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Low cost smart weather station using Arduino and ZigBee

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ABSTRACT

This paper presents low cost-effective weather station with monitoring system by using ZigBee communication technique that serves as a communication channel by using hardware and sensors to transmit and receive data in the weather station system. Using ZigBee over the Bluetooth for the short coverage distance about (1-10 m) and over the (WLAN) (wireless local area network) or Wi-Fi, a WLAN has limitation like delay, lacking BW of the handover of a large amount of data, and some areas have no internet coverage. The system includes implementation and design for the weather station using Arduino Uno board and five sensors gives sixth reading data (rain state, wind level, air pressure, dust density, temperature and humidity). The data can be stored in SD card on receiving (clouding and main processing side) from more than one transmitter node (ZigBee Network). It can be retrieved the data in any time and date. Results showed the system has no delay and the data reputedly changing ever second with the new reading.

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1. INTRODUCTION

Generally, in the worldwide, the weather is very important for people life in numerous situations of rainy, hot, dry, dusty, and windy weather state. We must know these states before going to anywhere to take precautions [1-3]. These precautions can be implemented by modern electronic and monitoring technologies. Arduino is an open-source board that contains individually a physical programmable circuit boarding (microcontroller) with a part software, or IDE which works in a PC, and writes with upload PC code in the board (Arduino board) [4-6].

The ZigBee technique is interoperable amongst constructers with maintenances having main number of nodes. System delivers contacting between several electronic procedures as a cooperative and graphical interface to control these devices [7-9]. The model has a parallel processing like joining one or extra microcontroller (built in projected system) and the interface among microcontrollers is composed to construct master/slave procedure that employs one main (master) with one or extra (slave) microcontrollers [10].

Related works in this section discussed various approaches by using Arduino and ZigBee technology Systems with their features. Shih-Pang Tseng et al. [11] presented smart house monitor & supervisor (SHMS), using ZigBee techniques based on the sensors with actuators that attached via ZigBee technique system. The design is smart socket that works by remote control by Zigbee. The computer host acts as an information data with motion sensing and the information is transported to VM on the cloud. Nayan and Ikhsan [9] designed and enhanced ZigBee technique that functions as a communication channel in

the hardware with sensors based on a house automation method in smart houses. LCD has used to give details about system receiver. ZigBee network has been used for the design and implementation effectively on prototype to improve the house automation system. Babarao and Ramesh [12] investigated a system identified as HEMS to decrease the power consumption in home energy. They conducted different home appliances connected over ZigBee communication to turn on or off the home appliance. Proposed architecture gives power saving and energy organization, and affords a security to the home by using different sensors and GSM circuits. Jabbar and Kawitkar [13], has introduced cheap commercial and powerful house control with monitoring system. Smart home has interfaces and practical descriptions to confirm interoperability amongst ZigBee systems for different electrical devices, meters and smart energy enablers. Hadi [14] has presented system design using XBee wireless technique communications, which is able to send and receive a transmission information among central controller unit and various house sensor nodes for reading and sending temperature, gas sensing and IR security information. The tested results are in the wireless usage monitoring and are recognized.

In Iraq, the weather states are always changing. Temperature degree is very hot in summer, and humidity is very high in south of Iraq as well as rainy weather in north of Iraq. To measure all these states of data, we need devices to measure the weather states in all areas to know their states and we used the wireless weather station device without Internet by using ZigBee Network with Arduino microcontroller and the sensors to measure these weather states. In this paper, the system has implementation and design for the weather station using Arduino Uno board and five sensors with sixth reading data (rain state, wind level, air pressure, dust, temperature and humidity). The data is transmitted from the station by using Zigbee communication technique (ZigBee Network) as the communication channel to the receiver. The weather station doesn't need the internet. Therefore, we can use it in any location since weather station is based on ZigBee communication technology that has high coverage area from 120 m to 64 km.

