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Research Paper

Design and development of bi-directional IoT gateway using ZigBee and Wi-Fi technologies with MQTT protocol

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Abstract

With evolution of the smart things, to acquire data, gateways play a major role in interconnecting with various sensor nodes. Using different wireless protocols and standards with sensor nodes, gateway can transform information into a unique format that transmits into the cloud for further use. Which accepts the commands from external users in the remote location through a personal computer or a smartphone? The proposed gateway has its added advantages; (i) ZigBee and Wi-Fi wireless technologies connectivity is enabled, (ii) transforms the information into required protocol format, (iii) uses a light weighted MQTT protocol in transmitting and receiving environment, (iv) It provides the storage and analyzed data and (v) the sensor values can be observed and the devices can be controlled by a smartphone from remote location. Here we demonstrate the proof of concept for controlling the smart home appliances. This also represents a design and implementation of Bi-Directional IoT gateway using ZigBee and Wi-Fi technologies with MQTT protocol.

Keywords: *Gateway; IoT; ZigBee; Wi-Fi; MQTT Protocol.*

1. Introduction

In the recent era IoT is emerging rapidly throughout our life by finding its path to improve the quality of life by connecting many technologies, applications to the physical objects around us by automating the things. [1] Enormous attention has been paid towards digitization of the physical world such as home, offices, factories, vehicle's, cities etc. [2] [3] [21] The research made by IDC confirms IoT solutions in increasingly recognized as transformative to consumers, business, governments each of them will innovates, experiences and operates in the world, where end user will fell the tangible benefits of IoT. [4] [20] All the physical objects relate to sensing elements enabled by wireless sensor network(WSN) technologies in our daily life. [5] WSN consists of different wireless technologies such as Bluetooth (over IEEE 802.15.1), ZigBee (over IEEE 802.15.4), Wi-Fi (over IEEE 802.11) etc., every protocol has got it advantages and disadvantages based on speed, power and transmission capacity. [6] The gateway should can receive the data from all the sensor nodes which may use different wireless protocols and send that to cloud and it must receive the data from remote location and act according to the commands given by user which is dealing with interoperability in IoT. [7] [8] By obtaining a common data format for the data received from the sensor nodes to transmit to cloud and a the converting the commands accordingly to sensor node which are given by the user from the remote location which solves the interoperability problems [9]. ITU has proposed the group of standards [10]and [11]. In this paper, we propose a design of Bi-Directional IoT gateway, with two wireless protocols ZigBee and Wi-Fi which enables the interoperability to two heterogenous wireless protocols by in cooperating the transformation of data received from different nodes. To transmit the data we use a lighted weighted protocol MQTT [18].

2. General system architecture

General IoT gateways consists of different protocols for transferring the data to the cloud which received from the sensor nodes. Here the main objective is to implement a Bi-Directional gateway to avoid interoperability by transforming the information. A gateway is proposed with the protocol ZigBee and GPRS facilitating the data transmission. [12] A similar gateway was proposed with three communication protocols [13]. Many Authors as proposed to transmit the data to local and network and to cloud [14] [15].

According to the literature available the gateways for interconnection of wireless devices are of unidirectional which takes the data and stores in the cloud. The efforts focus on many domains such as smart homes, telemetry, smart industries, and soon.

3. Proposed system architecture

The implementation of ZigBee and Wi-Fi gateway data transfer has to show over the network test data here is the data sent by the Arduino[16], the data is the paramareter values that are sensed by the sensors which are interfaced to the arduino as shown in figure 1.

