Analysis and Performance of a Low Cost SMS Based Home Security System

Sheikh Izzal Azid, Sushil Kumar
School of Engineering and Physics
The University of the South Pacific
sheikhizzal@gmail.com, kumar_su@usp.ac.fj

Abstract

The performance of the sensors of a low cost Short Message System (SMS) based home security system equipped with motion sensor, smoke detector, temperature sensor, humidity sensor and light sensors has been studied. The sensors are controlled by a microprocessor PIC 18F4520 through the SMS having password. The operation of the home security has been tested on Vodafone- Fiji network for emergency and feedback responses for 25 samples. The GSM experiment showed that it takes about 8-10s for the security system to respond the occupant and relevant civil authorities in case of emergency. It takes about 18-22s for the occupant to switch and monitor lights and appliances and then get feedback from home depending upon the network traffic.

Keywords: *Home Security, Sensors, GSM Network, SMS, Password.*

1. Introduction

The home automation refers to domestic environment that improves the quality of the resident's life by facilitating a flexible, comfortable, healthy, and safe environment. With the rapid development in computer and network, the Internet based home security has advanced a lot in the residential areas. The remote controlling and monitoring of a house using internet requires a computer, which is large in size and heavy to carry around. The wireless technology has some amazing achievements in the home automation via Bluetooth [1], ZigBee [2, 3], and Wi-Fi [4] and Global System for Mobile Communication (GSM) [5]. The wireless automation reduces the cost of the system unit as well as it is much easier to install. The GSM module system uses mobile network and is battery powered which makes home automation system safer from internet hacks. The GSM module has also been advanced to automobiles. GSM module can be interfaced with the car ignition system where the owner carries the mobile phone rather than to carry around the key [6]. Recent advances in the automation have been made in billing system for electricity, gas and water using the GSM module based SMS metering service rather than assigning person to visit each house and read the meter readings manually [7]. However, the GSM module has some drawbacks as it cannot behave like what the actual mobile phone does. The GSM module users have to remove the SIM card for recharge top-up. Exposure in using the GSM network is limited by GSM module than the mobile phone.

For a high-quality home automation the selection of sensors is very important. A control system is good if the sensors used to measure the desired variables are able to transmit the measured values of variables to the controller. It is crucial that the sensors provide accurate measurements of the variables to be controlled at the reference point in the control loop.

In order to enhance the occupant's safety and expediency, home security system is vital in the field of automated home. The necessities of the home security system should have low cost, easy installation, fast response, and low power consumption. All kinds of security should be fully considered and the control system should be user friendly. The home occupants need to be informed instantly in case of emergency. This paper presents an analysis and performance of a cost effective intelligent home that monitors home security, controls home appliances, and gets feedback from sensors by SMS.

2. Design of the System

For a typical home automation the smoke and motion detectors are essential for the home and the occupants' safety and security. The occupant should be able to control and monitor the temperature and humidity of the home. Under hot or cold weather conditions the occupant should be able to turn on air-conditioner or heater before reaching home to bring temperature to a comfortable level. The user needs the feedback from the home to be fully convinced with the automation. Light sensors are required to read the luminance level of the house and feedback the status of the light in the rooms.

After extensive work survey and analysis of the performance the sensors were selected to suit the needs of the Intelligent Home. The parameters that were considered for sensor selection are the sensors range, accuracy, repeatability, stability, vibration, response time, sensitivity, life expectancy, and the cost. The following sensors were studied for installation in the home security system.

Passive infrared (PIR) and ultrasonic sensors have similar characteristics in terms of overall performance. Ultrasonic sensors are more expensive but provide bigger coverage than PIR sensors. However, increased sensitivity means that ultrasonic sensors are more prone to false triggering due to any movement in the space. In some circumstances the movement of occupants behind partitions may be detectable by ultrasonic sensors, due to reflectance of the emitted sound waves around the partitions. The special beams of microwave sensor can penetrate most types of surfaces, except metals, therefore, the microwave sensor may detect motion where detection is not desirable. The PIR sensors have the widest view than other sensors and are most sensitive and advanced option. Thus the PIR sensor lights are ideal to any home security system and were selected for present automated home.

Most commonly-used electrical temperature sensors are difficult to apply. The thermocouples have low output levels, require cold junction compensation and are nonlinear. The band-gap temperature sensors are the best out of all the sensors but their output is related to the Kelvin temperature scale rather than the more popular Celsius and Fahrenheit scales.

