

## Wireless Sensor Network for Landslide Monitoring in Nusa Tenggara Timur

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### Abstrak

Tanah longsor di berbagai daerah telah merupakan bahaya serius secara substansial bagi jiwa manusia dan kerugian material. Untuk menanggulangi dan mengurangi kerugian tersebut berbagai upaya untuk melakukan monitoring tanah longsor dikembangkan. Salah satunya yaitu memanfaatkan teknologi jaringan sensor nirkabel (JSN). Hasil yang didapatkan dari penelitian yang dilakukan di desa Ikanfoti, Kab. Kupang, Propinsi NTT (pada koordinat 10°16' 21.9 LS dan 123°40'59.8 BT) sebagai tempat uji coba, memberikan hasil bahwa penerapan JSN dapat diterapkan dengan baik. Pengukuran sensor getaran (accelerometer) pada perangkat Micaz digunakan untuk mendeteksi getaran akibat adanya pergerakan tanah. Hasil dari penelitian ini menunjukkan bahwa perubahan nilai accellerator mulai dari 0,2g (gravity) sampai 0,49 g baik pada Accellerometert X maupun Y menandakan tanah mulai bergerak tapi belum secara signifikan. Nilai 0,5 g ke atas adalah nilai yang menunjukkan perubahan pergerakan tanah secara signifikan. Mulai pada 1 g pergerakan tanah sudah mununjukkan aktivitas yang sangat kuat dan sudah mengkuatirkan. Dari pemantauan pergerakan tanah dengan JSN ini diharapkan akan mengurangi kerugian akibat bencana geologi tanah longsor khususnya di NTT. Diharapkan penelitian ini memberikan landasan bagi penerapan JSN di berbagai daerah di NTT dan Indonesia pada umumnya.

**Kata kunci:** accelerometer, jaringan sensor nirkabel (JSN), Micaz, pemantauan tanah longsor

### Abstract

Landslides in many regions constitute serious hazards that cause substantial life and financial losses. To overcome and reduce the damages, efforts to monitor landslides are developed. One such technology utilizes a wireless sensor network (WSN). Results obtained from studies conducted in the Ikanfoti village, Kupang District, Nusa Tenggara Timur (NTT) Province (S 10°16' 21.9" and E 123°40'59.8") as pilot project, give result that the application of WSN can be applied properly. We detect and measure vibrations caused by landslides by vibration sensor (accelerometer) on Micaz devices. The results of this study indicate that changes in accelerometer values ranging from 0.2 g (gravity) to 0.49 g of either the X or Y of accelerometer indicate that soil begins to move but not significantly. Value above 0.5 g is a value that indicating a significant change of ground motion. The value of 1 g and above of ground motion indicates a very strong activity and should be alarmed. It is expected that this research provides the foundation for the application of WSN in various areas in NTT Province and Indonesia in general, for establishing thorough and reliable early warning system (EWS).

**Keywords:** accelerometer, landslide monitoring, Micaz, wireless sensor network (WSN)

### 1. Introduction

Within few years, the earth's population has increased very sharply, causes human need more land to live: (a) people in poor countries are beginning to explore mountains to live and farm, (b) people of rich countries are moving into areas of high to get peace and comfortable place to live. As a result, settlements occupy steep areas, which previously resulted in movement of land every year in all corners of the world. Losses suffered from movement of landslides for one year is equal to the damage caused by the earthquake for 20 years.

The landslide is a destructive geological process. Such process that at each occurrence is almost always results in losses both in material and immaterial. It always happens every year and makes losses of lives and properties. So research is needed to design a system that can help to prevent catastrophic geologically hazards.

In this paper, a landslide detection system was designing using wireless sensor network (WSN) very steep ramps up towards the foot of the slope exceeding the balance of power that hold its slopes.). Landslide in this activity refers is defined as the mass movement of land (including rocks), layer of sedimentary deposit that has not consolidated or layer of soil on the slopes that are very steep ramps up towards the foot of the slope exceeding the balance of power that hold its slopes.

Application of WSN technology for landslide mitigation of geological hazards has grown rapidly. The development is based on the character of WSN which are easily developed and relatively economical. The use of conventional sensor technology often encounters difficulties in data collection that came from the characteristics of landslides, causing some problems in research to predict and detect landslides. The presence of WSN provides simplicities in the measurement of field data, and makes the landslide prediction system becomes more effective. The main reason behind the use of wireless sensor networks is the flexibility in data density, easy long-distance communications to various points, improving overall accuracy, and the capability of real time control. WSN is a group of smart sensors, where each point of sensor has the capability for sensing, processing and communicating, but if they are developed in terms of numbers or connected to each other into networks, they will be able to function as the monitor of a physical state of the earth collectively. WSN is a new generation of sensor systems, although still limited in data processing capability and bandwidth for communication [1].

