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REAL-TIME MONITORINGOF GEOLOGICAL CO_2 STORAGE AND LEAKAGE BASEDON WIRELESS SENSOR NETWORKS

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Abstract: This paper addresses the area of wireless sensor network as it is applicable to carbon dioxide (CO2) concentration monitoring system .A remote real-time carbon dioxide (CO2) concentration monitoring system is developed, based on the technologies of wireless sensor networks, in allusion to the gas leakage monitoring requirement for CO_2 capture and storage. The remote real-time CO2 monitoring system consists of monitoring equipment, a data center server, and the clients. The monitoring equipment is composed of a central processing unit (CPU), air environment sensors array, global system for mobile communication (GSM) receiver module, secure digital memory card (SD) storage module and liquid crystal display (LCD) module. The sensors array of CO_2, temperature, humidity, and light intensity are used to collect data and the GSM receiver module is adopted to collect location and time information. 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.

Keywords: CO_2 capture and storage (CSS), General packet radio service (GPRS), Global system for mobile communication (GSM), Remote online leakage monitoring, Wireless sensor networks (WSN).

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INTRODUCTION

Atmospheric concentrations of the greenhouse gas (GHG) carbon dioxide (CO2) 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 [1]. CO2 Capture and Storage (CCS) is an effective way to realize effective greenhouse gas storage, and to improve oil and gas production[2]. Many countries such as the United States, Japan, and Canada are in search of effective approaches for CO2 storage in either geological formations or ocean. Once CO2 leaks from the storage reservoir, all human beings have made to fight global warming. Therefore, after the geological CO_2 storage, long-term terrain monitoring of the greenhouse gas leakage is needed. For this reason, the development of remote online monitoring system is of great significance to geological CO2 storage and leakage warning.

The remote online CO2 monitoring system consists of monitoring equipment, a data center server, and the clients. The monitoring equipment is composed of a central processing unit (CPU), air environment sensors array, global system for mobile communication (GSM) receiver module, secure digital memory card (SD) storage module and liquid crystal display (LCD). 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 center server. 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 CO2 concentration, temperature, humidity, light intensity, air pressure, wind power, wind direction, etc. The information is then wirelessly transmitted to data center server where they are integrated and analyzed for evaluating of geological CO2 storage and leakage.

II. BACKGROUND

A. monitoring of CCS leakage

Monitoring technologies should ensure for the safety of CCS projects, with respect to both human health and the environment, and will contribute greatly to the development of relevant technical approaches for monitoring and verification[4].Many tools exist for monitoring geological CO2 storage,including well testing and pressure monitoring: tracers and chemical sampling; surface and bore hole seismic; and electromagnetic/geomechanical meters, such as tiltmeters [5].

B.co2monitoring based on wireless sensor networks

WSN is a modern information technology with the integration of sensor technology, automatic control technology, data transmission network. Compared with traditional monitoring techniques, WSN is featured by its low-cost, low power consumption, simple to deploy, without onsite maintenance, etc., and it can achieve a variety of regional low-cost unmanned continuous monitoring. The development of CO2 remote real-time monitoring equipment is the core task of the whole system. The equipment can be deployed in CO2 geological storage monitoring region. It can collect CO2 concentration, temperature, humidity, light intensity and other air environmental information through sensors and then simultaneous data query, analysis and monitoring can be achieved on multiple clients.

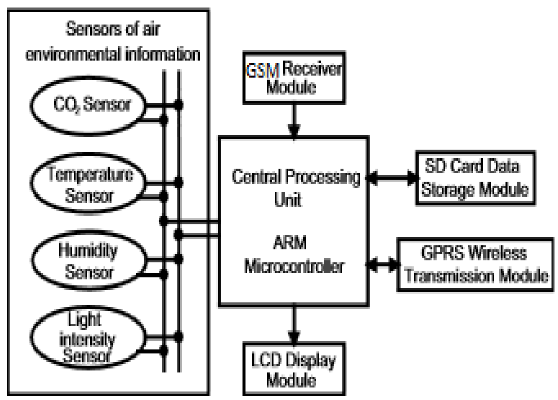


Fig 1. Hardware infrastructure diagram of geological CO2 leakage monitor.

III.HARDWARE INFRASTRUCTURE

Geological CO2 leakage monitoring equipment based on WSN are mobile devices used by humans. The equipment is composed of the air environment sensors array, GSM receiver module, central processing unit, SD card data storage module, LCD display module as shown in Figure 1.

A. microcontroller

The microcontroller (LPC2148 Chip) are based on 32-bit ARM7TDMI-S CPU with real time emulation and embedded trace support ,that combine the microcontroller with embedded high-speed flash memory ranging from 32KB to 512KB.Due to their tiny size and low power consumption,LPC2148 is ideal for applications where miniaturization is a key requirement, such as access control. The LPC2148 is specified as follows.

16-bit/32-bit ARM7TDMI-S microcontroller in tiny LQFP64 package.8 KB to 40KB of on-chip static RAM and 32 KB to 512 of on-chip flash memory.128-bit wide interface/accelerator enables high-speed 60 MHZ operation. In-system Programming/In-application Programming (ISP/IAP)via on chip boot loader software. Single flash sector or full chip erase in 400 ms and programming of 256 B in 1 ms.Embedded RT and Embedded Trace interfaces offer real-time debugging with the on-chip Real Monitor software and high-speed tracing of instruction execution.USB 2.0 Full-speed compliant device controller with 2KB of endpoint RAM. In addition, the LPC2148 provides 8 KB of on-chip RAM accessible to USB by DMA. One or two

(LPC2141/42 vs LPC2144/46/48)10-bit ADCs provide a total of 6/14 analog inputs, with conversion times as low as 2.44 us per channel. Single 10-bit DAC provides veriable analog output (LPC2142/44/46/48 only) .Two 32-bit timers/external events counters(with four capture and four compare channels each),PWM unit(six outputs)and watchdog. Low power Real-Time Clock(RTC)with independent power and 32 KHZ clock input.

