Design of Smart Socket for Monitoring of IoT-Based Intelligent Smart Energy Management System

Challa Krishna Rao, Sarat Kumar Sahoo, M. Balamurugan, and Franco Fernando Yanine

Abstract Smart socket is designed for collecting and sending the data from the various nodes in one field to other fields. Smart socket consists of the Arduino_Uno, XBee, sensors, gateway, computer, USB, and IDE. This works emphasis on design and development of smart socket with wireless capability, this can be used to collect the data from each electrical device by using sensors. An XBee transmitter and receiver node are used for data communication in wireless networks. Real-time data gathered at the central node can be used to prioritize and schedule the appliances. Then, the system analyzes the data to generate control commands to turn the devices attached to the smart socket on or off. This paper presents the operation and functions of smart socket in different sensor network topologies. The results show that the proposed smart socket can correctly read the data from the various nodes and also send it to different nodes of different parameters.

Keywords Smart socket · IoT · Energy management

C. K. Rao (✉) · S. K. Sahoo
Parala Maharaja Engineering College, Sitallapalli, Berhampur, Odisha 761003, India
e-mail: krishnarao.challa@gmail.com

S. K. Sahoo
e-mail: sksahoo.ee@pmec.ac.in

C. K. Rao
Biju Patnaik University of Technology, Rourkela, Odisha 760010, India

M. Balamurugan
Jain Deemed to be University, Bengaluru, Karnataka 560041, India
e-mail: m.balamurugan@jainuniversity.ac.in

F. F. Yanine
School of Engineering, Universidad Finis Terrae, 1509 Santiago, Providencia, Chile
e-mail: fyanine@uc.cl

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2021

G. T. C. Sekhar et al. (eds.), *Intelligent Computing in Control and Communication*, Lecture Notes in Electrical Engineering 702,
https://doi.org/10.1007/978-981-15-8439-8_41

1 Introduction

Most of the technologies are dependent on the internet, and operation of devices through the internet is called the Internet of Things (IoT). It gives the improved solution to environmental issues. In the renewable energy system, the updating of smart grid gives several investigating issues similar to a prerequisite for technology-based metering, self-healing, etc. [1]. This improving end product includes products such as smart socket, smart receptacles, plus ordinary applications as domestic devices, smart grid, and automation. Internet of things based system will process work development, prioritizing duties plus assignments based on continuing assessment at a point of time, so the type of the organization can be monitored and efficient at regular intervals [2]. It is adaptable to domestic devices like lighting and thermal system, electrical and electronic gadgets, turning ON and OFF from local and remote location [3].

A different analysis was completed to estimate the energy price savings to the customer's absence of turning off the electric lamps and remain domestic appliances. Monitoring plus control of electrical devices based on time and possession can be considerably reducing energy expenditure cost. Hall Effect sensors are widely used as proximity sensors, position sensors, automotive sensors, voltage and current sensors, etc. The features of Hall effect sensors are high-speed operation, long life, no moving parts, and operated for wide temperature range (−40 to +150 °C). Hall Effect sensors can be used to measure both DC as well as AC because of the static and dynamic measuring capability [4].

Sensors are used to detect the magnetic field around the measuring terminals and there is no electrical contact between them which will consider as an additional advantage because it provides more safety to the device as well as sensors and it has very low-temperature dissipation compared to other sensors [4].

A smart socket is a device that is used to communicate data from an individual application in the environment to a gateway node. It consists of a microcontroller, sensor, XBee, ZigBee unit, and relay [1]. The smart socket is used to collect the utilization data from each device node and send it to the gateway node. The collected information is processed and appropriate resolution is received based on the constraints used by the parameter.

2 Smart Socket Model

A smart socket is the hardware device in an electrical system. A smart socket reads the power utilization of any appliance close to it. The data transmitted in real-time into the main controller to operate as inputs to the management algorithm. The socket can control the attached electrical device by turning it on or off. Figure 1 shows the design of the smart socket [3].

