# Implementation of a USN-based disaster prevention system in Korea

DAE-HYUN RYU, HO-JUN NA, and SEUNG-HOON NAM

*Abstract*— The rapid economic rise of Korea has also led to the rapid development of infrastructure. As this infrastructure becomes more complex, it is becoming more and more of a challenge to appropriately monitor. As a result, there have been several occurrences of preventable disasters taking place and, if nothing is done, the frequency of such disasters is likely to increase. With wireless communication, sensor networks, and standards such as Zigbee becoming mainstream, it is now possible to implement disaster prevention systems for many applications. This paper suggests and designs an efficient ubiquitous sensor network-based disaster prevention system that monitors gas lines for leaks. Using our system, it's possible to monitor and control relevant facilities in real-time. This near-immediate reaction time will allow for the evacuation of affected people and rapid emergency response in the event of a leak, thereby saving lives and preventing a disaster from occurring. This system may be a key component of new government policy that holds the safety of citizens in the highest regard.

*Keywords*— ubiquitous, sensor, networks, disaster, prevention, USN, WSN, gateway, management server

## I. INTRODUCTION

INFORMATION and communication technology in a modern information-based society can have a great effect on the society and culture of a nation as a whole and is a measure to estimate a nation's level of advancement.

Information and communication technology also allows for the advancement of the state of the art in nation management. As society becomes more complex, the necessity to prepare for accidents and mass disasters is becoming increasingly evident and even expected by the population. Information communication technology can play an important role in feeding relevant data to a disaster prevention management system that can predict and inform of impending disasters and can help to co-ordinate an appropriate response to a given situation, thereby reducing the ripple effect that a disaster can have on emergency response resources. Generally, there are two types of disaster: man-made and natural disasters. Man-made disasters happen as a direct result of using some technology prevalent in a modern society. Examples of these types of accidents include: car accidents, fire, building collapse, explosions, radioactive spills, etc. Natural disasters occur as a result of some natural force such as: earthquakes, flooding, typhoon, tidal waves, hurricanes, tornados, damage caused as a result of cold weather, etc.

There are many ways in which the frequency of occurrence of man-made disasters can be reduced significantly because these incidents are caused by the misuse of some form of modern technology. The solution to the problem of preventing man-made disasters is generally technical in nature. This type of solution would consist of some type of system that can recognize disaster situations by comparing data collected from monitoring devices with a safety index. The system would then be able to assist in forming an appropriate rapid reaction scenario.

Good examples of man-made disasters include the subway explosion in Daegu (South Korea) in 2003 and the Humberto Vidal explosion that occurred in Puerto Rico in 1996. These two cases are typical examples in which the rapid transfer of disaster information, real-time monitoring, disaster scenario analysis, and prompt fire extinguishment could have been used to limit the impact of the disasters. Using ubiquitous sensor networking technology, available wired and wireless communication infrastructure, and a server with decision-making capabilities, it is possible to construct efficient disaster prevention and monitoring system in Korea.

In this paper, we design a USN (ubiquitous sensor

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network) platform which prevents man-made disasters based on the scenario of a gas-leak explosion. Using our proposed system, we can monitor and control relevant facilities in real-time and can protect people within the disaster area by deciding on a course of action before the disaster occurs and quickly informing affected people what the appropriate course of action is. Thus affected individuals would be able to evacuate to a safer area. In addition, timely information about an impending disaster allows for the possibility of preventing a disaster from occurring by removing the root cause. This system may be the key component to new government policy that places the safety of citizens as a top priority.

## II. Related Works in South Korea

In June of 2004, the Korean government established the National Emergency Management Agency (NEMA).

It has also created the National Safety Management System, National Integrated Command Wireless Communication Networks using TETRA (terrestrial trunked radio), 119 Rescue Service and has a National Disaster Management System Plan in effect. The prevention aspect of the National Disaster Management System Plan contains provisions that promote the construction of a database by government, industry, and schools in order to share disaster-related information, simulate disasters and estimate risk, and provide simulation training for various disaster types. In order to provide these services at the prevention stage, we have built an emergency support system that uses GIS and GPS which interface with PDAs and an electrical dashboard system. During the reconstruction stage, we should implement a function that automatically estimates reconstruction costs, assists in reconstruction planning, manages the reconstruction process, and provide a feedback functionality which would allow for post-reconstruction analysis, evaluation, and disaster prevention.

