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Autonomous Cyber Physical Systems for Monitoring of Methane Gas in Rice Field

Muhamad Komarudin[1,*] Hery Dian Septama[1], Titin Yulianti[1]

[1] *Department of Electrical and Informatics Engineering, University of Lampung* [*]*Corresponding author.*
Email: m.komarudin@eng.unila.ac.id

ABSTRACT
The agricultural sector is accused of increasing the concentration of greenhouse gases (GHG) that triggered climate change. Rice fields or wetlands are one of the largest sources of methane (CH4) emissions to agriculture. Rice fields play an active role in the release of methane emissions into the atmosphere. This paper explained the cyber physical system technology used to monitor the methane gas in rice fields or wetland as one of the efforts to support environmental monitoring. The system is autonomous and can be placed in remote areas as it is equipped with solar power station, geo-location and internet module. The result shows that the cyber physical system developed is working properly and that the user can monitor the result with the remote monitoring application. Temperature and humidity play a significant role in the methane level produced in the rice field. Methane concentration in the middle of the day is higher than in the middle of the night as the temperature in the middle of the day is higher with lower humidity.

Keywords: *methane gas, autonomous, monitoring, cyber physical system, rice field*

1. INTRODUCTION

Climate change is a global phenomenon that has occurred largely because of human activities. One of those activities has to do with land conversion. Land conversion activities have the potential to generate methane (CH4). The increase in the concentration of greenhouse gases (GHGs) resulting from various human activities causes an increase in radiation trapped in the atmosphere. The impact is an increase in Earth's temperature, resulting in global warming. It is expected that the temperature of the earth will rise between 1.4–

5.8℃ by 2100 without efforts to control GHG emissions.

Since the 19th century, it has been noted that the world's global temperature has risen between 0. 6–2 [1]. Over the next 100 years, greenhouse gas emissions are expected to double their pre-industrial levels. Under these conditions, various GCMs (global circulation models) predict an increase in the average temperature of the earth's surface between 1. 7–4. 5℃ in the next 100 years. The increase in global temperature will be accompanied by an increase in sea water as high as 15 to 95 cm caused by melting ice at the two poles of the earth [2].

The forest and land conversion in to agricultural is one of methane gas sources. Rice fields or wetlands are one of the largest sources of methane (CH4) emissions from agriculture. Rice fields play an active role in the release of methane emissions into the atmosphere. Over 90% of methane is emitted by parenchymal tissues and intercellular spaces of rice plants, while less than 10% is emitted by water bubbles. The dynamics of CH4 gas emissions are closely related to soil redox potential, fertilizer input and flood rate [3]. According to the Central Statistics Agency (BPS) of Indonesia, recorded that the total rice field area in 2020 in Indonesia was 10.66 million hectares (ha). Thus, Indonesia is one of the agricultural countries accused of producing large amounts of methane gas which results in global warming

[4].

This paper explained the cyber physical system technology used to monitor the methane gas in rice fields or wetland as one of the efforts to support environmental monitoring. The system consists of sensors, processing module, solar power system module, geolocation module, data communication or internet module, and monitoring application. The system is autonomous and can be placed in remote areas. As a result, methane produced by the rice field or wetland can be monitored at all times. Therefore, the government may offer education and treatment. Especially at the farm where his rice field detected high concentrations of methane to reduce the methane produced. Thus, this contribution will affect the concentration of greenhouse gases (GHGs).

2. RELATED WORK

The Cyber Physical System is a system with integrated computer and physical capabilities that can interact with people [5]. Cyber-physical systems technology is used to bridge two fields of knowledge, cyberspace and physical space. Embedded systems, sensor networks, actuators, communication and management processes working in the physical environment are also included in the integrated Cyber Physical System under the intelligent decision system. In general, the term Cyber Physical System replaces embedded systems which emphasize interaction with the physical world, including system reliability, real-time response and responsibility for human life and equipment. The term "cyber" also refers to a connection to the IT world, which emphasises complex indicator systems [6].

