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E-mail Based Kitchen Monitoring System Using a Wireless Sensor Network and GPRS Module

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ABSTRACT

An interactive kitchen monitoring system for monitoring environmental parameters, such as light intensity, room temperature, fire detection, motion detection and LPG gas level, has been developed. This system can monitor the status of kitchen and send an alert SMS via GSM network and/or an E-mail automatically to a concerned authority, if the conditions get abnormal. The concerned authority can control the system through his mobile phone by sending AT Commands to GSM MODEM or by taking the necessary steps in user E-mail, which is password protected. This system finds a wide application in areas where physical presence is not possible all the time. The ZigBee device and ARM1176JZF-S microcontroller are used in the implementation of sensor module. The system offers a complete, low cost, powerful and user friendly way of real-time monitoring and remote control of kitchen. A prototype model is developed and tested with high accuracy result.

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INTRODUCTION

Home automation represents a potential research area, and their significance is growing rapidly because of rise in community demand. With the advancement in Internet technologies and Wireless Sensor Networks (WSN), a new trend in the era of ubiquity is being realized. Enormous increase in users of Internet and modifications on the internet working technologies enable networking of everyday objects (Surie, 2008). Humans usually inside their home interact with the environment settings like light, air, etc., and regulate them accordingly. If the settings of the environment can be made to respond to human behavior automatically, then there will be several advantages. The automation of home settings to act according to the inhabitant's requirement is termed as intelligent home automation system. Ambient intelligence responds to the behavior of inhabitants in home and provides them with various facilities (Eisenhauer, 2009).

In general, intelligent home automation system consists of clusters of sensors, collecting different types of data regarding the residents and utility consumption at home. Several systems using Bluetooth, Infrared (IR), ZigBee and Radio Frequency Identification System (RFID) based communication protocols have already been utilized to monitor homes wirelessly within a short range. For example, the Bluetooth technology was utilized to build an intelligent home security system (Liang Hsu, 2009). In addition, remote-controllable power outlet system for home power management (Chia-Hung Lien, 2007), a networked monitoring system for home automation (Guangming Song, 2007) and intelligent home appliance control system (Hyung-Bong Lee, 2010) have also been proposed. An IR interactive remote control of legacy home appliances through a virtually wired sensor network has also been reported (Chun-Liang Hsu, 2010).

ZigBee–based technology has been used in local monitoring and controlling of home appliances within homes. For example, ZigBee-based remote information monitoring devices for smart homes and home automation systems were developed and reported (Zualkernan, Gill, 2009; Gao Mingming, 2010). Monitoring and protection building electrical safety system utilizing ZigBee was also presented (Li-Chien Huang, 2011). RFID technology has also been utilized in home automations (Ching-Hu, 2011), homes safety (Hui-Huang Hsu, 2010; Xuemei, 2008) and health monitoring systems for elderly in nursing homes (Dong-Her Shih, 2010). The above wireless local range monitoring systems have been extended to a wider remote range using GSM/GPRS networks (Gao Mingming, 2010) and wireless TCP/IP based communications (Dong-Her Shih, 2010). In addition, a low cost wireless gateway utilizing a GSM/GPRS

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based system to monitor fire and door knobs were reported (Zhao, 2008) and many others to mention. The above mentioned systems are utilized for local monitoring or remote monitoring using wireless components like wireless access points and GSM/GPRS modems.

The paper proposes a Raspberry pi based kitchen monitoring system through E-mail with ZigBee based technology. Raspberry Pi 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, 2 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 (Maik Schmidt, 2012).

In this paper, we have described a novel design and implementation of a compact wireless sensor network with internet (E-mail) capability. The system can monitor the status of kitchen and send E-mail and/or an alert SMS via GSM network automatically to users. The system has the capability to control through internet (E-mail), where the subject of received E-mail is read by the developed algorithm fed into Raspberry pi and then the system responds to the corresponding instruction with high security. It has a variety of features such as energy efficiency, intelligence, low cost, portability and high performance.

System architecture:

The kitchen monitoring system hereby reported consists of two components (Fig. 1), Wireless Sensor Network units (WSNs) and a Wireless Information Unit (WIU) linked by radio transceivers that allow the transfer of temperature, light intensity, motion detection, fire detection, LPG gas detection data, implementing a WSN that uses ZigBee technology. The WIU also has a GPRS module to transmit the data via the public mobile network. Raspberry Pi has been chosen as the processing unit of WIU. Python coded Algorithm has been fed into it and is connected to the internet to access and send E-mail to the consumers.

