Remote Monitoring System with Optical Fiber Sensors and the Internet-Standard Protocol

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***Abstract*—Services exploiting environmental information collected by sensor networks are in great vogue. Even though many sensor networks adopt wireless sensor devices, wireless sensor networks hold the battery life problem of sensor devices. Therefore, Optical Sensory Nerve Network (OSN) using the hetero-core optical fibers can simultaneously conduct sensing and communications without batteries. In this paper, the data collection method with the Internet-standard protocol in OSN is proposed. Additionally, this paper describes a remote monitoring system and development results of the remote monitoring system in OSN.**

***Keywords*—sensor network; optical fiber sensor; simple network management protocol.**

I. Introduction

In recent years, information of human behaviors collected by sensor networks has been widely used for various services. The networks with capacity of sensing are utilized for security purpose in houses and environmental monitoring in forests and rivers [1][2].

Although wireless sensor devices are commonly used for monitoring systems, they need to implement batteries in themselves or generate electricity by themselves with solar power because each sensor is mutually independent. However, the power generation is unstable and limited because the amount of generation is influenced by climate conditions. As a result, the wireless sensors are forced to save power by limiting functions and communications among sensors. In order to solve this problem, *Optical Sensory Nerve Network* (OSN) using the hetero-core spliced fiber optic sensors (hetero-core sensor) has been developed, and this wired sensor technology simultaneously realizes sensing and communications with a fiber [3].

This paper proposes a method to collect data in OSN and acknowledge conditions of hetero-core sensors with Simple Network Management Protocol (SNMP) [4]. Furthermore, we also propose a remote sensor identification system from outside of OSN using a database and a web application. The objective of this study is to remotely monitor the multiple sensor conditions in OSN from outside of OSN.

In Section II, hetero-core sensors and the characteristics of OSN are explained based on previous researches. Moreover, this section proposes the identification method of multiple sensor conditions. Finally, remaining issues of the sensor identification method related to SNMP are described, and the remote monitoring system for OSN that reduces complexity of access from distant locations caused by SNMP is proposed in Section III. In addition, an example behavior of the developed system is described.

II. Optical fiber sensor network

This section explains the previous work related to OSN. Furthermore, the multiple sensors identification method with SNMP is proposed.

A. Hetero-core Spliced Fiber Optic Sensor

A hetero-core spliced fiber optic sensor is utilized in OSN. This sensor plays two roles of sensors and communications links in OSN [5][6]. Figure 1 shows the structure of a hetero-core sensor. The sensors can be simply fabricated by fusion splicing. The sensors in our system are made of two kinds of single mode fibers whose diameters are 9 μm and 5 μm. The portion consisting of a thinner fiber is called *hetero-core part*. If the hetero-core part bends by pressure, a part of light is lost as leakage in the hetero-core part. Therefore, pressure on hetero-core part can be detected by measuring amount of the light leakage. Besides, this attenuation of light from hetero-core parts does not negatively affect data communications [7].

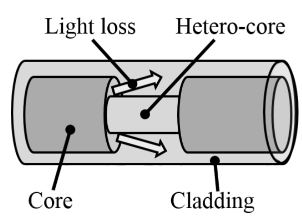

Figure 1. Structure of hetero-core sensor.

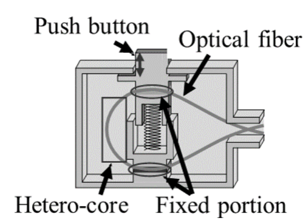

Figure 2. Binary switch sensor.

In this paper, a binary switch sensor using a hetero-core sensor is utilized, and Figure 2 shows the structure of a binary switch sensor. When the button at the upper part is pushed, the hetero-core part bends. As a result, the amount of light leaking to outside increases, and ON/OFF status of the sensor is identified by measuring the attenuation amount. Note that, the sensor condition is defined as *ON status* when the button is pushed.

B. Optical Sensory Nerve Network

The OSN is a sensor network that is developed by adding sensing function into Ethernet [3]. Hence, optical fibers in

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OSN are used for not only data communications but also sensing. Because a hetero-core sensor detects environmental information by using transmitted light in the optical fiber, provision of electric power is not needed for sensing. Thus, OSN solves the problem related to limitation of sensor functions in wireless sensor networks.

