Chapter one

Introduction

Chapter one

Introduction

1.1 Introduction

1.2 Problem statement

1.3 Proposed solution

1.4 Objectives

1.5 Methodology

1.6 Thesis outlines

Chapter one

Introduction

1.1 Introduction

Meteorology is the study of the earth's atmosphere .it includes the study of winds, and weather patterns weather phenomena such as rainbows and pollution, and the study of day to day weather[1].

To study the day-to-day weather we connect couple of instruments together to form a weather station, Weather stations are facilities with instruments and equipment for measuring atmospheric conditions, to provide information to study weather and climate, for weather forecasting for aviation, agriculture, construction, or shipping[1].

Weather stations can be Automated weather station which is an updated version of the traditional weather station that uses sensors to measure it's different parameters it is either used to save human labor or to enable measurements from remote areas, Or it can be manual weather station is a more traditional one which always involve the human effort, skills, power and energy to get its results.

A sensor network is a network of microcontroller integrated smart devices, which are spatially distributed and sensors. A sensor is a primary component of network essential for monitoring real world physical condition or variables such as temperature, humidity, wind speed, wind direction, barometric pressure and precipitation amount[2].

The remote stations are networks of weather stations which are located in remote areas because of this, they usually are not connected to the electrical grid but have their own solar panels and a battery. This network is a distributed network that sends data to central data storage. These distributed networks are connected to each other by the concept of the internet of things and cloud computing.

The Internet of Things (IoT) is a computing concept that describes a future where every day physical objects will be connected to the Internet and be able to identify themselves to other devices[3].

Cloud computing is a model for delivering information technology services in which resources are retrieved from the internet through web-based tools and applications, rather than a direct connection to a server[4]. Data and software packages are stored in servers. However, cloud computing structure allows access to information online which allows working remotely.

Listing some basic types of weather stations: the first one is the Synoptic Weather Station which makes local observation of weather at fixed times, it has the basic elements that is on most of the weather stations, which is temperature, humidity, pressure, wind speed and direction and rain gauge. The second one is climate weather station that is used in separated times and it has the same earlier said parameters but it doesn’t need rain gauge. The third one is the agriculture weather stations that is needed by the farmers to guide their work, it have special factors like the soil temperature and the sunlight and then with the application the weather station should has its own parameters that serves that application.

1.2 Problem statement

Personal weather stations lack self-sustainability, autonomous logging capabilities and the ability to transmit data wirelessly compared to professional weather stations. On the other hand, professional weather stations are too expensive for the average consumer. In both cases long range transmission and automatic location acquisition are most often not available.

1.3 Proposed solution

Design an automated weather station that uses relatively low cost and energy efficient electronic components and with long range data transmission capabilities. The heart of the solution is a microcontroller which acquires and interprets data from weather sensors connected to it.

1.4 Objectives

The main objectives of this project are:

- To design an automated weather station.
- To simulate software of weather station.
- To build hardware implementation of the weather station.

1.5 Methodology:

Firstly determine the objectives of the project and how to achieve them, secondly collect information about implemented weather station in Sudan, after that review previous studies and researches in the area of weather station and write literature review, and then choose the mechanism that helps in achieving the design requirements.

Thirdly build a simulation design to check the weather station is working. Fourthly build hardware prototype that contains a microcontroller, weather sensors. Finally write the conclusion and recommendation.

1.6 Thesis outlines

- Chapter one includes introduction, problem statement, proposed solution and methodology.
- Chapter two includes definitions for the components and related works.
- Chapter three includes specification for the used components, design block diagram, flow chart and the system scenario.
- Chapter four includes the system simulation design and the hardware implementation.
- Chapter five includes conclusion and recommendation.

Chapter two

Literature review

Chapter two

Literature review

2.1 Back ground

- 2.1.1 Embedded Systems
- 2.1.2 Microcontroller
- 2.1.3 Microprocessor
- 2.1.4 Arduino
- 2.1.5 Sensors
  - 2.1.5.1 Rain gauge sensor
  - 2.1.5.2 Temperature sensor
  - 2.1.5.3 Wind Sensors
  - 2.1.5.4 Humidity Sensor
  - 2.1.5.5 Pressure Sensor
- 2.1.6 GPRS
- 2.1.7 Protocol
- 2.1.8 Power supply

2.2 Related works

2.3 Field visit

- 2.3.1 Types of weather stations
- 2.3.2Power efficiency
- 2.3.3 Stations of the center
- 2.3.4 Center stations' problems

Chapter two

Literature review

2.1 Back ground

2.1.1 Embedded Systems

An embedded system is a computer system, which is designed for a dedicated functionality. It is a combination of hardware and software systems either fixed or programmable in capability. Embedded systems that are programmable are usually provided with programming interfaces. When compared to with general purpose ones, embedded systems have the following prosperities:

- Low power consumption.
- Low cost.
- Small size.
- Speed.

However, by building an intelligent mechanism on top of the hardware can optimize and manage available resources and provide more functionalities beyond available. The core of modern embedded systems is the microcontroller.

2.1.2Microcontroller

A microcontroller (MCU) is a small computer on a single integrated circuit containing a processor core, memory and programmable input/output peripherals. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers to perform other general purpose applications.

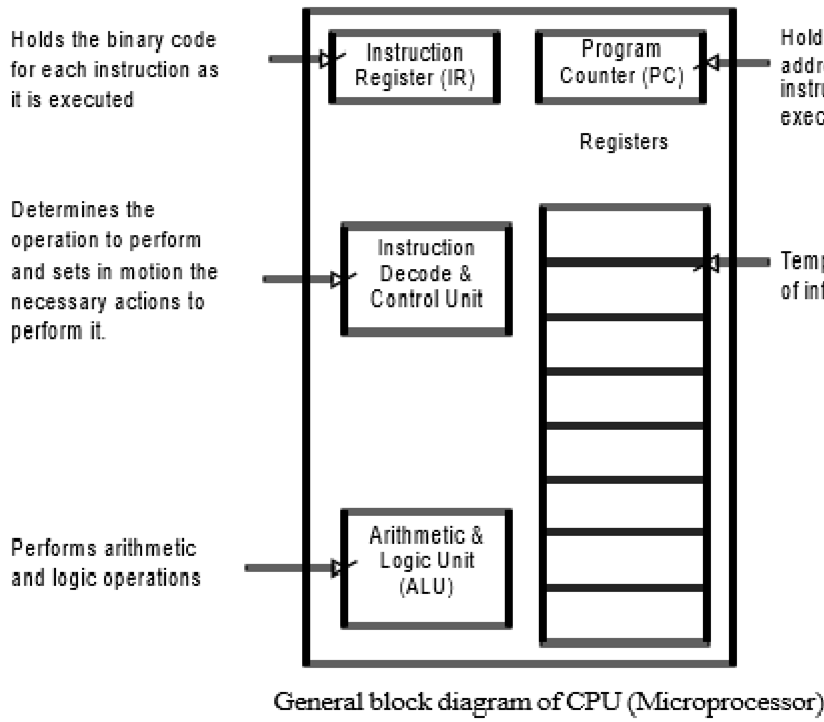

Figure 2-1: general block diagram of CPU (Microprocessor)

2.1.3 Microprocessor (CPU or MPU)

The CPU is an electrical part that manipulates data according to predefined set of instructions that is loaded into the MC. It handles all arithmetic functions needed to be performed. In addition it uses buses to communicate with the memory components, communication systems, I/O ports and registers. Because of this features it is the most power consuming component on the MCU. Microprocessor consists of:

- **Registers:**

The CPU uses registers to store temporary information (in bytes) that it is using at any given time.

- **Memory:**

Programmed memory in the form of Ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM.

- **programmable input/ output peripherals:**

Digital and analog signals can be received and sent through these connections. To receive and send analog signals they must first be converted with analog to digital converters (ADC) and digital to analog converters (DAC).

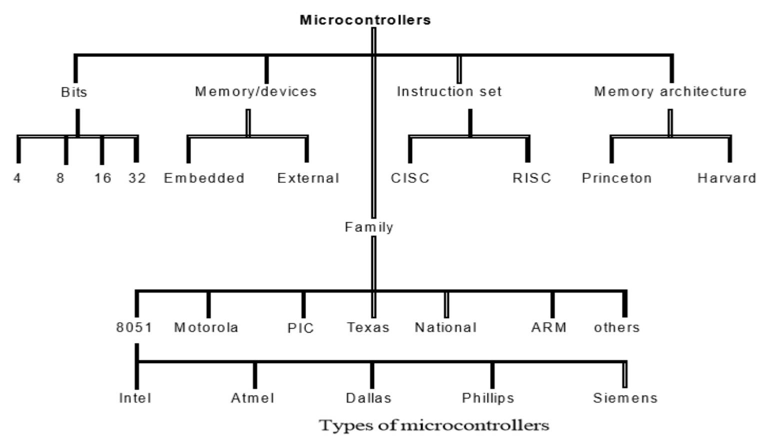

Figure 2-2: Types of microcontroller

2.1.4 Arduino

The Arduino microcontroller is used in art and design as an open source programmable tool to create interactive works. It can drive motors, LEDs, sensors and other components.

While microcontrollers have had a presence in the arts for decades, the Arduino microcontroller is among the first microcontrollers specifically designed for artists and designers. The Arduino microcontroller allows artists and designers to execute electronic-incorporated works without knowing the internals of the hardware or software. Artists and designers have been influential in the evolution of the Arduino microcontroller since its birth. That indicates that it is easy to use easy to deal with. These reasons also denote Arduino's differences from other similarly intended microcontrollers:

- It is inexpensive.
- It is packaged with the Integrated Development Environment (IDE).
- It is programmable via USB.
- It is supported by a community.

