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WIRELESS HOME AUTOMATION SYSTEM BASED ON MICROCONTROLLER

MUNA H. SALEH*, QUSAY SH. HAMAD

Electrical Department, College of Engineering, University of Baghdad,
Al-Jaderia City, Baghdad, Iraq.
*Corresponding Author: drmuna4@yahool.com

Abstract

This paper presents the development of Global System Mobile (GSM)-based control home air-conditioner for home automation system. The main aim of the prototype development is to reduce electricity wastage. GSM module was used for receiving Short Message Service (SMS) from the user's mobile phone that automatically enable the controller to take any further action such as to switch ON and OFF the home air-conditioner. The system controls the air-conditioner based on the temperature reading through the sensor. Every period temperature sensor sends the degree to Micro Controller Unit (MCU) through ZigBee. Based on temperature degree MCU send ON or OFF signal to switch. Additionally, system allows user to operate or shut down the air-conditioner remotely through SMS.

Keywords: GSM; Power saving, Smart home, Wireless sensor network (WSN).

1. Introduction

Air conditioning is the process of altering the properties of air to more comfortable conditions, typically with the aim of distributing the conditioned air to an occupied space to improve thermal comfort and indoor air quality. The air conditioner is very important for every house, hospital, institutional, market and etc. A lot of time the air conditioner operates in both summer and winter. From time to time the temperature degree has become comfortable, but the air conditioner still operates. So that air conditioner will consume power when there is no need for air conditioning that leads to waste in power, high budget to consumer and environmental pollution. Home/office automation is the control of any or all electrical devices in our home or office, whether we are there or away.

Nomenclatures

N	*Working hours*
P	*Cost of one hour of consumption in the diner, kwh*
P_T	Total cost of consumption

Abbreviations

AES	Advanced Encryption Standard
CSMA\ CA	Carrier Sense Multiple Access\Collision Avoidance
GSM	Global System Mobile
GPRS	General Packet Radio Service
IDE	Integrated Development Environment
ICSP	In-Circuit Serial Programming
MCU	Micro Controller Unit
MAC	Media Access Control
PWM	Pulse Width Modulation
SMS	Short Message Service
TCP/IP	Transmission Control Protocol/Internet Protocol
USART	Universal Synchronous, Asynchronous Receiver and Transmitter
WSN	Wireless Sensor Network

Home/office automation is one of the most exciting developments in technology for the home that has come along in decades. There are hundreds of products available today that allows us control over the devices automatically. An automated device can replace the good amount of human working force, moreover humans are more prone to errors and in intensive conditions the probability of error increases, whereas, an automated device can work with diligence, versatility and with almost zero error [1]. A Wireless Sensor Network (WSN) of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. WSN is used to monitor and collect the temperature degree from covered area and deliver this data to control center (MCU) [2]. ZigBee technology was used in the proposed system because its low power consumption, security and high coverage distance.

The system has GSM module, the purpose of using SMS is to provide wider coverage at minimal cost. Therefore, the use of SMS would facilitate in controlling the electrical device at home from long distance and low in maintenance and independent from any physical geographical boundary [3]. In this paper, a home automation system using ZigBee, the microcontroller and GSM has been proposed. The main core of this system is the novel algorithm that controls the operations of the involved air-conditioners [4, 5]. This can be performed by receiving the temperature degree from the allocated terminals of the covered area by the base station, which can be called the control center, the control center sends the ON or OFF signals to air-conditioners based on degree received from sensor that cover the area [6]. It is concluded that at a time, not all air-conditioners are running, but just the required ones. This is to save more power. Different case studies have been considered in the simulation to test the efficiency of the proposed algorithm in terms of saved power [7].

The remaining of the paper is organized as follows. In Section II, the related works have been discussed. The system components have been given in section III. Section IV describes the methodology used in the proposed system. Section V explains the obtained simulation results. The conclusion is given in Section VI.

2. Related Works

Home automation or smart homes (also known as demotic) can be described as introduction of technology within the home environment to provide convenience, comfort, security and energy efficiency to its occupants [8]. In [1] author purpose home automation system for fire detection and security reason. The main difference between the work of [1] and the proposed system is the monitoring fire and using wire communication between sensors and microcontroller, so it cannot cover a wide area. While the difference between the works of [9] "automatically switch ON and OFF the lamp remotely using SMS" is controlling the electrical home appliances according to the user order by the mobile phone, the proposed system doesn't use any sensors, so can't make decisions independently.

