



CONVIVIAL: Connecting Homes

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Abstract: Convivial, a French word, meaning ‘user friendly’ is a new concept of home automation and security. This project aims to eradicate human efforts by automation. Nowadays, in an era of digitizing everything from a small scale to large scale. The main aim of this project is to make lifestyle easy at the tip of the fingers. Taking into consideration the cost as well as the quality, the idea of this project was developed. The already existing products which are available in the market are either very costly or not as effective as it is needed to be. The existing market provides two different products for the purposes, which has been inculcated in one i.e. automation and security both. The exclusive thing in this project is that it can support multiple room and multiple switches option with a customizable mobile application for controlling the home appliances. The project will make use of ZigBee. It is a technical standard for communication protocols using small, low power, digital radios for personal area networks (PAN), IEEE International Standard 802.15.4, typically operating at 2.4 GHz. Its target market is low power applications with infrequent data transmission needs. Xbee is Digi International's in house Zigbee communication module brand.

Keywords: Automation, ZigBee, Raspberry pi, Smart Home, Android Application.

I.INTRODUCTION

Home automation is not new! Throughout history, we have continuously strived to automate tasks in the home in order to make our lives easier. Technology has now advanced to the point at which we wish to take an integrated approach to home automation, allowing appliances to communicate with each other and to be controlled in flexible ways. A wireless network approach to this communication and control provides an easy, cost-effective and scalable solution to home automation. Home automation is a modern technology that modifies the home to perform different sets of tasks automatically. Today, automation technology is gaining more recognition among the people not just for home modification but in industrial and business sectors too. Home automation is developed to make life more relaxed for people as well as easier. In the project “Convivial – Connecting Homes”, the flexibility for the user to add and change the number of rooms and the number of appliances according to his home requirement is kept. A mobile application will help to do all the changes mention Ned in a go. The user can access all the appliances just with the help of an application thus making life simpler. The project will make use of ZigBee. It is a technical standard for communication protocols using small, low power, digital radios for personal area networks (PAN), IEEE International Standard 802.15.4, typically operating at 2.4 GHz. IEEE 802.11 is a family of standards; IEEE 802.11b is selected here because it operates in 2.4 GHz band, which is common with Bluetooth and ZigBee. IEEE 802.11b has a high data rate (up to 11 Mbps), and providing a wireless Internet connection is one of its typical applications. The indoor range of IEEE 802.11b is typically between 30 and 100 meters. Bluetooth, on the other hand, has a lower data rate (less than 3 Mbps) and its indoor range is typically 2–10 meters. One popular application of Bluetooth is in wireless headsets, where Bluetooth provides the means for communication between a mobile phone and a hands-free headset. ZigBee has the lowest data rate and complexity among these three standards and provides significantly longer battery life. ZigBee's target market is low power applications with infrequent data transmission needs. Xbee is Digi International's in house Zigbee communication module brand. ZigBee standard offers a mechanism to allocate addresses to devices in a tree network. This is known as the default distributed address allocation. ZigBee Home Automation (HA) is a public application profile that has been devised by the ZigBee Alliance to support home automation solutions based on the ZigBee PRO wireless network protocol. ZigBee PRO is fully described in the ZigBee PRO StackUser Guide (JN-UG-3101). A Mesh network topology is employed. Therefore, for maximum routing flexibility, all the network nodes of an HA system should be ZigBee Routers (although ZigBee End Devices are permitted, they cannot perform Mesh routing). The manufacturer application that runs on an HA node provides the interface between the HA profile software and the hardware of the node (e.g. the physical switch mechanism of a lamp). The HA profile contains a number of ‘devices’, which are ZigBee software entities used to implement particular functionality on a node - for example, the ‘On/Off Light’ device is used to switch a lamp on and off. The set of devices used in a node determines the total functionality of the node. Each HA device uses a number of clusters, where most clusters used in the HA profile come from the ZigBee Cluster Library (ZCL).



