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Design and Implementation of Humidity and Temperature Automation and Monitoring for Public Building Comfortable Climate Based on Cloud Platform

Abstract. *This research focuses on the study of monitoring and controlling the internal climate of a public building by controlling temperature and humidity through designing and implementing an automation system. This system can be completely operated and secure using Wi-Fi networks as communication protocol, and Node MCU as a wireless hub. There are also new possibilities for remote control and monitoring of network-enabled devices as a result of the rapid expansion of the Internet. The proposed system consists of temperature and humidity sensors, a relay, and an ESP8266 Wi-Fi module that stores sensor data and transfers it to a cloud server database via Appatshy and Mysql formats to the web server. The web page is designed using HTML/CSS program language with a distinct and simple interface. The system has been implemented with a high latency so that all readings are automatically updated and displayed. The designed proposed system has efficient, secure, rapid responsive real time, and control it automatically and manually at the same time.*

Streszczenie. *Badania te skupiają się na badaniu monitorowania i kontrolowania klimatu wewnętrznego budynku użyteczności publicznej poprzez kontrolowanie temperatury i wilgotności poprzez zaprojektowanie i wdrożenie systemu automatyki. Ten system może być w pełni obsługiwany i bezpieczny przy użyciu sieci Wi-Fi jako protokołu komunikacyjnego oraz MCU węzła jako koncentratora bezprzewodowego. W wyniku gwałtownej ekspansji Internetu pojawiły się również nowe możliwości zdalnego sterowania i monitorowania urządzeń pracujących w sieci. Proponowany system składa się z czujników temperatury i wilgotności, przekaźnika oraz modułu Wi-Fi ESP8266, który przechowuje dane z czujników i przekazuje je do bazy danych serwera w chmurze za pośrednictwem formatów Appatshy i Mysql na serwer WWW. Strona internetowa została zaprojektowana w języku programowania HTML/CSS z wyraźnym i prostym interfejsem. System został zaimplementowany z dużym opóźnieniem, dzięki czemu wszystkie odczyty są automatycznie aktualizowane i wyświetlane. Zaprojektowany proponowany system posiada wydajny, bezpieczny, szybki czas reakcji w czasie rzeczywistym, a jednocześnie steruje nim automatycznie i ręcznie.* (***Projektowanie i wdrażanie automatyki i monitoringu wilgotności i temperatury dla komfortowego klimatu budynków użyteczności publicznej w oparciu o platformę chmurową***)

Keywords: Node MCU board, DHT22 sensor, Cloud computing, Web page, Arduino system automation.
Słowa kluczowe: automatyka klimatyzacji, technologia chmury, Arduino.

Introduction

One of the most popular technologies that have become an integral part of the computing world nowadays is the principle of cloud computing. Cloud computing is a utility technology while using the Internet to access applications. Cloud computing provides on-demand storage, devices, networks, databases, and software applications [1]. With the spread of the concept of computing, the approach to managing and controlling the building environment has become a basic need especially in workplaces in institutions and company buildings for two main reasons; namely reducing energy consumption to the largest possible extent, in addition to creating suitable working conditions in terms of thermal comfort and indoor air quality [2]. In general, a monitoring system refers to an electronic machine that can constantly track and report one or more physical parameters including but not limited to the temperature and relative humidity [3]. Maintaining surveillance in any critical area is vital to fulfilling protection and regulatory enforcement needs. All over, there are a broad array of systems in which the control of temperature and humidity levels are crucial components [4]. Deterioration monitoring would provide early warning of initial problems enabling maintenance programs to be planned and scheduled, thereby reducing related costs. Furthermore, data from tracking systems (which would be introduced in part by enhanced efficiency prediction models) brings potential savings in life cycle costs. Thermal comfort is the condition of what a person thinks and experiences while they are in a certain setting such as temperature, and humidity [5]. It can be judged subjectively. If the atmosphere is not healthy, it can impact the work performance of the human being and trigger health hazards. Temperature and humidity should be selected primarily depending on the purpose of the room. Comfortable values for people are assumed to be 20-23˚C and humidity 40-60%. These values are also safe for the building and objects inside it, such as furniture, books and fabrics [6]. However, it could be more efficient to have human capital to track the temperature and humidity of the data center at night, rather than during the day [7]. Periodic surveillance by IT staff which involves physical access through a computer network, which may raise the likelihood of getting static build up, burglary, vandalism of infrastructure, and unauthorized access [8].

