Design and Development of an IoT Based Agro-Farm Security System in Bangladesh

A PROJECT REPORT

BY

NAFIS SADIQUE SAYEM
ID NO: 1805046
REG NO: 48355
SESSION: 2017-18

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BACHELOR OF SCIENCE

IN

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Department of Farm Power and Machinery

Faculty of Agricultural Engineering and Technology

Bangladesh Agricultural University, Mymensingh-2202

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ABSTRACT

The agricultural sector in Bangladesh is facing a growing concern regarding theft and rival aggressive activities targeting dairy farms, poultry farms, and machinery sheds. This research addresses the lack of existing studies in this area and proposes the design and development of an IoT based smart agro-farm security system to mitigate these security risks. The system consists of one sender station, namely the farm shed, and two receiver stations, namely the farmer's house and the farmer's mobile device. The sender station is equipped with a GSM module, an HC-12 module, a speaker with an indicator alarm light, a laser sensor, and a vibration sensor, all integrated into an Arduino Mega. The farmer's house acts as receiver station one that comprises an Arduino Uno, an indicator light system, and a high sound alarm system with an HC-12 module. The farmer's mobile device acts as a receiver station two, enabling remote access to real-time notifications and alerts. The laser sensor is strategically positioned on a stand, while the vibration sensor is installed at the entrance gate of the farm shed. The research methodology involves a comprehensive design and development process, including hardware integration, programming, and testing. The agro-farm security system aims to detect unauthorized access, intrusions, and suspicious activities within the farm premises. In the event of a security breach, the sender station triggers the alarm systems, activates the indicator light & alarm, and sends notifications to both the farmer's house and mobile device. By providing immediate notifications and enabling prompt response, the system empowers farmers to protect their valuable assets from theft and rival aggressive activities. This research contributes to the field by introducing a novel solution for enhancing farm security in Bangladesh. And we found the efficiency or responsiveness of this system is 90%. Further advancements and enhancements can be explored to improve the system's capabilities and contribute to the overall security and productivity of the agricultural sector. The agro-farm security system offers an initiative-taking approach to address the increasing security challenges faced by farmers in Bangladesh, promoting the sustainability and growth of the agricultural industry.

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CHAPTER–I

INTRODUCTION

1.1 Background of the Study

Bangladesh is a densely populated country with an agrarian economy. Agriculture is one of the largest employment sectors in Bangladesh, making up 12.5 percent of Bangladesh's GDP and employing about 40 percent of the workforce (BBS, FY 2020-21). Agriculture also plays a crucial role in food security, poverty alleviation, human resources development, and social and economic stability. Bangladesh produces a variety of agricultural products such as rice, wheat, corn, potato, legumes, fruits, vegetables, meat, and dairy products. And total market size for agricultural products for the year 2016 to 2021 is 34,927 USD to 47,549 USD (International trade administration). The livestock contribution to the country's GDP is about 2.5 percent (BIDS) and has increased at an average rate of 5.39 percent over the last five years (DLS). And Bangladesh's poultry sector produces 1.5-1.6 percent of the country's GDP and commercial poultry farms are growing at a rate of 15% a year (BPICC & OHP, 2020). The volume of food grains production in FY 2019-20 stood at 453.44 lakh MT (MoA & BBS, 2020). Recently, the government has taken up a project titled 'Mechanization of Agriculture Work through Integrated Management' at a cost of Tk 3,020 crore with a target to distribute 51,300 units of agro- machinery under twelve categories between 2020 and 2025 (DAE, 2020). However, agriculture in Bangladesh faces many challenges and risks due to factors such as climate change, natural disasters, land degradation, water scarcity, pest and disease outbreaks, market fluctuations, etc. These factors affect the productivity, quality, and profitability of farming, as well as the sustainability and resilience of the agricultural sector.

In addition to these challenges, farmers in Bangladesh also face significant security risks. Theft and vandalism of crops, equipment, and livestock are common problems that can have serious economic and social consequences for farmers and their communities. The cost of these security risks can be particularly high for small-scale farmers, who often lack the resources to invest in expensive security measures.

To cope with these challenges and to meet the growing demand for food and agricultural products, Bangladesh needs to adopt modern technologies and innovations that can enhance the efficiency and effectiveness of agricultural production, management & security. One such technology is Internet of Things (IoT), which refers to the network of physical objects embedded with sensors, actuators, software, and connectivity that enable data collection, communication, and interaction among them. IoT has various applications in agriculture such as smart irrigation, precision farming, soil monitoring, crop health assessment, improving product quality, fertilization process control, livestock management, etc. (IoT can help farmers to optimize their inputs and outputs, reduce their costs and risks, increase their yields and quality, improve their decision making and problem solving, access real-time information and feedback & also ensuring proper security of the farm.

However, implementing IoT-based solutions for agro-farm security is not a simple task. It requires a proper design and development of IoT-based agro-farm security system that can address the specific needs and challenges of theft or robbery activity of the local context. Such a system should consider various aspects such as architecture, security solutions, data management, communication protocols, cost-effectiveness, durability, reliability, etc. Moreover, such a system should also consider the socio-economic and cultural factors that may influence the adoption and acceptance of IoT technology by farmers and other users.

1.2 Justification of the Study

Nowadays farmers, entrepreneurs, farm owner are keen interested in security system of their farms and farm related properties or assets because circumstances are becoming sensitive and there is much fear about threats, thieves, intruders, rivals, dangerous causes, etc. The use of IoT technology has the potential to address some of these security challenges by providing farmers with cost-effective and reliable solutions. Ensuring the security of agro-farms, IoT based smart security system is an innovative approach applied in many developed countries. Real time monitoring based security system with smart alarming mechanism in Bangladeshi agro-farm is not available yet. Despite the potential benefits of IoT-based security systems for agriculture, there has been also relatively truly little research on this topic in Bangladesh. Traditionally, during nighttime, cattle farms, poultry farms etc. are overseen by humans guarding all over the country which is very laborious, time-consuming, and costly. Recently CC camera-based security system is also available in some limited commercial industries in Bangladesh which is not possible to monitor at the real time situation. CC camera-based security system is not readily acceptable and suitable in rural area of Bangladesh as its need continuous supervision and maintenance personnel. On the other hand, there is no alarming system during unwanted intrusion in any agro-farm. These problems can be resolved by using smart sensor-based security mechanisms. As described above, many studies in the developed countries have been conducted on developing agro-farm security system using sensors and IoT based alarming system. However, due to the importance of securing agro-farm product and assets in national food security and country's economy, developing smart, reliable, low cost & user-friendly farm security system in Bangladesh is also necessary.

Therefore, this study is justified by the need to fill the research gap and to explore the potential of IoT technology to improve security and productivity in agriculture in Bangladesh. So, the proposed project has been undertaken to design and develop an IoT based smart security system for agro-farm (dairy farm, poultry shed, and machinery shed) using laser sensor, vibration sensor, long range wireless transmitter and GSM with three alarming mechanisms.

In addition, the development and evaluation of an IoT-based security system for agro-farms in Bangladesh will have practical implications for farmers, agro-businesses, and policymakers. Furthermore, it contributes to the advancement of knowledge and innovation in the field of IoT and its applications in agriculture, which is a rapidly growing and promising area of research and development, particularly in developing countries. It has potential benefits and impacts for various stakeholders in the agricultural sector, such as farmers, extension agents, policy makers, researchers, etc., by improving their security, productivity, quality, profitability, and sustainability by exploring the challenges and opportunities of implementing IoT-based security systems for agro-farms in Bangladesh, this study can provide valuable insights for researchers and practitioners working in similar contexts.

Overall, the justification for this study lies in its potential to address an important and understudied problem, to contribute to the development of the agriculture sector in Bangladesh, and to inform policy and practice in the use of IoT technology for agricultural security. Therefore, this study aims to design and develop an IoT-based agro-farm security system in Bangladesh that can provide security and monitoring for agro-farms using the latest technologies such as IoT.

1.3 Specific Objective of the Study

Based on the proposal and the potential solutions to the problem

- To design and develop an IoT based smart security system with a programmable controller interface for agro-farm in Bangladesh;
- To install and conduct on-farm test of the smart security system.

CHAPTER – II

Review of literature

In the world, some research work has already been done on the development of IoT based agro-farm security systems. But in our country Bangladesh there is no research journal made in the development of such farmer friendly, low cost, IoT base agro-farm security system except one study in aquacultural field till this proposed date.

Before entering the study for developing IoT based farm security system some of the relevant literatures of farm security system around the world have been reviewed and presented to have better understanding on the subject.

Kumar (2022) proposed a Farm Intrusion Detection System using IoT. Through this device the farmer will be receiving an alert on the application installed in their mobile when someone intrudes into his/her farm. On receiving the alert, which will enable the farmer to go to his farm and check if any strange movement is happening. There will also be an alarm installed in the farmer's land which will alert the neighboring localities/farmers. Through this any type of intrusion into his/her farm can be prevented. This system might greatly help in reducing farmer's worries on safety of his/her farm and cattle's.

Kini et al. (2021) conducted a comparative study on advanced farm security systems using IoT and image processing. IoT devices were enabled other devices connected to the app and send data to various servers and combining IoT with image processing in the agriculture sector can lead to a more technology driven system in terms of agriculture security which can create a Smart Agricultural Security System. This study can help farmer to monitor the farm even if farmer is away from field by installing various sensors in farm to detect motion of local animal and sent data to farmer app directly and farmer can see live streaming of the farm with help of camera installed in farm. This also ensured complete safety of crops from animals and thieves thus increasing can lead to a more technology driven system in terms of

agriculture security which can create a Smart Agricultural Security System. Financial gain with a proper security surveillance system is also possible.

Hossaina et al. (2020) designed and implemented a smart security system for farm protection from intruders. Structure of device which has arduino based operational function that can make security of farming area from various types of intruders that may reach harm or destruction for farm related goods such as crops, paddy, barley etc, by their activities or nature. As clear words, animal can destroy all crops by eating or doing incoherent activities. As same not only animal every kind of intruder can be detected by this device and can be able to notify owner of farms. It is an unconventional approach for giving security to farms for relieving destruction of crops. This device operation is an indication of digitalization, in analog way of security of firm by using Arduino, GSM module and ultrasonic sensor etc. There is a fundamental need to develop such environmentally friendly devices which can ensure the safety of farm that will be make advantage for farmers as well as farm owners. This device will be able to give less physical effort and pollution free output of farm security off by the respondents.

Banerjee et al. (2019) proposed Arduino UNO and GSM based real-time home security system using self- generated password protection in Kolkata, India. The main function of the study was to provide a security system to detect the presence of human beings and make the user alert by sending text message to user's mobile phone. In the primary stage, the presence of any human being will be sensed by a Pyroelectric (PIR) motion sensor and after that, the person will have to enter the right password through a keypad. The self-generated password protection provides a double-sided benefit to this system viz. any unknown person will have to prove his/her identity by entering the right password into the security system. Every time a password is used, it expires, and a new password gets generated by the system and is sent to the registered mobile number. The real time protection has been performed using a SIM 900 TTL module which sends and receives text messages between the user's mobile phone and microcontroller, i.e., Arduino.