The Arduino components can be seen as the core of the station as they provide main functionality from sensor communication up to data logging. Sensors can be attached to a digital input / output pin or to an analog input pin.

2.1.5 Sensors

A device that measures or detects a real world condition, such as motion, heat or light and convert the condition into an analog or digital representation. Sensors are sophisticated devices that are frequently used to detect and respond to electrical or optical signals. A sensor converts the physical parameter (for example: temperature, blood pressure, humidity, speed, etc.) into s signal which can be measured electrically[5].

2.1.5.1 Rain gauge sensor

There is many types of rain gauges used nowadays with difference in designs and
Functions for accomplishing a main purpose which is to measure the Cumulative rain fall over certain area in certain time.

- **Standard (graduated cylinder) Rain Gauge:**

The standard rain gauge consists of a funnel attached to a graduated cylinder that fits into a larger container. If the water overflows from the graduated cylinder the outside container will catch it. So when it is measured, the cylinder will be measured and then the excess will be put in another cylinder and measured. In most cases the cylinder is marked in mm.

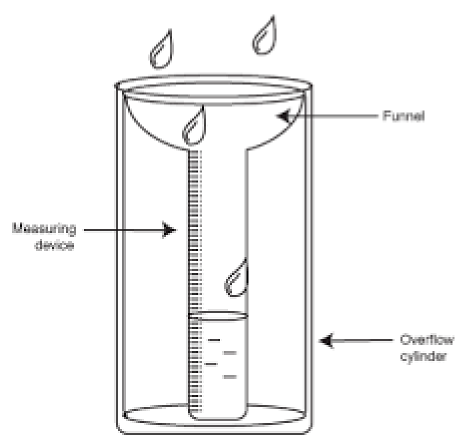

Figure 2-3: Graduated cylinder rain gauge sensor

- **Tipping bucket:**

The classic professional rain gauge operates by filling and dumping two buckets, one mounted on either end of a beam that pivots around a central axle in a manner somewhat reminiscent of a playground seesaw. Rainwater gathered in the lid portion of the gauge trickles down into the upper bucket through a small-diameter hole in the lid's funnel-shaped bottom. When the bucket has received the proper amount of water, it empties itself by pivoting around the axle and pouring the water into the base. This action raises the other bucket into position and the cycle repeats. Holes in the base allow the water to drain away.

Each time a bucket empties its contents, it moves a magnet past a magnetic reed switch and causes it to close. With representing in each closure a measured amount of rainfall there for the total amount of rainfall at a time[6].

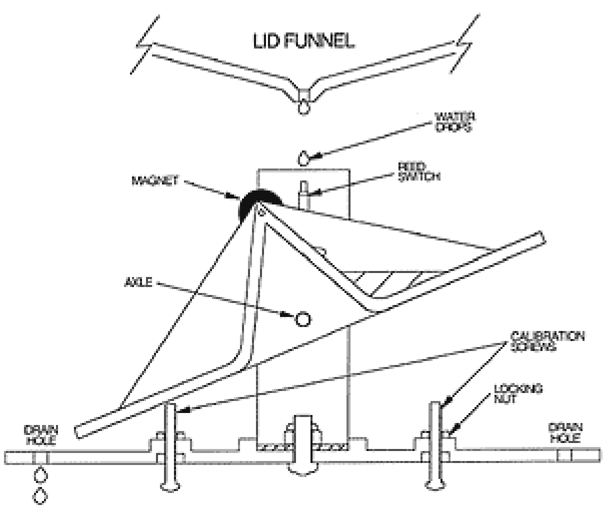

Figure 2-4: Tipping bucket rain gauge sensor

- **Weighing Precipitation Gauge**

A weighing-type precipitation gauge consists of a storage container, which is weighed to record the mass. Certain models measure the mass using a pen on a rotating drum, or by using a vibrating wire attached to a data logger.

The advantages of this type of gauge over tipping buckets are that it does not underestimate intense rain[7].

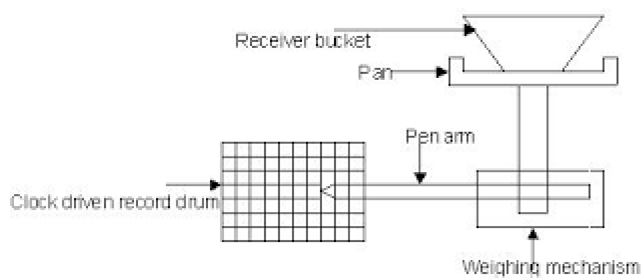

Figure 2-5: Weighing rain gauge sensor

- **Optical Rain Gauge**

This type has row of collection funnels In an enclosed space below each is a laser diode and a phototransistor detector. When enough water is collected to make a single drop, it drips from the bottom, falling into the laser beam path. The sensor is set at right angles to the laser so that enough light is scattered to be detected as a sudden flash of light. The flashes from these photo detectors are then read and transmitted or recorded[8].

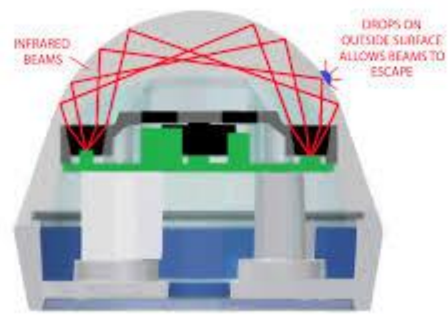

Figure 2-6: Optical rain gauge sensor

2.1.5.2 Temperature sensor

There are currently several options to measure ambient temperature and acquire its measurements in a digital form. Their main differences are cost, accuracy and ease of use.

- **Thermistor**

The word “thermistor” is a combination of the words “thermal” and “resistor” indicating that it measures temperature by measuring changes in resistance. There are two variations of thermistors, the negative temperature coefficient (NTC) where resistance decreases with increase in temperature and the positive temperature coefficient (PTC) that does the opposite to the NTC.

A Voltage divider circuit has to be implemented to get the thermistor working with a MCU and the MCU reads the thermistors analog value with its ADC port to acquire its value digitally. Hence, the resolution of the ADC is a limiting factor in the accuracy of this method.

- **Thermocouples**

Thermocouples can measure a much higher temperature ranges than thermistors and are often used in an industrial environment. With this method a Seed beck effect (voltage generated) is measured at a junction between two metals of different materials. Because this method is not considered among the most suitable for the project it will not be researched further,

- **Analog Output Thermometer ICs**

With this special purpose integrated circuit the task of temperature measurement has been optimized and is easier to use than with the thermistor, but at a higher cost and less accuracy. This circuit has three pins: input voltage, ground and a linear analog output that varies with temperature.

- **Digital Thermometer ICs**

A MCU connects to a digital thermometer via a serial interface and receives a digital signal representing measured temperature. Since the data is transferred digitally they are suitable for remote sensing as there is less chance of electrical interference.

Table 2-1: Overview and comparison of different temperature sensor technology:

sensor	**Typical temp range (°C)**	**Accuracy (±°C)**	**pros**	**cons**	**application**
Thermistor	-40 to +125	1	Low cost	-	Ambient environment

Thermocouple	-200 to +1350	3	Low cost	Metal part of the sensor inaccurate	Industrial environment
Analog IC	-40 to +125	2	Simple	More expensive	Domestic
Digital IC	-55 to +125	0,5	Simple and accurate	More expensive	Domestic

2.1.5.3 Wind Sensors

Different technologies and methods have been invented to measure wind and those measurements are becoming more precise and accurate with the evolution of electronic wind sensors.

Wind sensors can be categorized into two categories.

- Anemometers or wind speed sensors
- Wind direction sensors

Anemometers

There are three types most commonly used in applications today; the cup anemometer, the propeller anemometer and the sonic anemometer.

Cup anemometers

Electronic cup anemometers give measurements of instantaneous wind speed by sending a corresponding analog signal as the cup spins around, see Figure 2-7. Three factors determine the anemometer’s response and accuracy: weight, physical dimensions and internal friction. For turbulence measurements, small, lightweight and low friction sensors are preferred. Typical accuracy levels are about ±2%.

Figure 2-7: A cup anemometer

Propeller anemometers

Electric propeller anemometers use the wind to turn its propeller, as seen if Figure 2-8, and in return turn a shaft that drives an AC or DC generator. The analog output generated is them measured to acquire wind speed. It is also possible to use a photoelectric switch as in the case of the cup anemometer[9]. The propeller is often kept facing the wind by a tail-vane that can also serve as a wind direction indicator.

Figure 2-8: An aero-vane is a combination of a propeller anemometer and a tail-vane wind direction meter

Sonic anemometers

Sonic Anemometers use ultrasonic sound waves to measure wind speed and direction. Travel time of sonic pulses between two transducers is used to measure wind speed, see Figure 2-9.

Figure 2-9: A sonic anemometer

Wind direction meters

Normally a wind vane is used to measure wind direction. It consists of a tail-vane that is mounted on a rotating shaft with a bearing to minimize friction, see Figure 2-10.

Figure 2-10: a tail vane used to measure wind direction

2.1.5.4 Humidity Sensor

A film capacitor element measures the relative humidity. The working principle is a thin film substrate between two electrodes that are changing their dialectric constant with the moisture level. This change can be measured in the capacity of the element[10].

2.1.5.5 Pressure Sensor

A pressure sensor is an instrument used to measure barometric pressure. It has different types such as barometer and electronic sensors. one can find the atmospheric pressure using the barometer and this equation:

$Patm = \rho g h$ where ρ is the density of mercury, g is the gravitational acceleration, and h is the height of the mercury column above the free surface area.

2.1.6 GPRS

GSM is a communication standard is developed to describe protocols for second generation (2G) digital cellular networks used by mobile phones.

