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鳥取県環境学術研究等振興事業費補助金研究実績報告書（環境創造部門）

研究期間（３年目/３年間）

<table>
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<tr><td>研究課題名</td><td colspan="3">湖沼の水質モニタリング用MEMSセンサとユビキタスセンサネットワークシステムの開発</td></tr>
<tr><td>研究結果</td><td colspan="3">・樹脂を構造体と接着剤とする新しいpHセンサを試作できた。動作確認を行った結果、改善が必要であることがわかった。
・開発中のpHセンサと集積化が可能なBODセンサとして湖沼に存在する電流生成菌を用いる方法を提案し、有機物量と電流生成量の関係を導くため基礎実験を行った。その結果、有機物量と電流生成菌の電流生成量とは相関があることがわかった。
・pHセンサ、クロロフィルセンサ、濁度センサの集積化に向けたマイクロ流体デバイスの構造設計を行った。
・センサノードの電源として発電デバイスを検討した結果、温度差を利用する発電方式が最も適していることがわかった。また高温部と低温部との距離がメータオーダーで離れている状況での温度差発電には新しい材料の検討が必要であることが明らかになった。
・無線センサネットワークのノード筐体の改善を行い、再設計をし、システムの実現可能性を見極めるため試作を行った。</td></tr>
<tr><td>研究成果</td><td colspan="3">・樹脂を構造体と接着剤とする新しいpHセンサの作製技術が確立できた。樹脂の硬化条件の最適化は必要であるが、マイクロ流体デバイスとしての動作確認はできた。
・設計・作製した無線センサネットワークシステムのノードは湖沼水でも問題なく動作できることが確認でき（システムとしての動作確認と筐体の水耐性に対する確認）、応用可能性が実証できた。
・湖沼に存在する電流生成菌を用いる新しいBODセンサは有効であることが検証できた。
・pHセンサ、クロロフィルセンサ、濁度センサなどを集積化したマイクロ流体デバイスの構造設計ができた。
・温度差を利用する新しい発電素子の提案ができた。
・無線センサネットワークシステムに関する研究成果の一部を国際会議で発表した。また濁度センサとクロロフィルセンサに関する研究成果を学術雑誌と国際会議で発表した。</td></tr>
<tr><td>次年度研究計画</td><td colspan="3">・本年度は最終年である。</td></tr>
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注１）表題には、環境部門、地域部門、北東アジア学術交流部門のいずれかを記載すること。
　２）「研究期間（　　年目/　　年間））」及び「次年度研究計画」は、環境部門のみ記載すること。
　３）研究者の知的財産権などに関する内容等で、非公開としたい部分は、罫線で囲うなど明確にし、その理由を記すこと。
　４）研究実績のサマリーを併せて提出すること。

A Wireless Sensor Network Platform for Water Quality Monitoring

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***Abstract*—We have developing a wireless sensor network system for water quality monitoring. It consists of various sensors for the sensing of physical and chemical properties of water, and systems including wireless communication module, power module and interface between sensors and wireless communication module. In this paper, we report the development results of a novel wireless sensor network platform for water quality monitoring, which is proposed for rapid prototyping of wireless sensor network system. In order to demonstrate our novel wireless sensor network platform, we fabricated the platform as a sensor node and field-tested it with several sensors in the lake. As a result, we could confirm that our proposed novel platform was operated successfully in real environment.**

Keywords*—*wireless sensor network; platform; sensor node; water quality monitoring; protocol; field-test

I. INTRODUCTION

The natural water resources monitoring is important issue especially from the viewpoint of environment preservation and human health care. As a water monitoring method, a wireless sensor network (WSN) system is considered as a proper and effective one, because we can obtain the real time and over the wide area monitoring data through the WSN system. Currently, the main components of WSN system such as sensors and wireless communication modules are small and cheap, by which tremendous sensor nodes can be easily implemented. It makes precise and accurate water quality monitoring, and also a step towards the trillion sensor era.

We have developing a WSN system to monitor the natural water resources quality. It consists of sensors for the sensing of physical and chemical properties of water, and systems including wireless communication module, power module and interface between sensors and wireless communication module. Until now, as sensors for water quality monitoring, we have developed the pH sensor [1] and the turbidity sensor [2]. Other sensors such as chlorophyll sensor, BOD sensor and temperature sensor are under developing at present. Moreover, we have also developed a novel WSN platform to achieve complete WSN system for water quality monitoring, which is originally proposed for rapid prototyping of a WSN system. In this paper, we report the development results of our proposed WSN platform including its design, fabrication and field-test results.

II. DESIGN OF WSN PLATFORM

Sensors under development for a new application such as water quality monitoring systems are immature, not optimized for use and frequently replaced for test, while the sensors are utilized in the generic devices such as smartphones are well optimized. Therefore, it is necessary to develop a new WSN platform flexible to arbitrary various sensors for water quality monitoring. In the development of such flexible WSN platform integrating various sensors, the most important issue is the communication protocol. There are many wireless communication protocols for the sensor node [3]. Currently, as communication protocols, GPIB and USB protocols are popular and often used in many research fields. However, GPIB is not suitable for small devices in terms of size although it is robust. Moreover, USB is complicated and not easy to handle. Here, we propose a simple internal protocol used within a sensor node for the flexible WSN platform. Details are described as follows.

