Monitoring and Controlling of Smart Homes using IoT and Low Power Wireless Technology

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Abstract
Background/Objectives: IOT is the network of physical objects that are incorporated with electronics, software, sensors and connectivity to enable objects to exchange data with the manufacturer/operator/other devices connected. The objective of this paper is to monitor and control the smart home system from anywhere around the world. Methods/Statistical Analysis: With more and more applications of IOT in various domain, it also steps into smart homes. Smart home system is one of the most essential application using IOT. In this paper the ZigBee technology is used for the networking of smart things i.e., the objects that are to be monitored and controlled. The smart home system consists of various sensors like temperature sensor, motion sensor, air flow sensor, ultrasound sensor and actuators for controlling the smart home system. These sensors are connected to the ZigBee modules which are interfaced with Arduino boards. This setup forms the network with the WiFi modem through which the monitored data's are entered into the internet server. An android application is established with which the user can monitor his/her home anywhere in the world. The performance of IEEE 802.15.4 (ZigBee) is also analyzed, which includes the parameters such as the SNR and BER. This is in dubiously going to be a milestone for the next generation since it moves the field forward by automation of home. Findings: The performance analysis of SNR and BER was carried out it was inferred that as SNR increases the BER decreases with respect to the number of bits transmitted. Application/Improvements: Android application can be developed to monitor and control the smart home system.

Keywords: Arduino, Actuator, Coordinator, IOT, Router; Sensors, ZigBee

1. Introduction
There’s a lot of talk these days about ‘Smart’ Things, ‘Smart’ Phones, ‘Smart’ Homes. What the word ‘Smart’ really does is to take some input from somewhere, apply some processing and take some actions. These notions has been in existence for many years till now and also in the future. Almost all technical communities are clear about producing a smart thing, which has a drastic evolution. These mostly belong to the research community. One of such prominent research community is the IOT (Internet of Things)¹. There are no appropriate definitions for IOT as its still research oriented. IOT is nothing but the network of physical objects that are incorporated with electronics, software, sensors and connectivity to enable objects to exchange data with the manufacturer/operator/other devices connected². In simple words IOT is just connecting any object to the internet it can either be a fan or TV or A/C etc., Many people including myself hold the view that the entire world will soon be overlaid with the concept of sensing and actuation, which is often referred to as the ‘smart world’. In this system sensors such as the temperature sensor, Pressure sensor, Motion sensor, ultrasound sensor and humidity sensing platforms are incorporated. Currently there are many projects that Concentrate on Smart Home System. All these projects just involve with the monitoring of the smart homes for example like monitoring the temperature, to check if any devices are switched on etc. The main drawback of the existing smart home system is that you can just monitor

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the home but it cannot be controlled. Another factor is that they consume more power. Thus in my paper I bring into the scenario of monitoring as well as controlling of smart homes from anywhere around world using an Android application, is introduced where IPT plays a major rule incorporating a low power wireless technology like the ZigBee technology.

In the distant future is presented. The eight key research topics are enumerated and research problems are also being discussed.

In gives the detailed status of development of IOT in China's perspective is given. It depicts such technologies, applications, and standardization, and also proposes an open and general IOT architecture consisting of three platforms to meet the architecture challenge. It also discusses the opportunity and prospect of IOT.

In mentioned that there has been increased interest in the ZigBee standard, in particular for building automation and industrial controls. The ZigBee Alliance has identified six application spaces for ZigBee: Consumer electronics, PC and peripherals, residential/light commercial control, industrial control, building automation and personal healthcare. This article deals mainly with industrial control and building automation. Increasingly, companies developing monitoring and control applications in industrial and commercial building environments are looking to wireless technologies like ZigBee to save the cost of wiring and installation and also to allow more flexible deployment of systems.

2. System Model

2.1 Working Principle

The main aim of the work is to monitor and control the smart home system. Parameters such as the temperature, humidity etc., has to be monitored and the required electronic devices has to be controlled. Various sensors are incorporated to monitor the corresponding data. Initially all the ZigBee modules have to be interfaced with the Arduino boards. Then the ZigBee's are to be configured as routers and coordinators to form the network. All these sensors that are to be used are first connected to the ZigBee routers and the corresponding codes for the sensor to sense the data are dumped into the microcontroller. Each Zigbee router transmits the sensed data to the ZigBee coordinator, which then sends the resultant to the server. These data that are put up on the server can be accessed by the user with the help of an Android application thus enabling monitoring and controlling.

