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LoRaWAN Technologies to Enable Landslide Disaster Prone Areas Monitoring

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Abstract

The rapidly growing communication technology makes communication easier for human-to-human, human-to-machine, and machine-to-machine communication to occur through the internet. Machine-to-machine communication over the internet is known as the Internet of Things (IoT). IoT gives machines the ability to communicate with each other about what they saw, heard, and even think. The purpose of this research is to utilize IoT technology to anticipate catastrophic risks in disaster-prone areas or to reduce impacts when disasters occur. The built-in device design includes several parameters, namely air quality, weather conditions, water conditions, and soil conditions. Rainfall sensors, wind speed and direction, air temperature, and humidity are used to observe the weather conditions. Altitude and water quality sensors are used to observe the water condition. Soil temperature and humidity sensors to observe soil conditions and sensors to measure air quality. Each sensor will send data to the transmitter using the Web service, which will then be managed using IoT and cloud computing technology to provide reports and warnings related to the situation on the research site. Data sent by each sensor can be captured by the server using the Web service and can be managed to be shared with the user through developed applications. The architecture is designed to monitor disaster-prone areas by utilizing rainfall sensors, soil vibration sensors, and soil moisture sensors combined with cloud computing technology to produce an IoT for disaster management.

Keywords: Internet of Things, disaster management, LoRaWAN

I. INTRODUCTION

Nowadays, the smart city becomes a solution for some cities where everything is integrated with digital devices. It can make easier access to information (Kitchin, 2013). Five elements involved in the smart city program, such as smart sensors, machine-to-machine communication, machine-to-people communication, cloud computing, as well as social media, and geographical information system (GIS) (Muhammad and Supangkat, 2012). Indicators can make the smart city a great program are the smart economy, smart mobility, smart living, smart government, and smart environment.

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Those things had to be integrated into a real-time and accurate system. Mobility makes the need for the smart city bigger than before. Modern citizen tends to be moving with transportation from one place to another will increase the traffic. Increased traffic will lead to traffic jams and usually end with chaos. The smart city can lighten this problem using a virtual traffic control center (Peˇ, 2017). it can monitor traffics in real-time, determine the patterns, and also can become the input for any other smart systems.

Internet of things (IoT) can turn the smart city into a better system with cloud computing in service technology such as computation, communication, and storage (Papageorgiou *et al.*, 2003; Santiko and Rosidi, 2018). That data can be used to build a smart environment for many things (Sung *et al.*, 2016); one of them is a smart environment for natural disaster monitoring. Monitoring is important to disaster management (Novianta, 2011). IoT is a crucial part of monitoring and mapping since it can provide data from the dangerous and unfeasible area. Data provided by using input from weather sensors, rainfall sensors, air humidity sensors, soil humidity sensors, and surface height sensors not only autonomously but also in real-time (Pounds *et al.*, 2004; Gurdan *et al.*, 2007; Bergen *et al.*, 2009; Lu *et al.*, 2012). Cloud computing with its services (IaaS, PaaS, and Saas) can provide almost anything that system needs as long it has internet access.

Information technology brings massive change to the monitoring pattern of disaster-prone areas. The monitoring efficiency of disaster-prone areas depends on autonomous control of every device (Pratomo, Zakaria, and Prabuwono, 2009). Autonomous control can make robots or smart agents take over human's works like environment monitoring (Sung *et al.*, 2016). The smart agent needs a sensor system to recognize the environment change that depends on the environment condition, and environmental conditions are unique based on their location. This uniqueness needs collaboration between autonomous sensors and devices. This collaboration can bring an autonomous agent to make a big impact on smart technology, especially in natural disaster management.

II. LITERATURE REVIEW

Internet of things (IoT) as monitoring and preventive technology is widely used. There are geographical hazards such as landslide, debris flow, rockfall, surface collapse, and earthquakes that can be monitored using IoT technologies (Fosalau and Zet, 2018; Lwin *et al.*, 2019; Karunarathne *et al.*, 2020; Mei *et al.*, 2020). IoT connection and platform can be used to send and receive not only simple data from the sensors but also complex data such as geospatial data or even video like data (Van Den Abeele *et al.*, 2017; Aggarwal *et al.*, 2018; Hanumanthaiah *et al.*, 2019; Lwin *et al.*, 2019). The ability to communicate between sensors and devices also made the resource management and monitoring can be more efficient, notification for the user can be done in real-time, and made the response team can act faster (John Wellington and Ramesh, 2018).