The SHT75 band-gap temperature sensor was chosen as it can measure both temperature and humidity. The SHT75 is a single chip relative humidity and temperature sensor module that gives calibrated digital output. It utilizes a capacitive polymer sensing element for relative humidity. Both temperature and humidity sensors are seamlessly coupled to a 14 bit analog-to-digital converter and to a serial interface circuit on the same chip. This results in a superior signal quality, a fast response time, and insensitivity to external disturbances. The Kelvin temperature is converted to degree Celsius by the microprocessor programming.

The photo or light sensors are highly reliable. The photodiodes or the infrared sensors are much more expensive than the Light Dependent Resistors (LDR). For the home security the task of the light sensor is to detect the electrical light status. The LDR was chosen for light sensing as it is the cheapest light sensor of all and it does its required task effectively. Infrared sensors or the photodiodes have other advantages which are not desirable in the case of the home automation system. The LDR sensor also has longer life when compared to other light sensors.

The ionization smoke detectors are generally quicker in detecting particulate (smoke) generated by flaming (hot) fires. Obscuration is the effect that smoke has on reducing visibility. Higher concentration of smoke results in higher obscuration levels, lowering visibility. The obscuration for ionization is 2.6 to 5.0% obs/m while for photoelectric 6.5 to 13.0% obs/m [8]. Therefore, the ionization detector detects the smoke first. Table 1 gives the sensors finally selected for home security from the above sensors initially selected for the home automation. The working principle and the performance of the sensors are given in table 1 and are described in the following section 3.0.

Table 1: Sensors Selected for Home Security.

Sensor Type	Sensor Chosen	Sensor Name
Motion	Passive Infrared	PIR Motion Sensor N555
Temperature	Band-gap	SHT75
Humidity	Capacitive	SHT75
Light	Light Dependent Resistor	Light Dependent Resistor Chip
Smoke	Ionization	CHUBB Smoke Detector

3. Working Principle and Performance of Sensors

3.1 Passive Infrared Sensor

Passive Infrared Sensor (PIR) (N55) is mounted between 1.1 to 3m height. 12V DC is given to the PIR to power up the sensor. For the outside motion detection the link connector on the sensors Printed Circuit Board (PCB) was slotted to the “High Range”. The circuit switch is normally closed when the motion is not activated. As soon as the PIR senses the considerable temperature change, which can be due to motion or fire, the circuit switch opens. 5V DC is given to the normally closed switch. The current flows to the ground of the normally closed switch rather than through the resistor to PIN B0 of the PIC. As soon as the sensor activates, the switch opens and the current has to flow through the resistor to the PIN B0 of the PIC, hence logic high (5V) is detected by the interrupt pin B0.

To observe the performance of the PIR motion detector, the detector was mounted at a height of 2m on the wall of the home automation. From the point of installation of PIR detector, the semicircular lines are drawn of the radius of 10 feet (3.048 m) intervals till 50 feet (15.24 m). The detection range of PIR tested was found up to 40feet (12.19 m).

3.2 SHT75 Temperature and Humidity Sensor

5V DC is given to power SHT75 sensor. Power supply pins (VDD, GND) were also decoupled with a 100 nF capacitor. The serial clock input is used to synchronize the communication between a microcontroller and SHT75 sensor. Since the interface consists of fully static logic, there is no minimum Serial Clock Input (SCK) frequency. The DATA pin is used to transfer data in and out of the device. DATA changes after the falling edge which is valid on the rising edge of the serial clock input. During the transmission the DATA line must remain stable while serial clock input is high. The microcontroller only drives DATA low to avoid signal disputation. An external pull-up resistor is required to raise the signal high.

An experiment was setup to test the performance of SHT75 sensor against the Lutron HT-3006 temperature and humidity sensor. Temperature and humidity measurements at an interval of an hour with both the sensors were logged simultaneously for 24 hours on 9 December 2009, which have been plotted in Figure 1 and Figure 2, respectively. It can be seen from the Figure 1 that the room temperature increased from sunrise and reached its peak at midday. The temperature remained high till afternoon, then decreased slowly with the time and dropped after the sunset. The high daytime temperature as compared to the nighttime is obvious from the Figure 1. The weather on 9 December, 2009, was sunny and humid during whole day except some clouds in the morning hours (about 7-9 hrs LT) and at the midday. There were light showers in early nighttime. The temperature difference (ΔT) was around 0.7°C for most of the time of the day. It was lowest of 0.1°C at 1 pm. The accuracy of SHT75 sensor is ± 0.4°C and Lutron is ± 0.8 °C [9]. The average ΔT of 0.7°C is due to sensors accuracies, hence the overall performance of SHT75 sensor was satisfactory.

