ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645
Indian Journal of Science and Technology, *Vol 9(40), DOI: 10.17485/ijst/2016/v9i40/98360, October 2016*

An Integrated Approach to Automated Control for Air-Conditioned Home Apartments using Wireless Sensor Network

Moses O. Onibonoje*, Oladipo Folorunso, Adedayo Ajibade and Kehinde A. Adeniji

Department of Electronic/Electrical and Computer Engineering, Afe Babalola University, Ado Ekiti, Nigeria; onibonojemo@abuad.edu.ng, folorunsoo@abuad.edu.ng, ajibadea@abuad.edu.ng, adenijika@abuad.edu.ng

Abstract

Objectives: Home automation is achievable with an integrated approach using Wireless Sensor Networks (WSNs). This paper presents the implementation of such integrated approach to automating the air-conditioning of various apartments. **Methods/Statistical Analysis:** The developing of an integrated system consisting of network of wireless sensor nodes with well selected components and resourceful capabilities is explained. This network is incorporated to a control unit connected to air-conditioning systems in various home apartments for automation and central remote control through short service message (sms). **Findings**: An integrated system comprising three resulting characterized sensor nodes and one sink node being integrated with the automated control unit for the air-conditioning systems were implemented and tested. The system was designed with well selected intelligent temperature/humidity DHT22 sensors, homogenous XBee radios, arduino boards and wireless network protocol to deliver remotely monitored parameters from the sensor nodes to a base station. The resulting composite units of the implemented system were products of the best parameters trade-off in the selection of components and protocols. The same sensor nodes can be increased to the number of target apartments and integrated to the network system. The transfer of monitored data to the central hub was wireless and the mode of sending commands to the control unit was through short message service. The approach conserves energy consumption as it saves the loss time involved in continuous operation of air-conditioning systems. The system also reduces the health risk in poorly air-conditioned environment for elderly and infants. **Applications/Improvements:** The approach can be extended to controlling other appliances in full home automation set-up.

Keywords: Automated, Air-Condition, Integrated, Nodes, Wireless, WSN

1. Introduction

As air is the only media that encompasses the whole of human body, we need to condition this air to provide comfort. Air conditioning encompasses temperature control, humidity control, ventilation and filtration of the air volume to ensure human general comfort[1]. Humans are sensitive to high humidity because the human body uses evaporative cooling, enabled by perspiration, as the primary mechanism to rid itself of waste heat. Perspiration evaporates from the skin more slowly under humid conditions than under arid conditions. Because humans perceive a low rate of heat transfer from the body to be equivalent to a higher air temperature, the body experiences greater distress of waste heat burden at high humidity than at lower humidity, given equal temperatures[2,3]. Humiture is the index that reflects the combined

**Author for correspondence*

effect of the air temperature and humidity on the cooling effect of the atmosphere on the human body.

Air conditioning systems treat air in a defined, usually enclosed area via a refrigeration cycle in which warm air is removed and replaced with cooler and more humid air. The comfort applications aim of such systems is to provide an indoor environment that remains relatively constant in a range preferred by humans despite changes in external weather conditions or in internal heat loads. General human comfort conditions range between temperature of about 18–26°C and relative humidity of 30–70%. There is a level of discomfort experienced at conditions beyond these ranges. Poorly managed air-conditioning systems, especially large centralized systems can occasionally promote the growth and spread of microorganisms that are responsible for infectious diseases, respiratory problems, and eye irritation. Good air-conditioning is necessary for elderly, children, sufferers of allergies and Asthma[4].

However, the life span of such conditioning systems can be extended by reducing the loss time in their operations. Also, the energy efficiency of the entire installations can be improved upon by controlling the operations of the systems based on the actual body comfortability needs only[5]. Each air conditioner has an energy efficiency rating that lists how many British Thermal Units per hour (Btu per hour) are removed for each watt of power it draws. For room air conditioners, this efficiency rating is the Energy Efficiency Ratio (EER). Room air conditioners generally range from 5,500 to 14,000 Btu per hour. The total energy usage results from the power consumption by the various air-conditioning units over a period of time[6].

