temperature.

Table 4.1

Sample (in 10°)	Mean Square Error
Orange juice	3.02%
Blueberry juice	3.84%
Apple Juice	12.72%
Lemon juice	3.07%

Table: 4.2

Sample (in 20°)	Mean Square Error
Orange juice	2.65%
Blueberry juice	4.54%
Apple Juice	9.08%
Lemon juice	3.87%

Table: 4.3

Sample (in 25°)	Mean Square Error
Orange juice	4.49%
Blueberry juice	1.63%
Apple Juice	2.17%
Lemon juice	1.21%

When it comes to the distribution of fruit beverages there are many important aspects to consider, particularly those having to do with the health of the consumers. As a result, several research papers on the various parts of this matter has been written. One such part is the pasteurizing of the fruit juice, where we get rid of the harmful bacteria and/or microorganisms living in the juice.

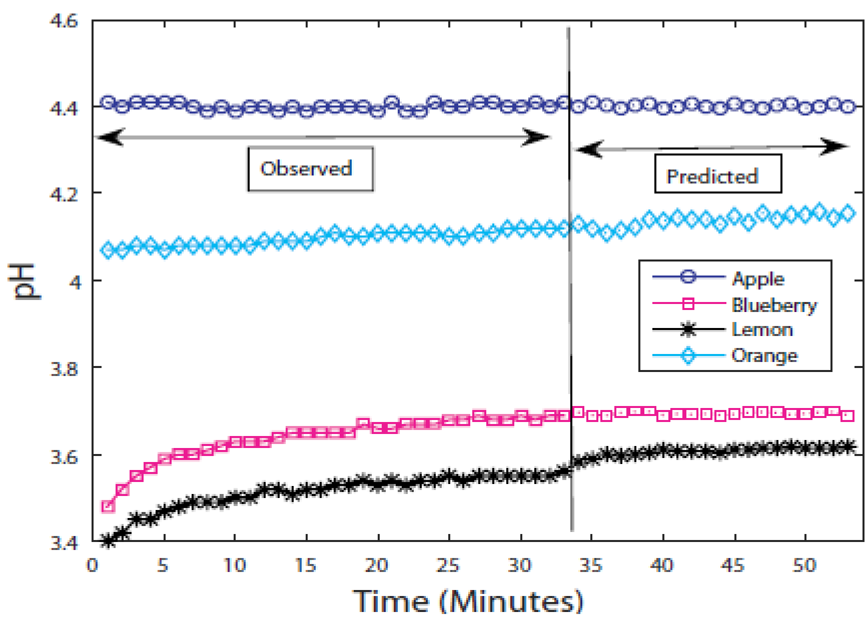

Fig 4.6: pH value at 20 degrees.

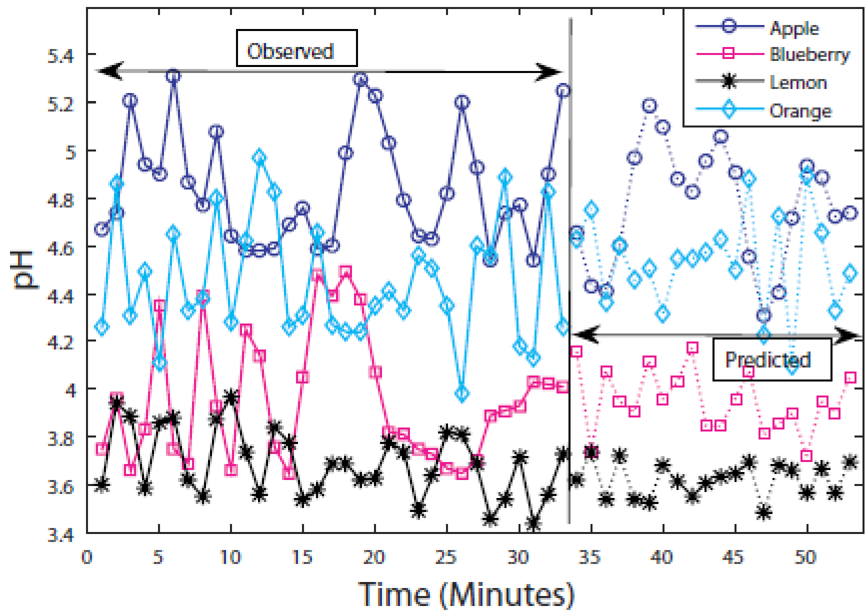

Fig 4.7: pH value at 10 degrees.

