ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Monitoring of Geological CO_2, based on Wireless Sensor Networks

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Abstract

Carbon Capture and Storage (CCS), also known as Carbon Capture and Sequestration, includes geological storage CO_2. Safe, long-term geological storage (sequestration) of CO2 also requires a continuous monitoring system to detect CO_2 leakage from reservior. This paper gives details about a remote carbon dioxide (CO2) concentration monitoring system developed, based on the technologies of wireless sensor networks, in allusion to the gas leakage monitoring requirement for CO2 capture and storage. The remote online CO2 monitoring system consists of monitoring equipment and a data centre server. The monitoring equipment is composed of a central processing unit (CPU), air environment sensors array, secure digital memory card (SD) storage module, liquid crystal display (LCD) module, and general packet radio service (GPRS) wireless transmission module. The sensors array of CO2, temperature, humidity and light intensity are used to collect data. The CPU automatically stores the collected data in the SD card data storage module and displays them on the LCD display module in real-time. Afterwards, the GPRS module continuously wirelessly transmits the collected information to the data centre server.

Keywords: Non-dispersive Infra Red (NDIR), ARM LPC2148, General Packet Radio Service(GPRS), Secure Digital (SD) Card, Wireless Sensor Network (WSN).

Introduction

Atmospheric concentrations of the key greenhouse gas (GHG) carbon dioxide (CO_2) well above pre-industrial levels constitute the main cause for the predicted rise at average surface temperature on Earth and the corresponding change of the global climate system. CO_2 Capture and Storage (CCS) is on the one hand an effective way to realize effective greenhouse gas storage, and on the other to improve oil and gas production. To reduce atmospheric emissions, carbon capture and sequestration is proposed as a means of collecting CO_2 gas generated through industrial and consumer processes and sequestering it to prevent its release into the atmosphere. Many countries such as the United States, Japan, and Canada are in search of effective approaches for CO_2 storage in either geological formations or ocean. In China, the first demonstrative industrial project of CO_2 storage has come into operation in Shenhua mine area.

However, once CO_2 leaks from the storage reservoir, all the efforts human beings have made to fight global warming would be go down the drain. Therefore, what is in needed after the geological CO_2 storage is long-term terrain monitoring of the greenhouse gas leakage, which is absolutely crucial to help ensure that geologic sequestration of CO_2 is safe. For this reason, the development of monitoring system is of great significance to geological CO_2 storage and leakage warning.

Recent advances in information and communication technologies have resulted in the development of more efficient, low cost and multi-functional sensors. These micro-sensors can be deployed in Wireless Sensor Networks (WSN) to monitor and collect air environmental information such as CO_2 concentration, temperature, humidity, light intensity, air pressure, wind power, wind direction, etc. The information is then wirelessly transmitted to data centre server where they are integrated and analyzed for evaluating of geological CO_2 storage and leakage. Deploying sensor networks allows inaccessible areas to be covered by minimizing the sensing costs compared with the use of separate sensors to completely cover the same area.

Proposed System

Geological CO_2 leakage monitoring equipment based on WSN are mobile devices used by humans. The system mainly consists of geological CO_2 leakage

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monitoring equipment, data center server, as shown in Figure 2.1.

Figure 2.1. System structure of geological CO2 monitoring system.

The development of CO_2 remote real-time monitoring equipment is the core task of the whole system. The equipment can be deployed in CO_2 geological storage monitoring region. It can collect CO_2 concentration, temperature, humidity, light intensity and other air environmental information through sensors. The General Packet Radio Service (GPRS) network will send the collected data to the data center server. The equipment is composed of the air environment sensors array, central processing unit, SD card data storage module, LCD display module and GPRS wireless transmission module, as shown in Figure 2.2.

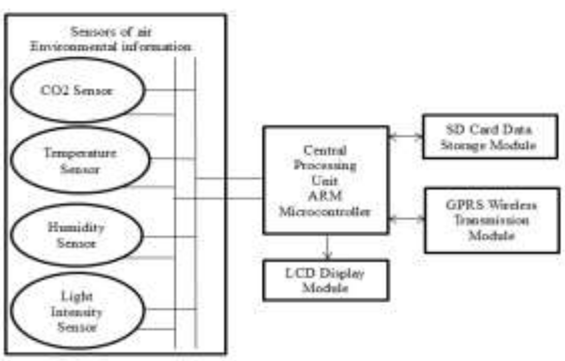

Figure 2.2 CO2 Monitoring Equipment

The microcontroller manages the operation of each module. Its ARM based microcontroller for embedded applications featuring a high level of integration and low power consumption. Air environmental information acquisition sensors array includes: CO_2 sensor, temperature sensor, humidity sensor, and light intensity sensor. These sensors, respectively, provide real-time collection of air data to the central processing unit. The CPU automatically stores the collected data in the SD card data storage module and displays them on the LCD display module in real-time. In addition we can also use GPS (Global Positioning System) receiver module to collect location and time data. The transmission of Real-time collected data is via GPRS wireless transmission module.