Wireless Sensor Network (WSN) has in recent years found vast applications in monitoring, control and automation[7]. Had explained WSN as a network of sensing nodes otherwise known as motes deployed to collect data and transmit the gathered data to a sink node typically through wireless channels[8,9]. A wireless mote consists of sensing, computing, communication, actuation, and power components. The sink node generally consists of a gateway, which is a device that collects data from the sensors and logs it to a computer or to the internet. Had proposed industrial automation using wireless sensor network cluster with low cost MSP430 processor and radio frequency transceivers[10]. The author established the network for easy modification to suit the needs of a particular process.

This paper presents an integrated approach of using wireless sensor network to smartly control the air conditioning systems in various home apartments based on the uncomfortability level in those locations. It aims at developing an approach that can easily determine the uncomfortability or otherwise in various locations and remotely control the air-conditioning systems in the locations. The approach automates the operations of the various air-conditioning systems and integrated them to provide the needed feedback for operational control as a veritable means of achieving the longevity of the entire system. Moreover, this provided the necessary means of ensuring good health for inhabitants of orphanages and elderly care-giver homes, who are hitherto unable to manually control the operations of their air-conditioning systems whenever they feel uncomfortable.

2. Methodology

The integrated approach involved wirelessly connecting various hardware and software components of sensor nodes, air-conditioner control units and sink node together. The basic architecture of the system is as shown in Figure 1.

A sensor node and a control unit are being installed in each air-conditioned apartment. The block diagram of hardware units of the sensor node is as shown in Figure 2.

All the home apartments are being networked together through RF transceivers to the central hub (sink node). The sensor node monitors the environmental condition of each home apartment by sensing the air temperature and relative humidity. It calculates the humiture index with equation 1 and communicates it via its RF transceiver to the sink node. The block diagram of hardware units of the sink node is as shown in Figure 3.

$$H = a + bT + cR + dTR + eT^2 + fR^2 + gT^2R + hTR^2 + iT^2R^2 \qquad (1)$$

Where:
H – Humiture (^{0}F)
T – Temperature (^{0}F),
R – Relative Humidity (%)

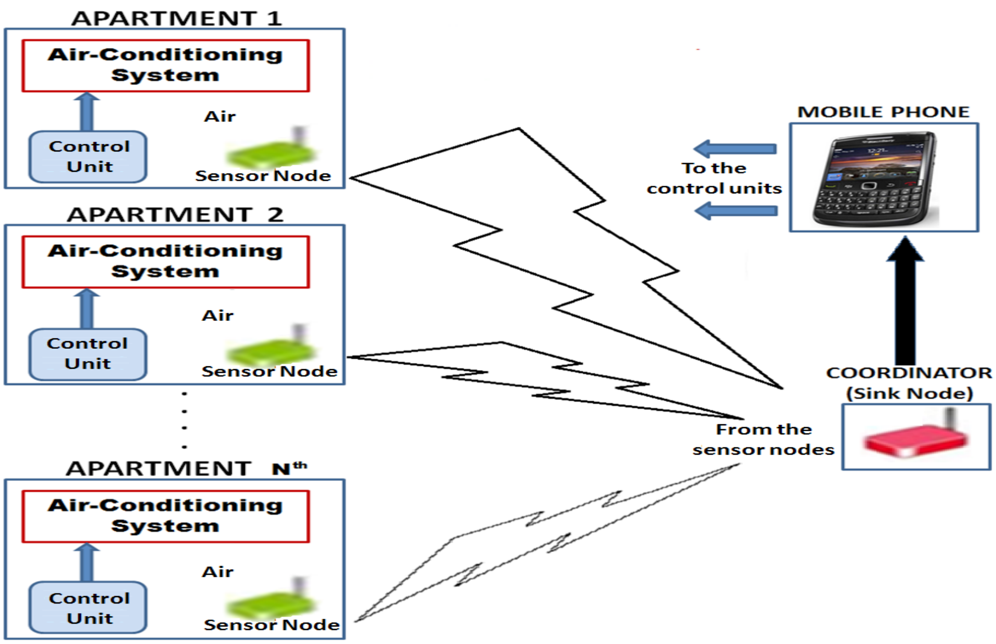


Figure 1. System architecture.

