Environmental Monitoring Using Short-range Multihop Wireless Technology

Yoshihiro Itoh†, *Kazuhiro Takaya, and Takumi Watanabe*

Abstract

Environmental information needs to be measured effectively at all times and applied to simulations and evacuation instructions as a defense against natural disasters. This article introduces environmental monitoring technology that combines short-range multihop wireless communications (less than a few hundred meters) with environment-monitoring sensors to collect multipoint environmental information over a wide area.

1. Importance of environmental monitoring

During the past period of high economic growth, environmental pollution in the form of waste water and smoke discharged from factories presented a major problem to society because of its harmful effects on the surrounding environment and local residents. At one time, though, it was relatively easy to isolate the sources of pollution and the effects of toxic substances and to determine the causes of environmental degradation. As a result, various countermeasures were applied. However, today's environmental problems, such as global warming, are not as easy to deal with. Finding the actual sources of these problems and determining cause-and-effect relationships are proving to be difficult. Dealing with these problems on a local basis has been found to be inadequate, so measures must be implemented on a long-term basis over a wide area or even on a global scale, which is not a trivial task.

The purpose of environmental monitoring should therefore extend beyond the mere collection of data with the aim of satisfying legal regulations. It should also include the comprehensive acquisition of environmental information collected from diverse observational targets and the conversion of that information to a form that people can easily understand. Natural disasters that have recently struck various places in Japan have raised the nation's consciousness about disaster prevention. They have emphasized the need for an accurate picture of changes in the natural environment and the provision of readily understandable disaster-prevention information.

NTT Energy and Environment Systems Laboratories has been developing environmental monitoring technology that combines ubiquitous network technology and environment-monitoring sensors. It has been researching disaster-prevention information-provision technology for providing collected environmental information in an easy-to-understand form to both the government and the general population. This article introduces environmental monitoring technology that uses short-range multihop wireless technology to collect useful environmental information from many points over a wide area.

2. Multihop wireless technology

Optical broadband networks, cellular phone networks, and local area networks (LANs) are being constructed with the aim of creating a ubiquitous-network environment. These communication infrastructure components are quite extensive in regions where the population density is relatively high. However, to monitor the environment in preparation for natural disasters, including storms, floods, and mudslides, we need to deploy flexible networks that can be constructed in a relatively cheap and simple manner in mountainous regions, the upstream sections of rivers, and other areas in which a communication infrastruc-

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ture has not yet been established.

The use of multihop wireless technology is one way to satisfy this need. This technology enables us to construct a network anytime, anywhere, and without difficulty using only wireless devices that incorporate a built-in relay function. In this type of network, however, the communications control method and power-consumption control method will differ according to the type and amount of information collected and the scale of the network. These functions must therefore be optimized according to the application in question.

2.1 Long-range multihop wireless technology

An example of an environmental/disaster-prevention monitoring system [1] using long-range multihop wireless communications (200 m to 2 km) applied to a local government is shown in **Fig. 1**. Here, connection to a local intranet enables the construction of a broadband network with diverse applications including special and temporary collection of disaster-prevention information, environmental monitoring, monitoring for illegal dumping, and instructional lessons on how to take environmental surveys.

This environmental/disaster-prevention monitoring system can accommodate mobile personal computers (PCs), personal digital assistants (PDAs), Web cameras, Internet protocol (IP) phones, and other devices having built-in LAN interfaces, which means that a ubiquitous network can be formed using broadband communications with image, video, and audio media. When a disaster occurs, the system connects this ubiquitous network to relatively remote bases in the region and interconnects those bases, thereby establishing a special means of communication for a temporary period.

2.2 Short-range multihop wireless technology

Another type of environmental monitoring for disaster-prevention purposes aims to improve the accuracy of flood predictions and the reliability of evacuation instructions. This type of monitoring will need to deploy various types of environment sensors in a high-density arrangement, especially in high-risk areas, and collect environmental information on a realtime, long-term basis. Here, the amount of information transmitted by each sensor per unit time is small, and transmission intervals have a range of lengths. This calls for a network design that pays more attention to power consumption and implementation/operating costs than long-range multihop wireless technology does.

