Research on IoT-based water environment benchmark data acquisition management

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Abstract. Over the past more than 30 years of reform and opening up, China’s economy has developed at a full speed. However, this rapid growth is under restrictions of resource exhaustion and environmental pollution. Green sustainable development has become a common goal of all humans. As part of environmental resources, water resources are faced with such problems as pollution and shortage, thus hindering sustainable development. The top priority in water resources protection and research is to manage the basic data on water resources, and determine what is the footstone and scientific foundation of water environment management. By studying the aquatic organisms in the Yangtze River Basin, the Yellow River Basin, the Liaohe River Basin and the 5 lake areas, this paper puts forward an IoT-based water environment benchmark data management platform which can transform parameters measured to electric signals by way of chemical probe identification, and then send the benchmark test data of the water environment to node servers. The management platform will provide data and theoretical support for environmental chemistry, toxicology, ecology, etc., promote researches on environmental sciences, lay a solid foundation for comprehensive and systematic research on China’s regional environment characteristics, biotoxicity effects and environment criteria, and provide objective data for compiling standards of the water environment benchmark data.

1. Introduction
Water environment benchmark is not only the scientific foundation for national water environment management and pollution control, but also the scientific basis for the formulation of water environment standards. The benchmark refers to the maximum acceptable dose or limit that the pollutants or other harmful factors in the water environment do not produce adverse or harmful impacts to the specifically protected objects and is mainly obtained through scientific judgment according to the data of exposure of specific objects to the environmental media and the dose-effect relationship data with environment factors. The water environment benchmark can be divided into the benchmark to protect aquatic organisms and their functions, the benchmark to protect human health, nutrient benchmark, and sediments quality benchmark, biological benchmark, etc. The basic data needed for different types of water environment benchmark research is not entirely the same.

Aquatic species data of key river basins, basic physical and chemical data of typical waterbody, content distribution of heavy metal pollutants of typical waterbody, and content distribution of new pollutants of typical waterbody is the basic data that shall be researched and acquired in China; the data about toxicity of heavy metals to aquatic organisms in typical waterbody, the data about toxicity of new pollutants to aquatic organisms in typical waterbody and so on can be analyzed by acquiring such data. However, such data is always acquired from rivers and lakes in China and considerable manpower and
material resources are required for each time of sampling; furthermore, manual sampling cannot collect and observe the data of sample water environment in a real-time manner. The data acquired by samples always has large difference therefore it cannot provide services to the water environment benchmark research of China and seriously hinders the development of environmental chemistry, biology, toxicology, ecology, risk assessment and other shared platforms and scientific research.

Based on the ZigBee, GPRS and other advanced technologies in the Internet of Things (IoT), the paper designs a water environment benchmark acquisition terminal to realize the real-time sampling and data acquisition in key river basins and lakes in China. Utilization of the IoT to build a water environment benchmark data acquisition and analysis platform suitable to the conditions of China is a major scientific and technological need of China, also is an inevitable choice to improve the scientificness of water environment benchmark of China, and plays a very important role in the water environment benchmark research platform and environment protection research of China. The creative contributions of the paper mainly involve two points: (1) Application of IoT technologies in acquisition of basic data of water environment. And realization of dynamic and on-demand acquisition of basic data of water environment through IoT technologies. (2) Design of ARM core board-based water environment data exchange and control panel.

The first part introduces the background and innovation points of the paper; the second part describes the water environment benchmark data acquisition state at home and aboard and the application state of the IoT in the water environment management; the third part introduces the design of IoT-based water environment data acquisition terminal and CNC panel; and the last part is the summary of the paper.

2. Literature Review

During the research of China’s environment benchmark, the basic data is generally acquired by summarizing foreign basic data (for example, ECOTOX database of the US) and the literature data. The investigation and compilation of China’s water environment benchmark-related data is still at the early stage; there is lack of corresponding national standards and technical specifications during the data compilation and research; meanwhile, it is time consuming for investigation, sorting, editing and local acquisition of data; and there is seldom work done relating to this; such factors become the bottleneck of China’s water quality benchmark development.

