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ZIGBEE BASED COAL MINE SAFETY MONITORING AND CONTROL AUTOMATION USING IOT

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ABSTRACT

Recently, the frequent coal mine safety accidents have caused serious casualties and huge economic losses. It is urgent for the global mining industry to increase operational efficiency and improve overall mining safety. This paper proposes a lightweight mashup middleware to achieve remote monitoring and control automation of underground physical sensor devices. First, the cluster tree based on ZigBee Wireless Sensor Network (WSN) is deployed in an underground coal mine, and propose an Open Service Gateway initiative (OSGi)-based uniform devices access framework. Then, propose a uniform message space and data distribution model, and also, a lightweight services mashup approach is implemented. With the help of visualization technology, the graphical user interface of different underground physical sensor devices could be created, which allows the sensors to combine with other resources easily. Besides, four types of coal mine safety monitoring and control automation scenarios are illustrated, and the performance has also been measured and analyzed. It has been proved that our lightweight mashup middleware can reduce the costs efficiently to create coal mine safety monitoring and control automation applications.

Index Terms— Coal mine safety, control automation, mashup, monitoring.

1. INTRODUCTION

UNDERGROUND mines are usually extensive labyrinths, of which the tunnels are generally long and narrow with a few kilometers in length and a few meters in width. Thousands of mining personnel are needed to work under extreme conditions according to the construction requirements, and hundreds of miners die from mining accidents every year [1]–[3]. It is now widely approved that the underground mining operations are of high risk. In view of this, a monitoring and control system needs to be deployed as one important infrastructure in order to ensure the mining safety and coordinate various tasks. However, underground coal mines mainly consist of random passages and branch tunnels, and this disorganized structure makes it very difficult to deploy any networking skeleton. In such a case, the utilization of a wireless sensor network (WSN) and other sensing devices may have special advantages for realizing the automation of underground monitoring and control due to the rapid and flexible deployment. In addition, the multihop transmitting method can well adapt to the tunnel structure and thus provide enough scalability for the construction of a mining system [4]–[7], and it is very suitable to the comprehensive monitoring and control in coal mines, which can effectively compensate the deficiencies of the exiting underground cable monitoring system. Traditionally, coal mine safety monitoring and automation systems were typically designed to meet the requirements of a single monitoring application. The coal mine application has already gone beyond the interconnection of a few large back-end systems, and more and more underground physical devices make the state of objects and their surroundings seamlessly accessible to software systems. As a matter of fact, most works are based on monolithic system architectures, which are brittle and difficult to adapt. A necessary step towards coal mine monitoring and control automation is to provide timely and fine-grained comprehensive alarming information and corresponding disposal process. It is necessary so that it allows the users to identify the levels for coal mine safety alarming, and possibly to adjust monitoring and control rules to ensure the coal mine safety. Furthermore, the user can also control the physical devices remotely via the Web. Currently available coal mine safety monitoring and control systems that focus on the real-time information collection are useful, but cannot meet the user needs fully with a very high usage obstacle and often requires a complex operation definition and configuration for monitoring and control automation applications, and cannot meet the demand for ad-hoc services by the end users. Recently, in the area of comprehensive application integration, some works have introduced the use of "mashup" concepts [8]–[14], also known as user-generated comprehensive applications. However, they mainly focus on mashing up information services and do not address the requirements that come with a physical devices integration. The mashup middleware for coal mine monitoring and control automation needs to rapidly coordinate interaction between the business processes and distributed, multisource sensory devices. Also, the mashup middleware for coal mine monitoring and control automation should change dynamically in a real-time way confronting with continuously and constantly changing for the underground coal mine physical world. With the help of visualization technology, the graphical user interface of different underground physical sensor devices could be created, which allows the sensors to combine with other resources easily.

1.2 RELATED WORKS AND CHALLENGES

The coal mine monitoring and control system can be classified into four categories: database oriented, message oriented, service oriented, and REST-based approaches.

A. Database Oriented Approach Database oriented coal mine safety monitoring system, which is a Structured Query Language (SQL)-based approach [15], [16] to query underground coal mine sensors and other devices in a simple declarative style from the application layer. Thus, this is not the useful and essence of the all collected sensory data, and the device-specific data filtering and feature extraction is essential. Since this method is focused to collect the data from the network, and the data processing technology is needed in the network and the sensor nodes to reduce the amount of data and energy consumption. Hence, a large number of safety monitoring data are generated and processed in the process of coal production. It is also important for safety production in coal mines by analysis of massive of historical safety monitoring data with SQL-based approach to achieve forecast of the safety of coal mines.