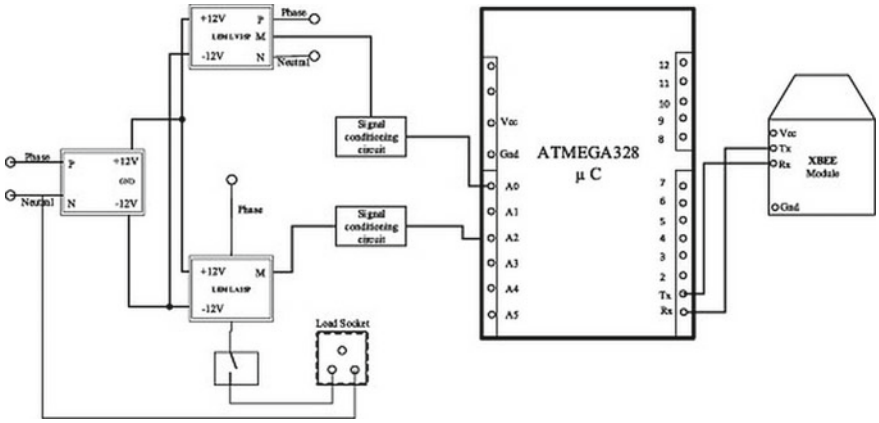


Fig. 1 The smart socket model [3]

Different methodologies are followed in the plan of the functionalities of a smart socket. The different protocols are used to collect the data from the sensors in the fields. This collected data transmitted to the gateway location with the help of communication techniques. Naturally, smart sockets carry out wireless communication by the main controller.

3 Smart Socket Components

This section describes the different components of smart socket and its functional operations.

3.1 Arduino_Uno

Arduino_Uno is integrated with different type's sensors, relays, and actuators and also allows monitoring and controlling different devices as shown in Fig. 2. It is used to collect information from different nodes deployed in the fields and also send information to different nodes in other fields. Arduino_Uno has functional libraries and can be downloaded from open-source and have different programming statements like other programming languages. It is used in many IoT based applications. Table 1 represents the specifications of Arduino_UNO.

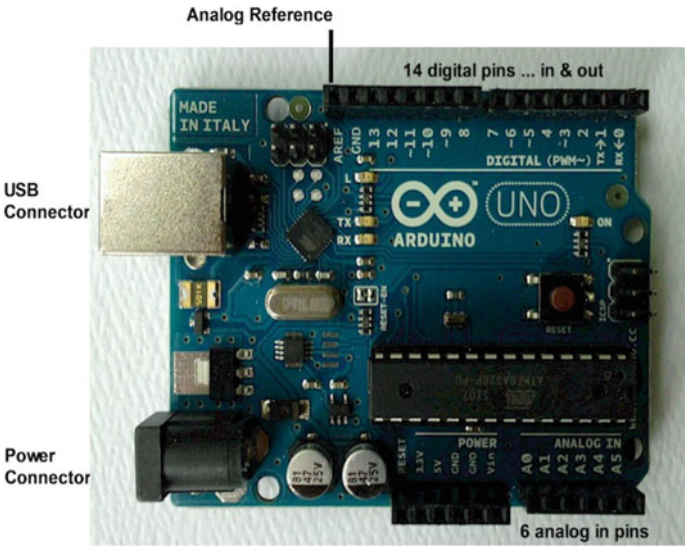


Fig. 2 Arduino_Uno pin diagram [5]

Table 1 Arduino_UNO specifications [5]

Parameter	Rating
Operating voltage	5 V
Clock speed	16 MHz
Digital input-output pins	14
Analog input pins	6
PWM pins	6
UART	1
Universal asynchronous receiver and transmitter	Dependent

3.2 XBee Module

This is a communication module, which is used to communicate data between two points. Figure 3 depicts the block diagram of XBee module and its pin configuration. Its operation can be divided into two main series, first one series is used for point-to-point communication, and second series used for different network topologies like star, tree, and mesh topologies. It is also an embedded system and provides the communication path with XBee protocol [1]. The parameters used in the XBee module is illustrated in Table 2.

Table 3 represents the comparison analysis of various communication protocols used.

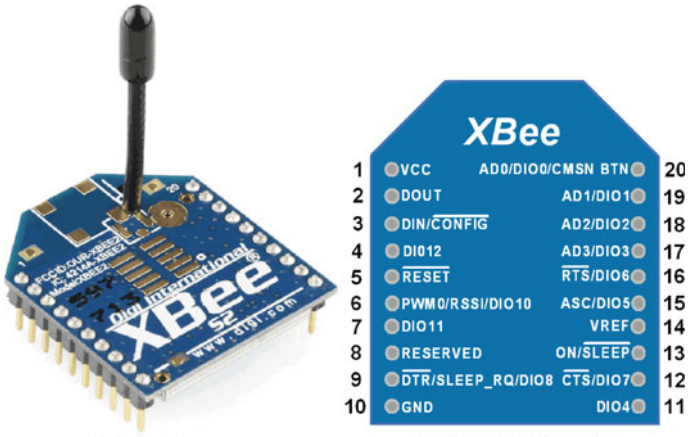


Fig. 3 XBee series [6]

