WPAN-Based Energy Efficient Automation System for Buildings

Manish Kumar Mishra, Rajesh Singh, Anita and Rohit Samkaria

Abstract Nowadays the building energy management systems (BEMS) or implementing control automation in buildings is very significant and well known, because they can play an important role in regular energy management and therefore these type of system can achieve the possible both cost and energy savings. The key driver of the building automation market is focused upon better facilitation to the user in terms of comfort at reduced operation cost. Energy efficiency improvement will also contribute to environmental protection. Therefore, there have been regulations and rating systems made that mandates the requirement of energy monitoring and control in a building. For example, the above mentioned building utilities and equipment's control and automation plays an integral role in achieving the green building rating points from certifying authorities such as GRIHA and IGBC. The proposed system includes the control of various active systems such as lighting including artificial lighting (On/Off and dimming control) and day lighting (motorized blinds or shutters), air conditioners and safety features like fire alarm and gas alarm. In future the existing idea can be implemented for the whole building, i.e., various rooms or areas, and then all of them can be integrated on a common platform for monitoring and control of different energy consuming equipment. Also, it can be further extended to the integration of different building systems in a particular area on a single platform.

Keywords Building automation · WSN technology · Arduino · Energy efficiency improvement

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1 Introduction

Mostly the building HVAC systems run on set schedules and do not make use of any fine grained control based on in depth occupancy information. Therefore, the design and implementation of a presence sensor platform is needed for accurate occupancy detection at the level of individual offices [1]. The need for the necessary thermal comfort, visual comfort, and indoor air quality are increased, especially in the prevailing situation of price fluctuations and the technology's evolution. Towards this course, the role of the BEMS is well known and important, since these systems can add to the continuous energy management and therefore to the accomplishment of the possible energy and cost savings [2]. The high energy necessary for appliances make our buildings one of the most critical areas for the impact of energy usage on natural environment. Therefore, a wireless sensor network is proposed to monitor and control physical parameters as well as monitoring the presence of users in the rooms [3]. Building automation systems (BAS) present automatic control of the conditions of interior environments. Its prime goal is to recognize significant savings in energy and diminish cost. Yet the reach of BAS has extended to incorporate information from all kinds of building systems, working toward the objective of "intelligent buildings" [4]. To attain a major reduction in energy utilization apart from the typical energy efficiency methods, innovative technologies must be employed. Therefore, logicality of customary and new energy efficiency options becomes necessities. To move towards the thought of sustainable buildings, a small amount of advanced steps are required, regarding energy, water, land, and material management, collectively with environmental loading, and the characteristics of the indoor and outdoor environments [5]. Enabling the behavioral models in superior lighting simulation programs, such as DAYSIM and the Light switch Wizard permits for an additional practical estimation of lighting use under dynamic conditions. A sub-hourly occupancy-based control model (SHOCC), which allows advanced behavioral models inside entire building energy simulation is presented [6]. Present monitoring control modules compute load current and power monitor modules examine power consumed by selected loads, both modules transmitting bus messages signifying load status and status changes. The utility company can access chosen utilization data and control at least a few loads via message exchange to and from microcomputers [7]. User activity and behavior including occupant presence is considered as a main element and has long been used for control of a variety of devices such as artificial lighting and HVAC. The most capable and suitable activity detection technologies and approaches allow in developing principles and perspectives for energy intelligent buildings based on user activity [8]. Wireless sensors and their networks have approached ahead in the field of recently developed technologies. The application of these sensors and the prospects of managing them into networks have discovered many research matters and have emphasized new ways to deal with definite problems [9]. BAS are employed to control and develop indoor building climate at cheaper costs. By incorporating BAS with wireless sensor networks, the requirement for cabling can be detached, and installation and operational expenses significantly diminished [10].

2 Proposed System

The methodology implied over the system is explained in the block diagram as shown in Fig. 1 in which the main central unit is the Arduino Uno platform. The various sensors are connected with the Arduino Unit. Gas and fire sensors are connected for the safety requirements. light dependent resistor (LDR) sensor for sensing the lux level in the concerned area or room, passive infrared (PIR) sensor for sensing the occupancy in the room, a magnetic reed switch door sensor is also used for better and accurate detection of occupancy and LM65 sensor for temperature sensing would be given as the input to Arduino Uno, a microcontroller board having digital input/output pins with analog inputs as well. A seven segment display is connected to the microcontroller for monitoring of the different energy parameters in the area or room. In system programming (ISP) connector is linked for the programming purpose with the controller.

