Web-Based Online Embedded Door Access Control and Home Security System Based on Face Recognition

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***Abstract* – Smart home security control system has became indispensable in daily life. The design and development of a home security system, based on human face recognition technology and remotely monitoring technology, to confirm visitor identity and to control door accessibility has been reported in this paper. This paper describes about the implementation and deployment of wireless control system and accessibility in to a home environment for authenticated people only. A wireless network technique ZigBee based and image processing technique PCA based, dedicatedly make the security system alive as per the request. ZigBee module and electromagnetic door lock module combinedly operate the door accessibility, has been designed and developed. Face detection and recognition algorithms, as well as a wireless interface are used to detect and identify visitors and send an email and/or an alert message about the current home environment status via GSM network automatically to the home owner's mobile phone or any communication devices. The concerned authority can control the system through his/her mobile phone or any communication devices by sending AT Commands to GSM MODEM or by taking necessary actions for authentication through email, which is again password protected. Users can monitor visitors and control the door lock on active Web pages enhanced with JavaScript and HTML. This system finds a wide application in areas where physical presence is not possible all the time. The entire control system is built using ARM1176JZF-S microcontroller and tested for actual use in home environment.**

Index Terms – Embedded Web Server, Door Access, Microcontroller, Face Recognition, GSM, ZigBee.

I. INTRODUCTION

An efficient and accurate embedded access control system based on face recognition is very important for wide range of commercial and security application. Many countries are gradually adopting smart home security control system [1], [2]. The most important part of any home security system is accurately identifying visitor who enter and leave through the door [3], [4]. An entrance guard can be managed using passwords, RFID sensors, finger prints and face recognition methods [5]. Face recognition is probably the most natural way to perform biometric authentication between human beings. Additionally, it is the second most popular biometric trait, after fingerprints [6]-[8].

Only few researchers have implemented the face recognition techniques in an embedded system for real time applications, such as a wireless door access control system. Most of the system was implementing a principle component analysis (PCA) algorithm[9]-[12] for face recognition on hardware platform for its simplicity and dimensionality reduction[13]-[17]. Wireless technologies like radio frequency identification
(RFID), ultra wide band (UWB), and ZigBee [18] etc. are used in access control systems.

The proposed system is a wireless access control system designed and developed for smart home environment. The paper proposes a Raspberry pi based door access control and home security system through webpage with ZigBee based technology. The system identifies the visitor's presence, capture and transfers the image through email and/or an alert SMS via GSM network automatically to home owner to recognize the visitors. The system capability to provide access through internet, where subject of received email is read by the developed algorithm fed into Raspberry pi and system responds to the corresponding instruction with high security. The user can directly login and interact with the embedded device in real time without the need to maintain an additional server. It has a variety of features such as energy efficient, intelligence, low cost, portability and high performance.

The article is organised as follows. The system architecture is discussed in Section II, followed by system description in Section III. The system implementation and Experimental work are presented in Section IV and Section V with result respectively. Finally, Section VI draws conclusion

II. SYSTEM ARCHITECTURE

The door access control and home security system hereby reported, consisted of two components (Fig. 1), wireless control units (WCU) and a wireless information unit (WIU) linked by a radio transceivers that allowed the transfer of control information's, implementing a WSN that uses ZigBee technology. The WIU has also a GPRS module to transmit the data via the public mobile network. Raspberry Pi has been chosen as the processing unit of WIU, which is a single board computer developed by Cambridge University. The Pi has been extremely popular among the academic fraternity due to its low cost. The model B+ of the Pi ships with 512Mb of RAM, 4 USB ports and an Ethernet port. It packs an ARMI176JZF-S 700 MHz processor, Video Core IV GPU into the Broadcom BCM2835 System on Chip which is cheap, powerful and also low on power. The Pi has HDMI support and has an SD card slot for booting up due to lack of BIOS and a persistent memory [19]. Python coded Algorithm has been fed into it and is connected to the internet to access and send email to the consumers.