The goal of this research is to build and create a real-time temperature and humidity monitoring device that can be implemented quickly using the usage IoT cloud platform. In addition, this study is interested in mainly Interest the thermal comfort of people in public building environment. The proposed system includes how to monitor and control climatic inside the building by a special web page for the any public building in which the principle of security is observed and only authorized persons are allowed to control it. Furthermore, data is stored and transferred to the cloud server database through Apache and Mysql formats, which are programmed to the web server and updated it every 5 seconds to give accurate and immediate decisions for appropriate action.

The paper is presented as follows: a literature survey related to this work is reviewed in section 2. Section 3 represented component description of the proposed system. Proposed system scenario in section 4. The results and discussion detailed in section 5. Finally, the conclusion and suggestions for future work can be found in Section 6.

2. Literature survey

The researchers established other methods in temperature and humidity automation topics. A brief overview of some significant contribution's literature is provided in this section.

In [2], the authors study the construction of a model weather station, including temperature and humidity, to measure different weather data. This type of weather station is designed to conduct uninhabited weather data measurements. The calculated data is sent wirelessly to the remote station for the information to be registered and displayed on different gadgets. Wi-Fi links that create an interlocking network for secure data connections are used to plan this wireless link. In addition, the results encourage residents to take the appropriate precautions.

In this study [9], an automated device for regulating room temperature was suggested using a pic- sized microcontroller. This is a device that is suitable for older persons. The gui in this device calculated ambient temperature using an LM35 temperature sensor and showed the temperature on an LCD terminal. The temperature sensor captures the daily temperature. Dependent on the temperature adjustments, the fan can automatically turn on or off. The fan's temperature was higher than the reference temperature and lower than the reference temperature at a specified interval. The reference value is entered by keying in numbers. Relay works to complete the switching role. Software proteus 8 is used to produce the simulation result.

The proposed and validated IoT-WSMP device for controlling temperature, relative humidity and light has been proposed in [10]. This system has used wireless sensing and tracking capability to track temperature, humidity, and illumination in buildings. In the built system, data is transmitted from the transmitter node to the receiver node by using a custom hopping mechanism. An Android application built which runs on a smartphone and transfers data from the LabVIEW program to the application.

The authors in [11] introduced a novel platform that enables functionality to interoperate between sensors and actuators. They aimed to minimize energy use and find a new approach to aggregate data that would appeal to the desires of the people utilizing it. It is hoped to leverage all the data accessible utilizing the proposed architecture. Deep models are used by customers who aim to change their regular habits in an energy efficient manner.

In [12], the smart air conditioner controller which implements the technology of the Internet of Things (IoT) is proposed in this paper. This research develop application that can control temperature and humidity-based power consumption in air conditioners. In this analysis, an additional system to track the use of electricity called Termo has been created. Termo consists of an ESP8266 microcontroller, a temperature sensor, an infrared LED transmitter, and a humidity sensor.

In this paper [13], automation is accomplished by the use of a microcontroller that facilitates the regulation of auto room temperature and toggle switching. Depending on the changes in the environment's temperature, the electric fan dynamically adjusts the pace. A combination of sensor, controller, driver and motor with the integration of embedded driven programming includes this electrical hardware system. The machine takes the data from the temperature sensor, transfers it to the microcontroller and controls the performance of the AC heater and shows the output status on the LCD monitor.

In this study [14], authors proposed an IoT based server room monitoring system to provide information while controlling temperature and humidity within the server room. In order to track data from everywhere, the proposed device continuously transfers data to the cloud. The device is fitted with features for direct monitoring and control to dynamically provide users with alerts via the telegram application. The conclusion of this paper is that the generated framework will retrieve the server room's temperature and humidity data and the website will display the temperature and humidity data that has been taken. If the temperature and humidity in the server room exceed the cap, the device will send telegram alerts and set the temperature of the air conditioner.

