RFID BASED E-MONITORING SYSTEM FOR MUNICIPAL SOLID WASTE MANAGEMENT

By

Mahbubul Alam

MASTER OF ENGINEERING

IN

INFORMATION AND COMMUNICATION TECHNOLOGY

Institute of Information and Communication Technology

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

2012

The project titled **"RFID Based E-monitoring System for Municipal Solid Waste Management"** submitted by Mahbubul Alam, Roll No: M10063115, Session October-2006 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Engineering in Information and Communication Technology (ICT) on 13th May, 2012.

Board of Examiners

____

1. Dr. Md. Liakot Ali Chairman and Supervisor
Professor
Institute of Information and Communication Technology
BUET, Dhaka-1000

____

2. Dr. S.M. Lutful Kabir Member
Professor and Director
Institute of Information and Communication technology
BUET, Dhaka-1000

____

3. Dr. Md. Abul Kashem Mia Member
Professor and Associate Director
Institute of Information and communication Technology
BUET, Dhaka-1000

Candidate's Declaration

It is hereby declared that this project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Mahbubul Alam

Dedicated

To

My Mother

Acknowledgement

At first I would like to express my heartiest thanks to my supervisor Dr. Md. Liakot Ali for giving me the opportunity to do my master‟s project under his supervision. I am also grateful to him for all his support, advice and encouragement throughout this project.

I gratefully acknowledge the valued advice and support from Professor and Director Dr. S.M. Lutful Kabir, Professor and associate director Dr. Md. Abul Kashem Mia and Professor Dr. Md. Saiful Islam of IICT, BUET.

Finally, I want to thank my parents and all of my family members who helped me to make this work a success.

Table of Contents

List of Figures

List of tables

List of Abbreviations of Technical Symbols and Terms

AIDC	Automatic Identification and Data Capture
ASP	Active Server Page
DCE	Data Circuit-Terminating Equipment
DTE	Data Terminal Equipment
GPRS	General Packet Radio Services
GSM	Global System for Mobile
GUI	Graphical User Interface
HTML	Hyper Text Markup Language
IIS	Internet Information Services
ISWM	Integrated Solid Waste Management
MSW	Municipal Solid Waste
POS	Point of Sale
RF	Radio Frequency
RFID	Radio Frequency Identification
SCI	Serial Communications Interface
SQL	Structure Query Language
SMS	Short Message Services
SWMS	Solid Waste Management System
UPC	Universal Product Code
USART	Universal Asynchronous Receiver Transmitter

Abstract

With the increase of population of a country, proper management of cumulative of Municipal Solid Waste (MSW) becomes more acute for maintaining green environment. In conventional approach a number of trucks collect the MSW and then transport and transfer these MSW in a pre-specified location, but all the above jobs are not properly monitored. It is very important to monitor the trucks and record the information related to the collecting time and area from a central location to ensure the job well done. This project exploits the tremendous power of RFID technology and presents the development of an electronic monitoring (e-monitoring) system to overcome the above problem in the conventional approach. The proposed e-monitoring system is an embedded system that consists of RFID technology interfaced with PIC microcontroller and a web based computerized software. It has been tested in the laboratory environment as well as in the field environment. The test results show that the system functions properly and is working real time. Municipal authority can monitor the SW collecting status through the system and can generate different reports to improve the performance of their service. The prototype developed in this project can be further improved and used for commercial purpose.

Chapter 1
Introduction

1.1 Introduction

Green environment is a demand of the 21st century. The major environmental concerns in the 21st century are: atmospheric pollution and its consequences for human health, global warming and ozone layer depletion etc. [1]. Municipal Solid Waste (MSW) is one of the most critical and worldwide environmental challenges. A lot of polluting sources like haze, emissions are generated from the indiscriminate dumping of MSW. MSW includes household‟s refusal and solid wastes generated from industrial, commercial and institutional establishments such as hospitals, markets, streets and industry etc. Now-a-days with the increase of population of a country and its rapid growth of urbanization and industrialization, the cumulative volume of MSW and its proper management have become more acute for maintaining green environment. In the conventional approach, a number of trucks from the municipal authority are sent to the waste bins to collect the SW. The wastes are loaded in the truck and then transport and transfer it to the pre-specified locations. However the category of the people involved in collecting and transporting the wastes are usually not responsible enough to make the job well done. Very often the wastes are not collected from each and every waste bin properly due to driver‟s attitude and fatigue. The conventional waste collection and management approach has the following problems [2]:

i) Lack of information about the collecting time and area.
ii) Lack of proper monitoring system for tracking all activities related to solid waste management.
iii) Loss of productivity due to inefficient utilization and unauthorized use of vehicles.
iv) There is no quick response to urgent cases like truck accident, breakdown, longtime idling.
v) There is no quick way to response to client's complaints about uncollected waste.
vi) There is no analysis of finding best route path of collecting waste.

For proper MSW management the above problems must have to overcome. For this purpose, it is very important for the municipal authority to monitor the status of collecting the waste in real time from a central location.

This project presents an e-monitoring system which consists of an embedded system and web based software integrated with RFID and GPRS technology. Using the proposed system, the municipal authority can monitor the waste collecting status and record the collecting time and area from a central location. Then they can take quick actions in urgent cases. The customer can also lodge their complains through our proposed system. The authority can generate different reports and measure their productivity and then can take corrective actions to improve their performance.

1.2 Motivation and Scope of the project

Every year, the municipal authority spends a major portion of its budget for collection and transportation of solid waste. It is reported in a survey that in developing countries MSW management costs consume 20-50% of municipal revenues whereas collection service levels remain low with only 50-70% of residents receiving service and most disposals being unsafe [3].

A small improvement in MSW management will result in a big savings in overall cost. An intelligent monitoring system is essential for this purpose. Moreover the statistical data stored in the system related to the solid waste can help the environmentalists and urban planners to build a green city. Now-a-days the tremendous power of RFID technology is explored and it has been used in enormous applications such as supply chain management, logistics and personnel identifications, hospital management, airport and luggage control building access, transportation security etc. [4-8]. The concept of using RFID technology in MSW management is mentioned in a literature [9]. Here RFID technology is interfaced with a personal computer which makes the system costly as well as bulky. It is also not portable. The system is also not tested in the field environment. To overcome all the drawbacks, this project has proposed an e-monitoring system where RFID and GPRS technology is integrated with a micro-controller based embedded system.

The system is low cost and portable. It can be easily mounted in a municipal vehicle and it is capable of sending information related to solid waste to a web based software system running in a server in a central location. The current scope of the project is to develop a prototype system and test the system in the laboratory environment as well as in the field environment.

1.3 Objectives with specific aims and possible outcome

The project work will focus on the following objectives:

- To develop an electronic monitoring system for solid waste management.
- The system will have the facility to send SMS to the workers and supervisors.
- To develop a web based GUI so that the system can be accessed from anywhere and information can be viewed by different group of people.
- The GUI will have the facility for the citizens to put their complains and comments on the service

1.4 Organization of the report

This report is organized with five chapters. Chapter 2 describes an overview of RFID and micro-controller technology. Chapter 3 focuses on the system design and implementation technique. Overall system concept, dataflow diagram, system block diagram, communication between RFID and microcontroller are described in details in this chapter. Chapter 4 of this report narrates results and discussions. Chapter 5 presents conclusion and scope of the future work. This report ends with an appendix that contains the source code of the project.

Chapter 2

Overview of RFID and Microcontroller Technology

2.1 Introduction

This chapter describes the fundamental technologies using which the project is developed. It will help the reader of this report to understand this project clearly.

2.2 An Overview of RFID Technology

An RFID system uses wireless radio communication technology to uniquely identify tagged objects or people. It consists of three basic components as shown in Figure 2.1:

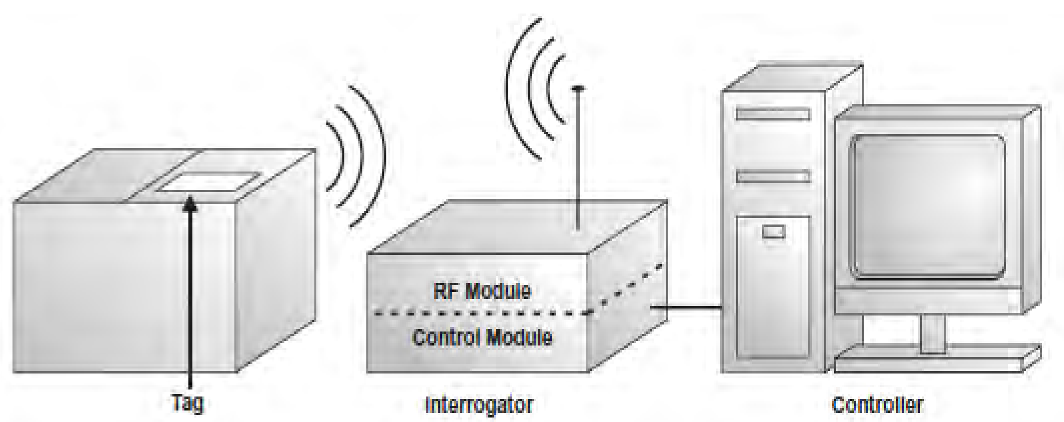


Figure 2.1 The Basic Building Blocks of an RFID System.

Those are:

i) A tag (sometimes called a transponder), which is composed of a semiconductor chip, an antenna, and sometimes a battery

ii) An interrogator (sometimes called a reader or a read/write device), which is composed of an antenna, an RF electronics module, and a control electronics module

iii) A controller (sometimes called a host), which most often takes the form of a PC or a workstation running database and control (often called middleware) software

The tag and the interrogator communicate information between one another via radio waves. When a tagged object enters the *read* zone of an interrogator, the interrogator signals the tag to transmit its stored data. The Tag holds many kinds of information about the objects they are attached to, including serial numbers, time stamps, configuration instructions, and much more.

An RFID system could consist of many interrogators spread across a warehouse facility or along an assembly line. However, all of these interrogators could be networked to a single controller. Similarly, a single interrogator can communicate with more than one tag simultaneously. In fact, at the present state of technology, simultaneous communication at a rate of 1,000 tags per second is possible, with an accuracy that exceeds 98%. RFID tags can be attached to virtually anything, from a pallet, to a newborn baby, to a box on a store shelf.

2.2.1 RFID Frequency

A key consideration for RFID is the frequency of operation. Just as television broadcasts in VHF or UHF band, similarly RFID systems also use different bands for communication as shown in Figure 2.2:

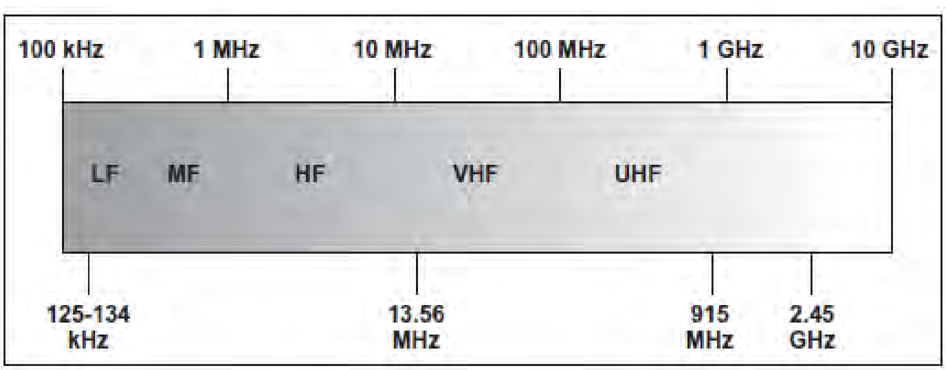


Figure 2.2 Radio Frequency Spectrums [9]

In RFID there are both low radio frequency and high radio frequency bands in use, as shown in the following list [10-11]:

Low Frequency RFID Bands

- Low frequency (LF): 125–134 KHz
- High frequency (HF): 13.56 MHZ

High Frequency RFID Bands

- Ultra-high frequency (UHF): 860–960 MHZ
- Microwave: 2.5 GHz and above

Because RFID systems generate and radiate electromagnetic waves, they are justifiably classified as radio systems. The function of other radio services must under no circumstances be disrupted or impaired by the operation of RFID systems.

The need to exercise care with regard to other radio services significantly restricts the range of suitable operating frequencies available to a radio frequency identification (RFID) system. For this reason, it is usually only possible to use frequency ranges that have been reserved specifically for industrial, scientific or medical applications or for short range devices. These are the frequencies classified worldwide for Industrial-Scientific-Medical (ISM) frequency ranges or Short-Range-Devices (SRD) frequency ranges and they can also be used for RFID applications. Table 2.1 shows different frequency ranges used for RFID-systems [12].

