Waspmote-Based Landslide Early Disaster Detection System with GSM Communication

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Abstract. Landslide early detection system consists of a sensing system and an alarm system that is not in the same location (remote area). The sensing system is located in a vulnerable area, while the alarm system is placed in a residential area. The sensing system uses sensors found in Plug and Sense from Libelium to read rainfall, soil moisture and soil movement and use a 3G module. The alarm system uses Arduino Uno R3 as a controller and has a Relay and SIM800l module. The installation area of the system depends on the area that has an internet network. From the overall test results, the system successfully measured rainfall, soil moisture, and soil movement. The system also managed to activate an alarm if there is a potential for landslides and successfully sends measurement data to the website. The activation of the alarm system has a delay of about ± 30 seconds. Keywords: Landslide Early Warning, Plug and Sense Smart, 3G, Arduino, Waspmote.

1. Introduction

According to the National Disaster Management Agency (BNPB), landslides are the third most common natural disaster in Indonesia after floods and tornados. Landslides cause hundreds of thousands of deaths and injuries each year and also losses in the form of damage to public services and human settlements [1].

Early detection systems for landslide events are very varied, many have been developed so that standards are needed for the implementation of early detection systems and increasing the alertness of the community in dealing with landslide events. Appropriate and applicable systems in locations that have the potential for landslide events must be developed to minimize the number of victims and damage to public facilities [2].

There are several methods that have been carried out to monitor and predict landslides. For example, as did Chinh D. Nguyen [3], using rainfall calculations to detect landslide events. Sensor networks use star and tree topologies to adapt to the weather to maximize data transmission. Another study conducted by S. Dapporto [4], conducted an analysis of water content in the soil to evaluate the potential for slope collapse. Changes in pore pressure in the analyzed part allow accurate analysis of slope stability conditions. In addition, measurement of water content in the soil is important, because slope failure often occurs when water content in the soil increases pore water pressure and reduces soil strength [5]. Another study conducted by H. Z. Kotta [6], measured vibrations caused by landslides by using an accelerometer and controller in the form of Mica Z. However, information about the exact slope or ground motion is not mentioned.

In this research, a landslide early detection system was built by a prototype system to monitor the potential for landslides and to give a warning if a landslide potential is detected. Landslide early
detection system is divided into two, namely the sensing system and the alarm system. Sensing system
and alarm system are not in the same location (remote area). The sensing system is located in a
monitor-prone area that is monitored while the alarm system is placed in a residential area. Sensing
system is designed using IP-based data communication protocol in the form of Smart Plug and Sense
from libelium, accelerometer sensor, weather station sensor and soil moisture sensor. While the alarm
system is designed using Arduino, SIM800l Module, and Relay.

2. Approach

2.1 System Overview
Landslide early detection system is divided into two, namely the sensing system and the alarm system.
Sensing system and alarm system are not in the same location (remote area). The sensing system is
located in a monitor-prone area that is monitored while the alarm system is placed in a residential area.
The sensing system uses the Waspmote Board Plug and Sense as a sensor reading data processing
center where there is an ADC in the board for processing analog sensor to digital signals and the
sensor data obtained will be sent via a 3G module. The reading data is processed to be sent to the
server using HTTP Request using the GET Method. The data sent is then stored in a database and then
reprocessed for online and real time monitoring purposes. In addition, the stored data is processed and
analyzed to determine the decision to give a warning if there is a potential for landslides.

The alarm system uses Arduino as a microcontroller and is equipped with a SIM800l module to
receive warnings of potential landslides or landslides. If Arduino receives an SMS that indicates a
potential landslide or landslide, then Arduino will activate the relay to turn on the siren. In Figure 1 a
picture of the design of the device is shown in the form of a system block.

![Figure 1. Block System Diagram.](image)

The alarm system has three warning levels designed to classify dangerous levels. The three levels of recall can be seen in the following Table 1.

| Status/level | Cause | System action |
|--------------|-------|---------------|
| **CAUTION**  | Rainfall that exceeds 29.41 mm / hour. | Activate alarm 1 for 30 seconds |
| **WARNING**  | Rainfall that exceeds 43.89 mm / hour or soil moisture approaches saturation level | Activate alarm 2 for 1 minute |
(in the range of 10 - 30 cbar).

**DANGER** Rainfall exceeds 51.21 mm / hour or soil moisture reaches saturation level (<10 cbar) or the presence of soil movement.

Activate the alarm 3 minutes.

2.2. *Sensing System Design*

In the sensing system three nodes are used to monitor the state of the slope. Node 1 is used for monitoring soil moisture along with rainfall and two other nodes are used for monitoring ground movement.

![Diagram of Block Node 1](image1)

**Figure 2.** Diagram of Block Node 1.

At node 1, Plug and Sense Smart Agriculture is used as a monitor of soil and weather conditions. The following is a block diagram on the node section, which is the reading of the ground state shown in Figure 2.

In nodes 2 and 3, Plug and Sense is used as a monitor for ground movement. The following is a block diagram on the node section, which is the reading side of the ground state shown in Figure 3.