This paper [15] describes how to design and implement a device using wireless sensor networks to obtain environmental data. The framework is designed for web-based and mobile-based applications where data is fed into a web-based application and then processed at the cloud. Using the Internet and mobile apps, consumers can view their own data, as well as data from other users. In these applications, temperature and humidity sensors are used. To reduce reliance on human intervention, the web application sends a warning if a measured property exceeds a specified range. The results of the QKMF and Telcom applications indicate that this device is accurate and can be used to monitor air temperature and humidity. The data can be used to send warning emails and to analyze how the environment is improving.

In [16], an interoperable Internet of Things (IoT) platform was created using Web of object (WoO) and cloud for smart home system. The proposed architecture offers inter-operability between existing devices and communication protocols, which allows users to access their devices from anywhere. The device assigns each sensor data and actuates a specific URI that is managed by the device. Based on temperature and humidity sensors, the gateway offers interoperability with other devices such as lights, fan controls, and tank monitoring. The gateway also incorporates information from sensors and actuators in the cloud, and stores it for later use.

Based on the literature review, the key drivers for this paper are focused on designing monitoring and controlling system for temperature and humidity of a building by a special web page with a distinct and simple interface.

3. Component description of the proposed system

The proposed system has extension in its concepts in a successful way to encourage the sensor network for IOT cloud-based data storage service. The system consists of two parts; hardware components and web application.

3.1 Hardware device

Which can be divided into three main parts as shown in figure 1.

3.1.1 Temperature and humidity sensor

Temperature / Humidity sensor (DHT22) is used to measure the values of (T) and (H). The sensor is reliable and stable because it uses a digital signal and data to realize the sensing of temperature and humidity. Humidity sensor is constructed of a resistive working element and an NTC element that measures temperature. The sensing element is made by a microcontroller that demonstrates reliability, sensitivity, stability, high response, no interference and low cost [17]. The employed temperature / humidity sensor (DHT22) is provided by 3 pins that are identified as the 5-volt power supply, ground connection, and data pin connection.

3.1.2 Node MCU board

Board node MCU is open source and can work with in micro-controller. The hardware consists of firmware which runs on ESP8266. It is programmable, cheap, and still associated via Wi-Fi. node MCU has ESP-12 embedded Wi-Fi on-board, besides GPIO, PWM, ADC, I2C and USB-TTL serial. This gives the sensors the capability to be combined with it. Operating voltages are in the range of 3.3V ~ 3.6V. (2.4-2.6 GHz). It uses HTTP, FTP, UDP, and TCP network protocols. This configured is for both the Android and iOS platforms [18].

3.1.3 Relay

Two channels with an optocoupler are used with a relay. It is an electronic unit that binds to the majority of the machinery via a single electrical circuit. The scale and the power dissipation of the relays are considerations in the design [19]. The relay is used to trigger the switches based on the character. Simply the relay is the portion that is operated by the 5V input, which implies, 0V is mapped to 0 and 5V is mapped to 1.

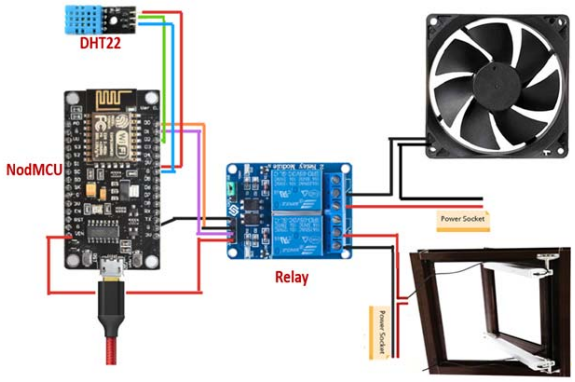

Fig. 1. Hardware connection proposed system

3.2 Web application

The web application considers as a system central controlling and monitoring unit. The design web page shows the real time location of information about temperature and humidity for public building, for example company building. The web page is designed to be secure and inaccessible by unauthorized people. The modern programming languages; such as: HTML/CSS, Java-Script, AJAX, and other, give more flexibility to design a secure web page [20]. The proposed web application is designed using HTML/CSS. HTML is a format that informs a machine what sections of a web page it wants to output. The records are plain text files with unique "tags" that a web browser uses to parse and view the documents. Software Composer Studio is a platform to program Texas Instruments (TI) Microcontroller and Embedded Processors. Code Composer Studio (CCStudio or CCS) is a software creation suite used to debug and create embedded apps. Users will use common resources and interfaces to start operating quicker than ever before. Code Composer Studio utilizes the functionality of the Eclipse applications developer environment with superior features. Figure 2 illustrate web page for the company building that be designing by HTML/CSS language.

