Automated Rain Gauge Stations with A GSM Data Transmission Link

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Abstract –**An automated, remote rainfall gauging system is developed to monitor the rainfall in five remote areas from one base station. The automated rain gauge stations (ARGSs) were installed at five selected locations in Sri Lanka. Two replica base stations are going to be installed at the Department of Meteorology, and National Building Research Organization (NBRO). The base stations and the ARGSs are connected with a Global System for Mobile communication (GSM) link. The ARGS sends rainfall data every hour and if the intensity of rainfall exceeds a pre-determined threshold level a warning is given and rainfall data sent at a higher rate. The automated rain gauge station consist of a microcontroller based acquisition and controlling system, a GSM modem based communication link, A Real Time Clock (RTC), a lightning protection system, and a surge protection system. Rain gauge is built with a Tipping Bucket. Rainfall together with date and time obtained from the RTC is sent as an SMS every hour to the base stations. Current rainfall can be observed by an LCD (Liquid Crystal Display) attached to the ARGS and the backlight of the LCD is automatically illuminated by capturing the presence of human being via IR (Infrared) proximity sensor. The base station consists of a PC and a GSM modem. Application software displays the rainfall individually for all ARGSs in graphical and tabular formats. The captured rainfall data from all ARGSs are also saved to a database**

I INTRODUCTION

Collecting rainfall information is a crucial requirement of many areas in science as well as in natural disaster warning systems. The rainfall intensity and soil water level are key factors causing landslides. Rainfall is measured once a day as an average value. Almost all the weather stations located in Sri Lanka are manually operated systems.

Manned weather stations have inherited drawbacks. Obviously those require a lot of man power. Rain gauges, like most meteorological instruments, should be placed far enough away from structures, and trees. Due to that reason, it is difficult to obtain readings during rainy or stormy periods. Also the time information is hidden in the conventional method, instead an average rainfall is measured. But for an early disaster warning system, it is essential to have the rainfall with time information. Also it is not realistic to establish a manned weather station, where it is difficult to reach.

With such drawbacks, for an early disaster warning system, manned weather stations are not good solutions. Thus an automated, standalone, remote operable rainfall gauging system is developed to monitor the rainfall. The automated rain gauge stations (ARGSs) and the base stations are connected with a Global System for Mobile communication (GSM) link. Communication is done through short messaging service (SMS). The ARGS sends time together with rainfall every hour unless an abnormal rainfall (when the intensity of rainfall exceeds a pre-determined threshold level) is detected. In the event that an ARGS detects a high intensity in rainfall, a special warning message with rainfall is sent to base stations as an alert, and rainfall is sent to the base station every five minutes until the abnormality is disappeared.

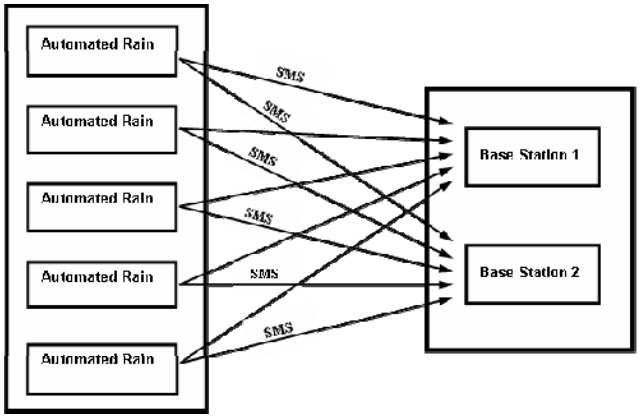

Fig. 1 ARGSs and Bases station communication

II METHODOLOGY

A ARGS and Base Station Components

The system consists of two components. ARGSs are the on site operating component and the other component is the base stations. Data capturing is done by ARGSs, and sent to the base station (See Fig. 1).

