Kufa Journal of Engineering
Vol. 16, No. 4, October 2025, P.P. 600-614
Article history: Received 11 January 2025, last revised 4 April 2025, accepted 5 April 2025

IMPLEMENTATION OF WIRELESS SENSOR NETWORK FOR ENERGY CONSUMPTION MONITORING AND CONTROL IN SMART HOME

Anas Ali Hussien[1], Ali Saadi Abed[2], and Mahmoud Al-Quzwini[3]

[1] Al-Nahrain Renewable Energy Research Center, Al-Nahrain University, Jadriya, Baghdad, Iraq.

[2] Computer Engineering Department Al-Nahrain university, Jadriya, Baghdad, Iraq.

[3] Stevens Institute of Technology, New Jersey, United State of America.

https://doi.org/10.30572/2018/KJE/160435

ABSTRACT

The increasing demands for electric power in daily life with the consuming power increasing day by day. The energy optimization that used in homes has grown importance in the era of smart technology. This will force us for a goal is to design and implement a wireless sensor network (WSN) for real-time consume energy monitoring and controlling in smart homes and save electric power that leads to sustainable energy by reduce the power consuming in electric device and to afford homeowners precise control over how much energy can be using, lower total consumption, and support in the creation of smarter, greener residential environments. the task of proposed system is to influencing the technology of advanced sensor and effective communication protocols so that electric power can be conserved throughout the deactivation of devices that are not in use. The methods used are: creating a systematic architecture for the wireless sensor network that is suitable for monitoring and controlling smart home energy consumption and indicating the accurate sensors for detecting various parameters. The system model consists of (microcontroller (UNO R3), temperature and humidity sensor (DHT22), electric device (fan) and Xbee as wireless communication module). The system saved the power throughout turn OFF Fan if the temperature of room below than 26 C° and turns ON if its exceeds or equal 26 C°. These events are monitoring and control by using internet of things (IoT). The system has two location area End Node and Base Station; the data sent from End Node to Base Station by Xbee modules in real time. The following results were obtained: the power in KWh has been calculated and it's recorded about 1.43 kwh in one day and 42.9 kwh in 30 days (in April) and the cost reach 815.9 Iraqi dinar. Conclusions. If the model didn't used the fan is in ON state in all days therefore the power reach 2.64 kwh in one day and 79.2 kwh in one month and the cost recorded 1504.8 Iraqi dinar. This paper emphasizes how WSNs can transform smart home energy usage monitoring and control. The usefulness of the arrangement and the encouraging results give prominence to how vital WSN technology is to improving sustainability and energy efficiency in residential settings.

KEYWORDS

Wireless Sensor Networks, ZigBee, Sustainable Energy, Power Consumption, Internet of Things (IoT).

1. INTRODUCTION

The power demand is increasing, and arise in locally as well as industrial sectors (Iman & Anas, 2018) (Mohammed & Mohammed,2018) . Owing to the rising energy usage, there is a growing request for electric energy and a decreasing supply of fossil fuels. Furthermore, the mismatch between request and supply besides absence of monitoring and automation tools have already produced main blackouts worldwide (Muhammad & Hafiz, 2022). At present, the rapid development of wireless communication technology, sensor equipment and micro-electrical-mechanical scheme technology creates it promising for setting up a wireless sensor network (WSN), that is collected of smart micro sensors interconnection (Jia et al., 2020). The wireless communication technology module called Xbee which contains features of low consumed power, low cost in addition to robust self-organization (Ling, 2020). ZigBee topology network consist of star, mesh and tree networks all these topologies shown in Fig. 1 where ZigBee in star network comprises of one coordinator and a few End Nodes related directly to it. While ZigBee mesh network has several routers, End Nodes, one Coordinator, and is self-healing by design. In order to route data from the end node to the coordinator or vice versa, routers be able to communicate with each other and with the end nodes (Khandaker et al., 2022). WSNs have become popular in the commercial sector such as it used in smart home to remotely controlled devices and monitored through the internet. the technique of control and monitor device in remotely way called internet of things (IoT) (Victor et al., 2024). IoT envisions connecting daily life, where Everything from paying bills and buying goods to email and social networking is done online nowadays (Heba et al., 2024). through objects and integrating them to the internet using sensors, transceivers, and protocol stacks. (Shojib et al., 2025). Software and hardware technologies permit for sensor system customization, that enables the deployment for environmental monitoring (Olcay et al., 2023). Furthermore, energy harvesting may be obtainable as an substitute to node power in regions with sufficient ambient radio frequency signals for sustained time periods (Bharany et al., 2023). Though the sensors were in the sleep mode, they used energy when they are sensing data then transmitting data Some important factors that directly affecting the network lifetime is the energy amount that the sensors consuming (Paolini et al., 2021).

