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Development of wireless sensor network for landslide monitoring system

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Abstract. A wireless sensor network has been developed to monitor soil movement of some observed areas periodically. The system consists of four nodes and one gateway which installed on a scope area of 0.2 Km^2. Each of nodehastwo types of sensor,an inclinometer and an extensometer. An inclinometer sensor is used to measure the tilt of a structure while anextensometer sensor is used to measure the displacement of soil movement. Each of nodeisalso supported by awireless communication device, a solar power supply unit, and a microcontroller unit called sensor module. In this system, there is also gateway module as a main communication system consistinga wireless communication device, power supply unit, and rain gauge to measure the rainfall intensity of the observed area. Each sensor of inclinometer and extensometer isconnected to the sensor module in wiring system but sensor module iscommunicating with gateway in a wireless system. Those four nodes are alsoconnectedeach other in a wireless system collecting the data from inclinometer and extensometer sensors. Module Gateway istransmitting the instruction code to each sensor module one by one and collecting the data from them. Gateway module is an important part to communicate with not only sensor modules but also to the server. This wireless system wasdesigned toreducethe electric consumption powered by 80 WP solar panel and 55Ah battery. This system has been implemented in Pangalengan, Bandung, which has high intensity of rainfall and it can be seen on the website.

1. Introduction

Nowadays, the development of communication system has been enhanced significantly. It is not only the increase of data transmission speed but also the absence of wire in communication system. The absence of wire in communication system is called wireless system. It leadsmany meritsto simplify the electronic system especially for data logger system that collect the data and send it to the database. Moreover, it reduces the complexity of installation of electronic system because of wire or cable for media communication and the wire installation cost. On the other hand, wireless systemalso has the disadvantage which needs more power consumption and data transmission stability. Unfortunately, the two problems takean important thing in every communication system. However, wireless system still becomesthebest choice for communication system in which the stability and power consumption has to be solved [1].

Related to the aspect above, Optoelectronics Research Group in Research Centrefor Physics has developed some sensors for Geotechnical Instrumentation [2]. These sensors are inclinometer, optical extensometer, and electrical extensometer. The extensometers and inclinometers have been used to measure the physical properties of a soil in slope. It can give the data of displacement of soil movement in a slope and the tilt or inclination of a reference structure respectively [3]. If the data can be processed and analysed correctly, it can providethe information about the stability of the slope itself. Nevertheless, in the reality,it is hard to install these sensors especially in a remote area whereasthere are many limitations to install the sensor connected to the wire. Therefore, the use of wireless system is needed to overcome this problem in order to simplify the installation in observation area [4,5].

In 2015, collaboration between Research Center for Physics and Research Center for Geotechnology has made the installation of landslide monitoring system in Pangalengan, Bandung. It begins with the report from the inhabitant that has seen many cracks in their village. Team of Research Center for Geotechnology has conducted pre-installation survey using geoelectrical equipment. This survey can analyse the underground condition to investigate the cause of those cracks. It also provides suggestion to improve the proper location for the landslide monitoring system installation where wireless system network is used in this system which presented in this paper.

2. Methodology

Landslide monitoring system is a system that consist of sensors, controllers, data logger and communication devices to measure the physical properties of observation area in order to monitor soil movement. This system is divided into some node units and a gateway module. Each node has one pair sensor that consistsof an extensometer and an inclinometer. This node is equipped by 20 WP solar panels, 10A solar charge controller, 12A/12V battery, data logger unit and Xbee module as the wireless communication device. Likewise, the gateway module has one rain gauge, 80WP solar panel and its controller, siren and rotary lamp, 55AH Battery, Xbee module as a wireless communication device, microcontroller, GSM Module, and relay controller. This system is shown in Figure 1.