In a normal rain gauge rain is manually collected and most often readings of the gauge are also logged manually. But in automated rain gauge all the data should be acquired and processed automatically. In addition ARGS broadcasts rainfall figures via a GSM link to a base station. The ARGS also determines the intensity of rainfall and change its rate

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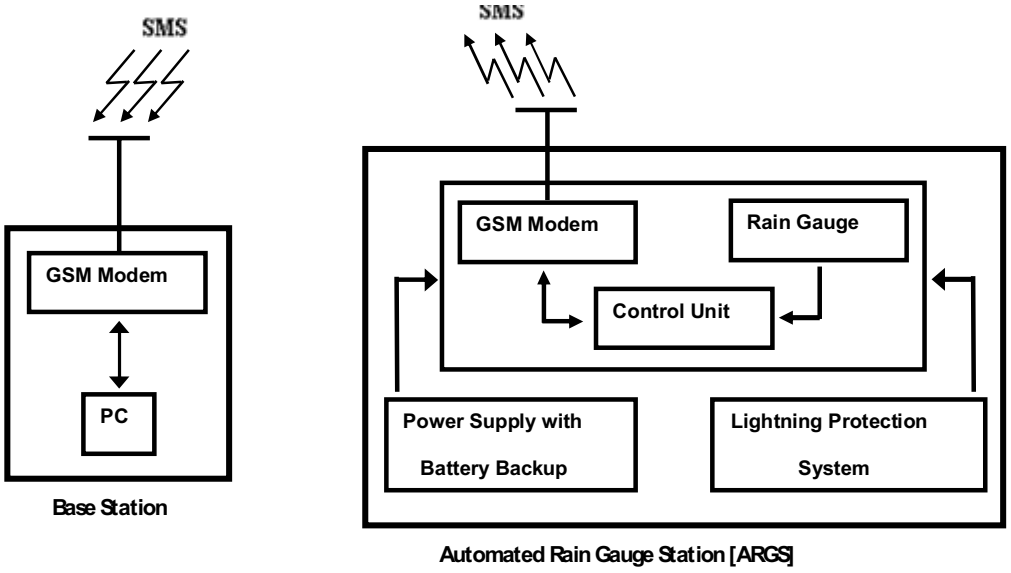

Fig. 2 ARGSs and Bases station components

of acquisition accordingly. In order to achieve these tasks a microcontroller based system is utilized in the ARGS (see Fig. 2). The functionality of these components is discussed below.

B PIC18F452 Microcontroller

The PIC18F452 microcontroller is the heart of the ARGS. Acquisition of rainfall figures and real time from RTC, displaying the results in the LCD and most importantly communicating with base stations through the GSM Link is done by the microcontroller.

PIC18F452 is a RISC driven by a 40 MHz clock and this gives an execution speed of 10 MIPS. The main features of the microcontroller include hardware counters and timers, hardware UARTs, several interrupt sources and five IO ports. Throughout this project these features are been utilized in order to achieve the final task.

Microcontroller firmware was developed using a C language compiler called HI-TEC PICC integrated into MPLAB IDE. To program and debug code Microchip ICD2 was used. The complete firmware development life cycle starting from writing code, simulating, programming and In Circuit Debugging was carried out with this development platform.

The final firmware is programmed into the microcontroller using a Boot-loader software making use of PIC18F452's self programming feature. This enables the firmware updates to be done using the serial port of the microcontroller without removing it from the control box. This also enables remote firmware upgrades directly from base stations with few modifications to firmware and Base Station software in the future.

C The Tipping Bucket

This is a mechanism developed to measure rainfall in an unattended area (See Fig. 3). It has a funnel of about 160 mm in diameter contained in an Aluminium jar. Whenever there is rain the water collected in the funnel is allowed to drop to the tipping bucket mechanism. Usually the mechanism tips for every 0.25 mm of rain. The tipping action turns on a magnetic Hall Effect sensor (Honeywell SS441A) momentarily. By counting the number of times the bucket tips an accurate measurement of rainfall is acquired. The output of the Hall Effect sensor is connected to built-in 16 bit hardware counter of the PIC18F452 microcontroller. This allows a maximum rainfall measurement of 4096 mm per day without overflowing the counter.