In order to further develop the USN industry, the Korean government is currently in the process of creating and verifying a USN service model. The focus is on providing for the needs of next generation services, and enabling service verification. The National Information Society Agency (NIA) in Korea has developed application service models for USN field tests in the following scenarios: ocean, construction, form, village, and hospital. They also verified the technological, industrial, and economic properties of each scenario.

One example is the Marine Environment Information Monitoring System near the Jeju island, which is based on a USN. The objectives of the project are to monitor changes in the ecosystem and manage fishing resources efficiently. Sensors collect and analyze the amount of dissolved oxygen in the water and ocean temperature. Ten buoys which communicate with each other using a 2.45GHz wireless network are installed in the vicinity of the Jocheon port on the Jeju Island. The sensors and networking hardware contained within the buoys is designed to be powered by batteries that recharge automatically using solar and wind energy. Using this system, we can more accurately predict the weather, which depends largely on the changing temperatures of the ocean. It can also track ocean currents and be used to provide an early warning system in the event of a disaster. The migration path of fish can also be predicted by analyzing the amount of dissolved oxygen in the ocean water and water temperature.

Ubiquitous Sensor Networks may also be used to analyze concrete structures during construction. These sensors analyze a concrete structure's temperature, humidity, and strain which allows for accurate planning of the construction process. In the summer, if the sensors detect a low humidity level, fabrics can be used to prevent moisture loss. In the winter electric heating fans may be used to prevent newly poured concrete from freezing if sensors detect a temperature that is below a certain threshold. Despite using various automatic measuring systems, a field expert must always be on-site to supervise the construction project. This causes costs to rise. A USN can be used instead to monitor data collected while concrete structures are made and to control various equipment of field. In field experiments, monitoring information and controlling field equipment was successfully performed over long distance using mobile communication.

After the collapse of the Seong-Su bridge over the Han river, other bridges have installed sensors that verify that bridge movement is within tolerance. This information is sent to a management center. In the future, a safety check sensor which collects bridge telemetry will be installed on every bridge over the Han River. There are also plans in place to predict natural disasters such as floods, landslides, and typhoons using USNs.

Some embedded system or SoC companies in Korea are developing devices that support wireless sensor networks which use micro-sensors. These networks are based on the IEEE 802.15 standard and support UWB communication and Zigbee. The companies are also developing sensor modules for use in wireless networks which are ideal for monitoring applications.

## III. REQUIRED TECHNOLOGIES FOR USN

### *A. Short range wireless communication*

Short range wireless communication is a high frequency wireless communication technology which enables the exchange of data between devices over relatively short distances. Until recently, short range communication was local communication that required using wires as a medium.

Wireless communication has been developed to the point where it offers many advantages over short distances such as mobility, easy installation, and expansion. Short range wireless communication technologies include wireless LAN, Bluetooth, IrDA, and Zigbee.

There are a wide variety of applications for modern wireless communication technologies. Wireless LAN allows computers to network together over medium distances, Bluetooth and IrDA allow for close-field communication, and mobile phone technologies such as CDMA and other technologies such as Zigbee are commonly applied to sensor networks. Ultra-wide Band communication is being combined with the Zigbee platform to create the next-generation of short range communication. This type of technology is currently being developed to solve a multitude of varying problems, but the requirements for this technology often overlap. There is currently a race to develop the next generation short range wireless communication system.

### *B. High speed wireless internet*

a) HSDPA (High Speed Downlink Packet Access).

HSDPA is a packet data service with high downlink speed which uses the same frequency as WCDMA Release 99 and Release 4.

The maximum speed of HSDPA is 14Mbps, however due to the fact that multiple users on the same frequency must share bandwidth, average speed drops to between 2 and 4 Mbps. HSDPA supports a feature called ‘focus on peak speed’ in which bandwidth is optimized for signal strength, number of concurrent users, etc.

b) Wibro.