In transmitter, basically six building block of the system are data acquisition unite (sensors), controller unit, display unit, RF modem, power supply unit, and serial communication module. To operate various sensors and controller the power supply is fed through power supply unit which having the regulator IC. The data from various sensor is fed to controller unit and the corresponds data of the sensors unit display over the display unit and at the same time this data is serially provided to RF Modem which wirelessly transmit this data to the surrounding.

In the receiver module basic building blocks of the system are same as used in the transmitter unit. RF Modem receives the data transmitted by the transmitter unit

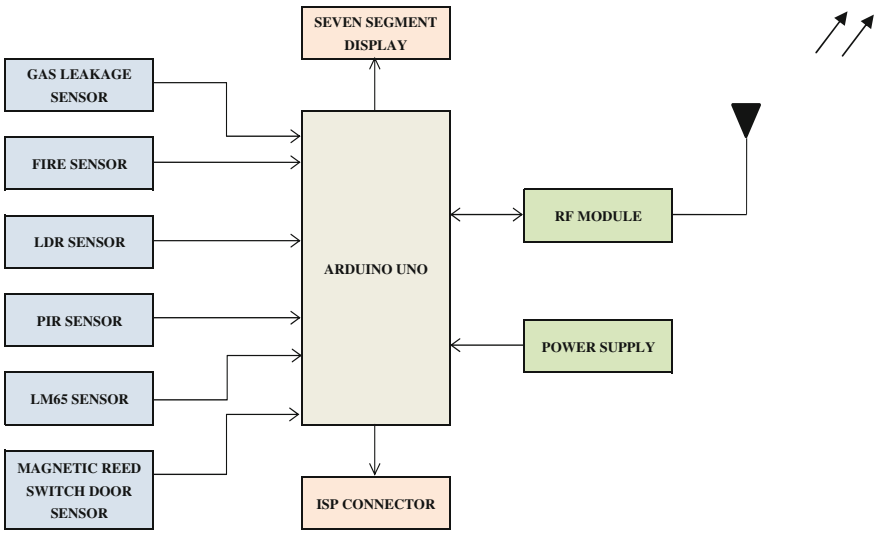


Fig. 1 Block diagram of transmitter unit

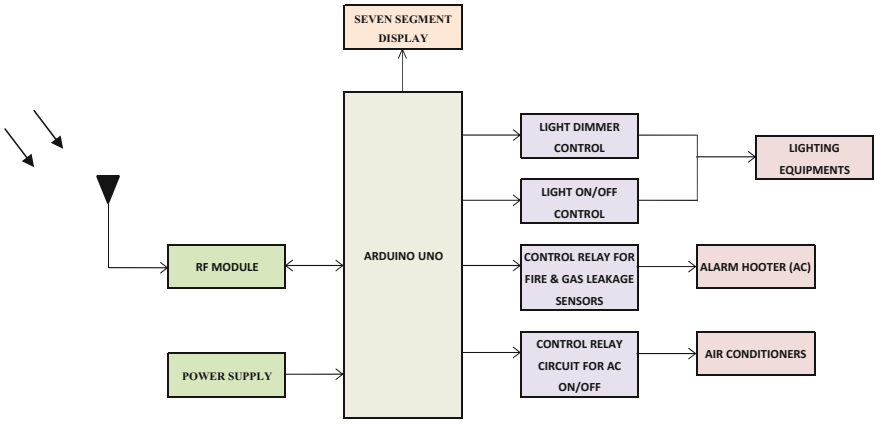


Fig. 2 Block diagram of receiver unit

and this data is processed by the controller unit and according to the sensor data parameters further various controls are activated (Fig. 2).

After the connection of a RF module, on the output side, through the controller different outputs are given, such as the lighting dimmer controlling and ON/OFF circuit, control relay for fire and gas leakage and control relay circuit for switching of AC. The above explained methodology is proposed to be implemented for two different areas or rooms in a building for better analysis in terms of energy efficiency and energy cost savings.

3 Prototype Development

Arduino Uno platform is used as the controller unit of the system through which data is detected through the sensors unit and transmitted to surrounding and another controller unit receives the data and according to the data various control operation are performed at the output.

Figure 3 shows the circuit diagram of the transmitter unit in which the analog sensors are connected to A0–A5 pin of the controller unit. The controller unit having 10 bit ADC which converts the analog input into 1024 level as $2^{10} = 1024$. The fire sensor, PIR sensor and magnetic red sensors are connected to the pin no. 8, 9, 10 of the controller unit.