D GSM Modem and SMS Generation

SMS alert generation is done with a Fargo Maestro GSM100 modem connected to the microcontroller. The modem supports GSM V 7.05 text messaging specifications. PIC18F452 microcontroller and the modem are connected serially via a RS232 interface. This interface consists of hardware UART at the microcontroller and a RS232 transceiver IC (MAX232).

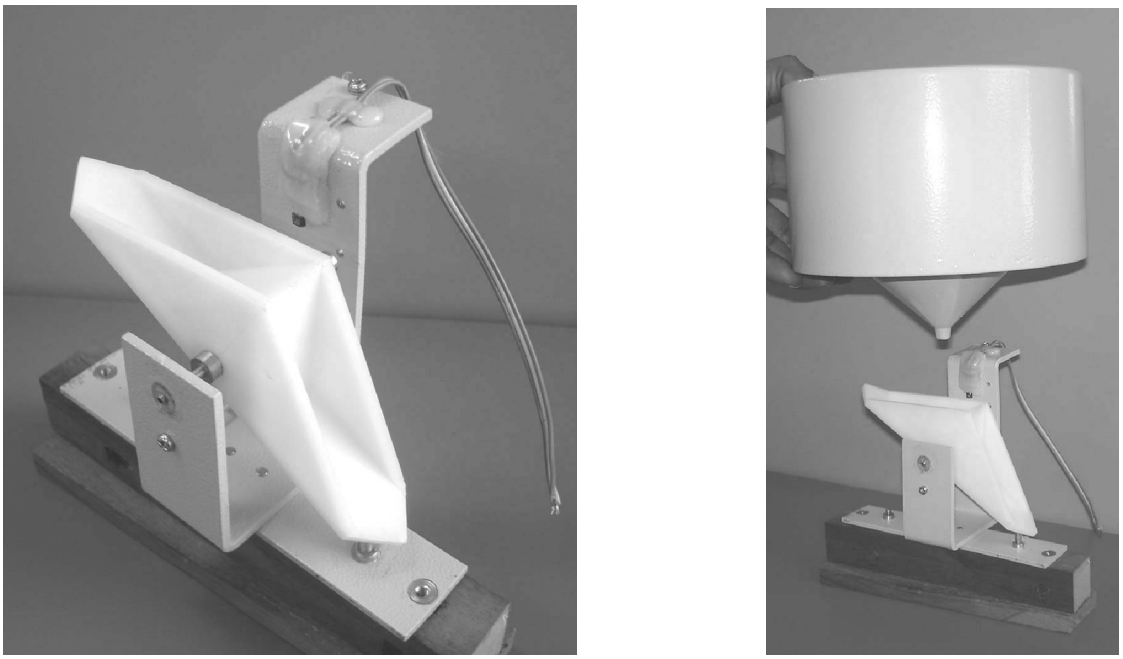

Fig. 3 Left: the tipping mechanism, Right: the tipping bucket with the funnel

Like any other modem a GSM modem is also controlled with a set of text commands called AT commands (Table 1). At the power on, microcontroller sends the necessary commands to detect the modem and to initialize it. Then the microcontroller waits for the GSM modem to get registered with the GSM operator. After a successful network registration microcontroller begins its main function of taking rain gauge measurements and keeping track of time.

TABLE 1
Sample AT commands and descriptions

Code	Description
START045.25 05-01-2007 09:30STOP	Sample SMS body
AT+CMGS="+94776955737\"\nSTART0 45.25 05-01-2007 09:30STOP \x1A	AT Command with SMS Body
AT+CFUN=1\n\r	AT command to reset modem
ATE0	AT command to put modem into no echo mode

The critical factor, when controlling the GSM modem with the PIC18F452 microcontroller, is receiving and processing the responses from the modem. For each AT commands the modem responses with a text string which indicates whether the command was successful or not. These responses should be correctly interpreted and necessary steps should be taken in order to maintain a successful operation. For an example, sending an SMS might fail due to network conditions and in this case it should be resent. Because of the limited processing power of the microcontroller (10 MIPS at 40 MHz) this is achieved with highly optimized text comparison routines at the microcontroller firmware.