WiBro (Wireless + Broadband) is a high-speed wireless Internet service that provides reliable wide coverage.

WiBro guarantees high data speed (upload at 1Mbps, download at or below 3Mbps) while moving at up to 120km/h in a dense urban area. WiBro is the next generation communication standard that will allow for the development of a variety of new and novel solutions in the future. WiBro integrates the most desirable communication characteristics of the present and provides a platform for next generation communication services.> WiBro can be used on various devices such as cellphone/smartphones, PDAs(Personal Digital Assistants), HPCs(Handheld PC), Laptops, Ultra Mobile PCs, and PMPs (Portable Multimedia player). New and innovative convergence-centered business models can be created because of this platform potential. Mass-implementation of WiBro allows for the creation of a ubiquitous network, therefore digital content will no longer be subjected to platform restrictions, thus increasing its value to consumers.

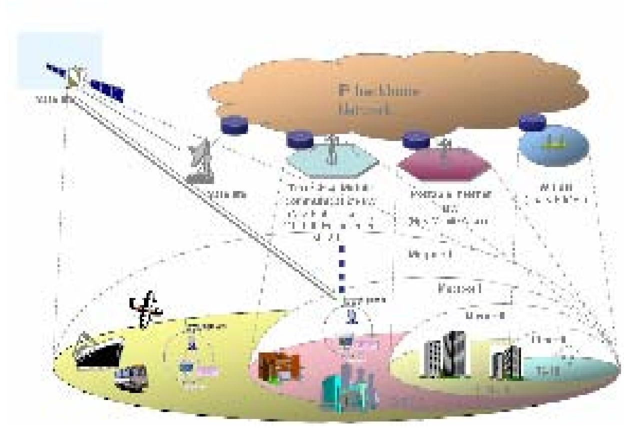

Fig. 1 Conceptual Diagram of Overall Networks

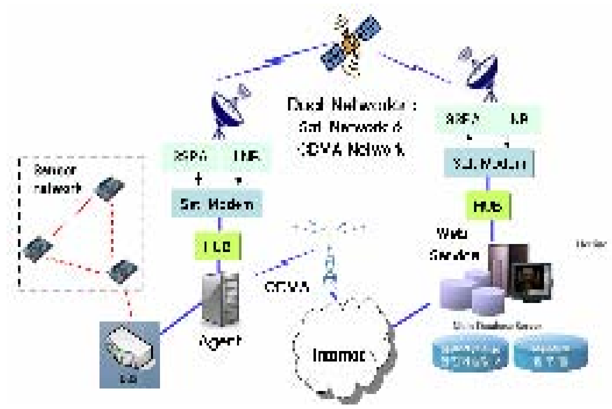

Fig. 2 Redundancy of Networks

### *C. IP based survival networks*

In a disaster situation, network survivability, flexibility, adaptability, reliability, and security are paramount. Sensor networks must therefore be a part of the Broadband communications Network (BcN) which an open platform incorporating communication satellites which automatically switch in when local wireless communication fails. Satellite communication has superior features of survivability, broadband, channel flexibility, QoS, broadcasting, and economically efficient unlimited communication range. Our IP-based survivability network incorporates satellite communication. Our system utilizes HSDPA and satellite communication in order to maximize the survivability of our network. It can transfer critical disaster-related information in any situation.

### *D. Standard web application framework*

Applications for web services implementing standard interfaces between web applications are diverse. New business models incorporating this functionality are gradually appearing. In the early stages of web services, the IT resource integration of a company utilized EAI (Enterprise Application Integration) and ESB (Enterprise Service Bus). B2B applications also began to use web service applications at this point. Amazon, Google, and Travelocity are good examples of this. More recently, web services are based on the BSN (Business Service Network) environment, business process fusion, and RTE (Real-Time Enterprise) operation models. Also appearing are business models which adopt open web service application models based on ubiquitous computing utilizing wireless network services like those offered by the Parlay group. Ruby on Rails (RoR) is a persistent web application framework. Its structure incorporates a model-view-control pattern. The framework includes everything needed for the development of web applications. This study presents a standard web application by prototyping a web application using the RoR framework. We verify availability using a basic function test and adopt it to the prototype system.