Table 2 Parameters of XBee

Parameter	Rating
Working voltage	3.3 V
I/P pins	20
Digital I/O pins	12
Analog I/P pins	4
Clock speed	2.4 GHz
UART	1
Universal asynchronous receiver and transmitter	Dependent

Table 3 Comparison of wireless communication protocols [5]

	XBee	Bluetooth	Wi-Fi
Price	Low	High	High
Coverage (m)	10.0–100.0	10.0	100.0
Network topologies	Point–point, star, mesh, and tree	Piconet	Service set
Power required (mW)	63.0	100.0	0–500

3.3 Gateway

The gateway is a component, which is used to communication between different devices like smart socket, seniors, actuators, and web server. It is combination of Ethernet, XBee radio, an Arduino_Uno and power source, and interconnection between components as shown in Fig. 4.

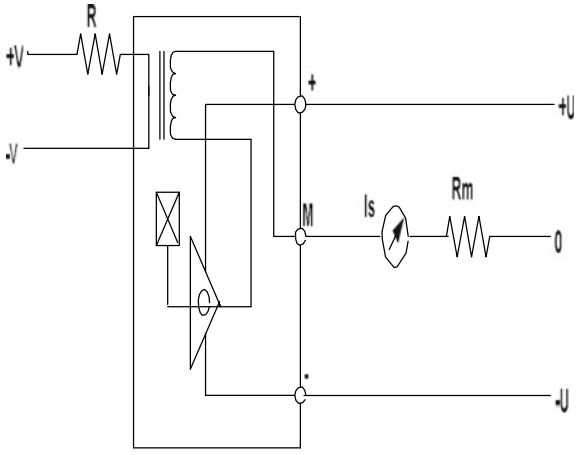
Fig. 4 Gateway module [7]

3.4 Voltage Sensor

Hall-effect voltage sensors are extensively used in power electronic applications as an important element of a control loop in industrial systems. Due to inherent galvanic isolation, the measuring capability of the sensor has a very high bandwidth compared to the other sensing techniques [8]. In Hall effect voltage sensors the voltage can be measured by inserting a resistor across the terminals of the primary coil of measuring device. The magnetic flux around the primary coil is balanced by secondary coil. Therefore the balanced voltage can be measured by using this sensor [8].

Figure 5 shows the connection diagram for LEM LV 25-P Hall effect voltage sensors which consists of resistor R, the input voltage ($+V$, $-V$), Is is the secondary coil current, Rm is the tunable resistor (trim pot) and output voltage ($+U$, 0, $-U$). It can sense the voltage up to 500 V (AC or DC). The features of Hall Effect Voltage sensors are excellent accuracy, linearity, isolation. A safe environment is provided for device safety, temperature drift is low and measurement can be done for high

Fig. 5 LEM LV 25-P voltage sensor [8]



voltage in networks. The applications of Hall-effect sensors in electrical systems are to detect, monitor, and regulate voltages of the different systems.

3.5 Current Sensor

The current sensor is used to measure the continuously changing current in order to afford feedback for the control systems which will pave the way for correct and smooth operation of the converter. In order to detect the transient response, inductor waveform is required [4]. The features of the current sensor are response time is fast, excellent accuracy, temperature drift is low, no insertion losses, excellent linearity, and it have also been operated in wide frequency range [4].

Figure 6 shows the connection diagram for LEM LA55-P Hall Effect current sensors, here, Ip is the primary coil current, Is is the secondary coil current, Rm is the tunable resistor (trimpot) and output voltage ($+U$, 0, $-U$). It can sense the current up to 50 A (AC or DC) and generate the output signal in the range of (0–10 V) by adjusting the gain of Trim pot (Rm). To protect the circuit against overloading conditions the current rating of the system should be monitored which will seriously affect the system and it will lead to short circuit, failure, or malfunction of a device if some appropriate measures are not taken. So, sensors play a vital role to detect the fault and to minimize its effect. The utilizations of current sensor will also improve the transient response and efficiency of the system and it is also used to detect the ground fault.

