XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

LANDSLIDE DISASTER MONITORING BY WIRELESS SENSING NETWORK

Shigeru TAKAYAMA [1], Motoshi HIRAOKA [2], Koichiro MORI [3], Komyo KARIYA [4]

[1-4] Ritsumeikan Univ.BKC, Shiga, JAPAN, s-tkym@se.ritsumei.ac.jp

Abstract: Sensing system to monitor natural disasters faces much hard conditions. Natural disaster occurs suddenly, and damages sensor system. Then, the sensor system should be designed as distributed node network. In addition to that, the network should have some characteristic functions like self-recovery, autonomous operation and effective data transmission in urgent. This paper describes the construction of autonomous sensing node network to recover the damage by landslide disaster and to transmit urgent data effectively. The sensing node network is operated by three mode(initializing mode, measuring mode and urgent mode). By switching these operation modes autonomously, the sensing node network becomes robust system to the loss/insert of sensing node and the dynamic control of data transmission. Finally by some experiments, the effectiveness of operation is shown

Keywords: sensing network, landslide monitoring.

1. INTRODUCTION

It is so difficult to predict exact the time, date and place of occurrence of natural disasters like landslide. Then, diary monitoring around the dangerous area is important. If we can get indications before the occurrence, the information is very helpful to report to inhabitants and to operate the monitoring system[1-3]. To monitoring the landslide disaster, the monitoring system should have some characteristic functions. The monitoring system should transmit precision measuring data urgently to host system corresponding to the disaster occurrence. And as the occurrence place of disaster is not known exactly, it is necessary to monitor an area by using distributed sensing nodes. And the monitoring system should prevent the loss of measuring data as possible by redundant data storage with cooperation among the sensing nodes. And also, as the sensing node is easy damaged and stops the functions, the sensing node network should have self-recovery function..

This paper describes the construction of sensing node network system which operate flexibly toward disappear/insert of sensing nodes and urgent data transmission. And the operation is shown by monitoring of landslide disaster.

2. LOCAL SENSING NODE NETWORK FOR LANDSLIDE DISASTER

Fig.1 shows an example of local network of sensing nodes. The local network is connected to host system by long distance communication function of Node0. Fig.2 shows a prototype of sensing node. The sensing node has measuring function, data processing function, temporary memory function and communication function. To monitoring landslide, plural sensing nodes are distributed on a closed area.

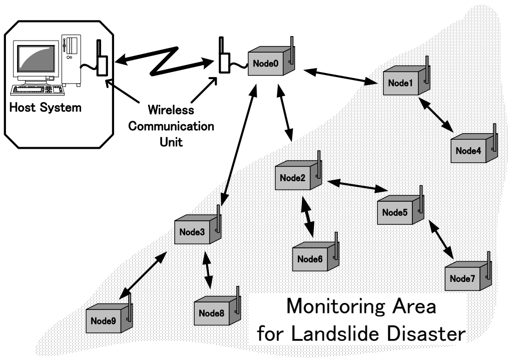


Fig.1 Example of local network of sensing nodes

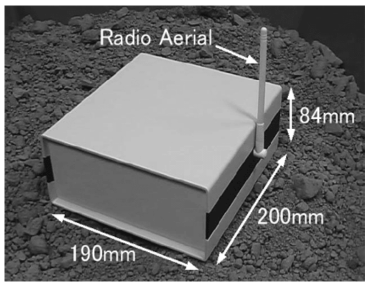


Fig.2 Prototype of sensing node

These sensing nodes are constructed tree type local network autonomously. Node0 is a special node to communicate message (commands and measuring data) to the host system. Then the Node0 has wireless communication unit to out of network with normal wireless communication function among sensing nodes. Each sensing node measures land movement, acceleration of landslide and temperature regularly. Usually, stationary measuring data is stored temporally. And simultaneously, they are also stored by surrounding sensing nodes redundantly.