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Embedded web server refers to import Web Server at the scene the monitor and control equipment, in support of appropriate hardware platforms and software systems, transfer traditional monitor and control equipment into an internet base, possessed with TCP/IP protocol as the underlying communication protocol and Web server technology as its core [20]. The embedded system can be utilized to serve the embedded web documents, including static and dynamic information about embedded systems, to Web browsers. This type of web server is called an Embedded Web Server (EWS) [21].

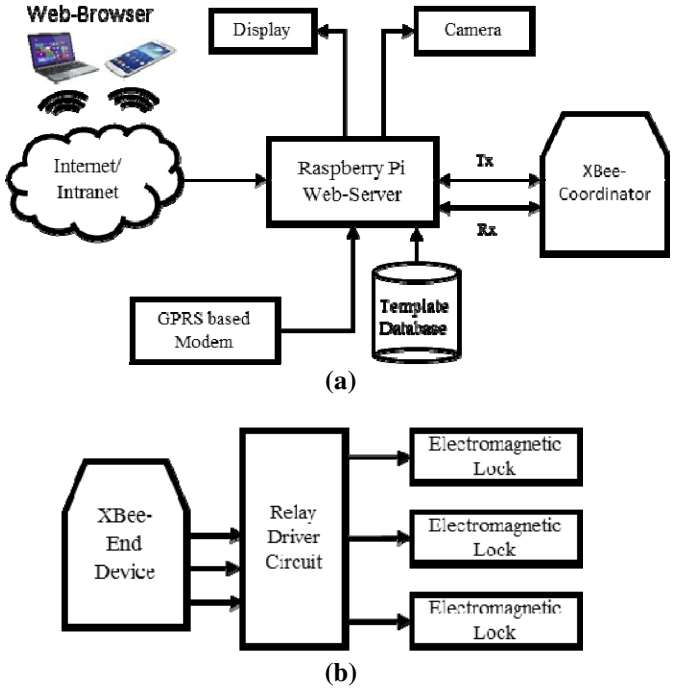

Fig. 1 Layout of the proposed system configuration; (a) Wireless Information Unit, (b) Wireless Control Unit.

III. System Description

The remote monitoring and controlling of the embedded equipments over the Internet can be mechanized by following certain network architectural design strategies and applying ZigBee communication standards. The data transmission of smart camera augmented with ZigBee over the internet can be done by integrating an internet gateway with ZigBee network. In a ZigBee network, end devices collect and forward data to a coordinator and then ZigBee protocol data format is translated to Internet protocol (IPV6) format by the gateway.

The virtual home security System is a software developed in python. All communication and instructions are checked for security and safety, in the virtual environment, before implementation in the real home environment. The Raspberry Pi unit and the camera are installed in a home through ZigBee. If any visitors arrive, the Raspberry pi sends an appropriate SMS and/or email including the details to an Internet-based server using user email-id. The server then sends to the home owner the name and photo of visitors for further action. The owner can directly login and interact with the embedded device in real time through webpage without the need to maintain an additional server.

A. *Face Recognition Module*

Principal Component Analysis technique, effectively and efficiently represents pictures of faces into its eigenface components. It reduces data dimensionality by performing a covariance analysis between factors. When applied on conditions, PCA will explore correlations between samples or conditions. If we consider an image as a point in a very high dimensional space, the principal components [22] are essentially the eigenvectors of the covariance matrix of this set of face images, which Turk and Pentland termed the Eigenface [23]. Each individual face can then be represented exactly by a linear combination of eigenfaces, or approximately, by a subset of "best" eigenfaces - those that account for the most variance within the face database characterized by its eigenvalues. After performing PCA the output is shown in Fig. 2.

