

A framework for Predicting Temperature, Humidity Using Raspberri pi 3

V Rajita¹, Balajee Maram², P Mani³, K Sireesha⁴, Y Mounika⁵

^{1,2,3,4,5} GMR Institute of Technology, JNT University, Kakinada, INDIA.

*Corresponding author: Balajee Maram, E-mail: balajee.m@gmrit.org

Received: March 12, 2018, Accepted: April 15, 2018, Published: April 15, 2018.

ABSTRACT

Internet of Things (IoT) is used to control any electrical and electronic equipment embedded with software, sensors and network connectivity that enables the devices to collect and analyze data. Raspberry pi3 is a single-board computer that was designed using Python Programming language and can be controlled and accessed remotely through an Internet of Things platform. This project is about humidity and temperature monitoring system using Raspberry pi3 and IoT. DHT11 temperature and humidity sensor is used to collect the data of temperature, humidity and sends the information to the database using Raspberry pi3 model B. From the database, temperature and humidity values are then displayed on the screen. In addition to that, the limits are set for temperature and humidity values. This project is a kind of environmental condition monitoring.

Keywords: *raspberry pi3, DHT11 sensor, IoT*

INTRODUCTION

Temperature is one of the most important activities around us. Temperature and humidity place a vital role in many industries and different fields of science. The temperature along with humidity monitoring places a crucial role in lot of industries like the pharmaceutical industry and the food factory. Here the monitoring node is raspberri pi 3 model B module. Programming language for raspberri pi3 model B is Python. Here the utilized sensor is DHT11 sensor which is used for monitoring temperature and humidity. The advantage of DHT11 sensor is economical and light weight. The jumper wires are used for interface between sensor and raspberri pi3 model B module. The surrounding temperature and humidity is sensed using the sensor DHT11. SQLite database is used to store data from the sensor. The raspberri pi3 model B is a popular 64-bit embedded hardware platform along with few sensors it is used to sense and control the surroundings. Comparing to other monitoring node like arduino uno, it has a disadvantage like space complexity and time complexity. In raspberri pi 3 model B^[1], python code is used. So, the line of code is decreased and time complexity and space complexity is decreased.

In order to get the information regarding temperature and humidity we place LCD to display the values, by using sensors and getting the data in the place where the sensors are placed but the data is not stored anywhere.

Disadvantages of Existing System

- cannot get the previous information.
- cannot get the messages.
- Not efficient
- Data cannot be stored.

2.1 STUDY OF TECHNICAL COMPONENTS

What is "IOT"?

The Internet of Things^[4] is the network of physical devices, vehicles, home appliances and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these objects to connect and exchange data. That includes an extraordinary number of objects of all shapes and sizes – from smart microwaves, which automatically cook your food for the right length of time, to self-driving cars, whose complex sensors detect objects in their path, to wearable fitness devices that measure your heart rate and the number of steps

you've taken that day, then use that information to suggest exercise plans tailored to you.

What is "Raspberri pi3 model B"?

Raspberri pi 3 is one of the version of the raspberri pi, a tiny credit card size computer which was released in February 2016. It contains a 1.2 GHZ ARM Cortex-A53 CPU. It is the first version of the raspberri pi which support the arm64 architecture. Raspberri pi is a mini computer and wireless technology. Various sensors are interfaced with raspberri to get information from surroundings and the data from sensors is stored in SD card. Here, SD card act as memory storage. The GPIO (general program input and output) pins are used to interact with sensors.

How to connect Sqlite to database?

Operations on a database are preformed atomically. This means a group of changes to a database can be written in one operation. If there is an error during the operation, the changes will be undone. If there are no errors during the operation, the changes are permanently committed. Databases keep a journal of transactions. If there's a power cut or the computer crashes during an operation, and the computer must be restarted, the journal can be checked to see if there were any operations in progress when the failure occurred. If the journal lists any changes that weren't committed, they can be rolled back so that the database is returned to its original state. This ensures that the database won't be corrupted in the event of a failure.

The sequence of events in a transaction is:

- begin the transaction,
- perform some SQL operation,
- if no errors occurred, commit the changes to the database and end the transaction,
- if there were any errors, rollback the changes and end the transaction.