Hardware Infrastructure

Geological CO_2 leakage monitoring equipment based on WSN is composed of the air environment sensors array including CO_2, temperature, humidity and light sensor, microcontroller as a central processing unit, SD card data storage module, LCD display module and GPRS wireless transmission module.

A. Microcontroller (ARM LPC2148)-

The ARM LPC2148 microcontroller manages the operation of each module. Its ARM based microcontroller for embedded applications featuring a high level of integration and low power consumption. 16-bit/3-bit ARM7TDMI-S microcontroller is in a tiny LQFP64 package, 8 KB to 40 KB of on-chip static RAM and 32 KB to 512 KB of on-chip flash memory, 128-bit wide interface/accelerator enables high-speed 60 MHz operation, CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads and twon10-bit ADCs provide 14 analog inputs, with conversion times as low as 2.44 µs per channel makes it more suitable for this application.

Figure 2.3 ARM LPC2148 Microcontroller

B. Sensor specifications and circuit design-

Air environmental information acquisition sensors array includes: NDIR CO2 sensor, temperature sensor, humidity sensor, and light intensity sensor. These sensors, respectively, provide real-time collection of air data to the central processing unit. Each sensor is described in the following:

NDIR CO2 Sensor-.

COZIR CO2 sensor represents a breakthrough in low power gas detection making it ideal for battery powered, energy harvesting or wireless applications with tight energy budgets requiring long operating life. This Infrared LED based sensor offers a number of distinctive features over conventional CO_2 sensors. COZIR sensor shown in Figure 2.4 has continuous power consumption of 3.5mW with reasonable duty cycling, measurement ranges of 0-2000 ppm, 10 second warm up time, shock and vibration resistant and built in auto calibration feature makes it more suitable for this application.

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Figure 2.4 COZIR CO2 Sensor

Temperature Sensor-

The LM35 series are precision integrated circuit calibrated directly in ° Celsius (Centigrade) linear +10 mV/°C scale factor temperature sensors, with an output voltage linearly proportional to the centigrade temperature. Thus the 0.5°C ensured accuracy (at +25°C) LM35 has an advantage over linear temperature rated for full −55°C to +150°C range sensors calibrated in ° Kelvin, as the user is not suitable for remote applications required to subtract a large constant voltage from the output to obtain convenient centigrade scaling. The low cost due to wafer-level trimming LM35 does not require any external calibration or operates from 4 to 30 V trimming to provide typical accuracies of ±¼°C at less than 60-µA current drain room temperature and ±¾°C over a full −55°C to +150°C temperature range. Interfacing with microcontroller is shown in Figure 2.5.

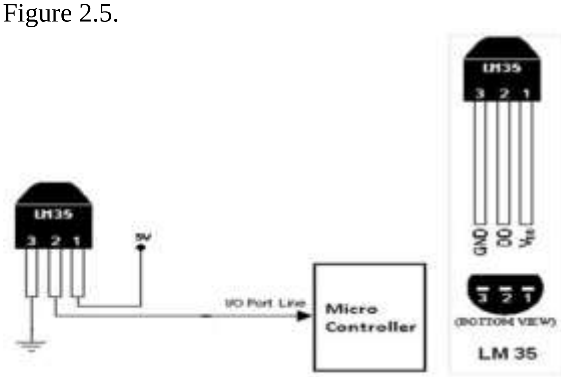

Figure 2.5 Interfacing LM35 with LPC2148

Humidity Sensor-

Humidity sensor is used for acquiring humidity sensor data. Here Humidity sensor SY-HS-220 is used to sense humidity. This humidity sensor is of capacitive type, comprising on chip signal conditioner. The measurement range is of 30~90% RH and voltage input of 5 V DC. SY-HS-220 is shown in Figure 2.6.

Figure 2.6 SY-HS-220 Humidity Sensor

Light Sensor-

LDR is Light Dependent Resistor which is used as light sensor. It gives output in terms of voltage which indicates the light intensity of the surroundings. The cell resistance falls with increasing light intensity. Its operating voltage is 320V AC or DC peak. LDR is having two terminals with it's signal conditioning is shown in the Figure 2.7. The one is data pin that is always connected to Vcc, output is taken from this pin, and another pin is grounded.

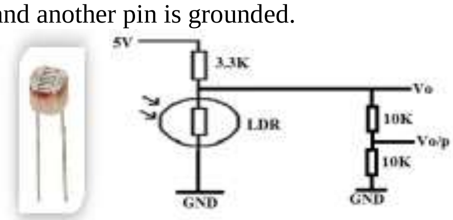

Figure 2.7 LDR

C. GPRS Remote Transmission

The transmission of Real-time collected data is via GPRS wireless transmission module–SIM900A. It is characterized by the small chip, compact, high reliability and low power consumption. Central processing unit uses Universal Asynchronous Receiver Transmitter (UART) to reach the connection to GPRS wireless transmission module to further realize wireless transceivers of data collecting. It is shown in Figure 2.8

Figure 2.8 SIM900A GPRS Module

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Algorithm-

Algorithm includes two main parts, real-time data collection and wireless transmission. First, the sensors array of CO_2, temperature, humidity and light intensity are used to collect data, afterwards, for the collected data, through GPRS wireless transmission module, continuous wireless transmission is conducted. Specific procedures are as below:

1) Power on the equipment, then initialize to the entire CO_2 remote real-time monitoring system, including the circuit initialization of air environment sensors array, central processing unit and all modules. Display the control signal in a fixed time and monitor the operational status of each module real-timely.