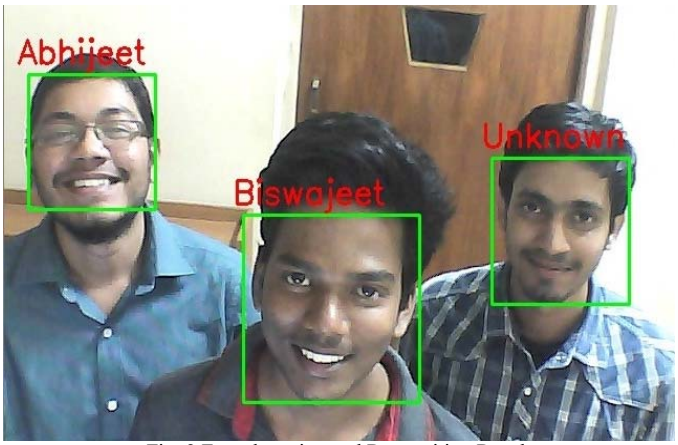

Fig. 2 Face detection and Recognition Result

B. *ZigBee Wireless Sensor Network*

In the development of home security system the ZigBee communication has been used. The ZigBee device is an energy efficient, high accuracy, self configuring, low cost, communication technology [24], [25]. The communication between the control module and sink module is performed from side to side in a ZigBee module. In this paper, we have chosen the XBee S2 module, which is working on the 2.4 GHz band but it's data transmits and receives serially. We have configured the Zigbee module through X-CTU software. In our system networks, the eight control modules data converse is possible to the single sink module, which is coupled to a raspberry pi. The private area network ID is same as that of the developed control and sink modules. If the working of the setup is correct, the network connection between the control modules and sink node is automatically established. Every equipment can send their status every 4s to the coordinators. We have used the unlicensed 2.4 GHz frequency band for this.

C. *Lock Module*

Lock module includes a ZigBee end device (ZED), a control circuit and an electromagnetic lock. A 5v DC circuit has been

designed to operate the ZED. The electromagnetic lock has been controlled by the ZED through the control circuit. When the command received is "open", the control circuit will de-energize the lock to open the door. Else the lock gets energized to close the door are shown in Fig. 3.

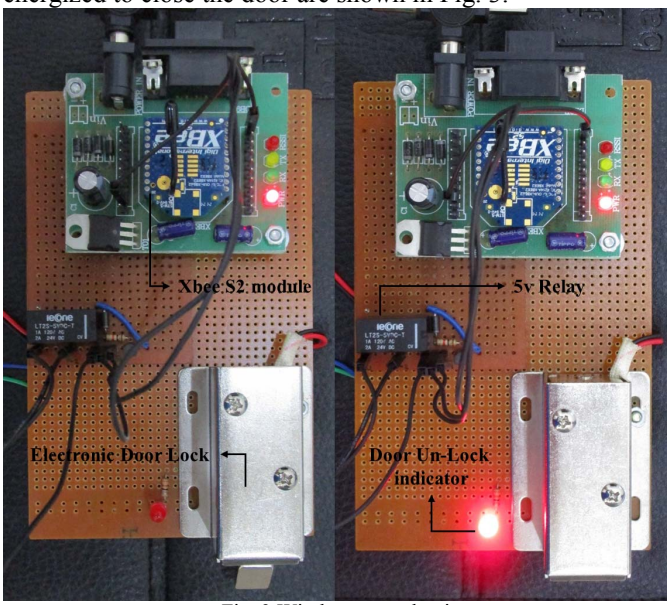

Fig. 3 Wireless control unit

D. IoT Application Gateway

The transformation of control information between the ZigBee and IPv6 network is executed by a program at the IoT application gateway, as the ZigBee network does not have the architecture to communicate with internet protocols. The IoT application gateway consists of a program for transforming ZigBee addresses and encapsulating data payloads in an internet protocol.

The XBee-S2 modules produce sample packets which are converted by the application gateway to IPv6 User Datagram Protocol (UDP) packets and sent to a server. Command packets to control the XBee-S2 modules are encapsulated in an UDP packet by the server, and converted by the IoT application gateway to ZigBee packets.