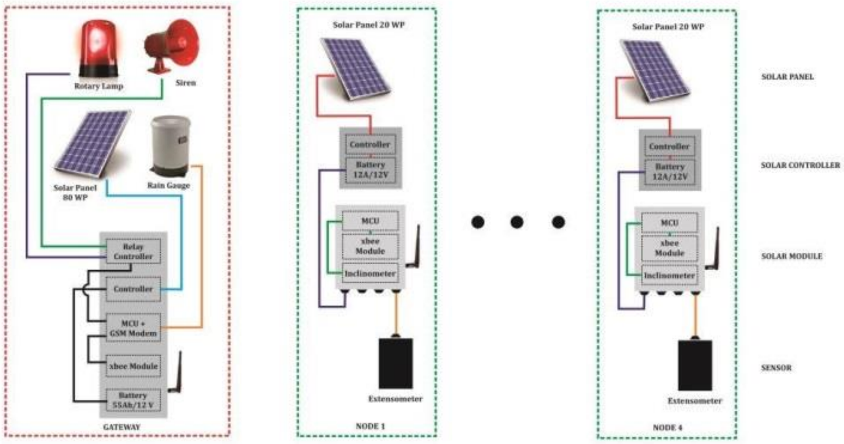


Figure 1. Scheme of wireless sensor network for landslide monitoring system

There are four nodes and one gateway to communicate each other. The gateway is a unit that send the instruction code to collect the data from each node whichhas an address. If the address sent is match to the node,this node will receivethe data from the sensor and send it to the gateway. It works in same way for each node. However, if a node position is too far from the gateway, this node still can end the data to the other closer nodes to it until the data send successfully to the gateway as the final data storage. After the gateway received completely the data from node 1 to node 4, this data is gathered and sent to the server via GSM/GPRS module.

The communication among nodes is provided by Xbee module. It is used as a wireless communication device that used to receive the instruction code and transmit the data. In this case, it uses Xbee Pro S2B that can be set in a mesh network topology and in a power save modes. Mesh network topology guarantees the data can be sent to the receiverin a long range yet takesthe short or medium range of Xbee module.This Xbee module can be seen in Figure 2.

Figure 2. Xbee Pro S2B Module [6]

Xbee module also can be set up in a power save mode. It is used to reduce the power consumption where the power supply has a limitation especially in remote area. This can be activated by setting the power down of Xbee in whichthe Xbee Pro S2B is the lowest current consumption. Thiscomparison between Xbee and Xbee ProS2B can be seen on the Table 1 as well.

Table 1. Specifications of the XBee/XBee-PRO2B RF Module[6]

Specification	Xbee	XBee-PRO (S2B)
Indoor/urban range	up to 133 ft. (40 m)	Up to 300 ft. (90 m), up to 200 ft (60m) international variant
Outdoor RF line-of-sight range	up to 400 ft. (120 m)	Up to 2 miles (3200 m), up to 5000 ft (1500 m) international variant
Transmit power output	2 mW (+3dBm), boost mode enabled 1.25 mW (+1dBm), boost mode disabled	63mW (+18 dBm) 10mW (+10 dBm) for International variant
RF data rate	250,000 b/s	250,000 b/s
Supply voltage	2.1 - 3.6 V	2.7 - 3.6 V
Operating current (transmit, max output power)	40 mA (@ 3.3 V, boost mode enabled) 35 mA (@ 3.3 V, boost mode disabled)	205 mA, up to 220 mA with programmable variant (@3.3 V) 117 mA, up to 132 mA with programmable variant (@3.3V),International variant
Operating current (receive))	40mA (@ 3.3 V, boost mode enabled) 38mA (@ 3.3 V, boost mode disabled)	47 mA, up to 62 mA with programmable variant (@3.3 V)
Idle current	15mA	15mA
Power-down Current	< 1 uA @ 25^{o}C	3.5 pA typical @ 25^{o}C

It can be seen that Xbee Pro S2B is a good choice for wireless device to use in landslide monitoring system that has longer range than regular Xbee. It also has good specification to be operated with the lowest current consumption when the power down mode is activated. To activate this mode,microcontroller controls each node and gateway. Beside Xbee Pro S2B, microcontroller and inclinometer sensors are the power down mode device which can be set in order to reduce their power consumption. For extensometer itself, the power consumption of extensometer cannot be reduced because it does not have power save mode. Moreover, it must not be switched off because it can cause the data loss.