2. RESEARCH METHOD

The main work in this paper is to propose design and implementation a weather station system. The work has two parts (hardware and software) implementations, and block diagram for the weather station is depicted in Figure 1.

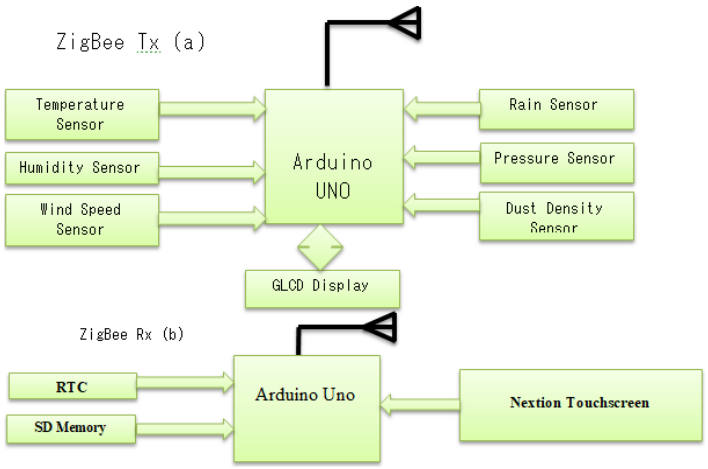


Figure1. Block diagram of the station: (a) sender section (TX), and (b) receiver section (RX)

2.1. Hardware implementation

Hardware implementation primarily involves two Arduino Uno parts, temperature and humidity (DHT11), two ZigBee circuits, wind speed sensor (Type (0-9V) SKU: SEN0170), BMP180 digital barometric sensor module – model GY-68, rain sensor, dust sensor (GP2Y1010AU0F), SD memory, real time clock (DS1307) sensor, GLCD and nextion display which are being discussed with their specific functions.

a. Arduino Uno

Arduino is microcontroller boarding built on ATmega328P. The Arduino has 14 digital input/output pins (6 pins which uses as PWM outputs), 6 analog inputs with 16 MHz quartz crystal, USB connection, power jack and ICSP header with a reset switch as explained by Figure 2 [15]. Uno boarding has a series for USB Arduino boards, with reference typical to Arduino boards.

b. ZigBee technology

ZigBee technology works on open global standard based on IEEE 802.15.4 MAC/PHY. It defines network layer over 802.15.4 layers that are supporting advanced mesh routing capabilities [5]. The xBee signal uses AES encryption method. This method is a symmetric-key secret message that is in cooperation with the transmitter node and the receiver to employ a solitary key for encrypting and decrypting. Encryption has procedures of transforming the text words into a layout that is uneasily decipherable which is known as cipher. The cipher is acquired by performing a sequential arithmetical operation based on iteration levels [16].

ZigBee networking element circuit with sensors stand for modern categories for wireless, short, low power network communication techniques with several technological advantages, such as a low complexity, low power consumption, high cost, high efficiency, high reliability and wide network coverage area [13]. Differences among Bluetooth, WLAN and ZigBee are clarified in Table 1. The XBee module uses medium to be as interaction with the communication module among microcontrollers and serves like wireless network for information transfer. There are two kinds of XBee devices used for house automation: XBee S1 and XBee S2 as depicted in Figure 3 [13]. The characteristics of the XBee S1 and S2 modules are shown in Table 2.