Landslide is a natural calamity of rock or soil movement, which can be lead to multiple deaths and property loss (Aggarwal *et al.*, 2018; Moulat *et al.*, 2018), so there are many IoT development towards landslide monitoring and preventing. Landslide monitoring can be done using video camera monitoring (Aggarwal *et al.*, 2018; Riasetiawan *et al.*, 2019) or by using sensors (Moulat *et al.*, 2018; Hanumanthaiah *et al.*, 2019; Susanto *et al.*, 2019; Karunarathne *et al.*, 2020). The challenges in this development are of data communication and the sensor placement areas. Some places are blind spots for cellular and some far from residential areas. LoRaWAN technology can overcome the challenge with its long-range antenna and become essential to data communication. LoRa using radio frequency transmission with a low power level that makes it possible to combine with other devices even in non-residential places with minimal electricity (Romdhane *et al.*, 2017). LoRa network can communicate one to one or more gateway available in the area, has great coverage, easy development, cost efficiency, low power cause longer battery life, and has good scalability (Karunarathne *et al.*, 2020).

Based on some previous research, we are building a landslide monitoring system placed in landslide-prone areas which far from the residential area using some sensor such us soil moisture, soil vibration, soil temperature, rainfall sensor, and air temperature. LoRaWAN is used in this technology to enable long-range data communication between nodes and gateway also to enable IoT technology to monitor landslide-prone areas. It helps to save battery life with solar panels as its sole electricity source despite its ability to connect with other nodes or gateway within the long-range.

III. RESEARCH METHODOLOGY

III.1. System Architecture

The design of the system architecture consists of several entities that are users who can access the system to access location information containing climate data in the form of charts, and detailed data can be printed by the user. The cave's flood monitoring and early warning system will accurately provide information to the users regarding the state of rainfall and climate. The data obtained from the devices will be sent through the cloud, the previous tool will be registered by the admin, one tool is located in one location to provide information on rainfall, temperature, and humidity in the cave as a reference in determining conditions in the cave. The proposed architecture is shown in Figure 1.

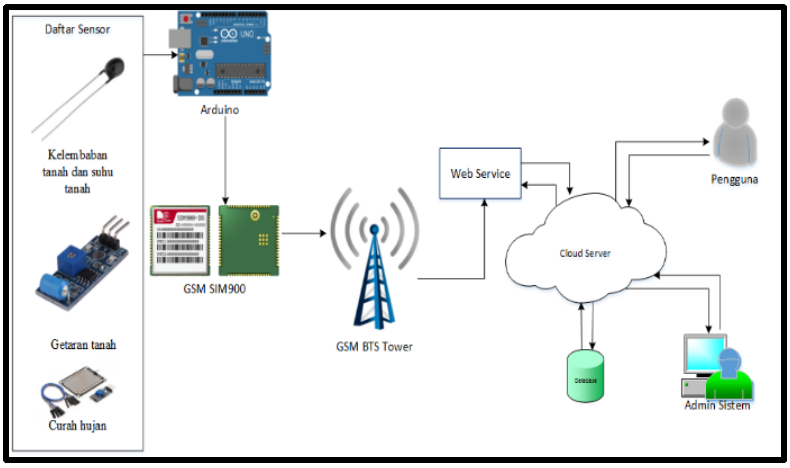

Figure 1. System Architecture

III.2. Cloud Services

This study used cloud computing technologies as a medium used to the server. Infrastructure built-in cloud used as a place to process the system created. The sensors planted in the mountain slope or disaster-prone areas will send data through the internet to the cloud server. The raw data then configured into structured data and saved in the database. The proposed cloud services are shown in Figure 2.