In this system, the used sensorswere inclinometer and extensometer. Inclinometer is developed by using MEMS accelerometer SCA100T-D01 where The SCA100T Series is a 3D-MEMS-based dual axis inclinometer family which provides instrumentation grade performance for levelling applications [7]. It has resolution of 0.0035° and measuring range ±30°. It can measure the tilt of object referenced to gravity axis. On the other hand, extensometer is built using rotary encoder E40S6-2000-3-T-5 from Autonics. It has a resolution of 5000 pulses per revolution that is used to measure the displacement. In this case, the translational displacement can be converted from the counter of encoder pulse [8].

3. Result and discussion

3.1. Sensor characterization

There were two characterizationsdone in this research. Firstly, inclinometer characterization is presented in Figure 3

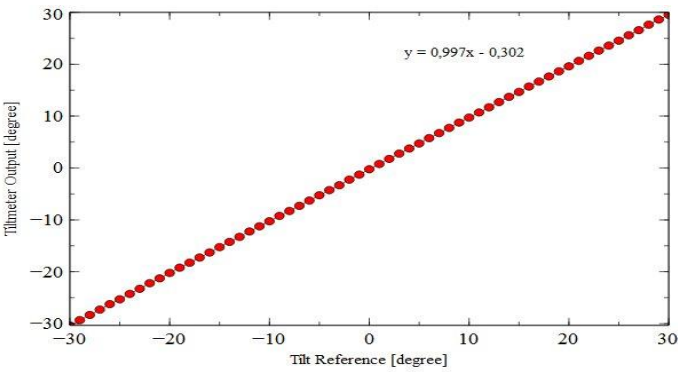


Figure 3. Inclinometer Characterization

In this graph, it is shown the result of inclinometer characterization where the x axis is the tilt references while the y axis is tiltmeter output. The range of measurement is limited at -30º to 30º and it gives very high precision of the tilt measurement. Thecalculated equation from the measurement result was y=0.997x-0.302. This equation referred to the 0.997 of sensor sensitivity of and 0.302º of sensor offset . It can be seenthat this inclinometer has good linearity to measure the inclination.

Secondly, the characterization of extensometer is presentedin Figure 4.

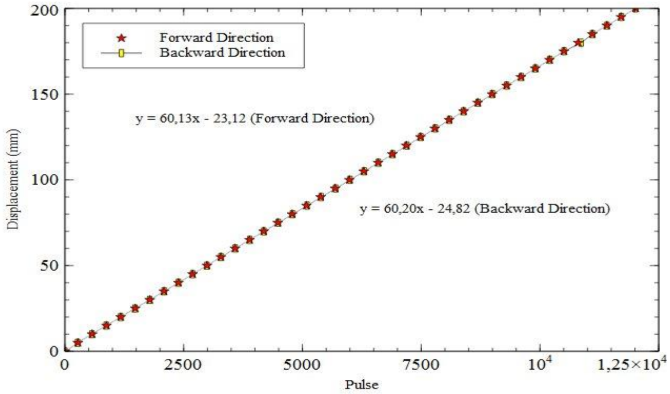


Figure 4. Extensometer Characterization

From the Figure 4, x axis is pulse of encoder while y axis is displacement of translational movement. This extensometer wasdesigned to measure the displacement for 1 m range. But in this characterization, it is onlymeasured by 200 mm range to represent the actual displacement range. They weretwo kinds of characterization that has been tested for extensometer. The first kind of characterization was forward direction with the equation of y = 60.13x – 23.12. The value of 60.13 figured out the sensitivity of extensometer sensor with-23.12 of offset value. Another characterization was backward direction with the equation of y = 60.20x – 24.82. Both equations between forward and backward direction werealmost similar inwhich the sensor is not affected by the direction.

