AN IOT BASED
BABY MONITORING SYSTEM

HIEW KUET SHANG

Bachelor of Engineering Technology
(Electrical) With Honors

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : HIEW KUET SHANG

Date of Birth : 6 JANUARY 1995

Title : AN IOT BASED BABY MONITORING SYSTEM

Academic Session : SEMESTER 2018/2019

I declare that this thesis is classified as:

- ☐ CONFIDENTIAL (Contains confidential information under the Official Secret Act 1997)*
- ☐ RESTRICTED (Contains restricted information as specified by the organization where research was done)*
- ☑ OPEN ACCESS I agree that my thesis to be published as online open access (Full Text)

I acknowledge that Universiti Malaysia Pahang reserves the following rights:

1. The Thesis is the Property of Universiti Malaysia Pahang
2. The Library of Universiti Malaysia Pahang has the right to make copies of the thesis for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

_______________________	_______________________
(Student's Signature)	(Supervisor's Signature)
_______________________	_______________________
950106-13-5245 Date:	DR. WAHEB ABDUL JABBAR SHAIF ABDULLAH Date:

NOTE : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach a thesis declaration letter.

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Engineering Technology in Electrical With Honors.

____

(Supervisor's Signature)

Full Name : DR. WAHEB ABDUL JABBAR SHAIF ABDULLAH

Position : SENIOR LECTURER, FACULTY OF ENGINEERING TECHNOLOGY, UNIVERSITY MALAYSIA PAHANG

Date :

____

(Co-supervisor's Signature)

Full Name : EN. MOHD. ALZAN BIN SAYUTI

Position : TECHNICAL STAFF, FACULTY OF ENGINEERING TECHNOLOGY, UNIVERSITY MALAYSIA PAHANG

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at University Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : HIEW KUET SHANG

ID Number : TB 15034

Date : 10 January 2019

AN IOT BASED BABY MONITORING SYSTEM

HIEW KUET SHANG

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor of Engineering Technology (Electrical) With Honors

Faculty of Engineering Technology
UNIVERSITI MALAYSIA PAHANG

JANUARY 2019

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere and deepest gratitude to my supervisor, Dr. WAHEB ABDUL JABBAR SHAIF ABDULLAH for the unlimited support, patience, motivation, guidance and knowledge for completing my thesis. Throughout the process of doing this senior design project (SDP), I have gained a lot of knowledge, skills and expertise such as time management skill, work together with project members inside the workshop, communication skill and so on. It is really an honour for me to work under his supervision as he has offered me her precious time and efforts in completing this SDP.

Apart from my supervisor, my sincere thanks to Professor Dato' Dr. Zularisam Ab Wahid, Dean of the Faculty of Engineering Technology, for providing me with all the necessary facilities and financial budget to complete the whole senior design project. My sincere thanks also go to the rest of the staffs from Faculty of Engineering Technology (FTEK) in University Malaysia Pahang (UMP), all the lecturers and technical staffs' for helping and guiding me in the workshop for the circuit designs, product building, experimental analysis and data collection. Their kindness and patience offering helps are very much appreciated.

Besides that, I would like to thank my fellow project members, FATINI FIRZANAH BINTI YUSOF and SAIDATUL NUR IZZATI BINTI SHAHUL HAMID for their advices, discussions and encouragement from the beginning until the end of this SDP. Their continuous supports do help me to overcome all the obstacles that I have faced during doing this SDP.

Finally, I would like to express my love and thanks to my beloved family who always support me spiritually and financially throughout the duration of my degree study in University Malaysia Pahang (UMP).

ABSTRAK

Bilangan ibu bekerja telah bertambah banyak berbanding beberapa dekad yang lalu. Selepas itu, penjagaan bayi dalam kehidupan seharian menjadi cabaran kepada banyak keluarga. Oleh itu, kebanyakan ibu bapa menghantar bayi mereka ke rumah datuk nenek atau penjagaan bayi untuk menjaga bayi mereka. Walau bagaimanapun, ibu bapa tidak dapat memantau keadaan bayi mereka secara berterusan. Oleh itu, projek ini mencadangkan sistem yang berasaskan Internet (IoT) yang cekap dan kos rendah untuk pemantauan bayi secara langsung yang boleh memainkan peranan penting dalam menyediakan penjagaan bayi yang lebih baik sementara ibu bapa berada jauh dari bayi mereka. Dalam reka bentuk sistem, NodeMCU dieksploitasi sebagai mikrokontroler utama untuk mengumpul data yang dibaca oleh sensor dan dimuat naik ke pelayan MQTT AdaFruit. Sistem yang dicadangkan mengeksploitasi sensor untuk memantau parameter vital bayi seperti suhu, kelembapan, dan menangis. Sensor yang digunakan dalam projek ini ialah sensor bunyi KY-038 dan sensor suhu dan kelembapan DHT22. Perisian Proteus digunakan untuk memeriksa sambungan litar dan Arduino IDE digunakan untuk memeriksa kesalahan pada kod dan kompilasi kod ke dalam mikrokontroler. Perisian Nx Siemens digunakan untuk mereka bentuk buaian bayi. Kayu Meranti merah digunakan sebagai bahan untuk buaian bayi. Bagi pembinaan buaian bayi, kayu dipotong dengan teliti dan dikendalikan menggunakan alat dan mesin yang terdapat di UMP untuk memastikan keselamatan. Seni-bina sistem terdiri daripada buaian bayi yang secara automatik akan berayun menggunakan motor apabila bayi menangis. Ibu bapa juga boleh memantau keadaan bayi mereka melalui kamera web luaran dan menghidupkan mainan lullaby yang terletak di buaian bayi dari jauh melalui pelayan MQTT untuk menghiburkan bayi. Prototaip sistem yang dicadangkan sedang dibuat dan diuji untuk membuktikan keberkesanannya dari segi kos, kesederhanaan, dan memastikan operasi keselamatan untuk membolehkan pengasuhan bayi di mana sahaja dan bila-bila masa melalui rangkaian internet. Akhirnya, sistem pemantauan bayi terbukti berfungsi untuk memantau keadaan bayi dan suhu sekitar prototaip yang dibina.

ABSTRACT

The number of working mothers has greatly increased compared to the past few decades. Subsequently, baby care during daily life has become a challenge to many families. Thus, most of parents used to send their babies to grandparents' house or baby care-house to take care of their babies. However, the parents cannot continuously monitor their babies' conditions either in normal or abnormal situations. Therefore, this project proposes an efficient and low-cost Internet of Things (IoT) based system for baby monitoring in real time which can play a key role in providing better baby care while parents are away from their babies. In system design, NodeMCU Wi-Fi Controller Board is exploited as the main microcontroller to gather the data read by sensors and upload to the AdaFruit MQTT server. The proposed system exploits sensors to monitor baby's vital parameters such as surrounding temperature, moisture, and crying. The sensors used in this project are KY-038 sound sensor and DHT22 temperature and humidity sensor. Proteus software is used to check the connection of the circuit and Arduino IDE is used to check errors on codes and compilation of the code into the microcontroller. Nx Siemens software is used for designing the baby cradle. Red meranti wood is used as the material for the baby cradle. For the building of baby cradle, woods are carefully cut and handled using the tools and machines available in UMP to ensure safety. The system architecture consists of a baby cradle that will automatically swing using a motor when the baby cries. Parents can also monitor their babies' condition through an external web camera and switch on the lullaby toy located on the baby cradle remotely via the MQTT server to entertain the baby. The proposed system prototype is being fabricated and tested to prove its effectiveness in terms of cost, simplicity, and ensure safety operation to enable the baby-parenting anywhere and anytime through the network. Finally, the baby monitoring system is proven working for monitoring the baby condition and surrounding temperature on the built prototype.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

V	Voltage
A	Ampere
ºC	Degree-Celcius

LIST OF ABBREVIATIONS

MQTT	Message Queuing Telemetry Transport
SIDS	Sudden Infant Death Syndrome
NICHD	National Institute of Child Health and Human Development
IoT	Internet of Things
NODEMCU	Node-Microcontroller Unit
IDE	Integrated Development Environment
CoSHE	Cloud-based Smart House Environment
M2M	Machine-to-machine
GSM	Global System for Mobile communications
IBM	International Business Machines
LCD	Liquid-crystal display
LED	Light Emitting Diode
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, female participation in the work force in the industrialized nations has greatly increased in present society. This will bring disadvantage to infant care to many families in their daily life. Parents will worry about the health of their baby.

For low cost of living, both of parents need to word and look for their babies, therefore it will be more workload and stress to that families especially to their mother. With a baby monitoring system that consists of video camera and microphone with no limitations of coverage that can send the data can make an urgent situation can be quickly be noticed and handled within less time. Usually, when babies cried, the cause can be either they are hungry, tired, not feeling well or need their diaper changed.

Sudden Infant Death Syndrome, abbreviated as SIDS also known as crib death, people call SIDS as crib death because many babies who die of SIDS are found in their cribs. It occurs to infant younger than 12 months of age. Most SIDS death occur in infants younger than 6 months (Willinger, James, Catz, & Participants, 1991). SIDS is a rare case in Malaysia. Even though the professionals did not know what causes SIDS but they do know how to reduce the risk with is place the baby to sleep on a firm surface (crib mattress). One of it is never put the baby sleep on pillow or another soft surface. Researches do not know why sleeping on such surfaces would increase the risk of SIDS but they warn that could be dangerous (Academy et al., 2005). For instance, in 2003, a NICHD- supported study showed that placing an infant to sleep on soft bedding as opposed to on firm bedding appeared to pose five times the risk of SIDS (Infant & Syndrome, 2000). Secondly, avoid overheating during sleep. Babies should be kept warm during sleep, but not too warm. In winter or cold weather, the risk for babies get SIDS increase because the parents will overdress or place under heavier blanket, which can give them overheat (Malloy & Freeman, 2004). So, in general if the room temperature is comfortable for an adult, then it is appropriate for a baby.

Therefore, we developed a prototype which can monitor the activities of the babies along with finding one of the above causes and give this information to their parents in this project. This should give parents a better sleep at night because it able to keep track of baby conditions in easy way and every parents and guardian could use it. The proposed project will be using the Internet of Things concept, which is one of the technology pillars in the Industry Revolution 4.0 (IR4.0)(Vaidya, Ambad, & Bhosle, 2018). The information of the measured reading from the sensors can be reached to the user through the network just within few seconds.

The Internet of Things, abbreviated as IoT, simply refers to a network of objects that are connected to the internet. It provides devices with the ability to transfer sensor data on the Internet without requiring intervention. Since the Internet of Things is such a broad category, it encompasses many devices and is growing at a rapid rate. In 2015 there were approximately 15.4 billion IoT devices. IHS Markit, a financial resource company, expects there to be 30.7 billion IoT devices by 2020 while Intel, a technology company, expects there to be 200 billion by 2020 (Kelvin Claveria, 2017). Currently of the 15.4 billion devices, about 28.3 million are wearable, but that number is expected to increase to around 80 million by 2020.

The total global spending on the IoT in 2016 was 737 billion dollars and was projected to reach 1.29 trillion dollars in 2020 as shown in Figure 1.1. As one can see based on the numbers alone, the IoT is a prominent field that will only getting bigger. The figure 1.1 shows that IoT is growing exponentially. The function of IoT is to control, real-time monitoring, autonomy or autonomous function and optimize. Perhaps one of the main reasons why the IoT is so large is that it aims to make life more convenient, and people are more likely to invest in things that make their lives easier. The IoT is integrated into our baby monitoring system for a quick response time and to provide a greater sense of security for parents during the daily life.

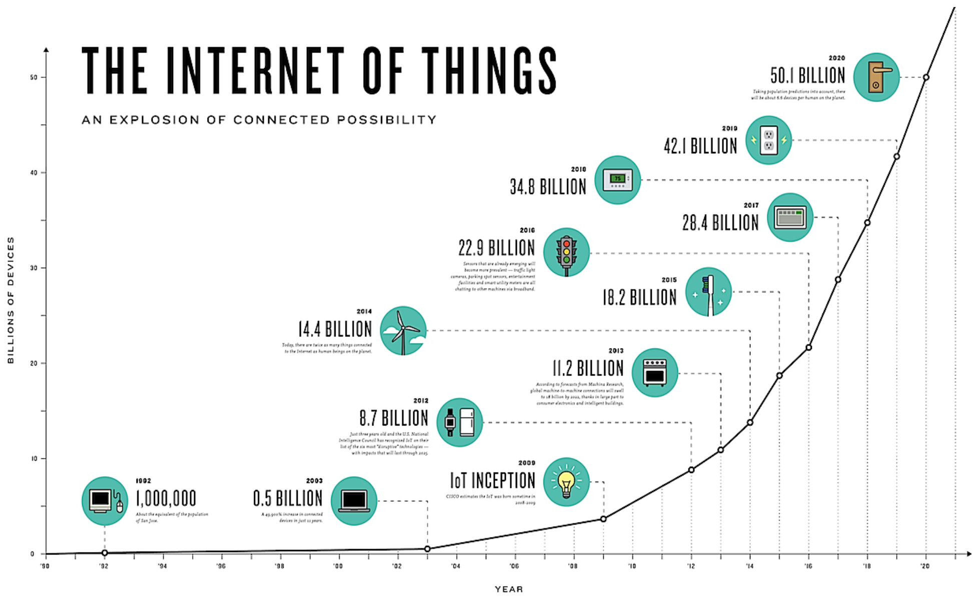


Figure 1.1 Increment of devices connected to internet
Source: Kelvin Claveria (2017)

NodeMCU Wi-Fi Controller Board is an open source IoT platform and is used as the main micro-controller in this project. It is basically used to gather data read by the sensors and upload the data to the MQTT server. Besides, it also receives commands given by the user to do specific tasks via the MQTT server. NodeMCU consists of physical programmable circuit board like any other development boards do, such as Arduino board and Raspberry Pi. The programming of the NodeMCU can be done by using Arduino software which is an Integrated Development Environment (IDE) to a write the code of instructions and upload to the micro-controller.

1.2 Problem Statement

In today's fast paced life, everyone is busy in their professional life including parents. They might leave the home early in the morning and come back right before dinner time. That shows how busy someone can be. Nowadays, even the mothers are working, it becomes a problem when they do not get enough time to take care their babies. Not all parents could afford a nanny to help them with their children. After long working hours, the moms still had to manage the house and had to take care of their babies simultaneously on a tired condition.

Secondly, parents might not have time to swings their baby to sleep or rocking their baby back to sleep in the middle of the night. Studies have been carried on the effect of rocking on a baby and concluded that baby sleeps better while being rocked or swung lightly (Pederson, 1969; Bayer et al., 2011). This is because the rhythmic movement mimics the gentle rocking they felt while in the mother's womb (Barnard, 1972). Most of the available automated cradles were designed to rock non-stop but this can cause the baby became nauseous and uncomfortable. Thus, unable to swing baby to sleep every moment especially middle of the night is also one of the problems.

Next, not all the babies were placed in the same room as the parent sleep. This can cause the parents did not hear well if their baby was crying. Or parents were too busy doing house chores around the house until cannot hear if their baby needs their attention. Moreover, sometimes baby just need a little distraction until they can completely get in deep sleep. There are several types of baby cradle that available in stores but the costs for most of them were quite high and not everyone can afford it. Thus, parents are unaware enough to give full attention to their babies while doing house chores.

1.3 Objectives of Project

The main aim of this project is to develop an efficient and cost effective IoT-Based baby monitoring system. To accomplish this, the following objectives must be achieved:

1) To design and fabricate a simple baby cradle that can swing automatically based on baby conditions and provided with web camera, relaxing sounds and musical toys.

2) To implement an IoT-based monitoring system by utilizing sensors and NodeMCU Wi-Fi Controller Board and enabling data transmitting to AdaFruit MQTT server.

3) To examine and evaluate the performance of the developed prototype and validate its effectiveness.

1.4 Scope of Dissertation

The scopes that are related to this project are:

1) This study focuses on designing a baby monitoring system that can real time monitoring the babies at the ages of one month to one-year-old and protects the safety of the babies with designed cradle.

2) Establishing a control system through the internet to remote the switches built in the system and read recorded data in the MQTT server.