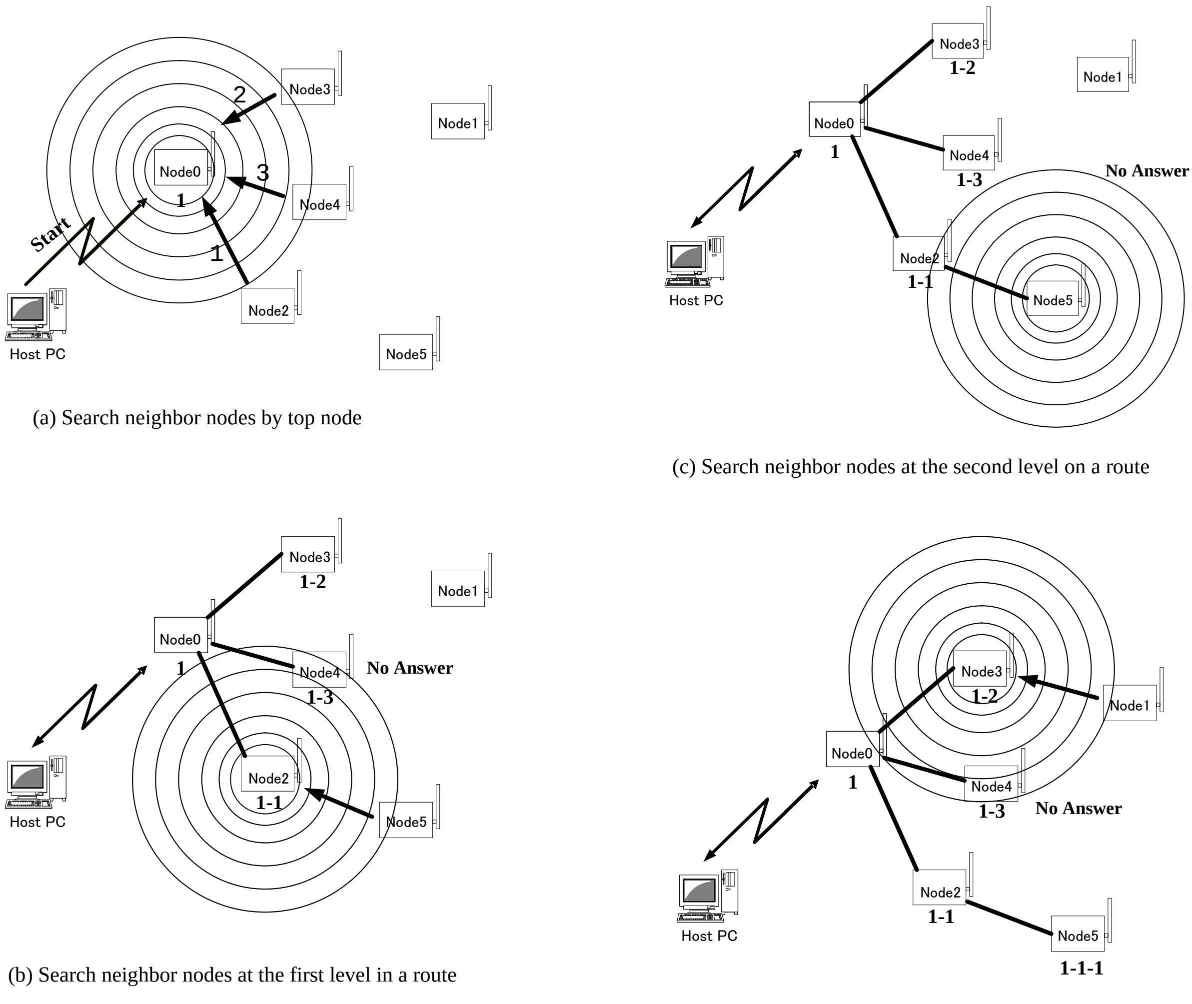
The local sensing node network has three characteristic operation modes(initialling mode, measuring mode, urgent mode).