2.2 Study on related concepts

2.2.1 Raspberri Pi Based Weather Monitoring System

Various weather monitoring techniques have been reviewed in the paper (Meetali V. Rasal, Prof. Jaideep G. Rana). Recorded information is kept in the device for further use. User can find out the data saved by the system anytime as per the request. A weather monitoring model or system has been developed as discussed in this paper to record and displaying of the weather parameters like temperature, humidity, [6,13]wind direction

speed, rain fall detection and atmospheric pressure Various weather monitoring techniques have been reviewed in this paper. Recorded information is kept in the device for further use.

2.2.2 IoT-based Temperature and Humidity Monitoring System for Agriculture

Taking care of these things manually requires a lots of human work and time and also it is a costly affair (Akash, Amit Birwal). Hence the aim of the project is to make an IoT-based temperature and humidity monitoring system ^[6,13] which reduces the human work and taking cares of these factors.

2.2.3 An IoT application for environmental monitoring and control using Raspberry-Pi

Raspberry Pi hardware board is an economical Internet of Things (IoT) hardware platform that can be used for wide variety of applications. This paper (Ravi Kiran Varma P, P L N Raju, M Priyanka) discusses the hardware, software platforms and implementation details of an IoT application for environmental monitoring and control using Raspberry PI 3 Model B. The DHT11 sensor is used to monitor temperature and humidity to further control the air conditioning system.

3. PROPOSED SYSTEM

In this paper the updated data regarding temperature and humidity in any areas can be accessed using sensor, raspberry pi3 and IOT technology ^[3]. The main aim of the proposed system is to monitoring the real time temperature and relative humidity in a cost effective at fixed interval of time. In this monitoring node is raspberry pi3 and sensor is DHT11. Raspberry pi is used to store and display the temperarure and relative humidity, and is programmed using python language. The DHT11 Temperature & Humidity Sensor^[2] features a temperature & humidity sensor provides digital output but DHT11 is mainly used for the humidity measurement. Features of sensors includes high reliability and long term stability In this the temperature is displayed degree celsius or Fahrenheit. Raspberry pi processed data will be updated continuously on SQLite database and we get stored data on hourly or daily. WIFI is attached so that it fetches data with help of internet and user can access or control temperature and humidity from any part of the world.

3.1 ADVANTAGES OF PROPOSED SYSTEM

- We can get present information regarding temperature and humidity in a particular place.
- In raspberry pi 3 model B, python code is used. So, the line of code is decreased and time complexity and space complexity is decreased.
- It is very useful for industries, pharmacies as it is used to detect the temperature.
- Accessible from any where, efficient, user friendly.

3.2 REQUIREMENTS SPECIFICATION

3.2.1 FUNCTIONAL REQUIREMENTS

In software engineering, a functional requirement section defines a function of a software system or its component. A function is described as a set of inputs, the behavior, and outputs. Functional requirements may be calculations, technical details, data manipulation and processing and other specific functionality that define what a system is supposed to accomplish. Behavioral requirements describing all the cases where the system uses the functional requirements are captured in use cases Functional requirements are supported by non-functional requirements (also known as quality requirements), which impose constraints on the design or implementation (such as performance requirements, security, or reliability). How a system implements functional

requirements is detailed in the system design. In some cases a requirements analyst generates use cases after gathering and validating a set of functional requirements. Each use case illustrates behavioral scenarios through one or more functional requirements.

The functional requirement of the system defines a function of software system or its components. A function is described as set of inputs, behavior of a system and output.

- This project aims at monitoring the real time temperature and relative humidity in a cost effective way. Here the monitoring node is raspberry pi. Programming language used for raspberry pi is Python..
- The Internet of Things is termed as network of physical objects or "things" embedded within network connectivity, electronics, software or sensors, which enables the objects to collect as well as exchange data simultaneously.
- Raspberry pi project is the best way to get started on working with the IOT and to build your knowledge to expand it to other applications.

