Wireless Sensor Network Applications For Measuring Soil Movement Using a 3-axis Acceleration Sensor In Landslide Prone Areas   
Kurniawan Dwi, Imron Rosyadi, ST, M.Sc, Vishnu Widhi Aziz N, ST, M.Eng   
Electrical Engineering Program, Faculty of Science and Engineering, University General Sudirman   
Jl.Mayjend Sungkono KM 05 Blater Purbalingga Indonesia   
Abstract-One of the efforts in mitigating landslides are periodic monitoring of ground movement. It is possible if there is a device that can measure ground displacement.H48C accelerometer is a device capable of measuring dynamic acceleration and static so that it is possible to measure the displacement of the soil material. Problem in the design of ground displacement measurement system is a field that is generally located on the slopes of hills and mountains. Manufacture of wireline system will certainly have limitations in terms of flexibility and portability. Wireless Sensor Networks (WSN) is one solution to these problems. Transfer data on WSN can use the XBee RF module using ZigBee communication protocol.   
  
Index Terms-Accelerometer, Wireless Sensor Networks, Landslide, ZigBee Network.   
  
I. INTRODUCTION   
The main components in the design of WSN for measuring ground motion consists of a sensor unit, and communication unit. Accelerometer sensor units composed perpinahan used to measure soil material. For communication unit composed by XBee module that transfers data between nodes can be done wirelessly. In addition to the sensor unit and the communication unit are also units of the Real Time Clock (RTC) as the unit that regulates the timing of data delivery.   
Displacement of soil material position can be detected using H48C accelerometer sensor integrating with multiple on acceleration data obtained from accelerometers.Data obtained from the accelerometer containing noise so that the necessary filtering of data. The filter used is a digital filter Low Pass Filter (LPF) and using Bessel filter prototype.   
  
II. SYSTEM DESIGN   
A. JSN Architecture   
WSN is designed using a star topology (Figure 1) by using 2 units and 1 unit gateway router. Router malakukan duty for land acquisition movement data periodically and then sends it to the gateway. While serving gateway receives the data sent by the router and sends it back to-server.   
    
Figure 1. JSN Architecture   
B. Accelerating Data Acquisition Method   
    
Figure 2. Accelerometer H48C   
  
H48C accelerometer reading acceleration data using 12 bit ADC. To convert data from ADC 12 bits per axis acceleration (g) can be calculated by the following equation:   
 (1)   
Where:   
g = Acceleration   
The output voltage of each axis = axis   
ADC reference voltage Vr =   
Position for the axis H48C accelerometer is shown in Figure 2.   
III. RESULTS AND DISCUSSION   
A. Characteristics H48C   
At H48C accelerometer static measurements performed when the sensor is not got the style from the outside but only the force of gravity. In the static measurements will generate data that represent the position of the sensor relative to the earth's surface. To obtain the roll angle (φ), pitch (ρ), and theta (θ).   
    
Figure 3. Angle φ, ρ, θ in a 2D representation   
  
Formation of each - each angle φ, ρ, θ shown by figure 2, while the readings each - each angle is shown by Figure 3.   
    
a   
    
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Figure 4. Reading of the angle φ (a) and ρ (b) where Ax = acceleration X axis, Y-axis acceleration = Ay, and Az = Z-axis acceleration   
    
In the dynamic measurement data obtained acceleration sensor movement. This dynamic acceleration represents the influence of outside force that causes the sensor to switch positions. To test the dynamic acceleration is done by shifting the position of the sensor on each - each axis.   
Direction of movement is shown by the graph acceleration sensor is formed. The movement begins with the positive direction of a hill and ends with the valley while the negative direction of movement begins and ends with a valley with a hill. Figure 4 shows the difference in graphics acceleration that is formed on the movement towards the positive and negative directions.   
    
Figure 4. Difference in acceleration graphs formed at the direction of the positive (left) and negative direction of movement (right)   
  
Figure 5 shows the results obtained from the accelerometer on the movement in the x-axis as far as 10 cm, 20 cm, 30 cm, 40 cm and 50 cm.   
    