In the paper, the water environment benchmark data mainly include the aquatic species data of key river basins, basic physical and chemical data of typical waterbody, content distribution of heavy metal pollutants of typical waterbody, and content distribution of new pollutants of typical waterbody. Carvalho et al. pointed out that the establishment of the water environment reference library is the priority of water environmental studies [1]. Zhu Huakang et al. put forward the idea of establishing water environmental management in United States Delaware River Basin Management Research in late 19th century[2]; Chen Simo et al. presented the impact of pollution on the water environment around water pollution prevention and control in some rivers and river Basins abroad [3]; Tang Zhengsheng et al. studied the characteristics of the Tennessee Valley Management [4]; Zhang Qingfeng studied watershed management, making a comprehensive analysis of the water environment management[5]. Wu Fengchang et al. [6] and Meng Wei et al. [7] analyzed the importance of water quality benchmarks from the perspective of the protection of aquatic ecosystems. USEPA established an aquatic organisms benchmark library from chemical and physical point of view [8-9], and Zeng Weihua studied and compared domestic and international water management systems [10].

3. Design of IoT-based Water Environment Data Acquisition Platform

3.1. Overall Design of Data Acquisition Platform

It is to set up a set of water environment benchmark data acquisition platform for real-time and dynamic acquisition of aquatic species data of key river basins, basic physical and chemical data of typical waterbody, content distribution of heavy metal pollutants of typical waterbody, and content distribution of new pollutants of typical waterbody according to current development state of China's water
environment, under the guidance of advanced technologies and ideas, and by full use of IoT technology, ZigBee and GPRS. And it to realize real-time data monitoring on the water environment system, enhance and improve the management capability to the water environment benchmark data, and provide strong technical support for the water environment development and governance by the government.

The IoT-based Water Environment Data Acquisition Platform is mainly composed of three major parts: terminal acquisition device (namely hardware), embedded software design and application system design; details are shown in Fig. 1.

Terminal acquisition device (namely hardware) mainly involves the design of terminal data acquisition nodes, design of terminal control nodes and design of gateway device circuit principles. The embedded software design involves the design of embedded program of wireless terminal acquisition system, embedded program of gateway device, etc. The application systems mainly include the sensor sub-system, data acquisition sub-system, information processing sub-system, etc.

In the water environment benchmark data, waterbody’s pH, hardness, temperature, and dissolved organic matters, nitrogen and phosphorus contents, eutrophication condition, main characteristic pollutants and so on are critical to the environment; therefore, real-time and dynamic monitoring and timely sampling to related data of water environment can acquire objective and real water environment data.

The water environment benchmark data adopts the IoT (combination of bus type and GPRS) design idea.

At the monitoring sites in river basins or lakes, acquisition terminal nodes are connected with the host computer via CAN or RS485 or terminal nodes are connected via CAN or RS485; nodes are connected with the Internet through wire or wireless mode after data gathering. Each terminal node is connected with the background server via GPRS module and users can access to relevant information at any place and any time as long as there are computers or telephones connecting to the Internet.
Each terminal node is connected with the background server via GPRS module and users can access to relevant information at any place and any time as long as there are computers or telephones connecting to the Internet. The acquisition terminal adopts the ZigBee technology and realizes the interconnection of devices; terminals are connected with the Internet via wire or wireless mode; after uploaded to the background data server, the data is transmitted to the user via WEB mode.

Advantages and disadvantage of the IoT-based design idea:
Advantages:
- No wiring requirement, reduced system installation costs.
- Low costs, low power consumption, small volume and easy maintenance.
- Excellent data sharing, favorable to eliminate Information Island.
- Excellent compatibility and expandability.
Disadvantage: there is higher requirement on the stability of gateway device; the system may crash once the gateway device fails.

3.2. Design of IoT Terminal
The data acquisition nodes of water environment benchmark data terminal regularly or instantly acquire the data of waterbody’s pH, hardness, temperature, and dissolved organic matters, nitrogen and phosphorus contents, eutrophication condition, main characteristic pollutants in the river basins or lakes and upload the data to the gateway device. Such nodes also can receive the instructions sent by the gateway device and instantly monitor some values.