3.2.2 NON-FUNCTIONAL REQUIREMENTS

In systems engineering and requirements engineering, a non-functional requirement is a requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors. This should be contrasted with functional requirements that define specific behavior or functions In general functional requirements define what a system is supposed to do whereas non- functional requirements define how a system is supposed to be. Non-functional requirements are often called qualities of a system. Other terms for non-functional requirements are "constraints", "quality attributes", "quality goals" and "quality of service requirements," and "non-behavioral requirements. "Qualities, that is, non- functional requirements, can be divided into two main categories:

- Execution qualities, such as security and usability, which are observable at run time.
- Evolution qualities, such as testability, maintainability, extensibility and scalability, which are embodied in the static structure of the software system.

The main aim of defining non-functional requirements to any system to exhibit software quality attributes such as Accuracy, performance, security and modifiability.

3.3 HARDWARE AND SOFTWARE REQUIREMENTS

HARDWARE REQUIREMENTS

The most common set of requirements defined by any operating system or software application is the physical computer resources, also known as hardware, a hardware requirements list is often accompanied by a hardware compatibility list (HCL), especially in case of operating systems. An HCL lists tested, compatible, and sometimes incompatible hardware devices for a particular operating system or application. The following subsections discuss the various aspects of hardware requirements.

The selection of hardware is very important in the existence and proper working of any software. In the selection of hardware, the size and capacity requirements are also important.

HARDWARE USED

- Raspberry pi 3
- DHT 11 Sensor
- USB Cable
- Ethernet Cable
- Jumper wires

Raspberry pi 3

Raspberry pi 3 is one of the version of the raspberry pi ^[5,9,10], a tiny credit card size computer which was released in February 2016. It contains a 1.2 GHZ ARM Cortex-A53 CPU. It is the first version of the raspberry pi which support the arm64 architecture. Raspberry pi is a mini computer and wireless technology. Various sensors are interfaced with raspberry to get information from surroundings and the data from sensors is stored in SD card. Here, SD card act as memory storage. The GPIO (general program input and output) pins are used to interact with sensors.

DHT11 sensor

DHT11 digital temperature and humidity sensor^[11,12] is a composite Sensor contains a calibrated digital signal output of the temperature and humidity. The advantage of this sensor is it is highly reliable, low price, good quality, faster response time, and inference free design. The DHT11 Temperature & Humidity Sensor is a 4-pin low cost highly reliable sensor. Pin-1 is Vcc, Pin-2 is data pin which collects data from outside world and gives data to the microcontroller. Its temperature range is 00-550C with an error of plus or minus 20C and Humidity range is 20-90%. It can directly provide a digital output with its own serial communication protocol. It uses Negative Temperature Coefficient (NTC) based temperature sensing component, and moisture substrate based humidity sensing component.

USB Cable

The term USB stands for “Universal Serial Bus” USB cable assemblies are some of the most popular cable types available, used mostly to connect computers to peripheral devices such as cameras, camcorders, printers, scanners, and more. USB is a cross-platform technology that is supported by most of the major operating systems.

Ethernet Cable

Ethernet is commonly used in Local area networks(LAN), Metropolitan area networks(MAN) and Wide area networks(WAN). It was introduced in 1980 and first standardized in 1983 as IEEE 802.3, and has since been refined to support higher bit rates and longer link distances. Ethernet has largely replaced competing wired LAN technologies such as Token Ring, FDDI and ARCNET. When using an Ethernet network, the network’s router also serves as a bridge to the Internet. The router connects to the modem, which carries the Internet signal, sending and receiving data packet requests and routing them to the proper computers on the network.

Jumper Wires

A jumper wire also known as jumper, jumper wire, jumper cable, DuPont wire, or DuPont cable. It is an electrical wire or group of them in a cable with a connector or a pin at each end, which is normally used to interconnect the components of a bread board or other prototype or test circuit.

Types of Jumper wires

1. Female to Female Jumper wire.
2. Male to Male Jumper wire.
3. Female to Male Jumper wire.

SOFTWARE REQUIREMENTS

Software Requirements deal with defining software resource requirements and pre-requisites that need to be installed on a computer to provide optimal functioning of an application. These requirements or pre-requisites are generally not included in the software installation package and need to be installed separately before the software is installed.