Table 1. Comparison of characteristics of Bluetooth, WLAN and ZigBee [9]

Characteristics	Bluetooth	WLAN	ZigBee
Protocol (IEEE)	802.15.1	802.11 b/g	802.15.4
Range (meters	10	50-100	10-100
Data rate (bit/s)	1 M	11 & 54 M	20, 40 & 250 k
Battery lifetime (days)	7	0.5-5	>100
Operating frequency (Hz)	2.4 G	2.4 G & 5 G	868 M, 902-926 M & 2.4 G
Complexity	High	High	Low
Power consumption (mW)	198	1050	72
Security	64 & 128 kbits	IEEE 802.11i (WPA2)	128-bit AES & application layer security
Application	Wireless communication	Internet, website, & e-mail	Control & monitoring

Table 2. The characteristics of Series 1 and Series 2 Xbee modules [13]

	Series 1	Series 2
Distance (m)	30	40
Optimal range (m)	100	120
Transmitter/receiver current (mA)	45/50	40/40
Firmware	802.15.4	ZigBee
Digital input	8	11
Analog input	7	4
PWM	2	No
Point-topoint & point-to-point topology	Yes	Yes
Mesh & tree topologies	No	Yes

c. Wind speed sensor

The three-type wind speed sensor is a device that determine wind speed by using 9 V DC voltage. Its features are high hardness, corrosion protection, waterproofness and high precision [17].

d. Barometric pressure sensor

The sensor is highly low-cost circuit to measure barometric pressure, temperature, and altitude. The sensor is welded on PCB of a 3.3V regulator, with pull up resistors of I2 pins [18].

e. Rain sensor

The rain sensor are tools to detect rain that can be worked like switch when rain drop falls over rainy board with the ability to measure the rain fall intensity [19].

f. Dust sensor

An infrared emitting diode with light depending resistor (LDR) phototransistor was organized on the hardware. It can be used to find out the reflected light from dust in air [20].

g. Temperature and humidity sensor (DHT11)

The board is sensor with the ability for measuring temperature with humidity. It has high reliability, excellent long-term stability with very fast response time [21].

h. Real time clock (DS1307)

Real time clock (RTC) is similar to the clock, works on the battery with retain time even if the power is off [22].

i. SD memory

The SD Memory is used to store the data from sensors immediately. This data can be displayed on nixtion touchscreen and old data can be searched at any date and time.

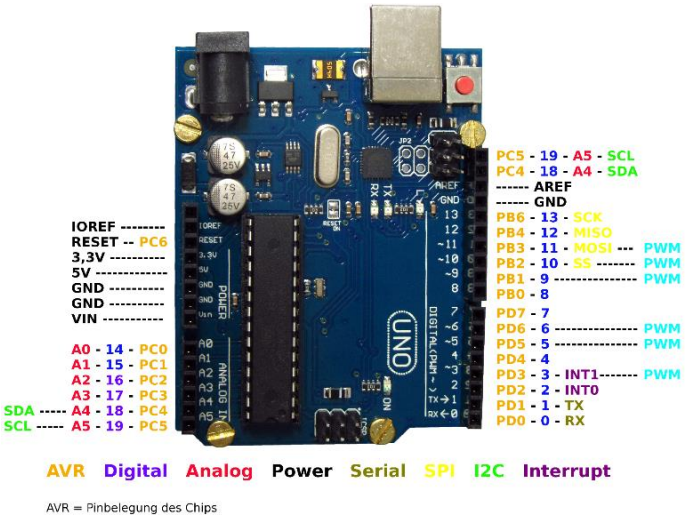


Figure 2. Microcontroller board (Arduino Uno)

