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Challenges to Enable Quick Start of an Environmental Monitoring with Wireless Sensor Network Technology

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Abstract—With the advancement of wireless sensor network technology, its practical utilization is becoming an important challange. This paper overviews my past environmental monitoring project, and discusses the process of starting the monitoring by classifying it into four steps. The steps to start environmental monitoring can be complicated, but not well discussed by researchers of wireless sensor network technology. This paper demonstrates our activity and challenges in each of the four steps to ease the process, and argues future challenges to enable quick start of environmental monitoring.

Keywords—Environmental Monitoring, Wireless Sensor Network, Field Experiment and Research Challenges.

I. Introduction

THIS paper discusses the process of starting environmental monitoring using wireless sensor network (WSN) technology based on our past field experiments, and discusses the research challenges including our challenges to enable quick start of the environmental monitoring.

Environmental monitoring is an activity to investigate the characteristics of the environment. Researchers study the target environment from various viewpoints such as weather, biogeocenosis of animals and plants, quality of soil, air and water, and correlation of these elements. Usually, environmental monitoring is conducted in order to clarify the impact of human activities on nature. Before starting a civil engineering project, an environmental assessment including environmental monitoring is required to do in order to prove that the project do not destroy nature. Today, environmental monitoring is a fundamental activity to make the natural environment sustainable, and strengthen the relationship between nature and our modern life.

Environmental monitoring is long considered to be a promising application of wireless sensor network technology. There are various advantages in applying WSN technology to the environmental monitoring. As our past work revealed[1], utilization of WSN technology clarify the condition of the environment with enormous temporal and spatial resolution. There are many kinds of phenomenon that can be observed only with numerous densely-set sensors, and that is what WSN technology enabled. Also the WSN technology reduces cost in conducting environmental monitoring. The WSN technology enables us to make a widely distributed network without spending much money for the infrastructure. The WSN technology also eliminates cost in gathering and sharing the observation data. After decade of research on WSN technology itself, first-generation WSN devices are now available in commerce. Now, it is time to promote environmental monitoring to the prospective users such as researchers of environment[2].

Basic devices for sensing is commercially available today, however, if you want to start environmental monitoring, it is still needed to develop a suite of software systems from scratch. In the most environmental monitoring projects, the researchers of the environment are required to store, analyze and visualize the data. In addition, the importance of sharing the data with ordinary people is increasing. Even when they use the same monitoring device, researchers often develop software as ad hoc solution in each monitoring project.

Also, the process of negotiation to start environmental monitoring is tough. Researchers have enthusiasm to know condition of the environment, but the enthusiasm is usually not easy to be shared with other people. Ordinary people do not know how the sensor technology works or how it affects to the environment, their life and the society. It is needed to eliminate anxiety of security, safety and various possible troubles and persuade people in the areaby.

This paper introduces our activity of environmental monitoring and argues the future research direction, which we learned from our past activities. In the next section, we introduce our past challenges of field experiments of environmental monitoring. In section 3, we classify the starting process of monitoring into four steps, and discusses details and challenges in each step. After the discussion, we argue future challenges to enable quick start of environmental monitoring. Finally, we conclude this paper.

II. Field Experiment of Environmental Monitoring

In 2006 and 2009, we conducted experiments of environmental monitoring with wireless sensor network technology. In each experiment, we adopted the latest equipment at that time as monitoring devices and software systems. This section overviews our past projects.

A. Airy Notes Project

Airy Notes Project was our first challenge of environmental monitoring utilizing wireless sensor network technology. In

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the Airy Notes project, we monitored environmental condition using tiny sensor modules and showed the characteristics of places intuitively on a map and cell phone. The Airy Notes system is designed to help easy understanding of the effect of greening by enabling high density placing of sensor nodes. We conducted the experiment of the system in Shinjuku Gyoen garden with 160 sensors. Gardens are generally considered to keep urban environmental condition calm with their green. We monitored the change of temperature, and observed that the temperature of the inner place was lower than the edge of the garden.

We started Airy Notes Project in April 2006 as a team of ubiquitous computing researchers and landscape design researchers. The aim of the Airy Notes Project is to develop monitoring system of natural environment, and develop a new method for environmental management utilizing the system. In this paper, we introduce the activities of the project. Figure 1 illustrates the sensor and example of utilization of the data.

Fig. 1. A sensor and a cell phone accessing to the temperature data

B. Mebius Sensor Project

In 2009, after three years from the Airy Notes Project, we started the second environmental monitoring project called Mebius Sensor Project. At the time we started the project, a commercial product of wireless sensor network device designed for field monitoring called "eKo Mote"[3] had already been available from Crossbow Inc, which is known as a company of Mote, a sensor network device for laboratory use. We adopted eKo Mote for the experiment, and tried not to develop original software for the experiment, but instead, we tried to use web-based commercial service for storing, sharing and visualizing the data.