Its main emphasis was on voice transfer, which was later found not suitable to handle data packages. GPRS was added to the GSM network to adapt standard data packet to the communication medium of the GSM interface[9]. Its main objective is to offer access to standard data networks such as TCP/IP. GPRS is a best-effort service, implying variable throughput and latency that depend on the number of other users sharing the service concurrently, as opposed to circuit switching, where a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 Kbit/second.

2.1.7 Protocol

Client/server architecture is a program relationship in which one program (the client) requests a service or resource from another program (the server). Client/server model can be a best fit for distant access and remote embedded systems. New client/server architecture are provided in the internet of things (IoT).

The internet of things is the connection between devices with a unique identifier. It works by giving each device or "thing" an identifier to connect to network using its sensors.

Figure 2-10: Concept of Internet of Things

Devices must communicate with each other (D2D). Device data then must be collected and sent to the server infrastructure (D2S). That server infrastructure has to share device data (S2S), possibly providing it back to devices, to analysis programs, or to people. From 30,000 feet, the protocols can be described in this framework as:

- **MQTT**

  A protocol for collecting device data and communicating it to servers (D2S), it targets large networks of small devices that need to be monitored or controlled from the cloud.

- **XMPP**

  Stands for Extensible Messaging and Presence Protocol. It is a protocol best for connecting devices to people, a special case of the D2S pattern, since people are connected to the servers

- **DDS**

  The Data Distribution Service distributes data to other devices. It is a fast bus for integrating intelligent machines (D2D).

- **AMQP**

  The Advanced Message Queuing Protocol is a queuing system designed to connect servers to each other (S2S). It sends transactional messages between servers[11].

2.1.8 Power supply

A power supply is a device that supplies electric power to an electrical load. The term is most commonly applied to electrical power converters that convert one form of electrical energy to another, though it may also refer to devices that convert other form of energy (mechanical, chemical, solar) to electrical energy.

Every power supply obtain the energy it supplies to its load, as well as any energy it consumes while performing that task, from an energy source. Depending on its design, a power supply may obtain energy from:

- Electrical energy transmission systems. Common examples of this include power supplies that convert AC line voltage to DC voltage.
- Energy storage devices such as batteries and fuel cells.
- Electromechanical systems such as generators and alternators.
- Solar power.

Normal weather stations can be connected directly to the local electric grid, to power the station. For a remote weather station, it mostly is connected to one or more chargeable battery, charged by a solar panel or sometimes a wind turbine.

Solar cells convert sunlight directly into electricity they only work during the day, there for most solar electric systems contain batteries to store energy produced during the day for use at night.

Each location on earth has varying amounts of solar energy shining on that location, so, most of the time wind turbines are used instead of solar panels in the case of low sunlight to provide power.

2.2 Related works

In a research articled by Ahmed Al-Kharusi(2010)

A prototype system of the Smart Weather Station has been successfully built, accommodating four sensors being responsible to measure four key weather parameters; temperature, air pressure, relative humidity, and light intensity. An embedded C8051F020 microcontroller was used to control the interfacing of sensors and their data conversions. ZigBee communication protocol was used to communicate between the central station (coordinator) and the weather stations (end-devices) in the network.

Weather Parameters Sensor:

The proposed Smart Weather Station will have four different sensors which will measure temperature, relative humidity, Light and pressure.

Temperature Sensor: A wide range of temperature sensors are available in the market. Here he was looking for the sensor that is of high accuracy, and high performance-to-price ratio.

Humidity Sensor: Measures the relative humidity (RH) of the surrounding air. Most RH sensor has a range of readings between 0 and 100%.

Atmospheric Pressure Sensor: Searching for an appropriate pressure sensor. It results in a variety of types that differ in size, accuracy, and price.

Light sensor: Sunlight is considered an important factor for the well-being and existence of living creatures. For this reason, it has been suggested to integrate a light sensor in the proposed system to provide a measure of intensity of the incident light on a specified area.

The developed prototype was found to satisfy, to large extent, the general requirements and specifications drawn for this project, providing accurate and reliable measurements. It is however recommended for future enhancement to design a casing for the prototype, check it under longer test than 24 hours, and implement a two-way communication between the coordinator and the end devices[12].

A research article by Karl Ingi Eyjólfsson (2014):

His foundation is laid upon a low cost, energy efficient and a fully automatic weather station which was **Portable Weather Station.**

The novelties of the station are its ability to acquire GPS coordinate information automatically in addition to weather data send it via the GSM network to a communication server. It is also portable and includes most common weather sensing options and good accuracy. The station can be beneficial for receiving and collecting data at relatively low cost and transmits the data wherever there is GSM coverage.

The station is comprised of several components that, when assembled, are called an embedded system. Its main components are a microcontroller, a GSM communication module, a GPS module and weather sensors. Key terms and technology behind the system are explained and defined.

The highest ranking components compared and thus, most appropriate are the STM32L053R6 ARM M0+ microcontroller from STMicroelectronics, the SIM908 GSM GPS combination module from SIMCom, a digital thermometer and an aero vane wind sensor.

A prototype of the station was constructed that simulates its functionality. The construction was split into two phases, a hardware circuitry design and construction phase and a firmware design and development phase. Weather sensors are simulated with potentiometers that send signals that are acquired and interpreted by the MCU. The MCU also acquires GPS coordinates and sends the information to a communication server, via the GSM network, for storage and from there the data can be viewed online.

The main hardware components used in this project, the NXP LPC11U24 MCU and the SIM908 GSM/GPS module, were selected in accordance with the hardware components comparison, and also for their capabilities of supporting fast prototyping by being available in a development edition. Both components are mounted on a developer's board that makes the hardware development process easier. On the other hand the boards include peripherals not essential or not used and hence, increases power consumption. For prototype purposes the ability of faster prototyping outweighs power consumption.

The firmware was written in mbed's online compiler which has a pre-configured compile engine. It has all basic IDE features but lacks debugging support which would have been useful. The UART to USB converter proved to be a really useful component to be use as a debugging tool.

The GPS system is stable, well maintained, with a long term operating plan and delivers coordination information to receivers free of charge. It is thus an ideal system to receive coordination information. The SIM908's integrated GPS module receives GPS information as supposed to and delivers it to the MCU via the GSM module's serial connection. It is operated with the same serial connection by using AT serial commands.
Sending data via the GRPS network is the most power consuming part of the system. Lowering it by even a few percents would be a great benefit for the system's operating lifetime. One option that can be explored to achieve lower power consumption is to see if using 3G or 4G connection can reduce the modules uptime without it using more energy than is saved. Another option is to see if the GSM initial registration time can be shortened by preloading BTS information from last registration made. And yet another is to increase internal memory to save more amounts of data and thus send it less frequently[9].

A research articled as Wireless sensor networking using AADI Sensors with WSN Coverage by Babar Khan in 2012:

A sensor network which has four basic components in a sensor network is used, the components are:

(1) An assembly of distributed or localized sensors;

(2) An interconnecting network (usually, but not always, wireless-based);

(3) Data logging or information gathering;

(4) A set of computing resources for data analysis for example event trending, and data correlation.

A wireless sensor network (WSN) is a wireless network which consists of spatially distributed autonomous devices or nodes, sensors to monitor physical or environmental conditions, routers and a gateway. It is used because it has: Anywhere and anytime, Greater fault-tolerance, improved accuracy and Lower cost[13].

The Automatic Weather Station 2700 consists of:

- Air pressure sensor 2810
- Air temperature sensor 3455
- Wind speed sensor 2740
- Data logger 3634
- Cable 3204 with 1.5m length using serial communication RS-232C
- Cable 3321 with 10m length

It uses this also:

- Gateway NI WSN 9791

The NI WSN-9791 Ethernet gateway coordinates communication between distributed measurement nodes and the host controller in NI wireless sensor network (WSN). The gateway has a 2.4 GHz, IEEE 802.15.4 radio based on ZigBee technology to collect measurement data from the sensor network and a 10/100 Mbit/s Ethernet port to provide flexible connectivity to a Windows or LabVIEW Real-Time OS host controller. It requires 9 to 30V DC external power supply (National Instruments). The gateway is connected to host controller via an Ethernet cable.

- Node NI WSN 322

The NI WSN-3202 measurement node is a wireless device that provides four ±10 V analog input channels and four digital Input/output channels. It is powered with four 1.5 V, AA alkaline cells. It can be externally powered with a 9 to 30 V supply. It transmits data to the WSN gateway wirelessly at 2.4 GHz radio based.

2.3 Field visit

The main target was to gain more knowledge on the structure of a weather station, so we paid a visit to the Center of Meteorological Observation in Khartoum. The outcomes of the visit were as follow:

2.3.1 Types of weather stations

There are different types of weather stations in which the parameters of measuring may differ. There are agricultural weather stations which has a sensor of measuring the soil moisture. The synoptic that gives readings in specific time intervals. The coastal stations which measure the temperature of the sea and the solar density.

