The Design and Implementation of A GSM Based User-Machine Interacted Refrigerator

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[1]***Abstract*—Today, many user-machine interacted devices are tailored at the service of people. This paper presents a new low cost smart fridge in which GSM is used as the media of communication between the machine and humans. The proposed solution demonstrates remote monitoring of the fridge (its temperature and food and beverage contents) as well as power cut and return alarms through text messages that are sent to stored number in response to a call or a message request or initiated by the system in case of power cuts. The software is utilizing a conditional looping using C and standard AT commands are used for communication between the micro-controller and the modem.**

Keywords—Information Technology, Embedded systems, GSM enabled devices, Home automation, Refrigerators

I. INTRODUCTION

House automation or smart home technologies aim to make our daily life more comfortable. These systems serve some periodic and non-periodic tasks using electronic sensors, switches, machines, and some special purpose devices. In addition to this, communication between people and machines is extremely important today. There is a significant potential of demand for the remote control and monitoring of any system [1]–[4]. Hence, a rapid expansion in the usage of GSM (Global System for Mobile Communication) enabled devices has been witnessed [5], [6]. Mobile devices have a wide application in many areas for remote control and monitoring such as in homes and offices for security and device control; in industry for getting informed about machine situations, temperature, gas and humidity control; in agriculture for getting weather forecasts, status of silos, to control irrigation systems; in health for patient care, etc. [2], [7]–[10].

A GSM modem is a specialized type of a mobile phone. The dedicated GSM modem is usually preferable to a GSM mobile phone, due to some compatibility issues that can exist with mobile phones when developing a GSM enabled device [11]. GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages [8], [12]–[15]. SMS (Short Message Service), which is one of the common communication protocols allowing the interchange of short messages between mobile devices was developed as part of the GSM [16].

Dedicated GSM modems have been transferred to some devices previously. Aranguren *et al.* [17] conducted a study, which provided wireless communication between machines using the GSM module to prove that mobile phones are effective in a wide range. Yüksekkaya et al. [18] developed a wireless home automation system with speech recognition by using GSM networks. Wu and Jin [15] utilized SMS protocols to control smart homes. Bekiroğlu and Daldal [7] managed a remote alarm system by a mobile phone. Mohanta and Khanaa [19] introduce a friendly system to control home appliances remotely by the use of mobile phones. Salman and Vrindavanam [20] have developed an interactive control system based on GSM. The system allows remote control of different appliances through text messages.

This paper presents a new fridge connected to GSM network. It allows the user to gain information about the product quantities and cooler temperatures inside, whenever the user requires by sending a text message or a phone call. In addition to allowing users to control the home appliance from remote places, it notifies them about any electricity faults in the system with an instant text message.

The system is suitable for widespread use due to its compatibility with all mobile phones, not only smart phone systems such as Android, iOS, Windows Phone but also older ones. Although the real target area of the project are especially farm or village houses, which are often in the status of second homes and are located away from the actual living area, it can provide the same benefits for ordinary people in everyday life. This GSM-based home automation system has significant benefits. For instance, individuals can learn about required products any time while away. Furthermore, this project also aims to demonstrate that in practice smart home systems may not require much expense, as opposed to common belief.

II. SYSTEM ARCHITECTURE

The proposed system is a new, low-cost and flexible,

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refrigerator, which provides user-machine interaction to allow users to remotely monitor and control their home devices. For this purpose, an embedded device with GSM modem was integrated onto the refrigerator prototype. The application of the proposed system consists of integrating hardware and preparing the software for the modules. While developing the project, first circuit elements used in hardware were determined, algorithms for the software were created, and programming was realized. Fig.1 shows that the block diagram of the proposed system.

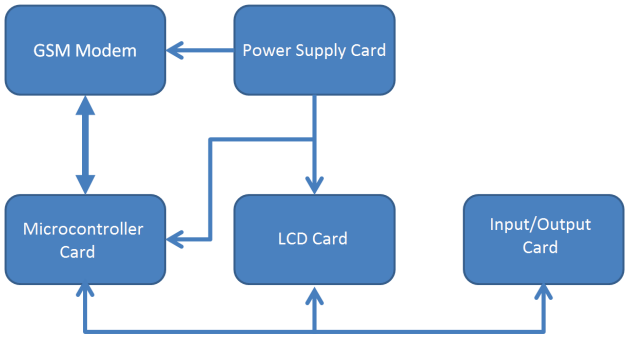

Fig. 1. The block diagram of the system.