1.1. OBJECTIVES AND APPROACHES

Based on reports from recent literature, Many researchers are suggested the wireless network for monitoring the environmental factors by applying ZigBee such as (Ling, 2020). that establish a design of distributing wireless temperature detection system created by ZigBee technology, and (Zhixiong et al., 2021) that considered to Monitor of Environmental Parameters in real time in a Commercial Gestating Sow House utilizing a ZigBee-Based Wireless Sensor Network. and (Shuyu et al., 2021) that apply a ZigBee Wireless Communication Technology in Developed Automation Control. Table 1 represents a comparison between system model and other researchers.

The proposed system aims to save the cost by reduce power consumption using ZigBee technology. The DHT22 sensor has distributed in location area and the data recorded will transfer to base station so as to monitoring the system. IOT technique establish in proposed system for real time monitoring by sending data from Base station to Smartphone using browser-based flow editing called Node-Red.

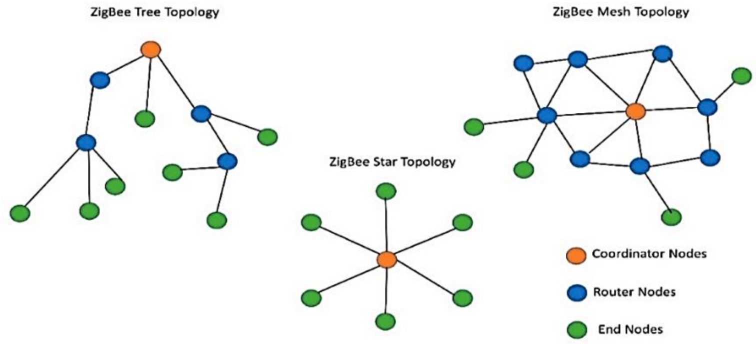


Fig. 1. Different topologies of the ZigBee standard (Khandaker et al., 2022)

Table 1. Comparison with related work.

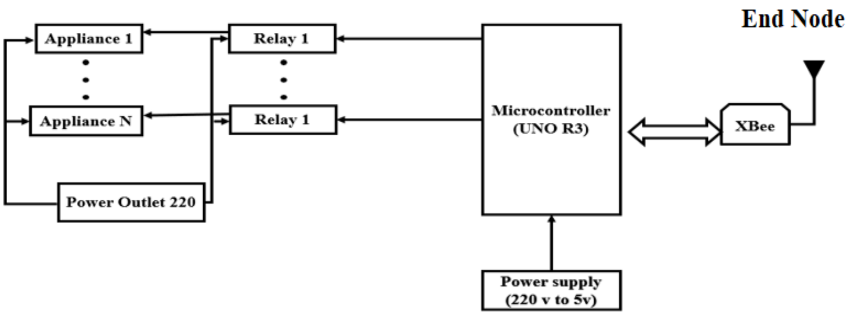
Ref	Feed back	Power consumer	IOT	Sens monitoring
(Olcay et al., 2023)	√	×	×	Temperature
(Paolini et al., 2021)	×	×	×	Level and Temperature
(Bharany et al., 2023)	×	×	√	temperature, relative humidity, concentrations of carbon dioxide and ammonia.
Proposed system	√	√	√	Temperature and humidity

2. MATERIALS AND METHOD OF RESEARCH

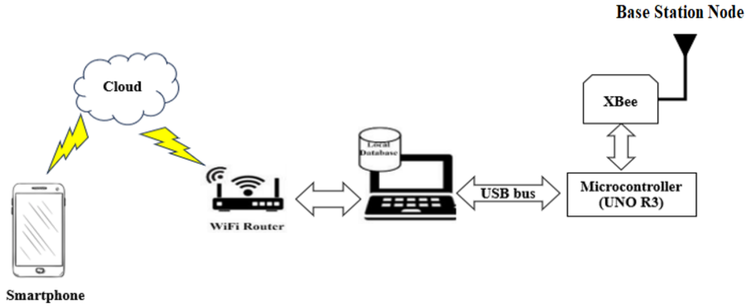
The system hardware design consists of three modules the End Node, Base Station, and smartphone application. All these modules create wireless sensor network that responsible of monitor data and control system (Walzberg et al., 2019). Fig.2 display a block diagram of proposed system.