![Diagram of Node 2 and Node 3 Block](image2)

**Figure 3.** Diagram of Node 2 and Node 3 Block.

2.3. *Design of Alarm Systems*

The alarm system is designed by using hardware from Arduino, SIM800l Module, DC-DC Step-down Regulator, and Relay. The alarm system uses the GSM SIM800l module, so the alarm system is not adjacent (remote area) to the sensor node that is placed in the monitored area. Arduino will receive an SMS if there is a potential for landslides and will activate a relay that will turn on the siren. Block diagram of the alarm system can be seen in Figure 4.
2.4. Design of Landslide Prototypes

Overall system testing is carried out using a slope prototype that is designed so that it resembles landslide prone conditions. The type of soil used is mineral soil. The following is the design of a landslide prototype.

In Figure 7 we can see that laying nodes is designed to form an equilateral triangle. Laying nodes with equilateral triangles is intended so that the tool can reach all plots of land.

3. Results and Discussion

3.1 Rainfall Analysis

Rainfall is one of the most crucial factors causing landslides. The intensity of high relative rainfall with a long duration can cause changes or increase in water content in the soil which will affect the stability of the soil. The following is the result of rainfall analysis obtained during testing.
3.2 Moisture Analysis
Soil humidity is directly proportional to the intensity of rainfall, as rainfall increases, soil moisture will also increase. When soil moisture gets higher the higher the possibility of landslides. This is caused by the water contained in the soil, so that water can no longer be absorbed by the soil causing the soil to become saturated. When the soil condition is saturated, the water that cannot be absorbed will become a burden on the soil surface and slowly erode the surface. The following is the result of soil moisture results obtained during testing.

![Figure 8. Graphic Results of Soil Moisture](image)

In Figure 8, it is shown that at 15.09, the humidity value 1 exceeds the first threshold value and at 15.19 the humidity value 2 exceeds the first threshold value, thus the server will process the data and will send an SMS to the alarm system to activate alarm level 1. When at 16.09, the humidity value 1 and humidity 2 pass the second threshold value, the server will process the data and will send an SMS to the alarm system to activate the alarm level 2.

3.3 Accelerometer Analysis
Monitoring of ground movement will be carried out if an interruption occurs. When interruptions occur in the form of shifts or ground movements, the sensing system will immediately send an SMS to the alarm system and send data recorded just after the movement. The following is a graph of measuring the value of the x axis accelerometer.

![Figure 9. Measurement Chart of X-axis Accelerometer Value](image)

In Figure 9 it can be seen that the interruption occurred at 16.02, changes in the x-axis values of node 2 and node 3. When an interruption occurs, the sensing system will send an SMS to the alarm system. The alarm system will process the SMS and will activate alarm level 3. However, in the process of activating the alarm system there is a delay of about ± 30 seconds. This is caused by the communication network when the sensing system sends an SMS and the communication network when the alarm system will receive an SMS. When sending and receiving SMS requires a stable network, therefore the system will look for the most optimal network first to make the process of sending or receiving SMS, so there is a time delay when searching for the optimal network.
3.4 Power Consumption Analysis

In a landslide early detection system, power consumption is a very important factor for the system’s lifetime. This is because the system is placed in an area not covered by the electricity network. So we need components and equipment that have relatively low power consumption. The landslide early detection sensing system uses a Lithium type battery with a capacity of 6600 mAh and an output voltage of 3.7 Volts. Therefore, to save power consumption it is necessary to use sleep mode which is one of the features of Wasp mote. The sensing system performs 2 actions repeatedly, namely performing sensor readings and sending data for 3 seconds, then enters sleep mode for 1 minute 30 seconds. Current consumption for 3 seconds for sensor reading and data transmission is 619,885 mA. While the current consumption during sleep mode for 1 minute 30 seconds is 0.033 mA. Then, it can be calculated the average current used that is equal to 20,028 mA. With a current consumption of 20,028 mA and a battery capacity of 6600 mAh, the sensing system can still work for 13.73 days without any external power supply. The sensing system is equipped with a 3 Watt solar panel with a maximum voltage of 5.8 V and a maximum current of 520 mA, but the maximum current that can be received by the Wasp mote battery is 300 mA. With a 6600 mAh battery capacity and the current received by the solar panel when it is bright at 300 mA, charging the battery fully using the solar panel takes 22 hours.

4. Conclusions

From the results of testing and implementation that have been carried out in the previous chapter, the following conclusions can be obtained:

- Data sent can be received and stored in a database, the system succeeds in giving a warning if there is a potential for landslides and the monitoring page can display the reading data.
- Plug and Sense installation locations are limited by areas that have a 3G network, so they do not allow installation in areas not covered by the network.
- Wasp mote can work for 13.73 days if there is no power supply from the solar panel and charging the battery fully using the solar panel takes 22 hours if in sunny conditions.
- Early warning has a delay of about ± 30 seconds to turn on the alarm. This is due to the influence of the communication network.

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