2.1. Initializing mode

Initializing mode is the operation mode to construct network of sensing nodes autonomously. The mode plays important roles

1) at the first construction of local network,
2) at transmit the measuring data urgently to host system,
3) at loss of sensing nodes by landslide disaster.

Fig.3 shows the process to construct the sensing node network in the initializing mode. Each node distributed in an area has an identification node number. By Start command form host system, Node0 start to search neighbor nodes. In this time, Node2, Node3 and Node4 response to the call. As the response time is in proportion to node number, the Node0 assigns network labels (1-1) to Node2, (1-2) to Node3 and (1-3) to Node4(Fig.3 (a)). After that, Node2 assigned (1-1) searches neighbor. In this time, Node5 only responses to the call. Node4 does not response, because it has already had network label (1-3)(Fig.3 (b)). Then, Node5 is assigned network label (1-1-1). After that, Node5 searches neighbor node. But, no node answers to the call(Fig.3 (c)). Then Node0 changes the route to search. Next, Node3 searches neighbor node(Fig.3 (d)). In this time, Node1 only responses to the call. Node4 does not response again. Then, Node1 is assigned network label (1-2-1). After that, Node1 searches neighbor node. But, no node answers to the call. Then Node0 changes the route again to search. Next, Node4 searches neighbor node. But, no node answers to the call. In this way, the sensing node network is constructed finally.



(a) Search neighbor nodes by top node

(c) Search neighbor nodes at the second level on a route

(b) Search neighbor nodes at the first level in a route

(d) Search neighbor nodes on other route

Fig.3 Construction of node network by initializing mode

2.2 Measuring mode

In measuring mode, to monitor the indication of occurrence of landslide, the sensing node measures a signal and stores the measuring data in common among surrounding sensing nodes. To enhance the communication efficiency in local network, the sensing node measures by irregular sampling time interval based on stochastic parameter. At small difference of fluctuations of measuring data, the sensing node measures by long sampling interval. On the other hand, at large difference of fluctuations of measuring data and at crossing a threshold level, the sensing node measures by short sampling interval. Fig.4 shows data flow in measuring mode. Node2 and Node3 are relay point nodes. These nodes store own measuring data and received data from other node to their own memories temporarily. These storage is to prevent data loss of damaged node in emergency. In this way, the measuring data is carried to Node0 through relay point nodes in local network, and finally transmitted to the host system(Fig.4).

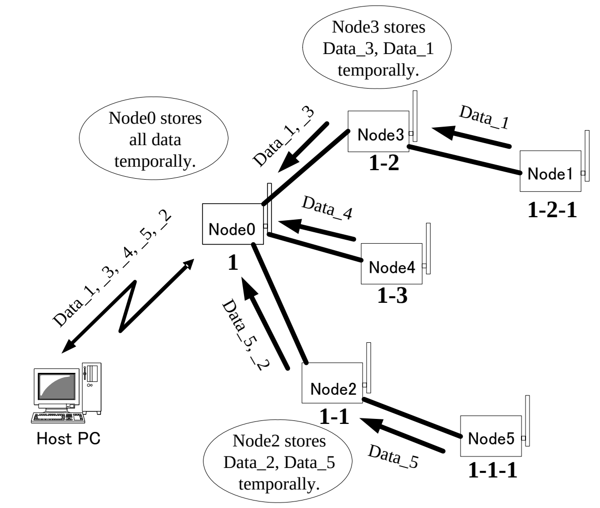
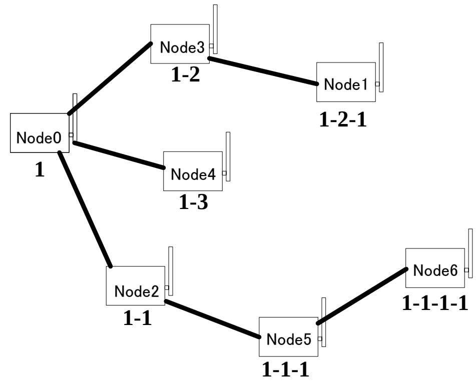
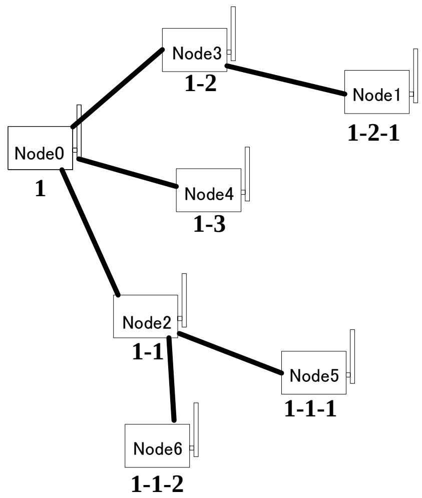