II. PROPOSED SYSTEM

Home automation systems face four main challenges; these are high cost, inflexibility, poor manageability and advanced security. The main objective of project is to design and to implement a cheap and highly reliable home automation system which will be capable of controlling and automating most of the house appliance through an easy manageable web interface to run and maintain the home automation system. The proposed system has a great flexibility by using internet and server based technology to interconnect its distributed modules to home automation server. This decreases deployment cost and will increase the ability of upgrading, and system reconfiguration. The ZigBee technology used here can expand its network up to 65000 devices thereby opening an option for expansion of the range and can be deployed on a large scale networks for eg. building automation. Each system will be inter-connected to the controller fetching data from the server end. The main motive of the proposed project is to minimize the cost as well as provide efficient services. An application is to be built which will accommodate details of each and every room and will be flexible enough to add or subtract number of rooms. The use of a common application is necessary for upgradation from maybe a single room to multiple rooms. The application and the hardware have to be flexible enough to work in all possible situations. Coming to the security aspect of the project, a security system can consist of several sensors, including motion detectors, glass-break sensors, and security cameras. These devices need to communicate with the central security panel through either wire or a wireless network. ZigBee-based security systems simplify installing and upgrading security systems. Despite ZigBee's low data rate, it is still possible to transfer images wirelessly with acceptable quality. For example, ZigBee has been used in a wireless camera system that records videos of visitors at a home's front door and transmits them to a dedicated monitor inside the house.

III. CIRCUIT COMPONENTS & BLOCK DIAGRAM

Circuit Components:

- XBeeDigiMesh 2.4 as a coordinator (XBee Gateway)
- XBeeDigiMesh 2.4 as a node (Receiver)
- Protoboard and XBee Protoboard Adapter
- XBee USB Explorer
- X-CTU tool
- Python script to receive XBee signals and insert sensor values into mySQL database
- mySQL database on server
- Power Supply cable of 3.3V
- Raspberry Pi v3B
- HDMI cable
- 7 inch LCD screen

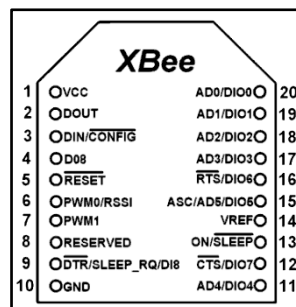


Figure 1 Pin Configuration of XBee S2C

IV. METHODOLOGY

ZigBee defines three different device types: Coordinator, Router, and End device.

COORDINATOR

ZigBee networks always have a single coordinator device. This device Starts the network, selecting the channel and PAN ID distributes addresses, allowing routers and end devices to join the network buffers wireless data packets for sleeping end device children. The coordinator manages the other functions that define the network, secure it, and keep it healthy. This device cannot sleep and must be powered on at all times.

ROUTER

A router is a full-featured ZigBee node. This device can join existing networks and send, receive, and route



information. Routing involves acting as a messenger for communications between other devices that are too far apart to convey information on their own. It can buffer wireless data packets for sleeping end device children. It can allow other routers and end devices to join the network. Routers cannot sleep and must be powered on at all times. The network may have multiple router devices in a network.

END DEVICE

An end device is essentially a reduced version of a router. This device can join existing networks and send and receive information, but cannot act as messenger between any other devices. It cannot allow other devices to join the network. End device uses less expensive hardware and can power itself down intermittently, saving energy by temporarily entering a nonresponsive sleep mode. They always needs a router or the coordinator to be its parent device. The parent helps end devices join the network and stores messages for them when they are asleep. ZigBee networks may have any number of end devices. In fact, a network can be composed of one coordinator, multiple end devices, and zero routers.