E. SMS Module

The SIM900A is a GSM/GPRS module which works on various frequencies such as 8S0MHz, 900 MHz, 1800 MHz and 1900 MHz to send SMS [26]. The modem is designed with RS232 level converter circuitry which allows it to be connected to the microcontroller serial interface. It also has TCP/IP stack which enables the microcontroller to connect with internet via GPRS. An SMS activation system is implemented to communicate the home owner [27].

The SMS module consists of GSM modem and a control program. The control program, GSM-dial up and communication protocol are stored in the embedded gateway and the GSM modem is connected to the Raspberry pi via serial interface to the switching module. The SMS module acts as an interface between the embedded processor and the GSM network, making the system login to the network and ready to make any data transfer and communication. The module takes the AT command from remote terminal or mobile devices and sends them to switching module via the GSM network.

IV. Embedded Web Server Implementation

The server was implemented on a Raspberry pi development board in Linux environment, which supports SLIP, TCP/IP, HTTP and AT Commands protocols. The web server Flash File System supports dynamically generated files that can include output data from hardware resources. This type of file is called an embedded server page (ESP).

A. Embedded Server Pages

Embedded Server Pages is created using the following technique: HTML, JavaScript, PHP & SQLite. Dynamic HTML allows Users to add embedded equipments data to their pages that are otherwise difficult to achieve. So that user can both control and observe the secure environment (See Fig.4).

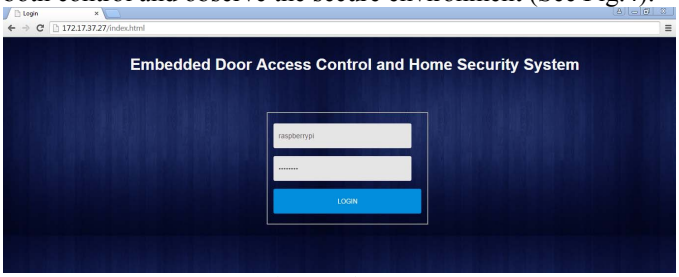

Fig. 4 Login page

Use of JavaScript is to make user friendly interaction with equipments to HTML. Pages Scripts are embedded in or included from HTML pages and interact with the database of home security system. Java script also used for resizing data field of HTML pages and validate the input values (See Fig. 5).

Fig. 5 monitor and control interface

SQLite is used as embedded database for local storage in application software such as embedded equipment data records for present and future use of web browsers. It is arguably the most widely deployed database engine, as it is used today by several widespread browsers, operating systems, and embedded systems, among others.

B. Storage of Data

The UDP packets produced at the gateway encapsulate sample data to be sent to Linux based server. An application running on the server uses the standard socket interface to receive UDP packets on an arbitrary port, and stores the

relevant information in the SQLite database. The database table has 4 columns; source address, time, source channel and sample data. Rows are added to this table for each UDP packet received. This allows samples to be sorted by time, sensor node and sensor channel. In the present system, programs for address, packet transformations and data transmission are written using 'python' programming language, programs for packet reception and data storage are written using 'python' and Web interface is developed using PHP and Java Scripts.

C. *Display on Web Interface*

A Linux based server collects sample data by receiving the UDP packets containing sample data from the IoT application gateway and store in a database. These samples can be accessed from the database through a website hosted on the server. The raw sample data, sample source and time of arrival are stored in the database. This enables the samples to be ordered by date and organized by their source. The current data is displayed on the website is shown in the Fig. 6.

