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REMOTE MANAGEMENT SCHEME FOR LANDSLIDE MONITORING SYSTEM APPLYING WIRELESS SENSOR NETWORK

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Abstract – In natural disaster mitigation, many methods and systems are being developed to reduce the effects cause by the phenomena to the lowest possible level. We introduce a landslide monitoring system based on wireless sensor network with strong processing nodes. For this system, a management scheme is necessary for operators to perceive the status of the system. The scheme being constructed has a potential to apply to similar systems if they possess same characteristics with this system.

Keywords: wireless sensor network, remote management, landslide disaster, distributed processing

1. INTRODUCTION

The current monitoring system is designed for monitoring the landslide disaster. This disaster is the phenomenon in which rock, soil, mud and other elements move down the slope under the effect of gravity and some other factors, usually the rain and ground vibration. The landslides happen every year, from small ones which only create a trail in the forest, to big, deadly ones that destroy a whole village.

Monitoring the landslide as well as other disaster is an attracting field to apply engineering and technology. The monitoring systems like wireless sensor networks (WSN) have been confirmed to be suitable and effective in detecting occurrences and warning. The system is designed in form of an event-driven wireless sensor network but also be able to function in programmed mode or on-demand mode [1].

During the operating time, the designers always want the system to run smoothly without any failure. Therefore, the robustness and reliability are very important. The system needs a management scheme which can monitor the current statuses and conditions of the elements. Knowing that information, the observer can easily understand the current situation at the field while staying dozens of kilometers away. Depends on the quality of the information and the complexity of the system, the reaction can be operate manually or automatically. Without management functions, it would be very difficult, or even impossible to perceive the current state of the monitored area. Because of this, a management system became indispensable for a better performance.

The previous researches on management for WSN are done in various forms, including frameworks, models, and systems [1], [3], [4], [5]. Each research had shown different view point, which became the motivation of this research. The frameworks and models provided broad views and specific prospective. The systems introduced in [6] and [7] possess early warning capability. However, the deployment is expensive and time consuming as the devices needs to be buried into the ground.

In this paper, we propose a management scheme for our current landslide monitoring system. The remaining part of the paper is organized as follow: Section 2 introduces the system as an object to implement the management scheme with some feature properties. In section 3, the management scheme is constructed based on the specialties of the system. Some valuable contributions of the management system for the whole system are shown in section 4. Finally, section 5 gives the conclusions.

2. THE LANDSLIDE MONITORING SYSTEM

2.1. System Elements

The system for monitoring landslide consists of three subsystems: Local Sensing Node Network System (LSNNS), Cloud System, and Host System (HS) [2]. Fig. 1 shows the model of the system.

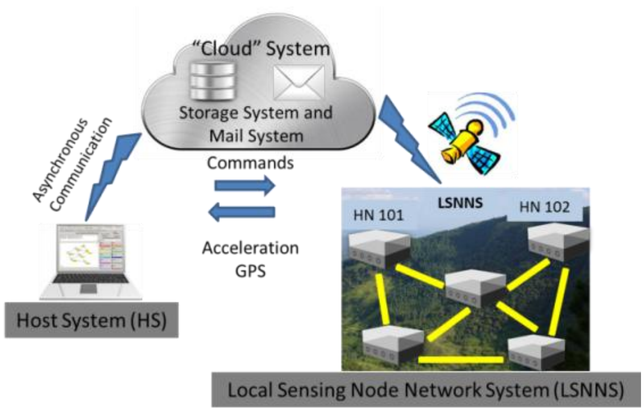

Fig. 1. The Landslide Monitoring System.

LSNNS includes a number of Sensing Nodes (SN) and Host Nodes (HN). SN can be equipped with different kinds of sensors: accelerometer, GPS, thermometer, soil moisture sensor, etc. Of all these sensors, accelerometer/acceleration sensor is the most important one since it can detect the movement of the soil. SNs also possess a strong processing capability to handle all the tasks: measuring, analyzing, and communicating with different sensors and other attached devices. Fig. 2 shows the logical functions of the elements in a SN.

In LSNNS, there is a small number of Host Nodes take the role of data collectors. These nodes communicate with SNs to gather various information before transmit to the HS. HNs also can forward the commands from the HS to the SNs since they can connect to HS via Cloud System while SNs should focus on measuring and analyzing. Fig. 3 shows the appearances of Host Node and Sensing Node. The nodes are light enough so the deployment can be very quick and does not need any special preparation.