MESH TOPOLOGY

In a mesh topology, in contrast to the tree topology, there are no hierarchical relationships. Any device in a mesh topology is allowed to attempt to contact any other device either directly or by taking advantage of routing-capable devices to relay the message on behalf of the message originator. In mesh topology, the route from the source device to the destination is created on demand and can be modified if the environment changes. The capability of a mesh network to create and modify routes dynamically increases the reliability of the wireless connections. If, for any reason, the source device cannot communicate with the destination device using a previously established route, the routing-capable devices in the network can cooperate to find an alternative path from the source device to the destination device.

ROUTING

Routing is the process of selecting the path through which the messages will be relayed to their destination device. The ZigBee coordinator and routers are responsible for discovering and maintaining the routes in a network. A ZigBee end device cannot perform route discovery, and the ZigBee coordinator or a router will perform route discovery on behalf of the end device.

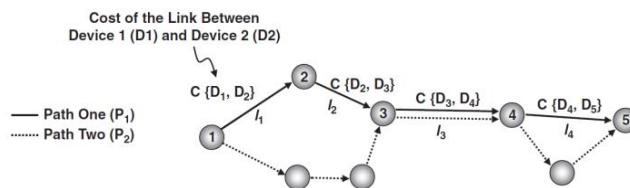


Figure 2 Path Configuration

Table 1 Routing Table

Field Name	Size	Description
Destination Address	2 bytes	The route will lead to this destination address
Status	3 bits	The route status can be one of the following: ACTIVE, DISCOVERY_UNDERWAY, DISCOVERY_FAILD, INACTIVE, VALIDATION_UNDERWAY.
Many to one	1 bit	If the destination has issued a many-to-one route request, this field is set to one.
Route record required	1 bit	If this flag is set, the route taken by the packet will be recorded and delivered to the destination device.
Group ID flag	1 bit	This flag is set if the destination address is a group ID.
Next hop address	2 bytes	This is the 16-bit network address of the next hop in this route.



The length (L) of a path is defined as the number of devices in the path. Figure shows an example of two paths with the lengths of five (L = 5) and seven (L = 7). The connection between two consecutive devices in a path is called a link. The links are numbered 1 to 4. The parameters such as link quality, number of hops, and energy conservation considerations can be used to decide on the optimal path for each routing scenario. To simplify this process, each link is associated with a link cost. The probability of successful packet delivery on each link will determine the link cost. The lower the probability of successful packet delivery, the higher the cost of the link. The cost of each link is shown as $C_{i,i+1}$

A device in a ZigBee network also maintains a neighbor table, which contains information about the devices in its transmission range. This table is updated every time the device receives a packet from one of its neighbors. The neighbor table is useful when the device needs to find a nearby router or rejoin the network. The device also uses the neighbor table when it seeks a new parent. Table 3.11 includes all required fields and some of the optional fields. The list of all optional fields is provided in the ZigBee specification.

Field Name	Description
Extended Address	64-bit IEEE 802.15.4 address
Network Address	16-bit network address
Device Type	ZigBee coordinator, router, or end device
RxOnWhenIdle	If the device keeps its receiver ON during idle mode, this field is set to TRUE
Relationship	This field determines the relationship of the neighbor to the device as parent, child, sibling, previous child, or none of the above
Transmit Failure	A high value in this field indicates that many of the previous transmission attempts resulted in failure
LQI	The estimated link quality
Incoming beacon timestamp	The time that the last beacon was received (optional field)
Potential Parent	This field determines whether this neighbor is a potential parent (optional field)

Table 2 The Neighbor Table

Modes of operation

The XBee ZigBee RF Module is in Receive Mode when it is not transmitting data. The device shifts into the other modes of operation under the following conditions:

- Transmit Mode (Serial data in the serial receive buffer is ready to be packetized)
- Sleep Mode
- Command Mode (Command Mode Sequence is issued, not available when using the SPI port)

X-CTU is a free software tool available from Digi International to interface with Xbee modules. The tool provides a GUI and terminal interface to configure the modules as well as a built in tool to test the Xbee range and reliability of packet transmissions. The first step is to connect the XBee node and coordinators. We make use of the software XCTU to set PAN ID and encryption settings of the XBee coordinator to match those of the nodes.