3) Establishing programming codes for NODEMCU microcontroller to interact with the MQTT server by publishing and subscribing feeds.

4) Utilizing a suitable app that can supports both android and iOS version by linking the app to the MQTT server to enable the reality of real-time monitoring anywhere and anytime.

1.5 Thesis Contribution

The expected outcome of this project is that the baby cradle will be able to rock by levels according to the baby crying decibels. When baby starts to cry, the cradle will start to swing slowly then gradually increase the speed based on the crying of the baby. Due to the sound sensor limitation, the detected sound value is fluctuated and not very accurate. The system is then modified become the cradle will swing whenever sound detected value exceed the threshold value. A mini fan will turn on when the cradle's surrounding temperature exceeds 28^{o}C. Other than that, parents can remote the cradle, mini fan and toy using mobile apps or laptop through the network. Parents also can see their baby condition using wireless camera and talk with their baby through built-in microphone in the wireless camera. However, the wireless camera is only able to connect in local network, which means the user had to connect to the same network as the wireless camera connected in order to use the wireless camera.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we will discuss about the Internet of Things (IoT) concepts, the history of baby cradle, market available products and some related works. Some examples of the hardware and software that are used in this project will also be mentioned.

2.1 Internet of Things (IoT) Concept

The term “Internet of Things” is first coined by Kevin Ashton executive director of the Auto-ID Centre in 1999 (Ashton, 2009). In 1999, Ashton proposed a concept that could improve the business of Proctor & Gamble(P&G) by linking Radio Frequency Identification (RFID) information to the internet (Lopez Research, 2013). RFID and sensor technology allow the computer to record the track of the products and identify the quantity of products without spending too much money on hiring workers to those tasks.

Internet of Things (IoT) is the idea of data and information exchanges by connecting any devices to the internet and to other devices, which is known as machine-to-machine (M2M). IoT is a massive network that connects things and people together by collecting data on the sensors embedded in a device or people themselves share the data to the internet via various communication protocols (Jen Clark, 2016). The things can be various sizes and shapes from a mini-size sensor to an advance automation car, which has up to hundreds or thousands of detective sensors.

With the aided of Internet of Things cloud-computing servers, all data uploaded to the servers will be aggregated and analysed to become valuable information or data to address specific needs. The information can be used to display reading patterns in term of graph, and then detect possible occurring problems before things go bad and give recommendation or alert the user.

Figure 2.1 Wearable health tracker
Source: Jen Clark (2016)

Many of us have a smartphone, a device that can connect to other device through various protocols, it is also considered as an IoT device. Figure 2.1 showed a smartphone is connected to a wearable health tracker to view the data read by the sensors in the health tracker. With the emerging of technologies, more and more smart devices that can connect to the internet have been produced such as wearable health tracker, smart home devices, smart cars, city road systems and more. The market research companies had made an estimation that devices connected to the internet will have a huge increase from 16Billions in 2014 to 50Billions by 2020, which means this situation will create a global market for IoT products and services in coming future (Weinberg, Milne, Andonova, & Hajjat, 2015).

IoT is widely used in modern smart home application recently as the technologies are getting more advance. Before the era of IoT started, a smart home application was involving simple application control with Bluetooth connection. However, the advancing technology is enabling the control of the home from anywhere to be possible via the internet. G. Demiris and B. K. Hensel had explained that a smart home is an advance technology that can monitor the activities in the home to maintain and even enhance functional health, security, safety and life quality of the residents (Demiris & Hensel, 2008).

Healthcare is another field that are starting to use the IoT. Not just in hospital area, remote health monitoring can be used at home to monitor non-critical patients to reduce unnecessary waste of resources like doctors and beds. The measured data can be viewed by the doctors in hospital through the internet to analyse and predict the health condition of the patient. (Baker, Xiang, & Atkinson, 2017) mentioned that the IoT based systems for remote health monitoring will become crucial to healthcare in the future. It will provide an easy access to patients who are living in rural areas or elderly patients to live independently at home. (Pham, Mengistu, Do, & Sheng, 2018) presented a Cloud-based Smart House Environment (CoSHE) that enable accurate home healthcare monitoring that allow the patients to stay at their comfort homes. However, a full medical check-up is advised to be done yearly to have a better understanding on the health condition.

2.2 Baby Cradle History

Figure 2.2 Boxes Mounted Cradle

A baby cradle is a small cradle that is designed for baby to sleep in. Before babies had cradles like nowadays, parents used to be sleeping with their babies. The earliest type of cradle was known as a rocker and was made from a hollowed-out log. Simple boxes mounted on curved pieces soon had replaced the rocker. Early American colonials used cradles that had sloping sides and a hooded end, as shown in Figure 2.2.

Figure 2.3 Hanging Cradle

The design for a baby cradle is changing across time. In 1800's, the cradle hangs on a wooden pole at the ceiling and the cradle itself is made from natural breathable cotton, as shown in Figure 2.3. A futon mattress is put in the cradle so that baby is completely comfortable while resting on it. A cradle has become compulsory for new parents to keep their baby to have a comfortable sleeping place as well as a safety place to prevent fall from bed.

Figure 2.4 Modern Hanging Cradle
Source: I. (2012)

Then, the cradle in Figure 2.4 is designed to hang under springs held by metal frame to enable the cradle to be moved around, unlike the cradle in Figure 2.3 which is fixed at a certain place. Modern cradles vary in size and shape and some are even available with motors to rock the cradle automatically, for example the MamaRoo shown in Figure 2.6 and the SNOO smart sleeper in Figure 2.7.

A baby cradle can be one of the safest places for a baby to sleep other than parents' cuddles. A baby cradle might look like an adult bed in first view, but baby cradle has been designed specifically for the needs of infants and little children. It is a place for baby to get some rest as well as fall asleep to the morning. Using a baby cradle can also make it a lot easier to get the babies off to sleep, if you employ a gentle rocking motion along with the security, the rocking feels will work together to get your baby to drift off to sleep. Compare this to having your baby sleep on a straight mattress, whether it is a bed or a crib. It is clear to see the advantages of using a cradle.

Figure 2.5 Baby Prone Sleeping Posture
Source: Cornwell, Ph, & Einstein (n.d.)

A benefit of baby cradle is to reduce the risk of Sudden Infant Death Syndrome (SIDS) and it's the leading cause of death for babies within one-year-old life (Cornwell, Ph, & Einstein, n.d.). SIDS is more likely happen among babies placed on their stomachs to sleep as shown in Figure 2.5 than among those sleeping on their backs. Incidences of SIDS have been proven to be higher in babies that sleep on their stomach. For your information, SIDS is not any one illness or disease. Rather, it is the diagnosis given when a child under a year- old sudden death without able to detect the real cause after a death scene investigation, an autopsy, and a review of the child's medical history. That it can happen without warning makes SIDS particularly devastating for families.

2.3 Products Available in Markets

As the advance in technologies in the 20th century, there are various type of baby cradles on the market with not just safety protection function, but also with some smart features that can reduce parents’ burden and increase both babies’ and parents’ sleeping time. The following description show some elaborations on the currently available baby cradle products that can help the parents to take care of their loved-one.

a) **MamaRoo by 4moms**

Figure 2.6 MamaRoo
Source: 4moms: Meet the 4moms® mamaRoo® infant seat. (n.d.)

MamaRoo is a product available in the market that has the function of bouncing up and down and swaying side to side, just like parents do while holding the baby. According to the product’s advertisement, the company claimed that they set up sensor vests on parents to understand those motions and then replicated the bouncing and swaying in the mamaRoo to soothe and entertain better than traditional infant seats. Alan Lantzy, MD, a neonatologist and paediatrician, said that “The mamaRoo is calming because it provides an environment that is similar to still being in utero, babies feel contained, they’re moving, there’s a bit of sound and we find that very soothing for our babies.” (“4moms: Meet the 4moms® mamaRoo® infant seat,” n.d.)

It comes with 5 different unique motions, which are car-ride motion, kangaroo motion, tree-swing motion, rock-a-bye motion and wave motion. These motions can be selected according to the baby’s favourite and the speed is adjustable. Besides, it is MP3 compatible with Bluetooth enabled cradle where the parents can control the motion and sound from their smart devices. The product comes with an adjustable seat recline and interactive toy balls for the comforts of the baby.

This product is mainly focus for baby from birth to child that reaches a maximum weight limit of 25pounds (11kg). The materials used are classic and plush fabrics which are washable and easy to take off.

b) **SNOO smart sleeper**

Figure 2.7 SNOO Smart Sleeper
Source: SNOO – Happiest Baby. (n.d.)

SNOO is a product of *Happiest Baby*, a smart-tech and parenting solutions company. It supports 2.4 GHz wireless, 802.11 b /g /n with separate Wi-Fi control switch for the parents to control via Wi-Fi. It can boost baby's sleep with soothing white noise and motion. From their product advertisement, it is known as the safest baby bed in the market ("SNOO – Happiest Baby," n.d.). It has a responsive surrounding light sensor for detecting the surrounding light intensity to adjust the built-in LED intensity.

It has a gently rock function to assist the baby to be a good sleeper during naps or nights with no noisy sound from gears or springs. It has several microphones with leading audio processing to detect sound accurately. Once the sound is detected, it has embedded system that will play three distinct white-noise sounds to calm the baby as well as to enhance sleep. The system will choose soft rain sound for sleeping purpose or womb sound if baby is crying. For the motion, the system will choose the motion that suits the baby either slow swing for sleep or faster jiggles to comfort upset baby.

SNOO comes with a protective swaddle wings that will keep the baby safely. Baby is wrapped in a SNOO Sack and the SNOO Sack's wings have to be slide on the safety clips to the baby sleeps on his back. SNOO will only start to swing when the baby has been wrapped with SNOO Sack and clipped to the safety pin. SNOO comes with organic fitted sheet and 3 SNOO Sacks with organic cotton, which are user-friendly to prevent allergies on baby.

c) Raybaby

Figure 2.8 Raybaby Smart Monitor
Source: Raybaby - World's First Non-Contact Vital Monitor. (n.d.)

Raybaby was invented by RIoT (Ray IoT) Solutions, a startup founded in 2015. Raybaby is a baby monitor product that can tracks respiration, movements and sleep patterns using a technology that works on the principle of ultra-sound ("Raybaby - World's First Non-Contact Vital Monitor," n.d.). It alerts parents when the baby experiences variations in respiratory or breathing rate. Such variations have been associated with fever and other conditions like asthma or bronchitis. It alerts the parents also when the baby rolls-over or does any sudden movements.

In addition, Raybaby comes equipped with an integrated infrared video camera that enables live video streaming even in pitch darkness, built in speakers, and audio monitoring that uses a highly sensitive microphone. Many vital and movement trackers have wearables for the baby, some even containing lithium-ion batteries. Lithium-ion batteries are considered a safety risk to infants, and other wearables require upgrades depending on your baby's growth. Raybaby on the other hand is completely non-contact.

It constantly monitors the baby from a distance, analyses and relays any change in their sleep, roll-over movement and breathing pattern along with a host of additional baby health information. Whenever the baby is not in line of Raybaby, it will notify the parents through the internet. Raybaby has revolutionized existing cumbersome and invasive techniques to accurately collect health data of babies that include sleep, movement and breathing data.

Other than that, parents can access the monitoring of the baby condition with smart devices via internet. It can receive audio and video where parents can view them on the internet and talk to the baby through Raybaby whenever they are outside the house. Parents can create custom playlist in Raybaby and playback the music or sounds whenever the playlist is finished played.

2.4 Related Works

A baby monitoring system is proposed by suggesting an enhanced noise cancelling system which has the function of monitoring the baby and reducing sound pollution. The main function of the system is to reduce the noise that might disturb the baby by playing relaxing songs. This system can also adjust the room's light intensity with the aids of light sensor. (Brangui, El Kihal, & Salih-Alj, 2015) However, this system could have some advance improvements such as the implementation of the web camera and transfer data via network to the user.

Misha Goyal introduced her low-cost E-baby cradle that can swing automatically when it detects baby crying voice and stop swinging when the baby stops crying (Goyal, 2013). The speed for the swinging cradle can be controlled based on the user's need. It has an alarm embedded in the system, which will notify the user when 2 conditions occurred. First, the alarm will alert when the mattress is wet, it indicates that it is time to change the mattress to keep the baby hygiene. Second, whenever the baby does not stop crying for a certain time, the alarm will ring to alert the parents to spend their times on the baby, whether the baby need to change diaper, or the baby is hungry. However, it is only applicable when parents are available near the cradle since it uses only the buzzer as an alarm to alert the parents, the buzzer alarm itself might frighten the baby as well. Parents cannot monitor their baby when they are not available at house compound, for example during work time or travelling on other places.

A new approach of automatic baby monitoring system has been proposed. (Palaskar, Pandey, Telang, Wagh, & Kagalkar, 2015) They have proposed a low-budget system which will swings the cradle when baby crying sound is detected, and the cradle will stop when the baby stop crying. The inbuilt alarm will alert if either one of the following conditions (the mattress is found wet or baby did not stop crying after a certain period) is hit. A video camera is placed above the cradle to monitor the baby. Even so, the parents can only receive the notification via SMS which could be improved to a better level, such as via internet. In other words, the parents can access an account via cloud platform to monitor the baby condition anywhere and anytime they want if there is any further improvement by connecting to the internet.

An Arduino-based resonant cradle design with infant cries recognition was proposed by (Chao, Wang, Chiou, & Wang, 2015). First, a ball bearing design is adopted to reduce system damping and let the cradle swing freely, even without electricity. Subsequently, an appropriate sensor is designed to detect the swinging status or angle. Finally, the force is put under the cradle to increase torque, but it engages only during a critical time. In other words, a small motor rotation angle is enough to make the cradle swing. The proposed design is an improvement on previous intelligent cradles as it naturally achieves the energy saving target in accordance with resonance theory. In addition, it has a much lower operating noise which will be welcomed by parents. The infant cries recognition is designed to increase the functionality of the proposed resonant cradle. Infant cries recognition provides inexperienced parents or babysitters with a reference for when an infant cry. With this function, the intelligent cradle can start swinging autonomously when the baby cries and stops when the swinging motion is no longer needed. The proposed design allows parents to record infant cries due to hunger or pain on a SD card stored in SD module.

(Symon, Hassan, Rashid, Ahmed, & Reza, 2017) have presented a paper on designing a baby monitoring system based on Raspberry Pi and Pi camera. The authors have designed a system that will spot the motion and crying condition of the baby. They used condenser MIC to spot the crying condition of the baby. PIR motion sensor is used to spot the movement of the baby meanwhile Pi camera is used to spot the motion of the baby. The camera will be turned on only when the condenser MIC sensed any sound, which will send a signal to Raspberry Pi. However, the output of this system is only available on monitor display; in other words, the parents can only see the data in limited area.

(Kaur, 2017) propose a system that can monitor pulse rate and body temperature of the person with dedicated sensors along with Raspberry Pi and IoT. According to Kaur, the system is wearable to monitor the health condition by storing the data read by the sensors to Bluemix cloud. The data stored will update to doctor for health analysis and abnormality detection of the user. The pulse rate and temperature of the user are measured by using KG011 (heart rate sensor) and DS18B20 (temperature sensor). Then, the readings are shown at IBM Watson IoT Platform in the graphs form. The article proposed a good point about using the sensors to send data to the IoT platform. However, this system is not suitable for infants since their body immune systems are weaker than adults. There is concern that this wearable system might emit some radiation that could harm the infants and cause some side effects.

Patil & Mhetre (2014) had presented a monitoring system based on GSM network. They built a prototype that can measure infants' pulse rate, body temperature, movement and moisture condition and send information through GSM network. It consists of sensors, LCD screen, GSM interface and buzzer, which are controlled by PIC 18f4520 8-bit microcontroller. The LCD module will show the result measured by the sensors and the GSM interface will send alert to the user mobile number. Although the system was proposed to monitor the baby condition, proper control actions are required to take accurate readings since baby could has crawled around and the sensors might be detached. The baby might also get injured or electric-shock whenever the parents are not at house compound and the baby touches the system circuit. The system should be improved in terms of baby safety and user-friendly.