Table 2.1 Frequency ranges used for RFID-systems

Band	Regulations	Range	Data speed	Applications
120–150 kHz (LF)	Unregulated	10 cm	Low	Animal identification, factory data collection
13.56 MHz (HF)	ISM band worldwide	1 m	Low to moderate	Smart cards
433 MHz (UHF)	Short Range Devices	1–100 m	Moderate	Defense applications, with active tags
868-870 MHz (Europe) 902-928 MHz (North America) UHF	ISM band	1–2 m	Moderate to high	EAN, various standards
2450-5800 MHz (microwave)	ISM band	1–2 m	High	802.11 WLAN, Bluetooth standards
3.1–10 GHz (microwave)	Ultra wide band	up to 200 m	High	requires semi-active or active tags

2.3 RFID TAGS

Basic function of an RFID tag is to store data and transmit data to the interrogator. A tag consists of an electronic chip and an antenna encapsulated in a package to form a usable tag, such as a packing label that might be attached to a box. Generally, the chip contains memory where data can be stored. One can read that written data. Some tags contain batteries. Details about the RFID tag are as follows:

2.3.1 Active vs. Passive Tag

Active RFID tag contains an on-board power source, such as a battery. When the tag needs to transmit data to the interrogator, it uses this source to derive the power for the transmission. For this reason active tag can communicate with less powerful interrogators and can transmit information over much longer ranges, up to hundreds of feet. Moreover, these types of tags have larger memories, up to 128 Kbytes. They are much larger and more complex than that of passive tags. So, active tags are very expensive. The longevity of the batteries in active tags is from two to seven years. Passive RFID tags have no on-board power source. Instead, they derive power to transmit data from the signal sent by the interrogator. As a result, passive tags are typically smaller and less expensive to produce than active tags. However, the effective range of passive tags is much shorter than that of active tags, sometimes less than two feet. Moreover, they require more powerful interrogators and have less memory capacity.

Some passive tags have batteries on-board but do not use these batteries to assist in radio signal transmission. These types of passive tags are called battery-assisted tags and they use the battery only to power on-board electronics.

2.3.2 Read-Only vs. Read/Write or “Smart” Tags

On the basis of memory type tags can be differentiated. There are roughly two kinds of tags read-only (RO) and read/write (RW). RO memory can just only read. RO tags are similar to bar codes. Once the tags are written cannot be altered, as like CD-ROM cannot be altered after it is burnt at the factory. They only can be read. These types of tags are usually programmed with a very limited amount of data that is intended to be static, such as serial and part numbers, and are easily integrated into existing bar code systems. RW tags are often called “smart” tags. Smart tags present the user with much more flexibility than RO tags. They can store large amounts of data and have an addressable memory that is easily changed. Data on an RW tag can be erased and re-written thousands of times, much the same way a floppy disk can be erased and re-written. For this reason, the tag can act as a “traveling” database of sorts, in which important dynamic information is carried by the tag, rather than centralized at the controller. Thousands of different types of applications can be developed using smart tags.

Some tags can contain both RO and RW memory at the same time. For example, an RFID tag attached to a pallet could be marked with a serial number for the pallet in the RO section of the memory, which would remain static for the life of the pallet. The RW section could then be used to indicate the contents of the pallet at any given time, and when a pallet is cleared and reloaded with new merchandise, the RW section of the memory could be re-written to reflect the change.

2.3.3 RFID "Smart" Labels

RFID smart labels are considered to be the next generation bar code. Just as the bar code sparked a revolution in supply chain and asset management in the early 1980s, smart labels may do the same in the coming years. Like bar codes, these labels are able to easily applied, unobtrusive, quick to read, cheap, and disposable. Some RFID technology manufacturers have made implementing RFID technology as simple as printing out a document on a PC. There are several companies that now offer smart label printer solutions, which both print out adhesive smart label tags and write data to tag memory. There are even some hybrid bar code and smart tag solutions that both print a universal product code (UPC) bar code symbol on an adhesive smart tag and write data to tag memory simultaneously, in order to assist customers in migrating between the technologies. Price, technological maturity, and ease of implementation are the obstacles for diverse use of RFID smart labels like bar code. However, the benefits that smart labels offer over bar coding systems are beginning to outweigh the shortcomings and the costs of implementing smart labels solutions, making smart labels a cost-effective technology.

2.3.4 "SMART" TAGS vs. BAR Codes

A bar code is a series of vertical, alternating black and white stripes of varying widths that form a machine-readable code as shown in Figure 2.3. Bar code is an optical electronic technology, in which laser light is reflected off a bar code symbol and read by a scanner. The ubiquitous Universal Product Code (UPC) symbol is the form of bar code familiar to most of the people.

Figure 2.3 A typical UPC symbol

In bar coding, laser light is used as the data carrier. In contrast, smart labels and RFID in general use radio waves to carry information. Bar coding is therefore referred to as an optical technology and RFID is called a radio frequency or RF technology. This has several implications for automatic identification and data capture (AIDC).

Below is a detailed comparison between RFID and Bar Code technology:

- **Memory Size/Data Storage**

Bar codes can only hold a limited amount of data. The smallest tags, in terms of data storage, are UPC E symbols, which hold only eight numeric characters. On the other hand the spectrum, the Data Matrix bar code standard permits the storage of 2000 ASCII characters, on a two dimensional tag.

RFID tags are capable of holding far more information. Though RFID tags can be made with smaller memories to hold only a few bytes, minimum upper limit is 128 K bytes. The uses of RFID Tags are more versatile than that of barcode.

- **Read/Write**

Bar codes are not able to be modified once they are printed, therefore bar coding is a RO technology. In contrast, RW RFID tags, such as smart tags, have an addressable, writeable memory that can be modified thousands of times over the life of the tag. That‟s why RFID technology is so powerful.

- **Non-Line-of-Sight**

Another advantage of RFID technology over bar codes is that RFID systems do not require a line-of-sight between a tag and interrogator to work properly. Radio waves are able to propagate through many solid materials. Tags embedded inside objects can also be read easily. Bar codes, on the other hand require a direct line of sight with the scanner in order to work properly. So, bar codes must be placed on the outside of packaging and objects must be removed from pallets in order to be read. In supply chain management applications, in which large quantities of materials are on the move all the time, this gives RFID a great advantage over bar codes.

- **Read Range**

Typically read ranges of bar code are just a few inches. The read ranges of RFID tags vary widely, depending on frequency of operation, antenna size and whether the tag is active or passive. Typically read ranges of RFID tags run from a few inches to a couple of yards. Table 2.2 shows the read range comparison between RFID and Barcode:

Table 2.2 Read range comparison between RFID and Barcode

RFID	**Barcode**
Passive UHF RFID: - Up to 40 feet (fixed readers) - Up to 20 feet (handheld readers) Active RFID: - Up to 100's of feet or more	Several inches up to several feet

- **Multiple RW and Anti-collision**

Unlike other automatic identification and data capture (AIDC) technologies, in which items must be physically separated and read individually, RFID systems can read multiple tags simultaneously. Whereas a pallet of bar-coded items would need to be unpacked and scanned individually in order to be inventoried, in RFID systems the entire contents of a pallet could be inventoried at once as it passes an interrogator. RFID is the only AIDC technology that is capable of this. For this advantage RFID is superior to all other technologies in supply chain management.

- **Access Security**

Bar code data is not very secure. Because bar codes require a line-of-sight and are therefore placed very visibly on the outside of packaging, anyone with a standard bar code scanner or even a camera can intercept and record the data. RFID systems offer a much higher level of security. RFID systems present the user with the ability to prevent third-party interception, to restrict unauthorized access to the system, and to encrypt sensitive data.

- **Difficult to Replicate**

RFID tags and electronics behind are much more complex than bar codes. RFID systems are very difficult to build or replicate. So one cannot easily cheat to access or alter tag data.

- **Environmental Susceptibility/Durability**

RFID technology is better able to cope with harsh and dirty environments, such as those found in warehouses and supply chain facilities, than bar codes. Bar codes cannot be read if they become covered in dirt, dust, or grease or are torn or dented. Intense light can also interfere with bar code scanners and render them unable to read bar code tags. RFID technology is relatively immune to these problems.

- **Read Reliability**

In supply chain applications, first-pass read accuracy is important to maintaining a high level of efficiency. Damaged bar codes often have to be scanned through a system two times or to read it manually. The anti-collision and multiple RW features of RFID eliminate the need to scan misread items multiple times.

2.4 Microcontroller

A microcontroller is a computer-on-a-chip, containing a processor, memory, and input/output functions. It is a microprocessor emphasizing high integration, in contrast to a general-purpose microprocessor (the kind used in a PC). In addition to the usual arithmetic and logic elements of a general purpose microprocessor, the microcontroller integrates additional elements such as read-write memory for data storage, read-only memory for program storage, EEPROM for permanent data storage, peripherals devices, and input/output interfaces. At clock speeds of as little as a few MHz or even lower, microcontrollers often operate at very low speed compared to modern day microprocessors, but this is adequate for typical applications. They consume relatively little power (milliwatts), and will generally have the ability to sleep while waiting for an interesting peripheral event such as a button press to wake them up again to do something. Power consumption while sleeping may be just nanowatts, making them ideal for low power and long lasting battery applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, remote controls, office machines, appliances, power tools and toys. By reducing the size, cost and power consumption compared to a design using a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to electronically control many more processes.

Figure 2.4 Microcontroller

A microcontroller is a single integrated circuit, commonly with the following features:

- Central processing unit – ranging from small and simple 4-bit processor to complex 32 or 64-bit processor.
- Discrete input and output bits, allowing control or detection of the logic state of an individual package pin.
- Serial input/output such as serial ports (UARTs)
- Other serial communications interfaces like I2C, Serial Peripheral Interface and Controller Area Network for system interconnect
- Peripherals such as timers and watchdog
- Volatile memory (RAM) for data storage
- ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage
- Clock generator – often an oscillator for a quartz timing crystal, resonator or RC circuit
- Many include analog-to-digital converters

Recent microcontrollers are integrated with on-chip debug circuitry. When accessed by an in-circuit emulator via JTAG, allow debugging of the firmware with a debugger.

2.5 GPRS Module

General packet radio service (GPRS) is a packet oriented mobile data service on the 2G and 3G cellular communication system's global system for mobile communications (GSM). GPRS was originally standardized by European Telecommunications Standards Institute (ETSI) in response to the earlier CDPD and i-mode packet-switched cellular technologies. It is now maintained by the 3rd Generation Partnership Project (3GPP). GPRS usage is typically charged based on volume of data. This contrasts with circuit switching data, which is typically billed per minute of connection time, regardless of whether or not the user transfers data during that period. GPRS data is typically supplied either as part of a bundle (e.g., 5 GB per month for a fixed fee) or on a pay-as-you-use basis. Usage above the bundle cap is either charged per megabyte or disallowed. The pay-as-you-use charging is typically per megabyte of traffic.

GPRS is a best-effort service. In GPRS users share the service concurrently. But in circuit switching a certain quality of service (QoS) is guaranteed during the connection. In 2G systems, GPRS provides data rates of 56–114 kbit/second. 2G cellular technology combined with GPRS is known as 2.5G. , This technology is between the second (2G) and third (3G) generations of mobile telephony. It provides moderate-speed data transfer by using unused time division multiple access (TDMA) channels in the GSM system. GPRS is integrated into GSM Release 97 and newer releases.

SIM300 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS1900 MHz. SIM300 provides GPRS multi-slot class 10 capabilities and support the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4. The SIM300 provides RF antenna interface with two alternatives: antenna connector and antenna pad. Figure 2.5 shows the hardware design of SIM 300 GPRS module. The antenna connector is MURATA MM9329-2700. The SIM300 is integrated with the TCP/IP protocol.