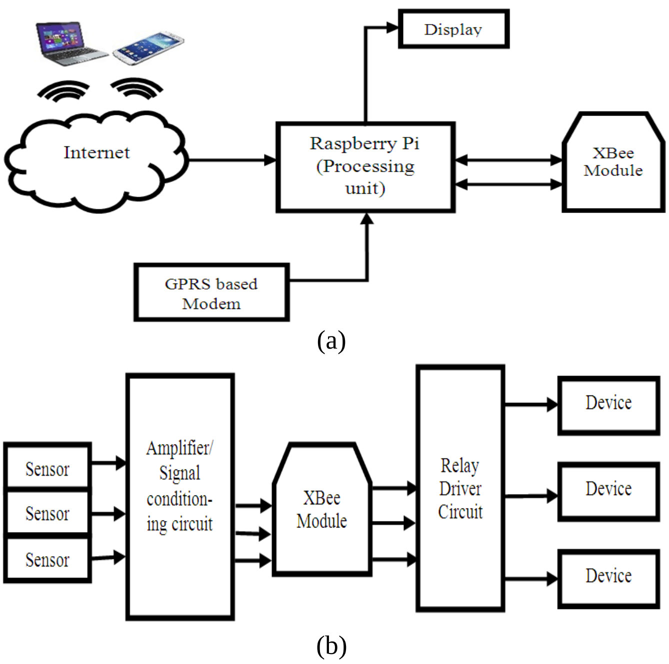

Fig. 1: Layout of the proposed system configuration; (a) Wireless Information Unit, (b) Wireless Sensor Unit.

Proposed Algorithm:

The virtual home is a software construct developed in python. The virtual home is implemented on the home gateway. All communication and instructions are checked, as illustrated in Fig. 2, for security and safety in the virtual environment before implementation in the real home environment.

The virtual home waits for input from an external source. All the devices on the ZigBee network incorporate the ZigBee microcontroller and a dedicated raspberry pi. If the conditions get abnormal raspberry pi sends an E-mail and/or alert SMS to concerned authorities. Once the security E-mail has been received, the virtual home checks the safety implications of the E-mails. After decryption the destination device address is extracted from the E-mail and is checked for its existence in the device database. Once the device's existence on the network has been established, the subject included in the E-mail is extracted. The existence of the command for the respective device is checked to ensure the real device offers the requested functionality. The extracted parameters are compared against predefined safe ranges for the respective device and command. Only after the E-mail has been processed by the virtual home algorithm for security and safety, and declared safe, the E-mail is re-encrypted and forwarded to the real home network device.