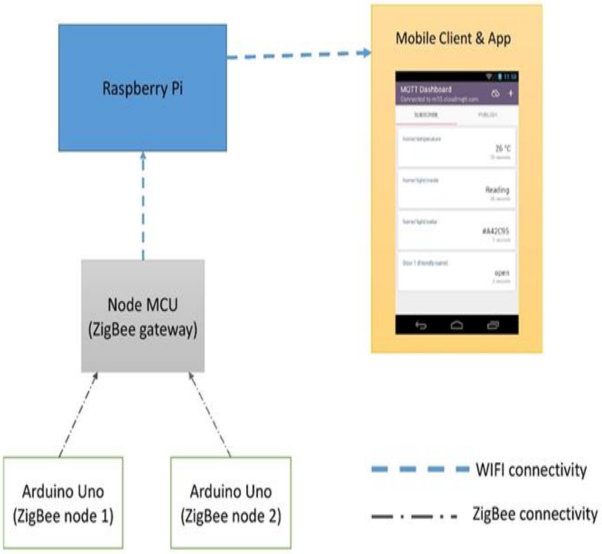


Fig. 1: Block Diagram Showing the Basic Implementation of Gateway.

The primary tasks of the gateway is to transform the data and differenciate the information recived from different ZigBee nodes and then publish that data on to the different topics. The NodeMCU [17] consists of Wi-Fi module will publish the data. It should be connected to the MQTT Broker as client. The Raspberry pi 3 which is acting as server with MQTT broker software contains facilitates the communication between different clients pushing messages from publisher to subscriber. And a client is used for monitoring the data So android phone with a dashboard application is used.

3.1. Broker

The Server used here is a single board computer running Raspbian OS and the MQTT broker software is mosquito this broker is the crucial element in the network and it is responsible for the total transmission of message between clients and the communication paradigm is publish/subscribe paradigm.

3.2 Client as ZigBee-Wi-Fi network gateway

Most of the sensor networks communicate using the communication protocols like ZigBee and other low power communication protocols which when needed to go over internet it should be sent through Wi-Fi and to do this a ZigBee gate should be needed and this can also use MQTT protocol to send data over Wi-Fi. So, one the client is acting as ZigBee Wi-Fi gateway.

3.3. ZigBee sensor nodes

The sensor nodes transmitting data in ZigBee communication protocol to the ZigBee gateway and the sensor node here is the Arduino Uno with XBee module for ZigBee connectivity and two of these transmit different parameters to the gateway that is MQTT client which Is acting as ZigBee network gateway.

4. Experimentation

To show the implementation of MQTT client as ZigBee- Wi-Fi network gateway, ZigBee sensor network is required. So here Arduinos with Xbee modules act as sensor nodes transmitting the data. The data is transmitted data from two Arduino's will be received by the broker and then gets pushed to the client subscribed to the topic. In two Arduinos one of the Arduino is interfaced with a DHT 11 sensor which sends temperature and humidity values to the ZigBee network gateway and the other is interfaced with MQ2 light intensity sensor as show in the below figures 2 and 3.

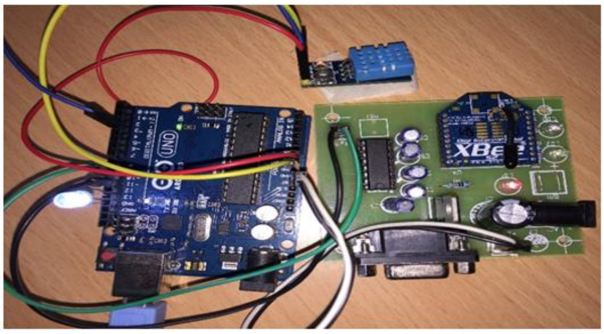


Fig. 2: Showing Interface of DTH11 Sensor and Xbee Module with Arduino.

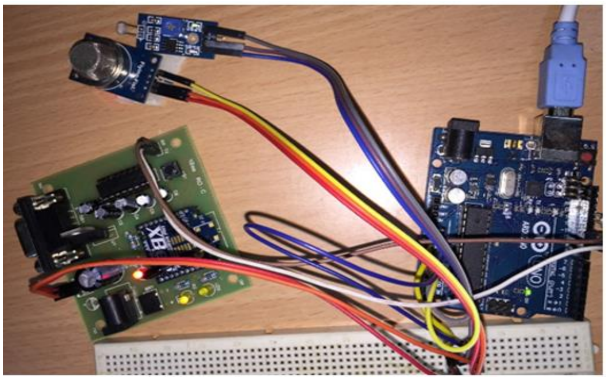


Fig. 3: Showing Interface of Light Sensor, MQ2 Sensors and Xbee Module with Arduino.