- Advanced IP Scanner

- Putty
- Xming Server
- Raspbian OS

Advanced IP scanner

In a few seconds, Advanced IP Scanner can locate all the computers on your wired or wireless local network and conduct a scan of their ports. It has a fast networking scanning, MAC addresses detection, Remote access. It is a free, fast and powerful network scanner with a user-friendly interface. The program provides easy access to various network resources, such as HTTP, HTTPS, FTP and shared folders. The remote pc shutdown features lets you shutdown any remote computer or group of computers running windows.

Putty

Putty was written and is maintained primarily by Simon Tatham .It is a free and open-source terminal emulator, serial console and network file transfer application. Putty supports many variations on the secure remote terminal, and provides user control over the SSH encryption key. It can also be used with local serial port connections.

Xming server

Xming is an X11 display server for Microsoft windows operating system. Xming provides the X windows system display server, a set of traditional sample X applications and tools, and a set of fonts. It features support of several languages and has Mesa 3D, OpenGL, and GLX 3D graphics extensions capabilities. Xming may be used with implementations of Secure shell(SSH) to securely forward X11 sessions from other computers. The Xming project also a portable version of putty. By using this GUI interface is obtained. It is act like a server for windows. It is fast, simple to install.

Raspbian OS

Raspbian is a Debian Linux and is optimized to work efficiently with the Raspberry Pi computer. As we already know an OS is a set of basic programs and utilities that runs on a specified hardware, in this case the Pi. Debian is very lightweight and makes a great choice for the Pi. The Raspbian includes tools for browsing, python programming and a GUI desktop.

4.SYSTEM ANALYSIS AND DESIGN

4.1 SYSTEM ARCHITECTURE

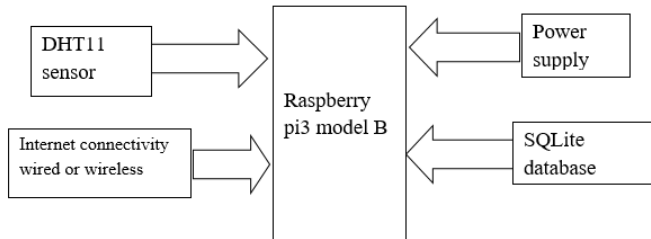
Block diagram

In this project, the proposed system target to monitoring the real-time temperature and humidity in a cost-effective way. Here monitoring node is raspberry pi3 model b and sensing node is DHT11 Temperature and Humidity sensor. The sensor is connected to raspberry pi3 model b with the help of jumper wires. The jumper wires must connect to GPIO pins of the raspberry pi3 model b. The raspberry pi3 kit is used to store the sensing data and display the real-time temperature and relative humidity. Raspberry pi3 module is programmed using python language. The output temperature is displayed in terms of degree Celsius or Fahrenheit or both as required. In this project, Sqlite queries is used to retrieve data from the database. By creating the tables data is stored into those tables along with date and time. Minimum, Maximum and Average values of the temperature and humidity over a certain period also known with the help of Sqlite. The sensing data is continuously entered into database.

SQLite queries is used to retrieve those data. The xming server is used to interact with raspberry pi 3 model b module. The block diagram of the proposed system is displayed below:

Raspberry pi 3

Raspberry pi 3 is one of the version of the raspberry pi, a tiny credit card size computer, which was released in February 2016. It contains a 1.2 GHZ ARM Cortex-A53 CPU. It is the first version of the raspberry pi which support the arm64 architecture.