Hoque (2019) has designed and implemented an IoT-Based Smart Home Security System. These systems usually consist of sensing and actuating layers that is made up of sensors such as passive infrared sensors, also known as motion sensors; temperature sensors; smoke sensors, and web cameras for security surveillance. These sensors, smart electrical appliances, and other IoT devices connect to the Internet through a home gateway. This paper lays out an architecture for a cost-effective smart door sensor that will inform a user through an Android application of door open event in a house or office environment. The proposed architecture uses an Arduino-compatible Eligo Mega 2560 microcontroller board along with the Raspberry Pi 2 board for communicating with a web server that implements a Restful API. Several programming languages are used in the implementation and further applications of the door sensor are discussed as well as some of its shortcomings such as possible interference from other radio frequency devices.

Kakade (2019) has designed and implemented another Advanced Security System for Farm Protection from Wild Animals. They proposed a method to protect farms from wild animals so creating a system which in accordance with the animals like (deer, nilgai, wild boar, etc.). To detect the animal and create the different sound that irritates the animal and animal will run away and alert the authorized person by sending a message. The proposed monitoring scheme is to provide early warning about possible intrusion and damage by wild animals. They also provide a way of identification of animals so that in accordance with particular geographical area it has been monitored that which types of animals are present mostly in the concerned area.

Balaji et al. (2018) introduced an IoT based smart crop monitoring of a farmland. The introduction of IoT along with the sensor network in agriculture refurbish the traditional way of farming. Online crop monitoring using IoT helps farmers to stay connected to his field from anywhere and anytime. Various sensors are used to monitor and collect information about field conditions. Collectively the information about the farm's condition is sent to the farmer through GSM technology.

Onwuka et al. (2018) designed and implemented of farm monitoring and security system in Nigeria. Farmlands and plantations in Nigeria and African countries are usually very large scale running into hundreds of acres and in most cases fencing these large expanses of land can be prohibitively expensive and very stressful. The present situations in Africa where farmers are facing security threats in their farms, especially with the Fulani herdsmen, the wireless sensor networks technology can be used in this effect to get real time information of the farm and know when an intrusion occurs, the nature or type of intrusion with the necessary action(s) to follow. The architecture of the WSNs system comprises of a set of sensor nodes, surveillance facilities and a base station that communicate with each other and gather information to make decisions about the situation at hand. The system overcomes the limitation of building fences using sticks which can be very stressful. It also has the advantages of motion detection, an alarm and alert system as a security measure.

Shabadi and Biradar (2018) designed and implemented an IoT based smart security and monitoring system in connection to smart farming in India. Automatic soil features and condition fetching and decision taking can be done by using sensors and actuators, growing the seed and getting the yield is not the only thing, they can also provide security to farmland as well as to the product (obtained yield).

Kylon et al. (2016) developed a smart farm security system with alarm mechanism using image processing. The proponents came up with this research to strengthen the existing security system and develop a new way of securing a particular area. This system will use image processing to determine the identity of the one who entered and distinguish if that one is authorized personnel, an intruder, or a crop-destroying animal. A Closed-circuit television (CCTV) will be used to monitor the area and provide a video record for security purposes. A motion detector controlled by the Arduino Microcontroller will be the one to address the Graphical User Interface (GUI) that is to be programmed by the proponents when to take the snapshot on the video which is displayed on the GUI that will be used on image processing to determine the identity of the captured object. An opto-isolator will be

used as the switch for the alarming system; it is connected on parallel port which is converted from USB port to command when the switch will be on or off. If the system detects that there is an intruder or crop-destroying animal, an alarm will trigger until it is turned.

Sarkar (2016) introduced laser-based security system using wireless sensor network and GPRS/GSM technology for inland aquaculture in Bangladesh. This paper deals with the design and implementation of a novel laser-based security system for inland aquaculture such as Shrimp/prawn farming perspective to Bangladesh. The system implements laser as a means of detecting intruders. A wireless sensor network based on nRF24L01 trans-receiver is used to communicate with the gateway and the sensors. The number of lasers obstructed is determined by ldr attached to an Arduino board; which is programmed to take decisions whether to sound an alarm or call a desired mobile number through a GPRS/GSM network; depending on the number of lasers obstructed. The proposed work has been done and verified in real life.

Elfasakhany (2011) has developed a House-Mobile Security System. The objective of this work is to design, develop and implement an alarm system that triggers the alarm and alerts the owner via a mobile text message if the house has been opened or an attempt has been made to open it illegally. The system will also feature two different forms of activation/deactivation and will automatically open or close the door for the user. The advantages of this house-mobile security system (HMSS) are its high security level, robustness, low cost, and ease of use (uncomplicated) and that there is no distance limitation for contact. The system integrates different sensors via a microcontroller, which is the brain of the system, to avoid the problem of false alarms sent by other alarm monitoring systems to "Alarm Receiving Centers" or Police departments.

CHAPTER – III

Materials and Method

3.1 Location of the experiment

The experiment was conducted in the Post harvest loss innovation lab of the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh.

3.2 Study duration

The experiment started in March 2022. Experiment set up and data were collected during August 2022 to January 2023. Data analysis and report write up were performed during February to May 2023.

3.3 System design to develop the farm security system

The developed security system consists of sensors, microcontrollers, power sources, data transmission devices, speakers, and others.

The proposed system comprises of two sensors, a laser and vibration sensor for sensing and detecting intruder or unwanted activity in the farm shed. A GSM and two HC-12 transceiver modules for data communication among farmers house, farm shed and farmers' mobile phone. Two microcontrollers, both Arduino Mega and Uno were used to process input signal from the sensors, communication devices to create output alerting instruction for the output devices as speaker, indicator light and GSM/GPRS phone call. To power the entire system, both power adapter and battery were used for continuous supply of electricity. A set up of stands with mirrors were also used to reflect laser ray in the entrance gate of farm shed. Two breadboards for connection of those two circuits with different types of jumper wires.

3.3.1 Arduino MEGA 2560 microcontroller

Arduino Mega is a microcontroller board based on the ATmega2560microcontroller. It is one of the most powerful boards in the Arduino family, designed for more complex projects that require a larger number of input and output pins, more memory, and faster processing. This report aims to provide a detailed overview of the Arduino Mega board, its features, capabilities, and applications.

Features:

- The Arduino Mega board has the following key features:
- Operating Voltage: 5V
- Input Voltage: 7-12V (recommended), 6-20V (limit)
- Digital I/O Pins: 54 (including 15 PWM outputs)
- Analog Input Pins: 16
- Flash Memory: 256 KB of which 8 KB is used by bootloader.
- SRAM: 8 KB
- EEPROM: 4 KB
- Clock Speed: 16 MHz

Figure 3.1: Arduino MEGA 2560

The Arduino Mega board has a pinout that is different from other Arduino boards. It has a total of 54 digital I/O pins, 16 analog input pins, and 15 PWM outputs. The pins are divided into different groups, including digital pins, analog pins, power pins, and communication pins.

Digital pins:

The digital pins are labeled from 0 to 53 and it is used as input or output. They can also be configured as PWM outputs using the analog Write () function.

Analog pins:

The analog pins are labeled from A0 to A15 and can be used to read analog signals from sensors or other analog devices. The analog inputs have a resolution of 10 bits, which means that they can detect 1024 different levels of voltage.

Power pins:

The power pins include the 5V and 3.3V pins that provide power to the board and other components connected to it. The board also has a VIN pin that can be used to power the board using an external power supply.

Communication pins:

The communication pins include the Serial, SPI, and I2C pins that can be used to communicate with other devices or modules.

Programming:

The Arduino Mega board was programmed using the Arduino Integrated Development Environment (IDE), which is a software tool that provides an easy-to-use interface for writing, compiling, and uploading code to the board. The IDE uses the Wiring language, which is based on the C and C++ programming languages.

3.3.2 Arduino UNO microcontroller

Arduino Uno is an open-source microcontroller board that is based on the ATmega328P microcontroller. It is designed for prototyping various electronics projects and experiments. The board comes with digital and analog input/output pins that can be programmed using the Arduino IDE (Integrated Development Environment) to control electronic components such as LEDs, sensors, motors, and more. The Arduino uno is shown in Figure 3.2.

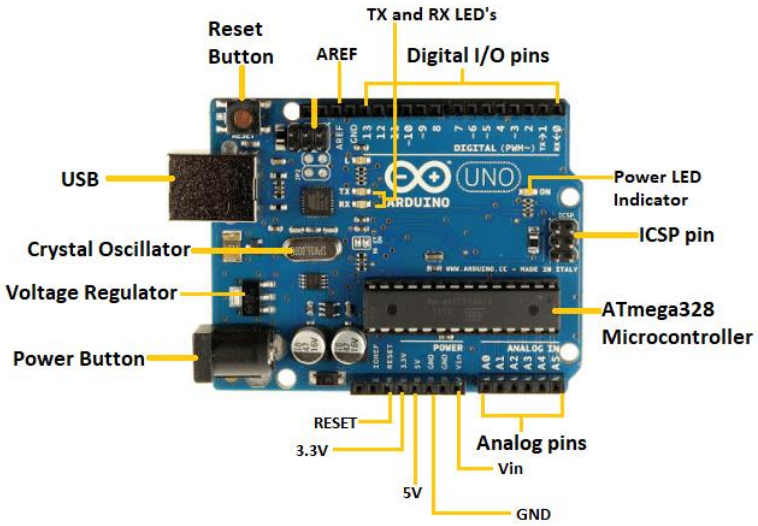

Figure 3.2 :Arduino UNO

3.3.3 A Laser Sender Module 650NM 5V

A Laser Module 650NM 5V sensor is a small electronic device that emits a laser beam at a wavelength of 650 nanometers (nm). It operates at a voltage of 5 volts (V) and is often used in electronic projects that require precise alignment or sensing. The laser module is shown in Figure 3.3.

Figure 3.3: Laser sender module

3.3.4 High level laser receiver non-modulator tube sensor module

This Laser Non-Modulator Tub Sensor Receiving Module Laser output High Level is a sensor for Raspberry Pi and Arduino to receive the laser output and decode it digital data. At input, the module Receive laser signal when output high level; Does not receive laser signal when output low level. On detecting a laser signal, output

goes at a high level (5V) until the laser signal is there. The laser receiver non-modulator tube sensor is shown in Figure 3.4. Here are some key features and specifications of a Laser Module 650NM 5V sensor:

- Working Voltage: 5V DC
- Operating Temperature: -30°c ~ 85°c
- Output high level when received the laser signal.
- Output low level when not receive laser signal.