2.2 Block Diagram of Smart Home System

Basically, there are five main modules which include an Arduino to which the ZigBee Module is interfaced. The sensors are connected to the above setup. The ZigBee wirelessly connects to LAN which is connected to the internet server. Figure 1 shows the block diagram of the smart home system.

2.3 Block Diagram Description

2.3.1 Control Module

The control module is basically an embedded board which implements the control and data busses to communicate with the sensor module. We use an Arduino Uno board in which it has 6 analog pins and 14 digital I/O pins. It also has an analog to digital converter which converts the analog value obtained from the output of the sensor to a digital value.

The control module consists of an inbuilt ATmega328p microcontroller. An ATmega328P on the board channels the serial communication over USB and appears as a virtual com port to software on the computer.

2.3.2 Sensors and Other Devices

The sensors includes the temperature sensor, Gas sensor, Air flow sensor, leakage sensor, motion sensor etc., these

Figure 1. Block diagram of the proposed smart home system.
are used to sense the corresponding data’s. Other devices can be a fan, light, Ac, refrigerator and anything that has to be controlled.

3. Software Configuration of Zigbee Module

3.1 Software Implementation

3.1.1 Simulation in X-CTU

XCTU is a free multi-platform application designed to enable developers to interact with Digi RF modules through a simple-to-use graphical interface. It includes new tools that make it easy to set-up, configure and test ZigBee modules. XCTU includes all of the tools a developer needs to quickly get up and running with ZigBee. Unique features like graphical network view, which graphically represents the ZigBee network along with the signal strength of each connection, and the ZigBee API frame builder, which intuitively helps to build and interpret API frames for ZigBees being used in API mode, combine to make development on the ZigBee platform easier than ever.

3.1.2 Steps for Configuring ZigBee in XCTU

- Open XCTU software.
- Select the Com port to which the XBee that is to be configured is connected.
- Click On Test/Query.
- Once it detects the module, click on modem configuration and click READ.
- Select the function set of the XBee module as a router or Coordinator.
- Now enter a PAN ID for the device.
- Enter the destination address High and Low.
- Click write.
- Repeat the above steps for other XBee modules.
- Click terminal window and type a message in a terminal of a router/coordinator and see if it is being received in the other terminal. This confirms that the communication link has been established between the two XBee modules.

The Figure 2 shows the screen shot of configuring the two ZigBee’s as router and coordinator.

The above Figure 2 shows the window of the X-CTU software in which the ZigBee is being configured as

Figure 2. Screenshot of ZigBee being configured as. (a) Router. (b) Coordinator.

Router. Under networking, the PAN ID has to be entered which is the unique identification id of the particular ZigBee that is connected to port COM6 as shown in the title bar of the window in Figure 2(a). Addressing plays the most prime role in configuring the ZigBee modules. It is where the destination address of another ZigBee module to which the communication link is to be established is given. Serial number high and Serial number low are the two unique numbers of the ZigBee module that we use (printed behind the XBee module). As we are establishing a communication link with another ZigBee the destination address high and destination address low are the serial number high and low of the destination ZigBee. Once all these required data are written now the ZigBee is completely configured.

3.1.3 Communication Link

Once the ZigBee’s are configured as routers and coordinators correspondingly as mentioned in Section 3.1.1-3.1.2 a communication link is established. Once a communication link is established it is tested by sending a test message from router to coordinator and vice versa. The X-CTU window of the message transfer is shown in Figure 3.

3.1.3 Uploading the Code into Microcontroller

The IDE used is AVR STUDIO 6. The steps used to run a code in an Arduino UNO board are:

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• Connect the USB to the board. A green LED blink ensures the power is ON.
• Open Arduino and write the program.
• Click ‘Verify’ Button to check if the code is error free.
• Click ‘Upload’ Button to dump the code to the microcontroller.
• Open ‘Serial Monitor’ on the Right top to view the output.

4. Sensors and Other Devices

4.1 Temperature Sensor

It measures the amount of heat energy or even coldness that is generated by an object or system, allowing us to “sense” or detect any physical change to that temperature producing either an analogue or digital output. In this case the room temperature is measured in Celsius using the temperature sensor LM35. The sensor is connected to the ZigBee router. The ZigBee coordinator is programmed in such a way to receive and display the measured temperature wirelessly. The room temperature is measured with a delay of 1 second. Figure 4 shows the experimental setup of the temperature sensor.

Figure 5 shows the serial monitor output of the temperature sensor. The temperature sensed at the ZigBee router side is transmitted to the coordinator and the serial monitor of the corresponding port to which the coordinator is connected displays the sensed temperature.