E DS12887 real time clock (RTC)

DS12887 is a parallel interfaced RTC chip with built-in lithium battery. Function of the RTC is to keep track of real time. The microcontroller reads the time from the RTC chip at regular intervals of 30 s. This data consist of an array of bytes where each byte contains the year, month, date, day of the week, hour, minute and seconds. The real time obtained with RTC is used to generate SMS alerts of rainfall at every hour. And in the event of intense rainfall SMSs are generated at every 5 minute. Because of the built-in Lithium battery, RTC chip retains correct date and time even at a complete power failure.

F Power Supply

ARGSs are powered by national power grid (230 V AC at 50 Hz) directly. Stepped down voltage is fed to the system through a 12V rechargeable sealed Lead-Acid battery. Therefore small voltage fluctuations are eliminated and the rechargeable battery acts as power backup for 5 days time in case of a power failure and recharging is done automatically. When a power failure is detected, the system moves to low power consuming mode by switching off LCD backlight, and other indicators. When someone is close to the control box of the ARGS, the backlight of the LCD is automatically illuminated and the proximity of a

personal is detected by the active IR transceiver. This IR proximity sensing system also helps to reduce the power consumption.

G Power Surge, Lightning and Electro Magnetic Interference Protection

The system is protected from the ground flashes with the help of a Franklin type Lightning Rod. A Galvanized Iron (GI) rod, covered with Gemco gel in order to make good contact with the soil, is buried up to 240 cm. This provides low resistance earthing via a copper stripe to the Frankling type lightning rod of 300 cm high. The metal box, where the system is placed provides Faraday cage protection to the system from external electromagnetic interference and the box is also connected to the ground by copper stripes. All the sensitive electronic circuitry is connecting to the control box are bypassed with capacitors to avoid high frequency interference. The Hall Effect sensor of rain gauge is connected to the control box with a screened wire to avoid EMI. The wire which supplies electricity to the system is also laid 30 cm underground to avoid generation of power surges by lightning. Further, the system is protected from the power surges with the help of Micropower DS1820 surge protector.

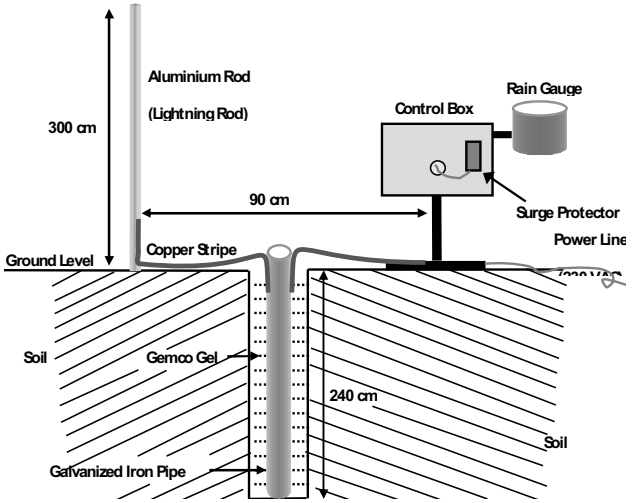

Fig. 4 Surge and lightning protection system in ARGS

H Base Station and Application Software

Base station is the data receiver from the automated rain gauge stations (ARGSs). All the ARGSs are directly connected to the base station via a GSM link. Two replica base stations are utilized in this project. One is installed at the Department of Meteorology, and the other is installed at the National Building Research Organization (NBRO). Both receive same data separately, but simultaneously.