## IV. Development of USN based Disaster Prevention System

### *A. System configuration*

A USN-based disaster prevention system consists of three parts the goal of which is to transform the disaster related signal from sensors in the field and apply them to a disaster index. A sensor module is composed of transducers, a microcontroller, and RF communication (Zigbee). The sensor modules of which the sensor network is composed collect disaster related environment information. Disaster Gateway System (DGS) works as a server collecting data from the sensor modules. It converts the corrected data and transmits it to a management server through the internet by Ethernet or HSDPA. The sensors (transducers) transform physical information to an electrical signal and a sensor module (Transducer + Microcontroller + RF) converts the analog electrical signal to digital data and transmits it to the DGS through an ad-hoc sensor network. Because the sensor data which is sent to the DGS is just the digitalized raw data of the electrical signal, a data transformation process is required. The DGS generates data to be sent to the disaster management server through a data transformation process using data collected from sensors data and the node ID of the sensor module. Also, the disaster watching server stores the data collected from the sensors which observe the local environment and thus is about to detect disaster situations and provide detailed information in real-time.

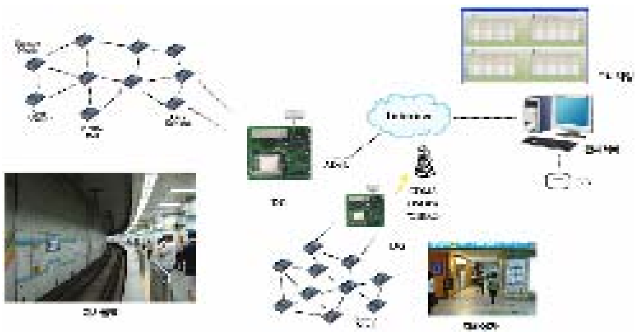

Fig. 3 Total System Configuration

### *B. Sensor node*

The sensor nodes in our system use on Atmega128 micro controller made from Atmel and CC2420 made from CipCon. CC2420 is 2400~2483.5MHZ bandwidth RF chip supporting IEEE802.15.4/Zigbee and 250Kbps data rate with O-QPSK modulation.

Each has send/receive data FIFO Buffer of 128Kbytes. Fig. 4 shows hardware block diagram of sensor module. Table 1 shows the Specification of Sensor Module. We ported TinyOS developed by UC Berkeley with AES for the security.

| | Device Node | Mobile Node | Sinc Node |
|---|---|---|---|
| OS | TynyOS | | |
| MCU | ATmega 128L | | |
| RF | CC2420(2.4 GHz) | | |
| Sensor | Gas sensor GS-02A | Temperature Sensor | Humidity Sensor |

Fig. 4 Block Diagram of Sensor Module

The sensors we use in each model of sensor module are as shown in table 2. Gas sensor GS-02A can detect and measure leaking Hydrocarbon (HC), CO.

Table 1. Specification of Sensor Module

| | | |
|---|---|---|
| MCU | Model | TI MSP430F1611 |
| | Type | 16bit RISC |
| | Program memory | 48Kbytes |
| | RAM | 10Kbytes |
| External Memory | Flash | 1MBytes(8Mbit) |
| | EEPROM | 128Bytes(1Kbit) |
| Radio | Model | CC2420(2.4GHz) |
| | Data Rate(Kbps) | 250 Kbps |

An ad-hoc network is constructed between sensor nodes. There are two kinds of sensor modules (sink node and sensor node). The sink node is a base node in a sensor network and also the final destination of collected data. Sensors are connected to sensor nodes which transfer collected data to the nearest base node.

Table 2. Model of Sensor Module

| Model | Sensor | Manufacturer |
|---|---|---|
| SHT11 | Humidity, Temperature | Sensirion |
| S1087 | Photodiode for visible range | Hamamatsu |
| S1087-01 | Photodiode for visible to IR range | Hamamatsu |
| GS-02A | CO | NIDS Co |
| B530 | $CO_2$ | NIDS Co |

*C. Disaster gateway*

The disaster gateway system works as a gateway connecting the sensor networks to a public IP network like internet (Fig. 5.)

