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Real-time Analysis of Sensors for Smart Home with Automatic and Remote control

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ABSTRACT:IoT, known as Internet of Things is spreading rapidly these days as a technology which will overpower any other technology in the next few decades. It has the power to connect even a minute piece in our life to the internet. Existence of sensors is a boon to the technology because any rapid change can be sensed and be acted upon. Exploiting ZigBee, various sensors will be able to send their data wirelessly to a server based system. This server will send the data to a web portal where a user can see and analyze the variations in the data. This web portal has been designed to have the functionalities of displaying the live sensor data and even controlling the readings through various actuators.An automatic message system, mail services and real time graph are attractive features of this portal. Apart from this, Arduino board is used for automatic controlling which will read the data itself and perform the actions automatically if needed.

KEYWORDS:Arduino board,Cloud, GCM, Sensors, Web services, XBee, XIG, ZigBee.

I. INTRODUCTION

Theconceptof ZigBee wasfirst coined in 1998 and got standardised in 2006. It is based on IEEE 802.15.4 specification for wireless communication between low power devices. ZigBee offers secured networking since it utilises the AES (Advanced Encryption Standard) for the data transfer between nodes. It makes use of the mesh topology, which is indeed considered the best among all the other topologies. Besides, the network range is about 10-100m line of sight. The network can be extended by including more nodes as ZigBee can add up to 65,000 nodes per network. IoT and ZigBee combined can have a plethora of applications for the society. Ranging from remote controlling of agricultural plants to remote controlling and monitoring of street lights, all becomes a cake walk to implement. Home automation is being researched upon very actively, with other protocols such as Wi-Fi or Z-Wave. Zigbee is considered more advantageous in terms of both cost and secure data transfer. Bluetooth can also be used for low range automation, since it also offers a 64 bit and 128 bit encryption method but its range is about 10m and it will consume more power relatively.This end to end system, involving ZigBee will be cost effective and provide better security and range. XBee-ZB modules work on ZigBee as the protocol for the data transmission. In this study, we have utilised these modules to transfer our sensor data wirelessly. There are three roles which an XBee module can perform. The coordinators lie at the top position in the hierarchy which receives all the data and sends to the system. Next are the routers and then the End devices. The end devices cannot receive any data and they can only send the data values. The routers are merely added to extend the network. Both the coordinators and routers don't sleep since the data flow should be continuous but the end devices can be made to sleep to save power.

Two such modules have been used for a comparatively smaller network for the experiment. One acts as a coordinator which receives the sensor data and the other acts a router which sends the data and receives the remote commands. There are two methods that have been tested to send the data to network. One is the famous Digi cloud which is offered for Digi devices (here, XBee) which stores the analog and digital data sent by the sensors for about a month. XIG (XBee Internet Gateway) connects the XBee modules to internet and to the cloud. This software has a log section which continuously gives the status of your transfer, either an error or a successful transmission. The other method is to use any other web server which connects the XBee data to the database. It is programmed to receive the input of the coordinator XBee and push it into the database. These data can be fetched by web services

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and displayed on the web portal. We have put to use various features to add to the utility functions of the web application, like mail services, automatic SMS system and a real time graph to analyse the room's conditions at any instant.

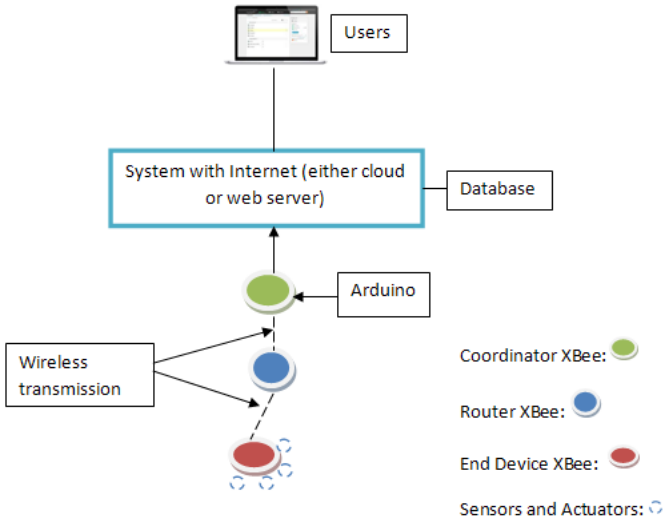

Fig. 1 Broad System architecture

The work in this paper is divided in the following stages. 1) Establishment of a network between the two XBees. 2) Connection of sensors and automatic control with Arduino. 3) Development of server side application which stores the sensor data in database. 4) Display the data on web portal 5) Control through actuators using the portal. 6) An automatic message system using GCM technology. 6) Real-time graph and mail services. The broad architecture (Fig.1) represents the flow diagram of how the sensor data ultimately reaches the user. Digi Cloud comes exclusively for XBees, though any web server can be utilised to connect the modules to network. Arduino board can be used for any logical operations and it is programmed to perform an action after analysing the data of the room. The web services have been exploited to make a user friendly GUI which helps the user to analyse the data through a real-time graph and send a message or a mail accordingly.