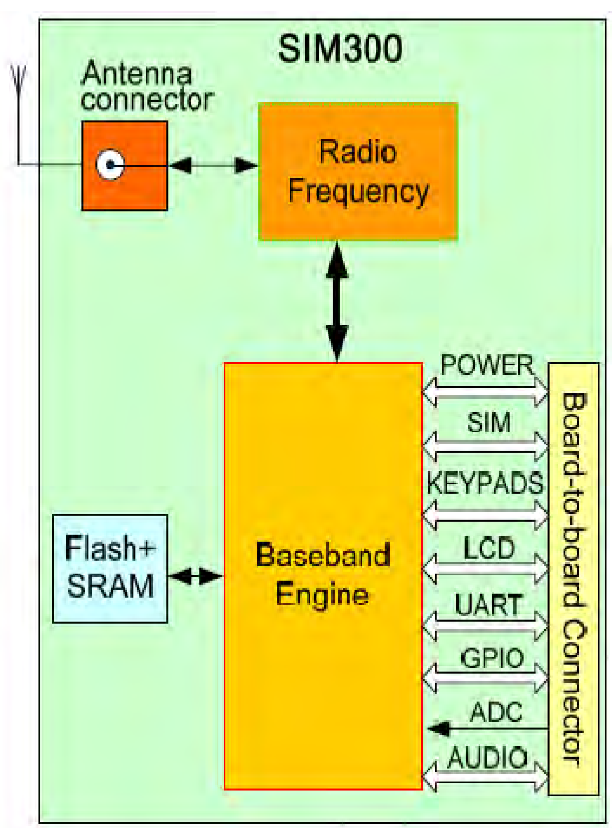


Figure 2.5 Hardware design of SIM 300

To enter a series of AT commands on separate lines it is required to wait for the final response (for example OK, CME error, CMS error) of last AT command. The SIM300 supports the following character sets:

• GSM format • UCS2 • HEX • IRA • PCCP437 • PCDN • 8859_1

The character set can be set and interrogated using the "**AT+CSCS**" command. The character set is defined in appendix. The character set affects transmission and reception of SMS and SMS Cell Broadcast messages, the entry and display of phone book entries text field and SIM Application Toolkit alpha strings. Flow control is very important for correct communication between the GSM engine and DTE. For example, the sending device is transferring data faster than the receiving side. When the receiving buffer reaches its capacity, the receiving device should be capable to cause the sending device to pause until it catches up. There are basically two approaches to achieve data flow control: software flow control and hardware flow control. SIM300 support both two kinds of flow control. Those are explained below:

- **Software flow control (XON/XOFF flow control)**

  Software flow control sends different characters to stop (XOFF, decimal 19) and resume (XON, decimal 17) data flow. It is very useful in those applications that only use three wires on the serial interface. The default flow control approach of SIM300 is hardware flow control. To enable software flow control in the DTE interface and within GSM engine following AT command is required:

  AT + IFC = 1, 1

  This setting is stored volatile. To use after restart, **AT+IFC=1, 1** should be stored to the user profile.

- **Hardware flow control (RTS/CTS flow control)**

  Hardware flow control achieves the data flow control by controlling the RTS/CTS line. When the data transfer is suspended, the CTS line is set inactive until the transfer from the receiving buffer is completed. When the receiving buffer is ok to receive more data, CTS goes active again.

2.6 Liquid Crystal Display (LCD)

A liquid crystal display (LCD) is a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. A low-power flat-panel display used in many laptop computers, calculators and digital watches, made up of a liquid crystal that is sandwiched between layers of glass or plastic and becomes opaque when electric current passes through it. The contrast between the opaque and transparent areas forms visible characters.

LCD is a display technology that users rod-shaped molecules (liquid crystals) that flow like liquid and bend light. When not energized, the crystals direct light through two polarizing filters, allowing a natural background color to show. When energized, they redirect the light to be absorbed in one of the polarizer, causing the dark appearance of crossed polarizer to show. The more the molecules are twisted, the better the contrast and viewing angle.

Because it takes less power to move molecules than to energize a light-emitting, device, LCDs replaced the light-emitting diodes (LEDs) in digital watches in the 1970s. LCDs were then widely used for a myriad of monochrome displays and still are. In the 1990s, color LCD screens caused sales of Laptop computers to explode, and in 2003, more LCD monitors were sold for desktop computers than CRTs.

Chapter 3

System Design & Implementation

3.1 Introduction

This chapter describes the system design and implementation technique. Different software and hardware used in the design are also discussed.

3.2 Functional block diagram of the system

The e-monitoring system has two parts:

i. One is embedded system

ii. Another is web based software system

3.2.1 Embedded System:

Figure 3.1 shows the functional block diagram of the embedded system:

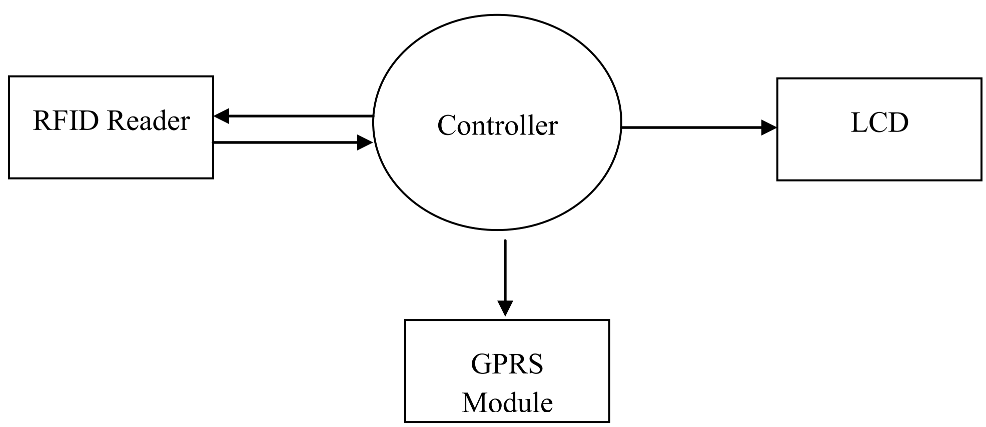


Figure 3.1 Functional block diagram of the Embedded System

It consists of an RFID reader, a micro-controller, a Liquid Crystal Display (LCD) and a GPRS module. The descriptions of the components are as follows:

1. RFID reader

In this project a Micro-reader RI-STU-MRD1 kit as shown in Figure 3.2 has been used as an RFID reader to read data from RFID Tag. It is an intelligent module providing RF and control functions to read and program TIRIS transponders.

Using attached antenna RFID reader sends data to detect RFID tags in its frequency range. When any tag comes to the range of the RFID reader it reads data from RFID tag. After reading data it sends data to the microcontroller connected to it.

The Micro-reader works together with a 47 mH, low-Q antenna, and therefore the system does not need tuning. So, it is a low range RFID reader which can cover only 10 cm distance. The Micro-reader module is a plug-in module which can be plugged into or soldered onto an application specific adapter board. It supports serial data communications between a PC and TIRIS transponders. With its serial communications interface (SCI) the Micro-reader supports TTL data communications, which with the addition of a communications driver (for example: RS232 or RS422) allows communication to a standard interface.

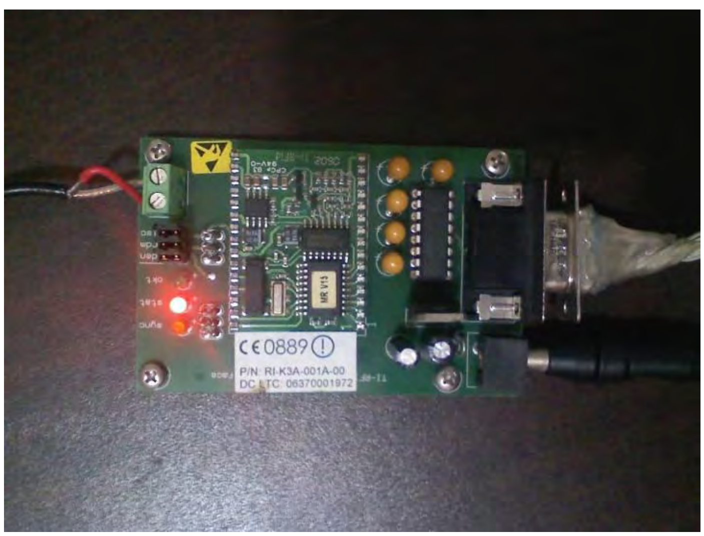


Figure 3.2 TIRIS Micro-reader RI-STU-MRD1 KIT

The two serial I/O pins are configured for 9600 Baud, 1 start bit, 8 data bits, no parity and 1 stop bit. They can be connected directly to a communications driver to allow a half duplex communication with a PC via its serial communications interface.

2. Controller

In this project a PIC microcontroller „PIC16F876A" mounted on an educational kit has been used as a controller. The controller collects data from the RFID reader. After collecting the data it decodes the data and then filters it. It discards the non accepted data and accepts only valid data. After filtering the data it arranges the data in a specific format. Then it sends the data to the web based software system for farther processing using the GPRS module. The data is also displayed on the LCD screen for checking purpose.

The PIC16F876A microcontroller has the following features:

- 256 bytes of EEPROM data memory
- Self programming
- 5 channels of 10-bit Analog-to-Digital (A/D) converter
- 2 capture/compare/PWM functions
- 2 Comparators
- The synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit bus
- A Universal Asynchronous Receiver Transmitter (UART)

Figure 3.3 shows the I/O pin diagram of the PIC16F876A.

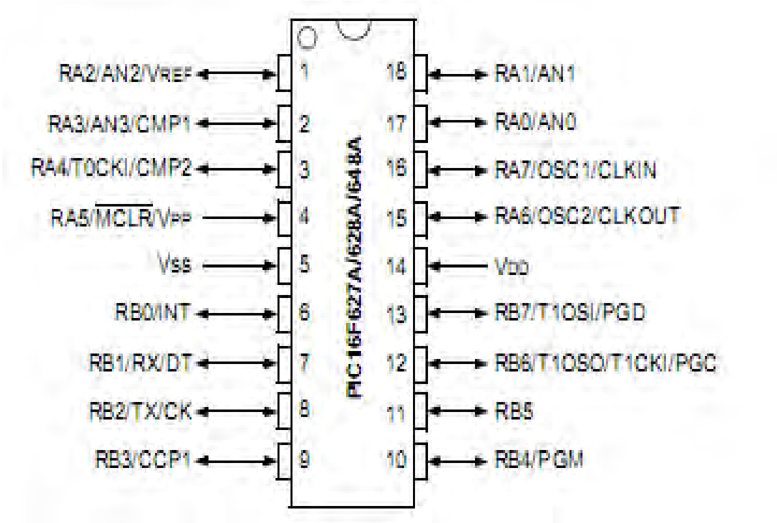


Figure 3.3 PIC16F876A microcontroller

The connection between the PIC and the LCD is as follows:

D7 → port.7 (pin13 on the 16F876)

D6 → port.6 (pin12)

D5 → port.5 (pin11)

D4 → port.4 (pin10)

E → port.3 (pin9)

RS → port.2 (pin8)

RW → port.0 (pin6)

3. Liquid Crystal Display

The model of the LCD that has been used in this project is „CFAH1602B-TMC-JP" of Crystalfontz America, Incorporated. Table 3.1 shows the general specification of the LCD.

Table 3.1 General Specification of the LCD

Item	Standard Value
Number of Characters:	16 characters X 2 Lines
Module dimension:	80.0 X 36.0 X 13.5(MAX) mm
View area:	66.0 X 16.0 mm
Active area:	56.2 X 11.5 mm
Character size:	(L)2.95 X (W) 5.55 mm
Character pitch:	(L)3.55 X (W)5.95 mm
LCD type:	STN, Negative, transmissive, Blue
Duty:	1/6
View direction:	6 o‟clock
Backlight	LED White

LCD screen shows the formatted information generated by the controller. Figure 3.4 shows pin configuration of an LCD.

Figure 3.4 LCD

4. GPRS Module

After formatting the data into a specific format the controller sends the information to the remote central server through the GPRS module. Controller sends data to a specific mobile number as an SMS. A GPRS module is connected with a remote server that receives the SMS that was sent from the controller.

SIM300 EVB GPRS module has been used in this project for sending SMS to server and mobile phone of authorized persons. SIM300 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS 1900 MHz. SIM300 features GPRS multi-slot class 10 and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.

The physical interface to the mobile application is made through a 60-pin board-to-board connector. It provides all hardware interfaces between the module and boards except the RF antenna interface. Figure 3.5 shows the GPRS module

Figure 3.5 GPRS module

GPRS module is connected with the microcontroller trainer board using serial interface which has been shown in Figure 3.6. Microcontroller works as data circuit-terminating equipment (DCE) and GPRS module works as data terminal equipment (DTE). The port of the transmission signal is connected with the port of the receiving signal.