The system mounted in the fridge consists of micro-controller card, GSM modem, I/O card, LCD card, power supply card, sensors and accumulator. The refrigerator senses products inside by micro switches and transfers data to the GSM module via micro-controller. A GSM query can be made by SMS or dialing the a predefined mobile phone number. The accumulator inside the refrigerator provides power for the electronic system to notify the user when power fails, and also ensure that the system is kept open during this interval. Fig. 2 shows the GSM enabled embedded electronic system mounted onto the refrigerator.

Fig. 2. The GSM enabled embedded electronic system mounted onto the refrigerator.

A. *The Operation Principle*

In the performed system, text messages are sent to the user by means of the GSM modem, which will communicate with the user's mobile phone. Whenever the GSM modem receives a text message command or phone call from a predefined mobile phone number, it transfers that information to the micro-controller. The micro-controller processes the command and loads them as ON/OFF according to the command sent to the GSM modem. If a status request text message or phone call was received by the GSM modem, the micro-controller automatically sends a text message about availability of products currently present in the fridge. Freezer and cooler temperatures are detected by the I/O card with NTC type thermistor, and interpreted by the micro-controller. As widely used in various embedded systems, the basis of communication between GSM modem and micro-controller was provided by using AT (attention) command set for sending/receiving text messages [13]. AT commands also known as 'Hayes command set', were originally developed by Hayes Company. The complete operation process is displayed on the 4 × 20 LCD module. The operation of the system is shown in Fig. 3.

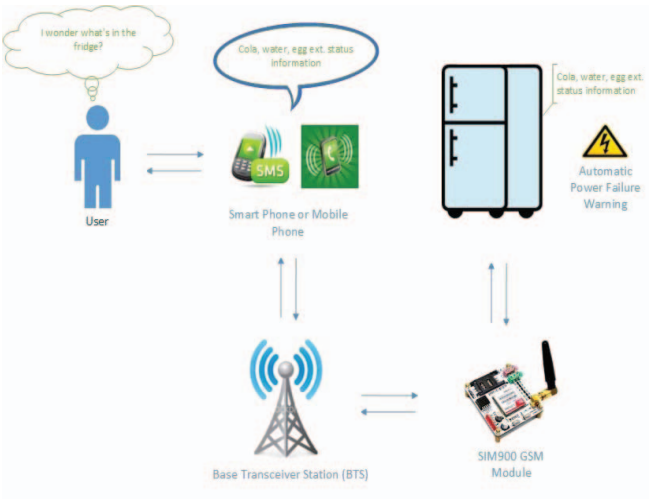

Fig. 3. The operation of the system.

The system, also, notifies the user when a device has an outage condition. In case of a power cut or return, a text message is transmitted to the user via a GSM modem. Even during power cuts users can get information about availability of products in the refrigerator and about freezer and cooler temperatures, due to an installed accumulator.

The response time differs between 6-10 seconds depending on the cellular operator and SMS traffic. This time interval involves:

- Sending a text message or a phone call to the refregirater
- Getting the information from sensors and preparation of messages
- Sending the messages from the refregirater
- Recieving the messages

B. *Hardware*

The products are detected by micro switches, which are of low cost and ease of use. To detect the temperature Negative Temperature Coefficient (NTC) thermistor resistances were preferred. The system uses a GSM modem (SIM900) interfaced to the micro-controller (PIC18F67J60) through an RS232 cable to interpret the information from micro switch and sensors. The micro-controller is built-in the Ethernet module. A Subscriber Identity Module (SIM) card is a

portable memory chip used in GSM modem that operate on the GSM network with a predefined number. The project is powered by an on board power supply, which provides required voltage to the microcontroller, and a 4 × 20 LCD (Liquid Crystal Display) module. PIC18F67J60 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. SIM900 is a dedicated GSM modem that operates as mobile phone. Therefore, GSM modems are used for providing mobile internet connectivity, dialing and receiving calls and sending and receiving text messages. To perform these tasks, an extended AT command set supported by the GSM modem was used for receiving commands sent from any mobile phones and sending reports and status messages to the predefined mobile phone by the system.