(Saadatian et al., 2011) proposed a mobile-based system that enable parents to get updated to the infants' status. The system measured the temperature, motion and heart rate then sent the data to server to be analysed. The analysed data will then be sent to parents and generated alert system if any abnormal is found. Parents will receive advisory first-aid information to immediate action, and nearby clinic will be notified by the system. The system was put on trial on adults during the prototype stage by collecting data and analyse it. They hoped to use GSM technology instead of currently using Bluetooth module in future as the communication component. They will also add other features such as position monitoring and other behaviour monitoring analysis like crying analysis into the system for future improvement.

(Mohamad Ishak, Abdul Jamil, & Ambar, 2017) have proposed on designing a monitor system that use an incubator that has pulse sensor attached on infant to measure infant's pulse rate and humidity sensor to measure humidity level. The recorded data will be sent to the computer through Arduino microcontroller, where the data can be referred by the Neonatal Intensive Care Unit (NICU) personnel for diagnostic purposes. An alarm system is designed to send alarm whenever the data readings reach danger level to prevent harmful situation. They had put the system on trial on infants from three level of ages, which are 0-3 months, 3-6 months and 6-12 months. However, the data recorded can only be transferred direct to computer and that can be improved by adding Wi-Fi module to send data via the internet. By doing so, infants' conditions can be monitored anywhere at any time.

(Chien, 2008) presented an ARM embedded platform project for baby monitoring. He proposed a system consisting of embedded system platform with a Linux kernel 2.4.18 operation system using TCP/IP protocol, CMOS image sensor and control system. The system is used to monitor baby activities and room environment through a web browser. If the system detected baby's cries, it will alarm the parents by transmitting the audio signal to parents' room. He used ARM9 processor as the CPU for the coordination of the system. A bi-directional triode thyristor (TRIAC) is used as power regulation component in light control unit and the infant's body temperature is measured by a TMP75 temperature sensor together with a wireless module to send temperature readings to the platform. An LCD display module is used to display the measured readings. There is an improvement can be implemented in this project by designing a cradle that is installed with this system to make the cradle swings itself whenever it detected baby cries to entertain the baby so that parents do not need to rush back home to take care their baby when they are outside the house.

2.5 Baby Monitoring System Components

The following section describes the hardware and software that are being used in this project.

A. <u>Hardware Lists:</u>

1. NodeMCU ESP8266 Wi-Fi Controller Board
2. 12V DC Power source
3. 4 channel 5V Relays module
4. Sound sensor module
5. Temperature & Humidity sensor
6. Mini fan
7. 12V DC Geared motor
8. Wireless Security camera
9. Baby cradle

B. <u>Software Lists:</u>

1. Arduino IDE software
2. MQTT Protocol server
3. Proteus Stimulation
4. Fritzing software
5. Nx Siemens software

Figure 2.9 NODEMCU Wi-Fi Controller Board
Source: Nodemcu. (2017)

NodeMCU ESP8266 Wi-Fi Controller Board V2

NodeMCU(Node Micro-Controller Unit) is the a open source software and development board that is embedded with a System-on-chip(SoC) named ESP8266, which was designed and manufactured by Espressif Systems(Michael Yuan, 2017). It is a self-contained Wi-Fi networking solution offering as a bridge from existing microcontroller to Wi-Fi and is also capable of running self-contained applications (Nodemcu, 2017). It has a built-in USB connector to be connected to the computer using a USB cable to upload coding, same as other development boards available in the market such as Arduino and Raspberry Pi.

Features:

Wireless 802.11 b / g / n standard
Support STA / AP / STA + AP three operating modes
Built-in TCP / IP protocol stack to support multiple TCP Client connections (5 MAX)
D0 ~ D8, SD1 ~ SD3: used as GPIO, PWM, IIC, etc., port driver capability 15mA
AD0: 1 channel ADC
Power input: 4.5V ~ 9V (10VMAX), USB-powered
Current: continuous transmission: 70mA (200mA MAX), Standby: <200uA
Transfer rate: 110-460800bps
Support UART / GPIO data communication interface
Remote firmware upgrade (OTA)
Support Smart Link Smart Networking
Working temperature: -40 deg ~ + 125 deg
Drive Type: Dual high-power H-bridge driver

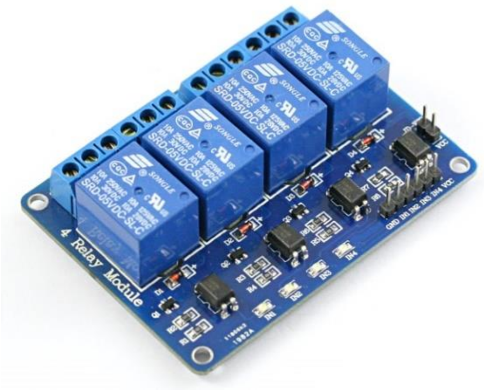


Figure 2.10 4 Channel DC 5V Relay Module

4 Channel DC 5V Relay Module

This is a LOW Level 5V 4-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with high voltage and current load. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by micro-controller ("Arduino IoT 4 Channel Ways Opto Isolator 10A 5V relay module," n.d.).

Features:

1) Relay Maximum output: DC 30V/10A, AC 250V/10A
2) 4 Channel Relay Module with Optocoupler LOW Level Triger expansion board, which is compatible with Arduino
3) Standard interface that can be controlled directly by micro-controller (8051, AVR, *PIC, DSP, ARM, ARM, MSP430, TTL logic)
4) Relay of high-quality loose music relays SPDT. A common terminal, a normally open, one normally closed terminal
5) Optocoupler isolation, good anti-jamming

Sound sensor module

A sound sensor is used for detecting sound intensity. It uses a microphone which transfers the input to the amplifier, peak detector and buffer. When the sensor detects a sound, it processes an output signal voltage which is sent to the micro-controller. Its accuracy can be adjusted for the convenience of usage.

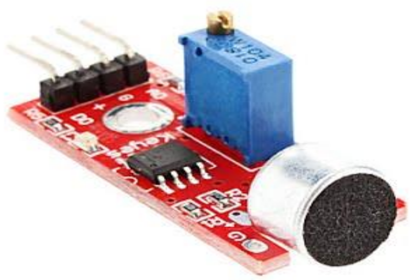


Figure 2.11 Sound Sensor Module

Temperature & Humidity sensor

Temperature and Humidity sensor consists of two parts, a capacitive humidity sensor and a thermistor. The humidity sensor measures and reports the relative humidity in the air. It therefore measures both moisture and air temperature (“what is a humidity, moisture sensors, temperature humidity sensor - Future Electronics,” n.d.). There is also a basic chip inside that does some analogue to digital conversion and spits out a digital signal with temperature and humidity values to be read by the micro-controller.

Figure 2.12 Temperature & Humidity Sensor

Mini fan

A mini fan provides strong wind with low power consumption. It comes with unique design, creative style, made of high-quality ABS, has a solid structure and pressure-resistant. With the clipper on the bottom, can be used in anywhere you want. The middle part and the cutting can rotate by 360 degrees without dead ends (“Rechargeable Portable Clip Mini Fan,” n.d.).

Figure 2.13 Mini Fan

Wireless security camera

The camera can send high-quality image and live video with sound through the internet. It can be connected to either wired or wireless network connections. It has a built-in motion detection alarm. When a motion is detected, the camera will send out alarm and record live pictures in TF card and send an alert message to the user phone or email automatically (“KKmoon Wireless Wifi 720P HD Security Camera,” n.d.).

Figure 2.14 Wireless Security Camera
Source: KKmoon Wireless Wifi 720P HD Security Camera. (n.d.)

DC Geared motor

The "gear motor" or "geared motor" is a motor having an attached "gear assembly" (or gear train) which enables the gear motor to provide greater torque at a lower rpm than the motor alone. A12V DC geared motor to control the speed and direction.

Figure 2.15 12V DC Geared Motor

Features

1. Low cost
2. High gear ratio and torque output
3. Compact
4. Balanced load distribution

Application

1. Automotive applications
2. Robotic applications
3. Used in industry
4. Power winches on trucks

Arduino IDE

Figure 2.16 Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them. Support for third-party hardware can be added to the hardware directory of your sketchbook directory. Platforms installed there may include board definitions (which appear in the board menu), core libraries, bootloaders, and programmer definitions.

Adafruit MQTT Broker/Server

Figure 2.17 Adafruit MQTT server

MQTT stands for Message Queuing Telemetry Transport. It is a publish/subscribe, extremely simple and lightweight messaging protocol, designed for constrained devices and low-bandwidth, high-latency or unreliable networks. The design principles are to minimize network bandwidth and device resource requirements whilst also attempting to ensure reliability and some degree of assurance of delivery. These principles also turn out to make the protocol ideal of the emerging “machine-to-machine” (M2M) or “Internet of Things” world of connected devices, and for mobile applications where bandwidth and battery power are at a premium.

Proteus Stimulator

Figure 2.18 Proteus Stimulator Software

The Proteus Design Suite is a Windows application for schematic capture, simulation, and PCB layout design. The suite combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete micro-controller base designs. Proteus has also the ability to simulate the interaction between software running on a microcontroller and any analogue or digital electronics connected to it. It simulates Input / Output ports, interrupts, timers, USARTs and all other peripherals present on each supported processor.

Fritzing software

Figure 2.19 Fritzing Software

Fritzing is an open source software initiative that allows the user to create and plan circuits out before creating them. The program comes with a bunch of pre-loaded circuit boards from different companies such as Arduino and Sparkfun. The user can use the given boards from the libraries to plan out the project accurately because they are made to be the actual size of the physical board. It is often used to build circuit in the Schematic view or the Printable Circuit Board (PCB) view.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology is a system of broad principles or rules from which specific methods or procedures may be derived to interpret or solve. This chapter explained in detail on the procedures of the implementation of control system in Baby Monitoring System. The methods used in this chapter are aimed to achieve the objectives of the project which will give satisfying results on the performance of control system in Baby Monitoring System.

3.2 Flow Chart of Methodology

Figure 3.1 shows the overall methodology of the project. Problems are identified through surfing the internet based on the monitoring of the babies. Several literatures reviews are made to find related projects and to think of the idea of combining the concept of IOT and the designed baby monitoring system. Modelling phase is where the phase of designing system, GUI of applications and prototype.

After the modelling phase, the designed baby monitoring system is then enhanced and optimised through several testing to get the expected outcome. After that, the system is installed on the prototype for testing phase before finalising the product. When the testing is failed due to some coding errors or other problems, the testing phase will be redoing again until the product achieved the expected outcome that satisfy the objectives of the project.

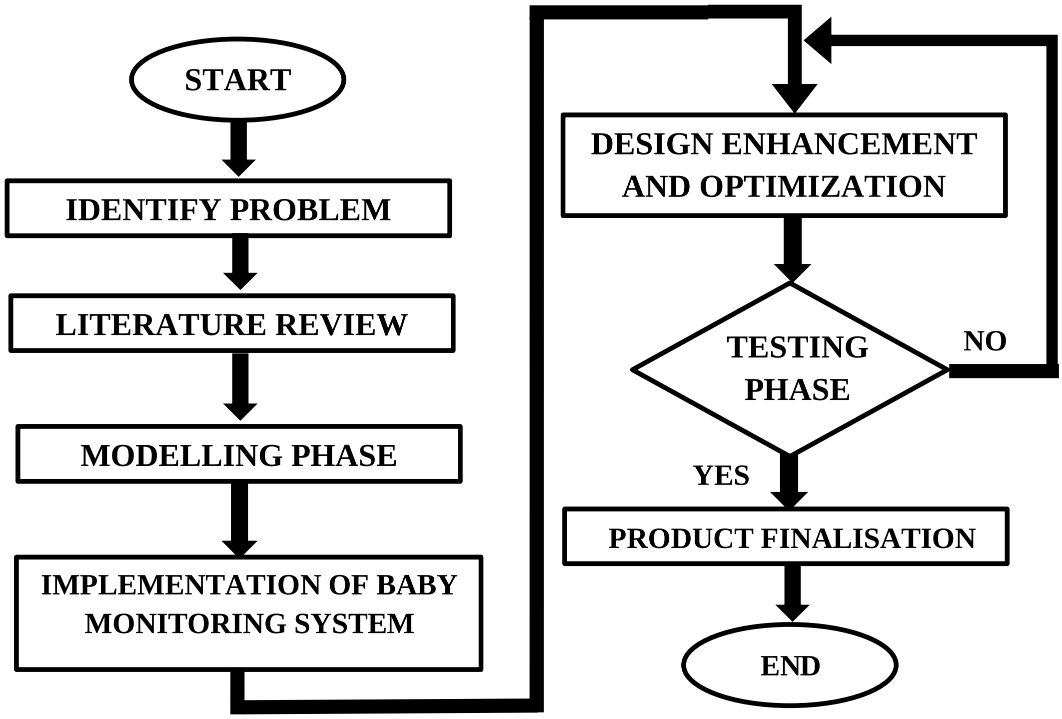


Figure 3.1 Project Process Flowchart

3.2.1 Identify Problems

In this phase, two problems had been identified as below:

- Some parents were placing their baby in the different room. So, parents could not hear the baby crying and could not continuously go to their baby room to swings and rocking their baby back to sleep in the middle of the night.
- With the existing system, there are many limitations, which is the output of this system is only available on certain area, so the parents can only see the data in limited area.

In order to overcome this problem, a new automatic IoT based baby monitoring system will be designed to allow the parents to be able to access an account to monitor the baby condition anywhere and anytime**.**

3.2.2 System Design

In this phase, the system design is separated into two parts, which are cradle design and program design. All the hardware and materials that will be used in building this system, which are suitable for the baby, were chosen. The priority is to make sure the chosen hardware is safe for the baby.

- For cradle design, a cradle prototype for Baby Monitoring System was designed. The building progress of the prototype can be found in Appendix C.
- In program design, the types of electronic components were decided and purchased to implement in the system. After that, coding was designed according to how the system was proposed.

3.2.3 Coding

An Arduino UNO is used as the basic tester to try out the codes and the equipment to make sure all the components, such as relay and sensors, were working well before compiling all the codes into the main controller board, the NODEMCU microcontroller. Several ideas of coding are learned and taken from the internet as the reference or foundation for the monitoring system, where most of them were from Home-automation projects.

The code for each sensor works as they were run by itself in Arduino UNO without interfering with other sensors. However, when compiling the codes together, there were a lot of errors in terms of contradicting and sequential. The arranging/sequence of the code must be rearranged according the idea of the whole baby monitoring system, whether which sensor runs first then followed by the next sensor with each respectively action once the sensors are triggered. Initially, the data/reading from the sensors is unable to upload to the Adafruit MQTT server, where the reading/data only can be viewed in the serial monitor of the Arduino IDE software. The relay module is only able to switch on/off by the sensors itself when a certain requirement was triggered, for example a fan connected to the relay would be turned on when the measured temperature by the temperature sensor (DHT 22) reached 30^{o}C or above. The user is unable to remote it through the internet, which is contradicted with the objectives of the project.