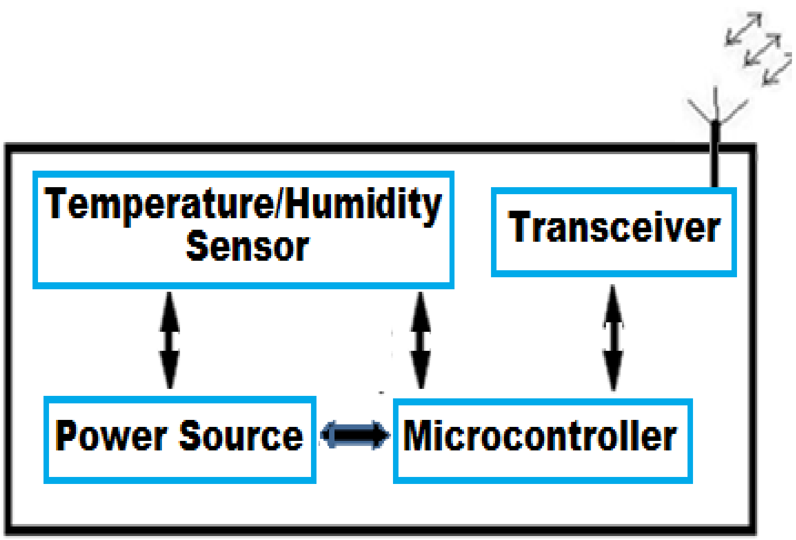


Figure 2. Block diagram of the sensor node.

a = -42.379, b = 2.04901523,
c = 10.14333127, d = -0.22475541,
e = -6.83783 x 10^{-3}, f = -5.481717 x 10^{-2},
g = 1.22874 x 10^{-2}, h = 8.5282 x 10^{-4},
i = -1.99 x 10^{-6}

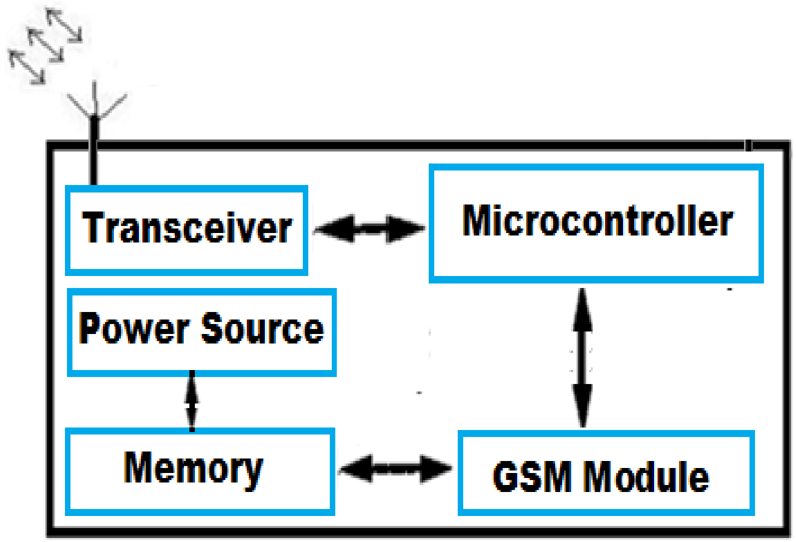


Figure 3. Block diagram of the sink node.

The sink node acts as the coordinating hub for the entire system architecture. It receives the humiture index from the remote sensor node through its RF transceiver. The sink node sends a short message service (sms) to the administrator's mobile phone based on the status of the data received from the sensor nodes. The administrator consequently sends a sms to the control units in the apartments to operate the air-conditioning systems. The block diagram of the control unit is as show in Figure 4.