The authors in [8] proposed a home control and monitoring system using Smartphone with Wi-Fi can be used to access and control the devices at home. The proposed system is using Wi-Fi to make it consume more power and less security compare with ZigBee. Also, it doesn't use any sensors, so it cannot make decisions independently, only get commands from a smart phone. Design, implement and monitoring system for smart house using LabVIEW is proposed in [10], while the development home automation system has been done usage GSM-based control home air-conditioner. Authors in [11] introduce a security system for fire hazards that may occur through smoke sensor and GSM module which is controlled by the controller, so it sends SMS to the user if the smoke is detected. In this work, an efficient monitoring system is designed based on the proposed algorithm and wireless sensor network.

3. System Components

Proposed system consists of a temperature sensor, ZigBee module, microcontroller, GSM module, relay and Analog to Digital Converter.

3.1. Temperature sensors

Temperature is one of the most commonly measured variables and it is therefore not surprising that there are many ways of sensing it. Heat is transferred by three methods: convection, conduction, and radiation. Temperature sensing can be done either through direct contact with the heat source, or remotely, without direct contact with the source using radiated energy instead. Radiated heat energy is an electromagnetic wave and (mostly infrared) and much of the discussion of light sensing will apply. Contact sensors use conduction or convection, while remote sensing uses radiation as the primary method of heat transfer. A temperature sensor is a semiconductor which measures temperature and displays the information in the voltage form. The output from the temperature sensor is analog, but is then sampled and quantized (Analog-to-Digital (A/D) converted) [2].

3.2. ZigBee module

ZigBee technology is a low data rate, low power consumption, low cost, wireless networking protocol targeted towards home automation, building automation, industrial monitoring and control, etc. It has been developed to become the global control/sensor network standard. The main characteristics of Zigbee are as follows [3]:

- Low power consumption: because of extremely low duty-cycle (<10 ppm) capability, sending and receiving messages on low-power and adopting Hibernation Mode, ZigBee Technology can run for six months to two years on just two AA batteries.
- Reliability: Media Access Control (MAC) layer using the full handshake protocol for transfer reliability.
- Supports large network orders (<= 65k nodes)
- Security (using AES-128): ZigBee employs Advanced Encryption Standard (AES) algorithm and Counter CBC-MAC (CCM*) mode to provide defense against attack. ZigBee provides functions of checking data integrity and sender authentication.
- Support for low latency devices: ZigBee is optimized for time-critical applications. Meanwhile ZigBee devices don't have to synchronize with other nodes before beginning communication. Thus, devices require only 30 milliseconds to join a network and 15 milliseconds to access and start communicating.
- Different topologies as illustrated in Fig. 1 below: star, peer to-peer and mesh network topologies supported.
- The ZigBee technology uses Carrier Sense Multiple Access\Collision Avoidance (CSMA\CA) protocol to scan the free frequency channel.

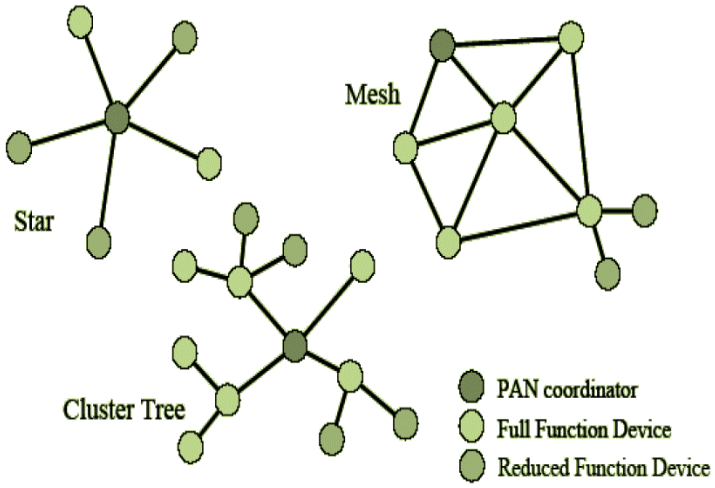

Fig. 1. ZigBee network topologies [3].

3.3. Microcontroller

A microcontroller already contains all components which allow it to operate standalone, and it has been designed in particular for monitoring and/or control tasks. In consequence, in addition to the processor it includes memory, various interface controllers, one or more timers, an interrupt controller, and last but definitely not least general purpose I/O pins which allow it to directly interface to its environment. Microcontrollers also include bit operations which allow you to change one bit within a byte without touching the other bits. Figure 2 shows the block diagram of a typical microcontroller. All components are connected via an internal bus and are all integrated on one chip. The modules are connected to the outside world via I/O pins [4].