Steps to configure the node to connect to the XBee Gateway –

1. Install X-CTU on your computer.
2. Attach the XBee ZigBee node to an XBee development board, and connect it to your computer using a USB cable.
3. Open XCTU and add the XBee node that is connected to your computer to the list of radio modules.
4. Select the node and wait for the application to read all its settings.
5. Under the Networking category, replace the current PAN ID with your custom PAN ID in the ID PAN ID field.
6. Once you have changed the setting, click the Write radio settings button to save the new PAN ID in the XBee module.
7. If XBee Gateway uses XBee security parameters, set the XBee security parameters (EE, EO, NK, KY) as needed. The security parameters are as follows:
 - EE: Enable or disable security in the network.
 - EO: Set the security policy for the network.
 - NK: Set the network security key for the network. If set to 0 (default), the device will use a random network security key.
 - KY: Set the trust center link key for the network. If set to 0 (default), the device will use a random network security key.



8. Click the Write radio settings button to save the new security settings in the XBee module. As soon as you save the new PAN ID in the XBee RF module, the module tries to connect to the ZigBee network that has the PAN ID that you configured.

ZigBee Home Automation offers the possibility of controlling the appliances in an HA system via the Internet. Thus, this control can be performed from any Internet connected device (PC, tablet, smartphone) located anywhere in the World (e.g. while on holiday in another country). Access from the Internet requires the HA system to include an IP router or gateway (connected to the Internet) as one of the network nodes. A gateway solution is described in the Application Note ZigBee Gateway (JN-AN-1194), available from NXP. In addition to the real-time control of an HA system over the Internet, the system could also be configured from a device on the Internet (e.g. groups, scenes and timers). IEEE 802.15.4 is a proper replacement for IR technology in remote controls because of the low cost and long battery life of ZigBee-based wireless communication. IEEE 802.15.4 can be used to create two-way communications between the remote control and the entertainment device.

I. WORKING OF THE SYSTEM

XBee Pro (S2) module is an XBee ZB ZigBee Mesh Protocol based wireless transceiver designed by Digi International with an excellent range of 1.6 kilometres (one mile) line of sight (for 50mW, U.FL connection) and 90 metres indoors. This device works on 3.3V DC @ 295mA in transmission mode and has a maximum data rate of 250kbps. The data from the processor to XBee module is transmitted via a serial port.

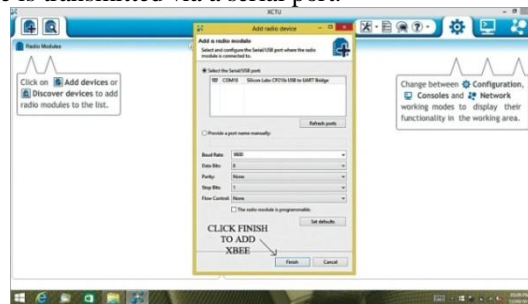


Figure 3 GUI of the application or web interface

To configure XBee module, connect XBee Explorer shield to a computer via USB.

To do that, click on 'Update Firmware,' set it to 'XBee coordinator AT,' click on the latest firmware available and then click on 'Finish.' Each XBee has two important keys, SH and SL, which help in transmission and reception of data. SL is unique to each XBee whereas SH is the same. The bottom view of a typical XBee module is shown in fig 5 along with its SL number as 406F70BE and SH as 0013A200. The coordinator sends the data, so the XBee is set as coordinator.