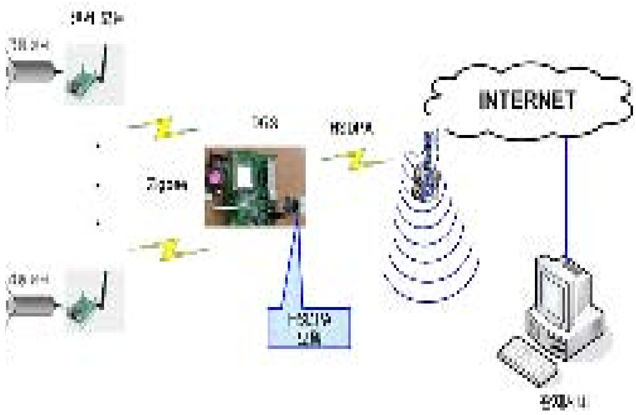


Fig. 5 Role of DGS

The DGS uses an ADM8668 for its main controller and is designed according to Fig. 6. The ADM8668 has a CPU inside with 8KByte D-cache and 8Kbyte I-cache of 32bit MIPS4KC with a working clock of 200MHz. It has two 802.3 Fast Ethernet MAC, one MAC supporting five LAN ports connected with a ADM6996I switch and the other one is used as a WAN port. It also supports a USB2.0 host controller, IDE and PCI interfaces. Fig. 7 shows the software structure of the DGS based on Linux. DGS includes the network stack and protocol needed for IP networking and can work as a router or AP. Dynamic IP addresses can be assigned from an outside network by calling an outer DHCP client function, it can also run service demon for assigning dynamic IP of the inner network.

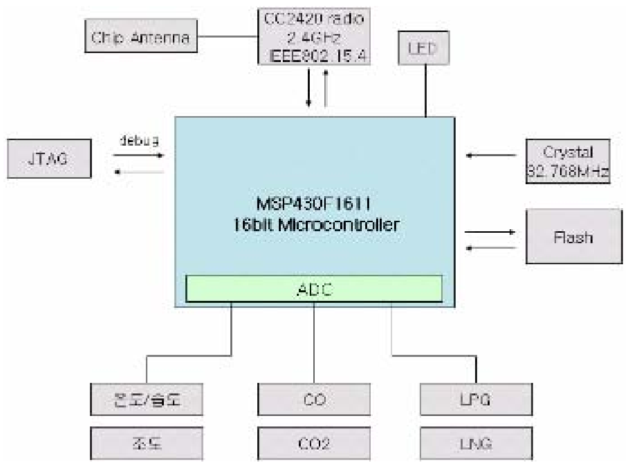


Fig. 6 Block Diagram of DGS Hardware

We can access internal settings via WAN using CGI. Internal settings are basic information used to control DGS functionality, WAN configuration and gateway IP address, and environment values for the sensor networks. DGS can connect to DHCP, Static, PPPoe and HSDPA through its WAN interface.

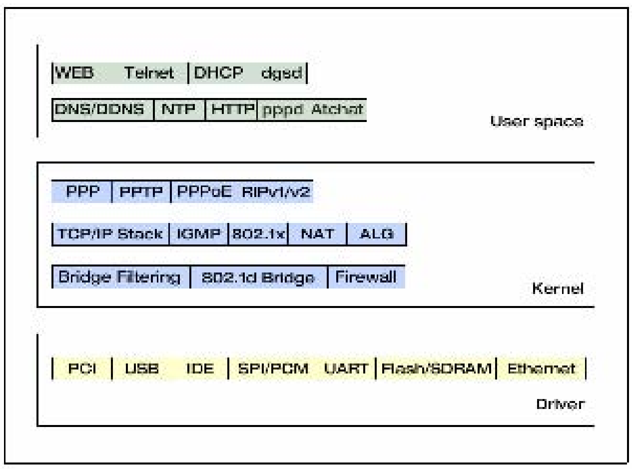


Fig. 7 Configuration of DGS Software

To connect to the sensor network the IP address and port number of the disaster monitoring server and the ID information of the sensor module are required. This information is managed as a file in the Linux system and restored when booting the system.