Fig. 2. The monitoring and controlling web page

The design of the web page has two basic features; the first is that the results are displayed on the web page through private IP, which cannot be accessed without obtaining it by the administrator of the control system. Secondly, in addition to the automatic control that the building is equipped with, it is possible these devices are manually controlled through the control button that was built into the web page, which gives complete freedom to control the system at any time and from anywhere within the company. In addition to all this, the protection system for this system has been activated by making the data stored on the central computer and not sharing it with the rest of the computers that have the ability to monitor and control the system, which gives an additional advantage in the ability to save data and the inability to penetrate it.

4. Proposed system scenario

Node MCU board microcontroller will be the main board at work and is considered to be the gateway between the sensors and the cloud computing that stores information sent via the Internet from the sensors as shown in figure 3. ESP8266 is an ultra-low-power UART-Wi-Fi platform built for IoT devices, which can be used as a wireless base station for Internet or LAN connectivity, thereby performing the wireless networking tasks. Temperature and humidity sensor (DHT22) connected to an ESP8266 Wi-Fi type Arduino and programmed in C++. The ESP Arduino connected to a router as an internet access point. HTML/CSS programming language used to connect Arduino to the internet and web server. The Arduino microcontroller transmits the sensing data to the PC control center through the network using the ESP8266 processor, which is the work of transmitting the sensing data using the Wi-Fi protocol while at the same time saving the data base in the PC hard disk using the APACHE and MYSQL formats.

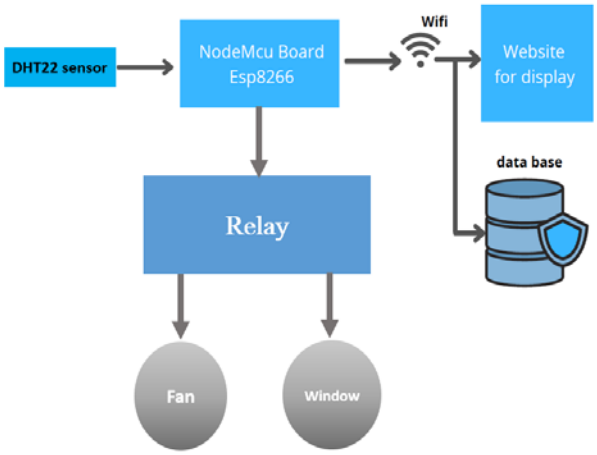

Fig. 3. Block diagrams of the proposed system

Each wire on the circuit board required to be attached to 5V and GND. Accordingly, data pin of DHT22 sensor is connected to pin D2 of the NodMCU. Relay1 module responsible of activating the electrical device (fan or/and air Condition) is attached to pin D1 to control the temperature of building. Relay 2 module that activates the (open/close) window is attached to pin D0 of NODMCU board to control the humidity inside the building. The proposed system follows a specific working scenario. The situation is suggested to meet device designer's requirements. The microcontroller dynamically switches the discrete (ON/OFF) states about the "fan" or "air condition" and "open/close" window in the business building digitally depending on the digital signals transmitted from the Arduino to the relay. The other side of the relay is for having an "on" and "off" feature by connecting/disconnecting the analog input to the digital port when pulses are added to digital port.

5. Result and discussion

To improve indoor building thermal comfort, the proposed system considers temperature and humidity using a DHT22 sensor programmed with the required codes by an ESP 8266 Wi-Fi Arduino. Numerous libraries were used to ensure compatibility between the ESP 8266 Wi-Fi Arduino and the system's design. The sensor's readings can be sent to the cloud server's data base via a cloud server access point (using router inside building as default access point). The cloud database is built using the Appashy and Mysql formats. On the computer's hard drive, the database and web server were stored. The database is connected to the http server, which provides a two-stage display of the measured values. The first stage is data collection, and the second stage is displaying the results in a category-based format using CSS. The displayed data will be the instantaneous values of the sensors. To simulate a real-time system, the data is updated every five seconds. The results indicate that sensors and systems respond quickly.