II. RELATED WORK

Wireless Sensor Networks can be deployed in various applications as described by Sanjit Kumar Dash et al. [1] where he integrates such sensor networks with cloud for society utility purposes. A comparative study has been done by ThorayaObaid et al. [2] which enlist various wireless communication protocols and presents ZigBee as the best protocol for home automation. One of the applications is comprehensibly explained in [3] where the network is used in safeguarding the fruits and vegetables. Xively is their cloud wherein they are storing the temperature and humidity of the atmosphere the fruits are in.Sensor networks are in vogue when it comes to agricultural applications. As described in [4], the sensors are attached to the rice plants for monitoring various parameters affecting the plant, like relative humidity, temperature, pressure, light, etc. They have used TinyOS framework to observe the data on computers. Further, the authors have experimented in a greenhouse as well. In [5], a basic structure is established how to connect from the nodes (the sensor nodes) to cloud and then the user. The structure includes the sensor layer, the coordination layer and the supervision layer. They have used REST web services along with the XBee devices.

III. MATERIALS AND SOFTWARE USED

Following are the hardware which are used, namely XBee modules, XBee Breakout boards, Arduino board, USB cable, jumper wires, resistors, breadboard, battery, LEDs, buzzer, DC motor, fan, diode 1N4001, Darlington transistor TIP122, photoresistor, PIR motion sensor, LM35 temperature sensor. The diode and transistor are used to run the fan

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mounted on the DC motor. Apart from the hardware, many software applications are used which include X-CTU, XIG, Eclipse IDE, Arduino IDE and any web server (here Tomcat Apache) will serve the purpose. Major of the components are explained below.

A. *XBee-ZB S2 modules:*

Digi offers XBee radios in many forms. The one used is the Series 2 model with wire antenna. It works on ZigBee protocol and makes use of mesh networking topology. The regular version of the modules is used instead of a PRO version. A PRO version costs more and intakes more power. Series 2 modules have a total of eleven digital input/output pins though only four of them can be configured for the analog inputs.

Fig. 2 An XBee S2 model mounted on a breakout board

B. *XBee Breakout boards:*

XBee breakout board is used to mount XBee on it. It comes with female sockets for each of the pin of the XBee so that there is no need to solder XBee on it. It simplifies the connection of XBee with either the breadboard or a computer system. It has a USB interface and a built in 5V- 3.3V voltage regulator. It has various indicators, RX, TX and RSSI and a reset button to reset the module. It is required while configuring the XBee.

C. *Arduino:*

Arduino is an open source microcontroller based platform and it increases the usability of a microcontroller (ATmega 328) by providing a USB interface, reset button. It includes a 16 MHz crystal oscillator, power jack and a 5V linear voltage regulator. It also has a supply of 3.3V which makes it compatible with the XBee module. The microcontroller has an 8bit AVR (CPU) and 32 Kbytes Flash memory, 1 KB EEPROM, and 2 KB SRAM. Along with this, it has 23 general input/output pins (6 analog pins). It has a UART (RX/TX) port to connect it with XBee (Fig.3). Arduino makes use of Arduino IDE to program the microcontroller. It has various in-built commands like pinMode(),Serial.read (), digitalWrite (), and digitalRead() to set up the pins as desired.

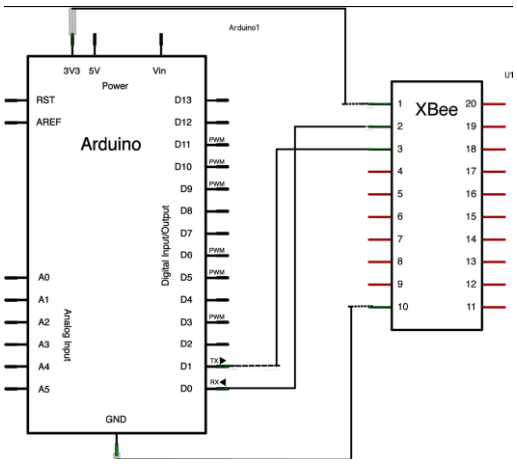

Fig. 3 The UART connections between Arduino and XBee module

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D. *X-CTU:*

X-CTU is open source software to configure and test the XBees. After setting up the port configurations, parity, flow control, etc. it recognizes the XBee module connected to the same port. It allows the user to configure the module either as the coordinator, router or end device and set up the latest firmware. One can change the operating modes for each of the module and configure them to act as nodes in the same network. This runs on Windows, MacOS and Linux. It includes an update process which updates the radio firmware library. The following shows the network of two modules (Fig.4).