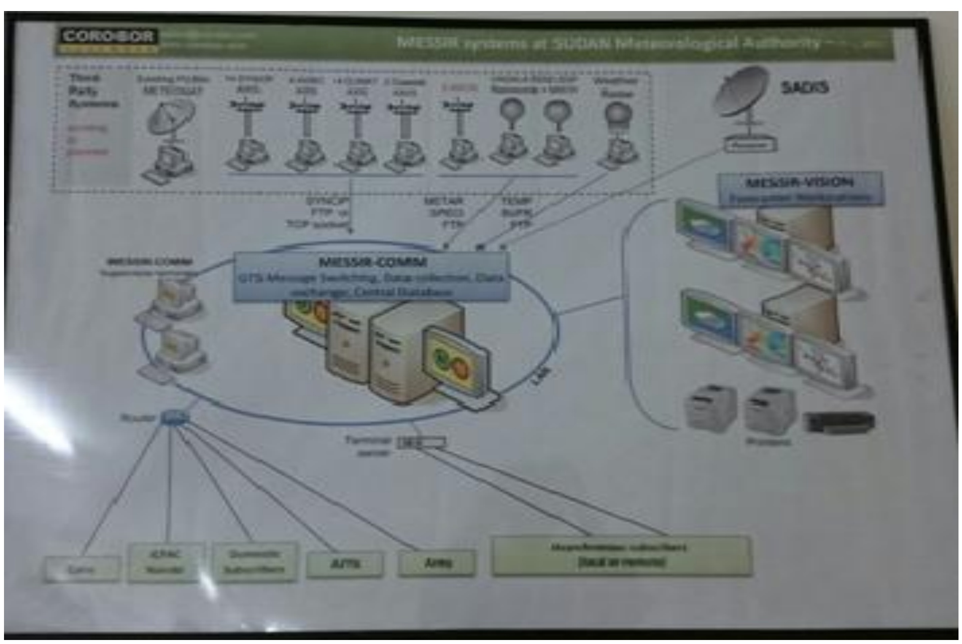

Figure 2-11: Types of weather station

2.3.2 Power efficiency

The station relies on the power of the local electrical grid, and has a chargeable battery.

Figure 2-12: AWS box containing battery and GSM module

2.3.3 Stations of the center

The center has many stations. Two of them were using old instruments for measuring temperature, humidity, pressure, and wind speed and direction. The other one was an automatic station designed by the VISALA Company.

Figure2-13: VISALA automatic station

2.3.4 Center stations' problems

1. Containing of mechanical parts.

2. The need of a technician to to take the measurement, which may result in inaccuracy.
3. The high cost of the AWS.

Chapter three

Methodology

Chapter Three
Methodology

Chapter Three
Methodology

3.1 Sensors

3.1.1 Temperature and humidity

The DHT11 DFRobot temperature and humidity sensor features a humidity and temperature sensor comlex with a calibrated digital signal output. By using the exclusive digital-signal acquisition technique and temperature & humidity sensing technology, it high reliability and excellent long-term stability [14].

The DHT11 was chosen for its accuracy, fast response, quality, cost effectiveness, and anti-interference ability. Table 3-1 and 3-2 show the main characteristic of the sensor taken from the datasheet.

Table 3-1: Prosperities of the DHT11 humidity sensor

Parameters	Conditions	Minimum	Typical	Maximum
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability			±1℃	
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e(63%)	6 S		30 S

Table 3-2: Prosperities of the DHT11 temperature sensor

Parameters	Conditions	Minimum	Typical	Maximum
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability			±1℃	
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e(63%)	6 S		30 S

For a connection to the seeeduino GPRS board, the DATA pin needs to be pulled up with a resistor to the power supply pin of the GPRS board. The DHT11 requires recommended source voltage of 3.3V. The connection pins between DHT11 and seeeduino GPRS board is presented in the table below:

Table 3-3: Cable connections between DHT11 Breakout and Seeeduino GPRS

DHT11	Seeeduino GPRS pins
VDD	3V3
DATA	4
GND	GND

The DHT11 requires recommended source voltage of 3.3V. Single-bus data format is used for communication and synchronization between MCU and DHT11 sensor. One communication process is about 4ms.

When MCU sends a start signal, DHT11 changes from the low-power-consumption mode to the running-mode, waiting for MCU completing the start signal. Once it is completed, DHT11 sends a response signal of 40-bit data that include the relative humidity and temperature information to MCU. Users can choose to collect (read) some data. Without the start signal from MCU, DHT11 will not give the response signal to MCU. Once data is collected, DHT11 will change to the low-power-consumption mode until it receives a start signal from MCU again.

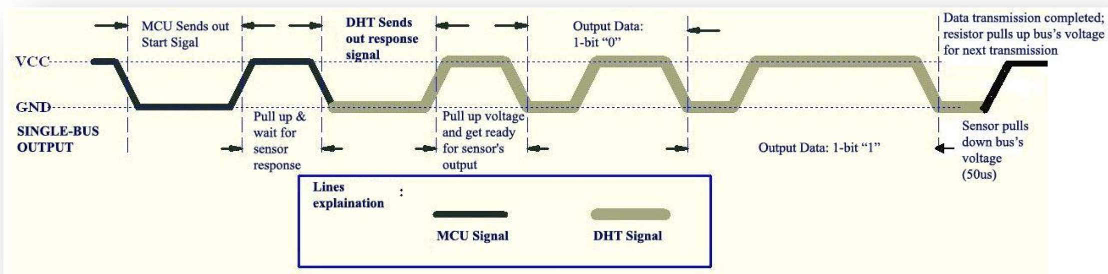

Figure 3-1: Overall communication process.

3.1.2 Pressure sensor

For air pressure readings, the digital pressure sensor BMP180 from Bosch Sensortec is used. The ultra-low power, low voltage electronics of the BMP180 is optimized for use in outdoor equipment. With a low altitude noise of merely 0.25m at fast conversion time, the BMP180 offers superior performance. The I2C interface allows for easy system integration with a microcontroller.

The BMP180 is based on piezo-resistive technology for EMC robustness, high accuracy and linearity as well as long term stability [15].

Table 3-4: Prosperities of the BMP180 pressure sensor

Parameter	**Symbol**	**Condition**	**Min**	**Typ.**	**Max**	**Units**
Resolution		pressure		0.01		hPa
Accuracy	typical			±1.0		hPa
Response Time	Mode		4.5		25.5	Ms
Operation Range			700		1100	hPa

The BMP180 is designed to be connected directly to a microcontroller of a mobile device via the I2C bus. The pressure and temperature data has to be compensated by the calibration data of the E2PROM of the BMP180.

For a connection to the seeeduino GPRS board, the SDA and SCL pins will be connected as below:

Table 3-5: Cable connections between BMP180 Breakout and Seeeduino GPRS

BMP180	Seeeduino GPRS
VDD	3V3
SCL	3
SDA	2
GND	GND

For the calculation of the pressure the mode (ultra low power, standard, high, ultra high resolution) can be selected by the variable *oversampling_setting* (0, 1, 2, and3) in the C code.

Calculation of true temperature and pressure in steps of 1Pa (= 0.01hPa = 0.01mbar) and temperature in steps of 0.1°C.

For calculating the altitude, with the measured pressure p and the pressure at sea level $p0$ e.g. 1013.25hPa, the altitude in meters can be calculated with the international barometric formula:

$$Altitude = 44330 * [1 - (p/p0)1/2.255]$$

3.1.3 Ultrasonic wind sensor

The wind sensor requirement are:

- High accuracy.
- Energy efficiency.
- Lows cost.
- Operating temperature.
- Small form factor.

As for the anemometer, cup meters have fair accuracy (±2%) and is less expensive than the sonic anemometers. Its current inducing type is more accurate although it is a more expensive. In the case of the wind direction sensor the sonic sensor can read direction when the cup can't do it without adding another direction sensor.

All sensor types researched have adequate operating temperature range and sensing range. The critical factor for the sensor is the accuracy. The ultrasonic wind sensor has superior accuracy compared to others and thus it is the sensor chosen for the system.

Depending on the number of ultrasonic used in the design it shows that the parameters measured with the wind sensor. One dimension sensor reads only the wind speed through two ultrasonic transducer. With using another couple of ultrasonic transducer that gives the ability to measure the wind speed and direction, that is called two dimension ultrasonic.

The **Ultrasonic Anemometer 2D** consists of 4 ultrasonic transducers, in pairs of 2 which are opposite each other at a distance of 200 mm. The two measurement paths thus formed are vertical to each other. The transformers act both as acoustic transmitters and acoustic receivers. The respective measurement paths and their measurement direction are selected via the electronic control. When a measurement starts, a sequence of 4 individual measurements in all 4 directions of the measurement paths is carried out at maximum possible speed. The measurement directions (acoustic propagation directions) rotate clockwise, first from south to north, then from west to east, from north to south and finally from east to west. The mean values are formed from the 4 individual measurements of the path directions and used for further calculations.

A measurement sequence takes approx. 10 m/sec at +20°C.

3.1.4 Rain gauge sensor

Rainfall is commonly measured with the fill-and-tip method. Rain enters the collector, drips through a small hole in its funnel-shaped bottom, and falls into one of two identical receptacles of known volume mounted on either end of a beam. One vessel is up, the other down. When the upper receptacle is full, that ends of the beam pivots down. The water spills out and drains away. This action raises the lower receptacle into the up position and the cycle continues. Each time the beam moves, a magnet mounted to it momentarily closes a reed switch, with each closure typically representing 0.01 in. of rain.

The differences between the weighing sensor and the tipping bucket sensor can be corrected for reliably by using calibration coefficients that are specific to precipitation type. The performance of the tipping bucket justifies its prospective use as a low-cost, independent backup to a weighing precipitation sensor.

3.2 Seeeduino GPRS

Seeeduino GPRS is an IoT panel that can connect to the internet through GPRS wireless network. It can make/answer voice calls and send/receive SMSes. It also supports FM Radio function and Bluetooth communication. Seeeduino GPRS is based on ATmega32U4 and SIM800H. ATmega32U4 is a microcontroller compatible with Arduino. SIM800H supports Quad-band 850/900/1800/1900MHz. It can transmit voice, SMS and data with low power consumption. SIM800H also brings some extra features like Bluetooth and FM Radio. Its low power design results in a current as low as 0.1mA in sleep mode.