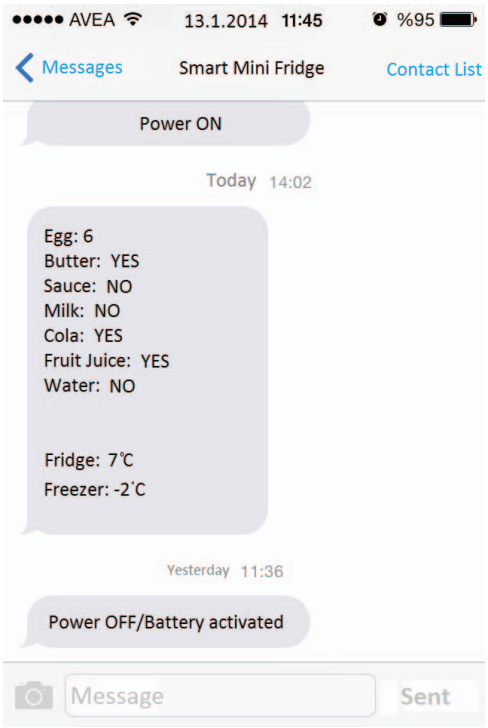

Fig. 4. The reports and status messages

Fig.4 shows some example messages used to receive information from the fridge. These messages are;
Main power failure and return messages:

- Power ON (While there is electricity)
- Power OFF/Battery Activated (When power cut)

Messages about product quantities and temperatures of the fridge and freezer parts (Whenever the user requires by sending a text message or a phone call):

- Egg (With a quantity 0-6), for the others Butter, Souce, Milk, Fruit juice, Water (Yes or No for the meanings available or not)
- Fridge 7°C, Freezer -2°C

As stated earlier, the refrigerator senses products by micro switches (switch position ONN/OFF digitally means 0 or 1) which are located under the products. These logical values are transferred to the GSM module via micro-controller. Message information are automatically generated based on these data owing to the software on the micro-controller. In the current prototype of the study, materials are required to have a place dedicated to them in order to transfer the results correctly for the system.

C. *Software*

At this stage of study, system software will be discussed. The system's main and control subprograms were developed in C programming language due to its efficiency in comparison to the others. The written codes were compiled by MPLABX C18 compiler so that the micro-controller can run them. The algorithm of the main program was constructed as shown in Fig. 5.

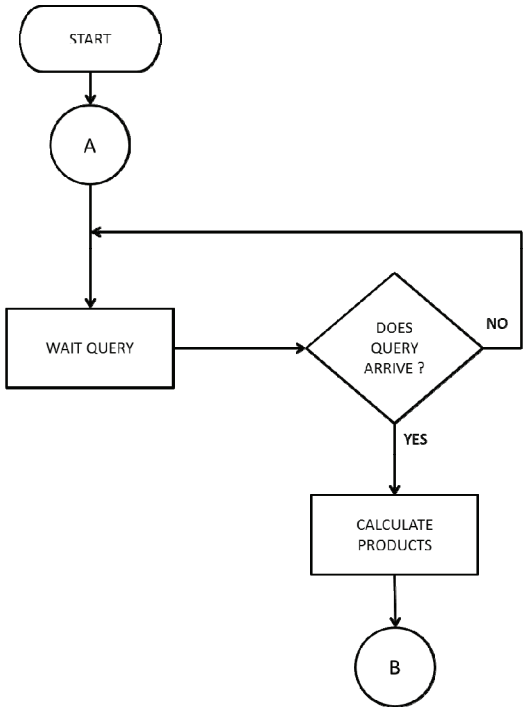

Fig. 5. Main Program Flow Chart

The main program involves the necessary software to provide contact with peripheral units. The decision mechanisms in this flow chart provide the transition to parts of the program that should be run optionally. It means that if any request does not reach the system, the main program flow continues normally, but if any phone call or text message is received, the program shifts to the subprogram, and makes some operations such as sending text message subprograms respectively.

As seen in Fig. 5, the micro-controller waits in ready status for any GSM query. In case of a query detection, the numbers of products inside the smart mini fridge are calculated, temperature values obtained from NTC thermistors and these information are transferred to variables. Then they are passed to a text message preparation stage, which will inform the user. Fig. 6 shows a flow chart that displays how the text message transmission is processed.

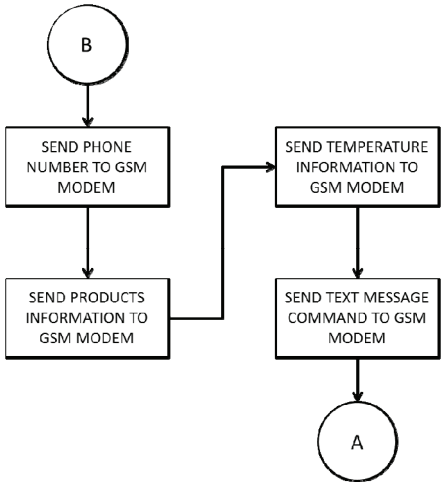

Fig. 6. Sending Text Message Subprogram Flow Chart

In the text message sending process, the AT codes are used to run the GSM modem. These AT commands are sent to the GSM modem by using the RS232 serial communication port through the microcontroller.