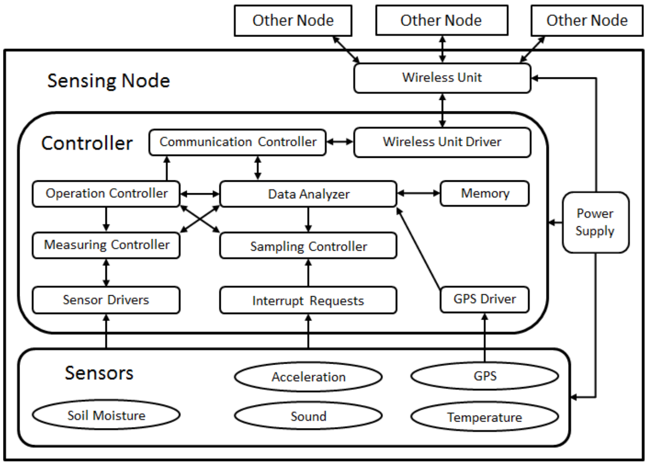

Fig. 2. Logical functions of Sensing Node.

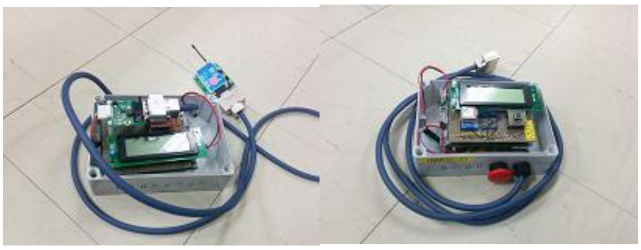

Fig. 3. Host Node (left) and Sensing Node (right)

Our system was designed to monitoring the disaster without posing any threat to human's lives. Therefore, the HS is placed far away from the monitoring field area. From here, the manager staff can see what happens at the field through the data sent from HNs. Data received at HS under the form of messages will be extracted and analyzed. The processing time should be very short and the results will be presented in different ways depend on the type of information. To perform control tasks, the staff can send commands from HS. Commands can be constructed by option selection or by typing with specific syntaxes. Either ways, the output commands are created in form of single messages with prepared syntaxes and can be decoded by Nodes. Fig. 4 shows the control interface of HS where commands are sent and received.

Since the HS and LSNNS are located at different locations, the Cloud System is used for the communication between these subsystems. Cloud System consists of the services provided by the Cloud providers. For the current system, free email and cloud storage services are being utilized. To connect LSNNS to Cloud System, we use Android smartphones in LSNNS to couple with HN. With Bluetooth and Internet connection, Androids successfully complete the tasks.

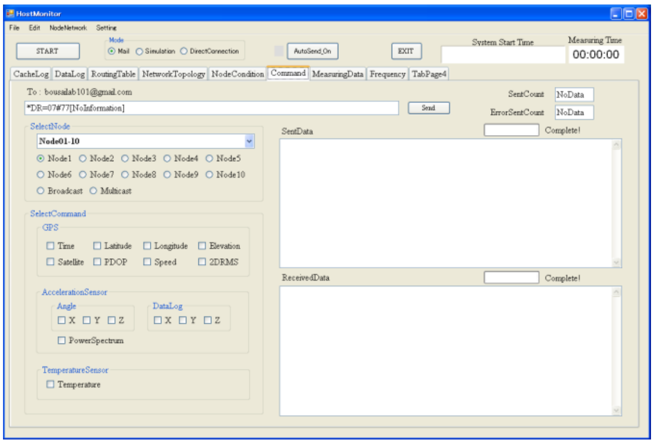

Fig. 4. HS control interface.

2.2. Management demands

Due to the nature of landslide phenomenon, the occurrence once happened would cause the effects spreading wider. Instead of using a high density but weak sensors, deploying stronger sensor nodes with lower density would be more efficient. With various sensors mounted on, SN is aimed to perform different analyses and provide a large amount of data so HS can have a better picture about the field. However, data sent to HS cannot be too large since it will consume both processing resources and communication resource. In this case, the data analyzing in each node becomes very important. Nodes can analyze data (distributed processing) then only transmit the post-processing information which is much lighter. The wireless connection may reach hundreds of meters, thus increasing the survival rate of the nodes. For this potential, a node may need to be stronger in physical design, power supply and operation.