In response to this need, NTT Energy and Environ-

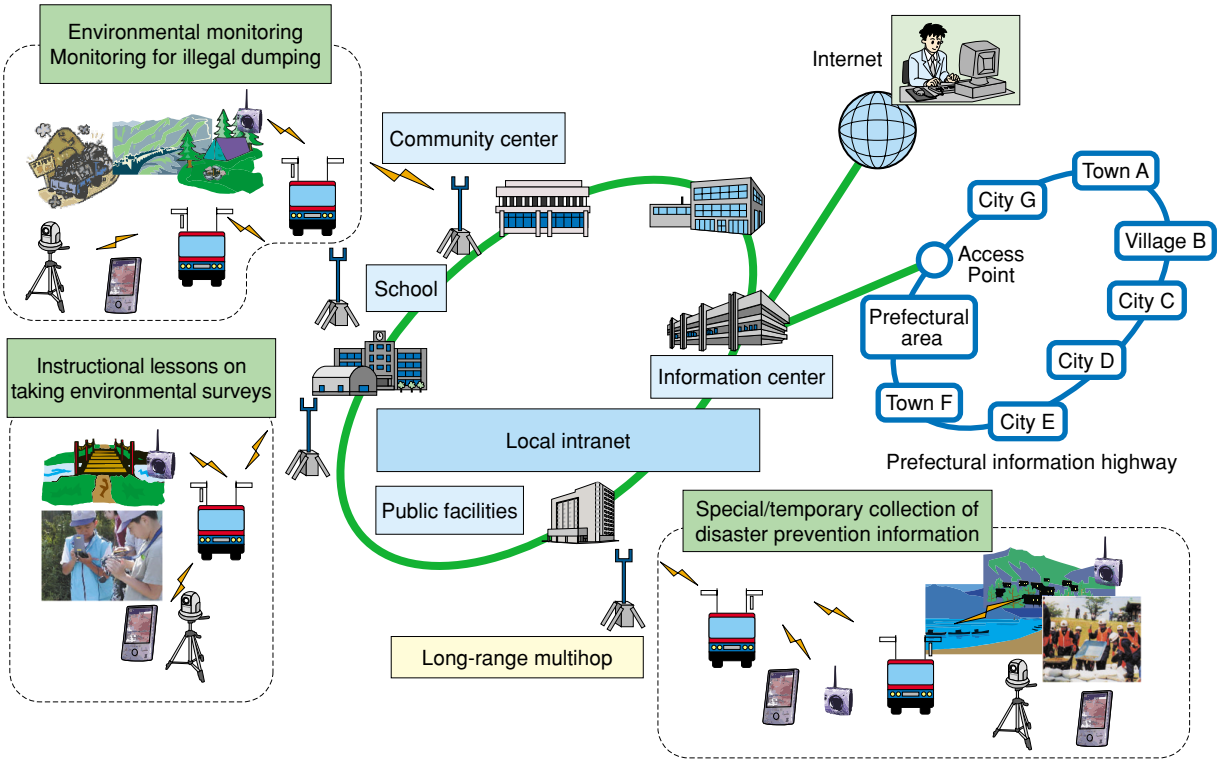


Fig. 1. Long-range multihop wireless technology.

ment Systems Laboratories has developed short-range multihop wireless technology (for communication under a few hundred meters) that can be used to perform effective, low-power environmental monitoring with diverse environment sensors and high-density sensor arrangements.

Figure 2 shows an example of environmental monitoring using both long- and short-range multihop wireless technologies, which provide wide-area communications and high-density sensor arrangements, respectively. Exploiting these features in this way enables effective collection of meteorological data and disaster indicators such as rainfall and water level and facilitates the provision of an environmental monitoring network that can easily connect to a trunk network to transmit audio and video information.

2.3 High-density, realtime environmental monitoring system

The configuration of a high-density, realtime environmental monitoring system using short-range multihop wireless technology is shown in **Fig. 3**. In this system, a remotely located monitoring PC commands wireless sensor modules to transmit the environmental data they have collected to a base station by multihop transmission. This environmental data can be monitored in real time from anywhere via the public network. This short-range multihop wireless technology has the following three features.

(1) Low power consumption

Many wireless sensor modules will have to be used in places where there is no mains power supply. These modules must therefore have low power consumption in order to collect data for a long time while running on batteries or other non-mains power sources. This will also lower the maintenance and management costs.