2.1. System architecture

According to the characteristics of the WSN, the Xbee modules distributed in specific area and the monitoring has been done. This method helps us to get more monitoring information. The End Devices can have a distribution in the location area designed to real-time monitor of temperature and humidity parameters, and their location may be varied to obtain effective communication range of the coordinator (Bagdadee et al., 2020). The coordinator transmits the sensor data to the computer so as to display data and then management, and these data sent to the cloud through nod red browser and by using remote node red application the data will monitoring through smartphone so as to realize the real-time monitoring. This procedure of monitoring the temperature and humidity will save the energy in smart home by controlling the electric device (Fan). Power saving is done by monitor if the temperature high, this lead to power ON (Fan work) and if the temperature low this leads to power OFF (Ahmed et al., 2020). The proposed system can have used to other device to saving the power consuming and therefor the billing for power consume in smart home will decrease. The design of block diagram of the system structure model can be illustrated in Fig. 3.



(a)



(b)

Fig. 2: System Overview (a) End Node (b) Base Station Node

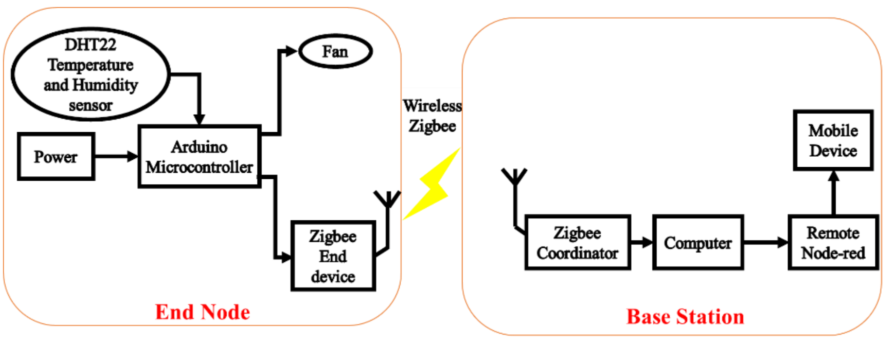


Fig. 3. System structure

The power saving system cause to decrease the cost for electric billing by reduce the KWh of the smart home, the electricity bills can calculate in the expression below (Taparci et al., 2024)

$$\text{Power in (KWh)} = \text{Power in (KW)} * \text{No.of hours} \quad (1)$$

to calculate bills for one month

Power in (KWh)for month= Power in (KW)* No.of hours*30 days (2)

Therefor the cost of one month can calculate by

Cost in one month = Power in (KWh) for month * Unit Prize (3)

Where Unit Prize is the prize for every KWh in the country

2.2. End Node hardware design

The equipment's of End Devices are running through power that represented as portable power supplies (batteries) allowing reallocation. The system illustrated the process of converting real-world signals to the digital domain (Analog to Digital) for display (data acquisition) this can complete by using temperature sensor (DHT 22) and then transmission data to the Base Station by ZigBee network establishment (Mokhtar et al., 2021).

The end node part has ZigBee End device that used to collect the measured data and transferring it to the base station (Anas& Adnan, 2020). Fig. 4 illustrated the schematic design it consists of (Fan, DHT 22 sensor, Xbee, batteries) all these devices are connected to microcontroller (Arduino board) that control and measured data, and Fig. 5 presents the circuit hardware of the End Node in two state (Fan ON and Fan OFF). The system can be located in any place such as in home or office or anywhere to measure the temperature and control the devices (air-condition or fan) this procedure will reduce the power consume by controlling the power of the device and saving the energy.