3.2. Landslide monitoring system implementation

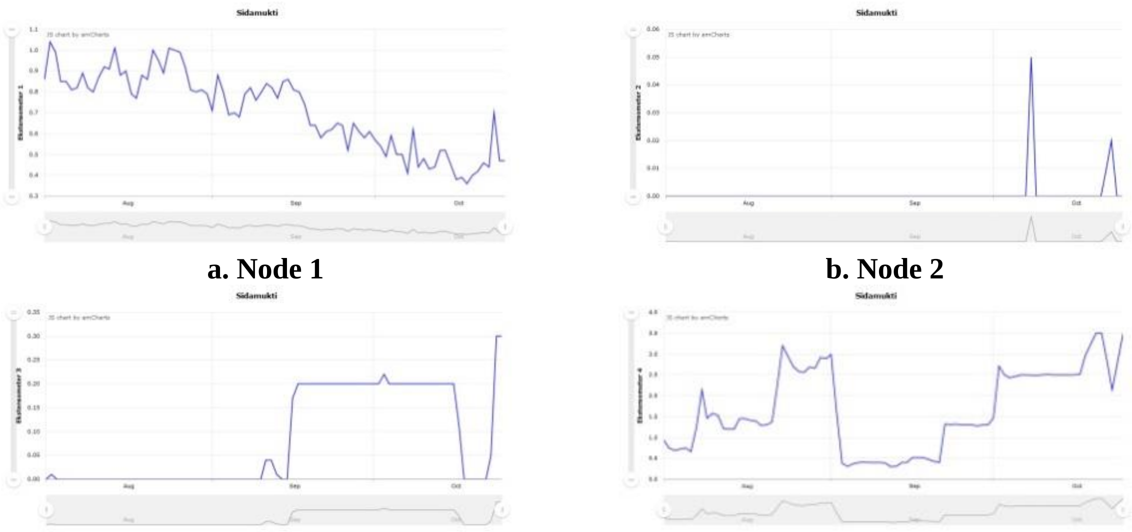
As it is mention before, this system has been implemented in Pangalengan, Bandung. This system consists of four nodes and one gateway unit that can be seen in Figure 5.

Figure 5. Location of Landslide Monitoring System Implementation

From the Figure. 5, it can be seen that four nodes is distributed in different pointsof area. The longest distance from the gateway is node 4 and the shortest distance is node 3. The distance of node 4 to the gateway is 274 meter while the other nodeshave theaverage of distance is 60 meter. This node can communicate each other to send data from the sensor ofeach node to the gateway.

3.3. Measurement result of landslide monitoring system

This landslide monitoring has been tested in Pangalengan within August – October 2016. The data was presented on the website. The graphic can be seen in Figure 6 where it represented the data of extensometer. There are four nodes that can measure the displacement of soil movement every 2 minutes. The x axis is the time while the y axis is displacement in mm.