Some features of current system can be summarized as follows:

- Distributed processing
- High capability nodes
- Low density network
- Cloud services utilizing
- Event-driven monitoring scheme

It is possible to manage down until the level of an individual node thanks to the high performance hardware. Strong hardware properties are effective not only in measuring data but also monitoring node conditions. A node can use the common resources for both management and measuring tasks. Because of this, the management elements can be embedded at the nodes to perform the tasks better.

The management tasks include controlling. Similar to monitoring, controlling can access to each node. The feature system would have management demands:

- Monitoring and controlling down to node's elements
- Handling multiple information in representing and controlling
- Improve the maintenance of communication links
- Internet-Cloud services monitoring
- Provide additional scheduled monitoring or manual monitoring scheme

The management job can keep the above mentioned requirement as the objectives to perform the management functions in the following areas: *configuration, accounting, fault, performance and security* [3]. Our disaster monitoring will focus on configuration, fault and performance more than the remaining two areas.

3. MANAGEMENT SYSTEM CONSTRUCTION

The construction of the management system for Landslide Monitoring System can be started with the common questions: Where? What? When? Who? How? The answers for these questions will determine the target of the management job.

3.1. Management targets

The objects to be managed in the system are: the nodes, the whole LSNNS and the Cloud System (where). In addition, the HS where data is managed also has its own data to be monitored. From this objects, we can extract many information belong to the following categories: node conditions, network conditions, operation, data (what). The information may differ depends on the operating condition. Therefore, the operation phases are the answers for the third question (when): initialization, network forming, configuring, idle, measuring, transmission, sleep and emergency. The management entities can be called managers and agents (who). The locations of the entities depend on the management architecture. Finally, the method to get the data (how) relies on certain entity and information.

When designing a WSN, there are evaluation criteria being considered: *longevity/energy, latency, accuracy, fault tolerance, good throughput* [3]. To adapt with the featured system, the management might need to make some changes in these criteria: Smaller number of nodes means the data accuracy; fault resistance and the lifetime of the nodes must be superior compare to other systems. Meanwhile, the latency and network throughput might be inferior. We still aim for the highest quality in data transmission. These lists are provided as a direction to promote the system efficiency.

3.2. Management Architecture

It is clear that a management system is to manage the main system. Therefore, *the efficiency of a management system is evaluated through the ability of monitoring and controlling the operation of its object system.* In general, the lower level system will be monitored by the upper one. At the highest level, human operators need to manage the system because no other system can be at that position.

HS only can perform the best on the tasks of displaying the management data and controlling by sending commands. HS acts as the manager which needs the help from agents of lower levels.

The agents can be implemented in the Android smartphones at the gate of LSNNS. The main tasks of these agents here are redirecting the information to the right destinations. Also the information of the LSNNS is kept at this agent so we can retrieve if necessary.

A lower level of agents can be discovered at each node. One agent monitors corresponding node directly and restrictively, therefore it does not have the information of other elements.

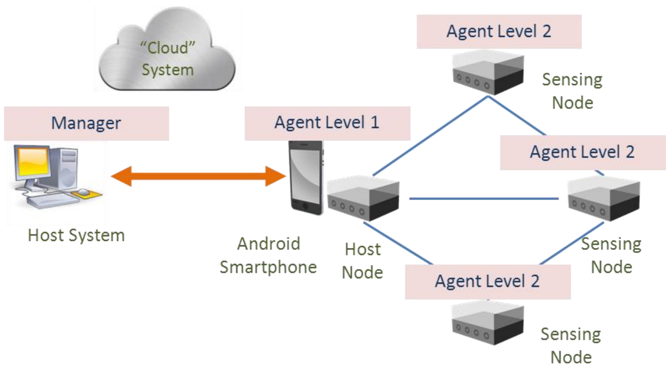

Fig. 5. Management architecture with 3 levels of management elements

The management architecture therefore consists of 3 levels. The model of this architecture is shown in Fig. 5.

Fig. 6 shows the differences between proportion of management and operation tasks at each elements. SN performs mainly operation tasks but still have a part for management tasks. On the other side, HS tasks focus on management.

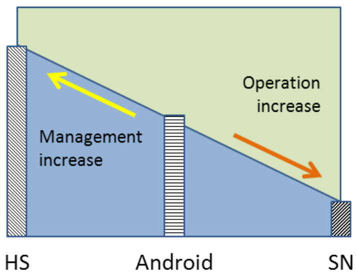

Fig. 6. Proportion of management and operation tasks between different elements

3.3. LSNNS Management

The information gathered from the nodes in LSNNS can be divided into 4 categories: Node data, node status, network (LSNNS) data and network (LSNNS) status. This information can be measured by the sensors or determined by other methods. A list of the information and corresponding categories is provided in Table 1. This list includes both measurable parameters and pre-defines functions.