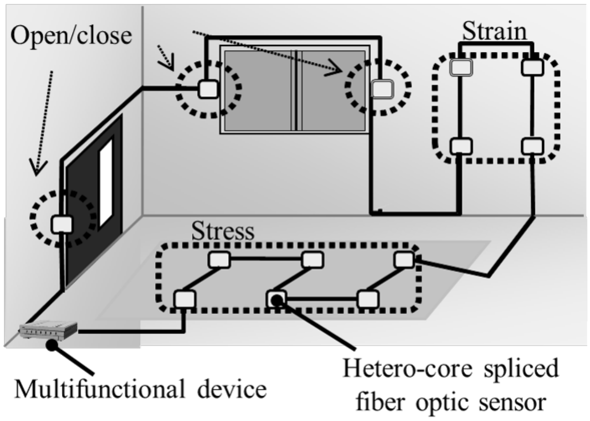

Figure 3. Example of a monitoring space using OSN.

Figure 3 indicates an example of a monitoring space using OSN. Sensors are embedded in walls, floors, doors, and windows in order to gather state information, such as strain of walls, pressure on floor, and open-close state of doors and windows.

C. *Sensor Identification Method with SNMP*

In order to identify sensor conditions in a sensor network, SNMP is utilized [4]. SNMP is a protocol that is implemented in general network devices to monitor and control network devices. A network with SNMP consists of *an SNMP manager* and *some SNMP agents*. An SNMP agent monitors a network device and it sends device information to the SNMP manager. The SNMP manager controls some SNMP agents, and it receives device information from the SNMP agent. If an exceptional event, such as a communication failure occurs, the SNMP agent sends notification messages called *Trap* to the SNMP manager. The sensor identification method utilizes this notification function to identify change of sensor states.

Figure 4 describes design of our system that identifies sensor conditions. This system contains three hetero-core sensors named A, B, and C. When the condition of any sensor becomes ON, the transmitted light in a fiber attenuates. The attenuation is always monitored by a measuring instrument which contains the SNMP agent function. In this measuring instrument, a script program that is defined to issue the Traps can be set.

Because attenuation of each sensor differs from each other, the total amount of attenuation also diverge depending on combinations of reacted sensors. There are seven patterns of attenuation amount in total because this system has three sensors. Attenuation amount is different in each combination, so the program in the measuring instrument can link each attenuation with different Trap numbers. When such an issued Trap is received by the manager, the manager can identify every sensor condition.

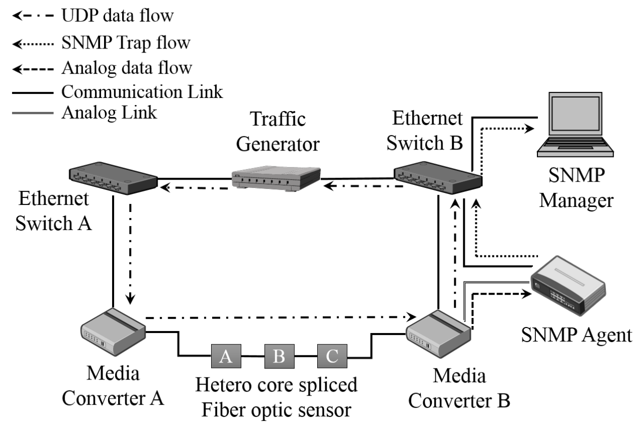

Figure 4. System configuration diagram.

Next, the identification results of this method are indicated and evaluated. TABLE I shows identification results of sensor conditions. The SNMP manager distinguishes sensor conditions by analysing the Trap number issued by the SNMP agent. Figure 5 indicates attenuation patterns of seven sensor combinations in decibel notation. The figure represents the different amount of attenuation among seven sensor combinations, which means that the sensor conditions are able to be identified.

TABLE I
EXPERIMENTAL RESULTS OF THIS METHOD.

Time	Trap number	Description
10:00:00	21	Switch A ON
10:00:10	28	OFF
10:10:00	23	Switch A&B ON
⋮	⋮	⋮

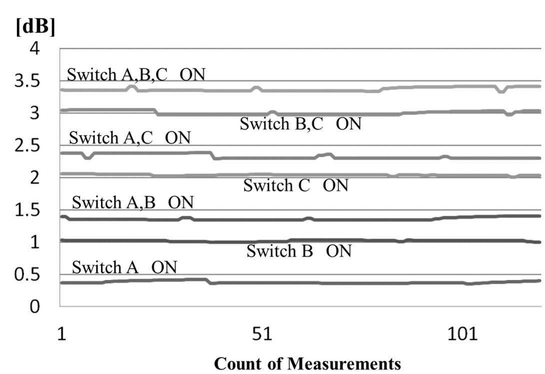

Figure 5. Attenuation of 7 patterns in dB notation.