Various studies related to ground motion with different focus had already been done. Among others [2] - [7], Jamaludin et al [2] analyzed the temperature of the soil and slope conditions, [3] and [4] focused on the detection of a prototype model, while [5] - [7] tried a WSN test bed for real-time measurement.

To the best of our knowledge, research on WSN and its prototype in the area of montmorillonite (expansive clays) has not been well studying yet. This research attempts to contribute to the implementation of WSN, not only the prototype model, but also to compare it with direct measurements at the test site research. This research is a continuation of previous research [8] of the geographic information systems (GIS) application for settlement of the hill zone on Nusa Tenggara Timur (NTT) Province. The expected contribution of this research will be useful in integrating the GIS system in an early warning system (EWS) [9] - [11].

## 2. Research Method

### 2.1 Accelerometer Data Analysis

Accelerometer reads a biaxial acceleration changes by providing a large voltage difference  $V_{out}$ , so that to know how much the angle changes that occur by using formula below

$$\alpha = \sin^{-1} \frac{V_{out} - V_{offset}}{S} \quad (1)$$

where:

- $\alpha$  : Tilt angle
- $V_{out}$  : Voltage output accelerometer
- $V_{offset}$  : Offset voltage power supply (0.4 V)
- $S$  : Sensitivity accelerometer (167 mV / G, 17%)

Accelerometer works by sending high-level analog signals in terms of stress (voltage) proportional to the acceleration measurements. Sensing mechanism of the accelerometer is described as

$$V_{out} = (\text{Scale\_factor} * \text{Acceleration}) + \text{Offset\_voltage} \quad (2)$$

where:

- Scale\_factor : sensor sensitivity (Volt/g)
- Acceleration : acceleration value of each axis (g)
- Offset\_voltage : voltage (zero-g)

The generated value of accelerometer, X and Y, show the changes in horizontal and vertical angle. In other words, the value of the accelerometer node X means changing corner to the left and right according to the X-axis, while the value of Y means that node changes accelerometer with vertical slope as Y-axis. Figure 1 shows a visual representation of the movement of nodes in the event of changes in accelerometer X and Y.

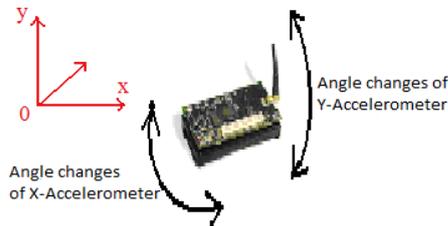


Figure 1. Visualization of Node Angle Changes [13]

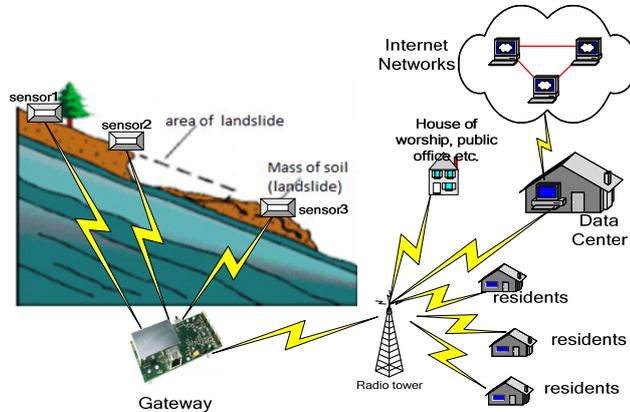


Figure 2. Measurement and monitoring of real-time data landslides as a real-time system (refer to [7])

## 2.2 WSN Configuration on data collection

In this research, the using ad-hoc type of network topology similar to [12]. This is a type of network topology in which a central 'root' node (the top level of the hierarchy) is connected to one or more other nodes that are one level lower in the hierarchy (i.e., the second level) with a point-to-point link between each of the second level nodes and the top level central 'root' node. While each of the second level nodes that are connected to the top level central 'root' node will also have one or more other nodes that are one level lower in the hierarchy (i.e., the third level) connected to it. Gateway that provides link between sensors and central processor acts as root, and nodes refer to every sensor in the system. Actually, every node can send data directly to gateway, but in certain case when link between one node to gateway is broken, it can send data via other node (ad-hoc).

The landslides monitoring in real-time system, that be used as the scheme in this research, is shown in Figure 2.

## 3. Results and Analysis

### 3.1 Measurement and Data Analysis

Measurement using a prototype is intended to facilitate analysis of data on various conditions. Simulation of the movement of land to see the avalanche effect is done manually by stressing the ground. Output of MoteView software [13], [14] which is used in this work is shown in Figure 3. It uses formula (1) that directly converted into the MoteView analysis software. The results of direct analysis in graphical form for each condition are shown in Figure 4.