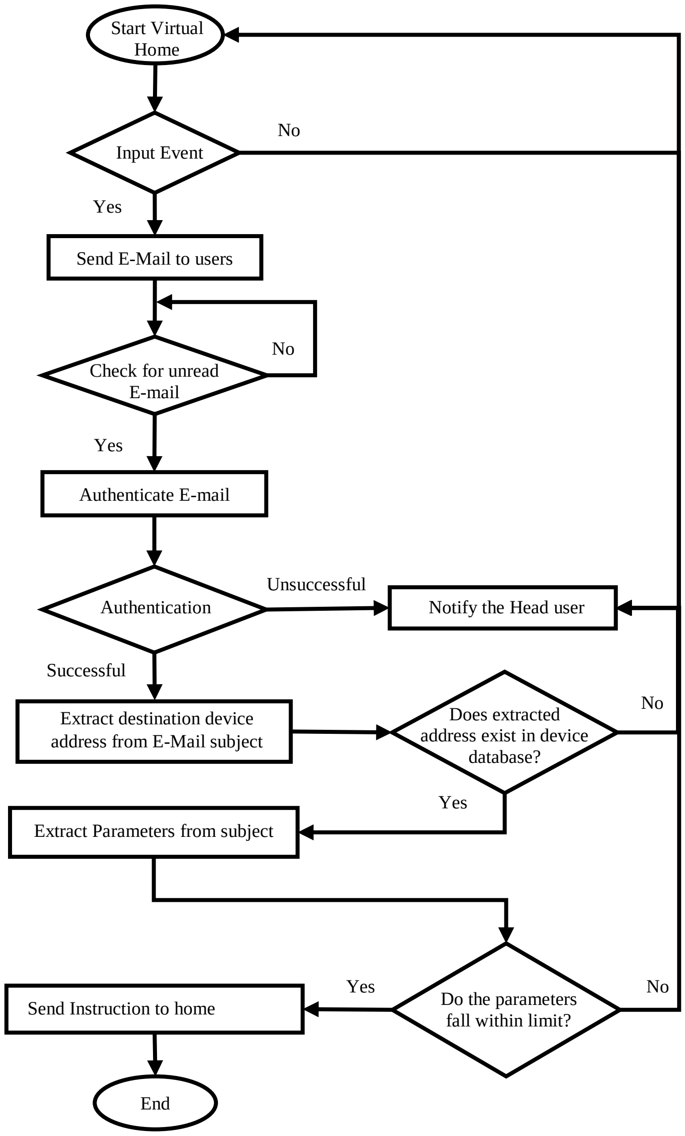

Fig. 2: Flowchart of the control algorithm.

System Description:

The remote measurement and controlling of home devices over the Internet can be mechanized by following certain network architectural design strategies and applying ZigBee communication standards. The data transmission of smart sensing devices 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 the ZigBee protocol data format is translated to Internet protocol (IPV6) format by the gateway.

The Raspberry Pi unit and the associated sensors are installed in a home through ZigBee and the threshold for each of the analog input is configured. If an abnormality is sensed, the Raspberry pi sends an E-mail indicating the status of the monitored sensors to an Internet-based server using the user E-mail-id. The system then sends a Short Messaging Service (SMS) message to the home owner informing about the abnormality.

ZigBee Wireless Sensor Network:

In the development of kitchen monitoring system, ZigBee communication has been used. The ZigBee device is an energy efficient, highly accurate, self-configuring, low cost, communication technology (XBee-PRO, 2013; IEEE 2003). The communication between the sensor module and sink module is performed from side to side a ZigBee module. In this paper, we have chosen the XBee S2 module, which is working in the 2.4 GHz band to transmit and receive data serially. We have configured the ZigBee module through X-CTU software. In our system network, the five sensor module data converse with the single sink module, which is coupled to a Raspberry pi. The private area network ID is same as the developed sensor and the sink module. If the working of the setup is correct, the network connection between the sensor modules and the sink node is automatically established. Every sensor sends its data to the coordinators for every 4s. We have used the unlicensed 2.4 GHz frequency band.

Sensing Units:

We have used five different types of sensors as sensing units for effective data management on the IoT networks. The sensing unit measures the environmental conditioning values such as temperature, light intensity, etc. Thus, the fabrication of different types of sensing units enabled remote monitoring and controlling of household appliances through IoT gateway and IoT application. Fig. 3(a, b, c, d, e) depicts the fabricated sensing units used in the IoT application wherein the data is forwarded through the IoT gateway integrated with ZigBee coordinator.

The gas sensor being used has high sensitivity to liquefied petroleum gas (LPG) (Hanwei Electronics CO., 2011). This makes the sensor appropriate for a kitchen. A signal conditioning circuit is designed to interface the sensor to one of the analog inputs of the ZigBee module. The sensor can detect the concentration of LPG between 300-10,000 ppm. Concentration of gas above 1000 ppm can be toxic [20]. When the value exceeds this threshold, the communication module sends an E-mail alert to the user through Raspberry pi.

The temperature value is acquired by a low cost temperature sensor, the DS1820. It consists of several electronic components to interface the sensors to the one of the input pin of ZigBee module. It can measure temperature from -55C to +125C. A light sensor is chosen for determining the light intensity, which also communicates through ZigBee interface. The sensor output is converted to digital value from which illuminance or the ambient light level in Lux is calculated using an empirical formula to approximate the human eye response. Fire sensor node is placed in the kitchen. The sensor can detect fire and send an E-mail and/or SMS and/or to the base station while sounding the alarms at the same time. A motion detection sensor (MDS) based on an infrared receiver is used (Vishay Semiconductors, 2001). It is interfaced to digital input pins of ZigBee module to monitor the door of the kitchen.

