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Research on Key Technologies of Coal Mine Groundwater Perception Based on IoT

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Abstract This paper reviewed technical status of groundwater monitoring and information processing. A new framework was proposed for the perception of coal mine groundwater based on IoT. On the sensing layer, NSS could be used as collection nodes and new sensing mechanisms should be applied to make novel sensors. On the transmission layer, different networks were integrated to realizelocal and remote communication. On the application layer, based on the powerful processing performances of cloud computing, six types of thematic information systems were designed for solving coal mine hydrogeological problems. In future, the perception system will provide supports for scientific decision-making and quick response to groundwater events.
Keywords internet of things, coal mine, groundwater, wireless sensors network, water-inrush

Introduction

Long-term coal mining activity causes serious damages on groundwater environment. Water-inrush, one of the hazards in coal mines, often results in casualties and property losses.. In coal mines, as an effective and immediate method to acquire information of hydraulic, temperature and chemical fields, groundwater monitoring serves for risk analysis of water inrush. China started a national project of groundwater monitoring in October, 2011. And over the next 3 years, 20401 monitoring sites will be constructed which covers 3.5 million square kilometers(Lin et al. 2012).

Internet of Things (IoT) extends Internet and communication network by using intelligent sensors to identify and measure physical objects, using multi-networks to transfer data, and using cloud computing to discover knowledge in data, which are archived to the perception of our physical world for control and management(Zhu et al. 2011). Environment monitoring is the earliest field of IoT application. However, up to now, IoT has not been applied deeply in the groundwater field.

This paper reviewed the technical status of groundwater monitoring and information processing. According to the special environment of coal mines and the three-tier architecture of IoT, a new framework was proposed for perceiving coal mine groundwater. Key techniques of the framework were discussed including smart sensor, distributed monitoring network on surface and underground, data mining and thematic application system based on cloud computing.

Overview of groundwater monitoring and data processing

Groundwater monitoring indexes usually contain water table, quality, flow rate and temperature. In principle, water table sensors could be divided into two types containing pressure and floats. Water quality sensors commonly use electrodes which can continuously work underwater. Although there were automatic extraction test equipments, the high cost limited the application of water quality sensors(Jørgensen 2009). Meanwhile, some new sensors have been used in groundwater. For instance, optical fiber sensor has been used to measure water temperature(Li et al. 2012).

Statistics showed 58% of areas in China and 12 countries in America and Europe have collected water table data automatically, but only the U.S. has realized automatic acquisition of water quality data. Automatic monitoring contains offline and online modes. Offline mode means that groundwater regime data are stored in sensors and people use PDA or other equipments to connect sensors by data cable or wireless communication and download data to equipments. Online mode means that data are directly sent to monitoring centers at specified time intervals. As many monitoring sites are scattered and located in wild areas, GSM is widely used as the data transmission network. In fact, the earlier information system mainly focused on records digitalized for query and statistics. GIS was later applied for visualization and analysis of groundwater data(Zhou et al. 2012). Nowadays, WebGIS has become as the popular platform for developing a groundwater monitoring system.

In coal mines, many sites are located in lanes underground like draining holes, ditches and observing holes. Underground data transmission mainly uses wired communications through substations which connect industrial Ethernet. In China, the hydrological monitoring systems have the disadvantages of low transfer efficiency, insufficient power supply in long distance and weak control of substations. Groundwater monitoring data are not stored in a unified database and underground monitoring data are isolated with surface data. The data could be accessed only by local clients and were not deeply mined and analyzed.

Framework of groundwater perception system in coal mines

According to three-tier architecture of IoT, groundwater perception system of coal mine is comprised of sensing, network and application layers. On the sensing layer, distributed monitoring and smart sensors were used to acquire water regime information. On the network layer, multiple networks were integrated to transfer data in different environments. On the application layer, resources are virtualized as shared-by-all pools based on cloud computing. The framework is shown as Fig.1.