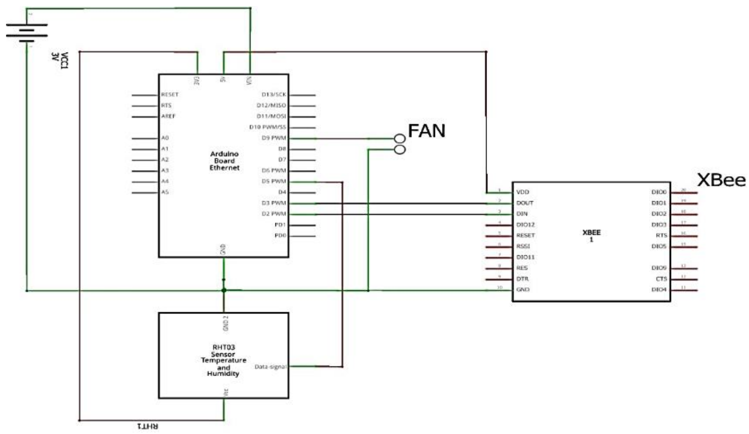
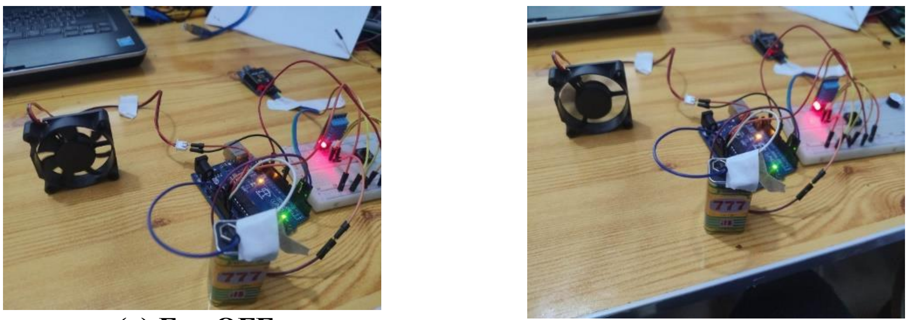


Fig. 4. schematic design for the End-Node module.



(a) Fan OFF **(b) Fan ON**

Fig. 5. Circuit hardware for the End Node

2.3. Hardware design of Base Station

The Base Station consists of Zigbee Coordinator and Computer. The essential target of ZigBee coordinator can be considered for receiving data acquisition of End Device node over wireless communication and then transmission such collected recording data to main computer with USB cable. The structure design of hardware block diagram of base station can be presented in Fig. 6.

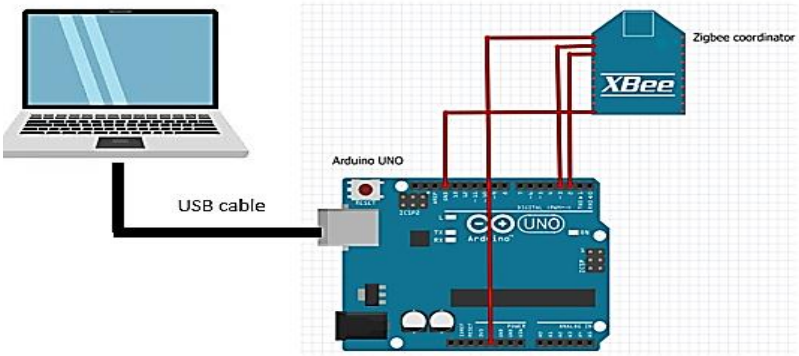


Fig. 6. Circuit design for Base Station

3. SYSTEM SOFTWARE DESIGN

The software design of the system consists of

a. ZigBee devices (should be configure as coordinator or end device through XCUT configuration program)

b. Arduino uno that set through (Arduino IDE platform)

c. Remote mobile monitors the measured data through remote-node application.

3.1. Configure ZigBee Devices

XCTU, shown in Fig.7 considers a free multi-platform application intended to assist designers to communicate with ZigBee RF modules over an ease-to-use graphical interface. It comprises fresh tools that create it comfortable for setting-up, organizing and testing ZigBee RF modules. It involves many tools that developer desires for rapidly getting up and running with ZigBee. Exclusive features such as graphical network view, that graphically denotes the Zigbee network accompanied by the connection's signal strength, and the ZigBee Transparent mode builder, merge for making development on ZigBee platform convenient than ever.