Raspberry pi is a mini computer and wireless technology. Various sensors are interfaced with raspberry to get information from surroundings and the data from sensors is stored in SD card. Here, SD card act as memory storage. The GPIO (general program input and output) pins are used to interact with sensors. The processing speed is 1.2ghz and RAM has 1GB. Raspberry pi 3 can access both Bluetooth and Wifi connection. It has 4USB ports, 1Ethernet cable, video Core IV3D graphics core, 3.5mm audio jack, full HDMI port, Micro SD card slot, Camera Interface (CSI), Display Interface (DSI), RASPBIAN operating system. Raspberry pi is used in different projects like smart street lights with wireless motion sensors, smart home monitoring system, smart egg tray, smart garbage collection and more. The RASPBIAN operating system is a Debian based operating system. The operating system for raspberry pi is RASPBIAN, it is official operating system. Actually why we call it as Raspberry pi is a lot of computer companies were named after fruit. There's Tangerine computer system, Apricot computers and old British Company Acron, which is a family of fruit. Pi is because, if we were going to produce a computer that could only really run python. so, the pi in there is python. One powerful feature of the **Raspberry Pi** is the row of **GPIO** (general purpose input/output) pins along the edge of the board, next to the yellow video out socket. These pins are a physical interface between the **Pi** and the outside world. Seventeen of the 26 pins are **GPIO** pins; the others are power or ground pins.

General Purpose Input/Output (GPIO)

It is a generic pin on a chip whose behavior can be controlled by the user at run time. The GPIO connector has a number of different types of connection: – True GPIO (General Purpose Input Output) pins that you can use to turn LEDs on and off etc. – I2C interface pins that allow you to connect hardware modules with just two control pins – SPI interface with SPI devices, a similar concept to I2C but uses a different standard – Serial Rx and Tx pins for communication with serial peripherals 3 • GPIO pins can be used as both digital outputs and digital inputs. • Output: turn a particular pin HIGH or LOW. – Setting it HIGH sets it to 3.3V; setting it LOW sets it to 0V. • Input: detect the pin being at HIGH or LOW – we can connect switches and simple sensors to a pin and check whether it is open or closed (that is, activated or not)