End device receives the data. Here we will use Console Mode of X-CTU to view received data, hence, XBee connected to the computer with XCTU should be set as end device. Router (sort of repeater) is an optional mode; in this, XBee simply receives and then transmits the same data, and so this mode is used to extend the range of transmitter. To configure XB2 as end device, repeat the steps done for configuring XB1, update the firmware and replace its SH and SL values with the SH and SL values of coordinator XB1, respectively. Now XB1 can transmit data and XB2 can receive it. One of the common ways to establish a communication network (wired or wireless) is to use the concept of networking layers. Each layer is responsible for certain functions in the network. The layers normally pass data and commands only to the layers directly above and below them.

ZigBee wireless networking protocol layers are based on the Open System Interconnect (OSI) basic reference model. Dividing a network protocol into layers has a number of advantages. For example, if the protocol changes over time, it is easier to replace or modify the layer that is affected by the change rather than replacing the entire protocol. Also, in developing an application, the lower layers of the protocol are independent of the application and can be obtained from a third party, so all that needs to be done is to make changes in the application layer of the protocol. The software implementation of a protocol is known as protocol stack software.

The application has the ability to add switches; add multiple switch names as per the convenience of the user for different appliances, update switch; this option is for the users who entered a wrong switch name before or want to change a switch name assigned before, delete switch; delete a particular switch name from the list of available switches, turn on/off; this option lets users to on a particular switch or turn off an on switch, check status; a table showing all the switches and their corresponding status will be shown in this option. The application or website used in this project is having the following interface.

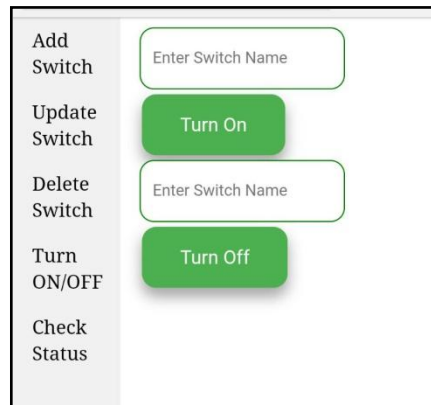


Figure 3 GUI of the application or web interface

V. CONCLUSION

The eradication of manual switching is a huge challenge which can be overcome by automation. Automation, nowadays, plays an important role everywhere from small industries to even large industries. Automation reduces, or rather completely removes human intervention when it comes to manual operation. There should be a device which helps to fulfil this requirement. This project exactly does justice to the above fulfillment. Making use of a mobile phone, this project automates the home appliances. The idea behind automating with the help of mobile phone is that mobile phones are readily available in every house. Exploiting the easily available open source android software, an application is being built which does all the work. Automating and thus making the system less bulky and even user friendly. The scalability is the main factor in such kind of systems. The application enables user to operate the system at anywhere around the globe, provided the system is installed in respective homes. Installing this system is very easy as it requires a one-time electrician to fit the switches which is required for normal home switches. Instead of wiring the manual switches, one has to do wiring for the electronic switches i.e. relay board. Looking into the complexities involved, the system allows up-to 20 switches extension at the cost of one system. The switches, thus can be controlled at ease. While leaving the house, people tend to forget to switch off all the switches which is quite natural. The beauty of this system proves to be a savior in such kind of situation. It aims at conserving electrical energy by controlling the appliances even outside the house. The real time status of the switch helps in keeping a track on all the appliances at ease. A user can set a particular switch on or off at any point of time from anywhere. Zigbee is a great alternative over WiFi in some applications like Home Automation. While compared to Bluetooth, it has several advantages. But despite of these advantages, it has not been implemented so far in many areas. One possible reason is the complexity in understanding of ZigBee. Its configuration, networking, operations are difficult to understand and learn as compared to Bluetooth or WiFi. However, if these things are understood it has a wide future scope. It is a time when Internet of Things (IoT) is making a place in this world and has impacted our society greatly with its capabilities. IoT also has a huge scope and maybe beyond our imagination for the time being. Keeping these things in mind, it is a great time to use the possibilities of ZigBee while new protocols like Lora WAN are also making way to this world.

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