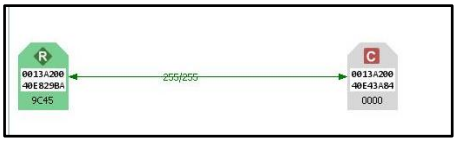

Fig. 4 The active XBee modules (router and coordinator) connected in the same network in XCTU

E. *XBee Internet Gateway (optional):*

XIG (XBee Internet Gateway) is an open source platform lead by Rob Faludi, Jordan Husney and Ted Hayes to implement IoT in a simplified manner. It connects the XBee devices to the internet and to Digi cloud. It also requires setting up the port settings. This allows the sensor data to directly get stored in a stream in the cloud (based in America). The cloud also gives features as the real time graph but it stores the data only for a month. The second alternative is to use any web server to store the data, making use of a database (here Postgresql).

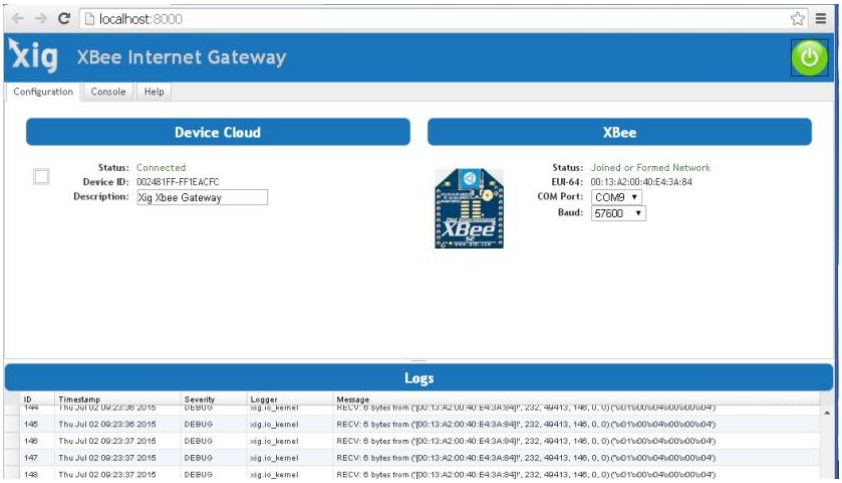

Fig. 5 XIG window connected to the coordinator

IV. METHODOLOGY

The XBees, the coordinator and the router are configured through X-CTU (software for configuration and testing of XBees) so that they can identify each other as a part of the same network. It is not necessary to have the XBee connected to sensors configured as an end device; even a router can connect to them. What important is the transmission between coordinator and router. The router XBee is connected to three sensors, two of them are analog ones and the other is a digital sensor. LM35, the temperature sensor and a light sensor, photoresistor act as the analog sensors while the motion sensor is a digital one. LM35 is connected directly to the ADC pin while photoresistor has to be added in a voltage divider circuit. Since ADC is defined for voltage measurements, a voltage divider is needed for photoresistor whose resistance gets affected by light. Apart from the sensors, this XBee is connected to three different actuators for the three different sensors. Actuators include a fan (DC), LED for light and a buzzer for motion detector. AC devices can also be connected to the XBee with the help of a relay, like a filament bulb can be easily employed with the help of a relay.

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The XBees can be connected to the internet using two methods, cloud or our own server. If we need to send the data to the cloud, we won't have to write any programs to receive the data sent by the coordinator. The application XIG identifies the XBee module, coordinator, connected to the system via a USB cable. After successful connection with XIG, it automatically connects the cloud to the XBee module and hence, all the sensor data flow as a stream to the cloud. Each of the pin values can be retrieved by fetching a URL which is supplied by the cloud itself. A better and a safer method to store the data is having your own web server. Here, Tomcat Apache has been used as a web server. Programs have been written in Java to extract the data from the coordinator and such programs are deployed as a web service such that whenever a particular URL is fetched, a sensor data gets fetched. Similarly, we have web services for other operations, mail, SMS, and real time graph apart from the control. The configuration of a pin can be changed also by programs using the Java XBee library. This has been utilised for the control feature. So, we can control temperature by switching on a fan, if temperature evaluates to be larger than threshold or alert the house members by buzzing an alarm if an intruder pops in. Real time graph makes use of the JSON object returned by the web service and includes them as the coordinates of the axis. The web service is fetched every one second so that the graph immediately updates itself after every receipt of data.

