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Arduino Based Weather Monitoring Telemetry System Using NRF24L01+

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Abstract-Weather is an important part of the natural environment, thus knowing weather information is needed before doing activity. The main purpose of this research was to develop a weather monitoring system which capable to transmit weather data via radio frequency by using nRF24L01+ 2,4GHz radio module. This research implement Arduino UNO as the main controller of the system which send data wirelessly using the radio module and received by a receiver system. Received data then logged and displayed using a Graphical User Interface on a personal computer. Test and experiment result show that the system was able to transmit weather data via radio wave with maximum transmitting range of 32 meters.

1. Introduction

Weather is an important part of the natural environment. It directly or indirectly affects many of our life activities. Thus, knowing weather information is needed before performing an activity, especially activities that directly relate to nature such as agricultural activities and so on. [1]

Furthermore, Weather or climate plays an important role in human life. The thermal comfort of human being is known to be influenced mostly by six parameters, i.e., air temperature, radiation, air flow, humidity, activity level and clothing thermal resistance. The advancement in technology has made these small and reliable electronic sensors capable of monitoring environmental parameters more favourably. [2]

In order to describe the weather accordance to the atmospheric conditions, certain key weather elements must be known. Some of those are temperature, sun intensity, relative humidity, and atmospheric pressure. So in this case, weather monitoring system is necessary to meet the needs of describing weather condition. [3]

However, the lack of wireless technology in conventional weather monitoring system is an efficiency and effectiveness issue. Therefore to overcome this issue a system which capable to transmit weather information wirelessly is needed? [4]

This paper aims to build a weather monitoring telemetry system which capable to acquire and record data wirelessly. Those ability may be beneficial in providing a portable and practical weather monitoring system. The proposed system has three sensors that measure temperature, relative humidity, atmospheric pressure, and light intensity respectively. Sensory data then transmitted via an NRF24l01 2.4 GHz transmitter. Transmitted data then received and displayed in a graphical user interface and logged to a tab delimited text file.

2. Literature Review

This weather monitoring system is implemented using Arduino Uno Board. The board is used to interface the DHT11 sensor, LDR sensor, BMP180 Barometric Pressure and the NRF2401 module. The Arduino accepts the data from the sensors and displays the output on the PC using serial communication. The NRF2401 module is responsible for transmitting the data obtained from the sensors DHT11, LDR and BMP180.

2.1. Arduino UNO R3

Arduino is an open source device, a prototyping board consisting of ATmega328P microcontroller providing a 5V and 3.3V output volatage options. It takes input voltage from either connecting USB to your computer or either using a coaxial cable using a portable power supply. The arduino board is also capable of reading Twitter messages and respond in order to that. On the arduino you can upload sketches using Arduino IDE. Arduino comes in various flavours and according to needs like Uno, Mega, Yun etc.

In this instrument I've used Arduino unoboard. It is cheap and flexsible. Also it is good to start as a beginner. It has 14 digital input/output pins, 6 analog inputs and a reset button. It takes input voltage in between 7-12V.

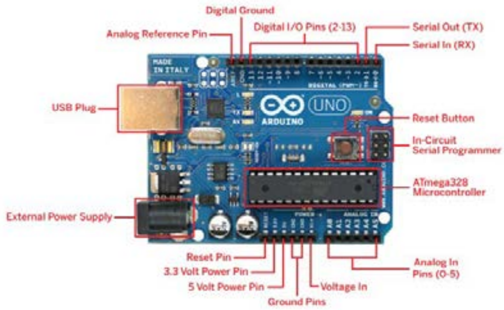

Figure 1. Arduino UNO R3

Related technical specification shown in Table 1.

Table 1. Arduino Uno spesifications.