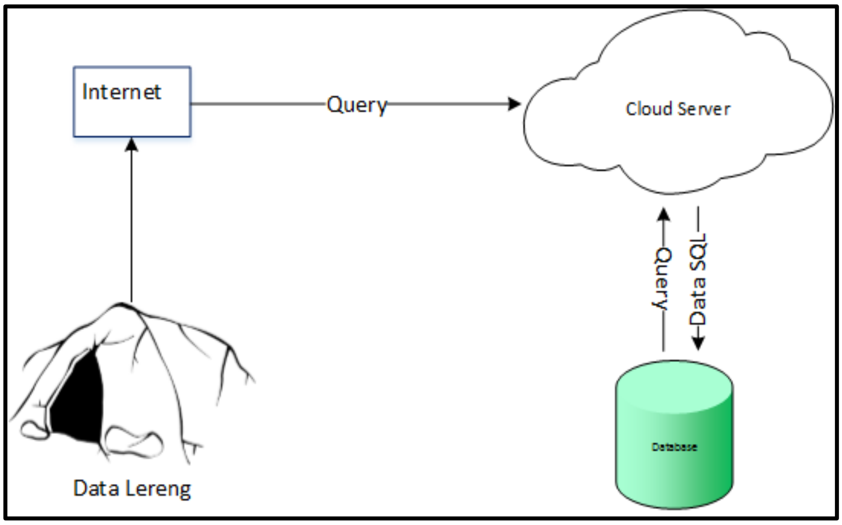

Figure 2. Cloud service for gathering sensors data

III.3. Low-Power Wide Area Network

The sensors were planted in areas far from the residential area, thus make the device also far from electrical and internet resources. Low Power Wide Area Network (LPWAN) has the capability to build a communication network for battery-powered devices placed in the cities or even in the resources-constrained area (Ebi *et al.*, 2019; Premsankar *et al.*, 2020). Lora is one kind of LPWAN that can work in approximately 3 KM radius that has been used in this research also have the lowest power requirement (Sadowski and Spachos, 2018). The LoRa connected devices are divided into two parts. The first one programmed as the gateway and the other as the node. The gateways and nodes can be added as much needed. The LoRa node connected with Raspberry Pi (RPi) that not only connected to sensors but also capable of data processing.

IV. FINDING AND DISCUSSION

IV.1. Device and Sensors

Raspberry Pi (RPi) is used in this research not only as processing units but also as an IoT device that can communicate through another device using a LoRaWAN communication network. Every input data from sensors proceed in the RPi before sent through the LoRa network through the gateway before going to the cloud. There are two types of sensors, underground and above-ground sensors.

Underground sensors are sensors that are planted in several places in the ground. There are five soil moisture sensors that are continuously sending real-time data to RPi. These sensors were planted in a different area with different soil textures in the same landslide-prone area to calibrate and show the difference moisture between textures in the same area. The higher score means that the soil became heavier and likely can cause a landslide. Moreover, there is a soil temperature that is planted in several areas to investigate soil temperature. Soil temperature determines the state when the water evaporated. The higher the temperature, means faster evaporation happens. It also shows the minimum temperature that can cause water in the soil to evaporate. The soil vibration sensor is the most important sensor in landslide/avalanche. This sensor detects soil movement and sent real-time data to RPi before forwarded to the cloud. Data processing in the RPi made the possibility for the user to know how big the movement of the time and alert the user when there are anomalies in the meantime.

The sensors put above the ground, such as rainfall monitor, air temperature, and humidity sensor. The rainfall monitor sensor takes rainfall to determine the rain condition in real-time. It works like a switch that can run automatically on when it's rain and off when it's not. Air temperature and humidity sensors detect the temperature and humidity in the area. Air temperature and humidity also affect soil weight and moisture in that prone areas. The low temperature causes the soil to be moister and carry more weight because there is not enough heat to evaporate the water.
All the sensor's data will be supplied to RPi, where everything will be processed before sent over the WAN network. This data used to determine whether the soil is in good condition, bad condition, or even the landslide condition. The illustration of this connection between sensors and RPi shown in Figure 3.