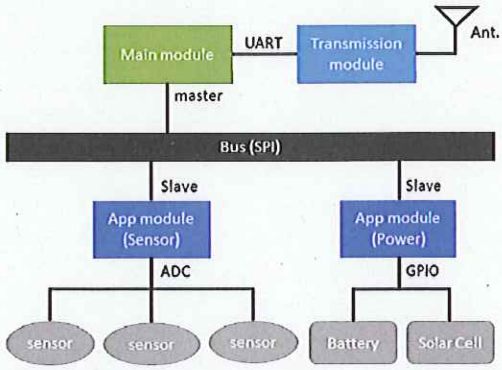

Fig. 1. Block diagram of system bus of our wireless sensor network platform. Main module is connected to the SPI bus as a master and the application modules are also connected to the SPI as a slave. Communication module and master are connected by an UART. An antenna is attached to the communication module. Application modules have sensors and power devices .

A. Bus

The bus structure of the WSN platform is shown in Fig. 1. The system consists of master, slave and communication modules. The main module (master module) manages other modules. Application modules have their own functions, which are connected to the main module through the serial peripheral interface (SPI). The main module behaves as an SPI master. By using the SPI, we don't need complicated address setting, which is easily available because it is implemented in most of

PinNo.	Description
1	MISO
2	Vcc
3	SCK
4	MOSI
5	SS
6	GND

Fig. 2. Pin assignment of the connector. The top view of the connector mounted on the board is shown in the left. The pin assignment is based on the ICSP, however, the RESET pin has been assigned to the SS pin in our design.

the microcontrollers. The main module is connected to the transmission module for the communication as well through the universal asynchronous receiver transmitter (UART). Moreover, an antenna is attached to the transmission module. Application modules in our WSN platform consist of sensors for water quality monitoring and power devices for power sources such as battery and solar cell. The connection was implemented based on in-circuit serial programming (ICSP), and the box pin header (6-pin) was used as the connector. The pin assignment is summarized in Fig. 2. The difference between usual ICSP and used in ours is that slave select (SS) pin is assigned instead of RESET pin. As a result, by the switching of connection, it can be shared with the programming terminal to the microcomputer, which causes the reduction of the system size and the manufacturing cost.

B. Power

The power supply system is illustrated in Fig. 3. Power management is performed by the power management module which is one of the application modules. It generates 3.3 V through the DC/DC converter (TPS63060) for the Li-ion 1 cell battery, which supplies power to each circuit. Power management module has two 3.3 V power supply systems. One is the system for supplying power constantly, and another one is the system that can be operated ON/OFF by the instruction of the master module. Furthermore, the power can be supplied directly from the Li-ion cell battery, and the master module is capable of controlling it as well. Thereby, for the modules which do not need to be supplied constant power such as sensors module, even if it has not taken measures insufficiently to reduce power consumption, it is possible to reduce the adverse effect on the battery. Moreover, the power management module is also connected the solar panel to charge the Li-ion cell battery during the day. In order to improve the charging efficiency, the charging circuit LT3652 was used, which has the maximum power point tracking (MPPT) function. In the power module, the voltage monitoring system and the safety circuit are also implemented.

C. Transmission

Communication with the outside of the sensor nodes is performed with the Internet connection using the 3G mobile network. This makes it possible to observe the water quality monitoring results at any location where the Internet is available. We adopted the post method of https in data transmission to achieve the certification of encryption and server. However, it takes large power consumption when the

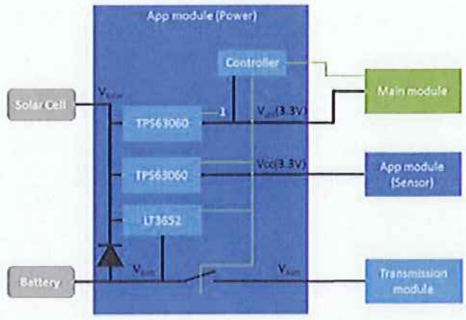

Fig. 3. Block diagram of the power supply system, which is simplified one to supply power to sensor node. Bold line and green colored line represent the power line and the control line, respectively. In the module, the voltage monitoring system and the safety circuit are implemented.

data are transmitted through the 3G network. If the power supply is limited, then it is necessary to perform the intermittent operation to save power consumption. In our prototyped WSN platform, the communication module is being powered directly from the Li-ion cell battery, which is performed by the master controller.

III. Fabrication of WSN Platform

In order to demonstrate our designed WSN platform, we fabricated a sensor node using our WSN platform. Our sensor node is designed in a form of buoy to monitor the lake water quality.

The fabricated main module, power module and transmission module in the sensor node are shown in Fig. 4. Moreover, power sources such as Li-ion cell battery and solar cell are connected to the modules. For the detection with sensors, sensor circuit is connected further.

The sensor node was fabricated based on easily obtainable materials such as PVC pipe for the main frame, acrylic dome for the cover of assembled modules and Styrofoam for ensuring buoyancy. The transparent acrylic dome was utilized as the cover of module for the electric generation with solar cell during the day. The fabricated sensor node has the height of about 500 mm and the diameter of about 300 mm. The

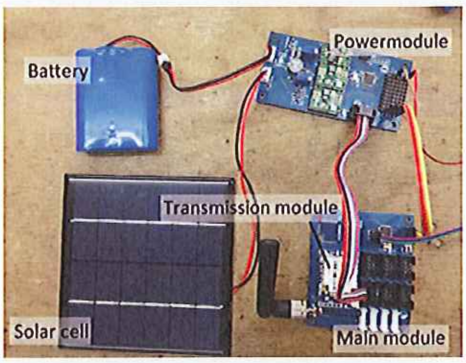

Fig. 4. The fabricated main module, power module (LT3652) and transmission module. The 6600mAh capacity Li-ion cell battery and solar cell are connected to power module.