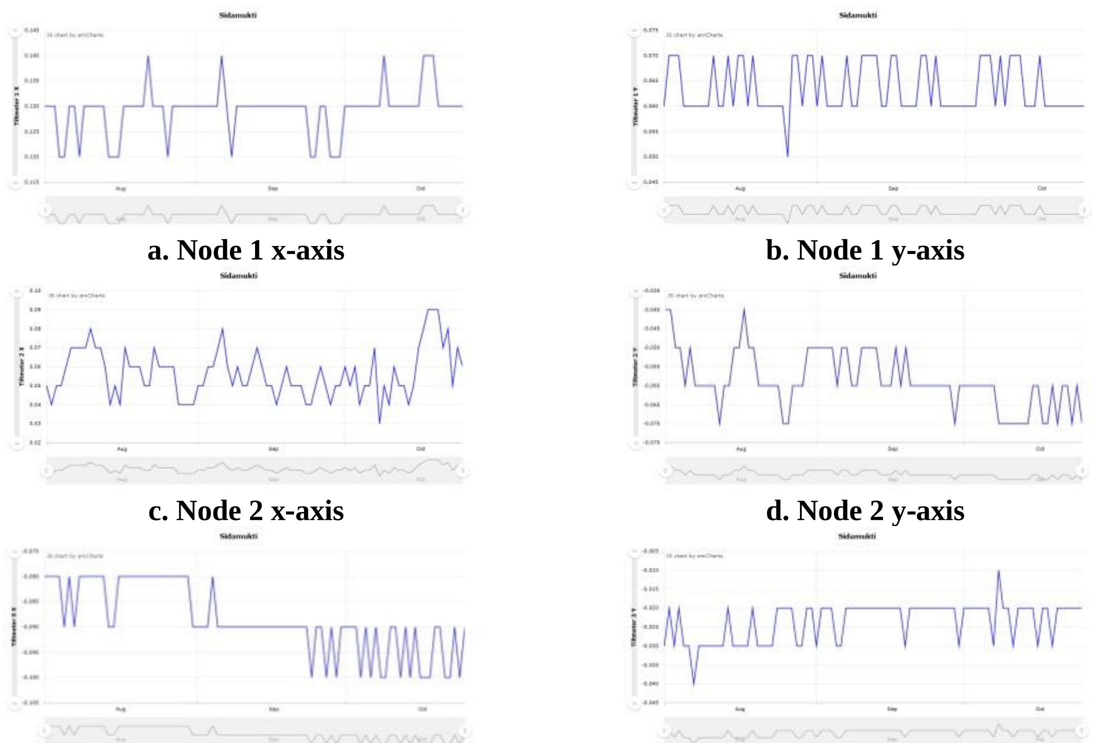
a. Node 1 **b. Node 2**

c. Node 3 **d. Node 4**

Figure 6. Extensometer Data

Another sensor is inclinometer that measures the tilt reference to gravity axis. The result can be seen in Figure 7 where the dual axis of x and y is measured in every 2 minutes. The x axis is the time stamps while the y axis is the tilt in degree. The x axis is in line to the soil movement direction in each node.

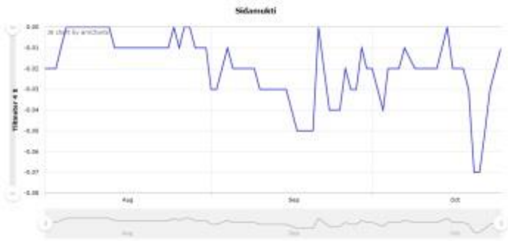
The interesting of this data was the trend of measurement result in every node. This might be caused by some factors like morphology, soil properties, humidity, and temperature of environment.The movement of soil can be in a shrinkage or expand that can be shown in graphic. The average of displacement was 0.5 to 1 mm. It can be concluded that it was still in normal condition.



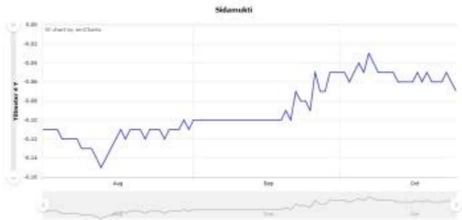
a. Node 1 x-axis **b. Node 1 y-axis**

c. Node 2 x-axis **d. Node 2 y-axis**

e. Node 3 x-axis **f. Node 3 y-axis**



g. Node 4 x-axis



h. Node 4 y-axis

Figure 7. Inclinometer Data

4. Conclusions

The Landslide monitoring system has been installed successfully in the period of August to October 2016. It can measure the displacement and tilt in observation area. The sensor in each node was connected using wireless communication system. It is helpful to overcome the limitation of sensor system installation in remote area similar to landslide monitoring system. The inclinometer and extensometer has been made and characterized before it is installed.

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