III. REMOTE MONITORING SYSTEM

This section describes remaining issues of the sensor identification method. Furthermore, this section proposes a remote

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monitoring system for OSN as solution of the issues.

A. Remaining Issues and System Requirements

As mentioned in Section II-C, it is possible to detect sensor conditions with SNMP. However, there are two remaining issues to be solved when the size of the system expands, or this system is utilized in outdoor [8].

The first remaining issue is the remote monitoring function. In the identification method with SNMP, sensor conditions can be monitored only within the OSN. However, it is assumed that observers connect to the OSN from outside and hope to remotely monitor the sensor conditions. Therefore, a method to confirm sensor information from remote locations is required.

In order to monitor the sensor network, the current identification method with SNMP requires Virtual Private Network (VPN) connection and an SNMP manager software at a computer of observers. Therefore, all network equipments need to be adjusted for VPN and SNMP in order to get sensor information. When a sensor network becomes larger in scale, the installation of the settings into all equipments may impair usability of OSN. Thus, a method to monitor sensor conditions from remote locations without complex settings is needed.

The second remaining issue is management method of sensor information. In the current identification method, the sensor information is stored in reaction time order as shown in TABLE I. This stored data format is a text file, so it does not have a search function, and the manipulation of data is difficult. Therefore, the identification method does not suit for long term monitoring. Hence, the data processing and search function are required.

In order to satisfy the listed requirements in this section, we have developed and designed the remote sensor identification system, which can provide sensor information on a web page using a web application and a database.

B. System Overview

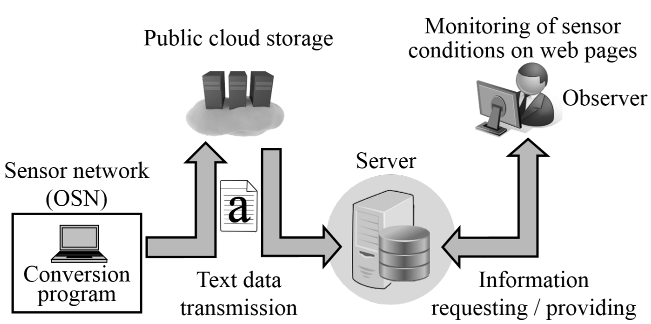

Figure 6. Remote monitoring system.

Figure 6 indicates the developed system. As a solution to the remote monitoring issue of Section III-A, text data containing the Trap numbers and sensors reaction time are sent to a server for sensor condition identification without using the SNMP manager software at a computer of observers. In order to remove the SNMP manager software from a computer of observes, a software that is called *a conversion program* receives an issued Trap from an agent in OSN. The conversion program creates text data contains a Trap number and sensor reaction time, and it sends text data to a server. Therefore, a manager software, which receives the SNMP messages is not needed. Furthermore, observers do not need to use VPN connections because sensor information is provided to observers on a web page. In other words, if observers can connect to the Internet, they can monitor sensor information from anywhere.

Next, as a solution to the sensor information management problem discussed in Section III-A, the database (DB) and the web application are utilized in the developed system. The use of the DB enables this system to manage sensor information, and the search and process of data also become easier. Moreover, the web application enables observers to deal with the data easily and to monitor in a long term even without any knowledge about DB.

C. System Components

This section explains software components of our remote monitoring system.

1) Conversion program: This program receives an SNMP message and converts an SNMP message to text data in a sensor network. A trap number and sensor reaction time are written in the converted text data for sensor identification. This program is executed at each time when it receives a Trap.

2) Database: The database in our system satisfies the following conditions.

- Sensors may be installed in some different locations.
- Trap number and sensor reaction time need to be saved.

In order to store the sensor information to the DB, *the DB storage program* is implemented in the server. This program has following functions.

- The program checks additional sensor information from the previous program execution. If there are any added text data, the program generate a trigger file.
- The program stores sensor information to the DB. If the storing process is completed, the program delete the trigger file.