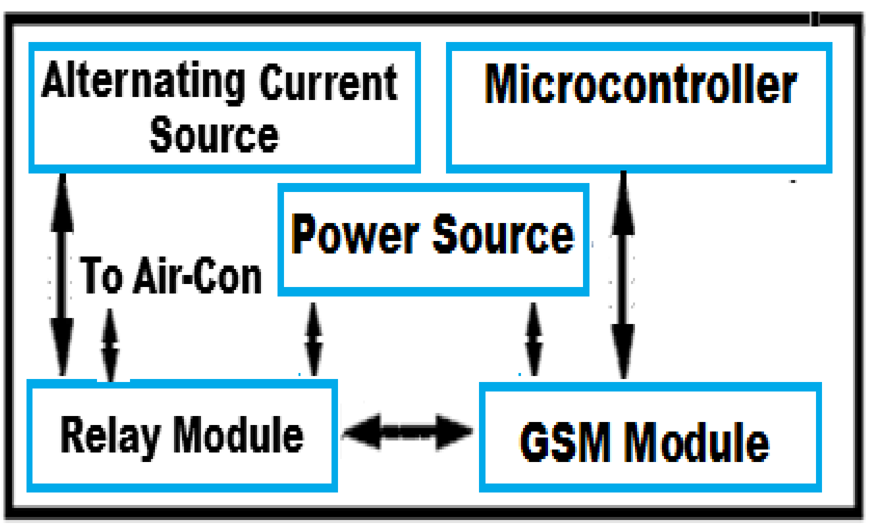


Figure 4. Block diagram of the control unit.

3. Implementation

The hardware unit of the system is implemented for best performances by selecting appropriate components for the sensor node, coordinator and the Global System Mobile (GSM) module. For the various categories of the hardware unit, different components are compared and the best among them are selected within varying considered characteristics.

Grove-DHT22 Temperature/Humidity sensor is selected based on its characteristic advantages. It provides calibrated, linearized digital signals, via 1-wire bus. It has a capacitive type humidity sensor and a band gap temperature sensor which produce a stable output at moderately high humidity levels. It does not require any soldering due to the grove pins. It also contains an amplifier, A/D converter, and One-Time Programmable (OTP) memory and a digital processing unit. It has operating range of (0-100) % RH and (-40 to +125)^{0}C. The sensor had a rated RH accuracy of ±2% RH (Max ±5 %) and temperature accuracy of ±0.5^{0}C. Typically, DHT 22 has a resolution/sensitivity of 0.1% RH and 0.1^{0}C. It has repeatability of 1% RH and ±0.2^{0}C. Also, it has humidity hysteresis of ±0.3% RH and long-term stability of ±0.5% RH/year. It is selected with trade-off of relatively higher cost and moderately slow response in comparison to other temperature and humidity sensors.

The transceiver in each node is XBee-PRO Series 1 RF module. It is engineered to support the unique needs of low-cost, low-power wireless sensor networks. The module provides reliable delivery of data between remote devices and operates within the unlicensed Industrial, Scientific and Medical (ISM) 2.4 GHz frequency band. The module supports the ZigBee IEEE 802.15.4 connectivity protocol. The PRO version is selected because of the needed range between the apartments and central hub. It has range up to 90 m indoor and up to 1.6 km outdoor line of sight. It has receiver sensitivity close to -100 dBm, and requires power supply of 2.8–3.4 VDC. It supports data transmission rate of 9600 (bps) needed for the network. It supports point-to-multipoint star topology, while it has RF data rate of 250 Kbps. It has easy-to-use serial interface and rich extendable ports, and socket compatible with the Xbee shields. The transceivers in the sensor nodes and sink node are configured with easy-to-use Attention 'AT' and application programming interface 'API' commands respectively using a free, multi-platform application XCTU by Digi.

Arduino Uno is selected for the microcontroller units of the system. It is a platform based on Automatic Voltage Regulator (AVR) microcontrollers. It has a robust ecosystem. It is also most suitable for real-time applications. It contains microcontroller ATmega 328, input voltage of 6 -12 V and DC current of 40 mA. The flash Memory is 32 KB of which 2 KB is used by the bootloader. It also has compatible pins with the GSM shield and XBee shield. The GSM modules in the system are SIM900A. Attention 'AT' commands 'AT+CMGS' and 'AT + CMGR' with car-