(2) Compact, lightweight, and inexpensive design

Since a high-density environmental monitoring system will require many networked sensors, the

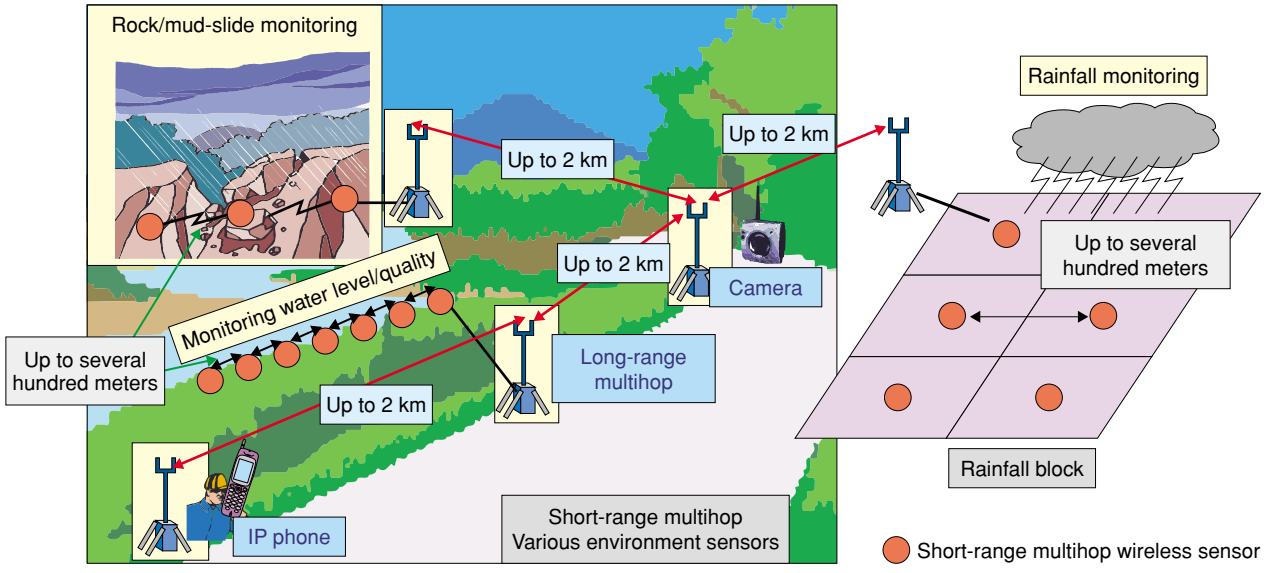


Fig. 2. Short-range multihop wireless technology.

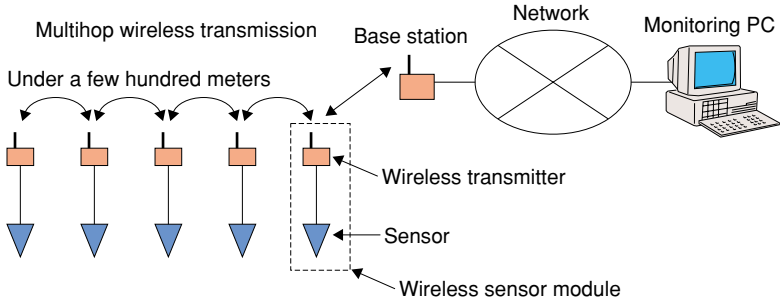


Fig. 3. High-density, realtime environmental monitoring system.

wireless transmitters installed in those sensors must be inexpensive. By using a simple, compact, and lightweight sensor configuration, we can create a low-power radio transmitter that is inexpensive.

(3) Short-range communications

The short distance between wireless transmitters for high-density monitoring means that they conform to the standard for low-power radio stations. Since radio stations of this type do not require a special license, the sensor modules can be used by anyone, and installers are not subject to any regulations.

2.4 Mechanism of short-range multihop wireless communications

In ordinary multihop wireless technology, a wireless device may have to relay data received from a neighboring wireless device in addition to sending its own data to a wireless base station. Therefore, the device must always be waiting to receive and this state consumes power just like a cellular phone. It has consequently been impossible to expect such a wireless device to operate for a long time without its battery being changed. In response to this problem, NTT Energy and Environment Systems Laboratories devised a low-power scheme in which the wireless device operates intermittently and the period of inactivity is controlled in an optimal manner.

The mechanism of wireless communications is shown in **Fig. 4**. First, at the time of initialization, the wireless base station sends a time synchronization command to all wireless devices in the system. Once this has been done, the wireless base station and wireless devices alternate between a wait state (standby mode) of fixed duration and a receive state (receive mode) of several seconds. In standby mode, most circuits including those of the wireless transmitter are inactive and power is supplied to only some circuits such as the timer. This reduces the total consumed power by about 90% or more. In this mechanism, the duration of the standby mode can be optimized according to the type of measurement to minimize the time lag of each wireless device. The wireless base station also sends out a time synchronization command at fixed intervals to correct the time clock on each wireless device and to keep the offset in time between each terminal within a fixed range. In this way, we can make a low-power system while ensuring that measurements will commence within a certain time after the user sends a command to begin taking measurements.