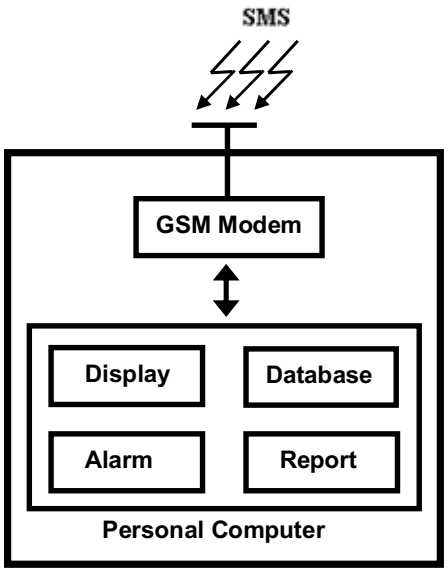

Fig. 5 Base Station Block Diagram

The base station consists of a PC running Microsoft® Windows® XP (SP2) and the Fargo Maestro100 GSM modem. Application Software is developed using Borland® Delphi 6 IDE. To get an instrumentation look and feel to the application TMS Software instrumentation components pack is utilized (Fig. 6). The application software at the PC end is the only part of the design which interacts with the user. Therefore every effort has been made to make this part efficient, user friendly and reliable. The application software is given the name "Automated Rainfall Data Logger."

GSM modem is connected to the computer via the serial port (COM1). The data at the com1 port is captured by a third party Delphi component called "CPORTLib" integrated to the software. When software initializing, GSM modem is registered in the GSM network. When registration gets succeeded, flashing indicator will display on the GUI of the software.

Each ARGS has unique GSM address (or number). The software uses this GSM address (or number) to identify the ARGS which sent the data. Since this is a general GSM modem it is possible to receive SMS from some other phones as well. If an SMS from a strange number is detected, the SMS will be automatically refused, and deleted by the software. If data from an ARGS is detected it will be recorded by the software.