4.2 Air Quality and Gas Sensor

The Air quality sensor MQ-135 is used to collect high resolution readings of NO₂ and CO concentrations outside the home. These two gases are the most indicative elements related to urban pollution that are sense-able by inexpensive sensors. The sensor is connected to the ZigBee router. The ZigBee coordinator is programmed in such a way to receive and display the measured concentration of NO₂ and CO in volts wirelessly. The concentration of NO₂ and CO is measured for every 1 second.

Figure 6. Shows the experimental setup of the air quality sensor and Figure 7 shows the serial monitor output of the air quality sensor.

4.3 PIR Sensor

Passive Infrared Sensor is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. They are most often used in PIR-based motion detectors. A PIR-based motion detector is used to sense movement of people, animals, or other objects. It detects any motion with coverage region of 10 meters and an angle of 15 degrees. The sensor is connected to the ZigBee router. The sensor senses the motion detected and sends it to the coordinator through the ZigBee router. The ZigBee coordinator is programmed in such a way to receive and display the motion detected wirelessly.

Figure 8 shows the experimental setup of the PIR sensor and Figure 9 shows the serial monitor output of the PIR sensor.
4.4 Humidity Sensor
Humidity sensors DTH-11 are employed to provide an indication of the moisture levels in the environment. Humidity sensing is very important, especially in the control systems for industrial processes and human comfort. For domestic applications, humidity control is required for living environment in buildings, cooking control for microwave ovens, etc. The sensor is connected to the ZigBee router. The sensor senses the humidity and sends to the ZigBee coordinator through the router. The ZigBee coordinator is programmed in such a way to receive and display the humidity in percentage wirelessly.

Figure 10 shows the experimental setup of the humidity sensor and Figure 11 shows the serial monitor output of the humidity sensor.

4.5 Ultrasound Sensor
Ultrasound sensors are used sense any obstacle and calculate the distance between the sensor and the obstacle. The sensor sends a sound signal in LOS and when incident on any obstacle it gets reflected back to the sensor. This distance is measured in terms of centimeters and is sent to the ZigBee coordinator through the router. The ZigBee coordinator is programmed in such a way to receive and display the distance in centimeters wirelessly.

Figure 12 show the experimental setup of the ultrasound sensor and Figure 13 shows the serial monitor output of the same.
Figure 10. Experimental setup of humidity sensor.

Figure 11. Serial monitor output of temperature and humidity sensor.

Figure 12. Experimental setup of ultrasound sensor

4.6 Smoke Detector
MQ-2 Smoke detector is the smoke sensor that senses smoke, typically as an indicator of fire. The sensor is connected to the ZigBee router. The sensor senses the changes in air and when it encounters any change then it gives an alert and sends it to the ZigBee coordinator through the router. The ZigBee coordinator is programmed in such a way to receive and display the humidity in percentage wirelessly. Figure 14 shows the serial monitor output of MQ-2 smoke sensor.

4.7 Fan Control
The below setup shows the Fan Control using XBee’s. We have one ZigBee Coordinator and one ZigBee Router. The fan that is to be controlled is connected to the router and the instruction for the Fan to be ON for particular time and fan to be OFF for particular time is sent from coordinator. The experimental setup is shown below in Figure 15.

4.8 Integrating ZigBee with the Internet Server
In order to transfer the acquired sensor data into the internet server we use the wifi module ESP-8266. ESP-8266 is a low cost wifi chip with full TCP/IP stack and microcontroller capability. ESP-8266 can be used for many IOT applications.

The transmitter pin TX of the ESP-8266 is connected to the receiver pin of the ZigBee module and the receiver pin RX of the ESP-8266 is connected to the transmitter pin of the ZigBee module. This ESP-8266 module is con-
Figure 15. Experimental setup of fan control.

figured so as to get connected with the wifi modem in its range. This initiates the transfer of sensed parameters to the modem wirelessly through which it is put up into the server.

5. Performance Analysis of IEEE802.15.4 (Zigbee)

The parameters such as the path loss, SNR, BER for IEEE802.15 (ZigBee) are analyzed. We know Linear path loss of the channel is the ratio of transmit power to receiver power.