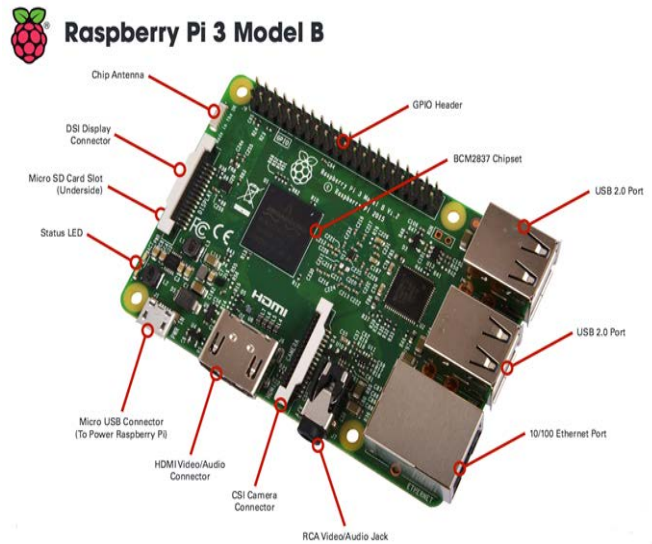


Fig 1: Raspberry Pi 3 Model B

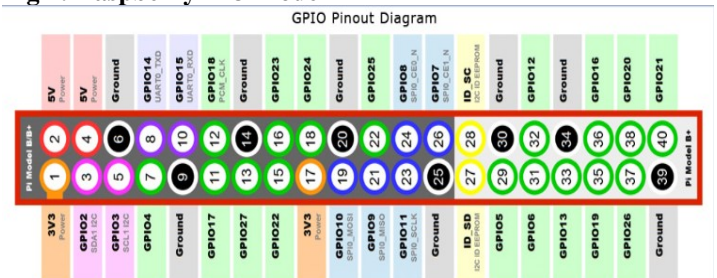


Fig 2: GPIO pin diagram

DHT11 sensor

DHT11 digital temperature and humidity sensor^[7, 8] is a composite Sensor contains a calibrated digital signal output of the temperature and humidity. The advantage of this sensor is it is highly reliable, low price, good quality, faster response time, and inference free design. The DHT11 Temperature & Humidity Sensor is a 4-pin low cost highly reliable sensor. Pin-1 is Vcc, Pin-2 is data pin which collects data from outside world and gives data to the microcontroller. Pin configuration for DHT11 sensor is shown in figure. It fortifies high reliability and excellent long-term stability. These sensors include a resistive-type humidity measurement component, and connects to a high-performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost-effectiveness. Its temperature range is 00-550C with an error of plus or minus 20C and Humidity range is 20-90%. It can directly provide a digital output with its own serial communication protocol. It uses Negative Temperature Coefficient (NTC) based temperature sensing component, and moisture substrate based humidity sensing component. Next we can do step by step process to complete this program. In this we have totally 10 steps included in it. Based on those steps we use our required components and done in Raspberry Pi3 by measuring the humidity and temperature in IoT of the given object or thing. We can detect various temperatures of the respective objects. The proposed IoT application for environmental monitoring and control using Raspberry Pi3 provides an eco-friendly web interface for monitoring and controlling IoT sensors. It is an automated, scalable, and cheaper solution. We can see the results from anywhere in the world through the web interface.

Features

Low cost, long-term stability, relative humidity and temperature measurement, excellent quality, strong anti-interface ability, fast response, digital signal output, precise calibration, and long distance signal transmission.

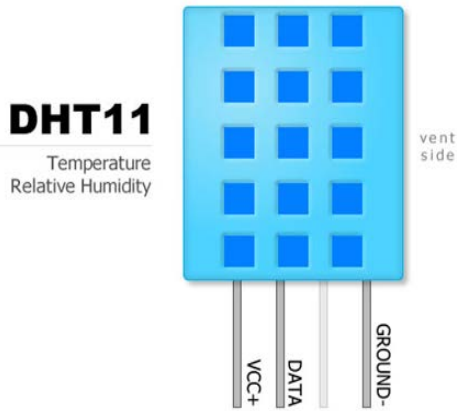


Fig 3: DHT11 Sensor

5. IMPLEMENTATION OF THE PROPOSED SYSTEM

Process to connect raspberry pi to laptop

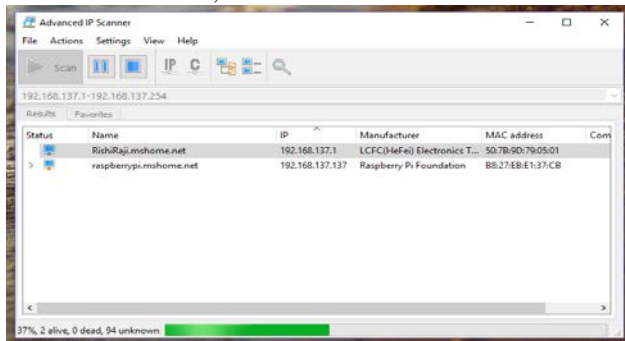
- Firstly make wifi connection into shared mode.
- Connect the raspberry pi to the laptop using USB cable and ethernet cable.
- Then advanced IP scanner is used to scan the IP address of raspberry pi.
- After that putty and Xming server is used to view the GUI interface.

Xming server

By using this GUI interface is obtained. It is act like a server for windows. It is fast, simple to install.

Advanced IP Scanner

In a few seconds, Advanced IP Scanner can locate all the computers on your wired or wireless local network and conduct a scan of their ports. It has a fast networking scanning, MAC addresses detection, remote access.



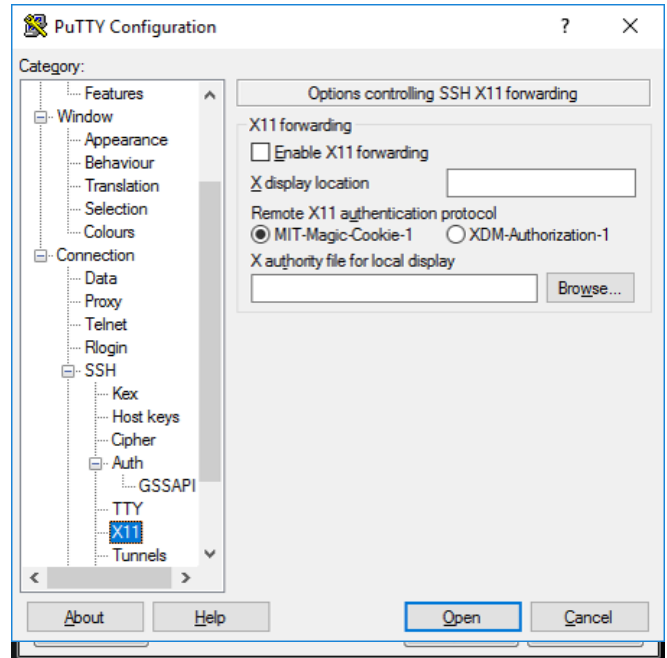
Putty

It is a free and open-source terminal emulator, serial console and network file transfer application.