Fig.4 Data flow in measuring mode

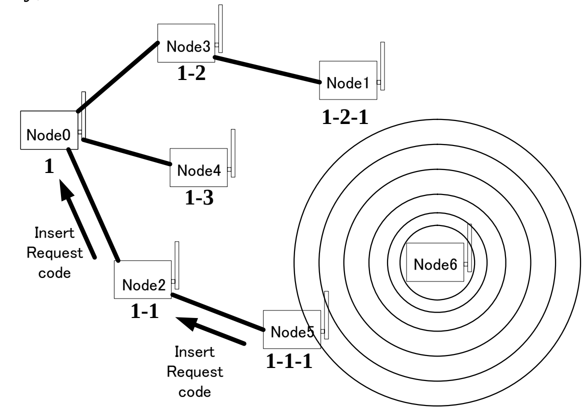


(b) Renewal of node network construction in initializing mode

Additionally, the measuring mode insert new sensing node in the local network to expand the monitoring area and to supplement a lack of sensing node. Fig.5 shows the initialization of node network by the insert of new node Node6. At first, new node Node6 sends special sign(Insert Request Code) to neighbor nodes to join in the network. Node5 received the code informs to Node0 via Node2. Then, Node0 start to initialize the node network. Now, the system drops into Initializing mode mentioned above. Finally, the node network renewed.



(c) Renewal of node network construction in initializing mode(by other arrangement)



(a) Relay of Insert Request Code from new node Node6 to Node0

Fig.5 Initialization of node network by the insert of new node

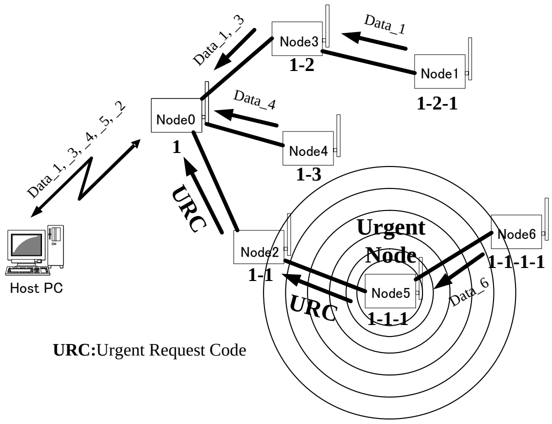
2.3. Urgent mode

Urgent mode is the mode to transmit measuring data urgently in local network when a sensing node discovers an indication of landslide disaster and senses the occurrence. The urgent mode resets the tree type network construction temporarily and realizes strait connection between Node0 and the sensing node through other nodes. Fig.6 shows request and data flow from the sensing node in urgent mode.

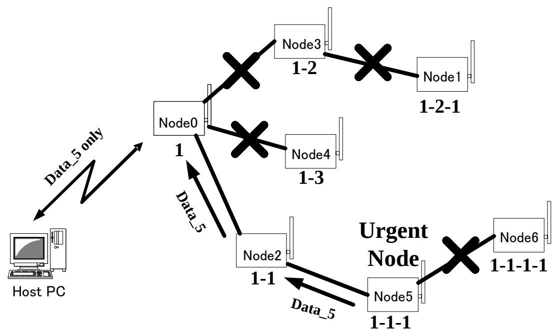
When Node5 sense a sign of landslide or the occurrence, it sends a request code(Urgent Request Code: URC) to Node0 and neighbors(Fig.6(a)). Then, system drops into Urgent mode. Node0 asks all nodes without Node5 to stop data transmission. As the result, only data from Node5 is transmitted to host system via Node0(Fig.6(b).