Microcontroller	Atmega328P
Operating Voltage	5V
Input Voltage (recommended)	7 - 12 V
Input Voltage (limit)	6 – 20 V
Digital I/O Pins	14
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3,3 V Pin	50 mA
Flash Memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
Length	68,6 mm
width	53,4 mm
Weight	25 g

2.2. Digital Humidity Temperature Sensor

DHT11 is a digital temperature and humidity sensor which provides a calibrated digital signal output of the temperature and humidity. Due to its exclusive digital modules and the temperature and humidity sensing technology, it makes sure that the output obtained is of high reliability and stability. The sensor consists of a resistive sense of wet components and an NTC temperature measurement devices, and connected with a high-performance 8-bit microcontroller. DHT11 sensor ensures fast response, low consumption of power, low cost. In addition to this, it also has the ability to avoid interference and can transmit data to a long distance. The communication and synchronization between microcontroller unit and the DHT11 sensor takes place using a single wire two way connection and requires single bus data format for the same. The information packet transmitted by the sensor is of 40 bits. The sensor operates in 2 different modes-low power consumption mode and running mode. The start signal signifies the transformation from low power mode to running mode. As the start signal is completed, the sensor sends a response signal containing the information regarding the relative temperature and humidity. [5]

For weather station, the sensor used is a 3 pin module consisting of Vcc, Data and Ground (GND).The Data pin is connected to the A0 pin of the Arduino board whereas the Vcc is connected to the 5V pin of Arduino. The sensor transmits the information of temperature and humidity to the Arduino board which is later displayed on the serial monitor using serial communication.

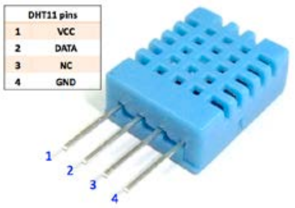

Figure 2. DHT 11

Figure 3. BMP 180

2.3. BMP180

BMP180 sensor It is a barometric pressure sensor which senses with an I2C interface As the pressure varies with altitude it can used to measure the altitude too. It has 4 pins SDA, SCL, GND and Vin. [6]

Table 2. BMP180 Spesifications

Pressure range	300 – 1100 hPa
Supply Voltage	1,8 – 3,6 V
Operating temperature	-40 to +85 ℃
Absolute accuracy pressure (0 to +65 ℃)	-4,0 to +2,0 hPa
Supply current	3 – 32 μA
Absolute accuracy temperature (0 to +65 ℃)	-2,0 to + 2,0 ℃
Dimensions	0.4 x 0.4 x 0.4 inches

2.4. Light Dependent Resistor (LDR)

An LDR is a component that has a (variable) resistance that changes with the light intensity that falls upon it. This allows them to be used in light sensing circuits. A light-dependent resistor (LDR) is a light-controlled variable resistor. The resistance of this decreases with increasing incident light intensity; in other words, it exhibits photo-conductivity. An LDR can be applied in light-sensitive detector circuits, and light- and dark-activated switching circuits. An LDR is made of a high resistance semiconductor. In the dark, an LDR can have a resistance as high as a few mega ohms (MΩ), while in the light, an LDR can have a resistance as low as a few hundred ohms. If incident light on an LDR exceeds a certain frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction

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band. The resulting free electrons (and their whole partners) conduct electricity, thereby lowering resistance. The resistance range and sensitivity of an LDR can substantially differ among dissimilar devices. [7]

Figure 4. LDR

Figure 5. NRF24L01+

2.5. *NRF24L01+*

The nRF24L01 is a single chip radio transceiver for the global, license-free 2.4 GHz ISM band. The low cost nRF24L01 is designed to merge very high speed communications (up to 2Mbit/s) with extremely low power (the RX current is just 12.5mA) [4]. The transceiver consists of a fully integrated frequency synthesizer, a power amplifier, crystal oscillator, demodulator, modulator and Enhanced ShockBurst protocol engine. In addition, the nRF24L01 also offers an innovative on-chip hardware solution called 'MultiCeiver' that can support up to six simultaneously communicating wireless devices. This makes it ideal for building wireless Personal Area Networks in a wide range of applications. The PCB of this WSN node is circular, having two inches diameter. [8]

Table 3. nRF24L10+ Spesification

Transceiver model	nRF24L01+
Frequency	2,4 GHz
Input Voltage	1,9 - 3,6 V
Modulation	GFSK
Data rate	250 kbps, 1 Mbps, and 2 Mbps
Output current (transmitter)	11,3 mA at 0 dBm
Output current (Receiver)	13,5 mA at 2 Mbps
Sensitivity	-82 dBm at 2 Mbps -85 dBm at 1 Mbps -94 dBm at 250 kbps
Operating temperature	-40 to +85 ℃
Dimensions	2.9 x 1.5 x 1.2 cm

3. Proposed System

The proposed system divided into two main parts. These are transmitter and receiver. The transmitting part consist of sensors, Arduino UNO, and nRF24L01 RF Module. Receiving consist of Arduino UNO, nRF24L01 RF Module, and a laptop. The block diagram shown in Figure 6.