B. Message Oriented Approach Message oriented coal mine safety monitoring system, allows underground sensor devices to communicate with each other regardless of the underlying hardware. This approach masks the underlying network interfaces from the application layer, allowing the user to focus on application development, which provides an asynchronous communication mode. In most cases, the coal mine safety monitoring and control applications are event-driven, and have more advantages on the traditional request-response models [17]–[20]. This approach operates as an asynchronous message, and event-driven communication paradigm that supports many-to-many interactions. Furthermore, advanced message oriented approach adopts publish/subscribe patterns, in other words, the published messages could be defined regardless of the number of subscribers, and consumers subscribe their topic of interests in events that they would like to receive. Therefore, a message oriented approach allows for a loosely coupled relation between publishers and subscribers while greatly enhancing scalability and heterogeneity support.

C. Service Oriented Approach Service-oriented architecture (SOA) [21], [22] makes the role of current industrial organizations more strategic as they establish high-level interoperability among the different components across the domain, which also provides the solutions for systems integration where the functionalities are encapsulated as interoperable services. In our early works, [23] and [24] presented a novel approach to integrate wireless sensor network into SOA environments using event-driven SOA technologies to develop a closed-loop coal mine safety alarming disposal process, and BPEL is used to define the coal mine safety alarming disposal process. Real-time coal miner localization and tracking system is also proposed in [25], which includes real-time coal miner dynamic display, 3D Geographic Information System (GIS) user interface, alarming, querying trajectories of all miners, and emergency rescue supporting.

D. Representational State Transfer (REST) Based Approach REST [26]–[32] is a series of guidelines to meet the Web standards presented in a distributed architecture software style. RESTful APIs do not require XML-based Web service protocols (SOAP and WSDL) to support their interfaces. In our early study, a wireless sensor network was combined with the controller area network (CAN) bus technology for the comprehensive and timely monitoring and intelligent early warning in the underground environment, the production data, and the operating status of the equipment, and also design the RESTful API interface for monitoring and control for underground sensor network. All types of parameters were collected and transmitted to the remote monitor center for analysis to provide decisionmaking information for clients. E. Challenges and Main Contributions The acquisition, distribution and integration of large-scale, multisource information, along with the need to appropriately respond to dynamic changes in the physical world in real time, which pose new technological challenges to the provision of coal mine monitoring and control automation services. First, the heterogeneous nature of underground sensory devices require an abstraction from the lower device level layer to a common access layer for other applications, which need an abstraction instance as it has the capability to gather and connect the data from different sensor platforms. Second, with the huge amounts of data to be made available from the edge of the sensor networks or electronic devices to the applications to be available anywhere at any time, how to dispatch, assemble/integrate those sensory data among the distributed, loosely coupled information systems across different business fields or even organizations.

Third, the deployment and provision of the coal mine monitoring and automation application is expected to consider with a new range of user-centric data services, how to meet the demand for ad-hoc services by the end users. Hence, we propose an easy to use, deploy and develop upon device-level coal mine safety monitoring and control automation middleware. Also, the middleware can empower the actual end users to create and adapt individual information centric applications. Hence, the situational monitoring and control applications can be created, which makes underground sensors accessible for the Internet applications and users over the Web.

To summarize, the primary contributions of this paper are as follows.

1) Propose a lightweight mashup architecture for coal mine monitoring and control automation application. From the perspective of the structure, the lightweight mashup architecture is divided into four layers, i.e., the device resource abstraction and access layer, uniform message space and data distribution layer, service mashup layer, and open service interface layer.

2) Propose a uniform devices access framework, which adopts the OSGi technology to create a uniform protocols management to access the different underground physical sensory devices, and also can dynamically manage the physical sensory devices and the corresponding protocols.

3) Propose a uniform message space and real-time data communication model, which adopts the distributed publish subscribe mechanism, and implemented as one or more message brokers, which matches messages sent from publishers with subscriptions and delivers them to the interested parties.

4) Propose a lightweight services mashup approach that supports the on-the-fly integration of different data services mashup level, and apply the REST principles to define an extensible interface to build comprehensive and situational mashup applications.