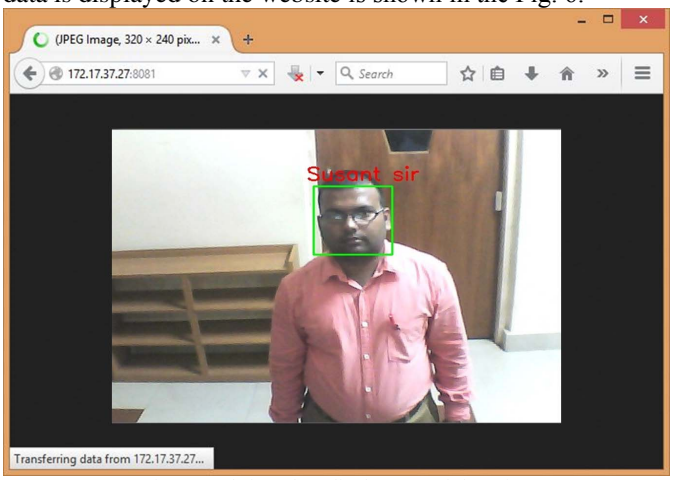

Fig. 6 Real-time data display on web interface

V. Experimental Results

The experimental setup shown in the Fig. 7 is monitoring the environment for visitor entry, the WIU sends the notification email and/or SMS indicating the update visitor to the authorized users and the user then sent mail to WIU for controlling action which is shown from Fig. 8 to Fig. 12, respectively.

The algorithm, read the subject and before forwarding to WCU, will check the existence and safe range of the devices wirelessly. If the system satisfies safety and security norms then WIU will forward the controlling command to WCU wirelessly to perform switching action. For example, an email with the subject ON1 was sent to raspberry pi account ('rpi.home3@gmail.com' in this case) from the consumer account (agrawalrishabh3@gmail.com' in this case).

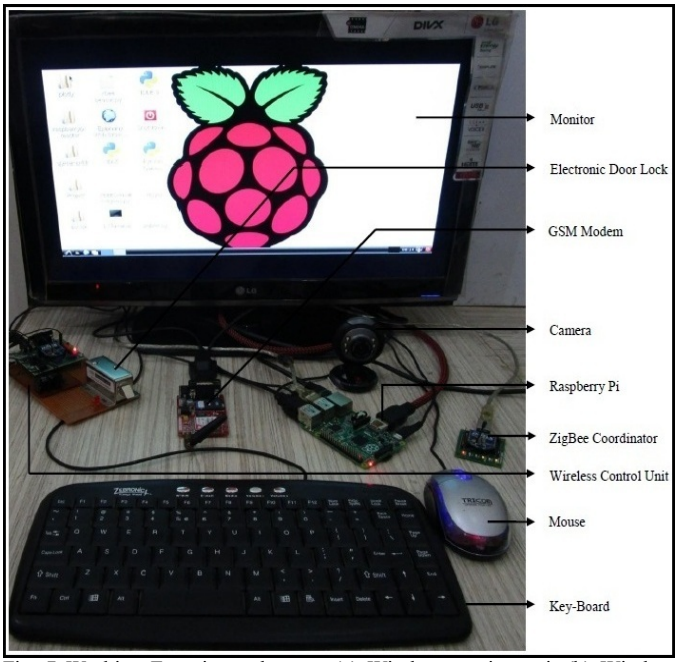

Fig. 7 Working Experimental setup, (a) Wireless sensing unit (b) Wireless information unit having GSM modem, Raspberry pi, ZigBee coordinator, monitor, keyboard and mouse.