One of the clients act as the gateway for ZigBee sensor network bridging between Wi-Fi based MQTT network and the ZigBee network the two Arduinos with sensors. XBee module configured as routers transmit the data to the NodeMCU connected with XBee module which is configured as coordinator as shown in figure 4. As the data is the received on NodeMCU it differentiates the data based on the address of the XBee module.

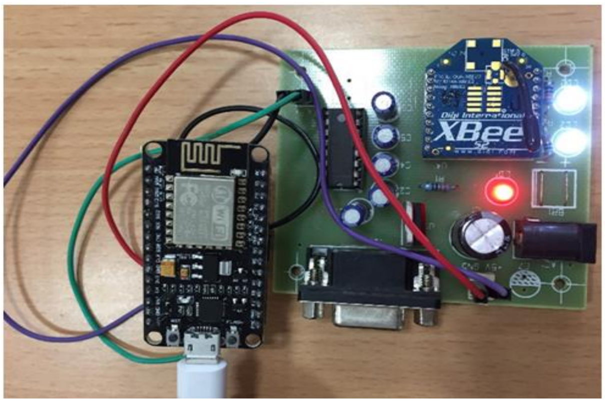


Fig. 4: Nodemcu (MQTT Client) As ZigBee-Wi-Fi Network Gateway.

The received data gets differentiated based upon its address and will be published onto the different I, e temperature data from the Arduino with DHT 11 module is published to the topic "tempb1" and humidity value from same board is published to the topic "tempb2" and LDR sensor values from board is published to the topic "lightb2" and the gas sensor value from board2 is published to "gasb2". This module transmits data to MQTT broker only if it is getting data from the sensor network.

4.1. Configuring raspberry pi as MQTT broker

To configure raspberry pi MQTT broker it should be preinstalled with as Raspbian OS and for raspberry pi to be as MQTT broker it should host a MQTT broker software and their number of MQTT broker software's. The software that is being used here is Mosquito MQTT broker software, which is developed by eclipse crop and

installing it on the raspberry pi and starting it starts a MQTT broker which handles the messages and the following steps to be done to install and start mosquito on raspberry pi.
Step 1:
Run the terminal of Raspbian OS and type following commands to update the repository package which involves in importing it and signing it with key.

```
pi@raspberry:~ $ wget http://repo.mosquitto.org/debian/mosquitto-repo.gpg.key
pi@raspberry:~ $ sudo apt-key add mosquitto-repo.gpg.key
```

Step 2:
This step involves in making the repository available for apt-get to get installed

```
pi@raspberry:~ $ cd /etc/apt/sources.list.d/
pi@raspberrypi:/etc/apt/sources.list.d $
```

Step 3:
Run the following commands in the super user mode to get dependencies of mosquitto

```
pi@raspberrypi:/etc/apt/sources.list.d $ sudo wget
http://repo.mosquitto.org/debian/mosquitto-jessie.list
```

```
pi@raspberrypi:/etc/apt/sources.list.d $ cd
pi@raspberry:~ $
```

Step 4:
Update apt-get and install mosquito using following commands

```
pi@raspberry:~ $ sudo apt-get update
```

```
pi@raspberry:~ $ sudo apt-get install mosquitto
```