The cyber physical system, nowadays is used in many sectors. The work in [7] used the cyber physical system in order to provide precision aquaculture by monitoring the water quality parameter in real time. The oil and gas industry has also produced methane and contributed to the production of greenhouse gases. The paper by [8] carried out research on methane measurement using the MQ-2 sensor and Arduino as a microcontroller. As part of this investigation, an audible warning device was added as an actuator if the methane gas exceeded the prescribed threshold. The work in [9] proposed the satellite-guided remote methane sensor system for methane detection in the oil and gas development area in the United States. The work is developing a mobile monitoring system to identify, locate and quantify methane leaks. The rice field, particularly in Indonesia, is a wetland which irrigates before planting till harvest. Rice fields are an artificial ecosystem and habitat type with dry and wet conditions depending on water availability. Methane (CH-4) is one of the greenhouse gases produced by anaerobic decomposition of organic matter [10]. Because of the large area of rice production, rice fields are therefore considered a primary source of methane emissions, accounting for 11% of global emissions [11]. Research in [12] also explained the factor that can affect the degree of methane gas emission, a good water management is one of the known techniques for reducing it. Soil type, fertilization, irrigation water management, plant varieties, soil temperature and growing season also contributed to methane emissions. The work of [13] to predict methane gas emission in rice fields using artificial neural networks.

3. SYSTEM DESIGN

The proposed design of the cyber physical systemis depicted in Figure 1. It is composed of several layers, namely user layer, proximity network layer, public network layer and cloud network layer. The physical parameters of the monitored rice field are captured by sensors. There are two sensors used in this device, namely the DHT11 sensor is used to gather temperature and humidity and the MQ4 sensor for methane gas. The geolocation parameter is also collected by the GPS unit to monitor the location of the device. All physical parameters, then processed by the processing card, NodeMCU. The NodeMCU board is chosen since it is had an integrated data communication module and enough I/O pin for the system at a low cost price. The GSM modem is used as an Internet module to send the data collected in the cloud database.

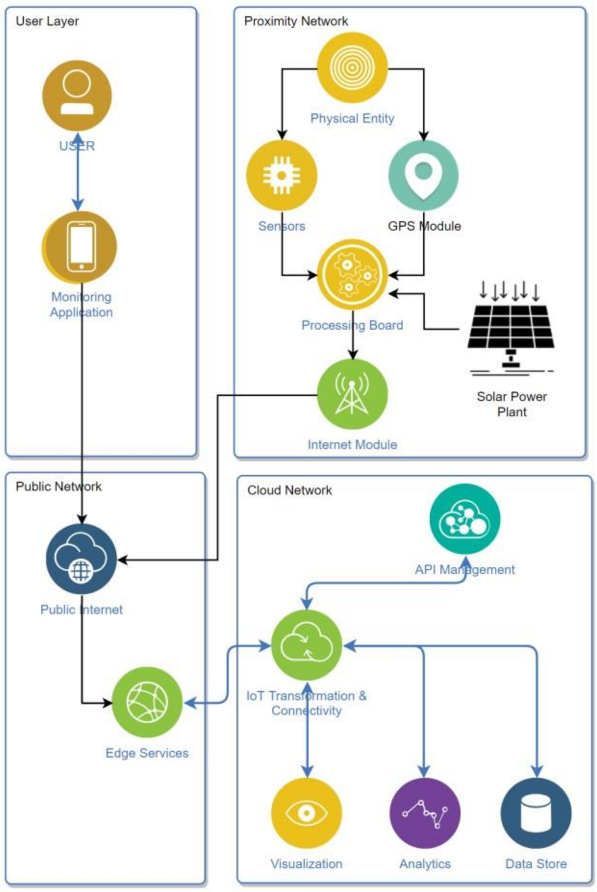

Figure 1 Projected system design.

This autonomous and integrated monitoring device mentioned above is powered by solar power plant, thus it may be placed remotely. The solar cell provides resources for the power bank, the power bank used has a capacity of 13000mAh or 13Ah with a high voltage = 5V. The estimated value for all system components is 3.15 Watt per hour. As the capacity of the power bank is 65 watts, the estimated usage of the power bank can provide energy for 20.6 hours. In the status of the battery is completely charged and in good condition.