*D. Agent*

We build the agent to between the DGS and the management server as Fig. 9. The agent can reduce the load of upper layer system (management server). The management server can control the operation of the agent through service interface call and monitor DGS and sensor networks in real time with UI as Fig. 8. Fig. 10 shows the needs for the agent like the compatibility through web service interface and portability.

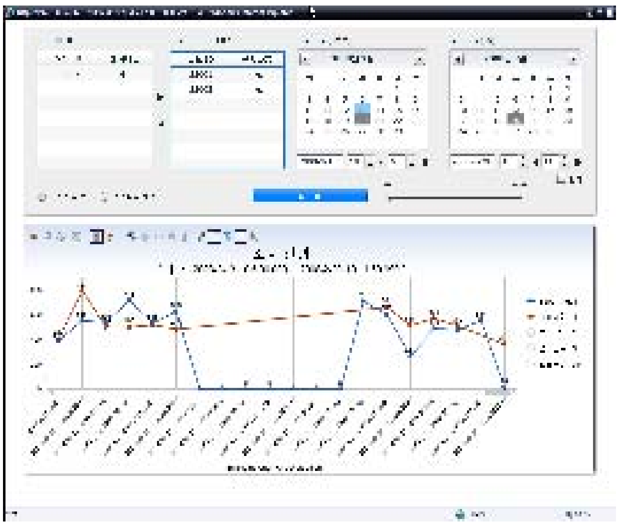

Fig. 8 UI of Agent

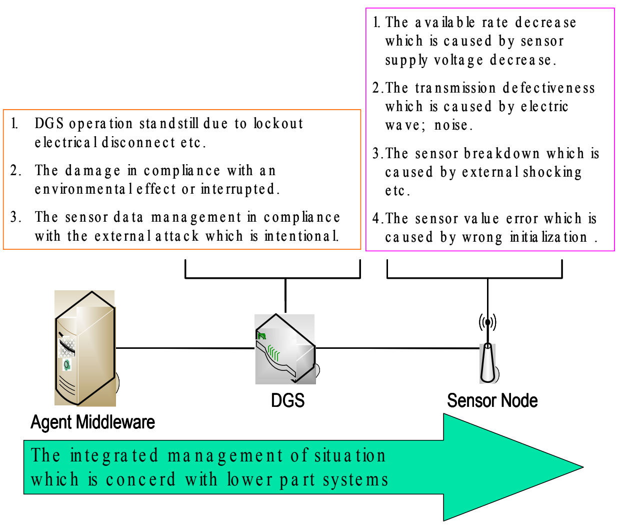


Fig. 9 Concept of Agent

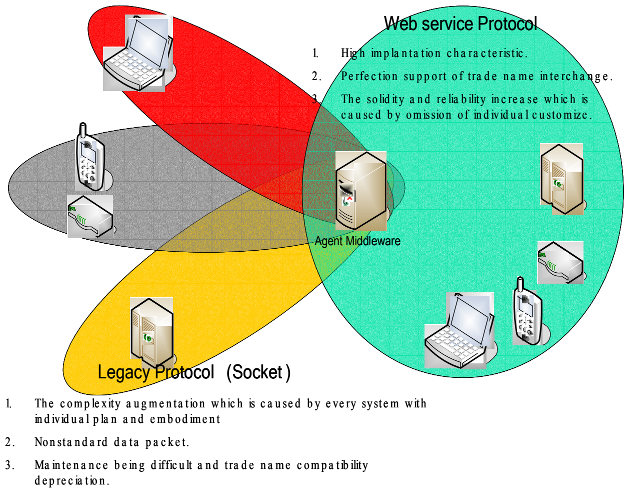


Fig. 10 Needs for the Agent

*E. Disaster management server*

Fig. 11 shows the output screen shown while monitoring environment information from sensors. Basic sensor information from the system DB and risk information is show on the monitoring screen. Dial shaped gauges and values in number format are displayed on the bottom of the UI in real time. The data from sensor is displayed as a graph. We can easily access basic sensor information such as sensor name, installed location, sensor model name, etc. Finally, our system evaluates disaster risk by analyzing the trend of collected data, the threshold value, and the risk index.