Figure 5. Acceleration data on the x-axis movement   
B. Displacement Measurement Module   
To get the position shift multiple integration process is carried out on the data obtained from the accelerometer acceleration. The first integration will produce velocity data.Equation (2) is an integration equation to obtain data on the speed of the n-th sample.While the transfer of data to obtain a position after the sample to - n used equation (3).   
 (2)   
 (3)   
Figure 6 shows the graphs obtained from the data of acceleration, velocity and displacement.   
    
a   
    
b   
    
c   
Figure 6. (A) graphics acceleration, (b) the speed chart and (c) displacement graph   
  
C. Bessel Low Pass Filter   
Data from the accelerometer, there are still a lot of noise so that the necessary filters.   
Acceleration data from the accelerometer signal information is represented in a discrete time series. So the selected filter IIR (Infinite Impulse Response) and analog prototype filter is selected Bessel filter LPF.   
The next step is to determine the parameters - parameters fiter the sampling frequency, cutt off frequency and filter order.   
Accelerometer data capture as many as 125 within 1 second of data so that the sampling frequency is 125 Hz, while the frequency of 5 Hz cutt off is made.   
The frequency response of the digital filter is in [0,1] while 1 represents π which is the Nyquist frequency so that π = 62.5 Hz. Cutt off frequency of the digital filter is ωc = fc / fs = 0:04 rad / s.   
 To find the recursion coefficients of the transfer function filter that will be made on these tests were performed using the filters available on the website helper http://www-users.cs.york.ac.uk/ ~ fisher / mkfilter by inserting a sampling frequency parameter, cut-off frequency (corner frequency) and filter order.   
Penentuaan order filter is done by comparing the value of RMSE (Root Mean Square Error) of the data obtained from the displacement response of each filter of order 1 to order 10. Filter with the best performance were selected.   
The test results of the filter order on the x-axis movement sensor as far as 30 cm is shown in Figure 7.   
  
    
Figure 7. RMSE value for each order   
  
RMSE of the graph can be concluded that the order of 10 gives the best performance so chosen order of 10.   
Recursion equations for order Bessel filter 10 is as follows (4).   
 (4)   
With a and b are coefficients recursion to value each - each as follows:   
b0 = 1   
b1 = 10 a1 = -0.0217   
b2 = 45 a2 = 0.3013   
b3 = 120 a3 = -1.8999   
a4 b4 = 210 = 7.1766   
a5 b5 = 252 = -17.9970   
a6 b6 = 210 = 31.3335   
b7 = 120 a7 = -38.3927   
b8 = 45 a8 = 32.7257   
B9 = 10 a9 = -18.5945   
b10 = 1 a10 = 6.3684   
Comparison of data before and after filtered acceleration shown by Figure 8. Looks striking difference between the data before the data is filtered after filtered.   
    
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D. Communications Unit   
Communication unit utilizing Xbee Pro Series RF module 1. Module is set in API mode with the data frame format that is used as follows:   
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2nd byte = 0x00   
3rd byte = 0x12   
4th byte = 0x81   
5th byte = MSB address   
6th byte = LSB address   
7th byte = RSSI   
8th byte = 0x00   
9th byte = hours   
10th byte = min   
11th byte = second   
12th byte = date   
13th byte = month   
14th byte = year   
15th byte = flag Dx   
16th byte = Dx   
17th byte = flag Dy   
18th byte = Dy   
19th byte = Flag Dz   
20th byte = Dz   
21st byte = 0x00   
byte to-22 = checksum   
Timing of data delivery is governed by utilizing DS1307 RTC unit. Data transmission is set at an interval of 5 seconds. 

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TABLE 1 shows the results of the testing movement on each axis. Error average - average obtained is equal to 1.96 cm on the movement in the X axis, 1.88 cm on the movement in the Y axis and 1.76 cm on the movement in the Z axis

TABLE 2 shows the value of cross-axis effect that occurs due to the movement on one axis. Highest value of cross-axis effect is 6.91 cm.

B. Testing the RSSI (Signal recieve stength)

For the RSSI testing done by two methods: Testing the RSSI on the condition of LOS and RSSI testing on berpenghalang field.