After some reconstruction on the coding, the reading obtained from the sensors, which was in value form, is able to upload to the MQTT server by using the special keyword “unknown.publish(value)”, where unknown is the declaration of an object and the value is the value that will be uploaded to the server. The example of the codes can be found in Figure 3.2.

```
if (! Humidity.publish(h)) {
  Serial.println(F("Failed"));
} else {
  Serial.println(F("OK!"));
  Serial.print("Humidity: ");Serial.println(h);
}
if (! Temperature.publish(t)) {
  Serial.println(F("Failed"));
} else {
  Serial.println(F("OK!"));
  Serial.print("Temperature: ");Serial.println(t);
  if(t>30)
  {
    Fan.publish(LOW);
    int Fan1_State = atoi((char *)Fan1.lastread);
    digitalWrite(Relay3, Fan1_State);
    }
```

Figure 3.2 The use of keyword “unknown.publish(value)”

In order to receive the command, for example TURN ON or OFF, from the server, the keyword mqtt.subscribe(&unknown) shown in Figure 3.3 is used to read the condition of the switches in the server(whether the switches were ON or OFF). After that, the condition is converted into integer numerical by using the keyword “atoi” to give the command to the NODEMCU to turn on or off the relay module.

```
  // Setup MQTT subscription for onoff feed.
  mqtt.subscribe(&Light1);
  mqtt.subscribe(&Fan1);
  mqtt.subscribe(&Light2);
  mqtt.subscribe(&Fan2);
}

uint32_t x = 0;

void loop() {

  MQTT_connect();

  Adafruit_MQTT_Subscribe *subscription;
  while ((subscription = mqtt.readSubscription(10000))) {
    if (subscription == &Light1) {
      Serial.print(F("Got: "));
      Serial.println((char *)Light1.lastread);
      int Light1_State = atoi((char *)Light1.lastread);
      digitalWrite(Relay1, Light1_State);
```

Figure 3.3 The use of keyword “mqtt.subscribe(&unknown)” and “**atoi**”

The problem of uploading and fetching the data to or from the MQTT server was solved but the relays are acting the opposite way from the command of the user. When the user remoted the relay to turn on via mobile apps or pc, the relay is turning off instead. Hence, the coding for receiving command from the MQTT server and turning on/off the relay is remodified by opposing the output and the received condition. The complete coding can be found in Appendix B.

3.2.4 Implementation of Baby Monitoring System

The control system in this system is equipped with 5V USB Power source, Sound sensor module, temperature and humidity sensor, Relays, NODEMCU, Baby Cradle and Geared motor**.** Figure 3.4 shows the stimulation of DHT22 temperature and humidity sensor in the Proteus software. After all the electronics stimulation in Proteus Simulation software are done, all the electrical and electronic components are assembled and connected to the micro-controller and being programmed by using Arduino software (IDE). Although NODEMCU can be compiled in Arduino IDE, it does not have same pin layout as standard Arduino UNO. Hence, the pin mapping of NODEMCU based on Arduino UNO is used during the circuit installation. The NODEMCU mapping diagram can be found in Appendix D.

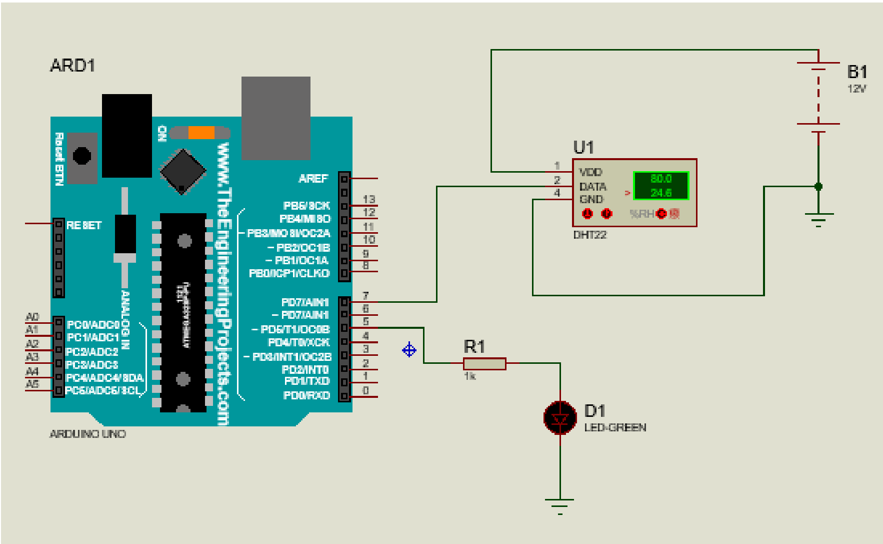


Figure 3.4 Proteus Stimulation

However, the Proteus software was not fully utilized because some of the components' libraries were not found in the software as well as in the internet. Therefore, the sensors and components had to be tested by trial and errors using Arduino UNO. A led is used as the replacement of the actuators due to the lack of the library in the Proteus software.

3.2.5 Design Enhancement and Optimization

This phase is useful to improve the system and can detect any error. In this phase, the error and problem that we faced during testing phase was identified and able fixed it. This step was repeated until a successful product was obtained.

In previous phase, Light-Emitting Diode (LED) was use as the replacement to read output, for example led as the replacement during trial for fan, motor and buzzer while waiting for the arrival of the real product. After compiling all the programming codes into the NODEMCU, the actuators such as buzzer, relay module and others were used as the real testing on the breadboard.

Figure 3.5 shows the connection and the testing of the outcome of the system for better optimization. In the coding, the fan was set to turn on automatically whenever the measured temperature reached 28^{o}C or above. The sound sensor was given a certain range of threshold values as the measured value by the sound sensor was having slight fluctuation. Whenever the measured value exceeded the threshold value, the DC motor connected to the relay would be turned on to swing the baby cradle.

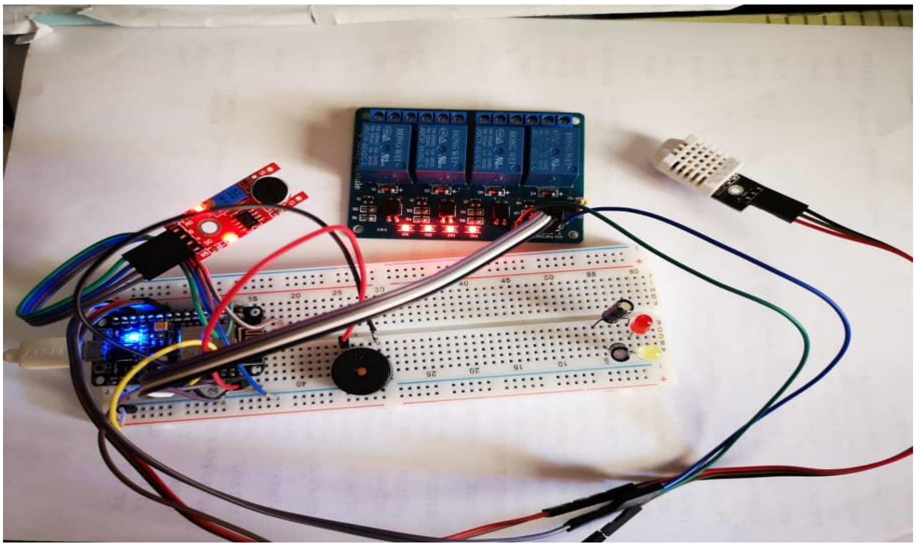


Figure 3.5 Connection of the sensors and actuators

3.2.6 Product Testing

After all the enhancement and optimization, some components are soldered on the Donut board. A pair of female headers are soldered on the donut-board for the microcontroller, where the microcontroller can be able to remove whenever any replacement might be requirement in future. Since the sound sensor and the temperature & humidity sensor are required to place outside the solder board to measure the surrounding readings, each of the microcontroller pins is extended using the female headers.

Each microcontroller’s female header pin was soldered to each extended female pin respectively on the donut-board and tested with the Digital Multi-meter to make sure the continuity and no short between each pin. Figure 3.6 shows the pin solder connection in top view and bottom view for better understanding purpose.

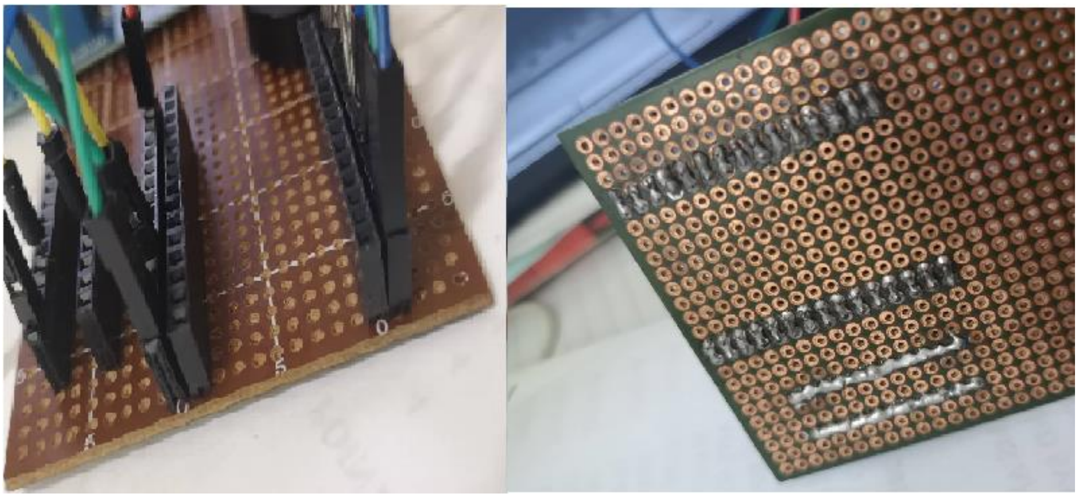


Figure 3.6 Pin solder connection

After the soldering process, the whole system is tested once again to make sure all the circuit connection, sensors and relays are properly installed. Other than that, the wireless camera is also tested but it is noticed to have some limitations. The wireless camera is only available for local connection where the user had to connect to the same wireless network in order to view the camera’s captured videos/images. The wireless camera can record video with memory card inserted and came with a built-in microphone where the user can talk to the baby.

3.3 Baby Cradle Design

Figure 3.7 Baby Cradle Design

This wooden baby cradle is made up of red meranti wood. It is designed as a classic baby cradle but has a newer technology mechanism. Most of the furniture that available at the market was made form Meranti wood. Technically, meranti wood is softer than other wood and it will ease the process of making it.

This baby cradle has rectangular shape and the fences consist 7 small bars that will block the baby from falling and baby still can have a look outside from their cradle. It has curve shape that means the base which is the lower part of the baby cradle has smaller size that the upper part. Furthermore, both side of the baby cradle is kept classic look by referring some of the past typed of baby cradle.

Other than that, all the electrical components are placed inside an electric box attached beside the wall of the cradle. It is placed there because it was secured, making it not effecting the working of the system and safe for the baby if there is any circuit shortage happen.

The cylinder that is on the top side of the cradle is to represent the baby musical toys that usually is placed on top of the baby head to calm the baby down and make the baby drowsy so that the baby can sleep easily. The baby cradle base is also made up from the meranti wood, but it is a little bit thick to ensure the safety and also by judging from the baby weight in Malaysia statistic.

3.4 Monitoring System

3.4.1 Baby Cradle

A Red meranti baby cradle is built in this project as shown in Figure 3.7. The cradle is designed to be connected to the shaft of geared motor and would swing when the switch is on by the user or the sound sensor detected baby cries. The progress of the cradle building can be found in Appendix C.

3.4.2 Materials Used

The material that has been used in this project is given below:

(i) NodeMCU
(ii) 12V DC power source
(iii) 4 Channel 5V relay module
(iv) Sound sensor module
(v) Temperature & Humidity sensor
(vi) Mini fan
(vii) MD10-POT 10Amp DC Motor Driver
(viii) Type-37 DC Geared motor
(ix) Wireless security camera
(x) Baby cradle

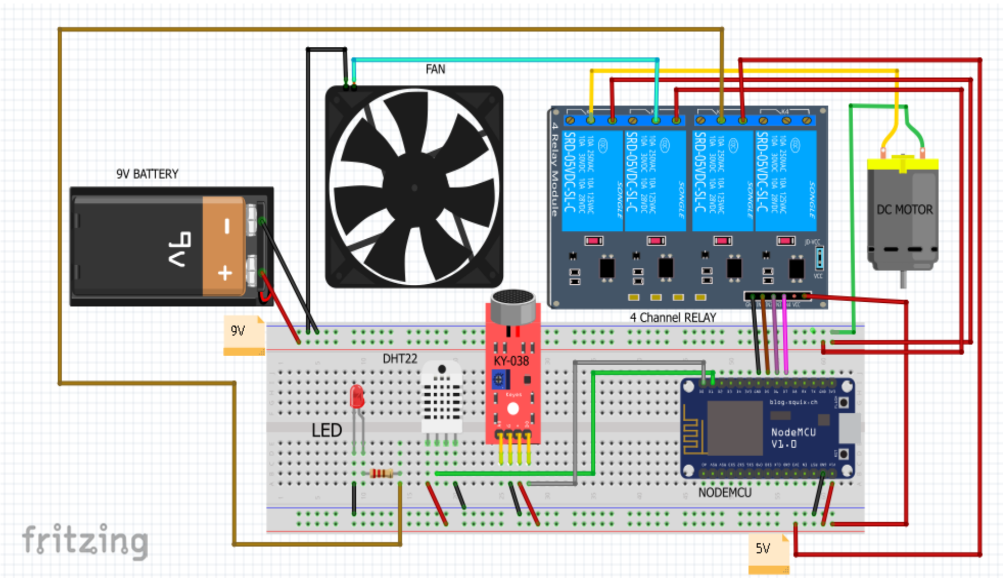


Figure 3.8 Components Circuit Diagram

In Figure 3.8, the circuit diagram shows the imaginary connection of components (i) to (vii) listed in chapter 3.4.2 using Fritzing software. The components are installed on the breadboard to make sure the system can work successfully before transfer the components to be soldered on the solder circuit panel. The shaft of the DC motor is connected to the baby cradle to enable swinging movement whenever baby cry is detected or remoted by the user. The LED in Figure 3.8 is a replacement to lullaby toy since the circuit designing software did not have the library of lullaby toy. The camera is installed externally to monitor the baby condition.

Figure 3.9 shows the actual donut-board connection after the optimization phase. All the electric components are working fine, and the system can operate as proposed.

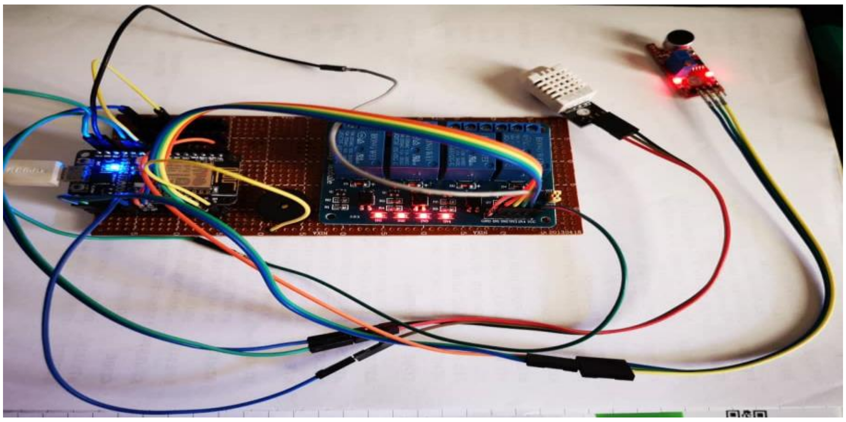


Figure 3.9 Actual connection on Donut board

3.4.3 System Architecture

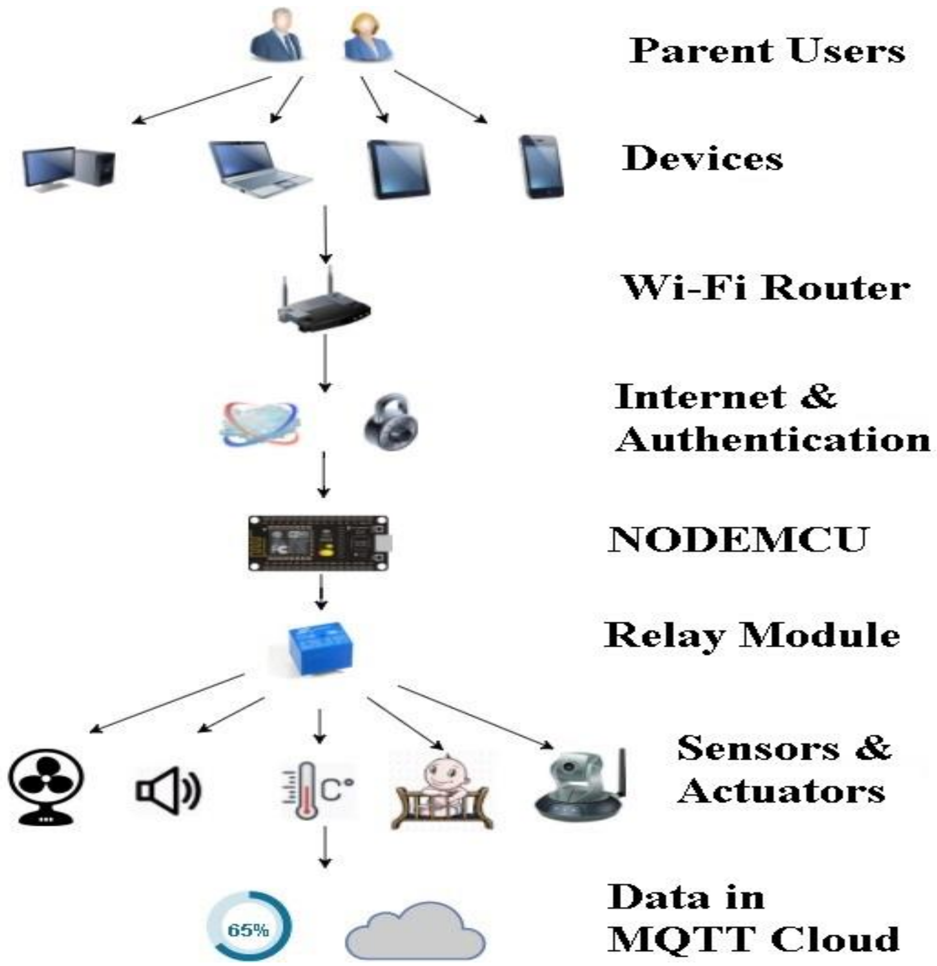


Figure 3.10 System Architecture

Figure 3.10 showed the overall system architecture of this baby monitoring system. The users can connect to the internet either through Wi-Fi or mobile data connection by using their smart devices such as PC, laptop, smartphones etc. Through the internet, the users can wirelessly remote and monitor the baby conditions by getting the data from the sensors and actuators connected to the NODEMCU. The system architecture consists of a baby cradle that will automatically swing using a motor when the baby cries. In addition, a mini fan will automatically open to give a cool temperature surrounding to the baby based on the temperature sensor. Parents can observe the normal data recorded in MQTT server cloud, such as room temperature and remote switches, through the Internet using MQTT server while the abnormal conditions conveyed to the parents with triggering alarm to take the proper actions. The parents can also monitor their babies' condition through an external web camera and switch on the lullaby toy located on the baby cradle remotely via the MQTT server to entertain the baby.