3.2. Software design for End Node part

It is necessary to setting the end node part that contain of Arduino uno represent of microcontroller to control the end node side. The code for Arduino is done by platform Arduino IDE. The operation of End Node shown in Fig. 8, the first step is to connect Arduino to a laptop to start programing, then initialization all pen of Arduino (define the variables of sensor, ZigBee and fan), after that create the connection between ZigBee (End device) and the ZigBee (coordinator) in the Base station side this connection can establish through library of ZigBee in the Arduino IDE and by define each channel in XCUT platform. After making the connection Arduino will check the measured data (temperature and humidity) from DHT 22 sensor if temperature greater or equal to 26 C° turn on the fan and if its below turn off the fan. The data that record is transferring in real time from the End Node to the base station through Zigbee wireless connection.

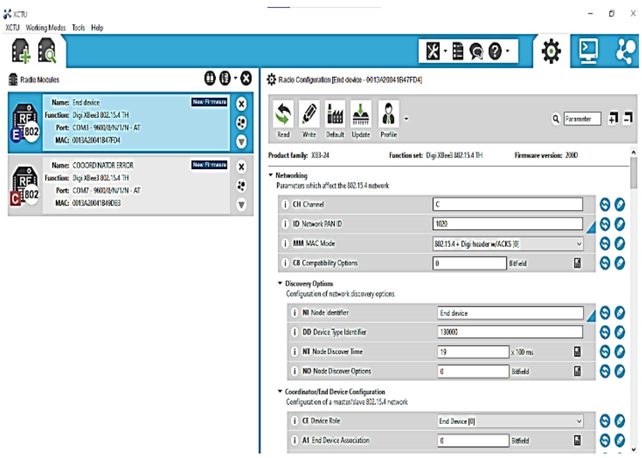


Fig. 7. XCUT platform in system model

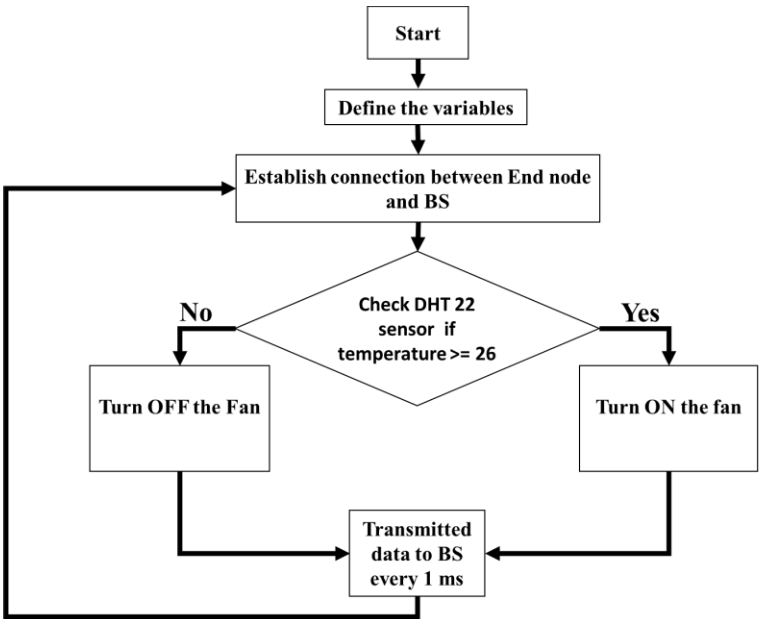


Fig. 8. End Node operation

3.3. Software Design for Base Station

When the coordinator turns ON the connection with End Node should be established. The operation of the End Node shown in Fig. 9 it is similar to End Node where the initialization and the ZigBee library must be written to make a connection between two ZigBee wireless.