The trigger file plays a role to inform the new added text data. The program will be automatically executed on the server at any scheduled time. The minimum execution interval is one minute.

3) Web application: In this system, the web application, which works together with the DB provides the sensor information to observers on a web page. Therefore, observers monitor the sensor information without any knowledge about DB. Furthermore, if the observers can connect to the Internet, they would monitor the sensor information from anywhere.

D. System Operation

In this section, the flow of the system operation is described.

First, attenuation of transmitted light in a optical fiber increases when the sensor becomes ON status. This attenuation is detected by an SNMP agent, and the agent issues a Trap that is unique number for each attenuation. After the conversion program receives an issued Trap, it converts a Trap to text data that indicate a Trap number and sensor reaction time. This created text data are sent to the server and stored. At this time, sensor information has not been stored in the DB yet.

Next, the process of the system is shifted the server. In the server, the DB storage program is executed every minute. The program checks the additional sensor data from the previous execution. If there are any additional text data, the program creates the trigger file in the server. When the storing process is successfully finished, the program delete the trigger file. If the storing process is failed, the trigger file is left. Therefore, the data, which is not stored in the DB can be easily checked.

Finally, the web application and the DB work together and provide the sensor information to observers on a web page.

E. Operating Results of the System

In this section, the operating results of the system are indicated and evaluated. The sensor system used for this operation is composed as same as the system architecture shown in Figure 4. It was verified that all sensor conditions are correctly monitored on a web page. Figure 7 indicates a display example of the web page.

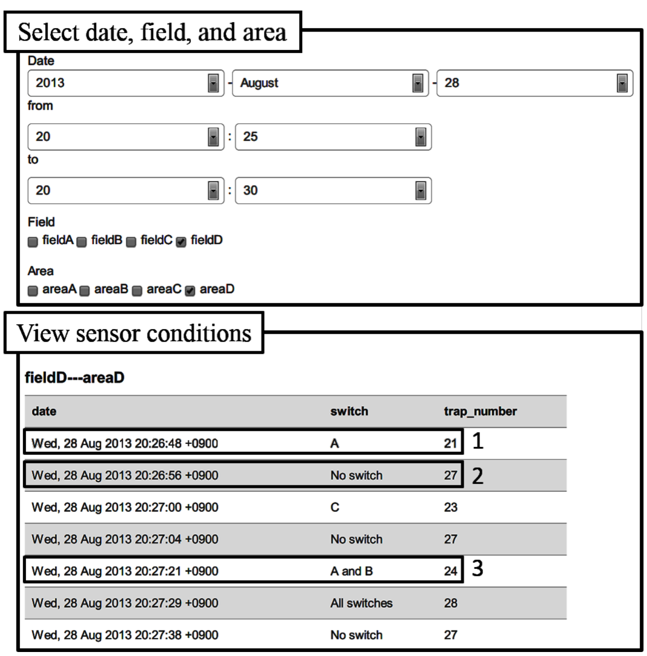

Figure 7. Display example of the web page.

This system enables the observers to search information more easily than checking all data with a list like TABLE I. Furthermore, the observers can monitor the OSN from outside of it. Results of this system operation indicates that state of each sensor can be represented through our sites. For example, the line **1** in the Figure 7 indicates the detection of switch A reaction. The line **2** indicates the completion of switch A reaction. Furthermore, the line **3** indicates the reaction of the switch A and B; therefore, it is also possible to display multiple sensor conditions by this system.

IV. CONCLUSION AND FUTURE WORK

In this paper, the SNMP is used to identify conditions of hetero-core sensors in the proposed OSN. Moreover, we proposed and designed remote monitoring system to solve the identified remaining issues. In order to monitor the sensor conditions from remote locations, we developed a system that utilized the web application and the DB. The sensor conditions can be remotely monitored on a web page by this developed system.

In the future, we will consider the utilization of OSN for outdoor and the construction of larger scale of sensor networks. For example, in the field of nursing, sensor network informs behavioral patterns of elderly people to caregivers. Moreover, in the field of agriculture, farmers monitor their scattered farmlands from remote locations. Therefore, this system would play a role to provide some practical usages for OSN. This system develops the capability of OSN because it has a remote monitoring function and a database function of sensor information. Moreover, we should increase the number of sensors in the sensor network because only three sensors are identified by the current system. This restriction is because the script capacity of the agent is limited. Thus, a development of an agent, which has no limit of the capacity is needed.

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