Power Supply unit consist of four diode 1N4007 followed by the filter capacitor. For the regulated output IC7805 is used which provide 5 V output and the output is provided to various sensors, RF modem and Display Unit. LCD is connected at pin no. 2, 3, 4, 5, 11, 12 of the controller unit. The RF modem is connected at Tx pin of the controller and is fed to the Rx pin of the RF Modem. RF modem receives this data and transmits further.

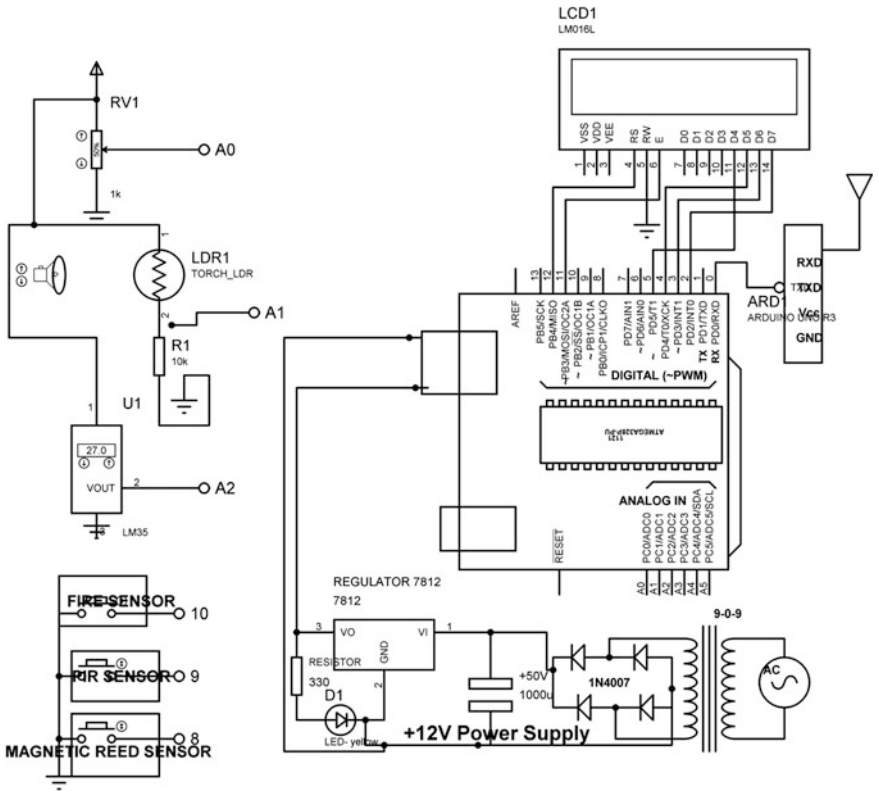


Fig. 3 Circuit diagram at transmitting end

In the receiver circuit diagram as shown in figure RF modem receives the wireless data and put this data to the Rx pin of the controller unit. LCD is connected to the pin no, 2, 3, 4, 5, 11, 12 pin of the microcontroller. To operate the various AC devices the relay based breakout board has used in which the output from the controller is fed to the relay 2N2222 transistor which act as switching circuit to operate the relay. The various AC appliances are connected to this relay board (Fig. 4).

4 Software Development

The software platform being used for the development of the proposed model is Proteus, and following circuits were developed for transmitting as well as receiving side of the model in which various virtual components taken from the Proteus library and placed in the workspace. Arduino platform utilized for the software development of the system. Figure 5 show the step by step flow chart of the system