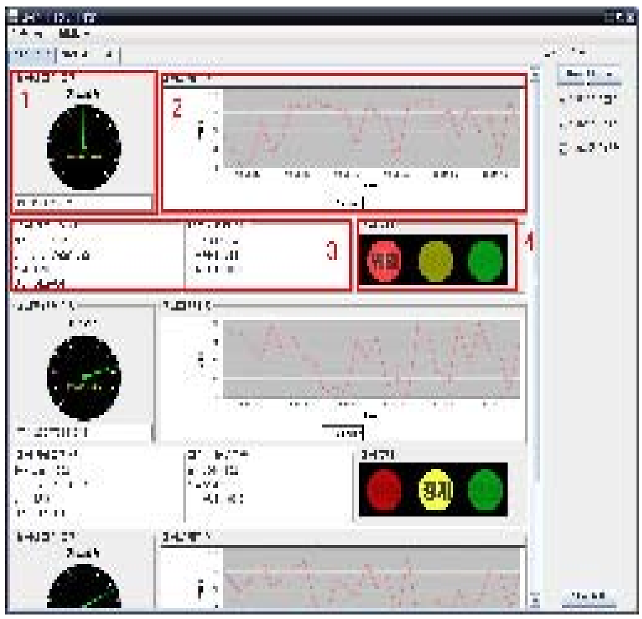

Fig. 11 Environment Monitoring

### *F. Real Time Risk Monitoring Program*

Fig. 12 shows the interface for the disaster monitoring system proposed in this paper. Disaster management systems can monitor an area which may be susceptible to risk and evaluate the risk to each area in two ways: a) Real-time: Sensors monitor a particular area of interest and send real-time information to the server. b) Trend analysis: information is collected every hour and output by graphically. c) Dangerous report information: The basic information of dangerous is saved on DB. d) The state of risk is may be one of three states: 'Danger', 'Caution', and 'Safe.

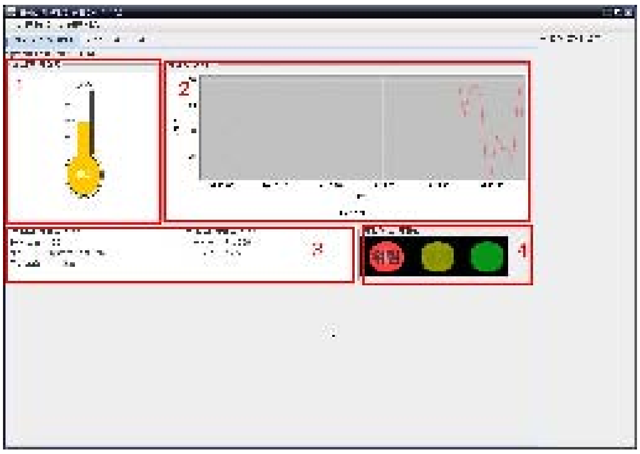

Fig. 12 Real Time Risk Monitoring

## V. Demo and Evaluation

Our man-made disaster management system consists of three components and its objective is to transform raw sensor data into a meaningful risk index.

The function of the middleware is to collect data from sensors and convert and send this data to higher level systems. The middleware collects the output values of sensors and converts this into data which the server can interpret. Our system collects output from sensors which consists of simple transducer-generated electronic signals and calculates an appropriate risk index.

The middleware combines sensor IDs and the values from each sensor to send to a local monitoring system. The local monitoring system monitors and saves the data collected from middleware at a certain time interval. The local monitoring system also evaluates the level of risk for the region in which sensors are installed. Using data collected from middleware, the local monitoring system evaluates the local risk level and transmits it to the risk management system. The risk management system monitors risk information collected from local monitoring systems in real-time. Fig. 13 shows the situation management process. The risk management system calculates the level of the risk of the total area in which the sensor monitoring system is deployed using the information from that system. The risk management system contains a DB which stores risk evaluation data, as well as basic information needed to display the results.