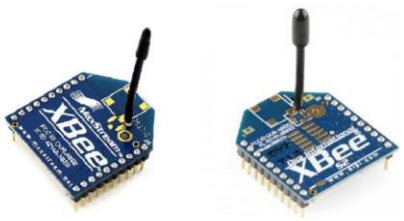
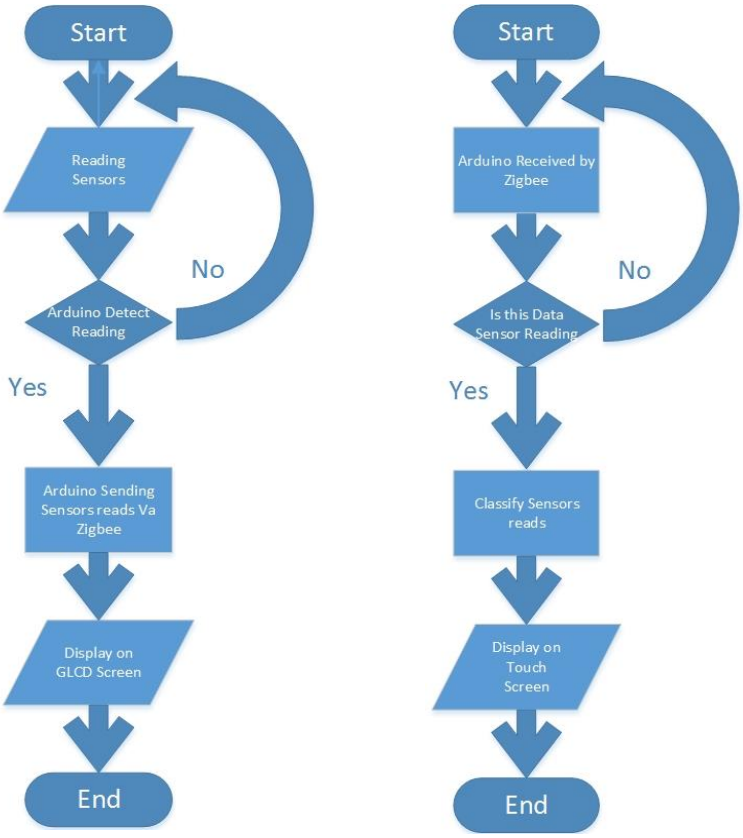


Figure 3. XBee S1 and S2

2.2. Software implementation

The software program for the station is based on Arduino C program language. At what time the program has completed, the system then uploads Arduino program to the microcontroller, and the device will transmit information serially to its TX through ZigBee. In this paper, the system is based on the ZigBee technology to receive and transmit the information. ZigBee wireless link is configured and could accept information for other ZigBee units connected to hardware. A flowchart for weather station is depicted in Figure 4.



(a) (b)

Figure 4. Flowchart of weather station ZigBee system: (a) Tx, (b) Rx

2.3. Experimental evolution

The weather station system has been designed by using Arduino Uno and ZigBee technology with the sensors. The weather station has two parts; the transmitter node weather station has an Arduino Uno and ZigBee with five sensors (wind speed sensor, pressure sensor, rain sensor, dust sensor, temperature and humidity sensor) as well as GLCD to show the data considered for transmitter node. The receiver part consists of an Arduino Uno and ZigBee with nextion to monitor the receiving data based on the proposed prototype as shown in Figures 5 (a) and 5 (b). The range distance from Arduino based system station (transmitter node) ZigBee is 1 mile, and the maximum range of ZigBee node (receiver sides or transmitter sides) is 40 miles.

(a) (b)

Figure 5. (a) Weather station transmitter node, (b) Receiver node

3. RESULTS AND ANALYSIS

Practical improved results from data values are determined in proposed weather system. The obtained results when station worked along one week in Baghdad Iraq from 8-12-2018 to 14 12-2018 for six reading (temp, hum, rain, wind, pressure and dust) twice per day (7:00 AM to 4:00 PM) from the transmitter node are shown in Tables 3 and 4. As it is shown in the tables, the difference between reading from Table 3 (www.weather.com) and the reading from Table 4 (proposed weather station) is minimum. The difference in temperature is about 2^{o}C, the difference in humidity is about 3%, no difference in rain status, the difference in wind speed is about 1 KMH, and the difference in pressure is about 1 MB.