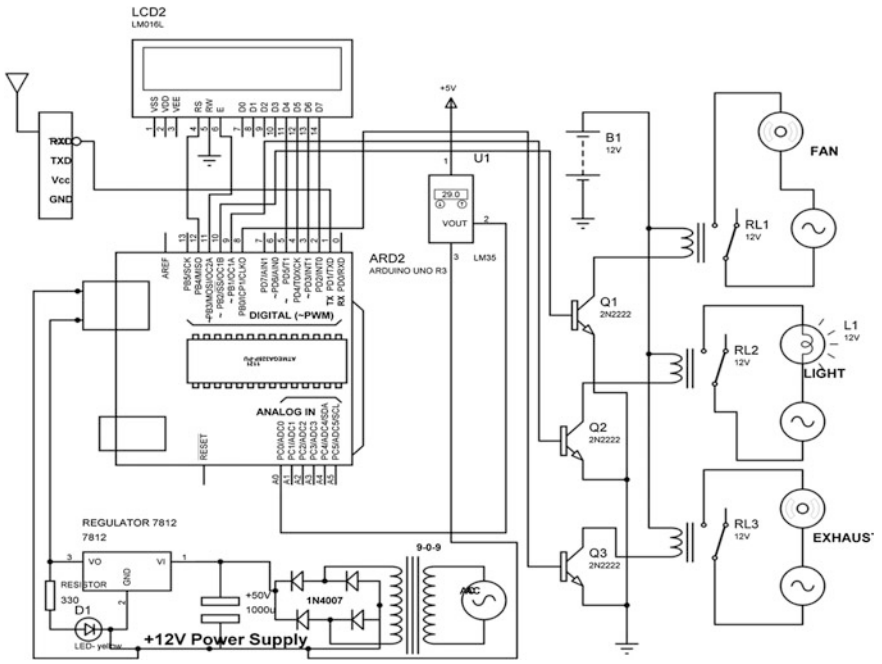
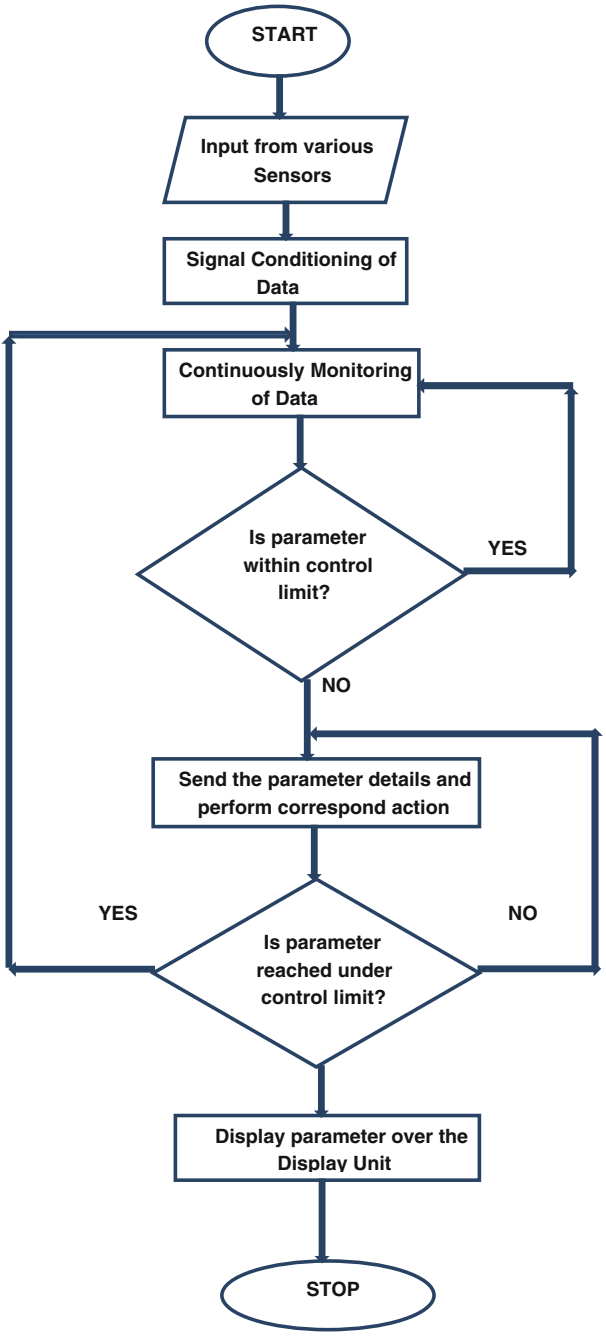


Fig. 4 Circuit diagram receiver unit

where various parameters are continuously monitored and the corresponding data is compared with the predefined limit. If the data rises above the defined limit then the corresponding action occurs and parameters bring back to normal condition.

In the Proteus simulation the virtual components from the Proteus library are taken and placed in the workspace and these various components and the program is dumped into the arduino.

As shown in Fig. 5 the various sensors which are placed in the different location within in the building provides the data corresponds to their operation. Some of the sensors provide digital data and we provide the analog data. The analog data cannot process directly by the arduino for that the signal conditioning to be done. The signal conditioning is done by the internal ADC of the Arduino which is 10 bit. Now the data from the analog sensor is converted to the 1024 levels and the sensors provide this level corresponds to the data of the sensor. Now these levels need to be calibrated according to the sensor data. After calibration this data fed to the arduino unit and sent to the remote location through the wireless medium. In receiver section the data is continuously compared with the defined levels inside the program. Now if any parameter rises above the defined level then the Arduino unit sends a signal and corresponding action is to be taken to normalize the raised condition.