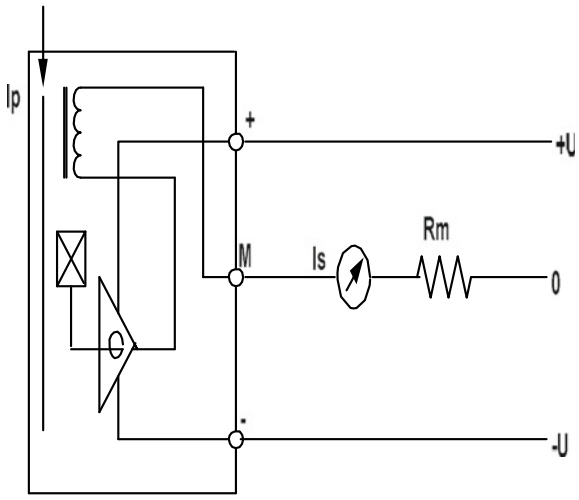


Fig. 6 LEM LA 55-P current sensor [4]

3.6 Breadboard

This is one of a kind board, which is used to integrate all components with the Arduino_Uno.

3.7 Relay Box

This box can be used to control the various tasks of the smart socket.

3.8 Ethernet Module

The Ethernet board as shown in Fig. 7. It is provided with the internet connection to the Arduino_Uno board and supports four-socket terminal points for external connection.

4 Implementation and Result

This section describes the implementation and result of the different components of smart socket and its performance.

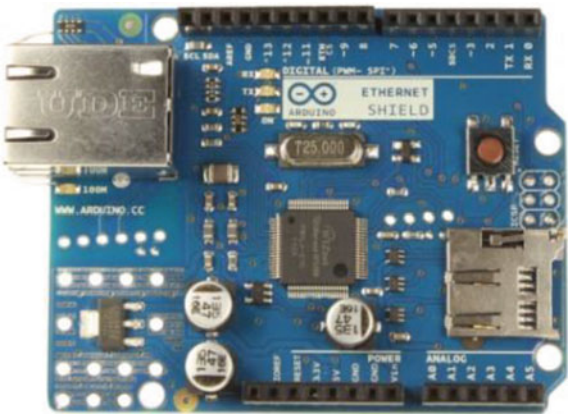


Fig. 7 Ethernet shield module [6]

4.1 The Block Diagram Model of Smart Socket

The smart socket is the main component of the system; its function is both controlling and monitoring of electrical devices. It is one kind of a socket linked to power source and to which the user connects the electrical devices. The smart socket consists of an Arduino_Uno, a microcontroller, sensors, XBee, plus relays. The smart socket diagram representation is shown in Fig. 8. The operation of Hall Effect based voltage and current sensor has described in the previous section with diagrammatic representation. The voltage rating of Arduino_Uno microcontroller is positive voltage with magnitude range (0–5 V). If the magnitude of input voltage is more than 5 V, it may get damaged. This problem can be solved by using a Zener diode with cut-off voltage of 4.70 V. The function of relay unit is the ability to turn the choosing device ON/OFF, i.e., depending on the information given by the controlling unit. The relay unit has a common pin which is connected to the other socket pin.

Figure 9 shows the various steps involved in the operations of the smart socket. It is based on developing programming code and uploading it to a board and getting results on the computer by program execution.