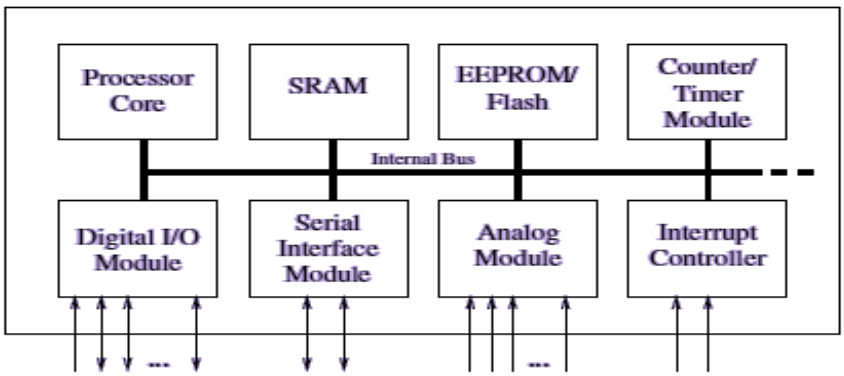

Fig. 2. Basic layout of a microcontroller [4].

- Today, microcontroller production counts are in the billions per year, and the controllers are integrated into many appliances we have grown used to, like
- Household appliances (microwave, washing machine, coffee machine, etc.)
- Telecommunication (mobile phones)
- Automotive industry (fuel injection, ABS, etc.)
- Aerospace industry.
- Industrial automation.

Arduino/Genuino UNO is a microcontroller board based on the ATmega328P datasheet has been used in this study. It has been fourteen digital input/output pins (six of them can be used as Pulse Width Modulation (PWM) outputs), six analog inputs, a power jack, a (sixteen MHz) quartz crystal, a Universal Serial Bus (USB) connection, an In-Circuit Serial Programming (ICSP) header and a reset button. Also, it's contained everything needed to support the microcontroller and very simply connect it to a computer with USB cable or it can power it with an AC-to-DC adapter or battery to get started In this work were used the microcontroller UNO.32-bit Atmel ARM processors, which connects to a personal computer via serial communications interfaces, including USB for loading programs from it. These systems provide sets of digital and analog I/O pins that can be interfaced to board and other circuits. For programming the microcontrollers, the Arduino platform has a capability to provide an Integrated Development Environment (IDE), which support C++ programming language. In

addition, there are two new pins placed near the RESET pin. One is the IOREF that allow the nodes to adapt to the voltage provided from the board [5]. The other is a not connected and is reserved for future purposes.

3.4. GSM module

GSM (Global System for Mobile) / GPRS (General Packet Radio Service) TTL - Modem is a GSM / GPRS device, works on frequencies 850 MHZ, 900 MHZ, 1800 MHZ and 1900 MHZ. It is very compact in size and easy to use as a plug in GSM Modem. The Modem is designed with 3V3 and 5V DC TTL interfacing circuitry, which allows User to directly interface with 5V Microcontrollers as well as 3V3 Microcontrollers. The baud rate can be configurable from 9600-115200 bps. This GSM/GPRS TTL Modem has internal Transmission Control Protocol/Internet Protocol (TCP/IP) stack to enable user to connect to internet through GPRS feature. It is suitable for SMS as well as DATA transfer applications in mobile phone to mobile phone interface. The modem can be interfaced with a microcontroller using Universal Synchronous, Asynchronous Receiver and Transmitter (USART) feature (serial communication) [6].

3.5. Relay

A relay is usually an electromechanical device that is actuated by an electrical current. The current flowing in one circuit causes the opening or closing of another circuit. Relays are like remote control switches and are used in many applications because of their relative simplicity, long life, and proven high reliability. Relays are used in a wide variety of applications throughout industry, such as in telephone exchanges, digital computers and automation systems. Highly sophisticated relays are utilized to protect electric power systems against trouble and power blackouts as well as to regulate and control the generation and distribution of power. In the home, relays are used in refrigerators, washing machines and dishwashers, and heating and air-conditioning controls. Although the relays are generally associated with electrical circuitry, there are many other types, such as pneumatic and hydraulic. Input may be electrical and output direct mechanical, or vice versa [6].

3.6. Analog to digital (A/D) converter

In the real world, most data are characterized by analog signals. In order to manipulate the data using a processor, we need to convert the analog signals to the digital signals, so that the processor will be able to read, understand and manipulate the data. The main goal of A/D Converter is to digitize the analog signals, which means to record and store the analog signals in the NUMBERS. There are two parameters to control in converting the analog signals to the digital signals [7]:

- Sampling Rate, fs – controls the number of samples taken in a second.
- Sampling Precision, N–controls the number of different gradations (quantization levels) for the sampling process.