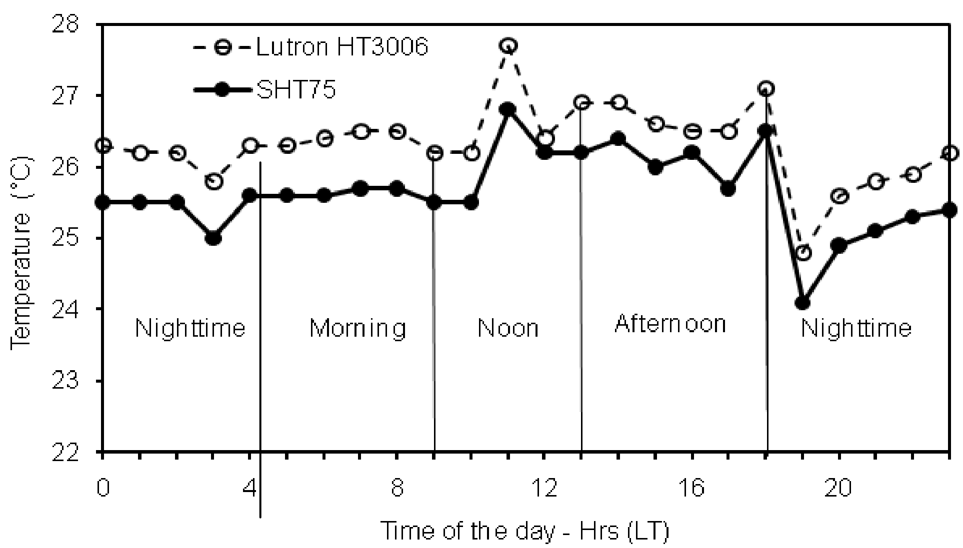

Figure 1. The Diurnal Variation of the Temperature Recorded with Two Temperature Sensors at Every Hour on 9th December 2009.

Figure 2 shows that reference humidity measurements of Lutron sensor are slightly lower than SHT75 observations. The humidity was maximum around noon hours (about 75%R H) and minimum in the evening hours (about 65% R H) and fairly constant of about 70% during the nighttime. The humidity difference measured with both the sensors was almost constant of about 5.5% except during 12-1pm (12-13 hrs LT).

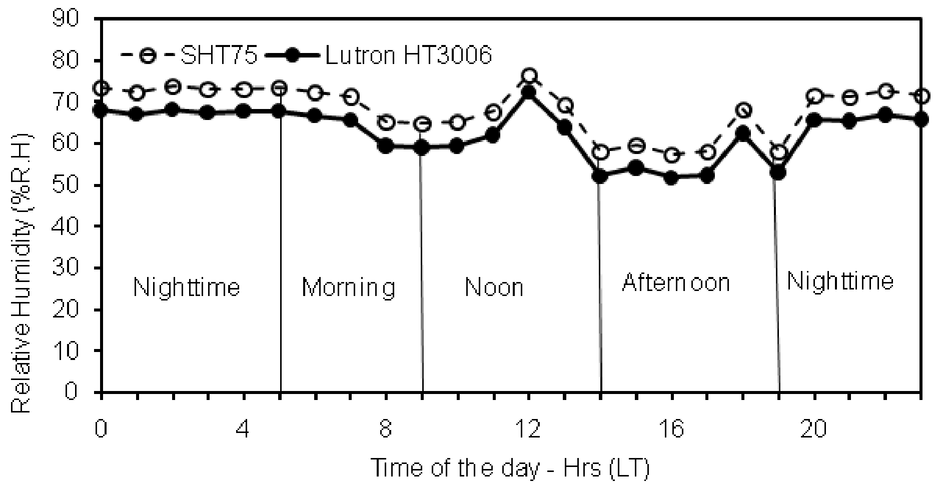

Figure 2. The Diurnal Variation in of the Two Humidity Sensors at Every Hour on 9 December 2009.