The mission of the Mebius Sensor Project is to sense the natural environment of Keio University's Shonan Fujisawa Campus (SFC). We have deployed 15 wireless sensor nodes each embedded with a temperature, humidity and luminance sensor on the circumference of the campus. Each sensor node was equipped with a solar battery panel, and formed a multi-hop network that coverd the campus. The Mebius Sensor system was designed to be a platform for various ubiquitous computing applications such as enhancing people's awareness of the natural environment.

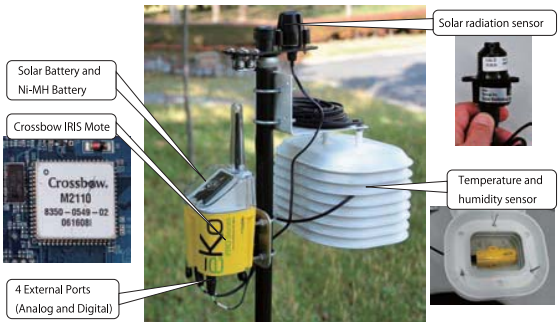

Fig. 2. The detail of the eKo Mote with sensors

III. Preparation to Start Environmental Monitoring

Although many researchers of wireless sensor network technology have confidence in realizing environmental monitoring with their technology in the actual field, not so many researchers have an experience of the actual field experiment. From our past experiments, we learned that the process to begin the monitoring is classified into following four steps.

A. Step1: Planing for the Sensor Deployment

As the first step of sensor deployment, it is needed to make a concrete plan such as the exact locations that the sensors will be placed and how to fix the sensor device considering both technical and scientific requirements. As technical requirements, 1) The place should be suitable to supply power and establish a network connection, and 2) The sensor should be accessible for maintenance. As scientific requirements, 3) The point to be sensed should represent its surroundings, in other words, the point should not be under the extreme condition such as under the strong sunshine or in front of the illumination, and 4) Human activities should not affect the sensor, or the sensor should not affect human activities either.

In our experiment, we made an initial plan of points for sensors using a map, but soon found the need of filed investigation to see the actual condition. Also, it was needed to decide how to fix the sensor to the point. Figure 3 is a part of the survey map which we made before starting the Mebius Sensor Project. We prepared a map of the target area, and walked around taking notes about the detailed condition of the area. In the survey, we were considering the way to place the sensors, whether we should put them as stand-alone setting, or we should attach them to the existing facilities. After the survey, we decided to place them stand-alone.

B. Step2: Negotiation with the Stakeholder

After fixing the plan, it is needed to persuade the stakeholder, especially a person in charge of the place, about the monitoring experiment. A researcher needs to convince them of not only the academic benefit, but also the benefit for the stakeholder. At least, researchers need to ensure safety and security during the experiment. In the Airy Notes Project, since

Fig. 3. A Part of the Survey Map at Mebius Sensor Project

the target area was a natural park, the person in charge mainly cared about the academic benefit and the safety not to destroy the nature there such as tree or grass. In the Mebius Sensor Project, in which the target area was a university campus, safety for students was an important factor to be convinced of.

In addition, if researchers are planning to release the observation result, it is needed to consider the unforeseen problems that the data might cause. For example, the data might drop the land price of the surrounding because of the bad natural condition, or the data might threaten the safety by releasing the activities of people in the area. It is needed to continue observing the effect of the publication of the data.

C. Step3: Development of Instruments for Installation

It is needed to develop instruments to install sensors before starting the final installation process. For example, in the Airy Notes Project, since the sensors were naked, we made hundreds of paper packages for sensors to protect them from sunshine and rain. In the Mebius Sensor Project, even though the device was covered with a plastic housing as it was a commercial product, it was still needed to develop several instruments to place the sensors. As Figure 4 shows, we designed the attachment from the blueprint, then, processed the material. Although these processes depend on the features of the monitoring site, there are too many missing parts to accomplish installation of sensors.

D. Step4: Installation of Sensors

After accomplishing the former three steps, researchers can finally install the sensors to the field. By preparing sensors ready to install beforehand assembling sensors and housings, we can reduce the needed task at the field. In addition to the exact installation of sensors such as digging the ground, screwing clamp or hanging the sensor, there are three important tasks that we need to do on site. The first task is confirmation of wireless signal and adjustment of the place.

Fig. 4. Developed Attachments and the blueprint for the eKo Mote Sensor

There is no way to confirm if the signal from the sensor reaches to the sink logically. Therefore, we need to adjust the place to install by checking the signal strength on site. The second task is association of sensor ID with the location. The result of observation is related only with the sensor ID as the data, which does not relate to the physical location. It is needed to associate the sensor ID with the location on site to handle the observation data. The final task is to record surrounding environment. For large scale monitoring of the environment, it is important to place all sensors under the same condition. But in the environmental monitoring, researchers want to know how the difference of the condition results in the environment. For the later analyses, it is important to consider the environment at the monitoring spot.

