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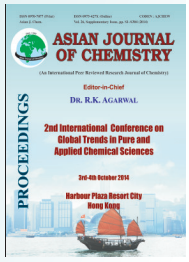

Online Monitoring of Geological Methane Storage and Leakage Based on Wireless Sensor Networks

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Geological methane monitoring is an important aspect of mining and other petrochemical industries. In hazardous environments local cabling and wiring for the sensors requires frequent maintenance and preventive installations. Proposed work is developed to monitor the concentration of methane using wireless sensor networks linked to Raspberry Pi. A series of methane sensors were developed for monitoring and transmitting the methane concentration. The collected data was transmitted to the base station connected to receiver GPRS connected to Raspberry Pi. Raspberry Pi connected *via* USB cable to the base computer was used for the data acquisition from various sensors installed on the site. The results obtained from the wireless sensors were compared to that of the acquired signals from the wireless sensor networks. The results obtained were accurate and leakage of methane gas was detected and acquired online using the Raspberry Pi.

Keywords: Methane, Raspberry Pi and wireless sensor networks.

INTRODUCTION

Methane gas sensors are used primarily in mine where there is presence of gas pockets beneath the rocks and soil. Majority of around 60 % coal seams currently being extracted worldwide are so far underground that cast mining cannot take place and therefore underground mining techniques are used. The hazards of methane are encountered in the mine gases. Under normally functioning environment in a coal mine ventilation shafts are used to eject the carbon monoxide, methane and other gases[1]. During excessive methane concentrations forced draft fans are used to eject the methane and carbon monoxide gases[2].

Automatic calibration of methane monitoring in a wireless sensor network was demonstrated by Zhang[3]. Automatic calibration technology was used on an intelligent sensing node to form a real time sensor network. The intelligent sensing node performed the automatic sensing autonomously[4]. Methane gas inspection and control was developed on a single chip microprocessor (SCM) by Chen[5]. Wireless transceiver nRF401 based data communication was used between field monitor and inspection tour equipment. During the experiment error rates of 0.3 % were observed. A METS gas sensor was deve-loped by Fukasawa *et al*[6]. The sensor was efficient in detecting the methane hydrate in atmospheric form. A multi-channel optical fiber methane monitoring system for detecting concentration of methane was developed by Zhao *et al.*[7]. A distributed feedback laser was employed as light source[8]. The narrow absorption line of laser was used to eliminate the cross sensitivity to moisture, ethane or other gases. The result showed that monitoring system had great utilities in coal mines and ventilation of air methane. Commonly used methane sensors have the problem of methane sensorapsilas stability that leads to the shortcomings in the methane detection[7]. A wireless connectivity was used for both data collection and calibration resulting in variable calibration[9].

EXPERIMENTAL

Fig. 1 shows the wireless sensor nodes installed in a methane geological region. The methane gas sensor works on the principle of an electrochemical sensor that reacts on sensing the gases with smaller heater inside supplied with an external voltage. The sensor is calibrated using the standard methane sensors for the calibrated output voltage. Other inbuilt sensors on the nodes are a temperature and humidity sensor to obtain the information about the flammability of the environment upon sudden changes in the geological reserves. Connected to the sensor modules is a GPRS module acting as a transmitter. The GPRS transmitter modules sends the signals back to the receiver station which has a GPRS receiving modem connected to the Raspberry Pi. Raspberry Pi here acts as a data acquisition unit and is an interface between the CPU server and the receiver GPRS[1].