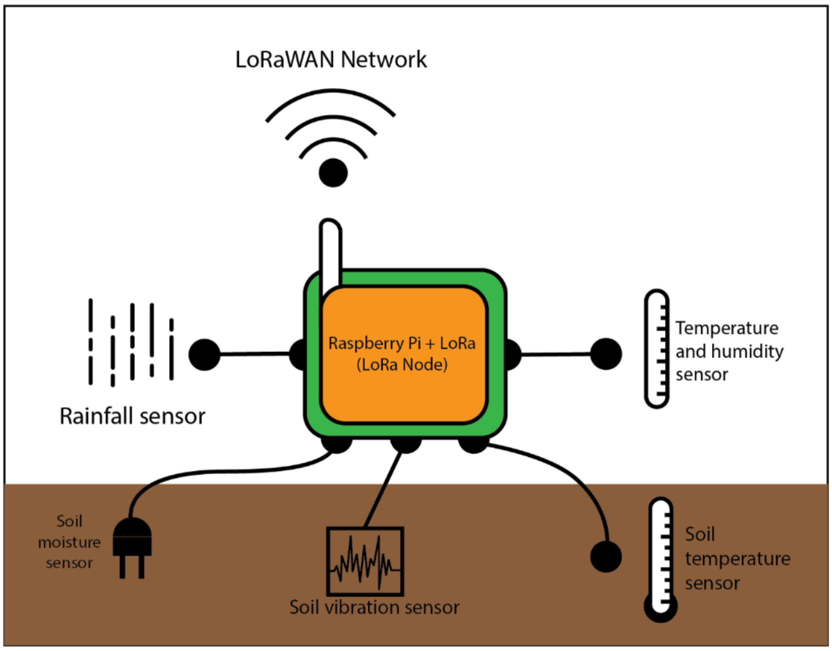

Figure 3. Device and sensors

IV.2. COMMUNICATION
The communication happened locally between LoRa nodes and the LoRa gateway. The Nodes connected to the RPi board so that every data coming from the sensor can forward right away using the LoRa network. Thus, the collected data did not transfer right away but going through data processing firsthand. The data also stored in the local storage to minimize the data loss because of a network error. Wide Area Network (WAN) is used in this research based on the LoRa module and makes it possible to send data in an approximately 2KM radius.
LoRa network in this research using 915 MHz frequency and work fine in sending data in a 2KM radius. The gateway received data from nodes and sent them to the cloud over the internet. IoT Platform is then used to monitor manage the data and user application programming interface (API) to provide data to the user. The architecture can be seen in Figure 4.

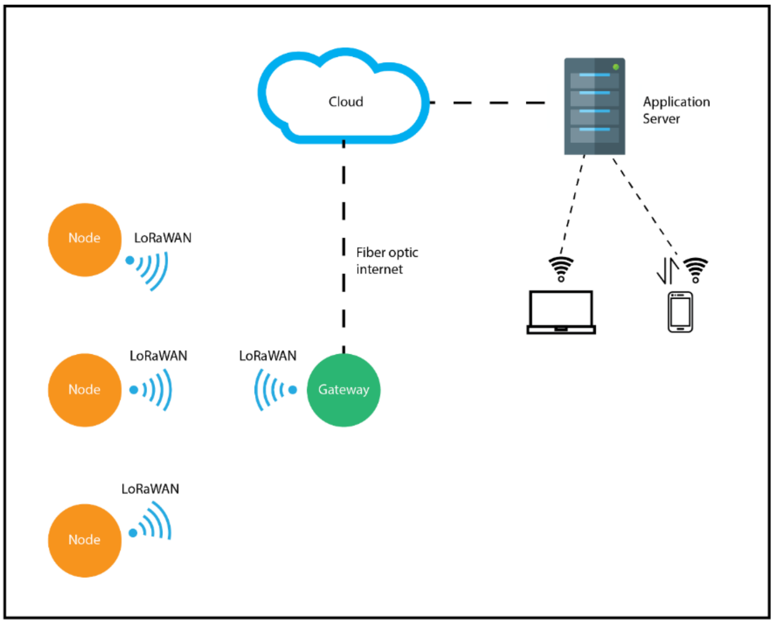

Figure 4. Communication

IV.3. Supporting

This research is conducted in landslide-prone areas and that happens to have a very low resource on electricity, and that can cause the device and sensor to underperform. Many sensors needed to be active every time. There is a 60WP solar panel installed to support the node and sensors. The panel is installed with a battery that can last at least 20 hours due to the maximum time to absorb only about 8 hours on a sunny day. While the node using solar energy, the gateway is attached to a safer place and have electricity access. This mainly because the gateway must stay on every time, or else the data sent to the cloud and users will be a loss. The gateway is also connected to fiber internet to make sure there is less possibility of data transmission loss.

IV.Application

The application built for these disaster-prone areas can be accessed by the locals and the governments as users. The users can monitor the landslide-prone area where the sensors are planted. They will get the warning when the system detects an anomaly such as the vibration or heavy rain happens in the area. This feature meant to alert people that the area is not safe for the time being, and it is better to evacuate themselves to a safer place.

V. CONCLUSION AND FURTHER RESEARCH

This proposed architecture works in resource-constrained areas such as in the countryside, in the mountain villages, or even in the city with many resources. This architecture can also build in to monitor such dangerous areas without depending on electricity from powerplant and make the definition of IoT wider in implementation. The LoRaWAN that makes the communication between nodes and gateway happen paly a big part in the communication part in this design, so that even if the no-internet area can become part of the IoT system. The solar energy plan also gives many options for the location of sensors as long as the area is exposed to sunlight. IoT platform can be used for faster development because it can read all data sent from the gateway and provide API for many applications on the users' side.

For further research, many fields in disaster management and IoT that can be combined, such as water monitoring system to monitor prevent flooding or tsunami monitoring with tidal monitoring. There are also several open problems in Indonesia, like forest fires that can be avoided by continuously monitor the area using the technologies of IoT, artificial intelligence, and cloud computing combined.

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