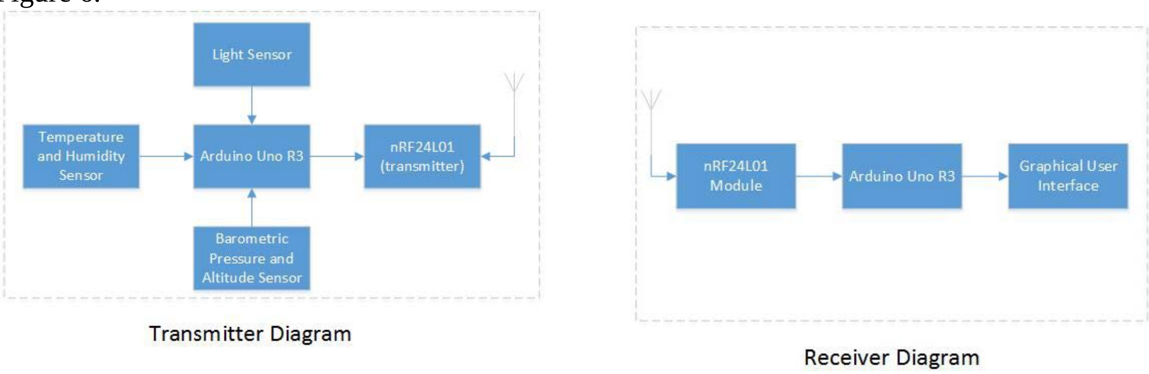

Figure 6. Transmitter and receiver block diagram

3.1. Transmitter System

Proposed transmitter system consists of DHT 11 sensor, BMP 180, light dependent resistor, Arduino UNO R3 and nRF24L01 module. Transmitter circuit design shown in figure 8. The modules and microcontroller used of the transmitter can be summarized as follows :

DHT 11

This sensor is used to measure current temperature and humidity.

BMP 180

Sensor is used to measure barometric pressure and altidude.

Light Dependent Resistor

This sensor is used for measuring the light intensity falling on the sensor.

Arduino Uno R3

is the main component that is centrally connected to all components.

nRF24L01

The RF module is used to transmit data that has been processed by Arduino Uno R3.

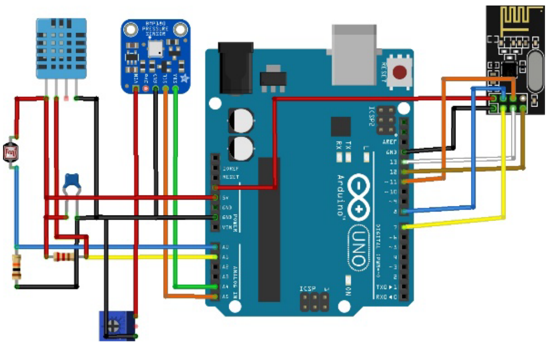

Figure 7. Transmitter circuit design

The transmitter system wiring table could be seen on Table 4.

Table 4. Transmitter System Spesification.

NRF24L01	**ARDUINO UNO R3**
VCC	VCC
GND	GND
CE	7
CSN	8
MISO	ICSP (MISO)
MOSI	ICSP (MOSI)
SCK	ICSP (SCK)
DHT11	**ARDUINO UNO R3**
VCC	VCC
GND	GND
DATA	3
NC	-
LDR	**ARDUINO UNO R3**
VCC	VCC
GND	GND
DATA	A0
BMP180	**ARDUINO UNO R3**
VIN	VCC
GND	GND
SCL	A5
SCA	A4

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3.2. Receiver System

Proposed receiver system consists of Arduino UNO R3, nRF24L01 module and a personal computer (PC). Receiver circuit design shown in figure 9. The nRF24L01 module is used for receive sent data from the transmitter, the received data then processed by the Arduino Uno R3 and the data is displayed on a laptop using a graphical user interface.