The analysis of each data using a prototype is as follows:

- Condition I: the normal condition (before the forced movement of landslide) is depicted in Figure 4. It appears that all nodes (sensors), 5, 6, 8, 9 and 10 remained unchanged in both X and Y accelerator data.
- Condition II: the condition that is affected by ground movement (landslides 1) depicted in Figure 5. This figure shows that node 5 from time 13:02 to 13:03 subject to change, the change position of x accelerometer, approximately -0.3 to -0.7 g while in y accelerometer changed significantly from position 0 to +1 g. There are visible but not significant changes in node 6 and 9.
- Condition III: the condition that is affected by ground movement (landslides 2) depicted in Figure 6. Node 10 has change from time 13:04 until 13:05. Position of x accelerometer is

changing from +0.38 to 0 g, while y accelerometer is changing position from 0 to about -0.1 g.

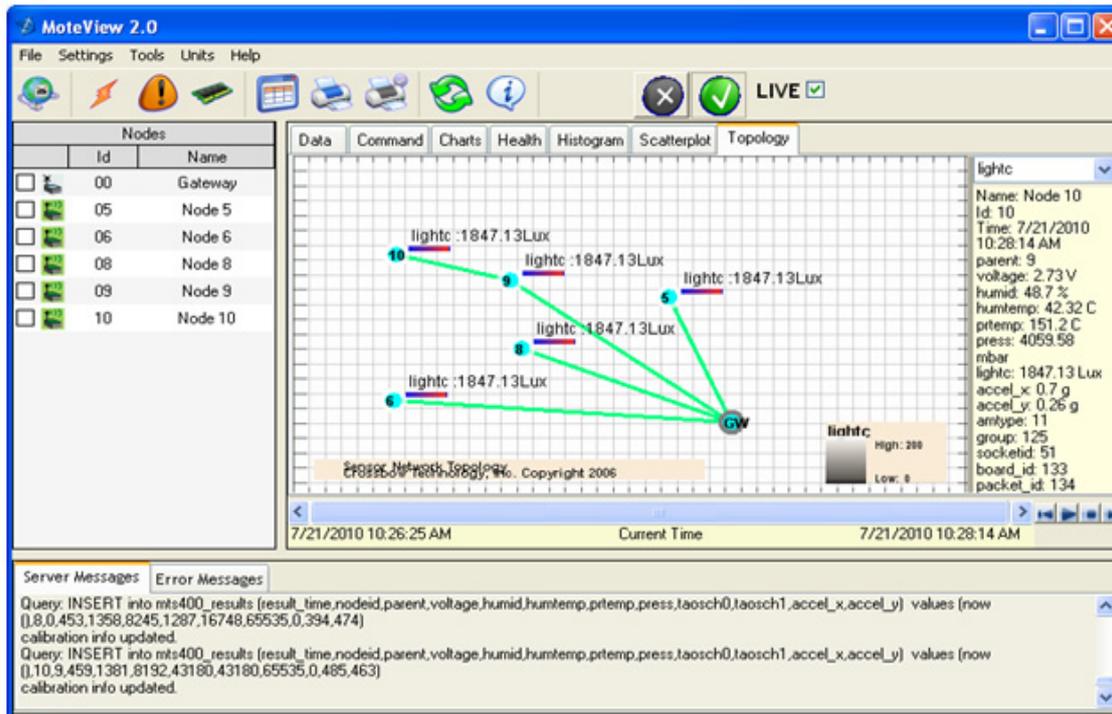


Figure 3. The topology of WSN on the data retrieval

- d. Condition IV: the condition that is affected by soil movement (landslides 3) depicted in Figure 7. At node 8 from time 13:05 to 13:06 of significant change, in x accelerometer it changed position from 0 to -3.34 g while in y accelerometer it changed position from 0 to -0.306 g. Node 6 experienced no significant change.
- e. Condition V: the condition that is affected by ground movement (landslides 4) depicted in Figure 8. In this condition, node 9 and 10 from time 13:08 until 13:09 of not significant change.
- f. Conditions VI: the condition that is affected by ground movement (landslides 5) depicted in Figure 9. It seems that nodes 9 and 10 change from time 13:09 until 13:10 but not significantly. At node 9: both x and y accelerometer is changing position from -0.2 to -0.1 g. At node 10: both x and y accelerometer are changing position from 0.22 to 0.1 g.
- g. Condition VII: the condition that is affected by ground movement (landslides 6) depicted in figure 10. It appears that only node 9 from time 13:11 until 13:12 of significant changes. X accelerometer unchanged while y accelerometer changed position from -0.2 to -0.1 g. At node 10: both x and y accelerometer are unchanged.
- h. Condition VIII: the condition that is affected by ground movement (landslides 7) illustrated in Figure 11. It appears that both nodes 9 and 10 from time 13:13 until 13:14 of change, the x accelerometer changed although not significant, and y accelerometer at node 9 changes of positions +0.1 to +0.34 g; at node 10 changes from y accelerometer position -0.3 to -0.56 g.
- i. Condition IX: the condition that is affected by ground movement (landslides 8) illustrated in Figure 12. It appears that only node 9 from time 13:16 until 13:17 of change, change of position x accelerometer 0.7 to -0.1 g, while the change of position y accelerometer -0.6 to +0.48 g.
- j. Condition X: the condition that is affected by ground movement (landslides 9) illustrated in Figure 13. The single remaining node 10 from time 13:18 to 13:19 changed in fluctuation, stable x accelerometer changed raised from -0.1 to +0.84 g and then fell to a -0.64 g, while y accelerometer on change of position around +0.2 to +0.52 g.