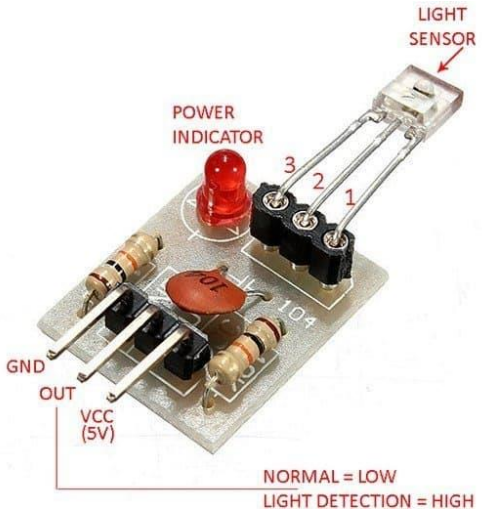

Figure 3.4: Laser receiver module

3.3.5 HC-12 transceiver

The HC-12 is a wireless RF UART communication module that can transmit up to 1 km. It has 100 channels in the 433.4-473.0 MHz range and can be set to different communication channels with a step of 400 kHz12. The HC-12 is a half-duplex wireless serial communication module that can be used to transmit and receive digital data1. HC-12 transceiver is shown in Figure 3.5.

Specification:

- Working frequency: 433.4MHz to 473.0MHz
- Supply voltage: 3.2V to 5.5VDC
- Communication distance: 1,000m in the open space
- Serial baud rate: 1.2Kbps to 115.2Kbps（default 9.6Kbps）
- Receiving sensitivity: -117dBm to -100dBm

- Transmit power: -1dBm to 20dBm.
- Operating temperature: -40℃ to +85℃
- Dimensions: 27.8mm x 14.4mm x 4mm

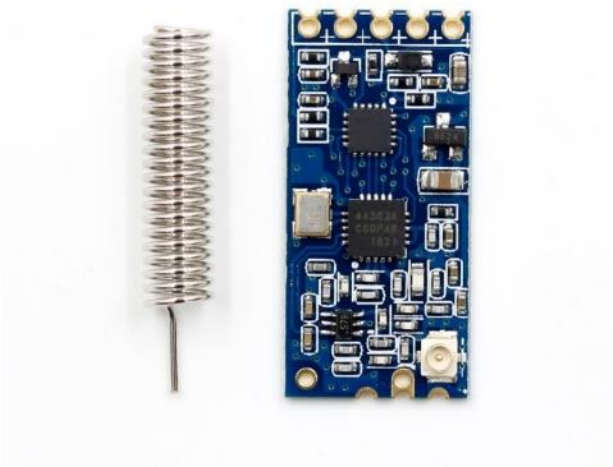

Figure 3.5: HC-12 module

3.3.6 801S Vibration Sensor Module

This 801S module changes its resistance level once vibration is detected. It can turn into a switch if the vibration is high. According to the datasheet, it is gold-plated and can withstand 60 million shocks. This module is connected in a voltage divider which can be measured through its digital pinout. It's a high sensitivity 801S Vibration Sensor module, which has one digital output pin (D0), When it detects some vibration up to a certain threshold, it can output High or Low level.

Comparing with other vibration or shock sensor, this 801S type has the following listed.

The 801S shock and vibration sensor, by itself, changes its resistance when subjected to vibrations. The resistance changes are so extreme that the 801S is like a switch. The datasheet claims that this gold-plated device can withstand 60 million shocks. As with most resistance-varying devices, the 801S is connected in a voltage divider circuit to get a voltage output. The vibration sensor is shown in Figure 3.6.

Features:

- Micro-Shock detecting

- 60,000,000 times shock guarantee (special gold alloy plated)
- Digital output signal
- The output valid signal is high, the light goes out.
- The sensitivity is adjustable (fine-tuning)
- The wide detection range of vibration, no direction
- With mounting holes, firmware installation is flexible and convenient.

Figure 3.6: 801s Vibration sensor

3.3.7 GPRS GSM SIM900 Arduino Shield

SIM900 GSM/GPRS shield is a GSM modem, which can be integrated into a great number of IoT projects. It can be used this shield to accomplish almost anything a normal cell phone can; SMS text messages, Make or receive phone calls, connecting to internet through GPRS, TCP/IP, and more! To top it off, the shield supports quad-band GSM/GPRS network, meaning it works pretty much anywhere in the world.

The SIM900 GSM/GPRS shield is designed to surround the SIM900 chip with everything necessary to interface with Arduino, plus a few extra goodies to take advantage of the chip's unique features. The GPRS GSM SIM 900 Arduino shield is shown in Figure 3.7.

Features:

- Supports Quad-band: GSM850, EGSM900, DCS1800 and PCS1900
- Connect onto any global GSM network with any 2G SIM.

- Make and receive voice calls using an external earphone & electret microphone.
- Send and receive SMS messages & GPRS data (TCP/IP, HTTP, etc.).
- Scan and receive FM radio broadcasts.
- Transmit Power: Class 4 (2W) for GSM850
- Transmit Power: Class 1 (1W) for DCS1800
- Serial-based AT Command Set
- U. FL and SMA connectors for cell antenna
- Accepts Full-size SIM Card.

Figure 3.7: GSM SIM 900

3.3.8 Multimedia Mini USB Speaker

A speaker is used to alert farm owner during any unwanted intrusion connected to microcontroller. Basically, in the study it is used in the farmers house (signal receiver station) to alert farmers. The USB speaker is shown in Figure 3.8.

Specification:

- Frequency response: 100HZ-18KHZ
- Power/ Voltage: 5W/1A
- Portable
- High Quality Sound and Bass

Figure 3.8 : USB speaker

3.3.9 Piezo Buzzer Alarm

Piezo Buzzer Alarm is a versatile and reliable component that produces a loud and continuous sound when activated. Its operating voltage range, sound level, mounting style, and dimensions make it suitable for use in various electronic systems. Its low current consumption and sound frequency make it an ideal choice for applications that require a low-power and high-frequency alarm or alert. It is used in farm sheds (signal sender station) for alarming application in the project. The piezo buzzer alarm is shown in Figure 3.9. The specifications of the buzzer alarm are as follows:

- Alarm Diameter:22mm/0.86″
- Alarm Height:10mm/0.39″
- 2 Mounting Holes distance:30mm/1.18″
- 2 Wires length:90mm/3.54″
- Buzzer Type: Piezoelectric
- Sound Pressure Level 95 dB
- Rate Voltage: 12V DC
- Operating Voltage: 3 – 24V
- Max Current Rating 10mA
- Frequency 3900±500Hz
- Drive Method: Drive Circuit Built in Mounting Holes

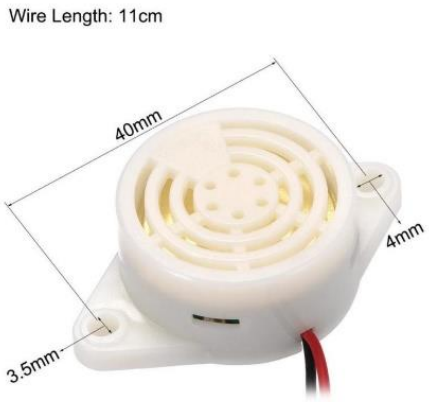

Figure 3.9: Piezo Buzzer

3.3.10 DS3231 Real time clock module

DS3231 RTC is a Precise Real-Time Clock Module with 32Kbit EEPROM and a built-in 10-bit temperature sensor having a resolution of 0.25C.

The DS3231 RTC module Precise Real-Time Clock Module is a low-cost, extremely accurate I²C real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input and maintains accurate timekeeping when the main power to the device is interrupted. The DS3231 real time clock module is shown in Figure 3.10.

Features:

- Two Time-of-Day Alarms.
- Register for Aging Trim.
- DS 3231 RTC with 2032 Battery Holder.
- Highly Accurate RTC Completely Manages All Timekeeping Functions.
- Real-Time Clock Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the Week, and Year, with Leap-Year Compensation Valid Up to 2100.
- Configurable I2C device Address for AT24C32 using SMD jumpers on PCB (A0, A1, A2).
- Programmable Square-Wave Output Signal.
- Low Power Operation Extends Battery-Backup Run Time

Technical Specifications:

Operating Voltage 2.3 to 5.5V (3.3 or 5V typical)

Current Consumption < 300μA (typ.)

Accuracy (0-40°C) ± 2ppm

Battery CR2032 (3V Coin)

Figure 3.10: DS3231 Real time clock module

3.3.11 MB102 Breadboard

The MB102 830-point solderless breadboard is a prototyping tool used for building and testing electronic circuits. It has 830 connection points arranged in a standard 0.1-inch grid pattern, allowing components and wires to be easily inserted and connected without the need for soldering. The MB102 breadboard is a type of solderless breadboard that is popular among hobbyists and students due to its ease of use and versatility. It features a compact size, making it ideal for use in small projects and tight spaces, and it can be easily powered by a DC power supply. The MB102 830-point solderless breadboard is a cost-effective solution for building and testing electronic circuits, making it a popular choice for many hobbyists and students. The MB 102 breadboard is shown in Figure 3.11.

Features:

- 830 Solder-less Points
- Ideal for Experimenting with Circuit Design in Labs
- Compatible with resistance, diodes, transistors, LED's, Capacitors, and other types of electronic components
- Completely reusable

- Colored coordinates for easy components placement.
- Phosphor bronze nickel-plated spring clips.
- Accept a variety of wire sizes 20-29 AWG.

Figure 3.11: MB102 Breadboard

3.3.12 Mini Breadboard

The SYB-170 Mini Solderless Breadboard is named for its 170 tie points. It has 17 columns of 10 holes, which are separated into two pairs by a central notch and labeled 1 to 17. Each column is also labeled, with a letter from A to J so that they can be easily referenced in instructions. The mini breadboard is shown in Figure 3.12.

Features:

- Use: experimental, testing, robot
- Matching jumper, diameter 0.8mm
- Accepts 20-29 AWG wire sizes.
- Adhesive-backed for permanent mounting.
- Phosphor bronze nickel-plated spring clips

Figure 3.12: SYB-170 Mini Solderless Breadboard

3.3.13 5 mm Red and Blue LED light

RED and blue light-emitting diode (LED) is a semiconductor light source. LEDs are used as indicator lamps in many devices and are increasingly used for other lighting. It is used in the project in the farmers house (signal receiver station) to alert farmer's family for laser and vibration sensor compromise indication during any unwanted intrusion. The red and blue LED lights are shown in Figure 3.13.

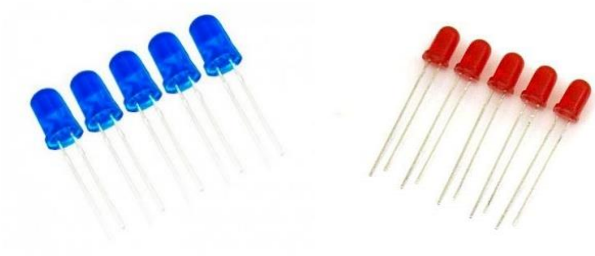

Figure 3.13: 5 mm Red & Blue LED light

3.3.14 5V 4000mA AC/DC Power Adapter

The brand new multipurpose 5V 4A Power supply Adapter with 5.5mm DC output. This adapter is compatible to handle up to 4A current so applications like toy cars, CCTV Cameras, Routers, Modems, Cordless Phones, Set-Top Boxes, Wireless Devices, and POS Machines are compatible with this adapter. The AC/DC power adapter is shown in Figure 3.14.