Path loss of the signal of 2.4 Ghz frequency band in indoor environment is given as

\[ PL = \frac{P_t}{P_r} \] (1)

Pt is the transmitted power and Pr is the received power

Path loss of channel in dB is given as

\[ PL(dB) = 10 \log_{10} \left( \frac{P_t}{P_r} \right)(dB) \] (2)

Path loss in free space is given as

\[ PL_{Free\,space} = 20 \log_{10}\left(\frac{4 \pi d}{\lambda}\right) \] (3)

Here 'd' is the distance between the transmitter and receiver, \(\lambda\) is the wavelength

Let us assume d = 10 m; \(\lambda = c/f\); where f = 2.4 GHz and c = 3x10^8 (m/s).

For studying the performance of Zigbee the important parameter considered is BER (Bit Error Rate). The BER of ZigBee is given as

\[ BER(Y) = \frac{1}{2} \sigma Y \left( \frac{1}{\log_2 M \tan(\pi/M)} \right) - \frac{1}{8} \sigma^2 Y \left( \frac{1}{\log_2 M \tan(\pi/M)} \right) \] (4)

Where \(Y\) is the SNR and M is the number of bits per symbol. For obtaining and substituting the SNR value in Equation (4), the Equation required is the system gain. The system gain is given as

\[ A_s = 10 \log_{10} \left( \frac{P_t}{SNRFKT_0B} \right) - D \] (5)

Where, \(P_t\) - Transmit power, F - Noise figure, T - Temperature, B - Bandwidth

From Equation (2) and (5), we get a relation between SNR and Path loss

\[ SNR = \frac{P_t}{P_{L,FK,T,B}} \] (6)

Here F is the frequency, ‘k’ is the boltzmann constant and ‘B’ is the bandwidth and ‘T’ is the room temperature.

We assume F = 10 dB and K = 1.38*10^-23, B = 2.4 GHz, T = 318.5.

By varying \(P_t\) from 0 dbm to 25 dbm, we get different values of SNR. Substituting these values of SNR into the BER Equation (4) the BER performance can be obtained. Using Mat lab simulation tool the output obtained is as shown in Figure 17.
The above graph Figure 17 shows the simulation result of the graph plotted for SNR vs BER of IEEE802.15.4. The parameters such as the path loss, BER, SNR of the ZigBee modules are determined theoretically. It is found that as the distance between the transmitter and receiver increases the path loss increases as it depends upon the distance. As the path loss increases the SNR decreases. Thus the BER increases. On the whole it is observed that if the distance increases, SNR increases and BER decreases. And s the number of bits ‘M’ increases the BER decreases hence SNR increases.

6. Zigbee to Internet

6.1 ESP8266 Wifi Module
In order to transfer the acquired sensor data into the internet server we use the wifi module ESP-8826. ESP-8266 is a low cost wifi chip with full TCP/IP stack and microcontroller capability. ESP-8266 can be used for many IOT applications.

6.2 Experimental Setup
The ESP8266 is connected to the Arduino wifi module which is connected to the laptop for configuring. The Tx of the Wifi module is connected to Rx of ESP8266 and Rx to Tx. Then the corresponding ground and Vcc pins are also connected. The ESP8266 works with the power supply of 3v from the Arduino wifi module. The GPIO 0 pin is connected to ground and CH PD pin is connected to the power supply of 5v. The GPIO 2 is connected to Tx of the ZigBee coordinator. The Figure 20 shows the experimental setup of the ZigBee being connected with ESP8266.

The ESP8266 is configured with the WiFi modem present in that home scenario to send the data to internet through it.

The Figure 21 shows the connection setup of ESP8266 with the WiFi module and Figure 22 shows the entire experimental setup of ZigBee being incorporated with ESP8266.

6.3 Thingspeak
Thingspeak is a web application that is associated with the Internet of Things. It provides facility to access anything from anywhere around the world. i.e., in our smart home system we are incorporating many sensors such as temperature, humidity, air quality, PIR and ultrasound sensor. The measured sensor data has to be viewed when we are physically not available at home. Hence the Thingspeak helps us to view these measured sensor data online. The measured sensor value is sent to the ZigBee coordinator which sends the data further to the ESP8266.

Figure 17. SNR vs BER graph.
Figure 18. ESP8266 Wifi module.
Figure 19. ESP8266 pin configuration.
Figure 20. Experimental setup of ZigBee connected with ESP8266.
6.4 Thingspeak Web Application

The below Figure 23 shows the thing speak webpage where the temperature and humidity is being viewed.

7. Conclusion

In this paper, Smart home system was built using IOT and low power wireless technology (ZigBee). This system is used to monitor and control the smart home through internet. The aim of this project is to monitor the home by employing various sensors in it and to control the electronic devices in home. This is achieved by updating all the obtained parameters in to the internet server and accessing it through the Android application.

8. References