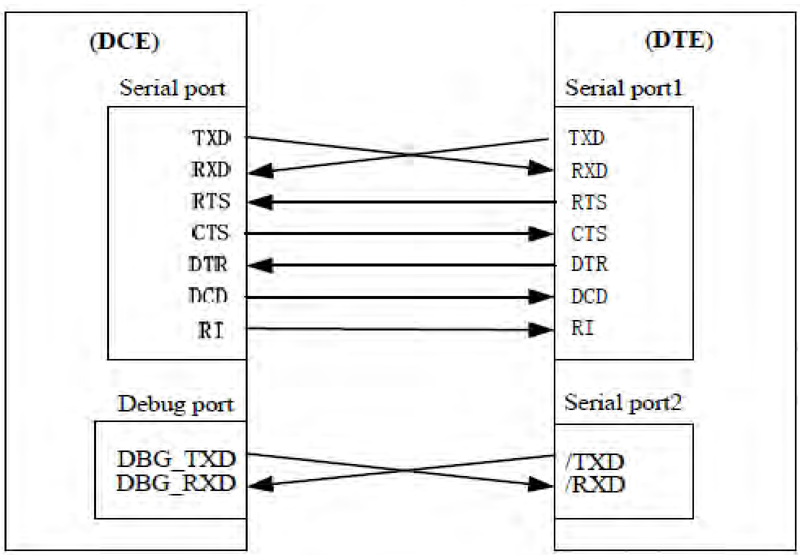


Figure 3.6 Connection of the serial interfaces

5. Operation of the embedded system

Figure 3.7 shows that a waste bin is mounted with an RFID tag and the container carrying truck is equipped with the proposed embedded system. When the truck comes to the signal range of the RFID Tag then the RFID reader of the embedded system starts reading data from the RFID Tag and sends the captured data to the controller. The controller filters the data received from the RFID reader and arranges the data in a pre-specified format. Then the controller sends this data to the central server via GPRS module.

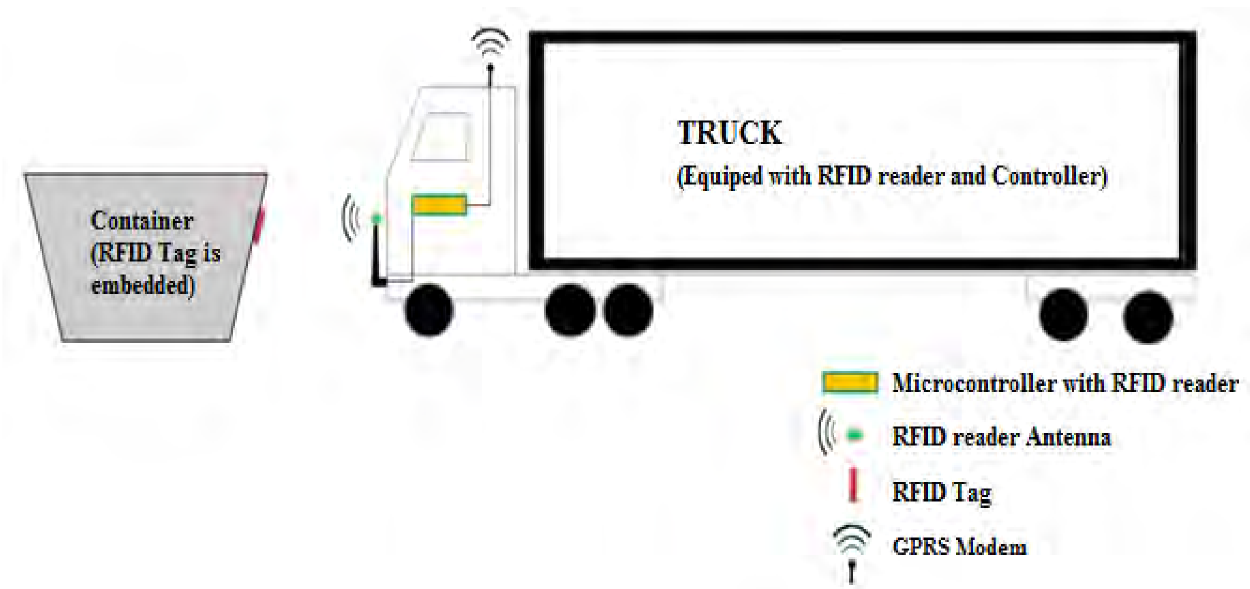


Figure 3.7 Technique of capturing and sending data

The controller program has been written in C programming language. The flowchart of the program is shown in Figure 3.8.

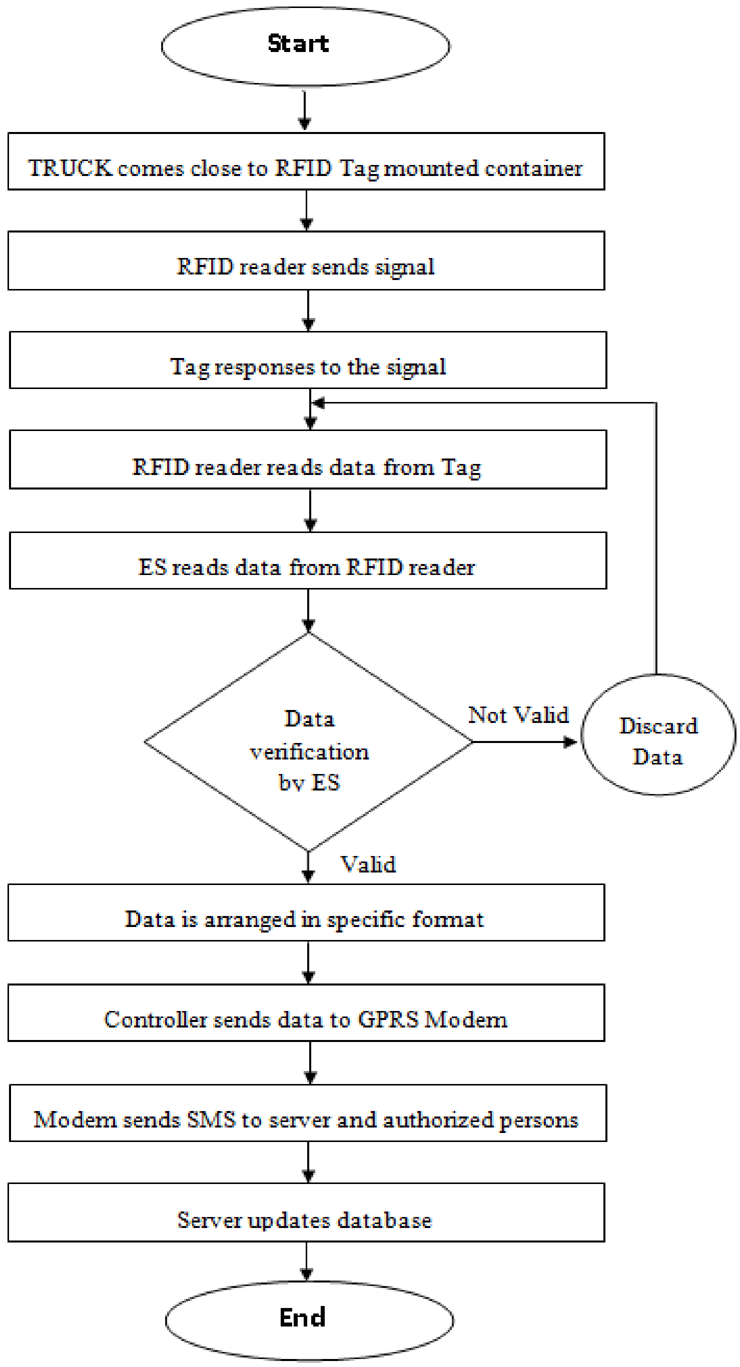


Figure 3.8 Flowchart of the system

The system is initiated by switching on the start button of the embedded system. Whenever any municipal vehicle equipped with the embedded system comes to the frequency range of RFID tag mounted with the waste collecting container, the embedded system sends a request signal to the tag. Then the tag responds and data is read by the embedded system through the RFID reader. After reading the data controller verifies it for further processing. If data is valid then the embedded system converts the data into specific format, otherwise it discard the data. After arranging the data in specific format, it sends the data to the GPRS module of central server as SMS. Central server verifies the SMS. If the system finds the SMS is in proper format then it updates the database server with the content of the SMS. Thereby municipal authority gets updated information from a central location through a web based software system. The related information is also sent to the mobile phone of the concerned authority from the embedded system.

3.2.2 Web based software system:

Figure 3.9 shows the block diagram of the web based software system:

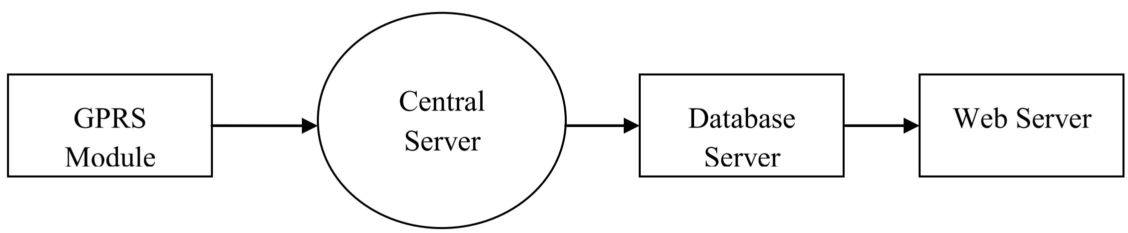


Figure 3.9 Block diagram of web based system

It consists of a GPRS module, a Central Server, a Database Server and a Web server. The description of the components is as follows:

1. **GPRS Module**

A GPRS module is connected with the central server. It is exactly the same as the one used in the embedded system. Whenever the GPRS module receives any information from the remote embedded system it delivers the information to the central server. GPRS module is equipped with a SIM module. It receives and delivers the information as a short message service (SMS).

2. Central Server

Central server receives information from the embedded system through the GPRS module. An application has been developed to record the information. The application is developed in windows platform and .NET framework 4 of Microsoft visual studio has been used. Any windows operating system can run this application. The application of central server processes the data and updates local/remote database on the basis of received SMS from the GPRS module. SMS that contains information in the specific format is considered only for further processing. A timer has been used in the application. When the application runs in automatic mode its timer is activated, as a result, the application checks SMS inbox automatically. If it finds any new SMS, it automatically fetches it and sends the message to the database server for recording the information. The application also has manual mode.

3. Database Server

Database server stores all necessary information for current and future use. Web page of solid waste management system web application shows the existing data of the database. The database server periodically updates its data. As a result users can get current data as well as historical data. SQL server 2008 has been used as database server. Proper security mechanism has been applied. Administrators have the highest privilege to work in database server. Administrators can do every configuration related and administrative works. Developers can only create table and insert values. General user has no direct access in the database. They only watch data via web application. Database server stores its data in a very secured and reliable fashion. If the server crashes, data can be recovered from the storage device without losing any data. Database server does its periodic data backup automatically. Database server can transfer data to different location and application in different formats. So users get the highest flexibility in field of using data in different report format.

4. Web Server

A dynamic web site solid waste management system (SWMS) serves monitoring and management support. Internet Information Service (IIS) web server has been used for hosting the web application. Dynamic web pages of web application are developed in ASP .NET and web reports are designed in Crystal reports. Web server is highly secured. Only a registered user can get all necessary information by accessing this site. The user also can make complain using complain form of the site.

3.3 Data flow diagram of the e-monitoring system

RFID reader sends signals to detect the RFID Tag in its frequency range. When any Tag comes to the range of RFID reader it automatically reads data from the RFID Tag. Then the controller collects data from the RFID reader, filters collected data and arranges the data into specific format. In SMS receiving part the GPRS module will receive only the formatted SMS. In received SMS text message controller will get the tag id preceded with two blank lines.

After formatting the data, the controller sends the formatted data to the central server. After fetching and verifying the data, central server sends the information to web server and also to authorized persons mobile phone. On the basis of received SMS, the web server is updated by current data. Web server hosts the SWMS dynamic web application. As a result user gets all the records in web site. Using personal computer or mobile web browser and internet remote and/or mobile users can easily get the updated information related to solid waste management system.

Figure 3.10 shows data flow diagram of the system. How data is collected and sent has been shown in the diagram. User can get information in different ways those also shown in the diagram.