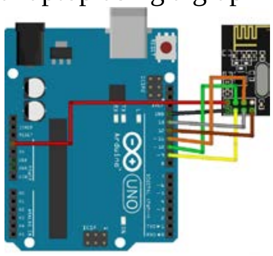

Figure 8. Receiver circuit design

The receiver system wiring table could be seen on Table 5.

Table 5. Receiver System Spesification.

NRF24L01	ARDUINO UNO R3
VCC	VCC
GND	GND
CE	7
CSN	8
MISO	ICSP (MISO)
MOSI	ICSP (MOSI)
SCK	ICSP (SCK)

3.3. Graphical User Interface

The graphical user interface was developed using C#. The software allows received data to be displayed in a user-friendly platform. This could simplify and made the data acquisition process. Beside of that, some of basic function of the GUI are to provide connection between receiver system and the PC, and to log all received data to a text file.

The GUI refresh in one second interval, updating to the latest received data on a real time update. Thus, more accurate weather monitoring could be achieved.

Figure 9. GUI display

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4. Experimental Result and Discussion

Before starting the experiment a full system testing was done to ensure minimum error and no fatal malfunction in both transmitter and receiver system. The testing of each sensor was carried out successfully. Resulting in minimum error in sensor readings as shown on Table 7 and Table 9.

The experiment is carried out by powering the transmitter system using a portable power source and the receiver system connected to a PC. The GUI was launched and established a connection to the receiver system and begin to log data. Then distance and condition between transmitter system and receiver system varied until the GUI displayed a constant value which represent loss of signal or maximum transmitting range.

4.1. Sensors Test and Calibration

Temperature and lux sensor testing was carried out by comparing sensors reading value with respectively termometer, and lux meter.

Atmospheric pressure and altitude was not calibrated due to limitation of the required instruments.

Table 6. Temperature sensor test and calibration data.

Trial	Temperature sensor reading (C)	Termometer reading (C)
1.	28.00	27.80
2.	30.20	30.30
3.	33.40	33.50
4.	35.30	35.00
5.	25.80	25.40

Table 7. Temperature sensor errors.

Trial	Error	% Error
1.	-0.20	0.71
2.	0.10	0.33
3.	0.10	0.29
4.	-0.30	0.84
5.	-0.40	1,55

From Table 1 and Table 2 it can be concluded that used temperature sensor was able to sense temperature in centigrade unit which error is less than 2%.

Table 8. Lux sensor test and calibration data.

Trial	Lux sensor reading (lux)	Lux meter reading (lux)
1.	82.2	83.8
2.	84.5	83.5
3.	84.0	83.6
4.	83.7	84.4
5.	84.8	84.2

Table 9. Lux sensor errors

Trial	Error	% Error
1.	1.6	1.94
2.	-1	1.18
3.	-0.4	0.47
4.	0.7	0.83
5.	-0.6	0.70

From Table 3 and Table 4 it can be concluded that used lux sensor was able to sense light intensity in lux unit which error is less than 2%.

4.2. Telemetry System Result

Each experiment attempt was done in a different time and location. First attemp was done at second floor of A8 building in Engineering faculty of Surabaya State University. The results obtained are summarized in Table 5 and Table 6,

Table 10. Experiment attempt 1. Transmitting range.