In Urgent mode, the urgent sensing node is easy broken or lost by landslide and other disasters. Then, the sensing node network should reconstruct to recover the damage. Fig.7 shows the reconstruct of sensing node network by loss of urgent node.

When Node5 is lost, Node0 and Node2 can not receive data from the urgent sensing node Node5. After a certain time interval without the data flow, Node0 understands that Node5 was lost. Then the system drops into Initialization mode mentioned above. Node0 starts to initialize the network construction. After that, the node network is renewed.

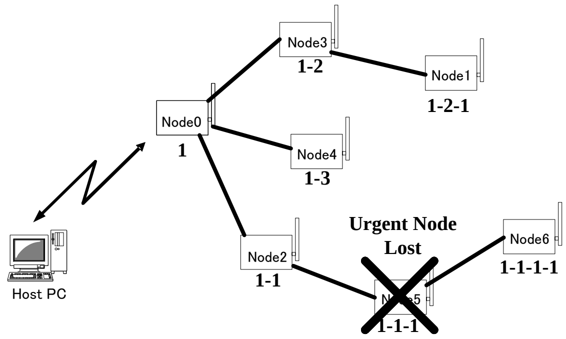


(a) Transmission of URC from urgent node to Node0

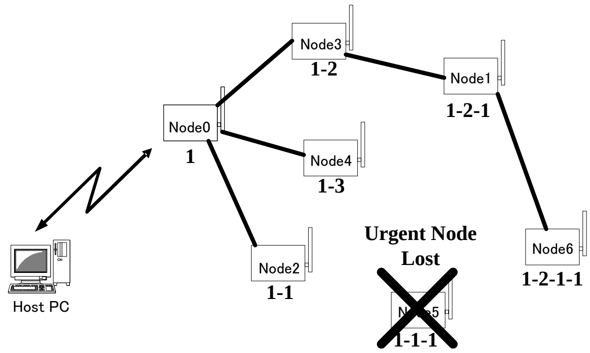


(b) Data flow from urgent node to Host System

Fig.6 Request and data flow from the sensing node in urgent mode



(a)Stop of data flow by loss of urgent sensing node



(b) Reconstruction of sensing node network

Fig.7 Reconstruction of sensing node network by loss of urgent node

Fig.8 shows the transition of three operation modes of sensing node. After Power ON, the system drops into the Initializing mode. After the completion of network, the system operates in the Measuring mode.

When any node senses sign of landslide or the occurrence, system changes modes to the Urgent mode. And also, to insert new Node or to delete lost Node, the system returns back to the Initializing mode.

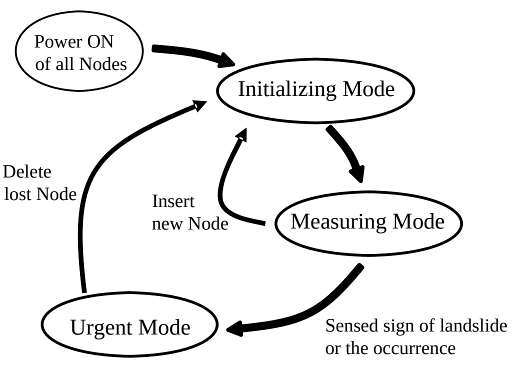


Fig.8 Transition of three operation modes of sensing node

3. DATA FLOWS IN A SENSING NODE NETWORK

3.1. Frequency of measuring data in Node

To observe the operation of sensing node by three operation mode, data flow in a sensing node is monitored. The local network is constructed of five sensing nodes(Node0, Node1, Node2, Node3, Node4). Node0 is for communication with host system. Node1 mounts a soil moisture sensor. Node2 and Node4 mount acceleration sensors. And Node3 mounts a temperature sensor. Fig.9 is the node network for test operation. The local sensing node network was tested by following timing diagram.