Figure 3-2: Seeeduino GPRS

Specification Compatible with standard Arduino Leonardo:

- Quad-Band 850/900/1800/1900MHz
- Headset jack
- Convenient external SIM card holder
- Control via AT commands
- Supports Bluetooth
- Supports FM Radio
- Power Input: 9-12V
- Current < 2A
- Bootloader: Leonardo[16]

3.3 MQTT Protocol

MQTT is a Client Server publish/subscribe messaging transport protocol. It is light weight, open, simple, and designed so as to be easy to implement. These characteristics make it ideal for use in many situations, including constrained environments such as for communication in Machine to Machine (M2M) and Internet of Things (IoT) contexts where a small code footprint is required and/or network bandwidth is at a premium .

When using the MQ Telemetry Transport protocol, it offers more advantages over the HTTP client/server protocol. MQTT is a lightweight publish/subscribe messaging protocol, while HTTP is designed as a request-response protocol for client-server. MQTT features faster response and throughput, and lower battery and bandwidth usage, making it well suited to use cases where:

- connectivity is intermittent
- bandwidth is at a premium
- an enterprise application needs to interact with one or more client

Other advantages built into the MQTT protocol are retained messages and multiple subscriptions 'multiplexed' over one connection. Basically, MQTT is designed for low latency, assured messaging and efficient distribution. HTTP is not optimized for low power usage or minimizing the amount of bytes flowing.

3.3.1 Publish/Subscribe

The publish/subscribe pattern (pub/sub) is an alternative to the traditional client-server model, where a client communicates directly with an endpoint. However**,** Pub/Sub decouples a client, who is sending a particular message (called publisher) from another client (or more clients), who is receiving the message (called subscriber). This means that the publisher and subscriber don't know about the existence of one another, this is called space decoupling. There is a third component, called broker, which is known by both the publisher and subscriber, which filters all incoming messages and distributes them accordingly.

Another thing is that MQTT filters the messages through a hierarchy structured string called topic when subscribed.

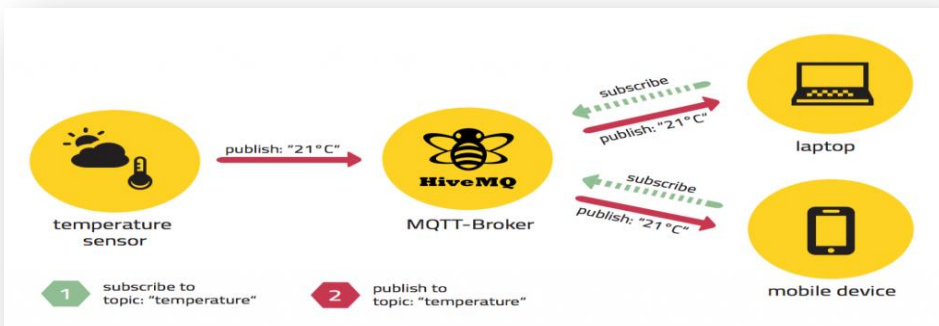

Figure 3-3: MQTT Publish/Subscribe

3.3.2 Client

A MQTT client is any device from a micro controller up to a full-fledged server, that has a MQTT library running and is connecting to an MQTT broker over any kind of network. This could be a really small and resource constrained device that is connected over a wireless network and has a library strapped to the minimum or a typical computer running a graphical MQTT client for testing purposes, basically any device that has a TCP/IP stack and speaks MQTT over it. The client implementation of the MQTT protocol is very straight-forward and really reduced to the essence. That's one aspect, why MQTT is ideally suitable for small devices.

3.3.3 Broker

The broker is primarily responsible for receiving all messages, filtering them, decide who is interested in it and then sending the message to all subscribed clients. It also holds the session of all persisted clients including subscriptions and missed messages. Another responsibility of the broker is the authentication and authorization of clients.

3.3.4 MQTT Connection

The MQTT protocol is based on top of TCP/IP and both client and broker need to have a TCP/IP stack.

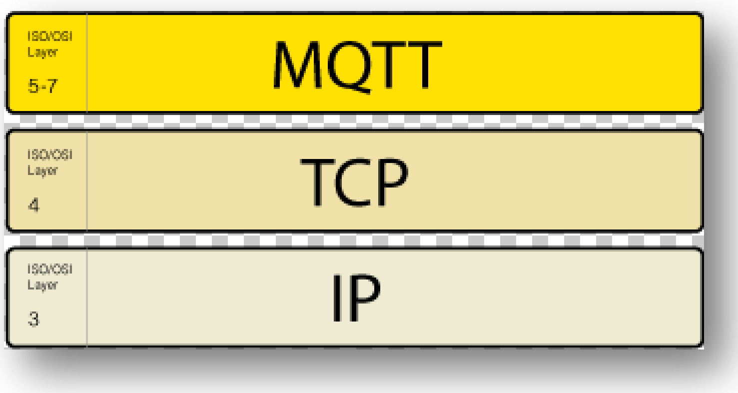

Figure 3-4: MQTT Connection

3.3.5 Topics

A topic is a UTF-8 string, which is used by the broker to filter messages for each connected client. A topic consists of one or more topic levels. Each topic level is separated by a forward slash (topic level separator). An example of a topic would be:

My home/living room/temperature

3.3.6 Quality of Service

The Quality of Service (*QoS*) level is an agreement between sender and receiver of a message regarding the guarantees of delivering a message. QoS is a major feature of MQTT, it makes communication in unreliable networks a lot easier because the protocol handles retransmission and guarantees the delivery of the message, regardless how unreliable the underlying transport is. Also it empowers a client to choose the QoS level depending on its network reliability and application logic. There are 3 QoS levels in MQTT:

- **QoS 0 – at most once**

The minimal level is zero and it guarantees a best effort delivery. A message won't be acknowledged by the receiver or stored and redelivered by the sender. This is often called "fire and forget" and provides the same guarantee as the underlying TCP protocol.

- **QoS 1 – at least once**

When using QoS level 1, it is guaranteed that a message will be delivered at least once to the receiver. But the message can also be delivered more than once. The sender will store the message until it gets an acknowledgement from the receiver.

- **QoS 2**

The highest QoS is 2, it guarantees that each message is received only once by the counterpart. It is the safest and also the slowest quality of service level. The guarantee is provided by two flows there and back between sender and receiver.

3.4 System scenario

Weather station is a package of software controlled instruments which collects data, performs some data processing and transmits this data to a specific server.

The design's instruments include a thermometer to take temperature readings, a barometer to measure the pressure in the atmosphere, rain gauge sensor to measure rain fall, electronic sensor to measure both wind speed and wind direction and humidity sensor.

Data from sensors is collected periodically, each sensor has a specific period depending on the probability of an actual changing in the inputs. When a command is issued to transmit the weather data, the weather station processes and summarizes the collected data. The summarized data is transited to the mapping computer when a request is received.