B. Sensor specifications and circuit design

Air environmental information acquisition sensors array includes:MG811 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.

MG811 CO2 sensor:MG811 CO2 sensor having a application of air quality control, ferment process control, room temperature CO2 concentration detection.

Specifications:

Parameter name	Technical	Remark
Heating voltage(V_H)	6.0 +-0.1V	AC or DC
Heating resistor(R_H)	30.0+-5%Ω	Room temperature
Heating current($I_{H)}$	@200mA	
Heating power($P_{H)}$	@1200mW	
Heating temperature(T_{ao})	-20-50	
Storage temperature(T_{as})	-20-70	
Output ?E??MF	30-50mV	350-1000ppm CO2

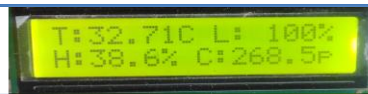
Temperature Sensor: The LM35 series are precision integrated-circuit. Temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant from the output to obtain convenient Centigrade scaling.

The LM35 device does not require any external calibration or trimming to provide accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power2 Applications supplies, or with plus and minus supplies. As the LM35 device draws only 60 µA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package.

Humidity Sensor: SY-HS-220 humidity sensor is used for acquiring humidity sensor data. The measurement range is for 20-95%RH and voltage input of 5V DC. Capacitor frequency conversion is applied so as to reach the connection to the central processing unit.

Light Intensity Sensor: LDR is used as light intensity sensor. Module A/D within the central processing unit is employed to achieve circuit switching and collecting of intensity and power supply voltage data. In LDR the cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems. The readings of sensors are given below.

S.N.	Time	Readings
1	7 am.	
2	9 am.	
3	11 am.	
4	1 pm.	
5	3 pm.	

6	5 pm.	
7	7 pm.	
8	9 pm.	
9	11 pm.	

C. GSM module

With the high sensitivity, good tracking performance, and high position and speed accuracy in the world. This product has standard AT command interface.

D.GPRS remote transmission

The transmission of Real-time collected data is via GPRS wireless transmission module–SIM300A. The module takes Surface Mount Technology (SMT) packaged dual GSM/GPRS as solution, the powerful processor ARM9216EJ-S as the core and the International Mobile Equipment Identity (IMEI) code as a unique identifier. 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

IV. FIRMWARE FLOW

Firmware process includes two main parts, real-time collecting and wireless transmission. First, the sensors array of CO2, temperature, humidity and light intensity are used to collect data; with GSM continuous wireless transmission is conducted.

Specific procedure are as below:

1) Power the equipment on, then is to initialize the entire CO2 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 (1 second intervals) and monitor the operational status of each module real-timely.

2) After the initialization of TCP protocol stack and the success of dial-up of 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.

3) Wait for the data of air environmental sensors and GSM receiver module, including CO_2 concentration, temperature, humidity, light intensity and timing from converters of UART and A/D.

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.

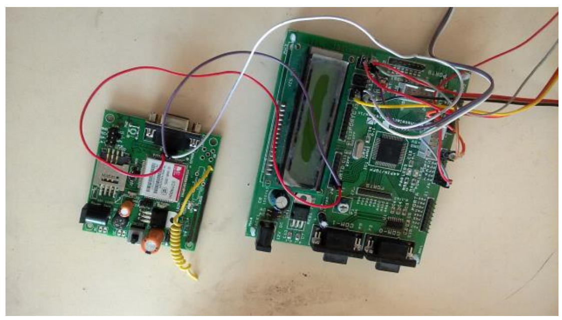


Fig 2 Circuit board of CO_2 remote real-time monitoring equipment.

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 (interval from 1 second to 30 minutes), pack the stored data according to UDP. 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.

V. IMPLEMENTATION

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

The implementation of circuit board is as shown in Figure 1. In fact, the process of CO_2 geological storage can be simplified to be the inverse process of coal bed methane extraction. And the core mechanism is the process of CO_2 adsorption and CH_4 displacement dynamics [2].

So power the equipment on and place it in the experiment of testing the mechanism of action of CO2 adsorption. For example in the experiment of testing the mechanism of action of CO2 adsorption. Table 1 shows the relationship,that is as the temperature increases, the equilibrium water coal sample needs more gas pressure to adsorb the same amount of CO2, which further proves that CO2 adsorption of coal belongs to physical adsorption. It also shows that CO2 adsorption capacity of the coal sample decreases as the temperature increases, which on the one hand is consistent with the conclusion that the change width of coal surface free energy determines the adsorption capacity of coal surface (as the temperature increases, the free energy of coal decreases) and on the other hand coincides with the fact that the CO2 adsorption of coal is exothermic. This equipment has effectively measured CO2 adsorption capacity of equilibrium water coal sample at different temperatures and verified the variation adsorption.

VI. CONCLUSION

Based on the sensors of CO2, temperature, humidity and light intensity, the equipment which is suitable for the surface CO2 concentration monitoring was developed in order to realize remote real-time acquisition of multivariate information in the monitoring of CO2 geological storage. This experiment adopts self-made portable CO2 monitoring equipment, which obtains localization and time service information through GSM, and it can cache 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 CO2 geological storage, leakage, diffusion and migration under complex air environment.

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