3.4.4 Hardware Process

Figure 3.11 showed the block diagram of the whole system. NodeMCU is used as the micro-controller to receive and upload data to the server with the embedded Wi-Fi module. When the sound sensor detects baby's cries, it will transmit output signal voltage to NodeMCU. Same goes to temperature and humidity sensor, the collected data will be sent to the micro-controller. After that, NodeMCU will upload the data to the MQTT server. In this project, we used Adafruit.io as the MQTT server for speed and ease data uploading. Parents can monitor the data in the server by login the server account using any device that has internet access. Parents can also switch on the DC motor, mini fan and lullaby toy if they wanted to by press the switch icons in the server. The server will then send the command to the micro-controller to switch on the relays. An external wireless Wi-Fi security camera is installed to enable the parents to real-time monitoring their babies.

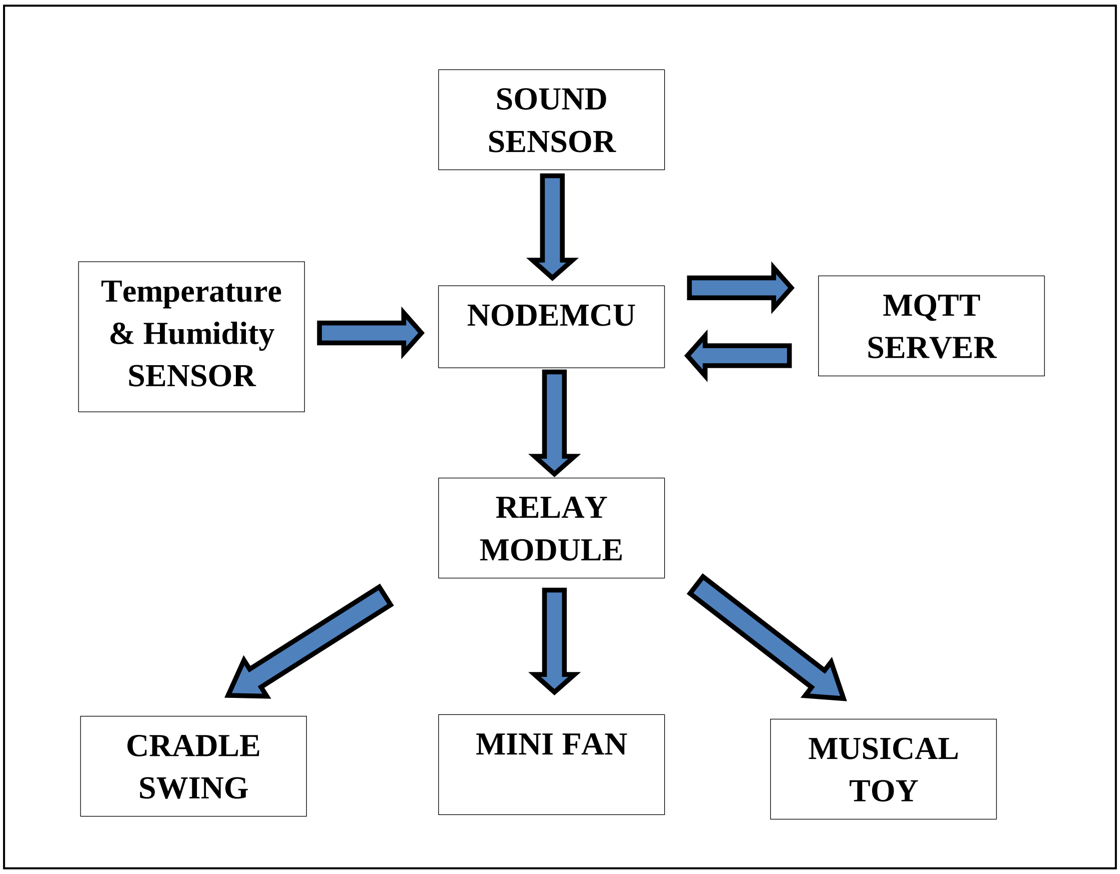


Figure 3.11 Block diagram for system's electronic component workflow

3.5 System Flowchart

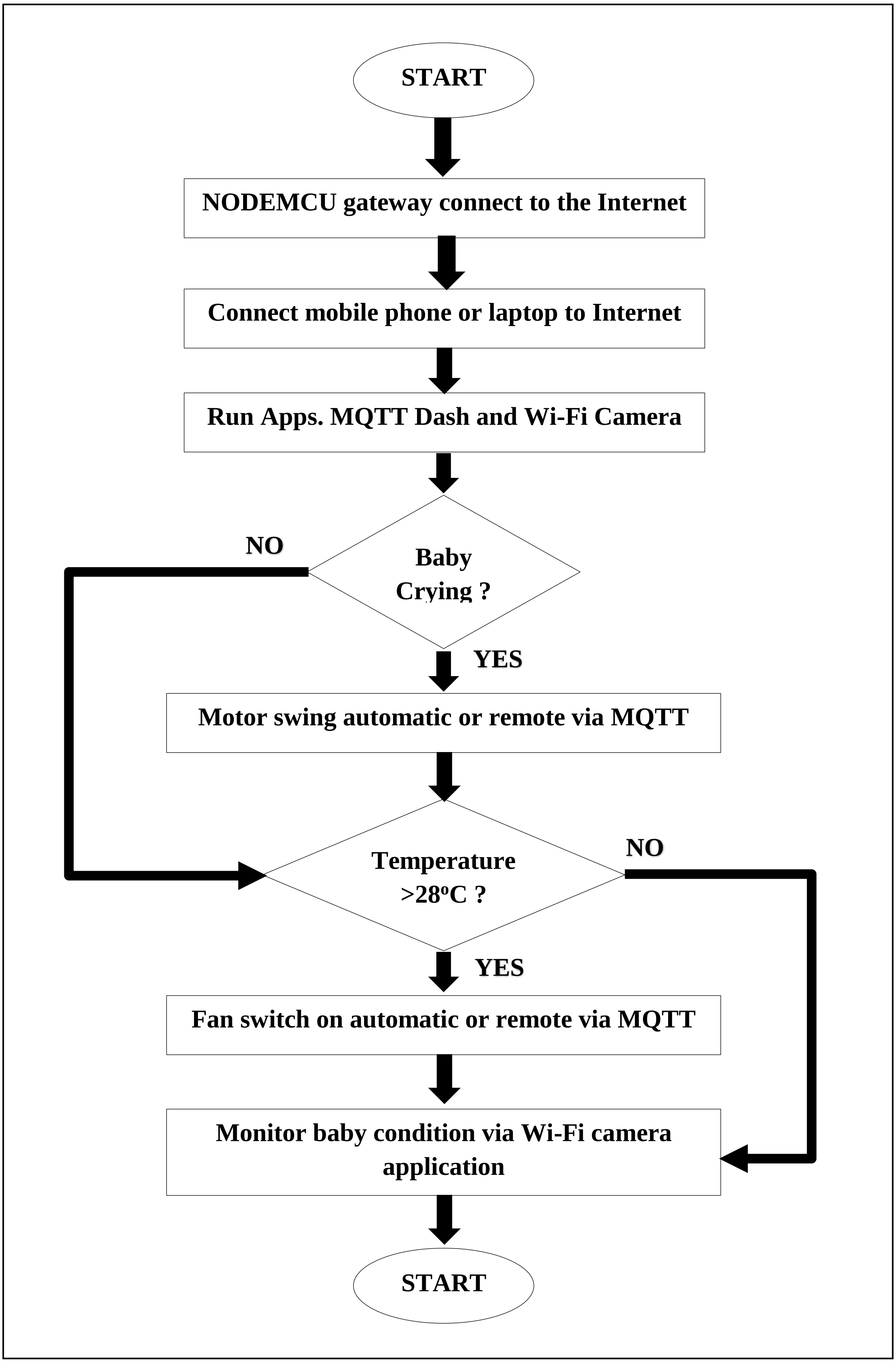


Figure 3.12 System Flowchart

Figure 3.12 shows the general work flow of the baby monitoring system. First, the microcontroller will search for the pre-set WiFi network once the microcontroller is powered on. The buzzer will ring for one second to indicate the microcontroller is connected to the WiFi network.

Next, the sound sensor will detect sound from the surrounding. The measured reading might fluctuate due to the wind or noise. Hence, a range of threshold value was set for the fluctuate detection so that whenever baby crying was detected, the measured value will exceed the threshold value and swing the cradle by turning on the Relay 1 connected to the DC Geared motor.

After that, the temperature sensor will measure the room temperature and turn on the mini fan when the room temperature exceeds 28^{o}C. In between the process, the measured reading will be uploaded to the MQTT server and the condition of the relays will also be upload to server every time the relays were turned on or off.

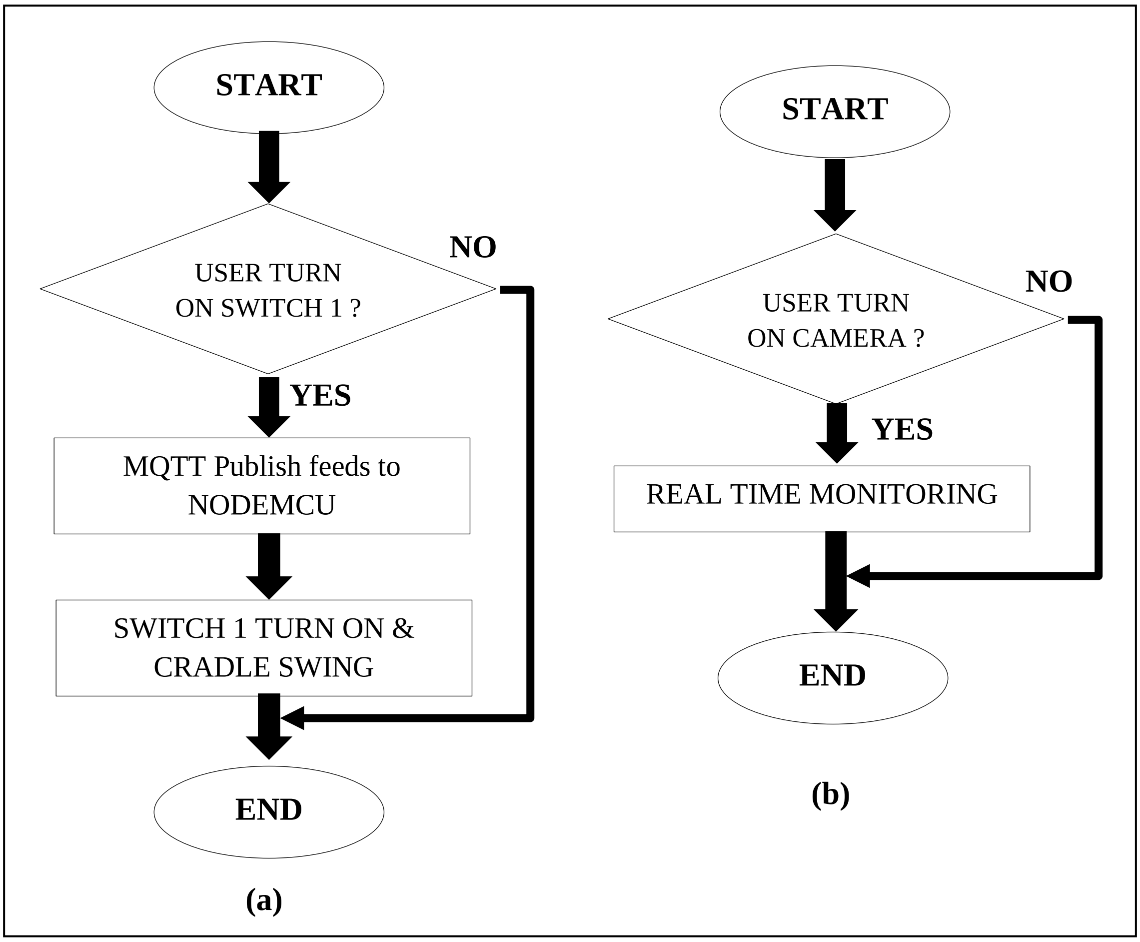


Figure 3.13 Manual Remote Flowchart

In this baby monitoring system, the user can also manually remote the system through the internet. Figure 3.13(a) shows the flow of turning on the Relay 1 to enable the swinging of the cradle. When the user pressed the button in smart devices, MQTT server will publish the feeds to the microcontroller and turned on the corresponding relay. The flowchart shown in Figure 3.13(a) is also applied for Mini fan connected to Relay 2 and Lullaby toy connected to Relay 3 as shown in Figure 3.8. Figure 3.13(b) shows the workflow of the external camera in the system. The user can monitor the baby by turning on the camera to do real-time monitoring.

3.6 Cost Estimation

Table 3.1 shows the cost estimation for the electronic components and other materials used to build the baby monitoring system, excluding the equipment used to building the prototype. The equipment used to build the prototype will be borrowed from UMP workshop if available, for example, hand drill, wood cutting machine, soldering set and others.

Table 3.1 Material cost lists

No	Items	Quantity	Cost/unit (RM)	Total (RM)
1	NodeMCU ESP8266 Wi-Fi controller Board	1	21.90	21.90
2	4 Channel Ways Opto Isolator 10A 5V Relay Module	1	15.90	15.90
3	40p Jumper Male to Male (MM) 20cm	1	3.90	3.90
4	Analog & Digital Mic Microphone Sound Detection sensor (4 pin)	1	5.90	5.90
5	Solderless Breadboard 830 Hole	1	5.90	5.90
6	Mini clip fan	1	30.00	30.00
7	Lullaby toy	1	30.00	30.00
8	KKMoon Wireless security camera	1	100.00	100.00

9	Red Meranti Wood (1’’ x 6’’)	60	2.50	150.00
10	12V DC Geared motor	2	55.00	110.00
11	AC to DC 12V power supply	1	48.00	48.00
12	Electrical Box	1	11.00	11.00
13	Buzzer	1	3.00	3.00
14	DHT22 Temperature & humidity sensor	1	22.00	22.00
15	DC motor coupler	1	21.00	21.00
16	MD10-POT 10Amp DC Motor Driver	1	20.00	20.00
17	USB Data cable	1	10.00	10.00
	Total			**608.50**

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In this chapter, the results and discussion of the final prototype in this project will be discussed in detail.