START
Input from various Sensors
Signal Conditioning of Data
Continuously Monitoring of Data
Is parameter within control limit?
YES
NO
Send the parameter details and perform correspond action
YES
Is parameter reached under control limit?
NO
Display parameter over the Display Unit
STOP

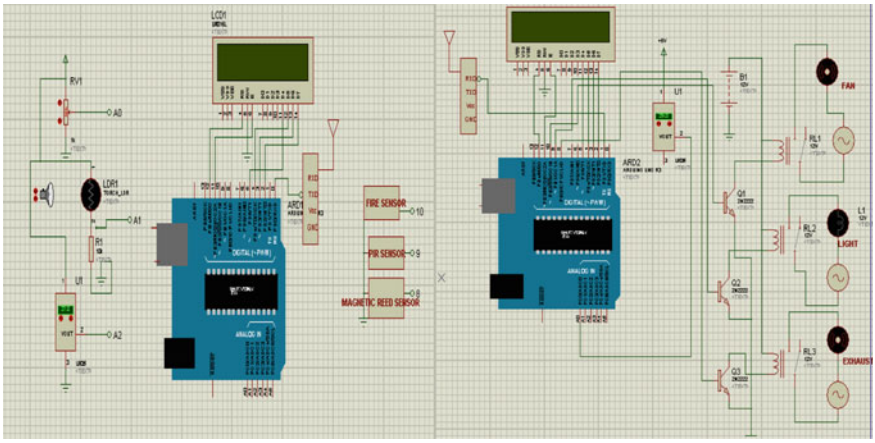


Fig. 5 Proteus simulation of the transmitter and receiver module

5 Result and Conclusion

So, the paper can be concluded with the fact that the combination of controller and information technology into the building energy management system are capable of supervising and controlling many of the actions and services related to buildings. Also, huge reduction over the cost can be taken which occur during installation and maintenance in BAS through wireless sensor networks. The potential use of wireless sensor networks expands over an enormous part of personal activities. Although, most of the functions and applications are still under study and only a small amount of accomplished services and products have developed into as available applications for public use, there is outstanding attempt and advancement. Wireless sensor networks are nowadays measured as mainly the one of the best technology for constructing inexpensive sensor networks similar to intelligent building. Energy intelligent buildings are capable of reacting to their genuine utilization and modifications in their environment. Energy intelligent buildings supported from client work and activity should be capable of identifying occupant actions and building background, and to get used to buildings for reducing energy.

References

1. Agarwal, Yuvraj, et al. "Occupancy-driven energy management for smart building automation." *Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building*. ACM, 2010.
2. Doukas, H., Patlitzianas, K. D., Iatropoulos, K., & Psarras, J. (2007). Intelligent building energy management system using rule sets. *Building and Environment*, *42*(10), 3562–3569.

3. Barbato, Antimo, et al. “Home energy saving through a user profiling system based on wireless sensors.” *Proceedings of the first ACM workshop on embedded sensing systems for energy-efficiency in buildings*. ACM, 2009.
4. Kastner, W., Neugschwandtner, G., Soucek, S., & Newman, H. M. (2005). Communication systems for building automation and control. *Proceedings of the IEEE*, *93*(6), 1178–1203.
5. Chwieduk, Dorota. “Towards sustainable-energy buildings.” *Applied energy* 76.1 (2003): 211–217.
6. Bourgeois, Denis, Christoph Reinhart, and Iain Macdonald. “Adding advanced behavioural models in whole building energy simulation: a study on the total energy impact of manual and automated lighting control.” *Energy and Buildings* 38.7 (2006): 814–823.
7. Ehlers, Gregory A., Robert D. Howerton, and Gary E. Speegle. “Energy management and building automation system.” U.S. Patent No. 5,572,438. 5 Nov. 1996.
8. Nguyen, Tuan Anh, and Marco Aiello. “Energy intelligent buildings based on user activity: A survey.” *Energy and buildings* 56 (2013): 244–257.
9. Arampatzis, Th, John Lygeros, and S. Manesis. “A survey of applications of wireless sensors and wireless sensor networks.” *Intelligent Control, 2005. Proceedings of the 2005 IEEE International Symposium on, Mediterrean Conference on Control and Automation*. IEEE, 2005.
10. Österlind, Fredrik, et al. “Integrating building automation systems and wireless sensor networks.” *Emerging Technologies and Factory Automation, 2007. ETFA. IEEE Conference on*. IEEE, 2007.