4. Methodology

4.1. Design scheme

In this sub-Section the designed scheme of the proposed home automation system has been introduced as shown in Fig. 3. This figure consists of three sensor nodes distributed in covered area every period sends the temperature degree to the center node through ZigBee. Center node consists of from microcontroller connect with ZigBee, GSM module, Keypad and LCD (used to enter comfortable temperature degree by the user). Microcontroller return ON or OFF signal to terminal (to operate or shut down air-conditioner based on receiving a degree. In addition, the system enables the user to operate or close the air-conditioner from any place through mobile.

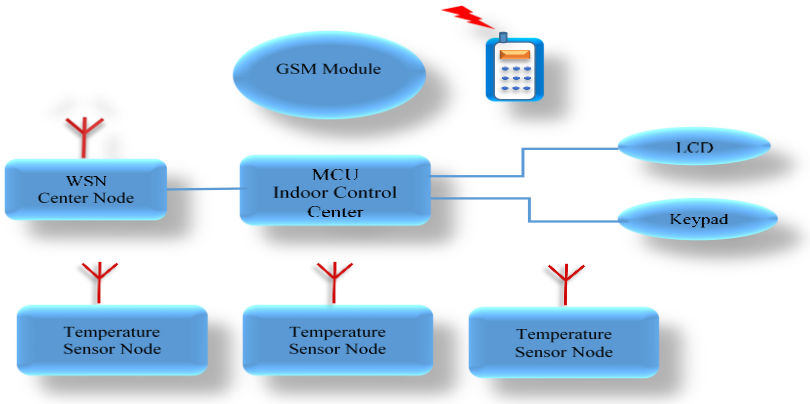

Fig. 3. System diagram.

Figure. 4 show component of each WSN node, it contains temperature sensor, ZigBee and relay (switch to open or close the air-conditioner). The interface portion between sensor node and microcontroller has been achieved by Zigbee. As known, the Zigbee had been connected with the sensor in the sensing points by the A universal asynchronous receiver/transmitter (UART), and connected with microcontroller in the main point for the same protocol.

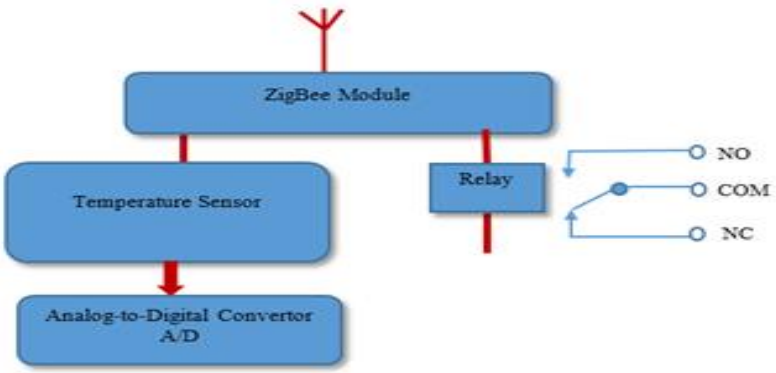

Fig. 4. Component of WSN node.

4.2. Proposed algorithm

There are several home automation technologies out there depending on the different requirements, e.g., different cabling requirements. There have been many attempts to standardize the forms of hardware, electronic and communication interfaces needed to construct a home automation system. As mentioned earlier, the proposed home automation system includes an algorithm used to control the operations of the involved air-conditioner. In other words, at a time just the only needed devices are working. This can lead to a sensible reduction in the power, budget and environment pollution comparison with full work of air-conditioner all the time. The designed scheme shown in Fig. 5, we are collected temperature data from the assumed environment. Sending the received data to the control center. The comparison between the received data with the threshold value the lowest level at which a stimulus can be detected. Because ZigBee is suited for high-level communication protocols. Also, the ZigBee devices can be transmitted data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. So that, sensor nodes have been distributed to work and ready to detect any change in temperature. These packets are continued to be transmitted until receiving an acknowledgment from the base station. At the base station or control center, the proposed algorithm collects the degree of the sensor node of the designed monitoring scheme. An acknowledgment signal is sent back to the terminal sensor node to confirm the receiving. Check threshold is based on stored degree (entered by Keypad or mobile because the comfortable degree is so different from person to another). Additionally, the user can operate and shut down any air-conditioner manually through mobile from anywhere.