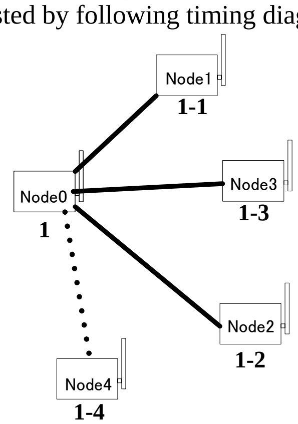


Fig.9 Node network for test operation

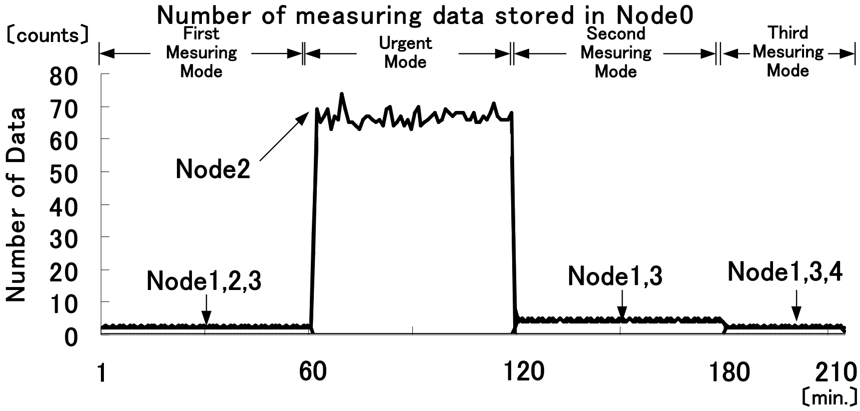


Fig.10 Time transition of number of measuring data in a minute stored in Node0

1) First term : 0-60 min.
 *Initializing mode after power on of all nodes
 *<u>The first measuring mode</u>
 (Operation nodes are Node0, 1, 2, 3)
2) Second term : 60-120min.
 *Initializing mode after a shock to acceleration sensor in Node2
 *<u>Urgent mode</u> by Node2
 (Operation nodes are Node0, 2)
3) Third term : 120-180min.
 *Initializing mode after power off of Node2 [instead of loss of Node2]
 *<u>The second measuring mode</u> after loss of Node2
 (Operation nodes are Node0, 1, 3)
4) Fourth term : 180-210min.
 *Initializing mode after insert of Node4
 *<u>The third measuring mode</u> after insert of Node4
 (Operation nodes are Node0, 1, 3, 4)

Fig.10 shows the time transition of number of measuring data in a minute stored in Node0. The time for initializing modes reconstructed the local network is within one minute. In the first measuring mode, the number of measuring data of Node1,2,3 are stored same stationary. In the urgent mode by Node2, sampling time interval of Node2 becomes short. The frequency of data transmitted to Node0 becomes high. As the result, the storage in Node0 is only measuring data of Node2. In the second measuring mode, as number of sensing nodes become few, number of measuring data becomes many compared with the first measuring mode. In the third measuring mode, as number of sensing nodes become same with the first measuring mode, then, the number of measuring data is same.

3.2. Observation of measuring data

To confirm the measuring data controlled by three operation mode, the data is monitored in host system. The local network is constructed of five sensing nodes(Node0, Node2, Node3, Node5, Node6). Node2 mounts a temperature sensor. Node3 mounts a torque sensor. Node5 mounts a soil moisture sensor. And Node6 mounts an acceleration sensor. Fig.11 is the node network for test operation. The local sensing node network was tested by following timing diagram.