3.3 Light Dependent Resistor

As the resistance of the light dependent resistor changes the voltage output to the PIC microcontroller also changes. The analog voltage is read in by the Analog-to-Digital (ADC) pin of the PIC microprocessor, which in case of the home automation is microprocessor PIC 18F4520 is PIN A0. The microprocessor then changes the analog input to digital for the feedback. 5V is supplied to the LDR. Therefore, at the maximum luminous intensity the voltage read by the microprocessor would be 5V and at no light it would be approximately 0V. This process is compared with the observations from the EXTECH light meter. The luminous intensity was measured using EXTECH 401027 Light Meter. The range for EXTECH Light Meter is 0 – 199.9 FC, the resolution is 0.1 FC, and the accuracy is 5%. The EXTECH Light Meter is designed to measure luminous intensity for experimental and laboratory purposes. The light meter reads the light intensity in Foot Candle (FC) whereas LDR gives the output voltage corresponding to the light intensity. Firstly, the experiment was carried out with lights turned on in the room. The results obtained both with light meter and LDR on 9 December 2009 are shown in Figure 3. From the Figure 3 it can be noted that the trends of both the curves are similar. The luminous intensity of the light bulbs and the daylight adds up in the daytime giving a higher value in the daytimes. As for nighttime the luminous intensity is less. The output voltage from LDR can be represented in terms of Foot Candela (FC) units using the relation,

$$\text{Intensity in (FC)} = 15.31 \times \text{LDR (Volts)} + 11.73.$$

This is obtained by the linear fit between both the quantities given in Figure 3. Secondly, the experiment was carried with light turned off in the same room and the results obtained are shown in Figure 4. The luminous intensity is more during the daytime because of sunlight. The LDR showed more precise reading. It showed that the luminous intensity was the maximum at 1 pm (1300 hrs LT).

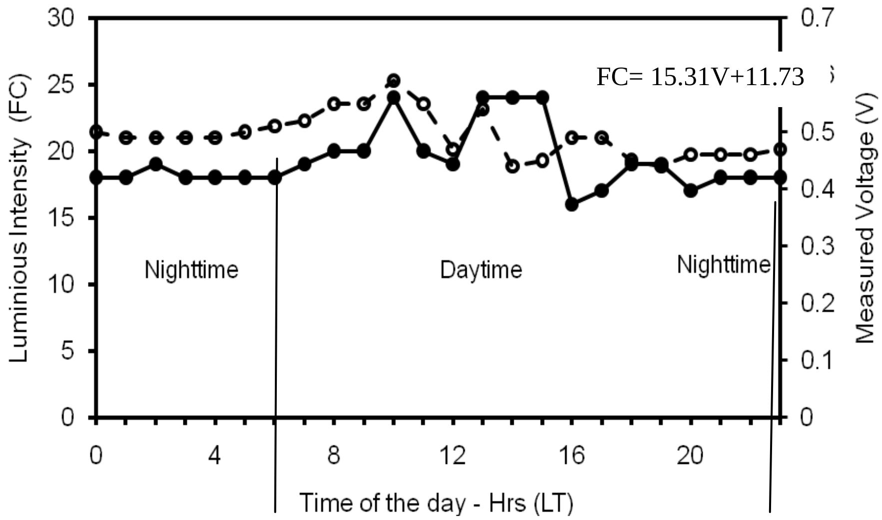

Figure 3. The Light Intensity Measured by Light Meter and LDR (Light on) on 9th December 2009.