LOS Distance (m)	T (C), RH (%), Lux (lux), Atmospheric pressure (hPa), Altitude (m)
1	27.4, 35, 890, 1007.97, 44.05
2	27.1, 38, 953, 1007.94, 44.31
4	27.2, 38, 958, 1007.99, 44.05
8	27.2, 38, 970, 1007.99, 44.05
10	27.1, 38, 1002, 1008.01, 43.30
12	27.1, 38, 1007, 1007.97, 43.89
14	27.1, 38, 1005, 1007.99, 43.97
16	27.1, 38, 987, 1008.04, 43.47
18	27.1, 38, 999, 1007.97, 43.89
20	27.1, 38, 1009, 1007.99, 43.72
22	27.1, 38, 1012, 1008.09, 43.80
24	27.1, 38, 1013, 1008.03, 43.39
26	27.1, 40, 1013, 1008.01, 43.72
28	27.1, 40, 1012, 1007.99, 43.89
30	27.1, 40, 1011, 1008.00, 43.63
32	27.1, 40, 1007, 1008.01, 43.72
34	27.1, 40, 1007, 1008.01, 43.72
36	27.1, 40, 1007, 1008.01, 43.72

Table 11. Experiment attempt 2. Transmitting range.

LOS Distance (m)	T (C), RH (%), Lux (lux), Atmospheric pressure (hPa), Altitude (m)
1	30.4, 33, 935, 1005.66, 63.39
2	30.4, 30, 935, 1005.65, 63.47
4	30.5, 33, 919, 1005.65, 63.47
8	30.6, 33, 928, 1005.64, 63.55
10	30.7, 34, 915, 1005.63, 63.64
12	30.8, 33, 927, 1005.64, 63.55
14	30.8, 33, 927, 1005.64, 63.55
16	30.7, 34, 929, 1005.62, 63.72
18	30.7, 33, 930, 1005.56, 64.22
20	30.7, 34, 929, 1005.61, 63.81
22	30.6, 26, 928, 1005.60, 63.72
24	30.6, 33, 926, 1005.60, 63.89
26	30.5, 18, 924, 1005.62, 63.72
28	30.5, 33, 924, 1005.58, 64.06
30	30.5, 34, 932, 1005.65, 63.47
32	30.5, 34, 932, 1005.65, 63.47
34	30.5, 34, 932, 1005.65, 63.47

Table 10 and 11 denotes received sensory data in a varied line of sight distance. Sensory data was not stay ini the same value due to the hysteresis effect of the used sensors, except lux variable. Light intensity was varied to make determination of the successful data transmission easier. Sensor hysteresis effect can be seen on Figure 10

It can be observed from Table 1 that the maximum transmission range is 32 meters, since the sensory value is constant. Meanwhile from Table 11, maximum transmission range is 30 meters. The difference in transmission maximum range between two experiment attempt could mainly due to different condition of the environment which was done at or another factors that were not considered.

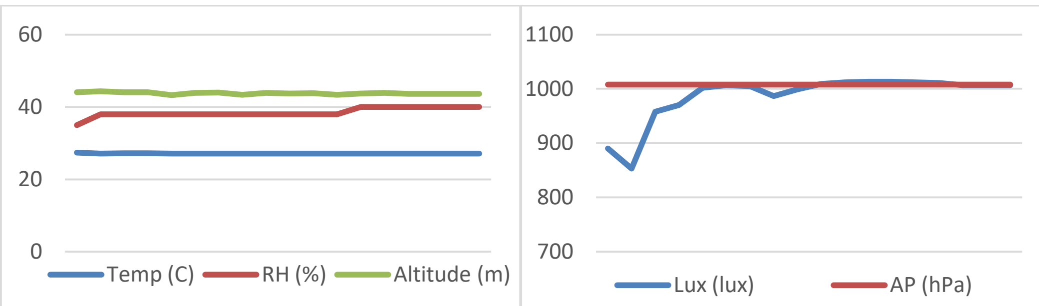

Figure 10. Sensors hysteresis effect value change

5. Conclusion

The main goal of this research is to develop and implement a weather monitoring telemetry system using nRF24L01+ 2.4 GHz RF Module. From the result obtained throughout the test and experiment carried out, it can be concluded: 1)The developed system work well, this can be known from the system's capability to transmit dan receive weather data via a radio waves at a certain maximum distance. 2) nRF24L01+ maximum transmitting range is 30-32 meter line of sight, this value may differ from another conducted research due to differences in implemented programs, environment condition, hardware quality, and other factors that affecting radio wave

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