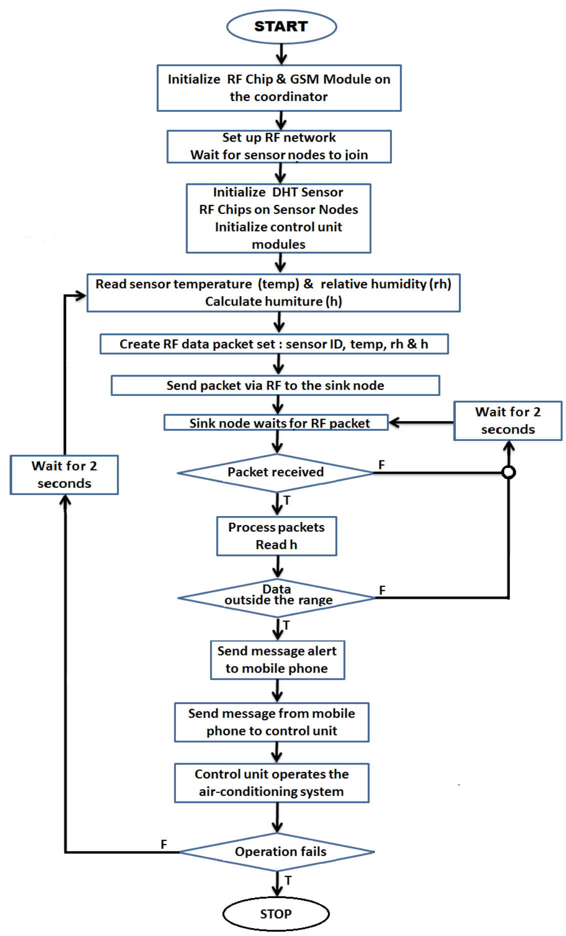


Figure 5. Flowchart of the communication network.

rier returns are incorporated in the programming of the arduino in order to send/receive messages to/from the mobile phone by the GSM modules respectively. Each node is being powered with 5 Volts rectified and regulated dc supply. The relay module selected has four attached relays through which four different loads can be connected and controlled separately.

The communication network is a special case of a star network topology in which the sink node (coordinator) has a peer relationship with the sensor nodes. The network is formed and managed by the coordinator and initially consists only it, while each sensor node searches for and later joins the network sequentially. The flowchart of the communication network is as shown in Figure 5.