3.7 System Flow Chart

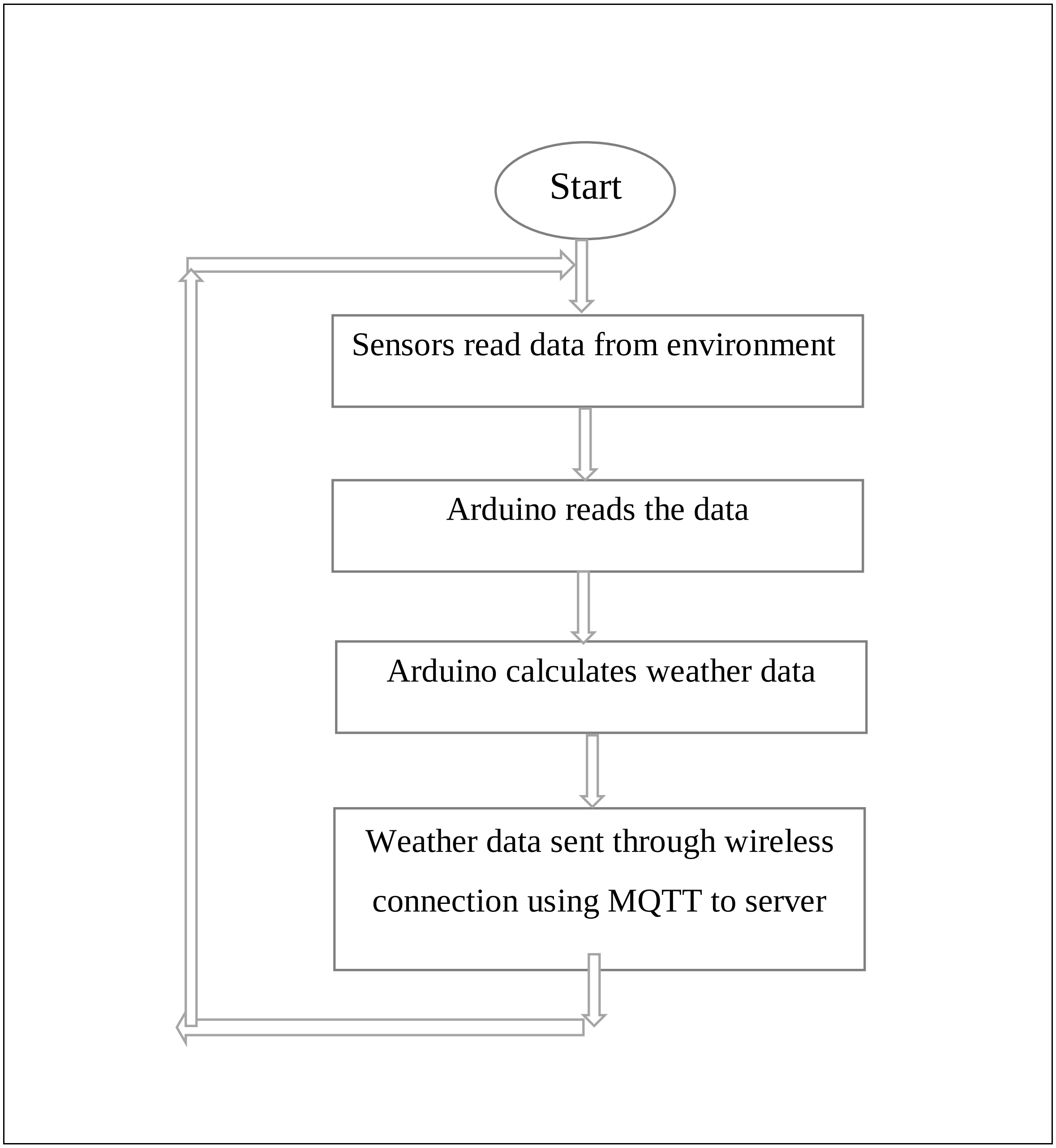

Figure 3-5: System Flow Chart

3.6 System Block Diagram

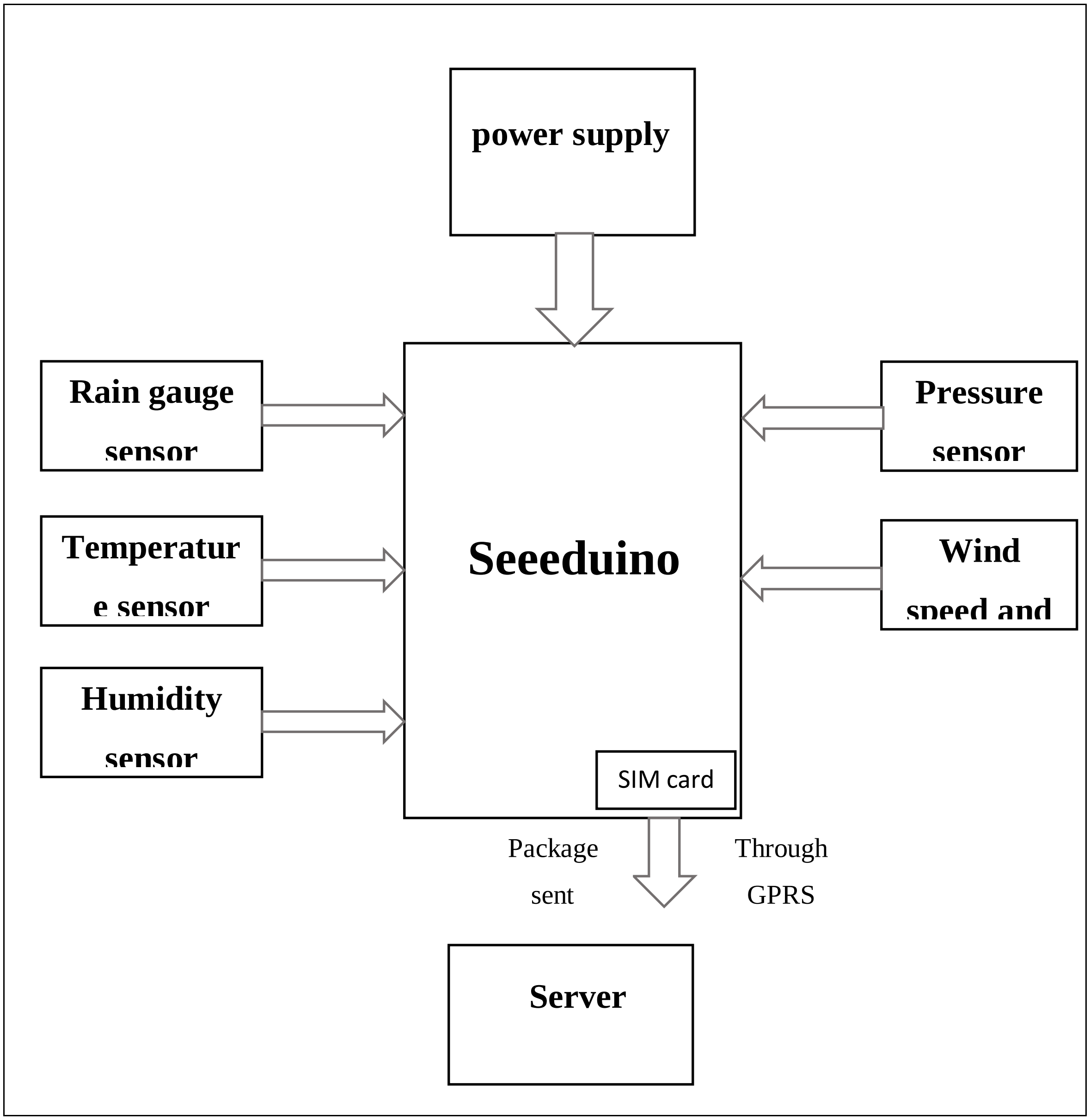

Figure 3-6: System Block Diagram

Chapter four

Simulation and Hardware

Chapter four

Simulation and Hardware

4.1 Simulation

4.1.1 Pressure Sensor

4.1.1 Temperature and Humidity Sensor

4.1.3 Rain Gauge Sensor

4.1.4 Wind Sensor

4.2 Hardware

4.2.1 Temperature and humidity measurement

4.2.2 Pressure measurement

Chapter four

Simulation and Hardware

4.1 Simulation

The simulation use arduino UNO to program the MPX4115 pressure sensor, the SHT11 temperature and humidity sensor, a rain gauge circuit and an ultrasonic circuit that works as an anemometer.

In the simulations (a, b, and c) bellow pin A_0, from the analog pins of the arduino, is attached with MPX4115. Pins 10(DATA) and 11(SCK), are digital pins used to connect SHT11 sensor. An LCD is used to display the readings of the two sensors, and it is connected to the arduino pins 2, 3, 4, and 5 for the data pins. Pin 12 connects the enable LCD pin (E), and pin 13 is connected to the VDD.