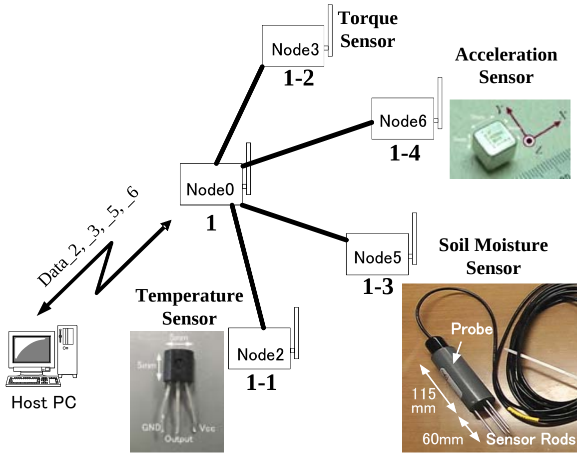


Fig.11 Simple node network to monitor measuring data

1) First term : 0-15 min.
 *Initializing mode after power on of all nodes
 *<u>The first measuring mode</u>
 (Operation nodes are Node0, 2, 3, 5, 6)
2) Second term : 15-25min.
 *Initializing mode after an urgent response of soil moisture sensor in Node5
 *<u>The first urgent mode</u> by Node5
 (Operation nodes are Node0, 5)
3) Third term : 25-40min.
 *Initializing mode after power off of Node5 [instead of loss of Node5]
 *<u>The second measuring mode</u> after loss of Node5
 (Operation nodes are Node0, 2, 3, 6)
4) Fourth term : 40-45min.
 *Initializing mode after a shock to acceleration sensor in Node6
 *<u>The second urgent mode</u> by Node6
 (Operation nodes are Node0, 6)
5) Fifth term : 45-60min.
 *Initializing mode after power off of Node6 [instead of loss of Node6]
 *<u>The third measuring mode</u> after loss of Node6
 (Operation nodes are Node0, 2, 3)
6) Sixth term : 60-75min.
 *Initializing mode after insert of Node5
 *<u>The fourth measuring mode</u> after insert of Node5
 (Operation nodes are Node0, 2, 3, 5)

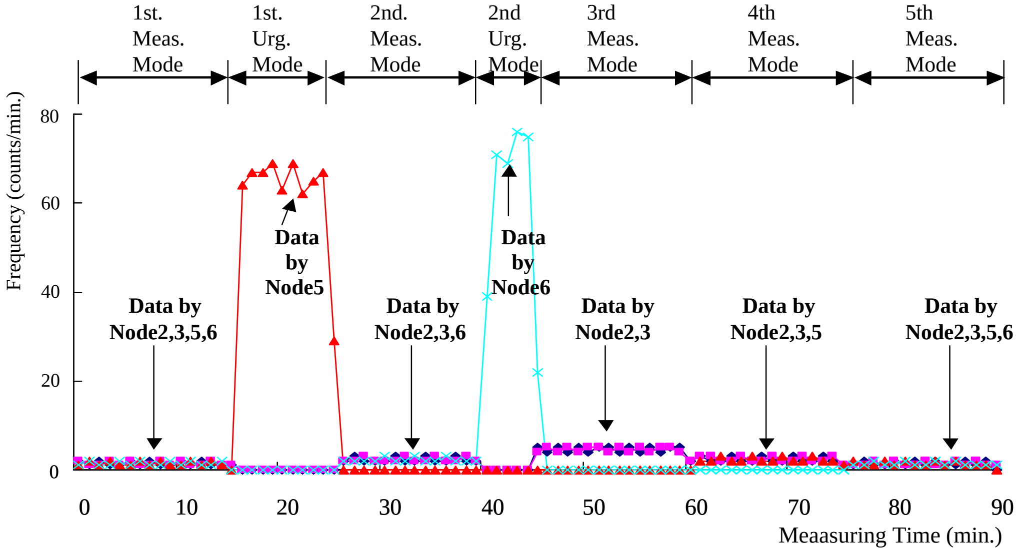


Fig.12 Time transition of number of measuring data in a minute stored in host system

7) Seventh term : 75-90min.

*Initializing mode after insert of Node6

*<u>The fifth measuring mode</u> after insert of Node6

(Operation nodes are Node0, 2, 3, 5, 6)

Fig.12 shows the time transition of number of measuring data in a minute stored in host system.