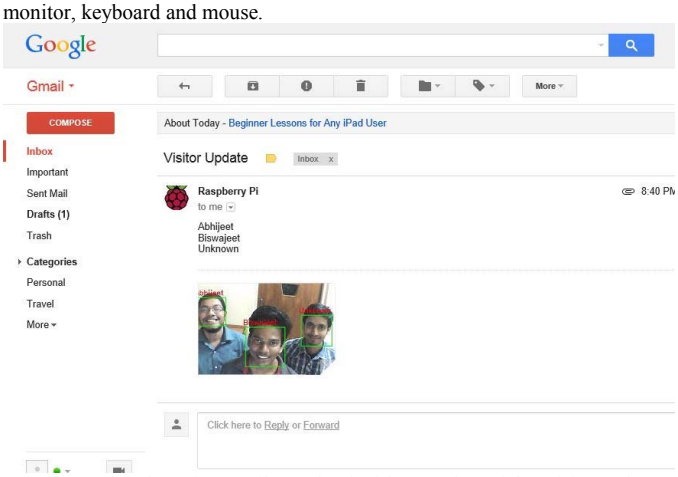

Fig. 8 Screen shot of "E-mail Received with Snapshot of the Visitors" from WIU

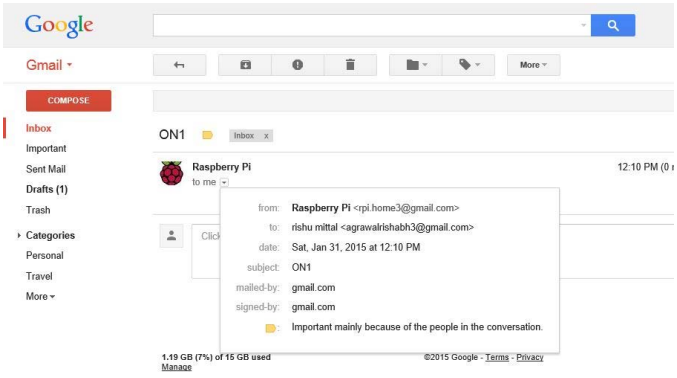

Fig. 9 Screen shot of "INBOX" received on WIU

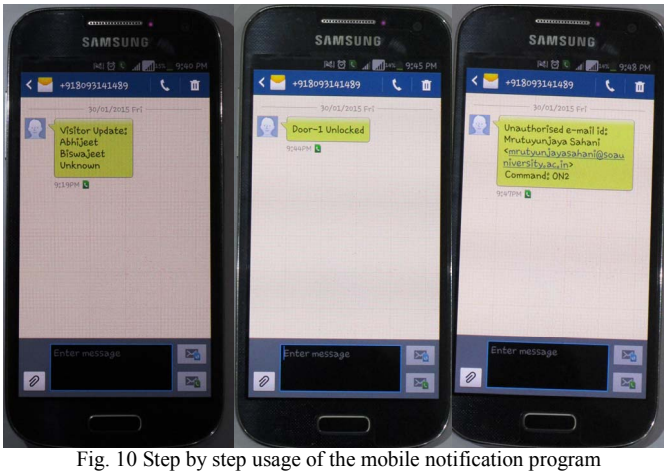

Fig. 10 Step by step usage of the mobile notification program

The algorithm, read the subject 'ON1' at WIU and send the command to WCU to unlocked door 1 and instantly reply to owner by an email - 'Door l Unlocked' under the subject- 'Notification on Home Security System'. Fig. 11 shows the screen shot of sent mail from WIU to sender indicating the details of action performed. The code also notify the security breach to prevent unauthorized users to access the system is shown in Fig. 13.