In the Airy Notes Project, we developed an assistance system of sensor installation as illustrated in Figure 5. It is an application running on a tablet PC with GPS. When you install the sensor, you can easily check the strength of the signal, input the location of the sensor on the map, and input the condition of the spot. However, in the Airy Notes Project, it did not work well due to the problem of network and battery. The place we intended to install sensor did not have WiFi, therefore, we needed to pay much for the cellular network. The battery of the tablet was not enough to accomplish whole activity. We finally gave up using it and ended up using paper and pen. Thesedays, however, iPhone, iPad and various smartphones make it possible to develop such assistance system.

IV. Future Challenges for Quick Monitoring

In order to make the process of starting environmental monitoring, it is needed to standardize the software and devices needed in each step. In the following, we demonstrate needed standardization based on the former discussion.

A. Standardization of Data Sharing Platform

Instead of developing software in each environmental monitoring project, it looks a good approach to create a cloud-based platform to share the sensor data. Pachube[4] is one of the candidates of the platform to share various environmental data. Pachube provides web-based API to upload and share the various spatiotemporal series of data including the output of an environmental sensor. Pachube is, however, mainly used for

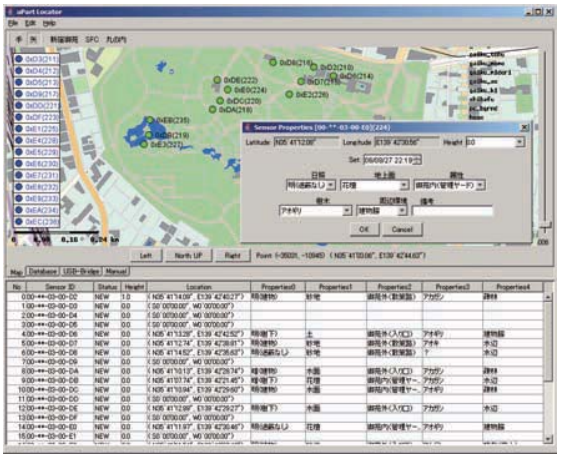

Fig. 5. A Screenshot of the Assistance of the Sensor Installation

media-art and hobby, and there are only a few cases that are used in large-scale environmental monitoring. There are also several other research projects to develop a platform to share the sensor data[5], [6], [7], [8], [9], [10]. Since the architecture to aggregate every sensor data into the single storage has some weaknesses, there are still various challenges in this field.

B. Standardization of Monitoring Process

Standardization is also required in the social part of the monitoring for the quick start of environmental monitoring. Although an environmental sensor might threaten our privacy, security and safety if someone use it with malicious motives, there is no consensus about the usage of the sensor. In order to judge whether the usage of the sensor is correct, a guideline should be needed. The guideline makes it easier for a stakeholder to judge if the proposed environmental monitoring is reasonable or not.

C. Enable On Demand Collection of Data

Every discussion on this paper assumes that a researcher who wants to start environmental monitoring needs to place the sensor by him/herself. However, if the platform to share the sensor data is available more widely, there is another way of monitoring: on demand monitoring. Instead of setting sensors to the target area, a researcher collects the output of the sensor available on the platform, which might be installed for other survey. Even if there is no sensor on the exact location, the researcher can still infer the result of observation at the point from the outputs of sensors around the point. With on-demand monitoring, a researcher can quickly start the environmental monitoring.

In on-demand monitoring, performance of each sensor and how each sensor has been installed might be different. Therefore, it seems difficult to aggregate and analyze the output from different sensors together even the outputs of both have the same unit. Although this approach seems effective for the survey of wide area, there are many problems to accomplish the project.

V. Conclusion

In this paper, we overview our past environmental monitoring project, and discusses the process of starting monitoring by classifying into four steps: 1) Planning for the sine's deployment, 2) Negotiation with the stakeholder, 3) Development of instruments for installation, and 4) Installation of sensors. These steps are not often discussed by researchers of wireless sensor network technology, but they are important to make the technology available for many other people including researchers of environment. We demonstrated our activity and challenges in each step, such as development of assistance system of sensor installation. After the discussion, we argued future challenges to enable quick start of environmental monitoring to reduce the difficulty in each step. We insisted three important challenges in the section such as the need of standardization of data sharing platform, monitoring process and promotion of on demand monitoring.

After decade of research on WSN technology, there are many technical proposals such as effective routing, power saving, data processing. These researches, however, tend to be too deep, and not effective to the actual utilization of WSN technology. As mentioned in this paper, there are many technological and social challenges that are important but not well formalized. It is important to start thinking of these problems.

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