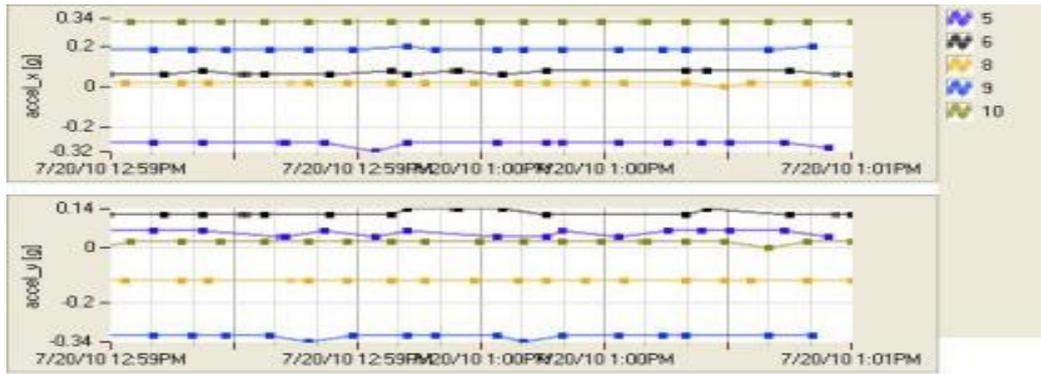


Figure 4. Condition I: normal

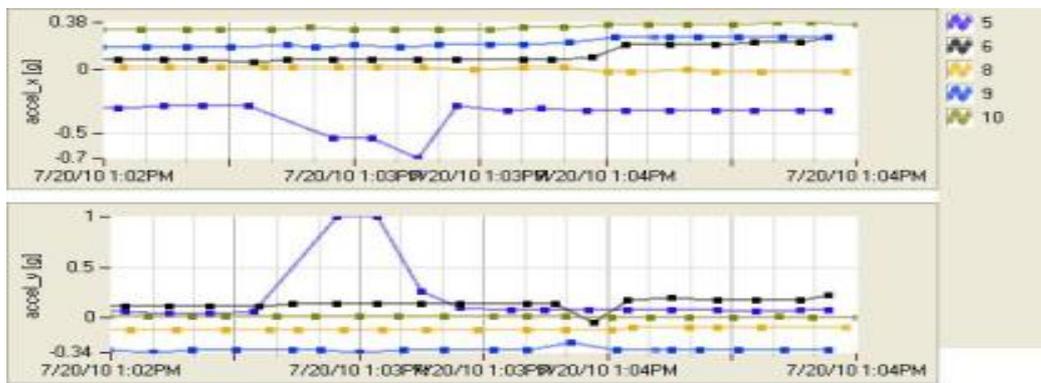


Figure 5. Condition II: landslide 1

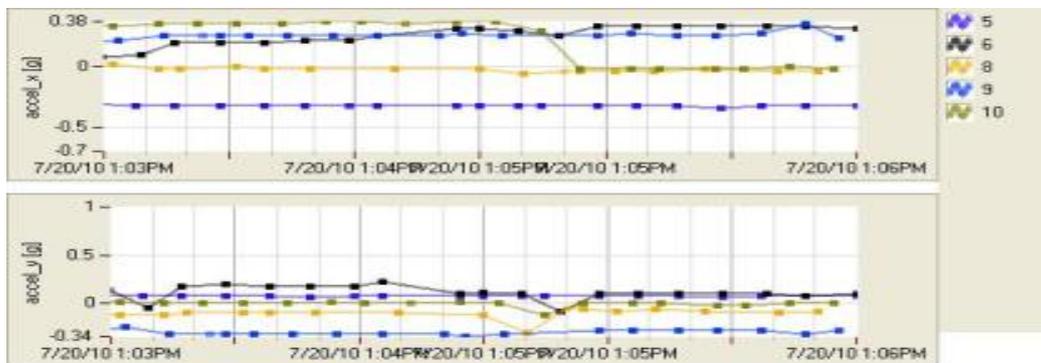


Figure 6. Condition III: landslide 2



Figure 7. Condition IV: landslide 3

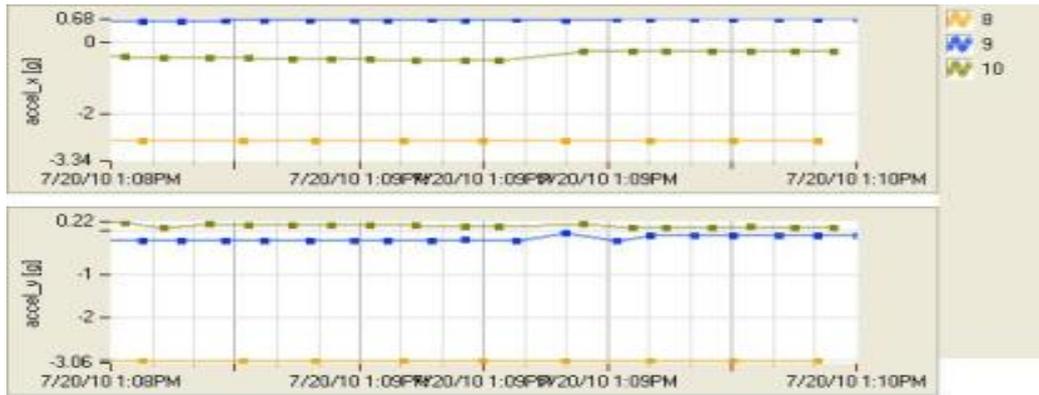


Figure 8. Condition V: landslide 4

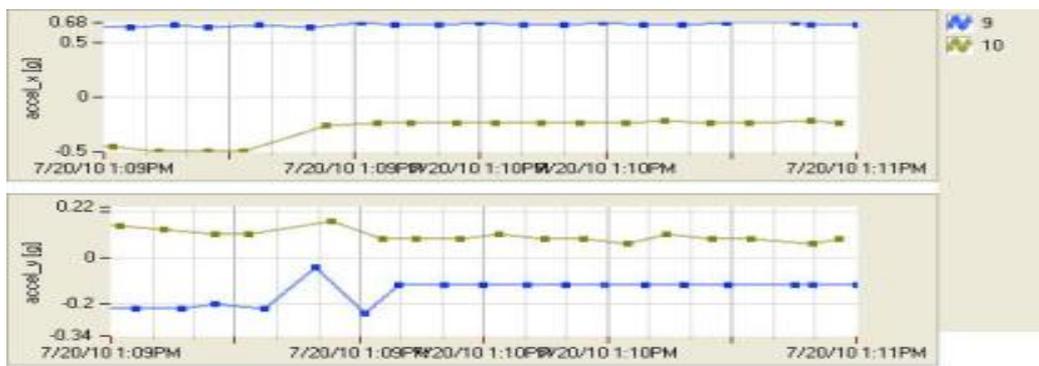


Figure 9. Condition VI: landslide 5

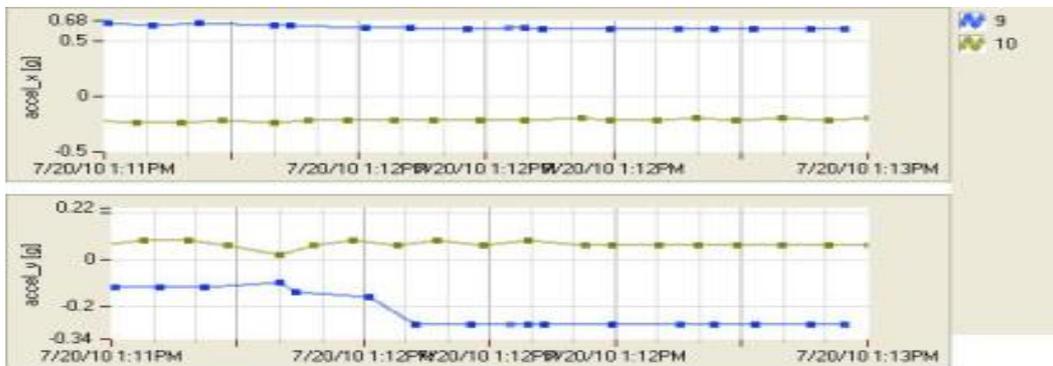


Figure 10. Condition VII: landslide 6

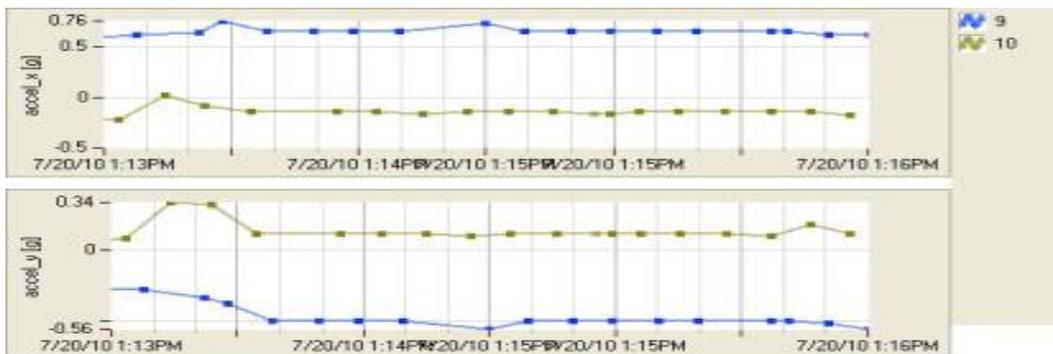


Figure 11. Condition VIII: landslide 7