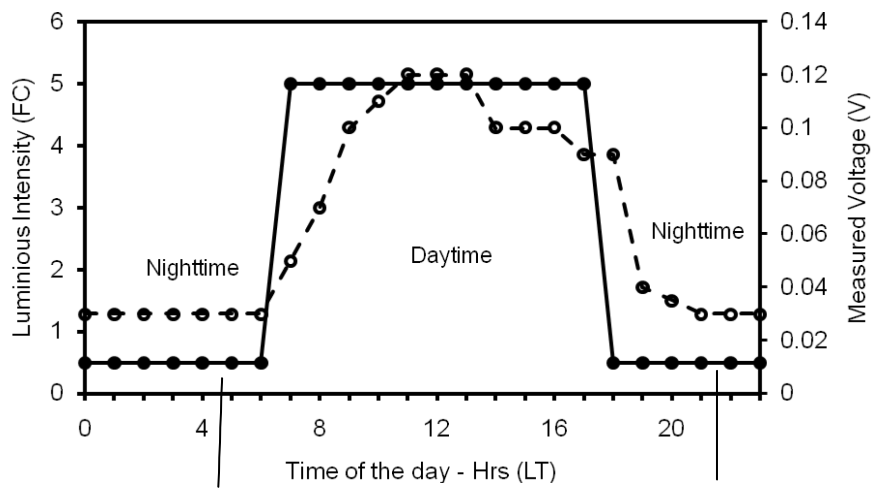

Figure 4. Light Intensity Measured by Light Meter and LDR when Lights were Off on 9th December 2009.

3.4 Chubb Smoke Detector

The smoke alarm is mounted on the ceiling. A 9V DC is supplied to the Chubb smoke alarm. The Chubb smoke detector uses MC14467-1 IC (Low-Power CMOS Ionization Smoke Detector, IC). The schematic diagram of smoke alarm connected to the microprocessor is shown in Figure 5. The MC14467-1 triggers the alarm via an external piezoelectric transducer and internal drivers [10]. The interrupt pin of the microprocessor is connected to detect the input pin of the IC. The smoke detector was installed in the intelligent home to alert the occupant and the appropriate civil authorities in case of smoke or fire. The experiment on smoke detector was not carried out since there were no instruments to measure the amount of smoke in the air. Smoke detector has an inbuilt “test button” to check if the detector’s alarm is functional. Hence, the detector was tested using the “test button” in the detector.

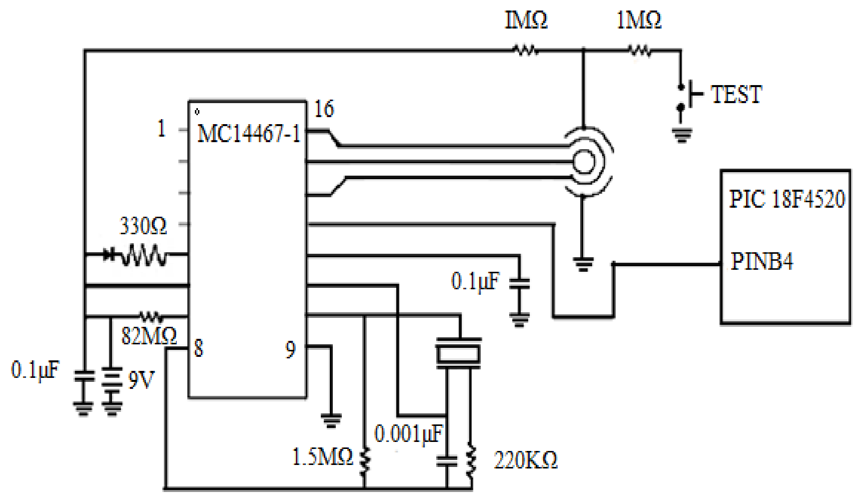

Figure 5. The Schematic Diagram of Smoke Alarm Connected to the Microprocessor.

The difference in measurements of different sensors with the measurements of standard sensors was within the accuracy limits of standard sensors. Thus, the sensors selected in this work are suitable for the intelligent home applications.

4. Operation of the Intelligent Home

The sensors used in the automated home are all interfaced with the microprocessor PIC 18F4520. The sensors are calibrated and programmed to read physical status of the intelligent home and give feedback. The smoke detector is on always in the Intelligent Home and is actively connected to the Interrupt PIN, whereas the motion detector has to be turned on/off by the user. The motion detector is turned on/off by either SMS or manual switch located inside the home.

When an event occurs which demands the microcontroller’s attention, an interrupt is generated, which instructs the microcontroller to stop what it is doing and take care of the higher priority task. In case of an interrupt the microprocessor checks the emergency mobile number saved by the user in the home. Then the microprocessor writes the message and sends it. The message to be sent is a stored message stating type of emergency and the location of the intelligent home. For example “Smoke Detected at 117 Laucala Bay Rd, Suva” After sending the message the microprocessor will jump back to the function it was doing before interrupt. C-language of the interrupt coding is shown is Figure 6.

```
///// Interrupt Motion Sensor/////////
#INT_EXT
void interupt_ext() {
  if(input(PIN_B0))   // Read pin B0
     delay_ms(1000);   // Wait 1 second

    rnumber[0]='\0';   // clear reply array
for (i=0;i<20;i++)
  {
     rnumber[i]=mymobile[i]; // store mobile number on reply array
  }
     message=mtnactive; // stores the message to be sent
     feedback(); // sends message
}
```

Figure 6. The Interrupt Routine Done in PIC C Compiler.