3. Future outlook

First, to assess the low-power-consumption feature of short-range multihop wireless technology, we plan to interconnect various environment-monitoring sensors and perform verification trials in the field. Based on the results of these trials, we will try to simplify the sensor structure to further reduce power consumption and improve sensor maintainability. Our aim is to make an environmental monitoring system that is suitable for applications where environmental monitoring was previously not feasible because of high deployment and operating costs.

Next, we plan to combine short- and long-range multihop wireless technologies to construct a wide-

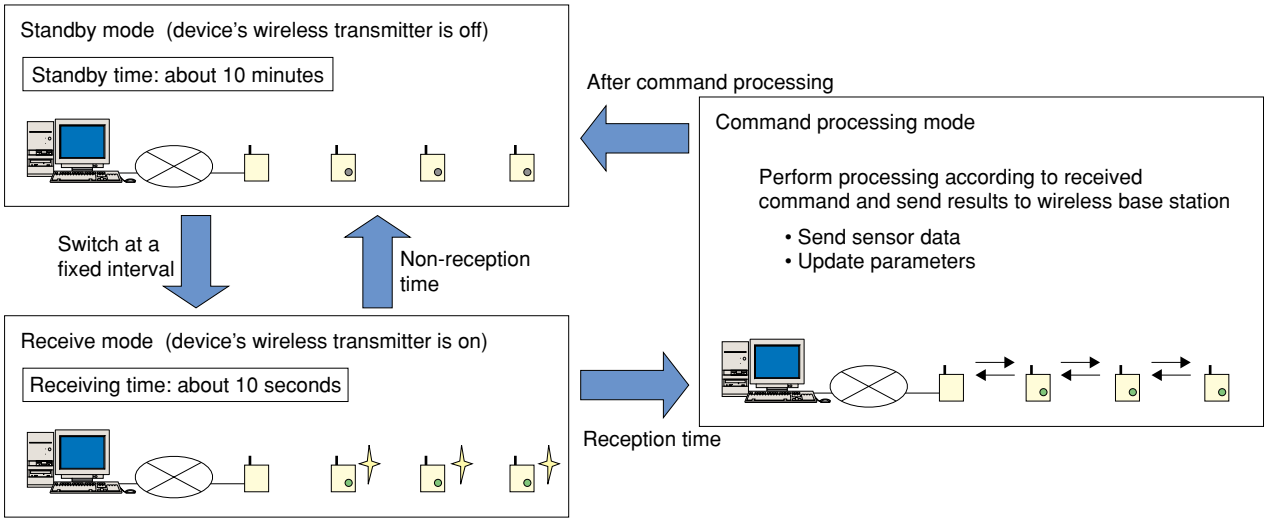


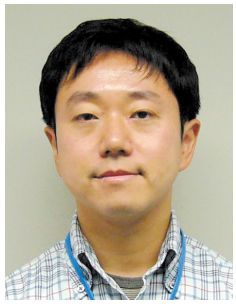
Fig. 4. Mechanism of wireless communication.

area environmental monitoring system to accumulate environmental data in mountainous regions and along medium- and small-scale rivers, for which there has traditionally been little observational data. Amassing diverse environmental and meteorological data over a wide area in this way has several benefits: it will enable the results of various disaster-prediction simulations to be checked for accuracy and it will enable environmental and meteorological data to be analyzed for correlations and temporal fluctuations. The results can then be used to develop advanced disaster-prediction technology and investigate methods for providing high-reliability evacuation instructions.

Research at NTT Energy and Environment Systems Laboratories is not just concerned with the development of environmental monitoring technology. It also aims to develop systems that can provide helpful disaster-prevention information at the most appropriate time in an easy-to-understand format to both the government and the people concerned. In the future, we plan to use the short-range multihop wireless technology presented here as an elemental technology for improving disaster-prediction simulation technology and disaster-related information sharing and provision technology.

Reference

[1] Y. Maeda and T. Shodai, "Environmental and Disaster-prevention Monitoring System," NTT Technical Journal, Vol. 17, No. 9, pp. 8-13, 2005 (in Japanese).



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