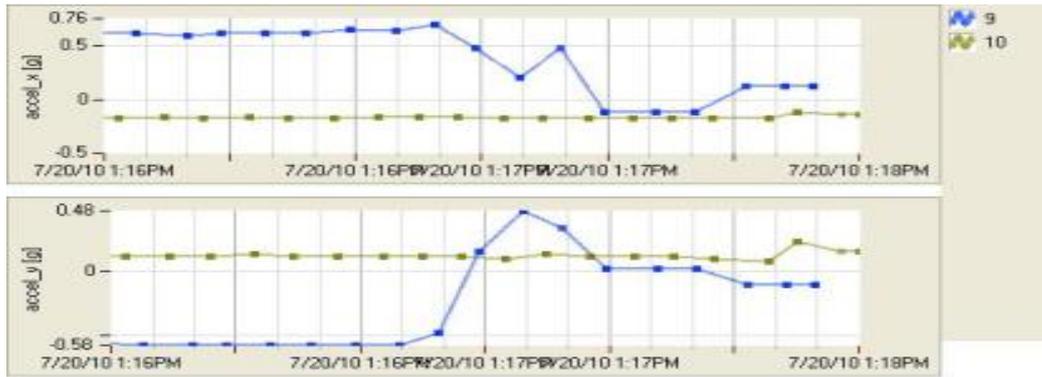


Figure 12. Condition IX: landslide 8

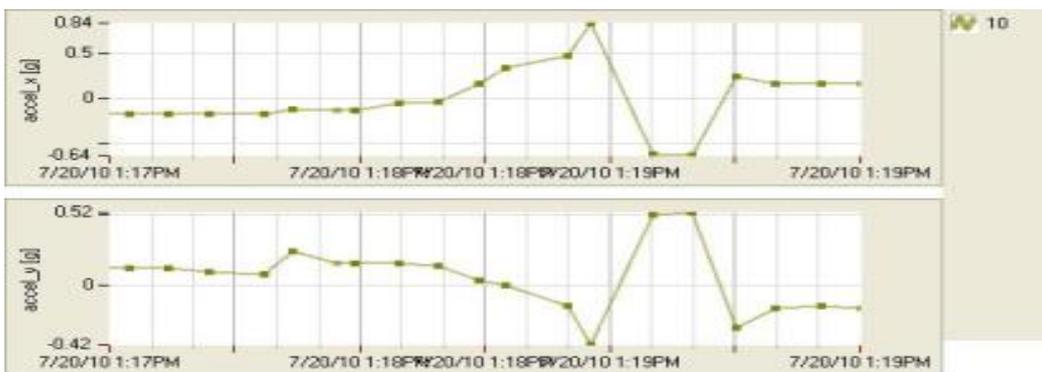


Figure 13. Condition X: landslide 9

From those data, it appears that changes in accelerometer values ranging from 0.2g (gravity) to 0.49g in both X and Y indicates soil has begun to move but not significantly. The value of 0.5 g or more is a value that indicating a significant change of ground motion. Starting on 1 g of ground motion indicates a very strong signal activity and should be alarmed. These results will be demonstrated and tested on a sample of research sites in the Ikanfoti village, Kupang District, Nusa Tenggara Timur Province ( $10^{\circ} 16' 21.9''$  LS and  $123^{\circ} 40' 59.8''$  BT).

### 3.2 Experiments and Analysis on Test bed Location

The test bed or test site is located at Ikanfoti village, Kupang District, East Nusa Tenggara Province on  $10^{\circ} 16' 21.9''$  LS and  $123^{\circ} 40' 59.8''$  BT (as Pilot Project). The primary consideration of the site location that prepared by Bobonaro Complex Formation is that the site consists of clay mineral or montmorillonite (expansive clays) and rock. Such sites are regionally widespread and can represent the general condition of the area in NTT.