2. LITERATURE REVIEW

Yongping Wu and Guo Feng implemented helmets that uses the Bluetooth wireless transmission system for the monitoring the working environment. As a standard of unified global short-range wireless communication, Bluetooth technology is to establish a common lowpower, low-cost wireless air interface and controlling software opening system . At the same time, the system uses CAN bus technology maturely, has realized the combination of wired and wireless data transmission system. The main difficulty of this system is that the Bluetooth is short distance wireless technology and use of cabling is difficult. When a natural calamity occurs,the cabling will gets damaged. So the reliability and long life of conventional communication system is poor. Jingjiang Song, Yingli Zhu proposed automatic monitoring system for industrial safety based on wireless sensor network. The sensor groups of the system intensively monitor temperature, humidity in the working area.The parameters measured are sent to wireless communication module by the micro-controller. The collected information is sent to long-distance monitoring centre by cable. So the reliability and long life of conventional communication system is poor. The another problem is that the working condition of industries is very noisy and if the distance of the workers and system is long,workers will not get proper message. Pranjal Hazarika presents implementation of safety helmet for workers. This helmet is equipped with methane and carbon monoxide gas sensor. This sensor sense the gas and the data is transmitted to the control room wirelessly, through a wireless module called Zigbee connected with the helmet. This system does not working conditions of the workers and whether the workers wear the helmet or not.The main difficulty of the system is the usage of zigbee technology.Zigbee technology has small area coverage and hence transferring to the monitoring agent is difficult to transfer data from the working area long distance monitoring unit

Chenge Quing and et al [2] have introduced an intelligent helmet for coal mines based on zigBee wireless communication, the main concept for this project is that identify the humidity level, methane concentration and the temperature in the working area. All these sense data which is transfer towards another ground station wirelessly by using ZigBee. In another station the person who is monitoring station alert the miner by using voice communication. The problem in this project is that miner gets alert by voice communication since miner will be working in a noisy area then he does not gets alert. D. Kock, et al. formulated automation for the coal mining industry in South Africa considering that of productivity, health and safety [3]. They conjointly investigated the coal interface detection (CID); to do this they used two well-known techniques such as vibration analysis and natural gamma radiation. Communication channels- they also considered infrared, power line carrier, radio and optical fibre communication channels for transmission of data in the coal mines. Here it needs to be more thoroughly explored to accomplish the prosperous implementation of computerized systems in underground mines. People commit to take ownership of the operation. Otherwise, the system, despite how fine it operates, is doomed to decline in the long spurt.

3. DESIGN OF HARDWARE

This chapter briefly explains about the Hardware implementation of Lightweight Mashup Middleware for Coal Mine Safety Monitoring and Control Automation . It discuss the circuit diagram of each module in detail.

3.1 LPC2148 (ARM7) MICROCONTROLLER:

The LPC2148 microcontrollers are based on a 32 bit ARM7TDMI-S CPU with real time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory of 512kB. For critical code size applications, the alternative 16-bit Thumb mode reduces the code by more than 30 % with minimal performance penalty.

Due to their tiny size and low power consumption, LPC2148 microcontrollers are ideal for the applications where miniaturization is a key requirement, such as access control and point-of-sale. A blend of serial communications interfaces ranging from a USB 2.0 Full Speed device, multiple UARTS, SPI, SSP to I2Cs and on-chip SRAM of 8 kB up to

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40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical systems.

4.2. BLOCK DIAGRAM OF LPC2148 MICROCONTROLLER:

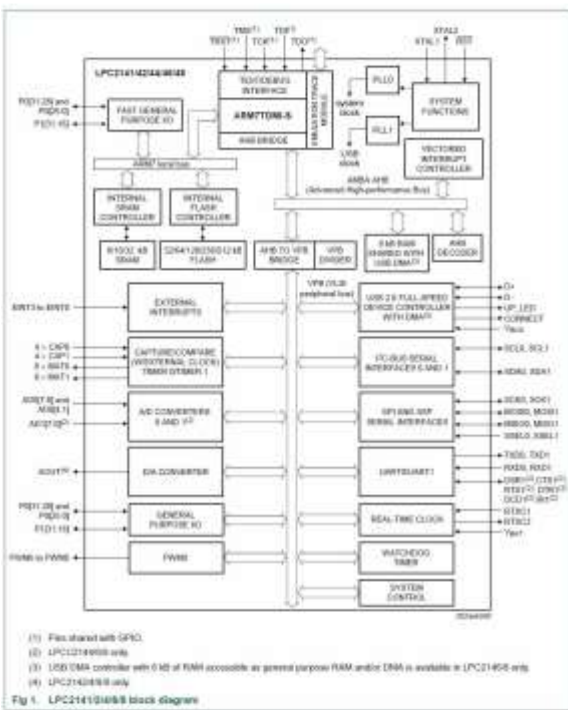

Fig:4.1. Block Diagram Of Lpc2148 Microcontroller

4.9. POWER SUPPLY:

The power supplies are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function. A d.c power supply which maintains the output voltage constant irrespective of a.c mains fluctuations or load variations is known as "Regulated D.C Power Supply".