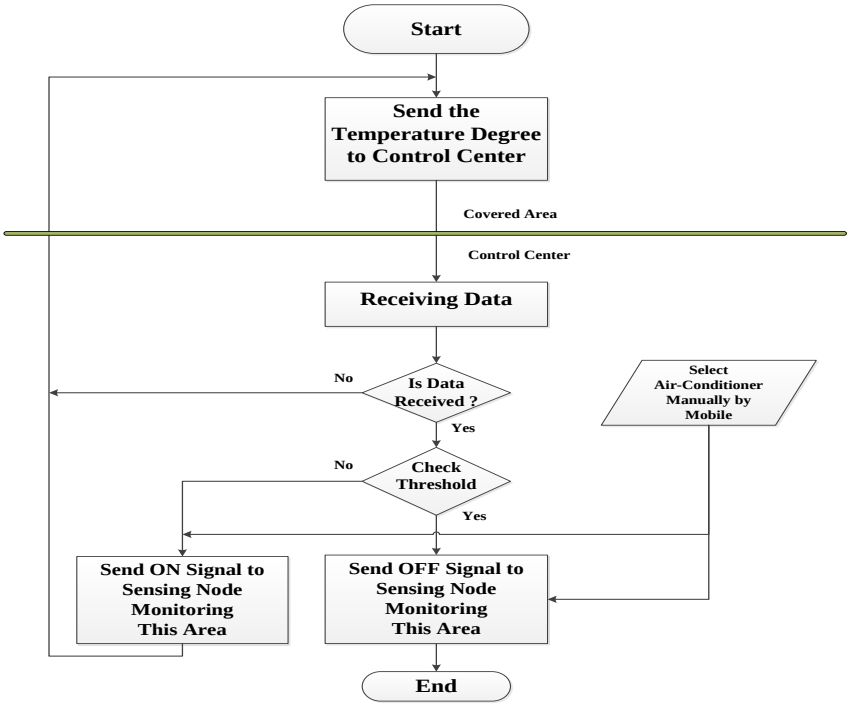

Fig. 5. Flowchart of the system.

4.3. Simulation results

The proposed home automation system is tested in this Section. In this paper, the required operating power of each air-conditioner is 900 kilowatt/hours [12]. Assuming that this system was able to reduce one hour for each air conditioning, so profit-powered for a week can be calculated by the Table 1.

Table 1. Power consumed in week.

Days of the Week	Operation Hour in Traditional System	Operation Hour in Proposed System	No. of Saved Hour	Power Consumed in Traditional System kWh	power Consumed in Proposed System kWh	Saved power kWh
Sunday	24	23	1	21600	20700	900
Monday	24	23	1	21600	20700	900
Tuesday	24	23	1	21600	20700	900
Wednesday	24	23	1	21600	20700	900
Thursday	24	23	1	21600	20700	900
Friday	24	23	1	21600	20700	900
Saturday	24	23	1	21600	20700	900

In Table 1, we have been taking the less likely values for reducing through the profit was calculated by comparison with the loss in the absence of the proposed system application. But in fact, the reduction period is not fixed on all day, but is changed by temperatures that day cannot be certain duration reduction at all. Since the price per kilowatt hour is 10 Iraqi dinars [13]. The cost of power consumption is calculated according to Eq. (1). Table 2 shows the cost consumed in the week.

$$P_T = P * N \quad (1)$$

Table 2. Cost consumed in week.

Days of the week	Power consumed in traditional system, kWh	Power consumed in proposed system, kWh	Saved power, kWh	Cost in traditional system Iraqi dinars	Cost in proposed system Iraqi dinars	Saved cost Iraqi dinars
Sunday	21600	20700	900	216000	207000	9000
Monday	21600	20700	900	216000	207000	9000
Tuesday	21600	20700	900	216000	207000	9000
Wednesday	21600	20700	900	216000	207000	9000
Thursday	21600	20700	900	216000	207000	9000
Friday	21600	20700	900	216000	207000	9000
Saturday	21600	20700	900	216000	207000	9000

5. Conclusion

In this paper, a wireless home automation system based on microcontroller has been presented. The proposed algorithm of the investigated system controls the operation of the involved air-conditioner depending on the received temperature degree from sensors. These degrees are change in the covered area so that proposed system controls the operation of air conditioner and maintain a comfortable temperature degree in this area.

As the whole air-conditioners of the system were not working at a time, the consumed power, cost and pollution were decreased efficiently, in addition, the ease which provided by the proposed system where the user can run the air-conditioning before coming to the house to get a nice environment by using mobile. As a future work, the hardware implementation of the simulated system will be performed to cover an area of 100X100 meters.

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