Analysis of each data measurement is as follows:

- Condition I: the normal condition (before the enforced movement of landslide) is depicted in Figure 14. It appears that all the nodes (sensors), 5, 6, 8, 9 and 10 remained unchanged in both X and Y accelerometer.
- Condition II: the condition that is affected by ground movement (landslides 1) depicted in Figure 15. It can be seen that only node 6 subject to change from time 10:37 to 10:38. The change position of x accelerometer approximately -0.8 to -0.6 g while the y accelerometer have -0.25 to about 0 g.
- Condition III: the condition that is affected by soil movement (landslides 2) depicted in Figure 16. This figure shows the change of the nodes 8, 9 and 10 from time 10:45 to 10:46. Node 10, which changed significantly, in x accelerometer changed from position -0.7 to 0 g and of y accelerometer from 0.25 to about 0.94 g. Node 9 is only experiencing small change from position -0.1 to 0.2 g at both x and y accelerometer. Node 8 only slightly changed, i.e. the x accelerometer from position -1.12 to -0.9 g.

- d. Condition IV: the condition that is affected by soil movement (landslides 3) depicted in Figure 17. It appears that only nodes 5 and 8 from time 10:49 to 10:50 are subjected to change. At node 5, the x accelerometer changed position to 0 -0.5 g while in y accelerometer changed from position 0.2 to 0.7 g. Node 8 are changing position, for x accelerometer until the position -1.58 to -0.9 g; while the y accelerometer changed from 0.6 to about 0.8 g.
- e. Condition V: the condition that is affected by ground movement (landslides 4) depicted in Figure 18. It can be seen that nodes 5, 8 and 9 from time 10:51 to 10:52 are subjected to change. At node 5; the x accelerometer changed position from 0 -0.5 g to 0.2 g, while y accelerometer to 0.7 g. For node 8; x accelerometer appears to change from position -1.57g to -0.9 g while in y accelerometer change from 0.6 g to 0.8 g. The signal node 8 ends at 10:51. For node 9; the x accelerometer change to position 1g 0.1 (significantly) while y accelerometer from -0.1 g to 0.6 g. Signal node 9 also seems to have subsided around the time of 10:51. Nodes 6 and 10 just still provide a constant signal (no change). The termination or loss of signal nodes 5 and 9 caused by significant ground motion, so nodes can no longer emit a signal to the gateway/network.