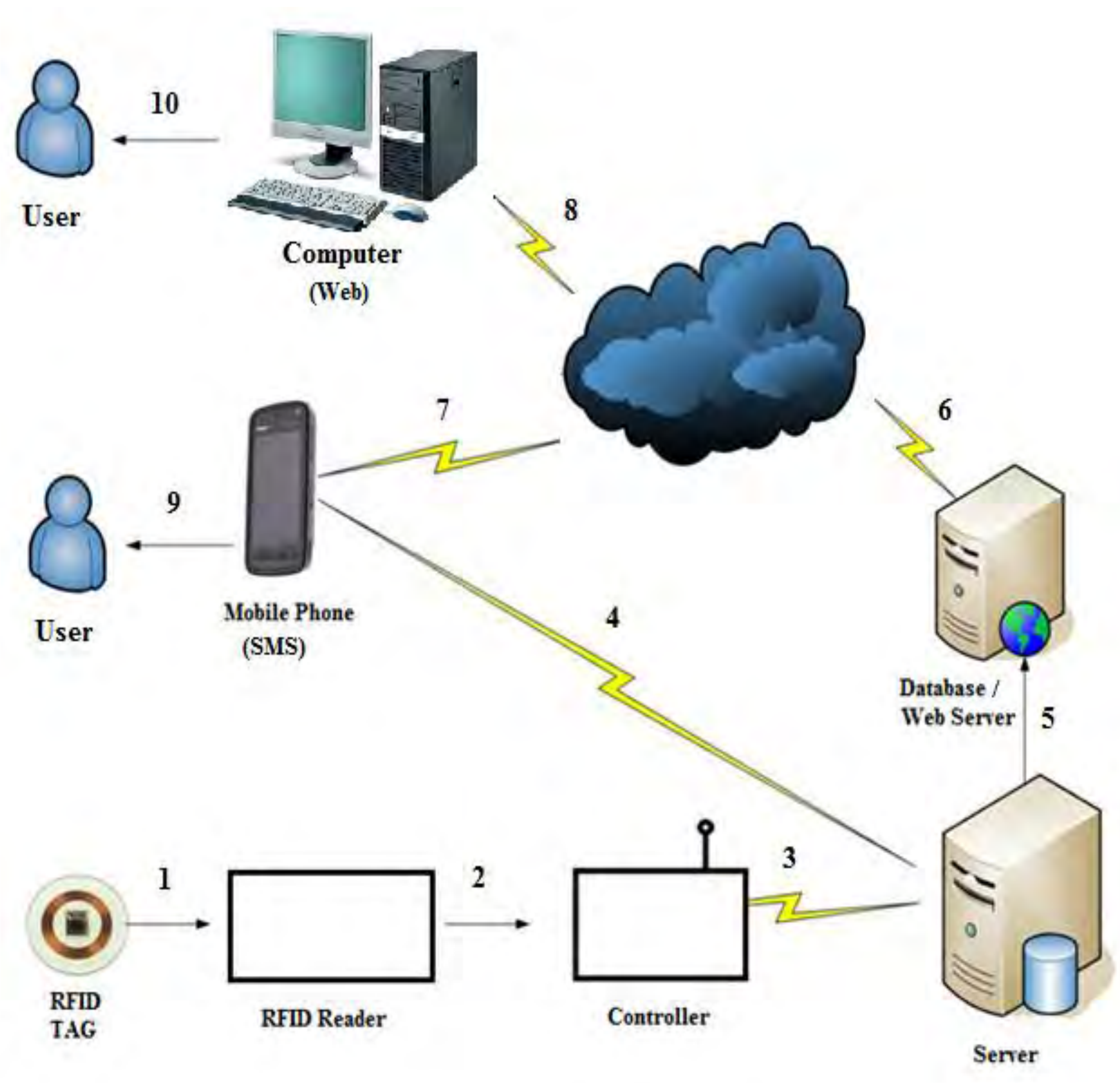


Figure 3.10 Data Flow Model

Authorized persons have the provision of accessing the system to view and maintain the system. The system has mobile short message service (SMS) feature for remote communication. Authorized persons can be notified through SMS.

3.4 Technique for Receiving, Sending and Storing Data

A customized application has been developed to receive data, store data and send data which has been shown in Figure 3.11. Visual Studio .NET has been used to develop this customized application. The application is very user friendly for necessary configuration through drop down menus. One can easily set port number of the modem, baud rate, data bits, stop bits, parity bits. In SIM number user will use the destination mobile number for sending SMS.

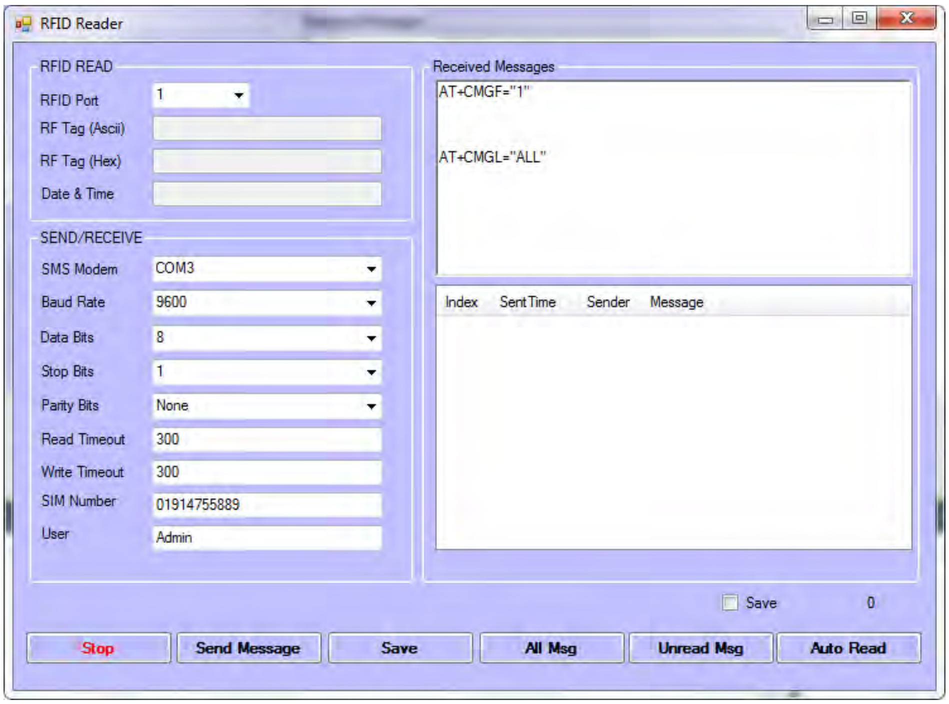


Figure 3.11 Receiving, Sending and Storing Application

There are few buttons for different types of operation. After setting up the configuration, user needs to press the „Start" button. If the configuration setup is okay then it will work. Otherwise, it will give a notification message and stop working. One can send message to a particular SIM number by pressing „Send Message" button. To see all incoming messages one should press „All Msg" button and for reading all unread message user should press „Unread Msg" button. To save the received messages into database manually user needs to press „Save" button. For reading and saving unread messages into database automatically user needs to press „Auto Read" button selecting the „Save" check box.

3.5 Software Used in the Project

In this project following software has been used:

1. Microsoft SQL Server: This DBMS software has been used to create, update and maintain database.
2. Microsoft Visual Studio: This software has been used to develop the application for receiving, sending and storing data from RFID tag.
3. IIS Server: This software has been used for hosting the developed SWMS web application.
4. ASP .NET: This dynamic web application development tool has been used to design the web pages.
5. MPLab IDE: This has been used to burn the microcontroller chip.
6. PICC: This software has been used to develop the application for microcontroller so that the microcontroller can work automatically.

Chapter 4

Results and Discussions

4.1 Introduction

This chapter describes the results achieved from this project. The system has been tested in the laboratory as well as in the field to ensure its proper functionality.

4.2 E-monitoring System for MSW Management

RFID based e-monitoring system for solid waste management has been developed in this project. It is shown in Figure 4.1. The system has been tested several times for analyzing the performance. After its laboratory test, a real time practical field test has been carried out using the system.

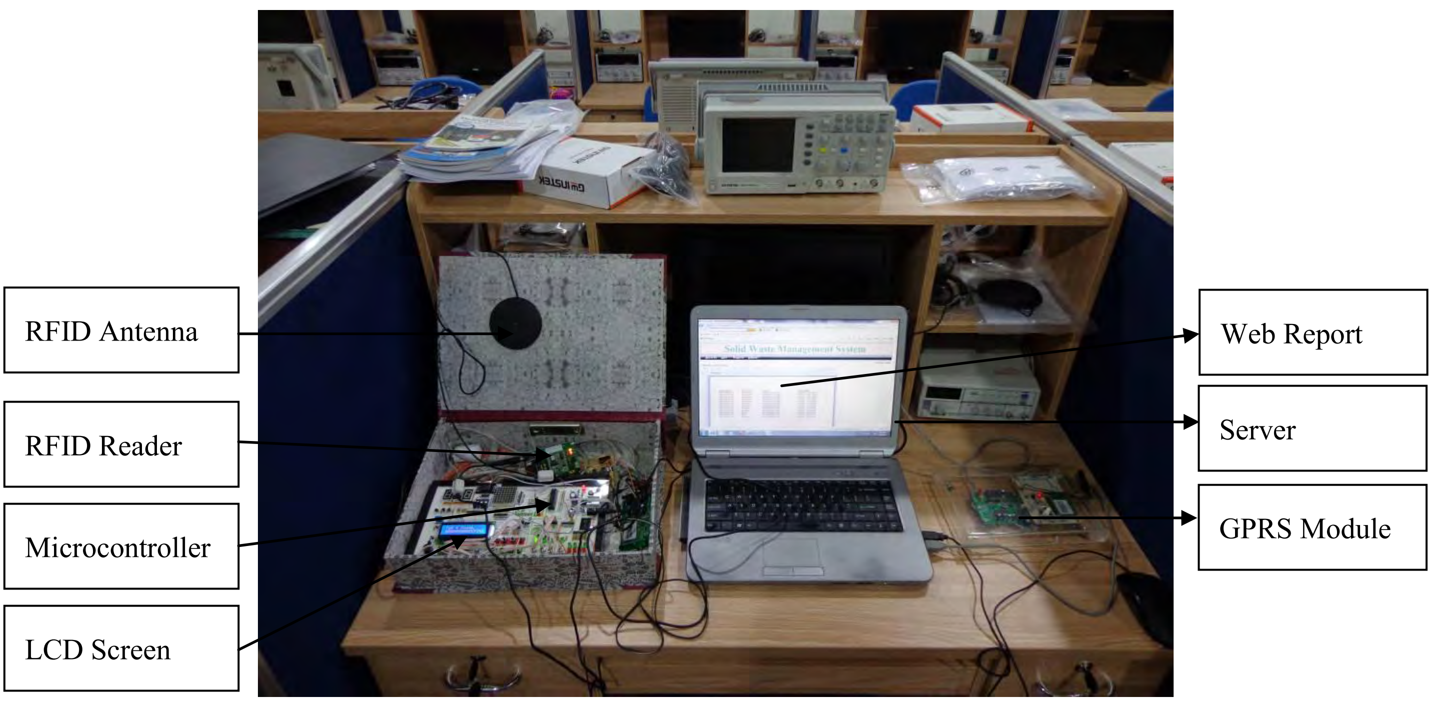


Figure 4.1 RFID based e-monitoring system

4.3 Functionality Testing in the Laboratory

The developed e-monitoring system displays RFID Tag number on the LCD screen of the system. Whenever RFID reader comes in the frequency range of RFID Tag, it automatically reads data from Tag, filters it, formats it and then displays in the LCD screen. Figure 4.2 shows formatted message of an RFID Tag. If the controller gets the valid data it converts the data into a specific format otherwise it shows „Unknown Tag‟ and the tag number.

Figure 4.2 Snapshot of displayed RFID Tag number on the LCD screen

After formatting the data controller displays the message in its LCD screen and at the same time sends that message as a SMS to the central server via attached GPRS module. Figure 4.3 shows a mobile phone receiving SMS through the e-monitoring system.

Figure 4.3 Snapshot of a mobile phone receiving SMS from the e-monitoring system

Central server sends data to authorized person‟s mobile phone and database server for updating the hosted web site with current data. Municipal authority can see the current and historical data by accessing the secured web application solid waste management system (SWMS). User needs to put user name and password to see the records. Figure 4.4 shows the logged in user screen of admin. After putting date parameters it is showing the records of tag item, user name and read time of that scanned item in that date range.