The “Intelligent Home” uses the Light Dependent Resistor (LDR) which detects the status of the light and gives an analog output. Corresponding to the status of the lights the ADC of LDR output is done by the PIC 18F4520 microcontroller programming. PIC 18F4520 microcontroller has five pins which can be used for ADC. These are port A, pins 0, 1, 2, 3 and 4. The five analog inputs are multiplexed into one sample and hold circuit. The reference voltage is logic 5V supply to the PIC 18F4520 microcontroller.

The AT commands are used to communicate with the mobile phone. AT is the abbreviation of “Attention”. The interfacing between the mobile phone and the microprocessor is such that it can communicate with any mobile phone which can be connected serially to modems.

Once the user sends the SMS, the program first searches for the mobile number from the received SMS and stores it. It then matches the password which is stored in the Electrically Erasable Programmable Read-Only Memory (EEPROM) with the password contained in the SMS. EEPROM is a memory storage area where the memory would not be deleted even if the power is off. If the EEPROM password matches with the password in the SMS to the microprocessor then the microprocessor goes ahead to next step, which is searching and doing task asked in the message. Finally, the microprocessor replies to the user about the status of the sensors and lights. If the password does not match, the program will look for advertisement and low credit message and omit it. The advertisement messages are promotional SMS which are sent to mobile network users whereas the low credit message is only send to the mobile phone if the credit is below one dollar. If the message is neither the advertisement nor insufficient credit message the microprocessor will then reply to the user stating “INCORRECT PASSWORD” hence the user can send the SMS again with the correct password.

5. GSM Network Experiment

An experiment was designed to obtain the time taken for intelligent home to perform task given by the SMS and send the feedback. In Fiji Islands there are two mobile networks namely Vodafone-Fiji network and Digicel-Fiji network. The mobile phones used for intelligent home operation was tested on Vodafone Fiji network.

First a set of 25 SMS were sent from the user using Vodafone Fiji Network to activate and deactivate the lights, switches and sensors in the Intelligent Home. Figure 7 shows that it takes about 18-22s and an average of 20.16s for the user to send the message to the intelligent home to respond to the message sent by the user and for the mobile phone based in the intelligent home to give feedback to the user between Vodafone Fiji to Vodafone Fiji network. Another experiment was designed to get the time taken of 25 samples for the intelligent home to send an emergency SMS to the user and appropriate civil authority. Emergency situation in the intelligent home includes smoke and movement outside home. Figure 7 illustrates that the user as well as the appropriate civil authorities will get an emergency SMS within Vodafone-Fiji to Vodafone-Fiji network in 8-10s or in an average time of 9.16 s.

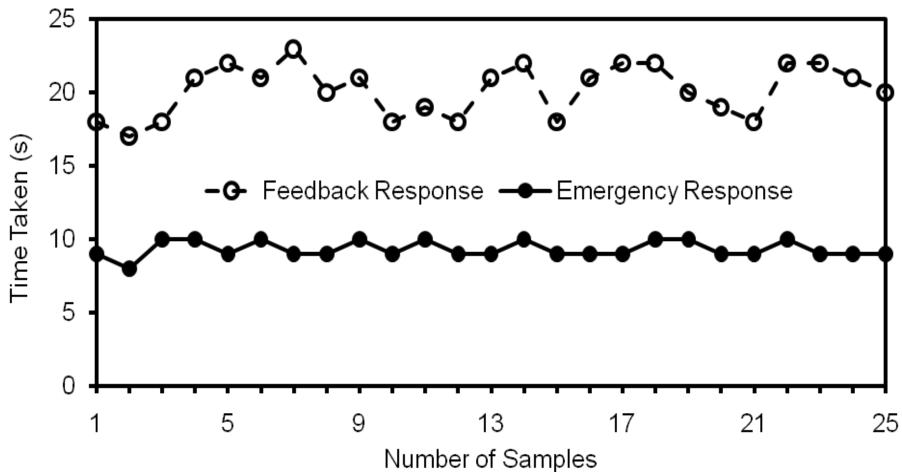

Figure 7. The Time Taken by Samples Between Vodafone-Fiji to Vodafone-Fiji Network for Feedback and Emergency Response.