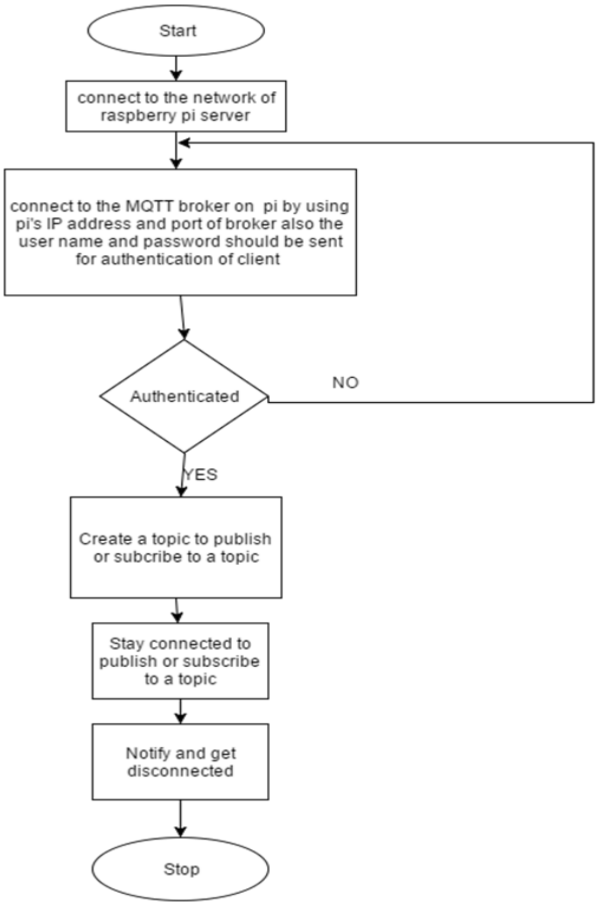
Step 5:
Start mosquito using following command and the appearance of following screen shot below ensures the correct installation and start-up of mosquito

```
pi@raspberry:~ $ mosquitto -v
```

Screenshot showing running of Mosquitto in Linux terminal

```
pi@raspberrypi:~ $ mosquitto -v
1484326030: mosquitto version 1.4.10 (build date Thu, 25 Aug 2016 10:12:09 +0100) starting
1484326030: Using default config.
1484326030: Opening ipv4 listen socket on port 1883.
1484326030: Opening ipv6 listen socket on port 1883.
```

4.2. Flow Chart



Flowchart 1: Flowchart for Getting Connected to Broker.

4.3. Android app configuration

To view data published by the clients a graphical user interface is required which is provided by any computer or portable Smart phone. Here an Android smartphone with MQTT dash board application is used to view the data.
First the smart phone should connect to the MQTT broker by using the user name and password and by giving the IP address of the raspberry pi and by using port number 1883 as shown in the figure 5 below.

Fig. 5: Screenshot of Android Application during Establishment of Connection with Broker.

5. Results

Data recived from different sensors is monitored and aslo controlled from the remote location using a mobile phone, tablet or personal personal computer. The Bi-Directional gateway can transfer the data from the sensors to the cloud for monitiring. In the same it can accept the commands given for controlling the devices connected to the gateway. The resulut are shown below in figures 6,7,8,9 and 10. Figure 6 show the graph of data acquired from the Gas sensor in different intervals which is placed in the kitchen of a home. The data of light intensityof room is shown in the figure 7 by using the LDR sensor. By using the DTH 11 sensor the humidity and temperature of the room are acqureid that are shown in the graph in figure 8 and figure 9. Figure 10 shows the MQTT dashboard in the mobile application with switches by which we can turn ON or trun OFF the home applicance from the remote location through the gateway.

Fig. 6: Screenshot of Graph in Mobile Application Showing Gas Sensor Data.

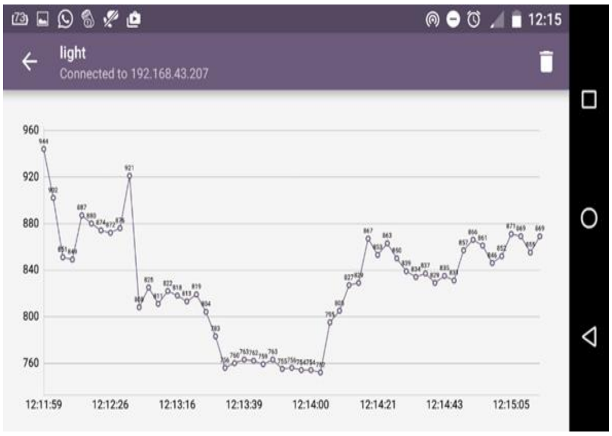


Fig. 7: Screenshot of Graph in Mobile Application Showing LDR Sensor Data.