Table 3. Weather data from www.Weather.com

	Time	Sat	Sun	Mon	Tus	Wed	Thu	Fri
Temp	7:00 AM	12oc	15oc	14oc	20oc	15oc	12oc	8oc
	4:00 PM	17oc	13oc	12oc	18oc	18oc	14oc	17oc
Hum	7:00 AM	91%	82%	82%	96%	91%	94%	91%
	4:00 PM	74%	87%	97%	63%	70%	68%	58%
Rain	7:00 AM	LIGHT RAIN	Sunny	RAIN	Sunny	Sunny	Sunny	Sunny
	4:00 PM	NO RAIN	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny
Wind	7:00 AM	18 KMH	10 KMH	18 KMH	5 KMH	8 KMH	11 KMH	8 KMH
	4:00 PM	10 KMH	10 KMH	11 KMH	3 KMH	11 KMH	5 KMH	3 KMH
Pre	7:00 AM	1019 MB	1021 MB	1021 MB	1021 MB	1020 MB	1021 MB	1019 MB
	4:00 PM	1020 MB	1021 MB	1021 MB	1021 MB	1020 MB	1021 MB	1019 MB

For the first day (8 December 2018) from the week the reading for both in www.weather .com and the proposed weather station were calculated. The Temperature reading was (11oC) determined by prototype weather station and the reading from www.weather.com was (12oC) and the difference is (1% oC) between them. For the Humidity reading, it was (90%) determined by prototype weather station and the reading from www.weather.com was (91%) and the difference is about (1% oC) between them. For the Pressure reading,

it was (1018 MB) was determined by prototype weather station and the reading from www.weather.com was (1019 MB) and the difference was about (1 MB) between them. For the Rain status reading, it was (rain) determined by prototype weather station, and the reading from www.weather.com was (light rain). For the wind speed reading, it was (17 KMH) determined by prototype weather station and the reading from www.weather.com was (18 KMH) and the difference is about (1) between them. The performance and data storages can be enhanced by cloud and internet of thing (IoT) technologies [23, 24]. In addition, the proposed weather station monitoring results can be adjusted by genetic algorithm (GA) as an optimization tool to enhance any wanted reading [25].

Table 4. Weather data from proposed weather station

	Time	Sat	Sun	Mon	Tus	Wed	Thu	Fri
Temp	7:00 AM	11oc	16oc	13oc	21oc	13.5oc	12oc	8oc
	4:00 PM	16oc	12.5oc	11oc	18oc	17oc	13oc	16oc
Hum	7:00 AM	90%	84%	84%	92%	91%	92%	88%
	4:00 PM	73%	88%	94%	60%	73%	70%	58%
Rain	7:00 AM	RAIN	Sunny	RAIN	Sunny	Sunny	Sunny	Sunny
	4:00 PM	NO RAIN	Sunny	Sunny	Sunny	Sunny	Sunny	Sunny
Wind	7:00 AM	17 KMH	10 KMH	17 KMH	6 KMH	7 KMH	10 KMH	8 KMH
	4:00 PM	11 KMH	11 KMH	10 KMH	3 KMH	10 KMH	6 KMH	3 KMH
Pre	7:00 AM	1018 MB	1022 MB	1021 MB	1021 MB	1020 MB	1022 MB	1020 MB
	4:00 PM	1019 MB	1021 MB	1021 MB	1020 MB	1021 MB	1020 MB	1019 MB
Dust	7:00 AM	0.07	0.06	0.09	0.08	0.07	0.06	0.07
	4:00 PM	0.09	0.07	0.1	0.09	0.07	0.08	0.06

4. CONCLUSION

In this paper, prototype system for low cost-effective weather station with monitoring system by using Arduino Uno and ZigBee communication technique, to transmit and receive the weather data has presented. It has feasibilities for six reading data (rain state, wind level, air pressure, dust density, and temperature and humidity). The data can be saved in SD card on receiving (clouding and main processing sides) from more than one transmitter node (ZigBee Network). It can be retrieved the data in any time and date. The difference in results from proposed weather system compared with (www.weather.com) is very good in all readings that calculated form the proposed weather station that gives an evidence that proposed model has tolerable performance to be applied reliably without internet connection in any area of Iraq.

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