In this classification list, there are four parameters belong to more than one category. In case of GPS data, it provides the location position for drawing network topology precisely. It is also treated as a data for recognizing slow occurrence of landslide. Adjacent information and routing table is kept at each node for connection purpose so it is node data. LSNNS also uses this for forming the network so it is LSNNS data too. The operation of LSNNS involves operation of nodes. Because these parameters are connected to both categories, it is better to leave them in both. Another note in this list is: the tilt angle is delivered from the acceleration sensor. The management system and main sensing system use the same hardware part. Because of this feature, although the logical functions should be divided separately, there are some parameters are used by both. Agent Level 2 can manage Node status while Agent Level 1 will manage statuses of Nodes and LSNNS.

Table 1. Classification of LSNNS information.

Parameters/Functions	Category
Node Power, Health	Node status
Tilt, Physical Angle	Node status
Hardware Fault	Node status
Operation status: Standby, Measuring, Sending…	Node status, LSNNS status
Location/GPS data	Node status, Node data
Sensing data: Acceleration, Temperature…	Node data
Adjacent/ neighbor data	Node data, LSNNS data
Network topology	LSNNS data
Routing table/Routing map	Node data, LSNNS data
Node links strength	LSNNS status
Traffic in links	LSNNS status

3.4. Cloud System Management

Basically, the Cloud System is provided by the service providers. The most important condition is the good quality of connections. Considering Android smartphone is a part of Cloud System, the connectivity to corresponding HN and Internet is the key feature. Aside from other parameters or functions belongs to Android, there are few others related to the Cloud Storage located on the Internet. A list of the parameters and functions is provided in Table 2.

Table 2. Cloud System related parameters and functions.

Parameters/Functions	Category
Connectivity (to HN and Internet)	Android
Email send/receive capability	Android
File recording	Android
File synchronization to Cloud	Android
Power status, Hardware status	Android
GPS/Location	Android
Memory capacity – Android	Android
Transmission status	Android
Operation status – Android	Android
Memory capacity – Cloud Storage	Cloud Storage
Accessibility	Cloud Storage
Operation status – Cloud Storage	Cloud Storage

The Cloud-related parameters can be accessed and verified easily from the HS once a good Internet connection is available. There are various parameters for monitoring Android but most of them can only be seen once the connection is made. For some functions, we can only know the successfulness after they are performed.

3.5. Host System Management

HS is the main manager in the system. Main task of HS is managing the other two subsystems. However, HS itself need to be managed too. Because HS can be controlled by human staff and a human manager should always be with the system, the management jobs can be defined without being mandatorily displayed. There are two categories showed in Table 3: HS setting and HS operation.

The connection settings are related to the Internet connection. The category HS operation introduces the tasks that HS would perform during the operation. Most of the tasks require analyzing the information in the messages. The success of the tasks is assessed by how the data is analyzed, manipulated, displayed… The tasks of sending command and receiving data does not rely on the information content but require the network connected to verify the operation performed on the data. The same situation happens with the tasks Real-time Monitoring/Analyzing.

Table 3. Monitoring parameters and functions of HS.

Parameters/Functions	Category
Connection setting	HS setting
Connection status monitoring	HS setting
Time monitoring	HS setting
Command Sending/Data Receiving	HS operation
Error Detection	HS operation
Message Filter/Duplicates Handling	HS operation
Message Reader/Log file analyzer	HS operation
Real-time Monitoring/Analyzing	HS operation
Display Tools: Graph, Table, Topology Draw	HS operation
Auto warning	HS operation

4. PROMOTING A MORE ROBUST SYSTEM

It is necessary to clarify the utilization of the parameters and functions which have been introduced in section 3. Fig. 7 describes the relationships among management functions, operation functions and parameters. From the viewpoint of an operator at HS, only management functions are needed since they are easy to understand and use. Each management function may call a set of operation functions which might not be familiar to the people who do not have knowledge of the system. The parameters can be access by calling corresponding operation functions. The result of operation functions and parameters will be returned to the HS and displayed by other management functions. Evaluation of the performance of each function set or other contributions of the system might be promoted base on this model.