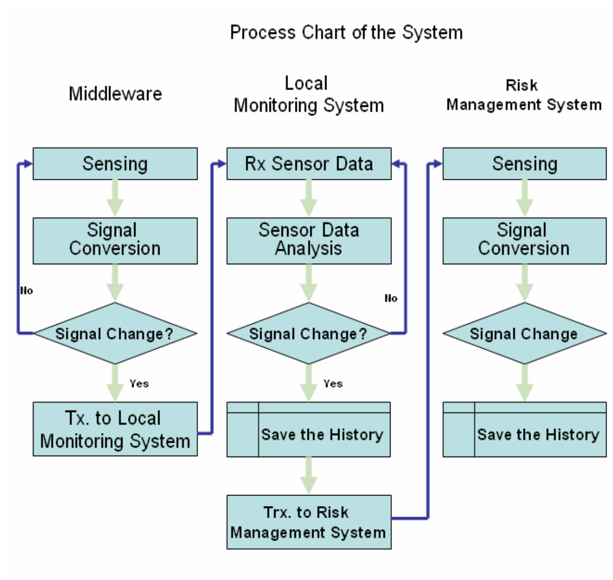


Fig. 13 Process Chart of Intelligent Man-made Disaster Management System

Fig. 14 shows the control room for monitoring man-made disasters. The risk management system updates the display if there is a change of risk information and logs that information in the DB. In this project we have also developed the risk index. Fig. 15 shows the process by which to apply the index to a gas spill. We classify the level of risk into four categories: 'safe', 'caution', 'warning', and 'danger' according to the risk index.


Fig. 14 Monitoring and Control Room for Man-made Disaster

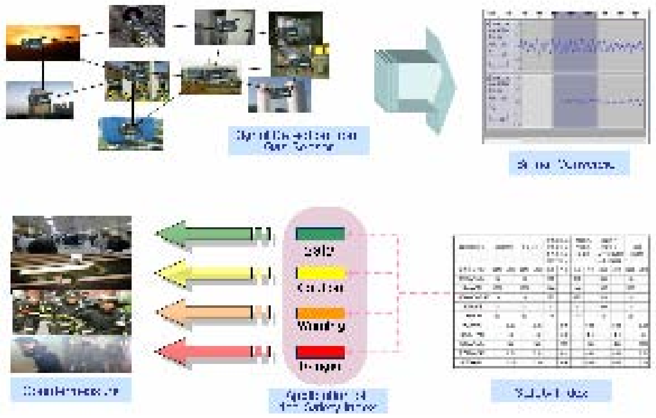

Fig. 15 Application Process of the Safety Index

## VI. CONCLUSIONS

A ubiquitous sensor network (USN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants. The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control.

Education of the causes and effects of man-made disasters is the most effective tool to prevent them. However, some in the cases, education is not enough of a preventative measure. An aging pipe that begins leaking dangerous gasses is difficult to detect and is generally not the result of lack of education. Thus, we can prevent this type of disaster using a real time sensing/monitoring system incorporating state of the art information and communication technologies.

In this paper, we suggest and design a USN (Ubiquitous Sensor Network) platform to prevent man-made disasters based on the scenario of a gas leak explosion. By implementing our system, we can monitor and control the situation in real-time and evacuate people from the disaster area or find a solution before the situation becomes critical.

In addition, it is possible that we can prevent the disaster from happening by quickly finding the root cause and removing it. Implementing our system can be a part of a policy that ensures that the safety of people is the top priority. We calculate a standard safety index by linking the policy DB, the DB containing risk data and disaster history, and sensor threshold values which determine if there is a gas leak. Because of rapid industrialization, cities having very high population density have appeared where infrastructure is very complex. This leads to a number of factors need to be considered: the likeliness of a disaster, expected damage, emergency response, and disaster prevention. Having accurate knowledge will lead to significant cost savings couples with increased public safety. This knowledge may be acquired by implementing the system which we have proposed in this paper.

Our system monitors vulnerable areas and calculates a risk factor accordingly, allowing rapid decisions to be made regarding the management of dangerous situations. Our system will also allow us to optimize disaster reaction strategies by analyzing responses to previous incidents. The ultimate goal of our system is to collect and analyze information quickly enough to prevent most disasters from happening. It requires that government extensively renovate the national disaster management system in order to shift the disaster situation management paradigm from reaction to prevention.

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