The collected data is then sent to the Thinkspeak cloud platform through the public Internet network. The data is then stored on the cloud base platform and can be used for visualization and analysis. The android based monitoring application is also developed for the user. The user may use the application in order to show the methane gas, temperature and humidity of the monitored rice field daily.

4. RESULTS AND DISCUSSIONS

4.1. Component Testing

Component testing aims to determine whether each component may work as expected, i.e. the sensor can detect the expected value. The model used consists of connecting the component one by one to the NodeMCU. The sensor is tested through data collection every five minutes. The data is then compared against the calibrated tools to compute the error rate. The error rate is calculated according to equation 1 below.

$$Error\ rate = \left(\frac{sensor\ data - calibrator\ data}{sensor\ data}\right) \times 100\% \quad (1)$$

Tables 1 and 2 are the test results from the DHT11 sensor as a temperature and humidity sensor. The average error rate is 2.39 for the temperature and 2.32 for the humidity. So the accuracy of the DHT11 sensor is very good. Concerning the methane gas is with the help of the MQ4 sensor. The MQ4 sensor is able to detect methane concentrations between 300 and 10000 ppm.

Table 1. Temperature results

No	Sensor (°C)	Calibrated Thermometer (°C)	Error (%)
1	24	24	0
2	31	32	3,12
3	32	33	3,03
4	34	35	2,85
5	33	34	2,94

Table 2. Humidity results

No	Sensor (°C)	Calibrated Thermometer (°C)	Error (%)
1	91	92	1,08
2	74	76	2,63
3	44	45	2,22
4	63	65	3,07
5	74	76	2.63

The results of the MQ4 sensor are still in the voltage parameter (analog), so conversion to ppm is necessary. The analog-to-digital conversion (ADC) is computed using equation 2. The ADC value is obtained by comparing the input voltage value (Vin) and the reference voltage (Vref) multiplied by the total bit (1024)

$$ADC = \frac{Vin}{Vref} \times bit\ total \quad (2)$$

The ADC value obtained is then converted to the concentration (C) of methane in ppm (parts per million) with equation 3.

$$C = X \times ADC \quad (3)$$

Where X is a constant comparison of the MQ4 sensor ppm detection range (range = max ppm - min ppm) with the total bit (1024) obtained by the equation 4.

$$X = \frac{range}{bit\ total} \quad (4)$$

Hence, the value for X is 9.47265625 ppm/bit.

$$X = \frac{10.000 - 300\ ppm}{1.024\ bit}$$

X = 9,47265625 ppm/bit

4.2. System Testing

Figure 2 illustrates the implementation of the system in the rice field. The sensor is placed under the system housing in order to obtain higher methane gas accuracy. The measurement is carried out in real time and on an ongoing basis. The system is autonomous as it is carried by the solar cell.

The collected data is sent to the cloud storage for visualisation and analysis of the data by the user. The geo-location setting is also sent to the database for monitoring the location of the system.

Figure 2 Implementation of monitoring device

For comparison purposes, data collected over three consecutive days in the middle of the night and in the middle of the day are compared. The water level of the rice field on the first day is also higher than on the second and third days. Figure 3 shows the result of the temperature measurement. The sensors show the actual temperature as shown in the figure that the temperature in the middle of the night is lower compared to the middle of the day. The opposite results are illustrated by Figure 4. Figure 4 shows the humidity of the rice field that has higher humidity in the middle of the night.