Features:

- This is a durable product.

- Wide input voltage range (100VAC-280VAC).
- Very low no-load power consumption.
- Protections against- under-over voltage/ overload/ short circuit with auto-restart on fault removal.
- Thermal shut down (140°C) with auto-restart on cold condition.
- Soft start & low inrush current.
- Isolation up to 3kv for 5sec.time.
- High operating ambient temperature up to 60°C.
- Highly efficient, compact, durable, and long life.

Figure 3.14: 5V 4000mA AC/DC Power Adapter

3.3.15 Sony 9V Rechargeable Battery 450mAh

It is used in the project for continuous supply of electricity in the circuit and modules during any power cutoff or load shedding. The rechargeable battery is shown in Figure 3.15.

Features:

- Constant 9V Output till lasts
- Metal Jacket Body
- Good Built Quality and hence Leakproof
- Easy to install and replace.
- Corrosion-free Connector Point for long-term use
- 0% Mercury and Cadmium. Environment-friendly

Figure 3.15: Sony 9V Rechargeable Battery

3.3.16 Mirror

It is used in the laser stand for reflecting the laser ray between laser sender and receiver module. The collected mirrors are shown in Figure 3.16

Figure 3.16: Mirror

3.3.17 MicroSD card module

Micro SD Card Reader Module also called Micro SD Adaptor which is designed for dual I/O voltages. The Module is a simple solution for transferring data to and from a standard SD card. The pinout is directly compatible with not only Arduino as shown in the diagram below but can also be used with other microcontrollers. Micro SD Card Reader Module has an SPI interface which is compatible with any SD card, and it uses 5V or 3.3V power supply which is compatible with Arduino UNO/Mega. SD module has various applications such as data logger, audio, video, graphics.

There are total of six pins (GND, VCC, MISO, MOSI, SCK, CS), GND to ground, VCC is the power supply, MISO, MOSI, SCK is the SPI bus, CS is the chip select signal pin; 3.3V regulator circuit: LDO regulator output 3.3V as level converter chip, Micro SD card supply. The micro SD card module is shown in Figure 3.17.

Features:

- Support Micro SD Card (<=2G), Micro SDHC card (<=32G) (high-speed card)
- The level conversion circuit board that can interface level is 5V or 3.3V

Figure 3.17: MicroSD card module

3.3.18 IRFZ44N MOSFET

IRFZ44N is a type of N-Channel Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). It is a voltage-controlled device that can be used as a switch or an amplifier, depending on the circuit configuration.

The IRFZ44N MOSFET has a maximum drain-source voltage (Vds) of 55V, a maximum drain current (Id) of 48A, and a maximum power dissipation (Pd) of 625W. It is capable of fast switching speeds and low on-resistance, making it a popular choice for high-power switching applications.

Some common applications of the IRFZ44N MOSFET include motor control, power conversion, power switching, DC-DC converters, and Class-D audio amplifiers. In the study it is used for automatic switching application. The IRFZ44N MOSFET module is shown in Figure 3.18.

Features:

- Advanced Process Technology

- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated
- Lead-Free

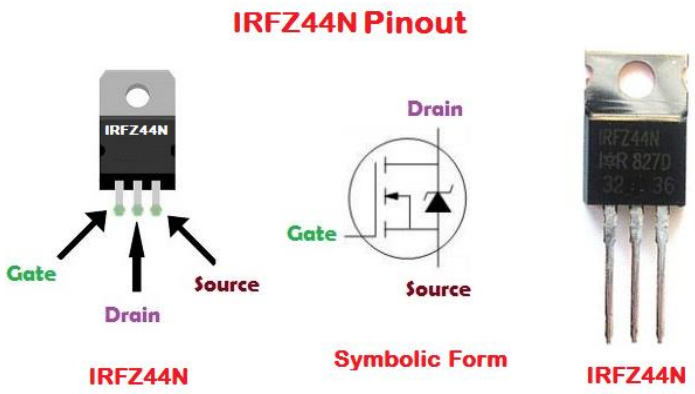

Figure 3.18: IRFZ44N MOSFET

3.3.19 Resistor

A 1/4w resistor is a type of resistor with a power rating of 1/4 watt. These resistors are commonly used in low-power electronics circuits for their compact size and affordability. The 1/4w rating indicates that the resistor can safely handle up to 1/4 watt of power without overheating or failing. The combination of a kiloohm resistance value and a 1/4-watt power rating make these resistors a useful component in a wide range of electronic projects and applications. In the study 1k and 10kohm resistors were used for developing the system. The resistors used in the study are shown in Figure 3.19.

Figure 3.19: 1K and 10K ohm resistors

3.4 Designing system flow chart and circuit block diagram

Before starting construction, there was a plan and design to develop the system algorithm and architecture which are given below in Figure 3.20 and Figure 3.21, respectively.

Figure:3.20 shows the alogorithom of the system which reflects the proposed working procedure of the secuity system. This system can be start and stop by making phone call. And it consists of microcontroller which process the data from the input devices as sensors to detect intruder activity and making instruciton for the output devices to alert the owners. And it also has a some safety feature in automation of the system corresposnding to the predetermined time schedule from owner. If the system detect any intrusion or the semsor are damaged by the intruder, it instanlty creat loud sound alerm and phone call to alert the farmer.

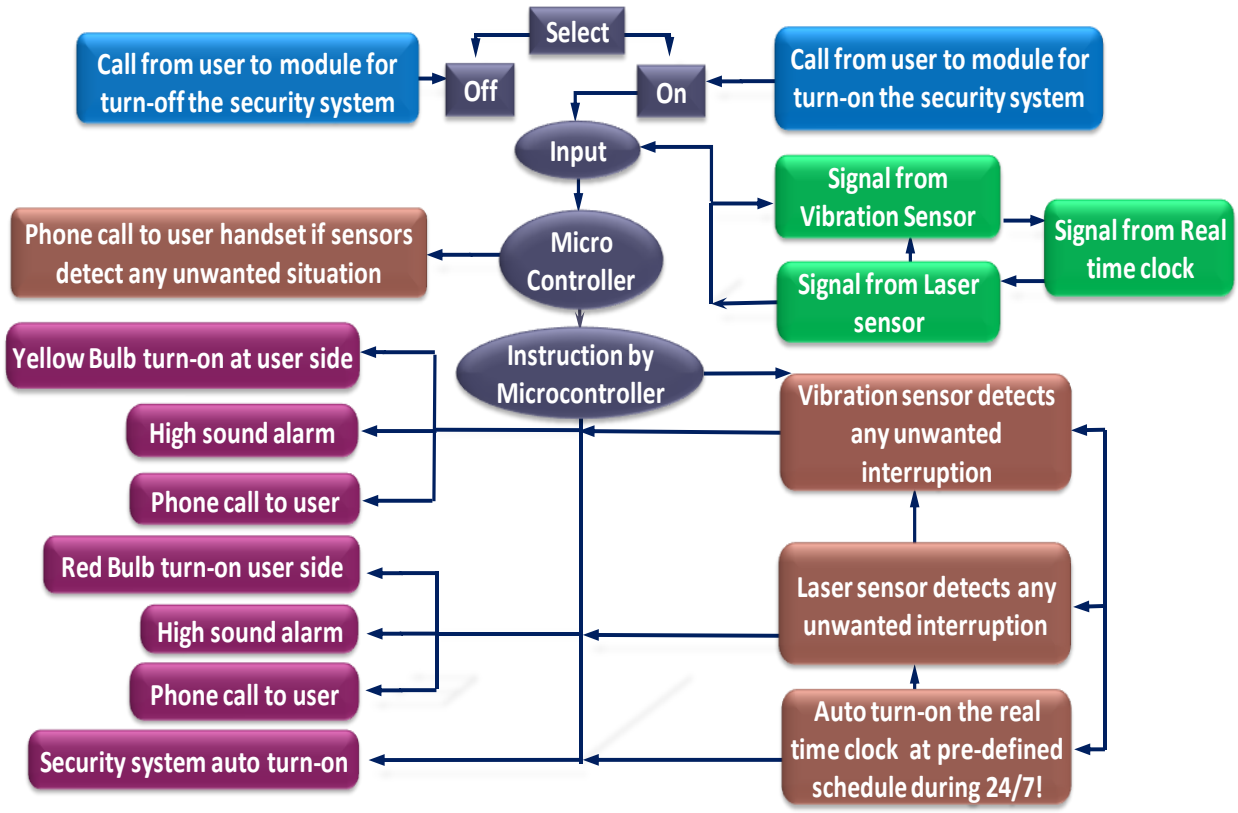

Figure 3.20: Algorithm of the proposed smart security system for agro-farm.

Figure:3.21 shows the architecture of the system which has two station as a sender station and another one as a signal receivers station. Both station has it's own

microcontroller. The entire system has two different sound alerm feature and also have indicator light for real time alerting the farmer/owner. Here, the input devices are laser sensor, vinbration sensor & realtime clock module. And output devices are speaker, indicator light and mobile phone.

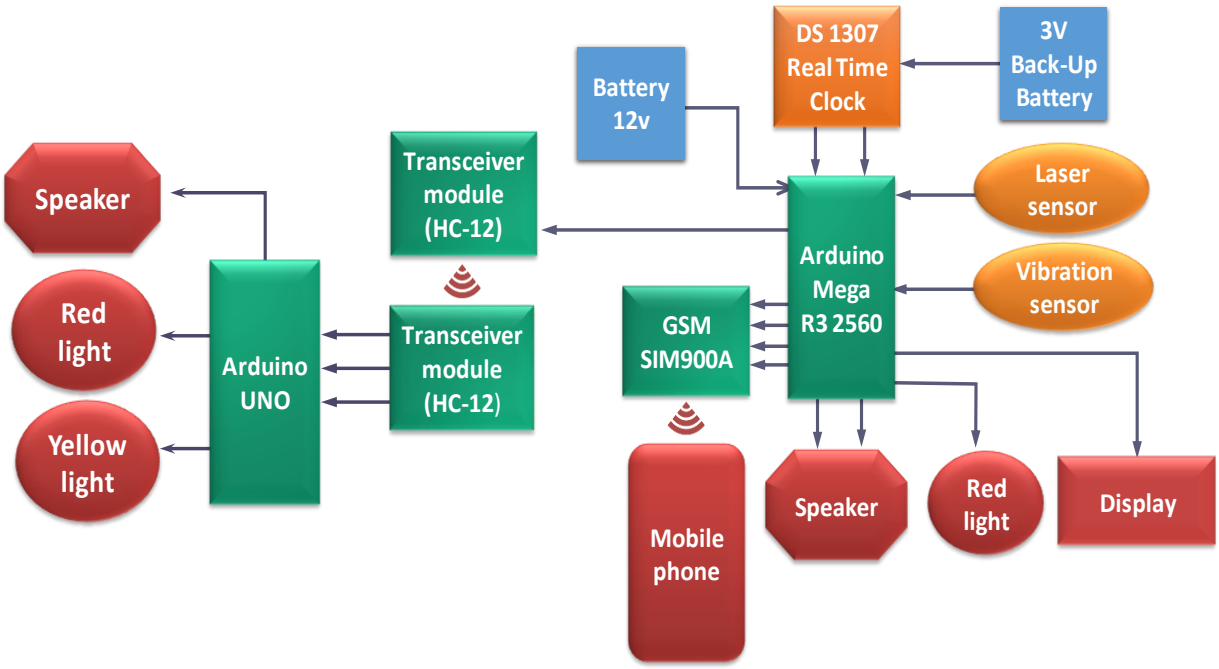

Figure 3.21: System architecture of smart security system

3.5 Designing the circuit diagrams of the entire security system

Two different circuit diagrams were designed in the study for communication between sender and receiver station. The first circuit diagram is for signal sender stations which are used in the farm shed side. And the other circuit diagram is for signal receiver station which stays in farmer's house. Both Tinker cad and Proteus software were used for designing those two circuits. The designed circuit diagrams are shown in Figure 3.22 and Figure 3.23