4.1.1 Pressure Sensor

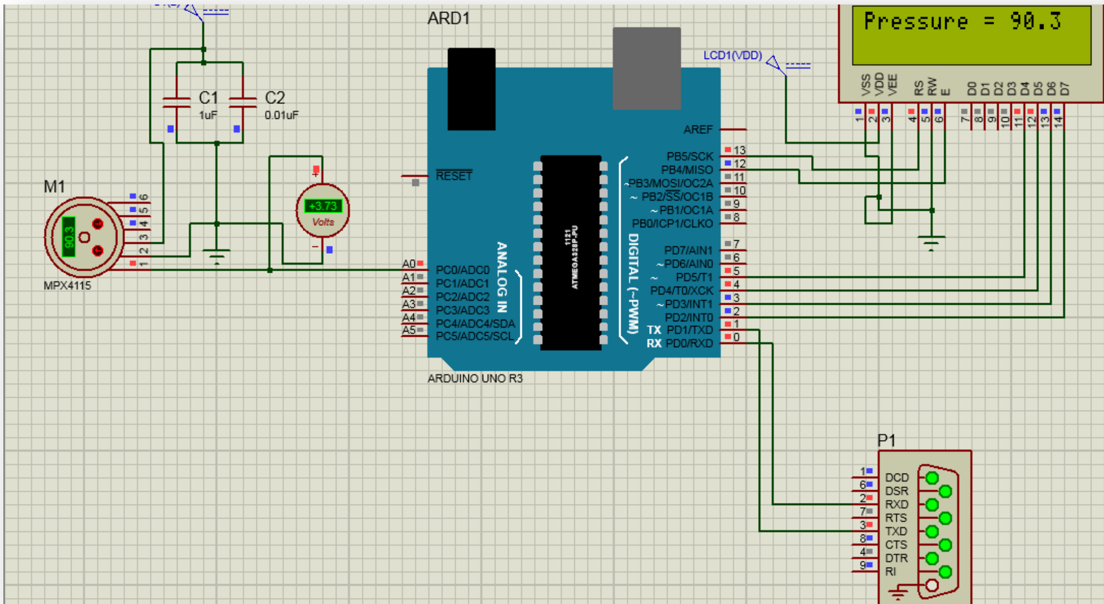

Figure 4-1: Pressure sensor readings

4.1.2 Temperature and Humidity Sensor

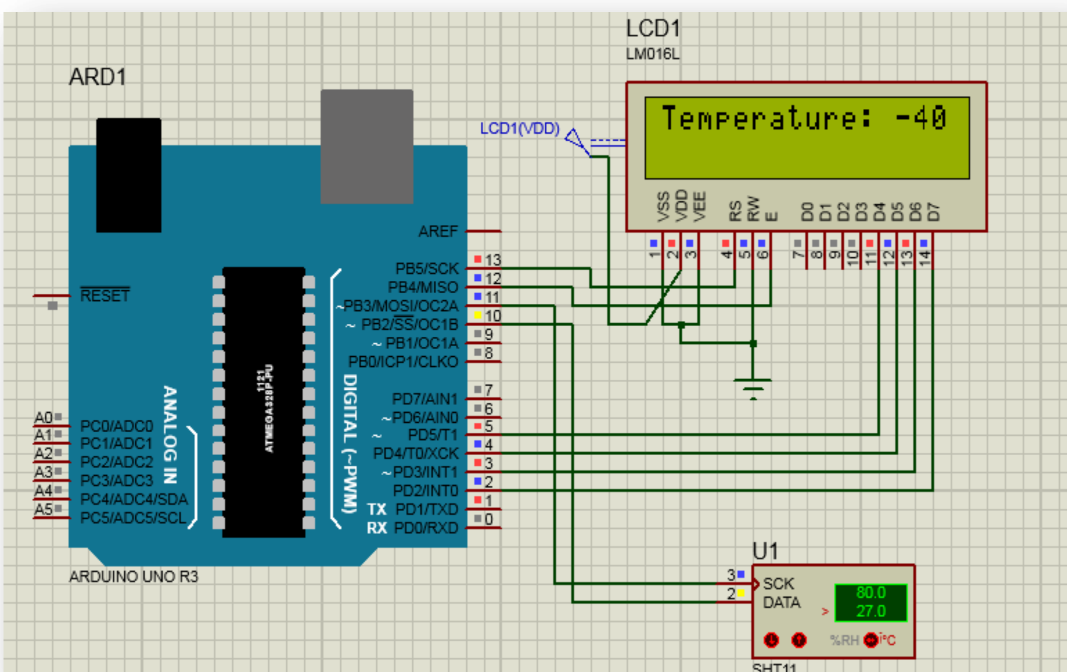

Figure 4-2: Temperature sensor readings

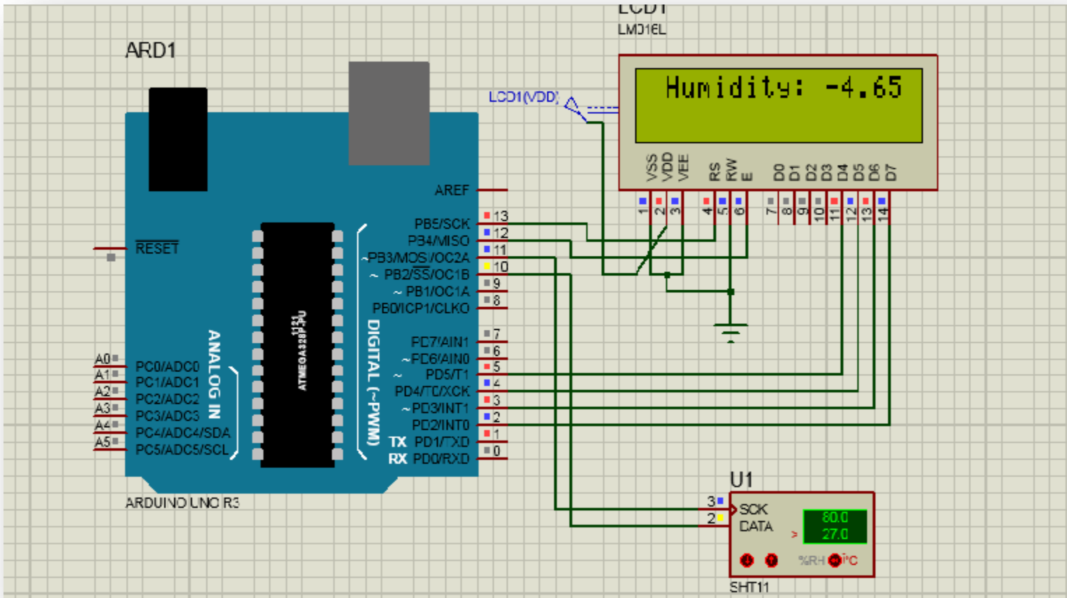

Figure 4-3: Humidity sensor readings

4.1.3 Rain Gauge Sensor

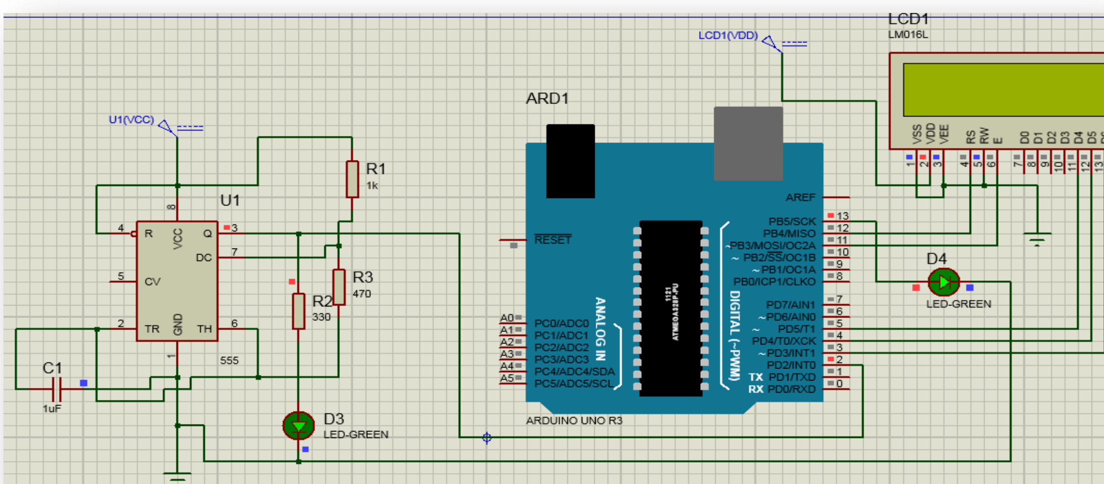

Figure 4-4: Tipping buckets rain gauge sensor

The figure above represents the concept of the rain gauge signal.

4.1.4 Wind Sensor

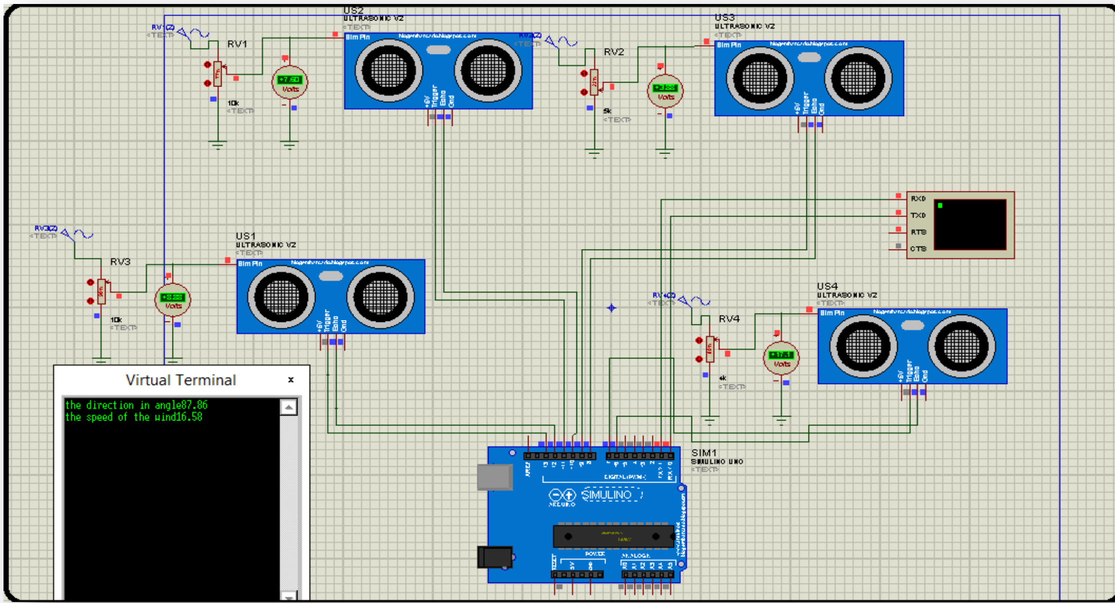

Figure 4-5: Ultrasonic anemometer

The figure above represent the concept of the ultrasonic wind sensor, the circuit consist of four ultrasonic transducers connected to Arduino.

The Arduino triggers one couple of ultrasonic and calculate the time until it receives the echo, and the same procedure for the second couple, from the given times the microcontroller calculates the wind speed and the direction.

Calculations:

$$V = \frac{L\ (T_2 - T_1)}{T_1\ T_2\ \cos D}$$

$$D = \tan^{-1}\frac{T_1\, T_2(\, T_3 - T_4)}{T_3\, T_4(T_2 -\, T_1)}$$

4.2 Hardware

The hardware is consistent of the temperature & humidity sensor, and the pressure sensor wired with the seeeduino GPRS board to give readings as follow:

4.2.1 Temperature and humidity measurement

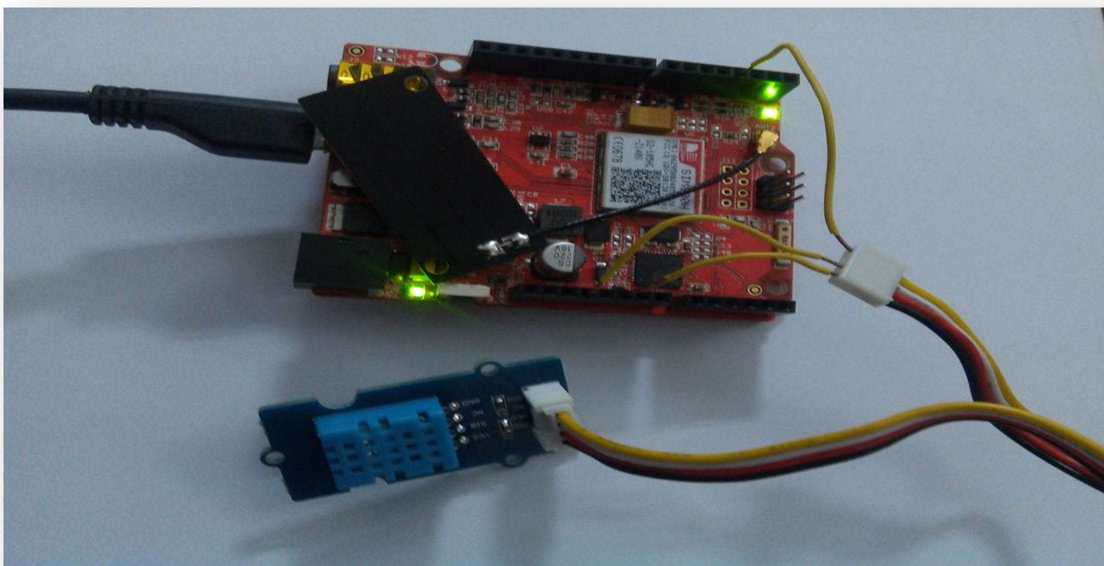

Figure 4-6: DHT11 connected with seeeduino GPRS

Firstly the code is compiled and then uploaded to the board so the sensor can start its reading as shown in.