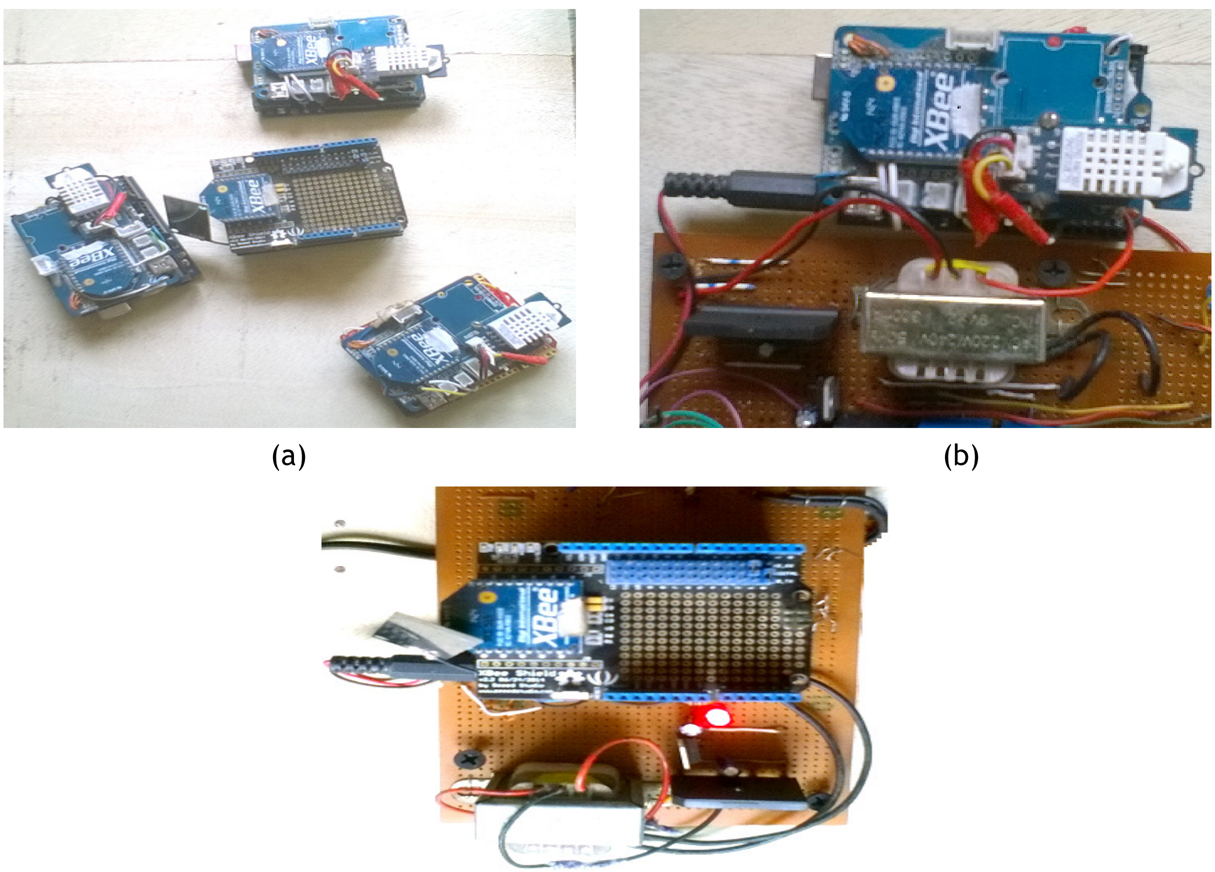
4. Results and Discussion

Three resulting sensor nodes and one sink node being integrated with the automated control units for the air-conditioning systems were implemented and tested.

4.1 The Resulting Nodes

The pictorial views of the resulting nodes are as shown in Figures 6.

The sink node was the coordinating access point for the entire system architecture. It received the humiture index from the remote sensor nodes through its RF transceiver as shown in Table 1. It determined the uncomfortability



(a) (b) (c)

Figure 6. The resulting nodes (a) all nodes, (b) a connected sensor node, (c) connected sink node.

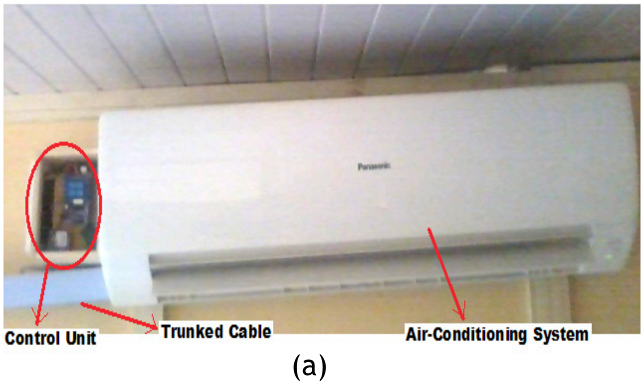
Table 1. Some transmitted data to the sink node

Node	R.H (%)	Temp (^{0}C)	Humiture (^{0}C)	Good Status
1	45.20	27.60	27.66	No
2	44.80	27.50	27.54	No
3	49.20	25.80	25.72	Yes
1	47.50	26.60	26.69	No
2	51.90	25.30	25.24	Yes
3	51.60	25.00	24.90	Yes

level in any of the apartments, and sent alert short message service sms to the administrator's mobile phone.

4.2 The Resulting Control Unit

The resulting control unit as shown in Figure 7 received command message from the administrator's mobile phone whenever there was a change in comfortability level in the apartments. The command messages and the response operation by the control units are as shown in Table 2.