6. Summary and Recommendation

A cost effective and SMS operated home security system has been designed and tested with the GPRS network. The performances of commercially available sensors were first studied for their feasibility before installation in the intelligent home. These sensors were tested for 24 hour period on 9th December, 2009. The AT commands have been used that provide a flexible way to control and explore the services of the mobile. The communication with the intelligent home is solely through SMS which has been tested with Vodafone-Fiji network but expected to work on any mobile network. The SMS should contain password anywhere in the message for the Intelligent home to respond. In case of no password or incorrect password it will reply incorrect password message. In case of emergency the system will send an emergency SMS to the user and relevant civil authority in an average of 9.16s

The present automated home can further be developed by introducing surveillance cameras with the service of third generation mobile network. The system can then stream live video to the user in the event of the emergency.

References

[1] Y. Tajika, T. Saito K. Termoto, N. Oosaka and M. Isshiki, "Networked Home appliance system using bluetooth technology integrating appliance control/monitoring with internet service", IEEE Trans. Consumer Electron., vol. 49, no. 4, (2003), pp. 1043-1048.

[2] K. Gill, S.H. Yang, F. Yao and X. Lu, " A Zigbee Based Home Automation system", IEEE Transactions on Consumer Electronics, Vol.55,No.2, (2009), pp. 422-430

[3] M. H. Jin, C. J. Fu, C. H. Yu, H.R. Lai and M. Whei, "IBM^3 Zigbee Positioning Method for Smart Home Applications", International Journal of Smart Home, Vol.2, No. 2, (2008), pp.127-133

[4] L. Ophir, "802.11 Over Coax – A Hybrid Coax – Wireless Home Network Using 802.11 Technology", Consumer Communications and Networking Conference, Jan. 2004, pp. 13-18,

[5] B. Yuksekkaya, A.A. Kayalar, M.B. Tonsun, M.K.Ozean and A.Z. Alkar, "A GSM, Internet and Speech Controlled Wireless Interactive Home Automation System", IEEE Transactions on Consumer Electronics, Vol.52, No.3, (2006), pp. 837-843.

[6] J. Karim, W.M.A.B.W. Amat, A.H.A. Razak, "Car Ignition System via Mobile Phone", International Conference on Future Computer and Communication, (2009), pp 474-476.

[7] M. W. Ur-Rahman, M. T. Ahmed, T. H. Khan and S.M.L. Kabir, "Design of an Intelligent SMS based Remote Metering System", IEEE Conference Information and Automation, 2009, pp. 22-24.

[8] Brazzell,D., 2009. "The Effects of High Air Velocity and Complex Airflow Patterns on Smoke Detector Performance", Afcom, pp. 1-38.

[9] HT-3006, "Humidity Meter/Type K Thermometer", HT-3006 data sheet.

[10] Ness., 2007. "Ness Quantum Dual Detector 100-204", PIR Datasheet. Ness Security Products, Ver.1.0.

[11] L. Zoref and D. Bregman, D. Dori, "Networking Mobile Devices and Computers in an Intelligent Home", International Journal of Smart Home, Vol.3, No.4, October, (2009), pp. 15-21.

[12] R. J. Robles, T. Kim "Review: Context Aware Tools for Smart Home Development", International Journal of Smart Home Vol.4, No.1, January, 2010, pp. 1-11.

[13] M. B. Chandak and R. Dharaskar, Natural Language Processing based Context Sensitive, Content Specific Architecture & its Speech based Implementation, International Journal of Smart Home Vol.4, No.2, April, 2010, pp. 1-9.

Authors

Sheikh Izzal Azid received his MSc in the area of Communication, Networking and Security in 2010 and BEtech in Electrical and Electronics Engineering from the University of the South Pacific. Present work has been part of his MSc thesis. His research interest include mobile and wireless communication, embedded microprocessor applications, mobile networks, automation and security.

Sushil Kumar received BSc and MSc (Physics with Electronics) from Agra University and PhD from University of Bhopal, India. He is currently Associate Professor in Physics within the School of Engineering and Physics at The University of the South Pacific, Fiji. He has more than 15 years of research and teaching experience at various universities and institutes. His area of current research interest is Communications and Electromagnetic Wave Propagation.