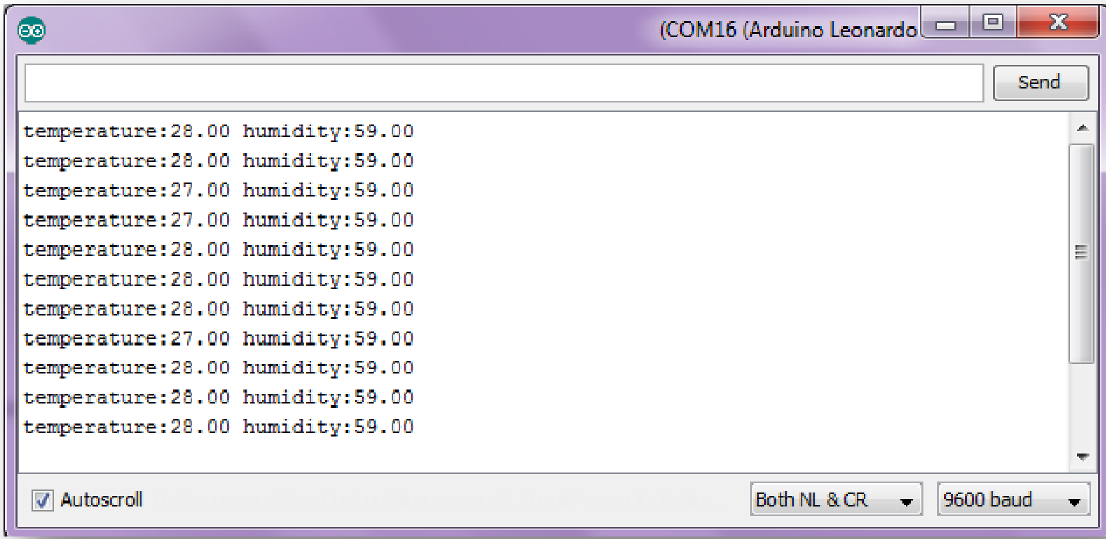

Figure 4-7: Displaying temperature and humidity readings

The readings of the DHT11 sensor for temperature and humidity are being displayed on the serial monitor of the arduino IDE window.

4.2.2 Pressure measurement

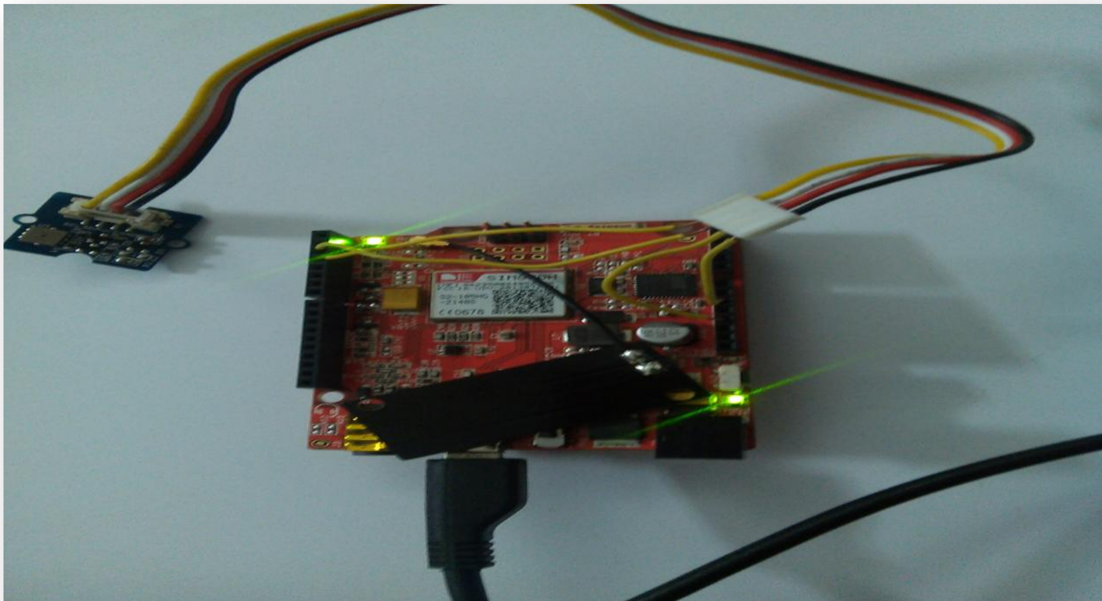

Figure 4-8: BMP180 connected to the seeeduino GPRS

As with the previous sensor, after the code is compiled and uploaded to the board it starts its readings as it's shown in.

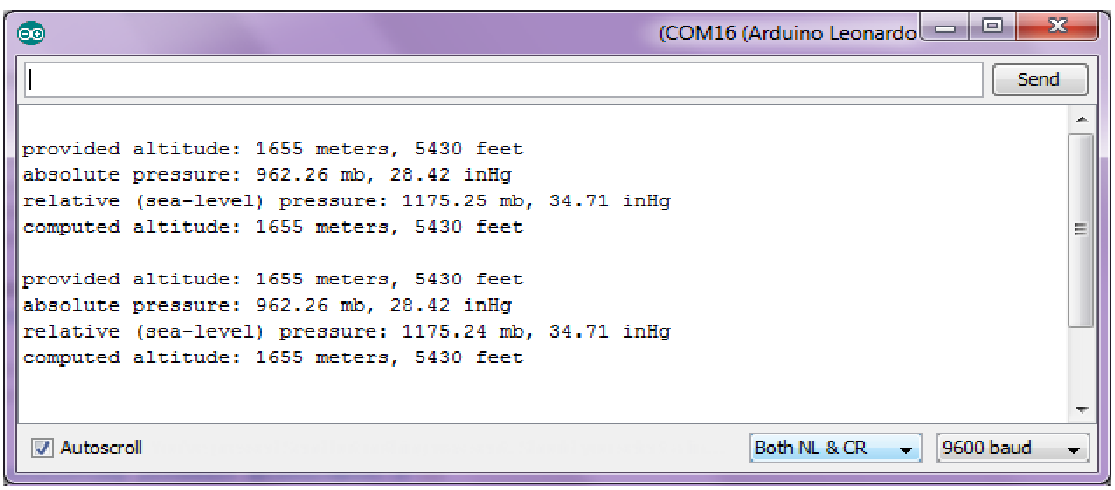

Figure 4-8: Displaying pressure and altitude readings.

The BMP180 pressure sensor reads the altitude at which the pressure is computed and compares it with the sea level altitude. Readings are displays on the serial monitor of the arduino IDE.

Chapter five

Conclusion and Recommendation

Chapter five

Conclusion and Recommendations

5.1 Preface

5.2 Conclusion

5.3 Recommendation

Chapter five

Conclusion and Recommendations

5.1 Preface

Weather informations are useful in many aspects of life. Yet not everyone can reach these informations, because of the obstacles in making a weather station and also for the high cost. The new technology has come to make things easier, that is shown in this project in using simple component capable of building such projects such as Arduino microcontroller.

If one person in the area was able to make such weather station and share his information through internet, every person can get the weather informations in that area, this could make it much easier to acknowledge the weather informations to be used or collect many of the previous data and the resent one to forecast the upcoming weather.

In software Arduino IDE ,the code has been written. For simulating the circuits we have used two versions of proteus 7 and 8. Sensor circuits were mostly build in proteus but for some of the sensors we had to design our own circuit. We designed the wind sensor using ultrasonic and for the rain gauge sensor we used a pulse generator to simulate the function of the tipping bucket.

In hardware we implemented some of the sensors humidity, temperature and pressure. The microcontroller take a signal from the sensors and calculate the weather data and collect this data to send it to a server.

5.2 Conclusion

The weather has always been a subject of universal interest, and the recent climate change issue, in particular, has driven the requirement to produce accurate, robust and reliable sensors that are capable of predicting change of weather conditions over a specific period of time. Nowadays, the need for weather monitoring instruments that can be counted on for real-time alerting and reporting on the varying environmental conditions becomes increasingly essential.

The proposed project has developed a platform by which is many weather monitoring sensors implemented to MC that sends it to a server. A prototype system of an automated Weather Station has been successfully built, accommodating five sensors being responsible to measure six key weather parameters; temperature, air pressure, relative humidity, rain fall, wind speed and wind direction. The hardware of the automated weather station consists of sensors and seeeduino microcontroller.

Looking at the implemented weather stations in Sudan face us with that no one have implemented a weather station or programmed it, plus the available ones were based on mechanical sensors that's life time is short compared to the electronic ones, if any defect happens it needs an expert capable to justify the problem before trying to fix it. In additional to that the weather changing can effect on the mechanical parts and changes its performance.

This leads us to the importance of implementing automated weather station to reduce the human interaction. And more electronically based weather sensors. We found the suitable sensors for our design and start implementing it in simulation, and sent any read data through GPRS to a server that saves the data base and make it available for users when needed.

5.3 Recommendation

The project discusses the design of an automated weather station. To increase the efficiency of this station, it's recommended to:

- To make this weather station fully automatic with no mechanical base there is an infrared rain gauge.
- For more accuracy you can use a 3D ultrasonic anemometer.
- As an energy source we can use solar power since it is outdoor weather station**.**
- As we have one way communication the station reads the data and send it, it is suggested to use two way communication so the station can receive instructions.
- To design a well-proofed casing, it is important to make well protected against water, dust, heat, sunshine and other external weather factors.
- Depending on the use of the weather station you can use other sensors.

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