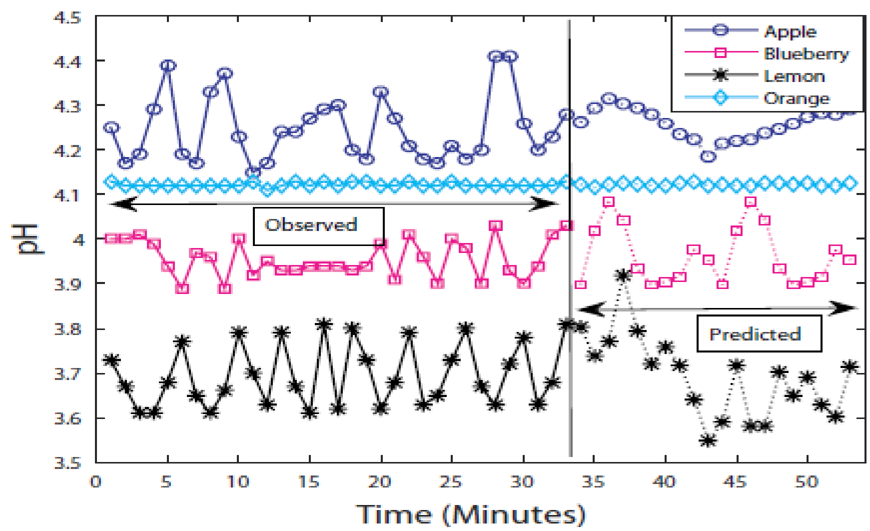

Fig 4.8: pH value at 25 degrees.

4.6 Conclusion

In this paper, the concept and implementation of an IoT based smart juice maker has been outlined. A mobile application enables users to input their desired sugar amount and type of drink to the machine, after which the output, the drink itself, is obtained. It will make connection between human and machine interface. Temperature sensor and pH sensor is used to show the juice quality in every minutes and water flow sensor will determine the juice quantity. Raspberry pi is used as the processor in this project; we used it to interact with the mobile app and the LCD screen and to show the amount of liquids according to the user input. We set out to create a customizable drink maker which people could use to easily get a drink just how they like it and we overall achieved that goal. Firstly, an automatic ice machine could be set up which will enable users to choose how they want their drink. Secondly, we will implement a system where all of the home appliances will be connected in a system by using IoT where people can control them easily using mobile app or smart watch. Furthermore, all of the data of the user will be served in central cloud and all home appliance will work smartly (ex for a diabetic user it will make sugarless drink in every time). All in all, it will create interaction between human and smart machines and can possible to control by only one click.

Chapter 5

Conclusion & Future Work

5.1 Conclusion

This thesis is to give a brief idea of IoT and its various sector, identify an energy efficiency problem that needs to be solved for power saving, propose a solution to the above problem, introducing smart home appliance system by the help of IoT and creating a smart health monitoring system using IoT concept. The major work of our thesis is summarized below:

a) In case of both single slope and two-slope model, it is shown that sharp rise of PRR occurs at a lesser transmission power for the two-slope model and the peak PRR is also reached proportionally early. It is also observed that 20% less transmission power is required for two-slope model.

b) When transmission power is very low or negative energy efficiency is tending to zero. From our simulation data, we have seen that efficiency of two-slope model is higher than single slope model during the sharp rise of curve. 21.1% lesser transmission power is needed for two-slope model rather than single slope for same efficiency.so, the peak efficiency is also better of two-slope model. (11.6 dBm against 13.8 dBm)

c) There lies a linear relation between optimal power and pathloss distance. In this experiment, two-slope model has lesser power value (46%) across all distance.

d) Considering the energy efficiency with respect to changingP_{RRmax}, P_{RRmax} rises at a better rate at two-slope model than for single slope model. For both model, energy efficiency w.r.t P_{RRmax} is 0.7. Energy efficiency is nil when we reached the absolute value ofP_{RRmax}.

e) The curve generated from MATLAB for Packet loss vs. SNR for temperature, heart rate, systolic BP indicates that the relation between packet loss and SNR is inversely proportional.

f) Systolic BP improves 6.410% in our simulation model.

g) Automatic IoT based smart home appliance which will provide pure juice.

h) Connection between human and machine interface has been proposed.