In the first measuring mode, the number of measuring data of Node2,3,5,6 are stored same stationary. In the first urgent mode by Node5, the measuring data(soil moisture) of Node5 is only transmitted. Other data is stopped. Fig.13 show the time transition of measuring data of soil moisture(Node5) stored in host system. It is confirm that the frequency of measuring data of soil moisture is high. In the second measuring mode, the number of measuring data of Node2,3,6 are stored same stationary. As Node5 was lost, the data is not monitored. In the second urgent mode by Node6, the measuring data (acceleration) of Node6 is only transmitted. Fig.14 show the time transition of measuring data of acceleration(Node6) stored in host system. It is confirm that the frequency of measuring data of acceleration is high. In the third measuring mode, the number of measuring data of Node2,3 are stored same stationary. As Node5,6 were lost, the data is not monitored. In the fourth measuring mode, Node5 is restarted. Then, the number of measuring data of Node2,3,5 are stored same stationary again. In the fifth measuring mode, Node6 is restarted. Then, the number of measuring data of Node2,3,5,6 are stored stationary again.

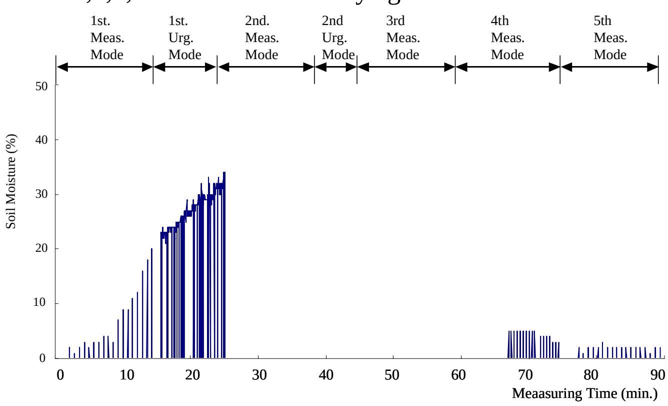


Fig.13 Time transition of measuring data of soil moisture in Node5

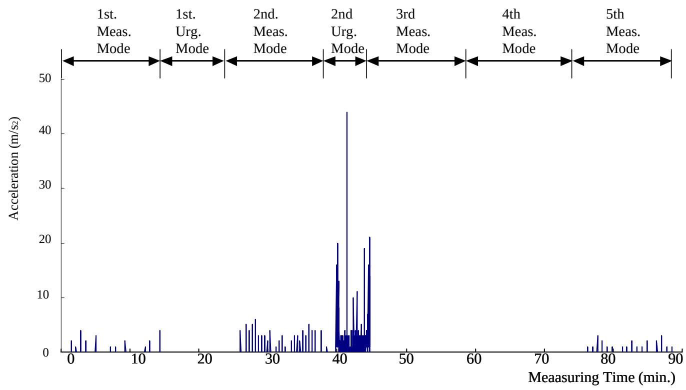


Fig.14 Time transition of measuring data of acceleration sensor in Node6

4. CONCLUSION

The time 10-20 minutes before the occurrence of disasters can save many human lives. To monitor landslide disasters, it is paid attentions that sensor node must transmit the data continuously at a sign or occurrence of landslide, and that sensor node is broken easily by landslide disaster. Then, it is necessary to construct robust and flexible sensing system. In this paper, an autonomous monitoring system by using local sensing node network has been proposed. It has shown that the sensing node network has some characteristic functions like node self-recovery, flexible node arrangement and effective data transmission at disaster.

REFERENCES

[1] Information-Communication System of Disasters Prevention Association, “Information – Communication System of Disasters Prevention”, Sankaido, pp.1-73, 2003

[2] Kyoto University Disasters Prevention laboratory, “Foundation Disaster”, Sankaido, pp.9-21, 2003.

[3] A.Takei, “Landslide,collapse,mudslide - Prediction and Measure - “, Kashima publishing, pp.65-77, 1980.