Compare to non-managed systems, a WSN-based monitoring system accompanied by a management system shows a better potential in performance improvement. At a first glance, the benefit of a management system is shown at the data seen at the HS. All the condition information of every element can be displayed alongside with measured data from sensors. By this first action only, many other works like collective statistic can be done. Now both sensor data and node/network condition can be viewed and analyzed.

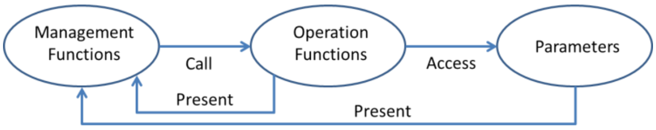

Fig. 7. Relationship between functions and parameters

The management system is constructed to work well under normal conditions and provide quick responses in emergency situations. We conducted several experiments to verify the ability to complete the tasks.

4.1. Experiment for managing the network topology

HS can manage network from afar display the nodes in graphic interface. The data acquired for this function is provided by the nodes: GPS position and links between nodes. If there is a connection between a pair of nodes, the link is displayed as a line. GPS information of the nodes is used to determine the position relatively to each other. The scale of topology is automatically adjusted to fit the interface.

In this experiment, 6 SNs were used. Some nodes could connect to all other nodes; some could not due to experiment condition. Along with graphical topology, the data also creates the routing table for statistic and other purposes.

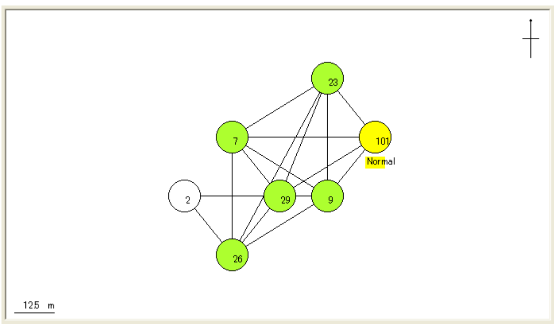

Fig. 8. HS display remote network topology in graphic

4.2. Experiment for monitoring the node condition

In this experiment, we tried to get the data about physical angle of the nodes. Knowing this information, we would know the current situation of the nodes. Combine with other information, we might assume the node condition in the past or predict the future.

6 nodes are arranged in similar positions and similar tilt angles. HS send commands to request the data via Android Smartphone, HN to SNs. After receive sufficient data from every node, the tilt angle is changed and HS request data again. In total, there are 4 tilt angle data are chosen for this experiment. Received data is averaged as in Table 4.

Table 4. Node physical angle data

Experiment		1	2	3	4
X	Expected	115	180	90	90
	Received	111.81	173.36	85.67	86.17
Y	Expected	90	90	0	90
	Received	87.05	85.36	6.56	83.89
Z	Expected	25	90	90	0
	Received	21.92	86.21	83.89	4.33

The data received showed that the HS can receive detailed data from each node with good accuracy. The maximum error data received is X angle in experiment 2, with 6.64 degree difference. This suggests that the surface for placing the nodes might not ideally transverse.

In this experiment, Agent Level 2 has completed the tasks of translating the measured data into the comprehensive messages. Agent Level 1 wrapped the messages into emails and send to Manager at HS. With the same method, HS can get other information as well.

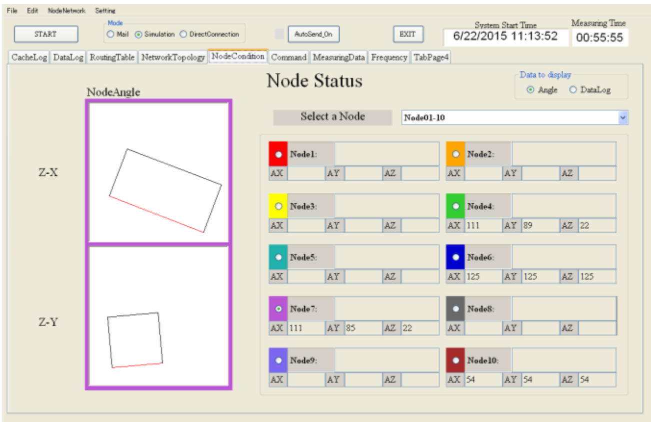

Fig. 9. Example of HS displaying physical tilt angles of a SN.