The SMS feature exploits the free technology provided by Google, known as Google Cloud Messaging (GCM). It provides the utility of sending free notifications to any mobile application. There are three parties which participate in GCM process. One is the web server where the user can write the message and send or a program which sends a default message to the number. Second is the mobile which will receive the notification as alert. Third is the GCM server which acts as an intermediate between the web server and the mobile application. The only requirement to successfully use this technology is that the mobile should be registered on the GCM server. After successful registration, the web and the mobile can interact and send downstream messages.

Arduino is connected to the coordinator end and has been programmed to receive the IO sample from the remote XBee and then issue commands on certain conditions. For this, the data patterns were studied and the conditions included in the program totally depend on that. The XBees have been configured to send and receive commands in API mode wherein the data are sent in frames. For controlling, Arduino is commanded to send the data in frames where each pin has its own command to either receive a lower voltage or a higher voltage. This is how we can control the actuators by either giving them high voltage to run or no voltage to stop. This is totally automatic and it doesn't require the user to be present on the web portal.

V. RESULTS AND DISCUSSIONS

Figures show the results obtained after effectively utilising each of the technology. The XBee modules are connected to each other since for effective transmission, each of the modules should know its destination node as shown in Fig.4. After connecting the modules in the network, the sensor data sent by the remote XBee to the coordinator is stored in the database. This is done by the Java program which commands the coordinator to send the received data.

Fig. 6 The pop up window showing the temperature details (fetched from Digi cloud)

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Various web services are written to fetch the data from the database for each of the sensorsas shown in Fig. 7 and from the cloud in Fig.6. Fetching from cloud is completely different from fetching from the database. Both make use of different methods.

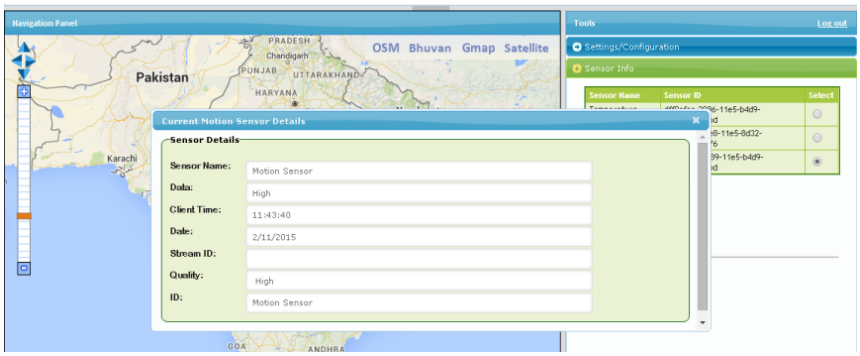

Fig. 7 The pop up window showing the motion details (fetched from own server)

Each of the functionalities has their own model in the MVC (Model-View-Controller) architecture which adds the fetching URL to the template.The real-time graph refreshes every second to plot the latest sensor data obtained depicted in Fig. 8. It also makes use of the web service to fetch the data and this data is plotted against time. A web service has been written to include message feature in the portal.

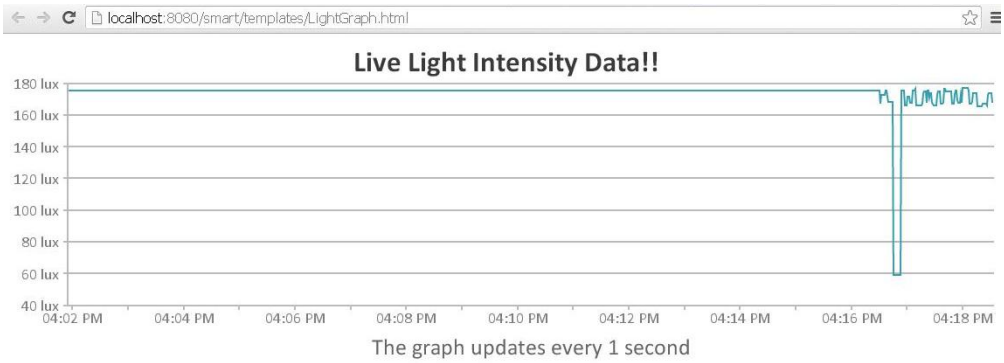

Fig. 8 Light Intensity (lux) vs. time graph, which updates itself every second

There are two web services pertaining to the message system. In Fig. 9, it can be seen that one of them allows the user to modify the content and then send the message. The sender can send any random message in this method and on clicking the send push notification button, the message gets sent.