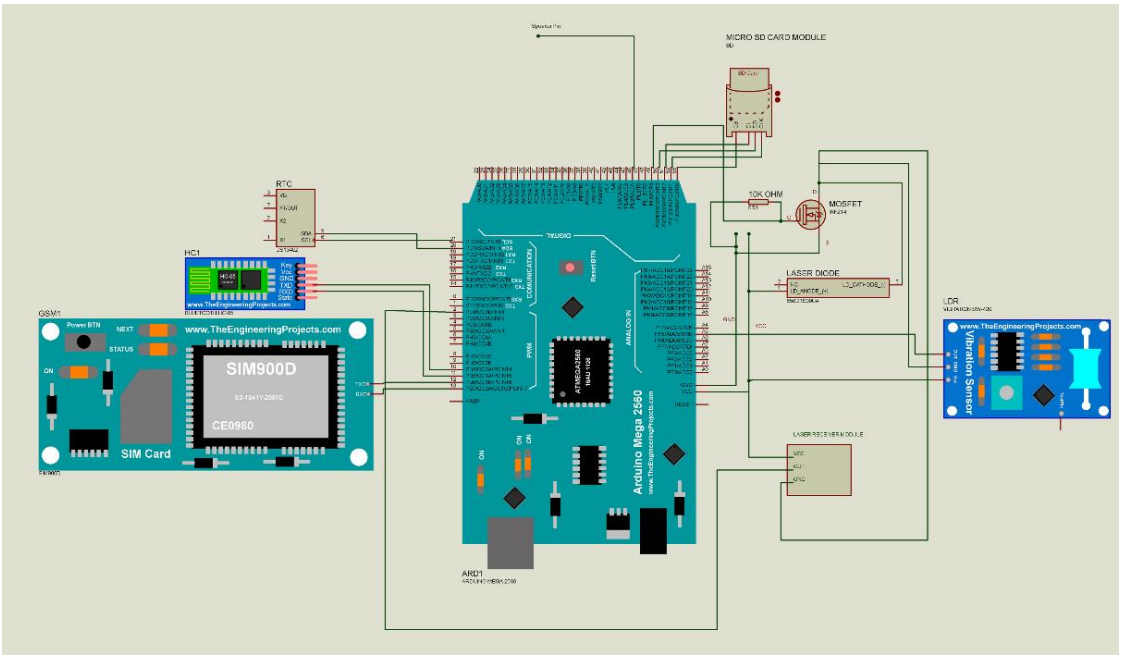

Figure 3.22: Circuit diagram for sender station (farm shed)

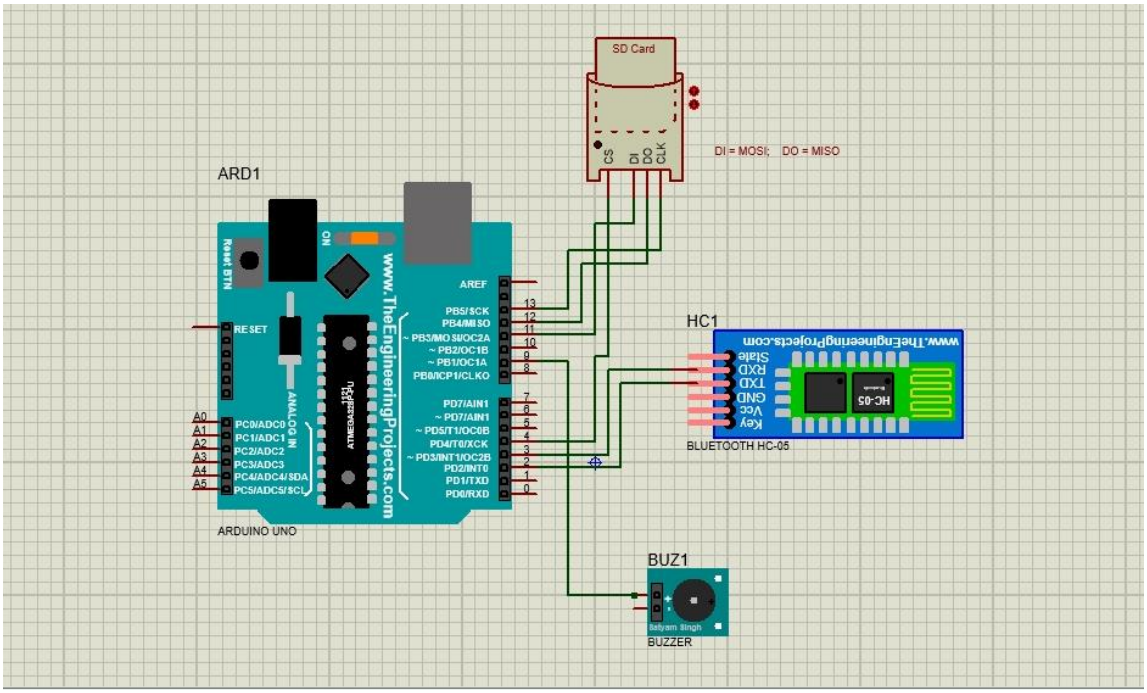

Figure 3.23: Circuit diagram for receiver station (farmer's house)

3.6 Construction of proposed prototyping circuit

Following the architecture of the circuit diagram the prototype has been developed consisting of microcontroller, transceiver, sensors, communication module, power source etc. All the modules were installed in the breadboard except the GSM module

and transceiver HC-12 module which required soldering work. Later on, the jumper wire and pins were soldered to the 5 pins of the HC-12 module. And then 3 jumper wire and pins were also soldered to the GSM module for transmission work. Finally, all the modules and sensors were connected to the bread boards according to the designer of the circuit diagram. Example of activities of all soldering and connection of different modules and wire are shown in Figure 3.24

Figure 3.24: Soldering activity with soldering Iron

Assembly of accessories in the breadboard

All connections of both signal sender and receiver stations circuits were joint to the respective breadboard according to the proposed design earlier. The connections of Arduino mega and uno with different accessories are shown in Figures 3.25 and Figure 3.26.

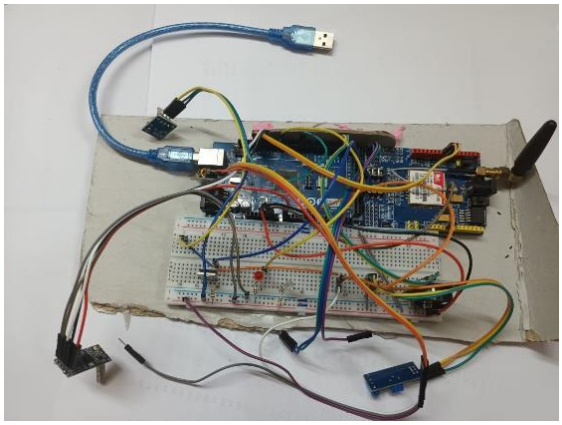

Figure 3.25: Arduino mega with other accessories as sender station

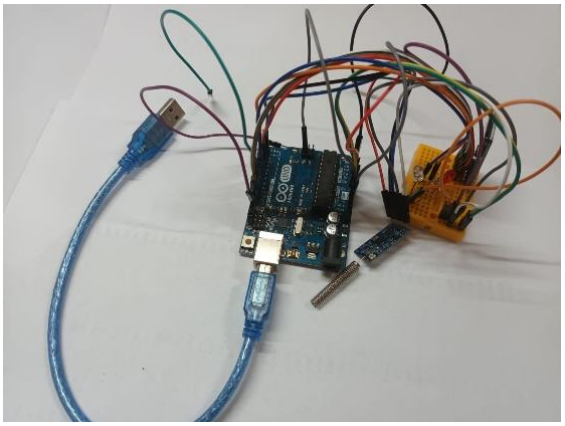

Figure 3.26: Arduino UNO with other accessories as receiver station

3.7 Powering up for action and checking functionality

Part programs for individual components were done carefully. Then complete program for entire system in Arduino IDE software were also uploaded. For checking the responsiveness two laptops were used for supplying the power to both the sender station and receiver station to check the functionality. There were lot of challenges to set up the sensors and accessories for doing the required tasks by correct order of programming and to run the entire security system. Several "trials and errors" methods were also considered to get complete functionality of the system. The checking of responsiveness is shown in Figure 3.27.

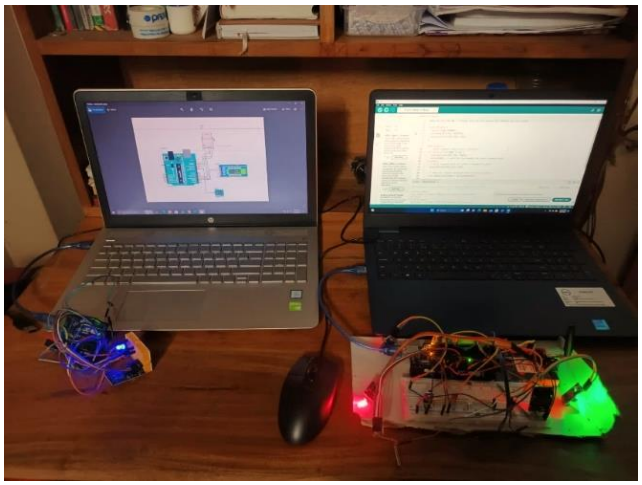

Figure 3.27: Functionality checking activity.

3.8 3D modeling of security system

In the study fusion 360 was used for developing a prototype modelling for laser stand and farm shed. 3D views of the laser stands, and machinery and cattle shed are shown in Figure 3.28 and Figure 3.29 respectively.