4.2 Project Outcome

Figure 4.1 shows the building process of the prototype. Figure 4.1 (Left) shows the final prototype view. The colour of the prototype is been changed from classic wood colour to the modern white colour. Several decorations are made on the final prototype as shown in Figure 4.1 (Right).

Figure 4.1 Before and after of the prototype

The result of the data measured from the sound sensor and temperature & humidity sensor can be obtained in both Adafruit MQTT server and MQTT Dash mobile application. From Figure 4.2 and Figure 4.3, both MQTT server and MQTT Dash apps are synchronized and displayed the same readings uploaded by the NODEMCU microcontroller in the baby monitoring system.

Figure 4.2 shows the interface of the MQTT server named Adafruit.io, with the https address: https://io.adafruit.com. The relay switch icons will turn green whenever the relays are turned on, while icon turns red would be indicating the relays are off. From the figure, three display blocks can be found with some values. Those blocks are the place where the data from the sensors would be uploaded to. The user can check the temperature condition of the room, where the baby stayed, by accessing to the server or through the mobile apps.

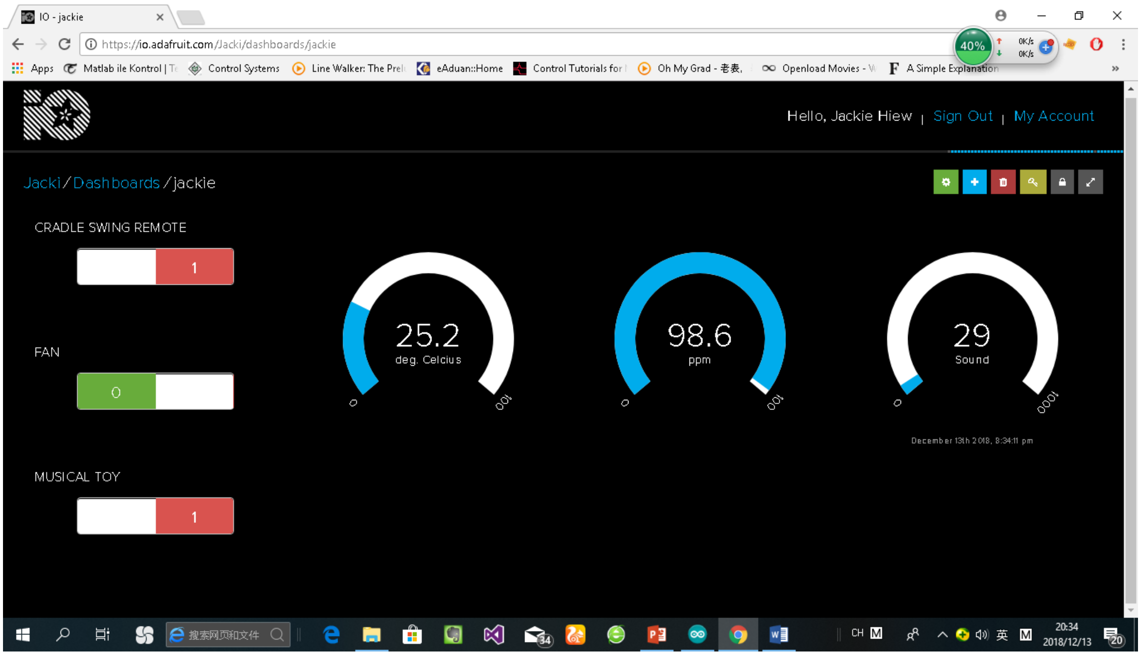


Figure 4.2 User interface on the Adafruit.io MQTT server webpage

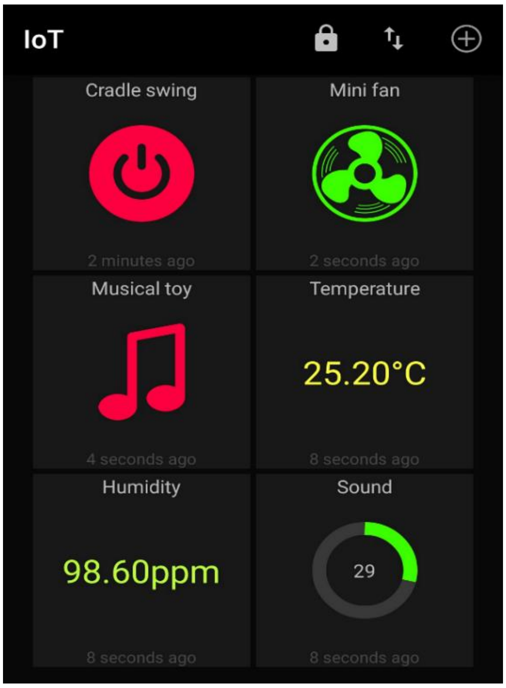


Figure 4.3 MQTT Dash mobile application interface

The final prototype can swing automatically whenever sound is detected by the sound sensor. A notification, shown in Figure 4.4, will be sent to the user through IFTTT mobile application to notify the user that crying is detected on the baby monitoring system. The user can also remote the cradle to swing manually by toggle the switch in the MQTT server or mobile apps. The mini fan is designed to turn on automatically whenever the room temperature, measured by the temperature sensor, is higher than 28°C. User can also remote the mini fan through both MQTT server and mobile application. A musical toy, which can be remoted by the user, is installed to entertain the baby.

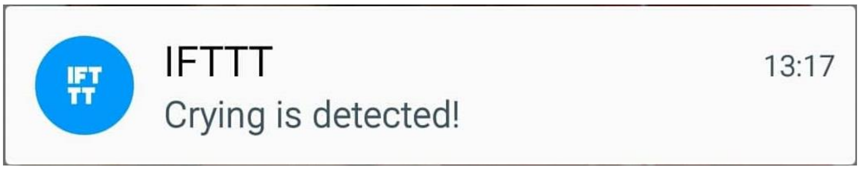


Figure 4.4 Notification to the user through IFTTT application

Figure 4.5 shows the camera view taken from a mobile application. The real-time monitoring is achieved by using an external wireless camera. The quality of the camera view can be viewed in High Defination (HD). With a photoresistor and IR LEDs, the camera could also record night vision of the house. The wireless camera head is rotatable with 355° pan and 120° tilt. The user can control it via the app and get a sweeping view on every inch of the entire house. The user can rotate the camera through the camera application by just swiping on the screen left or right for changing horizontal axis and up or down for changing vertical axis of the camera view.

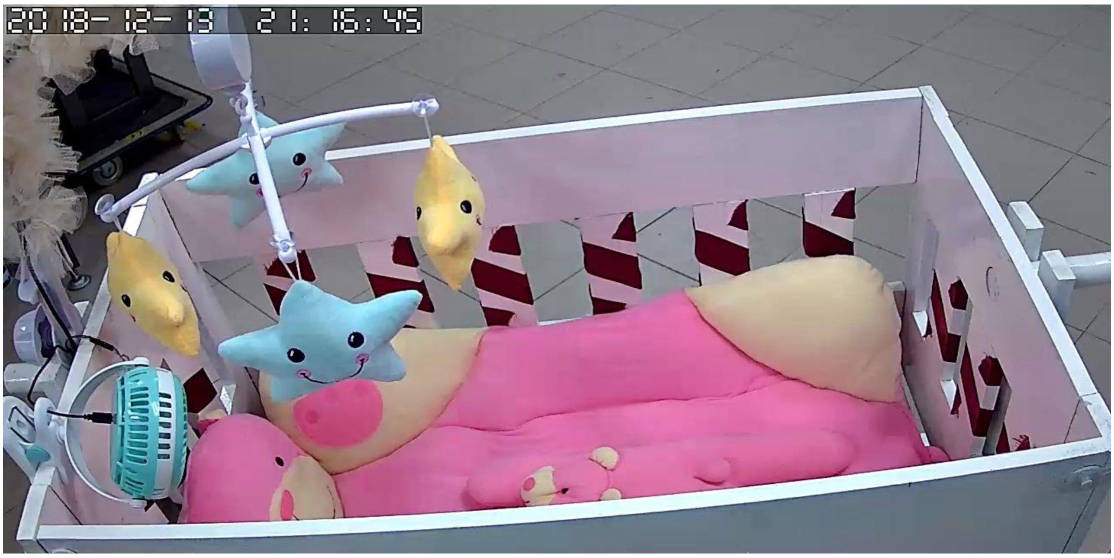


Figure 4.5 Wireless camera view

4.3 Discussion

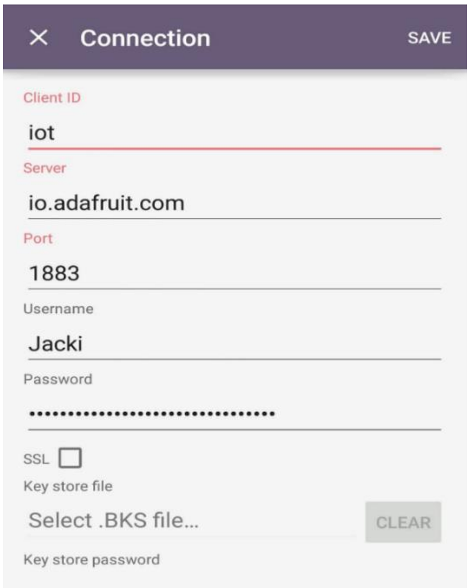


Figure 4.6 Process of synchronizing apps with MQTT server

A mobile MQTT application, which is applicable with the android operating system mobile phone, was downloaded from the google apps store. The application's name is "MQTT Dashboard" which can be synchronized with the Adafruit MQTT server. During the synchronization process, the targeted MQTT server address was required, followed by the host port, the username and the specified authentication token given by the server. Figure 4.6 shows the requirement needed for the synchronization process for the mobile apps to share the same data received from the sensors. The password was the authentication token (AIO key) generated by the MQTT server.

Figure 4.7 and Figure 4.8 show the data received from the data and the switches where the user can remote the relay through the internet. Figure 4.7 shows the on/off toggle switches that would give command to the relays by the user. Other than that, the condition of the relays will be updated as well whenever the relays are switching on/off due to the triggering of the conditions by the sensors or manually remoted by the user. Figure 4.8 shows the sensors' measured readings uploaded into the server by the NODEMCU through the network. The user must choose whether to see the measured values from the system or the condition of the switches in one time. In order to view the others, the user must click another interface, for example click the "Publish" to view relays condition or click "Subcribe" to view sensors' measured readings.

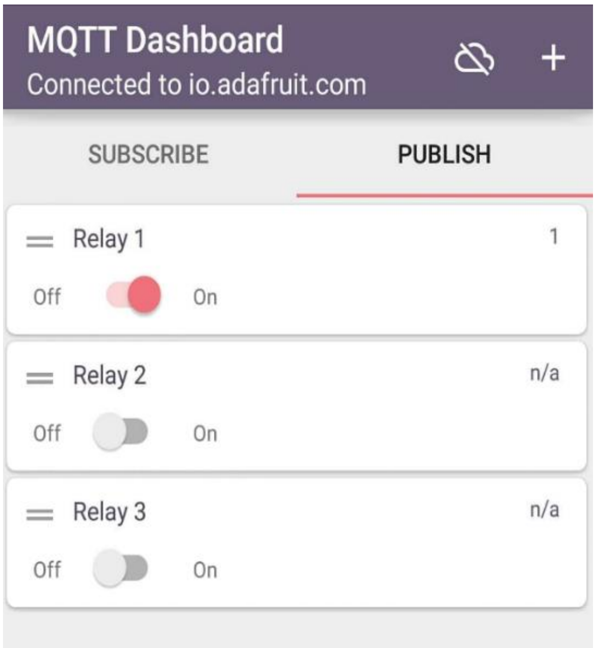


Figure 4.7 "Publish" interface

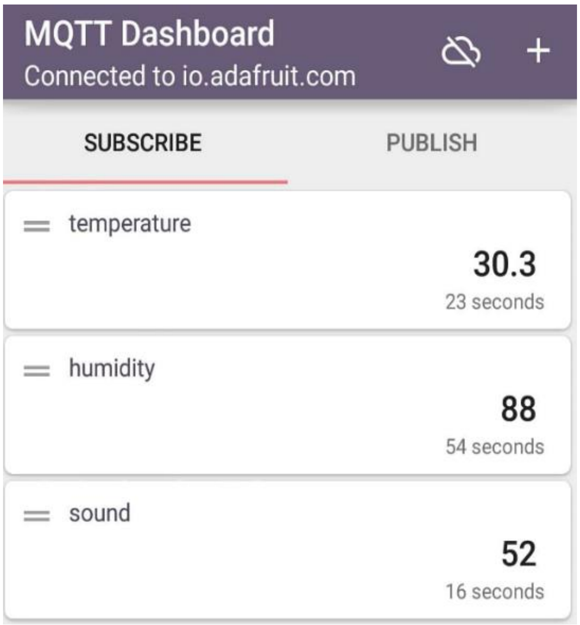


Figure 4.8 “Subscribe” interface

Figure 4.9 shows a new interface for the mobile application. The previous application, shown in Figure 4.7 and Figure 4.8 named “MQTT Dashboard” is not so user-friendly as expected because it could cause some misdirection for the user as it is not so straight forward to understand. After some optimization and testing, another application named “MQTT Dash” is decided to replace the previous application due to its simplicity usage and more user friendly in term of the view and usage.

From Figure 4.3, all the readings and switches can be viewed and remoted in one glance. Unlike the previous apps, the user does not need to switch the selection between “SUBCRIBE” to view sensors’ measured reading and “PUBLISH” to view the on/off condition of the relays. Everything can be viewed in the first glance once the application is opened under the condition where the mobile phone had network connection. However, if the mobile phone is not connected to the network, the application will notify the user by popping out an alert, writing “No network detected”, as shown in Figure 4.9.

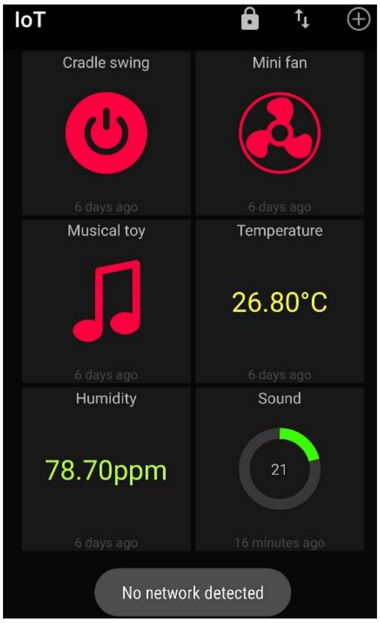


Figure 4.9 Notification of no network in MQTT Dash

All the circuit components are installed into the electrical box after the circuit testing phase, as shown in Figure 4.10. The original 9V DC battery source shown in Figure 3.8 was changed to an AC to DC 12V output converter because the 9V DC battery was unable to supply the current efficiently to the whole system. Hence, an AC to DC power supply is used instead to supply efficient current for the whole system.

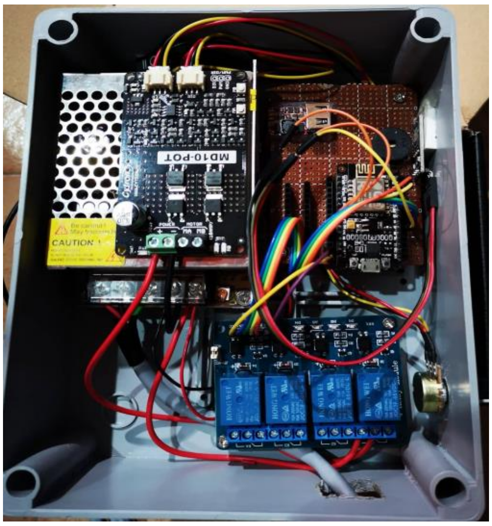


Figure 4.10 Installation of all components in electrical box.