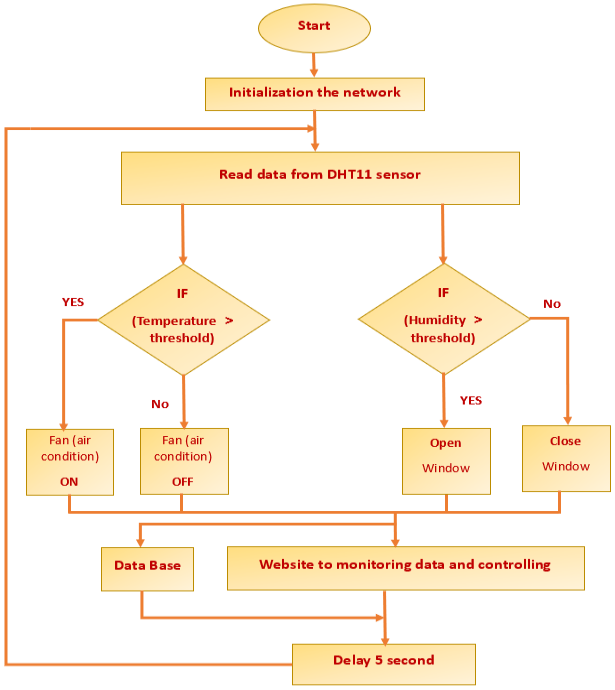

Fig. 4. Arduino code flow charts

The triggering of the actuators relies on the DHT sensor reading such that the air conditioner represented by fan is switched on through relay 1 when the temperature gets higher than the threshold amount (temperature is based on 25°C) and turned off otherwise. Further, the windows are open through relay 2 when humidity gets less/higher than threshold value (humidity is based on 50%) and close otherwise. Figure 4 show Arduino code flow chart.

It is simple to decide the software of the device by the flow chart seen in figure 4. Indeed, the flow map of the proposed machine programming language begins by reading the sensors, which gradually fill their required variables. Simultaneously, T-H inputs are calculated by the DHT sensor. Hereby, through using the web page and the input/output serial monitor, the collected data is passed through both the web page and the I/O serial monitor via Arduino microcontroller module. At the conclusion of this stage, processes would be automatically monitored according to system-specific requirements. In this method, many considerations are taken into consideration to render it such that, if temperature is higher than 25°C, the cooling system will be switched ON, otherwise the system will be turned OFF. Furthermore, if (H) gets greater than (50%), open the windows ON, and turn it OFF otherwise. In the same time, the data are sent and stored in data base via APACHE and MYSQL formats as shown in figure 5.

The page that was designed contains two indication lights and two control switches for temperature and humidity for the company's building. To show how to monitor and control through the web page, the conditions for temperature and humidity will be shown separately.

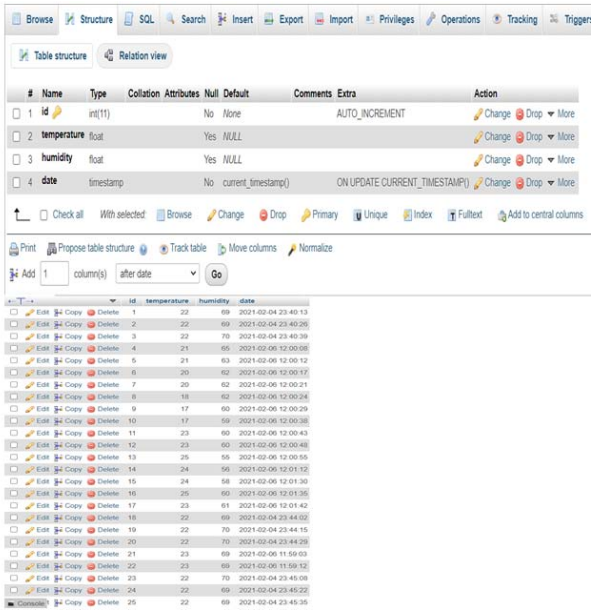

Fig. 5. Real-time web server page with sensor values

I. The first case (related to the building temperature)

When the climate inside the company's building is within the normal limits, the colour of the lamp will be green and at the same time the switch is in the case of (state off), while when the temperature rises above the set value, the lamp will turn from green to red to indicate that the cooling system has been activated after activating the relay 1 and the switch in (state: check temperature to switch) as shown in figure 6. At the same time, the switch is activated which gives the ability to turn off the devices that operate it manually whenever desired. This system, in addition to controlling the internal temperature, gave the ability to control the electrical energy consumption in the building.