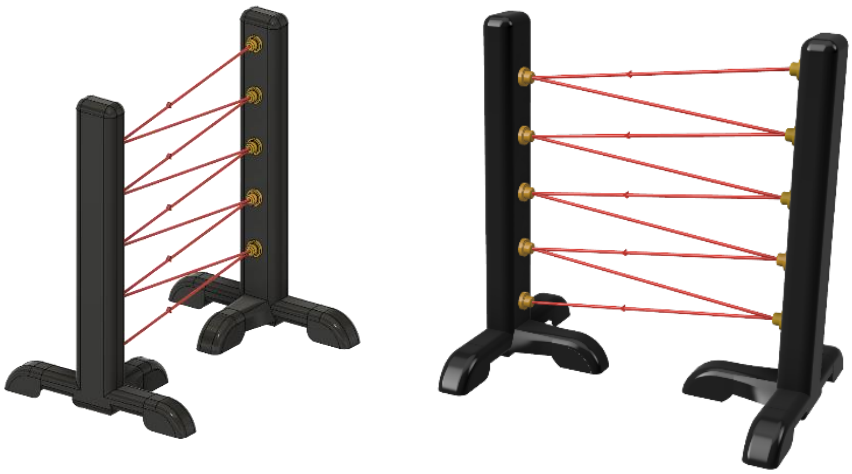

Figure 3.28: 3D view of the laser stands

Figure 3.29: 3D view of machinery shed and cattle farm

3.9 Construction of Laser stand with mirror

This stand consists of a laser sensor sender, a receiver module and 9 mirrors for complete covering the security of the entrance gate of the farm shed. Two separate stands were constructed for this purpose.

3.9.1 Construction materials required:

The following materials were used in the construction of the stands as

i. Wood ii. Mirror iii. Nut-bolt iv. Super glue v. Sand vi. Color paint vii. Wire nail

3.9.2 Construction machine required:

- Circular saw machine
- Wood planner machine
- Drill machine

3.9.3 Construction procedure:

At first, 1cft wood was collected and it was cut in length wise into two equal parts using circular saw as shown in Figure 3.30. A wood planner machine was used for smoothing the shape of these two pieces of wood as shown in Figure 3.31. Then the required 5.5 ft height was obtained by using a hand saw. The basement of the stand was also constructed to stabilize the stand. After finishing stand construction, 5 mirrors were attached in one stand and another 4 mirrors in the other stand with nut-bolt for providing required angle to reflect ray between laser sender and receiver modules as shown in Figure 3.32. The drill machine was also used to make two holes for attachment of the laser sender and receiver modules. Finally, both the stands were painted as shown in Figure 3.33.

Figure 3.30: Circular saw machine operation

Figure 3.31:Planner machine operation

Figure 3.32: finished work piece

Figure 3.33: Painting activity

3.10 Working principle of the IoT based agro-farm security system

If anybody touch the entrance gate of the machinery shed or somehow manage to enter the farm shed, the vibration sensor and laser sensor will sense/response the corresponding vibration wave signal and laser compromise signal from the touch activity and entrance activity. Instantly it sends the data to Arduino mega. It will create instructions to start the alarming light and sound both in the farm shed itself, also in the farmer's house via transceiver (HC-12) module where the receiver station is installed. The Arduino mega will also send calls and SMS signals to multiple owner's mobile phone using GSM module which acts also as another receiver station. Thus, the first receiver station's transceiver module HC-12 will receive the data and Arduino uno will create instruction to start alarming and intrusion indicator lighting to alert the farmer's family. The laser stands and all other necessary accessories of the security system were tested at the entrance of the agro-farm in Figure 3.34.

Figure 3.34: On-farm test of the developed agro-farm security system

Calculation formula:

$$\text{Laser sensor responsiveness } \% = \frac{\text{Total number of laser sensor responded}}{\text{Total number of trial}} \times 100$$

$$\text{Vibration sensor responsiveness } \% = \frac{\text{Total number of vibration sensor responded}}{\text{Total number of trial}} \times 100$$

CHAPTER – IV

Results and Discussion

The present study is mainly focused on the development and testing of an IoT based agro-farm security system in Bangladesh to enhance precise and robust farm security which will secure the farmer's assets and their farm. This Laboratory and field-based experiments were completed, and data collection was done properly. The developed security system was tested by Arduino IDE, Tinker cad and Cool term software simulation with respect to variation of time. And sensors responsiveness was found properly. Experimental results obtained from the present study were discussed in this chapter. The data have been presented in Table (s) and Figure (s). The results of each parameter have been discussed and possible interpretations wherever necessary have been given under the following headings.

4.1 Performance of the Laser sensor in the security system

Laser ray reflection among sender, mirrors & receiver were tested, and responsiveness was recorded with intrusion and without intrusion in the experiment successfully. From Cool term & IDE's serial monitor, laser sensor responsiveness was found as output (0, 1) with respect to time.

At the beginning of the experiment the laser ray was sent from the sender to receiver reflected via mirrors properly. In that time, continuous receiving of the ray by the receiver sensor is shown 1 as true value (Fig- 4.1). In the other case, if the laser sensor detects any unwanted intrusion or person passes the laser ray, the output will show false value and become 0 in the serial monitor (Fig- 4.1). The value, 1 represents the "ideal condition" of sending and receiving of laser ray among the two laser stands. And the 0 value represents the "detected condition" during any intrusion between the stands.

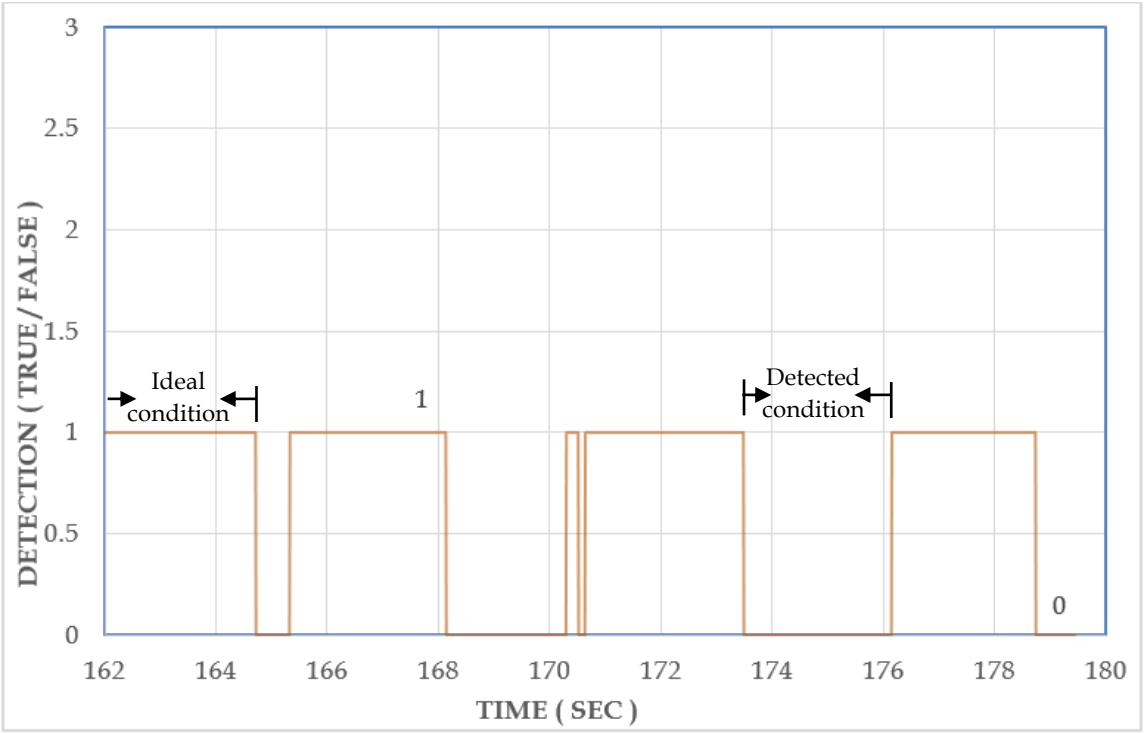

Figure 4.1: Laser sensor detection test

Table-1 shows laser sensor responsiveness as output with respect to time.

4.2 Responsiveness of vibration sensor

The strength of signal wave of the vibration sensor was measured and recorded with shock and without shock in the experiment successfully. From Cool term & IDE's serial monitor, the acceleration level (m/s^2) was found based on the regulating potentiometer of the vibration sensor respect to time.

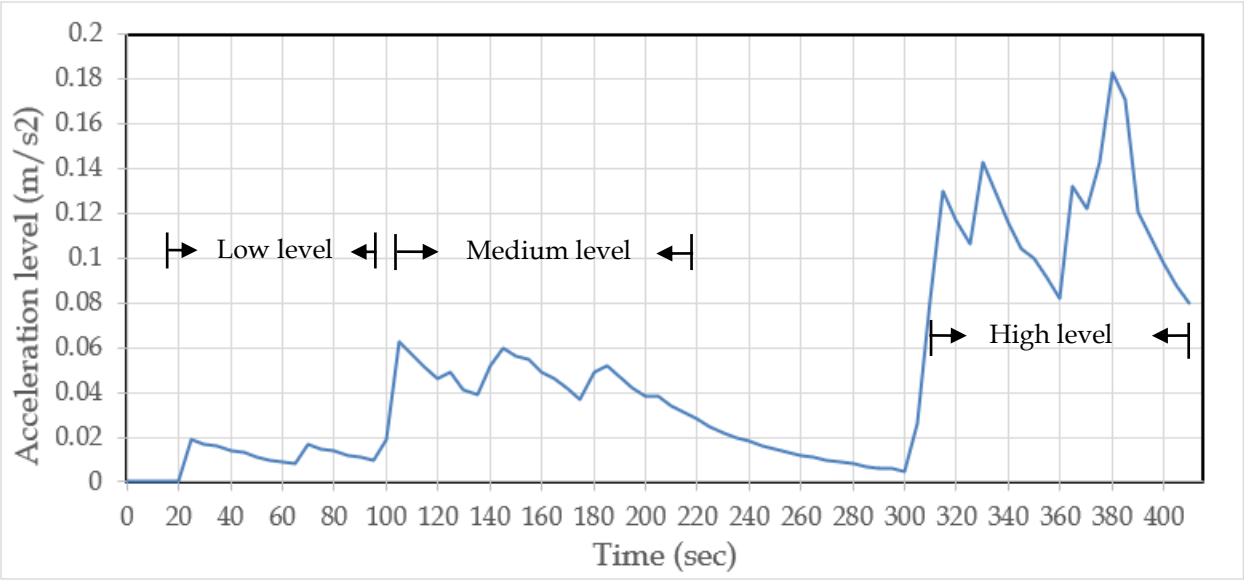

Figure 4.2: Vibration sensor sensitivity analysis

During the test of the vibration sensor, it is necessary to control three positions (Low, medium & high) of the potentiometer properly. In the low position of the potentiometer, the acceleration level was found between 0.006-0.031 m/s^2 (Fig- 4.2). On the other hand, in medium and high position the acceleration levels were found between 0.034-0.063 m/s^2 and 0.080-0.183 m/s^2, respectively.