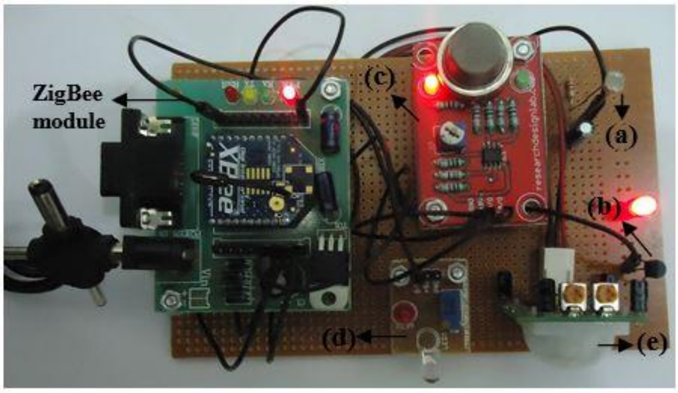

Fig. 3: Wireless sensing unit for Measuring (a) light intensity, (b) Measuring environment temperature, (c) LPG gas level monitoring, (d) Fire detection monitoring, (e) motion detection monitoring.

IoT Application Gateway:

The transformation of sensing information from ZigBee to 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 to IPv6 User Datagram Protocol (UDP) packets by the application gateway and sent to a server. Command packets to control the XBee-S2 modules are encapsulated in an UDP packet by the server and are converted to ZigBee packets by the IoT application gateway.

SMS Module:

The SIM900A is a GSM/GPRS module which works on various frequencies such as 850MHz, 900 MHz, 1800 MHz and 1900 MHz to send SMS (Rhydo Technologies, 2011). 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 to internet via GPRS. An

SMS activation system is implemented, which detects abnormal behaviour and communicates with a remote tele-care centre, the clients, and their caregivers (Barnes, 1998).

The SMS module consists of a 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, enabling the system login to the network and making the system ready for 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.

Experimental Results:

The experimental setup shown in Fig. 9 is polling the kitchen environment, when any parameter exceeds its threshold value, the WIU sends the warning notification E-mail and/or SMS indicating the update parameter (temperature, in this case) value to the authorized users and the user then sends mail to WIU for controlling action as shown in Fig. 4 to Fig. 7, respectively.

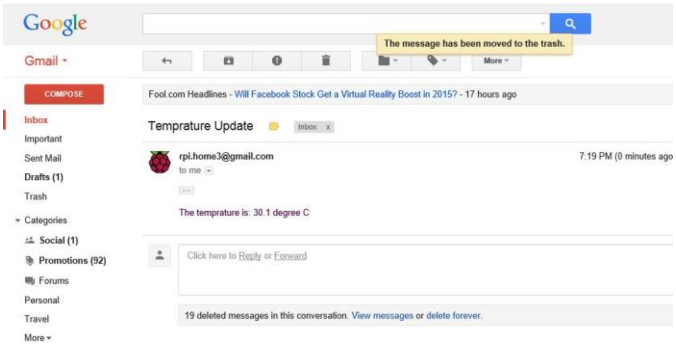

Fig. 4: Screen shot of "WARNING NOTIFICATION" from Raspberry Pi.

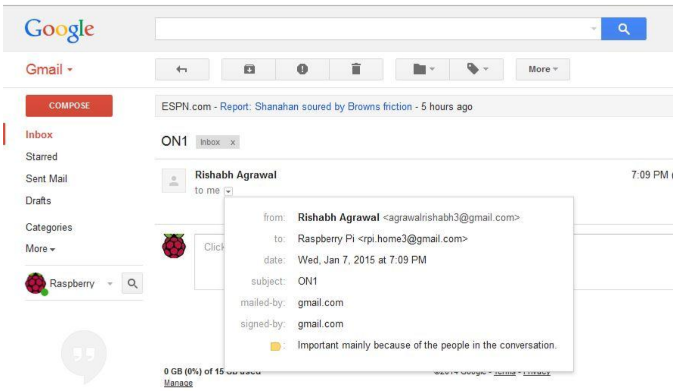

Fig. 5: Screen shot of "INBOX" received on Raspberry Pi

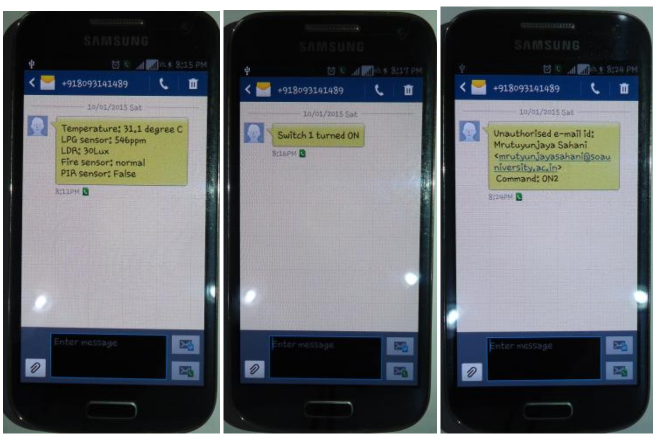

Fig. 6: Step by step usage of the mobile notification program.