II. The second case (regarding the amount of humidity inside the building)

With the same principle, when the humidity is within the normal limits, the colour of the lamp will be green and the switch for opening the window (state: off), while when the condition is met (meaning that the humidity value is higher than the set limit), the lamp will turn from green to red and the state of switch (check humidity to switch) as shown in figure 7, to give an indication to those in charge of building management that the window opening and the system has been activated by giving a notification to the relay. The windows can be closed manually from the switch (close window) if desired.

For clearer demonstration, the realized data shown in figure 5 was saved in a data base with the intent of obtaining the curves that explain shifts in the weather with respect to Temperature (T) and Humidity (H). The temperature readout is based on DHT22 sensor for the recommended spot (rooms inside the building), the curve shows the situation in figure 8 accordingly. Additionally, the

simulation curve in figure 9 indicates humidity read results given by a DHT sensor positioned near the proposed position within the building. The graph in figure 10 illustrates the ties among the proposed weather elements which enable improving the climate circumstances of the workplace.

Fig. 6. Illustrated temperature when above the set value

Fig. 7. Illustrated humidity when condition above the set value

Table 1 provides a comparison of the current study with previously published work. After the evaluation and validation of the proposed system, it is compared with related works presented.

The most important thing that distinguishes this work from previous studies is that the protection system was taken into account by making control by a central computer PC with the possibility of controlling and monitoring from anywhere within the building by designing a special web page. In addition, the stored data cannot be shared with other computers and remains stored in the mainframe.

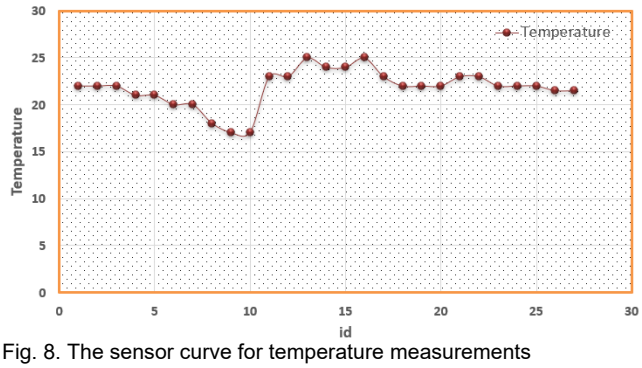

Fig. 8. The sensor curve for temperature measurements

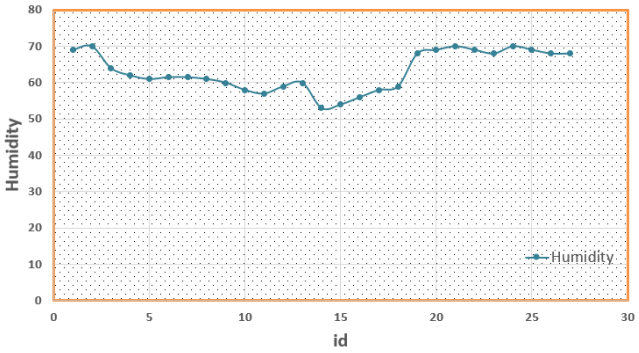

Fig. 9. Real measurement curve of humidity sensor

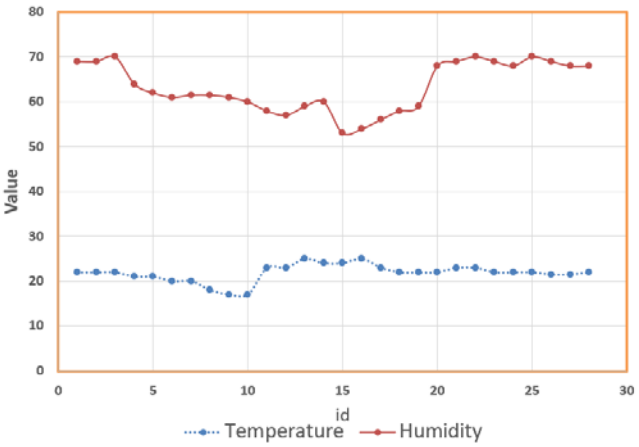

Fig. 10. Overall weather elements real relation curve

Table 1. Comparison of proposed work with previously published work (part 1)