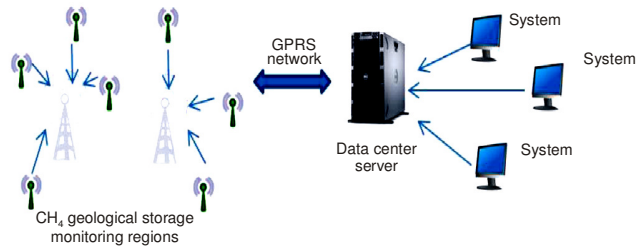

Fig. 1. Wireless sensor networks for monitoring methane for geological storage monitoring regions

Hardware description

Raspberry Pi: The Raspberry Pi is a credit card-sized single-board computer developed in the UK by the Raspberry Pi foundation with the intention of promoting the teaching of basic computer science in schools. The Raspberry Pi is based on the Broadcom BCM2835 system on a chip (SoC), which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU and was originally shipped with 256 megabytes of RAM, later upgraded (Model B & Model B+) to 512 MB. The system has secure digital (SD) or MicroSD (Model B+)[10] sockets for boot media and persistent storage. Python as the main programming language, with support for BBC BASIC[11] (*via* the RISC OS image or the Brandy Basic clonefor (Linux), C, C++, Java, Perl and Ruby (Fig. 2).

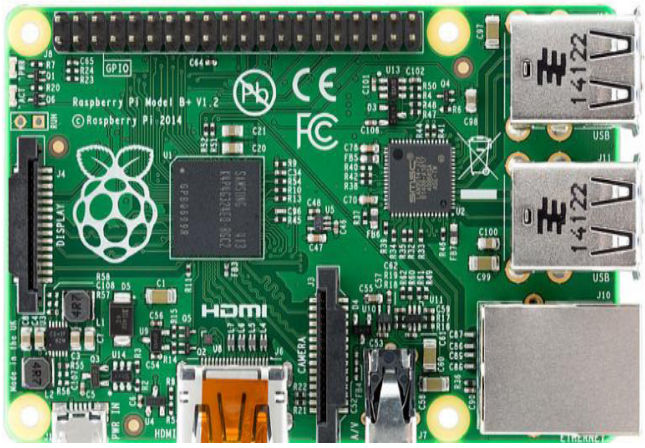

Fig. 2. Raspberry Pi computer model B+

Methane gas sensor: Some of the features of MQ4 type of sensor are high sensitivity to CH_4, natural gas, small sensitivity to alcohol, smoke, fast response, stable and long life and simple drive circuit. Structure and configuration of MQ-4 gas sensor is shown as Fig. 3. Sensor is composed by micro Al_2O_3 ceramic tube, tin dioxide sensitive layer, measuring electrode and heater are fixed into a crust made by plastic and stainless steel net. The heater provides necessary work conditions for work of sensitive components. The enveloped MQ-4 have 6 pin, 4 of them are used to fetch signals and other 2 are used for providing heating current[12].

Temperature sensor: RTD is used as a temperature sensor. PT100 model is used for the environmental temperature monitoring as its range falls in the near ambience range and is rugged to geological hazards and remains functional in the limits of -200 to 800 °C[13].

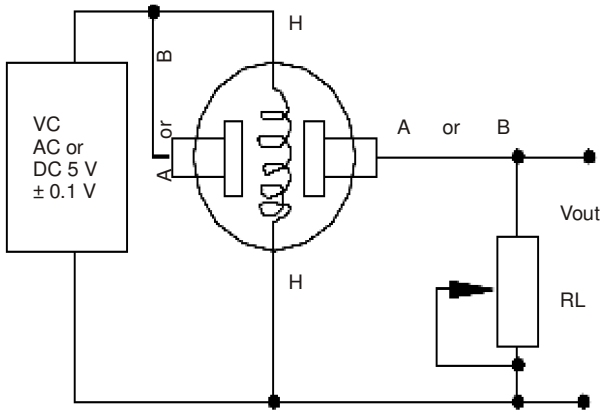

Fig. 3. Structural and signal connection of the MQ4 sensors

GPRS module: Frequency GPRS/GSM Module-EFCom Pro is used and is an ultra compact and reliable wireless module. It is a breakout board and minimum system of SIM900 Quad-band GSM/GPRS module. It can communicate with controllers *via* AT commands (GSM 07.07, 07.05 and SIMCOM enhanced AT Commands). This module support software power on and reset. EFCom Pro is base on SIM900 4 Frequency GPRS module. The GPRS is configured and controlled *via* its UART using simple AT commands. Fig. 4 shows the overall layout of the system. A gas sensor, humidity sensor and temperature sensors are connected to a data acquisition unit. The data acquisition unit consists of a calibrator and an inbuilt amplifier for the low frequency and amplitude signals. The signals after processing from the signal conditioning unit are fetched by the GPRS transmitter. The GPRS transmitter sends the signal to the receiver of the central server connected. The central server receives the measured value and stores in the server memory[14].