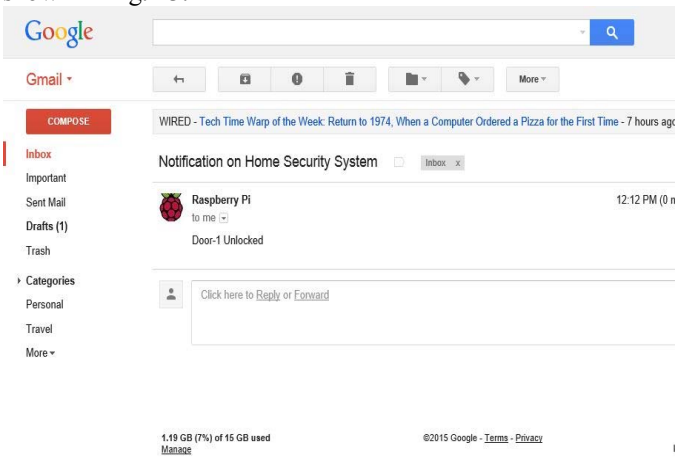

Fig. 11 Screen shot of "CONFORMATION MAIL" from WIU

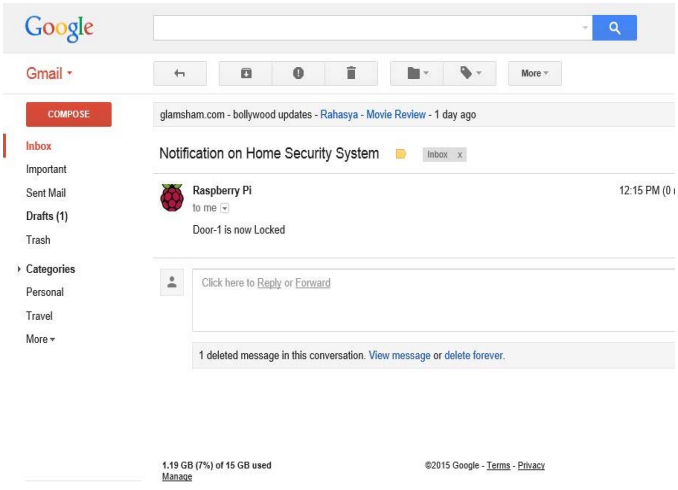

Fig. 12 Screen shot of "CONFORMATION MAIL AFTER CLOSING THE DOOR " from WIU

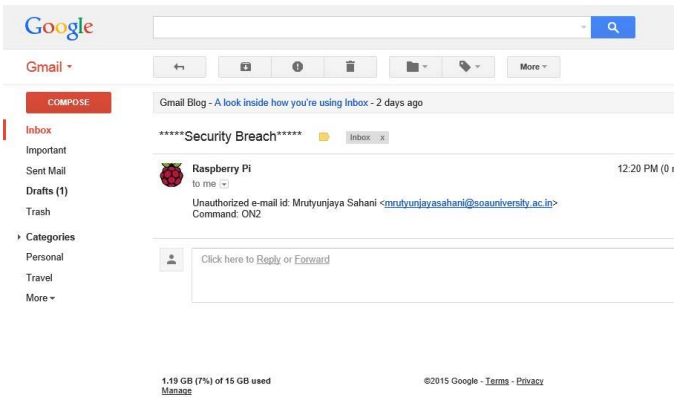

Fig. 13 Screen shot of "SECURITY NOTIFICATION" from WIU

The owner can monitor the visitors and control door lock through web site. The control program is running on the server. The application is flexible in usage as these devices can be controlled remotely using the secured website as shown in Fig. 14. Thus, through the website the home security system is monitored for effective remote management.

Fig. 14 Page to monitor and control appliances

The stability of the Web-based home security monitoring; relating to interconnection with the WSN and the IPv6 depicts that the IoT technology is reliable in transforming intranet of things to internet of things with low-cost system utilization.

VI. Conclusion

This paper presents the design and the implementation of an interactive home security system with the GSM, ZigBee communication and Web-enabled measurement and control systems. The Web based monitor and automatic control of equipment is forming a trend in automation field. Replacing PC with low-cost single chip processor which can make administrators to get parameters of different remote devices and send control information to field equipments at any time through Internet.

The GSM is an excellent choice for this due to its extensive coverage. Since SMS is a text based protocol, even the most basic GSM systems can have an access to the status of the devices or make changes on these states. The complete system is secured through a login E-mail and Webpage password based authentication. The design is completely wireless and integrated with the software to form a low cost, robust and easily operable system. ZigBee communication makes the system easy to install.

The GSM, E-mail and Web based controlled duplex communication system provides a powerful decision making device concept for adaptation to several smart home scenarios.

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