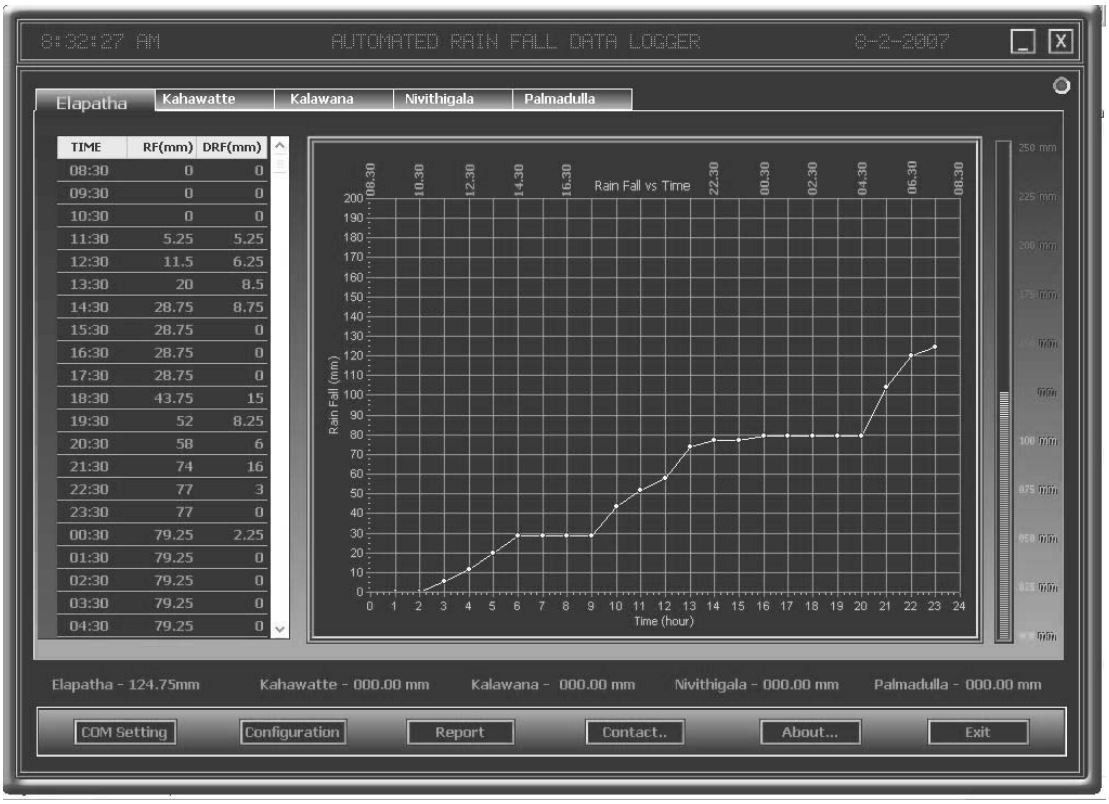

Fig. 6 GUI of Automated Rainfall Data Logger

Figure 7 shows a sample data from an ARGS. +CMT is a controlling signal generated by the modem, and the next +94777958112 is the GSM address of the ARGS, followed by the date and the time and then in between START and STOP is the data rainfall, date, and time.

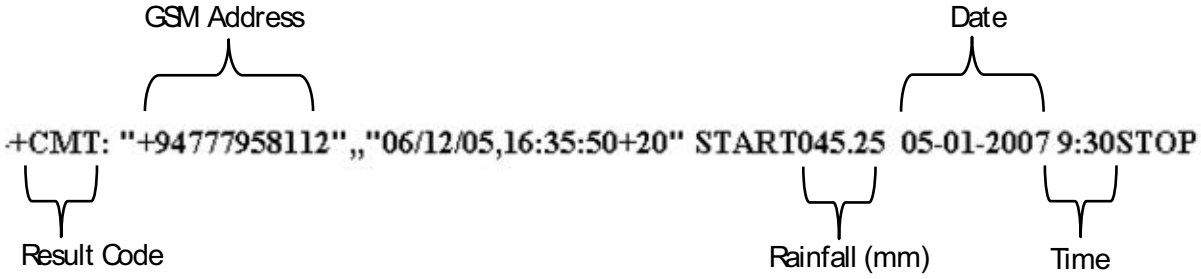

Fig. 7 Sample data from an ARGS

The data from individual ARGS is tabulated in separate tables and the graphs are automatically updated. The software allows user to retrieve data in tabular format as well as graphical format for individual ARGS. Cumulative rainfalls for all ARGSs are always displayed in the status bar of the GUI.

At the end of each day, the data is saved as .csv file (which can be opened through almost all the spreadsheet application). A new folder is created for each day and separate .csv files are created within that folder for each ARGS. A Sri Lankan Standard day for rainfall is defined from 8.30 AM to the next day 8.30 AM. Software starts an internal 'new day' at 8.30 AM every day.

III RESULT AND DISCUSSION

Fig. 8 Left: Full ARGS system (control box is closed), Right: Control box at ARGS opened

A Results

Five ARGSs were installed at five selected locations in Ratnapura district of Sri Lanka. (Ratnapura district is the most vulnerable for landslides in Sri Lanka). One base station is installed at Industrial Technology Institute (ITI) for testing purpose and it functions well. Two replica base stations are going to install at the Department of Meteorology, and National Building Research Organization (NBRO). Final objective of this project is to develop computerized early warring system to predict landslide possibilities using rainfall and ground water level value as input data.

While operating under normal conditions, the ARGS has a typical power consumption of 0.5 W. The battery allows running the system without any failure for 5 days. Also if there is a power failure in the base station. No data will be lost, because SMS are stored in the servers of the GSM service provider. As soon as power is resumed, all the SMS will be downloaded to the PC located at the base station.

The hardware requirements of the base station are an IBM PC or compatible computer with a processor equivalent to Pentium III 400 or better, serial (com) port, the recommended RAM for the operating system used. The PC should have Microsoft Windows 98, 98SE, 2000, ME or Windows XP operating system installed.

B Further Improvements

An ARGS must be located in an area where GSM network coverage is present. Sometimes there are delays in sending / receiving SMS in current GSM networks in Sri Lanka. But it can be easily eliminated by taking priority for the GSM numbers used for ARGSs from the GSM service providers. Also the cost for communication can be reduced by using GPRS as data bearer rather than SMS. Although there is a good lightning protection system is employed, still there is a treat of lightning striking to the system.

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