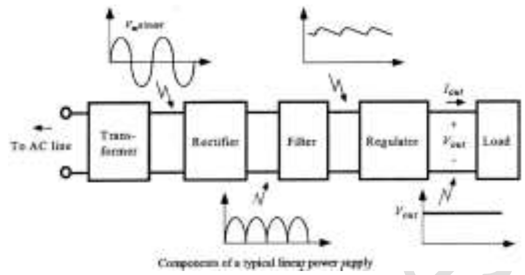

Fig:4.4. Block Diagram of Power Supply

4.13. LCD:

A model described here is for its low price and great possibilities most frequently used in practice. It is based on the HD44780 microcontroller (Hitachi) and can display messages in two lines with 16 characters each. It displays all the alphabets, Greek letters, punctuation marks, mathematical symbols etc. In addition, it is possible to display symbols that user makes up on its own. Automatic shifting message on display (shift left and right), appearance of the pointer, backlight etc. are considered as useful characteristics.

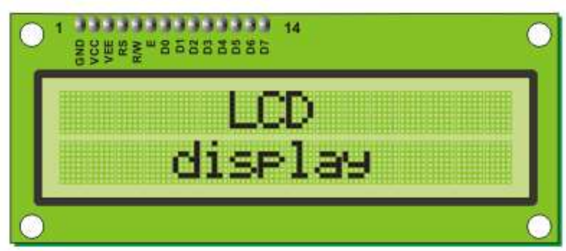

Fig: 4.10. LCD

BUZZER DRIVER CIRCUIT:

Digital systems and microcontroller pins lack sufficient current to drive the circuits like relays, buzzer circuits etc. While these circuits require around 10milli amps to be operated, the microcontroller's pin can provide a maximum of 1-2milli amps current. For this reason, a driver such as

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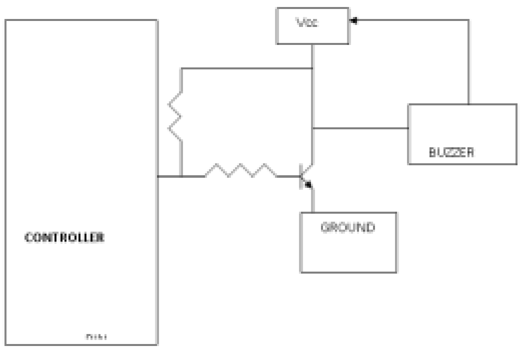
a power transistor is placed in between the microcontroller and the buzzer circuit.



AIR / GAS DETECTOR:

DESCRIPTION

MQ2 flammable gas and smoke sensor detects the concentrations of combustible gas in the air and outputs its reading as an analog voltage. The sensor can measure concentrations of flammable gas of 300 to 10,000 ppm. The sensor can operate at temperatures from -20 to 50°C and consumes less than 150 mA at 5 V.

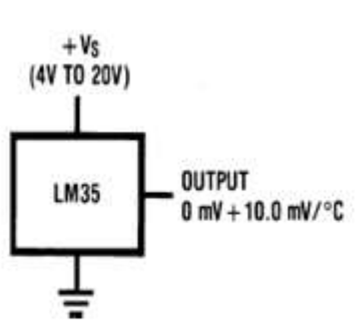
Connecting five volts across the heating (H) pins keeps the sensor hot enough to function correctly. Connecting five volts at either the A or B pins causes the sensor to emit an analog voltage on the other pins. A resistive load between the output pins and ground sets the sensitivity of the detector. Please note that the picture in the datasheet for the top configuration is wrong. Both configurations have the same pin out consistent with the bottom configuration. The resistive load should be calibrated for your particular application using the equations in the datasheet, but a good starting value for the resistor is 20 kΩ.

TEMPERATURE SENSOR (LM35):

in order to monitor the temperature continuously and compare this with the set temperature preprogrammed in the microcontroller, initially this temperature value has to be read and fed to the microcontroller. This temperature value has to be sensed. Thus a sensor has to be used and the sensor used in this project is LM35. It converts temperature value into electrical signals.

LM35 series sensors are precision integrated-circuit temperature sensors whose output voltage is linearly proportional to the Celsius temperature. The LM35 requires no external calibration since it is internally calibrated. . The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range.

The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air.



PROXIMITY SENSOR

A proximity sensor can detect metal targets approaching the sensor, without physical contact with the target. Proximity sensors are roughly classified into the following three types according to the operating principle: the high-frequency oscillation type using electromagnetic induction, the magnetic type using a magnet, and the capacitance type using the change of capacitance.