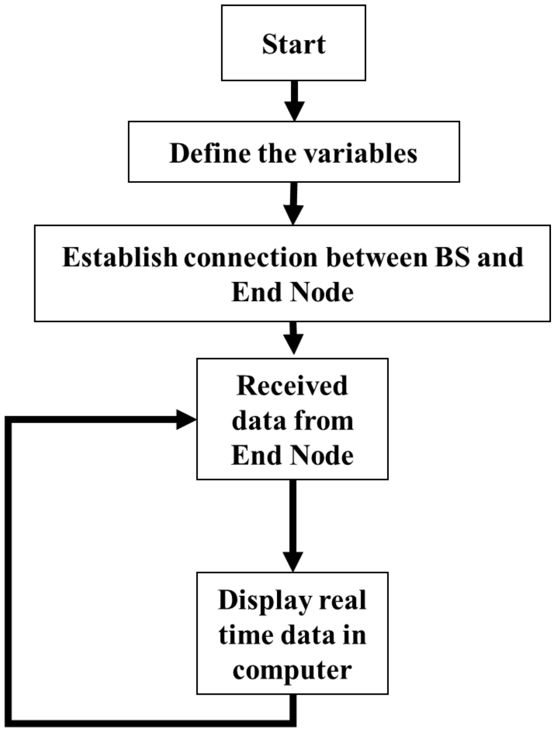


Fig. 9. Base station operation

3.4. Software Design for IOT Connection

The data is received in BS and it is display in the PC. However, to send that data to mobile device FOR monitoring system from anywhere this can be happened by using Node Red platform, there are many software which are related to IoT. Node Red is one of these software that will be used in the proposed system. Node RED shown in Fig.10 is a programming tool used to connect hardware devices and online services within new and exciting means. It is running in computer by written in commend window (node-red). It offers a browser-based editor for making it simple for wiring together flows utilizing the wide-ranging of nodes in the palette which may be organized to its realtime in a single-click.

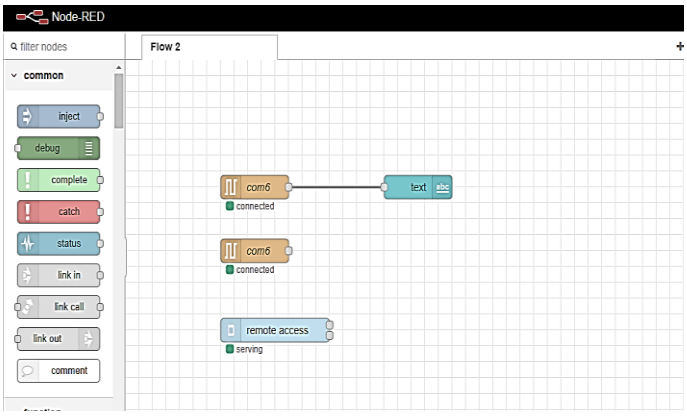


Fig. 10. Node Red browser of proposed system

However, the tool remote access enables anyone to monitor the system from mobile device by installing Remote-Red application in smart phone where after installing that application will ask for QR code to enter to the node-red data after scanning the QR code that appear in Fig. 11 the Mobile device can enter to the system and monitor the data.

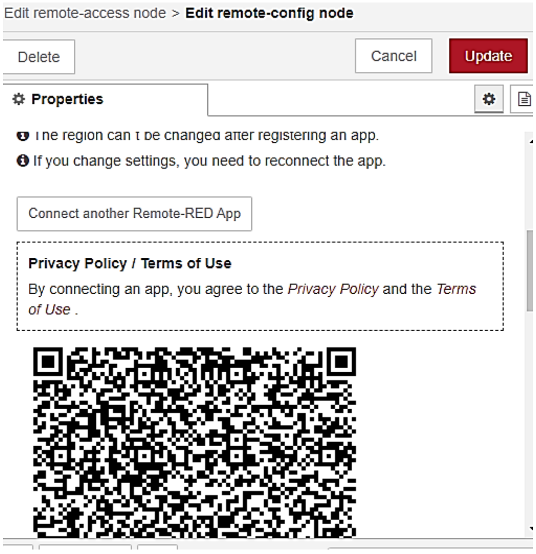


Fig. 11. remote red tool

4. SYSTEM TEST RESULTS

The system used to measure the temperature and humidity of a room or any place so as to power saving through turn on or off the fan, if the data exceed or equal 26 C° the fan will go to ON state and if below it will go to OFF states Fig.12 present the state of a fan with temperature change. the result of node side can see in Fig. 13 it shows the temperature and humidity data and the fan status and that data will be transferring to base station in real time, Fig. 14 shows the Real-time result in base station. Then after the result received in base station it's going to node-red browser, to enter to node red browser should written the IP address that shown in Fig.15 this IP appear when written node red command in command window. After that the node red will open and the measured data will display in the browser as presents in Fig.16. That data will send in Real time to smartphone after open the Remote-Red application. Fig. 17 shows the result that appear in smart phone.