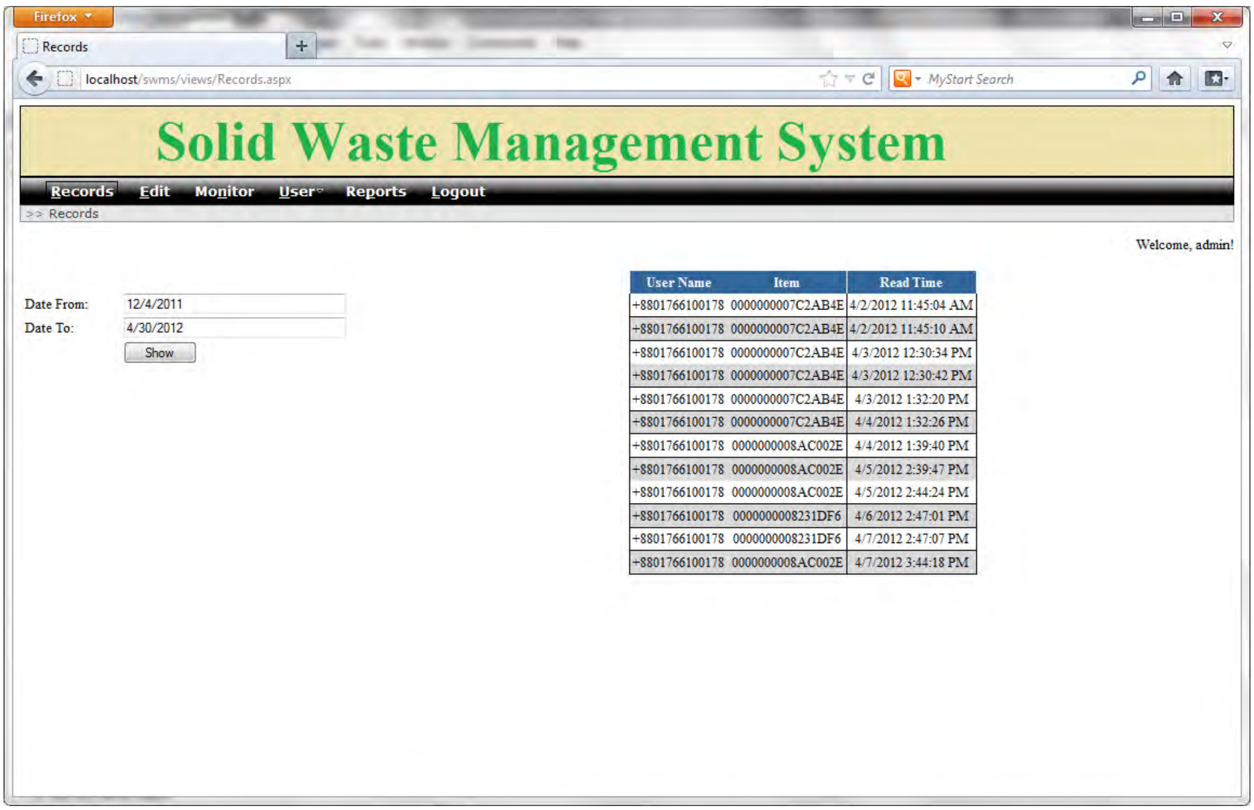


Figure 4.4 Snapshot of web records

4.4 Field test result

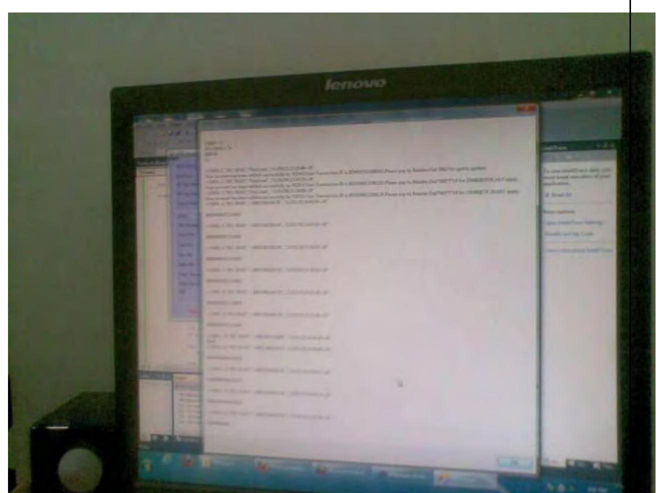
The e-monitoring system has also been tested in the field. Five waste bin containers located nearby BUET area has been selected as the test site. A BUET micro-bus has been used as a vehicle for carrying the developed embedded system to the waste bins. It has been observed that when the vehicle reaches to any of the waste bin containers, the system successfully detects the tag and sends the tag number to the central server within a very short time. Figure 4.5 shows some of the snapshots of the field work. Table 4.1 shows the field test results.

	
1. Embedded System of solid waste management system	2. BUET microbus is carrying the embedded system and BUET staffs.
	
3. Solid waste containers	4. RFID Tag is mounted on the container

5. Microbus comes closer to the tag

6. Embedded system finds the tag and sends SMS after fatching the data

7. GPRS module is attached with the central server



8. Application of the central server is showing the received data

Figure 4.5 Field work photo gallery

Table 4.1 Field test results

Sl. No.	Waste Bin No	Location	Tag No	Collection Date & Time	Driver's Name	Vehicle Number	Status	SMS Arrive Time
1	B-1	BUET Main Campus	000007C2AB4E	4/2/2012 11:45:02 AM	Mukul Shek	BUET Micro-bus	OK	4/2/2012 11:45:04 AM
2	B-2	Palashi	000008231DF6	4/4/2012 1:32:23 PM	Mukul Shek	BUET Micro-bus	OK	4/4/2012 1:32:26 PM
3	B-3	BUET CSE Campus	000008AC002E	4/6/2012 2:47:01 PM	Mukul Shek	BUET Micro-bus	OK	4/6/2012 2:47:02 PM
4	B-4	Agimpur	000008ACF840	4/7/2012 3:55:02 PM	Mukul Shek	BUET Micro-bus	OK	4/7/2012 3:55:04 PM
5	B-5	Sonali Bank BUET Branch	000007ACF014	4/7/2012 3:20:08 PM	Mukul Shek	BUET Micro-bus	OK	4/7/2012 3:20:11 PM

From Table 4.1 it can be concluded that the e-monitoring system works as per desired requirements and the system is capable of working in the field environment in real time.

4.5 Web based system

The MSW management authority can easily get the current and previous data by accessing the web site. They can get the report in printable format. Figure 4.6 shows the snapshot of the location and time wise report. Besides this registered customers can easily send their complain using the complain form of the web site. Figure 4.7 shows the user complain form.

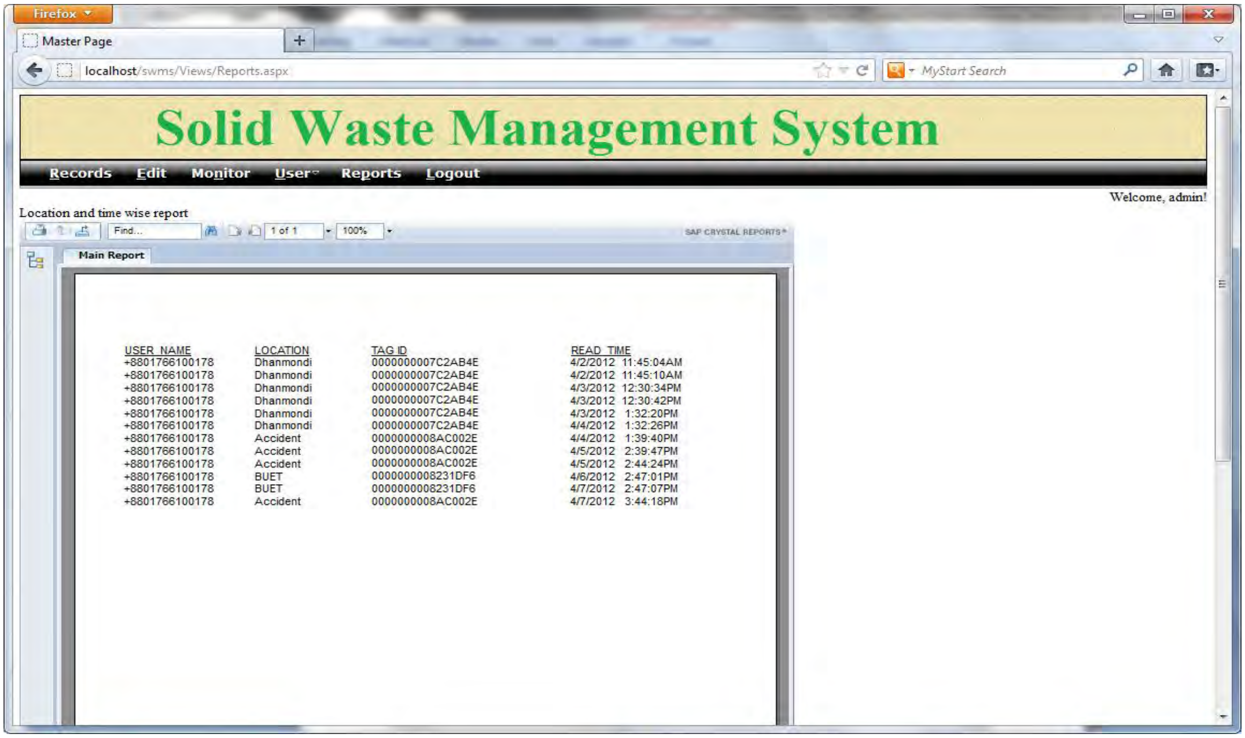


Figure 4.6 Reports in web site

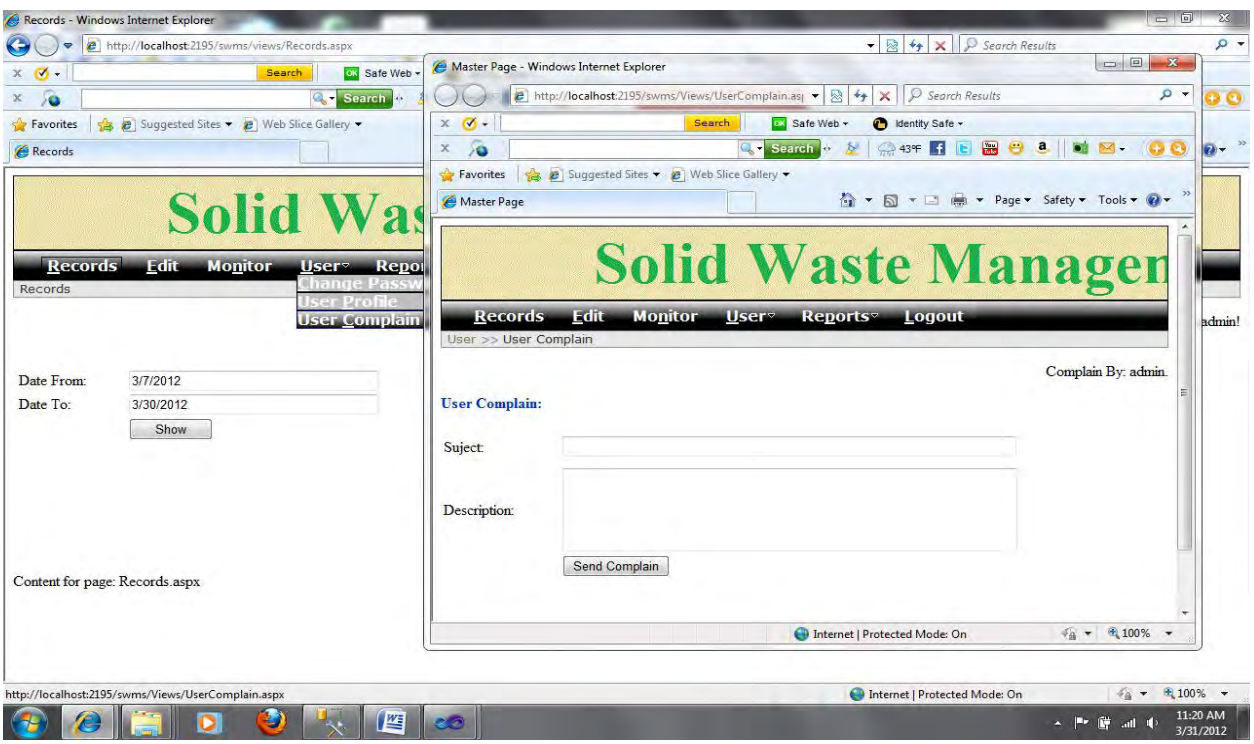


Figure 4.7 User complain form in the web site

4.6 Abnormal situation handling

The e-monitoring system can respond to any abnormal situation. Truck drivers carry some special tags with them to notify the abnormal situation such as truck break down, container missing etc. to the authority of solid waste management for taking necessary action.