Fig. 9 A web service implementing GCM to send the message to a mobile, a message Id is received on success

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The other method automatically checks the data every minute and sends a notification to the mobile when it finds abnormality in the data values. Similarly, we have a mail service in Fig.10 in the portal which allows the user to send a mail to the registered email address.

Fig. 10 Automatic mail service deployed in the portal to alarm the user

Fig. 11 depicts a model has been created to include GPS in the system which will allow the user to control multiple XBees based on the location. They can view and control the sensor values of two places at the same time. The connection diagram includes the Navika GPS module and the XBee series 2 module. The GPS data items will be sent serially between the remote XBee and the GPS module and wirelessly between the coordinator and router. The GPS data will then be parsed to obtain the coordinates and then the XBees can be geotagged in the portal to allow the user to select different XBees.

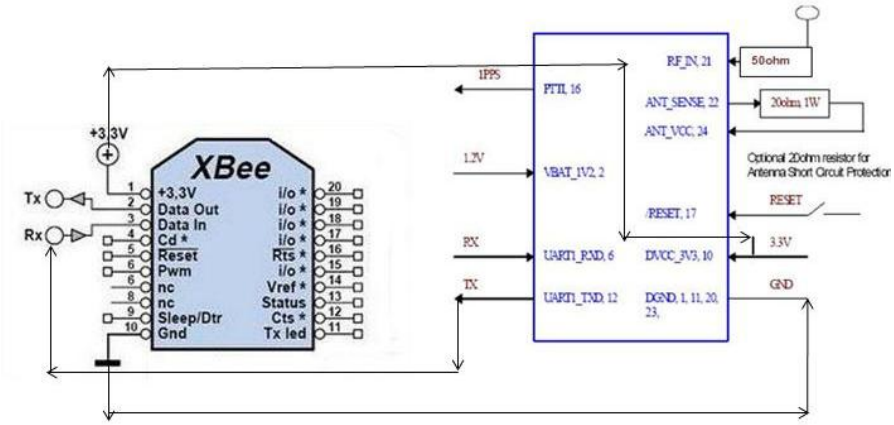

Fig. 11 A model to integrate GPS in the system to make it a location based service

Though ZigBee offers security in their nodes, and it can be enabled by X-CTU but still, there should be a security when the data reaches the server. The data can be breached and hence on the server side, the data should check the validity of firstly, the sensor data and secondly the data being thrown on the screen. Various attacks are common in wireless networks and for effective transmission, it cannot be ignored. Other factor which poses a challenge to the integrated system is the restriction of line of sight. The maximum range provided by the Xbee series 2 modules is up to 120m but it is should be in the line of sight. Else, several phenomena like scattering and diffraction creates multi path for the waves and hence, the data gets corrupted. Connections should be tight because a loose connection can bring change in the data values.

VI. CONCLUSION AND FUTURE WORK

An automated light, temperature and motion have been included where in you can control the various parameters of your house from a remote place, without being at your own place. So, you can switch on the lights for your grandparents so that they don't have to leave their place for such trivial purposes. The web application will show the sensor details which it fetches through the database for each sensor.The application will have features for the user to see the sensor details, whether it is normal or not.The web application will be controlled only by users who are registered in the site. Only those users can access the sensor details of their respective homes.There are various features

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included which enhance the usability of the application like an automatic SMS service which will cross-check the sensor data every one minute and if found abnormal, it will send a message to a mobile. Mail services and a real time graph have been included along with SMS. This will definitely be an initiative to include automation in our life. There can be a lot of future prospects to it, like one can have an android application for the web application. Then it is not necessary to operate via a desktop application. Apart from it, inclusion of GPS will make it a location based service, where one can control multiple XBees. The whole end to end system can be used in water bodies, to detect the humidity and temperature, let's say and accordingly take measures like sprinkling water. And, if it gets uncontrollable the message can be immediately sent to the managing staff. This will bring automation in agriculture. Similarly, it can be used in automating street lights which can be a great initiative to save electricity. Its cost effectiveness will lessen the cost of installation and automation can be brought to remote areas.

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BIOGRAPHY

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