Terminal data acquisition nodes adopt a design idea of reusability and modularization and the system has better compatibility, upgradability and expandability. Modules mainly include power supply module, wireless communication module, and sensor interface module. Each sensor is connected with the node motherboard via aviation plug with excellent plugging nature, reliability, and water-proof and moisture-proof functions. The power supply module supports the power supply system of battery and solar energy system, and it is also compatible with the mains; the system configuration is flexible and meets the needs of different levels of water environment data acquisition.
1) Wireless communication module
FR chip CC2430 is used to acquire data; the hardware design CC2430 of node is a real system-on-chip (SOC) COMS solution which can improve performance and meet the requirements of ZigBee-based 2.4GHz ISM wave band application on low costs and low power consumption. It involves 1 high-performance 2.4GHz Direct Sequence Spread Spectrum (DSSS) RF transceiver core and 1 industrial-grade compact and efficient control 8051; ZigBee RF front-end, memory and microcontroller are integrated on single chip. It has 2/64/128kB programmable flash memory and 8kb RAM and also includes ADC, timer, 32 MHz crystal sleep mode timer, power on reset circuit, brown out detection circuit and 21 programmable I/O pins; it can realize the miniaturization of nodes. CC2430 wireless single chip computer has very low power consumption; during standby, the current consumption is only 0.2μA; it operates under 32 MHz crystal clock and the current consumption is less than 1μA. The service life of small battery used can be up to 10 years.

2) Power supply module
The power supply must be treated because the operating voltage of CC2430 RF module is 3-3.3V, the voltage required by each kind of sensor is 5V or 3.3V and the needs of power supply by all places are different. In order to provide a stable operating voltage to the terminal module, SPX5205 linear power conversion chip, LY9803 synchronous boost chip, CN3063 solar charge management chip, and LY1036 DC/CD boost converter are adopted to treat the power supply of each part.

Terminal control nodes are used to control the related mechanical and electrical equipment; users can remotely control the data acquisition equipment according to the needs, such as water quality detector, and water collector.

A design idea of reusability and modularization is adopted and the system has better compatibility, upgradability and expandability. Users can flexibly configure according to needs. It is mainly composed
of wireless communication module, power supply module, control device and controlled device. The control node is powered by the mains; the block diagram of architecture is shown in Fig. 6.

![Fig. 6 Architecture of Terminal Control Nodes](image)

3.3 Circuit Diagram Design of Gateway Device
The gateway device is the bridge for communication between terminal node and PC programs and is responsible for the conversion of information formats and upload and download of data. The gateway device displays the values acquired by terminal nodes and the state information of controlled device to users in a friendly and intuitive manner; when some values or devices are in abnormal states, the gateway device can adopt diversified means to send warning information in a timely manner and inform relevant personnel about the abnormal information.

The gateway device adopts a design idea of modularization and reusability and the system has better upgradability and compatibility. It is mainly composed of CC2430 module, power supply module, ARM core board, and touch screen display module, GPRS module, acoustic-optic alarm, and printing device (option). The architecture of gateway device is shown in Fig. 7.

![Fig. 7 Architecture of Gateway Device](image)

4. Conclusion
The water environment benchmark research is the scientific basis for a country to formulate water quality standards, evaluate water quality, determine the environment capacity, control total amount, manage risks and carry out other environment protection work. Therefore, the research on the water environment benchmark is an urgent important task of scientific research of entire environment protection in China. In recent years, USA, Japan, Canada, Australia and other countries have included the benchmark research into their national security strategies. National water environment benchmark research becomes a major scientific need of the environment management of every country in the world.
The next step is to design and develop an embedded system and application software based on the acquisition terminal. Through such two parts, some parameters at the wireless terminal can be remotely configured and the water environment data can be sent to the server for storage and analysis via the wireless ad hoc network at the terminal. And a perfect water environment benchmark data analysis platform will be constructed.

Based on IoT technologies, the paper describes in detail the acquisition terminal of water environment benchmark data. The acquisition terminal designed by combining ZigBee and GPRS technologies can acquire the data information required by the water environment benchmark analysis in a real-time and intelligent manner, and can provide comprehensive and effective data support for the national water environment benchmark research and environment management and protection in China.

Acknowledgements
The paper is funded by National Natural Science Foundation Programs of China (NSFC) (71271012), dean fund (542016Y-4661-2016) as well as key and special project of MWR (Chinese Ministry of Water Resources) (2016YFC0403004).

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