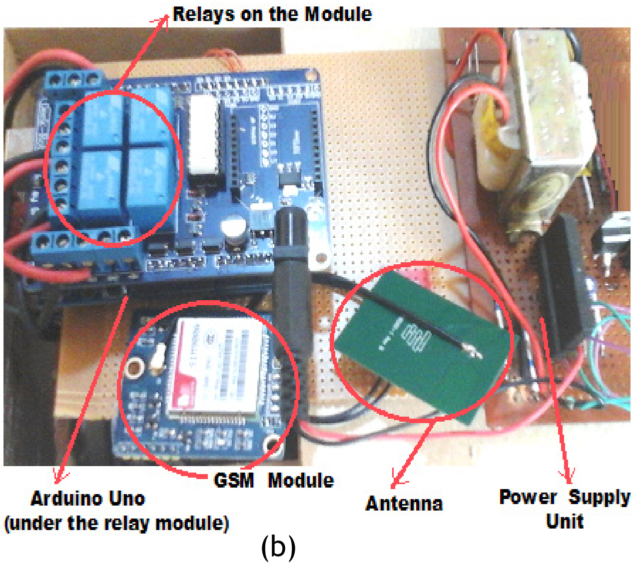


Figure 7. The connected control unit, (a) Connected with air-conditioning system, (b) Expanded interval view of control unit.

Table 2. The command messages and the operation by the control unit

S/N	Message	Operation
1	H1000	LOAD 1 ON
2	H0100	LOAD 2 ON
3	H0010	LOAD 3 ON
4	H0001	LOAD 4 ON
5	H1100	LOAD 1&2 ON
6	H1110	LOAD 1,2,3 ON
7	H1111	LOADS ON
8	H0000	LOADS OFF

5. Conclusion

An integrated approach to automating the control of air-conditioning systems in different home apartments using network of wireless sensor nodes was developed. A coordinating hub, three sensor nodes and control units were implemented and tested. The same sensor nodes can be increased to the number of target apartments and integrated to the network system. The transfer of monitored data to the central hub was wireless and the mode of sending commands to the control unit was through short message service. The approach conserves energy consumption as it saves the loss time involved in continuous operation of air-conditioning systems. The system also reduces the health risk in poorly air-conditioned environment for elderly and infants. The approach can be extended to controlling other home appliances in full home automation set-up. The mobile network dependency of the approach serves as its drawback.

6. References

1. Ahmadu TO, Folayan CO, Anafi FO. Modeling, simulation and optimization of a solar absorption air conditioning system for an office block in Zaria, Nigeria. International Journal of Air-Conditioning and Refrigeration. 2016; 24(2):1-12.
2. Salamaca F, Georgescu M, Mahalov A, Moustaoui M. Summertime response of temperature and cooling energy demand to urban expansion in a semiarid environment. Journal of Applied Meteorology and Climatology. 2015; 54(8):1756-72.
3. Kim Y, Yoon H. A high temperature measuring device development for die casting molten metal deposition. Indian Journal of Science and Technology. 2016; 9(24):1-5.
4. Arnold F, DeMallie I, Florence L, Kashinski DO. Method for collecting thermocouple data via secured shell over a wireless local area network in real time. Review of Scientific Instruments. 2015; 86(3):35112.
5. ParvezIqbal AKM, Aris I, Rahman MM, Misron N. Design and optimization of the housing of spray unit of a linear

motor operated spray gun. Indian Journal of Science and Technology. 2016; 6(8):5168–75.

6. Rudolf A, Walther T. Laboratory demonstration of a Brillouin lidar to remotely measure temperature pro¬files of the ocean. Optical Engineering. 2014; 53(5):51407.
7. Onibonoje MO, Umeh UN, Kehinde LO. Development of an Arduino-based trainer for building a wireless sensor network in an undergraduate teaching laboratory. International Journal of Electrical and Electronic Science. 2015; 2(3):64–73.
8. Indhumathi S, Venkatesan D. Improving coverage deployment for dynamic nodes using genetic algorithm in wireless sensor networks. Indian Journal of Science and Technology. 2015; 8(16):1-6.
9. Zhao G. Wireless Sensor Networks for industrial process monitoring and control: A survey. Network Protocols and Algorithms. 2011; 3(1):46–63.
10. Arvind RV, Raj RR, Raj RR, Prakash NK. Industrial Automation using Wireless Sensor Network. Indian Journal of Science and Technology. 2016; 9(11):1-8.