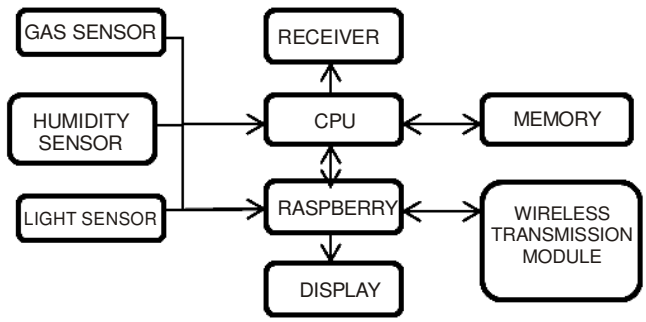

Fig. 4. Block diagram of the methodology

RESULTS AND DISCUSSION

The operation of the proposed methodology is as shown below in the flowchart (Fig. 5). Initially the Raspberry Pi module is initialized with the sensor module. The rotocol stack is initialized and the far ends of the sensor nodes are acknowledged for the data receiving. Upon acknowledgement of the sensor modules the measurement of various sensors starts and the data is received from the GPRS connected sensors. Upon collecting the data in a buffered stream the data string is verified at the Raspberry Pi end receiver for checking whether the full measured stream of data is received at the receiver or any missing data is present[15].