A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact. The object being sensed is often referred to as the proximity sensor's target. Different proximity sensor targets demand different sensors. For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target.

ZIGBEE:

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios.The technology defined by the ZigBee specification is intended to be simpler and less expensive than other wireless personal area networks (WPANs), such as Bluetooth or Wi-Fi.

This standard specifies operation in the unlicensed 2.4 GHz (worldwide), 915 MHz (Americas and Australia) and 868 MHz (Europe) ISM bands. Sixteen channels are allocated in the 2.4 GHz band, with each channel spaced 5 MHz apart, though using only 2 MHz of bandwidth. The radios use direct-sequence spread spectrum coding, which is managed by the digital stream into the modulator. Binary phase-shift keying (BPSK) is used in the 868 and 915 MHz bands, and offset quadrature phase-shift keying (OQPSK) that transmits four bits per symbol is used in the 2.4 GHz band.

Its low power consumption limits transmission distances to 10–100 meters line-of-sight, depending on power output and environmental characteristics. Outdoors with line-of-sight, range may be up to 1500 m depending on power output and environmental characteristics.

ZigBee devices can transmit data over long distances by passing data through a mesh network of intermediate devices to reach more distant ones. ZigBee is typically used in low data rate applications that require long battery life and secure networking (ZigBee networks are secured by 128 bit symmetric encryption keys.) ZigBee has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device

6. PROJECT DESCRIPTION

This chapter deals with working and circuits of “Lightweight Mashup Middleware for Coal Mine Safety Monitoring and Control Automation”. It can be simply understood by its block diagram &circuit diagram.

6.1 BLOCK DIAGRAM:

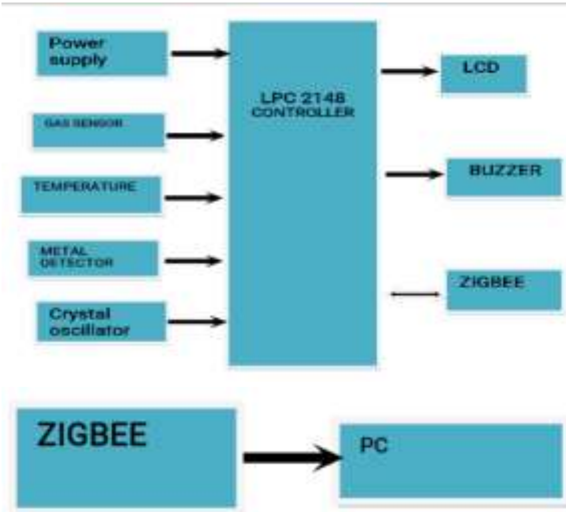


Fig 6.1 block diagram

6.4. WORKING

To explain the whole system, the system is divided in two sections. First section is the transmitter section and another is the receiver or monitoring section as show in above figure 1 and figure 2. Transmitter section consists of helmet removal sensor, air/GAS quality sensor, Metal and TEMP sensor, microcontroller and Zigbee module. All the sensors are connected to the microcontroller. The helmet removal sensor is used to detect whether the safety helmet is remove or not by the miner. Air/GAS quality sensor is used to detect air/GAS pollution in miners working area. In mining industry air is polluted because of mining operation such as drilling, blasting etc. And the collision sensor is used to detect whether any object is fall on the miner head. All these sensors data is process by the microcontroller, if any dangerous event is occurred. Microcontroller processes receive signal and gives towards LCD display and buzzer

In receiver section, when PC receiver receives alert signal then this signal is gives to the PC . Microcontroller processes receive signal and gives towards LCD display and buzzer

CONCLUSION

This builds a lightweight mashup middleware for coal mine safety remote monitoring and control visualization. Focus on the design and implementation for underground ZigBee wireless sensor network deployment, uniform devices access framework, distributed data distribution service, event-driven mashup service execution engine, and RESTful-based open API interface. The main novelty of this study is to develop a lightweight mashup middleware for coal mine monitoring and control middleware which is easy to use and install for engineers. Since most of the application is Web-based, any personal computer and a web browser can connect the Internet and enter the Web page to use the application, and which can reduce the costs of coal mine safety monitoring and control automation. Therefore, it is expected to be a main contribution to coal mines for better and safer working environments. Several issues remain to be addressed further. First, as the expansion of existing coal mine safety monitoring and control system, visualization technology can further improve the visibility of underground sensor objects, such as 3D technology, which provides significant support for decision making and real-time control in underground mines. Second, it is essential to optimize the real-time data distribution service and data congest scheduling strategy with different QoS constraints for a large-scale coal mine deployment. These works are currently in progress in our lab.

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