5.2 Future Work

IoT is a very vast field of today's technological world. We have only work on energy side, smart home appliances and smart health monitoring system of this technology. There are many sides of IoT which needs a lot of attention such as security of IoT, interoperability of IoT devices, creating sensor nodes to provide continuous data flow, durability of sensors, IoT standardization and many more. Apart from all major issues, there are still many issues and some of them are discussed below:

1) We have analyzed the single and two-slope model in terms of energy efficiency, PRR, optimal power, transmission power etc. These parameters can be also used to predict accurate path loss distance using retracing method.
2) Optimization results can be more accurate if SNR can be reduced. Low noise amplifiers can be applied to sensor to prevent internal noise.
3) A central server can be built which can store patient's data. It will help the doctor to understand patient's condition by seeing his/her previous data.
4) Built an app which can measure vital body signs automatically.
5) Our proposed smart juice model can be supplied to big restaurants for further improvement and research.
6) Various new drinks can be made by our appliance by further modification.
7) A cloud based prototype can be launched to make our device much more user friendly and easily accessible.

APPENDIX

Proof of Optimization;

Objective Function can be expressed as

$$EE = \frac{\left[1-0.5*\exp\left(-\frac{P_t+PL(d)-P_n}{2}\right)\right]^{8F}}{P_m t_m + P_t t_t + P_{tc} t_{tc}} \quad [1]$$

Constraint Function can be denoted as

$$\text{PRR}=\left[1-0.5*\exp\left(-\frac{P_t+PL(d)-P_n}{2}\right)\right]^{8F} \quad [2]$$

Lagrange Function can be calculated as

$$\text{L}= \text{EE}+\lambda_1*(PR_{max}-PRR)+\lambda_2*(F_{max}-F) \quad [3]$$

The first order derivatives of L with respect to $\lambda_2, \lambda_1, P_{T,}\ F$ respectively are expressed as;

$$\frac{\partial L}{\partial \lambda_2} = F_{max} - F \quad [4]$$

$$\frac{\partial L}{\partial \lambda_1} = PR_{max} - \left\{1 - \frac{e^{\left(\frac{PL}{2}+\frac{Pn}{2}-\frac{Pt}{2}\right)}}{2}\right\}^{8*F} \quad [5]$$

$$\frac{\partial L}{\partial F} = \frac{v_2 v_1\ [8]}{Pa\ ta+Pc\ tc+Pm\ tm+Pt\ tt} - \lambda_1 \lambda_2 v_2 v_1\ [8] \quad [6]$$

$$\frac{\partial L}{\partial P_t} = \frac{F\ [2] v_2 v_1}{Pa\ ta+Pc\ tc+Pm\ tm+Pt\ tt} - \frac{\boldsymbol{tt(1-\frac{v_2}{2})^{8F}}}{(Pa\ ta+Pc\ tc+Pm\ tm+Pt\ tt)^{\mathbf{2}}} - \boldsymbol{F} \lambda_1 v_2 v_1 [2] \quad [7]$$

Where $v_2\ and\ v_1$ is calculated as

$$v_2 = \log(1 - \frac{e^{(\frac{Pl}{2}+\frac{Pn}{2}-\frac{Pt}{2})}}{2}) \quad [8]$$

$$v_1 = (1 - \frac{e^{(\frac{Pl}{2}+\frac{Pn}{2}-\frac{Pt}{2})}}{2})^{8f} \quad [9]$$

From equation [5] WE GET

$$PRR_{max} - \left\{1 - \frac{e^{\left(\frac{PL}{2}+\frac{Pn}{2}-\frac{Pt}{2}\right)}}{2}\right\}^{8*F} = 0$$

$$PR_{max} = \left\{1 - \frac{e^{\left(\frac{PL}{2}+\frac{Pn}{2}-\frac{Pt}{2}\right)}}{2}\right\}^{8*F}$$

$$2 - 2(PR_{max})^{\frac{1}{8*F}} = e^{(\frac{PL}{2}+\frac{Pn}{2}-\frac{Pt}{2})}$$

$$\ln[2 - 2(PR_{max})^{\frac{1}{8*F}}] = \frac{PL}{2} + \frac{Pn}{2} - \frac{Pt}{2}$$

$$Pt = PL + P_n - \ln(PRR_{max})^{-\frac{1}{8F_{max}}} \quad [10]$$

From equation [4] we get,

$$F_{max} - F = 0 \quad [11]$$

Footnotes

1- M. Jahan, S. Haque, S. R. Sabuj, “An Analytical Study of Single and Two-slope Model in Wireless Sensor Networks,” submitted to the IEEE International Conference on Advanced Networks and Telecommunications Systems, India, 2018.

2- S.I. Milon, M.I. Pavel, S. Haque, S.R. Sabuj, “Application of Smart Appliance using Internet of Things,” submitted to the IEEE International Conference on Advanced Networks &Telecommunications Systems, India, 2018.

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