This following table-2 shows vibration sensor acceleration level (m/s^2) as output with respect to time.

Table 1: Vibration sensor's wave of acceleration record

Time(sec)	**Acceleration (m/s2)**	**Calibration level**	**Time(sec)**	**Acceleration (m/s2)**	**Calibration level**
0	0	No shock	170	0.042	Medium
5	0	No shock	175	0.037	Medium
10	0	No shock	200	0.038	Medium
15	0	No shock	205	0.038	Medium
20	0	No shock	210	0.034	Medium
25	0.019	Low	215	0.031	Low
30	0.017	Low	220	0.028	Low
35	0.016	Low	225	0.025	Low
40	0.014	Low	230	0.022	Low
45	0.013	Low	235	0.02	Low
50	0.011	Low	265	0.011	Low
55	0.01	Low	270	0.01	Low
60	0.009	Low	275	0.009	Low
65	0.008	Low	280	0.008	Low
70	0.017	Low	285	0.007	Low
75	0.015	Low	290	0.006	Low
80	0.014	Low	295	0.006	Low
85	0.012	Low	300	0.005	Low
90	0.011	Low	305	0.026	Low
95	0.01	Low	310	0.081	High
100	0.019	Low	315	0.13	High
105	0.063	Medium	330	0.143	High

110	0.057	Medium	335	0.129	High
115	0.051	Medium	360	0.082	High
120	0.046	Medium	365	0.132	High
125	0.049	Medium	370	0.122	High
130	0.041	Medium	375	0.143	High
135	0.039	Medium	380	0.183	High
140	0.052	Medium	385	0.171	High
145	0.06	Medium	390	0.121	High
150	0.056	Medium	395	0.109	High
155	0.055	Medium	400	0.098	High
160	0.049	Medium	405	0.088	High
165	0.046	Medium	410	.08	High

4.3 Monitoring of the GSM module signal of the system

The strength of the GSM module signal was tested and recorded by making phone calls to the module to another mobile phone, successfully. From Cool term & IDE's serial monitor, the strength level (dBm) of the GSM module was found with respect to time.

During the test of the GSM module, the phone calls was made to the module using sim in different time and found different signal strength. The signal strength within >= -55 dBm to -69 dBm is excellent, strong with maximum data speeds. For signal strength between -70 dBm to -77 dBm is good signal with good data speeds. And signal strength within -78 dBm to -85 dBm is marginal, but useful, fast, and reliable data speeds may be attained, but marginal data with dropouts is possible (Teltonika Mobility, 2015). Signal strength with time is shown in Figure 4.3.

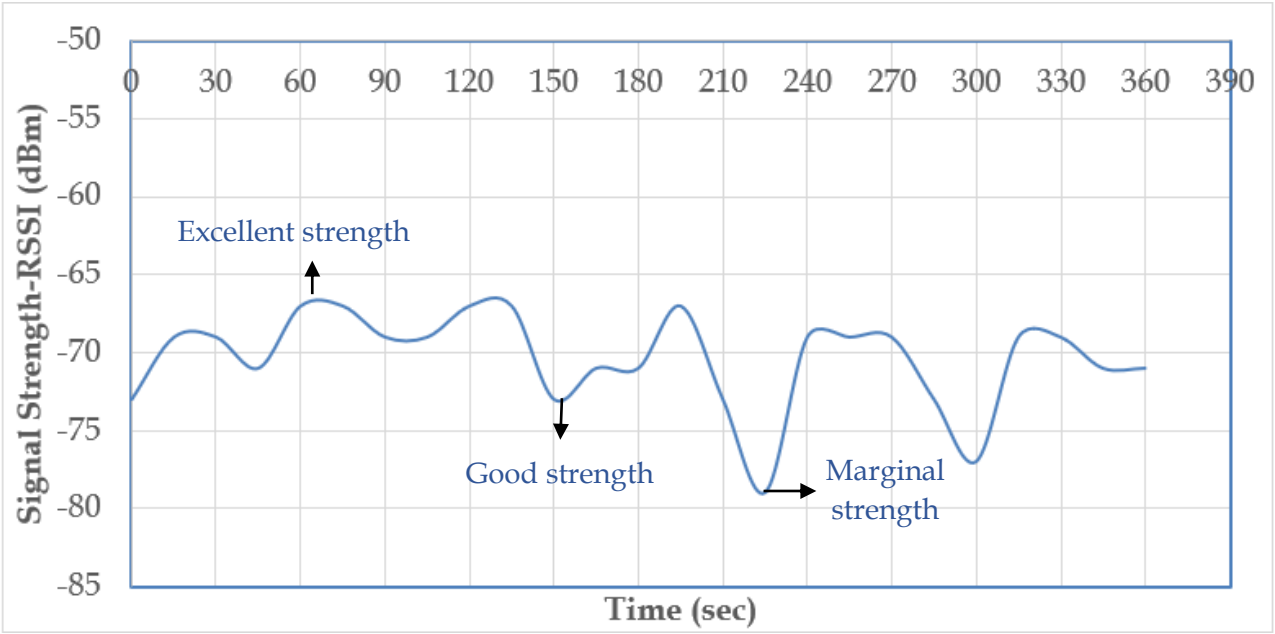

Figure 4.2: GSM Module signal test

This following table-3 shows GSM module's signal strength (dBm) and network quality as output with respect to time.

Table 2: GSM modules signal and quality record.

Serial no.	Signal strength (dBm)	Time (Sec)	Response	Quality
1	-73	0	1	Good
2	-69	15	1	Excellent
3	-69	30	1	Excellent
4	-71	45	1	Good
5	-67	60	1	Excellent
6	-67	75	1	Excellent
7	-69	90	1	Excellent
8	-69	105	1	Excellent
9	-67	120	1	Excellent
10	-67	135	1	Excellent
11	-73	150	1	Good
12	-71	165	1	Good
13	-71	180	1	Good

14	-67	195	1	Excellent
15	-73	210	1	Good
16	-79	225	1	Marginal
17	-69	240	1	Excellent
18	-69	255	1	Excellent
19	-69	270	1	Excellent
20	-73	285	1	Good
21	-77	300	1	Good
22	-69	315	1	Excellent
23	-69	330	1	Excellent
24	-71	345	1	Good
25	-71	360	1	Good

In the lab test, all the parameters including Laser, vibration sensors and GSM module are found to be well responsive and operational in the developed security system for securing the agro-farm shed.

4.4 Visualization of the functionality checking of the system

In the laptop the whole system was also monitored. Responsiveness and functionality of laser sensor and vibration sensor were visualized in the following Figures 4.3~4.6. The final visualization of the functionality of the entire system between its sender and receiver station is shown in Figures 4.3~4.6.

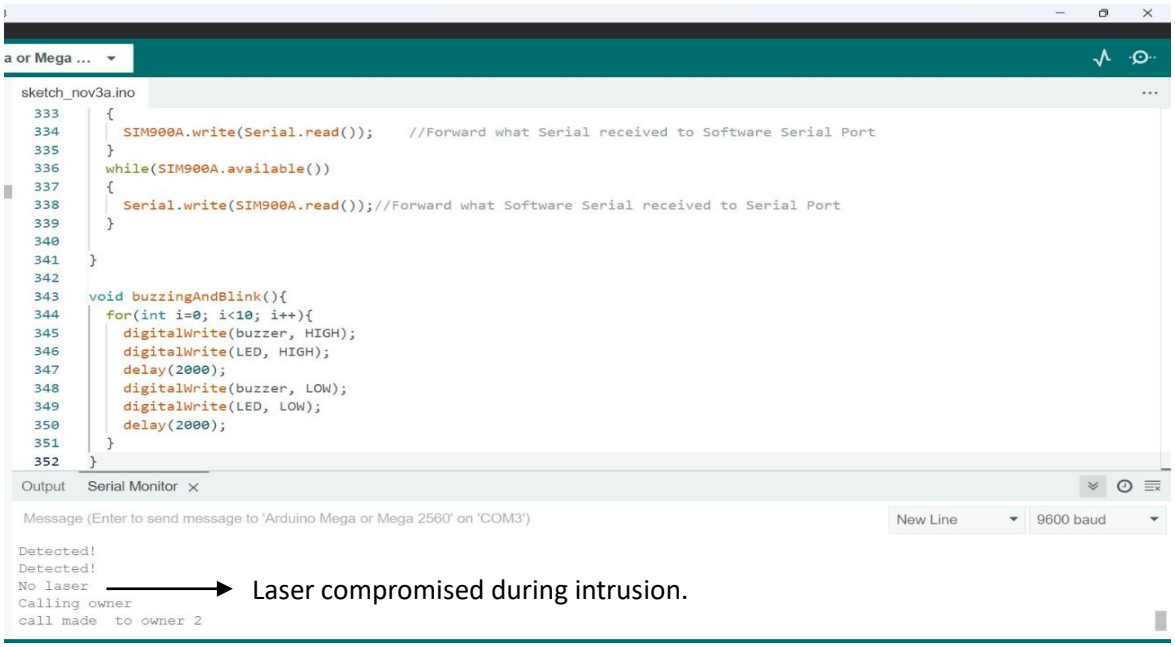

Figure 4.3: Laser sensor compromising showing at sender.

Figure 4.4: Vibration sensor sensing showing at sender.

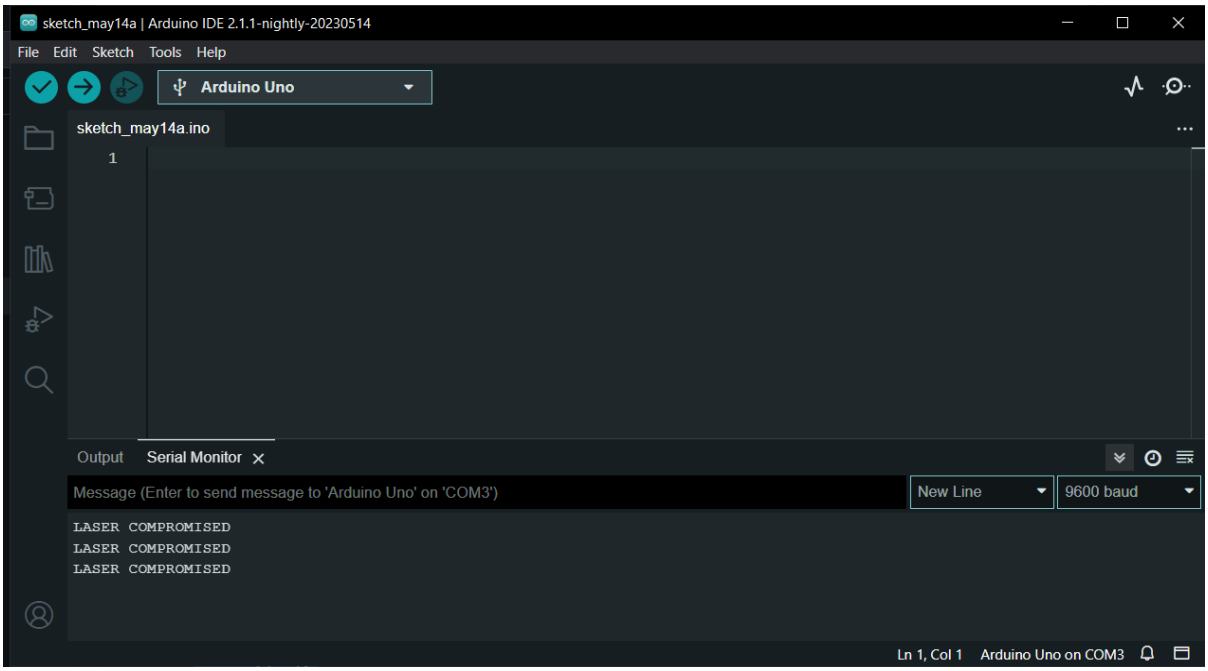

Figure 4.5: Laser sensor compromising showing at receiver.