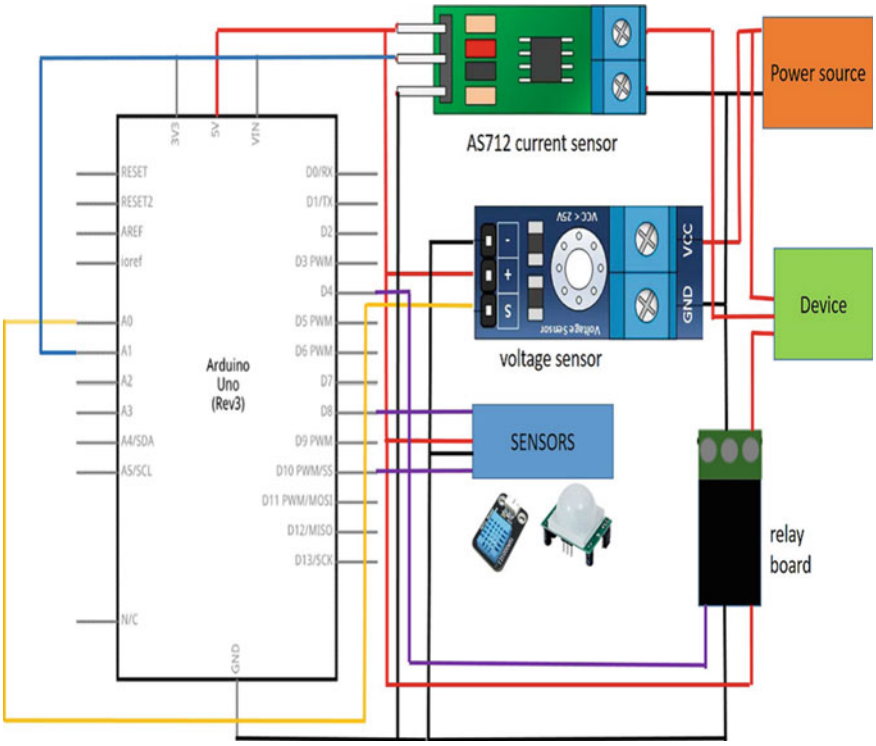


Fig. 8 Hardware setup block diagram of the smart socket [9]

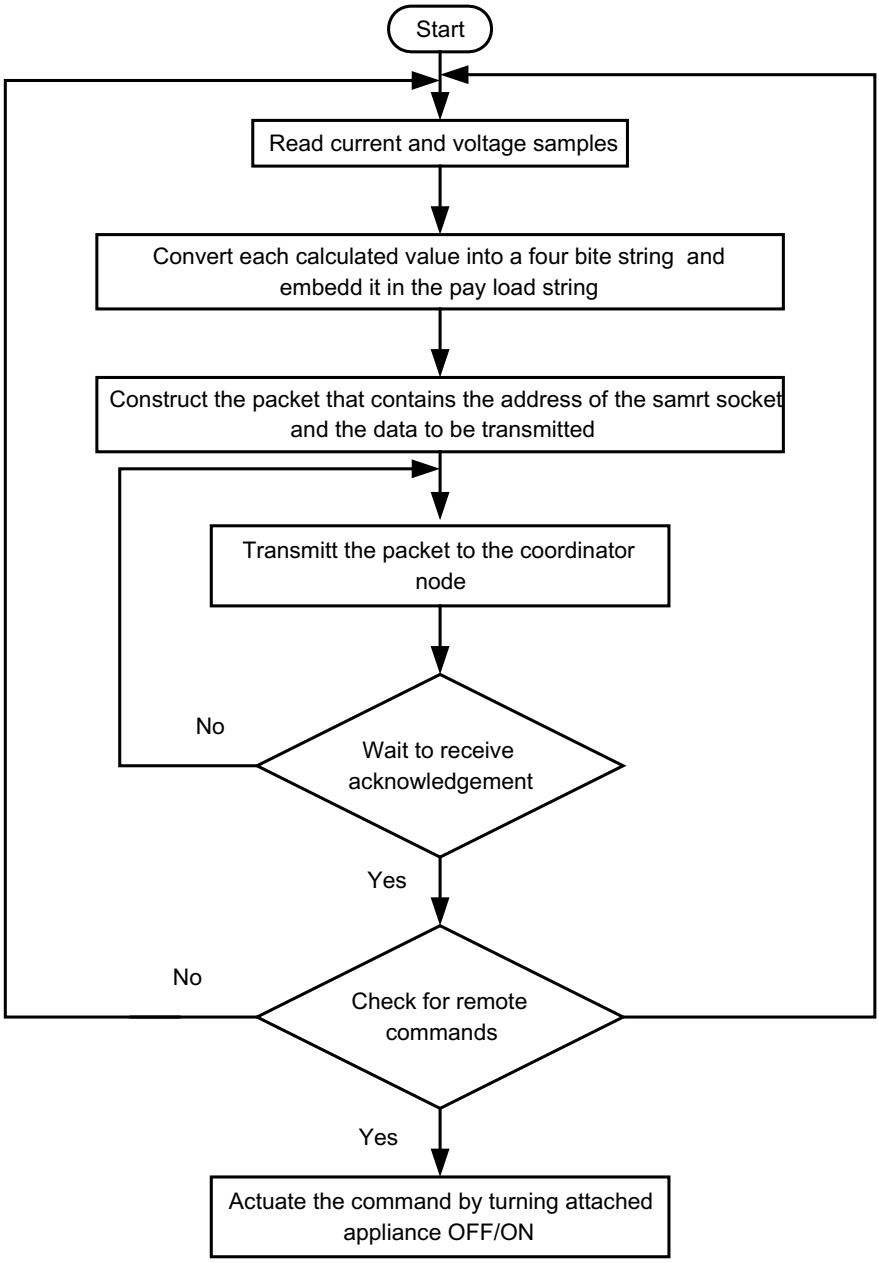


Fig. 9 Data processing in the smart socket [10]

4.2 Software Implementation of the Arduino_Uno

Nowadays, Arduino_Uno has become popular and an open-source programmable device in IoT. It is built with ATMEGA328 base microcontroller and IDE software. Figure 10 shows details of code uploaded to Arduino_Uno for the data receiving by serial communication. The function of the Arduino_Uno code is the collection of data from various sensors remotely. Second one is different coding for sending and receiving data from or to different components of the system.