For example, if an accident occurs then truck driver brings the Tag1 in the frequency range of the reader to report the authority that the truck is unable to arrive at the specified destination. At the receiving end the received code of the tag indicates a particular situation. In this case authority will get the record of Tag1 which indicates the specific situation. On the basis of received message authority takes necessary actions. Table 4.2 shows the code wise situation mapping list.

Table 4.2: Situation mapping code list

Code	Situation
Tag 1	Accident
Tag 2	Container Missing

Figure 4.8 shows the situation wise report that authority monitors:

USER_NAME	LOCATION	TAG ID	READ_TIME
+8801766100178	Dhanmondi	0000000007C2AB4E	4/2/2012 11:45:04AM
+8801766100178	Dhanmondi	0000000007C2AB4E	4/2/2012 11:45:10AM
+8801766100178	Dhanmondi	0000000007C2AB4E	4/3/2012 12:30:34PM
+8801766100178	Dhanmondi	0000000007C2AB4E	4/3/2012 12:30:42PM
+8801766100178	Dhanmondi	0000000007C2AB4E	4/3/2012 1:32:20PM
+8801766100178	Dhanmondi	0000000007C2AB4E	4/4/2012 1:32:26PM
+8801766100178	Accident	0000000008AC002E	4/4/2012 1:39:40PM
+8801766100178	Accident	0000000008AC002E	4/5/2012 2:39:47PM
+8801766100178	Accident	0000000008AC002E	4/5/2012 2:44:24PM
+8801766100178	BUET	000000008231DF6	4/6/2012 2:47:01PM
+8801766100178	BUET	000000008231DF6	4/7/2012 2:47:07PM

Figure 4.8 Situation report

Chapter 5

Conclusion

5.1 Conclusion

The objective of the project was to develop an intelligent monitoring system for proper management of MSW. With the objective keeping in front, a micro-controller based embedded system integrated with RFID and GPRS technology is developed in this project. Since it is a micro-controller based embedded system, it is portable and low cost. A municipal authority can use this type of system and monitor the waste collection status in real time and based on the recorded information they can prepare different reports and measure the performance of the team and thereby increase their productivity. The system also allow the customers to lodge their complains. The system has been tested in the laboratory environment as well as in the field environment. The test results prove that the system functions properly. The system can be further improved and added new features to make it a commercial product. However the system presented in this project has some limitations. In this system once the vehicle reaches to the container the tag is read and data of the tag is sent to the central server. Here it is assumed that the waste has been properly collected. If the waste is not collected the system cannot detect it.

5.2 Suggestion for future work

Author recommends the following suggestions to enhance the system:

i) In the current system low frequency RFID reader has been used. In the future version a mid-range RFID reader can be used to make the data reading from the tag easy and flexible.

ii) The current system cannot ensure whether the waste has been transferred to the proper location or not. To monitor and report this to the central server, we can add two more RFID readers in our system. One will be installed in the waste dumping area and other will be installed in the container dumping area. Once the waste is collected and fetched to those areas then the tag will be read and the information will be sent to the central server and thereby the system will ensure the authority that the waste collection and transportation job has been properly done.

References:

[1] http://www.managing-innovation.com/case_studies/Green Innovation management.pdf

[2] Hannan, M., A., Arebey, M., Basri, H. (2010). "Intelligent Solid Waste Bin monitoring and Management System", Australian Journal of Basic and Applied Sciences, 4(10): 5314-5319, 2010, ISSN 1991-8178

[3] Visvanathan, C., Ulrich, G., "Domestic Solid Waste Management in South Asian Countries – A Comparative Analysis", 3 R South Asia Expert Workshop, 30 August - 1 September, 2006 Kathmandu, Nepal

[4] Rahman, H., Al-Muyeed, A. (2010). "Solid and Hazardous Waste Management", ITN-BUET, Center for Water Supply and Waste Management

[5] Flora, A. (2009) "Towards a clean environment: A proposal on sustainable and integrated solid waste management system for universiti Kebangsaan Malaysia". Report from Alam Flora.

[6] Daniel V., Puglia *P.* A., and M. Puglia, "RFID-A Guide to Radio Frequency Identification", Technology Research Corporation, 2007

[7] Ping, L. I., & Yang, S, H. (2006). "Integrating GIS with the GeoEnviron Database System as a Robust Tool for Integrated Solid Waste Management in Malaysia", Available: http://www.gisdevelopment.net/application/urban/products/ma08.html

[8] Vicentini, F. Giusti, A., Rovetta, A., Fan, X., He, Q., Zhu, M., & Liu, B. (2008). "Sensorized waste collection container for content estimation and collection optimization", Waste Management.29, 1467-1472.

[9] Arebey, M., Hannan, M.A., Basri,H. ,"RFID and Integrated Technologies for Solid Waste Bin Monitoring System", Proceedings of the World Congress on Engineering 2010 Vol I, WCE 2010, June 30 - July 2, 2010, London, U.K.

[10] Pala, Z.,Inanc, N., “Smart Parking Applications Using RFID Technology “, RFID Eurasia Conference, 2007

[11] Chunxia, W., Weimin, Y., Yingyan, P., Huiyuan, X.,” Research on RFID Technology Adoption of Vegetable Supply Chain in China”, Information Technology and Applications, 2009

[12] Boginski, V., Mun, I.K., Yuzhou W., Mason, K.P., Zhang C., “Simulation and Analysis of Hospital Operations and Resource Utilization Using RFID Data”, IEEE International Conference on RFID, 2007

[13] Ouyang, Y., Hou, Y., Pang, L., Wang, D., Xiong, Z. “An Intelligent RFID Reader and its Application in Airport Baggage Handling System”, International Conference on Wireless Communications, Networking and Mobile Computing, 2008. WiCOM, 2008

[14] Johansson, O. M. (2006). “The effect of dynamic scheduling and routing in a solid waste management system”, Waste Management, 26, 875–885

[15] Chandravathani, S., (2006). “Waste Reduction: No Longer An Option But A Necessity”, Bernama, http://www.bernama.com/bernama/v3/newslite.php?id=179384.

[16] Maher, A., Hannan, M. A., & Hassan. A. (2009), “Solid Waste Monitoring and Management using RFID, GIS and GSM”. Proceedings of 2009 Student Conference on Research and development (SCOReD2009), 16-18 Nov. 2009, UPM Serdang, Malaysia.

[17] Hassan, Chong, M., N., T. L., & Rahman, M. M., (2005). “Solid Waste Management-What‟s The Malaysian Position”, Seminar Waste to Energy, Universiti Putra Malaysia.

[18] U.S. Code of Federal Regulations. The Atomic Energy Act of 1954, as amended (68 Stat.923)

Appendix A

A.1 Source code for retriving data from RFID Tag

```
PrivateSub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles Button1.Click
If Button1.Text = "Start"Then
      CommX.BAUDRATE = 9600
      CommX.COMPORT = ComboBox1.Text
      CommX.OPEN()
IfNot CommX.IsOpen Then
        MessageBox.Show("Error Openning COMM "& CommX.COMPORT)
ExitSub
EndIf
If OpenMobilePort() <>""ThenExitSub
      CommX.SEND(Chr(1))
      CommX.SEND(Chr(2))
      CommX.SEND(Chr(9))
      CommX.SEND(Chr(50))
      CommX.SEND(Chr(57))
      CommX.SEND(Chr(0))
      CommX.SEND(Chr(0))
      CommX.SEND(Chr(0))
      CommX.SEND(Chr(0))
      CommX.SEND(Chr(0))
```

```
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        CommX.SEND(Chr(0))
        Button1.Text = "Stop"
        Button1.ForeColor = Color.Red
Else
        smsport.Close()
        CommX.CLOSE()
        txtAscii.Text = ""
        txtBinary.Text = ""
        txtDate.Text = ""
        Button1.Text = "Start"
        Button1.ForeColor = Color.Black
EndIf
EndSub
```

```
PrivateSub CommX_OnReceive(ByVal sender AsObject, ByVal e As Axmcscomm.ICommXEvents_OnReceiveEvent) Handles CommX.OnReceive
    txtAscii.Text = e.dATA
    Decode()
    txtDate.Text = Now()
EndSub

PrivateSub Decode()
Dim txt AsString = ""
Dim result AsString = ""
Dim ch AsString = ""
Dim bin AsString = ""
Dim i AsInteger = 0
    txt = Trim(txtAscii.Text)
    txt = Replace(txt, vbCr, "")
    txt = Replace(txt, vbLf, "")
Dim loopcount AsInteger, strHold AsString = ""
For loopcount = 1 To Len(txt)
        strHold = strHold & Hex(Asc(Mid(txt, loopcount, 1)))
Next loopcount
    txtBinary.Text = strHold
EndSub
```

A.2 Source code for sending SMS from Microcontroller to Mobile phone

GSM modem is used to send data from microcontroller to server. Prior to send the data it is essential to establish connection. After sending data it is important to get the notification whether the data has been send or not. „AT" command is used for sending data and other GSM communications. Some of coding snapshot has given below:

```
PrivateFunction OpenMobilePort() AsString
Try
        smsport.PortName = cboPortName.Text             'COM1
        smsport.BaudRate = cboBaudRate.Text             '9600
        smsport.DataBits = cboDataBits.Text             '8
        smsport.StopBits = cboStopBits.Text             '1
        smsport.Parity = cboParityBits.SelectedIndex    'None
        smsport.ReadTimeout = txtReadTimeOut.Text       '300
        smsport.WriteTimeout = txtWriteTimeOut.Text     '300
        smsport.Encoding = Encoding.GetEncoding("iso-8859-1")
        smsport.Open()
        smsport.DtrEnable = True
        smsport.RtsEnable = True
IfNot smsport.IsOpen ThenReturn"Invalied port settings"
Catch ex As Exception
        MessageBox.Show(ex.Message)
Return ex.Message
EndTry
EndFunction
```

```
PublicFunction sendMsg(ByVal SerialPort As Ports.SerialPort, ByVal PhoneNo AsString, ByVal Message AsString) AsBoolean
'declare variables
Dim tdate AsString = Now.Day.ToString.PadLeft(2, "0") &"/"& Now.Month.ToString.PadLeft(2, "0") &"/"& Mid(Now.Year, 3)
Dim ttime AsString = Now.Hour.ToString.PadLeft(2, "0") &":"& Now.Minute.ToString.PadLeft(2, "0") &":"& Now.Second.ToString.PadLeft(2, "0")
Try
        SerialPort.Write("AT"& vbCrLf)
        SerialPort.Write("AT+CMGF=1"& vbCrLf)
        SerialPort.Write("AT+CMGS="& Chr(34) & PhoneNo & Chr(34) & vbCrLf)
        SerialPort.Write("User:"& txtUser.Text &" ID:"& txtBinary.Text &" Time:"& tdate &" "& ttime & Chr(26))
        DatabaseStore()
ReturnTrue
'exception handling
Catch ex As Exception
        MessageBox.Show(ex.Message)
ReturnFalse
EndTry
EndFunction
```

A.3 Source code for storing data in database

For future use it is very important to store data in database. At first it is required to establish a secured connection then to save data. ADODB record set is used to store data in SQL server database. Following code is used to store data:

```
PrivateSub DatabaseStore()

Dim SqlText AsString = "Provider=Microsoft.Jet.OLEDB.4.0;Persist Security Info=False;User ID=; Password=; Data Source=C:\Users\Mahbub\Documents\Visual Studio 2008\Projects\RFID_WEB\RFID_WEB\App_Data\RFIDDB.MDB"

Dim Conn AsNew OleDb.OleDbConnection(SqlText)

Dim newtablecmd AsString

Dim cmdresults AsInteger

Dim OleDBCommand As OleDb.OleDbCommand = New OleDb.OleDbCommand(SqlText, Conn)


    OleDBCommand.CommandType = CommandType.Text


Dim tdate AsString = Now.Day.ToString.PadLeft(2, "0") &"/"&
Now.Month.ToString.PadLeft(2, "0") &"/"& Mid(Now.Year, 3)

Dim ttime AsString = Now.Hour.ToString.PadLeft(2, "0") &":"&
Now.Minute.ToString.PadLeft(2, "0") &":"& Now.Second.ToString.PadLeft(2, "0")


    newtablecmd = "INSERT INTO RFID_READ VALUES ('"& txtUser.Text &"','"&
txtBinary.Text &"','"& tdate &"','"& ttime &"')"

Try

        Conn.Open()
```

```
        OleDBCommand.CommandText = newtablecmd
        cmdresults = OleDBCommand.ExecuteNonQuery()
        Conn.Close()
Catch ex As OleDb.OleDbException
        MessageBox.Show(ex.Message)
EndTry
EndSub
```