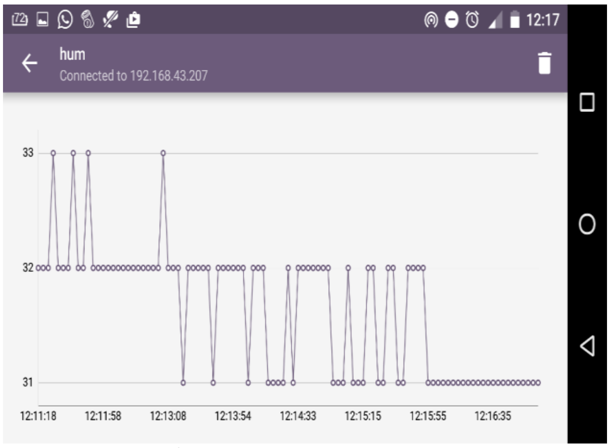


Fig. 8: Screenshot of Graph in Mobile Application Showing DHT 11 Humidity Data.

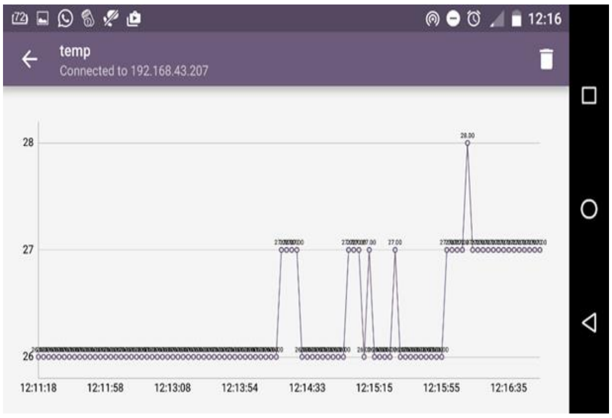


Fig. 9: Screenshot of Graph in Mobile Application Showing DHT 11 Temperature Data.

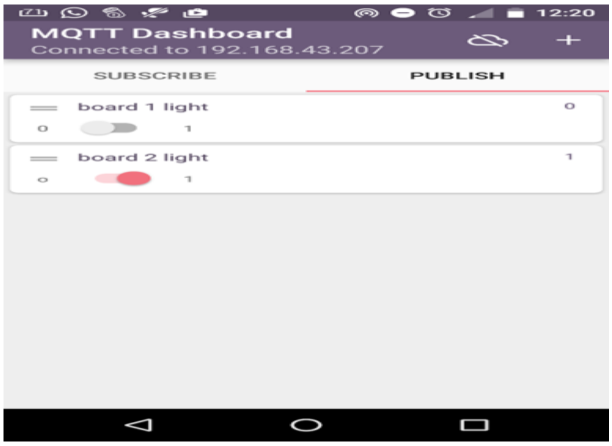


Fig. 10: Screenshot of Mobile Application Showing Switches to Turn ON or Turn OFF the Electrical Application in the Home From Remote Location Through the Gateway.

6. Conclusion

The main obstacle to adopt internet of things (IoT) is the existance of varrious hetrogenous devices. The new Bi-Directional gateway implemented in this paper enables the interoperatabilty at the devices. The Bi-Directional gareway acts as ceneral element allowing the inteconnection of devices wirks with Zigbee and Wi-Fi communication technologies. The gateway has been applied in the home domain, however it can be applied to several domains. As a future work we propose to extend the functionalities by integrating other wireless and wired communication technologies.

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