A 5V3A USB module is used to convert the 12V output to 5V output for the activation on the mini fan. It can also be used to supply electric to the NODEMCU microcontroller. The USB module had a built-in step-down converter that can lower down an input of 6V-24V to the output of 5V, with a maximum output current of 3A at full load.

The connection of the NODEMCU is coded so that it would connect to a certain Wi-Fi network with the given password written in the coding. It is due to the reason that the internet of UMP is having certain restriction, which would cause the connection of the system to be failed. The process is then retried by using the programmer mobile phone's data hotspot. The connection was successful and there was no time delay during the performance of the sending and fetching data to and from the MQTT server.

Figure 4.11 showed the MD10-POT 10Amp DC Motor Driver used in the project to vary the speed of the 12v DC motor that rotate the baby cradle. The motor driver supports motor voltage ranges from 7V to 30V and can withstand maximum current up to 10A continuous and 30A peak (10 seconds). The speed, round per minute (RPM), of the connected DC motor can be varied by tuning the potentiometer as well as the rotating direction with a two-direction switch. The installation of the potentiometer can be found in Figure 4.15.

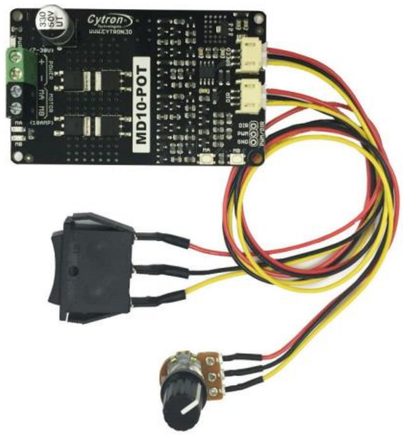


Figure 4.11 MD10-POT 10Amp DC Motor Driver

Four rotating wheels with locks on each wheel were used in the baby cradle prototype to allow the prototype to be able to move around the house of the user. The rotating wheels, shown in Figure 4.12, are installed under the four corners below the prototype. Whenever the baby is placed in the cradle, the user must lock the wheels of the cradle to prevent the movement of the cradle. The wheels could be unlocked or locked based on the user's preference.

Figure 4.12 Rotating wheel with built-in lock

Wireless camera

The wireless camera can be connected in three methods as shown in Figure 4.13. First method is by connecting to the available Wi-Fi network in the house. The user had to setup the configuration of the wireless camera during the first-time setting. Second method is by directly connect to the wireless camera built-in WiFi, which is known as AP connection. The benefit of AP connection is that the setting configuration can be faster due to the direct connection from mobile phone to the camera. Third method is by the wired connection using ethernet cable directly from the internet modem to the wireless camera. For all the three methods, the setup processes were the same.

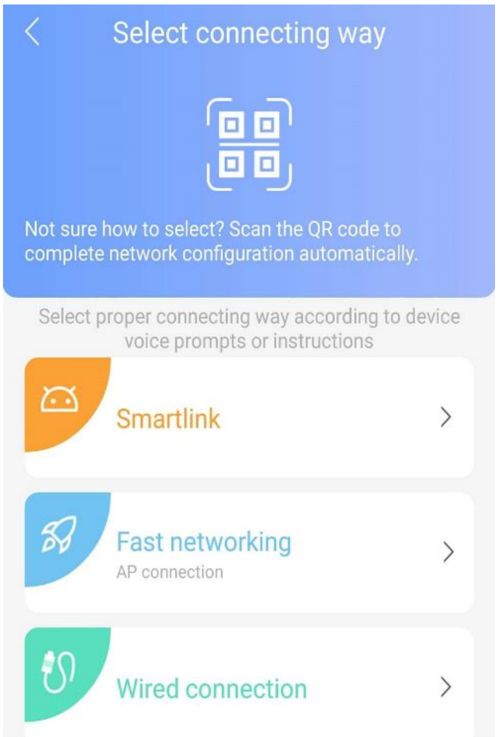


Figure 4.13 Methods of connecting the camera application

Motor shaft rotating mechanism

The rotating mechanism can be found in Figure 4.14. A piece of aluminium sheet is cut into a round shape. The DC motor is then locked with a motor coupler attached on the piece of round aluminium sheet. The edge of the aluminium sheet is punched into a hole by using drill machine. A wood is cut into 30cm long x 2cm width x 2cm height. The wood is then screwed into the edge of the aluminium sheet. The mechanism will swing the baby cradle by rising the cradle to one side and another side whenever the motor is rotating. It will cause the cradle to swing by elevate around 20-degrees on one side and demote while the DC motor is rotating 360-degrees.

Figure 4.14 Rotating mechanism of the baby cradle

Temperature sensor

In order to measure the room temperature, the DHT22 temperature and humidity sensor (white colour sensor) is mounded at the side of the electrical box by drilling a hole to enable the sensor to fit in the hole, shown in Figure 4.15. By doing that, the DHT22 sensor can be exposed to the surrounding temperature and measured it to be uploaded to the MQTT server. The black knob found under the DHT22 is the potentiometer of the DC motor driver to allow the user to manually adjust the speed of the baby cradle.

Figure 4.15 Side view of the electrical box

Sound sensor

A sound sensor is placed at the top side in the baby cradle to enable the sound detection process. A small box is 3D printed using 3D printer available in the UMP workshop with a dimension that fitted to the sound sensor. The small box, shown in Figure 4.16, is then screwed to the inner-side of the baby cradle to fix the location of the sound sensor.

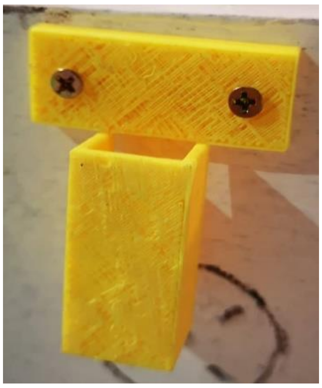


Figure 4.16 View of the 3D printed box

4.4 Prototype Validation

The prototype is tested with the aids of mobile phone by opening baby crying sound surfed from the internet. A mobile phone is brought near the sound sensor as the stimulation of real baby crying situation. The sound detection is having some time delay, probably due to the loop process in the programming codes. The cradle will start the swinging action whenever the value of the detected sound exceeded the set threshold value. The user will be notified whenever the cradle started to swing, indicated that the baby was crying at that moment.

The prototype is also tested out with the time delay of the upload data from the system to the MQTT server. It was noticed that the process of upload data and fetch data to and from the server are having some time delay around 1 second. Several testing processes are done and sometime there were no time delay, but some results of the testing showed a slight time delay. However, after several testing and fabrication processes, it is noticed that the possibility for the occurrence of time delay depends on the strength of the connected network. There would be no time delay when Wi-Fi connection is strong enough.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The team managed to build a low-cost baby monitoring system prototype that can measure the baby's vital parameters such as the baby crying condition and surrounding temperature. Some of the materials are not suitable but the team was able to modify the materials and repurchase suitable materials to be used in the project. The total cost spent was RM1000.00 in this project due to some repurchase components. The cost can be greatly reduced to around RM700 per unit in mass production once the prototype is finalised. NODEMCU is used as the main controller board in the project's circuit design because it had a built-in Wi-Fi module which enable the implementation of IoT concept in the project. The demand of IOT can be achieved by using the NODEMCU due to its simplicity and available examples from the network open-sources.

Red Meranti wood is used as the material to build the baby cradle because it is generally used in woodworks due to its workability. Improvements were made during the enhancement phases to make sure the outcome achieved the objectives of the project. The finishing prototype is tested by using a mobile phone with a baby crying ringtone which put in the cradle. Once the ringtone ringed for few seconds, the cradle would start swinging assuming the baby is crying because of the detected sound. A notification would be sent to the mobile phone of the user, notifying the user that the baby is crying. Temperature and humidity of surrounding would be taken and turned on the mini fan is the measured temperature is above 28^oC. With the aid of NODEMCU, parents can also remote the baby cradle and the mini fan with the tip of their fingers using mobile apps or the computer connected to the network. Real-time monitoring is achieved by the aids of the wireless camera. The user can monitor their baby through the camera mobile application and talk to the baby through the built-in microphone on the wireless camera.

5.2 Limitation of the project

In this project, there are some limitations found during the testing phase. The circuit system requires a stable network connection. Whenever NODEMCU is disconnected from the network, it will try to reconnect the network. However, if the network is totally disconnected, the system will be totally not functioning. Besides, some of the expected outcome mention in chapter 1 is not fulfilled. The sound sensor that used in the project is not precise in gathering decibels and hence the team is only able to modify it to turn on the relay to swing the baby cradle whenever the measured sound value exceeds the threshold value. Other than that, the wireless camera used is only able to be connected in local network. Parents can only view whatever the camera is looking at when they are connected to the same network as the wireless camera connects. A TF card can be used for the camera to record the baby activities, but it will not be real-time monitoring.

5.3 Recommendation

There are a lot of future works can be done in order to further improve this project. The coding for reconnecting the network had to be modified so that it will keep reconnect until it is connected to the network. A lighter and safer material, such as soft plastics, can be used to replace with wood materials so that the safety of the baby can be ensures as well as the weight of the baby cradle can be reduced. A better-quality sound sensor can be implemented for better noise capturing together with some coding to differentiate the level of baby crying, whether it is low dB crying, medium dB crying or high dB crying. Being able to detect that, the motor attached to enable the swing process can be coded to varies its speed according to the measure dB(s). 12V DC Geared motor can be changed to 12V stepper motor as the rotation direction of the stepper motor can be changed by coding. Wireless camera can be changed into IP camera to enable IP hosting viewing in the network. Parents can just type the set IP address for the IP camera in the network browser to real-time monitoring the baby conditions.

REFERENCES

4moms: Meet the 4moms® mamaRoo® infant seat. (n.d.). Retrieved April 15, 2018, from https://www.4moms.com/mamaroo

Academy, A., Pediatrics, O. F., Concept, T. C., Infant, S., Syndrome, D., Shifts, D. C., … Risk, R. (2005). The Changing Concept of Sudden Infant Death Syndrome: Diagnostic Coding Shifts, Controversies Regarding the Sleeping Environment, and New Variables to Consider in Reducing Risk. *Pediatrics*, *116*(5), 1245–1255. https://doi.org/10.1542/peds.2005-1499

Arduino IoT 4 Channel Ways Opto Isolator 10A 5V relay module. (n.d.). Retrieved April 5, 2018, from https://www.lelong.com.my/arduino-iot-4-channel-ways-opto-isolator-10a-5v-relay-module-robotedu-180170020-2019-07-Sale-P.htm

Ashton, K. (2009). That "Internet of Things" Thing. *RFiD Journal*, 4986. https://doi.org/10.1145/2967977

Baker, S., Xiang, W., & Atkinson, I. (2017). Internet of Things for Smart Healthcare: Technologies, Challenges, and Opportunities. *IEEE Access*, *5*, 1–1. https://doi.org/10.1109/ACCESS.2017.2775180

Barnard, K. E. (1972). The effect of stimulation on the duration and amount of sleep and wakefulness in the premature infant. PhD Thesis, University of Washington.

Best Quality Outdoor Baby Swing With Stand by. (2012, March). Outdoor Baby Swing With Stand. Retrieved March, 2018, from 18934–18949. http://outdoorbabyswingwithstand.blogspot.com/

Brangui, S., El Kihal, M., & Salih-Alj, Y. (2015). An enhanced noise cancelling system for a comprehensive monitoring and control of baby environments. *Proceedings of 2015 International Conference on Electrical and Information Technologies, ICEIT 2015*, 404–409. https://doi.org/10.1109/EITech.2015.7162982

Chao, C. T., Wang, C. W., Chiou, J. S., & Wang, C. J. (2015). An arduino-based resonant cradle design with infant cries recognition. *Sensors (Switzerland)*, *15*(8), 18934–18949. https://doi.org/10.3390/s150818934

Chien, J.-R. C. (2008). Design of a home care instrument based on embedded system.

https://doi.org/10.1109/ICIT.2008.4608363

Cornwell, A. C., Ph, D., & Einstein, A. (n.d.). Anne Christake Cornwell, Ph.D. Albert Einstein College of Medicine, N.Y. Flushing Hospital Medical Center, N.Y. Department of Pediatrics.

Demiris, G., & Hensel, B. K. (2008). Technologies for an aging society: a systematic review of “smart home” applications. *Yearb Med Inform*, 33–40. https://doi.org/me08010033 [pii]

Goyal, M. (2013). Automatic E-Baby Cradle Swing based on Baby Cry, *71*(21), 39–43.

Infant, S., & Syndrome, D. (2000). Task Force on Infant Sleep Position and Sudden Infant Death Syndrome Changing Concepts of Sudden Infant Death Syndrome : Implications for, *105*(3).

Jen Clark. (2016). What is the Internet of Things, and how does it work? Retrieved April 21, 2018, from https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/

Kaur, A. (2017). Health Monitoring Based on IoT using, 1335–1340.

Kelvin Claveria. (2017). 13 stunning stats on the Internet of Things - Vision Critical Blog. Retrieved May 5, 2018, from https://www.visioncritical.com/internet-of-things-stats/

KKmoon Wireless Wifi 720P HD Security Camera. (n.d.). Retrieved April 22, 2018, from https://www.kkmoon.com/p-s468-uk.html

Lopez Research. (2013). An Introduction to the Internet of Things (IoT). *Lopez Research Llc, Part 1. of*(November), 1–6.

Malloy, M. H., & Freeman, D. H. (2004). Age at Death, Season, and Day of Death as Indicators of the Effect of the Back to Sleep Program on Sudden Infant Death Syndrome in the United States, 1992-1999. *Archives of Pediatrics and Adolescent Medicine*, *158*(4), 359–365. https://doi.org/10.1001/archpedi.158.4.359

Michael Yuan. (2017). Getting to know NodeMCU and its DEVKIT board. Retrieved April 21, 2018, from https://www.ibm.com/developerworks/library/iot-nodemcu-open-why-use/index.html

Mohamad Ishak, D. N. F., Abdul Jamil, M. M., & Ambar, R. (2017). Arduino Based Infant Monitoring System. *IOP Conference Series: Materials Science and*

Engineering, *226*(1), 0–6. https://doi.org/10.1088/1757-899X/226/1/012095

Nodemcu. (2017). Handson Technology User Manual V1.2, 1–22. Retrieved from http://www.handsontec.com/pdf_learn/esp8266-V10.pdf

Palaskar, R., Pandey, S., Telang, A., Wagh, A., & Kagalkar, R. M. (2015). An Automatic Monitoring and Swing the Baby Cradle for Infant Care. *International Journal of Advanced Research in Computer and Communication Engineering*, *4*(12), 187–189. https://doi.org/10.17148/IJARCCE.2015.41242

Patil, S. P., & Mhetre, M. R. (2014). Intelligent Baby Monitoring System. *ITSI Transactions on Electrical and Electronics Engineering*, (21), 2320–8945.

Pederson, D. R., Champagne, L. & Pederson, L. L. (1969). Relative Soothing Effects of Vertical and Horizontal Rocking. ERIC Number: ED046504.

Pham, M., Mengistu, Y., Do, H., & Sheng, W. (2018). Delivering home healthcare through a Cloud-based Smart Home Environment (CoSHE). *Future Generation Computer Systems*, *81*, 129–140. https://doi.org/10.1016/j.future.2017.10.040

Raybaby - World's First Non-Contact Vital Monitor. (n.d.). Retrieved April 16, 2018, from https://www.raybaby.us/

Rechargeable Portable Clip Mini Fan. (n.d.). Retrieved April 22, 2018, from https://www.aliexpress.com/item/Rechargeable-Portable-Clip-Mini-Fan-360-Degree-Rotation-Desktop-USB-Fan-Mute-Baby-Stroller-Fan-for/32824864242.html

Saadatian, E., Iyer, S. P., Chen, L., Fernando, O. N. N., Hideaki, N., Cheok, A. D., … Amin, Z. (2011). Low cost infant monitoring and communication system. *2011 IEEE Colloquium on Humanities, Science and Engineering, CHUSER 2011*, (Chuser), 503–508. https://doi.org/10.1109/CHUSER.2011.6163782

SNOO – Happiest Baby. (n.d.). Retrieved April 15, 2018, from https://www.happiestbaby.com/pages/snoo

Sudden Unexpected Infant Death and Sudden Infant Death Syndrome, Centers for Disease Control and Prevention. Centers for Disease Control and Prevention 17 Apr. 2017, May 2017

Symon, A. F., Hassan, N., Rashid, H., Ahmed, I. U., & Reza, S. M. T. (2017). Design and Development of a Smart Baby Monitoring System based on Raspberry Pi and Pi Camera, 117–122.