4.3. Experiment for GPS data

In this experiment, position of each node is recorded by GPS sensor. The recorded positions are compared with GPS provided by Google Map to verify the error. The current using GPS sensor has the error at 2.5 meters. As the result, the data showed that the coordinates located in a 2.5 meters-radius-circle around the position.

As observed during the experiment, the node located near a tall building returned an incorrect GPS data. We can assume that the accuracy of the sensor is affected by the structure of the building nearby. The nodes far from the building do not show any sign of this fault.

Another experiment is conducted to see the ability of tracking the node’s position in real time. The nodes are moved slowly along one direction. GPS data is collected from before the movement until the movement completed. Usually, when the node moves, the acceleration sensor will work and detect the landslide. This experiment is to prepare for the cases of very slow landslides happen which do not trigger the acceleration sensor.

Data returned to the HS in form of coordinates values which can be recalculate easily and put on Google Map for checking the results. The GPS values showed correct direction of the movements. The errors are still within the allowed threshold.

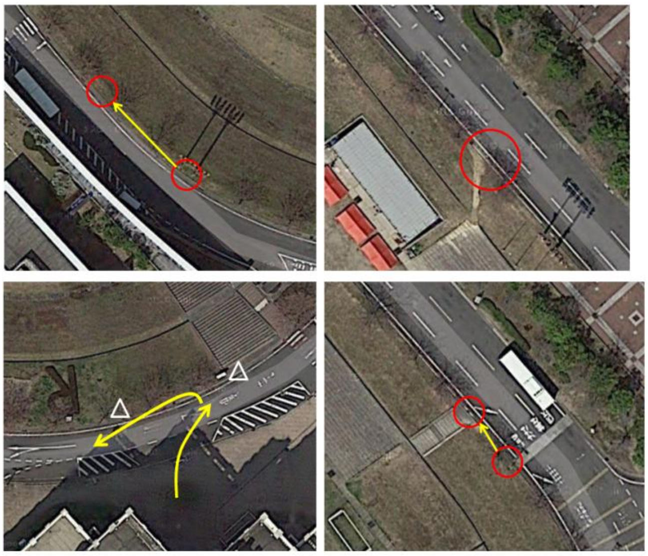

Fig. 10. Node positions and movements representing on Google Map

4.4. Experiment for recognizing the landslide occurrence

Two experiments were conducted to see the ability of recognizing two types of landslide. The first experiment is to recognize the landslide in *slide down* form. The second one shows the signs of *rolling down* form. 11 sensing nodes involved in these experiments.

Table 5. Landslide occurrence recognition

Experiment for	Slide Down	Rolling Down
Number of turns	107 (100%)	110 (100%)
Showed as Slide Down	89 (83.18%)	21 (19.09%)
Showed as Rolling Down	1 (0.93%)	80 (72.73%)
Showed as Collision	17 (15.89%)	9 (8.18%)

The result in Table 5 shows that the nodes can perform quite fair on distinguishing two different movements of the nodes. It is observed that some Rolling Down movements were recognized as Slide Down but only one Slide Down turned into Rolling Down. This can be explained that the Rolling Down movements occurred imperfectly and possessed some characteristics of Slide Down movement. *Collision* is not considered as occurrence of landslide so 15.89% on mistaking a Slide Down as a Collision is higher than acceptable level. However, most of the mistaken cases happened on some particular nodes. In order to improve the performance of the system, these nodes should be checked and calibrated carefully.

4.5. Summary of the experiments

In these experiments, the data was collected by the operation functions on the nodes and then processed to present at the HS by the management function. The information is recoded to be lighter from the SN before being displayed at the HS. The experiments showed the ability of sending, receiving, processing the data and commands of the HS and SN, also showed the communication ability of Android in landslide disaster monitoring.

Generally, to fulfill the task, an event-driven system does not need to have measuring frequently. However, the lifetime management and fault management require the system to be monitored once in a while. The schedule needs to be decided carefully for the balance. This may set the management system to programmed but still keep monitoring system as event-driven.

5. CONCLUSION

The Landslide Monitoring System is an event-driven system for mitigating the disaster damages. To enhancing the performance as well as the reliability of the system, a management scheme is necessary. In this paper, we proposed a scheme which is suitable for the system with strong processing nodes distributed at a low density.

In current system, a portion of the management functions has been deployed. The result can be seen at the HS display interface. We would like to continue developing this management scheme as the current scheme can be improved to be more complete, although it has already provided some valuable information.

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