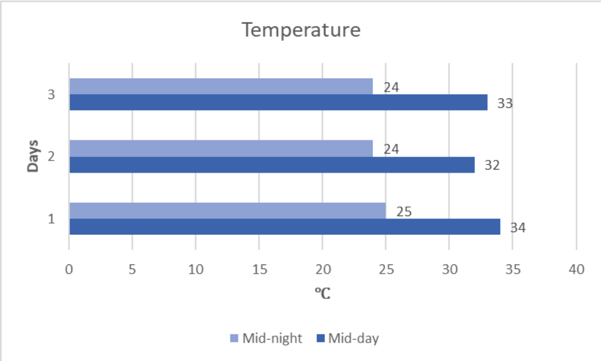

Figure 3 Temperature measurement

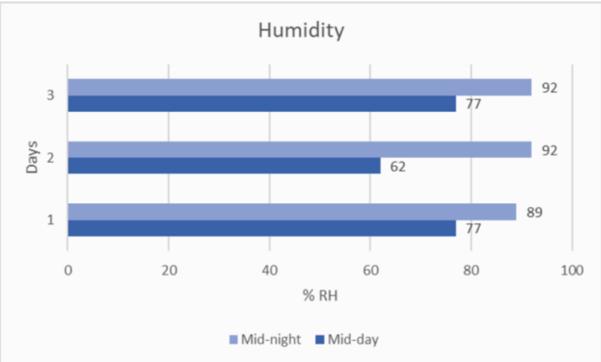

Figure 4 Humidity measurement

The correlation between temperature and humidity is given with the methane emission detected. At warmer temperatures and lower humidity methane gas emission detected is higher depicted in figure 5. Methane gas collected on the first day is 9700 ppm and decreased in the second and third days. The results indicate that the combined water level with temperature and humidity affected the methane emission level.

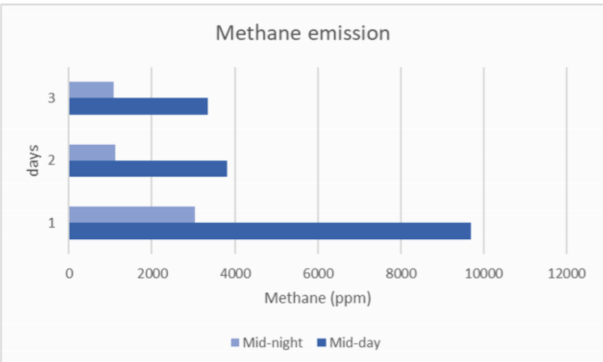

Figure 5 Methane emission measurement

Figure 6–8 shows the monitoring application developed for the user. With this web-connected app, users can view data on rice fields collected by the sensors and the location of the monitoring device. Figure 6 shows the menu of monitoring applications that includes monitoring for temperature, location, humidity and methane. Figure 7 illustrates the sample from daily temperature monitoring. Figure 8 illustrates the location of the cyber physical systemthat has already been planted in a rice field.

Figure 6. Monitoring application menu

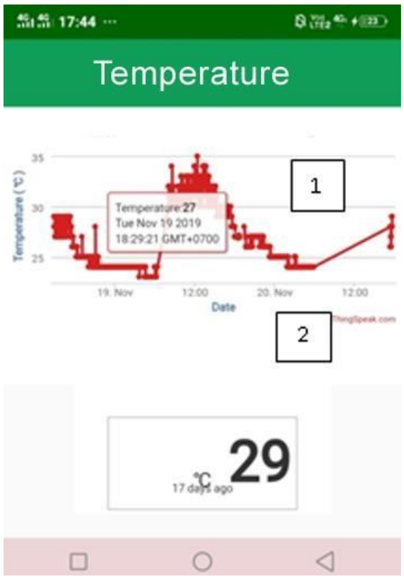

Figure 7 Temperature monitoring results

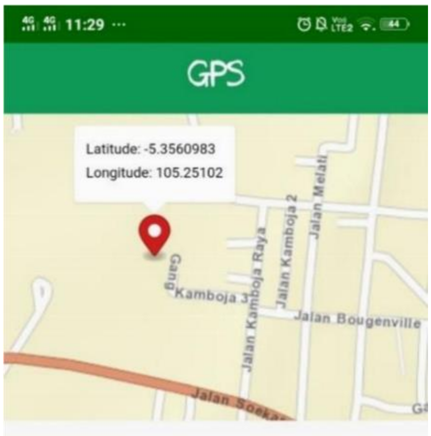

Figure 8 Location monitoring

5. CONCLUSION

The result shows that the cyber-physical system developed is working properly and that the user can monitor the result with the remote monitoring application. Temperature and humidity play a significant role in the methane level produced in the rice field. Methane concentration in the middle of the day is higher than in the middle of the night as the temperature in the middle of the day is higher with lower humidity.

AUTHORS' CONTRIBUTIONS

Muhamad Komarudin is contributed in design of cyber physical system and implementation, Hery Dian Septama is contributed to hardware implementation and Titin Yulianti is contributed in programming and system testing.

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