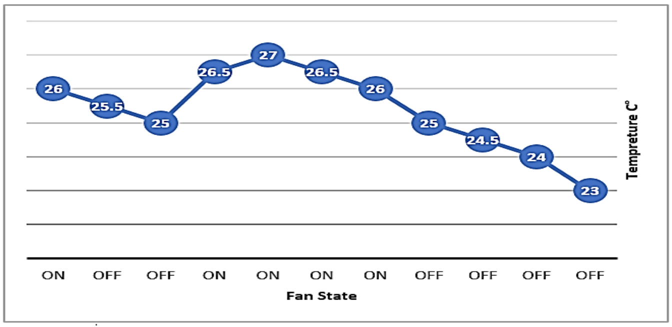


Fig. 12. Fan state with the temperature changes.

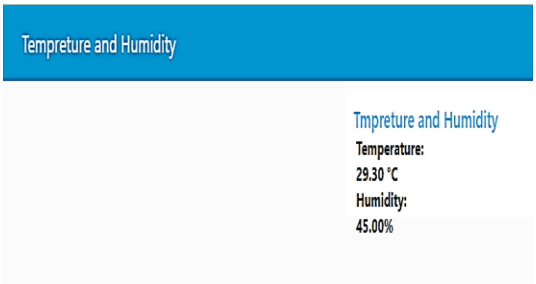


Fig. 13. end node data

Fig. 14. base station received data

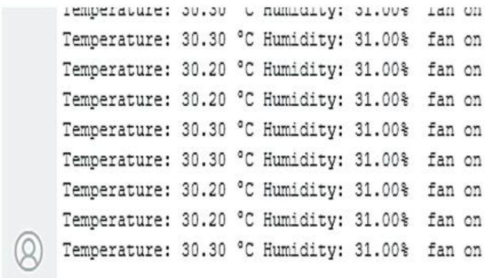


Fig. 15. IP address for Node Red

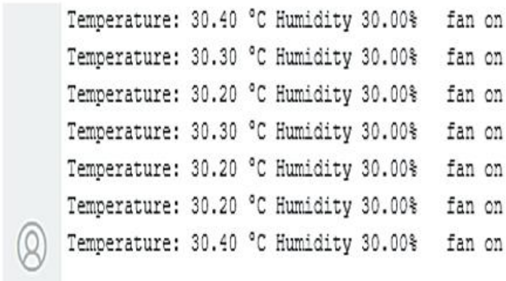


Fig. 16. browser Real-time data

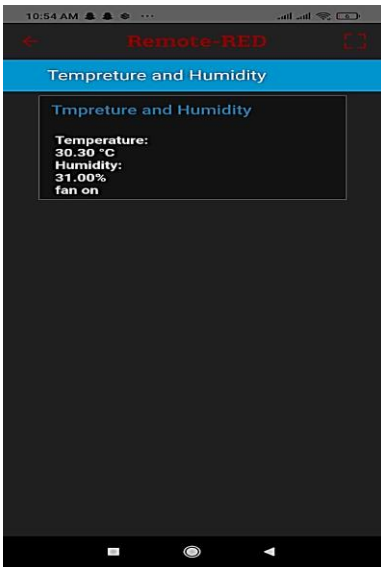


Fig. 17. application real time data

The power save the electric bills by decrease the number of hours of the device, in this model the reduction in cost appears when control the turning ON or OFF of the Fan where if using real electric fan by adding relay in the circuit to supply the Fan with 220 v and measured the current of the Fan by using multimeter found that the Fan consume 0.5 amp therefor the power that spend on the fan express as

$$\text{Power}=\text{Current}\times\text{Voltage} \tag{4}$$

Power =0.5 *220 = 110 watt

Power in Kw=(power in Watt)/1000=110/1000=0.11 kw

the cost is calculating with and without sensor in Table 2, where Unit price in Iraq equal to 19