2) After the initialization of TCP/IP protocol stack and GPRS wireless transmission module, the central processing unit achieves the connection to remote mobile network and then the point to point communication will be established.

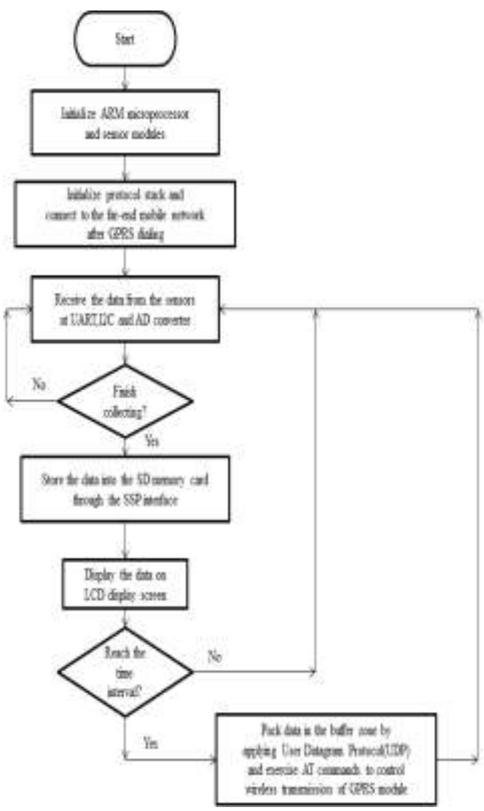

Figure 2.9 Flowchart of CO2 monitoring equipment

3) Wait for the data of air environmental sensors, including CO_2 concentration, temperature, humidity, light intensity.

4) If data collection is completed, the central processing unit will automatically store the collected data into SD card through the SSP interface, otherwise go to step three.

5) Central processing unit displays the collected data and power supply information on the LCD display module real-timely.

6) When the transmission time interval is reached, pack the stored data according to TCP/IP. The AT commands is applied to control GPRS wireless transmission module to connect to remote wireless communication network and the data packet will be sent wirelessly to a data center server.

7) We can collect data from multiple sensor units and can be sent wirelessly to same data center through GPRS transmission.

Implementation

Monitoring equipment for geological CO_2 leakage is successfully developed, which can realize automatic real-time display and wireless transmit the data of CO_2 concentration, temperature, humidity and light intensity.

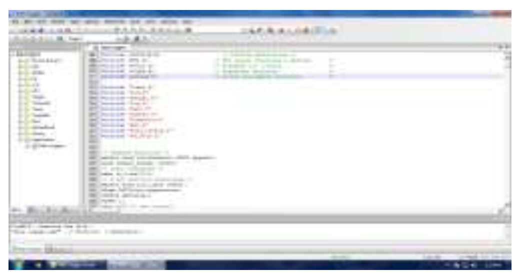

Figure 3.1 Keil µVision4 Software window

The development environment for the system software is Keil with embedded C program language been used. Keil Software window is as shown in Figure 3.1. I have further displyed results using Graghical User Interface (GUI) and PHP programming language is used for making GUI. Figure 3.2 shows Dreamweaver i.e.the php editor window.

Figure 3.2 PHP editor window (Dreamweaver)

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Results

Figure 4.1 and Figure 4.2 shows the system circuit boards for zone 1 and zone 2 respectively along with CO_2, temperature, humidity and light intensity parameters displayed on LCD display.

Figure 4.1 Circuit Board for Zone 1

Figure 4.2 Circuit Board for Zone 2

Figure 4.3 shows the GUI of the system on which CO_2 concentration, Light intensity, temperature and humidity parameters of zone 1 and 2 are displayed.

Figure 4.3 GUI of the System

Conclusion

Based on the sensors of CO_2, temperature, humidity and light intensity, the equipment which is suitable for the geological CO_2 concentration monitoring is developed in order to realize remote real-time acquisition of multivariate information, based on Wireless Sensor Network.

This experiment allows to store 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.

This monitoring system is simple in structure, easy to operate, convenient to carry and provides remote monitoring, automatic storage, real-time display and continuous wireless transmission.

Acknowledgements

This research project would not have been possible without the support of my mentor, guide, teachers and friends. I am thankful to all the individuals who encouraged and helped me directly and indirectly to carry this work. Their continuous knowledgable guidance throughout the course of this study helped me to complete the work up to this stage and hope will continue in further research.

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