A.4 Source Code for retriving data from database for web

VB and java script are used to develop the dynamic web application. Following code is used for the home page “index.aspx”.

```
<%@PageLanguage="vb"AutoEventWireup="false"CodeBehind="index.aspx.vb"Inherits="RFID_WEB.index"%>
<!DOCTYPEhtmlPUBLIC"-//W3C//DTD XHTML 1.0 Transitional//EN""http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<htmlxmlns="http://www.w3.org/1999/xhtml">
<headrunat="server">
<title>RFID ITEMS</title>
<styletype="text/css">
.style1
    {
color: #33CC33;
font-weight: bold;
    }
```

```
.style2
        {
text-align: center;
        }
.style3
        {
width: 100%;
        }
.style4
        {
width: 166px;
        }
</style>
</head>
<bodystyle="text-align: center">
<formid="form1"runat="server">
<divclass="style2">
<div>
<spanclass="style1"> <br/>
<br/>
            SCANNED RFID ITEMS<br/>
<br/>
</span>
<br/>
```

```
<tableclass="style3">
<tr>
<tdclass="style4">
 </td>
<td>
<asp:GridViewID="GridView1"runat="server"AutoGenerateColumns="False"
DataSourceID="AccessDataSource1"Width="820px">
<Columns>
<asp:BoundFieldDataField="USER"HeaderText="USER"SortExpression="USER"/>
<asp:BoundFieldDataField="ITEM"HeaderText="ITEM"SortExpression="ITEM"/>
<asp:BoundFieldDataField="READ_DATE"HeaderText="READ_DATE"
SortExpression="READ_DATE"/>
<asp:BoundFieldDataField="READ_TIME"HeaderText="READ_TIME"
SortExpression="READ_TIME"/>
</Columns>
</asp:GridView>
</td>
<td>
 </td>
</tr>
<tr>
<tdclass="style4">
 </td>
<td>
```

```
 </td>
<td>
 </td>
</tr>
</table>
<br/>
</div>
<asp:AccessDataSourceID="AccessDataSource1"runat="server"
DataFile="~/App_Data/RFIDDB.mdb"SelectCommand="SELECT * FROM [RFID_READ]">
</asp:AccessDataSource>
</div>
</form>
<p>
 </p>
</body>
</html>
```

A.5 AT Commands

AT Commands According to V.25TER

AT command are designed according to the ITU-T (International Telecommunication Union, Telecommunication sector).

Profile Commands

Table A.1 shows the profile commands of T300 GPRS modem.

Table A.1 Profile Commands

Demonstration	**Syntax**	**Expect Result**
The AT command interpreter is actively responding to input.	AT	OK
Display product identification information: the manufacturer, the product name and the product revision information.	ATI	SIMCOM_Ltd SIMCOM_SIM300 Revision:1008B10SIM300 M32_SPANSION
Display current configuration, a list of the current active profile parameters.	AT&V	[A complete listing of the active profile]
Reporting of mobile equipment errors. The default CME error reporting setting is disabled. Switching to verbose mode displays a string explaining the error in more	AT+CMEE=? AT+CMEE? AT+CSCS=? AT+CSCS=”TEST”	+CMEE:(0,1,2) +CMEE:0 +CSCS:”GSM” +CSCS:”UCS2”

details.	AT+CMEE=2 AT+CSCS="TEST"	ERROR OK +CME ERROR: +CSCS type not found
Storing the current configuration in nonvolatile memory. When the board is reset, configuration changes from the last session are loaded.	ATE0;&W AT [Reset the board] AT ATE1;&W AT	OK [No echo] OK [No echo] [Echo on]
Set ME to minimum functionality	AT+CFUN=0	OK

SIM Commands

Table A.2 shows the SIM commands of SIM300 GPRS modem.

Table A.2 SIM Commands

Demonstration	**Syntax**	**Expect Result**
Listing available phonebooks, and selecting the SIM phone book.	AT+CPBS=? AT+CPBS="SM"	+CPBS:("DC","FD", "LD","ON","SM","MC") OK
Displaying the ranges of phone book entries and listing the contents	AT+CPBR=? AT+CPBR=1,10	+CPBR:(1-150),41,14 [a listing of phone book

of the phone book.		contents]
Writing an entry to the current phonebook.	AT+CPBW=,"13918 18xxxx", ,"Daniel" AT+CPBR=1,10	OK [a listing of phone book contents]
Finding an entry in the current phonebook using a text search.	AT+CPBF="Daniel"	+CPBF: 5,"139181860 89",129,"Daniel"
Deleting an entry from the current phonebook specified by its position index.	AT+CPBW=2," " AT+CPBR=1,10	OK [a listing of phone book contents]

General Commands

Table A.3 shows general commands of SIM300 GPRS modem

Table A.3 General Commands

Demonstration	**Syntax**	**Expect Result**
Displays the current network operator that the handset is currently registered with.	AT+COPS?	+COPS: 0,0,"CHINA MOBILE"
Display a full list of network operator names.	AT+COPN	AT+COPN +COPN:"20201", "COSMO" [skip a bit] +COPN:"730100",

		"ENTEL PCS" OK
Power down the phone – reducing its functionality. This will deregister the handset from the network.	AT+CFUN=0 [wait for deregister] ATD6241xxxx; AT+CFUN=1	OK NO CARRIER OK
CFUN disables access to the SIM. CSMINS shows when the SIM is available again.	AT+CSMINS=1 AT+CFUN=0 AT+CFUN=1	OK OK +CSMINS:0 OK +CSMINS:1
Emulating the MIMI keypad to make a voice call.	AT+CKPD="6241xx xxs",4,4	OK [the voice call is connected]
Request the IMSI	AT+CIMI	460008184101641

GPRS Commands

Table A.4 shows GPRS commands of SIM 300 GPRS modem.

Table A.4 GPRS Commands

Demonstration	Syntax	Expect Result
To establish a GPRS context.	Setup modem driver Setup dial up connection with *99# Run internet explorer	Should be able to surf the web using Internet explorer.
There are two GPRS Service Codes for the ATD Command: Value 98 and 99. Establish a connection by service code 99. Establish a connection by service code 99, IP address123… and L2P=PPP and using CID 1.The CID has to be defined by AT+CGDCONT. Establish a connection by service code 99 and L2P=PPP Establish a connection by service code 99 and using CID 1 Establish a connection by service code 99 and L2P=PPP and using CID1. The CID has to be defined by	ATD*99# ATD*99*123.124.125.126*PPP*1# ATD*99**PPP# ATD*99***1# ATD*99**PPP*1# ATD*98#	

AT+CGDCONT Establish an IP connection by service code 98		
To check if the MS is connected to the GPRS network Detach from the GPRS network To check if the MS is connected to the GPRS network	AT+CGATT? AT+CGATT=0 AT+CGATT?	+CGATT:1 OK +CGATT : 0
To check the class of the MS	AT+CGCLASS?	+CGCLASS:B
Establish a context using the terminal equipment: defines CID 1 and sets the PDP type to IP, access point name and IP address aren‟t set.	AT+CGDCONT=1,"IP" ATD*99#	OK CONNECT <data>
Cancel a context using the terminal equipment Pause data transfer and enter command	AT+CGDCONT=1, "IP" ATD*99#	

AT Command syntax

The AT command set implemented by SIM300 is a combination of GSM07.05, GSM07.07 and ITU-T recommendation V.25ter and the AT commands developed by SIMCOM. Only enter AT command through serial port after SIM300 is power on and Unsolicited Result Code "RDY" is received from serial port. And if unsolicited result code "SCKS: 0" returned it indicates SIM card isn‟t present. If auto-bauding is enabled, the Unsolicited Result Codes "RDY" and so on are not indicated when you start up the ME. All these AT commands can be split into three categories syntactically: "basic", "S parameter", and "extended". These are as follows:

Basic syntax

These AT commands have the format of "**AT<*x*><*n*>**", or "**AT&<x><n>**", where "<*x*>"is the command, and "**<*n*>**"is/are the argument(s) for that command. An example of this is "**ATE<*n*>**", which tells the DCE whether received characters should be echoed back to the DTE according to the value of "**<*n*>**". "**<*n*>**" is optional and a default will be used if missing.

Parameter syntax

These AT commands have the format of "**ATS<*n*>=<*m*>**", where "**<*n*>**" is the index of the **S** register to set, and "**<*m*>**"is the value to assign to it. "**<*m*>**" is optional; if it is missing, then a default value is assigned.

Extended Syntax

These commands can operate in several modes, as following table:

Table A.5 Types of AT commands and responses

Test command	AT+<*x*>=?	The mobile equipment returns the list of parameters and value ranges set with the corresponding Write command or by internal processes.
Read command	AT+<*x*>?	This command returns the currently set value of the parameter or parameters.
Write command	AT+<x>=<…>	This command sets the user-definable parameter values.
Execution command	AT+<x>	The execution command reads non-variable parameters affected by internal processes in the GSM engine

Combining AT commands on the same command line

We can enter several AT commands on the same line. In this case, we do not need to type the "**AT**" or "**at**" prefix before every command. Instead, we only need type "**AT**" or "**or**" at the beginning of the command line. We have to use a semicolon as command delimiter.

The command line buffer can accept a maximum of 256 characters. If the characters entered exceeded this number then none of the command will executed and TA will returns "**ERROR**".

A.6 SIM 300 Key features

Key features of SIM 300 have shown in Table A.6:

Table A.6 SIM300 key features

Power supply	Single supply voltage 3.4V – 4.5V
Power saving	Typical power consumption in SLEEP mode to 2.5mA (BS-PA-MFRMS=5)
Frequency bands	• SIM300 Tri-band: EGSM 900, DCS 1800, PCS 1900. The SIM300 can search the 3 frequency bands automatically. The frequency bands also can be set by AT command. • Compliant to GSM Phase 2/2+
GSM class	Small MS
Transmit power	• Class 4 (2W) at EGSM 900 • Class 1 (1W) at DCS 1800 and PCS 1900
GPRS connectivity	• GPRS multi-slot class 10 （default）

	• GPRS multi-slot class 8 (option) • GPRS mobile station class B
Temperature range	• Normal operation: -20°C to +55°C • Restricted operation: -30°C to -20°C and +55°C to +80°C • Storage temperature -40°C to +85°C
DATA *GPRS:* *CSD:*	• GPRS data downlink transfer: max. 85.6 kbps • GPRS data uplink transfer: max. 42.8 kbps • Coding scheme: CS-1, CS-2, CS-3 and CS-4 • SIM300 supports the protocols PAP (Password Authentication Protocol) usually used for PPP connections. • The SIM300 integrates the TCP/IP protocol. • Support Packet Switched Broadcast Control Channel (PBCCH) • CSD transmission rates: 2.4, 4.8, 9.6, 14.4 kbps, non-transparent • Unstructured Supplementary Services Data (USSD) support
SMS	• MT, MO, CB, Text and PDU mode • SMS storage: SIM card
FAX	Group 3 Class 1
SIM interface	Support SIM card: 1.8V, 3V

External antenna	Connected via 50 Ohm antenna connector or antenna pad
Audio features	Speech codec modes: • Half Rate (ETS 06.20) • Full Rate (ETS 06.10) • Enhanced Full Rate (ETS 06.50 / 06.60 / 06.80) • Echo suppression
Serial port and Debug port	Serial Port: Seven lines on Serial Port Interface • Serial Port can be used for CSD FAX, GPRS service and send AT command of controlling module. • Serial Port can use multiplexing function. • Autobauding supports baud rate from 4800 bps to 115200bps. Debug Port: Two lines on Serial Port Interface /TXD and /RXD • Debug Port only used for debugging
Phonebook management	Support phonebook types: SM, FD, LD, RC, ON, MC.
SIM Application Toolkit	Support SAT class 3, GSM 11.14 Release 99
Real time clock	Implemented
Timer function	Programmable via AT command
Physical characteristics	Size: 40±0.15 x 33±0.15 x 3.3±0.3mm (including application connector)

	40±0.15 x 33±0.15 x 2.85±0.3mm (excluding application connector) Weight: 8g
Firmware upgrade	Firmware upgrade by serial port.