Ref. / Parameters	[21]	[22]	[23]	[24]	[3]
Hardware of control	Personal PC	MC with 32-bit ARM	Board of cubit rack	Personal network	Model B Raspberry Pi
Communication transceiver	ZigBee, Wi-Fi & GSM	EIB serial, ZigBee, & Bluetooth	ZigBee, Wi-Fi	Wi-Fi	ZigBee, Wi-Fi
Main aim	Monitoring of intelligent house	Monitoring of indoor ambient intelligence	HAS with IOT services	HAS with MQTT based	MQTT based HAS
Feature/ challenges	Delay caused by SMS	Many sensors, center of alarm control	Sensor reading for basic GUI	Achieves more feasibility and efficiency	High flexibility, interoperability, and scalability
Required cost	Low cost	Cost effective	Not specified	Not exist	Low cost
Stored data	No	No	No	No	No
Protocol of messaging	Ad-hoc	Ad-hoc	Ad-hoc	MQTT	MQTT
Actuator & sensor	Temperature sensor	Multiple I/O pins for attaching sensors and actuators	Temperature, light and current sensors	Luminosity sensor and buzzer	Current sensors, motion sensor, Temperature and humidity
Hardware of node	USB module of ZigBee	32-bit ARM MC for proprietary board	Xbee, ESP	ESP	Xbee Series2,

Table 1. Comparison of proposed work with previously published work (part 2)

Ref. / Parameter	[5]	[25]	[7]	Proposed work
Hardware of control	PC control center	Personal PC	Mobile & E-mail notification	Possibility of controlling from any pc inside the building
Communication transceiver	Wi-Fi	ZigBee wireless network, Wi-Fi	Wi-Fi	Wi-Fi
Main aim	Achieve balance between thermal comfortable and energy saving	Remote monitoring	Design real time temperature and humidity monitoring	Monitor and control
Feature/ challenges	Compatibility with multiple development environment	Low power data	Data send to IOT platform of AT&T M2X to stored	Safety, security, and use only one sensor in any node
Required cost	Low cost	Low cost	Not specified	Cost effective
Stored data	Yes	No	Yes	Yes
Protocol of messaging	IEEE 802.11	Ad-hoc	Ad-hoc	HTML/CSS
Actuator & sensor	Temperature & humidity sensor, wind speed sensor	Temperature & humidity sensor,	Temperature & humidity sensor,	DHT22 sensor & relay
Hardware of node	ESP 8266	CC2530 ZigBee, ESP	Arduino Mega 2560 R3	NodMCU 8266

6. Conclusion and future work

This research paper presented a novel way of a low-cost and convenient method for tracking and regulating temperature and humidity in public building. The availability of such system is extremely preferred particularly, with the establishments, companies. This system give comfort to employees within these institutions and raise their production capacity in addition to reducing electrical energy consumption by maintaining temperatures within their normal limits. In this study used DHT22 sensor examine information about the humidity and temperature of the company building. Arduino Uno is MCU, that get information of temperature from DHT22 sensor and process it and offer to an ESP8266 Module. The ESP8266 module is a Wi-Fi chip that can exchange information to Internet of Things cloud. The monitoring device first shows the monitoring information on the user interface on a web page that was developed, and the system used to view and process. When the device senses an indoor value within the building that is distinct from the fixed value, the device uses the wireless control method to control the temperature/humidity regulating systems to obtain the optimal effect of the thermal comfort. The administrative operations centre is responsible for all of the cloud-related activities. The proposed system provides a lot of flexibility in terms of programming languages and devices, using HTML/CSS websites to monitor and track data in the database to perform various algorithm analyses and then transfer sensor measurements to cloud server data base which is programmed to web server via Appatshy and Mysql formats. The system was designed with a fast response time, which meant that all readings updated and appeared spontaneously every five seconds. The designed system achieves a very good time response with an effective and secure real-time system.

It is proposed in the future work looks to improve this system by applying more sensors as gas and motion sensor in order to offer the system a robust functionality. In addition, it will transmit and demonstrate the sensed data wirelessly by attaching the smart phone via Bluetooth module or Wi-Fi chip. Finally, data from the sensors can be sent to unique phone numbers through cellular strategy.

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