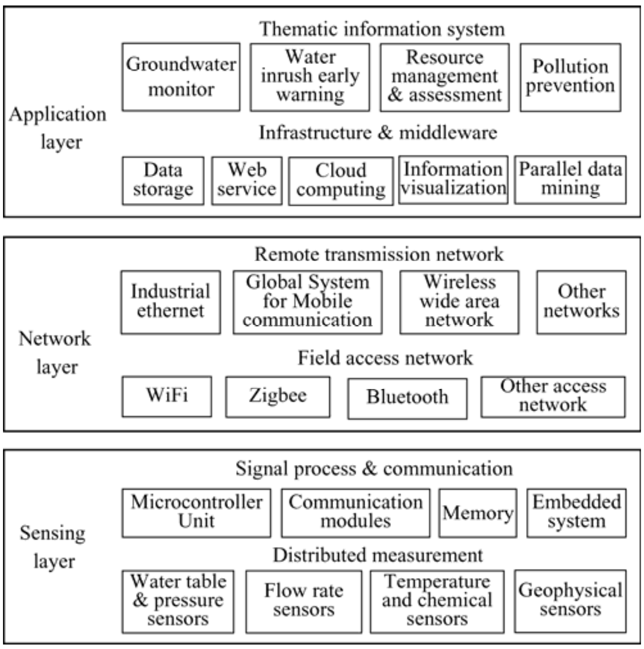

***Fig. 1** Framework of groundwater perception system in coal mines*

Distributed groundwater monitoring system in coal mines

Distributed monitoring system gathers sensors located at different places by network to acquire environment information from large geographic areas(Randrianarivelo etsl. 2012).It is composed by smart sensors and transmission network.

In monitoring sites of coal mines,the Networked Smart Sensor (NSS) would be used as sensing nodes.NSS contains smart transducer interface module (STIM), network capable application processor (NCAP) and controller. STIM connects water table, temperature, chemical and other type sensors. NCAP encapsulated CAN, Ethernet, WSN and other protocols. NSS could be installed anywhere and form a distributed monitoring network with route and sink nodes. Sink nodes are responsible for communication with backbone networks.

For data transmission,the industrial Ethernet would be used as the backbone network to collect data underground. Within the area covered by Ethernet, sensing nodes could be connected to switch with wired or wireless modes. What's more, sensing nodes out of the area can deliver data to route and sink nodes by wireless multi-hop communication. Field bus can also be applied in those areas by laying single cables. GSM is also used to transfer data remotely from surface sites to the centre, while WSN is used to transfer data from sensing nodes to route or sink nodes.

Furthermore, distributed monitoring system could work in three modes, including centralized control, autonomous and offline operationwhich could satisfygroundwater monitoring needs. Daily observation could use autonomous operation which configures sites to send data automatically on time. Centralized control could send order to sensing nodes for measuring at the same time, which is suitable for simultaneous measurement. Test observation requires higher sampling frequency. Offline operation allows sensing nodes to store records during tests and send to the centre after tests.

Thematic information systems based on cloud computing

Cloud computing centralizes and virtualizes infrastructures, platforms and software since many shared-resources pools provide different services to users through public, private and hybrid network(Kropf et al. 2014).It can both dynamically allocate resources to users according to their demands and avail us of cost and energy of servers and software. Thematic information systems developed by cloud computing could optimize groundwater data analysis performance.

For coal mines, different types and functions of thematic information systems are listed in table1. Groundwater monitoring information system provides interfaces of data visualization in 2D and 3D, while groundwater information pushing system delivers data to various terminals such as mobile phones and tablet PC. The remote control information system is used for configuring sensors to complete different tasks. Management and assessment information systems have been developed for groundwater optimal allocation, quality, pollution risk and environment assessment. Identification and location systems are typically applied to distinguish water sources flowing into coal mines and analyze hydraulic relationship among aquifers. Forecasting and early warning systems contained inflow yield prediction, water inrush and pollution warning.

Conclusion

A new framework of groundwater perception system has been proposed based on IoT. On the sensing layer, NSS can be used as collection nodes and new sensing mechanisms should be applied to make novel sensors. On the transmission layer, WSN, industrial Ethernet and GSM have been integrated to filed sensors networking and remote communication. On the application layer, cloud computing provides a new solution for large data sets storage and analysis. Besides, six types of thematic information systems have been designed for coal mine hydrogeological problems. Therefore, researchers from different subjects should cooperate to realize the framework. In future, the perception system will provide supports for scientific decision-making and quick response to groundwater events.

Table 1 *Types and functions of thematic information systems*

System Types	Functions
Monitoring	Data visualization in 2D and 3D
Information Pushing	Delivering information to intelligent terminals
Remote Control	Sensors remote configuration
Management and Assessment	Water flow optimal management Quality assessment Pollution risk assessment
Identification and Location	Headwater identification Hydraulic connection analysis
Forecasting and Early Warning	Inflow yield prediction Water inrush early warning Pollution warning

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