Figure 10 shows the information collected from sensors and sent to both smart socket and gateway and two-way communication between them. The main aim of this test is to show information flow on a computer is by serial communication and the data is collected from the sensors. Figure 10 shows the Arduino_Uno connected to sensors by analog pins. It displays the information with serial communication on a computer screen.

Result: The development of programming code on the basis of the above flowchart is done by using IDE software. It is used for collecting data from various sensors, uploading the developed code into Arduino_Uno, and getting data from various sensors on the computer.

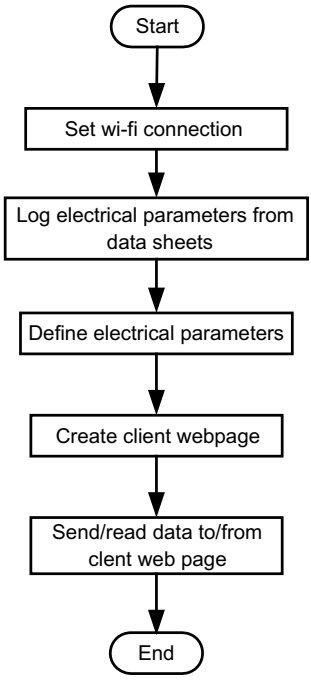


Fig. 10 Programming step of Arduino_Uno [11]

4.3 Implementing XBee-Arduino_Uno Interface

The XBee Series 2 unit has communication information device in the coordinator unit, based on the commands given by Arduino_Uno from various Router units via XBee unit and also collects the data that was obtained from the data uploaded to the local server using the Ethernet unit of the Arduino_Uno. The architecture of the XBee and Arduino_Uno interface is depicted in Fig. 11.

4.3.1 Router Node or End Node

This section describes the different components of Router node and its functional operations as shown in Table 4.

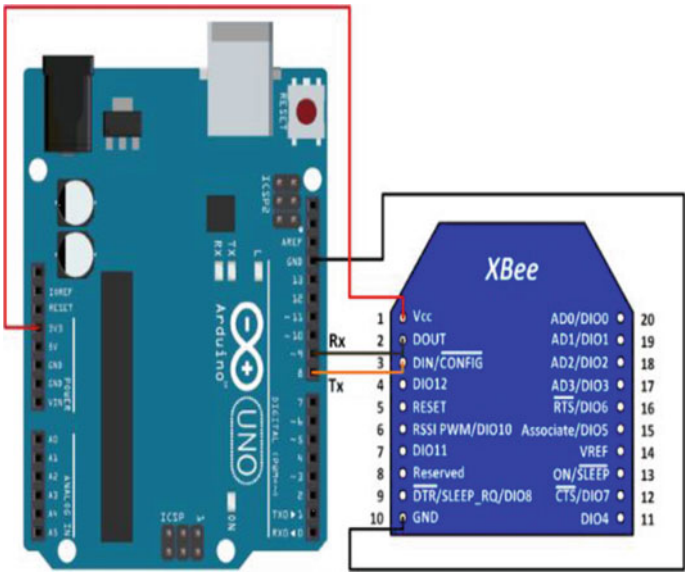


Fig. 11 XBee and Arduino_Uno interface [6]

Table 4 Components and its function [12]

Component	Function
XBee shield	Connecting the XBee and the Arduino
XBee series 2	Received sensing information from the Arduino plus sending the information to the coordinator node
Arduino_Uno	The program that collects the ongoing output used as communication link between the XBee and the sensors
Sensors' circuit	Receive information from the fields

Table 5 Components and its function [12]

Component	Function
XBee shield	A message link between the XBee and the Arduino
XBee series 2	Collect sensing data sent from the radio of the router node
Arduino_Uno	Communication link between the Bee and the computer
Ethernet shield	Message link between the coordinator and the database

4.3.2 Coordinator Node or Base Station

Table 5 describes the different components of coordinator node and its functional operations.