Enter IP address in the host name field.

Now open SSH and in that double click X11 , then enable X11 Forwarding.

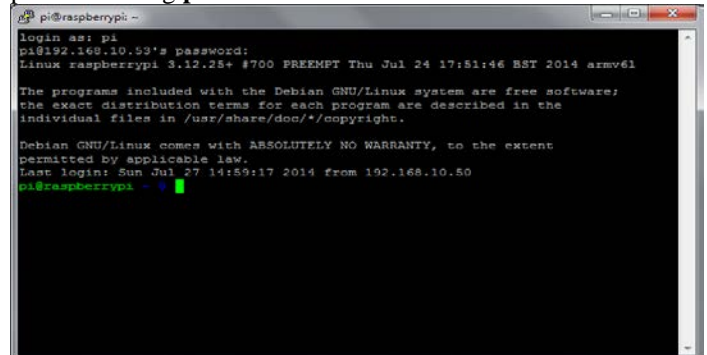
SSH, also known as Secure Socket Shell, is a network protocol that provides administrators with a secure way to access a remote



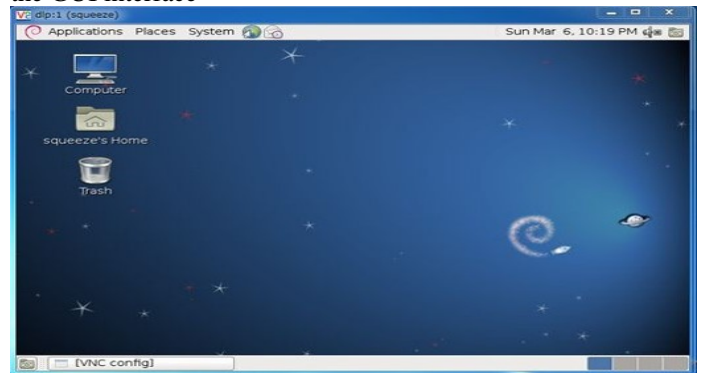
computer.

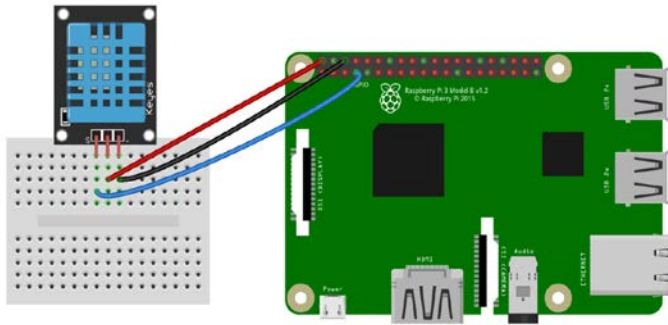
X11 forwarding can be useful when a GUI is required, especially for system and configuration tools that don't have a CLI interface.

After giving IP address in putty, a terminal will be displayed where we have to give login ID and password. By default login ID is **pi** and password is **raspberrypi** but we can change the password using **passwd** command.



Now the commands **lxterminal** and **startlxde** are used to view the GUI interface





values using dht11 sensor:

6. TESTING OF THE PROPOSED SYSTEM

6.1 TESTING TYPES /LEVELS

In general, software engineers distinguish software faults from software failures. In case of a failure, the software does not do what the user expects. A fault is a programming error that may or may not actually manifest as a failure. A fault can also be described as an error in the correctness of the semantic of a computer program. A fault can also turn into a failure when the software is ported to a different hardware platform or a different compiler, or when the software gets extended. Software testing is the technical investigation of the product under test to provide stakeholders with quality related information.