Vaidya, S., Ambad, P., & Bhosle, S. (2018). ScienceDirect ScienceDirect ScienceDirect Industry 4 . 0 – A Glimpse Industry 4 . 0 – A Glimpse Costing models for capacity optimization in Industry 4 . 0 : Trade-off between used capacity and operational efficiency. *Procedia Manufacturing*, *20*, 233–238. https://doi.org/10.1016/j.promfg.2018.02.034

Weinberg, B. D., Milne, G. R., Andonova, Y. G., & Hajjat, F. M. (2015). Internet of Things: Convenience vs. privacy and secrecy. *Business Horizons*, *58*(6), 615–624. https://doi.org/10.1016/j.bushor.2015.06.005

What is a humidity, moisture sensors, temperature humidity sensor - Future Electronics. (n.d.). Retrieved April 19, 2018, from http://www.futureelectronics.com/en/sensors/humidity-dew.as

Willinger, M., James, L. S., Catz, C., & Participants, P. (1991). Defining the sudden infant death syndrome (SIDS): Deliberations of an Expert Panel Convened by the National Institute of Child Health and Human Development. *Pediatric Pathology*, *11*(5), 677–684. Retrieved from http://www.tandfonline.com/doi/pdf/10.3109/15513819109065465

APPENDIX A

Task Name	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Timeline of the Project													
Research on Report													
Survey Shop													
Draft Design 1													
Problem Statement													
Fabrication of Project													
Problem Statement													
Draft Design 2													
Introduction													
Find Material & Survey													
Literature review													
Electrical about sensor & power supply													
Methodology Research													
Repair report													
Mid Semester Break													
Controller Motor													
Type of Process													
Survey Fabrication Shop													
Preparation for Presentation													
Presentation													

GANTT CHART

APPENDIX B
SYSTEM CODING

```
/*******************IOT BASED BABY MONITORING SYSTEM******************/

#include <ESP8266WiFi.h>
#include "Adafruit_MQTT.h"
#include "Adafruit_MQTT_Client.h"
#include "DHT.h"

/************************* Pin Definition *********************************/

//Relays for switching appliances
#define Relay1          D1
#define Relay2          D2
#define Relay3          D5
#define Relay4          D6

//DHT11 for reading temperature and humidity value
#define DHTPIN           D7

//buzzer to know the status of MQTT connections and can be used for any other purpose
according to your project need.
#define buzzer          D0

//Analog pin to read the incoming analog value from different sensors.
#define analogpin        A0

/************************* WiFi Access Point *********************************/

#define WLAN_SSID       "KS connectify"
#define WLAN_PASS       "0987609876"

/************************* Adafruit.io Setup *********************************/

#define AIO_SERVER      "io.adafruit.com"
#define AIO_SERVERPORT  1883                   // use 8883 for SSL
#define AIO_USERNAME    "Jacki"             //"techiesms"
#define AIO_KEY
"c351d29dc896488d9e416a6089e2a66a"//"912b30c900574034a653f41e2b4df838"

/************ Global State (you don't need to change this!) ******************/

// Create an ESP8266 WiFiClient class to connect to the MQTT server.
WiFiClient client;
// or... use WiFiFlientSecure for SSL
//WiFiClientSecure client;

// Setup the MQTT client class by passing in the WiFi client and MQTT server and login
details.
Adafruit_MQTT_Client mqtt(&client, AIO_SERVER, AIO_SERVERPORT,
AIO_USERNAME, AIO_KEY);
```

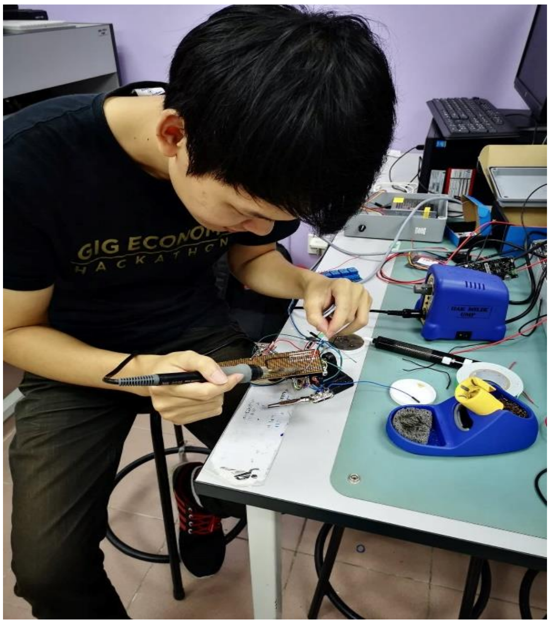
```
/***************************** Feeds ***************************************/

// Notice MQTT paths for AIO follow the form: <username>/feeds/<feedname>
Adafruit_MQTT_Publish Humidity = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME
"/feeds/humidity");
Adafruit_MQTT_Publish Temperature = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME
"/feeds/temperature");
Adafruit_MQTT_Publish Sound = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME
"/feeds/sound");
Adafruit_MQTT_Publish Fan = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME
"/feeds/relay2");
Adafruit_MQTT_Publish Light = Adafruit_MQTT_Publish(&mqtt, AIO_USERNAME
"/feeds/button");

// Setup a feed called 'onoff' for subscribing to changes.
Adafruit_MQTT_Subscribe Light1 = Adafruit_MQTT_Subscribe(&mqtt, AIO_USERNAME
"/feeds/button");
Adafruit_MQTT_Subscribe Fan1 = Adafruit_MQTT_Subscribe(&mqtt, AIO_USERNAME
"/feeds/relay2");
Adafruit_MQTT_Subscribe Light2 = Adafruit_MQTT_Subscribe(&mqtt, AIO_USERNAME
"/feeds/relay3");
Adafruit_MQTT_Subscribe Fan2 = Adafruit_MQTT_Subscribe(&mqtt, AIO_USERNAME
"/feeds/relay4");

/************ Necessary declaration for DHT11 ******************/
#define DHTTYPE           DHT22     // DHT 11

DHT dht(DHTPIN, DHTTYPE);
uint32_t delayMS;

/*************************** Sketch Code ************************************/

// Bug workaround for Arduino 1.6.6, it seems to need a function declaration
// for some reason (only affects ESP8266, likely an arduino-builder bug).
void MQTT_connect();
void setup() {
  Serial.begin(115200);
  delay(10);

  pinMode(buzzer, OUTPUT);
  pinMode(Relay1, OUTPUT);
  pinMode(Relay2, OUTPUT);
  pinMode(Relay3, OUTPUT);
  pinMode(Relay4, OUTPUT);
  pinMode(A0, INPUT);

  Serial.println(F("Adafruit MQTT"));

  // Connect to WiFi access point.
  Serial.println(); Serial.println();
  Serial.print("Connecting to ");
  Serial.println(WLAN_SSID);

  WiFi.begin(WLAN_SSID, WLAN_PASS);
  while (WiFi.status() != WL_CONNECTED) {
```

```
    delay(500);
    Serial.print(".");
  }
  Serial.println();

  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());

  //Setting up DHT sensor
  dht.begin();

  // Setup MQTT subscription for onoff feed.
  mqtt.subscribe(&Light1);
  mqtt.subscribe(&Fan1);
  mqtt.subscribe(&Light2);
  mqtt.subscribe(&Fan2);
  //initialise all relays close
  digitalWrite(Relay1, HIGH);
  digitalWrite(Relay2, HIGH);
  digitalWrite(Relay3, HIGH);
  digitalWrite(Relay4, HIGH);
}
uint32_t x = 0;

void loop() {
  // Ensure the connection to the MQTT server is alive (this will make the first
  // connection and automatically reconnect when disconnected).  See the MQTT_connect
  MQTT_connect();
  // this is our 'wait for incoming subscription packets' busy subloop
  Adafruit_MQTT_Subscribe *subscription;
  while ((subscription = mqtt.readSubscription(10000))) {
    if (subscription == &Light1) {
      Serial.print(F("Relay1: "));
      Serial.println((char *)Light1.lastread);
      int Light1_State = atoi((char *)Light1.lastread);
      digitalWrite(Relay1, Light1_State);

    }
    if (subscription == &Fan1) {
      Serial.print(F("Relay2: "));
      Serial.println((char *)Fan1.lastread);
      int Fan1_State = atoi((char *)Fan1.lastread);
      digitalWrite(Relay2, Fan1_State);
    }
    if (subscription == &Light2) {
      Serial.print(F("Relay3: "));
      Serial.println((char *)Light2.lastread);
      int Light2_State = atoi((char *)Light2.lastread);
      digitalWrite(Relay3, Light2_State);
    }
    if (subscription == &Fan2) {
      Serial.print(F("Relay4: "));
      Serial.println((char *)Fan2.lastread);
      int Fan2_State = atoi((char *)Fan2.lastread);
```

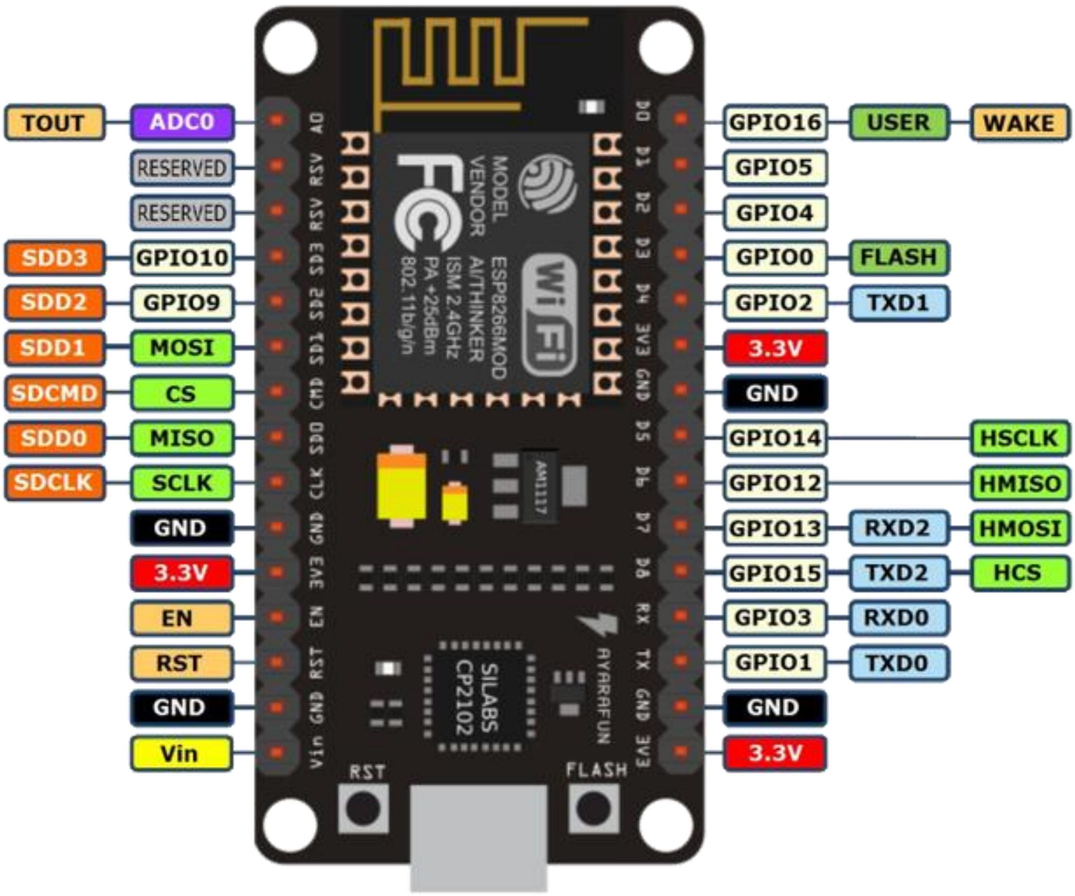
```
    digitalWrite(Relay4, Fan2_State);
  }
}

// Now we can publish stuff!
int raw_sound = analogRead(analogpin);
Serial.print("Detected sound: "); Serial.println(raw_sound);
Serial.print("...");
int Value = map(raw_sound,0,1024,0,100);
if (! Sound.publish(Value)) {
  Serial.println(F("Failed"));
} else {
  Serial.println(F("OK!"));
  if(raw_sound>=290 && raw_sound<=300){
    //Light.publish(HIGH);
    //int Light1_State = atoi((char *)Light1.lastread);
    digitalWrite(Relay4, HIGH);
  }
  else
    {
    //Light.publish(LOW);
    //int Light1_State = atoi((char *)Light1.lastread);
    digitalWrite(Relay4, LOW);
    delay(5000);
    }
}

// Reading temperature or humidity takes about 250 milliseconds!
// Sensor readings may also be up to 2 seconds 'old' (its a very slow sensor)
float h = dht.readHumidity();
// Read temperature as Celsius (the default)
float t = dht.readTemperature();

// Check if any reads failed and exit early (to try again).
if (isnan(h) || isnan(t) ) {
  Serial.println("Failed to read from DHT sensor!");
  return;
}
if (! Humidity.publish(h)) {
  Serial.println(F("Failed"));
} else {
  Serial.println(F("OK!"));
  Serial.print("Humidity: ");Serial.println(h);
}
if (! Temperature.publish(t)) {
  Serial.println(F("Failed"));
} else {
  Serial.println(F("OK!"));
  Serial.print("temperature: ");Serial.println(t);
  if(t>28)
  {
    Fan.publish(LOW);
    int Fan1_State = atoi((char *)Fan1.lastread);
    digitalWrite(Relay2, Fan1_State);
    }
```

```
      else{
       Fan.publish(HIGH);
       int Fan1_State = atoi((char *)Fan1.lastread);
       digitalWrite(Relay2, Fan1_State);
      }
  }

}

// Function to connect and reconnect as necessary to the MQTT server.
// Should be called in the loop function and it will take care if connecting.
void MQTT_connect() {
  int8_t ret;
  // Stop if already connected.
  if (mqtt.connected()) {
    return;
  }
  Serial.print("Connecting to MQTT... ");
  uint8_t retries = 10;
  delay(200);

  while ((ret = mqtt.connect()) != 0) { // connect will return 0 for connected
    Serial.println(mqtt.connectErrorString(ret));
    Serial.println("Retrying MQTT connection in 5 seconds...");
    mqtt.disconnect();
    delay(5000);  // wait 5 seconds
    retries--;
    if (retries == 0) {
      // if retry failed, alarm ring then go back to loop to reconnect
        tone(buzzer, 1000);
        delay(1000);
        noTone(buzzer);
        tone(buzzer, 1000);
        delay(1000);
        noTone(buzzer);
    }
  }
  Serial.println("MQTT Connected!");
  tone(buzzer, 1000);
  delay(1000);
  noTone(buzzer);
}
```

APPENDIX C
SDP PROGRESS



APPENDIX D
NODEMCU PIN MAPING



Source: http://trycircuit.blogspot.com/2017/07/nodemcu-pinoutarduino-ide-mapping.html

Arduino Program Pins	NodeMCU Pin		NodeMCU Pin	Arduino Program Pins
0	3		0	16
1	10		1	5
2	4		2	4
3	9		3	0
4	2		4	2
5	1		5	14
9	11		6	12
10	12		7	13
12	6		8	15
13	7		9	3
14	5		10	1
15	8		11	9
16	0		12	10

Source: http://icircuit.net/wp-content/uploads/2016/08/NodeMCU-to-Arduino-Pin-Mapping.png