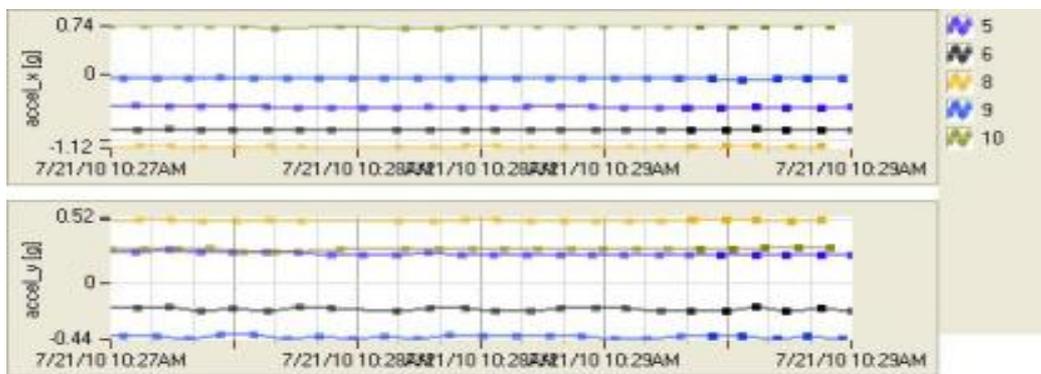


Figure 14. Condition I: normally

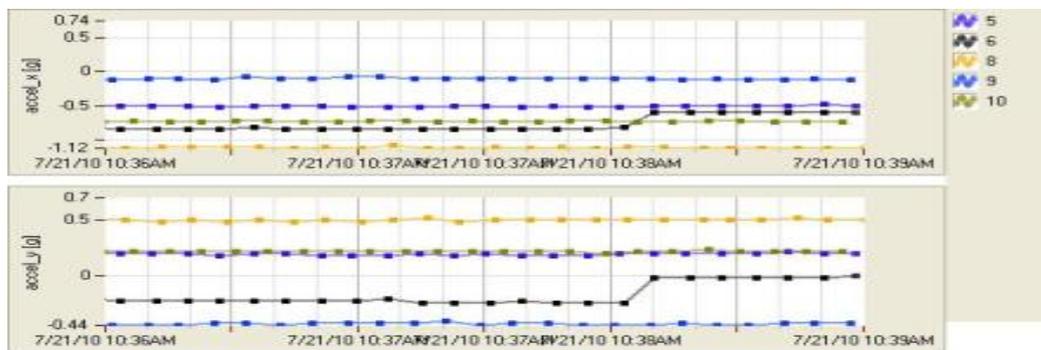


Figure 15. Condition II: landslide 1

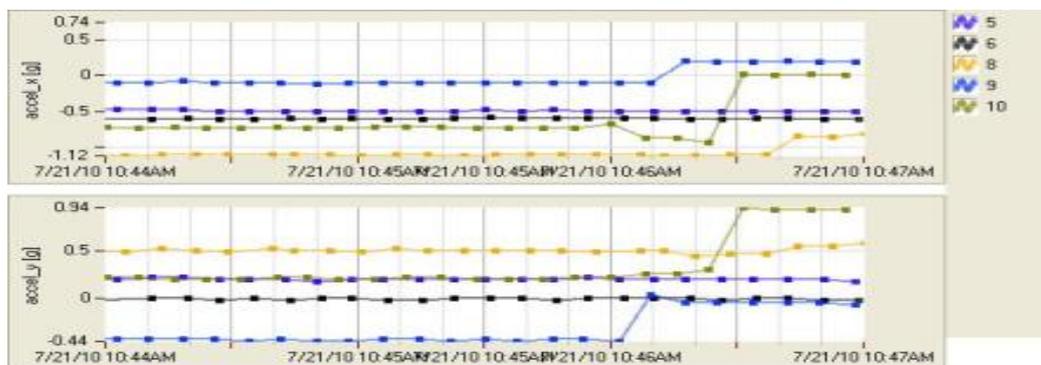


Figure 16. Condition III: landslide 2

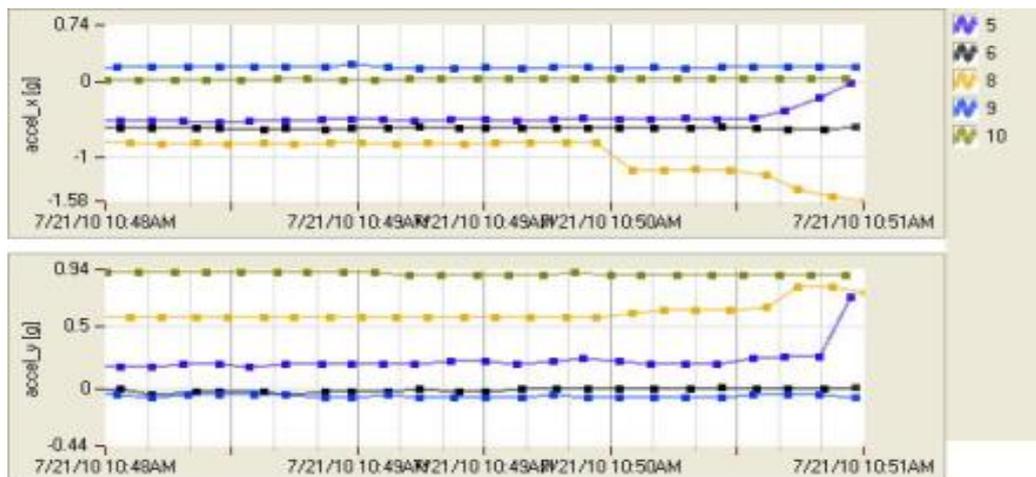


Figure 17. Condition IV: landslide 3



Figure 18. Condition V: landslide 4

The research has been done using either a prototype or sample of measurements directly on the site, giving the result that the application of WSN can be applied properly. The value of x and y accelerometer (Micaz device) are used to detect vibrations caused by ground movement in landslide area. The results of this works indicate that changes accelerometer values ranging from 0.2 g to 0.49 g in both x and y accelerometer indicates soil begin to move but not significantly. Above 0.5 g is a value that indicating a significant change of landslide. Starting on 1 g and above of landslide have a very strong signal activity and should be alarmed. This condition will be interpreted by Early Warning System (SPD) as a danger condition and to give signal to the community surrounding the location of landslides area [8].

#### 4. Conclusion

The paper has presented the research that demonstrates the implementation of WSN for monitoring landslide in NTT province. It can be concluded that the changes in the value of X and Y accelerometer result from ground motion from a position of 0.2 g to 0.49 g indicate the occurrence of slow ground motion. Value of 0.5 g on X and Y accelerometer show significant changes in ground movement and value of 1 g and above of ground motion could lead to disaster. The system can be integrated with an early warning system as part of continued research to provide information for immediate danger information to the public about the location of landslide. Further research is expected to be realized in a system that is connected into the Internet network by utilizing the GIS system.

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