Iraqi dinar for every 1 KWh

Table 2. Electricity bills with and without sensor for fan in proposed system

Cost without sensor (Fan in ON state all time) Cost in using sensor (Fan is controlled by sensor)

power in kwh= 0.11*24=2.64 kwh

power in kwh for on month=2.64*30=79.2 kwh

cost of one month=79.2*Unit Price

cost of one month=79.2*19=1504.8 iraqi dinar power in kwh= 0.11*8=0.88 kwh

power in kwh for on month=0.88*30=26.4 kwh

cost of one month=26.4*19=501.6 iraqi dinar

From Table 2 the cost is decreases when using sensor that control the fan work its express thar the bill is reduce about 1/3 when using sensor. Fig. 18 express the cost with and without sensor

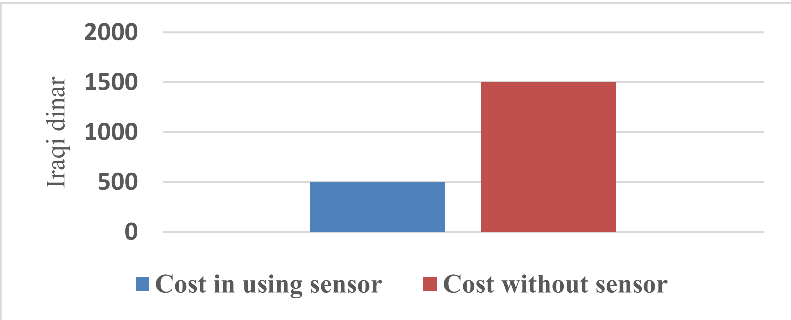


Fig. 18. Cost of electric bill with and without sensor

The power in (KWh) can be calculated for the fan by using expression (2) for proposed system the fan is ON approximately from 9 am to 10 pm. Table 3 shows the Kwh and the time when the fan in ON state and Fig. 19 shows the fan consumption when its ON in every day

Table 3 Calculate KWh with time when fan in ON state

KWH	TIME
0	12 am - 9 am
0.11	10 am
0.22	11 am
0.33	12 pm
0.44	1 pm
0.55	2 pm
0.66	3 pm
0.77	4 pm
0.88	5 pm
0.99	6 pm
1.1	7 pm
1.21	8 pm
1.32	9 pm
1.43	10 pm
0	11 pm
0	12 am

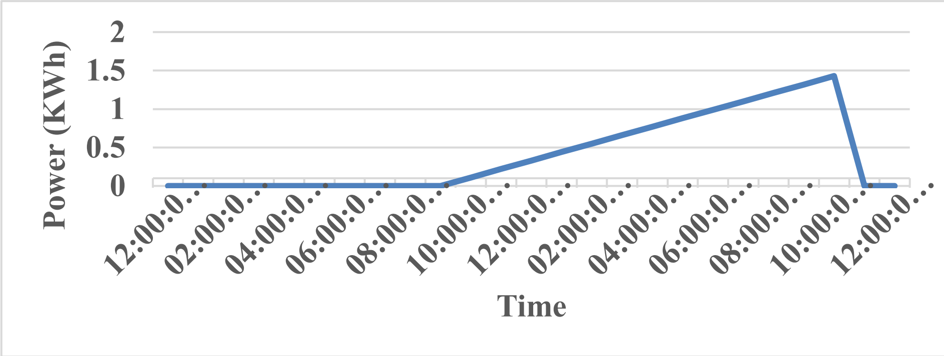


Fig.19. Consumption of the fan in one day

The Fig. 19 illustrates that the maximum values for the Kwh is in 10 pm its reach 1.43 kwh therefor from equation 2 for 30 days the power reach 42.9 kWh and the cost 815.1 Iraq dinar. The dht 22 sensor controlling the fan operation this help us to reduce the cost of electric bill. All the calculation above doing in Iraqi weather in April.

5. CONCLUSION

Reduce power consuming is the crucial way to save money, the proposed system is used to monitor and control devices in real time by using IoT application so as to power saving. The system shows that power can saved through turning off device in the smart home this lead to reduce the electric bills (save money) because of turning off the unused device make the power (kwh) in the minimum value. In the proposed system the fan is OFF if temperature below 26 C° and it will be ON if it exceeds or equal that temperature, this power saving system can apply to any device in smart home or in any where such as industrial.

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