The phone number is sent to the GSM modem first. Then the information stored in the variable is obtained and the fridge and freezer temperatures of the smart fridge are read from the sensors by the microcontroller. All this information is sent to the GSM modem after being converted to the appropriate format. After completion of the contents of the text message, the text message command is sent. Thus, the text message sending process is completed. Now, the program is ready to take the next query.

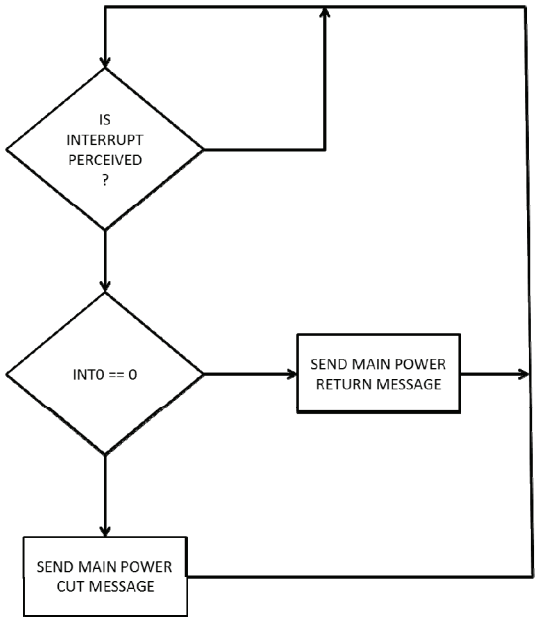

Fig. 7. Main Power Cut and Return Flow Chart

Fig. 7 gives a flow chart that shows the process of the text message notification to the user about the power cuts or returns. A main power failure and return are detected by the interruption codes, which are executed when micro-controller triggers a signal to its INT0 pin. Hence, INT0=0 means power cut, INT0=1 means power return. Whenever this logical values change, a text message is sent to the user stating Power ON or OFF. In case of main power failure, the accumulator in the system is activated so that the electronic system's operation will continue. In this way, it can be possible to establish communication with the mini-fridge for up to 20 hours.

III. Evaluation and Conclusions

In the project, human-machine interaction has been targeted by using the refrigerator. For this purpose, a mini-fridge was designed as prototype to be monitored remotely by retrieving data through a GSM module and various sensors. The system consists of micro-controller card, GSM module, I/O card, LCD display, sensors and battery mounted on the mini fridge. GSM query can be made by text message or a phone call to the SIM card number located in the GSM module. Also notifications about the amount of products contained in the mini fridge, freezer and cooler side temperatures, and power outages in uncertain situations have been conducted.

The most prominent features of the system are having a cheap design and for common use. Details are:

- The system mounted in the fridge consists of micro-controller card, GSM modem, I/O card, LCD card, power supply card, sensors and accumulator. It is performed with a very low cost (Almost 100$. This amount will drop more in series production.)
- Ability of operation with all GSM systems
- Ability of operation operation with all mobile phone systems
- It does not not require internet
- It does not not require smart phone
- There is no need to install any application or software on user phone
- Able to give information to report power outages and interruptions immediately
- Able to give the contents and temperature data even in power outage term

Hence, the proposed system contains many innovations and improvements when considered as a whole. Current commercial products are upper class refrigerators like Smart Thinq Refrigerator [21], which generally requires internet, smart phones, and works with new GSM systems. Therefore they are adressed to higher-income and limited community as a luxury consumer goods. Whereas, in the proposed system, the target of home automation with the mentioned features has been accomplished with an inexpensive way. However, the project can easily be used in larger refrigerators and cooling systems. The developed GSM based technology is also applicable on other household white goods to make life easier. Another mass appeal of the project is that it is compatible with all phone systems including Android, iOS, Windows Phone smart phone systems.

Some commercial freeze alarms are a simple way to prevent expensive damage to home and possessions. The system can send notifications automatically with SMS to predifined phone numbers, as well as monitoring for a temperature loss/rise, water leaks or over-flowing sump pumps, power outages, and the back-up battery status [22].

As a result, GSM technologies appear to offer quick and reliable results in terms of the smart home system. In the future, these developing systems will be widely available in people's daily lives saving time and costs, and offering comfort [23-25].

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