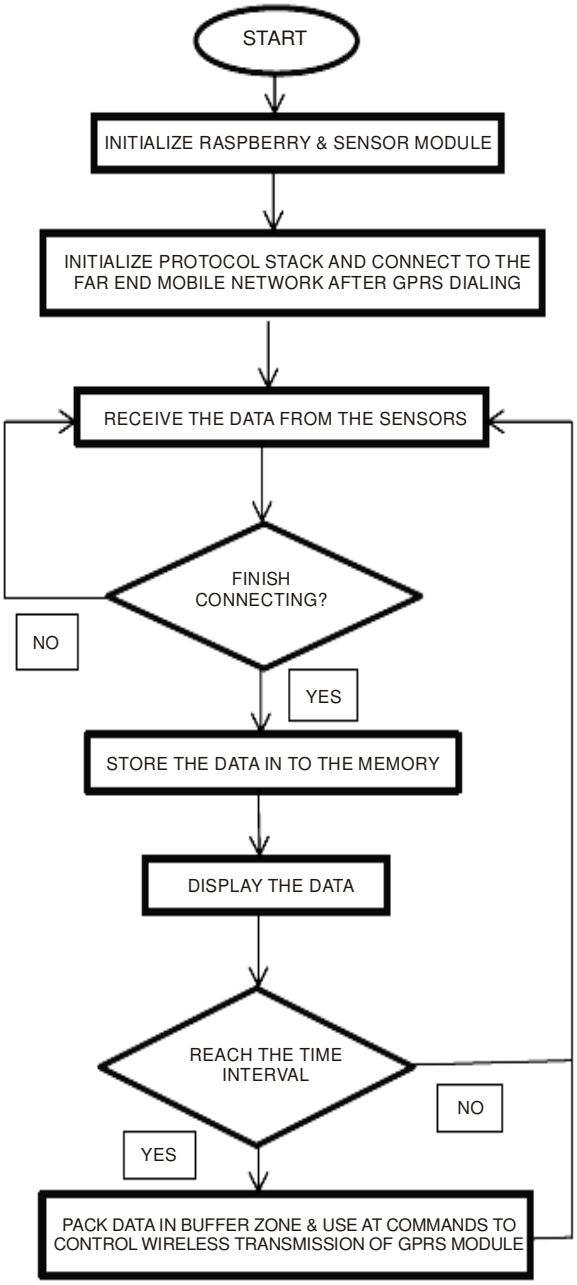

Fig. 5. Flow chart

Upon receiving the full data, the data string is stored in the memory and is displayed on the Raspberry Pi connected screen. Upon successful completion of the data storage the pack data and buffer unit use commands and controls from the Raspberry Pi for the control and communication of the next process as set by the installation requirement like turning alarms and actuators, *etc*[16]. The logged data of the wireless sensor network using Raspberry Pi is logged and plotted for comparison. Figs. 5 and 6 shows the plot of methane concentration of sensor node A and B separated by a distance of 20 m. The obtained readings are compared with that of the wired readings of another calibrated sensor[17]. Wireless sensors showed confirmative measurement of the methane concentrations in the geological mine installation[18].

Conclusion

Based on the sensors of methane, temperature, humidity and light intensity, the equipment which is suitable for the surface methane concentration monitoring was developed in order to realize remote real-time acquisition of multivariate informationin the monitoring of methane geological storage. This experiment adopts self-made portable methane monitoring equipment, which obtains localization and time service information through GPS and it can cacth dynamic changes of real-time monitoring data into SD cards. GPRS is employed to wirelessly transmit them to the server, which ensures the continuity of data acquisition and monitoring. Apart from the sound effects, the monitoring system is simple in structure, easy to operate, convenient to carry, remote monitoring, automatic storage, real-time display and continuous wireless transmission, which provide remote real-time monitoring means for further study of quantitative analysis and dynamic simulation of the process of methane geological storage, leakage, diffusion and migration under complex air environment.

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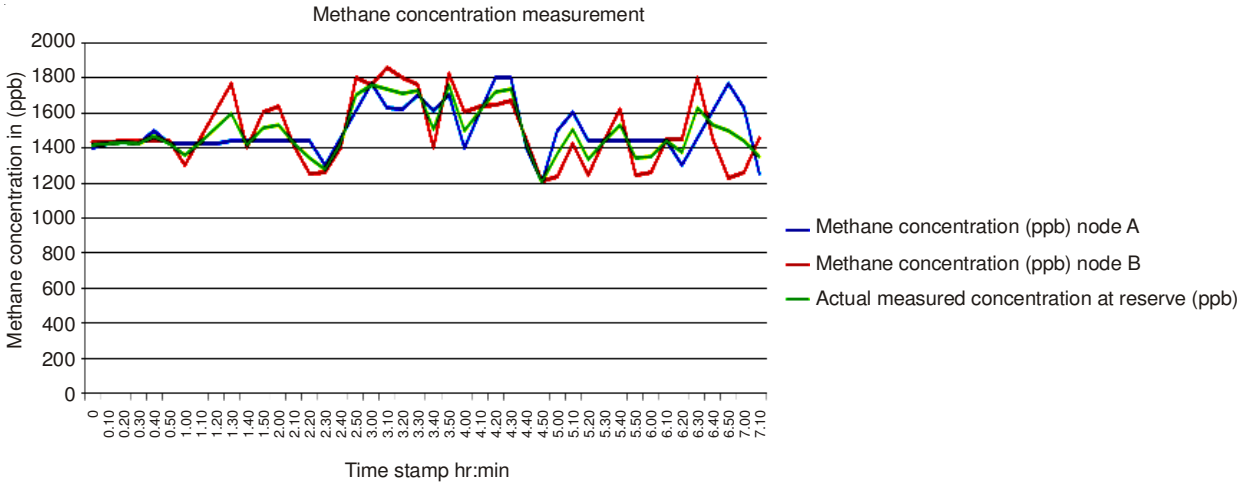

Fig. 6. Methane concentration measurement

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