6.2 TEST CASE DESIGN

The test cases determine that whether the implemented system is working properly or not. And it also used for producing the good design. If we look at the basic word count example for testing whether the system is working properly or not working properly, we will get the following sample test cases.

Connections

Now connect Raspberry pi with dht11 sensor using bread board and jumper wires

<u>RaspberryPi</u>	<u>DHT11Module</u>
3.3vP1	VCC(V)
GNDP6	GND(G)
GPIO17 P11	DATA (S)

Connections

simple code which is used to display temperature and humidity

Table 1: Test case design

Test No:	Test Case	Exp. Output	Actual Output	Final Output
1.	Invalid login	Enter password	Enter login id correctly	Failed
2.	Invalid password	Opens raspberry pi GUI	Enter password correctly	Failed
3.	Invalid choice	Display values	Enter the choice correctly	Failed

7.RESULTS AND DISCUSSION

Table 2: Overview of result

Date	Sample 1	Sample2	Sample 3	Max	Min	Avg
29.03.2018	Temp: 30 Humidity: 77	Temp: 31 Humidity: 78	Temp: 30 Humidity: 77	Temp: 31 Humidity: 78	Temp: 30 Humidity: 77	Temp: 30.33 Humidity: 77.05
31.03.2018	Temp: 29 Humidity: 75	Temp: 28 Humidity: 76	Temp: 30 Humidity: 77	Temp: 30 Humidity: 77	Temp: 28 Humidity: 75	Temp: 29 Humidity: 76
03.04.2018	Temp: 31 Humidity: 74	Temp: 32 Humidity: 72	Temp: 30 Humidity: 70	Temp: 32 Humidity: 74	Temp: 30 Humidity: 70	Temp: 31 Humidity: 72

From the above table, we take three samples of temperature and humidity. The sample are from three different days. Temperature and humidity are changes day to day in surrounding environment. From these three different samples calculate minimum, maximum and average values of both temperature and humidity.

8. CONCLUSION

IoT-Based temperature and humidity monitoring system provide an efficient and reliable system for monitoring. With the proposed methodology, we were able to interface the Raspberry pi. Consequently, by using DHT11 sensor we are able get the temperature and humidity values. And then these values are stored in the database with corresponding date. Therefore, the minimum, maximum, average values are retrieved from the database for the specified date.

REFERENCES

1. International Journal of Advanced Research(IJAR) in Computer and Communication Engineering-Vol. 5-October 2016` Raspberry Pi Based Weather Monitoring System Meetal V. Rasal, Prof. Jaideep G. Rana.
2. International Journal for Innovative Research in Science & Technology (IJIRST)-Volume 1-May 2015' The Real Time Temperature Sensing using Raspberry Pi.
3. www.raspbian.org
4. The Internet of Things, <http://www.gartner.com/it-glossary/internet-of-things>
5. BeagleBone and Raspberry Pi accessories: Adafruit Industries. <http://www.adafruit.com>
6. <https://www.rototron.info/projects/pi-temperature-monitor/>
7. <http://www.circuitbasics.com/how-to-set-up-the-dht11-humidity-sensor-on-the-raspberry-pi/>

8. <https://medium.com/dyi-electronics/raspberry-pi-and-dht11-humidity-sensor-ccc6b3072ad>
9. <https://tutorials-raspberrypi.com/raspberry-pi-measure-humidity-temperature-dht11-dht22/>
10. <https://www.raspberrypi-spy.co.uk/2017/09/dht11-temperature-and-humidity-sensor-raspberry-pi/>
11. <https://www.electronicshub.org/raspberry-pi-dht11-humidity-temperature-sensor-interface/>
12. www.uugear.com/portfolio/dht11-humidity-temperature-sensor-module/
13. <https://circuitdigest.com/microcontroller-projects/raspberry-pi-iot-weather-station-to-monitor-temperature-humidity-pressure>.

Citation: Balajee Maram *et al.* (2018). A framework for Predicting Temperature, Humidity Using Raspberri pi 3, J. of Advancement in Engineering and Technology, V6I2.04. DOI: 10.5281/zenodo.1219170.

Copyright: © 2018: Balajee Maram. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited