Forest Environment Monitoring Application of Intelligence Embedded based on Wireless Sensor Networks

Jung Hee Seo[1], Hung Bog Park[2]
[1] Department of Computer Engineering, Tongmyong University
Pusan, Republic of Korea
[e-mail: jhseo@tu.ac.kr]
[2] Department of Computer Engineering, Pukyong National University
Pusan, Republic of Korea
[e-mail: git@pknu.ac.kr]
*Corresponding author: Hung Bog Park

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Abstract

For monitoring forest fires, a real-time system to prevent fires in wider areas should be supported consistently. However, there has still been a lack of the support for real-time system related to forest fire monitoring. In addition, the 'real-time' processing in a forest fire detection system can lead to excessive consumption of energy. To solve these problems, the intelligent data acquisition of sensing nodes is required, and the maximum energy savings as well as rapid and accurate detection by flame sensors need to be done. In this regard, this paper proposes a node built-in filter algorithm for intelligent data collection of sensing nodes for the rapid detection of forest fires with focus on reducing the power consumption of the remote sensing nodes and providing efficient wireless sensor network-based forest environment monitoring in terms of data transmission, network stability and data acquisition. The experimental result showed that battery life can be extended through the intelligent sampling of remote sensing nodes, and the average accuracy of the measurement of flame detection based on the distance is 44%.

Keywords: Wireless Sensor Network, Monitoring, Forest Fires, Wireless Sensing Node

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1. Introduction

In recent years, an easily distributed wireless sensor network (WSN) receives attention due to intensive efforts by the diversity of application program scenarios [1] and provides new opportunities for the prevalence of physical environment and situational awareness monitoring [2].

In previous studies, wireless sensor networks have been applied to various fields, including in areas of the agricultural industry such as tea cultivation [1] and collection and management of jujube tree germplasm resources data [3], structural monitoring of concrete [4], pipelines [5] and combustible gas [6], animal monitoring of pasture management system [7], and environmental monitoring for forest fire detection [8, 9, 10]. In addition, it has been used for the application of medical systems [11] that can measure patients' biological parameters (heart rate, respiratory rate, movement, etc.).

The objective of many WSN(Wireless Sensor Network) applications is to provide long-term monitoring of the environment. As sensor nodes periodically need to report sink data and work for long periods of time so that users can make a request for an overall overview of monitoring environment on a regular basis, energy is considered to be a major concern for these applications [2].

In addition, the sensor is generally powered by a battery and has very limited capabilities. Accordingly, one of the most important points is about the hardware and protocol design on the method for saving energy limited to sensor nodes and sensor network. Therefore, it immediately observes, monitors, visualizes and records events that occur in the remote environment from the perspective of "real time" of the paper [1]. This real-time sensing and transmission of large amounts of data leads to an increase in the power consumption of remote measurement nodes.

In this paper, research on the wireless sensor network is focused on providing efficient environmental monitoring of forests in terms of reduction in the power consumption of remote sensing nodes, data transmission, network stability and data collection.

For the past few years, the wireless sensor network has mainly been applied to environmental monitoring applications among various fields. Unstable weather conditions revealed how important the deep understanding of recent development and environment is for humanity. Environmental monitoring has become an integral part of the wireless sensor network application program [12].

Paper [12] discusses the wireless sensor network application programs for environmental monitoring. Types of the environmental monitoring include agricultural, habitat, indoor living, greenhouses, climate change and forest monitoring.

Environmental monitoring [13] is closely related to peoples' lives, and natural disasters on the coast and forests or disasters caused by humans are costly and potentially life-threatening.

Forests are a major source of biodiversity and ecological balance. They offer many benefits, while water and soil conservation, plant and animal genes, timber supply and other forest products also serve as a main function of the source. Accordingly, it is important to implement an effective monitoring system for forest environments to ensure long-term forest autonomy [12].

Traditional monitoring systems of forest fires include ground patrol, tower and satellite surveillance, but there are still a lot of problems with these fire monitoring methods [9].

In addition, the instability of manned observation towers is added to the difficult living conditions of fire watch personnel and aimed at making fire fighters recognize forest fires as soon as possible, leading the development and use of various technologies such as charge coupled device (CCD) cameras and infrared (IR) detectors, satellite systems and images, and systems using a wireless sensor network [8].

CCD cameras and infrared detectors are very sensitive to unsafe environmental factors, and satellite systems through real-time monitoring using satellite images have difficulties in early fire detection due to various factors such as clouds. Additionally, people-centric monitoring activities are limited when it comes to environmental monitoring of vast areas such as a forest. To address these problems, monitoring combined with wireless sensor network technology presents a solution for forest management and forest fire detection. It is important to set the arrangement of remote measurement nodes and network topology configuration to be just right for the application environment.

In addition, it is important for the wireless sensor network[14, 15, 16, 17, 18] of environmental monitoring of forests to share information through the wireless network between remote nodes and implement an effective monitoring platform that can accommodate a wide range of sensors according to the remote node control and monitoring, extensibility of the area and low cost.

For monitoring forest fires, a real-time system to prevent fires in wider areas should be consistently supported. However, there has still been an overall lack of support for real-time systems related to forest fire monitoring. In addition, the 'real-time' processing in a forest fire detection system can lead to excessive consumption of energy. To solve these problems, intelligent data acquisition of sensing nodes is required, and maximization of energy savings as well as rapid and accurate detection by flame sensors needs to be ensured. Therefore, this study focuses on reducing power consumption of remote sensing nodes and allowing for efficient monitoring of forests based on wireless sensor networks from the perspective of data transfer, network stability and data collection. Therefore, it can contribute to extending battery life through intelligent sampling of the remote sensing node.

Since the occurrence of forest fires is very sensitive to a variety of environmental factors such as solar heat, ignition, humidity and temperature, this paper seeks to implement an intelligent embedded system in order to efficiently conserve the energy resources of nodes and propose an application framework for detection and prevention of forest fires using flame sensors based on a mesh network for the safety of the network.

In addition, as a large amount of data processing can lead to an increase in the energy consumption of the sensing nodes, filtering the data processing of remote sensing nodes and transmission methods are required to alleviate this problem. Accordingly, the data measured of the remote sensing nodes is analyzed by incorporating the intelligent sensing algorithm of the sensing node itself, and then it can be transmitted to a router or a gateway.

This paper is organized as follows. Section 2 discusses research related to WSN applications, and Section 3 describes the wireless sensor network-based intelligent embedded forest environmental monitoring application proposed in this paper. Section 4 describes the results of implementation and analysis, and Section 5 provides conclusions and references.

2. Related Work

For the prevention of natural disasters in environmental monitoring, it is almost impossible to require continuous monitoring by person in a conventional method. In addition, as outdoor wireless cameras in environmental monitoring are very sensitive to changes in the environment, they are vulnerable to natural disasters. As demonstrated in various literature, wireless sensor network technologies are applied to solve these problems, enabling long-term continuous monitoring.

The wireless sensor network applications are being applied in a variety of fields such as structural monitoring, environmental monitoring and animal monitoring, etc.

Paper [6] describes the development and characteristics of the wireless gas sensor network (WGSN) for the detection of combustible and explosive gases. WGSN consists of sensor nodes, relay nodes, a network coordinator and a wireless actuator. The sensors consume a large amount of electric power, which negatively affects the lifespan of the node. Accordingly, in this paper, a pulse heating profile was used to achieve significant energy savings. Additionally, the experimental results of this paper involve the method to determine the optimum temperature. The sensitive layer for detecting methane gas displays the response time of the sensor to various gases and evaluates the power consumption of the sensor node.

Paper [4] provides a solution that measures both temperature and humidity inside the concrete structure with respect to automated sensor monitoring on the civil engineering structures. The purpose of this paper was to develop prototypes of WSN to monitor specific concrete structures.

Paper [1] is about the application of environmental monitoring, and it describes major technical challenges and features as follows. (1) The sensor network has to be generally applied in micro-environmental monitoring with an open interface for data acquisition and processing. (2) It can be controlled through WSN monitoring and a web interface. In particular, the system of this paper is actually applied to general micro-environmental monitoring, and its execution is designed with the automated system. In addition, as sensory information is relayed by BS, extensibility can be improved. Also, among multi-hop routing protocols, surge routing protocol is used, and it is selected for nodes that establish a packet path with BS from each terminal nodes.

Paper [7] is about the monitoring of animals, and it describes research on the data communication needs for livestock agricultural monitoring using a wireless sensor network.

In terms of the data download of animal monitoring, a relatively short transmission range coupled with significant node mobility indicates sporadic network connectivity, which stems from the fact that sensor nodes are not close enough to form fully-connected networks due to the natural movement of the animals.

Paper [2] proposes a multi-resolution compression and query (MRCO) framework that supports data storage and network data compression in a wireless sensor network of the time and spatial domain to satisfy requirements that can inquire about detailed data of a particular area to allow users to analyze abnormal events aperiodically. The method of this paper can save energy of the sensors and support monitoring WSN application for a long period of time by considering the hardware limitations of the sensor nodes.

In the existing literature, multi-hop communication [1, 2, 3, 9, 12] that transfers environmental data such as the temperature and humidity of a neighboring node, and then transmits them to the host PC, a system administrator was used.

The multi-hop method can greatly extend the life of the network [1], and each sensor node is composed of small wireless devices in WSN. That is, it can subsequently collect environmental information and report it to a remote sink through multi-hop ad hoc network [2].

Paper [8] proposes a comprehensive framework on the use of wireless sensor network for detection and monitoring of forest fires. The framework includes a proposal on the wireless network architecture, sensor mounting scheme, clustering and communication protocols. The purpose of the framework is to detect the risk of fire as soon as possible and consider the energy consumption of environmental conditions that can affect the level of activity required for the sensor node and network. This paper shows that it is possible to ensure rapid response to forest fires, while efficiently consuming energy.

However, the sensor network is facing serious obstacles such as limited energy resources that need to be carefully considered and high vulnerability of harsh environmental conditions. In addition to early detection functionality, estimation of the direction and rate of the fire is important for the suppression of that particular fire. In case continuous monitoring of the entire forest is required but not carefully planned, it leads to excessive use of energy. Accordingly, the wireless sensor network for the detection of forest fires requires consideration of multiple parameters as well as merits and demerits. In other words, sensor nodes do not consume a lot of energy since there are no forest fires occuring during normal environmental conditions.

The distributed protocol that can be executed in each sensor node considers notification on the possibility and occurrence of a rapid fire to a control center in case of abnormal temperature changes.

However, data that arrives at the sink of the long distance between sensor nodes is not proper enough to rapidly detect fires and predict the direction of the spread of fire. In addition, the sensor node can be damaged by the spread of fire and the sensor network can fail to deliver data from all sensor nodes of a base station.

Paper [9] designs forest fire monitoring system based on the network and GPRS network to prevent the occurrence of forest fires. The data collected by the sensor node is transferred to the central node by means of multi-hop routing scheme through the deployment routing node, transmitted to the monitoring center, and handled by the central node.

Paper [3] describes real-time monitoring of a jujube tree based on WSN and GIS in the field of reproduction, and design and implementation of the management system.

This system includes two parts. First, it monitors data and collects some of them based on the WSN, and its sensor node can measure and collect various parameters such as air, temperature, soil information, wind speed, rainfall and image, and some information on videos. In addition, the communication protocol and node deployment method is discussed in this section. The WSN is a multi-hop sensor network and self-organization composed of static and dynamic sensors. This sensor can collect various kinds of detections and measurement (temperature, humidity, concentration of various gases and salt content, etc….) data.

3. Wireless sensor network-based forest environmental monitoring system

For forest fire monitoring based on WSN, a sensing node should be easily expandable and allow for efficient monitoring. That is, continued monitoring of forest fires and various environmental components for consecutive hours over vast areas. In this sense, such monitoring can be regarded as having a special significance. Therefore, forest fire monitoring should support a real-time system to continuously prevent fires from occuring in wider areas. However, there has still been a lack of support for real-time systems related to forest fire monitoring. In addition, 'real-time' processing in a forest fire detection system may result in excessive energy consumption. In addition, the real-time processing in a forest fire detection system can lead to excessive consumption of energy. To solve these problems, intelligent data acquisition of sensing nodes is required, and the maximum energy savings as well as rapid and accurate detection by flame sensors need to be performed.

In addition, another important purpose of forest monitoring is to predict sudden changes in the environment and take rapid countermeasures. If a flame sensor of an end node located in a forest detects a flame, the longitude and latitude of the flame can be transmitted to the manager's monitoring system through the database information on the node location. This way, rapid countermeasures can be performed. Furthermore, as analyses of changes in the forest environment require various parameters including temperature, humidity and sunlight, a multi-hop sensor network should be configured.

In this regard, this paper develops a node embedded filter algorithm for intelligent data collection of sensing nodes.

3.1 System Structure

This paper proposes a node embedded filter algorithm for intelligent data collection of sensing nodes for the early detection of forest fires. For a forest monitoring system for flame detection, the basic network architecture is constructed where dispersed sensing nodes acquired data and the measured data is transmitted to routers or gateways. Gateways provide remote monitoring connected to the host PC. The wireless data logging function can be added to the host PC.

Fig. 1 shows the overall system structure proposed in this paper. The forest environment monitoring system for flame detection based on wireless sensor network consists of gateways (G), sensing nodes (N), routers (R) and the host PC.

Gateways are network coordinators which perform node verification, message buffering and bridging to a cable Ethernet network from an 802.15.4 wireless network. It also acquires measured data from each node, transmits them to the manager and the host PC, through the Ethernet.

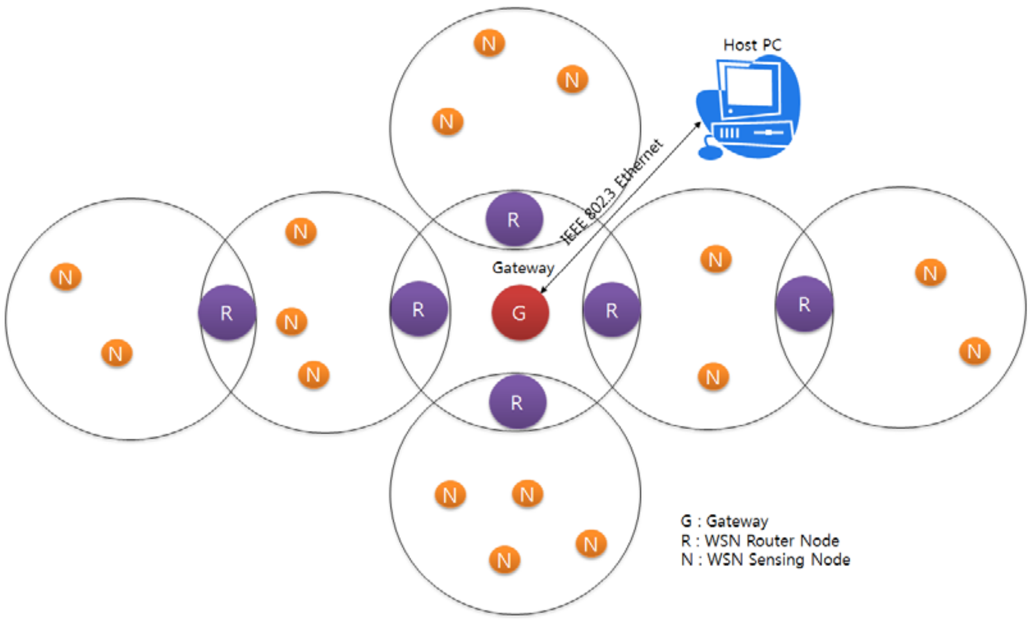

Fig. 1. Overall system structure

Sensing nodes are the end nodes in the system. Major functions that they provide include data acquisition and DIO channel control, as well as node operation and control using low-power processors. The developed program is capable of wirelessly downloading to the nodes, supporting life of up to 3 years through power supply from AA batteries, direct connection to the sensors and wireless data transmission to WSN gateways using an embedded 2.4GHz radio. Data is measured by directly connecting flame detection sensors, solar cells and other sensors to the sensing nodes.

As sensing nodes consume a lot of energy due to a rapid data transmission rate and frequent use of the radio, compromising with other factors should be considered to ensure energy consumption efficiency. Therefore, to support continuous environmental monitoring, development of an algorithm for lower power consumption must be seriously considered when developing applications to be built into sensor nodes.

Routers are used to expand the range of wireless communication between sensing nodes and gateways. If a router breaks down, the relevant sensing node automatically chooses the nearest router to use for data transmission.

In addition, sensing nodes and routers constitute a part of a wireless network managed by the gateways in terms of network management including client verification and data security.

The host PC is the manager of forest environment monitoring. Basically, it remotely displays the data transmitted through routers or gateways from sensing nodes, and it is capable of monitoring the information acquired by the sensors and the nodes status, as well as dynamic control of network status and node properties.

Fig. 2 shows data transmission/reception process between sensor nodes and the host PC.

The host PC and remote sensing nodes use network shared variables: they share and display real-time data through the shared variables displayed through the network. The network shared variables are communicated between the application installed in the host PC and the remote nodes through the Shared Variable Engine.

In terms of an application program, WSN is useful for such situations which require rapid distribution or distribution without infrastructure and continuous monitoring. Moreover, the work developed in this paper monitors real-time temperature and humidity changes. This greatly reduces the installation time and cost, which can be achieved by using the IEEE 802.15.4 network.

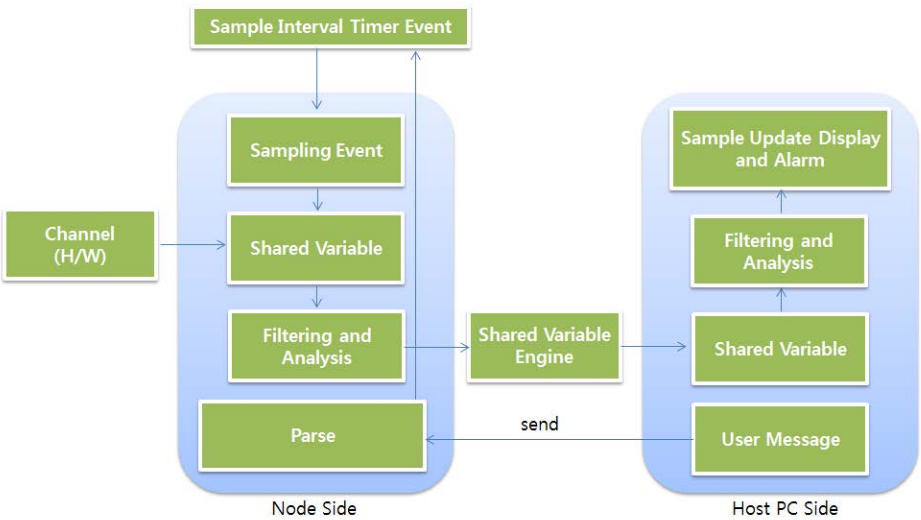

Fig. 2. Data transmission/reception process between sensor nodes and the host PC

This paper, to reduce power consumption, proposes an intelligent sensing algorithm related with data acquisition and transmission by remote sensing nodes and a monitoring algorithm for the status of remote nodes, which are described below.

First, the execution and measurement mode are applied to the intelligent sensing algorithm. The nodes' application use event-based execution framework to actively set the detection timing. For example, if the value of the sensed data is larger than the pre-set threshold, the detection timing is controlled and implemented for analysis and evaluation. And unnecessary information is filtered using selective tuning. The intelligent sensing algorithm is proposed in Section 3.2, Execution Model of Sensing Node.

Second, the node status monitoring algorithm is an algorithm to solve such issues as node malfunction and energy control/alarm set off, which is implemented in the manager, the host PC. The node status monitoring algorithm is proposed in Section 3.4.

This paper designs a multi-hop protocol-based sensor network that is appropriate for forest environments. Additionally, it performs tests on WSN through automatic distribution of the software that is to be embedded into the remote nodes, as well as sensing and analysis from the nodes that are remotely located. In this regard, our goal is to achieve continuous monitoring for prolonged hours and rapid flame detection using WSN connected with flame sensors.

In addition, the monitoring system proposed in this paper is capable of monitoring the time of the latest communication, battery and link quality of the nodes.

3.2 Sensor Node and Distribution

The WSN-based forest fire monitoring system consists of sensor nodes, sink nodes, transmission network and monitoring sensor. First, the sensor nodes dispersed throughout the forest acquire wind velocity, temperature, humidity and other signals in real-time [9].

As sensor nodes use batteries for operation, extending the network's life through reduction of power consumption is an important issue. They have very limited calculation capabilities and even smaller memory size. WSN is distributed to support long-term monitoring of a certain area. As the sensor nodes are required to regularly report sink data, the communication overhead will control power consumption. Due to the large amount of these regular reports, the nearest sink sensor nodes suffer from heavy traffic load and rapidly consume energy [2].

Therefore, it is imperative to reduce overall data transmission by sensor nodes.

To reduce power consumption of the nodes, this paper proposes an intelligent sensing algorithm which filters unnecessary information and reduces the volume of transmitted data using selective tuning, which sets the transmission volume from the sensing nodes depending on the environmental variables of the forest. This algorithm should not be complicated, as it is to be embedded into the sensing nodes.

Therefore, there are two strategies for forest environment data and flame sensing by the sensor nodes. First, a filtering algorithm which uses selective tuning to achieve efficient power consumption by the nodes can be performed. Second, dynamic alteration of the environmental parameters can also be performed by transmitting user messages from the host PC to WSN nodes. These types of dynamic applications in the sensors have sufficient sensitivity and accuracy of the wireless network, due to immediate response to changes in the environment and situation. For example, if the sample value is larger than the pre-set value of the environment parameter, data are transmitted to the host PC at a higher sample rate.

The execution model of sensing nodes for the intelligent sensing algorithm uses an event-based execution framework. The framework sets the node to the Sleep mode until the time to process the event (the Sleep mode is not set if the node is set to the router), and it is designed to optimize battery life. Events that occur during execution of other statuses are processed immediately after the completion of the current status. Statuses are classified into the following 5 statuses: Start, Sample, DIO Notification, Network Status Change, and Receive.

• Start status

The event-based status sets the connection of the node to the gateway, and it is called when the power is turned on in the node prior to joining the network. In the start status, the early sample interval timer of the node is set. By controlling the application of the WSN nodes, the nodes' properties are set so as to allow for setting of the sample interval rate. That is, the WSN node application is designed to control sample intervals. In this paper, the initial value of AI0, AI1, AI2, AI3 were set as (2, 1, 1, 1). AI0 represents the input node for flame sensor data, and AI1 represents the solar cell. Also, the initial value sets for AI0, AI1, AI2, AI3 are delivered to the sample status.

• Sample status

In the sample status, the I/O reading and writing, data transmission through WSN and application of various algorithms for power reduction can be achieved.

Therefore, this status performs certain I/O actions of the embedded targets of the measurement node. Measurement is performed from AI0, AI1, AI2, AI3 nodes, and the data between the host PC of the WSN network and the WSN nodes are transmitted and received.

To reduce power consumption by the nodes, if the environmental parameter values, such as the flame measured at the AI0 node, is larger than the threshold set under the start status, the node's sample interval timer setting increases the data transmission volume, otherwise, the usual sample interval timer is maintained.

• DIO Notification

DIO Notification is called when a value change event occurs at the digital circuit. It is configured with Generate Notifications property. If a digital value change event occurs, the DIO notification case stands by for execution.

• Network Status Change

The network status change is called when the node loses setting or gateway connection. In case of network status change, the connection setting is notified to the host, and node action change is performed until the connection is reestablished.

• Receive

This status is called when WSN nodes receive user messages from gateways. The user message is transmitted from the host PC, and stored into the gateways. The gateway delivers the message to the nodes as they perform radio activities that occur next. As for reception, the user message from the host PC is parsed. When the message is transmitted from the host to the nodes, it is stored in the FIFO memory buffer of the gateways. The gateways attempt transmission of each message to the relevant nodes.

Sensor nodes are distributed depending on specific algorithms in order to optimize the existing network resources. Efficient sensor network configuration is one of the most important issues in the monitoring field, in terms of sensor ranges and influence of communications [3].

The application developed in this paper to preserve power and extend battery life is downloaded and wirelessly embedded to the nodes. The remote sensing nodes perform custom analysis, embedding of decision making and extension of battery life.

3.3 Network Topology

Communication protocols for applications are divided into ZigBee with transmission range of 10-100m, wireless LAN with transmission range of several kilometers, and Bluetooth with transmission range of 10 square meters. Bluetooth offers low power consumption and cost, but its transmission range is too small. In comparison, ZigBee is suitable for environmental monitoring and supports low-speed data transmission at 20-25Kbps.

Most sensor networks use the conventional wireless network standards, that is, IEEE 802.11 wireless LAN or IEEE 802.15, ZigBee or Bluetooth. Bluetooth and wireless LAN operates at the ISM band at 2.4 GHz [5].

Despite the complexness in terms of network adoption, the multi-hop method was able to greatly extend the network's life [1].

Sensor nodes acquire data and transmits it to the data management system. Sensor nodes use the most power when transmitting the data. Therefore, appropriate communication protocols play an important role in extending the life of sensor nodes [3].

The sensor network in this paper uses an intelligent algorithm capable of processing network requirements when one or more nodes fail. First, upon discovery of a malfunctioning node, a network must be able to guide the data through various paths and prevent packet loss. To ensure multi-hop communication rather than P2P, the data will be transmitted to base stations using multi-hop [11].

3.4 Sensing Monitoring based on Shared Variables

Shared variables use the data of the node channels as data source, and supports data transmission through network. Therefore, shared variables are used to deliver the remotely measured data to the host PC. The detailed sensing monitoring is described in Algorithm 1.

The data measured by remotely located sensing nodes go through the following procedures to support monitoring by the host PC.

Step 1. References for WSN gateway are generated.

Step 2. References are generated for the sensing node to update the environmental parameters of.

Step 3. Host PC monitoring applications uses the shared variable on the AI node of the measurement node, and generates shared variable nodes for each measurement node. In this paper, to verify reception of new sensors by flame detection sensors, time stamps are added to the channels of flame measurement connection nodes.

Step 4. Shared variables are generated for the application at the host PC, and are activated with the shared variable nodes. The variable parameter of the shared value nodes display the current value read from the analog sensors into a graph.

Step 5. The update threshold is set. That is, an application is configured to deliver user message to nodes. The format of the strings is set to "threshold:AI0:AI1:AI2:AI3" and this format configures the data of user's message string into a single string.

Step 6. The user message designated at Step 5 is delivered to the relevant nodes.

Step 7. The status of the message transmitted to WSN nodes is returned to the host PC, which monitors the message status.

Algorithm 1 Sensing Monitoring

```
WSN gateway :
    Create Reference
Sensing Node :
    Sets an initial sample interval for the node
    Create Reference
    Return message status to Host PC
Host PC :
    foreach AI Terminal do
        Create Shared Variable Nodes
        if (Flame Channel) then
            Flame Channel ← Add Time Stemps
    end
    if (Shared Variable) then
        Activity Shared Variable
    Threshold ← "threshold:AI0:AI1:AI2:AI3"
    transmit updated Threshold message to Sensing Node
    if (message of Sensing Node) then
        message status monitoring
```

4. Experiment and performance Analysis

This paper proposed a forest environment monitoring system for early flame detection. The hardware for system structure consists of remote sensing nodes (routers), gateways and flame sensors.

The remote sensing nodes can be programmed with NI WSN-3226, and consists of 4-channel, 20bit, and programmable power/RDT combination. Additionally, the radio mode is IEEE 802.15.4. The gateway is NI-WSN 9791, and it is the network coordinator which connects to the Ethernet to deliver the information received from remote nodes to the host PC. The flame sensor for flame detection has an embedded R2868 sensor, and the wavelength of light to which the flame sensor reacts to ranges from 290nm to 260nm.

Table 1 shows the parameters used for this experiment. The radio of the gateway and nodes support lower power consumption at IEEE 802.15.4, 2.4GHz, and provides data rate up to 250Kbps.

The performance of a wireless network depends on energy efficiency, accuracy of detected data and quality of service. Among these elements, the energy efficiency holds the greatest importance. Therefore, in the experiment, the accuracy of network-based flame detection was measured while minimizing energy consumption.

This paper calculated the measured voltage when delivering data from a node to the host at a regular interval, to measure power consumption for early forest fire monitoring.

This paper measured the voltage of flame detection sensor at different distances using candlelight, to test flame detection.

Fig. 3 shows the voltage of flame detection sensor connected to the node with the candle unlit, without applying the filtering method for data transmission proposed in this paper. The distance between the candle and the sensors was maintained at 15cm. The host PC represents the voltage due to information transmitted to the sensing nodes at regular intervals.

Table 1. Experiment parameters

Device	Parameter	Value
Gateway	Ethernet Communication rates	10/100 Mbits/s
	Input voltage	9~30 V
	RF data rate	250 Kbps/s
	Frequency band	2.4 GHz
	wireless-channels	11-24
Node (Router)	RF data rate	250 Kbps/s
	Frequency band	2.4 GHz
	ADC resolution	Up to 20bits
	Sensor Power	12 V
	User Flash Size	188 Kbytes
	Number of channels	4
Flame Sensor	Current consumption	80~100 mA
	wavelength of light	180~260 nm
	Output pulse width	180 msec

Voltage during non-detection was infinitesimal, ranging between 0.00096 and 0.00108. The total of measured voltage is calculated by Equation (1).

$$Total\ of\ measured\ voltage = \sum_{i=1}^{n} V_{cal} \tag{1}$$

Where V_{cal} is the measured voltage, n is the number of measurements (2,000 in this case). Measurement was performed varying the distances for 34 minutes.
The power line filtering in this experiment is set at 50-60Hz, with an assumption of 50Hz(S), and resistance (R) of 0.1**Ω** . Thus, the average electric current is calculated with Equation (2).

$$I_{avg} = \frac{\sum_{i=1}^{n} V_{cal}}{S \times R} \tag{2}$$

Therefore, the average energy consumption is as shown in Equation (3).

$$Power_{avg} = \frac{\sum_{i=0}^{t} I_{avg} \times V}{t} \tag{3}$$

Where t is time, and V is supply voltage.

Fig. 4-10 shows the measurement result of flame detection at different distances. With the candle lit, the distance between the flame sensors of the measurement nodes was set at 15cm, 30cm, 60cm, 90cm, 120cm, 150cm, 200cm, respectively, with the data transmission filtering proposed in this paper being applied. The graphs represent accuracy of flame recognition by the nodes' sensing filtering algorithm at different distances. The correlation between distance and detection accuracy was evaluated as shown in **Fig. 11**. The figure shows that the detection rate drops when the distance between the candle and the sensor reaches 150cm. In addition, to add a function to extend battery life by controlling sample speed and determining data transmission timing, a mechanism was configured to deliver orders from the host PC to the nodes. Also, the host PC provides a user interface capable of monitoring the status and link data of the network of the sensor nodes.

The above experiment verified the long-term continuous monitoring capability of the nodes' intelligent algorithm, as well as the accuracy of flame detection under dispersal setting.

The topology for the monitoring application to forest fire detection is based on a mesh network for safety. This experiment was conducted by the simulation for flames detection through candlelight by placing a gateway(G), router(R) and WSN Sensing Node(N) in the laboratory. When assuming that materials are placed as Fig. 1 in the actual application, a node can search for another router nearby even when one router breaks down. The information may be ultimately transmitted through the application monitor. Accordingly, by placing nodes based on a mesh network in the actual application, it could be determined that there was efficiency in forest fire detection.

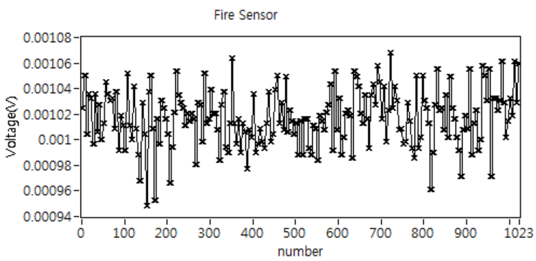

Fig. 3. With the candle unlit (without applying the filtering method - distance:15cm)

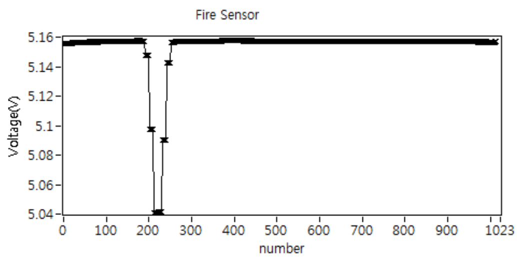

Fig. 4. With the candle lit (applying the filtering method - distance:15cm)

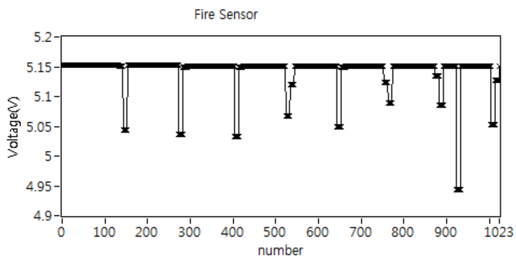

Fig. 5. With the candle lit (applying the filtering method - distance:30cm)

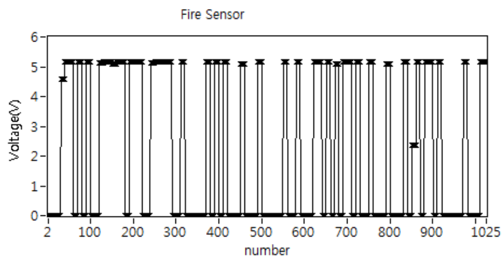

Fig. 6. With the candle lit (applying the filtering method - distance:60cm)

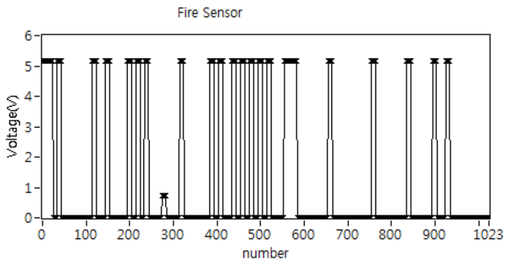

Fig. 7. With the candle lit (applying the filtering method - distance:90cm)

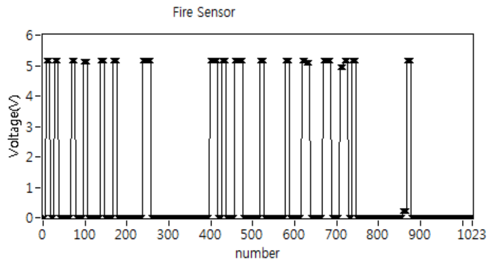

Fig. 8. With the candle lit (applying the filtering method - distance:120cm)

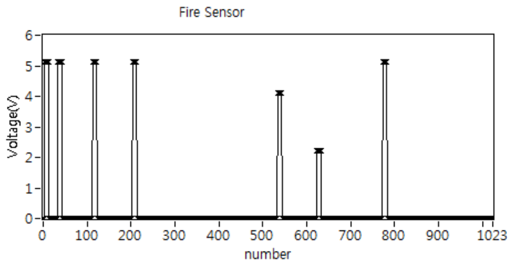

Fig. 9. With the candle lit (applying the filtering method - distance:150cm)

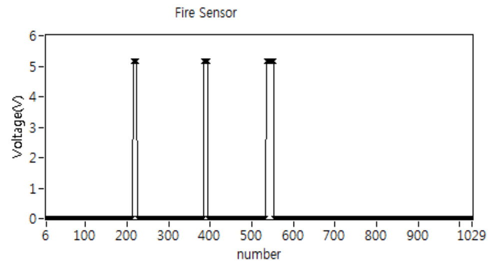

Fig. 10. With the candle lit (applying the filtering method - distance:200cm)

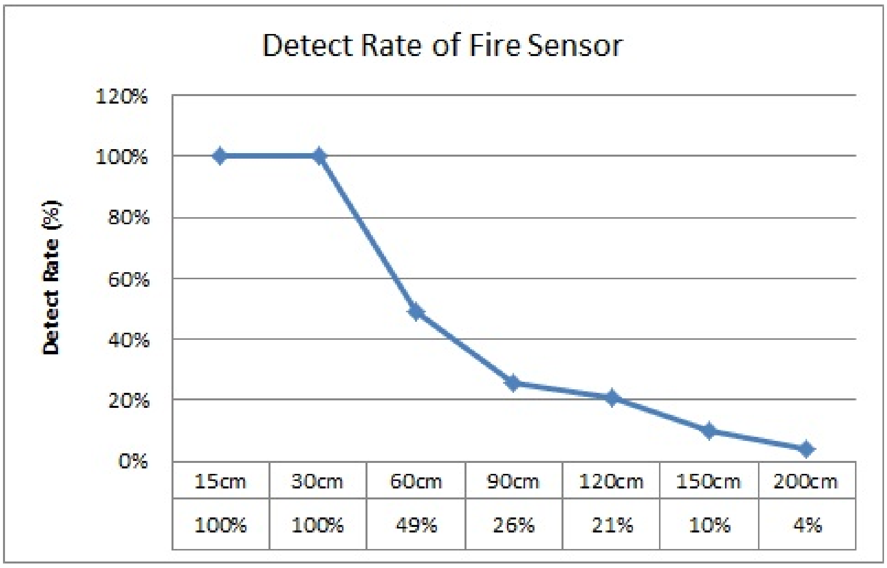

Fig. 11. Extraction rate according to the distance of flame detection

5. Conclusion

This paper proposed the wireless sensor network-based forest environmental monitoring system for efficient management of forests and rapid detection of forest fires.

As processing a large amount of data causes an increase in the energy consumption of sensing nodes, data processing and transmission methods through the filtering of the remote node side were used. In other words, the data measured at the remote sensing node is analyzed by incorporating the intelligent sensing algorithm of the sensing node itself and transmitted to a router or a gateway, which makes it possible to conduct continuous monitoring by providing efficiency of energy use of the node.

The wireless measurement and monitoring system of this paper can reduce the installation and maintenance costs and help to address the problems of a new application that is impossible to be solved through a wired system by simplifying the application deployment of remote nodes through a wireless one. In addition, the use of a wireless sensor network system contributes to the reduction of system construction costs and providing a wide range of embedded monitoring applications.

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Jung-Hee Seo received a B.S. degree in Computer Science from Silla University in 1994, M.S. degree in Computer Science and Statistics from Kyungsung University in 1997, and Ph.D. degree in Electronic Commerce System from Pukyong National University in 2006. She has been a assistant professor with the Department of Computer Engineering, Tongmyong University, since 2000. Her research interests includes Remote Education, Multimedia, Image Processing, Information Protection, Mobile Application.

Hung-Bog Park received B.S and M.S. degree in Computer Engineering from Kyung-pook National University in 1982 and 1984. Ph.D. degree in Computer Science from Inha University in 1995. Since 1996, he has been a professor with the Department of Computer Engineering, Pukyong National University. His research interests includes Multimedia Application, Remote Education, Compiler, Mobile System.