4.4 Programming the XBee-Arduino_Uno Interface

Arduino_Uno has a simple programming language and easy to use and flexible. It is open-source programming software and used to collects data from sensors deployed in the field. It is similar to other programming languages and based on processing. Using XBee protocol, to send data collected from sensors remotely from one to other station.

4.4.1 Programming XBee Coordinator or Router Node-Arduino_Uno Interface as Receiver

The router was collected information from the same field in environment as the coordinator and the programming was writing based on IDE software and the following flow chart shows the implementation steps.

Figure 12 shows, the connection details of an Arduino_Uno, XBee, USB to a computer, the sensor networks, and the router station and the programming code of coordinator node is shown in Fig. 13.

Result: When the router sending a message to the coordinator and that message received by the coordinator, it collects the data from the sensor as shown in serial monitor of the Arduino_Uno interface.

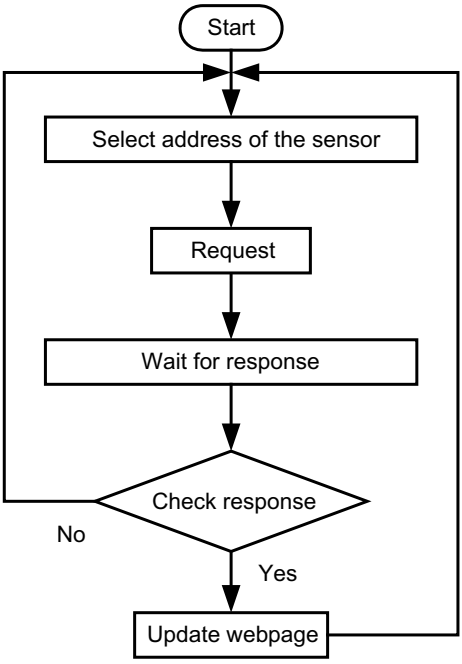


Fig. 12 Programming ladder of coordinator node [12]

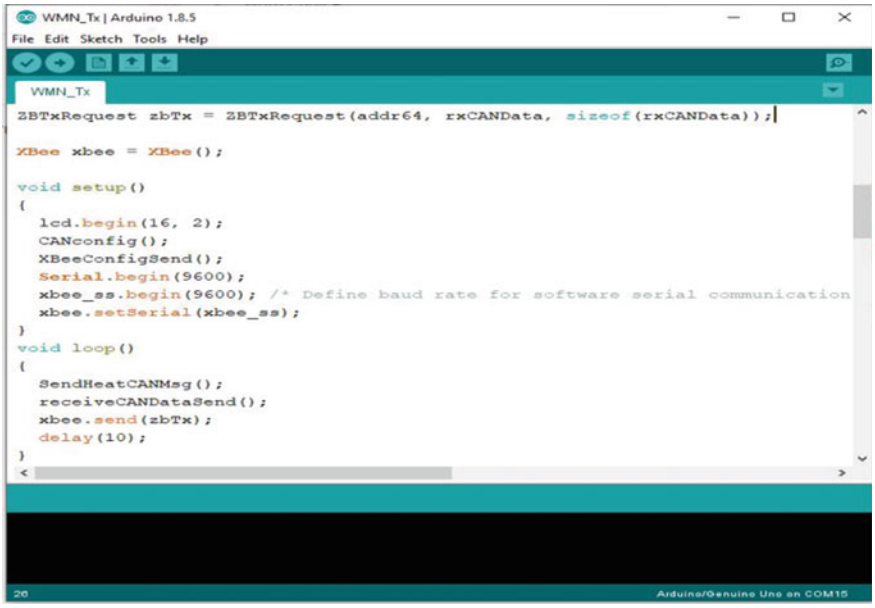


Fig. 13 Programming of coordinator node [5]

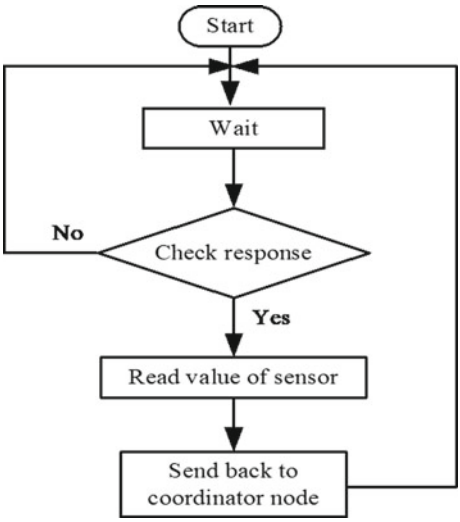


Fig. 14 Programming ladder of the coordinator node [12]

4.4.2 Programming XBee End-Device-Arduino_Uno Interface as Transmitter

The IDE software programmed end devices act as the transmitter connected to the sensor and received information from it and send the information via the router in the same field to the base station. The steps for programming method is shown in Fig. 14.