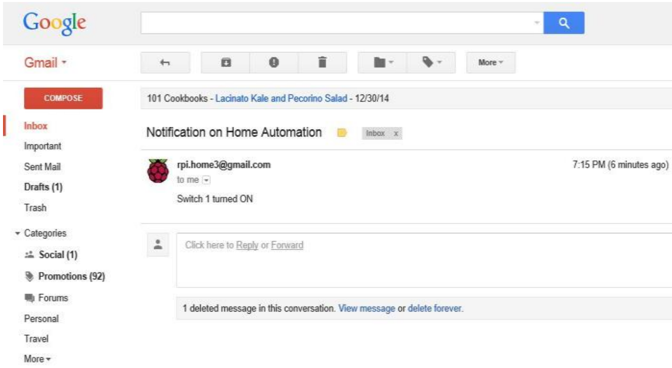

Fig. 7: Screen shot of "SENT MAIL" from Raspberry Pi

The algorithm reads the subject, and checks the existence and safe range of the devices wirelessly before forwarding the same to WSN. If the system satisfies the safety and security limits then WIU will forward the controlling command to WSU wirelessly to perform the switching action. For example, an E-mail 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).

The algorithm read the subject 'ON1' at WIU and sent the command to WSN to turn ON the device 1 represented by Switching Device and instantly replied to the sender by an E-mail - 'Switch l turned ON' under the subject- 'Notification on Home Automation'. Fig. 7 shows the screen shot of sent mail from WIU to the sender indicating the details of action performed. The code also notifies the security breach to prevent unauthorized users to access the system as shown in Fig. 8.

So the result shows that E-mail based kitchen monitoring system has been successfully implemented efficiently and reliably.

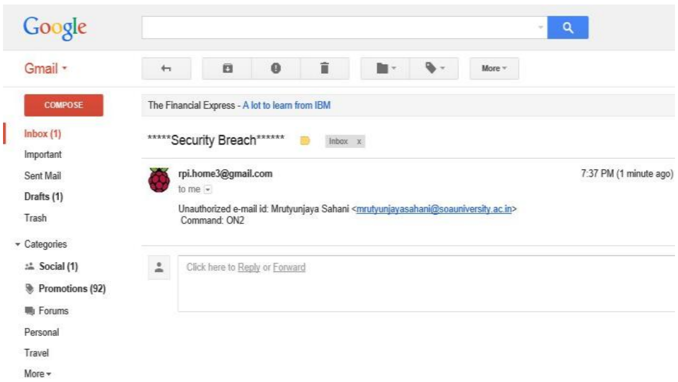

Fig. 8: Screen shot of "SECURITY NOTIFICATION" from Raspberry Pi.

Fig. 9: Working Experimental setup. (a) Wireless sensing unit responding to E-mail with subject 'ON1'i.e.

Switching Device is glowing representing the switching signal for switch 1, (b) Wireless information unit having GSM modem, Raspberry pi, ZigBee coordinator, monitor, keyboard and mouse.

Conclusion:

This paper presents the design and implementation of an interactive kitchen monitoring system with GSM, ZigBee communication and E-mail features.

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 access to the status of the devices or can make changes on these states. The complete system is secured through a login E-mail password based authentication. ZigBee communication makes the system installation easy. The design is completely wireless and is integrated with the software to form a low cost, robust and easily operable system.

The monitoring and automatic control of equipment through LAN or Internet is forming a trend in automation field. An existing monitoring system can be connected to Internet by sophisticated embedded processor to extend its function. Replacing PC with low-cost single chip processor can make administrators get parameters of different remote sensors and send control information to field equipments at any time through Internet. The E-mail controlled duplex communication system provides a powerful decision making device concept for adaptation to several smart kitchen scenarios.

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