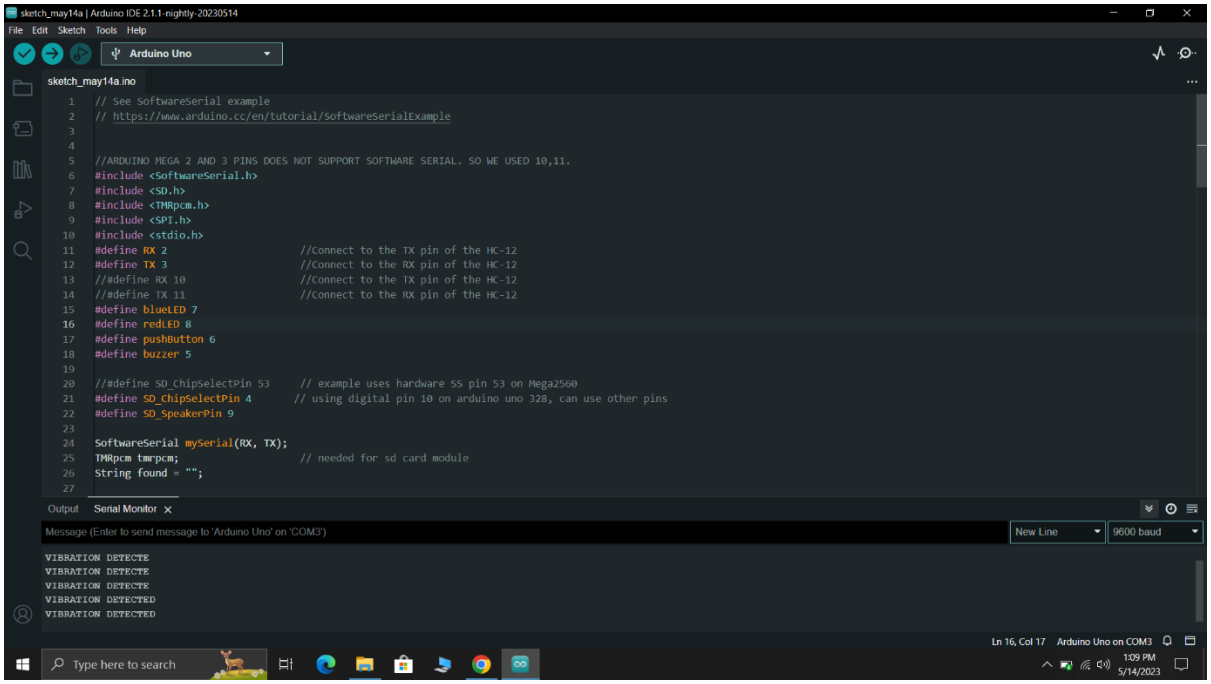

Figure 4.6: Vibration sensor sensing showing at receiver.

4.5 Performance evaluation

The whole smart agro-farm security system was tested at the on-farm. Total 20 trials were carried out at the Post harvest loss reduction innovation & Agricultural machinery testing lab, DFPM, BAU. In the test, the intruder knocked the entrance gate of the Post harvest loss reduction innovation lab and crossed the laser stand in every trials. Through this way all necessary data were monitored and recorded.

Table 3: Performance evaluation of the system

Trial no.	**Laser Sensor**			**Vibration sensor**		
	Red light	Phone call	Alarm	Blue light	Phone call	Alarm
1	On	Received	Activated	On	Received	Activated
2	On	Received	Activated	On	Received	Activated
3	On	Received	Activated	On	Received	Activated
4	On	Received	Activated	On	Received	Activated
5	On	Received	Activated	On	Received	Activated
6	On	Received	Activated	On	Received	Activated
7	On	Received	Activated	On	Received	Activated
8	On	Received	Activated	Off	Not Received	Not Activated
9	On	Received	Activated	On	Received	Activated
10	On	Received	Activated	On	Received	Activated

11	On	Received	Activated	Off	Not Received	Not Activated
12	On	Received	Activated	On	Received	Activated
13	On	Received	Activated	On	Received	Activated
14	On	Received	Activated	On	Received	Activated
15	On	Received	Activated	On	Received	Activated
16	On	Received	Activated	On	Received	Activated
17	On	Received	Activated	On	Received	Activated
18	On	Received	Activated	On	Received	Activated
19	On	Received	Activated	On	Received	Activated
20	On	Received	Activated	On	Received	Activated

In the study the laser sensor perfectly responded 20 times in 20 trials. But the vibration sensor responded 18 times in 20 trials. The cause behind the failure of 02 times due to the weakness of the vibration sensor. It can be easily overcome through incorporation of high quality and high configurable vibration sensor in the system. Finally, the responsiveness or efficiency of the entire system was found to be 90%. The analyzed results are shown in Figure 4.7.

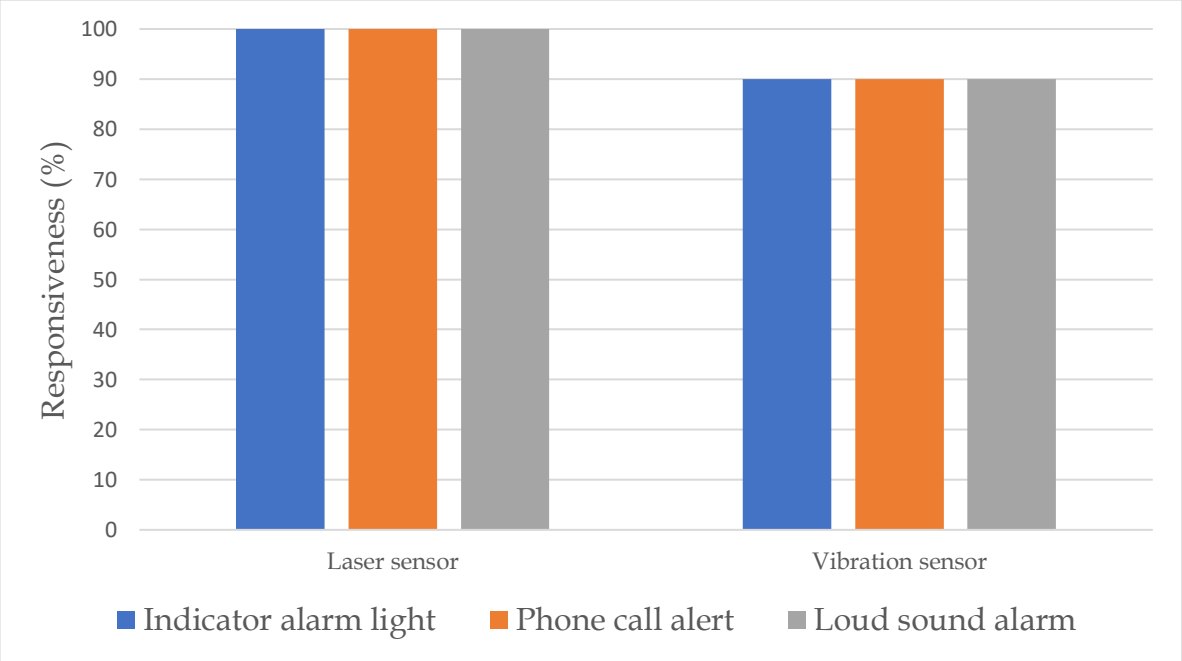

Figure 4.7: Responsiveness of the system

CHAPTER– V

Conclusion and Recommendations

5.1 Conclusion

An IoT based agro-farm security system has been designed in the perspective of Bangladesh to secure the Agro-farm sheds. It is found to be successfully securing the farm shed like dairy farm, poultry farm & machinery shed. It is planned to enhance the security of the agro-farms in Bangladesh to save the farm's assets from robbery and burglary. As the agriculture of Bangladesh is becoming commercialized and entrepreneurship in agricultural farming is also increasing day to day it is crucial need to have a robust and reliable smart security system. This security system offers precise, real-time detection and alarming function to the farm owner. It replaces the traditional practice of securing farm/shed like human guarding. In the study an IoT base smart technology has been designed and developed which will be good alternative to traditional one for increasing sustainable farm mechanization in Bangladesh. This smart IoT based security system developed two layers of protection in the farm sheds with the use of laser sensor, vibration sensor, GSM & transceiver module in the Farm Power and Machinery Department, Bangladesh Agricultural University, Mymensingh. The system is now ready to use in commercial agro-farm for real-time double layers security for sustainable agro-business in Bangladesh.

5.1 Recommendations

- The system can be used in any poultry farm, dairy farm or machinery shed.
- A simple training and demonstration at the stakeholder's level are required before using it at field level.
- It can be used in the existing CCTV camera for monitoring real-time situations as well and it will increase further security of the farms.
- The system can be more precise by using intelligence sensors like IR, Motion Detection Sensor & Photoelectric beam sensor.
- In addition, the system will be more convenient if smart phone based android application is used for real time monitoring.

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APPENDIX

Table 4: Laser sensor detection record

Serial no.	Time(sec)	Output (True/ false)
1	162	1
2	163	1
3	164	1
4	165	0
5	166	1
6	167	1
7	168	1
8	169	0
9	170	0
10	170.4	1
11	170.6	0
12	171	1
13	172	1
14	173	1
15	174	0
16	175	0
17	176	0
18	177	1
19	178	1
20	179	0
21	180	0

Calculation:

$$\text{Laser sensor responsiveness } \% = \frac{\text{Total number of laser sensor responded}}{\text{Total number of trial}} \times 100$$

$$= \frac{20}{20} \times 100$$

$$= 100\ \%$$

$$\text{Vibration sensor responsiveness } \% = \frac{\text{Total number of vibration sensor responded}}{\text{Total number of trial}} \times 100$$

$$= \frac{18}{20} \times 100$$

$$= 90\ \%$$

So, the entire system responsiveness = $.90 \times 1 \times 100\% = 90\%$