Result: When the router sending a message to the coordinator and that message received by the coordinator, it collects the data from the sensor as shown in serial monitor of the Arduino_Uno interface. The sensor output of the Coordinator node is depicted in Fig. 15.

5 Conclusion

This paper presents the design and software implementation of smart socket for IoT based smart energy systems. In addition to that, the characteristic feature of Hall Effect voltage and the current sensor has been presented in detail along with its application. The implementation of the smart socket based on Arduino_Uno, XBee, gateway, sensors, and software IDE. From the discussions, it has been conveyed that the socket is used to collect the data from various sensors and sending data to different fields. It is understood that this paper will afford a valuable source of information for researchers in the field of smart energy management systems.

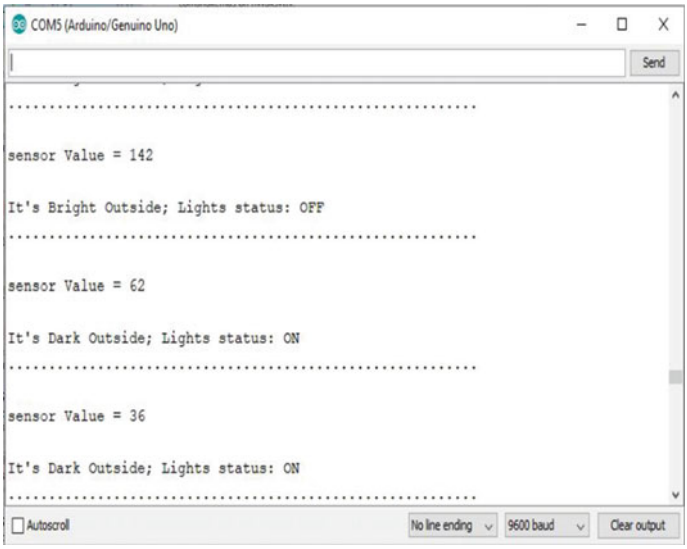


Fig. 15 Sensor output of the coordinator node [5]

References

1. Lem (2013) Voltage transducer LV 25-P I PN = 10 mA V PN = 10–500 V, data sheet. 18–20
2. Ziegler S, Woodward RC, Ho H, Iu C, Borle LJ (2009) Current sensing techniques: a review. IEEE Sens J 9
3. Pawar P, TarunKumar M, Vittal PK (2019) An IoT based intelligent smart energy management system with accurate forecasting and load strategy for renewable generation. Measurement
4. Rao CK, Sahoo SK, Balamurugan M, Satapathy SR, Patnaik A, Yanine FF (2020) Applications of sensors in solar energy systems. In: ICREISG-2020, Bhubaneswar, 14–15 Feb 2020
5. Tutorials point (2018) Arduino program structure. Available online: https://www.tutorialspoint.com/arduino/arduino_program_structure.htm
6. XBee 2 mW antena de PCB Serie 2. Available on https://5hertz.com/index.php?_page=product_info&products_id=324
7. Smart home energy management system monitoring and control of appliances using an Arduino based network in the context of a micro-grid. Available on https://www.aui.ma/sse-capstone-repository/pdf/Smart-Home-Energy-Management-System
8. Management system using rule-based controller on https://scholarworks.uaeu.ac
9. Lee S-H, Yang C-S (2017) An intelligent power monitoring and analysis system for distributed smart plugs sensor networks. Int J Distrib Sens Netw 13(7)
10. Al-Hassan E, Shareef H, Islam MM, Wahyudie A, Abdrabou AA (2018) Improved smart power socket for monitoring and controlling electrical home appliances. In: 2018 IEEE conference
11. Monzer KM, Tariq YM, Farouq A-T (2019) New design of socket modules for smart home applications. Instrum Mesure Metrol 18(1):43–48
12. DIGI International (2019) Zigbee wireless mesh networking. Available online: https://www.digi.com/resources/standards-and-technologies/zigbee-wireless-standard